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Труды симпозиума

General Information

The XXI International Symposium on Nuclear Electronics and Computing (NEC'2007) was held on 10-17 September 2007 in Varna, Bulgaria. The symposium was organized by the Joint Institute for Nuclear Research (JINR) (Dubna, Russia), European Organization for Nuclear Research (CERN) (Geneva, Switzerland) and the Institute for Nuclear Research and Nuclear Energy of the Bulgarian Academy of Sciences (INRNE) (Sofia, Bulgaria). More than 100 scientists from 12 countries (Russia, Bulgaria, Switzerland, Romania, Czech Republic, Poland, Germany, Great Britain, USA, Vietnam, Georgia and Ukraine have participated in NEC'2007. They have presented 57 oral reports and 37 posters.

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MAIN TOPICS

- Detector & Nuclear Electronics;
- Computer Applications for Measurement and Control in Scientific Research;
- Triggering and Data Acquisition;
- Accelerator and Experiment Automation Control Systems;
- Methods of Experimental Data Analysis;
- Information & Data Base Systems;
- Computer Networks for Scientific Research;
- Data & Storage Management;
- GRID computing.

CONTENTS

Parallelization of knowledge acquisition
system and submission to a Grid environment

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The challenges of decision-making in the future and appearing already today are characterized by increasing data volumes and requirements of the coordinated sharing of the resource of geographically distributed sites. The next generation of grid technologies promises to provide a necessary infrastructure facilitating sharing of computing resources in complex environments of decision-making. At present, there is no logically coherent structure to develop applications of data mining in grid.

The purpose of this paper is to show an approach to data processing in frames of the analysis of various complex systems; the proposed method is realized as parallel algorithms, and, hence, can be used for distributed data processing in the grid environment.

The problem of diagonalization of connection matrixes, in principle, is central when studying the large systems since necessarily results to in necessity of aggregation of elements of the large system, and statement of a problem of data matrix aggregation results to in a problem of diagonalization connection matrixes [1]. This problem naturally arises in various sciences at classification of objects.

Let us take a set of indexed general random objects $x_1, x_2, ..., x_n$, characteristic that all objects are interrelated and square matrix $A = \|\alpha_{ij}\|$ (n is order of matrix) of pair interrelations is defined:

$$
\begin{array}{c}
\begin{matrix} x_1 & x_2 & \cdots & x_i & \cdots & x_n \end{matrix} \\
\begin{matrix}
x_1 \\
x_2 \\
\vdots \\
x_i \\
\vdots \\
x_n
\end{matrix}
\begin{matrix}
& & & \vdots & & \\
& & & \vdots & & \\
& & & \vdots & & \\
\cdots & \cdots & \cdots & a_{ij} & \cdots & \cdots \\
& & & \vdots & & \\
& & & \vdots & &
\end{matrix}
\end{array} \quad ,
$$

where element α_{ij} is the number describing connection or influence of the object i on object j. The matrix A is called a matrix of connection. If $\alpha_{ip} > \alpha_{it}$, it means that the object i is "closer" to object p than to object t. The matrix A can be symmetric, but not always. A problem of finding such numbering objects $\{x_i\}$ (i.e. such arrangement of lines and columns of matrix) that in a matrix of connection A along the main diagonal square blocks with the large elements, and the elements located outside of these blocks were rather small, is called a problem of connection matrixes diagonalization. The process of grouping lines and

columns, and discrimination of diagonal blocks result in partitioning set $\{x_i\}$ of objects into such groups, where the objects are connected "strongly" and, on the contrary, the objects from different groups are connected "weakly".

Let us present examples of the conceptual problems that can be solved as tasks of connection matrix diagonalization.

Classification in biological sciences is used at studying new forms of living systems at different levels of the organization (genesis, molecular, organ, organism, population).

In sociological studies there are two problems solved by methods of matrix diagonalization: «optimum sample» and «optimum questionnaire». The optimum sample is understood rather a small group of people whose answers to questions of the optimum questionnaire fully enough reflect results which would be received on the entire assembly.

Aggregation of a matrix *of economic relations* of economy branches gives a relatively small number of macro-parameters describing a current status of economy and, consequently, is effective in problems of a long-term planning of the economic development.

Investigations in the field of international relations based on matrixes' diagonalization methods are used for revealing some stable dependence between various characteristics of social- economic and political development of countries. These laws are a basis for definition of tendencies of the development of countries, an analytical tool of scripts forecasting of the international economic and political relations development [2].

The problem *of the E-government or optimization of administrative structure* is reduced to diagonalization matrixes of organizational connections of the ministries, other government agencies that create the scientific base of reorganization of various parts of administrative-and-management personnel.

Organization of communication networks. If as a matrix of connection one takes the intensity of information interchange between separate points of territory, then the diagonalization of such a matrix of connection will give a pattern of the most expedient scheme of organization of communications and will allow one to select the most important directions of its development.

The basic approach to the problem of diagonalization matrixes of connection (MC) between elements $p_1, p_2, ..., p_M$ consists in consideration suitable functional, dependent on how these elements are partitioned on L groups $G_1, ..., G_L$ and that "good" in intuitive understanding the way of elements grouping corresponds to the extreme value of the functional. However, being simple at a first glance, the approach encounters a number of difficulties at realization, especially if the number of grouping parameters is large (hundreds).

First, it is not possible to find a functional which would give the separation reflecting the required idea about the "good" partition.

Secondly, in the essence, the problem of grouping parameters is a problem of integer programming, where, behind very rare and specific exceptions, there are no effective procedures (i.e. the procedures which are not reduced to complete enumeration) which would deliver a global extremum to a corresponding functional. Therefore, we can expect only for access of a local extremum. However, with growth of the number of elements, the number of the functional's local extremums grows and by that the probability of access of such a local extremum, which would be close enough to a global extremum, decreases. The efficiency of the variational approach falls with the growth of the number of elements.

Third, crockitude of those procedures which provide access of only local extremum of the functional sharply grows with growth of the number of elements and at several hundreds becomes practically unrealizable.

Therefore, having refused the variation approach which has the listed lacks, we came to heuristic algorithms. One can say about them what the exact mathematical problem they solve, but they reflect those or other aspects of our concept of "good" grouping.

In this paper, the solutions to the problems of aggregation of data matrixes which generalization on matrixes of connection are their diagonalization are considered. We assume that the matrix of data X has dimension N x n and all its lines and columns are known from the very beginning. The procedure begins with any random partition R of parameters (columns) and objects (lines) of an initial matrix. The parallel algorithms solving the problem of aggregation, form groups of parameters and classes of objects simultaneously. In the study, two functionals J_1 and J_2 are used at the assumption about standard normalization of initial data matrix.

Grouping R on k_2 x k_1 submatrixes X_{ts} we see that the set of parameters $G = \{j = \overline{1.n}\}$ is aggregated in k_1 not crossed groups, and in each group set of objects K_i $i = \overline{1.N}$, divided into k_2 classes.

Let G_s be a subset of indexes of parameters of S-th group, so $G = \bigcup\limits_{s=1}^{k_1} G_s$ and $G_s \cap G_s = \phi$ for any pair {S, S'}, if $S \neq S'$; K_{ts} - a subset of indexes of t-class objects in S-group of parameters.

For any S, $K = \bigcup\limits_{t=1}^{k_2} K_{ts}$, $K_{ts} \cap K_{ts} = \varnothing$, i.e. t classes which are not intercrossed, sets the vector: $\delta = \{\delta_1, \delta_2, ... \delta_n\} = \{+1, -1, ... +1, +1\}$, i.e. to either column in matrix X_{Nn} correlate +1 or -1.

On set of all possible pairs (R, σ) we shall define criterion J_1 numerically equal to the average dispersion of values of elements in matrixes X_{ts} at the fixture pair (R, σ):

$$J_1 = \sum_{S=1}^{k_1} \sum_{t=1}^{k_2} v_{ts} S_{ts}^2 , \tag{1}$$

$v_{ts} = \dfrac{N_{ts}}{N}$, N_{ts} – a number of elements in matrix X_{ts},

$S_{ts}^2 = \sum\limits_{\substack{j \in G_s \\ i \in K_{ts}}} (x_{ij} y_j - \overline{x_{ts}})^2$,

$\overline{X}_{ts} = \sum\limits_{\substack{j \in G_s \\ i \in K_{ts}}} x_{ij} y_j$.

The partition corresponding to a minimum of criterion (1) generates simultaneously such grouping of parameters, and in each group such separation of objects into classes at which each submatrix X_{ts} approximately can be considered as a matrix from the identical elements equal $X_{ts.}$

In other words, a matrix of figures $\left\| \overline{x}_{ts} \right\|$ of dimension k_2 x k_1 (it is usual k_1=2÷5; k_2=2÷10, i.e. the general number of elements $\left\| x_{ts} \right\|$ does not exceed 50) combined with the information of set of objects membership to classes on all groups of parameters (which volume also ≤ 50) give approximation of an initial large matrix of the data (containing tens thousand figures), and the more so exact, than smaller value of functional we shall get.

The variation of a vector σ strongly expands an opportunity of acquisition enough small values of functional J_1 without change of semantic value of parameters.

Therefore adds up alongside with a variation of partition R to select such vector σ (so to coordinate signs on parameters) that functional J_1 achieved the least value. Thus the resulting separation appears independent of the choice of directions on their axes.

The second functional

$$J_2 = \frac{1}{N} \sum_{s=1}^{k_1} \sum_{t=1}^{k_2} \sum_{\substack{j \in G_s \\ i \in K_{ts}}} (x_{ij} - \overline{x}_{ts}^j)^2 \, , \tag{2}$$

where $\overline{x}_{ts}^j$ - average of j-components of the lines compounding t-class on S-group of parameters; other designations same, as well as in J_1 (1).

Minimization of criterion J_2 means that the best partition at which each submatrix X_{ts} is described by the generalized vector $\overline{x}_{ts}^j (j \in G_s)$ average values of its lines on corresponding group of columns is found. At minimization (2) vector σ is not entered.

The functional J_2 generates more detailed than J_1 the description of submatrix X_{ts}. The vector of average is compared with each such submatrix: on t-class of objects of all parameters of s-group instead of one number - average on all parameters and objects of this submatrix.

For any separating parameters and objects the inequality takes place

$$J_1 \le J_2 \, . \tag{3}$$

The procedure (common for both algorithms) starts with any random separation R of parameters and objects. Thus for J_1 it is necessary to set a vector of signs σ.

The procedure is constructed as a consecutive step-by-step construction of two sub-procedures, in one of which all are looked through all columns of matrixes X (parameters), and in another - all the lines (objects).

At viewing the next column (or lines) it is transferred from one group in another (accordingly from one class in another separately on each group of parameters), and change of functional which gives such transfer is counted up. If reduction of functional occurs, transfer will take place; otherwise, the column (line) remains in a former group. The procedure is over when at the next viewing of all parameters and objects there was no change in the grouping of parameters and classification of objects.

The program is written in the C language. Under parallelization, after viewing of columns, on each processor, the separation which is turning out at viewing the lines of one group is searched. Further, using communications MPI (http://www-unix.mcs.anl.gov/mpi/), among them we find the partition corresponding to the minimal value of functional.

Simulation running on classification of three classes of images and processing of a data matrix of 1224 patients with acute myocardial infarction (AMI) investigations where each patient is described by 39 characteristics of a cardiovascular system status [3] have been carried out.

Images were classified on 3 and 4 classes; the values of criteria were in first computing experiment (CE) $J_1 = 5.497$; $J_2 = 1.157$, and in the second, -$J_1 = 5.495$; $J_2 = 1.0281$. Accordingly, the numbers of mistakes in both computing experiments were at the first criterion J_1 about 32 %, and at the second criterion J_2 did not exceed 10 %.

Partition of 39 attributes into 6 groups and classification of patients into two classes on an outcome of AMI also has shown advantage of criterion J_2. In two series of the simulation running average values of criteria were equal accordingly $J_1 = 34.738$; $J_2 = 24.959$.

Thus, suggested was the software applied in the Grid environment for large scale data processing with the purpose of extraction of new dependences from empirical data for analysis and decision-making.

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Project BNB-Grid: solving large scale optimization problems in a distributed environment[1]

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The paper gives an overview of different approaches to solving large-scale optimization problems in a distributed environment and discusses the BNB-Grid – a generic framework for implementing global optimization algorithms in Grid.

Introduction

In a most general setting the global optimization problem is stated as follows: given a function f and a subset G of a domain of a function f, find x_0 from G such that: $f(x_0) = \min f(x), x \in G$. Depending on the function f and a subset G the problem may be classified as belonging to one of several optimization problem families, e.g. if G is finite the problem is called a *discrete optimization problem*.

Global optimization problems frequently appear in various practical applications: computational chemistry, biology, market analysis, cryptography. Therefore developing efficient methods for solving such problems is very important. One of the main difficulties in global optimization is the huge computational resources required for locating global optima for majority of problems. Hence involving supercomputers and even Grids is highly desirable.

The Grid is a generic concept denoting an infrastructure for harnessing power of several computing and storage nodes interacting via some global network (usually Internet). Nodes may differ in performance and architecture and may be located in virtually any point in the world. Computers comprising the Grid may vary from workstations to high-performance clusters supercomputers or storage servers. The wording *distributed computing* is in principal denote the same notion as Grid. Though there are some subtle differences in the sequel we will use these terms interchangeably.

In some respects Grids are very similar to parallel systems: both operate on a number of independent interacting nodes. However despite significant similarities parallel and distributed computing have fundamental differences summarized in Table 1.

Table 1

Feature	Parallel system	Grid
Interconnect	Highly efficient with low latency and high bandwidth.	Relatively slow connection.
Nodes	Normally have similar architecture and performance.	Heterogeneous.
Availability (ability to perform computations)	The set of nodes assigned to an application is not changed during the computations.	Nodes may join or leave the computational space in virtually any moment during the application execution.

For execution on parallel and distributed systems the initial task should be decomposed into a number of subtasks. This phase is known as *decomposition*. The subtasks may share work with each other. The sharing policy is controlled by *load-balancing strategy*. The differences in parallel and distributed systems architectures summarized in the Table 1 imply differences in both decomposition and load-balancing. The relatively slow data transfer rate give an advantage to algorithms with coarse-grain decomposition i.e. when subtasks are large. It is desirable that the decomposition is done in accordance with computing power of nodes. Otherwise the performance may degrade because powerful nodes run out of work while the weak nodes complete their subtasks. The latter problem can be partially solved by a good load-balancing strategy. Unlike parallel systems distributed systems require load balancing strategies sensible to heterogeneity in performance of computing nodes and relatively slow data transfer rate.

Another important issue is the reliability of computations. As already mentioned in a distributed system nodes may join or leave the computing space at virtually any moment. Therefore a reliable distributed application should be able to cope with such situations.

Lots of numerical algorithms are suitable for running in a distributed environment. Examples of such algorithms are *branch-and-bound methods*. The generic branch-and-bound optimization algorithm works as follows:

1. Initial problem is put in the problem pool.
2. If the pool is not empty then take one problem from a problem pool and either prune it or decompose. If the pool is empty then finish the search.
3. If the problem was decomposed the resulting sub-problems are put into the problem pool.
4. Go to the step 2.

Pruning is based on a set of pruning rules which are specific to a concrete problem. Along the search the so-called *incumbent solution* which is the best solution found so far is maintained. Periodically a feasible solution is searched for problems taken from a pool. This solution replaces the incumbent solution if it has a better objective value. So far lots of methods from branch-and-bound family were developed for different kinds of global optimization problems.

Branch-and-bound methods perfectly suit for implementation in a distributed environment. Indeed splitting problems from a pool at the step 2 suggests a natural decomposition of work among computing nodes: the generated sub-problems may be processed independently. Though the idea is very simple the careful implementation is far from being an easy task. The major difficulties arise from a different complexity of generated problems. Moreover the amount of computational resources needed for a concrete sub-problem is not known before the problem is completely solved. Hence modern distributed branch-and-bound implementations employ sophisticated load-balancing strategy aimed at coping this issue.

An overview of distributed implementations of branch-and-bound methods

The FATCOP [1] system is aimed at solving mixed-integer programming problems in the Condor [2] environment. Condor allows running distributed computations on the idle workstations in a local network. FATCOP uses Condor infrastructure for process creation and Condor-PVM for interaction among different process. The computational process is organized in a *master-worker paradigm*. At the beginning of computations the master process is started on one of computing nodes, performs several steps of a branch-and-bound method and generates a pool of sub-problems. If new node is freed and may be added to the computing space the master process starts a worker-process on it and assigns it a problem from a pool. The

master process also assigns a problem from a pool to worker process if the process has completed its task. The worker process task consists in decomposing the problem into sub-problems and calculating bounds for generated sub-problems. After that generated sub-problems are sent to master-process which put them to the pool. In order to handle node failure the master process backs up sub-problem sent to a node: if this node fails to complete the assigned task the task is reassigned to another node. Such mechanism is standard and is widely used in different distributed branch-and-bound implementations.

Another project GRIBB (Great International Branch-and-Bound Search) [3] is aimed at solving problems with branch-and-bound approach in the Internet. In principle any computer featured with Java run-time environment may be a computing node. The node interaction is implemented on the top of Java-RMI. At the beginning of computations the master node generates several tasks. The free node takes a problem from master, solves it to the end, sends to the master the improved solution and takes another sub-problem from the master. Such simple load-balancing may work well for some kind of problems which admit coarse-grain decomposition. The authors demonstrate experimental results obtained for a large quadratic assignment problem.

More sophisticated approach to load-balancing is considered in [4]. The node running out of work issues simultaneously two queries for new tasks: one (local) within the local network and another (global) to nodes in other segments. The local query may complete while the global query is processed. Such an approach may reduce the time needed for finding tasks.

The hierarchical load balancing scheme is proposed in [5]. The supervisor process manages a set of master process. Each master process manages a set of worker processes. Only worker processes perform computations while the master and supervisor processes are responsible for work distribution. The supervisor process tracks the load of master processes and periodically transfers tasks from one master process to another in order to make their load maximally equal. The master process sends and receives tasks from and to work processes. All worker processes belonging to one master are located in the same local network segment. In this approach the global traffic is minimized.

The BNB-Grid architecture

The BNB-Grid is a programming infrastructure for solving optimization problems with branch-and-bound method in a distributed computing environment. As already noted the distributed computing environment is characterized by the following issues:

1. computing nodes may have different architecture and significantly differ in performance;
2. a computing node may not be available all the time along the computation: it may join or leave the system at an arbitrary moment;
3. computing nodes are connected via Internet or Intranet: links may be relatively slow and an access may be secured.

The approaches based on "Grid"-MPIs (MPICH-G2, PACX etc.) are unacceptable because of three reasons. First these versions of MPI do not efficiently cope with issue 2 listed above: there is no a reliable mechanism to handle occasional failure of one of computing nodes. Second MPI is not a best platform for shared-memory systems. Third, setting up a Grid-enabled version of MPI and its integration into a particular batch-system requires administrative privileges. That may not be feasible on a large system running in a production mode (like publicly available supercomputers). The completely distributed approach based on some Grid middleware like Condor or Globus Toolkit faces similar difficulties with administrative privileges. Second the comprehensive utilization of computing resources of a given node is

difficult: for shared memory machines tools based on threading technologies are better and on HPC clusters the conventional MPI is the best solution.

Hence that we use another approach: on a particular computing element the tool most appropriate for it is used and for global interaction among computing element the IARnet [6] environment for integrating distributed computing resources is used. For instance if the computing space consists of say two supercomputers then MPI might be used on both while IARnet is used for transferring data between them. This is done with the help of BNB-Solver [7] library which is portable among different architectures.
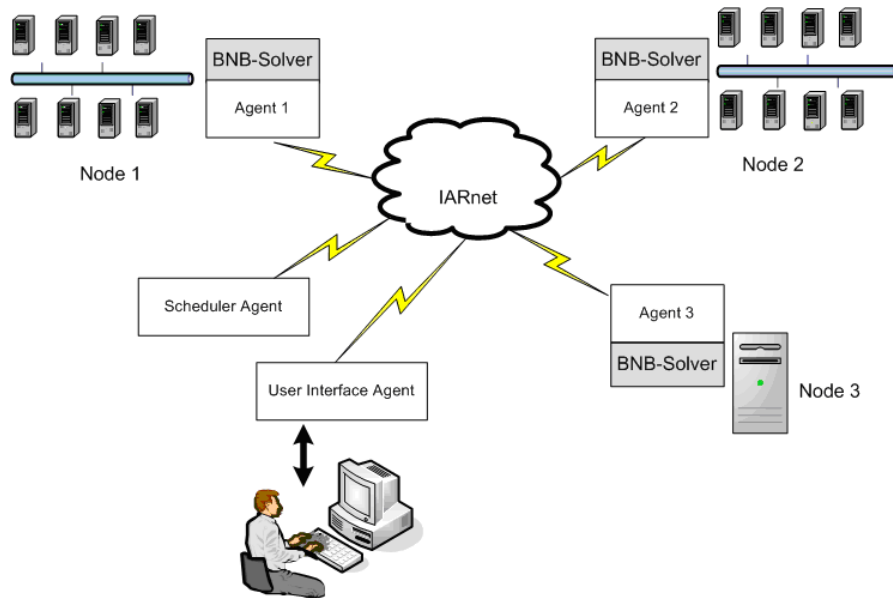
Fig. 1. The structure of the BNB-Grid application

From the outside the computing node is visible as an IARnet resource (IAR). Different IARs cooperate via IARnet. This structure is depicted at the Fig. 1. A sample distributed system consists of three nodes: nodes 1 and 2 are multiprocessor systems while node 3 is a workstation. Each computing node runs a BNB-Solver [7]: a branch-and-bound solver targeted at uni- and multi-processor systems. The BNB-Solver is represented in a system as an IAR through an agent (agents 1,2,3 in the case under consideration). Besides agents representing computing nodes there are also the scheduler agent and the user interface agent. The former manages work distribution among computing nodes. The latter handles the user input and allows the user to load problem type and data, manage the distributed environment and control the search process.

During the search computing nodes may join or leave the distributed system at virtually arbitrary moment. It may happen because nodes are turned on and off or because of batch system running on HPC cluster introduces delays in starting the BNB-Solver application or terminates it before the computation is completed. To cope with this issue BNB-Grid backs up tasks sent to a computing node agent and if the computing node fails the tasks are rescheduled to other nodes.

The branch-and-bound is a generic scheme for many algorithms in global optimization. Therefore it is wise to develop a generic framework suitable for implementing any optimization algorithm based on branch-and-bound scheme. This is exactly what is done in BNB-Grid: the overall architecture and interaction protocols are made independent of a con-

crete problem while the problem specific part is hide into BNB-Solver. In its turn BNB-Solver provides support for different sorts of optimization problems.

Experimental results

Computational experiments were run on a system consisting of a central workstation at Institute for systems analysis of Russian academy of sciences and two HPC clusters: MVS 15000BM and MVS 6000IM located at Joint Supercomputer Center and Computational Center of Russian academy of sciences respectively. Both clusters contain CPU nodes of approximately same performances on the considered kind of problems.

The following knapsack problem instance was selected for experiments: $\sum_{i=1}^{30} 2x_i \rightarrow \max$, $\sum_{i=1}^{30} 2x_i \leq 31$, $x_i \in \{0,1\}, i = 1,2,...,30$. This problem is known as a hard one: the number of vertices in the search tree is 601080389. Three configurations were tried. The average running times obtained from several runs are given in the Table 2.

Table 2. Running times for different configurations

#	Description:	Running time:
1	8 CPU MVS 15000 BM	5.57 minutes
2	8CPU MVS 6000 IM	6.03 minutes
3	8 CPU MVS 15000 BM + 8 CPU MVS 6000 IM	3.15 minutes

The simple stealing-based scheduling policy was used: when one node runs out of work the given number of sub-problems is "stolen" from the other node. Experimental results show that even with this simple scheduling policy remarkable speedup could be obtained. However for some problems the speedup is much less than the theoretically estimated. This is the subject for future research to improve the scheduling policy.

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3D B-spline approximation of magnetic fields in high energy physics experiments

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Abstract

   A problem of the magnetic fields description for high energy physics experiments is considered. As an example we present a three-dimensional B-spline approximation of the magnetic field in the working region of the CBM dipole magnet. Such an approximation allows one both to calculate accurately the values of the magnetic field in each point of the working region and to determine the derivatives of the magnetic field components up to the third order. This provides a possibility to use high-accuracy numerical methods for approximation of a charged particle trajectory in the inhomogeneous magnetic field.

   In this paper we consider a numerical problem of the three-dimensional (3D) magnetic field approximation. This is a typical problem not only for the CBM experiment [2], but for many experiments in high energy physics where one deals with a track fitting task. It arises in solving the motion equations of charged particles in the magnetic field. In practice, we deal with a non-homogeneous field known from field measurements or from mathematical calculations on some set of points. The problem of continuation of the field is usually solved by applying the piece-wise linear node functions. However, such field approximations provide neither only the existence of high-order derivatives of the field nor even the existence of first derivatives. The presence of high-order derivatives is very important when we apply high-accuracy numerical methods for solving the motion equation. These methods provide a good convergence of numerical solutions to continuous ones only in the case of existence of corresponding derivatives of the field. The best approach for continuation of the differentiable field is the spline approximation method. In this paper we discuss the application of B-spline methods [1] for description of magnetic fields in the CBM experiment.

   Let us consider a general problem of three-dimensional B-spline approximation of a function $f(u,v,t)$ in rectangular region $\Omega = [U_1, U_2] \times [V_1, V_2] \times [T_1, T_2]$. Let $\{u_k, k = \overline{1,K}\}$, $\{v_l, l = \overline{1,L}\}$, $\{t_m, m = \overline{1,M}\}$ be sets of nodes for variables u, v, t. We suppose that

$$u_k < u_{k+1}, \quad v_l < v_{l+1}, \quad t_m < t_{m+1};$$

and

$$u_1 = U_1, \quad u_K = U_2, \quad v_1 = V_1, \quad v_L = V_2, \quad t_1 = T_1, \quad t_M = T_2.$$

Let $\{f^{k,l,m}\}$ be

$$f^{k,l,m} = f(u_k, v_l, t_m), \qquad k = \overline{1,K}, l = \overline{1,L}, m = \overline{1,M}.$$

   The B-spline approximation procedure includes three steps. At first, we define $L \times M$ B-spline approximation functions $\mathcal{F}(u, v_{l_0}, t_{m_0})$ for all $\{l_0, m_0, l_0 = \overline{1,L}, m_0 = \overline{1,M}\}$ on the base $\{f^{k,l_0,m_0}, k = \overline{1,K}\}$. We use B-spline node functions of the third order. We also add two additional nodes u_0, u_{K+1} and two additional equations for the boundary derivative values to exclude the indefinition in the B-spline constructing. Then on the interval $[U_1, U_2]$ the function $\mathcal{F}(u, v_{l_0}, t_{m_0})$ may be expressed

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$$\mathcal{F}(u, v_{l_0}, t_{m_0}) = \sum_{k=0}^{K+1} a_{k,l_0,m_0} f_k(u), \tag{1}$$

where $f_k(u)$ is the node function associated with the node x_k. It should be noted that the function $\mathcal{F}(u, v_{l_0}, t_{m_0})$ has a third derivative and a continuous second derivative as a function of u. After this we repeat the procedure for variable v. For all $\{k_0, m_0, k_0 = \overline{0, K+1}, m_0 = \overline{1, M}\}$ on the base $\{a_{k_0, l, m_0}, l = \overline{1, L}\}$ we get a set of coefficients $\{b_{k_0, l, m_0}\}$. For all $\{m_0 = \overline{1, M}\}$ in rectangular region $[U_1, U_2] \times [V_1, V_2]$ the function $\mathcal{F}(u, v, t_{m_0})$ may be expressed

$$\mathcal{F}(u, v, t_{m_0}) = \sum_{k=0}^{K+1} \sum_{l=0}^{L+1} b_{k,l,m_0} f_k(u) g_l(v), \tag{2}$$

where $g_l(u)$ is the node function associated with the node v_l.

The last step for variable t will give us a set of coefficients
$$\{c_{k,l,m}, k = \overline{0, K+1}, l = \overline{0, L+1}, m = \overline{0, M+1}\}.$$

As a result, we have the following approximation $\mathcal{F}(u, v, t)$ of the function $f(u, v, t)$

$$\mathcal{F}(u, v, t) = \sum_{k=0}^{K+1} \sum_{l=0}^{L+1} \sum_{m=0}^{M+1} c_{k,l,m} f_k(u) g_l(v) h_m(t), \tag{3}$$

where $h_m(t)$ is the node function associated with the node t_m. By differentiating this equality, one can get the approximation of the derivatives of the function $f(u, v, t)$ up to the third order as a function of u, v, t.

It is very difficult to construct for some magnets the differentiable field approximations using only Cartesian coordinates. One can see 3D models of inclined magnets on Figs. 1-3. These magnets are considered as possible variants of the dipole magnet for the CBM experiment. The inclined poles version is also very popular for separator magnets. That is why we adopt the approach considered above for this case.

It is impossible to apply directly the above scheme for such type magnets. In this connection, we use special variables for the field description. Let **O** be the place of a target, see Fig. 4. Let the axes **Oz**, **Oy** be the direction of the beam and the ray perpendicular to the median plain of the dipole magnet. We define the axis **Ox** as a perpendicular line to the axes **Oz** and **Oy**. Let Ψ be the angle between the plain passing through the point $\mathbf{a} = (x_a, y_a, z_a)$, the axis **Ox** from one side and the median plane **Oxz** on the other side. We have

$$y_a = tan(\Psi) z_a. \tag{4}$$

Let Ψ_{max} be the acceptance of the magnet in the plain **Oyz**, $\pm X_{max}$ and $\pm Z_{max}$ be the maximum deviations for coordinates x_a, y_a, correspondingly. Then, we can use new variables $\{\Psi, X, Z\}$ which belong to the rectangular region

$$\Omega = [-\Psi_{max}, \Psi_{max}] \times [-X_{max}, X_{max}] \times [-Z_{max}, Z_{max}]$$

for field components $\{\mathbf{B_i}\}$ description:

$$\mathbf{B_i}(\Psi, x, z) = \sum_{k=0}^{K+1} \sum_{l=0}^{L+1} \sum_{m=0}^{M+1} c_{k,l,m}^i f_k(\Psi) g_l(x) h_m(z). \tag{5}$$

We have the inclination of the magnet working region in the plane **Oyz** only here, but one can see the magnet with the inclination in two planes **Oyz** and **Oxz** in Fig. 5. Let Φ be

the angle between the plain passing through the point $\mathbf{a} = (x_a, y_a, z_a)$, the axis $\mathbf{Oy}$ and the plane $\mathbf{Oyz}$, see Fig. 6. We have

$$x_a = tan(\Phi)z_a. \tag{6}$$

Let Ψ_{max} be the acceptance of the magnet in the plane $\mathbf{Oyz}$, Φ_{max} be the acceptance of the magnet in the plane $\mathbf{Oxz}$, and $\pm Z_{max}$ be the maximum deviations for coordinate z_a. Then we can use new variables $\{\Psi, \Phi, z\}$ belonging to the rectangular region

$$\Omega = \left[-\Psi_{max}, \Psi_{max}\right] \times \left[-\Phi_{max}, \Phi_{max}\right] \times \left[-Z_{max}, Z_{max}\right]$$

for field description in this case

$$\mathbf{B_i}(\Psi, \Phi, z) = \sum_{k=0}^{K+1} \sum_{l=0}^{L+1} \sum_{m=0}^{M+1} c_{k,l,m}^i f_k(\Psi)g_l(\Phi)h_m(z). \tag{7}$$

By differentiating this equality, we get the approximation for derivatives of the field components $\mathbf{B_i}$ up to the third order depending on $\{\Psi, \Phi, Z\}$.

In practice, we need the derivative not as a function of $\{\Psi, \Phi, z\}$, but depending on x, y, z. To calculate the derivatives of the function $\mathbf{B_i}$ depending on x, y, z, we can use the following equalities

$$\frac{d\mathbf{B_i}(\Psi, \Phi, z)}{dx} = \frac{d\mathbf{B_i}(\Psi, \Phi, z)}{d\Psi}\frac{d\Psi}{dx} + \frac{d\mathbf{B_i}(\Psi, \Phi, z)}{d\Phi}\frac{d\Phi}{dx}, \tag{8}$$

$$\frac{d\mathbf{B_i}(\Psi, \Phi, z)}{dy} = \frac{d\mathbf{B_i}(\Psi, \Phi, z)}{d\Psi}\frac{d\Psi}{dy} + \frac{d\mathbf{B_i}(\Psi, \Phi, z)}{d\Phi}\frac{d\Phi}{dy}, \tag{9}$$

$$\frac{d\mathbf{B_i}(\Psi, \Phi, z)}{dz} = \frac{d\mathbf{B_i}(\Psi, \Phi, z)}{d\Psi}\frac{d\Psi}{dz} + \frac{d\mathbf{B_i}(\Psi, \Phi, z)}{d\Phi}\frac{d\Phi}{dz} + \frac{d\mathbf{B_i}(\Psi, \Phi, z)}{dz}. \tag{10}$$

We have from (4) and (6)

$$\Psi = \arctan(\frac{y}{z}), \quad \Phi = \arctan(\frac{x}{z}). \tag{11}$$

It follows from here

$$\frac{d\Psi}{dx} = 0, \quad \frac{d\Psi}{dy} = \frac{z}{y^2 + z^2}, \quad \frac{d\Psi}{dz} = -\frac{y}{y^2 + z^2}, \tag{12}$$

$$\frac{d\Phi}{dx} = \frac{z}{x^2 + z^2}, \quad \frac{d\Phi}{dy} = 0, \quad \frac{d\Phi}{dz} = -\frac{x}{x^2 + z^2}. \tag{13}$$

The mixed partial derivatives of a higher order could be calculated similarly.

These procedures were used to construct a differentiable 3D B-spline approximation of the magnetic field for different types of dipole magnets for the CBM experiment.

The proposed method of the magnetic field approximation may be used for the description of wide class experiments. The 3D B-spline approximation has an advantage in comparison with the 3D cubic-spline approximation, because it permits one to decrease significantly the requirements to the computer memory for the same accuracy level.

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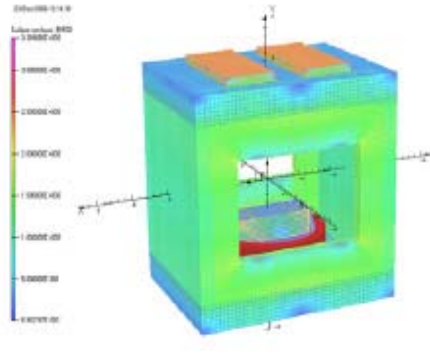
Fig. 1. 3D model of the HERA dipole magnet
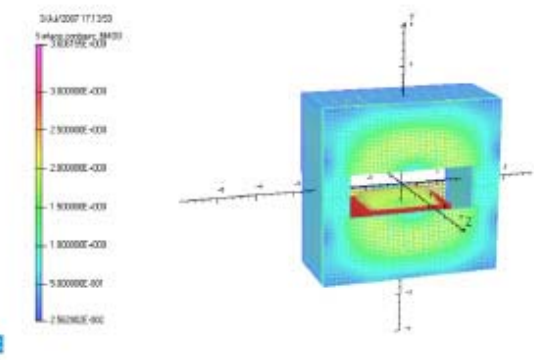
Fig. 2. 3D model of the HERMES dipole magnet
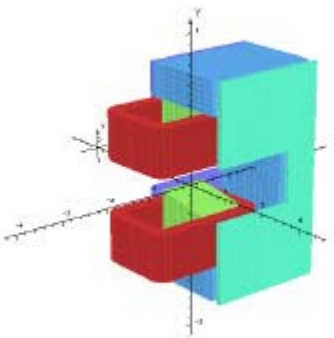
Fig. 3. Half of the HERMES dipole magnet
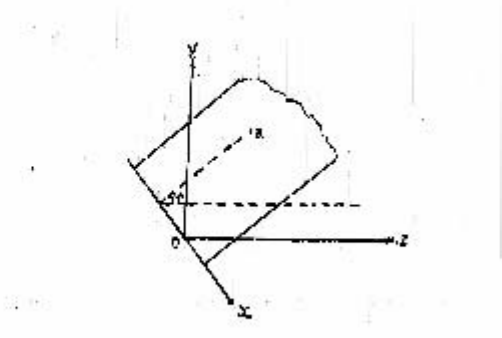
Fig. 4
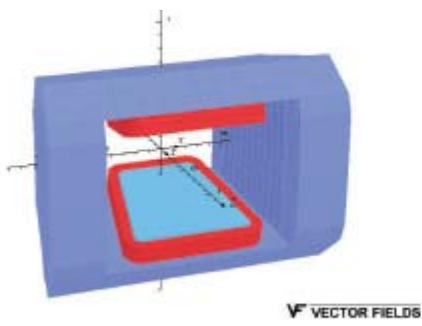
Fig. 5. 3D model of the inclined version of the CBM dipole magnet
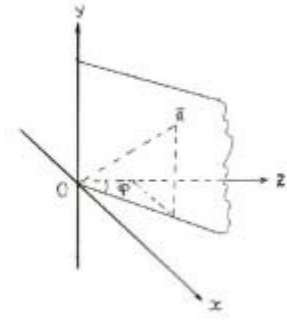
Fig. 6

3-dimensional mesh-generator for finite elements method applications

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1. Introduction

The finite elements method (FEM) [1] is one of the most effective numeric methods for solving linear and non-linear multi-dimensional scientific and technical problems. It allows modeling of systems with a complex geometry and an irregular physical structure. One of the most time-consuming steps when solving three-dimensional problems using the FEM method is building adaptive mesh. The mesh should satisfy FEM requirements, allow one to represent a complex geometry of unknown parameter areas and describe the medium interface in detail. The creation of an automated generator of the spatial mesh with a user friendly interface which is suitable for defining the calculation geometry, having visualization of incoming data and mesh quality control is a very complex and important problem [2-5]. Such type generator is a critical constituent of any large scale specialized software complex based on FEM. One of the most outstanding representatives of such generators is a mesh generator in OPERA pre-processors by Vector Fields vendor [6]. A similar automated generator of spatial mesh based on MAPPING approach [7] is considered in this article. An initial two-dimensional mesh is generated on the base plane just like this is done in OPERA. Then the mesh is extended into space keeping the topological structure. In this generator in order to improve the quality of the mesh, a library of standard fragmentations is used for triangular macro elements fragmentation on the base plane. A graphical interface for defining incoming geometry is created. Visual control of the quality of the mesh generation is also available.

2. Approach

There are specific requirements for two- and three- dimensional mesh which is used in FEM. The mathematical problem is formulated as follows: let's assume there is a simply connected domain $\Omega \subset R^3$. There is a polyhedron $\tilde{\Omega}$ which approximates Ω. We need to present $\tilde{\Omega}$ as an aggregation of a finite number of N_0 polyhedrons S_i ($\breve{\Omega} = \bigcup\limits_{i=1}^{N_0} S_i$), which meet the following conditions:

1) $\mu(S_i \cap S_j) = 0$, if $i \neq j$, i.e. the measure of different polyhedrons intersection is equal to zero.

2) The vertex of one polyhedron cannot be inside the points of facet or inside the edges of the other polyhedron, i.e. if two polyhedrons intersect they intersect either by a whole edge or by a whole facet or by just one vertex.
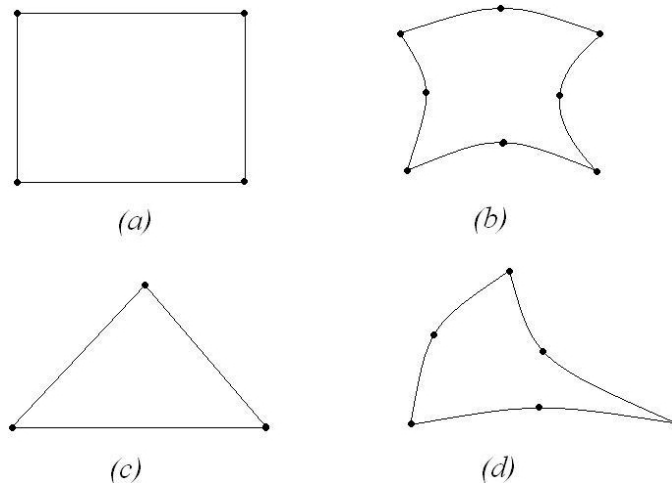
Fig.1. The fundamental two-dimensional elements

In general, if isoperimetric elements are used, their pre-images satisfy these requirements. In order to build a three-dimensional mesh, we use the approach in which primary two-dimensional mesh is built on the base hyperplane. After that the two-dimensional mesh is projected from the base hyperplane through space onto the next hyperplane keeping the topology, then it is projected to the next hyperplane and so on. Triangle and quadrangle elements or their topological analogues on the base plane are used as fundamental two-dimensional elements in this generator (Fig.1). This generates hexahedrons and triangular prisms or their isoperimetric analogues in the three-dimensional space.

To extend the three-dimensional mesh from two dimensional hyperplane into space serendipity family elements [1] are used (Fig.2).
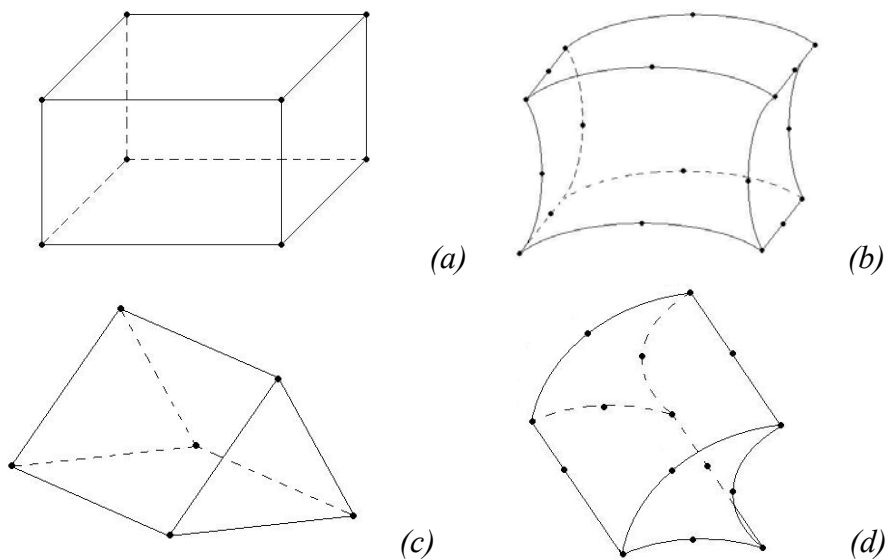
Fig.2. The fundamental three -dimensional elements

Firstly to simplify the algorithm and to define incoming data a coarse mesh is generated. On the second step the coarse mesh is refined if required. This results in a need for automatic algorithms for fragmentation of large macro elements into smaller microelements which will meet FEM requirements. Let F be the operator which transforms a standard element into the initial element. Firstly the process of fragmentation is done on a standard

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element. Let $\{S_i\}$ be microelements of a standard element fragmentation. Then $\{F(S_i)\}$ is the fragmentation of the initial element. There are certain limitations in terms of defining the number of partitions on the edges of macro quadrangles and macro triangles in this version of the program. For quadrangles the number of partitions on the opposite sides should be equal. On one hand, this allows one to build fast and effective algorithms for fragmentation of the base quadrangle. On the other hand this leads to a requirement to have the same number of partitions on the edges of elements which are topologically connected with the initial element. The library of standard fragmentations is used in this generator in order to improve the quality of triangle fragmentation which allows one to have an unrestricted number of partitions on the sides.

3. Generation of three-dimensional mesh

There are three major steps during the mesh generation. The first one is the generation of a base hyperplane. The second one is the extension of the built two-dimensional mesh into the following hyperplanes. The third one is a fragmentation of the initial three-dimensional mesh to meet the user defined requirements.

Working with the program starts with defining the base hyperplane. All the following actions on the first step will be done on this plane. There are 3 ways to define the input geometry. These are defining the points in text mode, defining the points in interactive mode using mouse pointer and defining the points as crossings of curves which have been built. The program has a feature for drawing functional graphs (straight lines and circles) both using equations and point by point definition.
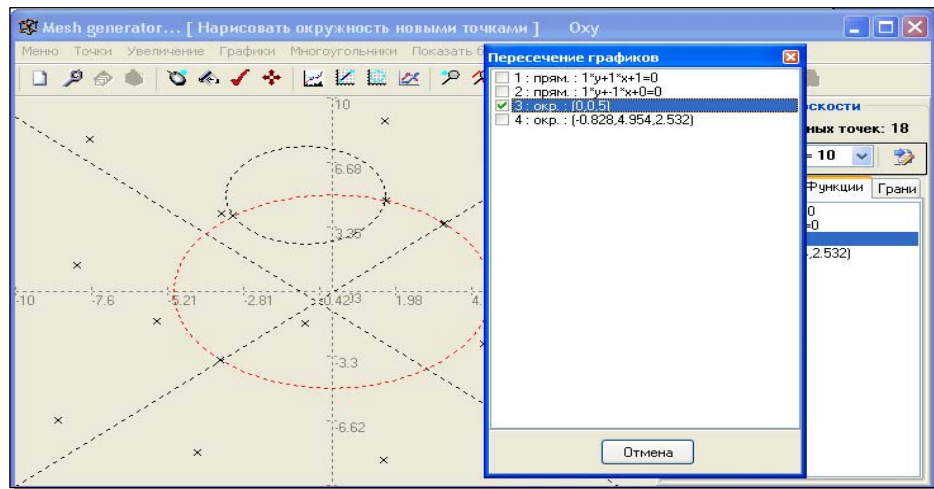
Fig.3. The mesh generator panel

The Fig.3 represents a generator panel which is the incoming interface for work with the program on this stage. There are several ways to change the point coordinates – changing coordinates in a text mode, moving the point using a mouse pointer, projection of a group of points onto the graph, parametrical change of coordinates for a group of points, rotation of a group of points around a fixed point at a defined angle. Once the points are defined, they are grouped into two-dimensional elements (Fig.1) using the pointer. Functionality is available for both deleting two-dimensional elements which have been created and for creating new elements.

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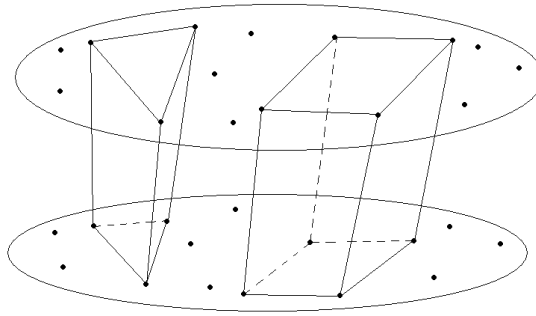
Fig. 4. Creation of three-dimensional macro elements
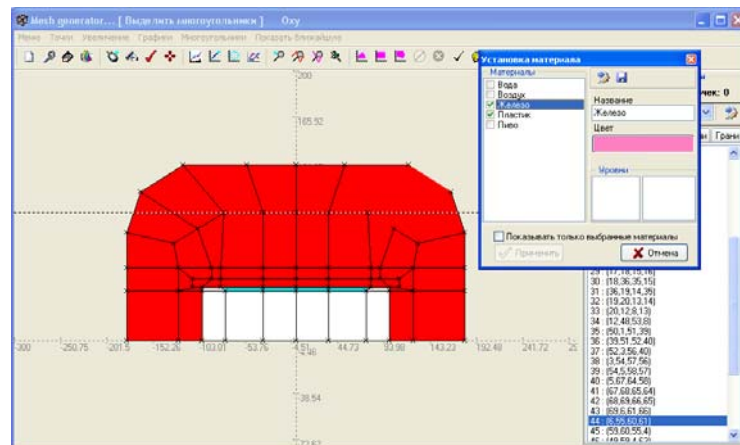
Fig. 5. The property representation panel

The next step in the mesh generation is the creation of three-dimensional macro elements (Fig.2). Points from the base hyperplane are extended into space keeping the topology of the already built two-dimensional elements until they reach the next hyperplane (Fig.4). Then they are extended to reach the next hyperplane and so on. The point coordinates can be changed not only within each hyperplane but also along the plane normal. During the elements generation (Figs. 2b, 2c) an additional intermediate hyperplane is used.

Once the second step of mesh generation is finished, all created macro elements can be broken down into groups in accordance with their properties (i.e. various material type filling in the elements, the difference in equations, the difference in coefficients, etc.) You can mark macro elements with various colors according to their properties (Fig.5). You can visually control the coarse mesh which is built, observation point as well as observation angle can be changed (Fig.6).

On the last step of generation a fragmentation of the coarse mesh which has been built, is performed in accordance with predefined requirements. The user defines a fragmentation number for each edge of every two-dimensional element of the base hyperplane. The fragmentation number will be the same for all topologically equal edges on the other hyperplanes, which were created via translation in the space of the base hyperplane. It should be noted that there are certain limitations in this version of the generator in terms of edges fragmentation. In particular, for all opposite edges of two-dimensional quadrangles the same fragmentation number should be defined. The user should also define the number of layers into which space is divided by any two hyperplanes. Macro elements fragmentation (Fig. 2) is done in the following manner. Let G be an etalon cube, which is a pre-image of the

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considered tree-dimensional macro element (S=F(G)). Initially, the etalon cube is broken down into micro elements by planes which are parallel to facets. So, macro element S will be broken down into microelements $\{S_i\}$ ($S_i = F(G_i)$). A similar approach is applied to triangular prisms (Figs. 2d, 2c). In the two-dimensional case firstly the initial triangle which is a pre-image to the considered macro element is broken down. A library of standard fragmentations is used to improve the quality of the fragmentation. Examples of various standard fragmentations for triangles are given in Fig.7. Both triangles and quadrangles are used for fragmentation (Fig.8).
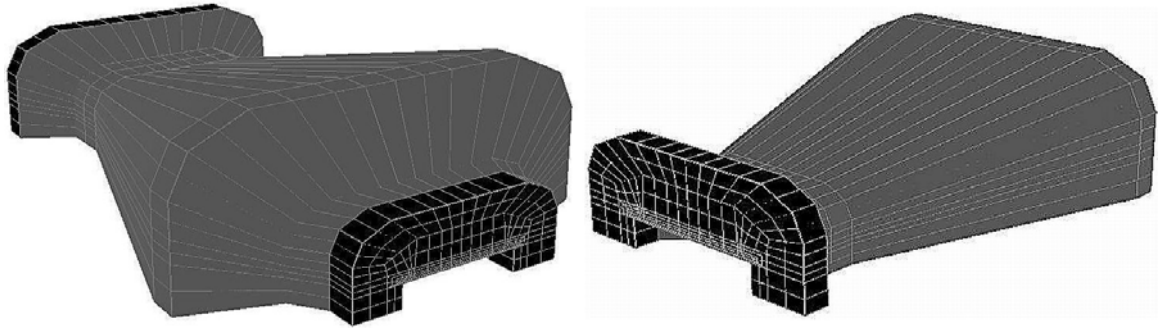
Fig.6. Change of observation point and angle
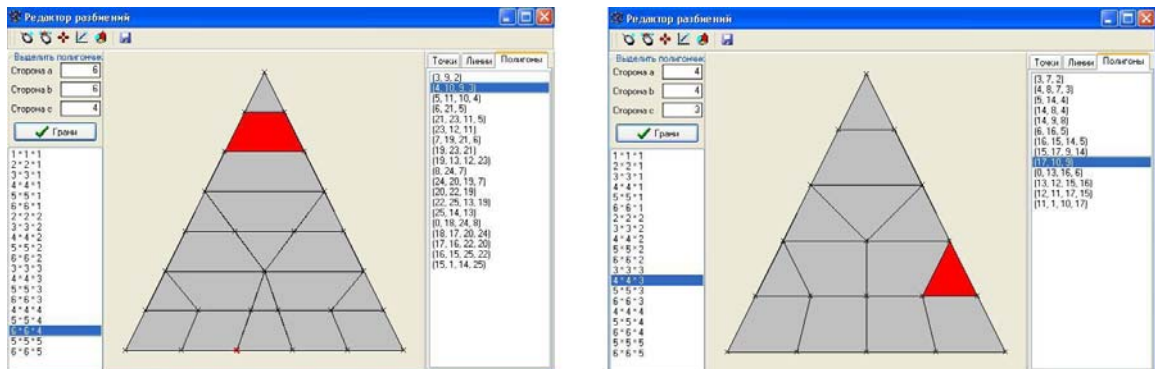
Fig.7. Fragmentations for triangles
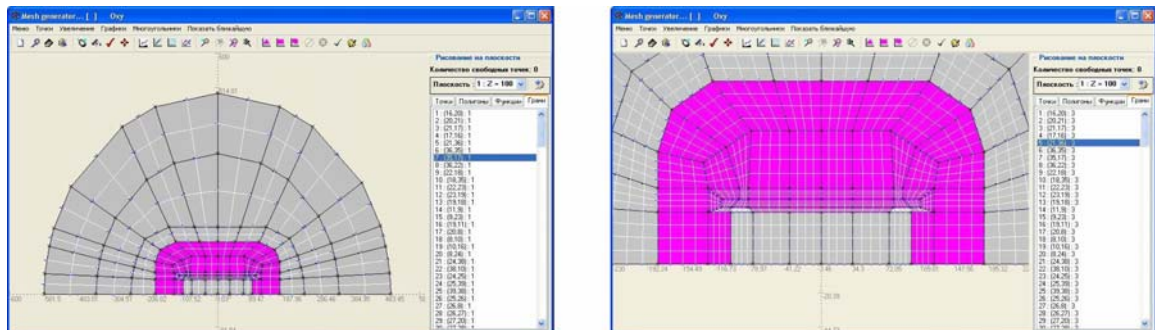
Fig.8. Fragmentation on the base hyperplane for the dipole magnet

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4. Conclusion

This article gives a description of the automatic generator of spatial mesh, which satisfies the requirements defined for finite elements method fragmentations. Such type generators are normally included as a module of large scale expensive commercial software, which is based on finite elements formulation of the solving problems. The described mesh generation method is similar to the existing ones. However, certain distinctions should be outlined. In particular algorithms for fragmentation of macro blocks into micro blocks are improved via creating a database of standard fragmentations. A user-friendly interface for defining input geometry is created. Visual control on all stages of generation is available. In particular the quality of the final fragmentation can be visually controlled. The proposed generator can be used as a preprocessor for solving a large spectrum of problems which are based on the finite elements method.

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Comparative analysis of statistical criteria for e/π identification applying the CBM TRD

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Abstract
Two approaches for charged particles (electron/pion) identification using the Transition Radiation Detector (TRD) in the CBM experiment are considered. Both approaches are based on the measurements of ionization loss of a charged particle and energy deposition of the X-rays in the n-layered TRD. The first approach deals with a method of the likelihood functions ratio. The second one is based on a successive application of two statistical criteria: 1) the mean value method, and 2) the ω_n^k test. A comparative analysis of these approaches is presented. The data used in this study are the measurements of energy deposits in the TRD prototype obtained during the test-beam in the GSI, February 2006.

1. Introduction

The CBM Collaboration [1,2] builds a dedicated heavy-ion experiment to investigate the properties of highly compressed baryon matter as it is produced in nucleus-nucleus collisions at the Facility for Antiproton and Ion Research (FAIR) in Darmstadt, Germany.
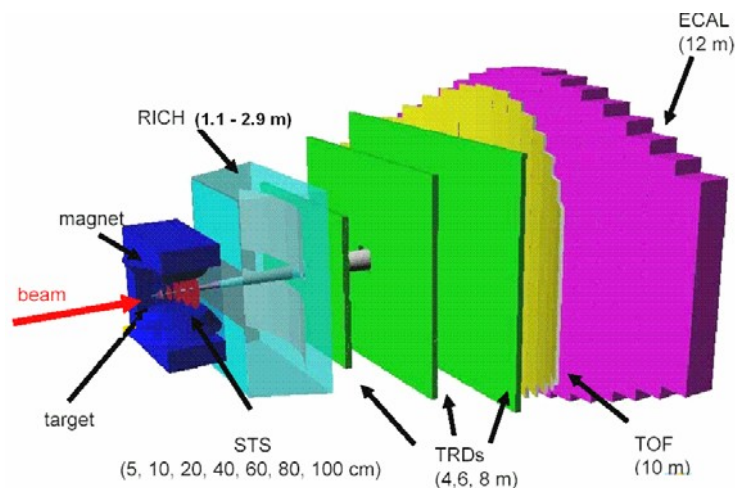
Fig. 1. CBM general layout

Figure 1 depicts a present layout of the CBM experimental setup. Inside the dipole magnet gap, there are a target and a 7-planes Silicon Tracking System (STS) consisting of pixel and strip detectors. The Ring Imaging Cherenkov detector (RICH) has to detect electrons. The Transition Radiation Detector (TRD) arrays measure electrons with momentum above 1 GeV. The Time of Flight (TOF) detector consists of Resistive Plate Chambers (RPC). The Electromagnetic Calorimeter (ECAL) measures electrons, photons and muons. The CBM setup is optimized for heavy-ion collisions in the beam energy range from about 8 up to 45 AGeV.

The TRD must provide both the electron identification in conditions of intensive background caused by pions and tracking of all charged particles. It has to provide, in conjunction with the RICH and the electromagnetic calorimeter, a sufficient electron identification capability for the measurements of charmonium and low-mass vector mesons.

The required pion suppression is a factor of about 100 and the needed position resolution is of the order of 200-300 μ m. To fulfill these tasks, in the context of high rates and high particles multiplicities in the CBM, a careful optimization of the TRD is required.

In the technical proposal of the CBM experiment, the preliminary results on the estimation of the electron identification and pions suppression applying a likelihood functions ratio test were presented(see details in [2]). The application of this test requires a very accurate determination of density functions of energy losses both for pions and electrons (see details on page 87 in [2]).

Recently the measurements of energy deposits for pions and electrons in one layer TRD prototype were realized during the test-beam in the GSI (February, 2006). The analysis of these measurements permitted us to found the forms of functions which with a high accuracy describe the statistical distributions of energy losses in TRD layers both for pions and electrons. This provided a possibility to construct correct density functions of energy losses for given particles and, as a corollary, to be confident that the calculated value of the likelihood test is correct.

Taking into account that this criterion is the most powerful among all possible statistical criteria (see, for instance, [3]), it is very important to get an estimate of the method for this specific problem, especially based on real measurements.

In addition, we propose another approach which presents a combination of two statistical criteria and is more simple and efficient from a practical viewpoint.

2. Distributions of e/π energy losses in the TRD

A major part of detecting J/ψ meson in its dielectron decay channel is the electron/pion separation. A schematic view of the TRD with n layers to be used for solution of this problem is shown in Fig. 2.
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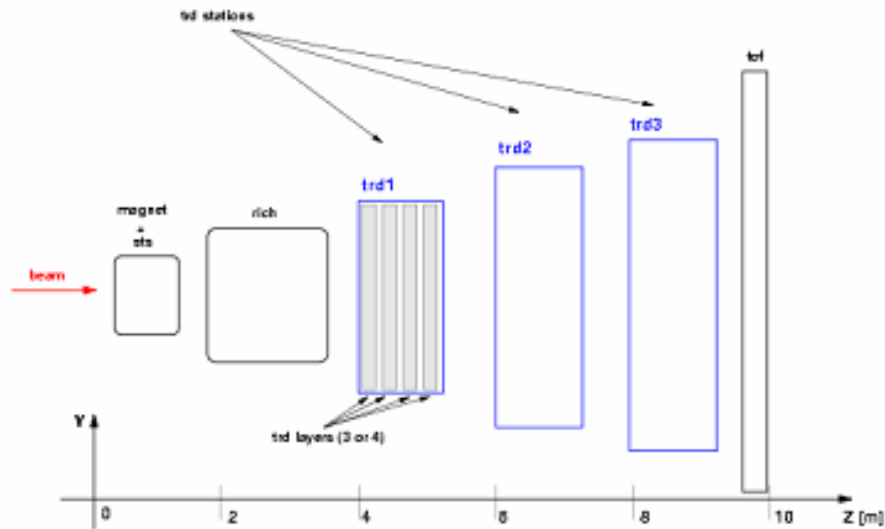
Fig. 2. Schematic view of the TRD

Figure 3 shows the measurements of ionization losses (dE/dx) for pions (top plot) and electrons (bottom plot), including energy losses on the transition radiation, in a one-layer TRD prototype: beam-test in GSI, p = 1.5 GeV/c, February 2006.
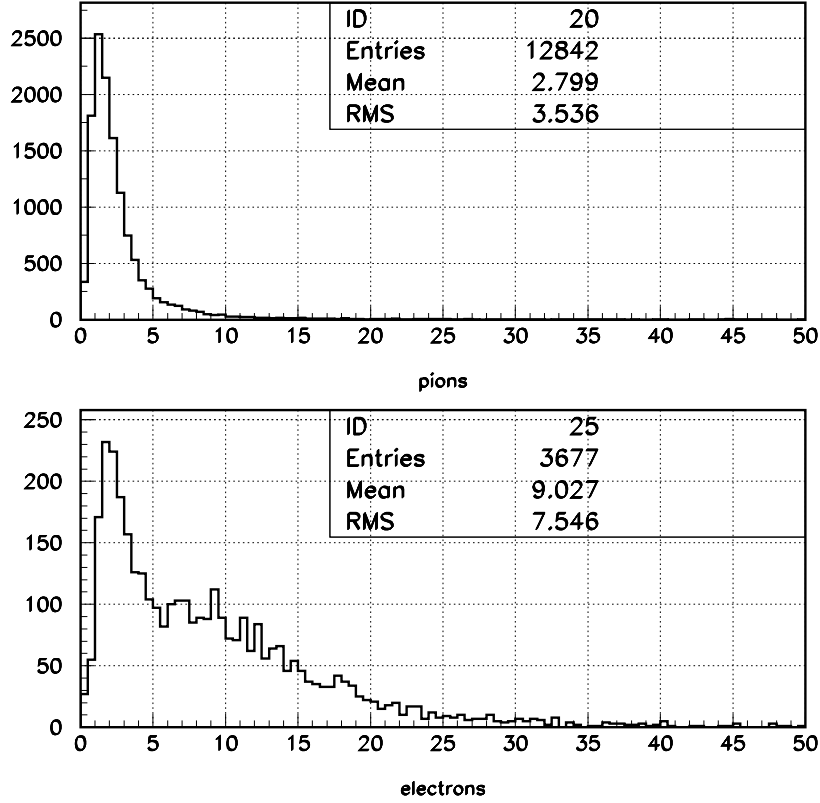
Fig. 3. Distributions of energy losses of pions (bottom plot) and electrons (top plot), including the transition radiation, in the TRD prototype: $p = 1.5$ GeV/c

These measurements have been used for simulation of energy losses by electrons and pions during their passing through the n-layered TRD shown in Fig. 2.

In order to prepare a set of n "measurements" of energy losses corresponding to a particle (electron/pion) passing through n layers of the TRD, we used the subroutine HISRAN [4] which permits to generate random values in accordance with a given distribution. The distributions related to electrons and pions were supplied in the form of histograms (Fig. 3) using the subroutine HISPRE [4] (once for each histogram).

A uniform random number is generated using RNDM [5]. The value of this number is then transformed to the user's distribution applying a cumulative probability distribution constructed from the user's histogram.

3. Method of likelihood functions ratio

In the first approach, a method of ratio of likelihood functions is used for particles identification: see, for example, [3,6].

While applying the likelihood test to the problem considered, the value [7]

$$L = \frac{P_e}{P_\pi}, \qquad P_e = \prod_{i=1}^{n} p_e(\Delta E_i), \qquad P_\pi = \prod_{i=1}^{n} p_\pi(\Delta E_i), \tag{1}$$

is calculated for each set of energy losses, where $p_\pi(\Delta E_i)$ is the value of the density function p_π in the case when the pion loses energy ΔE_i in the i-th absorber, and $p_e(\Delta E_i)$ is a similar value for electron.

In order to calculate correctly the value of variable L, it is necessary to construct the density functions which with a good accuracy must reproduce the distributions of energy losses of pions and electrons (see Fig. 3).

We have found that the distribution of ionizing energy losses of pions in the TRD prototype is quite well approximated by a log-normal function [3]

$$f_1(x) = \frac{A}{\sqrt{2\pi}\sigma x} \exp^{-\frac{1}{2\sigma^2}(\ln x - \mu)^2}, \qquad (2)$$

σ is the dispersion, μ is the mean value, and A is a normalizing factor (see Fig. 4).

ID	111
Entries	12842
Mean	2.799
RMS	3.536
χ^2/ndf 339.2 / 84	
P1	0.7320 ± 0.5430E−02
P2	0.6354 ± 0.6647E−02
P3	6269. ± 56.11
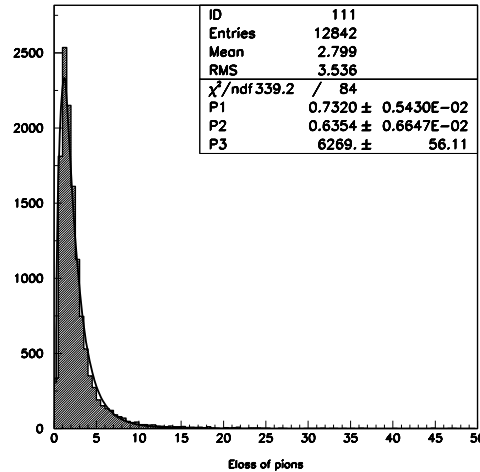
Fig. 4. Approximation of the distribution of pion energy losses in the TRD prototype by a log-normal function (2)

ID	222
Entries	3677
Mean	9.027
RMS	7.546
χ^2/ndf 96.50 / 82	
P1	0.3518 ± 0.2580E−01
P2	0.5374 ± 0.2788E−01
P3	0.9140 ± 0.4744E−01
P4	0.5884 ± 0.2635E−01
P5	0.5382 ± 0.2163E−01
P6	2.391 ± 0.2991E−01
P7	1905. ± 26.15
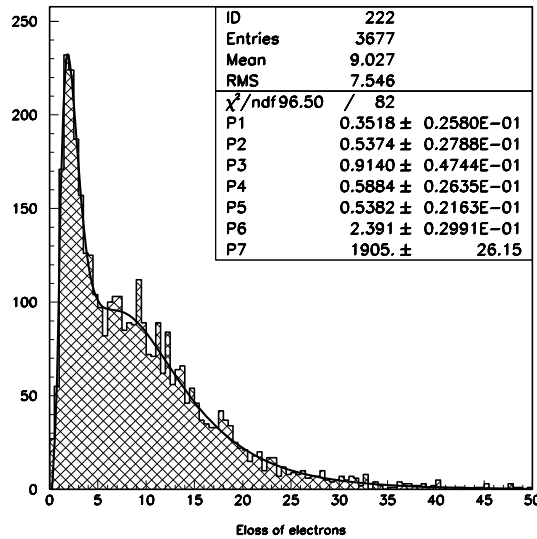
Fig. 5. Approximation of the distribution of electron energy losses in the TRD prototype by a weighted sum of two log-normal functions (3)

Our further analysis has shown that the distribution of energy losses of electrons (ionization and transition radiation) in the TRD prototype are approximated with a high accuracy by a weighted sum of two log-normal distributions (see Fig. 5)

$$f_2(x) = B\left[\frac{\alpha}{\sqrt{2\pi}\sigma_1 x}\exp^{-\frac{1}{2\sigma_1^2}(\ln x - \mu_1)^2} + \frac{\beta}{\sqrt{2\pi}\sigma_2 x}\exp^{-\frac{1}{2\sigma_2^2}(\ln x - \mu_2)^2}\right], \tag{3}$$

where σ_1 and σ_2 are dispersions, μ_1 and μ_2 are mean values, α and β are contributions of the first and second log-normal distributions, correspondingly, and B is a normalizing factor.

The expression (1) could be transformed to a more convenient, from a practical viewpoint, form

$$L_m = \frac{P_e}{P_e + P_\pi}, \tag{4}$$

where L_m changes in bounds [0,1].

The distributions of L_m in cases when only pions (top left plot) or only electrons (top right plot) pass through the TRD detector with n layers are presented in Fig. 6; the bottom plot shows a summary distribution for both particles.
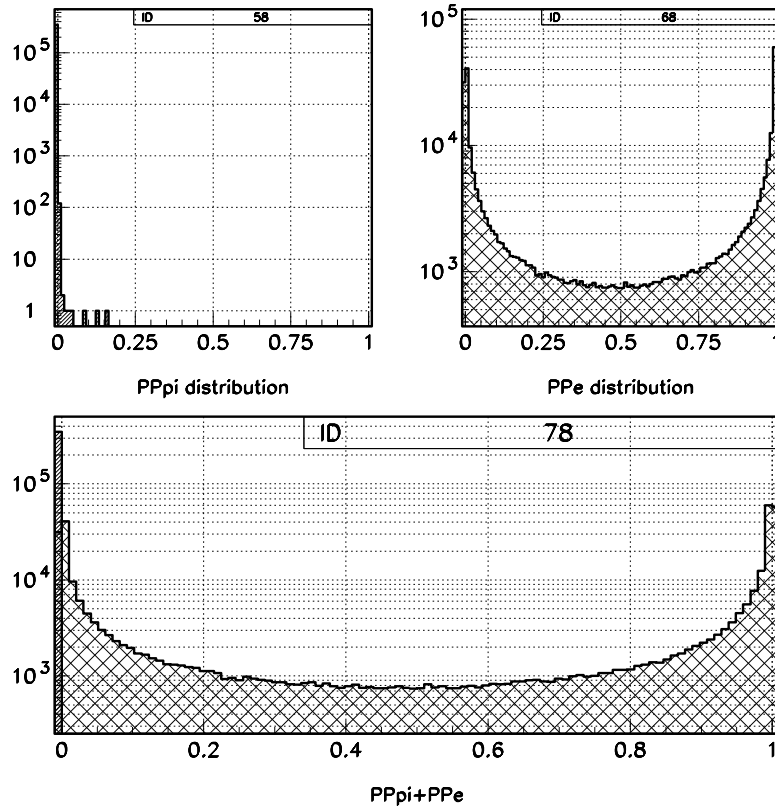
Fig. 6. Distributions of L_m in cases when only pions (top left plot) or only electrons (top right plot) pass through the TRD with $n = 12$ layers; the bottom plot is a summary distribution for both particles

The electron registration efficiency is determined by a ratio of electrons selected in the admissible region for the preassigned significance level α to part β of pions having hit in the admissible region (the second order error).

In our case α value was set approximately equal to 10%. In particular, the critical value $L_{cr} = 0.00035$ corresponds to the significance level $\alpha = 10.24\%$ thus, in the admissable region there will remain 89.76% of electrons. In this case, $\beta = 0.0274\%$. Thus, the

suppression factor of pions, which equals $100 / \beta$, will make up 3646.

4. Combined method for e and π identification

As it was mentioned above, the likelihood ratio test presents the most powerful test provided a correct determination of density functions of energy losses by pions and electrons in TRD, which is not so simple to be fulfilled in practice. Moreover, the distribution of energy deposit for electrons changes with changing the electron momenta. Therefore, for correct usage of the likelihood test, it is necessary to recalculate the parameters of density function $p_e(\cdot)$ for different intervals of momentum.

In this connection, we investigated another approach based on a successive application of two statistical criteria: 1) the mean value method, and 2) the ω_n^k-test.

In the mean value method a variable

$$\overline{\Delta E} = \frac{1}{n} \sum_{i=1}^{n} \Delta E_i, \tag{5}$$

is calculated, where n is the number of layers in TRD.

Figure 7 shows distributions of $\overline{\Delta E}$ for electrons (left top plot), pions (right top plot), and a summary distribution for both particles (bottom plot). It is clearly seen that the pion distribution is quite well separated from the electron one. If we set the critical value $\overline{\Delta E}_{cr} = 6.3$, then there will remain 90.62% of electrons β will form 0.055%. Thus, the factor of pions suppression will constitute 1833.
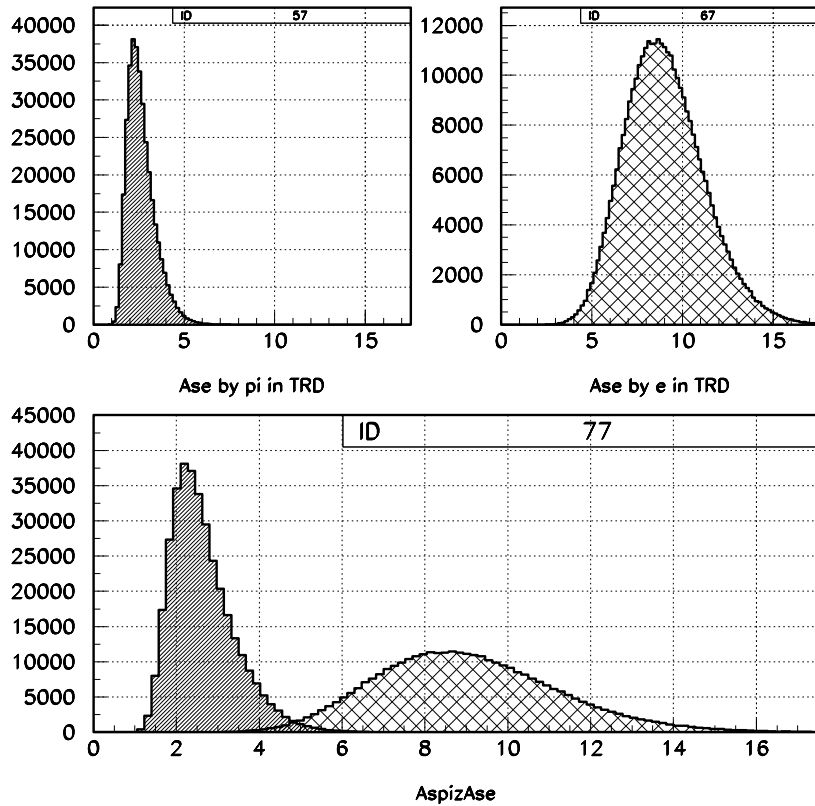
Fig. 7. Distributions of variable $\overline{\Delta E}$ for electrons (left top plot), pions (right top plot); summary distribution (bottom plot)

This result could be significantly improved, if we apply to the events selected in the admissible region the ω_n^k-test [8,9].

This test is based on the comparison of the distribution function $F(x)$ corresponding to a preassigned hypothesis (H_0) with empirical distribution function $S_n(x)$:

$$S_n(x) = \begin{cases} 0, & \text{if} & x < x_1; \\ i/n, & \text{if} & x_i \leq x \leq x_{i+1}, & i = 1,...,n-1. \\ 1, & \text{if} & x_n \leq x, \end{cases} \qquad (6)$$

Here $x_1 \leq x_2 \leq ... \leq x_n$ is the ordered sample (*variational series*) of size n constructed on the basis of observations of variable x.

The testing statistics is a measure of "distance" between $F(x)$ and $S_n(x)$. Such statistics are known as *non-parametric*. We suggested and investigated a new class of non-parametric statistics

$$\omega_n^k = -\frac{n^{\frac{k}{2}}}{k+1} \sum_{i=1}^{n} \left\{ \left[\frac{i-1}{n} - F(x_i) \right]^{k+1} - \left[\frac{i}{n} - F(x_i) \right]^{k+1} \right\}. \qquad (7)$$

The goodness-of-fit criteria constructed on the basis of these statistics are usually applied for testing the correspondence of each sample to the distribution known *apriori*.

On the basis of the ω_n^k test we have developed a method for classification of multidimensional events [9,6,10]:

1. The sample to be analyzed is transformed ("normalized") so that the contribution corresponding to the H_0 hypothesis is described by the distribution function $F_b(x)$.

2. Each sample, composed of the values pertaining to the transformed distribution, is tested with the ω_n^k goodness-of-fit criterion for correspondence to the $F_b(x)$ hypothesis. In this process the abnormal events, which do not comply with H_0, correspond to large absolute values of the ω_n^k-statistic, resulting in their clustering in the critical region.

Energy losses for π have a form of Landau distribution [11]. We use it as H_0 to transform the initial measurements to a set of variable λ:

$$\lambda_i = \frac{\Delta E_i - \Delta E_{mp}^i}{\xi_i} - 0.225, \qquad i = 1, 2, ..., n, \qquad (8)$$

ΔE_i – energy loss in the i-th absorber, ΔE_{mp}^i – the value of most probable energy loss, $\xi_i = \frac{1}{4.02}$ FWHM of distribution of energy losses for π [6].

In order to determine the value of most probable energy loss ΔE_{mp}^i and the value FWHM of distribution of energy losses by π in the i-th absorber, the indicated distribution was approximated by the log-normal function (see Fig. 4).

The obtained $\lambda_i, i = 1,...,n$ are ordered due to their values ($\lambda_j, j = 1,...,n$) and used for calculation of ω_n^k:

$$\omega_n^k = -\frac{n^{\frac{k}{2}}}{k+1}\sum_{j=1}^{n}\left\{\left[\frac{j-1}{n}-\varphi(\lambda_j)\right]^{k+1}-\left[\frac{j}{n}-\varphi(\lambda_j)\right]^{k+1}\right\}. \tag{9}$$

Here the values of Landau distribution function $\varphi(\lambda)$ are calculated using the DSTLAN function (from the CERNLIB library [12]).

Figure 8 shows distributions of ω_{12}^8 values for π (top left plot) and for e (top right plot: here all values of $\omega_{12}^8 > 15$ were set equal to 15); a summary distribution is presented in the bottom plot.
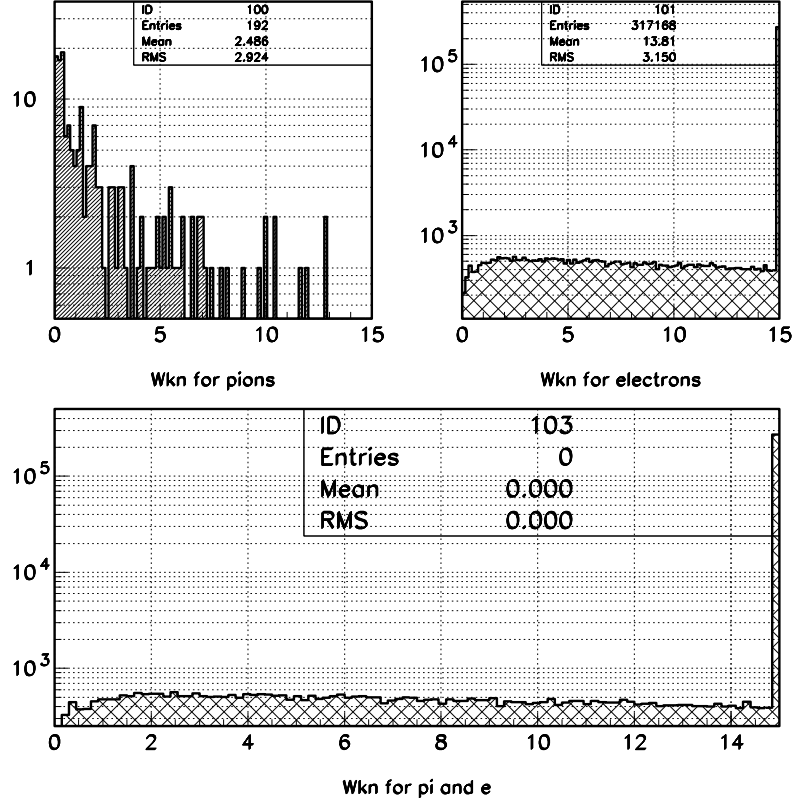
Fig. 8. Distributions of ω_{12}^8 values for π (top left plot) and for e (top right plot) events; a summary distribution for π and e events (bottom plot)

For instance, if we fix the critical value $(\omega_n^k)_{cr}$ = 1.5, then there will remain 89.44% electrons in the admissible region, and β will form 0.02857%. Thus, the factor of pions suppression will constitute 3500.

5. Comparative analysis of two approaches

Table 1 shows the results of comparison of the given methods: α is part of lost electrons, β is the fraction of pions identified as electrons, pion suppression factor equals $100/\beta$.

The results presented in Table 1 demonstrate that, under the condition of loss of approximately 1% of electrons, the application of the ω_n^k-test to the events selected in the admissible region permits us to increase the factor of pions suppression in almost two times.

Thus, we have achieved the result which is very close to the limit value obtained by the likelihood test.

Table 1. Comparison of the given methods

Method	α ,%	β ,%	Suppression of pions
likelihood	10.24	0.0274	3646
mean value	9.38	0.055	1833
mean value + ω_n^k	10.54	0.02857	3500

6. Conclusion

Two different approaches of electron/pion identification using ionization energy losses and deposit of transition radiation in the CBM TRD with n layers are presented: 1) method of likelihood functions ratio, and 2) combined approach based on the mean value method and the ω_n^k-test.

The data used for this study were the measurements of energy deposits in a one layer TRD prototype during the test beam in the GSI, February 2006. These measurements have been used for simulation of energy losses by electrons and pions in the TRD with $n = 12$ layers.

For the likelihood test application it is necessary to know the density functions of energy losses for both particles: pions and electrons. Our analysis of experimental data has shown that the distribution of energy losses for pions is well approximated by a lognormal function, and for electrons – by the weighted sum of two lognormal distributions. This provided a possibility to correctly calculate the values of likelihood functions for pions and electrons and to get the estimate of the efficiency of this test – for the significance level $\alpha = 10.24\%$ the factor of pions suppression constituted 3646.

The likelihood functions ratio test could be related to Neiman-Pirson criterion, which is the most powerful criterion for testing the hypothesis H_0 (in our case, the distribution of electrons) against the hypothesis H_1 (the distribution of pions) [3]. Therefore, for the given significance level $\alpha = 10.24\%$ the value of $\beta = 0.0274\%$ could be considered as minimally possible (which corresponds to the maximum factor of pions suppression).

The bottleneck of this method is that the distribution of energy losses for electrons is strongly dependent on their momenta. At the same time, the distribution of pions energy losses weakly changes.

The second approach does not run into this issue, because for application of the ω_n^k-test, it is necessary to know only the distribution of pion energy losses. This combined approach is simpler from a practical application viewpoint, and, as it has been demonstrated, it may provide the power close to the limit value – for $\alpha = 10.54\%$ the value of $\beta = 0.02857\%$, which corresponds to the factor of pions suppression equal to 3500.

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Neutron effective dose calculation behind concrete shielding of charge particle accelerators with energy up to 100 MeV

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Introduction

All accelerators of the charged particles with energy up to 100 MeV represent a complex geometrical design with set of sources of radiation. The most penetrating component of radiation at the working accelerator is the neutrons of a wide energy spectrum. The shielding should provide not excess of the required dose limits. Calculations of shielding and the doses of neutrons behind shield are used various methods and, created on their basis, algorithms.

Method Monte-Carlo allows carrying out direct modeling of radiation transport through substance in real geometry. The programs, created on its basis, require essential expenses of computer time at account of a dose behind rather thick shields. Much more practicable method is phenomenological approach based on existent experimental and calculated data of dose attenuation by shielding.

The purpose of work is the comparison of results of calculations of effective neutron doses behind concrete shielding by a method Monte-Carlo and by phenomenological method.

The initial data and geometry of calculation

Geometry of barrier shielding (see fig. 1) was chosen for comparison of calculation methods. The thickness of protection varied from 25 cm up to 300 cm with a step 25 cm. The calculations have been performed by Monte Carlo and phenomenological methods for monoenergetic neutrons with energy from 5 MeV to 100 MeV as well as for neutron spectra produced by protons with energies of 30 MeV and 72 MeV in thick targets/1, 2/.

The calculation by a method of Monte-Carlo was carried out with the program MCNP4B /3/ (package of libraries DLC189). The geometry of calculation is shown in a Fig. 1. The statistical error of the calculated data with method of Monte-Carlo did not exceed 5%.

Over a fairly wide range of shield thickness it has been found/4/ sufficiently accurate to estimate shielding with simple equations of the form:

$$E_{ef}(d, E) = \frac{f}{R^2} \cdot h(E) \cdot B(E) \cdot \exp\left(-d / \lambda(E)\right) \qquad (1)$$

This equation applies to a source of monoenergetic neutrons of energy E with symbols having the following meanings:

$E_{ef}(d, E)$ is the effective dose behind shield with thickness of d;

f is neutron yield per steradian;

R is the distance from the source to the point of interest outside the shield;

$h(E)$ is the conversion coefficient that relates neutron fluence to the effective dose/5/;

$B(E)$ is the build-up factor of neutrons /4/;

$\lambda(E)$ is the attenuation length for effective dose through the shield/4/.

This formula considers the energy dependence of neutron dose attenuation length with shield thickness by adopting the λ and the B values after deep penetration in a spectral equilibrium state. The phenomenological method based on expression (1) was used.
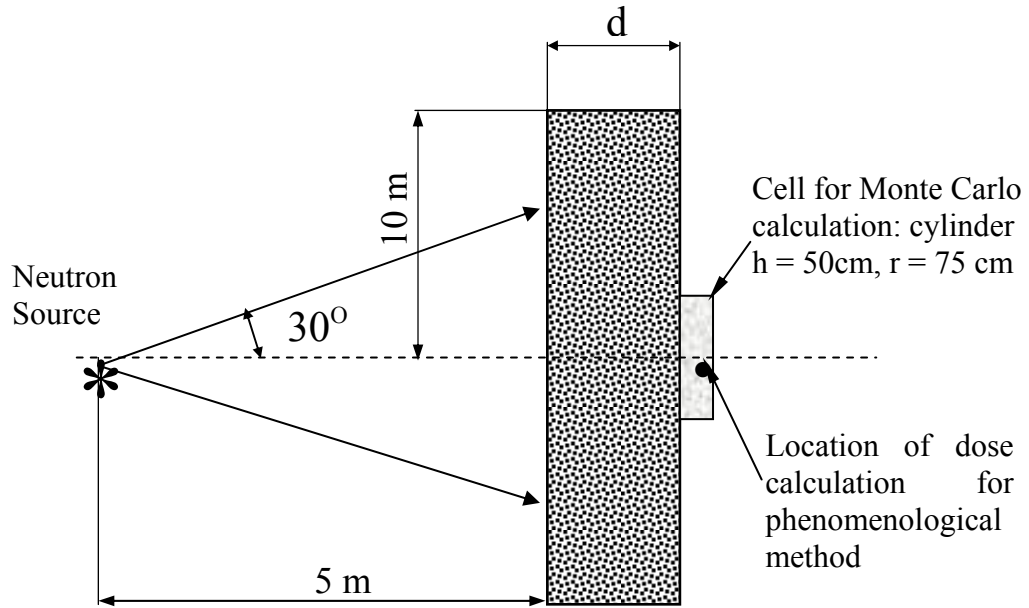
Fig.1. Geometry of shield for comparison of calculation methods. The thickness of the shield is varied from 25 cm up to 300 cm with a step of 25 cm

Results

The results of calculations are shown in a fig. 2-8. In a fig. 2 the results of calculation of attenuation of neutron effective dose by concrete shield obtained with use of two described above methods are submitted. Factor of attenuation of a dose k is defined as the relation:

$$k = E_{ef}(d, E) / E_{ef}(0, E), \hspace{2cm} (2)$$

where $E_{ef}(0, E)$ - effective dose of neutrons in a point located on distance R from a source at absence of shield.

The neutron effective dose as a function of incident neutron energy calculated for concrete shield of 1 m, 2m and 3 m in thickness is shown in Fig 3. Figures 4, 5 and 6 show the result of calculations of effective dose as a function of a concrete shield thickness when the shield irradiated by neutrons produced in a copper thick target by protons with energies 72 MeV and 30 MeV/1, 2/.

Attenuation length $\lambda(E)$ and build-up factor B(E) were calculated with MCNP code (Monte Carlo method) and compared with the same parameters used by phenomenological method/4/. Figures 7 and 8 show comparison of these parameters.

Conclusions

Data obtained by these two methods agree within factor 2 over considered range of neutron energies and shielding thickness. Comparison of the results shows that difference in shield thickness between calculated by Monte Carlo and phenomenological method is not exceeded half-value layer for neutron effective dose, which is from 10 cm to 30 cm for considered energies and thickness of shields.

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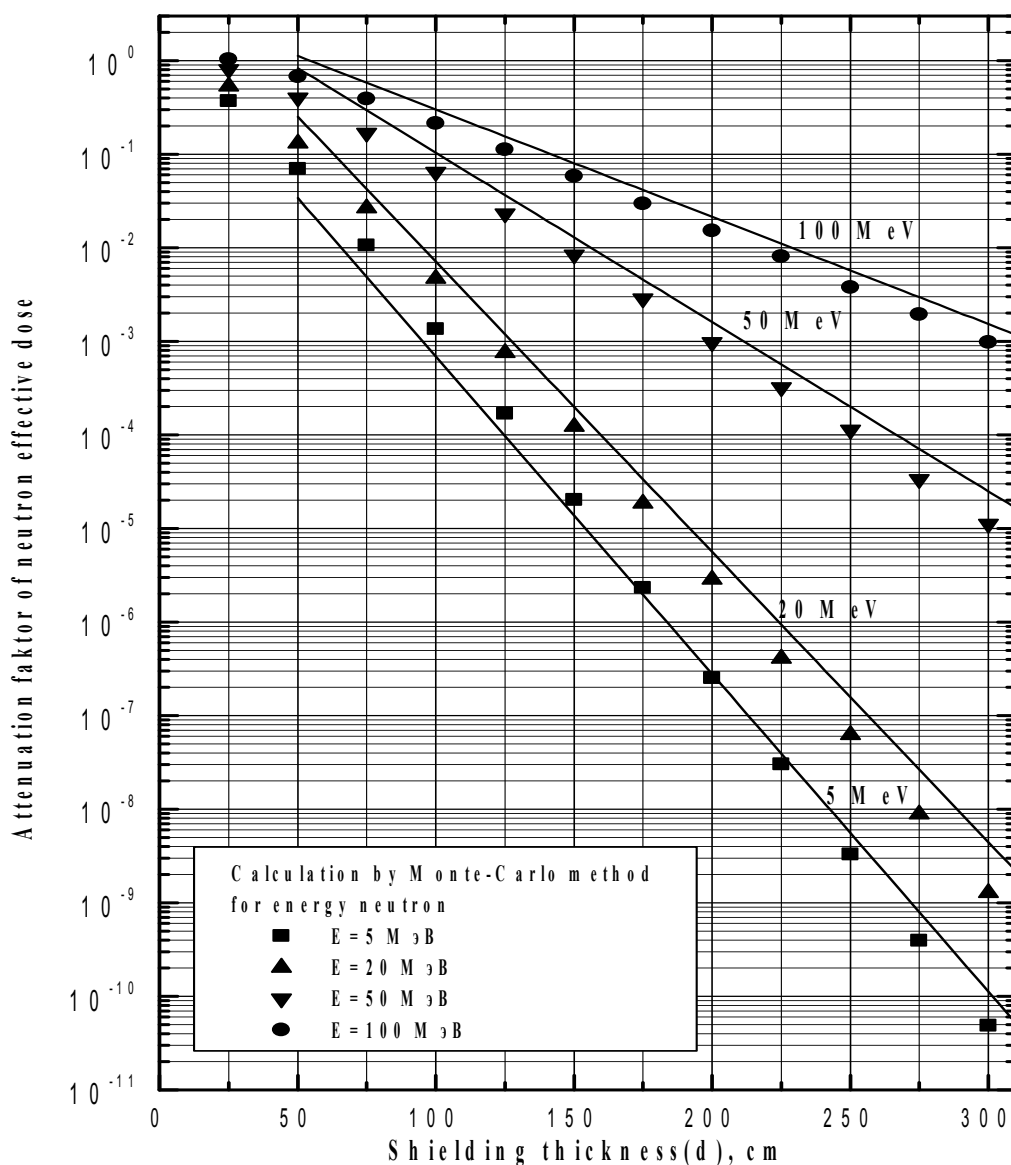
Fig. 2.

Comparison between Monte Carlo and phenomenological methods calculated data of neutron effective dose attenuation by concrete. Isotropic point neutron source with energy 5, 20, 50 and 100 MeV at 5 m from shield. ■,▼,▲,● – Monte Carlo calculation, curves – phenomenological method

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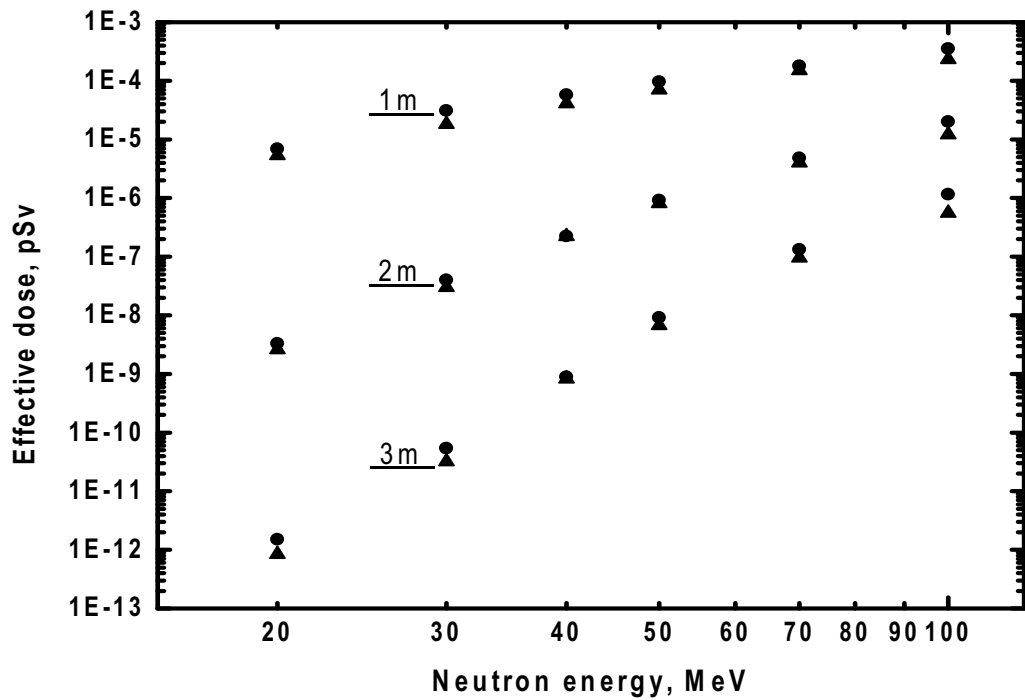
Fig. 3. The neutron effective dose as a function of incident neutron energy calculated for concrete shield of the thickness indicated. ● - phenomenological method, ▲ - Monte-Carlo
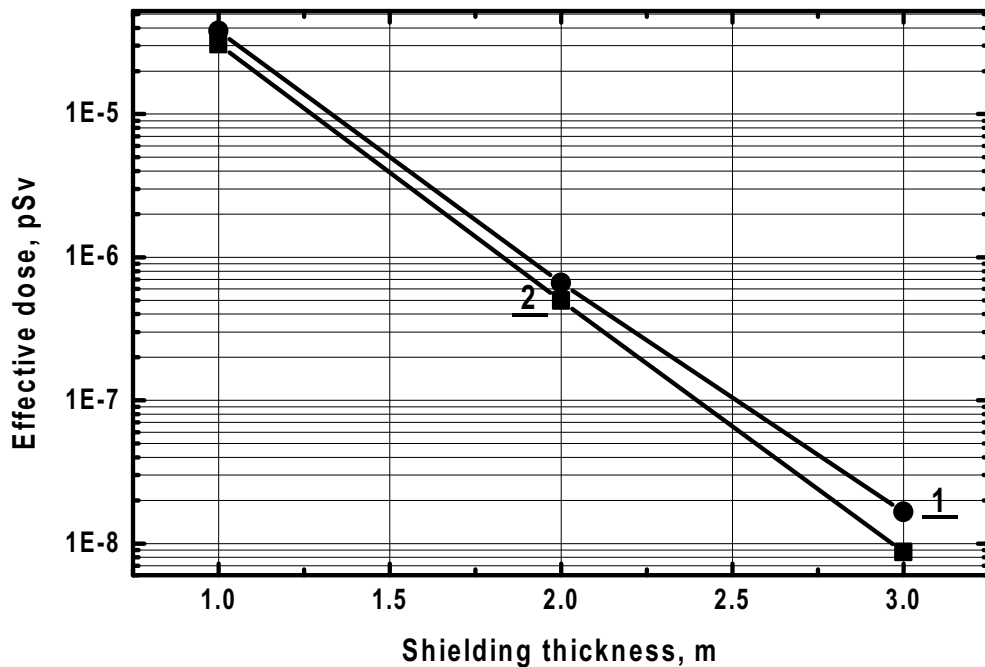
Fig. 4. Comparison of effective dose calculations as a function of a concrete shield thickness when the shield irradiated by neutrons in a copper thick target by protons with energies of 72 MeV produced at an angle of 9^0 with an axis of proton beam: 1 – phenomenological method, 2 - Monte-Carlo

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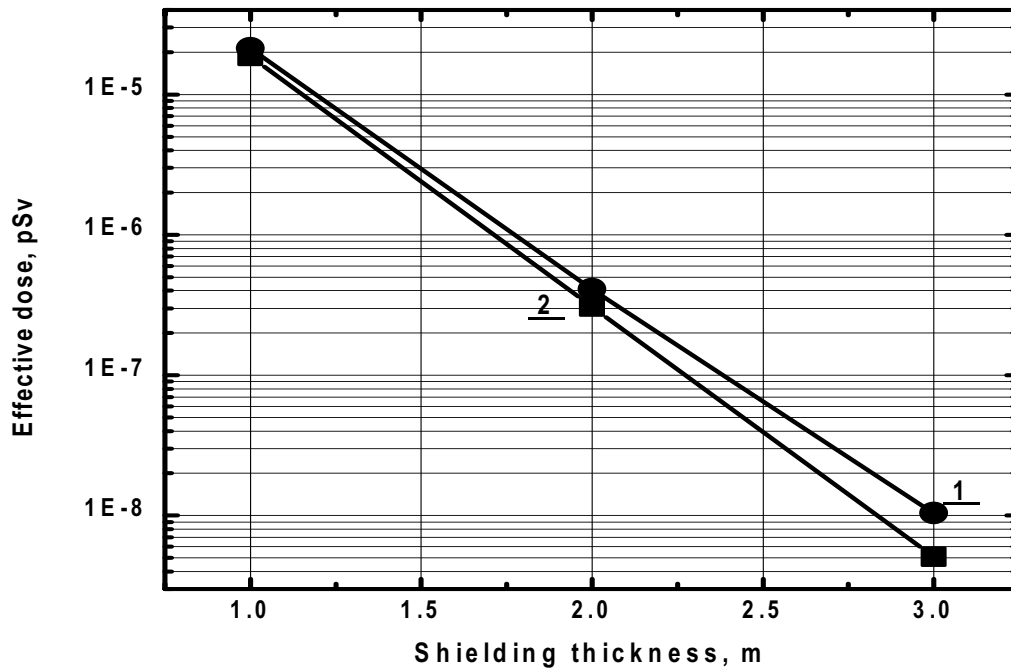
Fig. 5. Comparison of effective dose calculations as a function of a concrete shield thickness when the shield irradiated by neutrons produced in a copper thick target by protons with energies of 72 MeV at an angle of 90^0 with an axis of proton beam:
1 – phenomenological method, 2 - Monte-Carlo
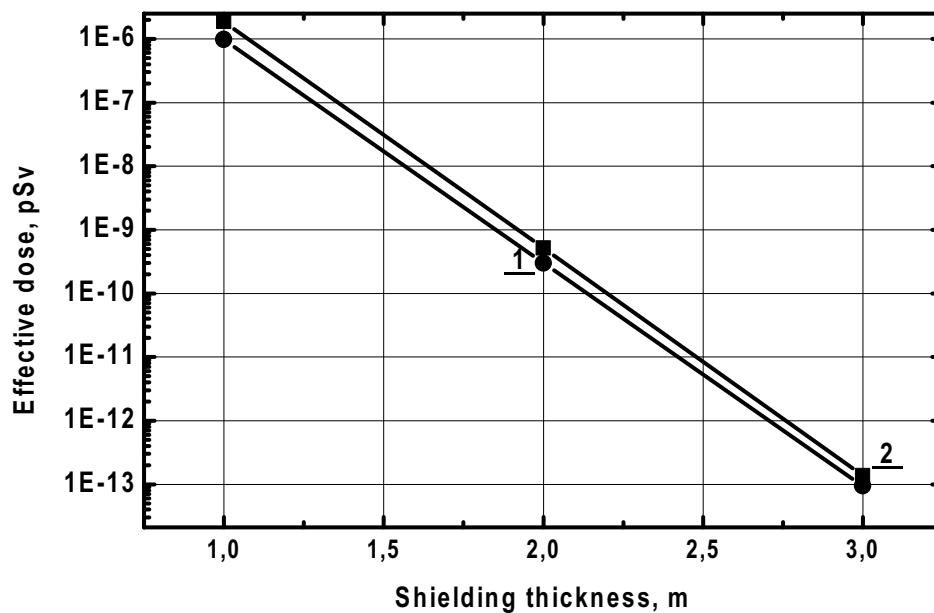
Fig. 6. Comparison of effective dose calculations as a function of a concrete shield thickness when the shield irradiated by neutrons produced in a copper thick target by protons with energies of 30 MeV at an angle of 0^0 with an axis of proton beam:
1 – phenomenological method, 2 - Monte-Carlo
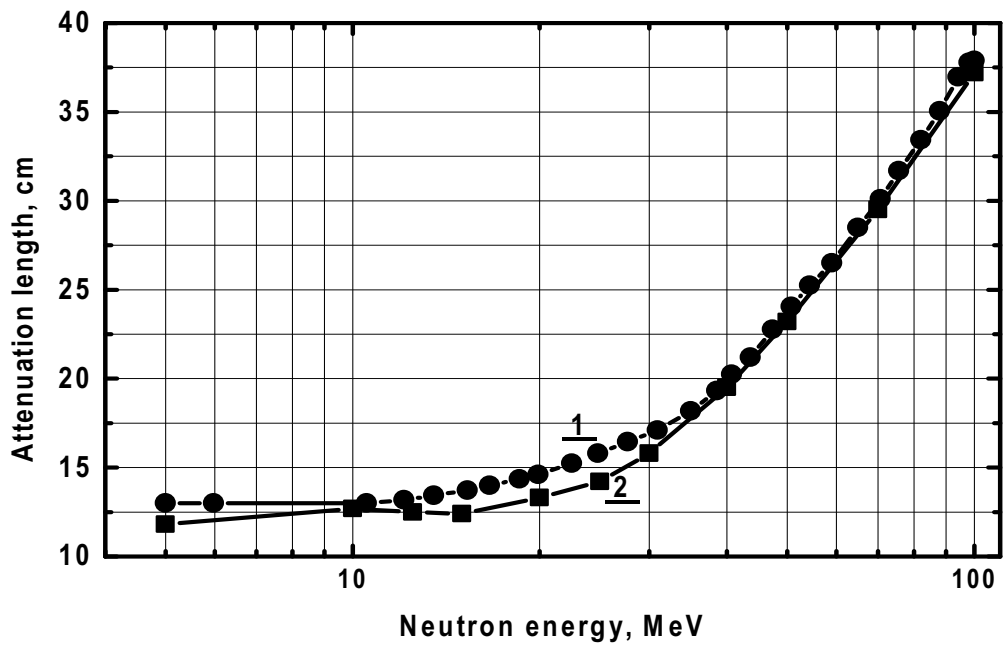
Fig. 7. The variation of the attenuation length of effective dose for monoenergetic neutrons in concrete as a function of neutron energy. 1 – phenomenological method, 2 - Monte-Carlo
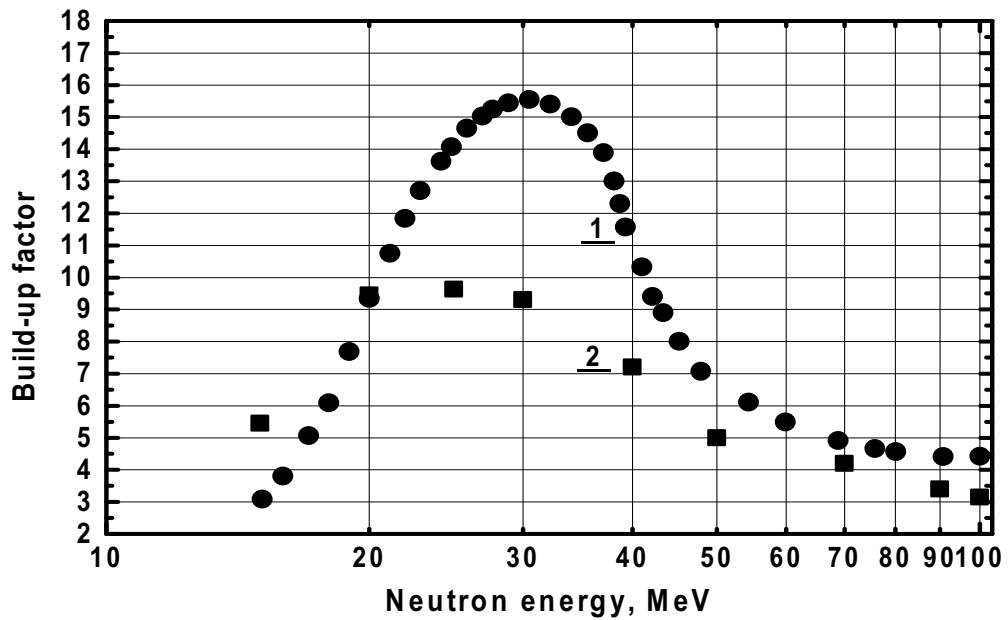
Fig. 8. Build-up factor for effective dose of neutrons:
1 – phenomenological method, 2 - Monte-Carlo

Integrating SMARTBOX-6 driver into control system of MC-400 cyclotron

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Abstract

The control system of MC-400 cyclotron is based on a commercial SCADA and it uses new data acquisition system SMARTBOX-6 designed in FLNR in 2006. It uses Ethernet as a communicating interface and has great flexibility. Basic ideas for SMARTBOX-6 driver and integrating it into commercial software using interprocess communicating are described.

1. Introduction

In 2007 the Control system of MC-400 cyclotron has been renewed. It uses big variety of devices from third party manufacturers and self made hardware. The hardware structure of the control system is shown on Fig. 1.
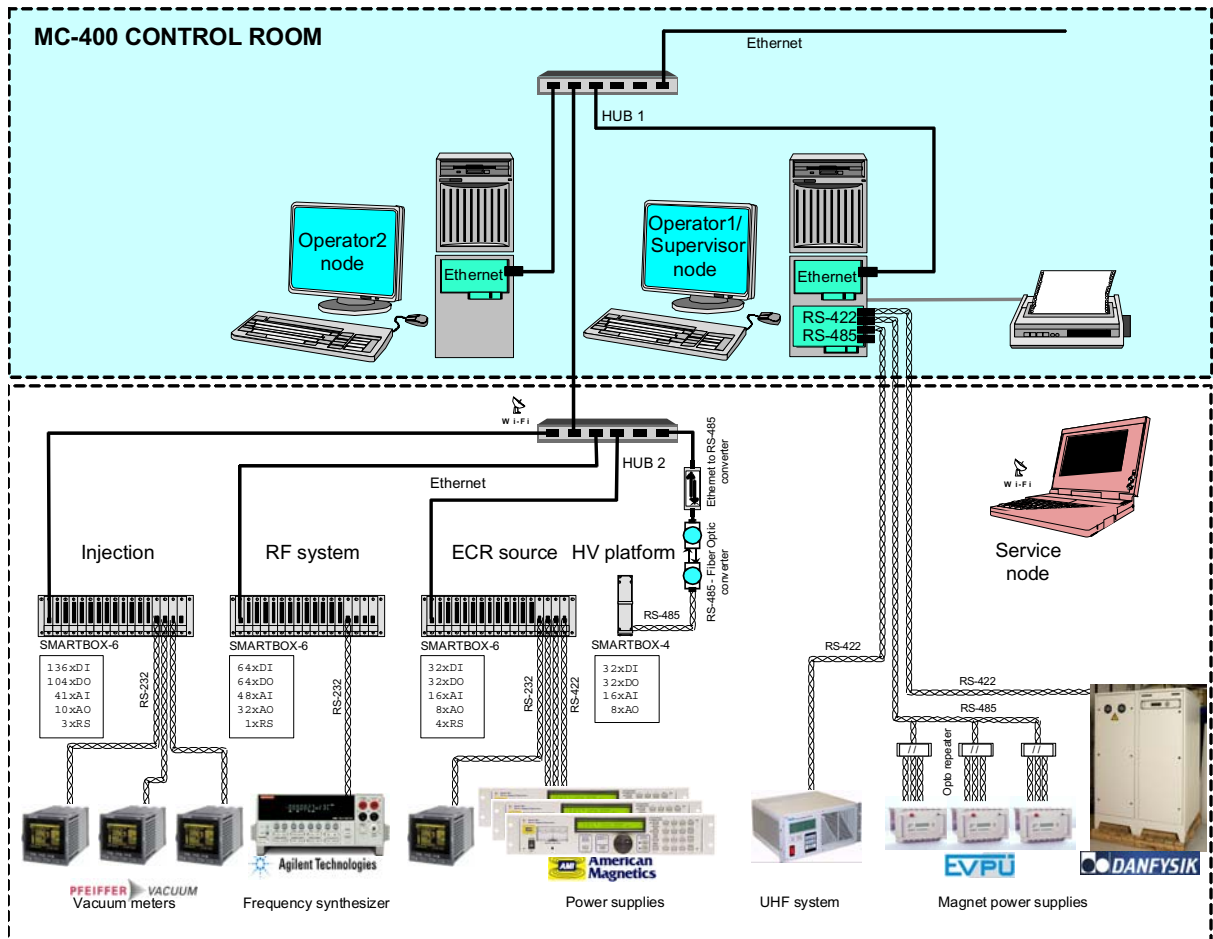
Fig.1. The hardware structure of MC-400 control system

The key role in data control and acquisition in FLNR is played by stand-alone I/O controllers of SMARTBOX series (FLNR, Russia)[1]. At present we have 6th generation of

the controller and we use it in MC-400. It offers compact, modular and economical solution to control and monitor most common types of digital and analog signals of an accelerator. It is designed in 19" Rack Form Factor crate 3U-high with 24 VDC power supply. The system comprises a main control unit (MCPU) and a number of I/O modules connected to the internal communication bus. One or more SMARTBOX-6 crates can be connected via Ethernet interface to the host computer.

2. Control system software

The software runs under UNIX-style commercial real-time operating system QNX (QNX Software Systems Ltd., Canada). The core of the application software is custom visualization server with a number of device drivers that interact Supervisory Control and Data Acquisition (SCADA) FlexCtrl 4 (BitCtrl Systems Ltd., Germany) [2].

QNX depends on the exchange of discrete packets of information – *messages* – to handle virtually all inter-process communication. Message passing lies at the heart of the operating system's microkernel architecture, giving the OS its modularity. This paradigm applies to all levels of programming, from device drivers to file system and LAN.

As well the hardware has different categories of devices as the software combines commercial products with custom drivers and applications. The software structure of the control system is shown on Fig. 2.
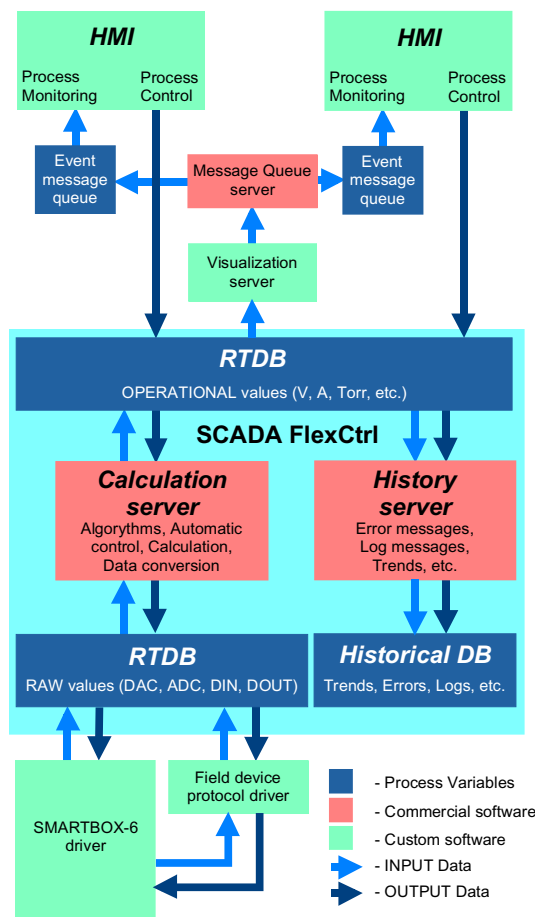
Fig. 2. The software structure of MC-400 control system

FlexCtrl is a process control system for the automation of technological processes. It is modular and extremely scalable. The interface to the system is open and the user has the possibility adding custom device driver to the system [3].

FlexCtrl strongly uses this message passing technique as for internal run-time communication as for interfacing to device drivers. The components of FlexControl can be partitioned, installed and run on several computers of standardized PC network. Every job of some significance in FC is handled through a single computational process (server). The tasks are able to communicate and synchronize with one another. The data from the transmitting process are exported via message passing over the network and imported directly into the address area of the receiver process [4]. Deadlocks and blocks do not occur in any form in FlexCtrl.

3. SMARTBOX-6 driver

The algorithm of driver program and protocol encapsulating is shortly described below.

1.1 Init

The configuration of all SMARTBOX-6 in the project is stored in the configuration file. At start up driver checks that all parameters meet the process model, establishes communication to devices and SCADA database. There is an algorithm of hot connection of new controllers while the driver is running.

1.2 Monitoring

For data monitoring (input signals) device driver cyclically reads device status and compares it with the old one saved in program memory. In case of any changes the driver writes new values to the real-time database (RTDB).

1.3 Control

Operator controls the process via Human-to-Machine Interface (HMI). He presses buttons, enters new values, etc. HMI writes new values directly to RTDB. Control Server manages real-time database access and triggers off driver for every instance the variable is changed in the real-time database. Device driver receives new data (output signals) from Control Server and issues write command to the SMARTBOX-6.

1.4 Protocol encapsulating and dataflow

The process data is transmitting from one process to another. Every process is dedicated to a particular purpose and uses its unique protocol to communicate to the outside [5]. To explain data flow and protocol encapsulating it would be a good thing to draw an analogy for a post. Let's imagine the process data as the information that should be mailed from sender to recipient.

- The sender writes the letter and put it into envelop. In control system operator issues the control event by setting via HMI new value of the RF frequency, for example.
- Than, postman takes letter from the postbox and brings it to the post, where it will be sorted, registered and put in container for further delivering. In control system new data is written to RTDB and the message to the appropriate driver is sent.
- Depending on the distance to the destination point (town, country, continent), the cargo will be loaded on a mail van, truck, boat or air plan. It can be delivered even by bicycle. Such can happen - the container with the letter is inside the car, the car is on the open goods truck, the truck is on the boat or ferry. This nesting is very similar to the protocol encapsulating in control system.

- Before the recipient gets the letter it should be unloaded from all kind of used transport including envelop. For example, in control system the command to write new value for frequency synthesizer can be nested inside 3 another protocols and should be striped in SMARTBOX-6 system before sending to the field device.
- The reply uses the same way as request in the backward direction.

The protocol nesting for data acquisition using SMARTBOX-6 and communicating to a field device via MMRS I/O unit are sown on figure 3.

FC-IPC	FlexControl database read/write protocol
SMBX	SMARTBOX-6 driver IPC protocol
TCP/IP	TCP/IP frame
MCPU	MCPU internat serial bus protocol
AGIL	Agilent frequency synthesizer command set
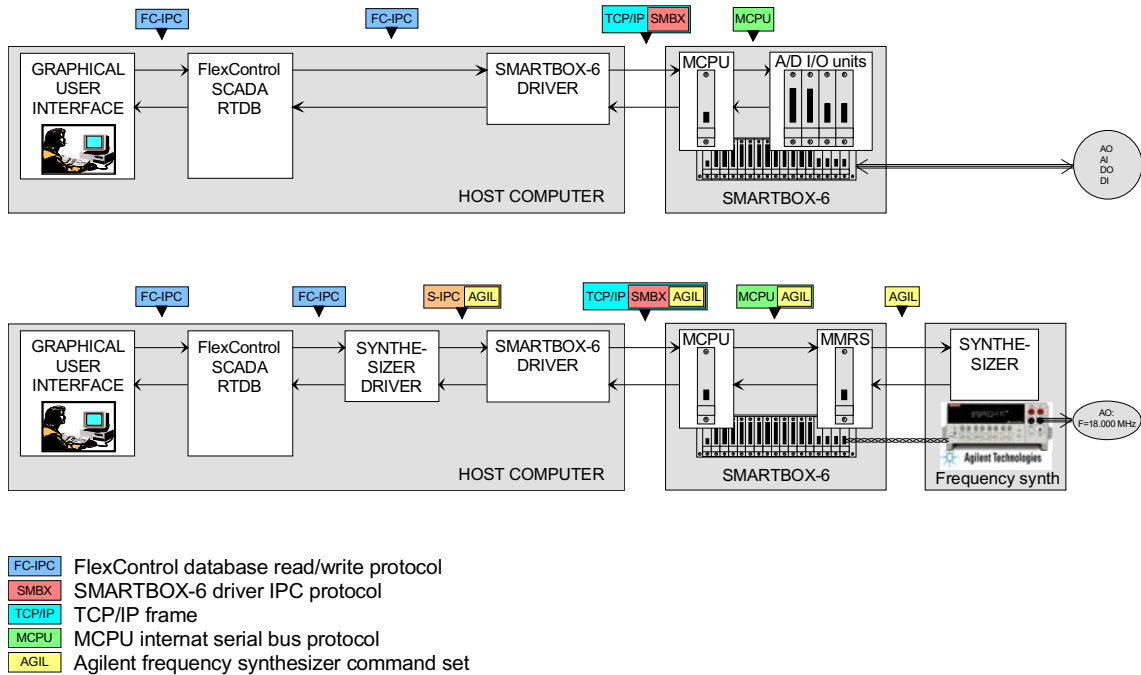
Fig.3. Protocol encapsulating and data flow

1.5 Data types and naming

Depending on the functionality each unit in a crate can process up to 6 types of data format (see Table 1).

Table 1. SMARTBOX-6 data types

№	Type	Description	I/O
1.	AI	Analog	input
2.	AO	Analog	output
3.	DI	Digital	input
4.	DO	Digital	output
5.	ST	Status register	input
6.	CL	Control register	output

As a result of flexibility every SMARTBOX-6 has its unique amount of every type of data. All SMARTBOX-6 signals are represented in FlexControl RTDB and can be accessed

only by unique address. Therefore, SMARTBOX-6 specific information is encoded in the name of the variable. It includes crate ID, type of signal and channel number (see Fig. 4).

```
14987 SB02AI007
```
— Channel number
— Variable type (AI, DI, AO, DO, ST, CL)
— SMARTBOX-6 ID
— SMARTBOX-6 specific prefix
— Process variable index in FlexControl RTDB
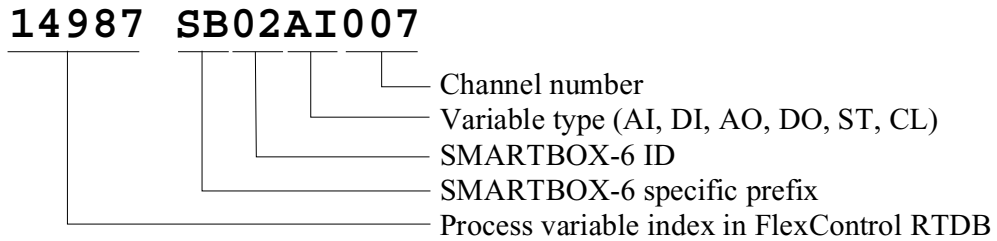
Fig. 4. Data naming format

4. Conclusion

At present time we have assembled and tested all the hardware for MC-400 control system using SMARTBOX-6 driver.

The SMARTBOX-6 driver has been integrated into the project software and tested with all types of available I/O units. Flexibility and good interaction possibility of the driver allows easily add graphical user interface without performance consumption.

Very important point for this kind of software is stability and we able to have it with this software.

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Computer system SANC for precision calculations for the standard model processes[1]

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Abstract

We describe the present status of the computer system SANC (Support of Analytic and Numerical calculations for Colliders) v.1.10, intended for precision calculations of the event distributions for various decays and processes of the high energy elementary particle interactions in the NLO of the Standard Model (SM). At present, the system realizes a semi-automatic chain of calculations from the SM Lagrangian up to a Monte Carlo (MC) event simulation for many $1 \rightarrow 2$ decays and $2 \rightarrow 2$ processes.

1. SANC I - Overview, Technologies, Shortcomings

The SANC project was started in 2001 at the Joint Institute for Nuclear Research (JINR) Dubna, Russia as part of the efforts to automate the high energy physics computations. The project has a long and astounding prehistory represented by the projects HECTOR [1], μela [2], ZFITTER [3], GENTLE [4] and other, which provided the theoretical support for many HEP experiments at SPS, HERA, LEP1, LEP2. These experiments on the other hand are part of the global efforts of the physicist's community to achieve a more profound understanding of the fundamental interactions in the Universe. Nowadays experiments require highest theoretical precision. In the field of high energy physics this implies computations in higher orders of the perturbation theory, which incredibly increases computational complexity.

Such computations are infeasible by means of standard methods or common software applications. This was the reason that one has driven the creation of automated computational systems such as SANC and its competitor projects - GRACE-loop [5], FeynArts [6] at the one-loop precision level for the present and future colliders - TEVATRON, LHC, electron Linear Colliders (ISCLC, CLIC), muon factories etc.

SANC was announced first in Ref. [7] and its first phase status report was widely presented at ACAT2002 in several talks [8].

The main goals of the project are:

- Creation of a computerized system for automated computation of pseudo- and realistic observables with one-loop precision for various processes of elementary particle interactions, such as: $1 \rightarrow 2, 1 \rightarrow 3, 2 \rightarrow 3, 1 \rightarrow 4, 2 \rightarrow 3$, etc.
- The system should provide the functionality to be effectively used for training of students, PhD scholars, etc. in the field of high energy physics.

Physics-wise, all the calculations at the one-loop precision level are realized in the spirit of the book [9] in the R_ξ gauge and all the results are reduced up to the scalar Passarino-Veltman functions: $A_0, B_0, C_0, D_0.$ This two distinctive features allow to perform several

checks: e.g. to test gauge invariance by observation the cancellation of gauge parameters dependence, to test various symmetry properties and validity of various Ward Identities, all at the level of analytical expressions.

Computer-wise, SANC was conceptualized as a client-server system that would provide access to multiple FORM [10] and FORTRAN applications. These applications had to be modularized as procedures in a most universal way so as to be used as building blocks for the computation of more complex processes.

The underlying technology of the entire system is JAVA, while the analytical computations are implemented in FORM, the numerical in FORTRAN. Also, there is a PERL module s2n generating FORTRAN programs and providing transmission from analytical results to numerical applications. The SANC server-tier has a database backend for storing different SANC programs and functionality for compiling them as well as for linking the various modules. The SANC client-tier is represented by IDE (Integrated Development Environment) clients which allow creating, editing and compiling of FORM and FORTRAN programs, as well as passing parameters to charts to display any numerical results. SANC client for version v.1.10 can be downloaded from servers at CERN *http://pcphsanc.cern.ch* and Dubna *http://sanc.jinr.ru*.

In the second phase of the project (2003-2005), the calculations were extended to a large number of HEP processes [11] with an emphasis on LHC physics. In Ref. [12] we have summarized the status of the SANC version v.1.00, into which we implemented theoretical predictions for many high energy interactions of fundamental particles at the one-loop precision level for up to 4-particle processes. In the recent Ref. [13] we described SANC version 1.10 upgraded both physics-wise and computer-wise compared to the version 1.00. As far as physics is concerned it contains an upgraded treatment of $u\bar{d} \to l^+ v_l$ and $\bar{u}d \to l^- v_l$ processes used for precision calculations of Drell-Yan processes (see Ref. [14]) and a complete implementation of $t \to bl^+ v$ decays up to numbers and MC generators [15]. We also implemented several processes like $f_1\bar{f_1}ZZ \to 0$ and $f_1\bar{f_1}HZ \to 0$, and the process $f_1\bar{f_1}HA \to 0$ in three cross channels [16] in the EW branch, $\gamma\gamma \to \gamma\gamma$ scattering [17] and $ll \to \gamma\gamma^*$ in the QED branch and new QCD branch [18]. Starting from Ref. [13] we use a generalized approach: we begin with a presentation of the covariant amplitudes for a process, say $f_1\bar{f_1}HZ \to 0$, where $\to 0$ means that all 4-momenta flow inwards. The derived scalar form factors can be used for any physically sensible cross channel (here two: annihilation $f_1\bar{f_1} \to HZ$ and decay $H \to Zf_1\bar{f_1}$, since it is known that $M_H > M_Z$ after an appropriate permutation of their arguments (*s,t,u*). Then we compute helicity amplitudes for every cross channel separately. Recently, in the same spirit we considered the three channels of the process $f_1\bar{f_1}ZA \to 0$ [19].

Whenever possible, we compare our results with those existing in the literature. For this comparison we widely used several well known codes or computer systems. At tree level we compared with GRACE-tree [20], CompHEP [21], PYTHIA [22], PHOTOS [23], whereas one-loop level results were checked against HORACE [24], WGRAD2 [25], ZGRAD2 [26], a code by S. Dittmaier and M. Kramer [27], GRACE-loop [5] and FeynArts [6].

2. Description of the current version 1.10
2.1. Processes available

This version of SANC deals with the three models of elementary particle interactions QED, EW and QCD. In the Fig.1 we show processes only for EW branch.
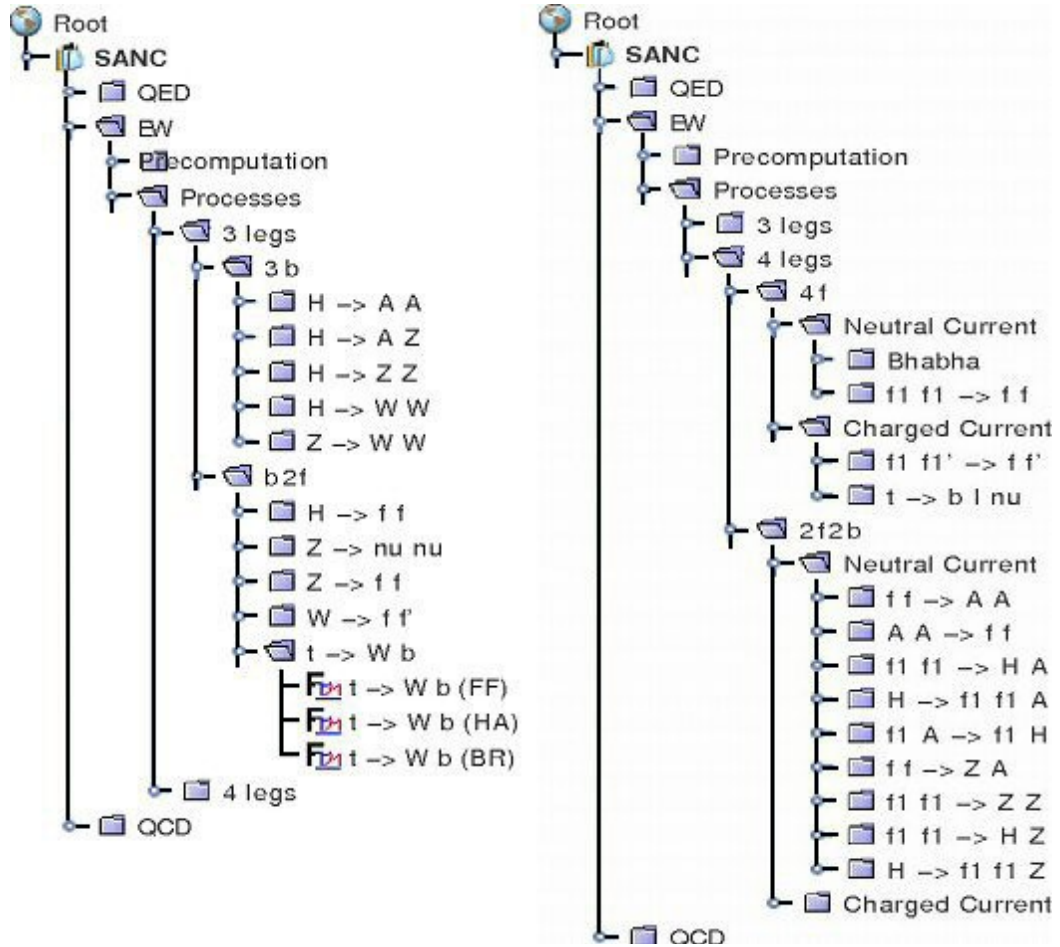
Fig. 1. Three and four particle EW processes available in SANC version 1.10

Each tree consists of several levels of "folders" which end up with "files", normally three: FF (Form Factors), HA (Helicity Amplitudes) and BR (Bremsstrahlung). For labels of folders we use notations: b - for any boson; $f(f_1)$ - for any fermion (f_1 for massless fermions of the first generation whose mass is kept only in arguments of logarithmic functions); A,Z,W,H - for a photon, Z,W,H bosons; for files - the same but t,b, which mean here top and bottom quarks.

For many processes SANC calculations end up with MC integrators or event generators. But only few of them are embedded into the system itself, see User Guide in Ref. [12]. The other codes are accessible as the stand alone ones. The latter widely use FORTRAN modules generated by the system.

2.2. Basic notions: precomputation, amplitudes, form factors...

Precomputation is one of important concept of SANC ideology. Since many one-loop calculations are enormously time consuming, the idea is to precompute as many one-loop diagrams and derived quantities (renormalization constants, etc) as possible. The precomputation trees are presented and exhaustively discussed in the Ref. [12] and we refer the reader to this paper.

As seen from an open folder for $t \to Wb$ decay in the Fig. 1, one has usually three files written in FORM, which compute:

- Covariant amplitude (CA) and scalar FF, cf. with the nucleon-nucleon-γ vertex parametrized by the two scalar FF $F_{1,2}$: $A \propto \gamma_\mu F_1 + \sigma_{\mu\nu} q_\nu F_2$;

- HA, which depend on FF, $H_{\{\lambda_i\}}(F_i)$, where $\{\lambda_i\}$ denotes a set of helicity quantum eigenvalues, typically spin projections onto a quantization axis. We remind that in the standard approach for an observable O one has: $O \propto |A|^2$, while in terms of HA: $O \propto \sum_{\{\lambda_i\}} |H_{\{\lambda_i\}}|^2$ and this drastically simplifies calculations since $H_{\{\lambda_i\}}$ are scalar objects which are computed as complex numbers. Many other examples of CA and HA maybe found in Refs. [12], [13] and [16];

- Accompanying real BR. This module computes the contribution of the real bremsstrahlung to a relevant process. Typically we have both the calculations of inclusive quantities and fully differential ones for a use in the MC codes.

2.3. From analytic results to numbers

The chain of SANC calculations starts with on-line execution of the module FF, followed by a s2n run (see short User Guide at our Project home pages, indicated in the Introduction), and subsequent execution of the module HA with another s2n run. As the result, the system generates a FORTRAN code for the contribution of virtual corrections to a chosen process in the following schematic form:

$$d\Gamma(d\sigma) \sim \sum_{\lambda_i \lambda_j \lambda_k \lambda_l} \left| H_{\lambda_i \lambda_j \lambda_k \lambda_l} \left(F^{Born+1loop+2loop} \right) \right|^2 .$$

Note, that the 2-loop corrections may be easily embedded into this scheme if available.

Real corrections consists of Soft and Hard bremsstrahlung. They are computed by modules BR.

The Soft has the Born-like kinematics, while Hard has + 1 particle's more phase space and typically the system creates a FORTRAN module which is used in subsequent MC calculations. For several processes, the system may compute complete one-loop corrections, including real bremsstrahlung for an inclusive observable.

For numerical computations we use the FORTRAN modules generated by the package s2n - a part of the system written in PERL. SANC includes its own FORTRAN library for numerical calculation of Passarino-Veltman functions and uses LoopTools as an alternative (see, [28]).

2.4. Types of SANC Outputs

Typical SANC outputs are:
- FORTRAN modules.
  These modules may be used in MC integrators and generators by ourselves or by the others.
- Standalone MC generators.
  As example, we have MC distributions obtained with:
  a) generator for $t \rightarrow bl^+\nu$ decay;
  b) generators for NC and CC Drell-Yan processes;
  c) generator for $H \rightarrow 4\mu$ decay in the single Z pole approximation.
- Contribution to tuned comparison.
  It has an impact on competition of precision MC generators at the LHC era. So far we participated in two workshops: Les Houches Workshop, see Proceedings 2006 [29] and TEVATRON for LHC Report, 2007, [30].

3. SANC application for selected processes

In recent papers, we presented many physical results obtained with SANC for several processes:

- $t \to bl^+\nu$ decay, [15];
- $f_1 \overline{f_1} ZZ \to 0$, [13];
- $f_1 \overline{f_1} HA \to 0$: three cross channels, [16];
- $f_1 \overline{f_1} ZA \to 0$: three cross channels, [19];
- $f_1 \overline{f_1} HZ \to 0$: three cross channels, [13];
- $H \to 4\mu$ decay, [13]; these results were used by experimenters, see [31];
- Drell-Yan-like W and Z production, [14].

3.1. Drell-Yan-like *W* and *Z* production

The description of Drell-Yan-like single W and Z production processes are rather advanced in SANC. As usual, we begin with partonic level calculations by running relevant FF/HA/BR files each by FORM and s2n.

3.1.1. CC and NC Drell-Yan processes distributions

The FORTRAN modules, generated by s2n package, are used in MC integrators and generators based on Vegas [32] and FOAM [33] algorithms. With the aid of the integrators we have produced numerous distributions presented in proceeding of Les Houches [30] and TeV4LHC [31] Workshops. Below we present a couple of distributions for CC case, see Fig. 2.

First of all, one has to introduce some notions.

- Charged current Drell-Yan (CC DY) production:
  1. $q\overline{q}'$ sub-process $p[q] + p[\overline{q'}] \to W^\pm \to X + l^\pm + \nu_l(+\gamma)$,
  2. gq sub-process $p[g] + p[q] \to W^\pm \to X + l^\pm + \nu_l(+g)$,
  3. γq or γ-induced sub-process $p[\gamma] + p[q] \to W^\pm \to X + l^\pm + \nu_l(+\gamma), (l = e, \mu)$.
- Neutral current Drell-Yan (NC DY) production:
  1. $q\overline{q}$ sub-process $p[q] + p[\overline{q}] \to \gamma, Z \to X + l^+ + l^-(+\gamma)$,
  2. gq sub-process $p[g] + p[q] \to \gamma, Z \to X + l^+ + l^-(+g)$,
  3. γq or γ-induced sub-process $p[\gamma] + p[q] \to \gamma, Z \to X + l^+ + l^-(+\gamma), (l = e, \mu)$.

For CC we computed $2 \otimes 2 \otimes 2$ distributions:

$$\begin{pmatrix} q\overline{q}' \\ g(\gamma)q \end{pmatrix} \otimes \begin{pmatrix} p_T \\ M_T \end{pmatrix} \otimes \begin{pmatrix} e \\ \mu \end{pmatrix}.$$

In the first column the partons participating a hard sub-process are shown. In the second column - the variable of distribution: transverse leptonic momentum $p_T = p_T^l$ or transverse mass $M_T = \sqrt{2 p_T^l p_T^\nu (1 - \cos\varphi_{l\nu})}$ of $l\nu_l$ system. In the third column - the type of final charge lepton μ or e. Moreover, for muons we use the so-called "bare" setup and for electrons - "calo" set up with some $e - \gamma$ recombination, see above mentioned Proceedings.
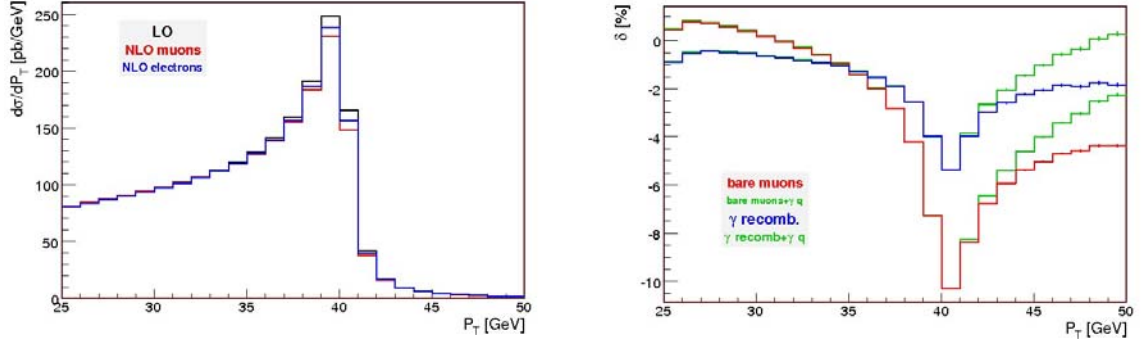
Fig. 2. The relative correction Δ due to electroweak $O(\alpha)$ corrections to the p_T distribution for single W^+ production with bare cuts at the LHC

For NC case only middle column has different and obvious meaning:

$$\begin{pmatrix} q\bar{q} \\ g(\gamma)q \end{pmatrix} \otimes \begin{pmatrix} p_T \\ M_{l^+l^-} \end{pmatrix} \otimes \begin{pmatrix} e \\ \mu \end{pmatrix}.$$

For initial parton $= \gamma$ we finished a paper [34]. We have also distributions with initial parton $= g$.

The distributions are produced for the cross-sections σ (pb) and the relative corrections $\delta(\%)$, where the last is defined by $\delta = \sigma^{1loop}/\sigma^{Born} - 1$ for EW corrections originating from the $q\bar{q}'$ sub-process and by $\delta = \sigma^{g(\gamma)q}/\sigma^{Born}$ for corrections originating from the gluon (photon) induced processes.

3.1.2. Drell-Yan processes: tuned comparison

The tuned comparison of EW corrections for CC Drell-Yan processes was started within the Les Houches Workshop [29], however, much more detailed study was performed within the TEV4LHC Workshop [30].

Three teams participated within TEV4LHC Workshop: HORACE - [24], SANC - [12]-[14] and W(Z)GRAD2 - [25].

An example of triple comparison within TEV4LHC workshop [30] is represented in Fig.3.
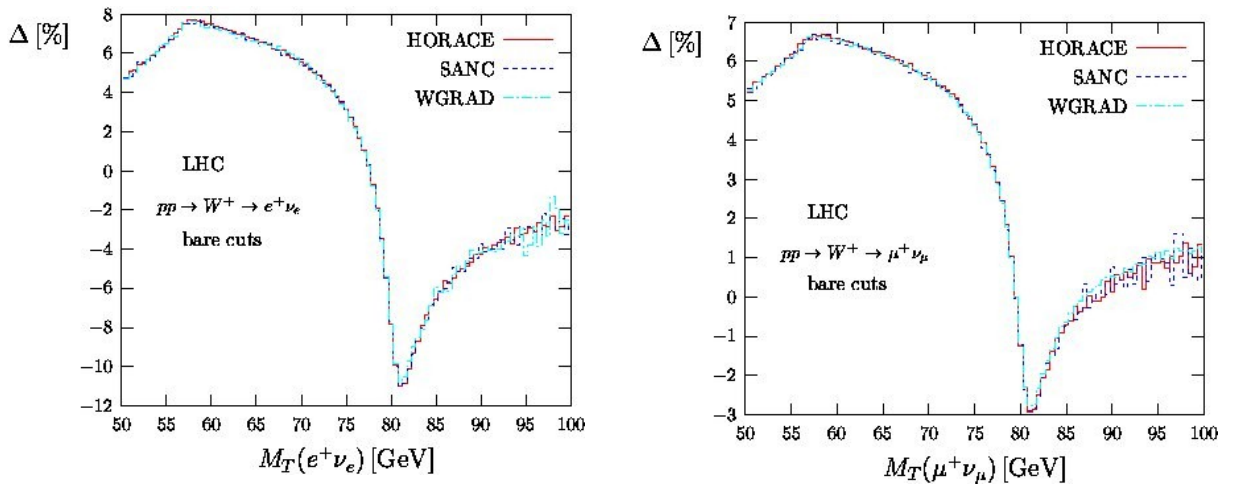
Fig. 3. The relative correction Δ due to electroweak $O(\alpha)$ corrections to the p_T distribution for single W^+ production with bare cuts at the LHC

This figure illustrates that the issue of "technical precision" of EW NLO corrections for CC DY is well under control.

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The nuclotron control system

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Abstract

Thirty-five runs of the superconducting synchrotron Nuclotron have been performed by the present time. The Nuclotron Control System (NCS) provided an efficient support for the machine operation during all runs. The NCS consists of two physical levels: an Operator Control Level, and a Front End Level. The former supplies all appropriate man-machine tools for operators to run the accelerator. Workstations and server computers are used at this level. The workstations act as operator consoles, while the servers provide a communication process, data storage, printing utilities, a common database, alarm service, a program library, and data exchange between the Nuclotron and the users. The Front End Level comprises industrial personal computers with digital and analog input/output boards. The NCS is a distributed system, where different subsystems are on distance of 500 m from each other. A backbone of the system is the Fast Ethernet Local Area Network.

Introduction

The Nuclotron [1] is intended to accelerate nuclei and multicharged ions including the heaviest ones (uranium) up to an energy of 6 Gev/u for the charge to mass ratio Z/A = 1/2. There are 96 dipole, 64 quadrupole, 32 correcting multipole SC-magnets in the Nuclotron magnetic ring of 251.5 m circumference. The maximum magnetic field value is about 2 T.

NCS Structure

General

The Nuclotron Control System in its present state, together with a Main Control Room and local consoles, comprise the following subsystems: thermometry, power supplies' control, beam diagnostics, radio frequency electric field control, beam injection and injection beam line control, slow extraction's control and diagnostics and others.

The NCS basic structure is shown in Fig.1. The control system architecture is hierarchical in nature and consists of two physical levels as an Operator Control Level and a Front End Level.

Operator Control Level

The Operator Control Level gives to operators all necessary tools to steer the accelerator running. High performance workstations, together with general-purpose server computers, are used at this top level. The workstations act as operator consoles, while the servers provide the data storage, a common database, alarm service, a software library, and data exchange between the Nuclotron and its experiments.

The NCS is a distributed system, where subsytems are geographically separated by as much as 500 m. A common backbone of the system is a Fast Ethernet Local Area Network (LAN). It runs under TCP/IP and IPX/SPX communication protocols. As soon as the system has four geographically separated parts, LAN is divided into four independent segments. A HP NetServer is used as a gateway between the General JINR Ethernet and Nuclotron LAN.
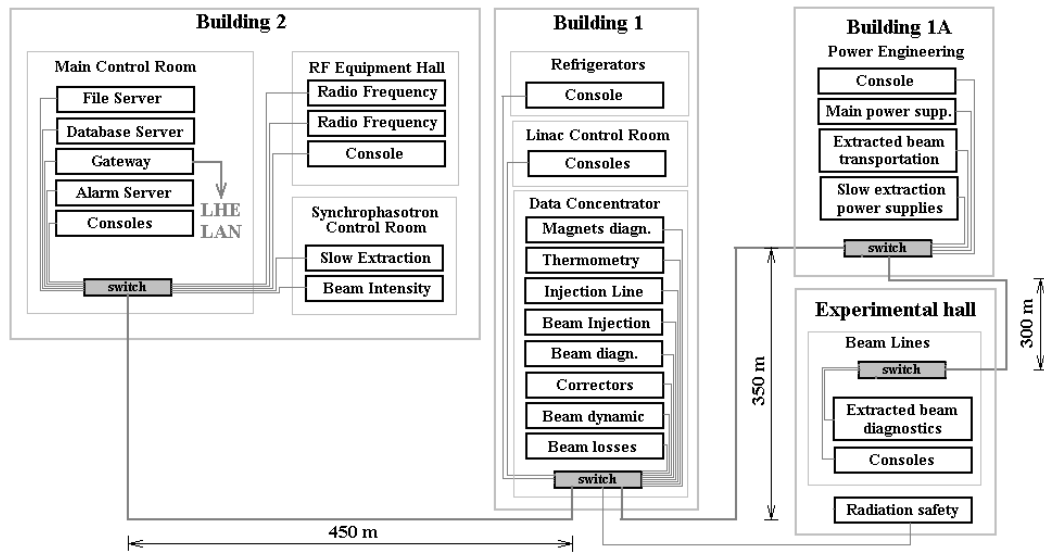
Fig. 1. Basic structure of NCS

Front End Level

The Front End Level concerns with real-time control. At present, the total number of measurement and control points is about 3500 (see Table 1)**.**

Table 1. The NCS subsystems measurement and control points and data amounts

Subsystem	Measurement points	Control points	Amount of data per cycle (kBytes)
Injection and Injection Line	550	6	270
Thermometry, Cryogenics	650	-	2
Main Power Supplies	10	3	412
Magnetic Field Correction	44	44	280
Circulating Beam Diagn.	84	-	128
Circulating Beam Intensity	2	-	2
Slow Extr., Beam Transp.	1900	70	300
Beam Losses Monitor	4	-	2
Radiation Safety	64	-	2
Radio Frequency	-	1	400
Beam Dynamics	2	-	16000
Total:	3310	124	17802

This level maintained by industrial rack-mountable PCs from ADVANTECH, equipped with I/O boards and data acquisition modules. Nowadays, the existent CAMAC standard hardware undergoes intensive upgrading with the ISA/PCI commercial or domestic, LHE-JINR modules.

The NCS Software

As a part of the NCS, the software development [2] has started simultaneously with the accelerator construction. It is still in progress at present. In general, every NCS subsystem is provided with a main software module, running on the front-end computer and driving the corresponding hardware, remote control and data viewing utilities, database interaction etc.

The NCS software evolution went through some stages. At the beginning, when the C-like and Assembler languages applied for programming, the codes where executing under the DOS. Applications, running on the front-end computers, uploaded working data to a file server every accelerator cycle. Thus, acquired information was accessible to the operators and experimenters. For a purpose of control the IPX/SPX and NetBIOS protocols supported direct data exchange between a front-end computer and an operator console.

Further, a new concept of data transfer, from the NCS subsystems to the accelerator operators and experimenters, was designed with a goal to use the file server for archive information storage only. Users are in able to get data directly from the subsystems by a client/server method. The new scheme of data transmission is realized on a socket technology, that is the standard lnk interface between two network programs.

Two primary versions of end-user data are proposed: 1) on request; 2) by a "publish and subscribe" method. In the first case, a client receives current information immediately on request, sent from the client and processed by the Server. In the second case, the client subscribed for periodical data, transmitted once on a measuring cycle completion.

Application of the new data transfer concept brings some sufficient advantages, such as solving the problem displaying information mistiming from different subsystems, and increasing the reliability of the NCS at whole (the file-server fault doesn't result in failure of subsystem operation).

For a moment, the new concept has been developed and successfully implemented in several subsystems, such as main power supplies' and slow extraction's control. In the future, the software complex for the rest of NCS subsystems would be upgraded in the same way.

Additionally, the NCS software provides yje users outside woth the Nuclotron operational data through a standard web browser. Four Java-applets have been developed to present the data from thermometry, main magnetic field control, internal beam and slow extraction's diagnostics.

A database development, founded on the Firebird DBMS, is in progress to store the operation mode parameters. In the future, a mode statistics will allow an operator to fast select a proper mode, as well as upload the most of subsystems with necessary parameters from the database. During the last runs, this application was successfully tested and improved while obtaining the initial statistics.

An actual NCS Software layout is presented in Figure 2.

NCS Local Area Network

The Nuclotron LAN [3] is one of the most important NCS elements. The Fast Ethernet technology has been chosen to construct the Nuclotron LAN. It gives a simple way to support communication of the local NCS parts over different accelerator's areas. Its capacity is quite enough to satisfy the control system demands. Also it was not so hard to upgrade the old Nuclotron LAN (Ethernet) for the new one. A topology of the Nuclotron Fast Ethernet LAN is presented in Figure 3.

As one can see, the LAN has a structure of a distributed backbone. The central nodes of network are 24-port switches, placed in corresponding buildings. These nodes are connected each other in series on physical layer 100Base-FX (fiber optic cable). The cables were installed through special underground and overhead tunnels between the buildings. Local nodes, such as servers, workstations, front-end computers and mini-switches, are connected to these backbone nodes on a star topology.
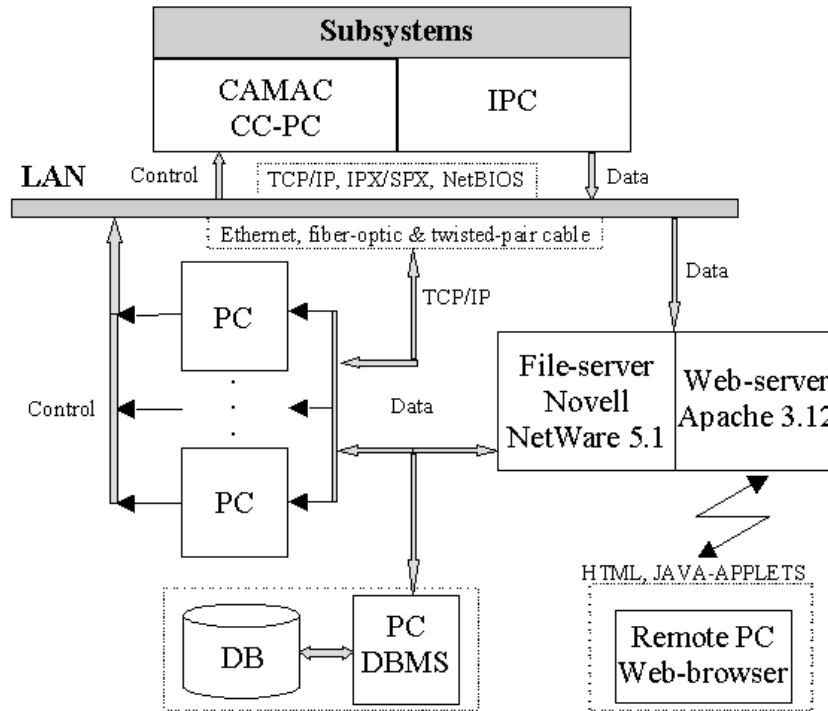
Fig. 2. Current NCS Software structure
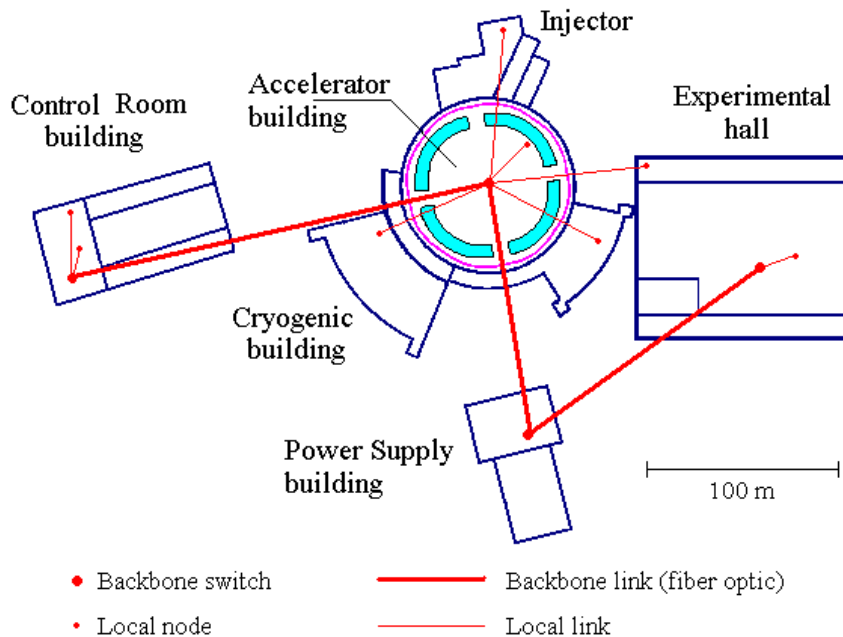
Fig. 3. Topology scheme of the Nuclotron LAN

Nowadays, the LAN supports more than 50 units: about 20 front-end computers and over 30 workstations. A mean information flow, produced by regular data exchange between the NCS components, highly depends on the accelerator cycle repetition mentioned above.

Now, this value is in from 150 kB/s up to 250kB/s. However, this value is going to be increased up to 2,2 MB/s after integration of the beam dynamic investigation subsystem with the NCS (see Table 1).

The Nuclotron LAN is a subnet of the LHE/JINR Network. The gateway computer provides connection of the LAN to the JINR Network backbone, as well as to the Internet. So an external user has an access to the NCS pulic data.

NCS Subsystems

RF Control Subsystem

An experimental version of the RF control subsystem is under development now. The digital synthesizer Acquitek CG100 PCI, working under the Direct Digital Synthesis (DDS) technology, is proposed for a master oscillator of the RF voltage equipment. The synthesizer is controlled by an industrial PC, that performs operative calculations of frequency variation while tuning beam acceleration and extraction. The frequency versus the main magnetic field dependence is performed by a synchro-signal of reaching the basic field level, and by syncro-pulses of the rising and falling field (every 10^{-5} T). During the development tests it has been shown that the output frequency was needed to follow the 3-4 µs interval of reprogramming. That allows RF to be steered with a step of $1\dots 2* 10^{-5}$ T and the magnetic field ramping rate of 2 T/s as maximum. A structure of the subsystem is presented in Figure 4.
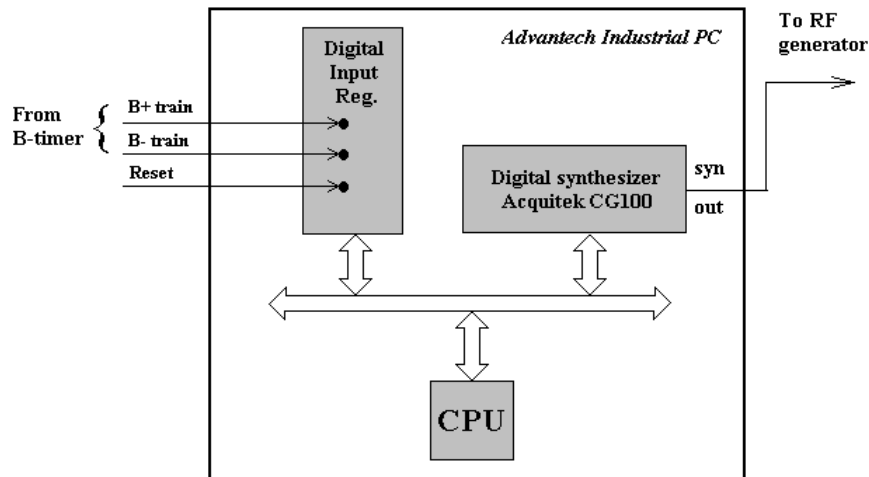
Fig. 4. Structure of the RF Control subsystem

Beam Dynamic Investigation Subsystem

The beam bunch intensity and shape [4] are measured with 2 electrostatic pick-ups, formed as diagonally cut boxes. These data allow monitoring the first turns' beam parameters, investigation of the beam losses, calculation of the bethathron frequency, and so on. Now, the signals from both pick-ups are measured by 2-channel 8-bit DAQ with sampling rate of 50MHz and 256K on-board memory. During accelerator runs, the algorithms of bunch detections as well as base line shift compensation, were worked through. The first results of beam dynamics investigation (during first 5 ms of acceleration) were obtained. Figure 5 demonstrates some parameters of the circulating beam (intensity, radial position, and bethatron oscillation frequency) from an injection start up to the beam breakdown on the surface of vacuum chamber.

For the upcoming run, a "Compuscope 14100 High Quality 14-bit A/D and Scope" PCI standatd card from Gage is foreseen to be used as the main DAQ unit. The on-board memory of this module is capable enough for 8M samples, so the total time of measurement could reach 80 ms (a structure of the upgraded system is presented in Figure 6). In the future, we are planning to cover the acceleration cycle at whole.

Fig. 5. Circulating beam parameters data presentation
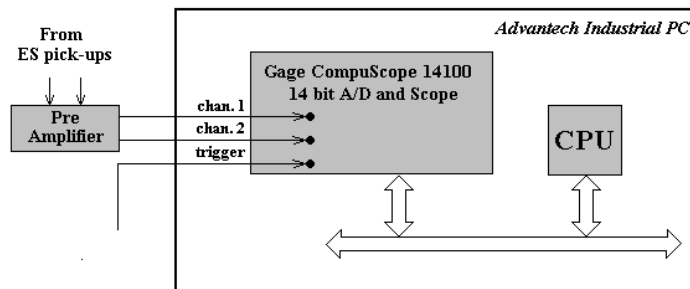
Fig. 6. Structure of the Subsystem for Beam Dynamics Investigation

Main Power Supplies Subsystem

This substystem [5] is one of the oldest NCS parts. A maximum value of the magnetic field is about 2 T. The banding (BM), focusing (QF) and defocusing (QD) magnets are powered by three supplies. At present the machine cycle has the following typical parameters: the 0.7 T/s ramping rate (as a rule); the 0.2 - 0.05 Hz cycles'repetition; the 0,1 - 16 s flat top duration.

The magnet cycle is specified at the B(t) level. The waveforms, driving the power supplies, are generated by the programmable function generators under console software. Originally, the BM ramp profile is forming as a digital image from the pulse function generator (PFG). The PFG produces reference bursts (Bo–train) with a 0.1 Gs resolution. This train makes increments or decrements within the pattern analog function generator, based on the 18–bit DAC. The BM induction transducer produces an analog signal proportionally to the derivative (DB) of the real magnetic field. This signal initiates a B–timer that generates a B–train with a 0.1 Gs resolution. The B–train from the reference bending magnet (digital function), and the corresponding analog function, are used for the feedback loop. The BM current magnetic field's scaled value is used as a reference for the defocusing magnets. The QD current field is used as a reference for the focusing magnets in the same way exactly.

The CAMAC standard interface was previously in use for the present subsystem's version. Up to 50 modules, occupying three crates, provided main magnet cycle of the Nuclotron. New version of the subsystem is based on an up-to-date industrial PC equipped with precise pulse and analog function generators, scaling multiplied DACs, multichannel DAQ in the ISA/PCI standard. Some comparison of the present facility with its upgrade is presented in Table 2. Actually, the advanced equipment is under adjustment and tests.

Table 2. Upgrade of the Main Power Supplies Subsystem

Performance	Present	Upgrade
Pulse function generator: – master oscillator frequency – number of vectors	1 MHz 4K	2.5 MHz 32K
Analog function generator: – resolution	16 bit	18 bit
Pulse train analyzer: – number of sampling points	0.4K	64K

Conclusion

At present, although being developed not up to its final scale, the control system is fully operational with the functionality proposed. An essential step, to provide the accelerator with a high performance and flexible computer control, has been accomplished.

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Positron annihilation versus electron cloud

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"Audiatur et altera pars"

Abstract

This report describes the possibility to use annihilation as an effective method to decrease the number of low energy electrons in the vacuum of the accelerators. The processes with thermalized positrons and secondary particles in the vacuum pipe and their behavior have been discussed. The next step is an estimation of the positron interaction with the vacuum chamber walls. Positron sources are an object of interest, too. Their creation or regeneration by the radiation fields of the particle losses is recommended. The implementation of the annihilation against the formation of an electron cloud causes some technology problems but they are not so severe in comparison with the other existing methods.

Introduction

Some accelerators have an unstable or limited performance because of the large amount of non-beam low energy electrons that have emerged in the accelerator vacuum chamber. This electron formation is known as Electron Cloud (EC) [1]. The EC parameters are relevant to the chamber-beam geometry, to the beam parameters, etc. Many methods could be applied to decrease the number of these electrons. The so far known methods have generally an electromagnetic nature and for this reason they interfere with the acceleration process. Besides, the application of such methods is difficult in the important positions of the accelerator structure such as magnet edges, junctions, transitions etc.

The proposal discussed in this report aims to use the positron annihilation to clean the low energy electrons in the accelerator vacuum chamber. If a number of positrons with selected parameters and energy is introduced in the chamber they will annihilate with electrons and will produce gamma radiation, which will penetrate through the chamber wall, outside of the beam area. In connection with this proposal many questions have arisen.

The basic problem is considered in the first part. The positrons in the vacuum chamber will interact not only with the free electrons but also with the residual gas and the particles escorting it. The interaction rates are relevant to the energy distributions of these particles. A conclusion about the most suitable positron energies based on the present knowledge on the cross sections of these processes is drawn. The main point in this conclusion is that positrons with very low energies are the most suitable for EC elimination purposes.

In the second part the problems with the energy distributions of electrons and positrons in the accelerator vacuum chamber are discussed. The LHC project will be considered in the examples that follow.

How to produce positrons with needed parameters is the issue discussed in the third part. There is not another possibility to introduce enough positrons in the vacuum chamber of accelerators except by inserting or creating radioactive isotopes. Some useful remarks on the probable production of needed isotopes in the stray radiation field of the beam are made. The isotopes with a high and prevailing positron emission produce MeV – energy positrons. By interacting with the chamber walls or the beam screen they are transformed into positrons with very low energies – some eV.

According to the author's understanding it is possible to obtain densities of positrons in the vacuum area in the vicinity of the wall, close to those of the electron cloud.

Part 1 – Processes with positrons in the accelerator vacuum

The processes with positrons in a vacuum are intensely investigated in astrophysics [2, 3, 4, 5]. The annihilation is a process responsible for the 0.511 MeV gamma radiation from different astrophysical objects. The density of the particles in these objects varies from that of the solid matter for the interstellar dust [2], via the plasma densities for the solar flares [3] to the fairly rare gas for the interstellar media [4]. The temperature of these objects also varies from 80 K for cold media to 10^5 K for hot ones.

The accelerator vacuum has about 10^{15} m^{-3} equivalent hydrogen density and 10^{13} m^{-3} electron density for the electron cloud [6]. This electron density number is a relatively modest value for the collimator areas but it is very high for the number of "seed" electrons in the general positions. These values coincide with the parameters of the astrophysical object known as H II region [5]. In such a region positrons and electrons can annihilate directly or they form positronium (Ps) first. Positronium can be produced by a radiative recombination with free electrons or by a charge exchange with hydrogen. Depending on the temperature and density of the medium the positronium can be created in two different forms – orto and para-positronium. The first is short-lived (10^{-10} s). The second is annihilated, too but with life-time 10^{-7} s. We shall consider only the processes with thermalized positrons because only 10% of positrons with MeV energies annihilate before their thermalization to eV energies via interactions with ambiance. There is not a noticeable difference in interactions of positrons with hydrogen atoms and heavier ones and their ions either. The thermally averaged annihilation rates per unit target density of the four main processes in these conditions are illustrated by curves on Fig. 1.
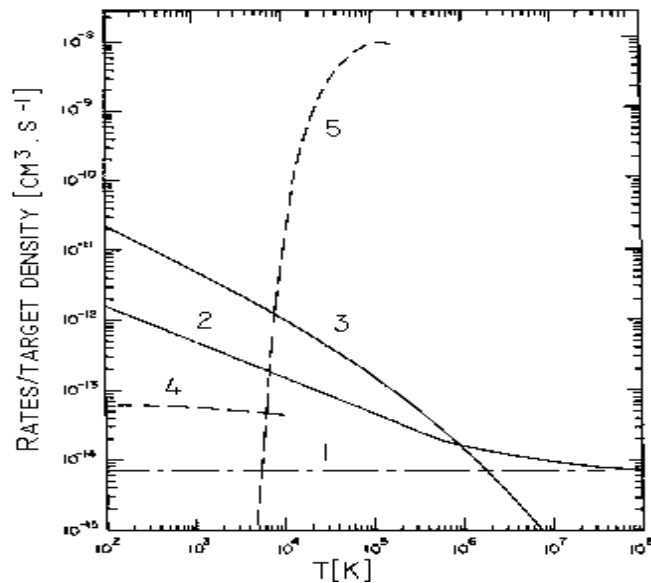
Fig. 1

Line 1 shows the direct annihilation rate on free electrons without Coulomb interaction. The Coulomb correction is important for low energies. Curve 2 is obtained including the Coulomb interaction in the cross section calculations. Curve 3 stands for the rate of radiative recombination with free electrons. Curves 4 and 5 are graphical presentations of the positron interactions rates with hydrogen – for a direct annihilation on atom electrons and for a charge exchange with neutral H, respectively.

The information on Fig. 1 is a compilation from different publications [2, 3, 4, 5]. Some of the processes are not well investigated in the full temperature scale. Anyway, some important conclusions based on this information can be made. Such is the conclusion that for positrons with very low energies (about 5 eV - 20 eV) the EC "cleaning" processes 2 and 3 prevail. The rates, shown on this figure are calculated with the assumption that interacting particles have a kinetic energy distribution close to the Maxwell-Boltzman distribution of velocities and both components are in a thermal equilibrium.

Part 2 – Energy distribution of electrons and positrons

The important parameter for estimating the rate of the processes with electrons is their energy distribution. The summarized information about measured energy distribution of the EC particles by electron cloud detectors is shown on Fig. 2 [1].
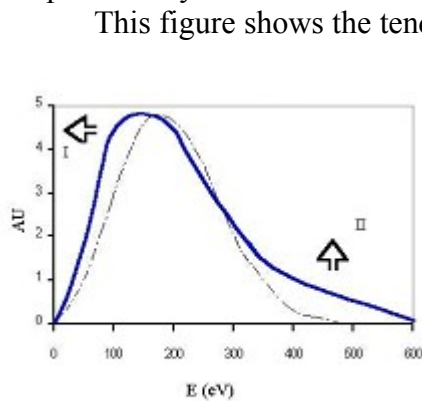
This figure shows the tendency of the measured distribution to change with changes of

Fig. 2

external factors. The arrow, marked by "I" points to the direction of the curve distortion when the secondary electron yield goes higher. The next "II" arrow shows the elevation of the distribution curve when the number of the beam bunches increases. For comparison, the Maxwell-Boltzmann distribution is drawn by a punctured-dashed line. The electrons in the interstellar media are supposed to have this type of velocity distribution.

According to the literature the secondary electrons will populate the very low energy zone, as shown on Fig.3 [7]. The same item is an object of special attention and experimental checks for the LHC in the expert article [8].

There are two different situations for the energy distribution of electrons. The first one becomes actual when the beam starts and the "seed" electrons are accelerated by its electrical field. The accelerated to some hundred volts electrons hit the wall and produce secondary electrons with energy about 5 eV and the process remain active for the beam time (see fig. 2). In the beam pause time the second type of electron energy distribution is realized. Then the energy distribution curve has maximum values in the region of 5 eV.
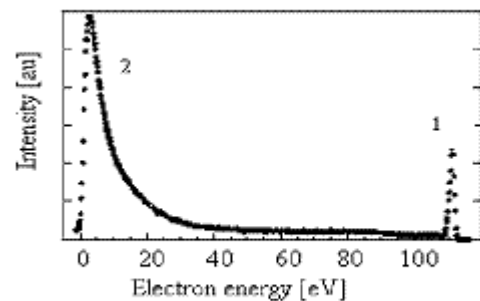
Fig. 3

For the purposes of the EC cleaning this second situation is the favorable one. According to the rates, shown on fig.1 the low energy electrons can be annihilated by a small number of low energy positrons.

The production of positrons in the accelerator vacuum chamber can be performed by positioning or creating there positron radioactive isotopes. The isotope positron sources [9, 10] produce positrons with MeV energies. The behavior of positrons in the accelerator vacuum chamber is flow-charted on fig.4.

- action

- medium

e+ generation/thermalization

wall surface

emission and reemission

vacuum

acceleration

vacuum

positron cloud

vacuum

annihilation

free electrons

rad. combination

free electrons

Ps

annihilation

hydrogen

chage exchange

hydrogen

Ps

G   A   M   M   A
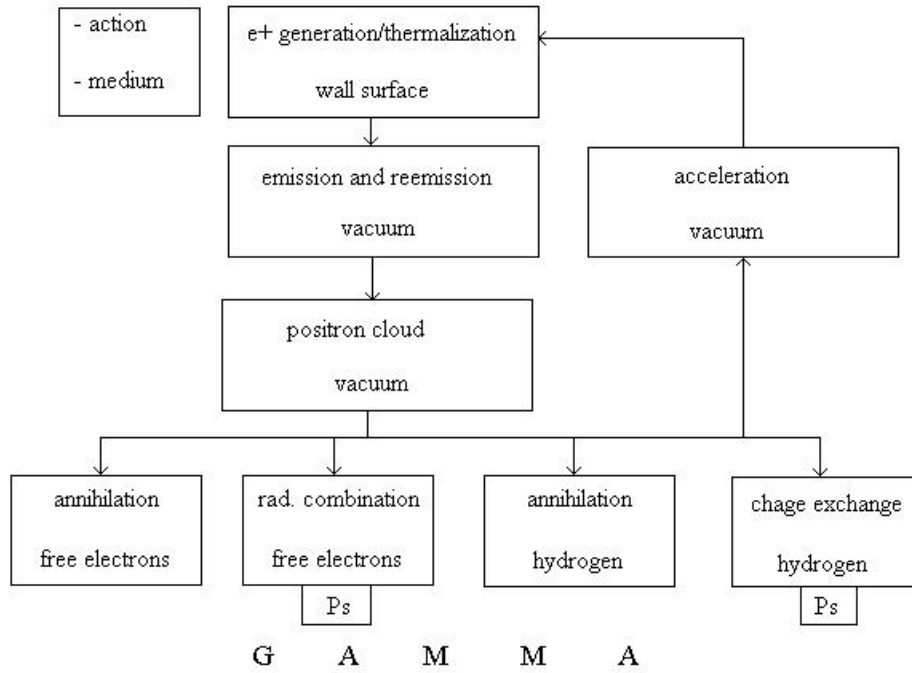
Fig. 4

The positron, produced by a nuclear decay near the surface of the vacuum chamber wall will thermalize to low energies very fast (10^{-11} s) [10]. After that it can be emitted with high probability if the work function of the wall material is negative [11]. The positrons form a positron cloud (PC) in the vacuum because of the good reflection of low energy positrons from metal surfaces [12, 13, and 14]. The PC interacts with EC according to the four processes scheme described in part 1. When the proton beam starts it will accelerate the free positrons and they can be "glued" to the metal surface because they will be trapped into the image-potential-induced state [15]. The positrons that penetrate deeper could change the electron emitting properties of the surface. For some materials this can be favorable for a low secondary electron yield.

Part 3 - Positron production

The isotope positrons sources can be of two origins, i.e. preliminary elaborated and embedded in the wall isotopes or created in the wall isotopes by the irradiation of the beam losses.

An example for the first type is described in [9, 10].

Information about the possibility to produce positron emitting isotopes by beam losses can be found in the published notes on the LHC project [16, 17, 18]. According to these papers the average loss rate around the LHC ring is 1.65×10^{11} m^{-1} y^{-1} (due to beam-gas interactions only). For the 250 h beam and the general position in the ring this will produce two basic radiation components:

1. Highly Energetic Hadron Fluence on the inner surface of the pipe with value estimated about 10^4 to 10^5 cm^{-2} s^{-1}.
2. 1 MeV Neutrons Equivalent Fluence with value 10^5 to 10^6 cm^{-2} s^{-1}.

The LHC beam screen, irradiated by this radiation has on the inner surface 75 μm

copper sheet [6]. Some of the isotopes produced by experimental irradiation of LHC copper [16, 17] are listed in Table 1.

Table 1

cooling time	Isotope	t1/2	Experiment (Bq/g)	Remarks
1= 34m	42K	12.36h	21.6 ± 15.3	%B-=100
2=1h 7m	43Sc	3.89h	24.6 ± 24.1	%EC+%B+=100
2	44Sc	3.93h	45.4 ± 9.5	%EC+%B+=100
1	52Mn	5.59d	18.3 ± 5.5	%EC+%B+=100
1	56Mn	2.58h	27.7 ± 5.8	%B-=100
1	61Co	99.00m	52.7 ± 12.3	%B-=100
1	60Cu	23.70m	16.4 ± 8.7	%EC+%B+=100
1	61Cu	3.33h	165.0 ± 27.2	%EC+%B+=100
2	64Cu	12.70h	595.0 ± 13.2	%EC+%B+=61, %B-=39

One can underline the hour isotopes 61Cu and 64Cu. They are the result of the exposure of the copper target to the stray radiation of the 280 GeV/c beam ranging from $1,6x10^{11}$ to $1,5x10^{12}$ particles and for a period of time from a few hours to several days. The comment is that positron production, concurrent to the electron production always exists in the vacuum chamber but the conditions to overcome EC are not favorable. This can be controlled by an especially designed metal alloy or compound for the inner surface of the pipe. Information about some useful elements is shown in table 2:

Table 2

Sensitivity (a.u.)	Elements
0.1	Dy, Eu
0.1 - 1	In, Lu, Mn
1 - 10	Au, Ho, Ir, Re, Sm, W
10 - 100	Ag, As, Br, Co, Cs, Cu, Er, Ga
100 - 1E3	Hf, Sc, V, Yb, Al, Cd, Cr, Gd, Mo, Nd, Ni, Os, Rb, Ru, Te, Zn, Zr
1E3 - 1E4	Bi, Ca, K, Mg, P, Pt, Si, Sn, Ti
1E4 - 1E5	Fe, Nb, Ne
1E6	Pb

In table 2 the sensitivity of the most suitable elements is graduated according to their thermal neutron activation ability.

Conclusions

The positrons in the vacuum accelerator chamber are a possible tool to control the number of the low energy electrons. The direct measurement of these particles in working conditions is very difficult. Experimental evidences for their influence on the EC formation can be obtained by positioning of a positron source near the electron cloud detector and then a comparison of the memory effect [8] times should be made.

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The telecommunications core of the JINR LAN

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The distributed information and computational JINR network structure should offer the same level of services as provided for the users in the different world famous research centers the JINR collaborates with, and JINR researchers should have an adequate work environment similar to that they have abroad during their missions within their scientific collaborations. Thus the JINR network structure is in the permanent process of incorporating of the new services and devices, new network solutions and mechanisms.

The network infrastructure elements are under permanent monitoring by specialized software tool for the staff to know the health of the entire network. Besides this, all work with JINR users is conducted through specialized IPDB data base. The first version of the data base was originally developed in LIT almost 10 years ago, and it is the subject of permanent modernization, reflecting the demands of the time and needs of the staff to better organize network users' activities. Last add-ons to the set of IPDB features are Kerberos, AFS, and User GUI.

Since March 2004 JINR LAN deploys Gigabit Ethernet technology with its 1000 Mbps data rate. During last two years we have made a few essential changes in the central telecommunication node of the JINR LAN:

1. the old edge router Cisco 7505 was replaced by new one Cisco 7606 with Gigabit Ethernet interfaces;
2. the second central Layer 3 Cisco Catalyst 6509E switch was installed in the core of the telecommunication facility;
3. the router Cisco 7513 took the role of VPN router Cisco 3640;
4. Cisco 7505 began to serve JINR modem pool.

This powerful network structure allows deployment of the huge amount of data - 40 Terabytes per month in both directions.

Fig.1 shows the single mode fiber optic cable structure of the JINR LAN. There are 3 separate optic cable segments used to form the transport media of the JINR network: one cable forms a ring across LJAP site, the second goes to BLHE/LPP site, and the last reaches the JINR Administration building #2. All cable segments have 16 single mode optical fibers.

Fig.2 reveals the details of the JINR fiber optics backbone design. Every Laboratory across LJAP site uses one optic fiber pair to be connected to the LIT main central switch, the rest of the fiber passes the entire ring and connects to the second main central switch in LIT. Thus we have reliable physical structure of the intra data communications. There is no an alternative link of the single mode transport for BLHE/LPP segment, and for the Administration segment, but there are some spare fibers in BLHE/LPP cable.

The diagram in Fig.3 shows the external JINR – Moscow MIX (Moscow Internet Exchange) data communication link. The single mode optic fiber goes through Dubna Satellite Space Center, through some intermediate places as Konakovo, Radishevo, and Starbeevo, reaches Moscow (Shabolovka), then comes in Moscow Internet Exchange MIX (Bootlerova Str.). JINR Edge Switch Cisco 7606 provides 3 Gigabit interfaces to be connected to different Internet Service Providers: to GEANT through RASnet, to Internet through RBnet, to RadioMSU, and 10 Gbps to CERN through Gloriad. 10 Gbps data communication link is expected to be provided in the beginning of 2008. The equipment of Nortel Company will be installed in three points: JINR, Radishevo – the middle point of the distance, and Moscow Internet Exchange.

In Fig.4 there is a diagram of the JINR LAN Central Telecommunication Core. It includes the most important devices of the facility such as main edge router Cisco 7606, main central switches Cisco Catalyst 6506, and Cisco Catalyst 6509E, and firewall Cisco PIX525, Cisco 7513, 7505, 3640 routers. The central Layer3 switches serve the main JINR divisions, while different types of remote connections are served by Cisco 7513, 7505, 3640 routers. Thus most powerful devices are busy with critical GRID applications used in the JINR Laboratories. On the diagram is shown as an example the LIT cluster "Ferma".

As it was said in the first article the process of the network structure modernization goes on and on. There are more services and solutions are to be applied to get better network and services parameters.
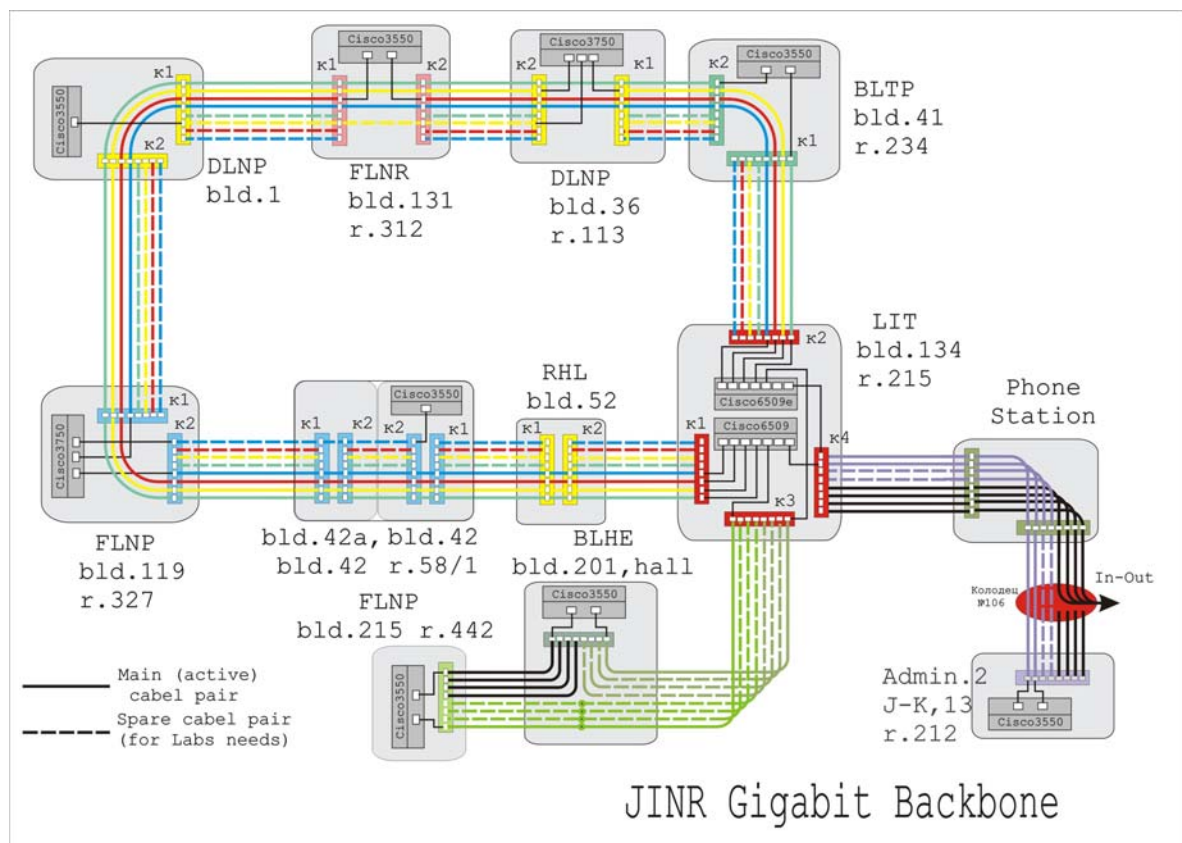
Fig.1. The single mode fiber optic cable structure of the JINR LAN
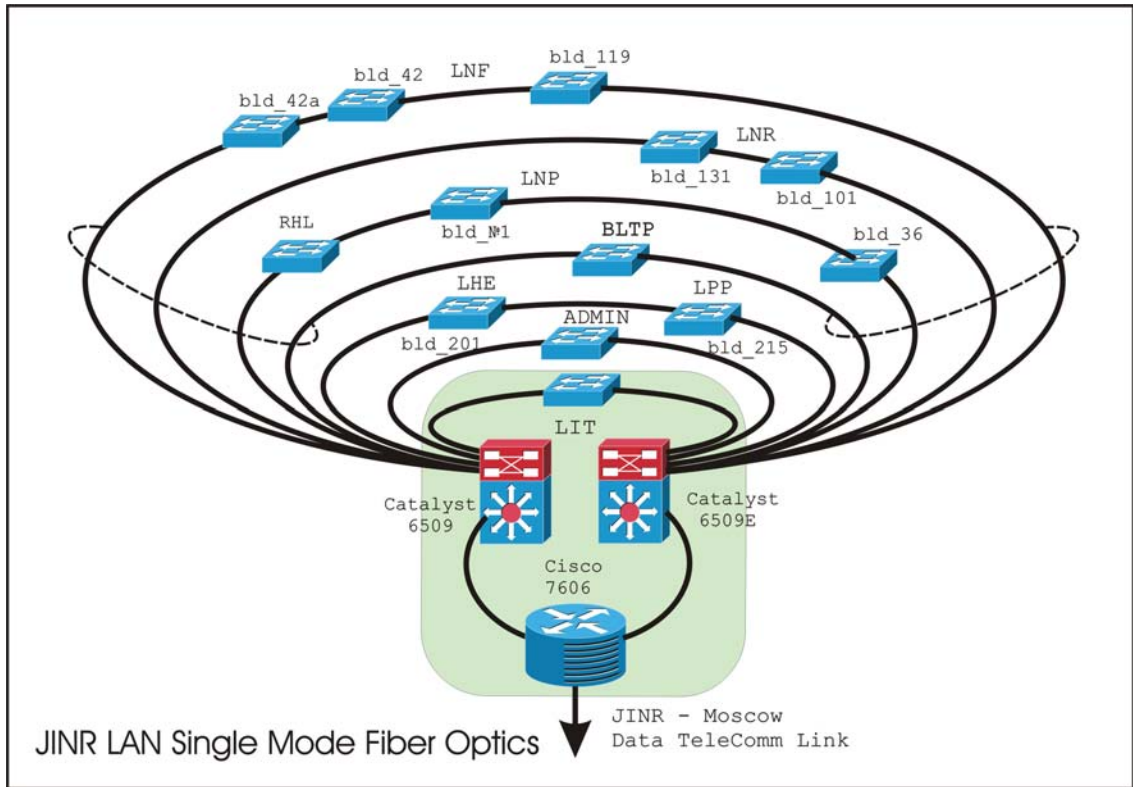
Fig.2. The detailed scheme of the JINR fiber optics backbone design
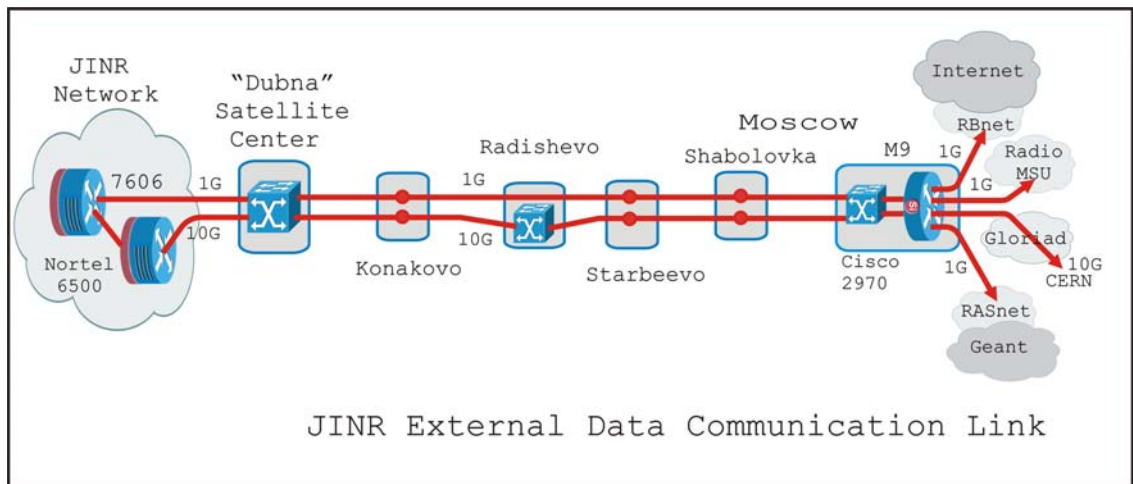
Fig.3. The external JINR – Moscow data communication link
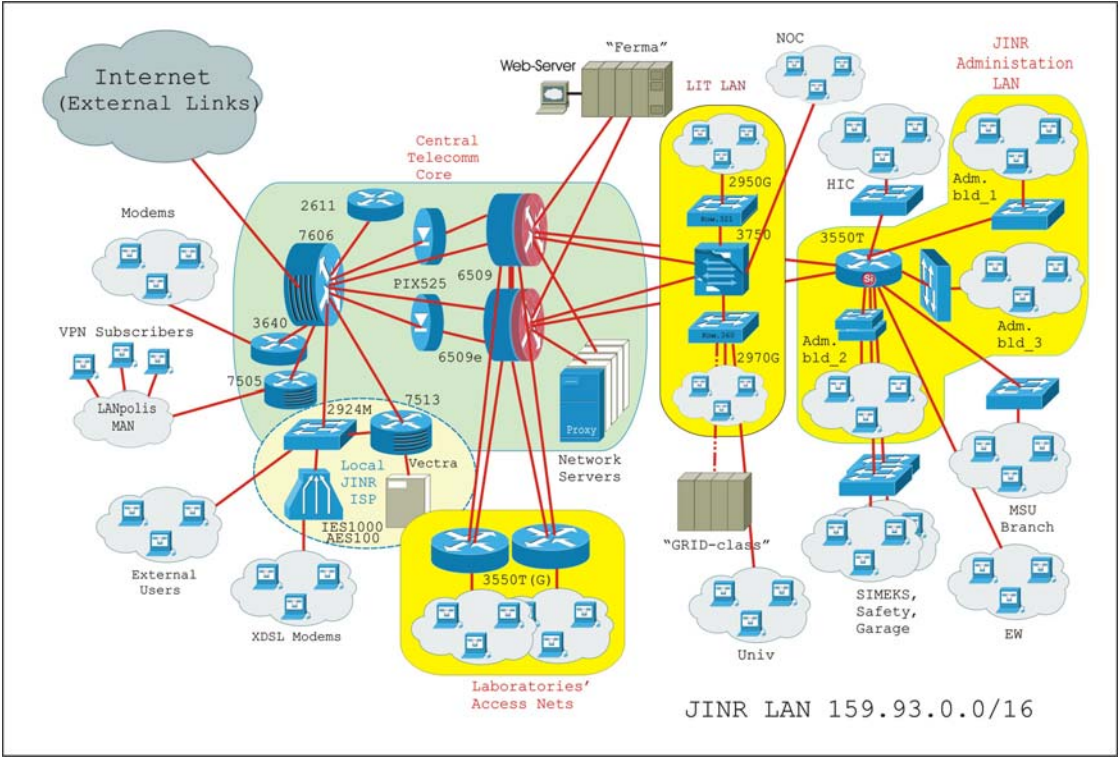
Fig.4. The JINR LAN Central Telecommunication Core

Digital spectrometer for sandwich type scintillator

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The architecture and the principle of operation of digital spectrometer designed for the pulse shape selection and measuring the gamma-ray energy recorded by a sandwich type detector (NaI[Tl]+CsI[Tl]) are considered. Digitizers with a sampling frequency of 40MHz and FPGA for preliminary digital processing were used. The spectrometer operates in 0.05 – 5 MeV range and has the enhanced sensibility in the range of low energies. The results of a spectrometer testing are presented.

1. Introduction

Gamma-radiation is an informative type of nuclear radiation, because of high penetrating ability. It permits to perform the remote detection for radiation sources. It also makes possible to identify sources by their energy spectra.

Gamma-ray sources being in environment as a result of the act of terrorism or man-caused disaster may contain a wide assortment of radioactive substances. These materials may be fissile materials, products of fission or spent nucleus fuel of different ages, radioactive materials for making "dirty" bombs. The energy of gamma-rays for most long-lived sources is 100-300 keV. For detecting and identifying these gamma-sources with the aid of air- or ground-based mobile systems at distance of 100-200 m, the recording apparatus should have sufficient sensitivity. It provide considerable counting rate to record the statistically significant number of desired events in the effective exposure time that is governed by the velocity of a carrier of the mobile apparatus. A promising sandwich-type scintillator offers the reasonable signal-to-noise ratio in identifying the low-energy gamma-emitters at the distance 100-200 m in the range from 50 to 300 keV.

Contrary to the standard detector these detector includes two crystals with different luminescence decay times. These crystals are glued together for ensuring the optic contact and are viewed from PMT. The signals are analyzed by a pulse shape selection device being a necessary part of the spectrometer section. Within the framework of fulfilling the tasks of the recording of gamma-rays with energies up to 300 keV, the crystal on the side of the incident radiation is a working one; the crystal on the side of PMT is a protecting one. The recording crystal has a thickness sufficient for total absorption of gamma-radiation with energy lower than 300 keV. Gamma-rays with the energy more then 300 keV lose a part of their energy in passing through the recording crystal. Then they are absorbed by the protecting one and excluded from the spectrum (on the base of analyzing the pulse shape) that is measured by the recording crystal. It permits the essentially reduction the Compton-part spectrum associated with gamma-rays of higher energies. The protecting crystal plays a role of passive and active protection.
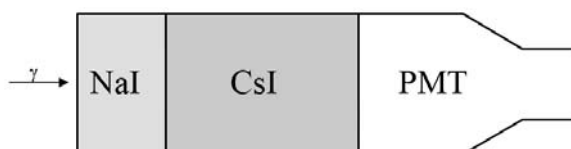
Fig. 1

For spectrometry of gamma-radiation with the energy in the 300-3000 keV range, both crystals in the sandwich-type scintillator can work as a whole one. As applied to measuring the spectrum of gamma-radiation in this energy range, the problem should be solved by "reconstruction" of the spectrum (determination of total gamma-ray energy) using electronics hardware and software to determinate the energy losses in each of crystals. Electronic tools should also make possible analyzing possible combinations in registrating gamma-rays in the two crystals.

An experimental model of the promising gamma-spectrometer has been developed on the base of sandwich-type scintillator detector SDK-07, produced by AMCRYS-H. This detector consists of two low noise 160x160mm scintillation crystals NaI(Tl)+CsI(Tl). The crystals are glued together to provide optical contact and enclosed in a container. The NaI(Tl) recording crystal of 22 mm thickness is located at the input window. The protecting crystal CsI(Tl) of 50 mm thickness is placed in the container at the output window.

2. Hardware and software tools for experimental model of device
2.1. Spectrometer configuration

Gamma-spectrometer consists of 2 (possible up to 4) channels (measuring modules), interface module and PC common to all of channels. Each channel includes the scintillation detector, spectrometer and power supply. The scintillation detector contains the sandwich-type scintillator and PMT. The power supply delivers high voltage to the PMT and low voltage to the spectrometers. The interface module connects all channels to PC by RS-232 or USB interface.

2.2. Electronic tools

The block-diagram of electronic circuit of measuring module is shown in Fig.2.

The analog part of electronic circuit contains charge-sensitive amplifiers (CSA), discharge circuit (DC), and operation amplifier with controlled gain. CSA should have the integration time substantially higher than the luminescent decay time of the slowest of two crystals. DC is used to discharge an integrating capacity after finding a flat part of the signal. Fast ADC is uninterruptedly digitizing the input signal and transfers 12-digit code into FPGA. It performs all digital processing and forms energy spectra for different parts of the combined scintillator

The FPGA contains digital part: a digital low level discriminator (DDLL), a digital maximum detector (DMD), RAM to memorize the digitized value of PMT pulses (can contain up to 160 counts) and a spectrum shaping logic to exert control over RAM 1-4.

DDLL contains a digit comparator and compares the signal with the threshold. DDLL activates digital maximum detectors when the signal exceeds the threshold. Then all the following signals are memorized in RAM. The digital maximum detector contains a comparator and counter of cycles. It uninterruptedly compares two successive samples, counts the number of comparisons and stop when two ore more successive samples become equal in value. After stopping the digital maximum detector generates a signal to discharge an integrating capacity and triggers a spectrum shaping logic.

If the number of cycles exceeds the maximum number T_{max}, it means that superposition of pulses has happened. In this case the system will be reset and the superposition counter will be incremented. If the number of cycles of DDLL is less than T_{min}, the count signals (false signals) counter will be incremented and the operation will be continued. The operation of the spectrometers can be controlled by the accumulation values in these counters.

RAM 1-4 is used for accumulating spectra. This RAM can accumulate up to 4 spectra with of 1024 channels and up to 65535 events channel recorded. The forth spectrum is the reserve one.

The maximum code ADC U=4095 should correspond to the maximum recorded energy (3000 keV) and to the 1023 channel of the spectrometer, because the light efficiency of NaI being more than the CsI one. Therefore the channel number in the spectrum for the energy recorded in NaI should be equal to U/4, and the channel number for the energy recorded in CsI should be equal to Uα/4, where α is inversely proportional to the light efficiency of CsI.

The algorithm of signal shape discrimination is realized in the spectrum shaping logic and works on the principle of measuring the rise time of signal up to two levels: low level TL and high level HL. If the time at rising the signal to preset levels lies in the range from T_{NaI} to T_{CsI} this event is considered as the mixed event and it requires to initiate the algorithm of separating a part of energy.
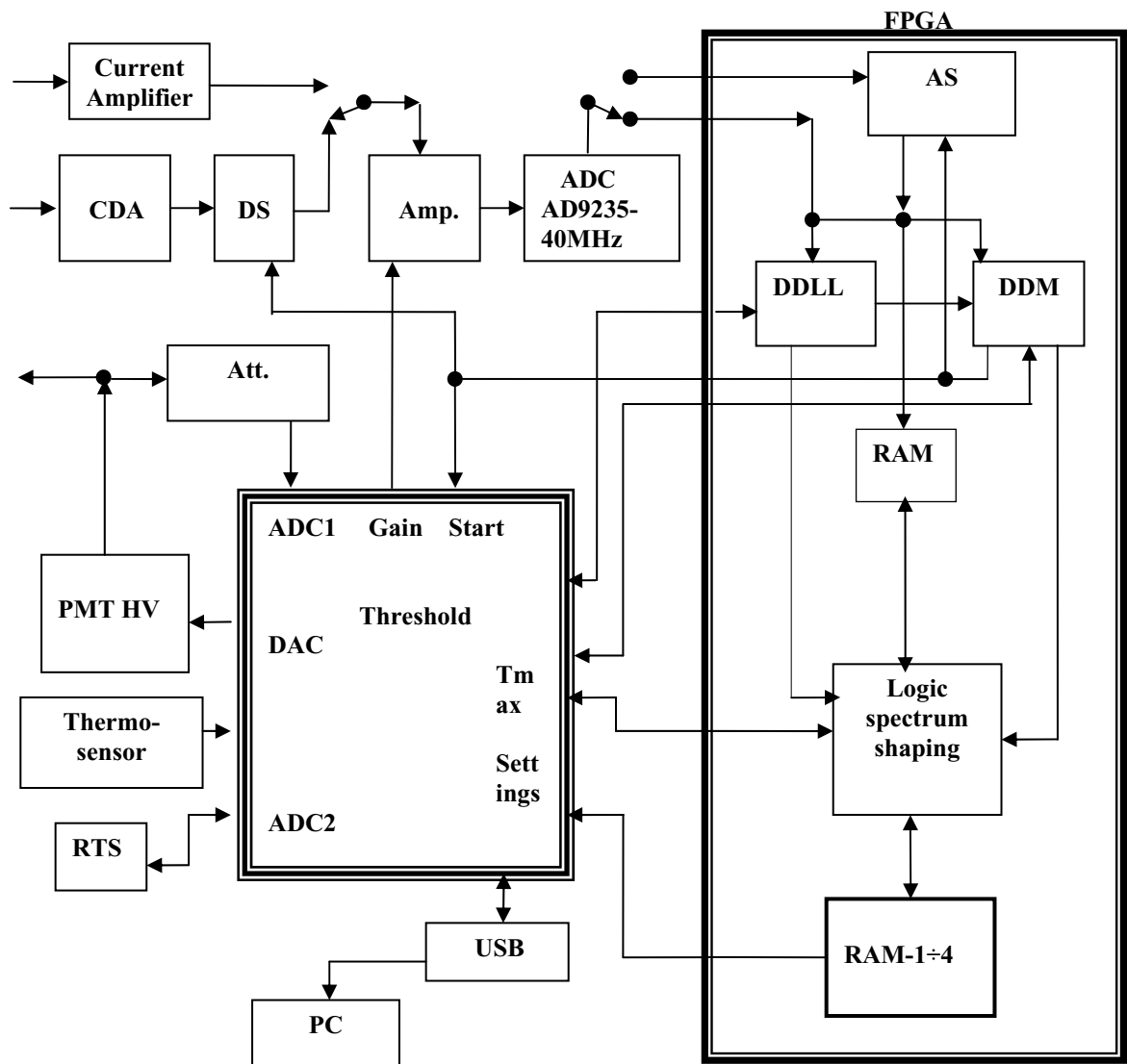
Fig. 2

The logic device of shaping spectra adds 1 in to the fast crystal spectrum if the number of cycles corresponds to fast crystal (**Tmin ÷ T$_{NaI}$**). If the number of cycles corresponds to the slow crystal (**T$_{CsI}$ ÷ Tmax**) the logic device of shaping spectra adds 1 in to spectrum of slow crystal. Values **T$_{NaI}$** and **T$_{CsI}$** are levels. Algorithm of separation of mixed events works between this levels. All intimidates values of numbers of cycles (**T$_{NaI}$ ÷ T$_{CsI}$**) should start algorithm of separation of parts of energy in fast and slow crystals and add 1 in to spectrum of mixed events and increase count of numbers mixed events. Value that is measured in digital maximum detector is proportional to energy U. This value is multiply with relative levels. Numbers n1 and n2 of tact's of digitizing with value of signals most accurate to received values.

Part of energy absorbed in NaI is equal to:

$$D_{NaI}=A-B(T_f-C) \text{ где } T_f= 0{,}025 \ (n_2-n_1).$$

Correspondingly,

$$U_{NaI}=U*D_{NaI} \text{ и } U_{CsI}=U(1- D_{NaI})\alpha.$$

A number of mixed events channel

$$N(\text{см})=U[\ D_{NaI}+(1- D_{NaI})\alpha \ /4.$$

The spectrum of mixed events in RAM – 3 is increment in conformity with this equation.

Values Tmin, T$_{NaI}$, T$_{CsI}$, Tmax, A, B, C and α are constants and are set before the operation.

Connections to real time controller (RTS) can allow realize time of exposition that is set by PC, and bind all measurement to uptime. The controller is connected to PC through RS-232 or/and USB interfaces. Controller's commands set the High Voltage on PTM, coefficient of amplifying, threshold of DDLL, constants for separation of mixed events, read accumulated information and control all preset parameters. The HV splitter 1:1000 serves for additional control of high voltage on the PTM.

The controller starts measurements, perform processing during exposition, and stops measurements by commands. Thermal sensor operator controls temperature in the spectrometer box, and compensates temperature drift.

ADC is using for high voltage control. It is locate in the controller.

2.3. Software

The software of gamma-spectrometer consists of two program blocks. First block is adapted in electronic track structure and provides accumulation of three energy spectrums: spectrum of events in NaI, spectrum of events in CsI and spectrum of mixed events. This information is transmitted to PC via USB interface for processing by second block.

The following commands can be run by gamma-spectrometer software:
Controlling of spectrometer state;
Start and stop of collecting of the spectrum;
Read and clear of the spectrum;
Display the spectrum;
Time set of exposure;
Set following parameters:
Gain;
High voltage on PTM;
Thresholds of low level discriminator;
Time of waiting the top in ADC cycles;
Levels for switching on the separation algorithm;

High and low levels to determine a time of front.
Constants to determine a part of energy absorbed in NaI;
Relative light out;
Recording spectra on the hard drive;
Adding and subtraction of spectra;
Printing of spectra.

3. Results of testing

In general, the hardware and software (being the experimental model of promising gamma-spectrometer) were tested in a laboratory using gamma-sources. Some of experimental spectra are given in Fig 4. They display a high quality of separation of signals from different crystals as well as high energy resolution.
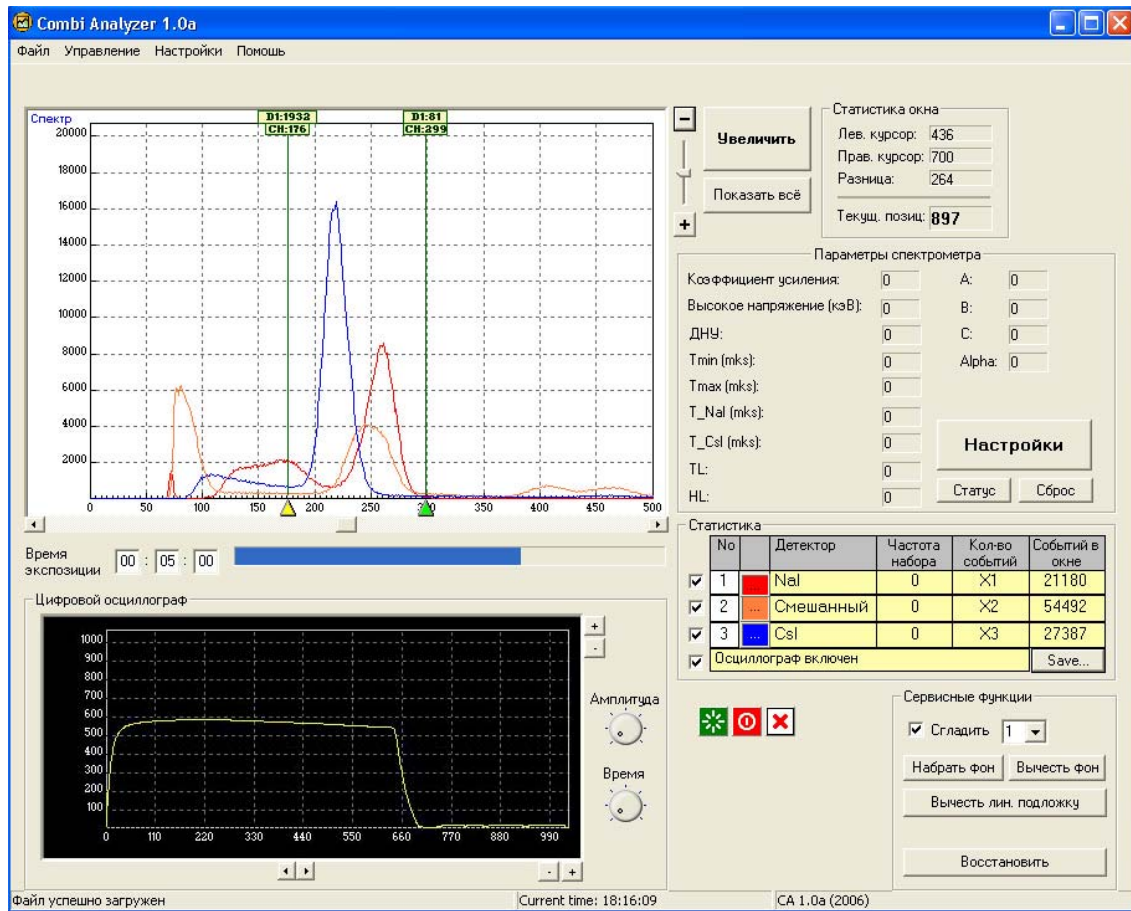
Fig. 3
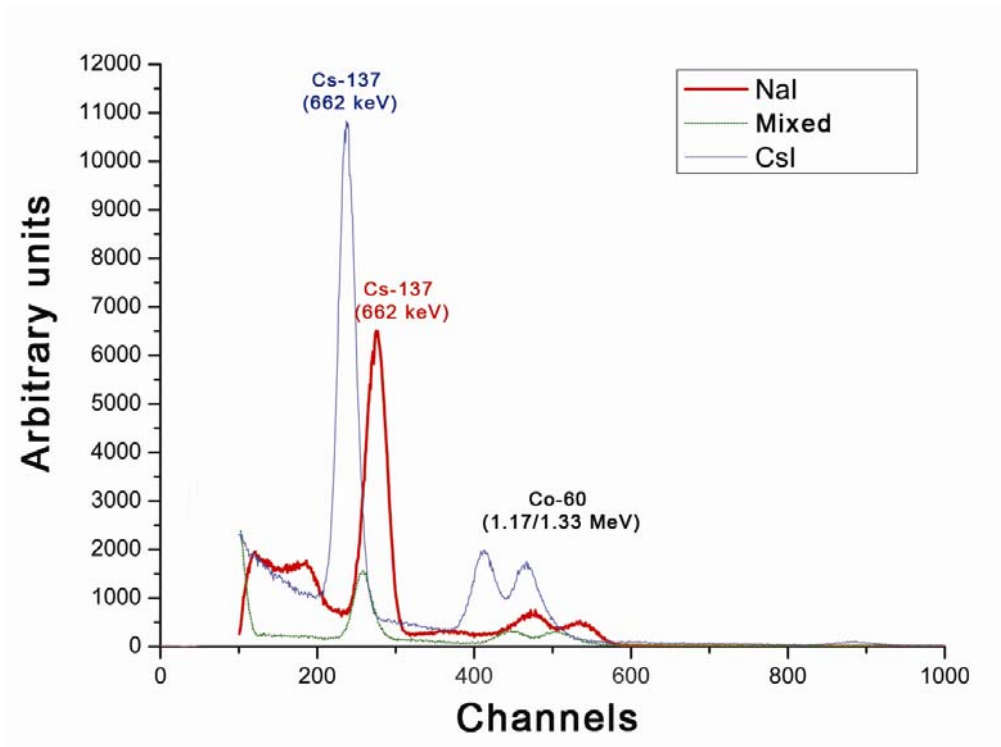
Fig. 4

New methodological and technological approach to the development of information and analytical systems

D.B. Arakcheev

VNIIgeosystem

The main results of research on the conditions of IT-industry performed recently in the USA are as follows:

– Only ~10% of the software development projects have got their successful realization (corresponding to the budget and time constraints);
– Efficiency of the methodology of organization and control of the process defines quality of result more than technological conditions;
– The quantity of non-finished and re-developed software shows imperfection of the process.

The main sad result is that the percent of fully successful projects in the software development on customer orders is extremely low. Its main reason is a high flexibility of the software development – a large amount of IT-technologies allows development of the same product by many different ways, so it is difficult to plan, monitor and control the process.

A lot of existing standards and models of a life cycle of the software development structure all phases such as requirement analysis, designing, developing, testing and deploying of the software systems. However, adopting and using these models have some difficulties.

– Each model cannot be used for the development of all type software;
– Greater difficulties during the adopting and using the models in groups of developers
– Models are separated from technological environment.

Due to specific conditions, every model can be used only for a limited part of software development projects. Adopting and using models in developers groups are very difficult, so many developers return to their usual unstructured and chaotic process. And last but not least: all models are not fully supported by any technological environment, model theories include just some recommendations to projecting, development, and testing tools.

The goal of our studies was to optimize the process of developing a specific class of software - information and analytical systems. A functional purpose of these systems is accumulating, storing, structuring and analyzing different arrays of information, thus providing a decision support in various business areas.

The main conceptions of our approach were defined by specific IAS development and use, and the most important of them are an integral model with specific orientation to IAS development, a complex of technological solutions with this model support and maximal automation of the technical part of the development .This integral model of the life cycle of the development is based on results of the analysis of the most effective models with IAS development specifics. This specific feature includes weak formalization on the projecting phase, floating specification, specific conditions of application areas which are well known only to the business specialists. So the most effective models to modern IAS development are: prototyping (realizing the working version of the system just from the beginning of the process), Rapid Application Development (RAD, using a powerful development environment based on the component architecture, program code generators, visual tools) and Increment model (partial realization of all the system and increasing its functionality). The integral

model has the advantages of every model and excludes its defects. Figure 1 shortly shows the main parts of the integral model.
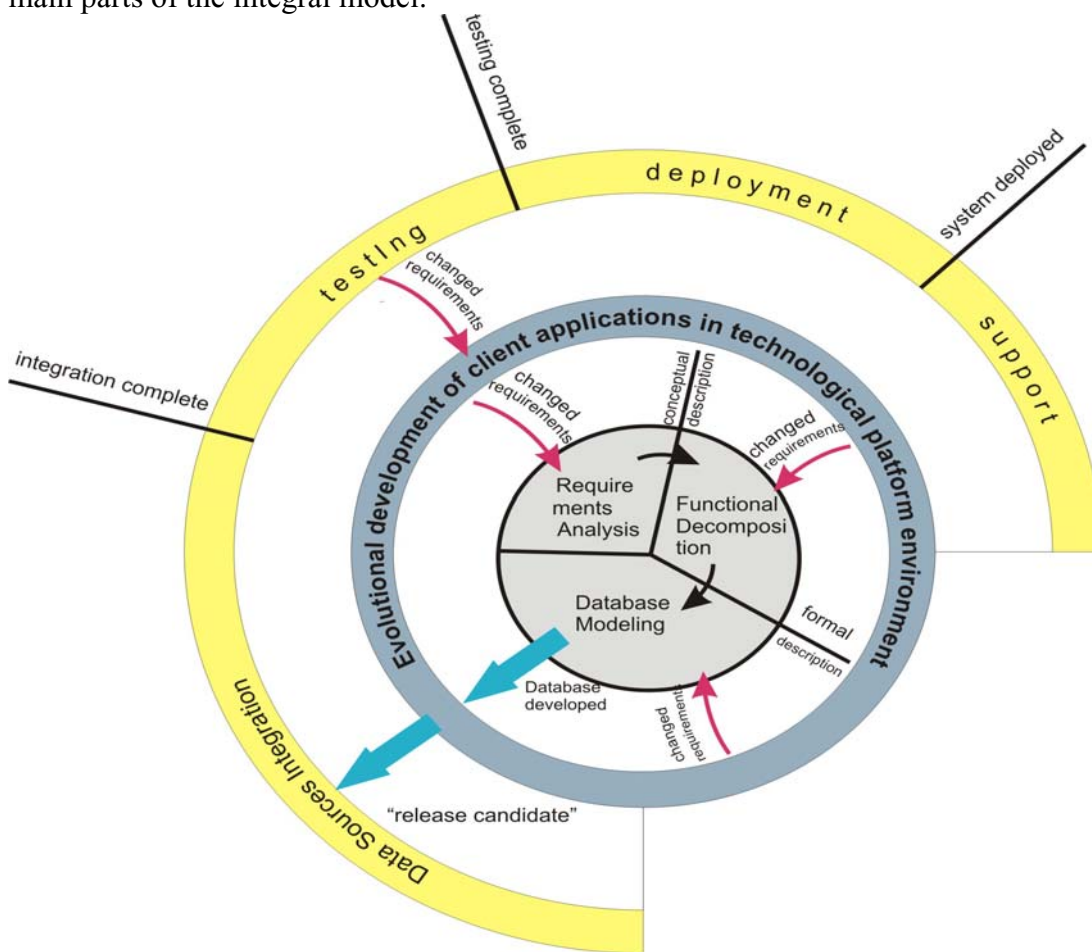
Fig. 1

The model structures all the development phases: requirements analysis, formalization, database model design, application development, testing, deployment, support. A very important feature of the model is an evolutional character of the development of the client applications by using a special technological platform environment. This means that we have a working prototype of the system, from base functionality to full realization. The specific of floating specification of the application fixed by the cycle's character of the process we can return to previous phases, and a negative influence of such re-developing will be minimized by technological platform possibilities, i.e. standard components, memory control, component architecture, etc.

Now we can describe some aspects of this technological platform. The platform must correspond to the requirements on modern powerful IAS, the main of them are as follows:

- using modern powerful RDBMS:
- system integration possibilities:
- geo-information components or integration with GIS;
- multi-user client-server architecture;
- windows- and Web- oriented applications;
- high reliability and stability of work;
- minimizing the client and server system resources.

The modern IAS works with a big amount of different information, so it needs powerful database management systems. IAS are often realized as expansion of the existing systems and databases as a unified program complex. This determines the system integration possibilities. A large amount of application areas of IAS have to work with geographical data, so IAS should have geo-information components or provide full integration with geoinformational systems.

The corporate level of the IAS application determines a multi-user character of work using LAN and Internet networks. The high importance of the results of processing information requires a high level of IAS work reliability.

The main principles of the technological platform are the following:

– Full visual design of applications helps to simplify and accelerate the process
– Internal mechanisms of control program components are intended to provide maximal technical control over the development and maximal reliability.
– Storing the descriptions of the client applications on the database server simplifies the process of realization and support of the IAS remote components.
– The last principle unifies the process of development and executing of different IAS.

The technological platform supports a multi-tier client server architecture (fig.2).
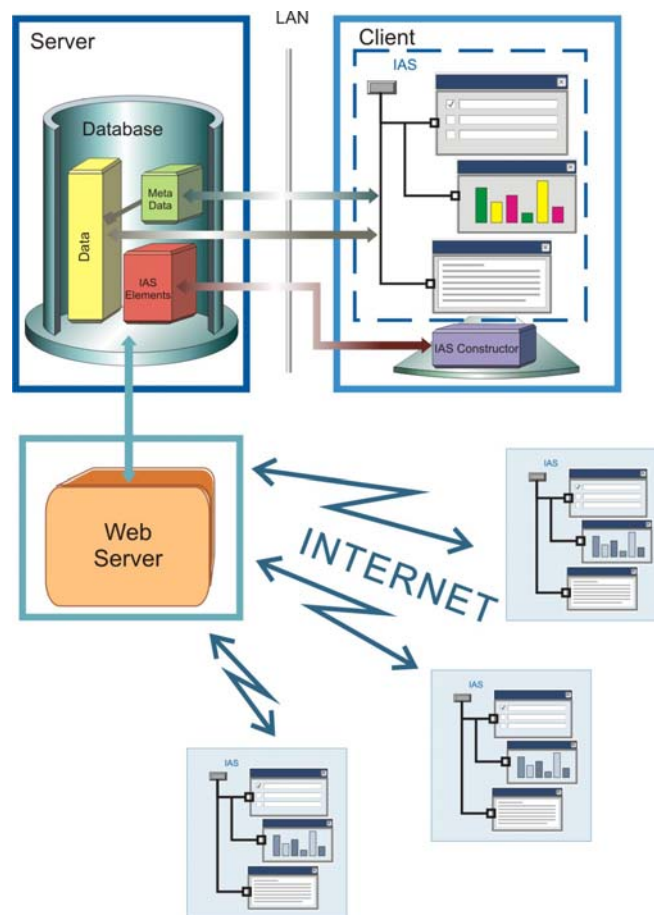
Fig. 2

Data storage can be managed by modern RDBMS like MS SQL Server, Oracle and so on. The Unified environment for IAS constructing is a universal browser of realized IAS in

the Windows operation system, web-server dublicates the IAS in Internet or Intranet. The Environment and Web-server provide realization of the descriptions of IAS components which are stored on the server as the ready program applications parts. Development of the environment allows one to build the ready systems by means of adding and adjusting special components, i.e. IAS-elements. A set of these elements includes all necessary functional IAS like interface forms, data queries, charts, reports, OLAP-analysis and so on (fig.3).

Fig. 3

The exclusion of the classic program coding from the development process must be ensured by unlimited possibilities and powerful visual tools. To provide all functional, powerful and flexible interface forms, numerous visual components have been developed. Data control components have wide internal possibilities (data searching, filtering, business-rules logics, etc). To fully avoid the program coding, the so-called "actions" have been developed – the components processing user actions. A very important feature is that the visual environment provides a unified process to development of Windows and Web-elements of client applications.

In case when the standard possibilities of the development environment are not enough to realize all necessary functional, it can be increased by specific plug-ins (Fig.4). This feature based on the component object model technology, the main applications interaction facility in the Windows platform. Plug-ins can be developed in any tool or program language with COM-support (Visual C, Delphi, Fortran, etc). IAS can be an automation client and

automation server. This means that the system can comprise external applications and plug-ins, and the system elements can be included into the external program complexes.
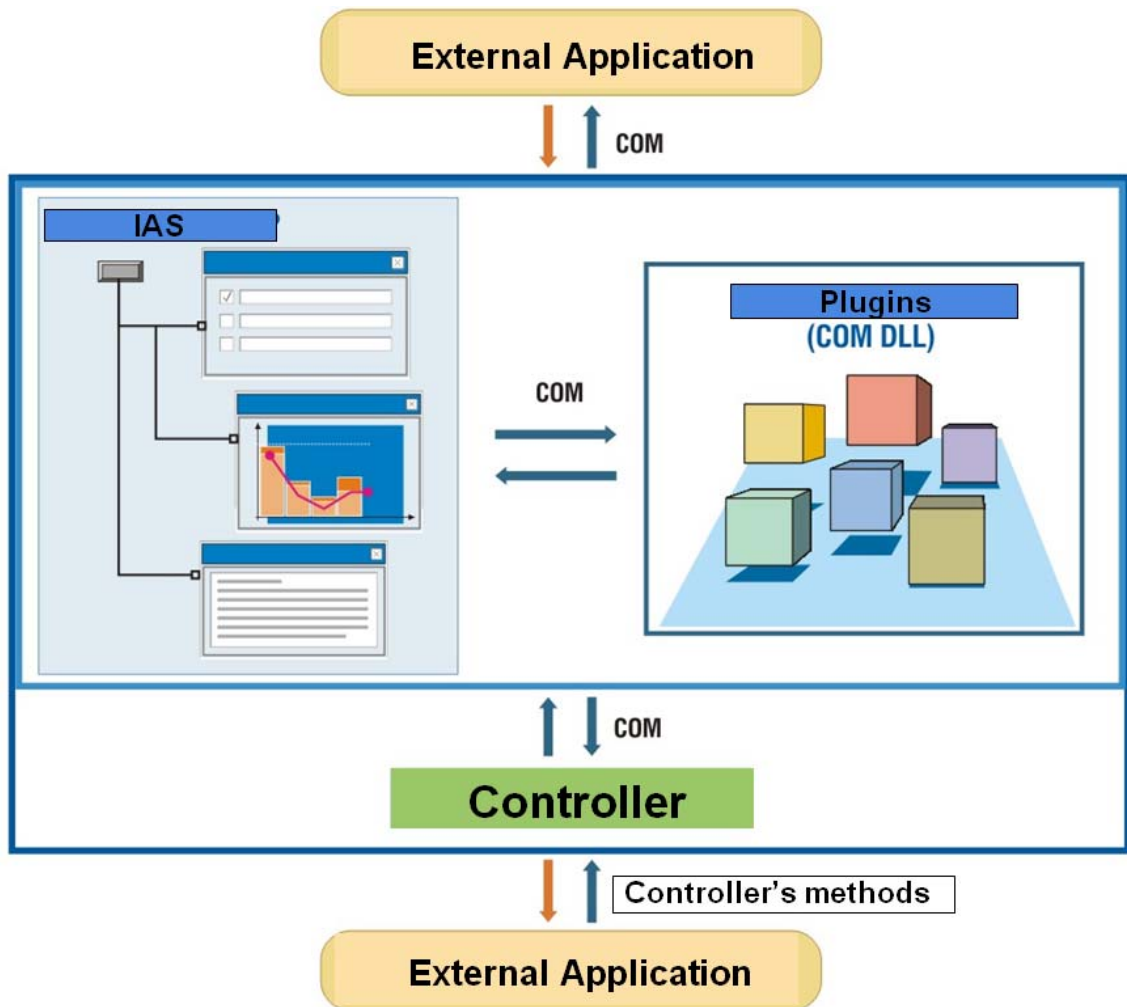
Fig. 4

Geoinformation analysis tools are a very important part of IAS, so the technological platform supports geodata on a database level, has its own Web-GIS component and fully integrated with such well-known GIS as Arcview, Arcinfo, Mapinfo, our GIS Integro.

The main advantages of this approach are as follows:
 – Economy of the development time (~50%);
 – Simplifying the process of organization and control of development phases due to internal mechanisms of management of the program components;
 – Simple to adopt and use by developers due to fully visual tools;
 – Does not require a big staff of high-degreed specialists in programming (near 90% of system parts may be developed in a standard platform environment);
 – Flexibility;
 – System integration possibilities;
 – High reliability and simple tech support.

The efficiency of this approach has been proved by fully realized and working systems in different business areas.

Automatic scanning system for viewing nuclear emulsion of the OPERA experiment

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A.V. Krasnoperov, E.G. Nikonov, V.V. Tereshchenko, S.V. Tereshchenko

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This paper discusses hardware performances of the scanning system intended for automatic analysis of nuclear emulsion which is under construction in JINR, Dubna. Nuclear emulsions are exposed in OPERA experiment [1].

The OPERA experiment exploits nuclear emulsions technique for the direct observation of v_τ appearance from $v_\mu \rightarrow v_\tau$ oscillations in the CNGS long baseline beam from the CERN SPS to Gran Sasso Laboratory. The experiment is based on the idea of so called Emulsion Cloud Chamber (ECC) detector (figure 1), a modular structure made of a sandwich of passive (Pb) material plates interspaced with emulsion layers. So on one hand nuclear emulsion is very high resolution tracking device for the direct detection of the particle interactions and on the other hand it is possible to create a modular detector of very large mass needed to meet the physics of the experiment). The amount of emulsion to be used in OPERA is about 40 tons. By ECC concept each brick has transverse dimensions of 10.2x12.7 cm^2 and consists of 56 cells. Each cell includes lead plate and emulsion layer (two layers of 45 μm emulsion on both sides of 200 μm plastic film). The detector consists of two supermodules, each includes 31 walls of 3264 brick per athe wall, so total emulsion film surface is about $1,76x10^5$ m^2. With the CNGS neutrino beam at its nominal intensity, ~30 neutrino selected interactions per day are expected. Therefore, ~2000 emulsion sheets per day must be scanned in order to find the vertex and analyze the event (in total, ~6000 cm^2 daily). This was the reason to construct an automatic scanning microscopes with required scanning speed of about 20 cm^2/h or more.
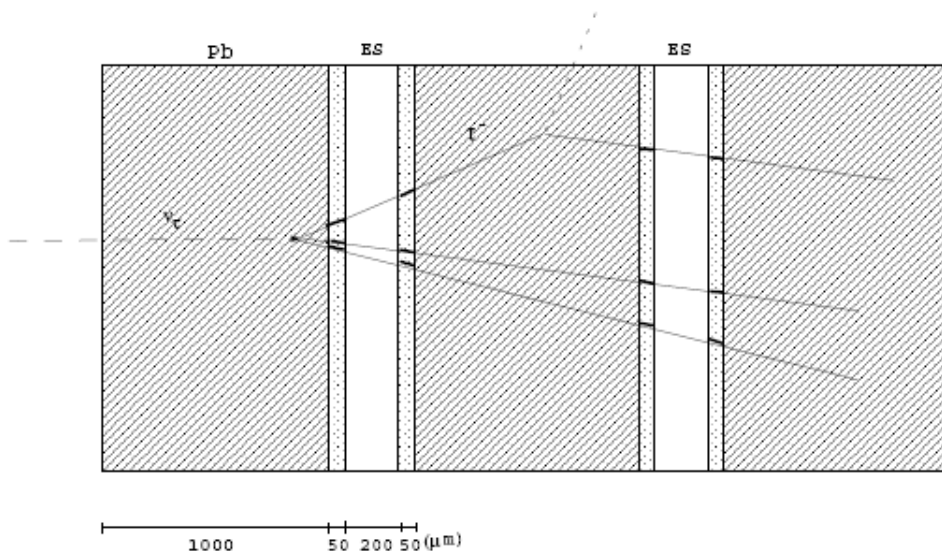
Fig.1. ECC cell and the τ decay kink reconstructed in the emulsion films

Principal elements of automatic scanning system are: computer driven 3-dimensional mechanical stage, appropriate optical system and high-speed digital camera with a special system of acquiring and preprocessing images. In order to recognize the presence of track penetrating almost perpendicularly the emulsion layer, a series of digitized tomographic images is recorded through the emulsion depth (figure 2). Assuming that focusing depth of objective is 3 microns, 15 views are taken to scan a 45μm thick layer. The track segments are identified by correlation of grains in different layers. Grains belonging to an emulsion plane can be combined to form a straight line, parameters of which are compared to those of a track predicted by electronic trackers. Microscope scans some area around predicted position in emulsion sheet, searching for the straight tracks segments of appointed slope. Digitized pictures are analyzed on-line so that microtracks are found and stored in the computer memory. Microtracks are combined together to make tracks and events.
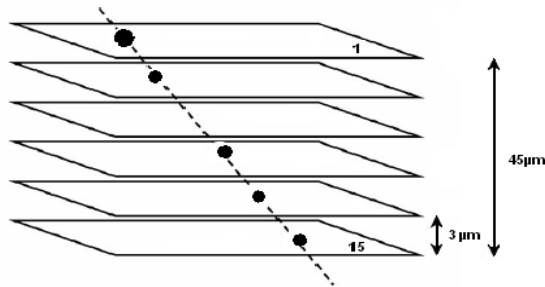
Fig. 2. Microtrack reconstruction procedure

The scanning system under discussion is based on optics and mechanics of commercial microscope MBI-9 (LOMO). Linear motors (LSIM-P-40, Ruch Servomotor, Belarus) and linear encoders (LIR-7, SKBIS, St.-Petersburgh, Russia) are mounted on standard MBI-9 X-Y stage. Stage controller was developed at JINR on the base of microcomputer Triscend TE520. This system provides positioning repeatability better than 3 microns and position measurement accuracy of 0.1 micron with velocity range from 0.1 mm/s up to 100 mm/s. Movement on Z-coordinate is performed by a brushless motor EC-22 (MAXON Motors AG) mounted on standard Z-stage. Stage movement velocity is steady and equal 1 mm/s, position measurement accuracy is 0.1 micron (LIR-7). Optical and illumination systems are standard for MBI-9. Dry objective used has following characteristics: planapochromat, numerical aperture – 0.8, working distance – 0.45mm, magnification – x40, field of view – 300x300 microns^2. Data acquisition system consists of high speed digital camera based on CMOS video sensor MICRON MT9M413C36STM (1280x1024 pixels, up to 500 frame per second) and computer.

The scanning speed requirement of 20 cm^2/h imply that field of view (300x300 microns^2, 15 frames) processing time must be less than 170 ms.

Scanning of an emulsion sheet is effectuated as follows:
- positioning on X and Y coordinates accordingly predicted data
- uniform movement on Z coordinate with frame taking every 3 micron, primary data filtration and binarization (~ 45ms)
- concurrently return to initial point on Z, movement to the next field of view on X-Y, mocrotrack reconstruction (~ 120 ms)

Row image processing can be divided in two stages: preliminary processing in DSP processor and microtrack reconstruction in computer.

For primary video data handling, a processor ADSP-TS201 TigerSHARC [2], manufactured by Analog Device company, is used. The choice of this processor is determined

by a number of it's powerful features, which allow to manage great amount of data received from video camera.

The key features of TigerSHARC ADSP-TS201S are:
- 3,6 GFLOPS (Giga FLoating Point Operations Per Second);
- 128-bit wide internal data bus;
- up to 600MHz, 1,67 ns instruction cycle rate;
- Static Superscalar™, RISC (Reduced Instruction Set Computer), VLIW (Very Long Instruction Word) architecture;
- 4 external full-duplex LVDS (Low Voltage Differential Signaling) LinkPorts with bandwidth up to 500 MByte/s.

The TigerSHARC is a dual-core 32-bit processor (Figure 3). The processor has the 128-bit internal data bus and the 32-bit address bus, integer arithmetic-logic units (IALU), two computer blocks, external I/O interfaces. The width of the external data bus is 64 bits.
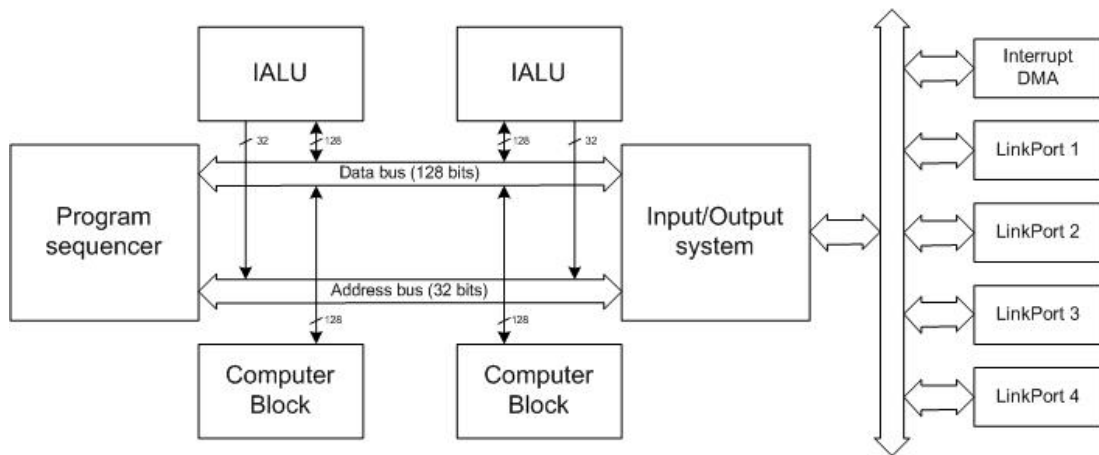
Fig. 3. The block diagram of TigerSHARC

The RISC architecture allows to utilize a reduced set of commands. The ADSP-TS201 processor's core can execute simultaneously up to four 32-bit instructions encoded in a VLIW instruction set using the DSP's dual computer blocks.

The IALU provides powerful address generation capabilities and perform many general purpose integer operations.

The LinkPorts and SDRAM on chip controller are intended for data transfers between the processor and external devices.

As it is seen from the plot on fig. 4, movement by z-axis between 15 and 60 microns lasts about 36 ms and occurs linearly. Assuming that in this period of time camera is to take 15 frames to obtain vertical resolution of 3 micron, the frame rate turns out to be more than 400 frames per second. So it means that maximum data rate can be up to:

$$v = x_{sens.} \times y_{sens.} \times f \times 2 = 640 \times 512 \times 500 \times 2 = 327,68 \ MByte \ / s.$$
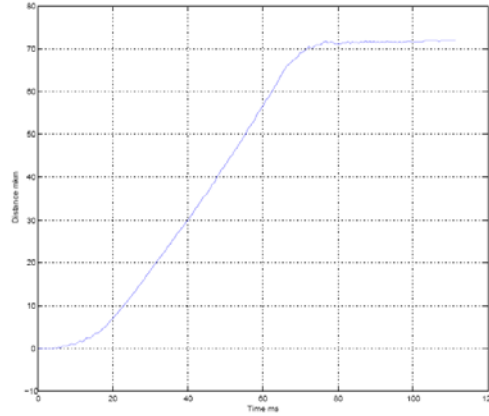
Fig. 4. Movement on Z-coordinate

The TigerSHARC processor has four communication channels (LinkPort) with adjustable clock frequency up to 500 MHz. With the ability of latching data on both rising and falling edges of the clock each link port can support up to 500 Mbytes per direction.

The maximum data rate from the sensor is about 330 Mbytes per second. It means that to transfer all the information, two channels are sufficient, each adjusted to transmit 165MBytes per second.

The 15 frames obtained in scanning of a field of view before and after primary processing are stored in SDRAM, then this data are to be transferred in an external store. The primary processing and transfer processes are to be carried out in 170 ms needed for a stage to move to another field of view.

The minimal size of memory necessary for primary data storage is:

$$V = 2 \times (x_{sens.} \times y_{sens.} \times k) = 2 \times (640 \times 512 \times 15) = 9.4\,MBytes \quad .$$

For a given system SDRAM MT48LCM32B2 manufactured by Micron company is used.

Gigabit Ethernet interface is applied to transfer the processed data to external store. This will allow connecting the system to any computer by TCP/IP.

The video image processing system is showed in Figure 5.

Primary data obtained from camera contains large quantity of redundant information such as illumination nonuniformity, spurious grains (fog), electronic noise etc. Preprocessing of the data obtained subdivides into two stages: (1) filtration and binarization of each frame that is elimination of maximum possible unnecessary information, and (2) recognition of microtracks in fifteen layers on whole emulsion depth. First stage is performed immediately in DSP processor.

For primary data processing a Laplace filter is implemented. In digital form two-dimensional Laplace filter is defined by an equation:

$$\nabla^2 f = [f(x+1, y) + f(x-1, y) + f(x, y+1) + f(x, y-1)] - 4f(x, y)$$
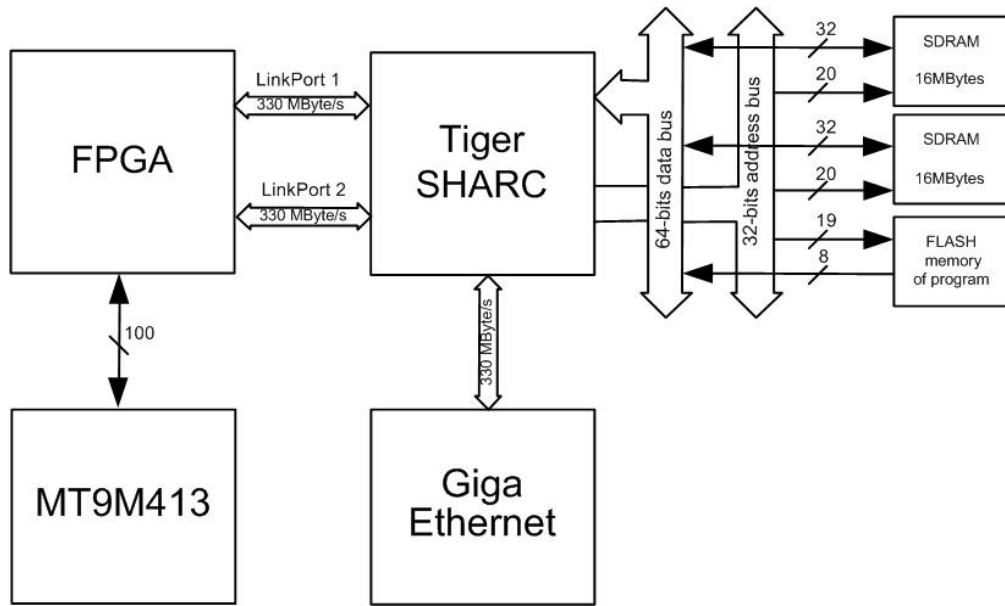
Fig. 5. Scanning station video image processing system block diagram

This equation can be presented in form of 3x3 matrix (figure 6a). Normalized form of this matrix, presented on figure 6b, allows all the results to remain in single-byte form.

Fig. 6. A discrete filter Laplace mask

ADSP TS201 processor needs only about 0.75 ms to process one frame by this digital filter. Thus all the 15 frames are treated in 12 ms. Filtration result is presented on Figure 7.
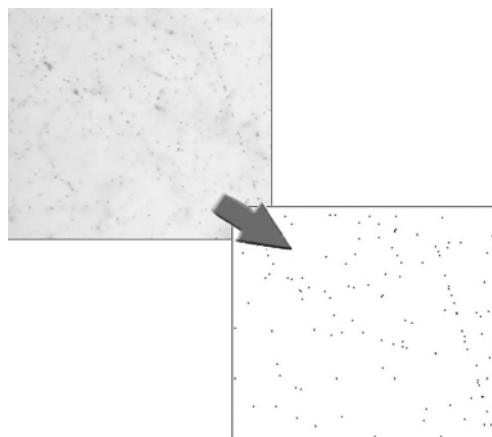
Fig. 7. Video information before and after filtration process

After this procedure useful data from each frame makes about one percent of total information volume (Figure 8).
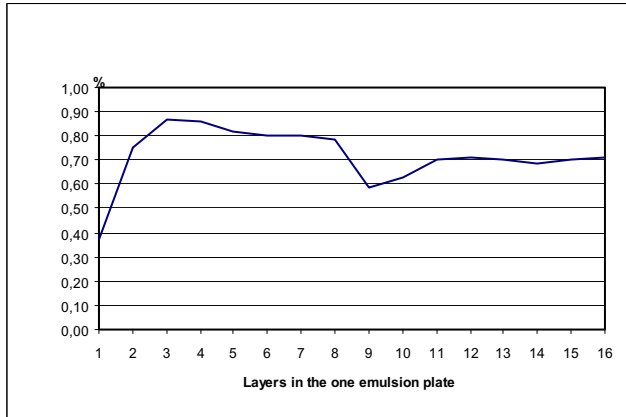
Fig. 8. Ratio of a number of useful pixels to total number of pixels in a frame after the filtration process

Having completed the phase of study and construction of prototypes according to experiment requirements, we are now optimizing scan station design and software. Features of the scanning system presented turn out to be applicable in emulsion experiment OPERA.

References

[1]   Proposal OPERA, CERN/SPSC 2000-028SPSC/P318 LNGS P25/2000 July 10, 2000.
[2]   ADSP-TS201S TigerSHARC Embedded Processor Datasheet, (Rev. A, September 2005).

Charge sensitive amplifier with extended dynamic range

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Abstract

The technique of extending the dynamic range of charge sensitive amplifiers is presented. It is based on splitting the whole dynamic range into two parts at least. At low input signals the classical charge amplifier architecture defines high gain and good signal-to-noise ratio, while at larger signals an additional class B amplifier is switched on and changes the equivalent feedback capacitance of the whole charge amplifier. In that way the dynamic range is stretched out.

The results of simulations and prototype tests, aimed on compromising between noise and dynamic range of charge amplifier at a low power consumption and reasonable speed are given.

Introduction

Charge sensitive amplifier is one of the most critical front-end unit in analog channels. Fig.1 shows a typical structural diagram. It was used, for example, for the 32-channel ASIC development of Nucleon project [1].

Each channel begins with a charge sensitive amplifier (CSA), which converts the signals of detector (current pulses or charges) into output voltage. The choice namely CSA as the basic configuration is caused by the necessity of ASIC to operate with a relatively wide range of detector capacitances (from units to several tens of pF) at preserving the rest specification parameters on speed, dynamic range and power consumption.
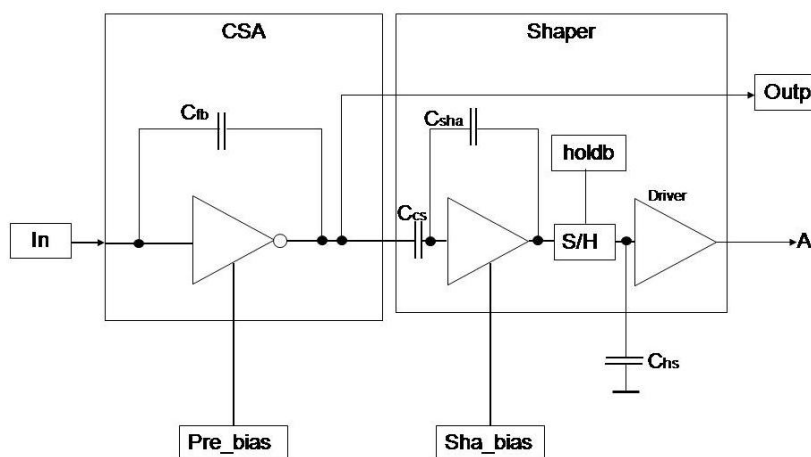
Fig.1. Structural diagram of analog channel

Description of CSA circuit

The CSA bias has been optimized for operation with a positive charge, arriving from detector. There at both the input and opuput CSA DC potentials remain about +1.2V. This is determined by the VDD suply voltage (+1.65V) and the threshold voltage of the input transistor (~0.45V) the CSA output signals have a negative polarity.

The first CSA stage is built as a folded cascode. The input transistor threat is chousen to be pMOS. That is caused by two factors: by the necessity to minimize the 1/f noise and by the polarity of input signals. For increasing transconductance and noise minimization the

input transistor has a great equivalent channel width W=8000 um at small channel length L=0.5um.

The principal distinction of the developed CSA from classical ones should be regarded to be the division of full dynamic range (from noise to saturation) into two subranges. Fig. 2 shows the CSA transfer function as planned in the specifications.

In practical case, the bending point of the given characteristic is placed at the input charge about 3 pCb. That, on one hand, permits to provide a greater slope of transfer function at small amplitudes and thereby achive a better signal/noise ratio. On the other hand, to provide a lesser slope at high amplitudes and thereby extend the dynamic range upwards to 100 pCb at least. The position of bending point can be adjusted by changing the potential of the pad "pre_bias".
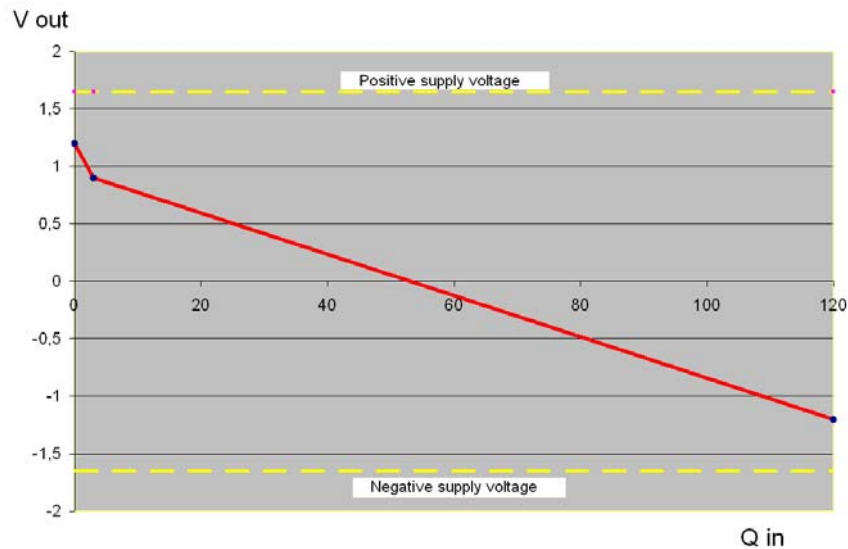
Fig.2. CSA transfer function

The subranges in the developed circuit are switched automatically (see fig.3). At low input signals the classical charge amplifier architecture with small feedback capacitor Coc1=6.6pF defines high gain ($KQ = Vout/Qin = 1/Coc = 0,15$ V/pCb) and good signal-to-noise ratio, while at larger signals an additional class B amplifier (or voltage follower) is switched on and changes the equivalent feedback capacitance (by adding Coc2) of the whole charge amplifier. In that way the dynamic range is stretched out.

In the implemented design [1] the equivalent feedback capacitance of whole CSA was a value about 67pF. In order to discharge this capacitnce the ASIC used a long-channel (L=100um, W=1um) nMOS transistor.

In the analog channel the CSA is followed by an shaper, representing the circuit of a CR-RC active filter. The shaping time was chosen about 2.2 us. The simulated transient responces are shown in fig.4 both for CSA (left figure) and shaper (right one) outputs at 1mip input signal. Fig. 5 shows the corresponding scope waveforms.
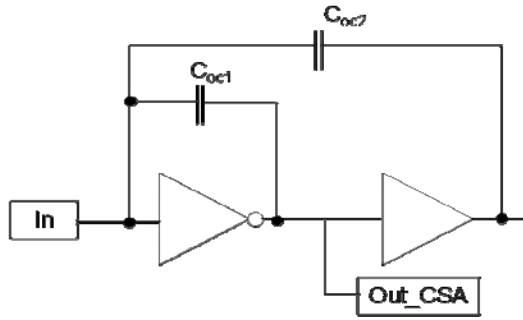
Fig.3. CSA structure
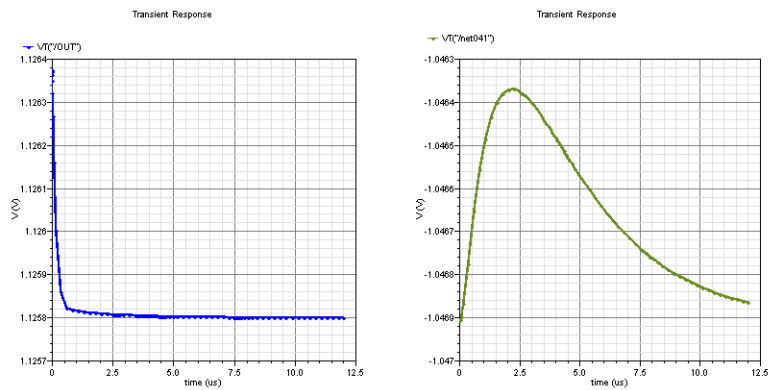
Fig.4. Simulated transient responces of CSA and shaper at 1 mip
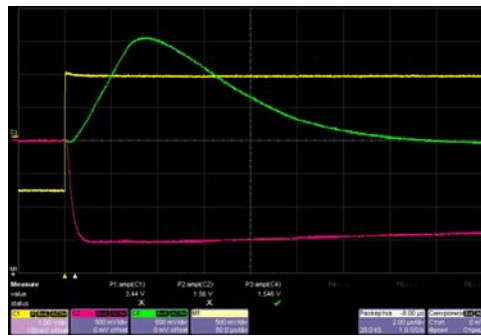
Fig.5. Waveform of CSA and shaper at 1 mip input pulse

Reference

[1]   E. Atkin, I. Ilyushchenko, A. Kluev, D. Podorozhny, Yu. Volkov, A. Voronin, Development of an ASIC for Nucleon project. See in these proceedings.

Development of an ASIC for Nucleon project

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Abstract

During the last three years there was developed a 32-channel ASIC for the silicon detectors (with capacitances up to 100pF) of the ROSCOSMOS Nucleon project. The ASIC was manufactured with the AMIS 0.35 um CMOS process via the Europractice. The main feature is the provision of a large dynamic range up to 100 pCb at a power consumption within 2mW. Each channel includes a charge preamp, shaper, track and hold circuit. The chip also contains a multiplexed output, buffered by a differential current driver. It also has a built-in calibration circuit. The main simulation and lab test results are presented.

1. Introduction

In the framework of the ROSCOSMOS project "Nucleon" a new generation of microstrip detectors for calorimetric applications is under development. Nowadays multichannel astrophysical experiments require electronics of very largely scaled integration. Thus one of the key tasks of the project is the development of a 32-channel Application Specific Integrated Circuit (ASIC). During the last approximately three years there were foreseen and made three iterations of the chip in order to reach the target, namely two 4-channel versions of the ASIC to elaborate the general structure and confirm the functionality of the analog and digital building blocks needed, followed by the design of a final 32-fold mixed-signal chip. Taking into account that Nucleon is a space experiment, the main specifications of the chip were rather tight. Power consumption, speed and dynamic range were the main competitive targets.

2. General Information

View of the layout of the Nuclon32HDR-1.0 ASIC is shown in Fig.1.
Technological process – 0,35 um CMOS of the Belgian AMIS available via Europractice foundation.

Chip size – 4.0*4.0 mm.sq.
Number of channels – 32 + 2 (dummy ones).
Connection with detector – AC mode.
No leakage current compensation.
Input signals – positive charges.
Number of contact pads – 114. Among those some remain merely for compatibility with prototype, namely 8 pads not used and 2 pads shorted inside the chip.
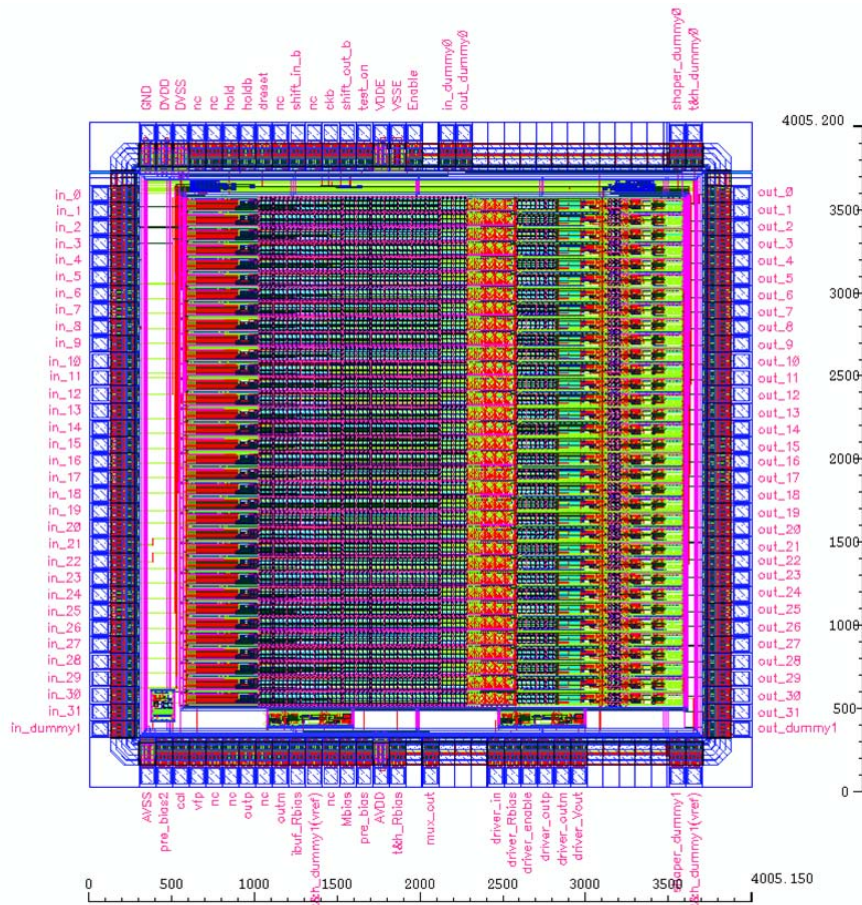
Fig. 1. General view of ASIC and disposition of contact pads

3. Electrical parameters

Main electrical specifications of the ASIC are given in the following table.

Specs	Value
Supply voltages	±1,65 B
Back side contacts	Not foreseen. However the chip back side is recommended to be biased at AVSS (-1.65V)
Current biases	No additional circuits are required
Shaper peaking time	~2.2 us
Power consumption	Within 2 mW/channel
Input protection	AMIS library ESD elements
Input stage	Folded cascode. Input transistor → pMOS (W=8000um, L=0.5um)

Gain	In the range of low signals 0.5 mV/mip (for Si detectors 300um thick → 1 mip = 3,6 fCb = 22500el) In the range of high signals – 2,0V/100pCb
Bending point of the transfer function	~3pCb Can be shifted by external potential "pre_bias"
Noise, ENC and slope	~8500el at Cdet=0 and ~8el/pF
Dynamic range	Not less than 100pCb
Nonlinearity	In the range of low signals – not worse than 3%; In the range of high signals – 10%
Calibration, testing	Calibration is built in. An external capacitance should be connected to the "cal" input for feeding the test signal

4. Description of structural diagram

The Va32HDR14.2 ASIC of Gamma Medica-IDEAS [1] is being the basic (functional) prototype of the final 32-channel chip considered. However, the latter has a whole range of changes and improvements, comparing with the prototype.

Fig. 2 shows the structural diagram of the ASIC version. It consists of an analog part, digital one and some additional analog blocks.

The analog part consists of 32 identical channels, intended to pick up and process preliminary the data, originating in silicon microstrip detectors. Two additional (33-d and 34-th) test channels are placed at the edges, playing role of dummy channels. They are implemented with a structure, similar to the basic channels. Additionally they have the most characterizing intermediate nodes, being tapped to contact pads. That permits a more detailed study of separate unit behavior in the analog part.

The digital part of ASIC executes 2 basic functions:
1) Post-analog processing, carried out by an interchannel multiplexer and a control shift register;
2) Channel calibration.

The additional analog blocks of ASIC are the following: the block, setting the reference potentials, and two identical voltage-to-current converters. One of the latter is "operative" – that is built in the signal processing channel after the digital multiplexer. The other one (conventionally the "test" one) is implemented as an independent unit and is intended for a more detailed study of the voltage-to-current converter`s operation. For simplicity Fig.4 shows one operative block (marked as «U → I») only.
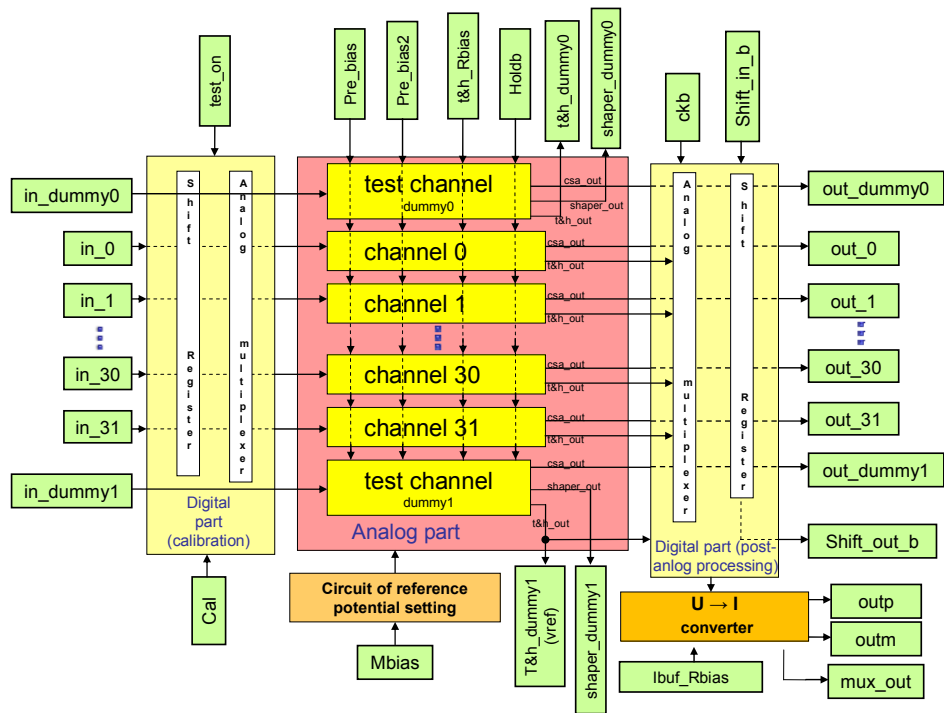
Fig. 2. Structural diagram of ASIC

Fig. 3 shows the structural diagram of the analog part of ASIC channel. In more detail the CSA block is described in [2].
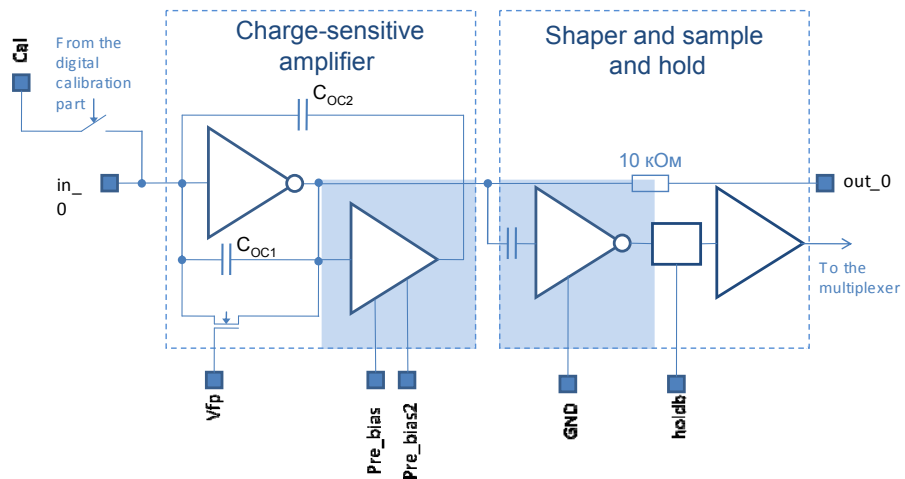
Fig. 3. Structural diagram of the analog part

5. Description of operation

In a normal mode of operation the CSA inputs are AC connected to the detector (through decoupling capacitors).

The signal, generated by the detector (positive charge) and entered into channel, is integrated. The output amplitudes of both the CSA and amplifier-shaper are thereat proportional to the energy of registered particle. The external control signal "hold" should be applied at the instant, when the output signal of amplifier-shaper reaches its maximum. That occurs approximately 2.2 us after the event of particle registration. The sample and hold circuit (SHC) switches over to the mode of fixed amplitude storage. Then the amplitude itself can be read out through the following digital part of ASIC.

6. Description of the digital part and its operation

The circuitry of the ASIC`s digital part has been synthesized as a functional analog of the corresponding part of the Va32HDR14.2 ASIC. It has two modes of operation: the normal working mode of reading out and multiplexing the detector signals and the calibration (test) one, when the test signal is applied via the "cal" pad to each of the 32 CSA inputs subsequently. In the calibration mode no signals from the "cal" pad arrive to the inputs of ASIC test channels («in_dummy0» and «in_dummy1»).

The output part of ASIC, responsible for the post-analog (digital) processing, is shown in Fig. 4 and the corresponding timing diagram of read-out circle – in Fig. 5, Fig. 6 presents the typical waveforms for prototype chip, where 4 channels among 32 are exited via the calibration circuit.
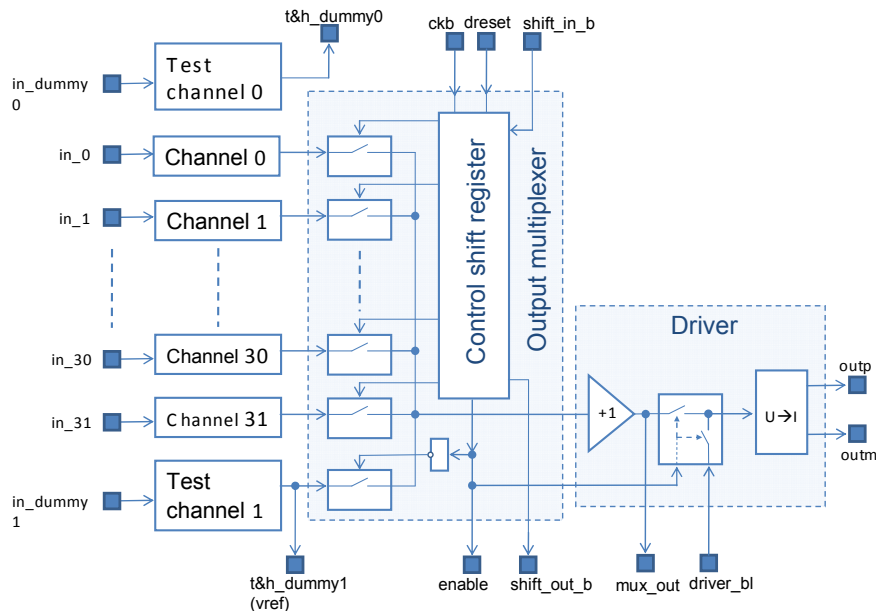
Fig. 4. Structural diagram of the digital part
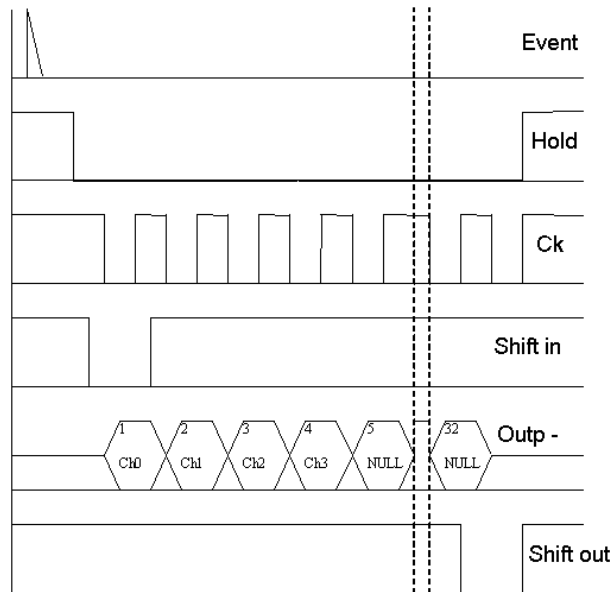
Fig. 5. Timing diagram of read out circle (digital part)
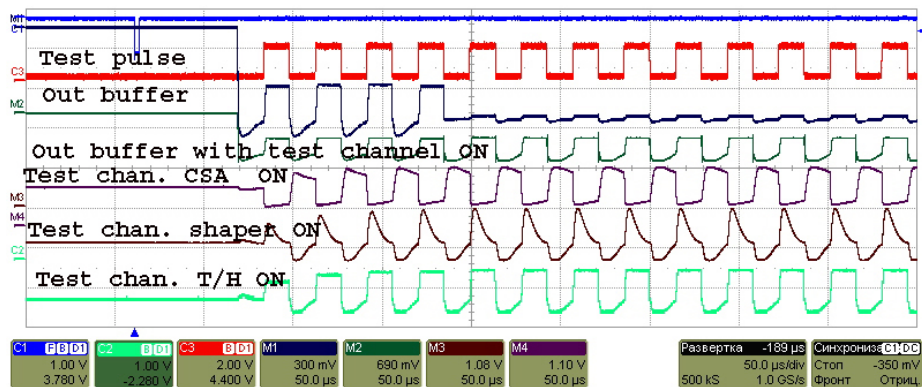
Fig. 6. Typical ASIC waveforms

Conclusions and outlooks

The 32-channel ASIC for reading out the microstrip detectors having capacitances up to 100 pF have been developed. At lab tests the existing prototype samples of the ASIC showed correct functionality with dynamic range of 100 pCb and are to be studied soon in more detail.

It is expected that the ASIC can find other applications since there are many different types of detectors featured with the indicated range of capacitances.

References

[1]   Va32HDR14.2. DATA sheet of Gamma Medica-IDEAS. Documentation V1R1, 2005, 13 c.
[2]   E. Atkin, Charge sensitive amplifier with extended dynamic range. See in these proceedings.

Design of data-driven architecture for multichannel detectors

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In modern read-out electronics for multichannel tracking systems very important parameters are power consumption and the area, occupied by the chip. Development of ASIC, using new architectures, can noticeably improve these characteristics. Taking in consideration that number of channel may be up to $10^6 \sim 10^7$, the use of "classic" multichannel architecture (full processing section repeated many times) is not a good idea. The alternative version is to apply a new, data concentrating architectures. The most progressive of them are data-driven ones. Because of random nature of the data, we face the problem of derandomization.

On fig. 1 there are some variants of data-driven derandomizing architectures. A lot of them studied and developed at BNL (for example [1]). We focus our work on arbitration logic. With relation to optimize the power consumption and area, occupied by the ASIC, architecture with multiple storages shared by channels is more interesting. We developed 1st prototype with such kind of architecture (4->2). It's structure shown on fig. 2. It's a system on crystal consisting of an array of charge-sensitive amplifiers (further CSA), array of comparators, crosspoint switch, arbitration logic and array of peak detectors. This prototype was made using UMC 0,18u technology. Some test time diagrams are shown on fig.3-fig.8.

This prototype has shown functional efficiency of a whole system and separated units. Crosspoint switch and arbitrates logic need to be revised however.

This time we designing new prototype with bigger derandomization factor. It is necessary to say some words about derandomization factor (further "d"). This parameter is equal to ratio of input channels to output (processing) channels.
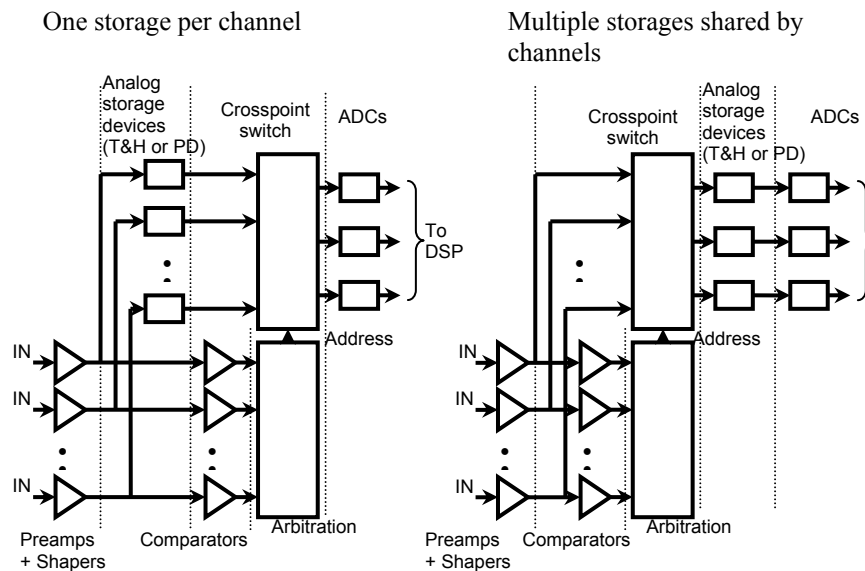
Fig. 1. Data-driven derandomizing architectures
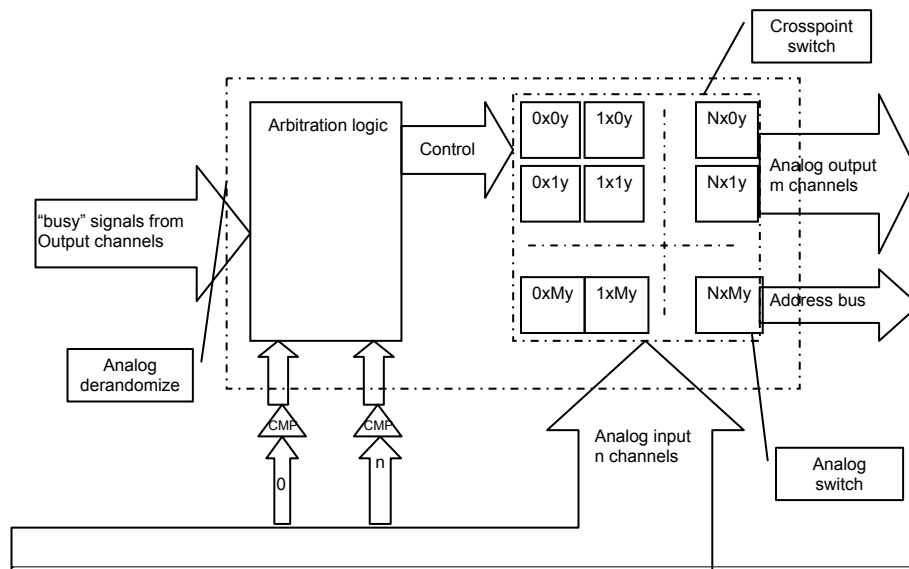
Fig. 2. Structure of derandomizer
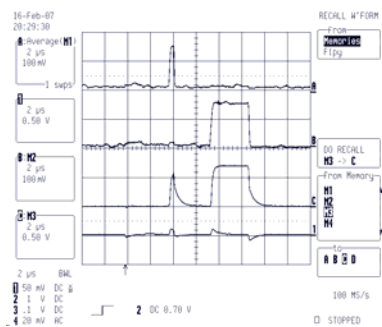
Fig. 3.
A – input channel 1, B – input channel 2, C – output channel 1, 1 – output channel 2
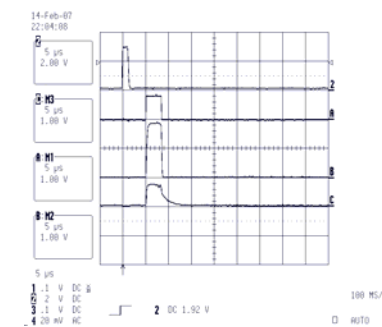
Fig. 4.
2 – reset, A – input channel 1, B – comparator of channel 1, C – output channel 1
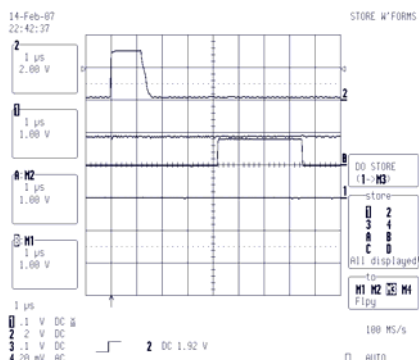
Fig. 5.
2 – reset, signal less than comparator reference
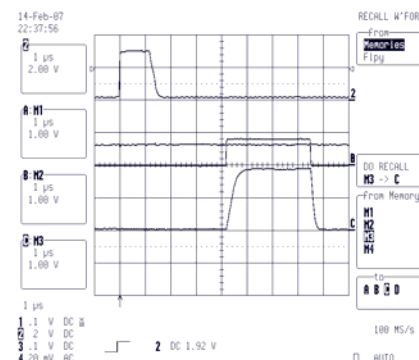
Fig. 6.
2 – reset, signal more than comparator reference
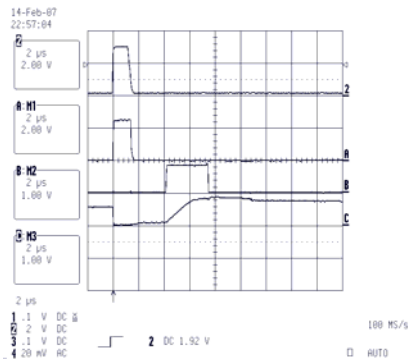
Fig. 7.
A,2 – reset, B – peak detector input, C – peak detector output
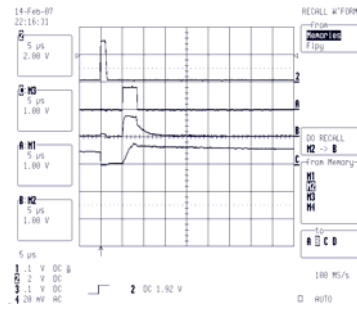
Fig. 8.
2 – reset, A – input channel, B – before peak detector, C – after peak detector

It is obvious that the more d we have, the more we reduce power consumption and area, occupied by the chip. In conditions that the system is unbuffered increasing d means decreasing load capability (maximum number of simultaneously occupied input channels without losing any data) however.

The choice of d is strongly depends on working conditions of the system. Let's consider 2 types of working conditions:

1. The most probably event – impulses occurs NOT simultaneously, uniformly in all channels and have equal duration. 1st prototype based on this variant. The finite state machine (further FSM) for this case exists and can be scaled to others d (128->16, 64->40, 59->19, etc. It is better when the number of the channels divisible by 2 however).

2. The most probably event – a lot of impulses occurs simultaneously (T>>Δt). It is really typical for the detectors, taking into consideration cluster nature of its impulses. For this case we have to modernize existing FSM, so it will be able to commutate one channel per clock.

> 1->1
> 2->2
> 3->4(3rd output channel occupied at this time)
> 4->5
> 5->6
> Etc.

Let's estimate some parameters of new prototype. We suppose that the duration of a "standard" impulse T_i=300nS. We are taking in consideration 2nd type of working conditions for the system. Also we know shape of the impulses (because we use shapers after CSA), so a half of an impulse is enough to precision measurement of amplitude (because of bell-shape of the impulse). For 128->16 system maximum load will be 16 simultaneous impulses. They communicates between channels in time T_{tc} (total commutation time) equals $T_{tc}=T_{clk}*16$, so for the system to be data-lossless we need to have $T_{tc}\leq T_i/2$. From this it follows that we have minimum necessary clock frequency $f_{clk}\geq 32/T_i\approx 107Mhz$

There are some methods to improve load capability of the system. For example, make it buffered. But this is not a very good idea because the system will not be real-time. Also it is possible to increase f_{clk}, so the impulses will be commutate faster. But f_{clk} increases power consumption and, as consequence, power dissipation increases too. The more perspective

method is to more modernize existing FSM in order to commutate multiple impulses per clock.

At these figures there are simulation of the arbitration logic and its structure.
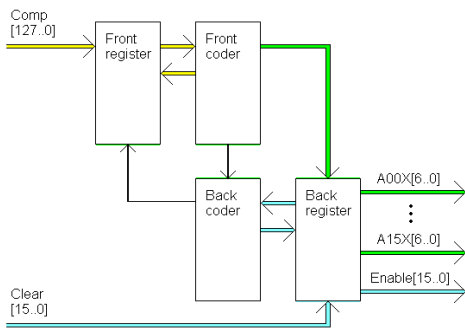
Fig. 9. Structure of arbitration logic
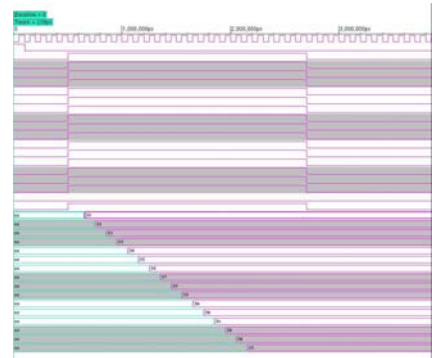
Fig. 10. Simulation of arbitration logic 128->16 with 16 simultaneous events

Outlook:
● development of a new prototype with bigger d
● making and testing of prototype

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[1]   P. O'Connor, G.De Geronimo, A. Kandasamy, Efficient Amplitude and Time Measurement ASIC with Analog Derandomization. Brookhaven National Laboratory, Symposium on Radiation Measurements and Applications, May 21-23, 2002, University of Michigan, Ann Arbor, Michigan, USA.

[2]   A. Klyuev, Prototype of analog de-randomizer. Moscow Engineering Physics Institute, CBM Collaboration meeting (September 20 - 22, 2006) @ IPHC, Strasbourg.

[3]   E. Atkin, A. Kluev, A. Voronin, Derandomizer electronics. CBM collaboration meeting, GSI, 28 Feb - 2 March 2007.

Use of the modern multimedia technologies in education and popularization of the modern science

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In recent years the basic requirements to the process of education have essentially changed. It is caused first of all by the fact that the huge amounts of information, which have to be learned, increase every day. In the modern society it is necessary to get an absolutely new quality of education – to teach how to learn. Constantly lots of new technologies and even new areas of knowledge appear which are indispensable for a successful career. For this reason nowadays a modern process of education should be focused not only on receiving some new data volumes but also on learning how to define a goal of the study and how to reach this goal.

In order to carry out this plan we should form for school students the following skills and competences:
- Desire and ability to study.
- Ability to receive and work with information.
- Ability to arrange arguments in the logical sequence.
- Ability to work in team over joint projects.
- Ability to reach the final result.
- Ability to apply the received knowledge in the real life.
- Ability to think independently and to solve nonstandard problems.
- Ability to see relations over the subjects in the studied material.

Use of the computer and electron educational materials at all stages of educational process can help with the solving of considered problems. Rapid development of information technologies allows providing a wide spectrum of considerably new possibilities helping to diversify educational process, to support independent and research work, teamwork in projects etc.

The most perspective way to reach all goals mentioned above seems to be found as an the application of multimedia educational products which give the following possibilities:
- Use of animation as means of the visual presentation of new material.
- Wide use of interactive work to support active form of learning new material.
- Use of photo and video materials.
- Support of means of independent search of the necessary information.
- Support of possibilities to save the necessary materials in formats of Microsoft Office for subsequent use in reports and presentations.
- Use of databases for storage of test results.

- Networking support which allows as to organize teamwork in projects, to discuss a studied theme by students, to facilitate the process of testing and analyzing of knowledge by teachers, as to use huge information resources of the world computer network.
- The minimum means of the product administration as it is supposed to be used either at school or at home for independent work of the student.

The choice of technologies and formats

At present there are a lot of worldwide technologies, allowing to create the integrated program complex meeting the above-listed requirements set.

As a rule the main criteria of the choice of these technologies are their compatibility and economic efficiency. In this case by compatibility we mean possibility of interaction of different technologies in the process of the application work in the network solving of the general problems and availability of the corresponding interfaces for information exchange between the modules realized by various technologies.

In this article the authors offer a methodology for creation of multimedia educational products based on using of the modern information technologies. Macromedia Flash is chosen as optimum tool of animation design (for our target audience). Technology portability and possibility to use it in WWW (see Fig. 1) played an important role in this choice.
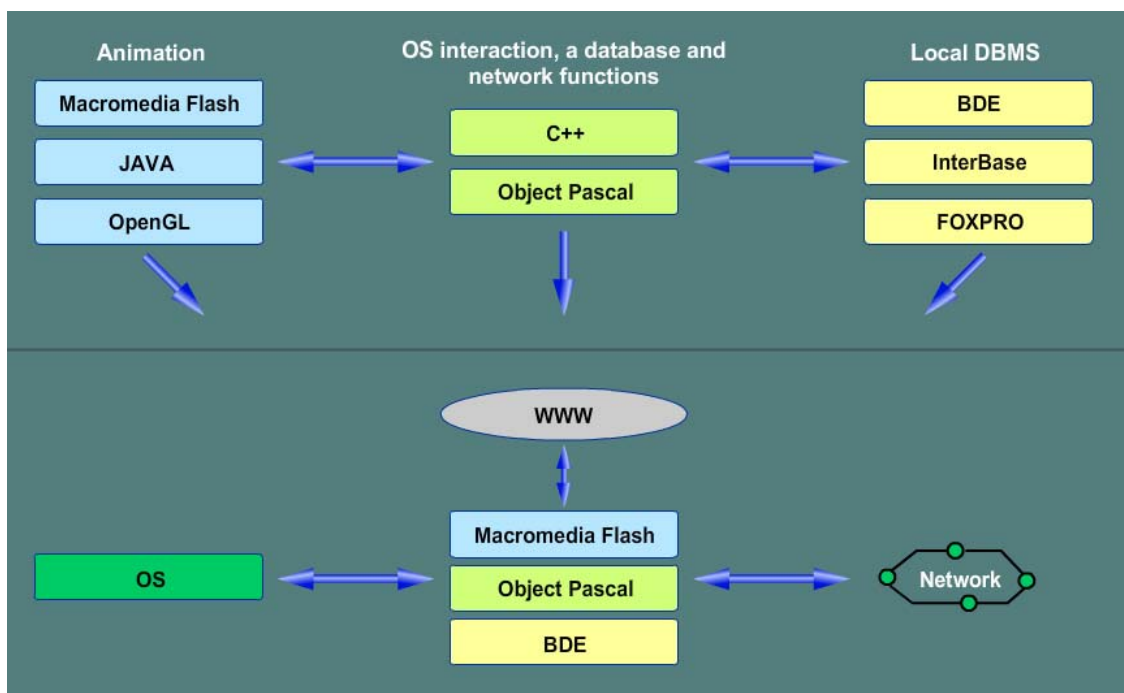
Fig. 1

Characteristic features of Macromedia Flash are simplicity, interactivity, safety and compactness. Originally the technology was created for use within the Internet. And it was oriented on creation of graphics. But it also has built-in objective programming language – Action Script 2 that allows its application for creation of complex interactive models and graphic user interfaces.

Database availability is a necessary condition for storage of examination and test results of students and analysis of their progress as well.

Developed by one firm, Borland Delphi and BDE (Borland Database Engine) as the technologies have a convenient interface of interaction. The development environment of Borland Delphi also allows to load the modules realized in Macromedia Flash by using the system object AciveX Control.

Paradox 4.0 together with the BDE is chosen as a local database. The system and network functions as well as the Macromedia Flash and database interaction are provided by one of high level languages – in our case Object Pascal (development environment of the Borland Delphi 7).

The optimal local network structure assumes the following subsystems:
1. A database server (storage of metadata and results of students' work).
2. An application server (communication applications and support systems of project activity).
3. A web-server (local publication of web-materials).
4. Access to the Internet (use of huge information resources of the world computer network).

Under all-round software integration the huge value belongs not only to the content of educational material but also to the form of its representation.

As a rule high quality of the material representation and possibility to use it out of the main application are incompatible. There are two methods to provide both these characteristics:
1. Dynamic formation of materials in the necessary format on-stream.
2. Availability of two copies of a material – for computer display and for distribution on paper.

In our projects (specifically in "Biology") we used the second method.

Fig. 2. Universality of formats

Use of multimedia means

As it was already mentioned one of the important components of multimedia products is the use of animation. Animation can make any material more lively, draw attention to the important problem. By means of animation it is possible to show the operation of any device or a mechanism; the wildlife phenomena (see Fig. 3).
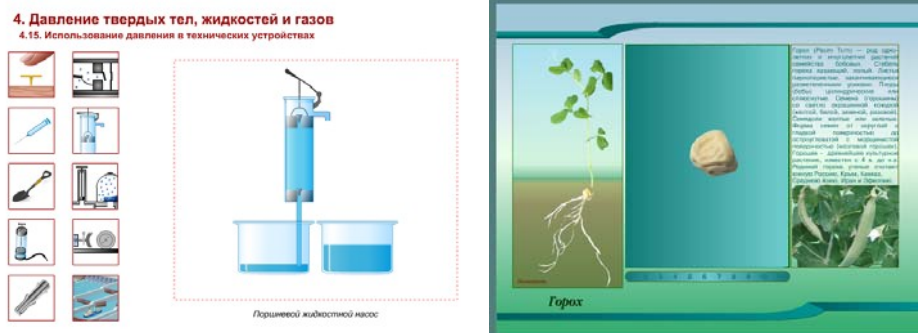
Fig. 3. Use of animation as a means of the visual presentation of new material

Interactivity or active interaction between the user and the educational product is the main advantage of computer technologies in education. By means of it the education becomes active and therefore much more successful (see Fig. 4).
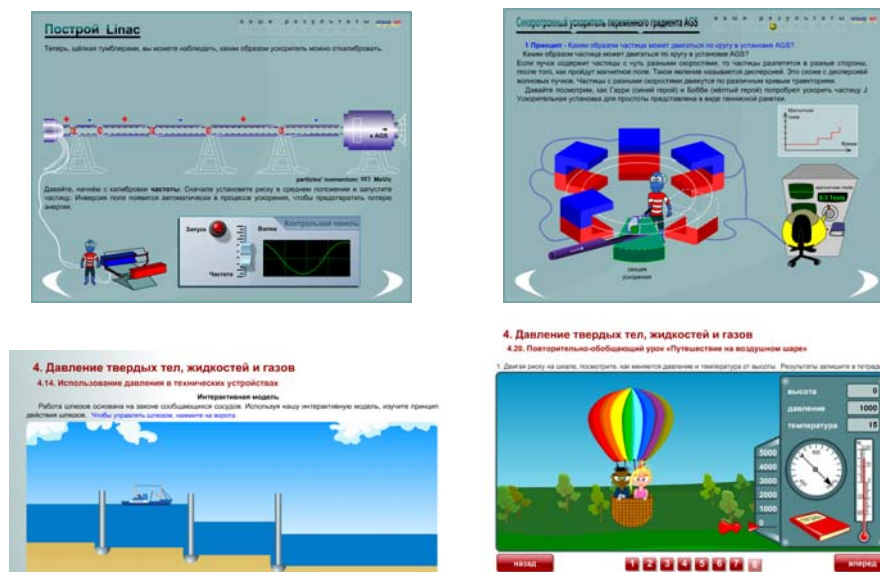
Fig. 4. Wide use of interactive work to support active form of learning of the new material

Modern teachers and psychologists assert that children now are out of reality: they are lost in the computer reality. Therefore the use of photo and video data in an educational product allows to give an evident representation of studied processes and the phenomena. Often it is the shortest way for understanding the material and its application in the real life. The principle that works here is: "it's better to look once, than much to hear about" (see Fig. 5).
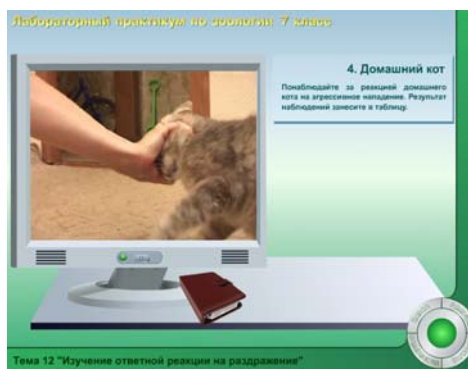
Fig. 5. Use of photo and video materials

Projects

The approach overviewed above has been realized at creation of innovative multimedia educational courses for school and university students in different fields of natural sciences such as "RHIC (Relativistic Heavy Ion Collider) Lessons", the electron application to the textbook "Biology. Grade 6", an innovative educational methodical complex "Physics. Grade 7". In the field of popularization of the modern science achievements one of the Internet projects for school students on natural sciences "Online Science Classroom" has been created (see ig. 6).

Fig. 6

The innovative educational methodical complex "Physics. Grade 7" is a complete multimedia product intended for the study of Physics in the 7th grade of secondary school. It consists of 5 sections. Each of them includes the lessons on new educational material, the lessons focused on problem solving, tests, computer laboratory works, computer examinations, refresher summary lessons, historical sketches and interactive quizzes. The methods of material representation are based on all stated above principles.

The Internet project "Online Science Classroom" includes sections: High Energy and Nuclear Research, Nanotechnology, Physics and Life Sciences and Science Museum. In each of these sections the students can study physics, biology, chemistry, ecology laws and learn about advanced achievements in science and techniques.

A lot of elements of the described projects have passed a successful approbation at schools and some of them are already introduced in the real educational process. All of them were highly appreciated by both teachers and students. Meanwhile students work with such educational materials with big interest and pleasure.

Current status of JINR participation in the WLCG and EGEE projects

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Since 2003 year the Joint Institute for Nuclear Research takes an active part in two large-scale worldwide grid projects: Worldwide LHC Computing project and Enabling Grids for E-sciencE project [1].

The JINR staff members participate in three LHC experiments (ALICE, ATLAS and CMS) and it is strongly important to provide the proper conditions for the JINR physicists for their full-scale participation in the experiments at the LHC running phase.

During 2006-2007 year the JINR participated in the following EGEE activities: SA1 - grid infrastructure support, NA2 – dissemination and outreach of knowledge on grid [2], NA3 – training and induction [3], NA4 – application identification and support [4].

By the middle of the 2004 year the LCG/EGEE infrastructure has been created at the JINR. This infrastructure can be considered as a part of the JINR Central Information and Computing Center (CICC). To follow the requirements of the global grid projects, a necessary level of all the elements of the JINR telecommunication, network and information infrastructure should be provided including high-throughput telecommunication data links, JINR local area network (LAN) backbone, central computer complex and grid segment, software support for the physical experiments using grid (at JINR they are ALICE, ATLAS, CMS and H1). The JINR LCG/EGEE farm consists of a complex of special servers providing the proper grid services and 251 computing nodes. In 2006 year the migration from the LCG middleware environment to the gLite new generation middleware has been done (the current version is GLITE-3_1_0) [5]. Also the Scientific Linux 3 operational system has been updated to SL4. Users can access the LCG/EGEE resources via User Interface (UI) service installed at one of interactive computers of the JINR CICC (*lxpub04.jinr.ru*). Also the following basic and special grid services are provided at the JINR: Storage Element (SE) service (42 TB dCache disk storage); Computing Element (CE) service as grid batch queue enabling access for 9 Virtual Organizations (VO) including ALICE, ATLAS, CMS, LHCb, HONE (H1 experiment at DESY); Resource Broker service (RB); Information Service (BDII-Berkley DB Information Index); Proxy service (PX); the advanced service for access to the LCG/EGEE resources (MyProxy); Workload Management System + Logging&Bookkeeping Service (WMS+LB); RGMA-based monitoring system collector service (MON-box); LCG File Catalog (LFC) service and VO boxes special services for ALICE and CMS. The software required for Virtual Organizations is currently installing at the JINR LCG/EGEE site including dCache xrootd door, AliROOT, ROOT, GEANT packages for ALICE; ATLAS packages; CMSSW packages for CMS, DaVinchi and Gauss packages for LHCb.

The special server has been installed and supported at the JINR to provide the RDIG EGEE/LCG sites monitoring based on the MonALISA system [6]. The RDIG monitoring and accounting system is accessible at the *http://rocmon.jinr.ru:8080*.

Monitoring is provided for CPU number (total, working, down, free and busy), number of running and waiting jobs, storage space (used and available) and current state of network bandwidth (see Fig.1 with an example of monitoring results). Accounting system provides information on a number of submitted jobs, total and normalized CPU time used, average time per job, waiting job time, average ratio waiting/used CPU time per job and some other information.
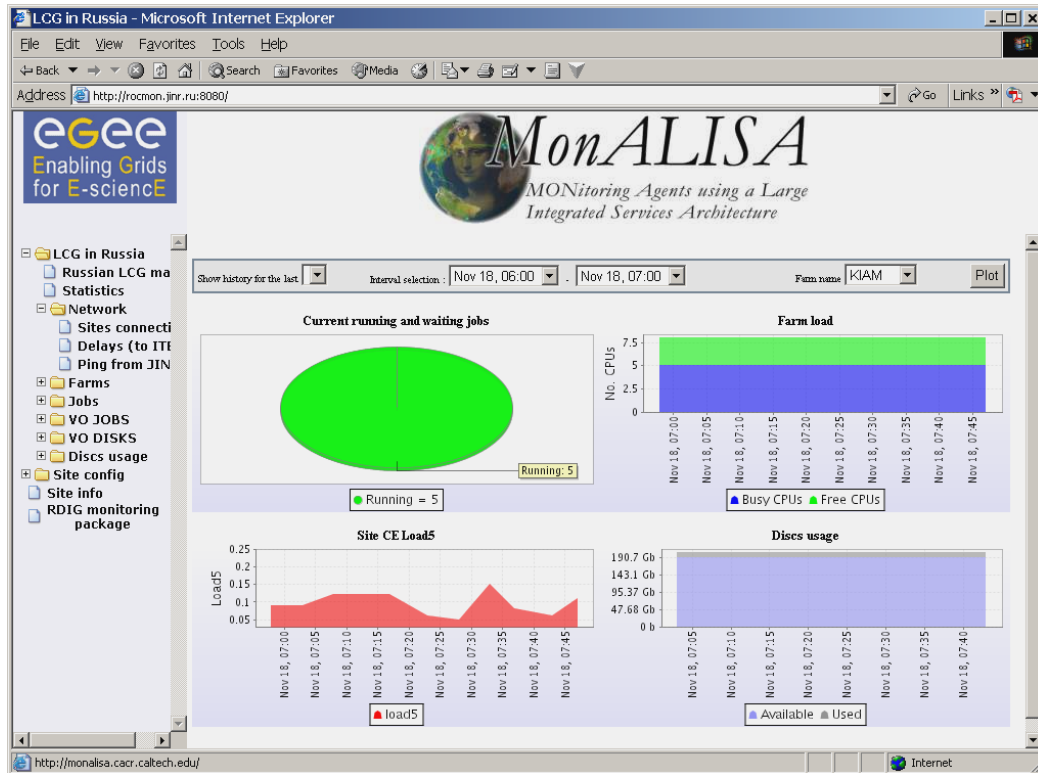
Fig. 1. Example of RDIG monitoring data visualization *(http://rocmon.jinr.ru:8080)*

Also a special web-page on RDMS CMS Phedex transfer statistics has been developed (*http://rocmon.jinr.ru/scripts/phedex*) with information on data transfer rates and amount of data transferred during different time periods (hours and days).

In the frames of the participation in the WLCG, EGEE and ARDA projects the following works have been done in a cooperation with Russian and foreign colleagues:

- support and development of the JINR LCG-segment in frames of the global LCG infrastructure;
- participation in Service and Data Challenges for CMS, ATLAS and ALICE [7,8];
- ALICE software support at 12 Russian LCG-sites;
- grid-monitoring and accounting system of Russian LCG/EGEE infrastructure;
- evaluation of new Grid technologies (OMII Open Middleware Infrastructure Institute, Globus Toolkit 3 & 4);
- gLite middleware testing/evaluation - testing of gLite AMGA metadata service[9], Metadata catalog, Fireman catalog, gridFTP and VOMS (Virtual Organization Membership Service) testing;
- participation in ARDA activities in coordination with experiments (CMS Dashboard development, condor-G monitoring, ATLAS Commander development) [10];

- FTS monitoring and testing: CERN FTS channels monitoring is performed by the JINR specialists from February, 2007 (*https://twiki.cern.ch/twiki/bin/view/LCG/ TransferOperations*) providing Daily logs with tracking of current problems and open issues, Weekly report for the Joint Operation Meeting at CERN and Weekly Castor Summary of issues noticed on the Castor Tier-0 service. Daily logs are keeping in the Daily log archive representing a history of situation on channels;
- development of the MCDB system (LCG Monte-Carlo physical events data base) - creation of a set of basic modules; web-interface development; access to MCDB from CMSSW package (*http:// mcdb.cerb.ch*) [11,12];
- dCache usage/development;
- participation in CASTOR2 system development;
- courses for Grid administrators and users.

Also the Russian testbed infrastructure for testing in the gLite 3.X environment was installed at several nodes located at PNPI, INR, IHEP and JINR.

Participation in the development of certification tests for VOMS can be considered as an example of our activities in gLite middleware testing. 32 programs were developed to test the operations of the administration of virtual organization (*voms-admin* operation) both with the use of a WEB interface and the use of CLI (Command Language Interface) and 28 programs were developed to test *voms-proxy-init* user command (generation of proxy certificate). All the programs developed have been integrated into the automated system SAM (Service Ability Monitor) and are in a regular use in the EGEE.

An overall coordination of NA2 activity in the RDIG EGEE consortium is accomplishing [2]. The RDIG-EGEE informational web-portal has been developed and is supported (*http://www.egee-rdig.ru*) at JINR. The portal is realized on the Apache 2 web-server with a usage of ORACLE DBMS and php-Personal Home Page (see the RDIG-EGEE portal information page at the Fig.2). All EGEE Info sheets and EGEE news releases are regularly translated into Russian and they are accessible at the RDIG-EGEE portal. The video-clip "JINR participation in EGEE" is created. A special presentation was prepared for the International Economic Forum in St. Petersburg (June 2007). The first "Grid Industry day" in Russia was organized in Dubna by JINR and it attracted a large number of industry organizations and companies interesting in deployment and usage of modern grid technologies.

The 2nd international conference "Distributed computing and Grid technologies in science and education" (GRID-2006) was organized and hosted by JINR (*http://grid2006.jinr.ru*). GRID-2006 gathered more than 200 scientists from Russia and CIS countries. It is the only conference in the Russian Federation devoted especially to modern grid technologies.

We work in a close cooperation and provide support to our partners in Ukraine, Belarus, Czech, Romania, Germany, South Africa, Bulgaria.

As a result of JINR participation in the WLCG and EGEE project, the JINR LGG/EGEE site is fully integrated into the worldwide LCG/EGEE grid infrastructure providing all the necessary resources, services and software for participation of JINR specialists in ALICE, ATLAS and CMS experiments after the LHC start which is expected in 2008 year. We plan to continue our participation in the WLCG project to support and develop

the JINR LCG/EGEE site at the running phase of the LHC experiments. The further JINR activities in the WLCG project are based on the Memorandum on Understanding signed in September, 2007 by Russia, JINR and CERN. This agreement gives a juridical and financial basement for participation of Russia and JINR in the WLCG project after the LHC start. Also we shall continue our activities at the next stage of the EGEE project taking into account that these two global grid projects are developing in a close cooperation.

Fig. 2. The RDIG-EGEE web-portal (*http://www.egee-rdig.ru*)

The results of JINR activities in the WLCG and EGEE projects have been presented at the international conferences ("Distributed Computing and GRID-technologies in Science and Education", Dubna, Russia, 2006; ACAT 2007, Amsterdam, 2007; NEC'2007, Varna, Bulgaria, 2007; CHEP'2007, Victoria, Canada; "Physics at the Future Colliders", Tbilisi, 2007), ICFA Workshop on Grid Activities within Large Scale International Collaborations (Sinaia, Romania, 2006) and the EGEE conferences (Geneva, 2006; Budapest, 2007) [13].

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2D position-sensitive detector for thermal neutrons

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The rapid expansion of neutron scattering research as well as high cost of operation of neutron beams on modern high-flux neutron sources calls for the most rational use of capabilities of these sources. In the case of pulsed neutron sources besides high accuracy in the measurement of spatial/angular distribution of scattered neutrons required in the studies of structure of substances by neutron diffraction methods, high precision is also needed in measuring the time of flight determining the energy of the incident neutron. The use of coordinate neutron detectors reduces the time necessary for obtaining diffraction patterns by one - two orders of magnitude. This makes it possible not only to increase the number of samples that can be studied in the time allotted for the experiment, but also to carry out qualitatively new types of experiments to study the dynamics of behavior of the sample under changes of external conditions, for example, under changes of temperature or pressure [1].

Nowadays practically all leading centers engaged in neutron research of condensed matter are equipped with neutron position-sensitive detectors (PSD) based on multiwire proportional chambers (MWPC) with coordinate resolution of 1.5÷10 mm, scintillation and thermoluminescence detectors, which makes it possible to make the most efficient use of the neutron sources [2].

In FLNP a two-dimensional detector has been designed and constructed with the following characteristics:

Table 1

Gas mixture	3000 мбар He^3+2000мбар CF_4
Efficiency	75%
Active area	225×225 мм^2
Coordinate resolution	2 мм
Count rate	~ 10^6 е./с

The detector is a multiwire proportional chamber with delay line data readout. The overall dimensions of the chamber are 342×342×54 mm (Fig.1). The entrance window is 7 mm thick, which only minimally weakens the incident neutron flux and makes it possible to endure mechanical loads that arise when filling the detector with a gas mixture. High voltage of positive polarity is fed via an MHV connector. Five BNC connectors serve for signal output. The detector has a gas connector of the "Swagelock" type.

In the chamber volume there are two cathode, two drift and one anode electrodes. Each of the electrodes is a textolite frame with a cut window with wound fine wires of gold plated tungsten for anode and cathode planes and an aluminum-evaporated mylar film for drift planes. The thickness of anode wires is 15 μm and of cathode wires – 100 μm. The anode wire spacing is 1 mm. A common bus connects the anode wires. The cathode wire spacing is 1 mm. The cathode wires are connected together in pairs and brought out to the delay line, each unit of which delays signals by 2.9 ns. The distance between the electrodes is 3 mm; the

anode is positioned in the middle. The drift electrodes are placed close working mixture. To detect neutrons, the chamber volume is filled with a mixture of neutron converter gas He^3 and quenching gas CF_4. The total pressure of the gas mixture is 5000 atm.
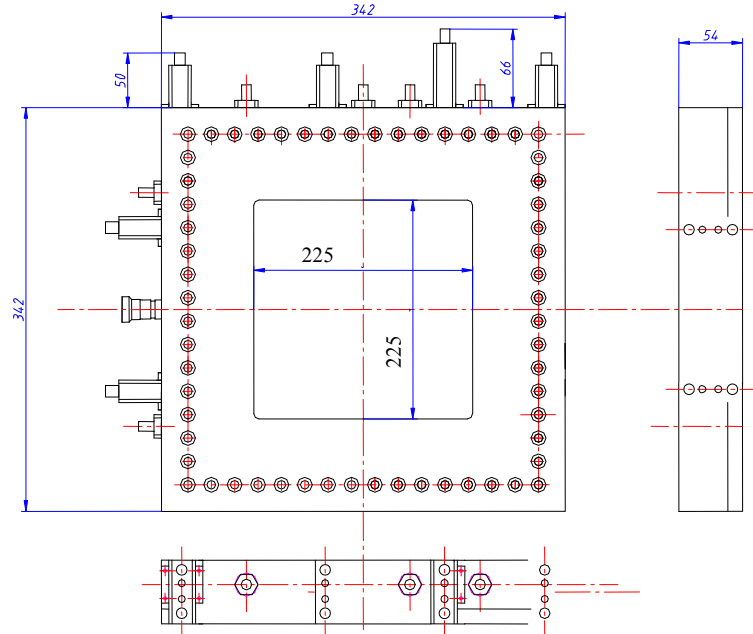
Fig.1. Assembly drawing of the 2D detector
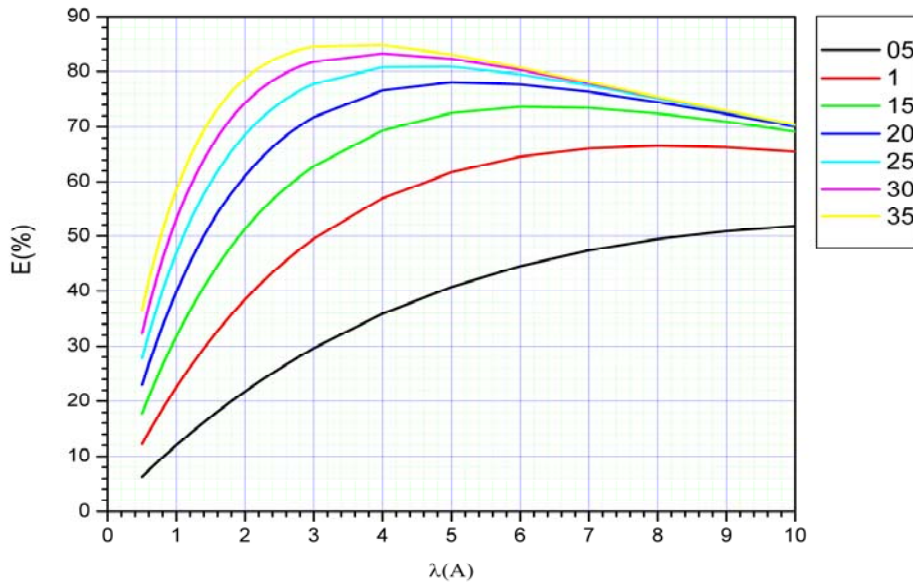
Fig.2. The calculated dependence of detector efficiency on neutron λ and pressure of ^3He

The detector was tested at a pressure of up to 7 atm. The technological degassing procedure was carried out. The working voltage at the anode is 4000 V, the detector walls, which rules out the presence of a shielding gap of the the voltage at the drift electrode is

2000 V. The gas mixture is 3 atm + 2.0 atm CF4. The measured detector efficiency at $\lambda_0 = 2.0\Delta$ is 74%. And the calculated value (Fig.2) is 75%.

It can be seen from the figure that at pressures higher than 1.5 atm a decrease in the efficiency for neutron wavelengths larger than 4A due to the scattering from the entrance window is observed.
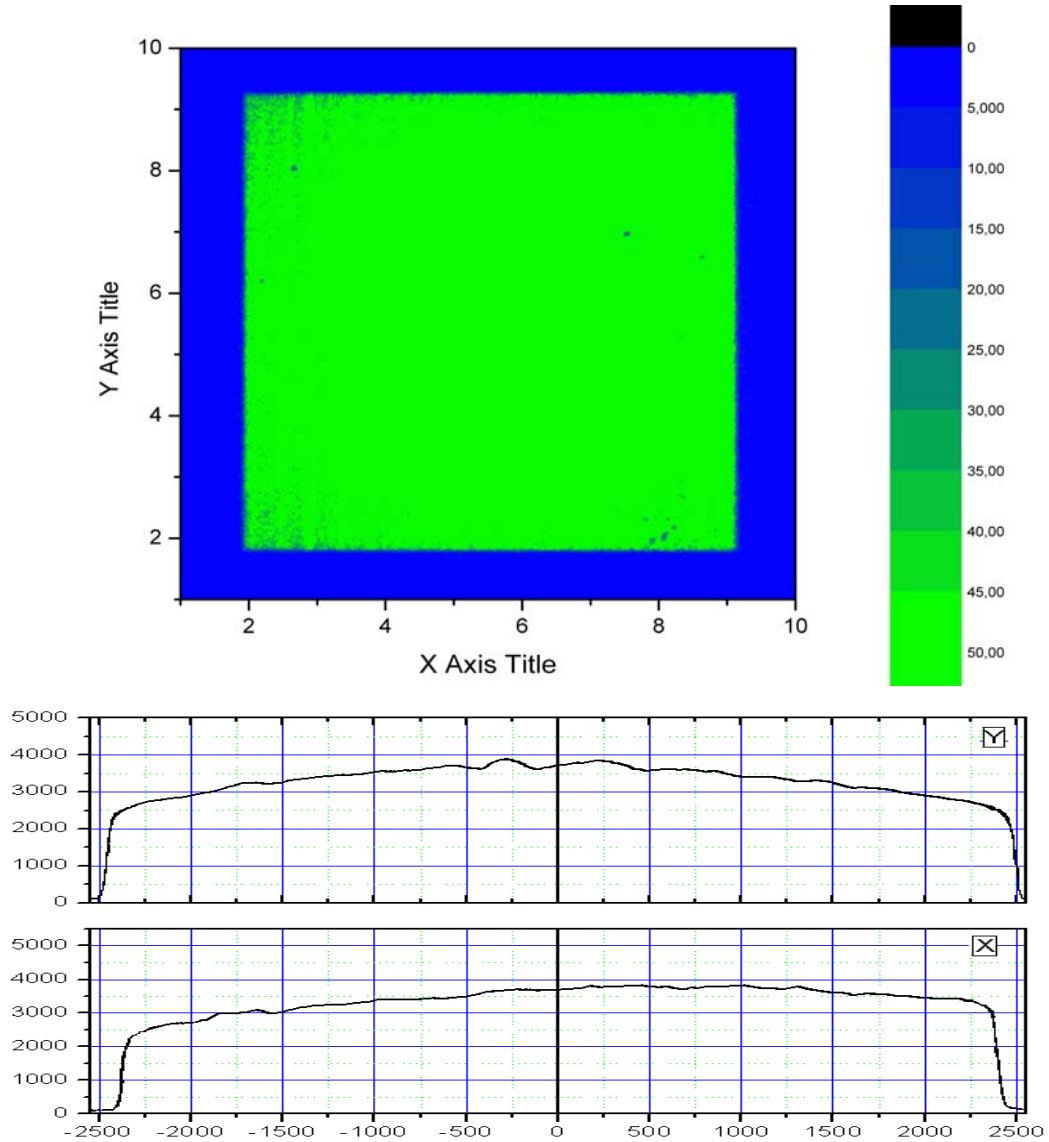
Fig.3. The result of a uniform exposure of the detector during test measurements by means of a neutrons source and the projection to axes X and Y

Signals from both delay lines and an anode signal through preamplifiers come to a five-channel constant fraction timing discriminator and are registered in data acquisition (DAQ) board [**3**] intended for acquisition and accumulation of data from 1D and 2D position-sensitive detectors based on a multiwire proportional chamber with delay line data readout. It comprises 8-channel TDC of F1 type (Acam), FIFOs of different types, CPLDs, FPGA, 256 Mbyte histogram memory and DSP TMS 320C6711. In the board, the determination of

X/Y coordinates of the event (by signals from both ends of the delay lines) and neutron time of flight (TOF) from the reactor start to the moment of detection, is executed; for the methodical purposes the amplitude of signals is measured as well. Two main operating modes are provided: histogram (on-line sorting of data and building of spectra) and "list" (accumulation of raw data with subsequent off-line processing). It is also possible to simultaneously accumulate histograms (for experiment control) and to write raw data. The DAQ board has a PCI-interface and is installed directly in the case of PC.

The software for the DAQ board based system includes the following modules, operating on three different processors [4]:

● The FPGA program operates on the programmable logic device FPGA-EP1K30 to provide TDC control and preliminary data filtering. The program is loaded from the PC disk to the device (using CPLD programmable logic device) after every board initialization.

● The DSP program operates on the board DSP processor TMS320C6711 to provide the board component communications, next level of data treatment, and data transmissions between FPGA, DSP and PCI-bus. The program is loaded from the PC disk to the device (also using CPLD) after the board initialization.

● The PCI-bus third party driver operates on the PC and provides access to the PCI devices from the PC user level program.

● The DAQ board interface module (PC level) is a dynamically loaded library that exports the necessary functions for full control of the DAQ board (using PCI bus driver).

● The end user (PC level) applications provide user interface for control of the board operation and the experiment, the necessary data treatment functions, the data visualization, and data persistency.

The present performance of the DAQ board is different for TOF and Non-TOF mode of operation, type of filtering, and for histogram accumulation and list mode measurements. In the regime of histogram accumulation the operating speed also depends on the quantity of histograms inquired for accumulation and on the frequencies of reading of histograms and of their updating on the screen. Depending on the mode of operation and regime of data accumulation, the count rate of the DAQ system changes from 10^5 events/s (histogram mode) to $8 \cdot 10^5$ events/s (list mode).

At present, F.V. Levchanovskiy has developed a new data acquisition and accumulation block (DAAB) for 1D and 2D MWPC detectors. The main distinction of the block from PCI DAQ board is that DAAB has no digital signal processor (DSP), which essentially reduces data accumulation rate. All functions of DSP (filtering, histogramming, data formatting, etc.) as well as control functions are performed by FPGA and partially by PC. In the new block 8-channel TDC-GPX (Accam), 1GByte histogram memory and high-speed optical interface to PC are used.

Logic and time simulation of operation of the block was carried out using Quartus II package from ALTERA. It was shown that the rate of acquisition, filtering and accumulation of events in the block may amount to $2 \cdot 10^6$ events/s. Real registration rate (taking into account data transfer and recording to a computer) is expected to be no less than 10^6 events/s. The block has been manufactured and at present is being debugged and tested.

Conclusion

The design of the 2D detector with an active area of 225×225 mm^2 has been worked out and the package of engineering documentation has been prepared. The detector has been manufactured. The system of the developed earlier detector electronics and the data accumulation electronics, as well as the software have been adjusted and debugged. The detector and electronics have been successfully tested with the event generator and the neutron source. This work is supported by grant of Goskontrakt № 02.452.11.7044 (2006) and BMBF(Germany).

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On a construction of distributed information system

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Abstract

Using a classic scheme of constructing information systems basing on a multilink technology "client-server" often leads to overload of some computers, while others remain idle. A solution to this problem related to construction of distributed data bases, will not be final. However, it should be noted there are technological solutions in the field of constructing the distributed systems based, for instance, on GRID technologies (Globus, Condor, etc), where the rendering of some user service is yielded by a remote service, and it does not matter where that service is located.

Such a distributed infrastructure can be used also to arrange the services serving the clients, thus reducing the cost of the system due to decreasing requirements to some sites of the system, and therefore, the cost of the whole system reduces too. Besides, reliability and fault tolerance of the system essentially increases, because of backup functions of separate sites.

This report deals with the architecture of such systems in which rendering of a user service of an information system is distributed between various sites of an electronic network within the technology suggested.

Introduction

Increase in the computing capacity of hardware complexes essentially outstrips the development of software for them, including applied one. Such a situation is typical of all large hard- software complexes worldwide as when creating the developers do not pay enough attention to the problems of exploitation and re-compensation of such systems.

JINR must solve not only problems of theoretical and experimental physics. Here, as well as in any organization, it is necessary to solve administrative, financial and other problems connected to its normal functioning. Now in order to solve such problems, one usually applies iterated information systems having one or two servers of databases, the same number of servers of applications and client workplaces. At present there is a tendency to use, as a client application, a standard browser, while services will be provided through a Web-interface.

The use of the JINR computer complex, as iterated client-server unit for the solving of information and analytical problems, shows that the most computers in a distributed network will remain unloaded. It leads to s necessity of their switching-off, i.e. to reducing the total performance of the whole system. Thus, if really labour-consuming problems appear, their solution in such a system becomes inefficient in view of restrictions on resources that function constantly.

On the other hand, the computing capacities of the created city metacluster complex "Dubna-Grid" can be used not only to calculate some physical problems, but also to solve the problems arising both inside the organization and in the municipal management: at paperless office-work, in providing reference sources and analytical materials on housing, municipal and transport facilities, communication and engineering networks, etc.

So far the existing architecture of the complex practically has no services for the end user, i.e. for performance within it some applied and informational - analytical computations. The client himself should create the software necessary for the solution of such type problems. It often leads to refusal of using this complex and causes transition to a standard firmware possessing a more friendly environment and an intuitively clear interface.

In order to solve the mentioned problems, the architecture of the existing software should be revised, some new constructive elements and mechanisms of functioning should be added to it.

The suggested architecture

The main disadvantage of the existing architecture is the mechanism of providing services concentrated in separate devices - servers. A controller of tasks in the system Condor that distributes computing tasks over machines within the network and an application server in structures like Globus, Corba, Enterprise Java Server, etc. belong to such servers. Such type structures have brokers through which an interaction is set between a client program application and a data server.

Historically, the appearance of such type application servers became an important step in the development of computing architectures both in local networks and in the global network Internet. However, concentration of a place of rendering all services by one machine (or even two-three ones) with a growing number of clients leads to excessive requirements to them while load of other resources remains low. Besides, a response time increases due to increase in the inquiries queue length. The available hard- software solutions are based on such an architecture and do not allow one to load in regular intervals all computers of the distributed environment when solving administrative tasks.

That is why it is the iterated architecture 'client – server' that becomes a brake in the development of the distributed computing systems as a non-uniform loading of any hardware-software computer complex is put in it. To solve the problem on the uniform load of all computers of the distributed computing environment, one should reconsider a mechanism of loading the computing system i.e. reconsider a mechanism of functioning the application servers.

A possible solution satisfying the task in view is the architecture based on virtual servers of services and virtual processes of providing services. Let us consider a scheme of the suggested mechanism of functioning this system shown on Fig. 1.

Fig. 1. The mechanism of receiving a service

Here for access to a service there is an application server - AS (mechanism of access to the server can be HTTP, Java application, C ++ Stubs, etc.). When setting connection with the client and receiving an inquiry for service (the inquiry on service rendering), in such a distributed environment a virtual server (VAS) is created as some process on a separate computer. A peculiar feature of this process is its applicability only for rendering certain type services for a concrete client. In order to execute the service, a virtual process should be created that will be placed on one computer which will provide this service to a corresponding client. Upon termination of providing the service, the process stops. Upon completing the work of the client, the process of the virtual application server stops. If the client needs several services at the same time, as many virtual processes are created, as many services are required. Each process will be placed on a separate computer of the distributed system.

For example, if a client needs to start computation of a labour-consuming problem, then for rendering such service a process must be started that interacts with a server such as Condor and carries out performance of jobs in the distributed environment. The result will be given the user through this virtual process. In the other case, for example, the client wants to have a look at the schedule of trains "Moscow – Dubna". Thus a virtual server providing

reception of the information from the external network Internet will be generated. Hence, a virtual process will be created intended for sending the inquiry to a certain address (IP) of receiving the information and giving it to the user in a certain format. In a third case, a user needs information on a power electric cable in a particular place in Dubna. To receive such information, a corresponding virtual application server will be loaded that provides work with two databases - cartographical and technological ones of Mosoblenergo Dubna. Upon reception of the result, the process created for realization of this inquiry, will be terminated, and management will be transferred to the virtual application server serving this client. If this client wishes to receive information on a water supply systems available in this place, the following actions will take place in this case. The working virtual application server will create a new virtual process for connection with a database of Mosoblvodokanal and receive from it needed information, it will transform it into a corresponding form and present it to the client. Upon the termination of the inquiry performance, the process finishes its work.

In such a system as well as in any other iterated architecture the client - server, a determinative factor is the time of establishing the connection with the database and inquiry performance. It is known that most time-consuming mechanism in the operation of iterated systems is the establishment of connection with databases which demand authentication and some other actions when connecting to DBMS. That is why, to provide the high-performance of the whole system, it is necessary to create virtual processes of access points to the distributed database.
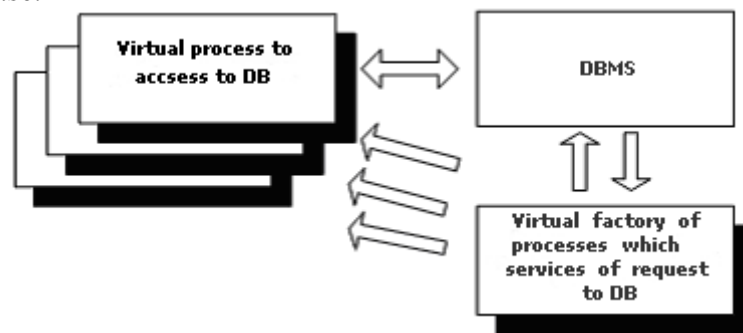
Fig. 2. Architecture of access to DBMS

The mechanism of functioning such access will be described as follows. There is a distributed database. To serve inquiries to it, there is a virtual factory of processes, that is the process generating the processes which will be registered and connected to the base, passive with respect to it though. In case of generating a virtual process realizing a client service (fig. 1), it establishes a connection through the factory of processes with the virtual process of access generated by it to the database. It means in this case that registration has been already executed in the base and DBMS is ready to perform inquiry. The result of inquiry performance is transferred to the virtual process of rendering service. Upon termination of work of the last one, the process of access to the database is destroyed too. The factory of virtual processes thus creates a new process which is registered in the database and waits for a corresponding inquiry.

Thus, omitting some details of the suggested architecture, we can say that realization of the service to the client will occur in several divided processes, each of which is optimized as much as possible as to time and space for its execution. A uniform load of the whole computing system is reached in this case.

A prominent aspect of this architecture is that it can work within existing hard-software platform.

Features of the suggested architecture

When realizing the suggested system, the following advantages can be reached:

· Essential reduction of time of delay for receiving an answer to the client's inquiry as this system practically excludes any queue for serving.

· Uniform load of the whole computing system, including network and server resources.

· High fault-tolerance of the system as its work does not depend on one or several computers.

· Decrease in requirements to separate objects of the computing environment such as application servers, database servers, communication equipment, etc.

· High scalability of the system that allows one to increase or reduce capacity if necessary.

· Low prime cost of separate elements and their high interchangeability.

· Territorial distribution of the system means its high security from damages, infringements in operation and terrorism threats.

· A unified mechanism of access to all resources of the information system, including a unified platform-independent Web-interface (unification and standardization).

· An opportunity of organizing a paperless document circulation at any level of the JINR management.

· Receiving of services at any point worldwide.

However, this architecture has some disadvantages, for instance, high complexity of the development as compared to the traditional architecture.

Conclusions

The suggested technology allows one to optimize load on the distributed computer complexes and to increase their efficiency at the expense of solving administrative and managerial tasks. The introduction of distributed computing in such an architecture essentially raises the reliability of functioning the whole system.

Besides, the suggested architecture possesses universality and can be used for solution of a wide spectrum of applied tasks in the distributed computing environment.

On a technology of paperless document circulation

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Abstract

The problem of a documentation circulation is of great importance for any organization. The effective functioning of the enterprise strongly depends upon how quickly and qualitatively the documents are compiled. A traditional approach to documentation processing leads to essential delays and is subject to the influence of human elements. Besides, a possibility of some errors arises when paper documents are transferred to an information system. Thus, the quality of work of such information systems reduces. This report suggests a methodology of paperless document circulation with no disadvantages mentioned above.

Introduction

It is well-known that management of any organization is regulated by documents that are produced at various hierarchical levels. The most decisions are formalize documentary in the shape of orders, regulations, coordinated plans, schedules, etc. Their contents form *an information field* of the organization. Probably, some decisions are accompanied by oral orders, but they do express some intentions and have a preparatory character that is not reflected in the information field of the organization. As referred to LIT JINR, the director, deputy directors, chiefs of departments, etc. possess the right to make some decisions.

In order to take a correct decision made out in accordance with the accepted legislation as a document, some corresponding information is required. This information can exist in various kinds: paper, electronic, verbal, visual ones, etc. It is clear, for functioning the information system (IS) one have to transform all this information into electronic form of a certain structure.

However, this procedure has a number of disadvantages. First, mistakes caused by human carelessness or abusing are possible. Secondly, the processes of formation of the electronic information lose touch with real vital processes so the information looses its urgency or ceases to be valid. Finally, the process of decision-making in paper realization is practically out control.

To eliminate these lacks, one should make the information change synchronously with real vital processes in the system. That is why the mechanism of functioning such a system should be based on the internal processes synchronously going by with real ones, while the system itself should be *"processor-oriented"*.

In this case, there is an opportunity of a paperless technology of conducting documentation. The creation of an electronic template of some document means initialization of a corresponding process in the system. The motion of the document from one instance to the other is the change of content and/or properties which this process possesses. A stage of decision-making, i.e. signing of the document and its registration actually means that the process is over. Here the information in the system changes as external processes and circumstances change and upon the end of the process is automatically fixed in IS. This procedure of making documents is called a paperless document circulation.

Function made out under a template

Let us mention the following operations performed while working at a document:
- *Initialization* of the document – the template of new docuvent formation function in IS.

Depending on its content, the document is conferred with corresponding properties.

- *Editing* of the document – amendment of the content of the document without changing its properties.

- *Transformation* of the document - modifying the properties of the document (during vising or signing), without changing its content (for example, change of the number of vising sides).

- *Vising* - acquaintance with the document of the persons authorized and their opinion due to it.

- *Signing* - acceptance of a positive or negative decision on realization of the document content.

- *Registration* – assignment of a number to the document and receiving a ready paper copy of the document.

- *Archiving* - transformation of the ready document to the form convenient for storage in electronic archive.

- *Dispatch* – the operation which informs all interested persons about some facts and/or events.

Types of processes

Any organization has a list of document-generating processes. In the scientific sphere, they can be divided into the following categories.

Personnel (staff) structure. A set of processes providing orders on giving employment/ dismissal/transfer of employees or change in their data. Work with the list of staff-members.

Administrative - financial activity of the organization includes financial numerous operations: accounting, planning, finance, immovable property, supply and other administrative activities.

Formation of scientific plans. A set of processes providing the opportunity of preparing plans for research from the moment of development to distribution of a degree of participation and financing.

Contingent. A set of processes allowing to generate a structure of scientific teams (without change of the staff list) to perform various researches for optimization of the quality and terms of scientific plans performance

Roles and rights

In order to divide the categories of access of users to IS in accordance with their official duties let us introduce a concept **of a role**.

Definition: ***The role*** *in the information environment is understood as attributing to a physical person of a set of rights to receive services in IS in some process in accordance with his official status.*

Hence, the assignment to some person of a certain role will mean an automatic attributing to this person of a set of opportunities, corresponding to his(her) position. We propose to use as roles the posts according to the staff list.

Besides, for differentiation of opportunities of users a concept of rights in the system

is introduced.

*Definition: **the conception of the right*** *in the system means accessibility or inaccessibility of some services, according to the role in IS with regard to some process.*

For a better understanding let us give examples of the rights:

1. *The right to use the role* means some amount of opportunities assigned to the person having access to the system.

2. The right to *transfer the rights* to another person means an opportunity of transferring a set of opportunities on performance of operations within the system. Assignation can be temporal or else to fulfill certain actions. Besides, the assignation can be carried out exclusively, i.e. the performance of the transferred actions is full or partial when the transferring person can fulfill the transferred operations in parallel.

The role assignment in some process comprises several phases:

1. Attributing to the person of an initial role corresponding to his official duties occurs at his initial registration in the system.

2. Assignment of temporal rights after initialization of some process which will demand performance of certain actions.

3. As soon as the assigned functions are complete or the process is over, those rights are restored which the user had before starting the process.

Thus, as against all modern IS realizations that have enough a bulky system of description of access rights of the user to data, these rights are prescribed beforehand and practically do not change during the work. The dynamic system of the rights assignment essentially simplifies the DBMS protection system because at the absence of processes there is no right of access to IS itself.

Architecture and ideology of IS construction

The realization of the processor-oriented IS essentially differs from usual database structures because it should comprise a mechanism of control over the processes. Besides, the dynamic assignment of roles to participants leads to a number of additional opportunities. On the other hand, the procedure of generating the templates of documents containing information that can be saved (or not to be saved in case of accepting a negative decision) in IS leads to necessity of extending the data field by additional sections.

Thus, the IS will consist of the following independent areas of the database shown on fig. 1.

Fig. 1. IS structure

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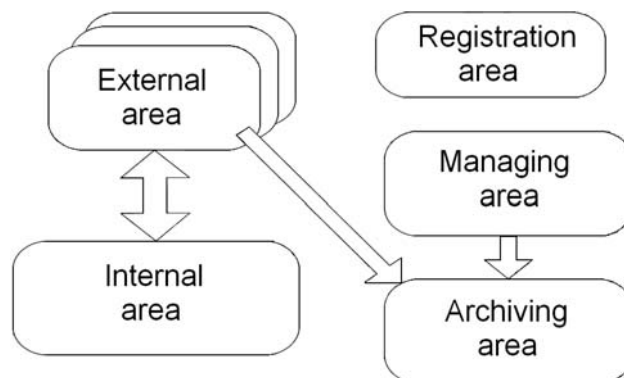
Internal area is a traditionally organized database containing all necessary tables and links between them. The architecture and the information content of the base is determined by needs of the organization and the nomenclature of the processes which should be performed in the system.

External area consists of separate tables, each contains a enumeration of not structured information used in one of the processes. As a rule, for each type process an individual table is created in external area. Initialization of the process leads to a new record in one of the tables in the external area. The termination of the process leads to deleting this record. During the process this record is filled by necessary data. They will be receiving as follows:

- they are read out from the internal area by means of the DB built-in procedure;

- they are filled with external interface by the user;

- they are generated by IS itself on the basis of the process performance rules.

Managing area contains a structure where the mechanisms of passing each process (a document-type) are registered: accounting, immovable property, supply, and other administrative activities. When initializing some process, there is an extraction of algorithm of its performance. The process participants are appointed, and their roles are prescribed. Corresponding records about transition of the process form one condition to another are made. Changes in the condition and filling of the document are fixed. Control over performance of the functions by participants of the process. There is an opportunity to re-distribute rights to other persons registered within the system, etc. Upon the end of the process all records about its performance are deleted from this area, including the rights of the participants of this process.

Archiving area contains several tables where the information is registered required for restoration of the outward appearance of the document in case it should be restored from the electronic archive. All data on the course of performing the process are written in these tables, i.e. which one, when and what actions have been done with the template. Besides, the information on documents with accepted negative decisions are also archived. Such information can be useful in case of repeated consideration of the questions at issue.

Registration area is a unique place when the user can cooperate with IS.

In order to fulfill the actions necessary for normal performance of the process, the built-in procedures are used. For example, at the stage of initializing the process, the procedures are called which fill corteges in the external model and managing model. After registration the procedures are started-up, one start-up keeps information in the internal area, while the others transfer the information from the managing area to the archive, and the third ones clean unnecessary data in the external area and the managing area.

Use of this architecture allows one to solve some more problems:

A first problem is the IS data protection. Use of several DB areas allows one to share statically the access rights to the DB data. For example, it is possible to forbid completely external access to the information located in the internal area. To extract and record information, only built-in procedures can be used which will be started from the other DB unit where external access is forbidden, too. For external access only the registration area is used, where access is controlled by the DB protection mechanisms. In case of a non-authorized access to IS, all areas, excepting the external and registration areas, will be not seen for an external BD user. Failure in the work of the external area will mean that time data are damaged. However, when the built-in procedures work, the data are checked-up on integrity.

If detecting a discrepancy, users will be notified about possible distortion of the data, and the process is restarted. Similar actions take place also in case of other attempts of non-authorized access.

A second problem which is solved within this structure consists in acceleration of work of the whole system. As all operations in the system are performed at the expense of built-in procedures stored as internal DB functions, so by their call they only execute their code. Inquiry SQL is checked-up first as to grammar and syntax, then the rights on its execution are checked, and finally it is performed.

A third problem which is solved at the expense of such type architecture is the maximal unification of the managing system that allows one to bring all information about the processes into the managing area. After that all processes are performed automatically. As a description of the processes, a mechanism based on the finite state mashine (FSM) is used. In this case, the implementation of such an automaton is very simple.

A fourth problem solved within this architecture is to provide a transparency of passing documents over all stages for all participants of the process. The initiator of process can watch at any moment at what stage the process is. On the other hand, the leader can see that a person vising the document does not want to work with it and thus compulsorily make him participate in the process or make a decision independently with no visa of the employee sabotaging this document.

Conclusions

The suggested ideology of IS functioning allows one to solve a number of problems which cannot be solved by usual ways or else a decision can be reached by a very complicated way. Besides, in the suggested ideology, the IS not only puts in order the information field of the organization, but also helps put things in order in administrative and managerial activities. In particular, in such a system it is impossible to change data without execution of some process that is release of a corresponding document. If a document is released wrongly, its correction can be made only by means of another process (document). All the processes are fixed in the archive and can be reproduced any time. A prototype of such an information system developed for LIT JINR is available on LIT website at lit.jinr.ru/DoctorDoc/.

Software development for linear accelerator control in LabVIEW and DSC environment

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Abstract

LabVIEW from National Instruments has been used for the implementation of the LUE-200 control system. Although LabVIEW is typically employed in table top experiments and test systems, it provides multi-threading, event-driven communication and a large number of hardware interfaces.

Features like alarming, trending and interfaces to field-busses like CAN and others as well as OPC-servers are required in such a control system. These SCADA functionalities are introduced by the DSC (Datalogging and Supervisory Control) module of LabVIEW.

Built-in DSC database Citadel is used for data storage and handling of historical trends.

The Tag-Engine of the DSC module is used for data transmission from server to client and conversely. All tag settings (alarm values, update rate, etc.) are configured in the Tag-Configurator and stored in configuration files.

The operator interface includes mnemonic circuit for visualization of current values of measured parameters (temperature, pressure and other), real-time and historical trends and alarm tables.

Introduction

The development of slow-control system software for the LUE-200 [1, 2] accelerator was implemented in the LabView+DSC [3] environment of the National Instrument Company [4]. The software for slow-control of accelerator systems and their status monitoring is a complex solution allowing to monitor system parameters, to timely alert to off-optimum situations in equipment performance, and to save data into the database for their future analysis and processing. While developing accelerator software, the following factors are considered: specialized and even non-standard equipment, the variety of hardware interfaces, the distance between the connected equipment and the operator, the necessity of on-line and off-line access to the data, and use of mathematical methods of data analysis and processing.

Nowadays, slow-control accelerator system software can be developed using both traditional programming methods and SCADA (SCADA – System of Control and Data Acquisition).

When using traditional methods, the following problems may evoke:

- high labor costs at every level of application development
- absence of a common solution platform
- passing the developed software to other programmers for support

SCADA help resolve the main part of these problems for they comprise a set of interrelated components allowing for simplification and unification of software development procedures.

The usage of the DSC [5] module makes LabView a full-featured SCADA that provides multi-threading, event-driven communication, and a large number of hardware interfaces.

Fig. **1** represents typical hardware equipment schema for accelerator systems management.

According to the above given figure, accelerator system software is composed of the following levels:

- data acquisition layer;
- data transmission layer;
- data processing layer;
- data storage layer;
- data presentation layer.

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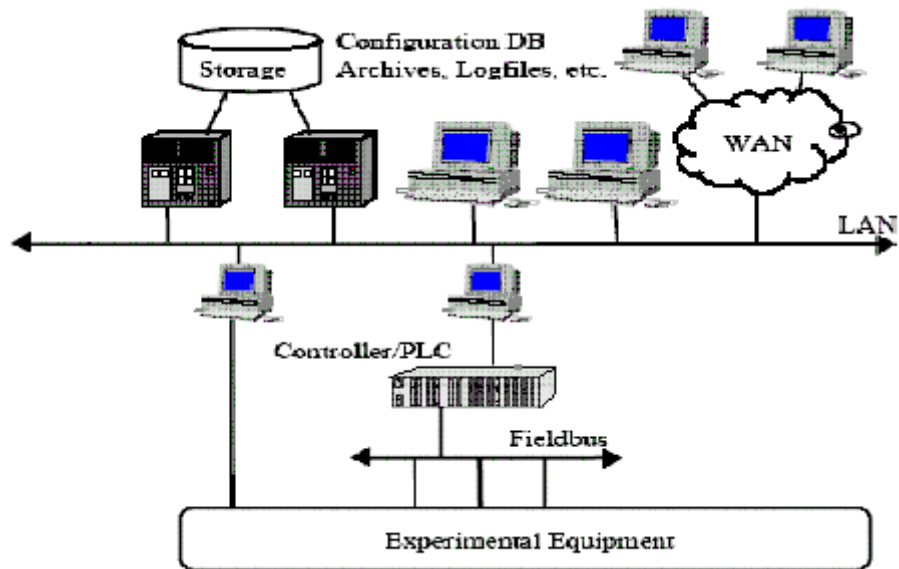
Fig. 1. Typical hardware organization

Software development in the LabVIEW+DSC environment

The accelerator system software development in the LabVIEW+DSC environment contains components presented in the Fig. **2**.
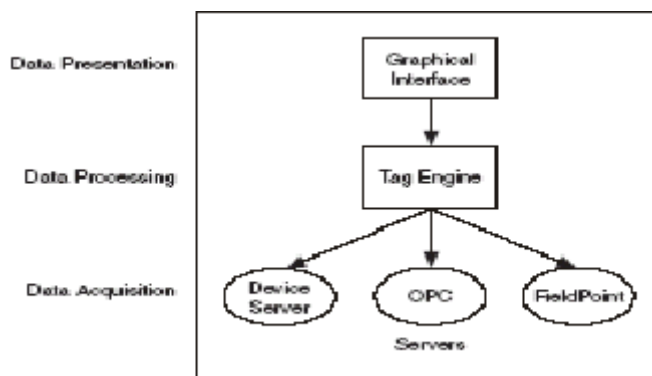
Fig. 2. Software components

The software development for accelerator systems in the LabVIEW+DSC environment includes the following phases:
1. Creating/installing, configuring and testing data servers which assure connection with devices.
2. Creating a configuration file, whose content conditions on the data processing process.
3. Creating user interface.

Communication with different devices is realized through data-servers, every one of them having certain input/output items which are used for data transmission to Tag-Engine.

The following server types can be used in Labview+DSC:

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- OPC (OLE for process Control-servers) delivered by standard equipment manufacturers or developed independently. The part of OPC-servers may be taken by Tag-Engines, which receive data from standard VI (Virtual instruments). This allows organizing data transmission over the network without the need of additional programming.
- VI-based servers, which represent VI developed by means of a special DSC module function [6].

The server settings are normally stored in one or more configuration files of any text or binary format or some specialized format.

LabView supports a large number of hardware interfaces; that is it has VI prepared for device connection. For the cases when functions are written using other languages and represent DLL libraries, Call Function Node or Code Interface Node are used to enable these functions in LabView.

Every device signal has a corresponding input/output item in the server. OPC-servers provide these items. When a Tag-Engine is used as an OPC-server, tags serve as input/output items. In this case, a configuration file with tag attributes settings should be created.

Special functions are used for registering VI-based server input/output items. For VI-based servers, the Interactive Server Tester utility is provided in the DSC module.

Information about available servers is registered and stored in the Common Communication DataBase (CCDB).

The server-to-client application and conversely data transmission is implemented using the embedded Tag-Engine mechanism and tags.

Tag-Engine supports real-time database, alarm handling, and event and data logging in the DB. It also can act as an OPC-server and provide data to be processed to other Tag-Engines.

Tags are used to transmit data between data-server input/output items and HMI applications interface elements. The use of input/output item-independent memory tags is also possible.

Every computer, where Tag-Engine usage is supposed, should be provided with a configuration file describing tags and setting their attributes (data transmission direction, data update rate, alarm causes, etc.). If the tag sends data to a server or receives data from the latter, the corresponding server and input/output item should be specified. Tags may be arranged in groups on basis of device dependency, or in input/output groups on basis of the update rate. All tag settings (alarm values, update rate, etc.) are configured in the Tag-Configurator.

As soon as Tag-Engine launches, the configuration file is loaded and starts all servers to deliver data to the tags described in the file.

For data storage and historical trends management, the embedded Citadel DB is provided. This DB may reside in any computer of the network and store events and alarms information as well as the data received from devices.

The initial settings of database record conditions and rate are defined in the configuration file, and then may be adjusted via HMI-applications and Tag-Engine.

The data stored in the DB may be accessed using historical trends, SQL-queries, and ODBC-compliant applications, such as Microsoft Query, Microsoft Access, or Microsoft Excel.

The operator interface (HMI-application) includes a mnemonic circuit for the visualization of the measured parameters' current values (temperature, pressure, etc) and for the device setting management, as well as real-time and historical trends and alarm tables.

The HMI-application receives and sends data to the tags described in the Tag-Engine configuration file.

Data changes are represented in real-time trends. Historical data are visualized using the Historical Trends Viewer (HTV) utility. Alarms are displayed by means of the visual interface (color changes, blinking) and sound notifications. Alarms are also registered in the alarm table with the confirmation option.

The functions that are used for on-line and off-line data analysis may be out-of-the-box or specially developed using LabView tools.

HMI-applications development is automated with the help of wizards, which permit to link operator interface elements with corresponding tags. When creating a mnemonic circuit, DSC module image library is widely used.

Conclusion

The main advantage when programming using the NI technologies is the time saving. This is achieved thanks to out-of-the-box components and solutions assuring the required functionality of the software. Using the DSC module tools, one can define initial software settings (tag settings, DB record) and change them onstream if necessary as well as automate the major part of the code creation by means of wizards. The embedded DB and ready-to-use tools for data review and analysis are also an advantage.

The use of unified technology in the software development allows avoiding problems related with software product compliance and support.

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Experience with monitoring of Prague T2 Site

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Abstract

Each tier 2 site is monitored by various services from outside. The Prague T2 is monitored by SAM tests, GSTAT monitoring, RTM from RAL, regional nagios monitoring and experiment specific tools. Besides that we monitor our own site for hardware and software failures and middleware status.

All these tools produce an output that must be regularly checked by site administrators. We will present our solution built on nagios that allows our administrators to check just one service (nagios) that encapsulates the results from all monitoring tools (outside and inside) and presents them in a single web page. The solution is based on simple plugin for every service. Nagios uses these plugins to check the results of monitoring tools. We use plugins developed at SRCE, RAL and Prague.

We will also present automatic configuration scripts that allow us to generate nagios configuration from local database of servers, services and some special HW (UPS, diesel unit, etc.)

Introduction

There are 2 sites in Prague involved in EGEE and WLCG projects. The first one praguelcg2 is middle-sized site with about 150 nodes and 450 cores. The second site prague_cesnet_lcg2 is smaller with 30 nodes but it runs several core services for VOs VOCE and Auger.

Reliability is one of the most important part in running EGEE site. It means that high-quality monitoring is crucial. There are many solutions for monitoring a site which differ in their configuration complexity, sensors, maintenance difficulty, extensibilty etc.

We will show why we have chosen nagios, how we configure it and how we generate its configuration.

Why nagios

There are many choices when selecting the monitoring tool:

	+	-
nagios[1]	wide community, many ready-to-use plugins, easily extensible	static configuration files, history in log (no database)
ganglia[2]	automatic host discovery, very robust, easy configuration	bugs in web interface, cpu intensive, not so easy to extend
cacti[3]	easy graph setup	graph oriented
zenoss[4]	great scalability, automatic discovery, built on ZOPE	built on ZOPE, young software
zabbix[5]	rapidly developing	less robust than nagios
moodss[6]	great graphing features	no web interface

We have chosen nagios because it used to be the only mature software three years ago when we made the decision. Currently we use last stable version 2.9 on fedora 7 and we are planning to upgrade to version 3 as soon as it gets released.

Nagios plugins we use

Any binary or script can become nagios plugin. There are many encouragements in documentation [7]. But the truth is that the only requirement for plugin to work is to return code representing the state of the service (0 - Ok, 1 - Warning, 2 - Critical, 3 - Unknown).

The following plugins are used at our sites:

- **default**
  - ping, disk, procs, load, tcp, swap, ldap, gentoo_glsa, gentoo_service_rc_all
- **SRCE sensors**
  - cert - checks certificates on nodes with gridftp, https, gram or web access
  - dpm - checks sanity of dpm-qryconf output for given host
  - dpns - checks sanity of dpns-ls output and existence of /dpm/<domain>
  - edg_broker - sends simple testing job via the tested RB
  - globus_gram2 - checks submission via gatekeeper
  - gridftp - checks if the gridftp can copy file to and from the host
  - lfc - checks sanity of lfc-ls output and dumps all subdirectories of /
  - srm - tests srmv1 transfer to and from the host
  - srm_ping - tests srm availability via srmPing function call
  - voms - checks availability of voms server to issue a proxy
- **RAL sensors**
  - lcg_same - checks status of the given service in SAM
- **locally written sensors**
  - hpacucli - checks status of physical disks on MSA20 disk array
  - blade_temp - checks temperature in enclosure for BL460c
  - ups - tests status of UPS
  - jobs - checks sanity of qstat output plus validity of job's proxy
  - gstat - tests status of GSTAT checks published on gstat web
  - rpm_versions - checks versions of given rpm packages

Our services are divided into 2 categories – common and critical. We have configured nagios so it sends notifications only when critical services are in failure. Other failures (of common services) are reported only in regular digest. We have developed a script that parses configuration and nagios log files. This script sends a report about service failures three times a day.

Some sensors (mainly the SRCE plugins and other gLite related) has to be launched from gLite user interface. We have installed the glite-UI in chroot and we launch the plugins via sudo mechanism. The sudo has to be used because chroot system call is limited to root account only.

Hardware and service database

One of the biggest problem of nagios is the static configuration. Every new node has to be added manually. At praguelcg2 we already had a database with hardware and network configuration. We have extended the database with info about services and added a SOAP server to it.

Now we generate the nagios configuration with web service client written in python.

Python SOAP libraries

During development of the python SOAP application we had to choose what library should be used. There is a plenty of SOAP implementation for python. Most of them are not

maintained. We chose the ZSI library [8] which is mature enough and the documentation is appropriate.

We have put the client with example server and the wsdl file to nagios exchange web site [9]. Both the client and the API is designed so it copies the philosophy of nagios configuration. It contains functions for querying hosts, services, contacts and any other nagios building blocks.

We use the web services only to query about things that can change often (hosts, services, contacts etc.). The static configuration like service detailed specification (e.g. time period or retry count) are stored in static template files which are simply copied from template directory which is coming with the client application.

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Romanian Physics Grid: recent progress and outlook

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Abstract

We report on the significant progress in Grid activities and networking in Romania during the last years. The emphasis is put on recent developments in the field of the physics research, in the frame of which the participation to the LHC Computing Grid plays a major role. The Romanian contribution to the Eastern Europe Grid collaborations is also discussed.

1. Introduction

Due to the interest of the particle physics community, the first grid application has been realized in Romania in 2002, in the frame of the ALICE experiment conducted by CERN.

Since then, the grid activities were greatly diversified, Romania taking part to the European grid projects EGEE/EGEE-II (Enabling Grid for ESciencE), and SEE-GRID / SEE-GRID 2 (South-Eastern European Grid).

The first years of the grid projects in Romania have been the subject of my presentation "Networking and Grid Activities in the Romanian Physics Research", at NEC-2003, here in Varna.

It is the purpose of this report to present the recent progress being made in the field of Grid computing in Romania, covering topics regarding the national grid strategy, the network infrastructure, the participation to the LHC Computing Grid, to the WLCG and to the regional Grid collaborations.

2. National GRID strategy in Romania

The grid strategy in Romania is coordinated by the Task Force for the National Grid Infrastructure, which has been created through the decision of the National Authority for Scientific Research (NASR), in July 2005. Its members are the Ministry of Education and Research, the Ministry of External Affairs, 7 universities, 7 research institutions, and the National Research and Education Network RoEduNet.

The goal of the Task Force is to promote a strategic plan to be implemented by the pilot project entitled "Implementation of the National Grid Infrastructure".

The guiding lines for the strategic plan are
- To create an opened national infrastructure, compatible with similar infrastructures at regional and European levels;
- To ensure balanced investments between the three segments: data communications and networking; the Grid hardware and software infrastructure; the developing of application software;
- The exploitation of the internal production of scientific software;
- Emerging of the Grid infrastructure in various domains of economic and societal life.

The strategic plan proposes the following objectives:
- Gradual and balanced development of the national Grid infrastructure, based on active centers of competence and reuse of the results provided by national and international cooperation in the domain;

- Integration of the Romanian information society into a virtual global information system environment which leads to
  - the increase the scientific potential and the existing capacities for applied software development;
  - new resources for the research field;
  - extends the impact of research results into economic and societal fields
- Promotion of the new specific Grid technologies in Romania by
  - focusing the academic, research and business communities towards the new virtual global environment;
  - training and specialization of the human resources;
  - supporting the transition towards the new system;
- Development of the data communications segment for the Romanian GRID framework.

The pilot project will be implemented as a national research programme, structured according to the main layers of the Grid infrastructure: broadband communication network, grid architecture (resources and middleware), and applications.

The Task Force will be in charge with the evaluation of the results produced by the projects financed within the programme in order to assure their mutual compliance and their convergence with the programme objectives.

There will be only project based financial support (no institutional financing).

Grid infrastructure development and deployment processes will be based on the reuse and exploitation of the results produced by EU co-funded research projects with Romanian participation; the EGEE infrastructure solution will be implemented considering the interoperability at regional and European level.

Among the recent developments, we mention:
- the recent signing by NASR of the Memorandum of Understanding for the Worldwide LCG (LHC Computing Grid) Collaboration;
- the Romanian Space Agency (ROSA) applied for Certification Authority (CA) to EuGRIDPMA, according to the decision of the NASR;
- an agreement between the Government of Romania and the Government of Hungary was signed concerning the cooperation in grid infrastructure;
- RoEduNet applied SEELIGHT project to the HiPERB program, the co-financing being supported by NASR.

3. Network infrastructure - RoEduNet

The high-speed network infrastructure of the grid is ensured by the National Research and Education Network RoEduNet, which represents at the same time an organization and a layered data communication system.

The Layer 0 consists of all the backbone links (including international links) and RoEduNet NOCs (Network Operation Center): Bucharest – RoEduNet headquarter and 6 regional NOCs.

The Layer 1 includes the 33 RoEduNet POPs (Points of Operation) from all county capitals and the communication lines between NOCs and POPs.

The institutions connected to RoEduNet form the Layer 2; this includes research institutions, universities, high schools and schools, hospitals, and other education related non-profit institutions.

The network is connected at present to GEANT through two STM4 circuits (giving a total bandwidth of 1.244 Gbps). The connectivity between NOCs varies from 2x E3

(68 Mbps) to 2 x STM 1 (310 Mbps), and the bandwidth between NOC and POPs is of 10 Mbps.

The main results for 2007 include: the new data center for the national NOC, located in the NASR building, where the international and national backbone connections will be separated; the launch of DANTEs tender for dark fiber (DF)mor lambda connectivity to Bucharest; SEELight project will start, based on regional funds, whose main goal is to provide DF connectivity to Hungary an Bulgaria (apart from GEANT connection)

RoEduNet Topology Q2 2007
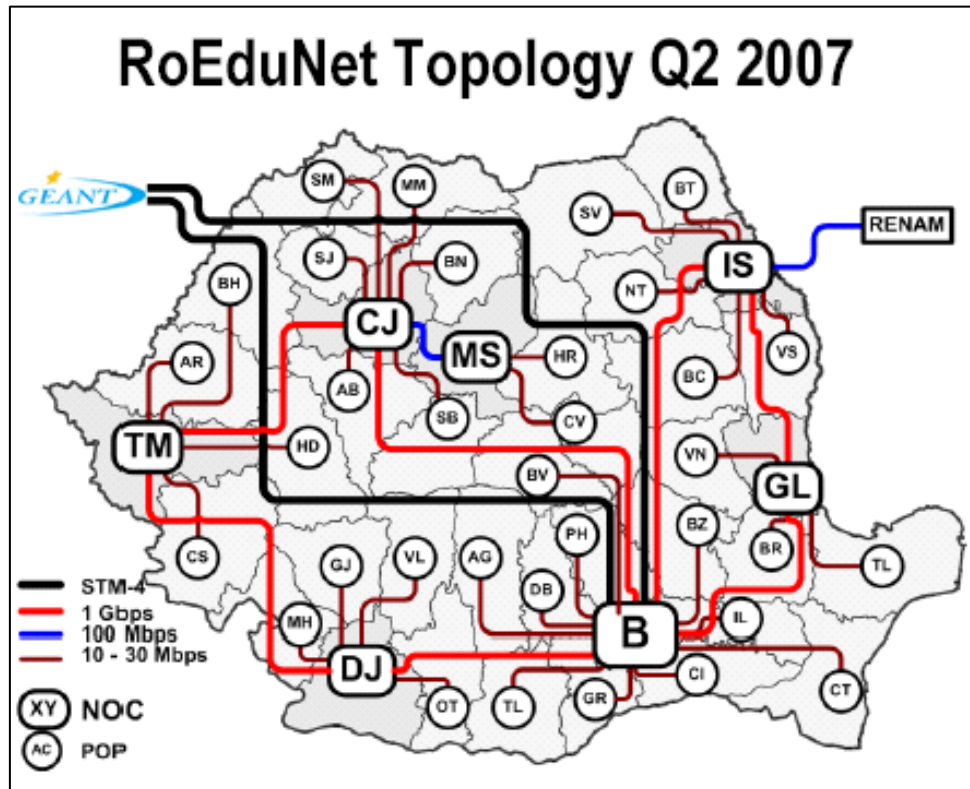
The short term plans include the realization of a production link between Budapest and Bucharest of 10 Gbps, which is essential to grid computing in the framework of the WLCG Collaboration. A pilot link will start for the SEELight project, providing 10 Gbps connectivity between Bucharest, Sofia, Budapest, and a possible connection to Belgrade.

Longer term plans will provide 2x10 Gbps connections between NOCs, at least 1 Gbps bandwidth betwoon NOCs and POPs, and the implementation of lambda based logical network for grid activities.

4. Particle physics GRID in Romania

The development of grid in Romania is closely related to the particle physics research, based on the long term collaboration with CERN.

The existing LCG sites in Romania united in a national federation to form together a Tier-2 centre in the frame of the WLCG collaboration, whose purpose is to provide the computing resources needed to process and analyze the data gathered by the Large Hadron Collider experiments. The Romanian Authority for Scientific Research has signed the Memorandum of Understanding with CERN in March 2006, as Funding Agency of the Romanian Tier-2 Federation (RT2F).

Currently, the RT2F contains 7 grid sites and 5 institutions: Horia Hulubei National Institute for Physics and Nuclear Engineering (NIPNE), the Institute for Space Sciences (ISS), the National Institute for R&D in Informatics (ICI), the National Institute for Isotopic andMolecular Technologies (ITIM), and the University "Politehnica" from Bucharest (UPB).
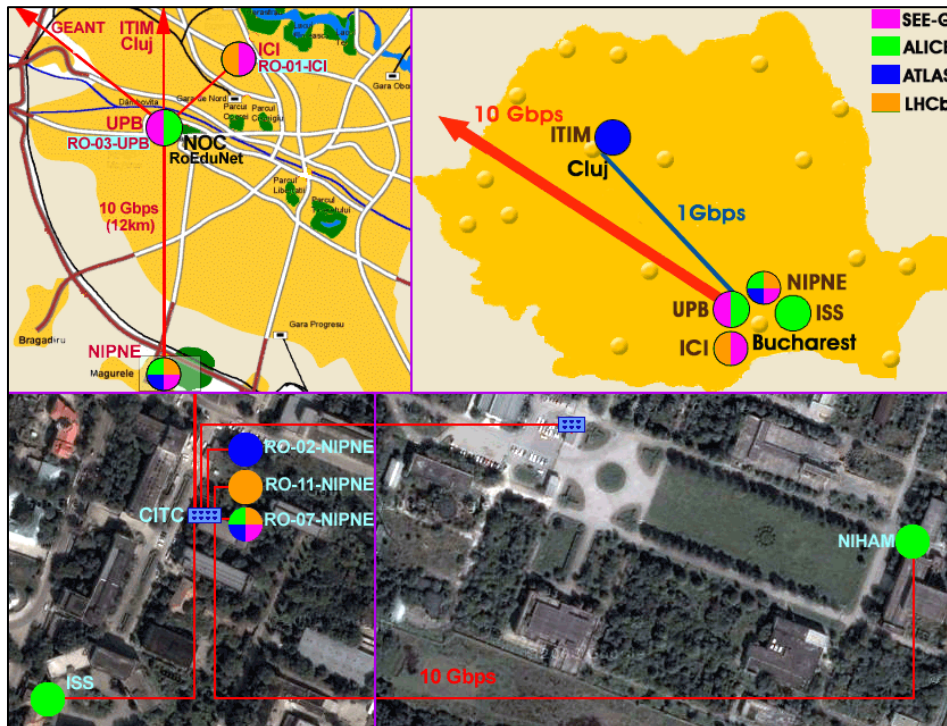
These institutions contribute to the LCG production with the grid sites NIHAM, RO-01-ICI, RO-02-NIPNE, RO-07-NIPNE, RO-11-NIPNE (http://egee017.cnaf.infn.it/gstat/), and to the ALICE Grid with the sites NIHAM and ISS (see the map above).

These sites process jobs for the LHC experiments ALICE, ATLAS, and LHCb, which are currently investigated by the Romanian particle physics groups.

According to the normalised CPU time published on the EGEE accounting portal, during the last 12 months the Romanian contribution to the grid production was in the first third of the world hierarchy (13th position from 41 countries, 7th place from 22 Tier-2 centers).

Most of the national grid activity (more than 80%) was coming from the four sites located in the departments of IFIN-HH, which will be presented below.

4.1. The hadronic matter center

The "Nuclear Interactions and Hadronic Matter" Centre of Excellence NIHAM (http://niham.nipne.ro), lead by Prof. Mihai Petrovici, is performing research in various areas of nuclear physics. Core members of the group were involved in the past or are involved now in many international physics collaborations, such as DRACULA (designed by the group), CHIMERA, FOPI, ALICE, and also in the preliminary phase of CBM. Also, members of the group were involved in the development of ALICE-TRD detector and frontend electronics, NIHAM producing now more than 20% of ALICE-TRD chambers.

The center hosts the NIHAM grid site which is dedicated to the ALICE experiment, and members of the group are involved in the EGEE project since 2004.

The NIHAM cluster currently counts 168 CPU cores with 2GB RAM / core, and includes a 50 TB RAW dedicated storage element. NIHAM is an integrated EGEE and AliEn grid site, and contributes with 6-7% to the worldwide ALICE production.
The datacenter possesses an industrial-grade cooling unit of 110 KW, industrial-grade UPS-es (240 KVA), and a Diesel generator.

4.2. Particle physics and theoretical physics departments

The grid site of the Particle Physics Department, RO-02-NIPNE, supports ATLAS-CERN and H1-DESY Vos, which are related to the research activities of the group.
100 logical CPUs are used for grid computing, with 1GB per logical CPU, and a 10 GB storage unit.
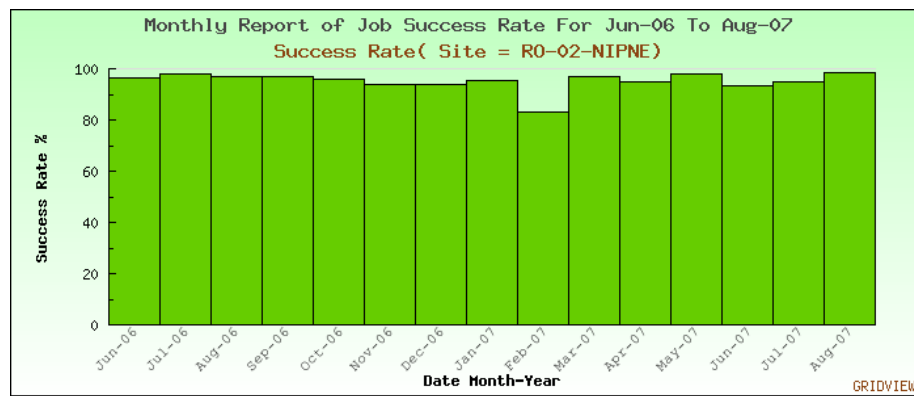
The LHCb experiment is supported on the grid site RO-11-NIPNE, which belongs to the Department of Theoretical Physics.
It hosts 18 servers dual Xeon at 3 GHz and 5 nodes dual Xeon Core Duo, with 2 GB RAM each, and a 2 TB storage unit.

4.3. IT&C Centre

The basic mission of the IT&C Centre at IFIN-HH Basic is to operate, maintain, and develop the computing and networking infrastructure of IFIN-HH, providing the technical support required by the international scientific collaborations. Its main activities are:

- Administration and development of the IT infrastructure of IFIN-HH
- Administration and development of the Grid site RO-07-NIPNE
- Coordination of the Romanian Tier-2 Federation
- Administration of the communication node at IFIN (10 Gbps)
- Grid computing, databases, algorithms for parallel computing

The Centre participates to the cooperation programme "Hulubei-Meshcheryakov" together with the Laboratory of Information Technologies at JINR - Dubna, that promotes activities in fields of the information technology and computational physics like: Grid technology, Grid software and Grid development; numerical algorithms, methods and tools for the description and modeling of complex physical systems; etc.
The grid site RO-07-NIPNE is dedicated to the ATLAS, LHCb, ALICE, SEE, and SEEGRID Vos, the resources alocated for these being 190 CPU cores (258 logical CPUs), with 3GHz, 2GB RAM/core, and a 7TB RAID 6 storage element.

5. Participation to the SE European GRID

Romania is taking parti to the South East European Grid Project SEE-GRID2 with 8 grid sites (RO-01-ICI, RO-03-UPB, RO-05-INCAS, RO-06-UNIBUC, RO-07-NIPNE, RO-08-UVT, RO-09-UTCN, RO-10-TUIASI) that are hosted by 5 universities and 3 research institutes.

The most important contribution to the SEE and SEEGRID VOs is coming from the site RO-07-NIPNE of the IT&C Centre, where some gridification activities are also performed.

We mention here the numerical simulation of earthquake generation in Vrancea county (Romania), which is based on the gridification of the algorithm proposed by *O. Carbunar (IFIN-HH), M. Radulian (Inst. for Earth Physics - Romania)* in *Geophysical Research Abstracts 9, 05522 (2007).*

The simulation algorithm reproduces the rate of the background seismic activity and the range of repetition of the seismic cycle for major events.

The application is under current development at IFIN-HH , being registered at SEE-GRID2 under the name EQUSIM - Earthquake simulation.
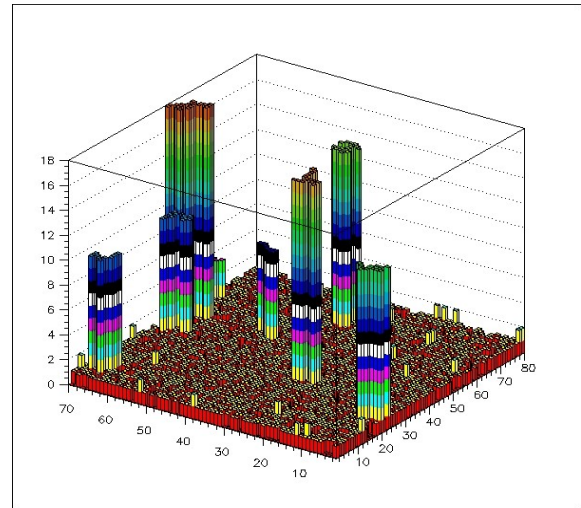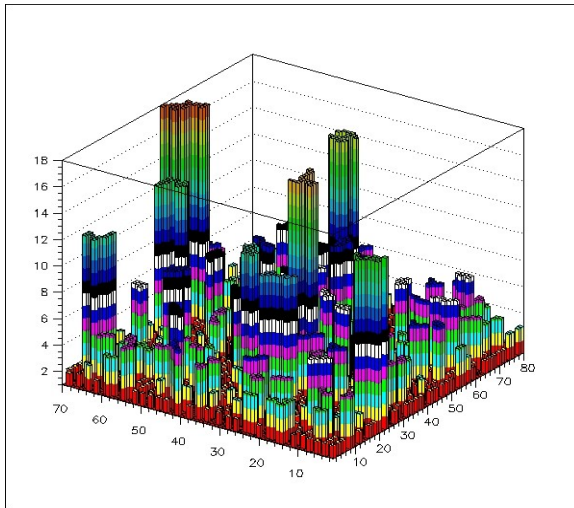
Weakening areas before major and after a major earthquake, simulated on the percolation model proposed by O.Carbunar and M.Radulian

6. Acknowledgements

Integrated analysis of multi-level geodata based on the GIS-technologies

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KEY WORDS: integrated analysis of heterogeneous geodata, decision making system, geographical information systems, environmental management of natural resources, analytical applications

The Laboratory of Geoinformatics, VNIIgeosystem, has accumulated great expertise in the development of methods, techniques, and solutions for different nature-use applications. At the core of it lies an integrated analysis of entire available complex geodata from different sensing levels: space, air, surface, wells. Based on the detailed study of proceeding approaches to such problems, an innovative process of integration of precisely formulated steps – from acquisition of initial geodata, its pre-processing and georeferencing, aggregation and analysis, to creation of end-user systems, presentation and publication of the results – was designed. Every stage of the process is implemented with the tools of the original integrated software package GIS "INTEGRO". The system deals with data of different types (vector and raster maps, regular and irregular observation grids, space images, etc.). It provides transformation of arbitrary data into diverse formats and offers software tools allowing one to integrate and jointly process the incommensurable variables. INTEGRO is based on a general procedure for statement and solution of applied problems, which is presented as a detailed branching data-processing flow chart. Implementation of this flow-chart depends on the initial problem statement, information about the locations of studied objects in the attribute space acquired from the analysis of available data and, also, depends on specific requirements of a geologist. Information is analyzed in a few stages. At the first stage, data quality is estimated using procedures of the classical one-dimensional analysis. Based on the results of this stage measurements are rescaled. The second stage is based on the problem statement analysis. As a result of this stage, weighting factors are assigned to the incommensurable attributes. At the third stage the locations of studied objects in the attribute space are analyzed. This analysis and the initial problem statement features allow one to choose an acceptable problem solution method. These methods and tools of the integrated data analysis were combined into several modulus allowing for different fields of nature-use studies:

- geology and mining: forecast of mineral resources, 3-dimensional modelling of deposits with economical evaluation of reserves,
- environmental management of natural resources: complex estimation of ecological state of territories and strong technogenic and mining pressure
- decision support for cadastre and municipal management.

Below we present the most interesting illustrations of applying the methods of integrated analysis for several nature-use projects developed with the use of GIS INTEGRO.

Processing and interpretation of geophysical data

The main objective of the presented technology is computer support of geophysical data processing in the following fields:

- Construction of 2D and 3D geological models for the study of the deep structure of the Earth crust;
- Computation of analytical characteristics of potential fields for the mineral forecast;
- Reconstruction of geological sections for the geological mapping;

The methodological approach is based on integration and complex analysis of geophysical data along regional profiles, potential fields and additional geological information for the area under study.

The package provides a set of tools for

- computation of derivatives from potential fields for the fields component separation, identification and localisation of anomaly-forming objects;
- computation of the structural (morphological) characteristics for the identification of area and linear elements of the fields;
- estimation of correlation between the fields, the spectral correlation analysis, in-line and area filtering;
- identification of weak anomalies comparable with random interferences of various origins;
- solution of the direct and inverse problems of gravity and magnetic survey, solution of the problems of non-formalised and formalized selection.

The technology and software were approbated for

- tectonic zoning of areas with a combination of geological and geophysical data (Ural, Jakutija, Rostov region, etc.);
- integrated processing and interpretation of geological and geophysical data along the regional profile 1-EB;
- construction of the integrated geological and geophysical model along the regional profile Ural-Seis-95;
- estimation of the oil and gas bearing potential from a set of geological and geophysical data (Brazil);
- construction of a 3D model of the deep structure of Pechenga mineralisation district (Cola Peninsula).

Complex forecast of mineral resources

For the last two decades the Laboratory has elaborated into the field of reduction of weakly structured geological and geophysical problems to a limited set of formal structures and algorithms and their adaptation for use by mathematically non-enlightened specialists. These efforts resulted in the development of a complex software package that comprises elements of expert systems with heavily computational algorithmic modules for statistical processing, pattern recognition, and other advanced techniques – for automation of prognostic tasks for all stages of geological exploration of mineral resources:

- identification of perspective areas;
- division of these area by genetic types of minerals;
- ranking by perspectivity;
- economical evaluation of reserves.

The model of the object under study is compiled based on the integration and analysis of information from all levels of study of geological environment (satellite – airborne – surface – well).

The software packages implement the following tasks:

- transformation of a subjective formulation to a formalized task of forecast;
- calculation of a wide set of indicators from source digital maps, raster and tabular data;
- optimization of workflow of the task, formal analysis of data quality for identification of most effective methods of the data processing;
- processing of the set of indicators based on original statistical and heuristic algorithms.

Several original heuristic approaches were developed and tested in the real production studies of
- forecast of gold bearing fields in Jakutija and copper-gold-polymetal fields in the Southern Urals;
- identification of tin ore fields in Primorskij and Chabarovskij regions;
- forecast of titanium-zircon placers in the Northern Caucasus;
- regional forecast of oil and gas perspectives of a basin in the South America.

3-D Modelling Technology

The goal of the technology is a computer support of the reconstruction block solid-based models based on prospecting data. The technology realizes a new approach to the problems of 3-D modelling, evaluation and monitoring of reserves, mine design and economic tasks. Technology is based on a synchronized modelling with use of geo-statistical procedures and algorithms, 3-D modelling and GIS including models constructor, 3-D visualization of wells, daylight and lower technological surfaces, tools for mine optimization.

Main features of the technological block include:

- vulti-variant calculations and multi-alternative solutions,
- operative examination of economic evaluation with support of access to intermediate results and models,
- open architecture (interfaces with various systems of deposits evaluation),
- effective manipulation of relational data bases of prospecting and 3-D spatial information including blocks and solids models on GIS level,
- multi-variant modelling of open pit mines with the 3-D optimization tools.

The engine and user interface are designed as 3-D GIS. Almost no operations need any menus or commands, everything has dynamic visual controls. Every on-screen object has several operations related to it, the user can visually operate even with everything deep inside the space.

The technology is suited for practical application by both mines and state organizations for operative GIS-access to data and models, expertise, etc. Technology was used for economic evaluation for several ore deposits (Mikheevskoe, Zun-Kholba, Oktyabrskoe, Sosnovoe, etc.), ore estimation for GKZ RF (Kuranakh, Dukat, Berezitovoe, Kkostomuksha, etc.)

Computer-aided geological mapping

The acquisition of new high quality geological data, emergence of new geological concepts, as well as the advances in the modern geographical information systems, facilitate the creation of the new generation geological maps closely integrated in the series of different

scales. They form a comprehensive information and analytical system of versatile cartographical and factual information – topographical map base; thematic maps, both in analogue and digital representation; relational and object-oriented databases; geological cross-sections, boreholes, and other specialised data; textual reports and any other non-structured information.

The goal was to provide computer-aided compilation and updating of geological maps with the use of map generalisation techniques. The implementation is based on the integration and analysis of large-scale geological maps compiled by different authors, field geological surveys, geophysical, and remote sensing data.

The developed technology provides:

– identification of tectonic structures of a studied area with the use of complex processing of source geological maps, magnetometric, gravimetric, and multi-band satellite surveys;
– compilation of stratigraphic schemes based on a complex analysis of general geological zonation, legends of source maps, and data of field geological surveys;
– matching of source maps by different authors and their generalisation in accordance with regional tectonic and geological structures;
– integration of source and resulting data in a GIS project and preparation of the updated map for publishing.

In close co-operation with GNPP "Aerogeologija" our specialists developed the original methods and techniques of computer-aided map compilation and refinement from the updated large scale data, based on the iterated generalisation of detailed geological data with its correlation to the other geophysical or remote sensing sources. The approbation included the compilation of sheets of the geological map of Krasnojarskij region, Eastern Siberia, Kazakhstan and Far East (scales 1:1,000,000 and 1:200,000).

Complex estimation of ecological state of territories

Intensive exploitation of mineral deposits is quite a serious environmental problem in Russia. The main purpose of information technologies in the management of mineral resources is to provide a set of decision support tools for implementation of nature friendly strategies of development and exploitation of mineral deposits based on complex analysis of parameters of ecological situations in the areas of mineral deposits development and estimation of possible consequences of this exploitation.

The goal of the technology is the information and analytical support for environmental management of mineral resources including:

– assessment of ecological implications of minerals exploration;
– estimation of possible negative environmental impacts of exploiting a mineral deposit;
– estimation of consequences of environmental emergencies.

The implementation is based on a computer modelling of the current ecological state of the studied area and an integrated analysis of the spatial characteristics of natural, technogenic, social, and economic factors, with the use of the multi-criteria zoning.

The received results are as follows:

– computer representation of the model including the hierarchical structure of the analysis factors, their weights, and a system of evaluation gradations;

– number of formal spatial characteristics of the model factors of the area under study represented in measured units or rank scales (based on the system of evaluation gradations) and approved for correlation and completeness;
– their integrated characteristics representing ecological state of the area in accordance with the author's model.

The technology presented was applied to the creation of the digital atlas of ecological implications of minerals exploitation in Russia (in collaboration with VIEMS), monitoring of ecological situation in oil and gas bearing areas of the Chanty-Mansi region and Caspian shelf and development of the environmental model of Long Island (USA).

Each of these projects has resulted in the launch of a complex information and an analytical system integrating the source data storage and calculated results, specialized calculation modules and advanced user interface implementation with high quality presentation tools to facilitate their further usage as a comprehensive decision support framework in the field of nature-friendly exploitation of mineral resources.

Study of the SiPM signal shape with the help of transient functions

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Abstract

Analytical formulas for the signal shape of the SiPM (Silicon Photomultipliers) are deduced at different load resistances and capacitances. At low resistance the shape has two falling exponents: one is very short and the other is long. At increasing resistance the compensation of the pole by zero in the transient function is possible, and the signal gets a one-exponent shape.

Experimental measurements of the dark-noise shape were carried out with the SiPM designed in Dubna. Real values of SiPM components were obtained from the transient function, when the SiPM was excited as a simple diode by current pulses.

1. Introduction

SiPMs have unique properties: high one-electron resolution, gain and quantum efficiency and so SiPMs are very promising devices for detection of low-intensity light. They have, however, shortcomings, like, for example, essential dark-noise, which is very difficult to decrease, therefore the study of this rather new devices is being continued for optimizing their characteristics [1].

In this work a possible SiPM equivalent circuit is proposed and analytical formulas are deduced for the output signal at different load resistances and capacitances. On this basis the change and development of the signal shape is shown.

The shape of dark-noise pulses was measured directly at the SiPM output and compared with pulses from the nanosecond generator. The photodiode parameters C_d, R_q, C_q were estimated.

2. The equivalent circuit

The SiPM consists of an array of about one thousand microphotodiodes (micropixels), all connected in parallel between two electrodes and operating independently on common load. Separately, these microphotodiodes have long been known as SPAD (single photon avalanche diode) and used up to now for time measurements because they are logic devices. But their principle of operation is the same as that of micropixels in the SiPM. Firstly, the diode capacitance C_d is charged to the voltage E more than the breakdown one E_{br}. The hitting photon is converted in the p-n junction to an electron-hole pair. Any of these carriers can trigger the avalanche discharge of diode capacitance. Due to the quenching resistance R_q the capacitor voltage very fast falls from the initial value to the breakdown value E_{br}, so we can use the step voltage equal to the overvoltage $E_{ov}=E-E_{br}$ as the input voltage for the equivalent circuit of the excited SiPM.

Figure 1 shows the SiPM equivalent circuit with one pixel is fired. As we see, the fired pixel is` broken` and the step voltage is inserted in this branch; thus the input charge $Q=E_{ov}*C_d$ arises in the SiPM. The rest of the photodiode pixels appear to be connected in parallel to the load R and C. The value of R_q is high enough (about 1 MΩ), therefore the parasitic capacitance C_q that is parallel to R_q is taken into account.
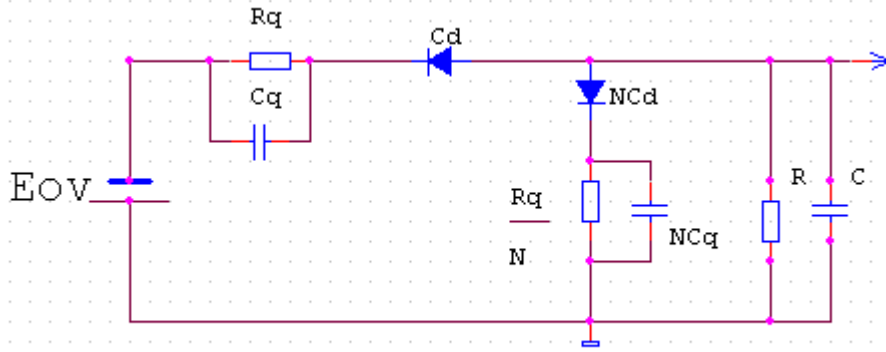
Fig. 1. The SiPM equivalent circuit, when one pixel is fired.
Eov is the overvoltage step signal, Rq is the quenching resistor, Cd is the capacitance of one micropixel, N is the number of pixels, R, C are the load resistor and capacitor

In the earlier work [2] the parasitic capacitance Cp of the connection between Cd and Rq to the ground was included in the circuit. In this case two variants of the load resistor R connection to the SIPM was considered: from the side of Rq or Cd. It is not nessessary if we take into account that in the former case the capacitance Cp is connected parallel to Cq, and in the latter parallel to Cd. Thus, both variants can be considered in one circuit and described by one equation. The very presence of the capacitance Cp may be detected by the signal changing at the different connections of the resistor R.

3. The signal shape

The Laplace transformation of the output signal Uout(p) is determined from the formula Uout(p)=1/p*K(p), where 1/p is the Laplace transformation of the step signal and K(p) is the photodiode transient function, obtained from the equivalent circuits.

$$Uout(p)= \frac{QR\ (1+pCq^* Rq^*)}{P^2\ R\ Rq^*\ (\ Cd^*C+Cq^*C+Cq^*Cd^*) +\ P\ [R(Cd^*+C)+Rq^*(Cd^*+Cq^*)] +\ 1},$$

where Cd*=N Cd, Cq*=N Cq and Rq*=Rq/N, R and C are the load resistance and capacitance. Q=Eov*Cd/N is the charge, arising from one fired pixel. If n pixels are fired, the charge will be correspondingly larger.

This transient function of the SiPM is characterized by one zero -1/CqRq and two poles, given by the roots of the denominator, and approximately equal to P1=1/[R(Cd*+C)+ Rq*(Cd*+Cq*)] and P2=1/ R [C+[(Cd* Cq*/(Cd*+Cq*)]].

At low load resistance the original is the sum of two falling exponents: one of them is fast and big, the other is slow and small:

$$U_{out}(t)= \frac{Rq^*}{Rq^*+R}\ e^{-\frac{t}{R[C[((Cd^*Cq^*)/(Cd^*+Cq^*)]]}} +\ \frac{R}{Rq^*+R}\ e^{-\frac{t}{Rq^*(Cd+Cq)+R(Cd^*+C)}}.$$

This signal shape is suitable for time measurements, but the signal amplitude is small. Sometimes it is better to work with highly resistive load, when. the signal amplitude increases

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proportionally to resistance while its rise time remains small (in our consideration the time is equal to zero, because we assume that the avalanche rise time is negligible in comparison with the signal duration).

At the load resistance increases, the compensation of the pole by zero in the transient function is possible when RC=RqCq and the signal shape becomes one-exponent with the time constant Tk=RqCd+R(Cd+C). In this case it is possible to introduce the clipping compensation in the amplifier and to obtain the shortest output signal (such compensation is used in spectrometric amplifiers). A short signal and proper minimization of the gate in the converter Q-COD can considerably decrease the dark-noise.

As the load resistance goes on increasing, the output signal durations and the rise time become equal to RC. When R>.50 kΩ , the charge sensitive preamplifier may be used and it is possible to work with rather low SiPM overvoltage, which also decreases the dark-noise.

4. Experimental measurements

For the experimental tests we used the SiPM MP3, designed by Z. Sadygov [3]. It has the capacitance about 25 pF at the operating voltage 40V. The signal shape was observed on the oscilloscope TEKTRONIX TDS 3032B, where the SiPM dark-noise and the pulse from the Cossor 1094 generator were recorded simultaneously. The latter was fed to the photodiode through the capacitor, imitating the step voltage Eov and forming the output signal like the one from a light or dark pulse. However, the amplitude of this artificial pulse corresponds to the case, where all pixels are fired, i.e. it goes through the all diode capacitances at once.

In Fig.2 the input generator signal is shown by the lower line and the reaction of the SiPM by upper line. On the same line the dark-noise pulse is seen which accidentally appeared on the oscilloscope scan. It is seen that the shapes of the pulses are practically the same. The pulse features an upper fast falling part, about 2 ns long, and a lower longer part. The estimation of Cq* from this upper part yields about 10pF. As in [4], the Rq value was determined from the forward I-V SiPM characteristics, Rq*=1kΩ. In the same work the dark-noise shape was obtained with a more pronounced pointed upper part. It may be explained by use of the amplifier with the band width 1/8 GHz and a faster oscilloscope.
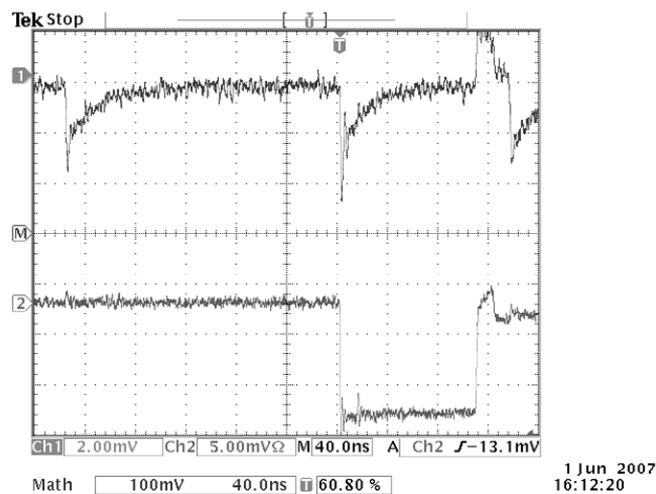
Fig. 2. Dark-noise and Cossor generator pulses

5. Conclusion

1. The SiPM equivalent circuit is proposed and the analytical formulas for the SiPM output signal shape are deduced at different load R.
2. At low R the signal is the sum of two falling exponents, one very short and high and the other long and small. This signal is preferable for time measurements.
3. The signal amplitude increases in proportion to increasing R and when RC=RqCq, the compensation of the zero by the pole takes place and the pulse gets a one-exponent shape. In this case the pulse duration may be minimized by introducing the second clipping compensation in the amplifier. It may be useful for minimizing dark-noise, because the gate of Q-COD may be the smallest.
4. As the resistance R goes on increasing the signal grows long and the rise time becomes equal to RC. If R is more than 50 kΩ, it is possible to use the charge sensitive preamplifier. In this case the low thermal noise allows one to work with small overvoltage.

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Status of the GRID in the Czech Republic

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Abstract

Czech Republic belongs to founding members of EU Grid projects. It started as associated partner to the European DataGrid Project in work packages of Workload Management, Testbed Integration and HEP Applications. The existence of strong HEP group and the local grid-like computing project METACentrum were the main ingredients that enabled it. Czech Republic then continued to take active role both in the Grid projects EGEE, EGEE II, contributes to the preparation of the EGEE III project and is involved in the EGI Design Study. Czech Republic also strongly contributes to HEP specific project WLCG by creation of the Regional Computing Centre for Particle Physics in Prague where main Czech HEP grid computing infrastructure is maintained. The Center acts as TIER-2 LCG center.

CESNET, Czech scientific network provider and supporter of advanced network technologies and applications, is the contractor to EGEEx projects. Internally, the projects are part of the national METACentrum project that delivers both grid and supercomputing services to Czech universities and research institutes. In the same time CESNET provides multiple 10 Gbps network backbone densely over the Czech Republic and adequate international connection to the GEANT2 and Internet2 networks. Also, for special purposes, CESNET can provide independent optical high capacity point to point links both locally in the CR and to other laboratories abroad, "owning" among others a dedicated experimental link to the StarLight in Chicago.

Existing grid infrastructure is integrated into the European grids, supports several particle physics experiments, runs specific services for the general Virtual Organization for Central Europe VOCE, astrophysical application VO AUGER and supports other research applications. However, all the mentioned very successful international activities and high quality initial local infrastructure are funded as part of the network activities and there is not (yet) any explicit financial support to create and maintain appropriate National Grid Initiative.

Introduction

Three independent activities contributed to the current status of the GRID deployment in the Czech Republic. They were strong and active particle physics groups well integrated into international particle physics projects, METACentrum project with its grid-like activities started already before the grid era [1] and international computer network connections run by CESNET, z.s.p.o. [2]. Czech research groups already used the needed computing and networking infrastructure to start grid development project when international particle physics community chose GRID as a response to its computing problem solution for coming experiments on the LHC accelerator at CERN [3] in 2000.

We will describe Czech contribution to the GRID projects, describe services for EGEE/LCG grids and give current status and performance of local grid infrastructure.

Pre-grid Activities

Particle Physics

Czech particle physicists have been involved in the LEP accelerator experiment DELPHI at CERN, HERA's H1 experiment at DESY and in several smaller experiments in nineties. The strongest groups came from the institutes of Academy of Sciences of the Czech

Republic and Charles University in Prague. Later during preparation for the LHC experiments, Czech Technical University in Prague joined the effort. The groups contributed to all aspects of the experiments from detector design and construction, running the experiment to organization of data processing and physics analysis.

METACentrum Project

Independently, in the framework of the METACentrum project Masaryk University in Brno in collaboration with other Czech university supercomputing centres worked on creation of single computing environment for academic users offering single user login to all resources, same user interfaces and same application interfaces independent on location or hardware and operating system specifics. Users got access to one general queuing system for job submission, seamless distributed file access has been provided through a shared OpenAFS Kerberized file system, access to services sharing the same authentication credentials (also based on the Kerberos system), access to software has been unified through the module system etc. This environment was offered to all academic users in the Czech Republic under the title METACentrum. Due to the infrastructure oriented METACentrum activities it was eventually moved under the auspices of CESNET and became one of its major activities in the area of network applications. METACentrum currently operates computing, storage and archive resources either directly owned by CESNET or provided as a contribution from West Bohemia, Charles, and Masaryk Universities. The computing resources are scattered through 4 sites and are mainly IA-32/64 architecture compatible, offering together almost 1000 CPUs. The data storage of some tens of TB on-line disk capacity follows the computing resources, while the tape archives are located in Pilsen and Brno.

METACentrum is involved in national projects—e.g. the MediGRID, focused on the semantic grid for medicine—and international activities, currently EGEE II and EGI_DS projects.

CESNET

CESNET emerged as scientific research network supplier with the first international IP line to Austria established in 1992. By following year CESNET created country-wide backbone network connecting 8 cities. It managed to keep the pace during nineties preparing national research network infrastructure and integrating it with European and non European research network initiatives. The legal structure of CESNET evolved into the Association of legal bodies created by Czech universities and Academy of Sciences of the Czech Republic with broader assignment adding to research network construction and deployment also a support for novel applications using the network, including the grid activities.

Grid Activities

Preparation for the LHC experiments clearly showed that the data production will be few orders of magnitude higher then standard computer resources evolvement and thus the new hierarchical distributed model for computing was suggested. The agreement within the community has been reached during CHEP conference in 2000 in Padova and EU has chosen to support the European DataGrid project (EDG) [4] proposed by CERN as the broad international project towards creation of Grid middleware. In parallel more specialized Grid projects have been approved by EU. Very similar situation has been in the U.S.A. where several grid projects have been approved and financed.

As mentioned above, Czech Republic has been in a lucky position, having a matured particle physics community needing and fostering the grid projects, experienced IT specialist

from the METACentrum project understanding the complexity of proposed solution and CESNET with high quality and throughput network to enable testbed activities. The Czech Republic joined the EDG project in the fields of testbed, workload management and HEP application support as associated partner with CESNET and the unpaid contractor Institute of Physics AS CR. While the Institute of Physics has been active in the testbed and HEP application support work packages, CESNET made contribution to Logging and Bookkeeping of the workload management package. The EDG task to produce high quality middleware was quite complex and difficult and the EDG project was followed by other two year projects in succession, namely EGEE (Enabling Grids for E-sciencE) and EGEEII [5], in both cases with CESNET representing the country. It is also actively contributing to the EGEE III project currently under preparation and expected to start from April 2008. CESNET is also member of a smaller consortium behind the EGI (European Grid Initiative) Design Study project (EGI_DS) that is looking into option to start preparation of the EGI project that in collaboration with NGIs (National Grid Initiatives) should be able to run extensive grid services with some similarities to the current GEANT2 computer network pan European service.

CERN launched a new LCG project (LHC Computing Grid) in parallel with the EDG project. The target of the LCG project is to propose and realize LCG grid hardware and software infrastructure for all the LHC experiments. Hardware equipment in collaborating countries is monitored and coordinated with the help of the WLCG (Worldwide LCG) project. The responsibility for hardware provision lies completely in the responsibility of collaborating countries.

The EDG/EGEE grid solution assumes distributed infrastructure of larger number of computer centers with various computing capacities that automatically collaborate with each other with the help of the grid middleware. The conditions are that any authorized user can use the whole grid and that local computing centers' administrators retain full responsibility and power over their computing centers. Centers are hierarchically grouped to bigger TIER1 centers and smaller TIER2 centers differing in computing resources and assignment of different tasks. Also, existence and roles for even smaller TIER3 and TIER4 centers is discussed. Virtual Organization (VO) concept has been introduced to gather together people working on a similar problem or a (usually international) project. The

Fig. 1. The Geant2 European network
as of November 2006

VOs are a way how to organize users on a distributed grid infrastructure. Each computing center can decide which level of resources will contribute to a specific VO. One of the targets of EGEE projects is to find and support research activities and projects beyond the particle physics that will also benefit from the grid infrastructure.

Grid Status

As part of the above mentioned projects a distributed TIER2 center has been established in the Czech Republic. It consists of two parts, the one called Golias is located in the Regional Computing Center for Particle Physics in the Institute of Physics of the Academy of Sciences of the Czech Republic and the other called Skurut in CESNET headquarters. More details on computing power and services delivered will be shown later. Since the EDG, CESNET is responsible for the Logging and Bookkeeping service which was originally part of the Workload Management package. CESNET has also proposed inside the EGEE Central Europe Federation creation of the VO for Central Europe (VOCE) [12] and supports in Prague all needed grid services to run it. The VOCE is meant as an all purpose virtual organization for grid tasks of researchers from the Central Europe Federation. Another supported VO is AUGER for astrophysical application of the international experiment Pierre Auger Laboratory in Argentina [13].

In next paragraphs we will show network situation in the Czech Republic, then give more detailed description of the local distributed TIER2 center and its performance.

Network Infrastructure

Czech research network infrastructure CESNET2 is embedded into European GEANT2, Figure 1, dark fiber basic backbone. The backbone of CESNET2, see Figure 2, is formed by redundant circles of dark fibers forming highly robust network infrastructure with high transfer potential.

Moreover CESNET can provide special network links for local projects. For the Czech TIER2 center CESNET provided local 1 Gbps links infrastructure between the TIER2 center and collaborating groups and also several international 1 Gbps links to TIER1 centers in FZK Karlsruhe, FNAL in Chicago [11], Taipei and a new link to BNL, and considers link to Canada. Figure 3 shows the existing links.
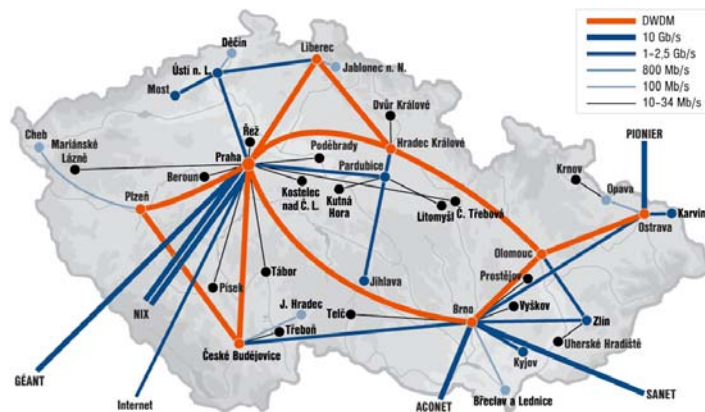
Fig. 2. Internal Czech CESNET2 infrastructure backbone
consisting of redundant circles of dark fibres
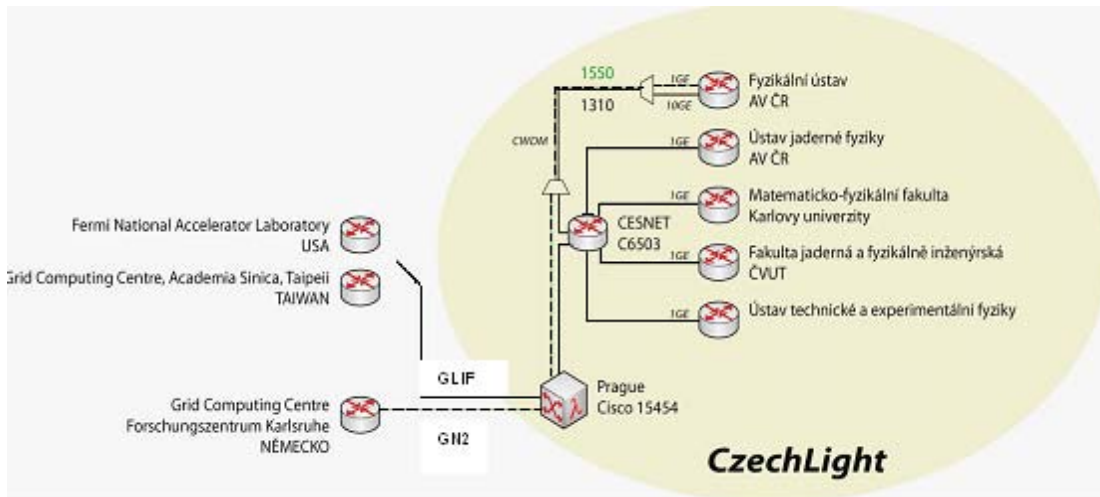
Fig. 3. Special 1 Gbps lines between Czech TIER2 centre and
other TIER1 centres and to local infrastructure to collaborating institutions

Local TIER2 centre and its performance
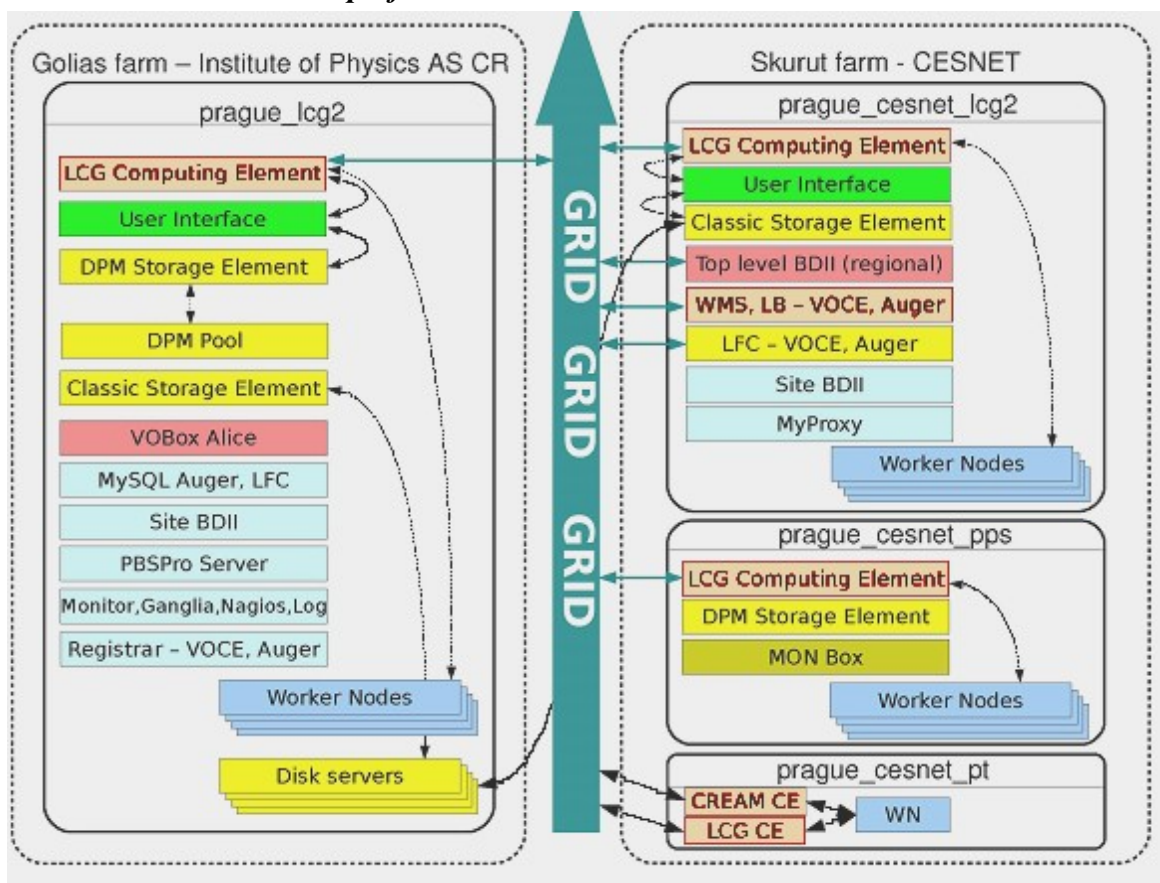
Fig. 4. Services provided by the TIER2 centre by the Golias and Skurut farms

As mentioned earlier the distributed TIER2 centre is formed by farms Golias and Skurut. The basic grid services provided by the centre are marked on Figure 4. Golias farm is designed as production LCG farm for the particle physics experiments and has bigger number of working nodes and disk space that is used also by the Skurut farm. Skurut farm is partly used for LCG production, its main resources are devoted to production tasks for virtual organization VOCE, EGEE pre-production service (prague_cesnet_pps) [6] for evaluation of new features and changes in production releases and the EGEE preview testbed (prague_cesnet_pt) [7] for testing of the new features by the development team. Skurut has the key role in running basic services for Central European and Auger virtual organizations.

Table 1. Computing resources of the CZECH TIER2 centre consisting of Golias and Skurut farms. Listed are raw capacities both of computing power and disk space. Skurut farm shares disk space via network from the Golias farm

End 2007	Computing Resources kSI2000	Number of processor cores	Disk capacity TB
Golias	670	458	60
Skurut	30	38	Shared from Golias

Table 1 shows computing capacities of the distributed TIER2 center.The centre can support both external grid users and local non-grid users. Experiment D0 [8] uses 50% of the capacity for non-grid local simulation of the detector. Resulting number of simulated events per week is shown on Graph 1. Czech Republic ranks third in the simulation contribution with mean of 0.5 million events per week in 2007. Next main usage of the centre is 20 % share of the non grid computation for solid state physics. For grid computing 27% of the capacity is used mainly for simulations for the LHC experiments and VOCE computing. The usage reflects the financial contributions to the computing centre resources by various experiments. Skurut is only used by grid tasks of VOCE and ATLAS virtual organizations. It is assumed that the grid usage for LHC experiments should dominate in future, as the demand for

End 2007	Computing Resources kSI2000	Number of processor cores	Disk capacity TB
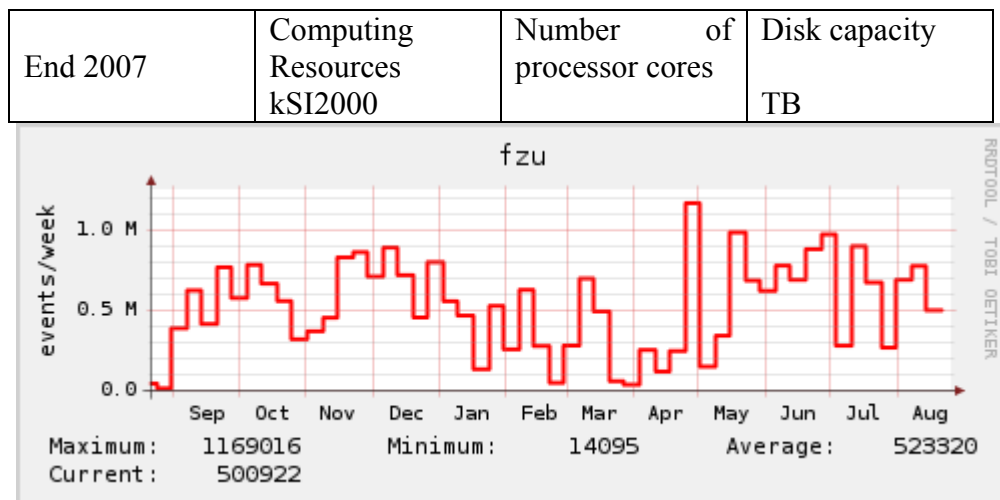
Graph. 1.Contribution of the Czech TIER2 centre to computer detector simulations for experiment D0 at FNAL

resources is planned to be ten times higher than now. Realization may be hindered by lack of financial resources.
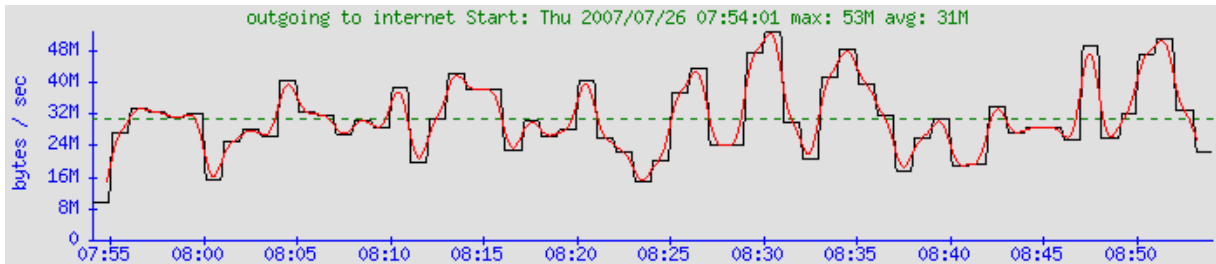
Graph. 2. DPM data transfer from Prague to Taipei over 1 Gb/s link using 50 streams per file, 10 files in parallel, size of file 1 GB, tcp buffer 100 MB

Important task of grid computing is the transfers of large amounts of data. We have made the transfer over 1 Gbps lambda line between Prague (praguelcg2) and TIER1 centre in Taipei (taiwan-lcg2). Graph 2 shows that mean value 32 MB/s has been reached for one hour data transfer. Transfer in the reverse direction from Taipei to Prague gave mean transfer rate of 20 MB/s over several hours period but serious instabilities of servers in Prague appeared. The transfers between Prague and Taipei may be compared to the transfer between Prague and FZK Karlsruhe which is a default TIER1 centre for Prague over similar 1 Gbps link. We reached 50 MB/s mean. The round trip time between Prague and Taipei is 310 ms as compared to few ms between Prague and FZK Karlsruhe. Big tcp buffer size and much bigger number of streams seem to cause Prague servers instabilities. The transfer studies are covered in a report [9].
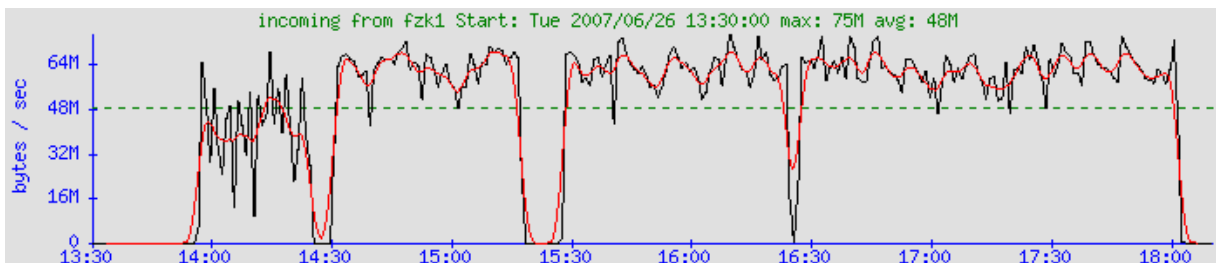
Graph. 3. DPM data transfer from FZK Karlsruhe to Prague over 1 Gb/s link using 10 streams per file, 10 files in parallel, size of file 1 GB, tcp buffer default value

Monitoring

We have chosen to use nagios with various plugins and workarounds to automatically check key behaviour of computing components for monitoring of distributed Prague TIER2 centre. We have built an interface that enables dynamic configuration of nagios depending on our database of hardware and services. Other need was to substantially reduce the amount of nagios warnings. We immediately dristribute critical nagios warnings only, all others warnings are summarized in a developed digest sent only three times per day. The technical details are described in [10].

Conclusion

Czech Republic is serious partner in the grid activities from launching of the first EU grid project. It takes part both in the grid deployment activities via distributed TIER2 center in

Prague and in the development of grid middleware components, particularly Logging and Bookkeeping and recently also Job Provenance services. Further it takes part in the deployment of the grid e.g. via support of the VOCE and AUGER virtual organizations.

The middle sized Tier2 center is able to visibly contribute to computing results of several experiments. Important part of the grid activities is high quality computer network CESNET2 and its integration to the Geant2 network, also ability of CESNET to create both domestic and international dedicated links for local project groups.

CESNET takes active role in the preparation of coming grid projects as EGEEIII or EGI. However substantial effort will be still needed to create National Grid Initiative in the Czech Republic to attract political support and to find adequate financial resources for it and for wider grid deployment.

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Network structure and computing at DLNP JINR

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Abstract

The paper describes the current state of the network and computer facilities working in the second part of the 2007 at the Dzhelepov Laboratory of nuclear problems of JINR. During last two years the network was rebuilt to implement 1 Gb/s fiber optic net links between JINR backbone segment and complex hierarchical DLNP network. Inside the lab the same links connect main network control room with the buildings of the lab. At users working places 1 Gb and 100 Mb twisted pairs links are in use. All equipment for the network control was purchased at CISCO and permits effective management of the net. The lab servers provide all necessary services including 1.5 Tb RAID multi disk storage, AFS, Kerberos, LDAP, mail and web servers. A computing power is provided by a number of new Intel platforms using LINUX and Windows OS and distributed around the lab in the physicists groups. New GRID elements were introduced into operation this year. The total number of the network devices in the DLNP net is more than 1000. The data traffic over the lab net is about 32 Tb per year now.

Equipment in the network operation room

The LNP LAN is based on 1 Gb/s switching technology using CISCO 3750 Series equipment as a main system-building units. The connection of the LNP network to the JINR fiber optic backbone is made in three points: main lab building, LNP phasatron building and point in the building of radiochemistry and nuclear spectroscopy (RHL).

The main access point is located in the lab building network operation room. The fiber optic links come to the lab connection points from two different sides. One end of the link is connected to the network equipment but the second one is normally disconnected to the backbone and is kept in the ready state to be connected in case of need. The JINR backbone is implemented as 8 pairs of fiber optic lines that run through the JINR Labs. At every connection point all lines may be may be commuted on a special patch board. Lines responsible for connection to other JINR labs are going through this patch board, meanwhile lines supplying information to the Lab of nuclear problems are connected to the fiber optic Gigabit Ethernet switch Cisco Catalyst 3750G-12S. This device serves 12 small form-factor pluggable (SFP) Gigabit Ethernet fiber optic ports, has internal 32-Gbps high-speed stacking bus and provides full dynamic IP routing. This fiber optic switch works as device that distributes Gigabit Ethernet packets over the buildings of the LNP.

Network groups included in the lab network are Laboratory building (No36), buildings of LNP phasatron (No 1), No2, No3, No4a, No4b, No108, No113, building of RHL. The connection to the main Lab building is implemented by means of the jumper cable that links Cisco Catalyst 3750G-12S to the Cisco Catalyst 3750-24TS-E switch that has 24 Ethernet 10/100/1000 ports and 2 small form-factor pluggable (SFP) transceiver-based Gigabit Ethernet ports. This provides the 24 twisted pairs 1000/100/10 Mbit/s lines available. Additionally four 100/10 Mbit/s Dlink DES-3326SRM high-performance, managed stackable Layer 3 Switches are connected to the Gigabit switch, providing 4x24=96 ports. The device permits expansion of stack of these switches to bigger size. All devices have the advanced security and manageability options.
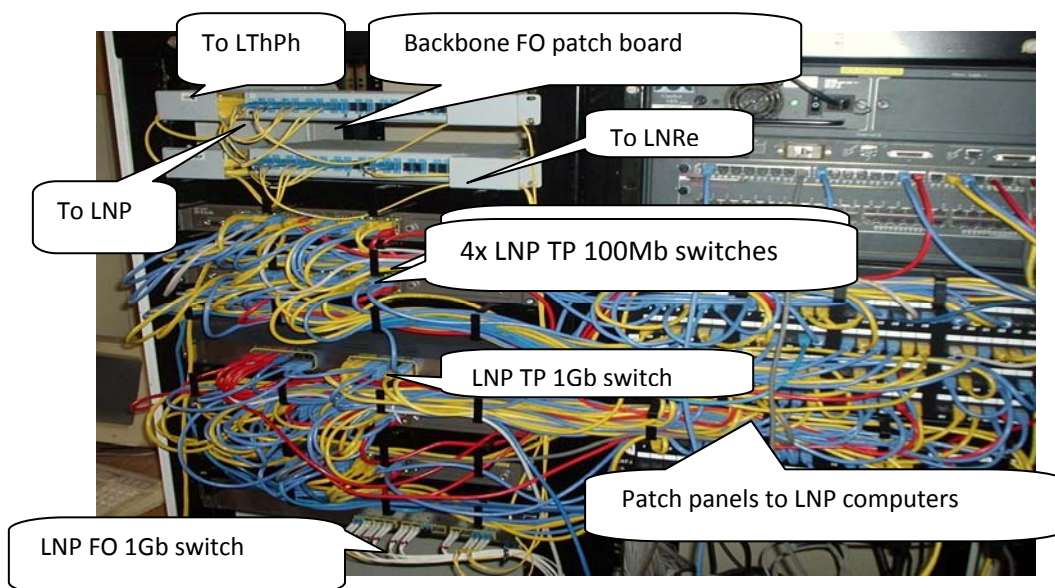
Fig.1. The LNP network control room equipment

In other buildings of the lab Cisco Catalyst 3750-24TS-E switches are used with fiber optic lines connected directly to device. Also Cisco Catalyst 5505, Cisco Catalyst Dlink DES10240, Dlink DES3226 and Compex SRX2224 switches are in use there. DSL modems for some alone remote workstations are present too.

The Cisco Catalyst 3750 series devices provide many useful options implemented. This includes auto configuration of new stack units using Dynamic Host Configuration Protocol (DHCP), auto sensing on each port the speed of the attached device and automatic configuration the port for 10-, 100-, or 1000-Mbps operation, easing deployment in mixed 10, 100, and 1000BASE-T environments. Auto negotiating on all ports automatically selects half- or full-duplex transmission mode to optimize bandwidth. Network wide security features allow dynamic, port-based security, providing user authentication managing access to all MAC addresses.

Table 1.
The distribution of the computers and network devices over the lab network in main buildings

6	GRID computers
136	Lab main building
60	Phasotron building
94	Physicists (Building 3)
204	Physicists (Building 4)
148	Radiochemistry and nuclear spectroscopy department
57	New accelerators department

Server room

The lab servers provide all necessary services including 1.5 Tb RAID multi disk storage, AFS, Kerberos, LDAP, mail and web servers. A computing power is provided by a number of new Intel platforms using LINUX and Windows OS and distributed around the lab in the physicists groups. New GRID elements were introduced into operation this year. The data traffic over the lab net is about 32 Tb per year now.
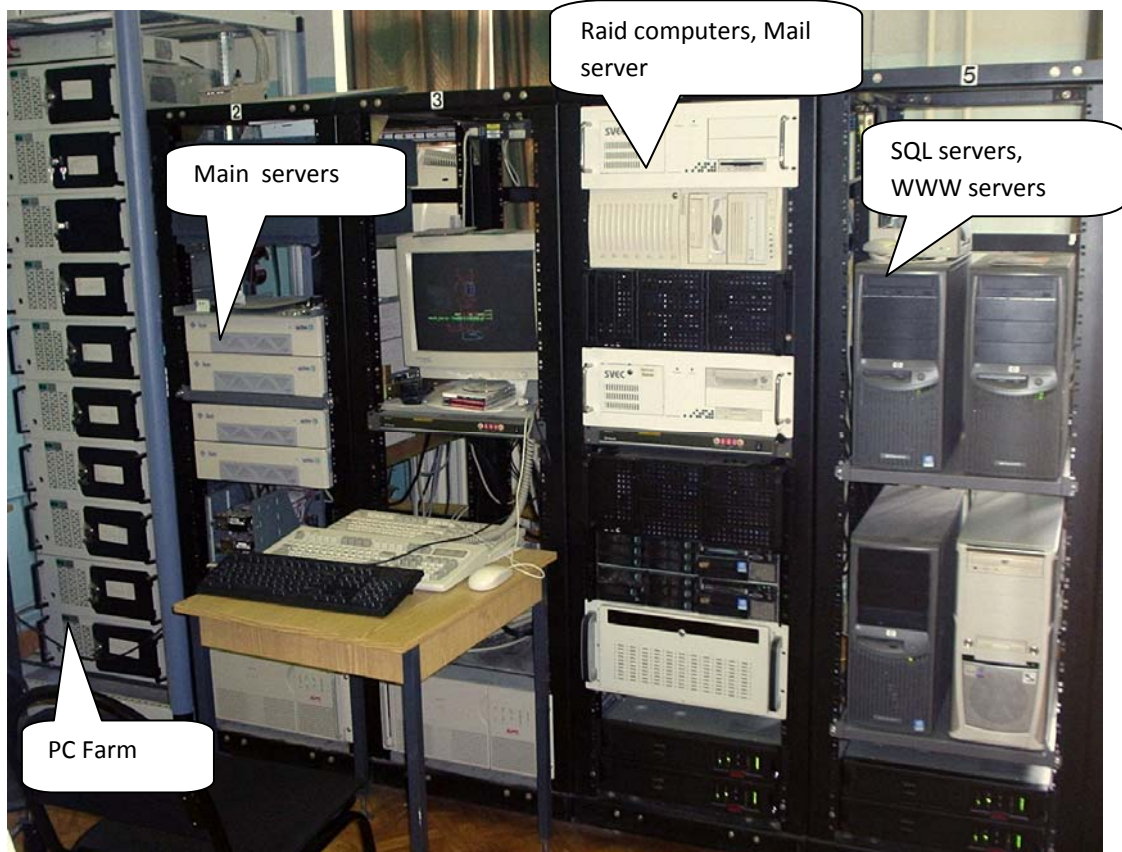
Fig. 2. General view of the server room at the JINR DLNP

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LHC computing GRID element at DLNP JINR

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Abstract

In the frame of the JINR plans to develop GRID segments the task force group was organized at the Dzhelepov Laboratory of nuclear problems of JINR. On the base of new powerful workstations a test GRID segment was built of the LCG2 type. It includes a computer element, worker nodes, some storage elements, user interface and other necessary middleware units. The LHC Computing Grid software is installed and tested. This segment was successfully used by physicists groups during one year and will be extended in the nearest future.

Introduction

It seems that idea to use number crunching resources joined into network arose simultaneously with the concept of computer network. First of all methods of informational exchange were developed. From the simplest FTP file transfers they migrate to the network file systems (NFS, AFS), email and finally WEB services that generally became the synonym of computer network for the most of people. Until now this type of computer interaction is prevalent.

A distribution of actual calculations (i.e. executable codes but data) came into use later because a support of such kind of the computer interactions requires rather big efforts even for computer clusters with similar processor architecture.

The simplest method of distributed calculations is represented by a usual batch system like PBS or CONDOR. The user puts his job into queue and do not need to worry how, when and what computer will be used to execute his job. As a rule such systems do not assume similar hardware and software environment only but also the similar user authorization features and synchronized updating of user data on all cluster machines. All this may be implemented by means of relatively simple tools applied to clusters of an enterprise scale where centralized administering is reachable. However bigger associations require cardinal extension for the user authorization mechanisms. Say for example on join use of calculating resources of a whole number of big organizations

In the middle of nineties the new method of distributed calculations named GRID was started. Papers [1] and [2] were a classic introduction to GRID containing basic definitions and principles. The conception of virtual organization (VO) was introduced. The user confirmed the membership in the given VO with the help of Certificate Authority (CA) acknowledged by all participants on all clusters of GRID members. In addition some principles were formulated. They

This approach was accepted in CERN for storage and processing of data that would be received from future experiments ALICE, ATLAS, CMS and LHCb at collider LHC. The software complex supporting the operation of GRID middleware on tens of thousands computers in hundreds of organizations was named LCG (LHC Computing GRID). The LCG Grid resources are accessible to a number of other GRID complexes. Among them there are both international ones (EGEE - Enabling Grids for E-SciencE and OSG - Open Science Grid) regional and national ones (say, INFN in Italy [5] and RDIG Russian Data Intensive Grid [6]). The software itself is very complex and overloaded because of the possibility to execute actual jobs on any computer that is member of the GRID. For example it is necessary to keep in mind features of every particular batch system (PBS, Condor et cetera) installed on

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a given counting element of GRID. At the moment the gLite implementation of the LCG middleware is accepted as basic one.

At JINR the creation of LCG segment started in 2002. On the base of JINR LIT servers the first GRID structure of the JINR-GRID was built. It had Computing Element CE, file Storage Element SE, Resource broker RB and a number of GRID service utilities necessary for segment operation.

In the beginning of 2004 the LNP administration formed a group that built the second at JINR GRID segment of LCG. The members of this group were A. Dolbilov, Yu. Ivanov, K. Gritsai and V. Olshevski.

Later we will discuss the main features of the cluster created. Using simple examples we will show how to use it for local jobs for usual and multiprocessor tasks in batch mode. Then the GRID mode will be demonstrated from user certificate acquiring to preparation and running GRID tasks. At the end we will point out results and future development of the LNP cluster.

Structure and features of the cluster

In the beginning the goal was formulated as more effective use of hundreds powerful computers at LNP. A majority of them was typically in a waiting idle state. The search concluded to a consideration of GRID technologies that was new.

First attempts were done to use for distributed calculations Globus Toolkit software. It became clear that this product is not fully developed and needs a lot of additional efforts to reach actually working GRID complex. Therefore it was decided to use LCG Grid also because LNP and JINR participate in ATLAS and other CERN experiments.

From the other hand even the use of the ready software packages also is not so ordinary. The package LCG Grid has all components necessary for professional operation. It contains compilers, libraries, text processors, multimedia tools etc. At the same time this workplace should be also Worker Node (WN) and/or Grid User Interface (UI) according to the LCG definitions. User programs require installation and updating to newest versions of OS while LCG middleware is much more conservative.

It is enough to say that base OS for LCG is Scientific Linux 3 (SL3) or similar distributions of the Red Hat Enterprise Linux 3 (RHEL3). In the spring of 2007 RHEL5 and SL5 versions appeared. They support modern 64 bit CPU and new versions of libraries. Trying to satisfy the needs of local users it was decided to select version Scientific Linux 4 (SL4) to be basic OS i.e. latest one at that time. Let us note that LNP cluster works on SL4 from 2005 and official versions of LCG middleware for WN and UI was released in the spring of 2007. At the same time the LIT cluster switched to SL4 too.

At the same time security issues were improved. For the users authorization the Kerberos 5 system was chosen although many applications support the weaker version Kerberos 4. This improving of the security level invoked some additional efforts to integrate with the file system AFS, which is used for the storage of the users' directories. The total size of the AFS disk space on the cluster is about 1.2 Tb that is enough for the users' files and programs.

We note that this day there are a number of AFS servers at JINR, so possibly they will be joined into one structure. For AFS the Kerberos 4 is a standard now and it is known how to migrate to version Kerberos 5. From other hand the join with the packet batch system PBS (version Torque) did require the modernization of the Password Storage and Retrieve system (PSR). This one should be used to get an AFS token for the period of file access time. It was

necessary to include into standard PSR code the possibility of autentification conforming to Kerberos 5. This kind of access to the passwords was implemented during renovation of the LIT central cluster in Spring of 2007. It is worth to mention also the use of new Secure Shell version that supports full set of options for the Kerberos 5. All this permits to implement transparent file exchange between cluster computers. That is necessary for PBS operation when host-keys Kerberos 5 are used for authorization.

The LNP GRID computing segment started in the beginning of the 2006. The first possibility is to work in usual local mode i.e. without GRID. The cluster consisted of one CPU Pentium 4 at 3GHz with 1 GB RAM. We note that only one lgdceOl runs SL3 because the LGD middleware up to now does not have a CE version for other systems. In the given case it is not critical because actually the user works with other machines. The User Interface and the Work Node operate under SL4. In the end of 2006 three new computers were added. They have dual CPU Intel Xeon at 3GHz and 2Gb RAM. Here lgdceOl works as CE supporting the operation of the batch system (Torque server) and task scheduler (Maui) for local users. Other computers (lgd2, lgd3…) are user workstations. They have compilers C, C++, FORTRAN, CERNLIB libraries, text processors T_EX/L^AT_EX, Open Office), web browsers (Mozilla, Seamonkey, FireFox), email agents pine, Mozilla Thunderbird) installed. As well as usual operation the user may send a task for a time consuming execution and it will be done on a free cluster computer.

Conclusion and perspectives

The LNP computing element of the JINR-LCG works over a year. At first time it supported jobs execution for all main experiments of LHC (ALICE, ATLAS, CMS and LHCb). At the end of the 2006 it was decided to use it for short jobs of ATLAS collaboration that takes less than 3 hours for execution. It was because the cluster consisted of 4 one-CPU computers so only 8 jobs were possible to be executed simultaneously. The multithreading Pentium 4 permits effective processing of two jobs at a time. This satisfied the requirement to have available a small number of CPUs not overloaded with other GRID jobs, say for example for ATLAS collaboration members working at LNP in A.Zhemchugov group.

The regular updating of programs has been done for all components of the operating system and application programs as well as for the LCG middleware. Some updates run automatically, some of them require detailed handwork for example job batch system and LCG system that is far from the perfect state until now.

The created configuration of cluster WN and UI computers seems to be fully completed variant of LINUX machine. It satisfies to wide number of requirements permitting program development, desktop applications, batch processing and better use of the GRID possibilities.

The number of working nodes in cluster is small now so we may speak about a prototype of a new counting cluster that should come to change existing old cluster of the Laboratory of nuclear problems. This old one consist of 10 two-CPU Pentium III 500MHz computers. In spring 2007 the central part of JINR-LCG segment at LIT was renovated. Now it includes 60 working nodes based on 64-bit Intel Xeon CPUs. The LNP segment should follow this direction by installing additional working nodes in the physicists groups.

This puts new problems for organization of the LCG middleware because up to now there in no certified 64-bit version for SL4 despite this type of configuration became

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dominant one. One of authors studies these problems at the GRID EELA [9] cluster of the Universidad Tecnica Federico Santa Maria, Valparaiso, Chile

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Linear high voltage supply for semiconductor silicon detectors

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Abstract

High voltage supply with linear regulation of the output voltage up to 400 V is described. Ten HV channels on one module are supplied from single DC-DC converter controlled by limit voltage. Both the output voltage and the load current for all channels have to be monitored. As the direct measurement of the load current is difficult in such configuration, this is avoided by using a current mirror and compensation of the current through the feedback resistor. The circuit diagram and the results of load regulation and temperature stability measurements are shown.

The development of silicon detectors has led to many applications in the form of pixel detectors or microstrip detectors in many fields – from charged particles tracking to X-ray imaging. Large detectors need large high voltage power supply systems. Due to low detector currents very often a common HV DC source and a HV distributor with a certain number of channels are used. To measure individual channel currents in this configuration is not a conventional task. A sensing resistor in the common HV return line cannot be used because this line collects the load currents of all distributor channels. A detailed survey of some possible solutions is given in [1]. A sensing resistor in the HV output is used in all reviewed examples.

We propose simple and reliable method of current measuring. For better understanding of the proposal the simplified block diagram of one distributor channel is build / fig 1/.

A   – amplifier
CCS – controlled current source
CM – current mirror
DA   – difference amplifier

Uin – HV input
Uout – HV output
Uc – control voltage
U1 – monitored voltage
R1, R2 – voltage divider
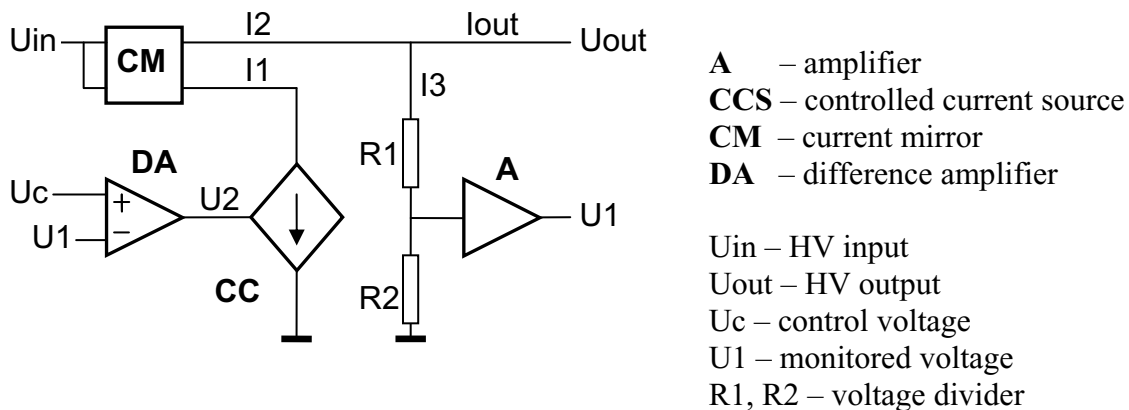
Fig. 1. Simplified block diagram

From the schematic, it is evident that:

$$U1 = k_1\ Uout$$
$$U2 = k_2\ (Uc - U1)$$
$$I1 = k_3\ U2$$
$$I2 = k_4\ I1$$
$$I3 = k_5\ U1$$

From the above equations we can see that

$$U2 = k_2\ (Uc - k_1 Uout)$$

rearranging $k_1 Uout = Uc - U2/k_2$

and assuming $k_2 \gg 1$ $Uout \approx Uc/k_1,$

Therefore, Uout slightly depends on U2, respectively I1 and I2.

On the other hand after some substitutions it is evident that
$$I2 = k_3k_4U2$$
$$Iout = I2 - I3 = k_3k_4U2 - k_5U1$$
Therefore, there is no need to measure detector current directly – it can be calculated from two easily monitored voltages. And this can be done by either the firmware or the hardware.

The special requirements to circuit elements are obvious – the R1 is a high voltage resistor and the working voltages of **CCS** and **CM** have to be higher than voltage Uin.

High voltage supply for semiconductor silicon detectors is suitable for realization of our approach, since the required voltages are not so high. The HV module with a built-in high voltage and ten channels distributor has been designed. The output voltage of the DC-DC converter is controlled by the limit voltage value. Every channel delivers of up to 400 V positive voltage and maximum current of 80 μA. The electrical diagram of one HV distributor channel is shown in fig 2.

The blocks from fig. 1 are well distinguished there.The improved Wilson type of current mirror (U1, Q1, Q2) is used [2]. Due to very small load currents the mirror ratio of 1:1 is chosen. The matched transistors (U1) of the mirror have very close U_{ce} voltages and the mirror ratio remains stable for the currents of whole range. It is obvious that the regulating transistor (Q1) has to be of high voltage type. The amplifier A is built around the operational amplifier U2 and includes the passive components R7, R8and C3. The regulating potentiometer P1 is added to voltage divider R3, R6 in order to adjust output voltage to correspond to control voltage Uc. It is seen that the HV return HVRTN is isolated from electrical ground. The difference amplifier (U4, R4, R9, R10, R11, C4 and C60 has amplification factor of 100. It controls the current source (U3, Q3, R5 and R12). The new block is added - the current monitoring circuit (U5, U6, R13, R14, R15, R16, R17 and C5). The compensation of the divider current is provided by current through the resistor R13. Thus the voltage Ui is proportional to the load current as it was shown above. An additional circuit, which is not shown, is provided to protect the output against short circuit or overload.
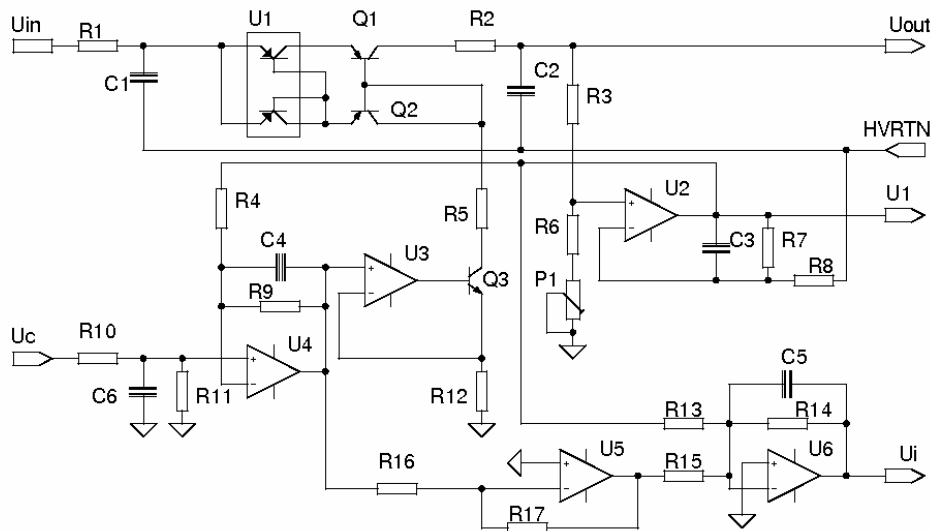
Fig. 2. Electrical diagram of 400 V/80 uA power supply

Two low pass RC filters can be seen at the input (R1, C1) and the output (R2, C2) of the channel. The common DC-DC converter has its own over voltage and over current protection circuits. As its output voltage is set to limit value the over voltage at the channel(s) output is avoided.

In table 1 the results of load regulation study can be seen. The output has been adjusted at 100 V and 40 μA load current. The curves are taken without the special procedure, which has been introduced in order to reduce the observed deviations. In short time after establishing of the output voltage, the firmware calculates the difference between expected and measured values and corrects the output value.

Table 1. Load regulation study

Uhv [V]	Ihv [μA]								
	5	10	20	30	40	50	60	70	80
50	49.55	49.31	48.89	48.47	48.04	47.62	47.18	46.77	46.34
100	101.57	101.35	100.92	100.47	100.02	99.63	99.18	98.76	98.38
150	151.61	151.38	150.95	150.53	149.91	149.48	149.05	148.60	148.13
200	201.50	201.25	200.80	200.40	199.87	199.50	199.00	198.60	198.20
250	251.40	251.20	250.80	250.30	249.90	249.50	249.00	248.60	248.20
300	301.60	301.40	301.00	300.50	300.10	299.70	299.20	298.80	298.40
350	351.10	350.90	350.40	350.00	349.60	349.20	348.70	348.30	347.80
400	401.00	400.80	400.40	400.00	399.60	399.20	398.80	398.40	398.00

The relative stability of the voltage is calculated (Table 2) and plotted (Fig 3) as well.

Table 2. The relative stability of the voltage versus load current

Uhv [V]	Ihv [μA]								
	5	10	20	30	40	50	60	70	80
50	1.0314	1.0264	1.0177	1.0090	1.0000	0.9913	0.9821	0.9736	0.9646
100	1.0155	1.0133	1.0090	1.0045	1.0000	0.9961	0.9916	0.9874	0.9836
150	1.0113	1.0098	1.0069	1.0041	1.0000	0.9971	0.9943	0.9913	0.9881
200	1.0082	1.0069	1.0047	1.0027	1.0000	0.9981	0.9956	0.9936	0.9916
250	1.0060	1.0052	1.0036	1.0016	1.0000	0.9984	0.9964	0.9948	0.9932
300	1.0050	1.0043	1.0030	1.0013	1.0000	0.9987	0.9970	0.9957	0.9943
350	1.0043	1.0037	1.0023	1.0011	1.0000	0.9989	0.9974	0.9963	0.9949
400	1.0035	1.0030	1.0020	1.0010	1.0000	0.9990	0.9980	0.9970	0.9960

The output voltage stability versus ambient temperature at 300V and 40μA are studied (Table 3 and Fig. 4), too.

Table 3. The absolute and relative stability of the voltage versus ambient temperature

T [^{0}C]	10	20	30	40	50	60
Uhv (40μA)	300.1	300.0	300.0	299.9	299.7	299.3
Uhv/Uhv (25 ^{0}C)	1.0003	1.000	1.000	0.9997	0.9990	0.9977
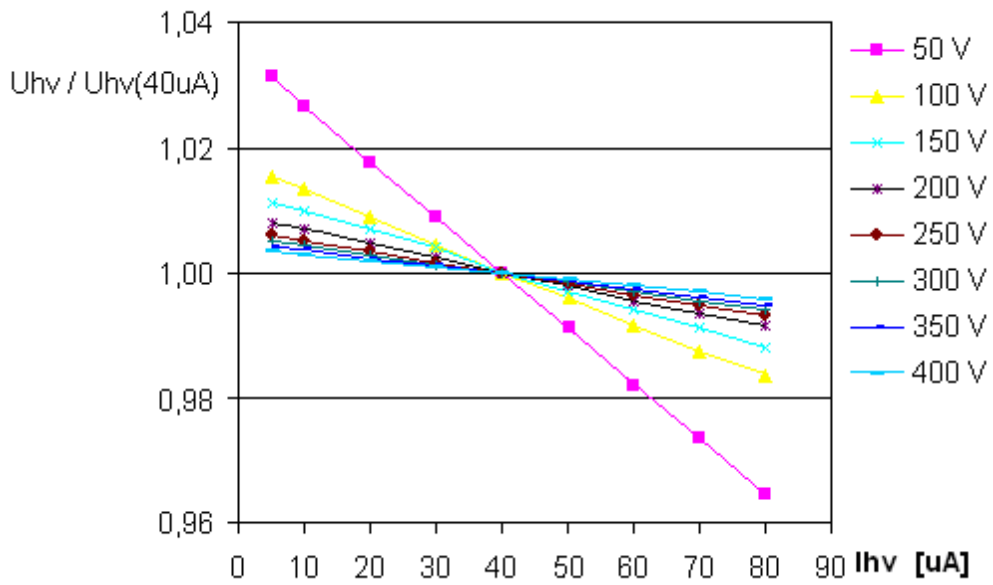
Fig. 3. Relative voltage stability versus load current
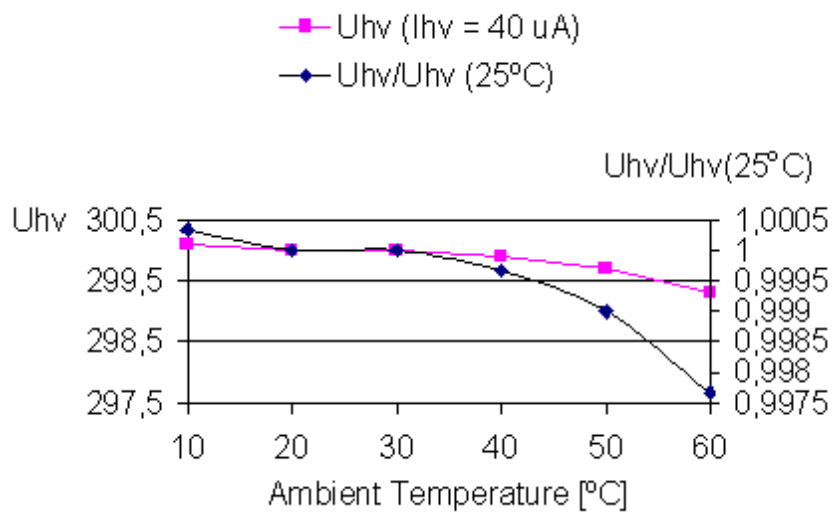
Fig. 4. Absolute and relative voltage stability versus ambient temperature

The module with a shielding cover removed is shown in Fig. 5.
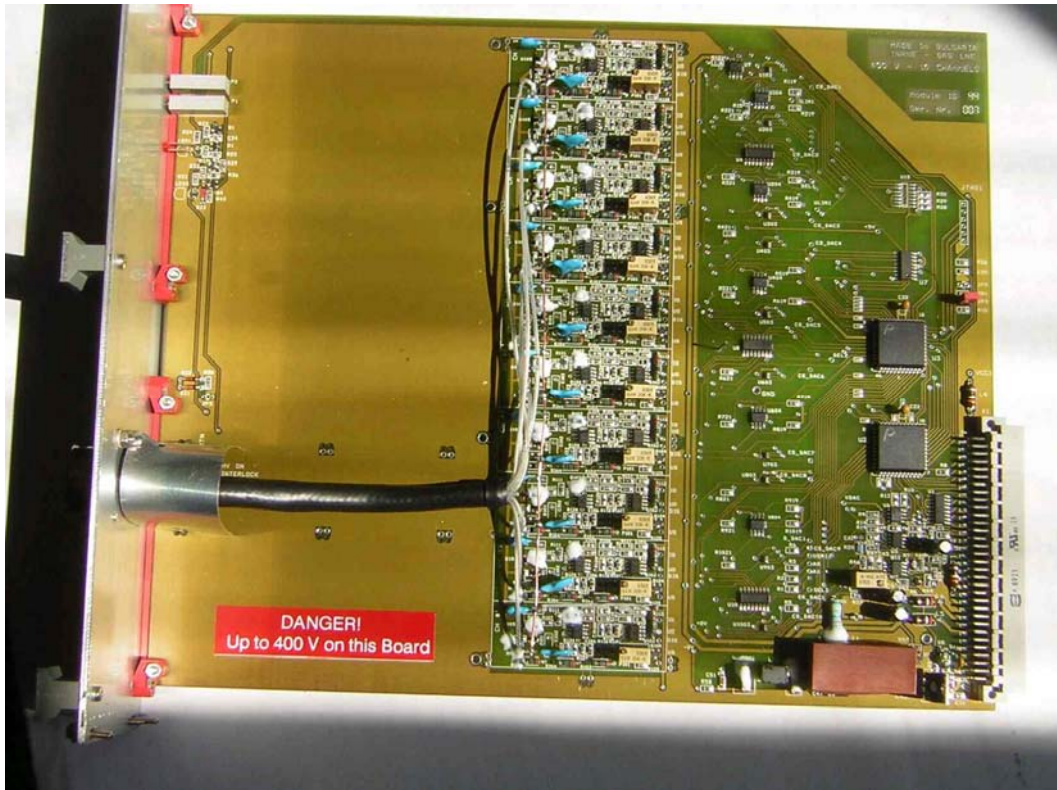
Fig. 5. Ten channel high voltage supply module

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Development of applications with service oriented architecture for Grid

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Abstract

Service Oriented Architecture (SOA) is the most attractive approach in the last years for development of highly distributed integrated enterprise applications. SOA is based on web services specified in WSDL and registered in repositories with UDDI. The basic mechanism for message exchange between services is SOAP. BPEL is used for specification of business processes described as networks of communicating services.

Development of SOA applications requires: process orchestration software for specified in BPEL business process; mediation software for exchange of messages between services; and repositories for registration and discoveries of services.

Grid is service oriented; it has repositories for service definition and discovery; but still there are no wide accepted mechanisms for orchestration and mediation. One more problem is end user communication which has to be supported by Grid portals.

In this paper IBM approach to SOA is investigated and its applicability to Grid for scientific applications is discussed.

Introduction

The intent of this paper is to investigate IBM approach to SOA and its applicability to Grid. First of all we have to explain what SOA by IBM is. Then we have to investigate what Grid by IBM is.

SOA by IBM

In [1] IBM defines SOA as: *"… an architectural style for creating an Enterprise IT Architecture that exploits the principles of service orientation to achieve a tighter relationship between the business and the information systems that support the business."*

From this definition is clear that SOA is following principles of service orientation. SOA is an architectural style. The main achievement of SOA is tighter relationship between the business and the information systems that support the business. From IBM point of view SOA is applied for development of Enterprise IT Architecture that integrates business information systems.

Information system by [2] is *"A system, whether automated or manual, that comprises people, machines, and/or methods organized to collect, process, transmit, and disseminate data that represent user information."* This means that processes in a research organization (including scientific computations) can be thought as business processes supported by information systems. Information systems are two kinds: On-Line Transaction Processing (OLTP) and long running as data mining process. OLTP information systems are composed of independent short transactions and the state of business process is supported persistently with the help Database System. These information systems are database centric. Long running information systems are more complicated their state have to be supported in the main memory, so a special support is needed in case interrupts or failures. We address here both kinds of information systems.

To clarify IBM SOA we give the definitions of terms used above in [1]:

- *"…service-orientation is a way of integrating your business as a set of linked services."* Or in other words service-orientation looks at business (business processes) as structured in services linked with each other.

- *"…a service is a repeatable task within a business process."* This definition of the service as repeatable task is not precise. From here it is not clear what is granularity of this repeatable task. Right understanding of service granularity is the condition for success or fail of a SOA based project. If the services are very small much execution time is spend for communications. If services are very large they are complex and hardly manageable. The experience shows that well designed business services are well granulated services. What the business name a service it is a service. It is possible some system services to appear later in the development, but they only support software design and implementation – they do not extract any functionality from the business services, they utilize implementation of some functionality of business services. This approach is in contradiction with IBM's Service-Oriented Modeling and Architecture (SOMA) [12] approach, but comments on this topic are out of scope of this paper.

- *"A composite application is a set of related and integrated services that support a business process built on SOA."* This means that composite application is a SOA implementation of business process.

The SOA standards widely accepted from the main players on the market (including IBM) are:

- The language is Business Process Execution Language (BPEL) [7]. This is a XML based language developed by OASIS consortium. In BPEL the business process is described as communicating web services.

- Web services are specified with Web Services Description Language (WSDL) [8] – XML based description language of web services. In WSDL are specified: operations on web service, messages that web service interchange through its operations and where web service resides.

- Message exchange among web services follows Simple Oriented Access Protocol (SOAP) [10] – exchange protocol of XML messages over a transport level protocol usually HTTP.

- Web services are registered (published) in repositories supporting Universal Description, Discovery and Integration (UDDI) [9] protocol.

Now, we will describe how IBM supports these standards. Business processes should be described from methodological point of view with WebSphere Business Modeler. This tool permits business process to be simulated and optimized. One of benefits in IBM SOA approach is optimization of business processes. The problem here is with the data for simulation - to achieve good results in simulation usually huge amount of real data have to be prepared. This is very expensive process and as result simulation frequently is shifted out from the development process.

Business processes in WebSphere Business Modeler are specified in diagrams with which users and modelers fill comfortable. All BPEL construct have graphic representations

including some IBM extensions. It is important to mention that WebSphere Business Modeler is mainly modeling tool and as such one it permits the business process to be described interactively going down in more details. Web services are described as tasks interchanging business items. The most detailed specification of a business item can be with XML Schema. A detailed task can be specified with all its operations. All elements of the diagram can be well documented using a rich set of properties.

WebSphere Business Modeler is integrated with another IBM tool Rational Software Architect. This integration supports Rational Unified Process (RUP) [11]. We will not go in more details on RUP and how it is integrated with SOA – this is out of scope of this paper. Only we have to mention that Business Use Cases Model and Use Case Model are very well integrated with WebSphere Business Modeler diagrams and other RUP artifacts.

When detailed business process is specified in WebSphere Business Modeler diagram we are ready to export it to WebSphere Integration Developer. Briefly, the tasks are exported as WSDL specification, business items as XSD Schemas, and business processes as BPEL specifications. WebSphere Integration Developer supports integration with external services and allows development of services on legacy software through so called adapters. WebSphere Business Modeler diagrams are exported in WebSphere Integration Developer diagrams. The last ones are again BPEL based diagrams, but they are straightforward graphical implementation of BPEL including IBM extensions. It is very important to know what is exportable and what is not exportable from WebSphere Business Modeler diagrams and using this knowledge to design suitable for export diagrams, else all this first phase of modeling and simulation of business processes would not be fully utilized.

WebSphere Integration Developer is not modeling tool but rather it is developer's tool. In reality, if the first modeling phase is unsuccessful for any reasons, the developers start implementation directly with this tool using the business process specifications achieved at design phase never mind how these specifications are specified. This is a bad news but good experts on both tools WebSphere Business Modeler and WebSphere Integration Developer are rear events.

With WebSphere Integration Developer newly developed services will be developed and integrated, legacy software will be integrated through adapters, and external services will be integrated too. Implemented business process is deployed to WebSphere Process Server for execution.

Business process specified in BPEL is template. This template is used by to instantiate an execution process. Templates are deployed to WebSphere Process Server. Process instances are created when an initiating message is received – there is no special notation for initiating, they are usual messages, but process templates are marked that these messages can create a new executing process instance. This means that a single WebSphere Process Server can run simultaneously many thousand processes in parallel. There is another alternative for process specification in WebSphere Integration Developer – business state machine, which is extended finite state machine. This is more traditional for IBM approach, but service orchestration with finite state machine is very different from business process diagram from business point of view. We will not go in more details about business state machines. Finally, we have to mansion that these many thousand of processes concurrently running is one of the challenges of SOA implementation.

BPEL is originally designed to support stateful processes on stateless services. This idea permits stateless services to be executed on any suitable working node and the process is orchestrated only from one working node containing the process state. But one of intends of IBM is to use SOA for integration of legacy software and it is clear that service based on legacy software in the common case is stateful. In IBM SOA stateful service is not an exception but rule. This rule permits system architects not to engineer the system but to reengineer it. Usually this reengineering attempt on monolithic software is badly accepted by the clients – they pay for a new system or at least for most of it, but at design time they find out that only part of it is new and integration is not visible (on user interfaces).

One more problem of IBM's SOA is human-computer interactions. The design of business process is design of process flow but not human interaction with the system. IBM offers WebSphere Portal as a mediator between WebSphere Process Server and human users. The problem is that when business process needs of human interaction the corresponding service implementing this interaction suspends the process until an answer from the human is not received. This service is called human task. The development of human tasks is supported by WebSphere Portal which is well integrated with WebSphere Process Server, but human tasks can be implemented with different tools. Let's return to suspended processes, when the system is big one with many users there are very many suspended processes blocking resources. One approach to resolve this problem is to design different workflow process for human-computer interaction that the business workflow process. These both kinds of processes can communicate with each other without blocking resources, but how to that is again out of scope.

The message exchange is supported through the concept of IBM Enterprise Service Bus (ESB). It is implemented directly in WebSphere and is supported in several other products among which is WebSphere Message Broker. These implementations are not very compatible with each other, by the way.

IBM, like the other SOA market players, claims that supports above mentioned SOA standards, but in reality supports functional and interchange compatibility. The reason is that all standards are XML based ones, which means overhead in performance and in traffic. For example, when one service sends a message to another one, first service has to convert the message from its internal representation to XML message, this message should be delivered to the other service, and then the second service has to parse the message and convert it in internal format. If both services are on the same computer then all this procedure, in some cases, can be shifted simply to pointer interchange. WebSphere Message Broker is very typical implementation; its intention is to convert messages from different formats. This product support messages in internal format. Every received message has to be converted in this internal format and only then in target format. XSLT transformations are supported, but WebSphere Message Broker faster work with ESQL transformation – internal language for describing message conversions.

There is no warranty that message interchange between services developed on different hardware/software platforms can be implemented without problems. Our experience shows that at least week is needed to implement such an interchange.

As result of last comments, it is clear that the best environment for business process implementation is homogenous one.

Grid by IBM

IBM started several research projects on Grid computing to formulate its vision on the topic. Initially IBM used Globus Toolkit as an implementation of Open Grid Services Architecture (OGSA) [3]. From the very beginning IBM look on the Grid as an environment for SOA. One successful scientific solution using Globus Toolkit and SOA is the Telescience project [14]. It is in area of Telemicroscopy and integrates remote instrumentation, grid-based distributed computing and data management.

Grid Medical Archive Solution [4] is used in University Health Care System [18] available in Georgia and South Carolina. This system is used to store, retrieve and deliver archived cardiology studies. IBM component is the hardware – IBM eServer xSeries and IBM TotalStorage DS4100 storage servers.

IBM developed for Zurcher Kantonalbank a cluster solution that accelerates risk assessment [15]. This solution uses Sun Grid Engine [16] and IBM Clusters 1350 servers. Solution of the same kind is advertized the IBM deployment of IBM hardware (IBM eSeries xServers, IBM SAN Dwitch device, IBM TotalStorage 4400 storage server, and IBM TotalStorage 3584 Ultrium Ultra Scalable Tape Library) for LHC tier-1 data center at FZK [17]. In IBM Grid and Grow for actuarial analyses [6] the grid element is IBM eSeries BladeCenter with some kind of grid middleware.

In all above mentioned solutions IBM Grid component is comprised of IBM BladeCenter Server, and the grid middleware IBM Tivoli Workload Scheduler LoadLeveler. This configuration is applicable to data intensive grid computing [5].

IBM defines Grid infrastructure objectives in [19] as:

- Creates a virtual application operating, storage, and collaboration environment;

- Virtualize application services execution;

- Dynamically fulfils requests over a virtual pool of system resources;

- Offers an adaptive, self-managed operating environment that offers high availability.

In [19] the following grid solutions are represented:

- Network Grid Infrastructure for File Downloading. A network of distributed file servers enables an optimized download upon a client request for a particular file. The system is built as a grid of dispersed download servers. This solution primarily addresses the enterprise optimization business driver. This is the first IBM project on Grid computing. Grid vision presented here is very much like that one in [20]. From architect point of view Grid consists of Grid coordinator and Grid nodes. Grid coordinator (downloadGrid management center) accepts jobs and distribute them work nodes. In this case the job is to download some file from the repository (Registration Module & Data Unit Distribution Module). The Grid coordinator creates optimized downloading plan using Feedback and Statistical Module and Optimized Plan Module. The system information database can be replicated by Replication Module. This system implements GSI as security mechanism.

- Public Health Data Grid. A network of servers stores digital mammographies that are associated with explanatory notes and comments about each image. The system is built up as a grid-enabled federated database. This solution primarily addresses the productivity and collaboration business driver. The Grid element is Globus Toolkit 3.0

- Computational Grid Infrastructure for the Upstream Oil and Gas Industry. A network of servers provides a high-performance virtual cluster to process oil field exploration applications, such as upstream petroleum processing. This solution helps to accelerate the business process and to optimize the enterprise. In this solution Globus Toolkit is used, but job submission is organized through Grid Portal. The last one automates user interactions with the Grid environment.

- Industrial Sector Data Grid. A network of data servers enables users to access heterogeneous files in different systems, regardless of where they are. This solution primarily addresses productivity and the collaboration business driver. This solution is for data intensive Grid computing how is presented in previous examples.

- Computational Grid Infrastructure for Trading Analysis. A network of desktops and servers helps to gain the necessary computing power to run long and complex algorithms that are required for trading analysis. This solution helps to accelerate the business process and to optimize the enterprise. In this example IBM WebSphere MQ is used to connect client software to DataSynapse GridServer. The last one is cluster management software. The most important idea here is that IBM WebSphere MQ can be used as mediator in standard client-server architecture between the client, Grid software and the server.

- Computational Grid for the Consulting Industry. A solution aims to release the computation consumption of an IBM mainframe by submitting heavy algorithm jobs to grid nodes. This solution addresses IT optimization as its primary business driver. This solution is like one presented above.

In [21] is stated:

"Grid computing, most simply stated, is distributed computing taken to the next evolutionary level. The goal is to create the illusion of a simple yet large and powerful self managing virtual computer out of a large collection of connected heterogeneous systems sharing various combinations of resources."

This idea for resource virtualization is the mail stone for IBM. It is not so important for IBM how Grid computing is implemented and what standards are satisfied – the most important is fundamentals of Grid computing to be followed. These fundamentals are not very different from those ones presented in [22]. One interesting concept introduced in [21] is Intragrid vs Intergrid in the just a same manner as Intranet vs Internet. By default IBM and the other commercial Grid solutions vendors view cluster computing as Grid computing. This vision is very well illustrated in the above examples.

SOA and Grid

In [23] Grid technology and SOA are presented as merging approaches from the architecture view point. Grid application architecture is presented in Fig. 1.
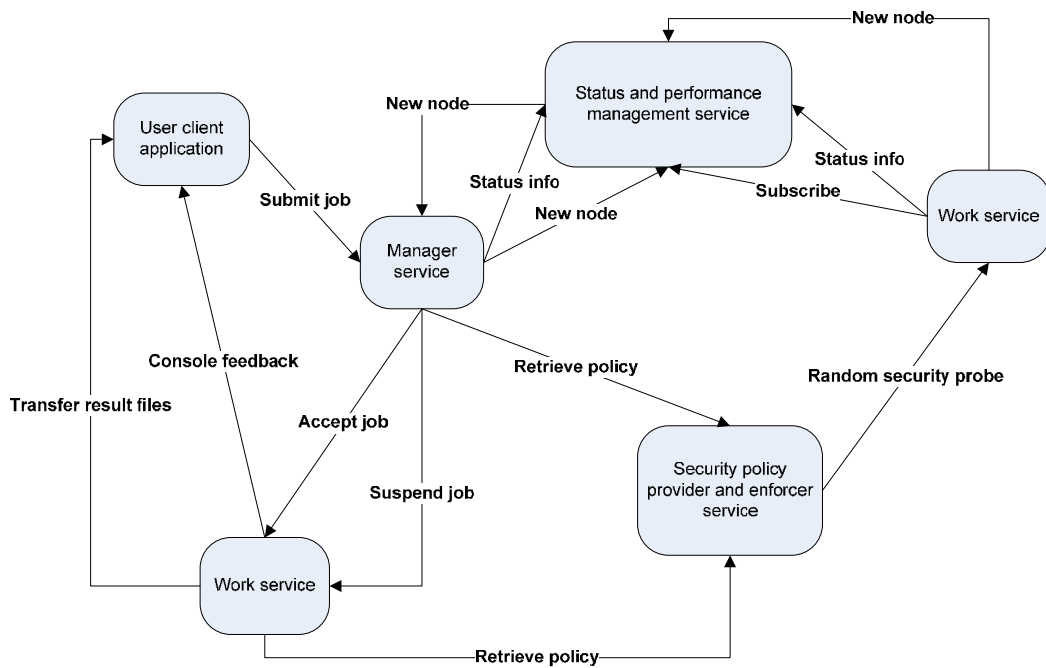
Fig. 1. Grid SOA application architecture

Merging Grid technologies with SOA means Grid application/system software to be developed (reengineered) in SOA. SOA standards are accepted and modified for Grid Computing by GGF. Starting from Globus Toolkit 3 SOA standards are implemented in the core services. The opposite process is going in IBM. The software tools supporting SOA standards - IBM WebSphere are incorporating Grid technologies [24]. IBM WebSphere Extended Deployment implements Grid concepts as resources virtualization. WebSphere Extended Deployment creates an On Demand Business infrastructure that spans both transactional and long-running workloads. This integrated environment dynamically determines how to optimally allocate application-infrastructure resources based on customer-defined business goals.

For IBM the corner stone is SOA and Grid is an infrastructure helping to realize the full benefits of SOA. What a kind of Grid and what a kind of software will be used is not so important for IBM. WebSphere Extended Deployment is in reality cluster management software that can be extended to use external services. The most important is that Grid standards are accepting and extending SOA standards.

There are two main points in using SOA for Grid:

- How SOA could be supported by Grid?
- Can Grid be reengineered in SOA?

SOA standards are: BPEL, WSDL, UDDI, SOAP, and XML. This means that these standards have to be implemented in Grid. Processes running on Grid have to be specified in BPEL and orchestrated by specialized nodes. Such candidate orchestration software for these nodes can be WebSphere Process Server, JBoss, Oracle BPEL Process Manager, or BEA WebLogic. The most advanced orchestration software is WebSphere Process Server. It can be

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integrated in Grid environment, but it works in combination with other WebSphere products, so it is hardly to imagine that nowadays WebSphere Process Server can be the software for the orchestration node. Oracle BPEL Process Manager and BEA WebLogic have just a same problem – they are not open enough to be well integrated with software not deployed by their vendors. The only realistic candidate is JBoss. Its problem is that it is not mature enough for serious usage.

It a standard for repositories to support WSDL and UDDI, so services could be registered and searched in Grid. The problem from mediation point of view is how effectively to support message exchange between services. ESB concept is based on the fact that it works in cluster where the communications are highly reliable and are at a level higher than inter cluster exchange. It is clear that first SOA applications will be cluster based.

Grid is diverging to SOA support environment, but many more work has to be done before we will have an environment in which processes are orchestrated on overall Grid infrastructure – when process services are geographically distributed.

Nowadays SOA is an ultimate architecture for development of distributed system. Grid software is older and does not have this architecture. It is possible to develop adapters for Grid software and start orchestrate it, but it is not sensible, because it would not run effectively. The only way is to redevelop Grid software in SOA which is very expensive.

Conclusion

What is the realistic scenario for development of SOA based Grid application? First, processes have to be executed as much as possible on one cluster. A worker node has to be specialized for orchestration with software like JBoss. Application software has to be reengineered for SOA. For this reengineering currently available tool like that one of WebSphere can be used. Some kind of ESB has to be developed for message exchange between services in the cluster. This ESB like software can be MPI based.

At University of Sofia we are doing research on deployment of SOA based applications for Grid. Currently, we are investigating deployment of BPEL processes to JBoss. There are many technical problems. Our intention is to demonstrate some SOA based CMS software.

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Distributed control systems for modernization of JINR linear accelerators and HV power supplies of polarized deuteron source POLARIS

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The main features of the described control systems are: the multi-level multi-channel client-server architecture based on TCP/IP asynchronous sockets, autonomous low level servers, object oriented programming, runtime configured from databases.

We have used these principles to develop synchronization systems to modernize JINR linear accelerators LIU-3000 (LPP), LINAC-800 (LNP), LU-20 (LHE), as well as the HV power supplies control system for the polarized deuteron source POLARIS (LHE) and the data acquisition system for Free-Electron Maser at LIU-3000[1] (LPP) in the frames of CLIC collaboration [1].

1. Introduction

Successive modernization of the linear accelerators is carried out. New control systems have to be developed without exploitation stopping. Some equipment of the facilities is obsolet, some has been modernized. So the control system should unite different control and diagnostic devices of several generations. Repetition rate of the accelerators is not high (several Hz) whereas the delay time scales of synchronization signals are extremely wide (from 1 ns to hundreds of seconds). So, the optimal solution for the control system is application of the universal synchronization system and distributed architecture based on independent low level subsystems with autonomous servers.

The same architecture is used for HV power supplies control of polarized deuterons source POLARIS and in a data acquisition system (DAQ) of the experiment on life time estimation of an acceleration structure for future linear collider CLIC.

2. Basic principles of control system construction

Concepts of the developed control systems are:

- distributed client-server architecture based on asynchronous sockets using the TCP transport protocol;
- multi-level multi-channel control - a task is divided vertically (among a client, server and controller, if it is active) and horizontally (among independent low level subsystems, crates, blocks and channels);
- each low level subsystem has an autonomous server capable to support an independent action of the diverse subsystem equipment with different speed and to provide information enough for an operator;
- parameters are saved and the system runtime is configured from the remote or local database or (.INI) files depending on the system complexity;

- object oriented programming approach - runtime creation, activation/inactivation of controllers, blocks and channels objects.

There are two logical levels in the control systems, which are realized as:

common level	unique level
universal synchronization system TCP server socket dispatcher in TCP/IP controller TCP server socket dispatcher in DAQ server TCP client socket dispatcher in client	special parts of client and server programs for original control equipment or original communication protocol (ISA, USB, TCP).

3. Synchronization system
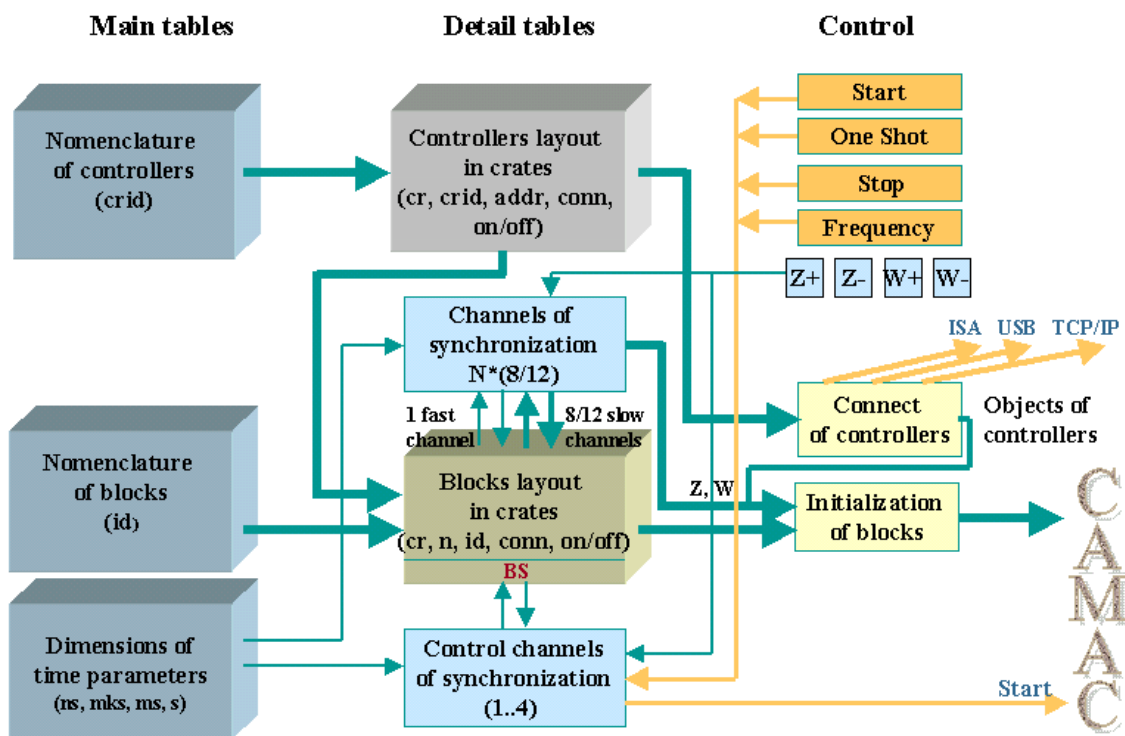
Fig. 1. Synchronization system: database structure and hardware control

Basic features of the synchronization system construction (Fig.1) are:
- each CAMAC crate is managed by an ISA, USB or TCP/IP controller;
- start is coordinated with AC circuit phase to reduce electromagnetic interference in measurement circuits and rise stable equipment action;
- each channel pulse delay is a tandem of slow delay (step 100 ns) and fast delay(step 1 ns), covers the range up to 429 s; pulse duration - from 100 ns to 6.5 ms;
- several variants of parameter sets can be saved in a remote database (SQL server);
- system parameters can be configured only in a database without hardware operation.

4. TCP/IP CAMAC controller for distributed control systems

TCP/IP CAMAC controller (Fig. 2) features are:

Network interface	Ethernet 10/100 Base-T
Network protocol	TCP/IP v4, TCP/IP v6
Network services	Telnet, FTP, HTTP
Transfer speed	100KB/sec (from CAMAC to remote host, block transfer mode)
Platform	TINI Platform: DS80C400 8-bit network microcontroller, real-time clock (RTC), 1 MB flash ROM, 1 MB static RAM for data, Ethernet PHY
OS, user applications	TINI OS, Java language.
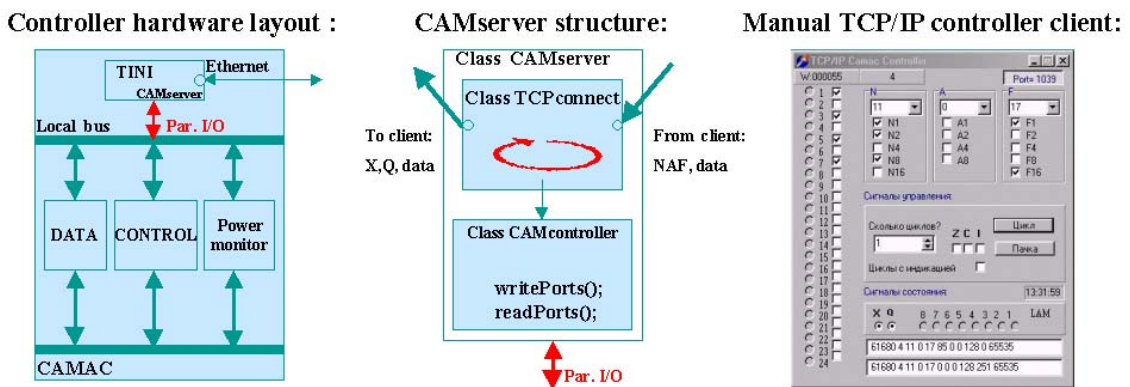
Fig. 2. TCP/IP CAMAC controller for distributed control systems

The Tiny InterNet Interface (TINI) developed by Dallas Semiconductor [2, 3] is a microcontroller-based development platform that executes the code for embedded web servers. The platform is a combination of broad-based I/O, a full TCP/IP stack, and an extensible Java freeware runtime environment including TINI classes that simplifies development of the network-connected equipment.

5. TCP/IP control of a 12-channels HV power supply of polarized deuterons source POLARIS

The HV client (Fig. 3) can asynchronously turn on all HV channels [4] by a HV voltage button, or turn on one channel and change its voltage (+/-12 kV). The HV client controls the voltage step, Umin, Umax, shift of zero, Kadc in every channel. It sends 12 DAC voltages to the server in CR_DAC_packet on one channel parameters changing.

The HV server is autoloading server. On connecting with the HV client (by IP, port) it begins to measure 12 ADC voltages (+/-12 kV) and send SR_ADC_packet to the HV client every 500ms.
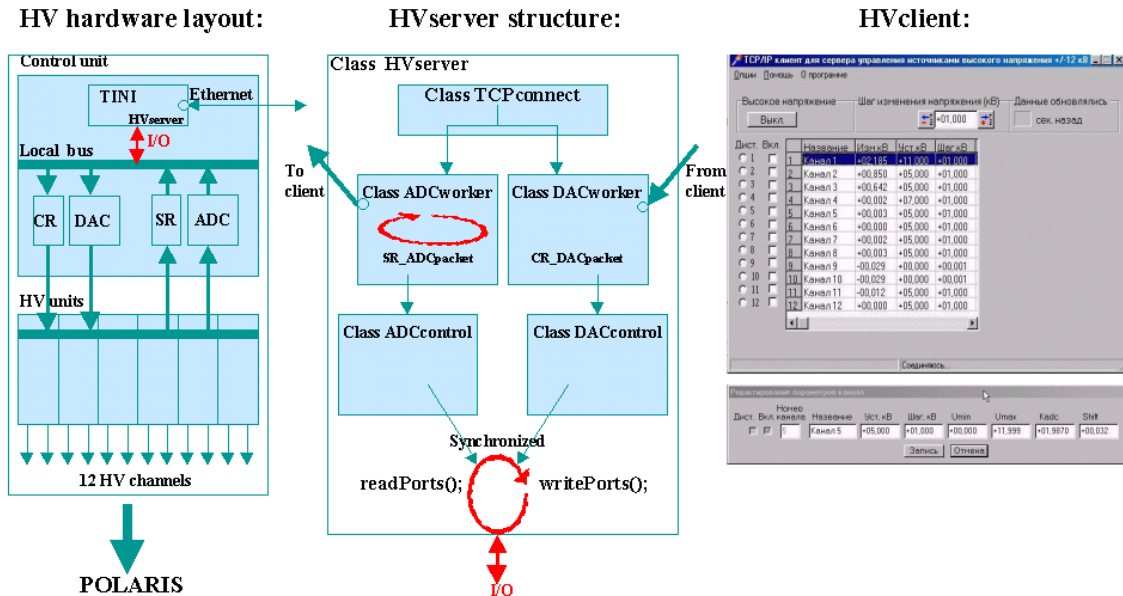
Fig.3. TCP/IP control of a 12-channels HV power supply of polarized deuterons source POLARIS

6. Data acquisition system for lifetime study of CLIC acceleration structure at LIU-3000

We have developed and tested the distributed-asynchronous-object-oriented multi-channel system of data acquisition from the accelerating installation constructed on the client-server principle [1, 5, 6, 7]. The measuring complex is divided into independent bottom level subsystems. To be flexible and universal the system layout takes into account the functional as well as the division on the measurement signal nature:

- permanent signals with high accuracy are measured by a slow integrating ADC (12 bits, 3 ranges of conversion time) with bipolar commutator;
- long pulse signals, where the amplitude but not waveform is important, are measured by multi-channel ADC (10 bits, 16 channels, conversion time 20 mks) with sample-and-hold, which snaps up on strobe pulse;
- short pulse signals about 100 MHz do not require high accuracy, where the amplitude and waveform are important, are measured by fast ADC (8 bits, 2 channels, 10 ns conversion time, 128 memory points per channel) with HF commutator;
- high precision pulse signals, where high discretisation frequency and high accuracy are important, are measured by digital oscilloscopes, p.e. Tektronix TDS3032 (bandwidth 300 MHz, 2 channels).

The low level subsystem has a server capable to support independent action of the diverse subsystem equipment with different speed and fulfil the signal math preprocessing with respect to the nature of measurements and functionality of each subsystem. Though the DAQ servers are aimed at solving the functional task of their own subsystem, they have been still done universal and easy configured to measure new signals with similar parameters. All the servers are equivalent for the client.

The data acquisition information is concentrated only in the client which protocols the run history parameters. These are IP-addresses of servers, quantity of currently connected servers, data recording conditions, current pulse number. The client organizes data acquisition from the whole installation and it is capable to support data exchange with viable

servers giving an opportunity of consecutive analysis of the cavity deposited energy. The realized principle "one crate - one computer - one server program" allows to reach flexibility, expandability and to have time to process signals from the equipment with different speed at high survivability of the whole system.

The information on the equipment is concentrated only at the server side. The server program is realized by means of objects - instances of class types which are created and configured on-line (an object is a measurement channel). Every server program has a data acquisition block, a math calculation block, a multi-channel graphical recorder, a cyclic stack block and a asynchronous TCP-socket block.

Ability to independent work of servers is the distinctive feature of servers of this DAQ system. High autonomy of the server action is provided not only by interrogation of the equipment, but also by all preliminary processing of the information, its graphic representation, its accumulation in a prehistory of a recorder and in a local cyclic stack. And all the above mentioned is carried out by means of a server. And its efficiency does not depend on presence and efficiency of the client.

All the connected servers begin to work, when there is a pulse: digitizing of pulse parameters in all of the subsystem equipment starts as well as drawing and storing of the information on the pulse in the subsystems. They asynchronously reply to the client with a line of obtained parameters. By the moment of arrival of a starting signal from the next accelerator pulse the servers are ready to work again. The client remembers the reply of each server in a file on the place corresponding to the pulse number and the number of the server, which has sent the reply. In the process of asynchronous answer of all working servers the client forms the total line of current pulse parameters from their answers and saves it on the disk.

Conclusion

Concepts of the developed control systems are:

- distributed client-server architecture based on asynchronous sockets using the TCP transport protocol;
- multi-level multi-channel control - a task is divided vertically (among a client, server and controller, if it is active) and horizontally (among independent low level subsystems, crates, blocks and channels);
- each low level subsystem has an autonomous server capable to support an independent action of the diverse subsystem equipment with different speed and to provide information enough for an operator;
- parameters are saved and the system runtime is configured from the remote or local database or (.INI) files depending on the system complexity;
- object oriented programming approach - runtime creation, activation/inactivation of controllers, blocks and channels objects.

We have used these principles to develop synchronization systems for modernization of JINR linear accelerators: LIU-3000 (Laboratory of Particle Physics), LINAC-800 (Laboratory of Nuclear Problems), LU-20 (Laboratory of High Energy).

We have developed HV power supplies control system for polarized deuteron source POLARIS being used for spin physics experiments at NUCLOTRON (Laboratory of High Energy).

The data acquisition system for the LIU-3000 based on the free electron maser (Laboratory of Particle Physics) has been in operation about 3 years. It is used for

experimental investigation of accelerating structure lifetime at multiple action of powerful 30 GHz radiation pulses carried out in Dubna by the Free Electron Maser group of JINR (Dubna) and Institute of Applied Physics RAS (Nizhny Novgorod) in the frames of CLIC collaboration.

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A modular system of the fast, stackable, adders-amplifiers-discriminators at large scintillator counters for triggering the TRD/ALICE cosmic test facility

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Abstract

An original system concept on the fairly fast rig, unified to perform the mostly used functions of analog channels within conventional detector electronics, is presented.

The concept is based on application of a compact *FAD (Fast Adder-Amplifier-Discriminator)* elementary unit, designed as a system core, allowing an experimenter to compose a modular stack of channels in quantity over the limit assigned per unit.

One *FAD* handles up to 4 detector signals and contains two identical channels, where each channel comprises a linear adder of pulses from the adjacent inputs, an amplifier of the sum pulse, and a leading edge discriminator with an output shaper as well.

An initial series of 10 NIM standard modules, incorporating the *FAD* units of 160 inputs in total, has been implemented and adjusted together with 2 planes of the large scintillator counters. This system is built up to trigger Transition Radiation Detectors (TRD), produced for the ALICE / LHC experiment [1], while verifying the TRD assemblies on a cosmic ray background at a test facility in the Muenster University (Germany).

An experimental investigation of the general system parameters, such as switching characteristics, an effective threshold of discrimination, and a signal charge sensitivity, is also described.

I. Design Motivations

I-1. Experiment-Oriented Specific

The R&D has been initiated by needs of the Front-End Electronics (FEE) to implement a 'Fast Cosmic Ray Trigger' at the TRD/ALICE large scintillator plane-based test facility, that forced to meet the following requirements:
- a low detector output pulse height's mean of ~ 10 mV at 50 Ohm load;
- a minimum FEE share in the total 100 ns TRD trigger budget, filled out with a lot of delays from scintillators, jittered Photomultiplier Tubes (PMTs), FEE, trigger logic, cables, etc.;
- a high density of inexpensive FEE channels, interconnected within the standard modular equipment.

I-2. Technical Wide-Purpose Point

A side-line interest concerns an attempt to elaborate a newly compact and fast basic unit - FAD (Fast Adder - Amplifier - Discriminator) as an elementary but universal-like analog appliance to form the registered detector signals.

II. Objective Features and Bulges

The main FAD's design objective is to achieve some definite features of projected instrumentation with the bulges on a similar equipment, applied for experiments in physics. The proper items are enumerated below.

II-1. Functional Aspects

a. The combined-in-each-channel   functions of 2-input linear adder,   sum's amplifier, and
    leading edge discriminator.
  F.i., in comparison with the widespread product from [2,3], these functions jointly provide:
    - an extended dynamic range of incoming signals to be processed ;
    - a better signal to noise ratio at the discriminator's input ;
    - a suitable, "analog-like", 'OR' of 2 signals at channel inputs directly;
    - a feasibility to discriminate the sum of signals from both sides of a scintillator strip.

b. The high-speed analog inlets to accept fast detector signals.

c. The simplest trigger pre-logic as 'OR' across all stacked FADs.

d. Compatibility to different low-voltage (LV) and high-voltage (HV) detector options
    due to an input impedance selected and the serial HV Capacitors embedded.

 II-2. Structural / Instrumental   Aspects

a. The portable, autonomous, and low power basic unit (FAD).

b. FAD's unification for a feasibility to aggregate a number of basic units
    within front-end modules and extended systems.

c. Commercially available and inexpensive components in use.
    F.i., in comparison with ASD [4], as a Custom Integrated Circuit,   this bulge on ASD
    might give an opportunity to save time under small-scale FEE production [5].

d. A simple interconnection of channels up to clusters with the same threshold setting.

e. The printed curcuit board's (PCB's) power and dimension,
    compatible with specifications of the miscellaneous standard buses.

III. The FAD Implementation   and   Performance
        A functional scheme for the basic FAD unit is shown in Figure 1.   The FAD accepts
up to 4 analog pulse signals via HF on-board connectors.   The unit contains 2 identical
channels, where each channel comprises a linear adder for 2 signals from the adjacent
inlets,   a fast amplifier of the sum pulse, a high-speed leading edge discriminator (LED)
of the amplified sum, and a fast ECL shaper.
        In outcome, 2 differential (+/- DECL) with one positive 'OR' ECL signals are
produced.
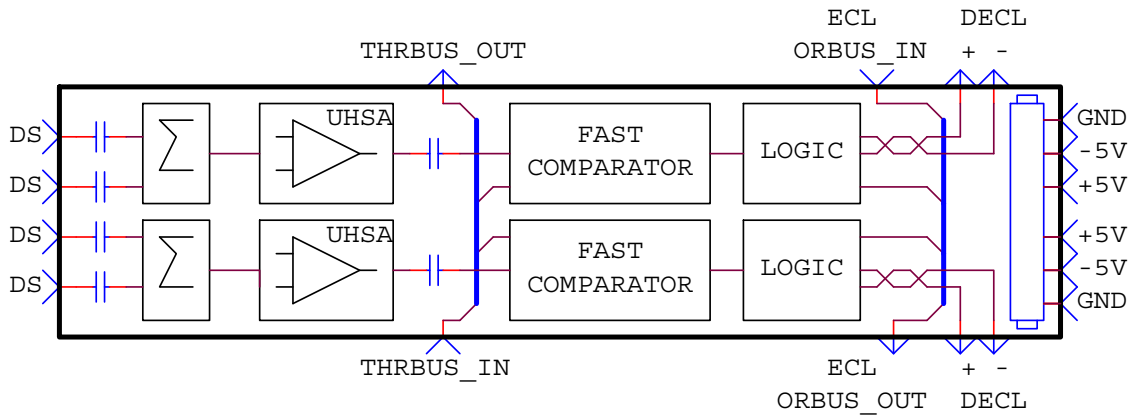
Fig. 1. Functional scheme of the FAD basic unit
(DS = detector signal inlets; UHSA = ultra high-speed amplifiers;
THRBUS, ORBUS = internal 'threshold' and 'OR' bus fragments)

III-1. Major Schematic Points

The advanced SMD integrated circuits, as a 1GHz current feedback amplifier with a slew rate of 5500 V/ms and an ultra-fast voltage comparator, both from the Analog Devices Co.[6], have been selected for the basic FAD components.

The FAD is encapsulated onto a PCB of the 120x30 mm^2 dimensions.

III-2. In-Lab Tests

In order to investigate the most significant parameter of discriminator's sensitivity, some preliminary in-lab measurements with a high-precision pulse generator were performed.

First, the correlation between a threshold voltage setting for amplified input signals, Uset, and a referred to input effective threshold voltage of discrimination, Ueft, had been obtained.

It's known that U_{eft} would be defined as a minimum signal amplitude, triggering a discriminator under applied U_{set}. In case of amplifying U_{eft} with a gain factor G, the compared variables GU_{eft} and U_{set} don't ever amount to the same, and their difference trends to the more essential gap when the smaller and the shorter signals become [7].

The U_{eft} versus (vs) U_{set} dependence must be found as a linear plot. In fact, the test measurements were performed for incoming triangular-like pulses of equal edges and a fixed FWHM =10 ns, under the selected amplifier's gain of 20 dB (10).

Results are presented in Figure 2.

The observable difference between GU_{eft} and U_{set} originates from a certain minimum of an "effective charge" Q_{eft}, which has to be carried with an incoming pulse in order to reach U_{set} at an equivalent comparator's capacity c_{cin}, and then to trigger the scheme by some additional charge Q_{tr} :

$$Q_{eft} = c_{cin} U_{set} + Q_{tr} \qquad (1)$$

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Fig. 2.
Effective threshold voltage
vs threshold voltage setting
for triangular-like input signals
of 10 ns FWHM and edges,
Gain = 20 dB (10)
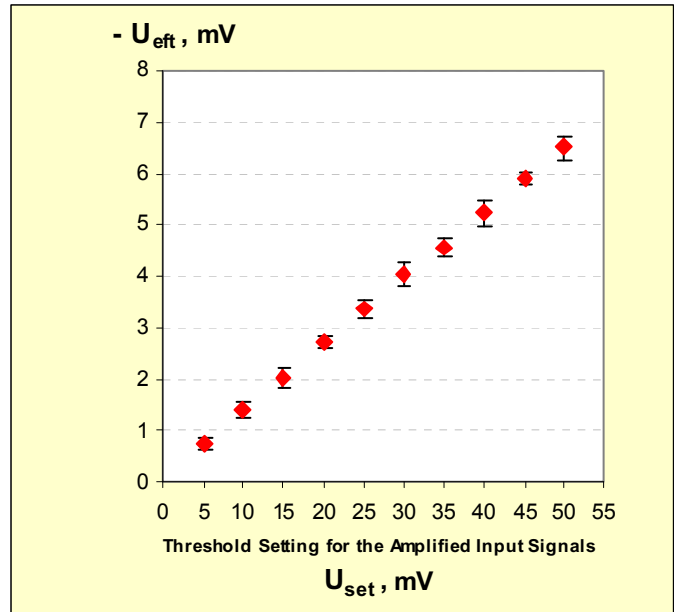
The Q_{tr} constant would be taken for a very significant, integral parameter of the tested schematic sensitivity. This is hard to measure Q_{tr} directly, but it could be inferred from the data on U_{eft} and the known time parameters of discriminated pulses.

In our case of fitting the pulses with an isosceles triangle-like shape, it's feasible to calculate a full electric charge Q_{pef}, carried by every pulse with the U_{eft} amplitude and τ edges, as a time integral of the pulse current $i_p(t)$ thru the FAD input resistance r :

$$Q_{eft} \cong Q_{pef} = \int_0^{2\tau} i_p(t)\, dt = \tau\, U_{eft}\, r^{-1} \qquad (2)$$

The calculated Q_{eft} values vs U_{set} are given in Figure 3.

Fig. 3.
Effective charge
vs threshold voltage setting,
Gain = 20 dB (10)
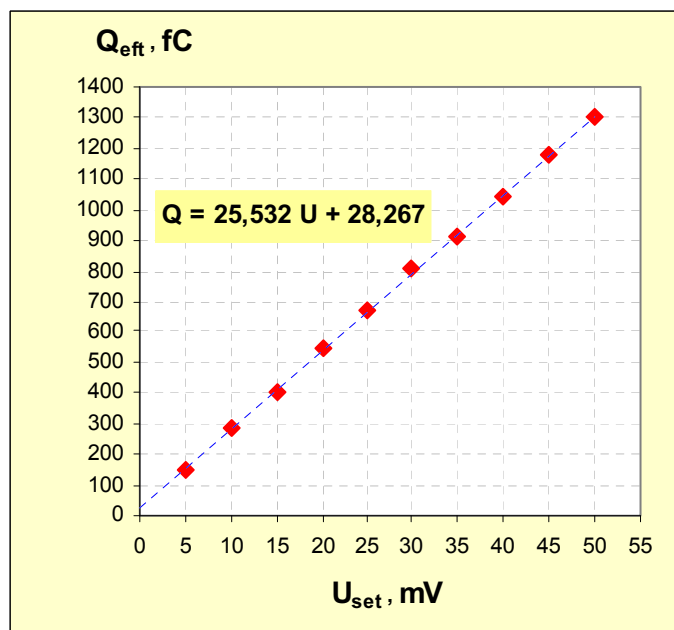
Q = 25,532 U + 28,267

An implicit linear Q (charge) vs U (voltage) fitted dependence corresponds to the analytical expression Q = 25,532 U + 28,267. A comparison of this formula with the equation (1) allows one to evaluate the sought FAD charge sensitivity as about 28,3 fC.

The general FAD parameters' list, with some necessary notes on the right, is given below.

DS Inputs:

Resistance	Ohm	50 or 100*	*for > 5VDC bias ref. ground
Polarity of signals	negative		
Gain factor (G)	dB	20 or 26	setting with on-board jumpers
Pulse height sweep	V	5	recommended as maximum
HV, DC decoupling protection	kV	2*	absolute maximum

Switching Characteristics:

Signal bandwidth (rise time)	MHz	130 (2,7 ns)	at G = 20 dB
Signal input to output delay	ns	20	
Channel's output signal width	ns	50	fixed as mounting option
Load Rate	MHz	15	

Threshold Limitations:

Input signal charge sensitivity	fC	28	
Minimum V-threshold at G = 20 dB	mV	4	if cabled (not on-detector placed)

Power Requirements:

- 5 VDC	mA	170
+ 5 VDC	mA	80

IV. The FAD-based Modular System at the TRD/ALICE Cosmic Test Facility

The Transition Radiation Detector (TRD) is not only one of the most important parts for the ALICE installation at the Large Hadron Collider of CERN (LHC / CERN) [1], but also one of the biggest TRD-like detecting instruments all over the world.

The TRD/ALICE contains 18 huge supermodules, each of about 7-meter length, to be used as a crucial component of the ALICE tracking and triggering system, allowing separation of high momentum electrons from pions in outcome of nuclei collisions. In order to be ensured with a full performance of supermodules, before placing ones down into the ALICE cavern at LHC, some preliminary tests are required to verify the produced TRD assemblies.

In this context, the most convenient and widespread way, while testing the TRD, concerns to application of a cosmic radiation as the unique and natural source of single charged relativistic particles, mainly muons, with ~150 $m^{-2}s^{-1}$ flux upon a sea level.

A general layout of the similar TRD/ALICE cosmic test facility, constructed at the Muenster University (Germany), is shown in Figure 4. Its detecting equipment, intended to register cosmic muons, combine two planes of large scintillator slabs, each of ones is attached to a rather magnet-proof, fast, and low noise PMT of the "FEU-183" type.
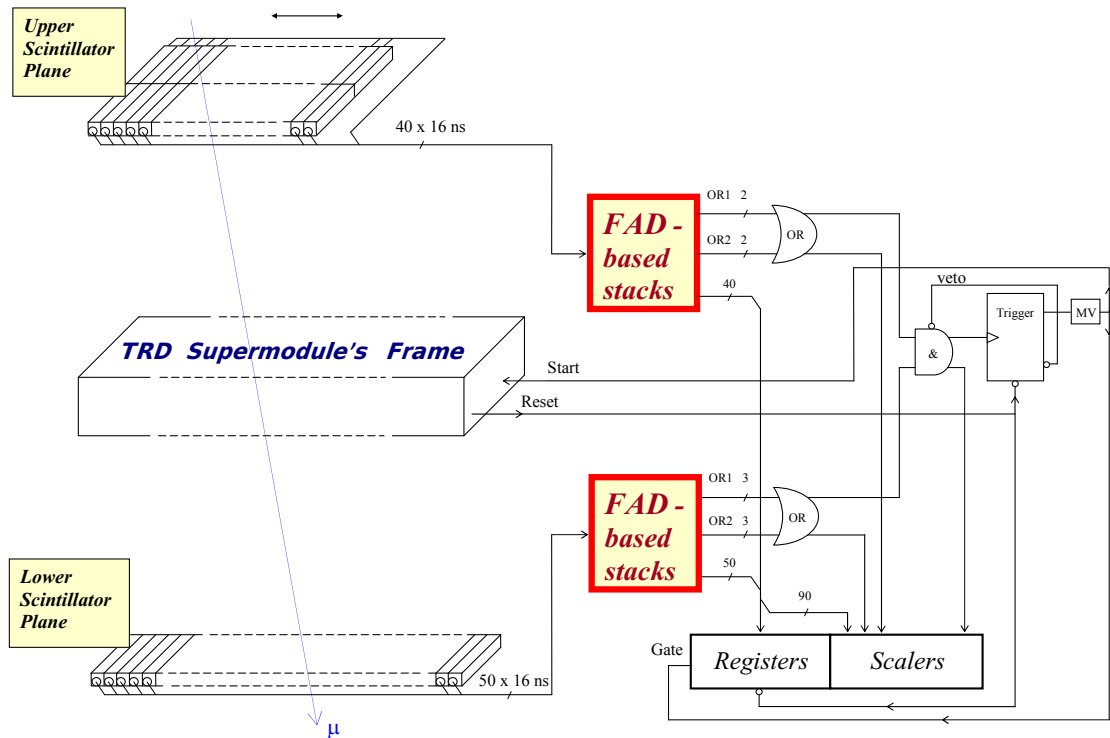
Fig. 4. General layout of the TRD/ALICE cosmic test acility
(MV = a monostable multivibrator to generate the 'Start' and 'Gate' signals)

A lower, motionless, scintillator counters' plane covers closely all space under
the whole supermodule's frame. In opposite to the lower plane, an upper one is fixed
on a movable platform over that frame, thus allowing to investigate different parts of
the tested TRD step by step. Besides, the upper plane consists of not one but two
counting rows, getting a wider acceptance for the cosmic rays in full accordance with
a trapezium-like geometric shape of the TRD/ALICE supermodule itself.

Both planes compose a hodoscope system of scintillator counters with
about 100 channels to produce and transmit the PMT signals, those require for
arrangement of the FAD units in a proper quantity.   In addition to the FADs, some
conventional elements of logic are needed to trigger the TRD on any coincidence of
signals   from the lower and upper planes, as well as to register and count the
PMT signals (Figure 4).

Because of a small value of the cosmic flux, the test facility triggering goes by
muons with a low estimated rate of $\sim 30\,\mathrm{Hz}$.   However,   there is a hard   timing
challenge of fast measuring a signal, induced on the TRD pad plane, so a total delay
from the pad signal up to the TRD trigger ('Start' in Figure 4) should not exceed 100 ns as a
tough budget. And, as it follows from the general FAD parameters' list above, a sought
solution can be successfully reached with the unique 20 ns of FAD's internal delay.

To implement the test facility with   lots of   the FAD units   in specified
quantity, an idea of the stackable FAD's structure has   been accomplished   while
designing and producing an initial series of 10 NIM standard modules, where each
one incorporates four FADs.

A functional scheme, as well as a front panel guide of the FAD-based NIM
module, are demonstrated in Figure 5.
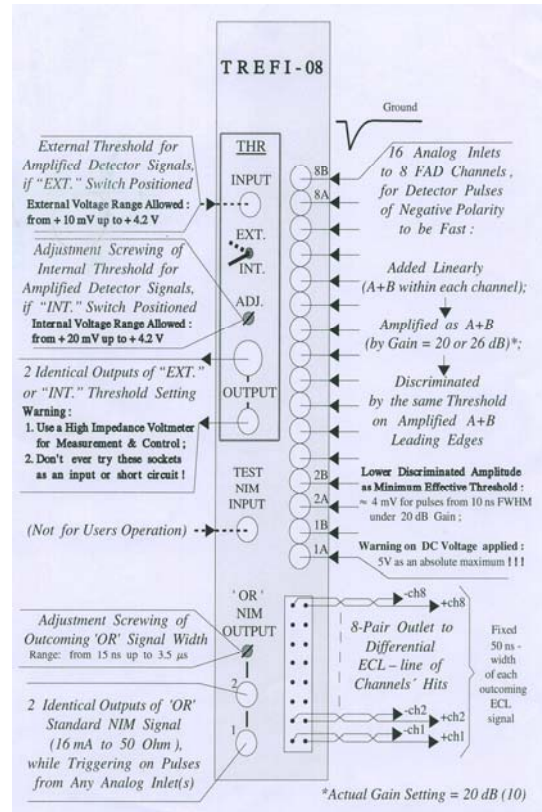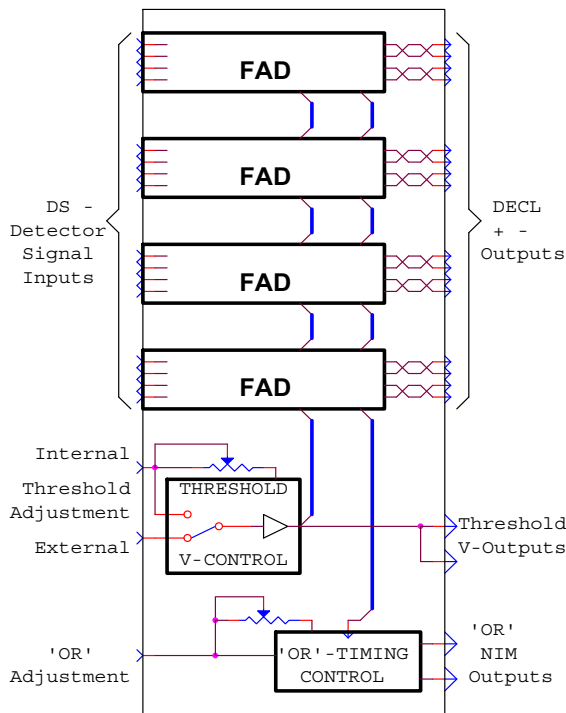
Fig. 5. Functional scheme and front panel guide of the FAD-based NIM module

As it follows from Figure 5, each of the NIM modules includes in its composition, besides 4 FADs as basic units stacked, some additional schemes for precision setting a voltage threshold and time parameters of two identical, NIM-level, 'OR' output signals.

Another point, in development of the stackable idea, is a feasibility to align any bank of the modules into a system row, operating under the same voltage threshold. This option goes right if the first module of a needed row is set with an 'Internal' position of the threshold control switch, while other modules, under 'External' switching, are tied with the first one and each other thru the 'Threshold Input'-'Threshold Output' connectors by the well known "daisy chain" cabling.

An investigation and a correct fixation of the voltage thresholds, discriminating PMT signals, was needed as the most important procedure over final preparations of the cosmic test facility.

For the first stage of investigation, an amplitude distribution of the PMT signals has been studied for every scintillator counter under the same value of HV powering. Then, in order to reduce an obtained dispersion of signals and to get a homogeneous-like distribution, all counters were divided into 10 groups, where each one has been individually adjusted with its optimum HV value.

Next, a counting rate of cosmic muons versus a regulated voltage threshold was measured by the sampled counter from every mentioned group in coincidence with one accessory triggering counter under a 3-minute exposition (see the scheme in Figure 6).

Two graphic patterns of 10 counting rate diagrams, obtained in result of these measurements, are also presented in Figure 6. Both plots indicate the long and flat plateaux with a distinct separation of a noise (at the left) from a signals' supression (to the right), that allowed an easy selection of operational thresholds in the middle of plateaux.
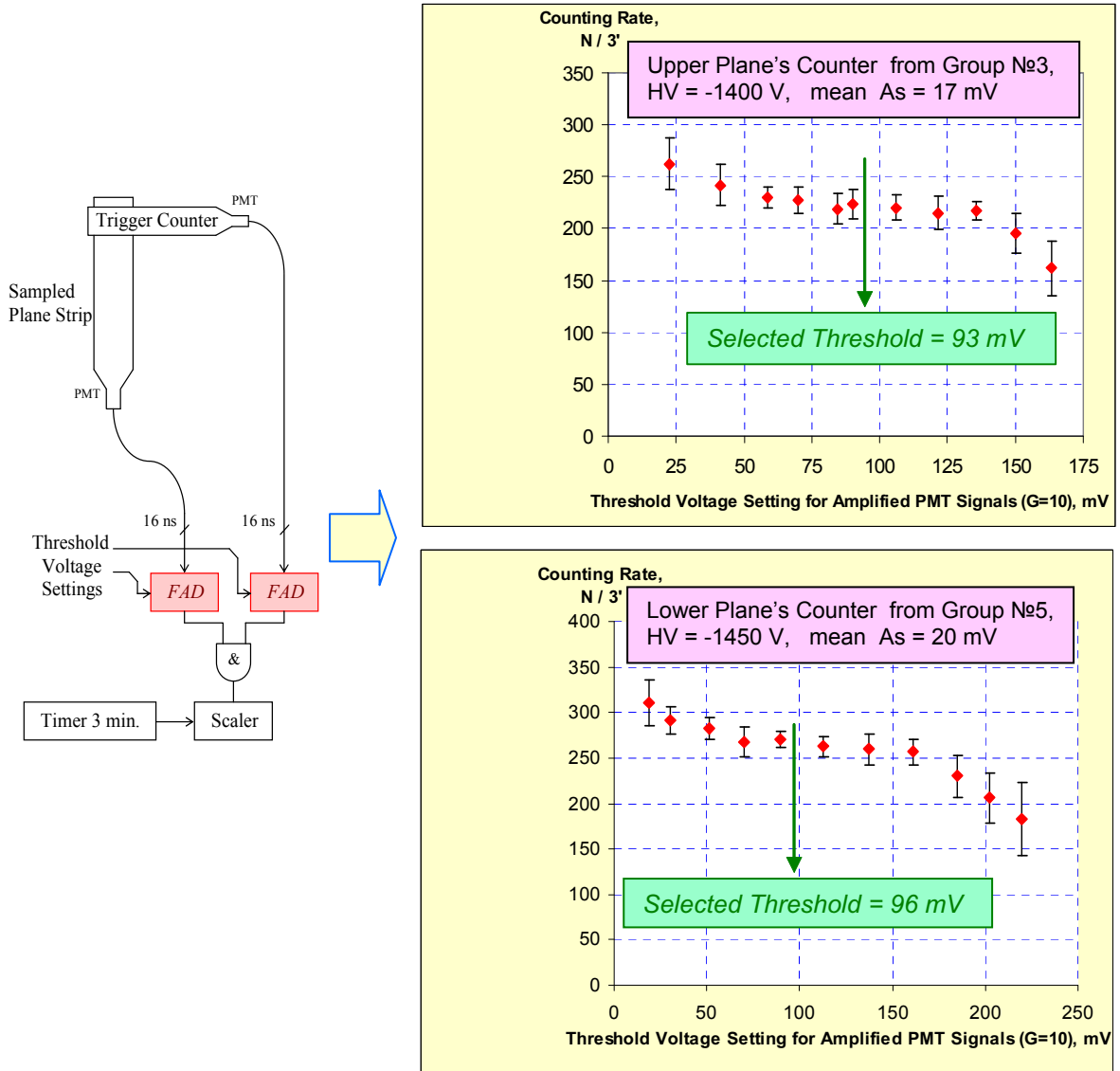
Fig. 6. Experimental counting rate of cosmic muons vs threshold voltage setting for 2 of 10 scintillator counters' groups at the TRD/ALICE cosmic test facility

Thus, for a lower plane counters' group № 5, powered with HV value of -1450 V, the operational threshold of 96 mV has been fixed to discriminate amplified PMT signals of the 20 mV mean amplitude value (As).

Similarly, the 93 mV threshold setting has been selected for an upper plane counters' group № 3, characterized by the mean As = 17 mV under HV = -1400 V.

Figures 7-8 comprise some snapshots over the most significant subjects reported.

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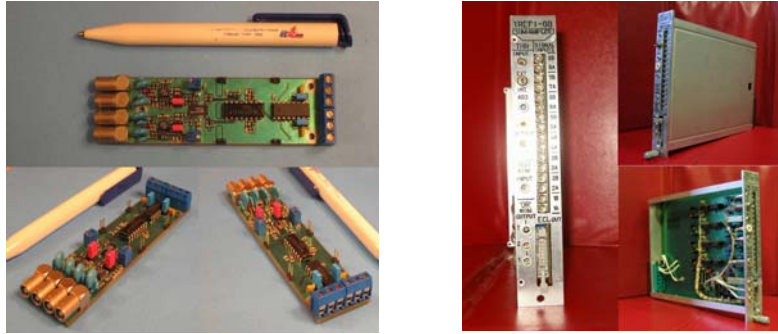
Fig. 7. Appearance of the FAD basic units (left) and the FAD-based NIM modules
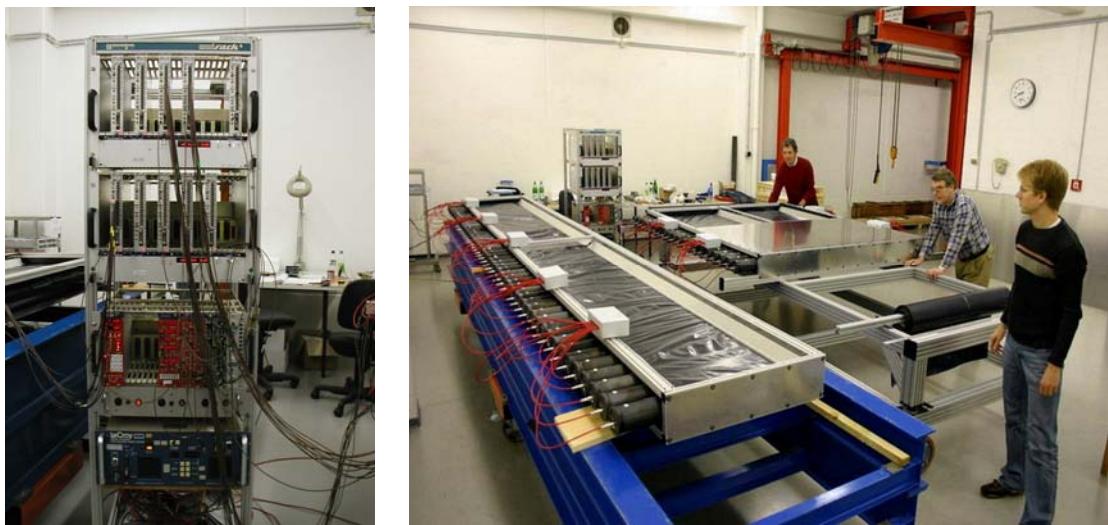
Fig. 8. The FAD-based modular system and the cosmic test facility under preparation

V. Conclusions

1. A distinctive version of the potentially "unified modular system for fast formation of registered detector signals" has been successfully designed and implemented.

2. A list of the system's analog parameters completely meets all of requirements from the TRD/ALICE cosmic test facility, also giving a feasibility of its further development towards performance of the best similar instruments [8].

3. The system should be considered like a pilot experience to any further development of the *FAD* concept. Due to the system architecture and component base stay open, any suggestions for next modifications are welcome.

Acknowledgements

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Ion beams intensity measurements using a magnetic induction sensor

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Abstract

A design of a high-sensitivity monitor for ion beam intensity measurements is presented. The device operates with short spaced bunches.

The monitor intended for nondestructive measurements of intensity of the U-400 cyclotron ion beams, has been successfully tested on the machine. Electronic equipment was designed to strengthen the sensor signal with a resonant amplifier. It can be easily integrated into the accelerator control system. PSpice software was used to simulate electronic circuits of the device. The electronic prototype was successfully tested on the U-400 accelerator. The equipment complex for 8 channels is planned to be manufactured in the near future.

Introduction

The systems for ion beam average intensity measurements based on the magnetic induction sensor have been developed. The sensor is installed outside the vacuum chamber. The system is intended for using in the U-400 cyclotron beam transport channels and also can operate on other accelerators.

- The range of measuring intensities is from 1 to 20 uA of the average current.
- The working frequencies are from 6 MHz to 8 MHz depending on the type of accelerated ions.

The absolute calibration for the given accelerator mode (bunches frequency, bunch length) is made by means of Faraday cup.

The main element of the system is the magnetic induction sensor. The sensor design is shown in Fig. 1.
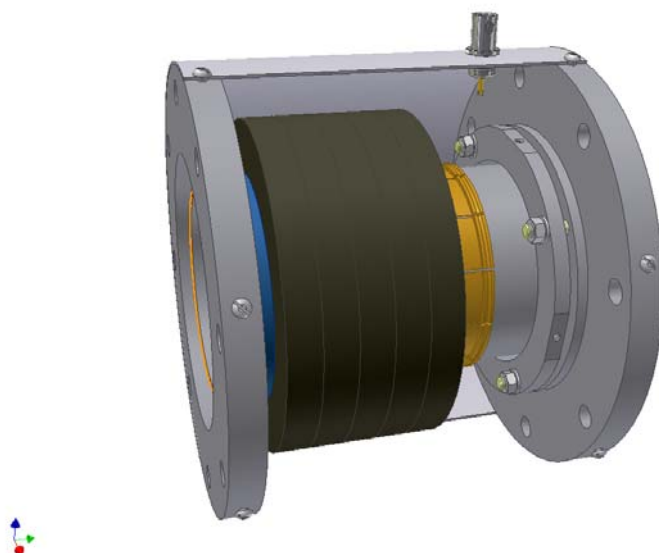
Fig. 1. Conceptual design of the monitor

The principle of the sensor operation is the following. When the charged bunch is moving along the vacuum chamber of an accelerator the image charge equal to it moves in the conductive wall of the chamber. When the image reaches a dielectric gap it becomes charged like a capacitor. The fast discharge of the capacitor through the screen (current bypass) is protected with the ferrite core. After that, there is a relatively slow oscillatory discharge of capacity with a high damping rate. The oscillation should be finished before the next bunch if the parameters of the ferrite core are chosen correctly. The device is directly connected to a coaxial cable and measurements of the signal amplitude in the beginning of a pulse allow one easily to calculate the full bunch charge.

By analogy to the wall current monitor, this device can be named as the wall charge monitor.

The simulation of electronics was made by means of PSpice software. The simplified equivalent electric circuit of the sensor is shown in Fig. 2.
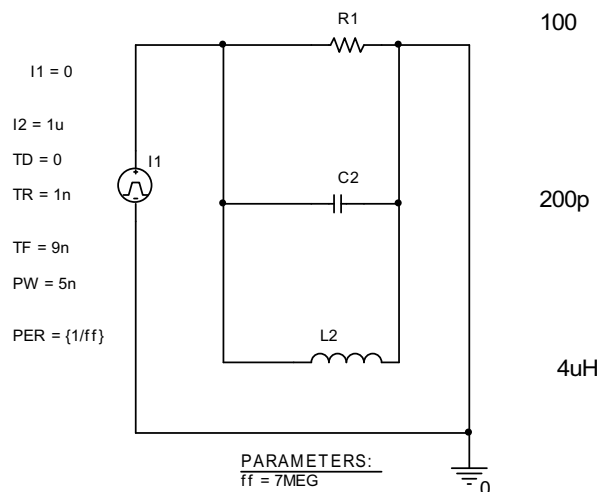
Fig. 2. The equivalent circuit of the detector

In the circuit, L1 is inductance of the ferrite core measured at low frequency; R1 is full equivalent resistance of the ferrite core and coaxial cable. The element parameters shown in the circuit correspond to the experimental device parameters.

Beams of modern heavy ion cyclotrons represent a continuous stream of short bunches with a length of few nanoseconds with duty rate of about 10 [1]. The integrating constant of the sensor does not allow one fully to integrate the current of every bunch. But, as a rule, it is not required because the average current of many pulses is usually measured in cyclotrons.

The calculated signal on the output of the sensor with the average current of 1 uA and 7MHz accelerating frequency is shown in Fig. 3.

The maximum amplitude of the sensor signal with the 1uA average beam current does not exceed 40 uV.
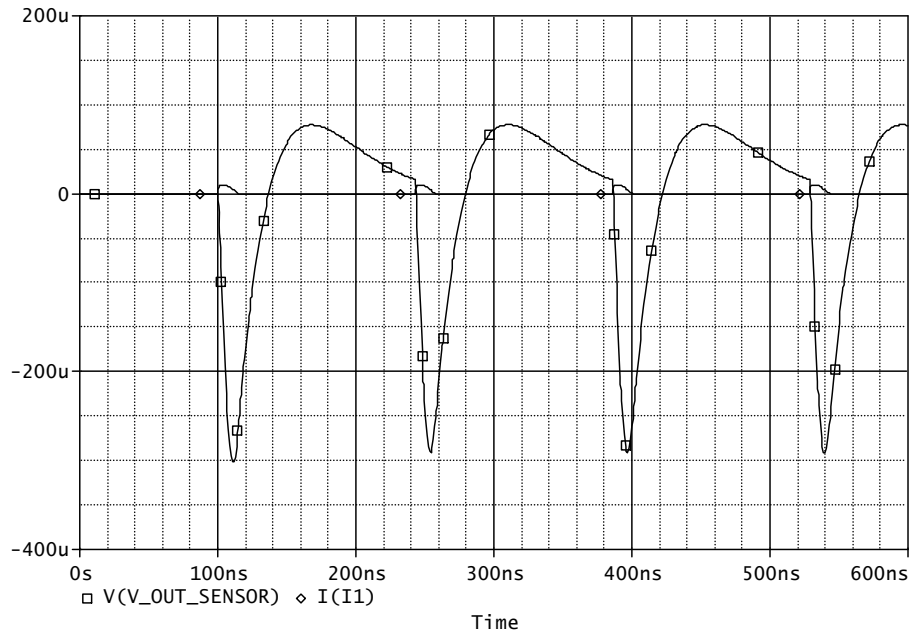
Fig. 3. The calculated signal on the output of the sensor

Variants of electronic processing of the magnetic induction sensor signal

Variant 1: using a preamplifier working on the coaxial cable. This device can be made on the basis of a high speed video amplifier, for example, AD8009. The recommended maximum gain of one stage with the necessary operating speed is 5. High values of input offsets and temperature drifts are usual for high speed amplifiers. Negative feedback realized on the precision operational amplifier can be used to compensate the factors when the number of cascades is increased.

The results of the 3-stage circuit modeling are shown in Fig.4. The input signal in the picture is a current source of 10 uA 10ns long. The scale of the input signal in the picture is increased by a factor of 100.

Fig. 4

199
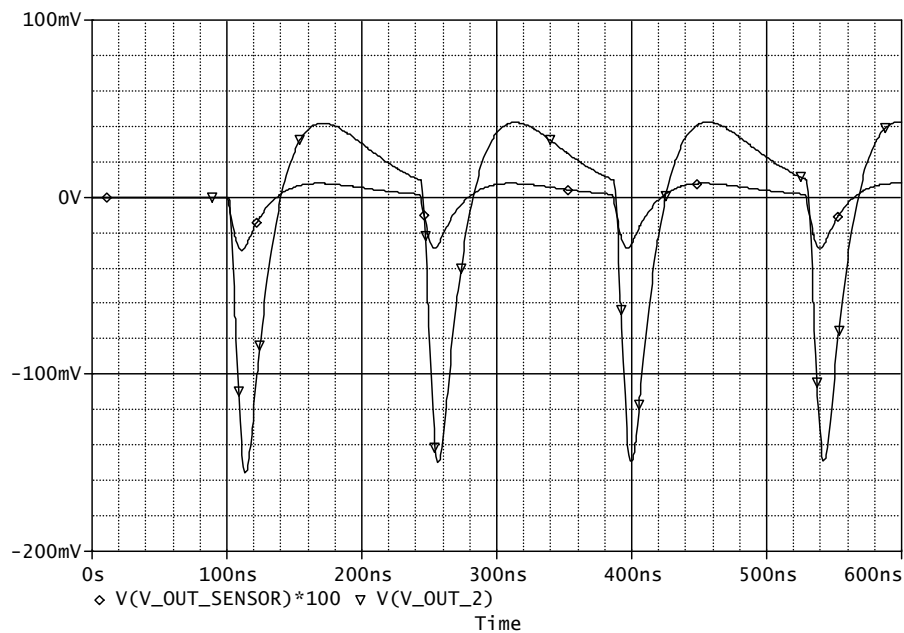
The signal from the amplifier output can be transformed by the detector or processed by fast ADC. In addition, two sensors in the channel can be used to carry out time-of-flight measurements. The variant of the circuit was tested on one of the U-400 channels. The experimental results corresponded to the calculated results.

Variant 2: using a resonant amplifier on the fixed cyclotron working frequency and further detecting and measuring of the signal. The device was developed and tested on one of the U-400 channels.

Variant 3: the radio receiver circuit technique can be used to perform average beam current measurements. It is efficient to use a circuit of a super heterodyne receiver with amplitude modulation. Unlike the household radio receiver, this device does not contain either an automatic gain and frequency adjustment or input resonant amplifiers. A digital frequency synthesizer is applied as heterodyne to measure the whole frequency range.

It is advisable to use the second harmonic of the detector signal to increase the noise immunity and increase the measurements precision. To perform this, we have used the band pass filter tuned to the second harmonic of the whole cyclotron frequency range.

The functional diagram of the device is shown in Fig.5
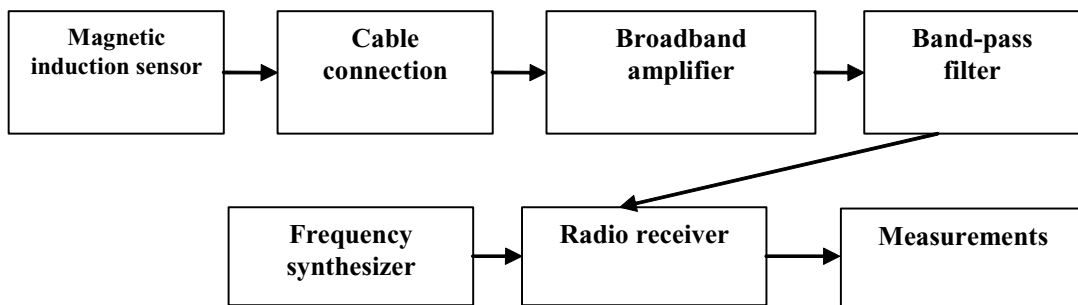
Fig. 5

The simulation results with the beam current scanning are shown in Fig.6.

The model of this variant was tested on the workbench and the results corresponded to the calculations.

Variant 4: synchronous detection of the magnetic induction sensor signal and RF signal of the accelerating field. The model of the synchronous detector circuit based on the balance mixer K174PC1 was used as the detector. The maximum frequency of the input signal for this device is not less than 200MHz. The automatic phase adjustment is required for this variant if the measurement frequency is changed.

The variant of the synchronous detector circuit is shown in Fig.7.
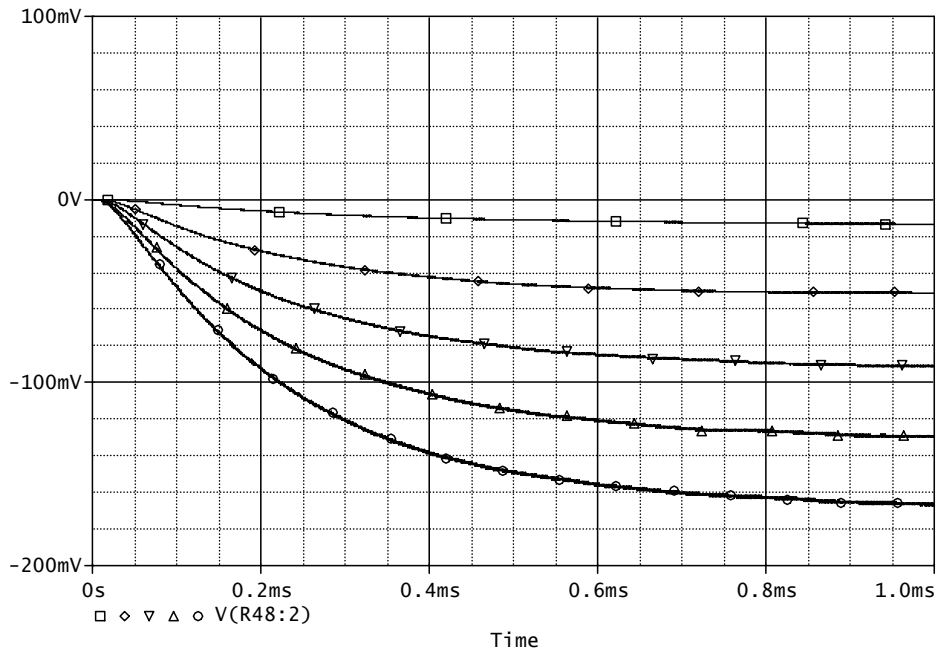
Fig. 6
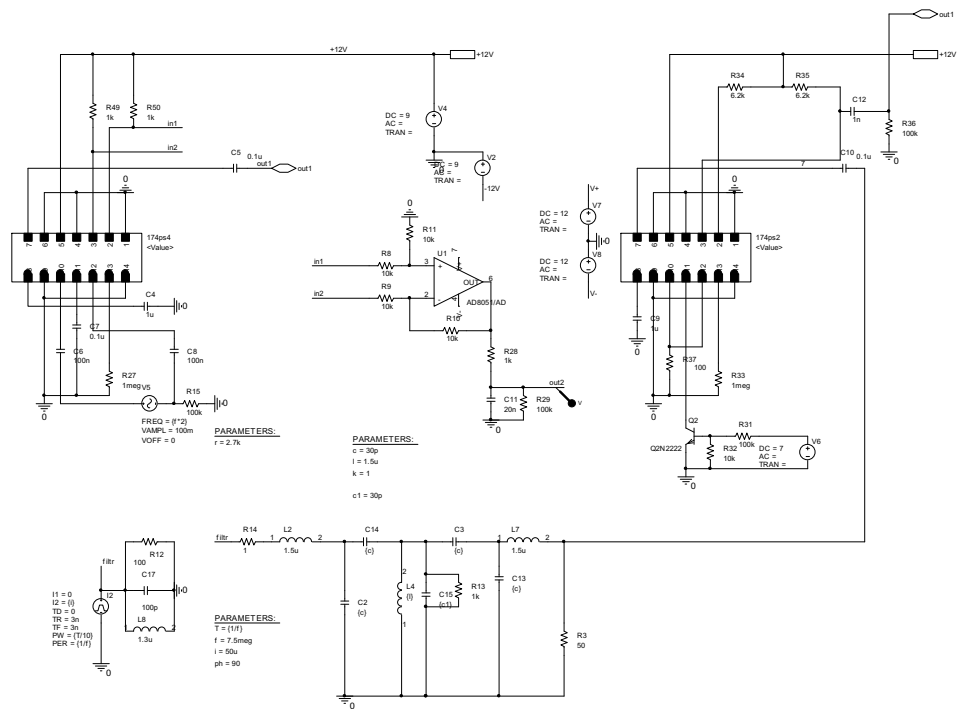
Fig. 7. The synchronous detector

The results of the circuit simulations are shown in Fig. 8.

201
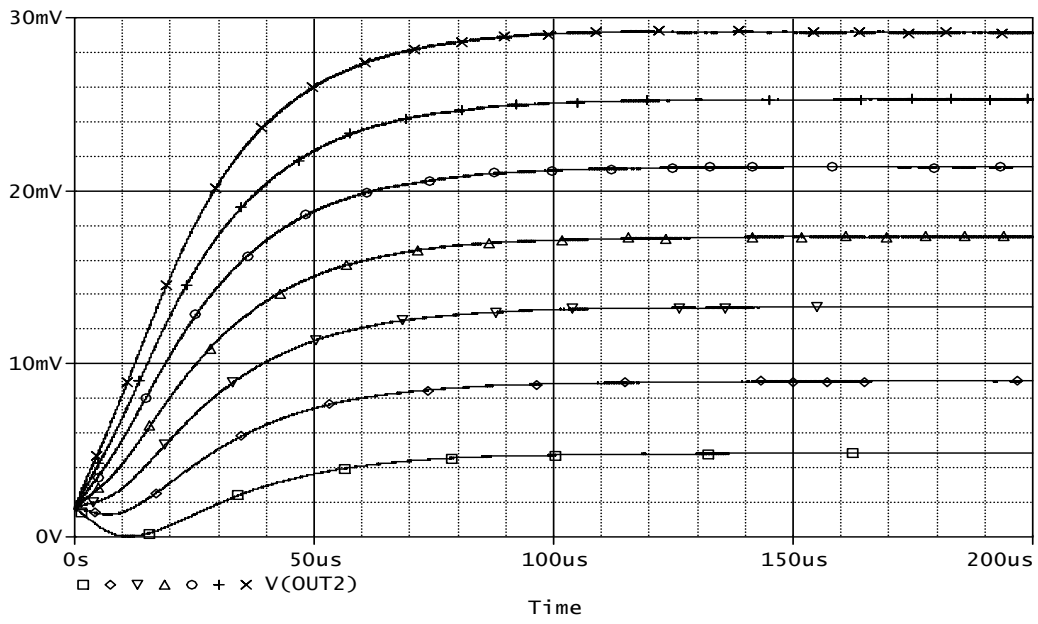
Fig. 8

Conclusion

Development and manufacturing of elements for the 8-channel beam intensity meter for the U-400 accelerator channels is in progress at the present time.

Current status of the RDMS CMS computing

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1. Introduction

The Compact Muon Solenoid (CMS) detector [1] is a high-performance general-purpose detector which is constructing now at the Large Hadron Collider (LHC) [2] at CERN [3]. The detector was designed and is currently being built by a worldwide collaboration of about 2300 physicists from more than 30 countries. Russia and Dubna Member States (RDMS) CMS collaboration was founded in the 1994 year and now it involves more than twenty institutes from Russia and Joint Institute for Nuclear Research (JINR) member states [4]. RDMS CMS is responsible for a number of CMS sub-detectors, in particular, hadronic endcap calorimeter (HE) and forward muon station (ME1/1) are of a full responsibility of RDMS CMS including management, design, construction, installation, commissioning, maintenance and operation. RDMS CMS physics tasks are selected taking into account the essential role of these sub-detectors for the corresponding physical channels. The overview of RDMS CMS physics tasks is presented in [5]. A proper computing support is required at the RDMS institutes for RDMS CMS physical tasks to be realized.

2. RDMS CMS Computing Model

An expected total size of experimental data at the CMS experiment is of Petabytes order per year. A distributed data analysis system for processing and further analysis of CMS experimental data has been developed and this model foresees the obligatory usage of modern grid-technologies. The CMS Computing Model makes use of the hierarchy of computing Tiers as has been proposed in the MONARC [6] working group and in the First Review of LHC Computing [7].

The RDMS CMS computing model should provide a valuable participation of RDMS physicists in processing and analysis of CMS data. Data processing and analysis scenario of the RDMS CMS computing model is developing now in a context of estimation of resources on a basis of selected physics channels in which the RDMS CMS plans to participate. The requirements for the RDMS CMS computing model should assure a realization of various methodical, reconstruction and physics tasks described in detail in [5]. RDMS offline hardware is supposed to be located at several computer centers and form a distributed Tier-2 cluster (according to the MONARC terminology [6]). It can be considered as so-called the "cloud" of Tier-2s. The RDMS CMS Tier-2 cluster will provide the facilities for simulation tasks, a number of analysis tasks as well as for detectors calibration, HLT and offline reconstruction algorithms and analysis tools development. The connectivity between the RDMS institutes should be more than 1 Gbs and the computing farms at the institutes will be combined into a common grid infrastructure. In addition to ordinary Tier-2 functions like

maintaining and analysis of AODs[1](end-user analysis), data simulation, digitization of simulated data and user support, a processing of a part of raw data is needed both for a calibration and alignment of some CMS detector systems for which the RDMS is responsible and for creation and testing of reconstruction software applied to some particular physics channels. As soon as the RDMS Tier-2 is planned to have some Tier-1 functionality, it will get data both RAW and RECO (the amount needed for the software/trigger/calibration development) and the proper set of AOD data needed for physics analysis of the dedicated channels. These data will be transferred and kept at the RDMS CMS Tier-2 cluster at the mass storage system located in one or two institutes.

Some fraction of RDMS Tier-2 resources (about 30%) will be scheduled for Monte-Carlo (MC) simulation of the standard CMS MC samples including the detector simulation and the first path reconstruction. MC simulation data will be distributed between the RDMS CMS institutes in accordance with the resources located at the institutes (the more resources, the more loading). The MC data will be moved to CERN or stored locally.

RDMS Tier-2 will publish all data located locally to be available for all CMS users. However the available datasets on the disks/tapes will reflect local user tasks. All CMS users will have an access to these data and will be able to submit jobs through a global CMS grid-infrastructure. Also RDMS Tier-2 will need the replication of databases (conditions DBs) used in reconstruction.
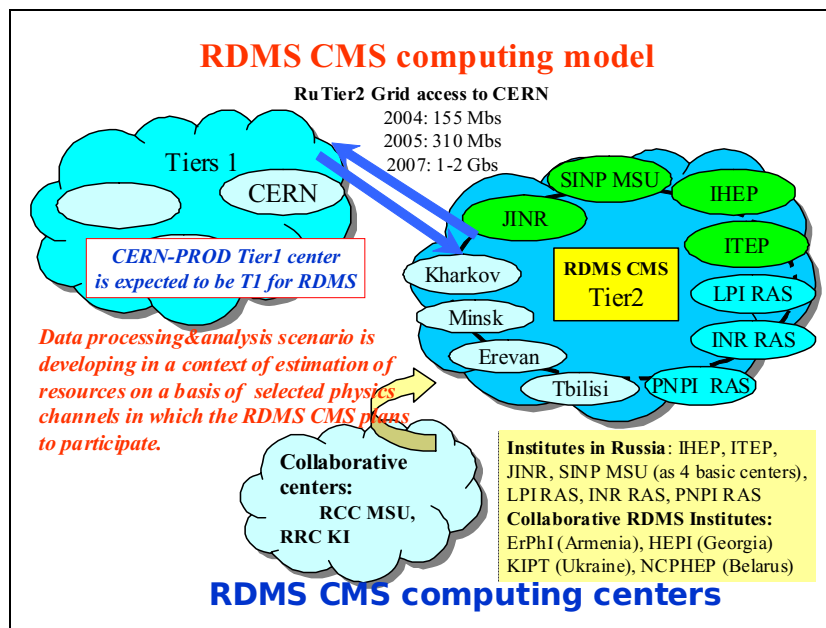
Fig. 1. RDMS CMS computing model scheme

This way, a conception of the RDMS CMS computing model could be formulated as it will be Tier-2 cluster of institutional computing centres with a partial Tier-1 functionality and summary resources at the 1.5 level of the canonical Tier-2 centres for the CMS experiment. The basic functions will be analysis, simulation, user data support, calibration tasks and reconstruction algorithms development. By the moment CERN is expected to act as a CMS T1 centre for the purposes of receiving Monte Carlo data from RDMS Tier-2 centers and will

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[1] According to the CMS data hierarchy, AOD (Analysis Object Data - data for physics analysis in a convenient, compact format) data are produced from RECO (reconstructed) data which are in turn derived directly from RAW data [8].

also act as the distribution point for RDMS Tier-2 access to CMS general AOD and RECO data.

A scheme of the RDMS CMS computing model is presented on Fig. 1.

3. Current status of RDMS CMS Computing Activities

Current RDMS computing activities [9] are mainly concentrated at RDMS Tier-2 computing infrastructure support, participation in CMS Challenges: Service Challenge (SC4), Computing and Software Analysis Challenge (CSA06 an CSA07), which are large scale deployment and test of CMS new software and computing infrastructure before the CMS start, and in Magnet Test and Cosmic Challenge (MTCC), RDMS users support in the LCG-2 environment, participation in ARDA project, RDMS CMS and LCG MCDB data bases design and support.

During the last few years, a proper grid-infrastructure for CMS tasks has been created at the LCG-2 [10] sites of Institute for High Energy Physics (IHEP), Protvino, Joint Institute for Nuclear Research (JINR), Dubna, Institute for Theoretical and Experimental Physics (ITEP), Moscow, Institute for Nuclear Research (INR) of the Russian Academy of Sciences (RAS), Moscow, Skobetsyn Institute for Nuclear Physics (SINP), Moscow, Petersburg Nuclear Physics Institute (PNPI) of RAS, St.Petersburg and P.N.Lebedev Physical Institute (LPI), Moscow. CMS software (current releases of the CMSSW package) is installed at all these LCG-2 sites. The RDMS LCG-2 computing resources are used for CMS simulation and analysis jobs. Also the RDMS CMS LCG-2 sites are testing by concurrent submitting of typical analysis jobs with the usage of CMS Jobrobot system (the JobRobot is a program, currently operated from a machine at CERN, that creates CRAB[2] jobs, submits them to specific SE (Storage Element) sites, and collects them while keeping track of the corresponding information. Its main objective is to test how sites are responding to job processing in order to detect possible problems and correct them as soon as possible). RDMS CMS physicists began their work in the LCG-2 environment, and now we are having 25 members of CMS Virtual Organization (VO). To help them to work in the LCG-2 environment, a number of training courses for CMS users have been conducted [11].

The RDMS institutes have been successfully participating in CMS PhEDEx[12] test data transfers from the 2006 year. A volume of data monthly transferred to the RDMS institutes is about 10 TB. An example of CMS PhEDEx test transfer for the JINR-LCG2 site is presented on Fig.2: transfer rate is 12 – 22 MB/s, 98% of successful transfers and 1.64 TB of data have been transferred from CERN to JINR The CMS Magnet Test and Cosmic Challenge (MTCC) [13] has been conducted in the year 2006 at CERN. The magnet test was a milestone in the CMS construction. It completed the commissioning of the magnet system (coil & yoke) before its eventual lowering into the cavern. The cosmic challenge included DAQ and network tests on cosmic data (850 GB/day). MTCC gave a good opportunity to test data transfer from DAQ to RDMS Tier-2. About of 600 GB of raw data have been transferred to JINR. A general scheme of realization of data CERN-JINR transfer management during MTCC is presented on Fig.3.

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[2] CRAB [14] is a Python program intended to simplify the process of creation and submission of CMS analysis jobs into a grid environment,

Transfers to JINR (04.08.2007)

Transfers to JINR (04.08.2007)

File transfers statistics
destination: JINR
date(s): 04.08.2007

Source site	Succeed transfers	Failed transfers	Total count	Success ratio, %
ASGC	0	0	0	0
CERN	676	9	685	98
CNAF	0	0	0	0
FNAL	0	0	0	0
FZK	0	0	0	0
IN2P3	0	0	0	0
PIC	0	0	0	0
RAL	0	0	0	0
Total	**676**	**9**	**685**	**98**

File transfers statistics
destination: JINR
date(s): 04.08.2007

Source site	Successful transfers, GB	Failed transfers, GB
ASGC	0.000	0.000
CERN	1639.962	21.802

Fig. 2. Example of CMS PhEDEx data transfer (04.08.2007)
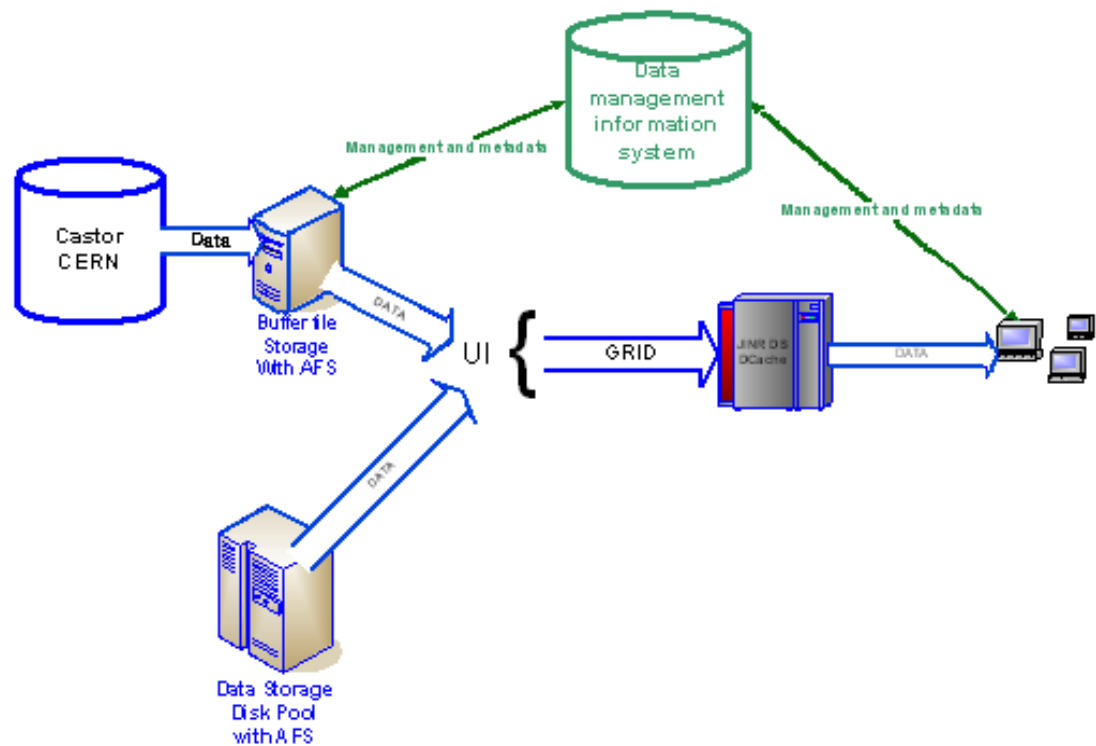
Fig. 3. CERN - JINR Data management for MTCC

Our participation in the ARDA project on distributed analysis for LHC [15] concerns the CMS Dashboard activities [16]: monitoring of Tier1 <-> Tier2 transfers through Dashboard (observation over Load test transfer); monitoring of production jobs with MonALISA [17] (monitoring of errors and monitoring of the WN (Working Node), SE, network, software installed); portability of the monitoring system; participation in the CRAB-Task Manager integration.

Work on the CMS informational systems and databases development and support is carried out in frames of the RDMS CMS activities on Endcap Hadron Calorimeter (HE), forward muon station (ME1/1) and Very Forward calorimeter (HF) [18,19]. It includes information to physically set up the detector, information about the sub detector construction, information required to bring the detector in any running mode, information about detector conditions etc. *HE Database* is intended for the storage of the technical parameters of different detector elements: tubes, index-bars, read-out boxes, megatiles; calibration results of the radioactive wire source, laser, LED and RBX calibration. Now the RDMS HE Calibration online DB system is integrated into CMS computing environment and provides a full calibration cycle support. At the present it contains about 30000 records [20]. *ME1/1 informational system* is realized on Oracle database server and CERN internet information web server. ME1/1 User Interface is realized by Web access. Web interface provides the initial filling of database, different access levels for users, information search on different criterions, adding and updating data. *HF Database* contains data for each detector wedge. HF data are wedge calibration, beam wedge calibration and channel calibration. Database is placed at DEVDB CERN Oracle server.

LCG Monte-Carlo data base [21] shares sophisticated MC samples between different groups. It provides the infrastructure to keep verified MC samples and sample documentation and facilitates communication between experts of MC generators and users in the LHC collaborations. At CMS MCBD was used by PRS (Physics Reconstruction and Selection) Higgs group for many years. Moreover, this system was originated from this CMS group. Now MCDB access libraries have been integrated to the CMSSW software. Several improvements have been made in the MCDB software: a new improved XML schema has been developed for High Energy Physics Markup Language (HepML) and the program libraries have been developed to work with the new HepML schema. The LCG MCDB is planning to use as storage in all CMS groups which need verified MC samples for hard processes. Lately a grid access to MCDB event files and multiple files upload (from Castor and AFS) have been realized, web interface improvements have been done.

4. Summary

RDMS CMS Computing Model has been in principle defined as a Tier2 Cluster of institutional computing centers with a partial T1 functionality. Data processing and analysis scenario has been developed in a context of estimation of resources on a basis of selected physics channels in which the RDMS CMS plans to participate. The very solution that CERN will serve as T1 center for RDMS would be a strong basement to provide the RDMS CMS computing model requirements. The proper RDMS CMS Grid infrastructure has been constructed at the RDMS Tier-2 cluster. The main task now is to test RDMS CMS Grid infrastructure in a full volume to be ready for the LHC start.

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[12]   http://cmsdoc.cern.ch/cms/aprom/phedex/

[13]   https://twiki.cern.ch/twiki/bin/view/CMS/CSA06

[14]   http://cmsdoc.cern.ch/cms/ccs/wm/www/Crab/

[15]   http://cms.cern.ch/iCMS/jsp/page.jsp?mode=cms&link=/MTCC.html&name =MTCC

[16]   http://lcg.web.cern.ch/LCG/activities/arda/arda.html

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[20]   HE Calibration DB browser: http://cms-he.web.cern.ch/

[21]   http://mcdb.cern.ch/

First level trigger for the NUCLEON experiment

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NUCLEON experiment aimed to the direct measurements of the elemental energy spectra of high-energy (10^{12}-10^{15} eV) cosmic rays (CR) during 5 years (2008-2012) abroad the Russian regular satellite. The main goal is to clarify the long-standing problems of CR origin sites and mechanism of acceleration, peculiarities of diffusion in the Galaxy in the energy region near the knee by the measuring of secondary to primary ratio, differences in slopes of different nuclear components[1].

The first level trigger[2] for the "NUCLEON" experiment (Fig.1) has been significantly changed after the detector upgrade. The NUCLEON instrument is planned to be launched in 2008 with exposure time in orbit not less than 5 years.
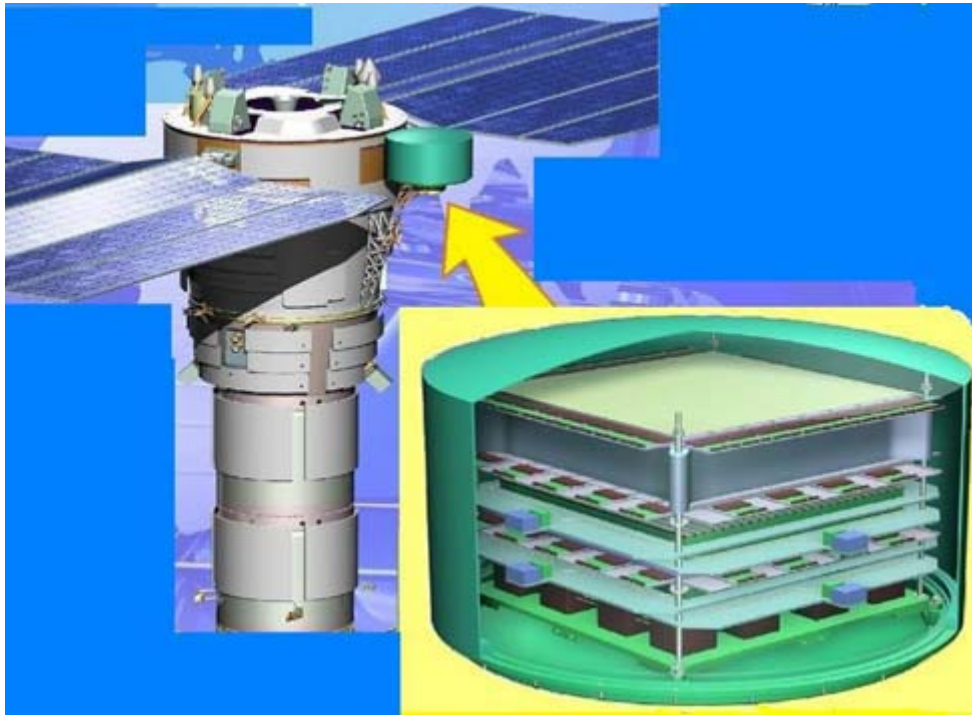
Fig. 1. KOSMOS type satellite with NUCLEON system

Currently the detector has a "sandwich" design which is schematically shown in Figure 2. The top three levels consist of pad semiconductor detectors capable of measuring charged particles. The fourth level is the carbon target. All consecutive layers are made of strip semiconductor detectors, scintillators and tungsten converters.
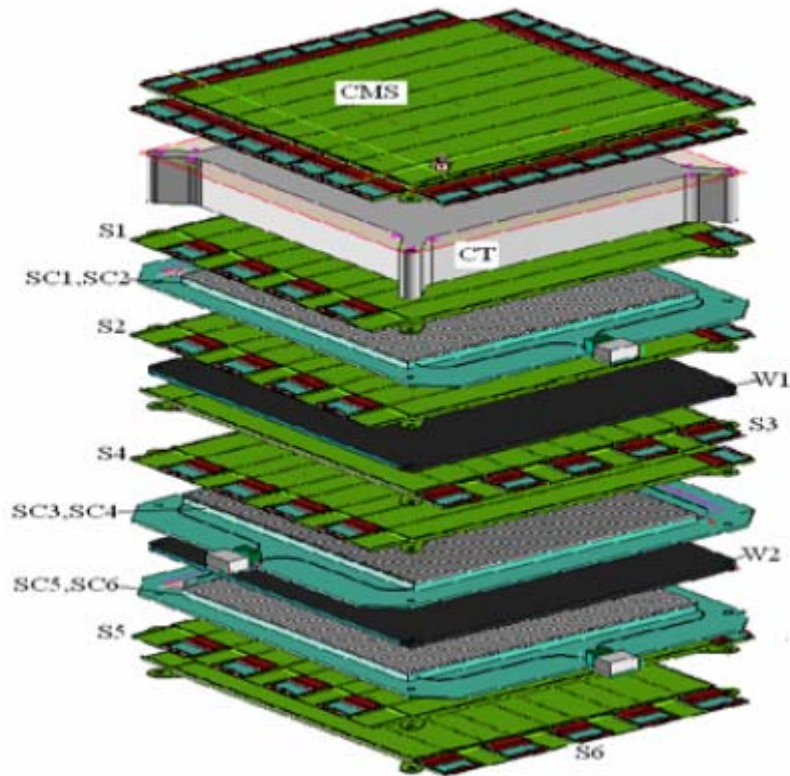
Fig. 2. Schematic view of NUCLEON instrument

Scintillating detectors[3] (sc1-sc6) provide a fast trigger. Each of the six detectors has 16 scintillating strips with dimensions of 5x31x500 mm^3. Seven WLS-optical links are glued into each strip and divided into three groups. The first two groups consist of two WLS-optical links per group and the third group has three optical links. Three fibers from each strip are connected to the corresponding channel of the 16 channel photomultiplier (HAMAMATSU H8711). Two optical links from each strip from a single plane are divided into two groups and connected to two single channel photomultipliers (HAMAMTSU H5733) therefore each single channel photomultiplier collects signal from the full plane. This ensures a robust and reliable performance of the trigger part of the detector.

Signals from the single channel photomultipliers are passed to the inverting amplifier with gain 5, based on the operational amplifier AD8055. This design allows us of using a single power supply (+12 V) for the photomultiplier's high voltage DC-DC converter, amplifier and trigger board electronics.

The need for fast processing of the short signals from the photomultipliers along with minimum dispersed power (< 1 Watt) imposes a restriction on the electronics components.

Two independent but identical chipsets on the trigger board provide "hot reservation". Each group has 6 registration channels. Each channel consists of a discriminator based on the comparator ADCMP601 and digital-to-analog converter, which provides an operation threshold for the comparator. The signal from the comparator is supplied to the monostable multivibrator which forms 50 nsec impulses. Signals from all channels are supplied to the majority coincident circuit, with a changing repetition factor from 1 to 6. Each channel can be switched off separately. This feature can be used for testing and allows for switching off of faulty channels. This testing procedure is explained later in the text.

Majority coincident circuit is based on PLA ALTERA EPM200, which supplies the trigger signal to the registers of the microcontroller and also through the formers of LVDS-levels to the processing system of the scientific and service information (PSSSI).

The microcontroller ATMEGA165P is managing parameter adjustment of the device. The block diagram for one of the groups is shown in Figure 3.
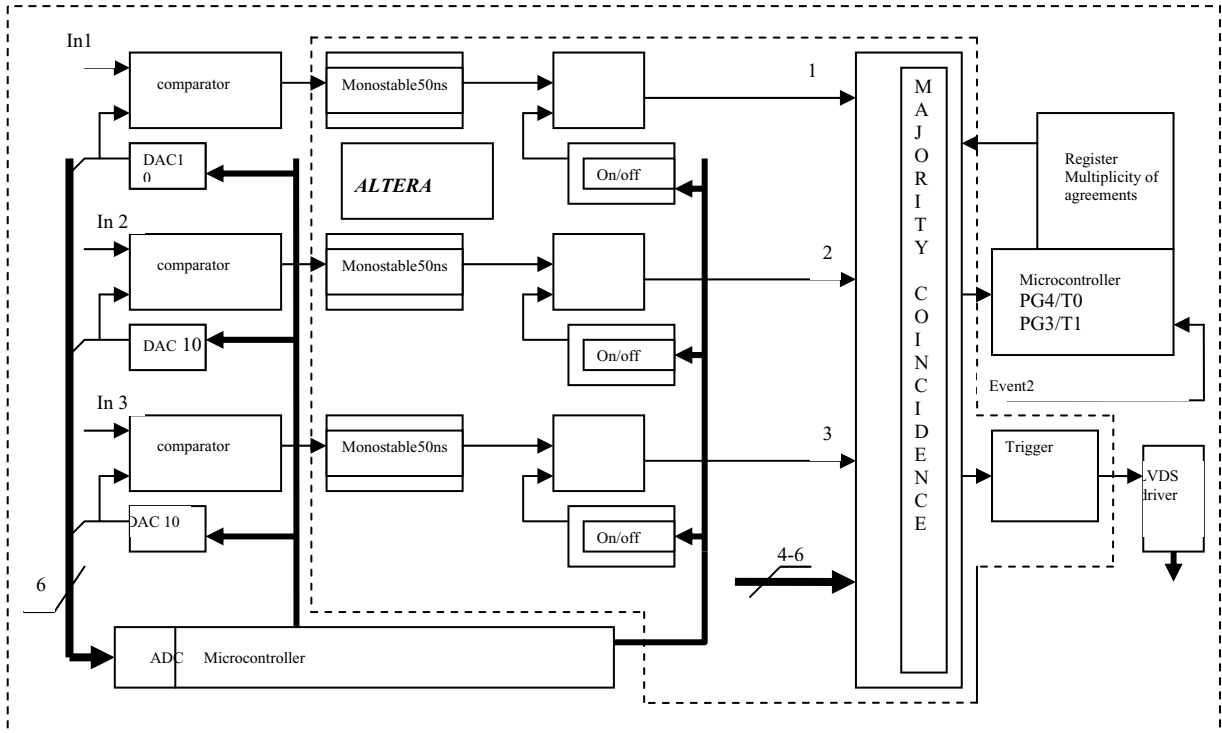
Fig. 3. Block diagram of one chipsets group

For each group the corresponding microcontroller measures current consumption, thresholds for channels of the group, and counting speed in both groups. The error code is sent by the power supply (3.3V) if the voltage variation exceeds 10%. The error code initializes the microprocessor and is passed to the PSSSI.

There are three possible scenarios of how the selection mode can be initialized:
1) The thresholds and coincidence configurations are defined at ground and initialized during the system power up.
2) The initial parameters are loaded as described above (1) and can be modified from ground.
3) Thresholds are defined and set at the orbit based on the counting speed of each channel. The multiplicity of agreements is equal one and only used channels are considered.

The selection mode is picked by the central processor PSSSI, implemented with microcontroller chip, which mounted on the trigger board.

The selection mode is picked by the central processor PSSSI and implemented with the microcontroller chip, which is mounted on the trigger board.

The second (2) selection mode has two implementations: the thresholds can be specified from ground or the counting speed can be specified from ground and once the desired counting speed is reached, the thresholds will be fixed and the system will be initialized. In

case (3), every channel, one after another, is connected to the input of the majority circuits of both groups (the repetition factor is set to one). The threshold for those channels is set to 10 mV and the result of the event counting during 10 seconds is stored in RAM. At the next iteration the same procedure repeats 20 times while the threshold is set to 20 mV. Based on the obtained measurements, the plateau and the threshold are picked. The threshold corresponds to the middle point of the plateau. Simultaneously the number of counts in both groups is compared. This initialization procedure is repeated for all channels.

During data taking, the counting rate is being checked regularly, values of the registers PG3/T1 and PG4/T0 are stored every 30 minutes in the RAM of the microcontroller and compared with previous measurements. This information is passed to the PSSSI upon the request from the central processor. At the same time, information about thresholds from all comparators, repetition factors, total event counts, and current consumption in every group is shipped to the central processor.

The performance of every group is evaluated based on the number of counts measured in it. The number of counts has to be the same within 5-7%. If the thresholds are the same but the numbers of counts differ by more then 5-7%, the thresholds are stored again for all channels. If the disagreement persists, then the number of counts compared for the same named channels from different groups with identical thresholds. In order to achieve a consistent comparison, the coincident repetition factor for the majority circuits is set to one and the registration channels are switched on one by one. Thus, two channels can be picked which have different numbers of counts with identical settings. Once the pair is picked, the number of counts of this pair is compared with pair counts in every group 1-2, 3-4, and 5-6. Through this comparison the channel with bad parameters is identified and the threshold for the comparator which corresponds to the problematic channel is adjusted. Finally, if the counts match each other, the settings are stored and data accumulation continues. If no proper settings can be picked the full group which contains the broken channel is switched off and only the second group is used for triggering. If the data accumulation speed has changed during data taking, the channels are checked again. Now the counts can be compared within pairs: 1-2, 3-4 and 5-6. Then the number of counts from channels 1, 2, 3, 4, 5 ,6 can be saved into RAM and the pair with a different count rate is identified. If the counting rate increased, then the threshold for this channel is increased until the global counting rate has been restored. If the global counting rate decreases, the threshold is gradually decreased as well until equilibrium is reached with old measurements. The defective channel is switched off if the total counting rate cannot be restored to match its previous value. The repetition factor may be adjusted in order to account for the channel loss.
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A highly configurable interlock system for RF stations at XFEL

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Abstract

The main task of the interlock system is to prevent any damage from the cost expensive components of the RF station. The implementation of the interlock system should guarantee a maximum uninterrupted time of operation. Self diagnostic routines and a repair strategy on the basis of module exchange are the tools to reach the goal.

The system implementation is based on a dedicated controller and different slave modules providing the interface to the components of the RF station. A special, user defined backplane connects the controller to all slave modules. The Controller incorporates a 32-bit NIOS-II soft core processor in a FPGA. It performs all control and monitoring functions, but not the interlock function itself. The interlock is implemented as hardwired logic and runs even if the processor stops or the software is not running properly. Before the interlock hardware is enabled, the software performs a system test on power-up to test the hardware functionality of each module including the backplane and the crate configuration.

A HTTP Server running on the NIOS-II processor provides utilities to view actual interlock status information and to reconfigure the FPGA's in the controller and the slaves. New software versions may also be uploaded via Ethernet onto the controller. Further tools on LabVIEW basis exists to support interlock system configuration and system diagnostic

Introduction

The RF system for the European XFEL will consist of about 33…40 RF stations supplying RF power at 1.3 GHz for the superconducting cavities of the linear accelerator of the XFEL [1]. Each RF station generates RF pulses of up to 10MW at a pulse duration of max. 1.5ms and a repetition rate of up to 10Hz. The RF station consists of a klystron, a pulse transformer, a pulsed high voltage power supply, a low level RF system, auxiliary power supplies and an interlock system [2]. The main task of the interlock system is the protection of the different subsystems of the RF stations and of all the

Fig. 1. XFEL Project - http://xfel.desy.net

components connected to the station. In addition it provides slow control functions for the subsystems. Since the interlock system will be installed in the accelerator tunnel, which gives no access during beam operation, the interlock system has to provide monitoring functions, which allow to localize failures remotely. During scheduled maintenance time the service personnel is able to exchange broken subunits quickly. In addition all monitored signals will be transferred to the main control system. The interlock system has a modular structure so that malfunctioning interlock modules can be exchanged without replacing the complete system.

Requirements

The interlock system has to deal with three types of errors:
⇨ Hardware failures (non-reversible malfunctions like broken cables, damaged contacts, dead sensors, ...)
⇨ Soft errors (e.g. sparks in the klystron or the wave guide system, temperature above a threshold, water flow...)
⇨ Error conditions caused by transient noise from the RF station itself (caused by the pulsed power operation)

Errors should be treated with two types of thresholds and channel masking:

⇨ Absolute max./min. thresholds: any violation of these thresholds will force the shutdown of one ore more subsystems or of all components of the RF station.

⇨ Programmable (soft) thresholds: a violation of these conditions will generate an alarm message to the Control System. Soft thresholds are only available for analog input channels.

Most of the input signals have a masking function implemented, which allows the exclusion of the channel from interlock logic. But for some critical inputs, the masking function is disabled. All mask configurations are protected by a password-secured access mechanism. Mask operations cause an entry into the LogFile.

Imlementation

The interlock electronic houses in a 19" 4U crate with a dedicated backplane optimized to the application. The interlock system consists of one controller and up to 20 I/O-slave-modules (Fig. 2). Signal cables from the RF station are connected over distribution panels to the interlock modules which make it possible to quickly exchange interlock modules.

A 3U Compact PCI like board format with two 5-row connectors is used. 235 pins per board to the backplane provide enough pin resources to build a compact and versatile interlock and slow control system. All modules communicate over the backplane, which contains separate bus systems for interlock status information and module access. There exist different slave modules for digital, analog and light signal types.

Fig. 2. Interlock Crate with distribution panels

Fig. 3 presents a more detailed view of the Interlock architecture. The red line highlights the strict separation between the CPU side and the Interlock function.
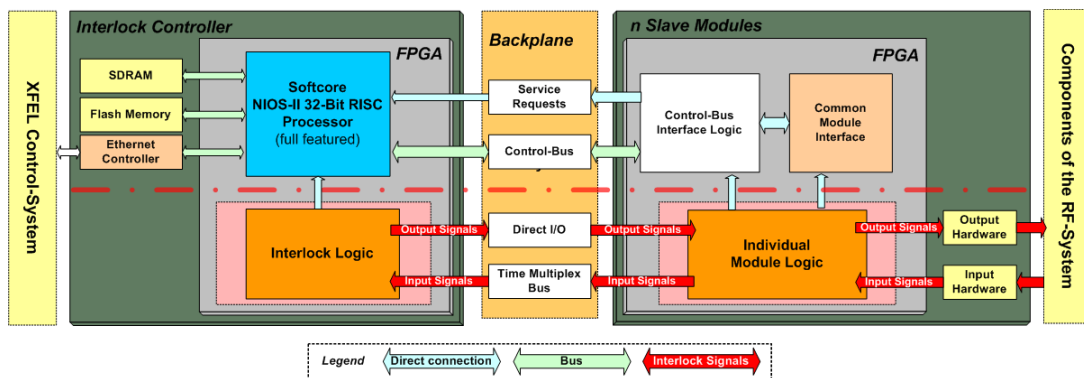
Fig. 3. Interlock Architecture

The Control-Bus interface is used to access and to configure the interlock slave modules on power-up. The initialization must be done by the software which is running on the soft core NIOS-II CPU on the Interlock controller. The slave module's interface consists of a *generic* and a module-*specific* address space. The *generic* address space contains the unique module-serial-number, module-identification and firmware update function. The module-*specific* address space contains all other registers for module-individual configuration and functionality.

Interlock Controller Board

The interlock controller board manages the interlock system and processes all interlock signals. An ALTERA FPGA, a Cyclone II EP2C35F484 device is used on the controller to implement the following functions:

⇨ logical interlock function for components of the RF station is based on signals preprocessed within the different IO-slave-modules
⇨ interlock signal mask function
⇨ NIOS-II processor to manage the interlock system
⇨ interface to the DOOCS control system via Ethernet
⇨ configuration of the IO-modules in the crate
⇨ slow control functions
system check after power-up

It is important to mention that the interlock functionality inside the FPGA is strictly separated from the software running on the NIOS-II CPU. The interlock will always work independently from the state of the CPU and software errors. A schematic view of this concept is shown in Fig. 4.
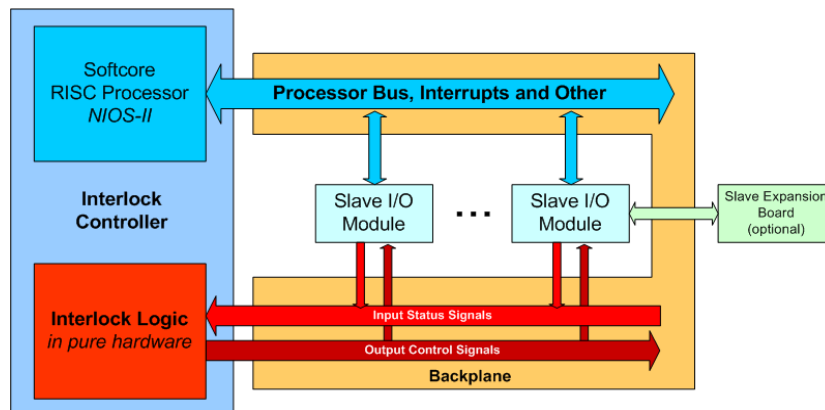
Fig. 4. Intern Backplane with Buses

Fig. 5. Interlock Controler & Slave Modules

Software

The main part of the software is executed on the NIOS-II CPU. One primary task is the interlock initialization procedure. This is done by the System-Test at each power-up. It makes sure that the interlock hardware will operate correctly. The System-Test checks the backplane buses and signals, all slave modules and the controller itself. It also tests firmware compatibility between the modules and software and the configuration. A watchdog process periodically performs software integrity checks and can detect intern memory corruption and unusual software behavior. It is possible to reboot the software during normal interlock hardware operation without complications.

On bootup, the Interlock System detects hardware changes by itself automatically and will demand for confirmation over the Web-Interface of the Interlock System. Each module has a unique serial number and a test-ok flag. The information is kept in the module ROM and is also collected in a separate hardware database for later hardware tracking and maintenance.

The interlock system will only work with modules with a valid serial number and a test-flag set to "ok". That guarantees that only proven hardware can be installed in the system after a repair or initial setup.

Fig. 6. Systest Output

Administration

The Interlock administrative functions are accessible over the HTTP Server over network. It has a small user management to limit access to authorized persons only and will check username, password and IP-address. The Web-Interface allows the authorized user to view signal status, to edit interlock-signal masks, to set thresholds of analog inputs like temperatures and it gives access to slow control functions.

It has a special mode for firmware-update with double password protection[1]. A separate tool under LabVIEW exists to upload firmware over network to interlock slave modules and edit their module information block. It is possible to update several modules simultaneously to shorten the time of a full-system firmware update. Firmware updates get active after reboot only and do not affect running interlock operations.

Fig. 7. Web Interface

Communication

There are several build-in interfaces for communication with higher level applications like the Control System and Diagnostic Tools. The Interlock System sends its signal status information periodically to the control system using a metaserver and to a LabVIEW Datalogger. The logged information can be analyzed by some LabVIEW tools and is helpful for error diagnostics during the installation process. The detailed signal

Fig. 8. Diagnostic Tools under LabVIEW

information is stored in a history of about several months. This allows offline signal analysis and helps to find error sources[2] in the RF-Station. Data recordings can be easily exported to applications like MS Excel for further analysis or for creating reports.

Conclusions

Several full featured interlock systems are actually in use at DESY in Hamburg and in Zeuthen. They are working very well and fulfill our expectations. Another system with small modifications is planned for the Electron-Gun at PITZ. More systems will be installed later this year.

The planned TINE [4] Server for the interlock system is still under development because of some incapabilities of the NIOS-II processor and problems with the LWIP-stack. Because the NIOS-II not fully fits our requirements nor owns a MMU[3] we designed a new

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[1] two independent persons have to login to execute the firmware update
[2] e.g.. error caused by transient noises or bad cables
[3] Memory Management Unit

Controller that incorporates a so called "Computer on Module" (Fig. **9**), which is connected to the backplane via PCI Bus. Advantages of using a "Computer on Module" are the standardized computer architecture with common interfaces (PCI, USB, etc.), a processor with MMU support, increased performance and the capability to run most of popular operation systems (e.g. Linux). Most parts of the Interlock Software will be ported to the X-Board [7] Platform and will run under Linux.

The Linux Platform is much more suitable for porting the TINE Server and other applications. Also, the metaserver (used here as protocol converter) will become obsolete with the next revision.

Fig. 9. Computer on Module - X-Board

- AMD Geode SC1200 CPU 266 MHz
- 128MB RAM / 128MB Flash on board
- On board 10/100MBit Ethernet
- PCI Bus

References

[1]   TESLA Technical Design Report, DESY TESLA-2001-011, 2001.
[2]   S. Choroba, T. Grevsmühl, H. Leich, S. Simrock, The TTF2 / XFEL Klystron Interlock: Requirements and Implementation (Requirements_Draft.doc) unpublished.
[3]   H. Leich, Architektur eines Interlock-Systems für TTF2/XFEL, Bericht der Frühjahrstagung 2004 der SEI, ISSN 0936-0891, S.12 – 27.
[4]   TINE (Three-fold Integrated Networking Environment), ttp://desyntwww.desy.de/tine
[5]   Micriµm Technologies Corporation, http://www.ucos-ii.com/
[6]   ALTERA Corporation, http://www.altera.com
[7]   Kontron, http://www.kontron.com

Science and emerging knowledge utilities

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1. Introduction

The "Joy of Insight[1]" is the important driving force for the sciences. It is about acquiring new knowledge in our fields of interest by making best use of what is known, the established knowledge. In the following we shall describe the interlinked processes of acquiring new knowledge and of making it generally known. We take particle physics, a 'state of the art' natural science as example[2] of today's natural sciences that collaborate and share their insights globally and make them generally and almost online available on the internet.

Knowledge here not only describes the published and peer reviewed results of the sciences but also the underlying data, their analysis and curation and, equally important, the technological and scientific development and know-how necessary to built the instruments required to obtain relevant data for advancing the sciences.

To describe these basic scientific processes we use here in chapter 2 and as specific example, the present international LHC programme of CERN, the grand challenge of global Particle Physics since more than a decade. We briefly recall there developments in particle physics leading to CERN's LHC programme and describe its methods.

We shall see there that worldwide collaboration and sharing of the efforts have emerged as a necessary and decisive feature of this science and we shall describe the adaptive mechanisms of collaboration, trusted by the funding agencies and giving voice to all participating scientists.

To collaborate effectively and mostly from home around the world requires an enabling infrastructure based on most recent Information and Communication Technologies, ITC, also described as e-science, e-infrastructure or cyber-infrastructure. We shall present the features of such infrastructures in chapter 3.

Similar collaborative and ITC based methods emerge today in many sciences with interesting differences of the methods employed. These differences concern mostly the heterogeneous nature, the treatment and preservation of the basic input data. Most promising developments are interdisciplinary efforts and projects that open new possibilities of advancing areas between sciences and their uses in industry. Some examples will be given in chapter 4.

As conclusion in chapter 5 we shall present sciences and resulting technologies as catalysers towards our way of living and that therefore we need to invest further in science, science education and the corresponding collaborative infrastructures to achieve a sustainable future in our societies and on our planet.

2. The LHC project in the global Particle Physics community

Particle Physics as subject emerged after the 2nd world war from nuclear physics creating around the world "big-science laboratories"[3], where accelerators, detection and

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[1] Weisskopf, Victor (1991). *The Joy of Insight: Passions of a Physicist.* New York: Basic Books
[2] Other natural sciences will be addressed in chapter 4
[3] US: Brookhaven National Laboratory, Fermi National Laboratory and Stanford Linear Accelerator Centre;
Russian Federation: the Joint Institute for Nuclear Research near Moscow, JINR, the Institute for High Energy Physics in Protvino, IHEP, the Budker Institute for Nuclear Physics, BINP,

recording facilities were constructed working together with a community of University based users, more than 10 000 scientific of them today and coming from 600 to 800, mostly university institutes in ~from about half of all countries of our planet.

Our knowledge about the microcosm has vastly deepened since that time.

Then, around 1959[4], the turn-on year of the CERN PS, the known particles were protons, neutrons, electrons, photons, muons, pions and kaons and most of their antiparticles and also a number of short lived nucleon resonances. The kaon was recognised by Gell-Mann and Nishijima as having "strangeness". Little was known about the strong and weak forces and there were limits to what one could calculate about electromagnetic interactions and what was known about gravity.

Today, several accelerator generations of ever increasing cm-energy of the colliding partons and ever increasing collision rates and many experiments and theories later, we have the Standard Model of particle physics with quarks and leptons as matter particles and gluon, photon, W and Z particles as carriers of the strong, electromagnetic and weak interactions respectively. We do not know why these particles have vastly different masses and we suspect the Higgs mechanism to complete the Standard Model. We have gravitational wave detectors and think about supersymmetry and strings or branes.

We know that the visible matter we know and describe with the standard model represents only a small fraction of all matter and that most of the energy content of the universe is dark matter and dark energy of which we know almost nothing except that they exist.

Most Particle Physicists agree from the past decades that higher energies are most likely to give access to new understanding of what we do not know.

Therefore the energy-frontier has always been the prime interest of particle physics and that makes the LHC project after the demise of SSC in the US and UNK in the Russian Federation the present grand challenge of particle physics.

As researchers from Particle Physics Institutes outside of the large laboratories mentioned above are relatively free to choose their work objectives and place as long as they intend to do good science and more than 60% of all particle physicists are now involved in the LHC programme, more than 8800 scientists[5] with an annual change-over of > 1000 persons. The available centre of mass energy at turn-on of the CERN PS in 1959 for proton-proton collisions was ~7 GeV. In 2008 and almost 50 years later the LHC will produce collisions at 14'000 GeV cm energy, a factor of 2000 more.

Between the two accelerators, PS and LHC there are worlds of difference of technologies such as superconductivity that moved from sheer text book knowledge of the phenomena to an industrial technology or the generation, observation and control of particle beams that has changed from rather basic methods into industrial technologies widely used in many thousands of medical or other purpose accelerators.

The design parameters of the LHC colliding beam machine are situated at a factor of ~10 in cm-energy beyond the next competing accelerator, the Tevatron at FNAL and at another factor of 100 more in luminosity or event rate. This comparison takes actually achieved performance of the Tevatron as compared to design expectations of the LHC.

KEK in Japan and CERN and DESY in Europe
[4] Mostly from: Particle physics: one hundred years of discoveries: an annotated chronological biography/ V.V. Ezhela et al; 1996 Springer
[5] 8845 scientists counted on 17-07-2007 as using CERN for their principal research objective of which 5695 came from the 20 CERN Member States, 2555 from 6 Observer States (India, Israel, Japan, Russia, Turkey, USA) and 605 from other 38 Non Member States (Armenia, . . , Vietnam), altogether from 64 countries. (Figures private communication from CERN Directorate Support Unit)

It is this envisaged large increase of performance that make the LHC the facility of choice for the next decade of a large fraction of the Particle Physics community.

In a similar manner today our knowledge of instrumentation has gone through many generations of detection devices allowing to determine today mass and momentum of the expected $\sim 10^{11}$ collision products from about 10^9 events per second at design luminosity with the precision necessary to select one in 10^7 of all online events and record them on tape and to refine the selection offline to one in $\sim 10^{12}$ events or better that promise interesting physics.

In the fields of instrumentation the advances made and technologies developed are striking. In the 1950's the particle physicist's toolkit consisted of scintillation and Cerenkov counters, time of flight between few detection elements, spark, cloud and bubble chambers, nuclear electronics establishing trigger signals, pulse heights, TOF spectra, coincidences, anti-coincidences and fast counters establishing counting rates in a variety of configuration channels, all supplemented by magnetic fields to measure momenta and novel particle beams. Digital recording worked at some Kbyte/s and more sophisticated information was stored on film.

Today we assemble "4π" and "hermetic" general-purpose detection apparatus using superconducting magnets and highly integrated electronics, semiconductor-, crystal-, liquid argon- and scintillator- detectors, assembled into very high rate full solid angle tracking and momentum measuring, em- and hadronic calorimeters as well as muon identification and momentum determination. These devices generate very large data streams (Petabyte/sec (equivalent if all information were digitized)) with online reduction making use of hardwired electronics, computer farms, software and networks, to name but a few. They permit 10^9 fold higher event rates at comparable resolution compared to bubble chambers 40 years ago.

The details of such apparatus of the ATLAS, ALICE, CMS and LHCb experiments and the LHC accelerator have been described recently[6] and cannot be described here.

To achieve such advances in few decades in terms of scientific progress and advances of instrumentation and analysis of data the Global Particle Physics community has developed a high degree of bottom-up self-organisation around peers or promising ideas combined with the cooperation and also the competition between the highly structured and well organised large centres constructing novel accelerators and large scale detection devices.

In the wake of these 50 years of open cooperation, scientific competition and rapid scientific advances the scientific community has developed a large body of the necessary skills, best practices, know-how and ideas throughout the community. The centres and the distributed university institutes cover and keep up to data a wide range of scientific tools and skills and keep an eye on all emerging, promising technologies and test them out for novel devices. The informed and creative use of electronics and information and communication technologies deserves special mention here since the revolution in the use of the internet after 1990, the WWW[7] emerged at CERN and it's environment of continuous world-wide communication and data exchange.

The community has a wide availability of persons skilled and specialised in a large variety of technologies and has developed bottom up and top down means to create collaborations of critical mass, able to address all technological and scientific challenges posed by the potential of the new generation of accelerators.

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[6] "The CMS experiment at the CERN LHC"; The CMS collaboration; submitted to JINST, similar publications were submitted for the other experiments and the LHC accelerator

[7] "Weaving the Web-The Original Design and Ultimate Destiny of the World Wide Web by Its Inventor.", Tim Berners Lee with Mark Fischetti; HarperSanFrancisco, a division of HarperCollinsPublishers, 1999 and "how the web was born", James Gillies and Robert Cailliau; Oxford University Press, 2000.

The community's skills are based on an almost online and complete communication pattern of conferences, workshops, meetings, tutorials, seminars, e-mail exchanges and collaboration in common ventures of changing composition as well as a most developed culture of publication immediately available throughout the community as preprints, eprints or open access publications.

Thus the community has developed new ways of openly sharing not only the scientific insights and their publications but also the details of the technologies and the derived practical know how.

The community has further developed the global e-infrastructure to effectively achieve useful collaboration of hundreds of institutes around the globe uniting thousands of scientists over decades.

Therefore we shall describe the workings of the large LHC collaborations here to some detail. As the LHC accelerator collaboration is less wide it will not be described her since it uses elements of what the experimental collaborations do.

The complexity of the tasks to construct the LHC and its four large experiments brings about unprecedented collaborations and all of the critical mass and capacity to do the job:

>15% of the LHC accelerator material is contributed by CERN observer state institutes or large Member State laboratories;

~80% of the material value of the four LHC Experiments is contributed by collaborating institutes and the remaining ~20% by CERN. Thus ATLAS (CMS) is constructed by 1800 (1960) scientists from 164 (180) institutes in 35 (37) countries[8].

The sizes of the collaborations are given by the complexity of the tasks and the desire of the physics institutes to be engaged in conception and construction of state of the art detector equipment and tasks such as software, simulation and other which are all subjects for student education and theses.

Since the first workshop on potential LHC physics and experiments in Lausanne (1984) many groups of scientists met regularly on tasks and concepts for potential LHC experiments. In the Aachen workshop (in 1990) "proto-collaborations" appeared with first ideas on experimental layouts, cost and resources as well as desirable detection schemes, electronics and computing.

To focus the work, the CERN management launched in the same year an intensive R&D activity on the missing technologies. CERN, in dialogue with the proto-collaborations worked out guidelines on available resources and a desirable composition of an experimental programme.

Soon after CERN called for "letters of intent" and set up a peer review committee of experienced theoretical and experimental physicists with the mandate to review the potential and feasibility of the described apparatus and the capabilities of the proponents.

CERN then asked for Technical Proposals to be submitted at the end of 1994. The technical proposals provided detailed descriptions and performance specifications of all parts of the apparatus, their fabrication schedules and material and manpower cost estimates. Those amounted to a material budget of 450 million CHF and 2500 person-years of construction effort, each, for the general purpose experiments ATLAS and CMS.

Further the collaborations were asked to describe their basic organisation principles. In ATLAS, for example, those were the separation of policy- and formal decision-making and executive bodies and the prominent role of the Plenary Meetings to involve all members of the collaboration in the overall goals of the experiment. The policy- and formal decision-making body was the Collaboration Board electing their own chairperson and with one vote

[8] Figures private communication from CERN Directorate Support Unit

per institute. The executive responsibility was with the Spokesperson(s), the Technical and Resource Coordinators, and the coordinators of the subsystems or other major activities. All these persons formed the Executive Board that directs the execution of the ATLAS project within the available resources and allocated construction time, with a view to the overall performance of the experiment.

CMS, LHCb and ALICE, the other approved LHC experiments, have similar arrangements. All these arrangements undergo constant change and adaptation to the actual needs of the collaboration as can be observed in the present phase of transition from construction to commissioning, operation and scientific exploitation. Leading people during construction will differ from those during operation and physics analysis. Collaborations are self-organising, "communitarian" and democratic but under scrutiny of the host lab via peer reviews and the host lab's practices and exigencies complementing the extensive internal quality assurance schemes for all aspects of their work and, in particular, for their use of resources.

These collaborations are, in fact, distributed, networked and "virtual" big-science laboratories, their existence based on Memoranda of Understanding (MoU) for the construction and operation, signed by all participating institutes or their funding agencies, based on the promise of best efforts, clearly defined common goals and "deliverables" by each participating institutes. The MoUs are recognised to have no legal value and the collaborations are represented by CERN and, for their individual deliverables, by the institutes responsible for them.

Because of the complexity of the collaborations' tasks and as ultimate quality assurance for the physics findings there is competition in all their doings. For example the ATLAS and CMS collaborations have the same overall scientific goals, schedule and potential. They will compete for the best results throughout the lifetime of the LHC programme.

Finally, somewhere around 2020 and about 3 decades after the first gatherings as "proto-collaborations" in 1990 and after many generations of participants, they will disappear when their objectives are achieved and the last data analysis ideas exploited and published.

The scientific workflows for the conception, construction commissioning and scientific exploitation of these virtual laboratories follow the same patterns from the detector as a whole down to subsystems and sub-subsystems:

- Agree on a work objective or work package;
- Achieve a particular development or work objective;
- Present and discuss its results with all colleagues and experts within and beyond the activity concerned for their opinions and views;
- Pass the experiments quality assurance;
- Repeat cycle if changes are necessary.

For example and for an experiment such as CMS in 2006 these typical work cycles were addressed in 2000 scheduled meetings with 15000 contributions (rounded figures)[9].

The results of all this work are continuously documented and made available in the collaboration and we demonstrate this taking CMS and its internal document server named "iCMS" as examples and use figures of the CERN Document Server, CDS. In CDS and under the key word CMS (summer 2007) there are >5000 documents (>700 alone in 2006), namely 3,485 Articles & Preprints, 55 Books & Proceedings, 19 Presentations & Talks; 5 Periodicals & Progress Reports; 1,336 Multimedia & Outreach.

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[9] Compare: http://indico.cern.ch/

iCMS, the internal CMS document database contained 2631 CMS notes, internal papers on important aspects of CMS, published since 1992 by one or few authors and comparable to e-prints with internal CMS peer review, ~90 thesis works in the CMS archives performed on CMS subjects, 17 technical design reports (TDRs) on major aspects of the CMS detector, each between 200 and 700 pages – the complete final technical descriptions of the all aspects of CMS, hardware, software, computing, hundreds of minutes of meetings, official documents such as the Memorandum of Understanding (MoU) for the construction of CMS from 1998, the MoU for maintenance and operation from 2002, one official list per year of the CMS collaborators; all documentation, ~15 documents per year, for the resource review boards with all funding agencies, and engineering documentation describing millions of pieces of hardware, cabling schemes electronics designs, and others.

Through these organisational, communication and work arrangements every interested participant of the experiments can make his or her own validated contribution.

And this is the strength of the system, to offer to each participant the possibility to make relevant contributions to a complex undertaking in a highly competitive environment of scientists, able to conceive and construct devices of >100 million sensors, mastering and selecting unprecedented data flows with expected selectivity of identifying unambiguously one particular event in 10^{12} others of similar nature and all of this reasonably within predetermined construction time and cost limits.

3. Underlying ICT infrastructure enabling the common efforts of large global collaborations

In the year 2000 John Taylor, then Director of the UK Research Councils defined his e-Science initiative as follows: "e-science is about more than networks, grids, high performance computing . . . ; e-science is about global collaboration in key areas of science and the next generation of infrastructure that will enable it[10]".The US-NSF launched a cyber-infrastructure initiative following the report of the Blue-Ribbon Panel on Cyber-infrastructure in the year 2002[11] and there were corresponding e-infrastructure initiatives in the European Framework Programmes[12].

As important parts of these infrastructures are treated in special talks in this conference, in particular the data and computational grid infrastructures and computing and analysis arrangements of the experiments we shall just list, reference and very briefly summarise the most important ingredients of the "e- services" for the virtual organisations, the large LHC experiments:

- E-mail, internet access, basic computing needs, campus connectivity, organized file storage and back-up for all users of CERN[13];
- Internet (video-) telephony or conferencing in many conference rooms at CERN and in collaborating institutes, allowing users to actively participate in all meetings and events of their interest[14].;
- The CERN agenda facility to organise meetings and conferences including virtual participation and with the widely used possibility of uploading and storing conference or meeting contributions[15];

[10] http://www.rcuk.ac.uk/escience/default.htm
[11] http://www.nsf.gov/about/budget/fy2008/pdf/39_fy2008.pdf
[12] http://cordis.europa.eu/fp7/ict/e-infrastructure/home_en.html
[13] http://it-div.web.cern.ch/it-div/
[14] For example: http://evo.caltech.edu/
[15] http://indico.cern.ch/

- The CERN engineering data management system, EDMS for life cycle and configuration management of complex apparatus, accessible over internet, but pass word protected and further protected concerning any changes of stored documents; containing all CAD drawings and engineering details, construction and manufacturer documentation and all other relevant documentation for the efficient and safe operation of the LHC accelerator and experiments[16];
- Experiment specific documentation systems containing all relevant documents of the experiment, in particular many tutorials and outreach material, compare for example iCMS mentioned above;
- The CERN wide electronic documentation system, the CERN Document Server, CDS, containing amongst others all preprints and publications and making them accessible to all CERN users; containing further complete records of academic training courses since 1968, summer student lectures, recordings of seminars, records of CERN physics, computing and accelerator schools, high school teachers training, outreach material and photos; CDS is openly and generally accessible over internet since its launching in 1990 for all content except journals that do not grant open access; the CDS team further leads the efforts of the "Open Archives Initiative[17]" together with other scientific libraries and CERN is far advanced in promoting a viable financing model for "Open Access[18]" - publishing named SCOAP3[19], considered widely to be the first viable model of financing open access publishing of scientific literature;
- The CERN archiving services for long term storage of documents relevant for CERN;
- Experiment specific data- storage- and analysis services and infrastructure allowing all participants of experiments anywhere in the world to access and work on their experimental data from home together with colleagues from anywhere in the world, the World-wide LHC Computing Grid[20], WLCG and its main partners EGEE[21] and OSG[22].

At this time these different facilities for recording scientific and technical objects and activities are loosely coupled across the various project organisations such as experiments or accelerator departments using them. Not all records will remain accessible for all time. For example recordings of meetings exist only since 1995 in the present agenda system and what happens to the many Petabyte of data to be available after some years of operating LHC will have to be determined by the experiments.

All data from CERN experiments have been analysed completely. Some data from previous particle physics experiments exist in some quantity and often unreadable fashion. For example there are still many tons of bubble chamber films but hardly anybody knows today under which circumstances the film was taken and how to analyse the pictures. Electronically recorded data can often no longer be looked at since the visualisation programs and the corresponding operating systems no longer exist.

Efforts are ongoing to preserve the EDMS data necessary for maintenance and operations of the LHC and its experiments and ancillary equipment throughout the lifetime of the

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[16] https://edms.cern.ch/cedar/plsql/cedarw.site_home
[17] http://www.openarchives.org/
[18] http://oa.mpg.de/openaccess-padua/index.html to give the most recent reference of the activities
[19] http://www.scoap3.org/
[20] http://lcg.web.cern.ch/LCG/ ; also treated in several contributions to this conference
[21] http://public.eu-egee.org/ and contribution to this conference
[22] http://www.opensciencegrid.org/

systems described. A major effort will be to reform the data for use with the new CAD system replacing the now obsolete system used the past decade.

In summary, in the above quoted communication, document and data services facilities all the knowledge, know-how, expertise and skills are recorded concerning the efforts of many thousand person-years of work. They are also condensed into technical and scientific papers trying to catch and publish the important features of what has been done.

In more than 50 years of reviewing particle physics data and results the Particle Data Group[23] reviews and summarises the scientific knowledge of particle physics such as best values for particle properties, referenced directly to the underlying publications. Further details of particle physics theory or colliders' or experiments' parameters providing a high level summary of what has been achieved with which means in particle physics and where it is published.

50 years ago it was a revolutionary act to launch this particle physics wide global effort. Its present use is not in question either and is, of course strongly supported around the world.

However, the internet and web permit much wider services than what was envisaged when the recording medium was paper. Imagine somebody wanted to know in detail how a particular piece of electronics worked in a particular part of an experiment. A reference from the publication describing the object to it's representation in EDMS would do the job. However, the object would have to have been given a persistent address in EDMS and a representation readable in a standardised and agreed manner over internet.

In this particular example the interest would be to reveal and make available technological know-how and practice.

Another question discussed with moderate interest and without conclusion was whether the underlying summary-data of particle collisions used in scientific publications could be preserved and made publicly accessible for other people to regard or to study after the end of the experiments. In essence the effort to do this could not be found in the past and it would be doubtful whether outsider's analysis could give meaningful results, given the intimate knowledge of the detector and its settings necessary to analyse the data with the required precision. Some such data, have been prepared and are available for schools and universities for educational purposes.

There may be other criteria for wanting to access particle physics data, know-how and technological best practices. Just imagine to look at all this information gathered in the facilities described above with the eyes of people interested in technology transfer, in science education, in alternative ways of physics analysis, of archiving relevant information of this multi-billion Swiss Franc/Euro undertaking or from any other reasonable interest. Then it would serve to introduce some organised interlinking of what exists in stand-alone manner in the interest of persistence of the information, knowledge, know-how or best practices elaborated. We advocate such a study.

In summary, particle physics is certainly an e-science, par excellence.

4. Other e-sciences and their requirements

There are many sciences in need to collaborate to join data and experiences in the interest of their sciences, internationally or globally. A most obvious example is astronomy where very different instruments record celestial objects in different wavelengths making use of very different observing devices such as radio-telescopes, x-ray satellites, optical telescopes and infra read wavelengths optimised telescopes. Several initiatives promote

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[23] http://pdg.lbl.gov/

virtual observatories where all the knowledge gathered with different observatories is cumulated and made available for astronomical objects of interest[24]. To quote from their Web-site: The International Virtual Observatory Alliance (IVOA) was formed in June 2002 with a mission to *"facilitate the international coordination and collaboration necessary for the development and deployment of the tools, systems and organizational structures necessary to enable the international utilization of astronomical archives as an integrated and interoperating virtual observatory."*

A number of gravitational wave detectors (LIGO, Virgo, GEO 600, AIGO, TAMA/LCGT) have agreed to collaborate closely in order never to miss a nearby supernova and to improve on the quality of data since at least 4 detectors in coincidence are needed to detect the location of sources and to determine the wave polarization.

Earth observation satellites such as ESA's ENVISAT serve a wide variety of communities with the set of instruments flying with this facility. This requires data archiving and availability for distributed communities concerning very large data flows.

In molecular biology very large data bases and data services are required to work in biology at the systems level. EBI, the European Bioinformatics Institute, which is part of the European Molecular Biology Laboratory, EMBL[25] provides an exemplary data service covering a wide range of databases for molecular biologists[26] coupled to the corresponding services for the users.

Medical databases to study details of medical cases would contain Petabytes of data for particular illnesses alone.

It is striking to observe the different role data play in other sciences. In particle physics the data are all of the same type and are analysed until the hopefully last scientific information has been extracted. In biology data are heterogeneous to the extreme. Preservation of annotated and curated data together with elaborate services explaining their validity and circumstances of their acquisition are of greatest interest to the science.

Therefore e-infrastructures in other sciences will be quite different from the one in particle physics and humanities and medicine will still be different, for example in protecting personal data. It is important to undertake e-science projects in many sciences to work out all the different requirements and to approach more common solutions.

There is consensus in all sciences that data and scientific knowledge and technological know-how are of highest value when they are openly and easily accessible, even if Intellectual Property or Copyright is claimed since good science needs complete information of what has been found already. There are most interesting thoughts to this matter in CODATA[27] and "Creative Commons[28]", suggesting internet based protection of some rights.

The operating modes and underlying principles of collaboration, at least for natural and fundamental sciences can be summarised as follows:

- Consensus on common goals by scientists and funding agencies;
- Mutual respect and recognition; work amongst equals;
- A considerable freedom to self organising (conception-construction-exploitation) the efforts;
- Agreements or, minimally, MoU based on declared best efforts, agreed by the partners and the funding agencies;
- Well defined rights, duties and "deliverables" of all partners;

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[24] http://www.ivoa.net/
[25] http://www.ebi.ac.uk/ ; http://www.embl.org/
[26] http://www.ebi.ac.uk/Databases/
[27] http://www.codata.org/
[28] http://creativecommons.org/

- Completely open communication/sharing of all relevant information, data, technologies, insights, at least within the specific virtual community and better beyond;
- QA of deliverables, schedules, resources internally and involving peers and funding agencies;
- Critical mass to address all problems posed ;
- Sufficient resources (skilled people, funds, time).

According to this cooperation model that asks for best efforts and mutual trust many more possible e-science projects of common interest could be launched in fields such as energy, climate, biodiversity, agriculture cultural heritage, languages and education to name just a few.

The sustainable future of our planet will require enormous common efforts and the underlying sciences could be launched rather easily taking the models of existing sciences operating globally. This is particularly important when addressing the UN's Millennium Goals, MDG[29]. In a study of the Millennium Task Force in 2005 on the roles of science, technology and innovation for reaching the MDG[30] it was clearly stated that without a focussed global policy on science, technology and innovation and the corresponding education the MDG could not be reached at all.

There are many more science subjects that would profit from a global point of view and global cooperation.

The model is further naturally and particularly suited to address interdisciplinary efforts. CERN itself is involved in the promotion of hadron therapy facilities that make use of light ion beams to destroy particular cancers. This oncological undertaking makes use of the latest ideas and practices of radiation oncologists and uses a number of technologies derived from particle physics. A number of interesting facts have been learned in the close collaboration of two different sciences and the added value of the collaboration for the patients is considerable[31]. The most important and obvious fact learned was that the medical doctors and medical scientists set the goals and that the physicists help to define and provide the means of achieving the goals.

5. Conclusion: Sciences and "Service oriented knowledge facilities"

We have discussed above how sciences and especially data intensive sciences produce global e-infrastructures to support their knowledge acquisition. These e-infrastructures contain knowledge in all its forms from detailed know-how and practice via data, experimental results to abstract theory. They are science specific and composed of stand-alone elements that do not interwork and mostly need not interwork depending on the objectives for which they were conceived.

Other objectives, however, can be imagined were interworking might be desirable. Therefore science-specific efforts would be indicated to explore which bits and pieces of knowledge should be preserved and for which purposes. People doing this should keep in mind the full potential of the web to have accepted standards of representing documents and digital objects in a way accessible to everybody.

In W3C people talk about the semantic web[32] that "*provides a common framework that allows data to be shared and reused across application, enterprise, and community*

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[29] http://www.un.org/millenniumgoals/
[30] http://www.unmillenniumproject.org/reports/reports2.htm
[31] http://enlight.web.cern.ch/enlight/
[32] http://www.w3.org/2001/sw/

boundaries. It is a collaborative effort led by W3C with participation from a large number of researchers and industrial partners."

In Europe a discussion has been launched on "Service oriented knowledge utilities, SOKU", a global infrastructure that supplies access to secure, dynamic, networked services that provide information and knowledge for anyone, anywhere and anytime[33].

There is therefore scope to advance and make more complete the integration of repositories of scientific data, knowledge, technological know-how and best practices. For publicly financed science we would hope that such knowledge would in the end be openly accessible and available with powerful services to find the most appropriate and complete information.

For CERN this obligation is laid down in its Convention[34]. Therefore I hope that CERN and the particle physics community will join the effort to make its science and know-how easily and openly available in an ever more complete manner.

We should keep in mind the purposes of scientific efforts beyond the "joy of insight". Abdus Salam, the Noble Prize particle physicist from Pakistan has stated that: "*in the final analysis, creation, mastery and utilization of modern science and technology is basically what distinguishes the South from the North. On science and technology depend the standards of living of a nation*" We can safely say that the standards of living of people on our planet and its sustainable future will depend on global scientific efforts very probably using the successful methods of the present global collaborations

We have seen that e-sciences exist, produce and can expand into other fields, in particular into interdisciplinary fields and also in terms of technology transfer and common projects with industry. We have seen that the model of virtual organisations using a minimum overhead of administrative procedures and rules operate professionally, adapt to circumstances, permit critical mass and sharing of resources around the world.

We believe that for some time "knowledge utilities" will remain science specific and hope that common tools will emerge towards a "Web of (validated) Knowledge**[35]**", the next generation of Library of Alexandria.

Most importantly however scientific insights and scientific data become more useful and are validated with them being applied elsewhere.

For being applied easily knowledge in all its forms must be available as a "utility" like tap water in our houses.

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[33] ftp://ftp.cordis.europa.eu/pub/ist/docs/grids/soku-brochure_en.pdf
[34] The convention for the establishment of the European Organisation for nuclear research, ratified by its member states in 1954, stipulates under "*Purposes*": "*The Organization shall provide for collaboration among European States in nuclear research of a pure scientific and fundamental character, and in research essentially related thereto. The Organization shall have no concern with work for military requirements and the results of its experimental and theoretical work shall be published or otherwise made generally available.*"
[35] Dahlem Konferenzen, Dahlem Workshop on "Globalization of Knowledge and its Consequences", to be published

Physicist's experience of the EGEE/LCG infrastructure usage for CMS jobs submission

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Abstract

The presentation is devoted to the HEP physicists experience in the work with EGEE/LCG grid infrastructure for CMS analysis. A special attention is paid to the necessary knowledge about grid that CMS physicists should have in stock for a successful jobs submission (certificate, virtual organization, CE, SE, WN etc). The overview of the existing and available for he moment frameworks for jobs submission at CMS (CRAB, ASAP) and their comparison are presented. One concludes that physicists should be provided with useful tutorials. We have already some experience of such kind tutorials at JINR and ITEP and describe them in the report.

Introduction

LHC experiment is planned to start in 2008. It will be difficult for HEP physicists to prepare a data analysis without getting a priori experience with the distributed analysis tools when LHC starts. There are two developed frameworks for jobs submission available in CMS at the moment: CRAB [1] and ASAP [2]. These frameworks are developing independently but it is better to know how to use both of them for analysis. So CMS physicists need to have some basic knowledge about grid and to gain their own experience of successful jobs submission with existing tools. Specialized tutorials for physicists are very useful and welcome.

1. What do HEP physicists need to know about grid?

It is not rather important for HEP physicist to understand all internal details of EGEE/LCG infrastructure in contrast to grid developers. However, the corresponding terminology should be clear. Physicists should have in stock such terms like UI (User Interface), CE (Computing Element), SE (Storage Element), WN (Working Node), RB (Resource Broker), VO (Virtual Organization), certificate and so on.

On other hand, the full chain of physics job creation and submission should be clear. The user should be able to find information about the needed data for analysis, to write the configuration file for the task, to organize the most useful saving of the output, to submit jobs and to check the status of the submitted jobs. If necessary, the physicists should be able to kill and resubmit the jobs, see and analyze the service output. Sometimes it's also useful to recognize the "bad" computing element and avoid it to keep efforts and time.

2. The existing frameworks for jobs submission in CMS

For the moment there are several available tools for jobs submission. CRAB and ASAP are the most widely used at CMS. They are target to simplify the work of users to create and to submit analysis jobs into the grid environment. They allow users, without specific knowledge of grid infrastructure, to access and analyze remote data as easily as in a local environment, hiding the complexity of distributed computational services.

The examples of configuration files for ASAP and CRAB are shown in Fig.1 and Fig.2, correspondingly. They look very similarly from user's viewpoint. The user just should specify a datasets name, a name of the configuration file of required CMS software, a number of events, paths and names for outputs.

```
# specify directory to store tasks
jobdir = /afs/cern.ch/user/n/nilina/ASAP
# store output at SE
store_output = 1
output_se = srm.cern.ch
output_se_path=/castor/cern.ch/user/n/nilina
# specify grid to submit to (lcg, my)
grid = lcg
#specify dataset
dbs_version = 2
primary_dataset = DY_mumu_10
tier = GEN-SIM-DIGI-RECO
processed_dataset = CMSSW_1_3_1-Spring07-1349
# pset file (CMSSW configuration file)
pset_file = Z2muons.cfg
output_files = MUONS.dat
events_required = 5000
events_per_job = 1000
# specify minimum time requirements for the job
min_wall_clock_time = 100
min_cpu_time = 100
```

Fig. 1. The example of configuration file for ASAP

```
[CRAB]
jobtype = cmssw
scheduler = glitecoll
[CMSSW]
datasetpath = /DY_mumu_10/CMSSW_1_3_1-Spring07-1349/GEN-SIM-DIGI-RECO
pset = test.cfg
total_number_of_events  = 20000
events_per_job = 1000
output_file = MUONS.dat
use_dbs_2 = 1
[USER]
copy_data = 1
storage_element = srm.cern.ch
storage_path = /castor/cern.ch/user/n/nilina/Z2tau
return_data = 1
use_central_bossDB = 0
use_boss_rt = 0
[EDG]
rb = CERN
proxy_server = myproxy.cern.ch
virtual_organization = cms
retry_count = 0
lcg_catalog_type = lfc
lfc_host = lfc-cms-test.cern.ch
lfc_home = /grid/cms
```

Fig. 2. The example of configuration file for CRAB

For some historical reasons, CRAB is more popular among CMS users, but ASAP has a very nice feature that should be mentioned. User can delegate responsibility for the tasks performing to ASAP server and the server can process and monitor the user's jobs and perform resubmissions in the case of failure. So it's not need to keep an eye on the jobs status in case of accidental jobs failure.

3. Specific of grid tutorials for HEP physicists

To be ready for data analysis at LHC, physicists should be able to use CRAB and ASAP. So the special tutorials on grid for physicists are quite relevant at the moment.

We have already got the experience with such tutorials in Russia (JINR, ITEP). For example, the tutorial in ITEP (in April 2007) [3] had two parts: lectures and practice lab. The

program of the tutorial included the following questions: "Short introduction to LCG/EGEE", "CMS user jobs submission with the usage of ASAP".

The content of such tutorials should be different from tutorials for the developers. Physicists do not need to know all details about the LCG infrastructure. However, at the same time they will need to get the results, the output files, in the easiest way and for short time. All practical steps of jobs submission should be clarified for participants of the tutorial: from data finding to results retrieving. So the tutorial has to have a practical part – to provide the participants with the first experience, as it was on the ITEP tutorial mentioned above. In such a case, it is very important that all participants got their grid certificates in advance.

4. Conclusion

LHC experiment's start-up is in the near future. So physicists should be able to do the data analysis with Grid. But they do not need to understand all internal details of LCG infrastructure in comparison with developers, but the full chain of jobs submission should be clarified to them. The existing tools in CMS (CRAB, ASAP) allow to hide the complexity of distributed computational services from users. At the moment the HEP physicists should be provided with corresponding tutorials.

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RDIG (Russian Data Intensive Grid) e-Infrastructure

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The EGEE project (*Enabling Grids for E-sciencE; http://www.eu-egee.org*) has been organized to create a global infrastructure for a scientific sphere and it is supported by the European Community. A number of Russian institutes and the JINR successfully participated in the EU DataGrid (*http://www.eu-datagrid.org)* and LCG projects [1] have been invited by the European partners to join the EGEE project. The aim of the EGEE project is to gather all current national, regional and application grid developments into a common grid-infrastructure for the scientific research. The EGEE project infrastructure provides a 24-hour access to the most high-performance computing resources independently of their geographical location. The world-wide distributed scientific communities can use this infrastructure in the accordance with the common access rules. Nowadays the Enabling Grids for E-sciencE project brings together scientists and engineers from more than 240 institutions in 45 countries world-wide and the EGEE Grid consists of 41,000 CPU, about 5 PB disk (5 million Gigabytes) and tape MSS of storage and maintains 100,000 concurrent jobs. As the EGEE project started in fact at the LCG global infrastructure, the EGEE and LCG projects infrastructures are considered as a common LCG/EGEE infrastructure. The monitoring map of the LCG/EGEE infrastructure can be seen at the Fig1.
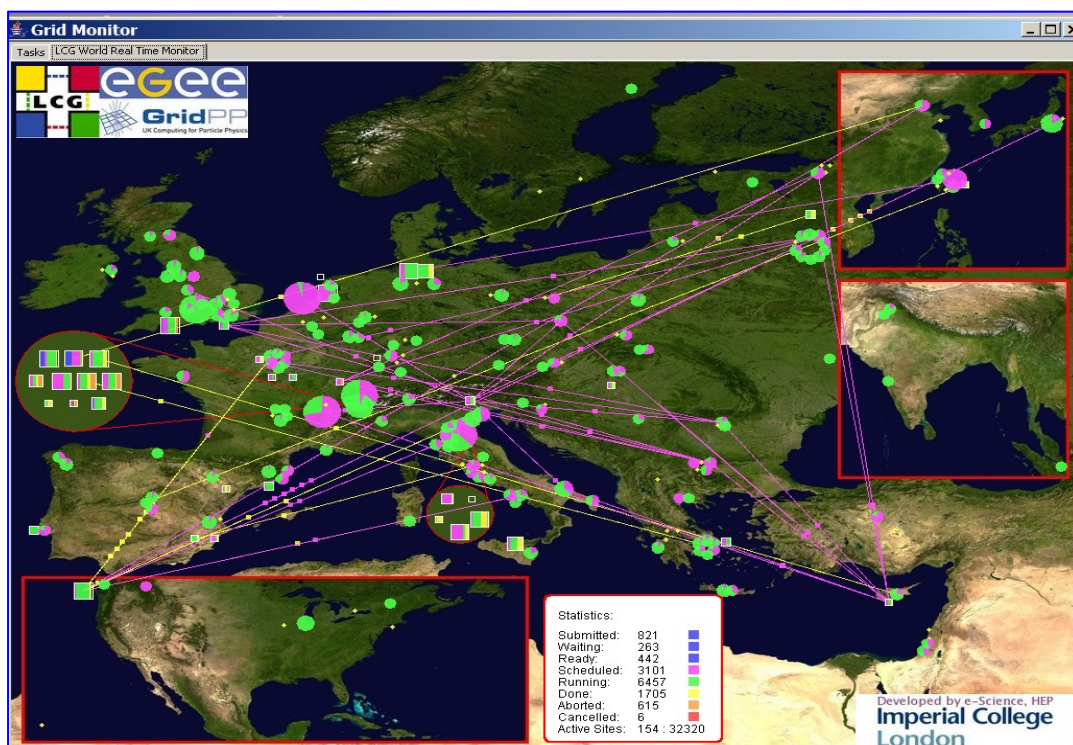
Fig.1. LCG/EGEE Infrastructure

The JINR and Russian institutes participating in the EGEE project founded the Russian Data Intensive Grid consortium (RDIG) as a national EGEE federation for to accomplish commonly the works in the EGEE project, develop the EGEE infrastructure in

Russia and involve another Russian organizations from different scientific, educational and industry spheres (see the RDIG consortium map at the Fig.2).
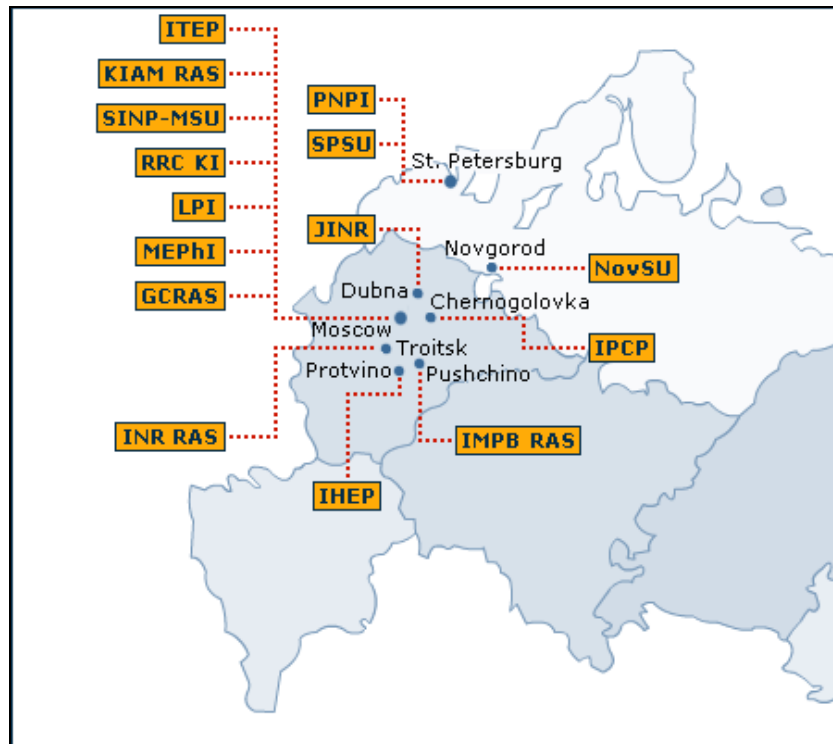
Fig.2. Russian Data Intensive Grid Consortium

The RDIG EGEE creation was fixed in an official document named the Memorandum on grid infrastructure creation in Russia signed in the 2003 year by the directors of eight institutes: IHEP - Institute of High Energy Physics (Protvino), IMPB RAS - Institute of Mathematical Problems in Biology (Pushchino), ITEP - Institute of Theoretical and Experimental Physics, JINR - Joint Institute for Nuclear Research (Dubna), KIAM RAS - Keldysh Institute of Applied Mathematics, PNPI - Petersburg Nuclear Physics Institute (Gatchina), RRC KI - Russian Research Center "Kurchatov Institute", SINP-MSU - Skobeltsyn Institute of Nuclear Physics,MSU.   Now the RDIG EGEE is a part of the global LCG/EGEE infrastructure and its infrastructure comprises 15 Resource Centers with more 1500 CPU and more 650 TB of disc storage. During 2006-2007 year the RDIG institutes participated in the following EGEE activities of the EGEE-I and EGEE-II phases of the project: SA1 - European grid operations, support and management, SA2 – network resource provision, NA2 – dissemination and outreach of knowledge on grid [2], NA3 – training and induction [3], NA4 – application identification and support [4].

The main directions in RDIG e-infrastructure development and maintenance are:
- support of basic grid-services;
- support of Regional Operations Center (ROC);
- support of Resource Centers (RC) in Russia;
- RDIG Certification Authority (CA);
- RDIG monitoring and accounting;
- participation in integration, testing, certification of grid-software;
- support of users, Virtual Organization (VO) and application;

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- user & administrator training and education;
- dissemination, outreach and communication grid activities.

The mission of the Worldwide LHC Computing Project (WLCG) is to build and maintain a data storage and analysis infrastructure for the entire high energy physics community that will use the LHC (*http://lcg.web.cern.ch/LCG/*). The modern grid technologies are the basis of the infrastructure building. The RDIG institutes participating in the LHC experiments (ALICE, ATLAS, CMS and LHCb) take part in the WLCG project. These activities were fixed in the Protocol between CERN, Russia and JINR signed and adopted in 2003. The following directions of the activities were defined:

- creation and support of the LCG infrastructure;
- testing of various new grid software to be deployed in the LCG;
- evaluation of the grid technologies in a context of their usage in the LCG: in particular, the Globus toolkit (*http://www.globus.org/*) or grid software from the industry (*http://gridcafe.web.cern.ch/gridcafe/gridprojects /industry.html);*
- development and support of the Monte-Carlo generator repository and data base *(MCDB; http://mcdb.cern.ch);*
- support and development of the Castor system (*CERN Advanced **STOR**age manager; http://castor.web.cern.ch/ castor/);*
- participation in the ARDA project (*A **R**ealization of **D**istributed Analysis for LHC*; *http://lcg.web.cern.ch/LCG /activities/arda/arda.html*).

By the middle of the 2004 year the LCG/EGEE infrastructure has been created at the RDIG institutes. In the 2006 year the migration from the LCG middleware environment to the gLite new generation middleware has been done [5]. Also the Scientific Linux 3 operational system has been updated to SL4. RDIG supports 16 Virtual Organizations. During the 2006 year about 500 000 jobs have been executed at the RDIG sites and about 50% of them were non-HEP jobs. The special server has been installed and supported to provide the RDIG EGEE/LCG sites monitoring based on the MonALISA system [6]. The RDIG monitoring and accounting system is accessible at the *http://rocmon.jinr.ru:8080*. Also the Russian testbed infrastructure for testing in the gLite 3.X environment was installed at several nodes located at PNPI, INR, IHEP and JINR.

Russia in the World-wide LHC Computing Grid can be considered as a cluster of institutional computing centers. The major centers of the Tier2 level are RRC KI, JINR, IHEP, ITEP, PNPI and SINP MSU, the others are expected to be Tier3 centers. Each of the Tier2-sites operates for all four experiments - ALICE, ATLAS, CMS and LHCb. This model assumes partition/sharing of the facilities (disk/tape and CPU) between experiments and the basic function are the following: analysis of real data; MC generation and users data support. Also analysis of some portion of RAW/ESD data for tuning/developing reconstruction algorithms and corresponding programming is planned with approximately equal partitioning of the storage between real AOD (Analysis Object Data), real RAW/ESD (Event Summary Data) and SimData (simulated physical events data). Tier1centers serving for Russian Tier2 sites as canonical Tier1 centers are: for ALICE - FZK (Karlsruhe), for ATLAS - SARA (Amsterdam) and for LHCb – CERN. CERN-PROD CMS center serves as CMS Tier1 centre for the Russian sites for the purposes of receiving Monte Carlo data from Russian T2 centres and also CERN-PROD is a special-purpose T1 centre for CMS taking a share of the general distribution of AOD and RECO (reconstructed) data as required. Current status of RDIG institutes connectivity to external links is: 1 Gbps now and 10Gbps in plans for ITEP, JINR, RRC KI, SINP MSU, LPI, MEPhI, SPbSU; 100 Mbps fiber-optic now and 1Gbps in plans for

IHEP; 45-100 Mbps for BINP (Novosibirsk); 100 Mbps - 1Gbps for PNPI (Gatchina) and fiber-optic 100 Mbps is under realization for INR RAS (Troitsk). The international connectivity for RDIG is the following: for connection with LCG centers in Europe GEANT2 PoP has been upgraded to 2.5 Gbps (plans for 10 Gbps); 1 Gbps connection Moscow-Amsterdam (a dedicated connectivity to "host" T1's (kind of LHC OPN extension) by use of GLORIAD). Also during the 2007 year a direct channel Moscow-CERN (310 Mbs - 1 Gbps) was in use and its testing by JINR has shown that average disk-to-disk transfer rate is 30 Mbyte/s.

In the frames of the participation in the WLCG, EGEE and ARDA [7] projects the following works have been done in a cooperation with foreign colleagues:
- support and development of the RDIG LCG-segment in frames of the global WLCG infrastructure;
- grid-monitoring and accounting system of Russian LCG/EGEE infrastructure;
- dCache usage/development;
- participation in CASTOR2 system development;
- FTS monitoring and testing (*https://twiki.cern.ch/twiki/bin/view/LCG/TransferOperations*);
- evaluation of new Grid technologies (OMII Open Middleware Infrastructure Institute, Globus Toolkit 3 & 4);
- gLite middleware testing/evaluation - testing of gLite AMGA metadata service[8], Metadata catalog, Fireman catalog, gridFTP and VOMS (Virtual Organization Membership Service) testing; test suite for gLite 3 User Interface; test suite for SRM; set of WMS stress tests;
- participation in Service and Data Challenges for ALICE, ATLAS, CMS and LHCb [9,10];
- participation in ARDA activities in coordination with experiments (CMS Dashboard development [11], condor-G monitoring, ATLAS Commander development);
- development of the MCDB system (LCG Monte-Carlo physical events data base) [12,13];
- courses for Grid administrators and users.

Users support and training (courses, lectures, trainings, publication of user guides in Russian) stimulates user's active usage of the WLCG/EGEE resources. During last years the induction courses (~ 600 people altogether attended), courses for application developers (~ 60 people altogether attended) and site administrators training (~100 participants in all) have been conducted at PNPI, RRC KI, JINR, IHEP, ITEP and SINP MSU. In the 2007 year more than 100 physicists from different LHC centers in Russia have got a special training how to submit their analysis jobs and access physical data in the WLCG/EGEE environment. It is especially important before the LHC start.

The RDIG-EGEE informational web-portal has been developed and is supported (*http://www.egee-rdig.ru*). All EGEE Info sheets and EGEE news releases are regularly translated into Russian and they are accessible at the RDIG-EGEE portal. The first "Grid Industry day" in Russia was organized in Dubna by JINR and it attracted a large number of industry organizations and companies interesting in deployment and usage of modern grid technologies. The 2nd international conference "Distributed computing and Grid technologies in science and education" (GRID-2006) was organized and hosted by JINR

(*http://grid2006.jinr.ru*). GRID-2006 gathered more than 200 scientists from Russia and CIS countries.

As a result of RDIG participation in the WLCG and EGEE project, the RDIG LGG/EGEE site is fully integrated into the worldwide LCG/EGEE grid infrastructure providing all the necessary resources, services and software for participation in ALICE, ATLAS, CMS and LHCb experiments after the LHC start which is expected in 2008 year. We plan to continue our participation in the WLCG project to support and develop the RDIG LCG/EGEE sites at the running phase of the LHC experiments. Also we shall continue our activities at the next stage of the EGEE project (EGEE-III) taking into account that these two global grid projects are developing in a close cooperation. A special attention will be paid to the grid deployment of new applications from the fields of nanotechnology, industry, medicine and engineering.

The results of RDIG activities in the WLCG and EGEE projects have been presented at the international conferences ("Distributed Computing and GRID-technologies in Science and Education", Dubna, Russia, 2006; ACAT 2007, Amsterdam, 2007; NEC'2007, Varna, Bulgaria, 2007; "Physics at the Future Colliders", Tbilisi, 2007), ICFA Workshop on Grid Activities within Large Scale International Collaborations (Sinaia, Romania, 2006) and the EGEE conferences (Geneva, 2006; Budapest, 2007) [14].

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Information technologies for experimental and theoretical studies conducted by JINR

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Introduction

The main tasks of the Laboratory of Information Technologies consist in the provision with modern telecommunication, network, and information resources, as well as mathematical support of theoretical and experimental studies conducted by the JINR, Member State institutes at JINR, and other scientific centers.

In order to fulfill the networking and computing tasks, it is necessary to provide: JINR and its Member States with high-speed telecommunication data links; fault-tolerant operation and further development of the high-speed and protected local area network of JINR; development and maintenance of the distributed high-performance computing infrastructure and mass storage resources; information, algorithmic and software support of the research-and-production activity of the Institute; a reliable operation and development of the JINR Grid-segment as a component of the global Grid-structure [1].

In the field of computational physics, it is needed to perform top research in computational mathematics and physics, aimed at solving specific problems arising in experimental and theoretical research carried out with the participation of JINR [1]. The successful realization of such research efforts assumes: development of mathematical methods and tools for modeling physical processes and experimental data analysis; creation of methods and numerical algorithms for modeling magnetic systems; development of software and computer complexes for experimental data processing; elaboration of numerical algorithms and software for simulation of complex physical systems; development of methods, algorithms and software of computer algebra; development of computing tools of a new generation. Application of the developed methods and algorithms to other topics in science and technology: nanotechnologies, biology, medicine, economy, industry, etc.

The creation of the distributed high-performance computing infrastructure and mass storage resources is centered around the JINR Central Information and Computing Complex (CICC) as a core of the distributed infrastructure. About 600 staff members of JINR and other research centres are using the JINR Central Information and Computing Complex. JINR CICC facilities were used by more than 15 experiments for mass event production, data simulation and analysis.

In 2006, the JINR CICC comprised 160 CPUs, and 57 TB disk memory. Total performance of computer centre was 100 kSI2K. In 2007, the JINR CICC has been substantially modernized and developed. A new supercomputing cluster was put into operation in June, 2007. At present, the CICC performance equals 670 kSI2K and the disk storage capacity 100 TB.

The performance assessment for parallel computing of the new supercomputer cluster of the JINR CICC was estimated by the High-Performance Linpack Benchmark. The Linpack performance output of 1.124 TFlops (peak performance 2 400 TFlops) ranks the JINR CICC cluster on the 12-th place in the Top50 list of the most powerful computing systems of the CIS states.

The traditional provision of information, algorithmic and software support of the JINR research-and-production activity included a large spectrum of activities both at LIT and JINR levels.

The elaboration of the JINR Grid segment and its inclusion in the European and global Grid structures have been done through the participation in the Worldwide LHC Computing Grid project (WLCG), the development of LCG/EGEE infrastructure, the participation in the development of the Russian Tier2 Cluster, Grid middleware evaluations, participation in the LHC projects ALICE, CMS, and ATLAS.

The project "Dubna-Grid" started in 2004 on the base of the Agreement between Administration of Dubna, JINR, and University "Dubna" for creation of a city-wide multi-purpose new generation informational infrastructure based on the Grid technologies. Some work was performed also in frames of participation in common projects: NATO project "DREAMS-ASIA", Worldwide LHC Computing Grid, and Enabling Grids for E-sciencE project. In 2005-2006 LIT JINR was a leading executor of work on the State Contract I-22.3/001 "Creation of a prototype of a new generation base Grid-services centre for intensive operations with distributed data of a federal scale". From the year 2007 LIT team participates in SKIF-GRID project.

The JINR Member States show a high interest in the LIT activities. The LIT cooperation with Romanian institutes is successfully realized within the Hulubei-Meshcheryakov programme. Protocols of cooperation have been conducted with INRNE (Bulgaria), ArmeSFo (Armenia), FZK Karlsruhe GmbH (Germany), IHEPI TSU (Georgia), NC PHEP BSU (Belarus), KFTI NASU (Ukraine), Tashkent (Uzbekistan), Wroclav (Poland), University of Bucharest, IFIN-HH (Romania) etc. In frames of this theme we have BMBF grant, CERN-JINR Cooperation Agreement on several topics, JINR-South Africa cooperation agreement.

Current state and future development of the JINR networking, computing and information infrastructure

The JINR networking, computing and information infrastructure is a distributed complex using specialized software and multipurpose equipment. The core of this infrastructure is the JINR Central Information and Computing Complex. The local area network of JINR (JINR LAN) is the basis of this infrastructure which integrates the information and computational resources of the Institute into a unified information environment accessible to all JINR users including the use of Grid-technologies thus providing a way of data exchange between scientific laboratories and administrative subdivisions. On its basis, through telecommunication channels, a remote access to the Russian and foreign scientific networks and a remote access to the resources of the Institute is provided.

Telecommunication data links of JINR

At present, JINR leases a 1 Gbps computer communication channel in the 2.5 Gbps channel of the Federal State Unitary Company "Space Communications". JINR has access to the Russian networks and information resources through the Russian networks RBNET+RUNNET.

The further development of JINR external communications assumes

· upgrade of the Dubna–Moscow channel up to 10 Gbps in 2008, 40 Gbps in 2010 and 100 Gbps in 2015;
· JINR's participation in the programme of creating a new generation research network;
· involvement in work on creation of the international segment, increasing the

throughput of the international channels up to 10 Gbps in 2008, 40 Gbps in 2010 and 100 Gbps in 2015.

JINR Local network

The JINR Local Area Network (JINR LAN) comprises about 6000 computers and nodes. The central communication centre has been modernized to create a failure-tolerant node of the LAN communication structure, to achieve a corresponding level of network safety, good parameters of data transfer and a toolkit for control, maintenance, access and reliability of the network.

Development of the JINR local network provides:

· transition to a 10 GB Ethernet technology for high-quality service of various type data, including multimedia and real-time systems;
· wireless and mobile access to all services and resources;
· implementation of novel decisions and methods to control the traffic, protect information and control, and effective ways of qualitative service.

JINR Central Information and Computing Complex

The development of the JINR distributed high-performance computing infrastructure and data storage resources is concentrated around the JINR Central Information and Computing Complex (JINR CICC) [2] which is a node of this infrastructure.

More than 600 staff members of JINR and other research centres are CICC users. At present, CICC comprises an interactive cluster, a computing farm for carrying out simulation and data processing of a number of physical experiments with an opportunity of parallel computations on the basis of modern network technologies (Myrinet, SCI, etc.), a computing farm LCG (LHC Computing Grid) for LHC experiments which is part of the computing infrastructure LCG/EGEE.

The CICC resources are used by participants of the experiments ATLAS, CMS, ALICE, COMPASS, D0, DIRAC, HARP, H1, NEMO, OPERA, HERMES, CBM, PANDA, etc. for simulation of physical processes and experimental data analysis.

Development of the JINR CICC provides:

· increase in the performance of the JINR CICC and of the data storage systems that provide the needs of data processing for LHC experiments and other experiments with JINR participation; development and support of base software;

	2007	2008	2009	2010
CPU (kSI2k)	1000	1250	1750	2500
Disk systems (TB)	150-200	400	800	1200
Mass memory (TB)			100	200

· development of software environment for information, algorithmic and software support of the research activity under way at JINR and institutes of Member States on the basis of the JINR CICC; development and support of Internet-resources with a dynamically generated content to provide JINR's participation in large international and national projects;
· development and introduction of distributed and parallel computing technologies:
  o development of parallel analogues for traditional programs of numerical methods where the basic tool of paralleling is supposed to be the MPI package, while the clusters from a big number of similar processors serve as a basic computing platform;

o step-by-step development and modification of re-engineering technology of distributed computing the key feature of which is the idea of automatic construction of a computing server from available, independently developed programs with the purpose of their integration into modern information processing systems, including the advanced tools of visualization, databases, expert systems and other mechanisms of the dialogue 'human being – machine'. The basic toolkit of creating the computing servers is a converter F2F developed at the JINR LIT.

Grid-technologies

· The development of the JINR Grid-segment as part of the global Grid-infrastructure with a full-function set of services provides:
o safety of Grid (reliable data transfer, user authentication, authorized access to resources);
o software maintenance;
o performance of jobs in the distributed environment;
o data transfer and management;
o data acquisition (work with files, databases, etc.);
o Grid-application programming interfaces.
· Participation in the creation of national and regional Grid-infrastructures of the JINR participating countries.
· Development of software "gridification" technologies for their use in the Grid-environment.
· Development of a distributed computing system for the JINR participating countries with use of Grid-technologies.

Information and software support of the research underway at JINR

In the nearest and distant prospect, LIT will continue its activity on information and software support of scientific research conducted by JINR. This activity traditionally includes development and support of informational WWW/FTP/DBMS-servers of JINR and LIT, creation and storage of electronic documents related to the JINR scientific and administrative activity, development, creation and support of information web-sites of workshops and conferences, administration and support of web-sites of JINR subdivisions and various conferences in a hosting mode as well as support, modernization and maintenance of computer systems of administrative databases (in cooperation with STD AMS JINR). Besides, work should be noted on supporting the automated system of bibliographic data processing for the JINR Library (in cooperation with the JINR Library) and conducting the LIT library with books and manuals for CICC users as well as support of the retrieval system as to ordering books available in the library, creation and support of electronic editions (web-sites) dedicated to the outstanding scientists of the Institute.

LIT carries out priority scientific research on creation and introduction of a paperless document circulation system which will allow one to exclude influence of the human element when conducting office-work in organizations (laboratories).

Another traditional direction of LIT activity is a consecutive development and support of the library JINRLIB [3], as well as support of program libraries developed by other science centres and organizations and information and technical help to users.

Computational physics: mathematical methods, algorithms and software

In the field of computational physics, it is needed to perform top research in

computational mathematics and physics, aimed at solving specific problems arising in experimental and theoretical research carried out with the participation of JINR. Key directions are:

· Creation and development of mathematical methods of data modelling and processing;
· Increase of efficiency of using applied software to solve problems of computing physics at the expense of paralleling by means of the MPI toolkit and development of new means allowing efficient use of multiprocessor personal computers;
· Development of numerical algorithms and software for simulation of complex physical systems;
· Development of methods, algorithms and software of computer algebra;
· Development of new generation computing means, research in the area of nanotechnologies, including, numerical modelling of structures with linear sizes less than ~100 nanometers to produce materials with predetermined properties.

Mathematical methods in particle physics and relativistic nuclear physics

Experimental data received with modern detectors, require new strategies of their analysis adequately answering such features as discreteness of images, complexity of the structure, a great volume of accumulated data, noise correlation, necessity of recognition of a large variety of objects – particle traces and particle showers, Cherenkov rings, etc.

Within this direction, the support of experimental and theoretical research will be carried out by the development of new methods and software complexes based on advanced applications of computational physics.

Strategically important items are:
· Development of new and modernization of existing mathematical methods to solve large-scale problems of particle physics and relativistic nuclear physics;
· Creation of methods and interfaces for enormous distributed data processing;
· Creation of middleware providing effective high-performance computing for solving scientific problems arising in particle physics and relativistic nuclear physics.

One of the traditional directions of LIT activity is the creation of distributed real time systems. This direction is developed, first of all, within participation in the creation of the data acquisition and ATLAS experimental data processing system. At the moment, an Event Dump component is being developed and supported which reads events from any data stream and interprets them according to the event type. The component can work locally, and also it can be built in other data visualization programs. A Resource Manager component responsible for using limited resources has been developed and is maintained. Both components are included into the latest release of the ATLAS data acquisition and processing system. In frames of this system, work is in progress on the development of a component WEB monitoring interface and a component Smart monitoring. Both components comprise a basis for elaboration of the JINR replica of the ATLAS Control Room at CERN. This will provide a way for the JINR scientists to participate directly from Dubna in real-time monitoring of the detector, in the shifts and data quality checking, as well as training the shifters before their visit to CERN.

Another promising project is the further development of the interactive system HEPWEB [4] and its integration into the Grid-infrastructure (within participation in the LCG project). HEPWEB is created for modelling physical processes in HEP. It is a system of interactive access to programs - generators of high- and intermediate-energy physics, access to information on their testing and check account at the LIT facilities with use of the WEB-interface. The long-term plans foresee development and use of the HEPWEB system for the problems of the ATLAS experiment.

Promising direction is software development based on large program complexes and

data visualization tools for modelling experimental installations with the use of statistical methods, Monte Carlo methods, artificial neural networks (ANN), cellular automata, wavelets, fractals, etc. In particular, for tasks of the ATLAS experiment, the development of methods to extract the insightful information in conditions of partial uncertainty is planned as well as hypothesis selection methods (in particular, a univalent choice of a hypothesis in the problem of definition of the top quark electric charge).

Within the CMS experiment, work is progressing in frames of the international collaboration RDMS-CMS (Russia - Dubna Member States), where LIT coordinates work on computing [5]. The basic directions of this activity include:

· coordination of operation and development of RDMS CMS Tier2 Cluster and its interaction with Tier1 with a centre in CERN;
· constant monitoring and testing of file transfer between the centre Tier1 at CERN and RDMS CMS Tier2 Cluster with using File Transfer Service (FTS) for data transfer;
· elaboration of a script of processing and analysis for physical processes;
· participation in the software development for the CMS experiment;
· installation and exploitation of modern software of the CMS experiment;
· development and support of RDMS CMS databases, experimental data transfer and management systems.

In frames of work on the development and support of RDMS CMS databases, a data storage scheme has been developed and realized that allows one to describe any type equipment and to store coupled structured and non-structured information (results of tests, calibration information, etc.). With the help of this scheme the universal Equipment and Conditions DB located at CERN and integrated with mass data storage has been implemented. Realized were necessary web-interfaces, API interfaces, specialized interfaces for data transfer and integration with other DB.

JINR is obliged to coordinate the participation of Russian centres in preparation and subsequent data processing for the ALICE experiment [6]. Currently eight Russian centres and JINR are included in the distributed data processing system of the ALICE experiment.

The coordination includes the following functions:

1) formulation of requirements for effective functioning of software in the ALICE experiment;

2) installation of services of the experiment on a special machine (VOBOX) in each centre, their adjustment with subsequent testing and commissioning;

3) daily monitoring of the status of all the centers. In case of problems in functioning the centre, their reasons are elucidated and directions of their prompt elimination are found;

4) regular update of the software of the ALICE experiment on the VOBOXs of all resource centres;

5) constant monitoring and testing of file transfer between the centre Tier1 FZK in Karlsruhe and the Russian centres with the use of service for data transfer - File Transfer Service (FTS).

Efficient methods of event reconstruction have been suggested for the experiment prepared at GSI (Darmstadt) as the expected enormous multiplicity of generated particles and the heterogeneous magnetic field make the event reconstruction considerably complicated [7]. In particular, two approaches to track reconstruction in the STS detector and algorithms of track recognition in the TRD detector have been developed, two alternative algorithms of finding Cherenkov rings in the RICH detector have been worked out, particle momentum determination methods have been elaborated. Work is in progress on particle identification applying RICH and TRD [8, 9], on the optimization of the geometry of the installation and the development of methods of extracting "useful"events.

For the experiments STAR and OPERA new, noise-resistant algorithms have been

developed with LIT participation on the basis of Radon-Hough transforms, artificial neural networks, cellular automata and wavelets [10].

The activity of LIT in particle physics and relativistic nuclear physics comprises computations of electromagnetic fields for magnetic systems of the planned experiments. For the ALICE experiment (CERN), designed was a three-dimensional map of the field of the magnetic system that includes a magnet L3, a muonic filter and a dipole magnet. For the project of an experiment with a polarized target developed at ITEP, computations were performed of the forces affecting the winding and poles of the magnet. Recently several variants of a dipole magnet have been simulated for the experiment CBM [11]. For the experiment PANDA, developed was an algorithm of constructing a computer model of a dipole magnet with the accuracy control.

Much attention is paid in LIT to new studies on the search for the mixed phase of strongly interacting matter. This trend addresses the following issues: modelling of transition processes in particle physics and nuclear physics, including formation of the quark-gluon plasma, evolution of dense nuclear matter and inelastic nuclear interaction: research in the properties of mesons and quark-gluon plasma within various quark models; research of phase transitions from the coupled states of mesons to quark-gluon plasma in frames of the "effective" models with separable interaction; construction of a phase diagram in T-μ plane; research on amplification of σ→ππ in point of phase transition and opportunity of resonant amplifications of two-photon spectra at final densities; estimation of probability of formation of the quark-gluon plasma in the central nucleus-nuclear collisions by comparison of computation results with experimental data [12].

Work is in progress on provision of a theoretical base of the experiments DIRAC and NA48 with the purpose of extraction from experimental data of information on lengths of ππ- and πK scattering: research in the properties of πK-atoms; calculations of the characteristics of interacting relativistic πK-atoms with the target; calculation of the probability of ionizing πK-atoms in substance on the basis of the specified characteristics [13]. Calculations of cross-sections of the processes of formation of electron-positron pairs in nucleus - nuclear collisions with capture of electron by one of colliding ones for LHC energies to make a more precise estimation of influence of these processes on decreasing intensities of the colliding nuclei beams are in progress. Simulation and calculation of nuclear effects in formation of hadrons with big cross pulses in nucleon-nucleon, nucleon-nuclear and nucleus-nuclear collisions at RHIC and LHC energies was performed.

Work is in progress on development of computing methods of QCD research: in the infrared area to study confinement mechanisms and scripts; on optimization of technique of fixing Lorentz calibration and Coulomb calibrations for non-perturbative computation of gluon and spirit propagators, a "running" a coupling constant and other calibration-invariant magnitudes in QCD lattice models; on study of the effect of Gribov copies on various calibration-invariant magnitudes; on computations with parallel supercomputers of big lattice calibration-invariant QCD magnitudes [14].

Mathematical methods in nuclear physics

Within this direction the support of experimental and theoretical studies will be conducted by way of the development of new methods and program complexes based on advanced applications of computational physics.

Strategically important issues are as follows:
- development of new and modernization of existing mathematical methods to solve large-scale problems of nuclear physics;
- elaboration of methods and interfaces for processing distributed data;

- development of middleware providing efficient high-performance computing to solve scientific problems of nuclear physics.

The script of the interaction assumes the formulation of the task coming from collaborations, its detailed study by experts in the field of computing physics and joint analysis of the results received. Successful examples of the implementation of such a script are given below.

Work is in progress on:

- Modelling of elastic and inelastic interactions of hadrons and nuclei with nuclei at intermediate energies with account of their microscopic structure and development of corresponding software complexes [15]. Application of the developed methods and programs for experimental data processing, including the data on interactions of exotic and stable nuclei obtained by FLNR JINR.

- Research on physical aspects of the electronuclear way of energy production and long-living waste transmutation [16]. Mathematical simulation of physical processes in nuclear reactions with heavy nuclei.

- Mathematical simulation of macroscopic phenomena and electromagnetic processes of superdense baryon matter of atomic nuclei and neutron stars in order to figure out laws of continual mechanics and macroscopic electrodynamics of nuclear matter [17].

- Analytical and numerical research of transition processes in the models of evolution of complex physical systems. Modelling of transition processes in a substance, including phase transitions, change of physical and chemical properties, appearing of localized structures caused by external sources. Development and numerical study of spatially non 1D models within the experiments on irradiation of materials by high-energy particle beams. Research based on the model of a thermal peak of temperature of electronic gas and crystal lattice in one-layer and two-layer materials with account of nonlinear thermal physical parameters [18].

Mathematical methods in condensed matter physics and nanotechnologies

The support of experimental and theoretical studies in this research field is focused on the development of advanced methods and program complexes of computational physics:

- Numerical simulation of the processes of appearance and evolution of localized structures in the systems described by nonlinear Schroedinger equation. Study of the properties of the localized structures depending on the parameters modelling dissipative and/or diffusion energy losses in the systems as well as energy inflow from the outside. Calculations of dependences of a "critical current - external magnetic field" type for the system of parallel coupled Josephson contacts in view of the highest approximations for Josephson current and for a two-layer system of contacts in the presence of heterogeneities [19].

- Simulation of the structure and properties of organic and biological materials within the experiments on small-angle neutron scattering. Study of water penetration of phosphorus-lipid membranes in single-layer vesicles depending on temperature and phase state of the membrane. Application of the developed methods and programs to study the properties of complex structured membranes [20].

- Numerical research in the evolution of biological difficult behaviour systems showing dynamic phase transitions and strong nonlinear effects. Development of a parametrical regulation method to control over the dynamics of complex systems by varying their control parameters.

- Construction of an exact self-consistent Bose theory of condensed systems. Research on the influence of strong random potentials on the properties of these systems. Computation

of basic thermodynamic and dynamic characteristics of systems with a damaged calibration symmetry. Development of the theory for regulating muddling up in systems of cold atoms in traps with coherent topological modes. Study of the opportunity of using a controlled muddling for data processing and in quantum computing [21].

- Study of a two-zoned Hubbard model for high-temperature superconductivity [22].
- Mathematical simulation of the electromagnetic properties of new heterogeneous nanomaterials (magnetic liquids, liquid crystals, firm small-disperse magnetics and electrics).
- Research in the electromagnetic response of nanoparticles of conductors, di-electrics and magnetics to estimate perspectives of their application in information and biomedical technologies.
- Development of the research in beam technology and nanotechnology for studying the influence of high-ionizing charged particles on materials using the thermal peak model.

Computer algebra and quantum computing
Key directions:

- Software development for using the system Reduce on various platforms and in various operational systems. Thus all the available memory (at present only 128 Mb RAM is accessible on 32-digit computers for system Reduce) will be accessible for use.
- The further development of original (involute) algorithms for their reduction to a canonical kind of systems of nonlinear algebraic, differential and difference equations facilitating their study and solution, and implementation of these algorithms in Maple, Mathematica, C/C++ [23]. Expansion of the system with open code GINV [24], which is a module of language Python, the most effective developed algorithms. Application of the developed algorithms and codes to the problems of theoretical and mathematical physics and applied mathematics.
- Development of specialized versions of involute algorithms and programs for modelling quantum computations with the help of the systems of polynomial equations and comparison of their efficiency with direct methods of linear algebra in the condition space of the multi-cubit quantum register.
- Application of a discrete relation method on abstract simplicial complexes to construction of a unitary matrix determining quantum computations, for a predetermined scheme of quantum computing.
- Research of cellular automata on 3-valent lattices with symmetric local rules which are getting of particular importance due to their possible application in nanotechnologies for research in new materials from carbonic forms, named by fullerens (nanopipes are their special case) and graphens [25].
- Development of symbolic numerical algorithms for modelling nuclear systems and quantum dots in external fields. Ions and quantum dots are, in particular, one of the most promising candidates for physical realization of cubits for quantum computers.

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The EGEE e-infrastructure: status and plans

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Abstract

Enabling Grids for E-sciencE represents the worlds' largest multi-disciplinary grid infrastructure today. Co-funded by the European Commission, it brings together more than 90 partners to produce a reliable and scalable computing resource available to the European and global research community. At present, it consists of 250 sites in 48 countries and more than 50,000 CPUs available to users 24 hours a day, 7 days a week. This article provides an overview of EGEE, its infrastructure, middleware, applications and support structures. From this experience, the current state of future plans will be explained, which is summarized under the term European Grid Initiative (EGI), and represents an emerging federated model for sustainable future grid infrastructures.

Keywords: Grid computing, e-Infrastructures, scientific computing, sustainability.

Introduction

Over the past decade, European states and the European Commission have invested heavily in grid technology. A report [1] by the GridCoord project in 2005 shows more than 100 million Euro per year of investment on a national basis without EU funding, in the years 2002 to 2006. The European Commission reported a spending of 275 million Euro over the same timeframe.

Initially, these efforts were driven by academic proof-of-concept and test-bed projects, such as the European Data Grid project [2], but have since developed into large-scale, production grid infrastructures supporting numerous scientific communities. Leading these efforts is a small number of large-scale flagship projects, mostly co-funded by the European Commission, which take the collected results of predecessor projects forward into new areas. Among these flagship projects, EGEE (Enabling Grids for e-SciencE) unites thematic, national and regional grid initiatives in order to provide an infrastructure available to scientific research in Europe and beyond[3].

The EGEE infrastructure and its usage has grown dramatically during the first four years of its planned six-year programme, and is now exploring ways to develop sustainable models to ensure the long-term availability of its grid infrastructure to the larger research community.

This paper provides an overview of the EGEE project, currently in its second two-year phase under the name EGEE-II. Section 1 introduces EGEE-II and some of its characteristics in numbers. Section 2 defines the grid landscape in Europe and EGEE's role in incubating collaborating grid projects. This is followed by a description of EGEE's infrastructure in Section 3, an overview of EGEE applications in Section 4, an introduction to EGEE III in section 5 and an outlook of the future sustainable model in Section 6. Concluding remarks end the paper in Section 7.

1. EGEE in a nutshell

The EGEE project has turned the vision of the seamless sharing of computing resources on an international scale into reality. Co-funded by the European Commission, it was launched on 1 April 2004 to establish a European grid infrastructure in support of the European Research Area.

The first two-year phase of EGEE ended successfully on 31 March 2006, exceeding almost all its goals, turning the proof-of-concept test bed developed by DataGrid into an early

production system In its second phase, EGEE-II, which started on 1 April 2006, over 100 partners in 32 countries are organised in 13 federations to make up the project's consortium. On the global landscape, EGEE has expanded beyond Europe, establishing international relationships with groups in the US and Asia.

The primary goal of EGEE is to produce and maintain a production quality grid infrastructure. Beyond this, it aims to spread knowledge about the grid and its benefits to researchers and students in high energy physics, life and earth sciences, astrophysics, computational chemistry, fusion and other fields. In addition, it has generated interest from a wide spectrum of IT vendors and business applications.

As a main result, the project has constructed an infrastructure with 250 sites in 48 countries, making it the world's largest multi-science grid infrastructure, offering a 24/7 service to its users. Currently, this infrastructure processes more than $100,000$ jobs per day from eight scientific domains, ranging from biomedicine to fusion science. In total, over 200 Virtual Organizations (VOs) use the EGEE infrastructure.

To organize and integrate the disparate computational facilities belonging to a grid and to make their resources easily accessible to users, the project has assembled its own grid middleware, the gLite distribution [4]. The gLite middleware was re-engineered by the project from a number of best-of-breed middleware components to contain a full range of foundation services as well as support for field- and application-specific high level services.

Built on the pan-European network GÉANT, EGEE has significantly extended and consolidated the EGEE grid in its second phase, linking national, regional and thematic grid efforts, as well as interoperating with other grids around the globe. The resulting high capacity, world-wide infrastructure greatly surpasses the capabilities of local clusters and individual centres, providing a unique tool for collaborative compute-intensive science, so-called "e-Science".

2. The pan-European grid landscape

Fig. 1. Countries within EGEE or connected to the EGEE Infrastructure via collaborating projects

The vision of grid computing that launched EGEE implies a sharing of resources across institutional, disciplinary and national boundaries, in contrast to 'enterprise grids'

which often exist within individual companies. The broader vision pursued by EGEE and others requires members of individual grids to be aware of and cooperate with other related grid efforts to work toward interoperability at both an European and global level.

While EGEE primarily attracts computing centres with clusters of commodity PCs, the project is also collaborating with supercomputing grids via the DEISA (Distributed European Infrastructure for Supercomputing Applications) project, also co-funded by the European Commission.

Europe contains a number of projects, generally co-funded by the European Commission, which extend the reach of the EGEE infrastructure to new regions. These include European member states as well as other countries in areas such as the Baltic States, Latin America, China, India, the Mediterranean and South Eastern Europe (see Figure 1 and Table 2).

Working closely with EGEE in Russia is the Russian Data Intensive Grid consortium (RDIG). Through RDIG, Russia is one of six teams who work in weekly rotation to be the EGEE Grid operator on duty, providing support for basic grid services. RDIG also supports local Grid users and VOs, the Regional Operations Centre and the Russian Resource Centres. RDIG is made up of eight institutes, all EGEE partners (see. Table 1).

Table 1. Russian partners of the EGEE-II project

Institute of High Energy Physics, Protvino	Keldysh Institute of Applied Mathematics of Russian Academy of Sciences
Institute of Mathematical Problems of Biology of Russian Academy of Sciences, Pushchino	Petersburg Nuclear Physics Institute of Russian Academy of Sciences
Institute for Theoretical and Experimental Physics, Moscow	Russian Research Centre "Kurchatov Institute"
Joint Institute for Nuclear Research, Dubna	Skobeltsyn Institute of Nuclear Physics of Moscow State University

On the global stage, EGEE has close ties to Asia through partners in Taiwan and Korea (both of which operate sites on the EGEE infrastructure) and works with Japan's NAREGI project. In the US, EGEE again has project partners but also works with the Open Science Grid (OSG) and TeraGrid.

Table 2. Infrastructure projects connected to EGEE and deploying gLite

PROJECT	COUNTRIES INVOLVED
BalticGrid	Estonia, Latvia, Lithuania, Poland, Sweden and Switzerland
EELA	Argentina, Brazil, Chile, Cuba, Italy, Mexico, Peru, Portugal, Spain, Switzerland, and Venezuela
EUChinaGrid	China, Greece, Italy, Poland, Switzerland and Taiwan.
EUIndiaGrid	India, Italy, United Kingdom
EUMedGrid	Algeria, Cyprus, Egypt, Greece, Jordan, Israel, Italy, Malta, Morocco, Palestine, Spain, Syria, Switzerland, Tunisia, Turkey and the UK
SEE-GRID	Albania, Bulgaria, Bosnia and Herzegovina, Croatia, Greece, Hungary, FYR of Macedonia, Moldova, Montenegro, Romania, Serbia, Switzerland, Turkey.

Both within Europe and world-wide, scientific research grid infrastructures face many of the same problems, and all are developing solutions for how to drive grid computing forward. One notable effort, organised through the Open Grid Forum (OGF) standards organisation, is Grid Interoperation Now (GIN)[5]. Through this framework, EGEE works with the other major infrastructures mentioned above to make their systems interoperate with one another. Already this has led to seamless interoperation between OSG and EGEE, allowing jobs to freely migrate between the infrastructures as well as seamless data access using a single sign-on. Similar efforts are currently ongoing with NAREGI, DEISA, and NorduGrid. As part of the OGF GIN effort, a common service discovery index of nine major grid infrastructures world-wide has been created, allowing users to discover the different services available from a single portal [6].

3. The EGEE Infrastructure

The computing and storage resources that EGEE integrates are provided by a large and growing number of Resource Centres in all regions contributing to the infrastructure, coordinated by so-called Regional Operations Centres, or ROCs. The gLite middleware binds these resources into a single infrastructure to provide seamless access for the project's user communities. Users thus have access to resources that would not be available without the grid, permitting scientific investigations that would otherwise not be possible. Such a grid-empowered infrastructure facilitates collaborations of geographically dispersed communities who can thus share data and resources.

In addition to the resources and services provided by EGEE, significant additional resources are made available to the research community through related infrastructure projects

and interoperation with grid infrastructures world-wide. A number of external groups from the research and business sectors also provide resources in order to gain experience as infrastructure providers. This makes up around 25% of the overall capacity of the EGEE grid infrastructure.

3.1. The EGEE Production Service

The Production Service is a supported infrastructure capable of maintaining the high throughput of jobs needed to be of daily use to the scientific and research communities.

This production service is spread across more than 40 countries, managed by 11 Regional Operation Centres (ROCs), who share overall responsibility for the infrastructure on a rotating 8x5 basis.

At present the production service has access to more than 20 petabytes of storage and 50,000 CPUs, with numbers expected to rise dramatically over the next year as extra resources for the experiments of the forthcoming Large Hadron Collider (a next-generation particle accelerator currently under construction at CERN, Switzerland) and other new applications come online. Already these figures considerably exceed the goals planned for the end of the four-year EGEE programme, demonstrating the enthusiasm within the scientific community for EGEE and grid solutions. In 2006 the production service processed 19.6 million jobs totalling 8400 CPU-years. In 2007 this figure rose dramatically to 44 million jobs.

The distributed operation model used by the project is key to the success of EGEE—a centralized operational model would not be scalable to the large amount of sites federated in EGEE. It is worth noting that in 2006, EGEE saw a three-fold increase of the workload together with significant increases of the infrastructure both in terms of sites and CPUs without any impact on the overall operations of the infrastructure. Fig. 2 shows the development of EGEE in terms of numbers of sites.
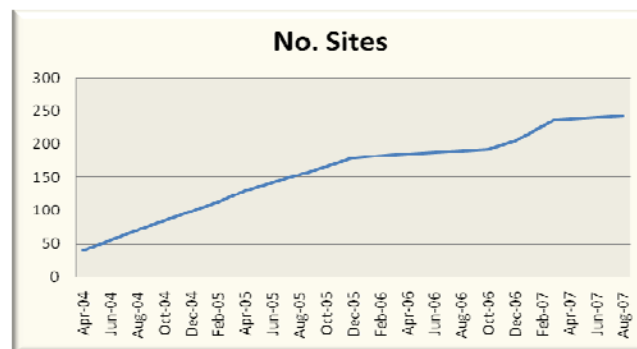
Fig. 2. Development of the EGEE infrastructure

3.2. The gLite Middleware

EGEE deploys the gLite middleware [4], a middleware distribution that combines components developed in various related projects, in particular Condor [7], The Globus Toolkit (GT) from Globus [8], LCG [9], and VDT [10], complemented by EGEE developed services. This middleware provides the user with high level services for scheduling and running computational jobs, accessing and moving data, and obtaining information on the grid infrastructure as well as grid applications, all embedded into a consistent security framework.

The gLite middleware is released with a business friendly open-source license (Apache 2), allowing both academic and commercial users to download, install and even modify the code for their own purposes.

The gLite grid services follow a Service Oriented Architecture [11], which will facilitate interoperability among grid services and allows to easily complement the services provided by gLite with application specific services, such as metadata catalogs and meta-schedulers, which is a common usage pattern on EGEE.

The focus of gLite is on so-called *foundation services*. These services provide the basic middleware infrastructure that defines the EGEE grid and encompass the security infrastructure, the information and accounting systems, as well as access to computing and storage resources, typically referred to as Compute Elements and Storage Elements. Examples of higher level services, like a meta-scheduler, replica catalog, or file transfer service are included in the gLite distribution as well. The gLite security infrastructure is based on X.509 certificates, involves sophisticated tools for VO management and local authorization and is currently being integrated with upcoming organization membership services based on Shibboleth [12]. The information system is based on hierarchical 'ldap' servers and the accounting system uses the OGF defined usage records facilitating interoperability with other infrastructures. Access to compute resources is provided via Condor and GT2 GRAM (which is currently being updated to GT4 GRAM), work on a HPC-Profile/BES [13] compliant interface is ongoing [14] and EGEE has standardized on the SRM [15] interface to storage resources, for which a number of production-level implementations are available. GridFTP is used for data transfer.

The gLite distribution is available from the gLite website: http://www.glite.org. The current version 3.1 was released in June 2007 and is presently supporting Scientifc Linux 3 and 4. More details on gLite are available in [4] and via the gLite documentation available from the gLite webpage.

EGEE has taken a conservative approach in defining the gLite composition, avoiding frequently changing cutting-edge software while tracking emerging standards. For a production infrastructure, reliability and scalability are of higher value than the exploitation of the very latest advances that still need time to mature. EGEE is moving towards web services adhering to WS-Interoperability recommendations wherever possible.

In order to achieve the required reliability and scalability to support the size and workloads of EGEE a strict software process, involving several stages of testing has been applied. This process, which has been modelled after industry strength processes, includes software configuration management, version control, defect tracking, and an automatic build system. The experiences gained with the gLite developments are made available to other software projects via the ETICS project [16] that offers the software development tools to a wider community.

4. EGEE Applications

EGEE actively engages with application communities, beginning with High Energy Physics and Life Science at the start of EGEE but expanding to support many other domains. These include Astronomy, Computational Chemistry, Earth Sciences, Financial simulations, Fusion science and Geophysics, with many other applications currently being evaluated by the project.

These applications are now at production status, with some communities already running large numbers of jobs on a daily basis. These communities are organized using Virtual Organizations, groups of people working in the same domain or specific research area. These allow users to access common data sets and tools, and enable remote collaborations in

research. Already, EGEE supports more than 200 such virtual organizations. These include both groups actively supported by EGEE, with help being provided for application porting and the inclusion of special features into the gLite middleware, and groups who simply make use of the general services EGEE provides.

4.1. Large Hadron Collider

Support for processing data coming from the forthcoming Large Hadron Collider (LHC), a next-generation particle accelerator under construction at CERN, Switzerland, was a major driver in the development of the EGEE programme. The LHC experiments are predicted to produce 15 petabytes of data per year, implying a scale of data-processing that made grid technology a natural choice. EGEE works closely with the Worldwide LHC Computing Grid (WLCG) collaboration set up to distribute and process this data. Through the EGEE infrastructure, members of the global physics community will be able to collaborate on the analysis of this data, which it is hoped will find the Higgs boson, an important step in the confirmation of the so-called 'standard model' in particle physics.
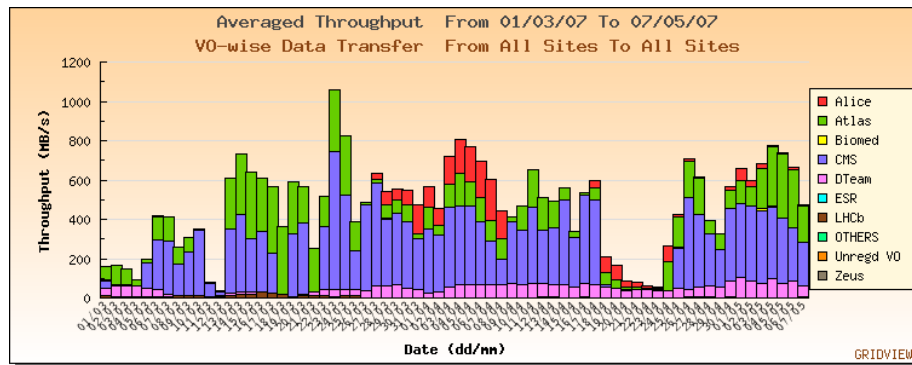
Fig. 3. Average throughput for High Energy Physics experiments

These LHC experiments also help to stress-test the EGEE infrastructure due to their large-scale requirements. An example of this is the network bandwidth needed for the distribution of the LHC data, where the experiments have each demonstrated capacity of one petabyte per month transfer, and aggregate speeds for the LHC experiments have reached one gigabyte per second with real workloads (see Figure 3). When the LHC is fully operational, the data from the experiments will account for 60% of the load on the Grid infrastructure

5. EGEE III – The next step

EGEE II will be succeeded by EGEE III, another 2-year phase co-funded by the EC. EGEE-III aims to expand and optimise the Grid infrastructure, through continuous operation, support for more user communities, and addition of further computational and data resources. In addition, a second goal is to prepare the migration of the existing production European Grid from a project-based model to a sustainable federated infrastructure based on National Grid Initiatives for multi-disciplinary use.

EGEE has become a critical infrastructure for a range of top European scientific undertakings. Most European countries have Grid infrastructures, at varying levels of maturity. A limitation of national Grids is their lack of access provision to international science

communities. Beyond the national level standards become important to allow ease of connectivity and sharing of applications. EGEE ensures that the European Grid infrastructure does not fragment into national and thematic Grid infrastructures, with less coherence at a European level. EGEE-III will provide a world class, coherent and reliable European Grid, ensuring Europe remains at the forefront of scientific excellence.

A proposed solution is an operational model based on National Grid Infrastructures (NGIs) coordinated by a body named the European Grid Initiative (EGI). Driven by the needs and requirements of European research community, the EGI Design Study [17] is a project for the conceptual setup and operation of a new organizational model of a sustainable pan-European grid infrastructure.

6. Conclusions

Since the launch of the EGEE programme in 2004, the project has made strides forward in both delivering a world-class production grid infrastructure and strengthening the grid field in general. Through provision of a reliable, scalable production infrastructure, high quality middleware and well developed support services, EGEE has attracted a wide range of users from the research and business communities.

These users began by experimenting with grid technology via EGEE, but are have now shifted to daily use of the EGEE grid. This is particularly notable with the two original applications groups associated with EGEE, High Energy Physics and the Biomedical field, but these groups are rapidly being joined by groups such as Earth Sciences as major grid users.

The LHC start-up in 2008 will provide EGEE with its largest challenge yet, and the opportunity to demonstrate Grid technology on an unprecedented scale. EGEE is the cornerstone of the LHC computing architecture, and without it the sheer volume of data the experiments will produce could not be processed, stored and analysed.

While the user base has grown rapidly, with more than 200 Virtual Organizations now making use of the EGEE grid, the short project lifespan of EGEE and EGEE-II is becoming a limiting factor in EGEE's ability to attract users. To address this issue, EGEE has worked alongside the European Commission and other members of the grid community to work on a long-term solution, namely the European Grid Initiative. This body would coordinate European grid computing in collaboration with the many emerging National Grid Initiatives to provide for long term support for grid users in Europe. Such a move will ensure that Europe keeps its place as a world leader in grid computing.

Acknowledgements

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Hardware optimization of devices based on tagged neutron technology

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Abstract

The possibility of background suppression by spatial and time discrimination of events stipulates the potentialities of Nanosecond Tagged Neutron Technology (NTNT) for neutron analysis. For practical application of NTNT, the multi-detector systems and high intensity (up to $1 \cdot 10^8$ 1/s) neutron generator with the built-in alpha-detector should be used. The total intensity of signals can exceed $1 \cdot 10^6$ 1/s from all gamma-detectors and $1 \cdot 10^7$ 1/s from all alpha-detectors. A preliminary "on-line" data processing (selection of useful events) by hardware sufficiently facilitates the data transmission interface and computer equipment. The basic criteria of selection are the presence of signals from alpha- and gamma- detectors in the certain time interval (tracking interval), range of gamma-ray energy, and absence of foldover of the signals. The suggested architecture of data acquisition and control system is discussed. The basic components of background and factors affecting the total time resolution are examined. The preliminary results demonstrate high efficiency of NTNT for suppression of background by spatial and time discrimination of events.

1. Introduction

One of basic challenges of neutron technologies of remote control is the high background affecting the accuracy of measurements. Last years, the nanosecond tagged neutron technology (NTNT) has been rapidly progressing [1]. This technology provides effective (by 2-4 orders of magnitude) suppression of background by spatial and time discrimination of events. NTNT is the most effective for solving such tasks as the detection, identification, and localization of chemical explosives. The composition of the object is identified by analyzing the spectrum of gamma-rays induced by inelastic neutron scattering on carbon, nitrogen, and oxygen nuclei (that enter into the composition of explosives).

NTNT is based on the following principle. Neutrons are produced at the $T(d,n)^4He$ reaction while deuteron beam bombards the tritium target. Vectors of escape of neutron and associated alpha-particle (^4He) are uniquely correlated [2]. A multipixel position- and time-sensitive alpha- detector measures the time and position of incident alpha-particles. It provides the angle and time of neutron escape (the "tags" of neutron). The fast "tagged" neutrons are directed to an object of interest and induce characteristic gamma rays produced through the inelastic scattering of neutrons. Individual nuclei inside the object are identified by recording energy spectrum of emitted gamma-rays by a gamma-detector array.

A data acquisition and control unit traces the number (position) of gamma-detector, gamma-ray energy and time between recording of signals from alpha- and gamma detectors, as well as a number of activated pixel of alpha-detector. The speed of 14 MeV neutron is as high as 5.2 cm/ns. Thus, the precision of timing for event localization with the accuracy of several cm should be around 1 ns.

For practical application of NTNT, the multi-detector systems and high intensity (up to $1 \cdot 10^8$ 1/s) neutron generator with the built-in alpha-detector should be used [1].The total intensity of signals can exceed $1 \cdot 10^6$ 1/s from all gamma-detectors and $1 \cdot 10^7$ 1/s from all alpha-detectors. The transmission of such intensive stream of data to the computer and its processing might heavily complicate the data transmission interface and computer equipment. Thus, it is reasonable to implement the on-line preliminary data processing by hardware. The basic criterion of selection of useful events is the presence of signals from alpha- and gamma-detectors in the certain time interval (tracking interval), range of gamma-ray energy, and absence of foldover of the signals.

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2. Data acquisition and control system for NTNT

The flow block of data acquisition and control system (DAC) system suggested by Russian Research Center "Kurchatov Institute" [2] and then realized in several versions is given in Fig.1. The signals from gamma-detectors come to the gamma-channel units; each unit processes signals from several gamma-detectors. The master is always the signal from gamma-detector. The constant fraction discriminator CFD at the input of each gamma-channel generates the logic signal T_γ that starts the time-digital converter TDC and initiates encoding of the number of activated gamma-detector (R_γ). The shaping amplifier ShA provides the required resolution of measurements of signal amplitude by analog digital converter ADC.

The alpha-channel unit issues a logic signal T_α (time stamp of alpha-particle recording) and code of the number of activated pixel of alpha- detector (R_α). These signals are transmitted to the timing and address buses of alpha-channels and shared by all units of gamma- channels. As far as the counting rate of gamma-detectors is much less than those from the alpha-detector the master is always the signal from the gamma-detector. However, as far as the signal from the alpha- detector comes first, the delay line DL (several dozens ns) is shifted the time of arriving of the T_α signal to TDC after the T_γ signal for proper timing.

The univibrator UV_T generates the pulse with duration equal to the tracking interval. If the T_α signal from the alpha- channel comes during the tracking interval, it initiates ADC to measure an amplitude of gamma-signal A_γ and initiates TDC to measure a time interval between signals from alpha- and gamma- channels $T_{\alpha\gamma}$. After completion of measurements, the codes A_γ, R_γ, R_α, and $T_{\alpha\gamma}$ are packed by the microprocessor and sent to the computer PC. The anticoincidence unit AC and foldover discriminators prevent the writing of the event at the presence of two or more signals from detectors during the tracking interval.

The main features of DAC systems developed by this scheme are as follows:
- Quantization of sampling time: 0.075- 0.2 ns
- Intrinsic time resolution of hardware: ≤ 0.3 ns;
- Digit capacity of time code: 8- 12 bits;
- Digit capacity of gamma-energy code: 8- 12 bits;
- Digit capacity of the code of gamma-detector number: 8 bits;
- Digit capacity of the code of alpha-detector pixel number: 8 bits.
- Options of the interface for data transmission to the computer: Ethernet; RS-422; RS-485; USB; Bluetooth.

The suggested architecture of DAC system allows alteration of the number of gamma-detectors, connection of alpha-detectors with various number of pixels, usage of scintillation units with different crystals. It makes possible to use unified DAC system with different devices utilizing tagged neutron technology for various applications- from explosives detection in sea cargo containers to inspection of hand luggage.

3. Testing of DAC system

The DAC system was tested with the experimental test-bench included the **NG-27** neutron generator (NG) manufactured by Dukhov All-Russian Research Institute of Automatics [1] with the built-in 9-pixel semiconductor alpha-detector. The tagged neutrons were directed to the graphite box (7 cm in height, 5 cm in width, 3 cm in thickness). The gamma-rays induced by neutrons were recorded by the **LYSO** gamma-detector 50 mm in diameter and 50 mm in height coupled to the **XP4372** photomultiplier [3]. A configuration of the test-bench and basic dimensions are given in Fig. 2. The signals from the gamma- and

alpha-detectors were processed by the DAC system described above. During the measurements, the intensity of NG was as high as $2 \cdot 10^7$ 1/s.

The time spectrum of alpha-gamma coincidences (upper curve) measured by DAC system is given in Fig. 3. The gamma-detector was shielded from the NG by 8 cm iron bar. The lower curve displays the background spectrum taken when the graphite box was removed.

A portion of "tagged" neutrons are scattered in the copper holder of target and the casing of NG inducing background gamma-rays. This peak of "correlated" background (indicated in Fig. 2 as NG peak) is partially suppressed by the iron shielding. Another component of "correlated" background (scattered neutrons peak) is caused by the elastic scattering of tagged neutrons in graphite towards the gamma-detector.

The "non-correlated" background includes:

- Gamma-rays induced by "non-tagged" neutrons (emitted at the high angles about the "tagged" neutron paths; the associated alpha-particle is not recorded by the alpha-detector).
- Gamma-rays emitted through the reactions other than inelastic scattering (radiative neutron capture, radioactive decay, etc.).

It can be seen a good time separation of peak of "useful" events (peak of graphite) from peaks of correlated background. The width (FWHM) of the peak of graphite on the time spectrum diagram can be assessed as $\tau = \sqrt{\tau_0^2 + \tau_f^2}$ where τ_0 is a total time resolution of the measuring system, τ_f is a time of 14-MeV neutron flight through the graphite box. As far as $\tau \approx 1.2$ ns and $\tau_f \approx 0.6$ ns, then $\tau_0 \approx 1$ ns. The time between the peak of graphite and NG peak corresponds to the time required for 14 MeV neutron to pass the distance between the NG and graphite.

As far as the events beyond the tracking interval are rejected by the DAC system, these components of "non-correlated" background are highly reduced as can be seen in Fig. 3 (lower curve).

Fig. 4 displays the time spectrum of alpha-gamma coincidences when the iron shielding was removed. It can be seen the increase of NG peak and "non-correlated" background, however, the peaks are still well separated, and the time resolution is close to 1 ns. The results of these measurements demonstrate that the NTNT based systems can operate without a massive shielding of a gamma- detector. It provides the opportunity to develop a portable hand-held neutron- based explosives detector with a sufficiently reduced weight.

4. Discussions

It was demonstrated that NTNT provides suppression of background by spatial and time discrimination of events. The efficiency of background suppression increases with the improvement of time resolution of NTNT system. The total time resolution τ_0 can be estimated as:

$$\tau_0 = \sqrt{\tau_i^2 + \tau_{D\gamma}^2 + \tau_{D\alpha}^2 + \tau_{G\gamma}^2 + \tau_{G\alpha}^2} \, ,$$

where τ_i is the intrinsic resolution of DAC hardware; $\tau_{D\alpha}$ and $\tau_{D\gamma}$ are the time jittering of alpha- and gamma detectors; $\tau_{G\alpha}$ and $\tau_{G\gamma}$ are the geometrical factors caused by finite size of alpha- and gamma- detectors. The value of τ_i for DAC hardware measured using the signals from external pulse generators was as low as 0.3 ns [4]. For the detectors used in the existing NTNT systems [1], the assessed values of $\tau_{G\alpha}$ and $\tau_{G\gamma}$ are less then 0.5 ns.

The jittering of gamma-detector $\tau_{D\gamma}$ is caused by PMT transit time difference, fluctuations of charge collection, etc. For small crystals (1 inch) the jittering can be as low as 0.5 ns for fast inorganic scintillators [4]. However, the scintillator for NTNT applications should have sufficient volume for full absorption of gamma-rays with the energy above 1 MeV. The jittering increases with the scintillator volume and active diameter of PMT. Currently, the several types of gamma-detectors based on **NaI(Tl)**, **BaF$_2$, LYSO,** and **BGO** scintillators have been assembled for measurements of time and experimental spectrums of alpha- gamma coincidences with the aim of a choice of the proper gamma- detectors for commercial NTNT systems. The diameter of scintillators varies from 50 mm to 60 mm; the crystals are coupled with ultrafast photomultipliers of similar type produced by Photonis Group [3].

Acknowledgement

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[2]   M.D. Karetnikov, E.A. Meleshko, G.V. Yakovlev, Implementation of Hardware Processing of Events for Recording of Alpha-Gamma Coincidences at Associated Particle Technology. Proceedings of the International Scientific and Technical Conference "Portable Neutron Generators and Technologies on their Basis", VNIIA, Moscow, 2004, p. 335.

[3]   http://www.photonis.com/Photomultiplier/Catalog.htm

[4]   M.D. Karetnikov, A.I. Klimov, K.N. Kozlov et al., Hardware&Software Module for Measuring Time-Amplitude Parameters of Coincidences at the Nanosecond Neutron Analysis. Instruments and Experimental Techniques. 49, n. 4 (2006), 134.
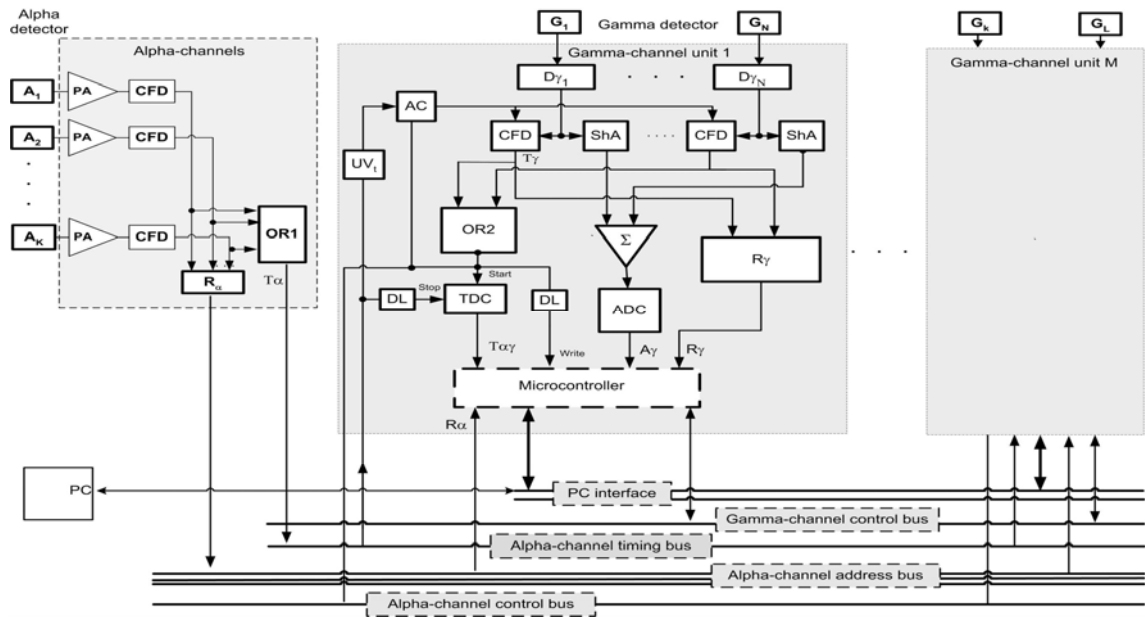
Fig. 1. Flow block of DAC system
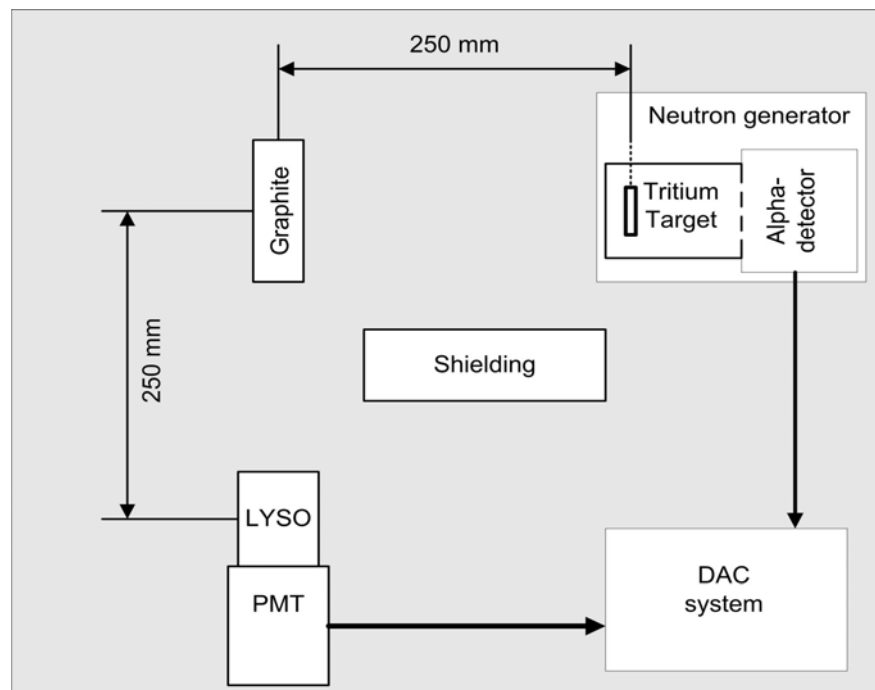
Fig. 2. Test-bench for testing the DAC system
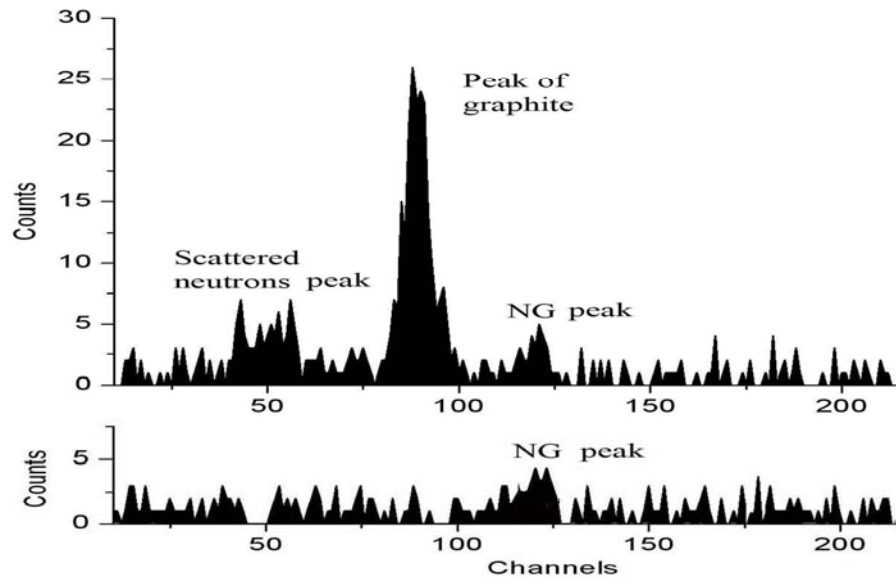
Fig. 3. Time spectrum of alpha-gamma coincidences for the shielded gamma-detector when the graphite box is installed (upper curve) and when the graphite box is removed (lower curve)
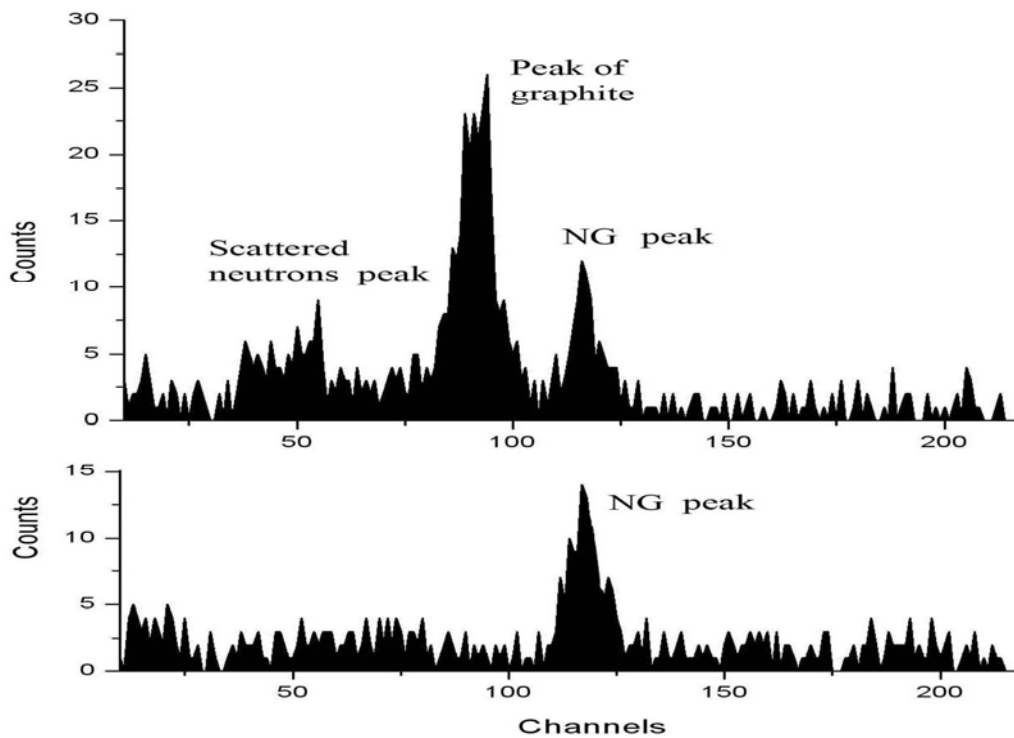
Fig. 4. Time spectrum of alpha-gamma coincidences for the unshielded gamma-detector when the graphite box is installed (upper curve) and when the graphite box is removed (lower curve)

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Simulation of tracer filtration for investigation and production control over oil reservoirs

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The petroleum is spent faster than its stocks grow up all over the world. The new deposits of petroleum are basically small or average, there are few large ones, while giant ones are absent at all.

The small and average deposits are characterized by a high geological heterogeneity what essentially complicates the production of petroleum and reduces the oil recovery factor. Due to a high price for petroleum in such deposits, it is profitable to apply specializes technologies of increasing the oil recovery.

For the effective application of methods of increasing the oil recovery it is necessary to investigate filtration flows on a maintained deposit of petroleum. An optimum method of study the flow filtration is a tracer method.

The tracer method consists in adding a label into water, pumped to an oil collector, analysis of time of arrival and concentration of the indicator in the liquid extracted from a petroleum layer.

The indicator is pumped in one injection well and is extracted from several production wells.
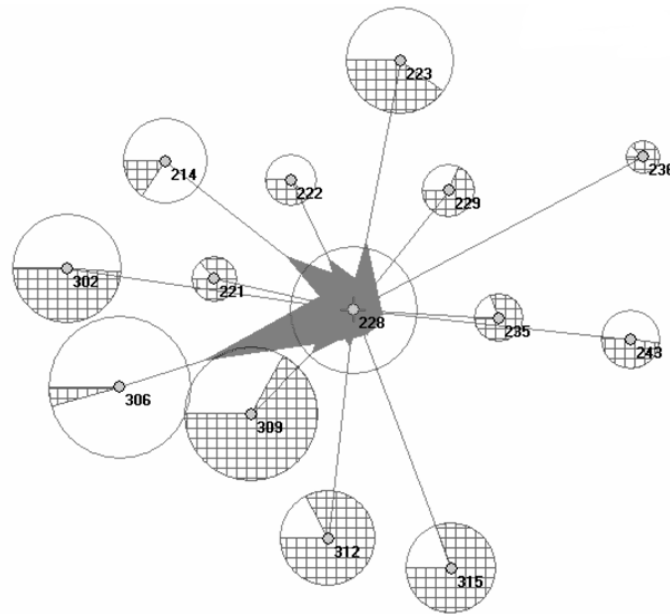
Fig. 1

Fig. 1 gives a typical example of indicator investigation.

Simultaneously in various injection wells different indicators can be pumped. It allows one to receive a distribution filtration of flows on the area of a petroleum deposit in some tens sq. kilometers. Such a result can be obtained with the help of specialized software.
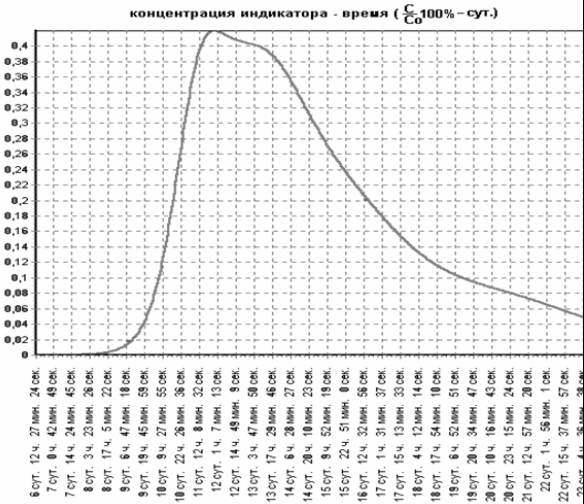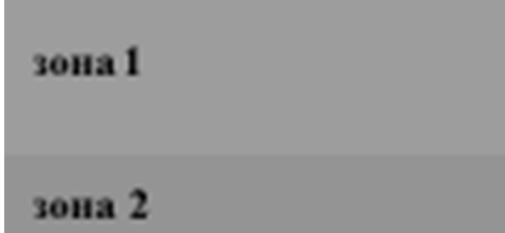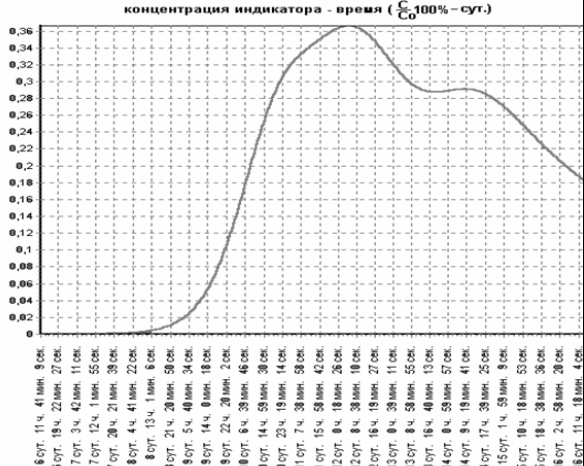
This special software should be compatible to the standard software used for modeling the exploration of the petroleum deposits on geological data received prior to the beginning of exploration of the oil deposit.

It should be noted that the standard programs are used for construction on a geological-hydrodynamic model of the layer given, received prior to the development start-up. The tracer method allows one to add the geological-hydrodynamic model of the layer to the results of the research received directly while exploiting the petroleum layer, i.e. when petroleum and water are in motion.

It is essentially new important information that also allows one to establish presence and productivity of anomaly penetrated ways of filtration.

Let us consider some examples that demonstrate the promising features of the method.
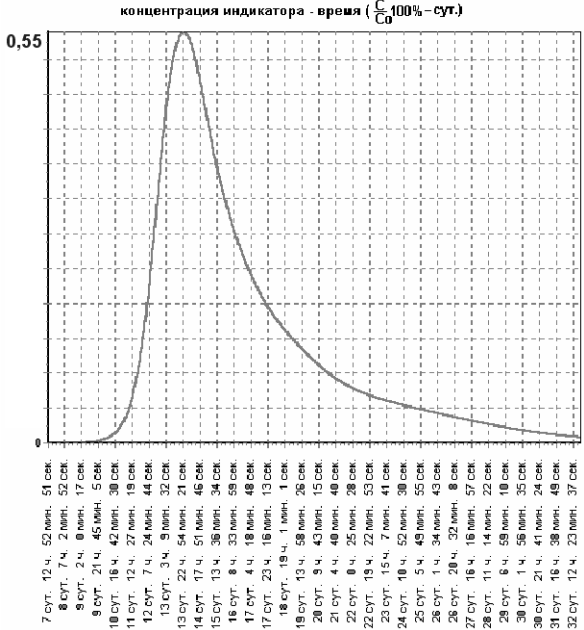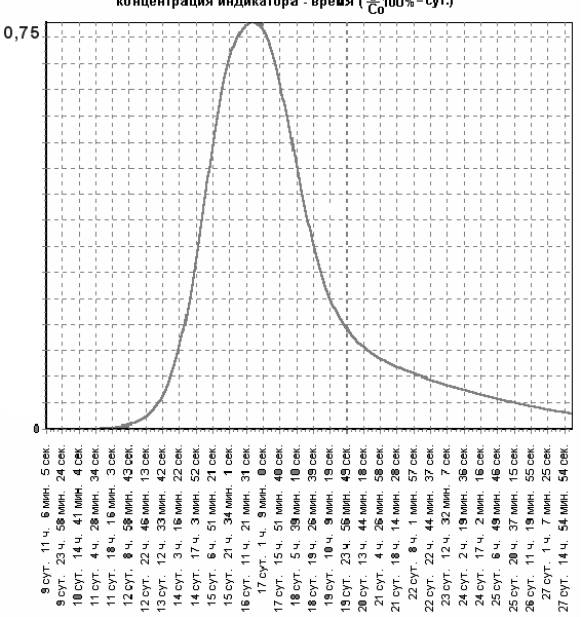
Table 1

site of the layer under study	Magnitude of concentration of the indicator in extracted water
Zone 1: permeability 1 mkm^2, Zone 2: permeability 1,15 mkm^2 The area of one zone 50 % of the common area of a site	
Zone 1: permeability 1 mkm^2, Zone 2: permeability 1,4 mkm^2, The zones have identical hydro conductivity	

Example 1 (see **Table 1**). Let us consider a case of two zones located along the direction of filtration of forced water. The pumping is conducted in a point located on the border of two zones. The curves "concentration of indicator - time" are given for those cases which show that the presence of two zones with various penetration located in the layer in parallel to the filtration direction, is determined since 15% distinction in penetration of these zones. However, it seems impossible to separate those zones in a real experiment.

Example 2 (**Table 2**). Simulation has been performed on the replacement of petroleum by water with a list of the labeled substance on a site having local heterogeneity in the centre of the site. As a base of comparison, a site, homogeneous on permeability, was used.

Table 2

site of the layer under study	Magnitude of concentration of the indicator in extracted water
Permeability 1 mkm^2	концентрация индикатора - время ($\frac{C}{Co}$ 100% – сут.) 0,55
Зона 1 Зона 2 Zone 1: permeability 1 mkm^2, Zone 2: permeability 0 mkm^2, The area 1/9 from the common area of a site	концентрация индикатора - время ($\frac{C}{Co}$ 100% – сут.) 0,75

The simulation results show that the presence in the centre of the site of a completely impenetrable zone results in a later occurrence of the indicator in the production well, as water has to approach it by longer ways, and in increasing the maximal concentration of the indicator, as dilution occurs in a smaller volume of the layer.

These results provide a basic opportunity of estimation of the size of scope of the layer by watering on the tracer data and opportunity of revealing zones which have been not covered with exploration.

In one of the deposits of Western Siberia, a unique experiment of simultaneous injections to twelve labeled liquids was put. The project applied 12 of 28 injection wells and 72 of 101 working producing wells. The motion of forced water with speed of more than 10 m/day was established. The motion of water with the specified speeds was observed all over the deposit simultaneously.
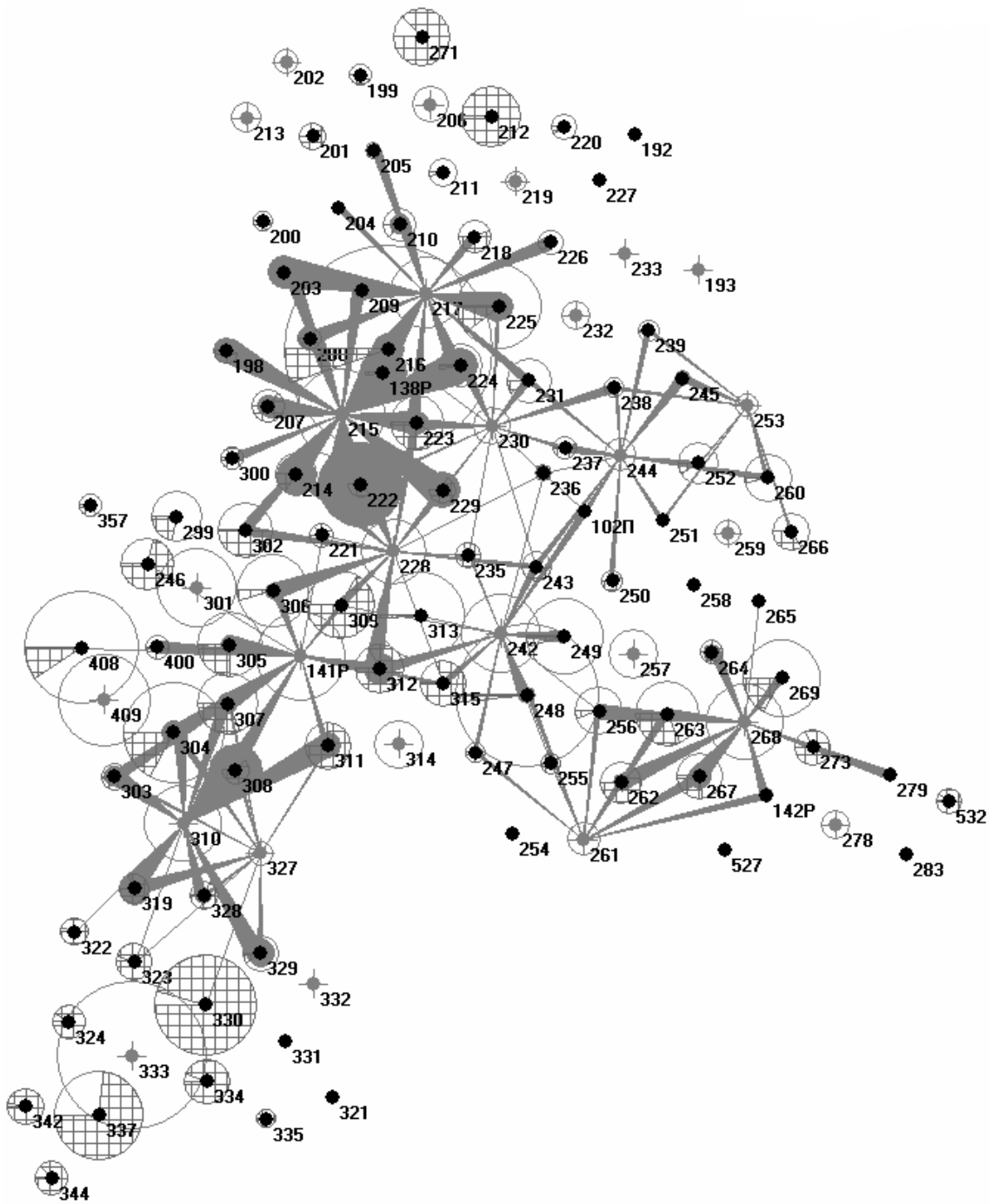
Fig. 2

Fig. 2 gives the received results on the influence by every injection wells on the percent of water in production fluid on each producing well.

An experimentally calculated model has been designed. **Fig. 3** shows the designed map of distribution of the ultra permeable ways of filtration.
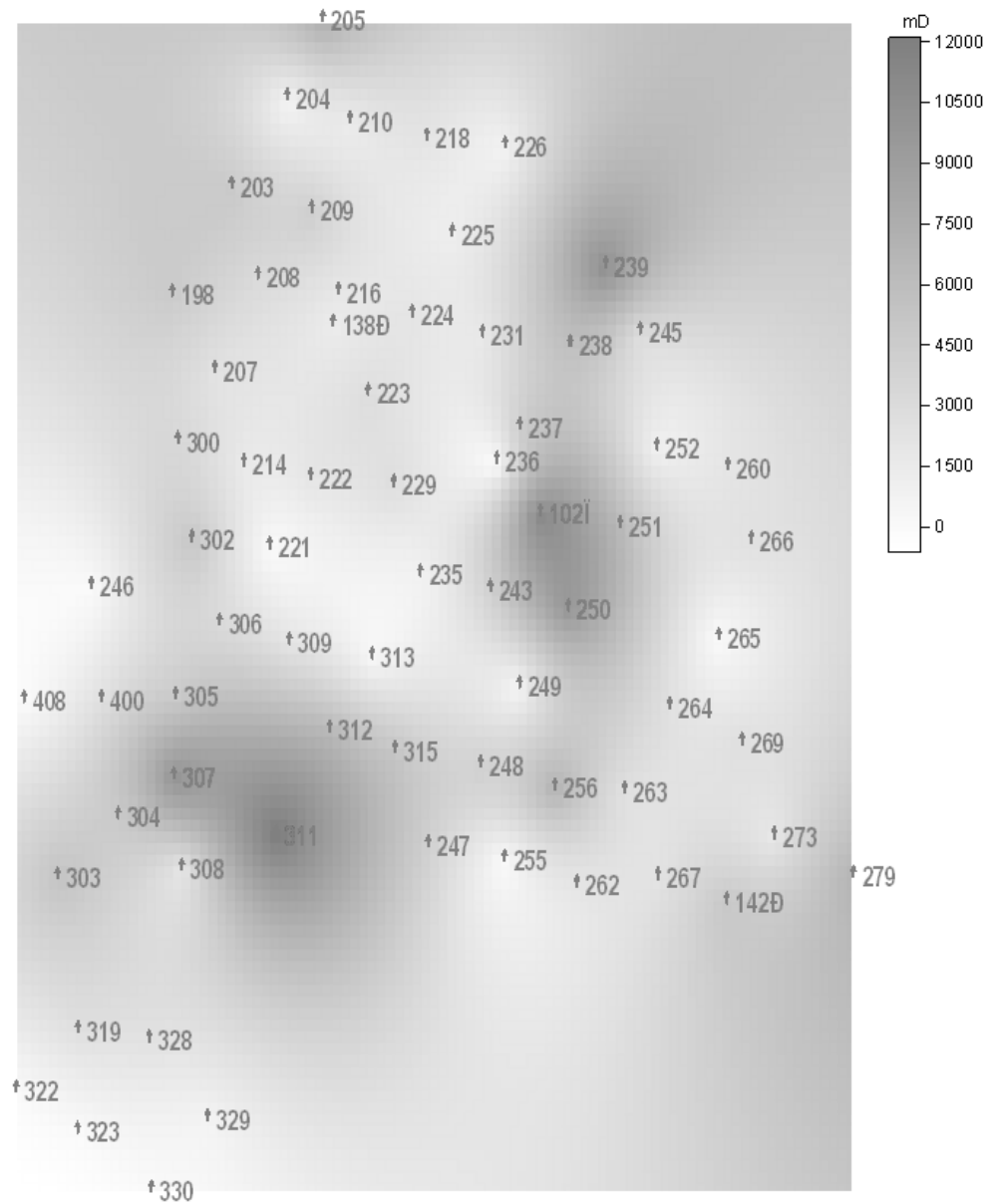
Fig. 3

The figure below (**Fig.4**) presents a map of distribution of hydro-conductivity.
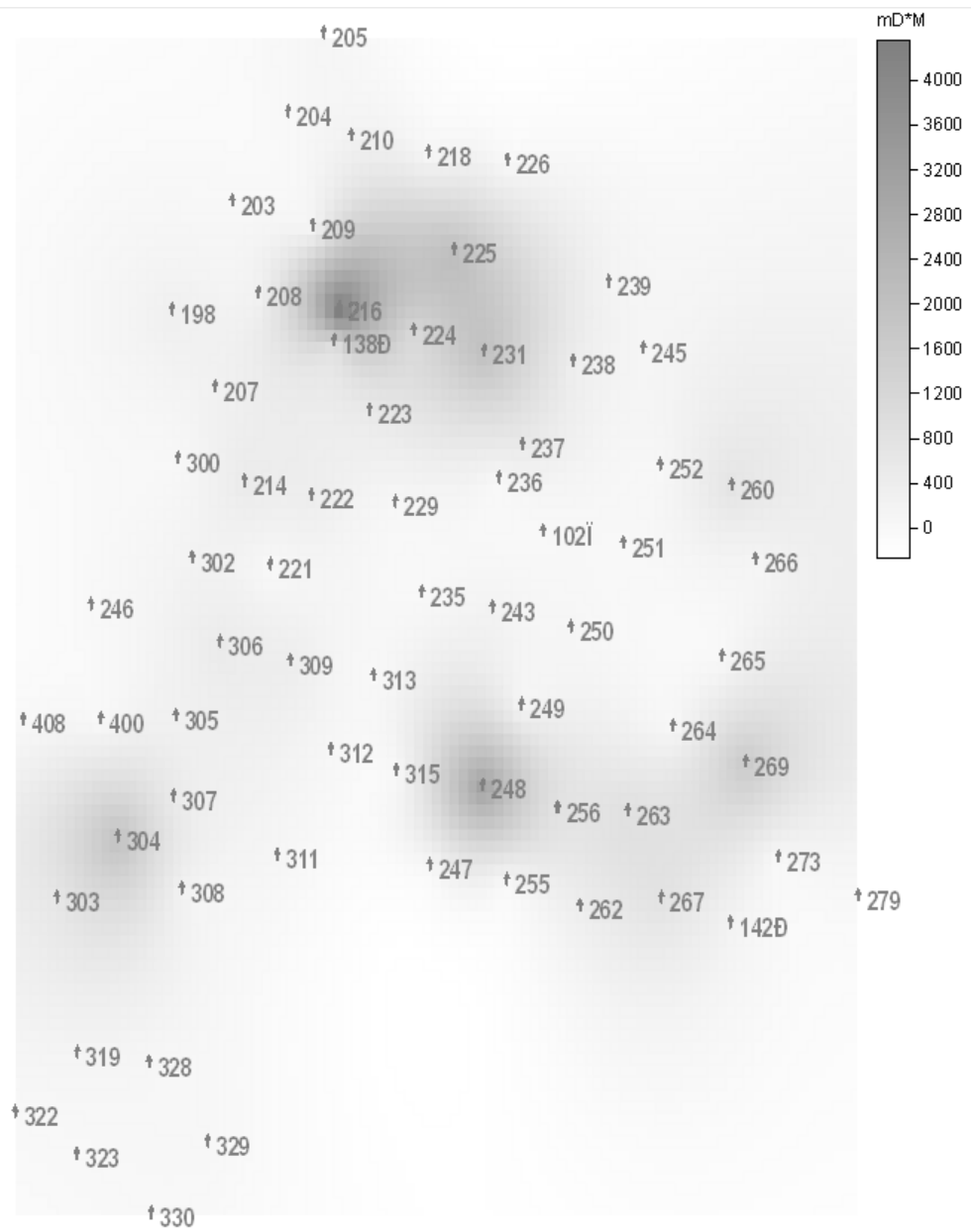
Fig. 4

Using virtualization techniques for large scale computing

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Abstract

Virtualization technology delivers many benefits in IT operational flexibility, speed of deployment, and application performance and availability. In large scale computing environments virtualization can provide hardware abstraction and as a result the ability to use older operating systems and applications on new hardware more easy. In addition it can significantly simplify the resource management for the such systems with very small impact on productivity.

1. Introduction

Virtualization technologies shows a significant interest from customers during last years. According to IDC, the virtualization market is expected to grow to $15 billion worldwide by 2009. The proliferation of servers in the data center has led to increased complexity and costs. Virtualization helps to reverse this trend by dramatically reducing the need for adding physical servers and their associated capital, power, software and management costs. "Overall, IDC views virtual machines as a foundational technology to the dynamic IT," said John Humphreys, program director with IDC's Enterprise Platform Group. "Virtualization, which decouples the application from the underlying hardware, allows the customer to create service oriented infrastructure whereby they can begin to manage services and employ policy-based automation to manage and deliver the underlying infrastructure" [1].

Virtualization helps to dramatically reduce the need for adding physical servers and their associated capital, power, software and management costs. Virtual systems can be completely independent of physical resources, so IT groups will have more time to devote to solutions that increase business value. Virtualization also makes it possible to avoid application incompatibility problems by running them in separate, isolated virtual servers on the same physical server.

Virtualization reduces risk by creating redundancies, mirroring physical systems both to back up information and to provide an alternative if the physical system fails. At the same time, a single physical server can be securely divided into multiple virtual servers, isolating and shielding individual pockets of information as if they were stored on separate physical servers.

Not surprisingly, those tantalizing capabilities have prompted just about every major high-tech vendor (and many lesser-known ones) to launch virtualization initiatives. Some of them becomes a part of Linux distribution like Xen [2] and KVM [3], while other solutions are distributed separately like VMware. We describe below the possibility to use the virtualization technology in large scale computing environments.

2. Virtual Machines Performance Comparison

The key feature for large computing is CPU and memory performance of virtualized hardware. The second one is parameters of input/output subsystems (disks, network and other). There are several ways to achieve the appearance of real hardware for the guest. The most direct method is to completely emulate the underlying hardware platform in software, including the processor's instruction set architecture. This way is used in KVM/Qemu and VMware[1].

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[1] VMware uses proprietary technique called "binary translation" while KVM requires virtualization support from CPU

An alternative way to achieve virtualization is to present a virtual machine abstraction that is similar, but not identical to the underlying hardware. This approach is called paravirtualization, and was introduced to the x86 architecture in the Xen hypervisor[2]. Paravirtualization offers significantly improved performance, but it does require modifications to a guest operating system.

We used nbench-byte-2.2.2 to compare the CPU and memory performance. The results of the comparison for open source virtualization solutions[3] show that the difference between virtual machine and the native hardware is not worse than 10%.

CPU Indexes
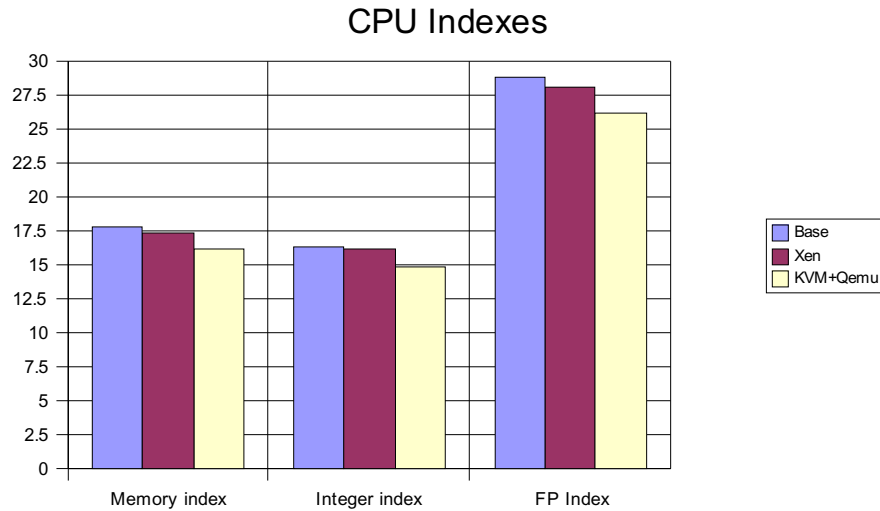
Though the CPU and memory performance for virtual machines good enough, the situation with disk subsystem performance is more complicated.

Bonnie++-1.02c was used in our test for disk subsystem I/O benchmarking. When we deal with the stream performance (writing to file, reading from file etc), the results for virtual machines is similar to native as we can see for Xen paravirtualized mode or at least acceptable for majority tasks in large scale computing[4].

The performance for inode (file) operations looks similar for both open source solutions which we analyzed. The results here depend very match on type of the operation and the relative performance for different virtual machines demonstrates the significant scattering. Though the create and delete rates for inodes are 30-80% smaller then the native performance, they are still comparable at the level of the magnitude. The read rate for inodes is approximately 100 times lower and this can be a problem for applications which operate with large number of files, for example squid or any task which requires source compilation.

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hardware (Intel® VT and AMD-V).
[2] VMware introduced the interface for paravirtualized clients in VMware Workstation 6 in May 2007.
[3] The comparison results for Xen (in paravirtualized mode) and KVM+Qemu is presented here. Presentation of bench-marking results for VMware products is restricted by license agreement and they were omitted here.
[4] Though the read/write rates for KVM+Qemu is several times lower than the native performance, the absolute values for them are 15-20 MB/secs.

Disk I/O Performance (steam)

Disk I/O Performance (inodes)
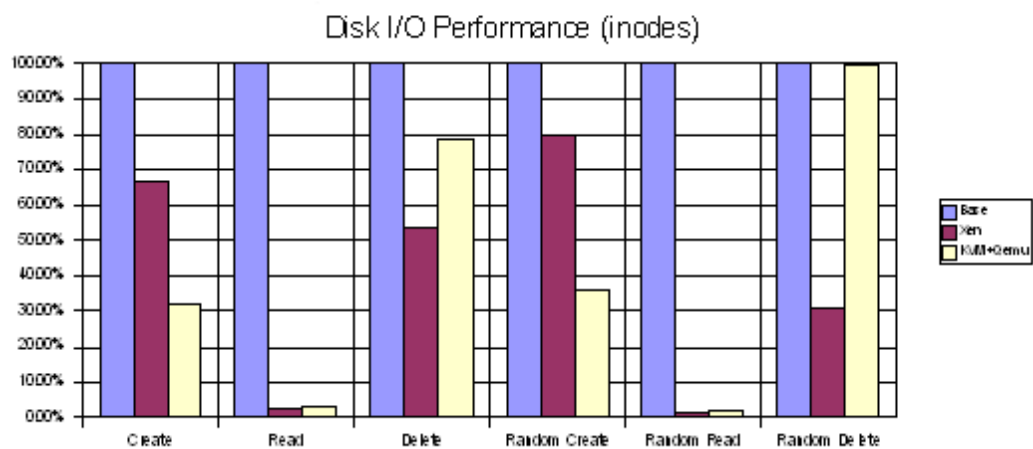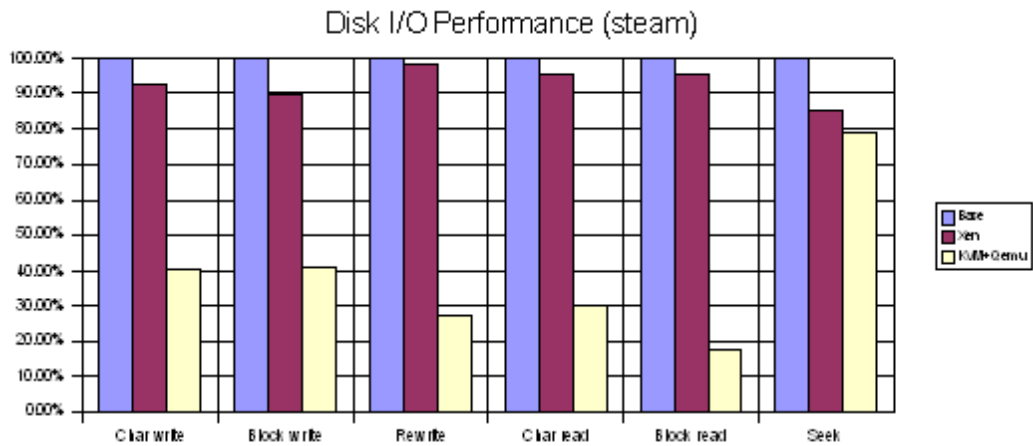
The comparison of the performance for the application was done the following tasks: physical simulation using GEANT 3 program, data processing application with moderate I/O level (transcode) in two modes (disk I/O and network I/O) and applications which operate with large number of small files – rebuild of the openoffice.org[5] and rebuild of the samba. The results for the typical applications can be explain by the benchmarking results which were presented above.

If the I/O level of the application is below the I/O subsystem rate for the virtual machine, the performance depends mainly on its CPU and memory speeds. We can see the such behavior for GEANT and transcode programs. The package rebuilding require a lot of file operations, especially inode readings, and as a result we can find 2.5-3 times performance degradation for this type of applications[6]. Thus using open source virtual machines for products like squid will not be a good idea, but this type of application are very rare used in large scale computing.

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[5] The rebuilding of openoffice.org for Xen was crashed due to the lack of disk space and this result is absent.
[6] Xen and KVM+Qemu have partially common code base for I/O subsystem and this can explain the similar I/O performance for these different approaches to virtualization. VMware has inode reading rate at comparable level to native hardware and as a result much better results for compilation speed. So such behavior for the open source solutions is not the result of the virtualization approach. This caused by quality of code and can be improved in future.

Application results compared to native
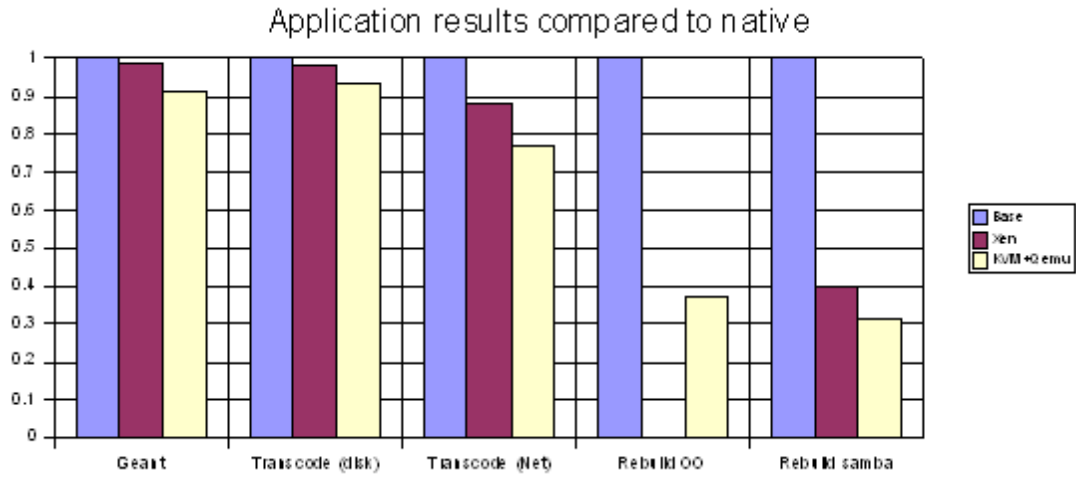
The main conclusion from these tests is the possibility of using of the modern virtualization solution in large scale computing environments.

3. Schema of the Production Environment

One of the possible schemes of the production environment is represented below.
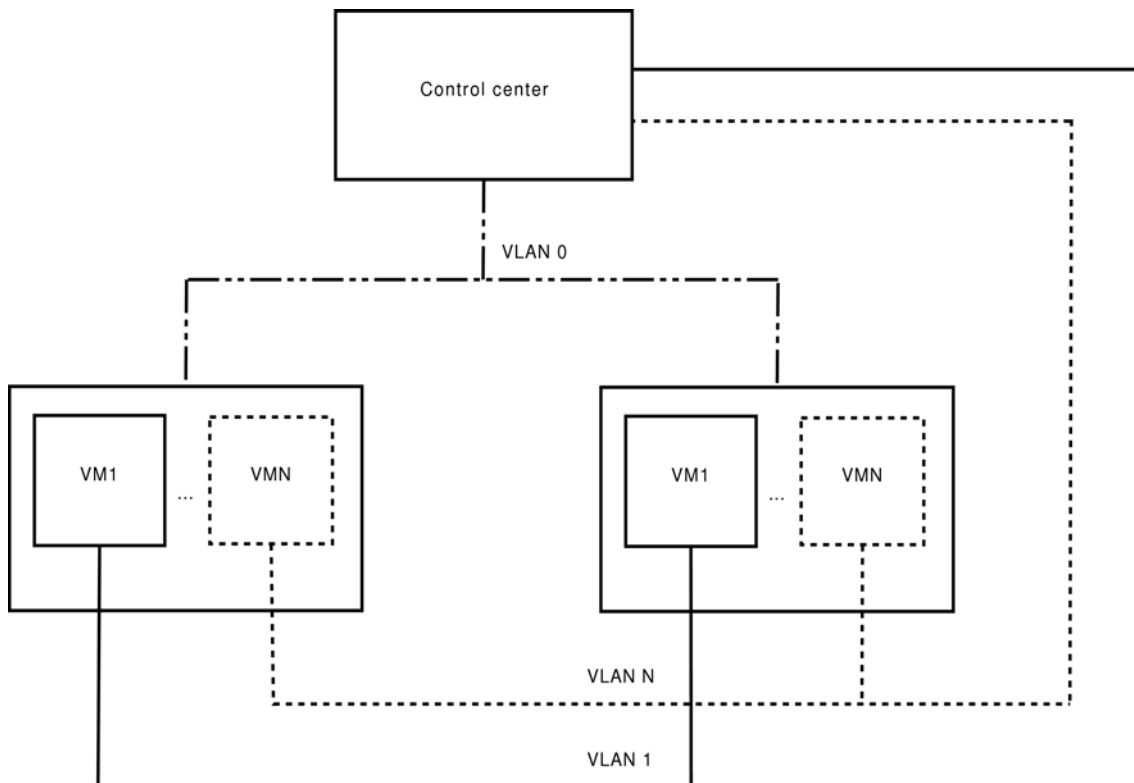
In this environment physical nodes and virtual machines are interconnected by the different VLAN-s. The such schema is possible even with single physical network interface on the node (virtual machines in this case will be bridged to virtual (VLAN) interface of the node). In this way you can increase the security by isolating the physical hardware from the outside network and simplify the management of the such farm.

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The benefits of the visualization is the ability to use obsolete systems on modern hardware, simplification of the management (the virtual machine is a file which can be copied or moved from one physical machine to another), possibility to have minimal downtime even during the system upgrade (you can prepare new system while old one remains in use and when new system ready replace old virtual machines), increasing the availability of the production environment using virtual machines migration and check points.

4. Conclusions

The performance of the virtualization solutions which exists in this moment is enough to be used in large scale computing environments. The measurements which were presented here and in other articles [4][5] demonstrate that the performance of the virtual machines in terms of CPU, memory and partially disk I/O is very close to the performance of the native hardware.

A this moment hardware support of the virtualization from the Intel and AMD make possible to use open source solutions even for full virtualization (the commercial one exists in this field last 10 years). Moreover the such solutions provide almost full range of features which exist in commercial products including process migration, check points, virtual networks etc. It is possible to create the cost effective production environment.

Using virtual solutions can make the management of large production environments more easy while the performance degradation for the CPU intensive calculations remains negligible. In addition it is possible to increase he availability of the production environments using the virtual solutions. Virtual machines provide the possibility for different operating systems to coexist on one physical hardware and to utilize it in most effective way.

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[4]   XenSource, Inc., A Performance Comparison of Commercial Hypervisors, 2007.
[5]   Michael Larabel, Linux KVM Virtualization Performance, 2007,
       http://www.phoronix.com/scan.php?page=article&item=623&num=1

Structure of services and functions of the Data Quality Analysis package of the remote access system to the ATLAS control room (RDQMF)

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Introduction

Data quality monitoring is very important for the data processing in ATLAS experiment [1, 2] on LHC (CERN). Data checking will be realized not only in the TDAQ but data quality will be analyzed in Tier 0-2. The aim of this work is to discuss the main aspects of the data quality architecture in the offline Remote Data Quality Monitoring Framework with reference to the TDAQ DQMF [3]. The structure of services and functions of the Data Quality Analysis (DQA) package are discussed. The article follows main ideas, which will be included in the DQA User Requirements Document (URD) and design guidelines. The data quality checking in JINR (Dubna) will be a part of the distributed offline Data Quality Assessment [4] analysis. These activities will be based on the software developed under the coordination of the Monitoring Working group [5] at CERN and using the experience of the common works with ATLAS TDAQ.

Data Quality Analysis package

The main task of the Data Quality Analysis package (DQA) in the RDQMF environment is performing of the data quality checking. The system will be work with the different data types: histograms, counters messages etc. Data quality checking algorithms will depend from types of the checked data and from the additional information (for example from calibration).

DQA will play a similar role in RDQMF as DQMF package in the online TDAQ environment. It will provide the data quality checking in the automatic and manual modes, display the DQ results (calculated by it-self or stored in the DQ DB). All analyzed data will be received by DQA from the DQ DB. DQ DB manager will collect the data from CERN DBs (Conditional DB, CASTOR, TDAQ via WMI) using predefined subscription for the required data or by direct request if these data are absent for this moment in the DQ DB. DQ DB will have the different data sources but for the DQA it will have the similar data access API (for the similar data types). More detailed aspects of the DQ DB realization are discussed in our second paper presented on this conference.

The same algorithms and references (histograms, thresholds etc) for analysis will be used in CERN and in RDQMF to have the similar data checking procedure as will be applied online in TDAQ or offline in Tier 0-2.

DQA will have 3 user types: operator, expert and ordinary user.

The expert can change reference histograms, chose algorithms from an algorithm library, make assessment and can commit this assessment with the DQ results in the DB, send alarms in CERN to the ATLAS shift operator.

Operator is an expert, which has extended privileges to make system administration of DQA (adding (deleting) a new reference histogram in the repository, adding (deleting) a new algorithm, setting data list for the subscription in CERN).

Ordinary user has restricted rights including browsing the DQ results published by CERN and by RDQMF and stored in DB. This user will have Web-based interface to the RDQMF. We think that it will be similar to the DCube [K.Ciba].

RDQMF context

DQA will be built on the DQM common release including the TDAQ DQMF core [2] realization. Full version of the TDAQ RDQMF is integrated with online CORBA-based TDAQ middleware services (such as IS, OH, ERS etc). Offline RDQMF environment will not contain these ones.
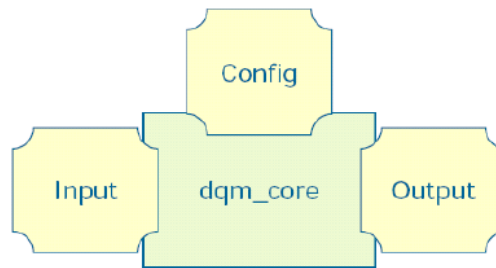
Fig.1. DQM Framework [6]

That is why the RDQMF implementation of the data quality analysis package – DQA package will contain its own realizations of the I/O system and DQ configuration [6]. HAN package from the ATLAS Offline Release will be used as the core for the DQA. It gives possibility of the RDQMF integration with the offline DQ analysis and assessment.

DQA architecture

Here we consider the architecture of the DQA package.

Preprocessing Task performs the preparation of the raw data for DQ analysis. This application can be used to prepare data required for the data quality analysis. These data will be saved in the DQ DB or directly used by DQ Task.

DQ Task will perform data loading for analysis from DQ DB and applies corresponding DQ algorithms and references (i.e. reference histograms, thresholds, etc) according with the DQ configuration.

DQ Manager runs Preprocessing Tasks or DQ Task using descriptions in the DQ Config.

DQ Tasks and Preprocessing Tasks can contain user-defined algorithms to adopt system for specific problems, which can be investigated locally using DQA.
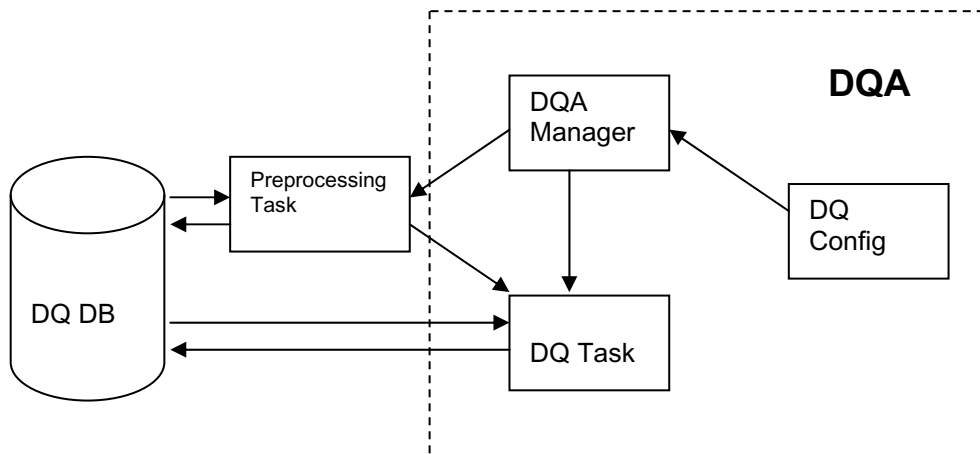
Fig.2

Conclusion

Data Quality analysis [2] and assessment [4] will be performed on the different levels of the ATLAS data processing from the online TDAQ data taking up to the offline data analysis in Tier 2. The results of the RDQMF data quality checking will be available for the offline Data Quality analysis and assessment participants. The implemented software will be available for the ATLAS collaboration.

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Distributed data control and acquisition system SMARTBOX-6

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Abstract

SMARTBOX series devices are intended to data control and acquisition in FLNR control system. New SMARTBOX-6 system is designed in FLNR in 2006. It is made upon 15 years experience of building cyclotron automation. SMARTBOX-6 is based on a modular principle that allows configuring the number and type of required signals to serve particular installation. Main features, functional structure, programming algorithm and technical characteristics of SMARTBOX-6 are described in this article.

Introduction

The SMARTBOX-6 [1] series is a new family of compact, modular, intelligent and rugged, distributed I/O (input/output) systems, designed for data acquisition and control in industry, research and education. This new series offers a flexible, versatile, and economical solution to a wide range of applications from Data-Acquisition, process control, test and measurement, to energy and building management.

SMARTBOX-6 is designed to read sensor data, on/off status, and to control the on/off status of devices via Ethernet or RS-485 remotely from a host computer or PLC controller. Support for the standard Modbus protocol makes SMARTBOX-6 compatible with most SCADA software, such as Intellution iFix, Wonderware, and LabVIEW DSC.

General description
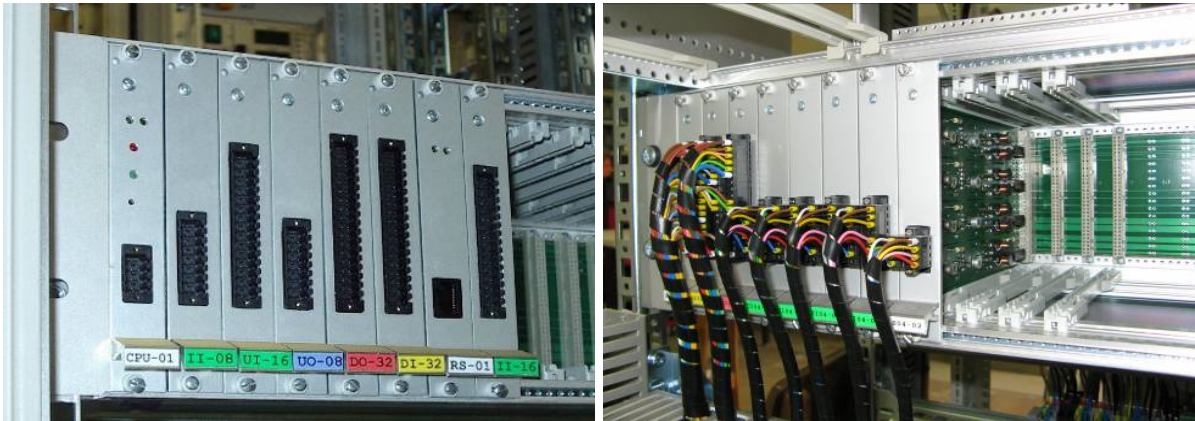
Fig. 1. SMARTBOX-6

The SMARTBOX-6 is a modular network based system with the capability of connecting I/O through local bus. The system comprises a main control unit (MCPU) with a range of standard communication interfaces and an I/O bus (crate with communication bus). The bus is providing the facility to connect serial I/O modules. The unit can communicate using serial communications (RS232, RS485), Ethernet, or CAN bus. The Ethernet version of the product supports an integrated web server permitting Internet and Intranet applications

The SMARTBOX-6 can be used as an intelligent distributed data acquisition front end connected to a host machine running a standard SCADA package, or alternatively it can be

user programmed as a stand-alone controller running an embedded software application. Significant non volatile memory is available for data and program storage.

SMARTBOX-6 was designed in 19" Rack Form Factor crate 3U-high with 24VDC power supply (Fig. 1). The main control unit with network interface and up to 16 modules of input-output can be installed in crate. The design of modules provides fast installation, ease in exploitation. The connection of wires directly to devices using the socket with tension clamp type. It is possible to optimize quantity and type of inputs and outputs using variable input-output modules. Adding or replacing of any modules can be done without crate power off [2].
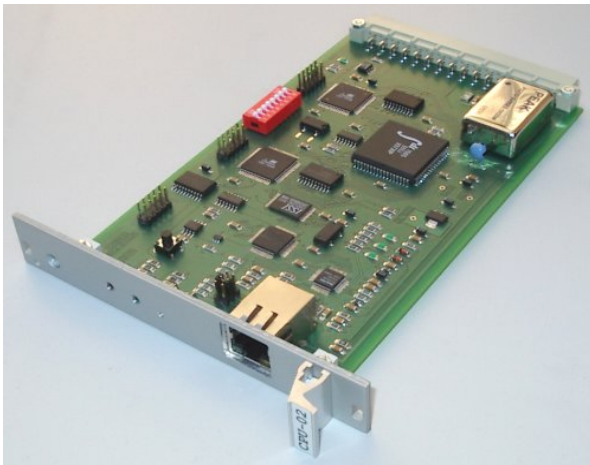
Fig. 2. Module MCPU-02
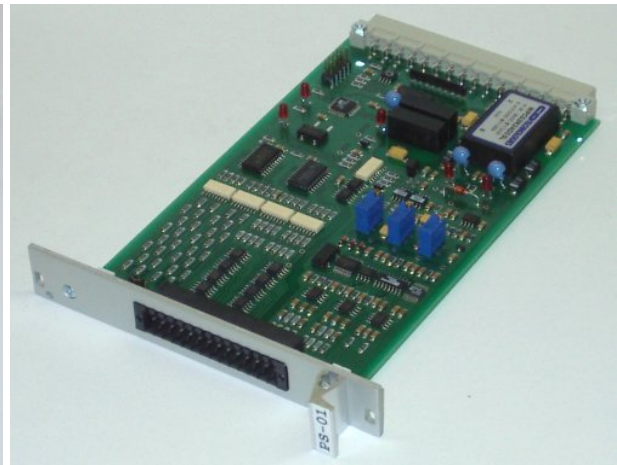
Fig. 3. Module MMPS-01

Main CPU modules
- MCPU-01. Communication module for system SMARTBOX-6 and host computer via RS-485 interface, Baud rate 921.6 kb. For communication is used industrial protocol PROFIBUS.
- MCPU-02. Communication module for system SMARTBOX-6 (Fig. 2.) and host computer via Ethernet TCP/IP.
- MCPU-03. Controller module for system SMARTBOX-6. The main features of the MCPU-03 are:
    - Embedded IPC@CHIP® Web-Controller with powerful 96 MHz processor for demanding control and communication tasks
    - Large memory capacity with up to 8 MB RAM and up to 8 MB Flash
    - 2 x Ethernet 10/100BaseT
    - CAN 2.0
    - USB host and device
    - 4 x UARTs
    - RTOS Real-time multi-tasking Operating System with TCP/IP, web-server and security protocols
    - Unlimited use of CoDeSys SP@CHIP in the IEC products included

I/O Modules
Analog input modules
- UI16-01. 16-channel analog input, range ±10V, resolution 16 bit, Σ-Δ ADC, time of measurements 267ms.

- II16-01. 16-channel analog input, range ±1uA, resolution 16 bit, Σ-Δ ADC, time of measurements 267ms.
- II16-02. 16-channel analog input, range ±100nA, resolution 16 bit, Σ-Δ ADC, time of measurements 267ms.
- MI08-01. 8-channel analog input, 1 measurement channel, range ±1mA ±100uA ±10uA ±1uA, resolution 16 bit, Σ-Δ ADC, time of measurements 133ms.
- UI04-01. 4-differencial channel analog input, range ±25mV, resolution 16 bit, Σ-Δ ADC, time of measurements 267ms.

Analog output modules
- UO08-01. 8-channel analog output, range 0–10V, resolution 14 bit.

Digital input modules
- DI32-01. 32-channel isolated digital input, logic level "1" 10–24Vand logic level "0" 0–5V.

Digital output modules
- DO32-01. 32-channel isolated output, fully autoprotected power MOSFET. Built in thermal shutdown, linear current limitation and overvoltage clamp protect output in harsh environments.

Special function modules
- MMRS-02. Module provides connection between SMARTBOX-6 and fieldbus devices via serial interface RS-232/422/485. Communication speed up 115200 baud, receiver buffer 64 bytes, transmitter buffer 64 bytes.
- MMPS-01. Multifunction module (Fig. 3.):
  - 4-channel analog input, range ±10V, resolution 16 bit, Σ-Δ ADC, time of measurements 267ms.
  - 2-channel analog output, range 0–10V, resolution 14 bit.
  - 8-channel isolated digital input, logic level "1" 10–24Vand logic level "0" 0–5V.
  - 8-channel isolated output, fully autoprotected power MOSFET.
- CI10-01. 10-channel counter module, frequencies range 10Hz - 100 kHz, input signal level 5V TTL/CMOS compatible.

Software

The SMARTBOX-6 can be used in two specific ways, either as a slave I/O unit driven by a standard SCADA package or user written application, or alternatively as a user programmed stand-alone I/O controller.

MCPU-02 - slave I/O unit

TCP/IP communication parameters can be configured by build-in web-configurator or by UDP-broadcast program (Fig. 4.) from PC. There are drivers and support software for QNX (QNX Software Systems Ltd., Canada) and for Windows. LabVIEW [3] has the flexibility of a programming language combined with built-in tools designed specifically for test, measurement, and control. By using the integrated LabVIEW environment it is very easy to create applications for SMARTBOX-6 using LabVIEW.

MCPU-03 - slave I/O unit or user programmed stand-alone I/O controller

SC-143 Web-Controller by IPC@CHIP® with IEC1131 CoDeSys license was applying in this module. It has software support from Beck IPC GmbH [4] and 3S - Smart Software Solutions GmbH [5].
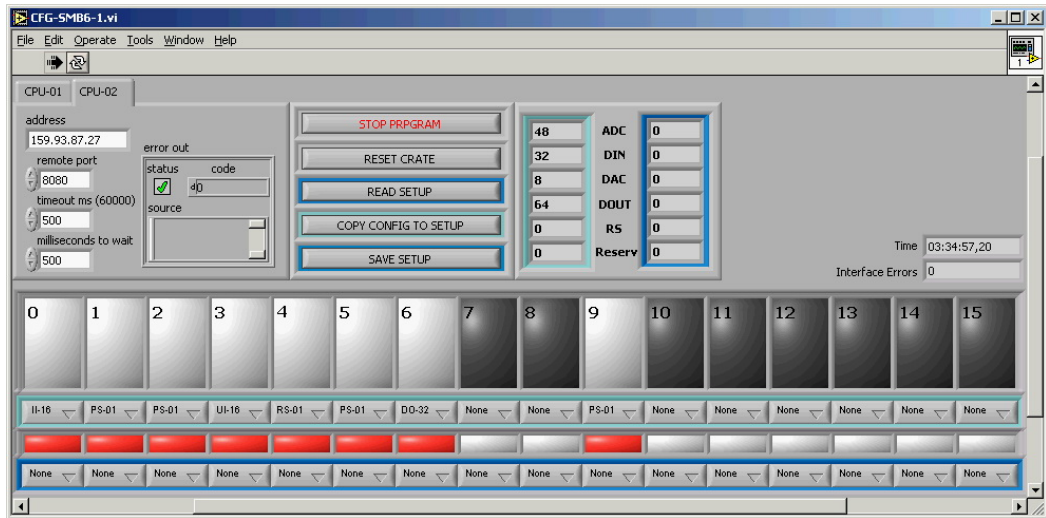
Fig. 4. LabVIEW Configuration utility for SMARTBOX-6

CoDeSys Overview

CoDeSys is one of the most powerful IEC 61131-3 programming tools for controllers applicable under MS Windows. All five programming languages of the standard are supported. CoDeSys combines the power of advanced programming languages such as C or Pascal with the easy handling and operational functions of PLC programming systems. CoDeSys provides competitive advantages:

A Practical, Easy-to-Use Approach

Functions such as Autodeclare, Autoformat and a context-sensitive input assistance greatly simplify the use of CoDeSys. All functions are accessible by use of the keyboard. What additionally ensures fast and efficient work is the exceptionally low number of resources CoDeSys requires.

High Performance

Native code generators for all common processors guarantee the optimal use of your control system. Due to intelligent algorithms such as 'incremental compile' large projects with thousands of global variables and hundreds of components can be realized in surprisingly short compiling time spans. CoDeSys supplies users with a broad range of high-performance program development functionalities, e.g. almost all data types specified in the IEC 61131-3, offline simulation as well as powerful online functions such as breakpoints, single stepping, power flow, sampling trace and online change.

CoDeSys-OPC Overview

The CoDeSys-OPC Server is included in the standard CoDeSys delivery package. It is compliant to the OPC specification 2.0 and runs under Windows NT/2000/XP. OPC is a standardized interface giving access to process data. It is based on the Microsoft standard COM/DCOM and was extended to meet the needs of data access in the automation process where it is mostly used to read and write data from the controller. The typical OPC clients are visualizations and programs for recording operational data etc... PLC systems and field bus cards are usually supplied with an OPC server(Fig. 4.).

The OPC server is not a passive subprogram but an executable program which is started as soon as a connection is established between the client and the controller. It can therefore inform the client whenever the value of a variable or its status has changed.

Due to the features of DCOM it is possible to gain access to an OPC server which is installed on a remote PC. Via OPC it is also possible for several clients to gain access to a

source of data simultaneously. Another advantage offered by OPC due to COM technology is programming language independence (C++, Visual Basic, Delphi, Java). Nonetheless OPC substantially increases the resource consumption (memory and CPU time).

The CoDeSys OPC server is based on the CoDeSys Gateway Server (Gateway). At the same time that a project is loaded form the CoDeSys programming system onto the controller a symbol file (*.sym or *.sdb) can be generated and placed in the Gateway or on the controller. The symbol file contains so called items. One item (data object) corresponds exactly with one variable in the control application program. The variables on the controller can be reached via these items.
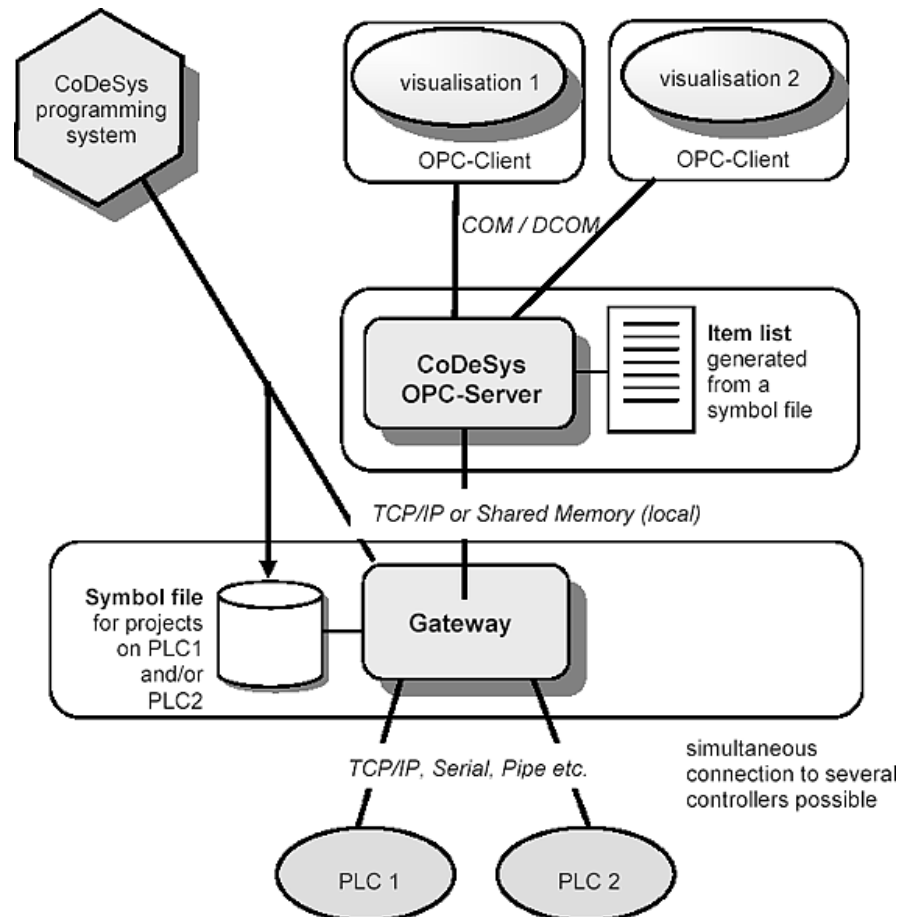
Fig. 5. Architecture of the CoDeSys OPC-Server V2.0

The OPC server requests the Gateway to submit the contents of the symbol files and then produces an item list using the received information. As the contents of the item list is determined by the accessibility of variables in the controller it can not be influenced by the OPC client. In each case the OPC server reads the symbol file which was last loaded over the Gateway channel for a project. Items of different projects, meaning of different application programs, can be reached simultaneously if the symbol file was provided by the same Gateway channel.

The item list in the OPC server is updated with the data from the controller or controllers at fixed intervals. In comparison to direct access to the controller, reading and writing of variables via this cache list leads to an increase in access time (max. approx. 1ms per item).

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Conclusions

The new control system of cyclotron MC-400 is based on slave unites SMARTBOX-6 with MCPU-02. The software runs under UNIX-style commercial real-time operating system QNX. The core of the application software is custom visualization server with a number of device drivers that interact Supervisory Control and Data Acquisition (SCADA) FlexCtrl 4 (BitCtrl Systems Ltd., Germany). The main advantages of using controller are:

- Decreased time and price of control system development due to possibility to optimize the quantity and type of inputs and outputs. The tension clamp type socket connection simplifies control system wiring.
- Ability to add or replace I/O modules without crate power off makes useful the maintenance.
- Fast communications interface: 100 Mbps Ethernet.
- Expandable architecture for future project development.
- Increased reliability and efficiency of control system due to possibility to program SMARTBOX-6 as a stand-alone controller running an embedded software application.

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Collaboration of CERN with CIS and South-East-European countries

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CERN, Geneva, Switzerland

1. Introduction to CERN and Large Hadron Collider (LHC)

CERN (European Organization for Nuclear Research) is the largest laboratory in the world devoted to particle physics research and has several fundamental missions as for to answer essential questions about the Universe, to advance the frontier of science, technology and engineering, to train young scientists and engineers, and to link scientists all over the world with unique facilities. 20 countries signed the Convention of CERN and are the CERN members; some countries and international organizations participate at CERN as the Observer and non-Member States.

CERN possesses of the World's Most Complete Accelerator Complex, the big part of which has been running since the beginning of CERN (more than 50 years) and has to be reconstructed and upgraded. Moreover, as you all know, CERN is now at the final stage of the LHC construction which will be the most powerful accelerator whenever built. The construction of the LHC is engineering challenge; its first run will start in the middle of 2008. Four big experiments have been constructed to answer the most important questions for physicists as for determination of the origin of mass; of nature of Dark matter; of primordial plasma; matter and antimatter etc. Surely, the LHC results will determine the future course of High Energy Physics.

2. Importance of the contributions from Non-Member States to the CERN research programme and LHC

Even if 20 European countries form a CERN core as Member States, all continents are involved in the CERN activities. Over 40 countries participate in the CERN research programme as Non-Member States (NMS) and some of them have an observer status. More than 30 non-Member States contribute significantly to the LHC programme and to the worldwide LHC computing Grid. About 2700 NMS physicists and engineers participate in the CERN programme (over 1/3 of the total number of the CERN personnel).

3. Contribution of CIS and SEE countries to LHC

Commonwealth of Independent States (CIS) or the countries of the former USSR and South-East European countries have been actively participating in the LHC programme. The contribution from the Russian Federation is the most important. As an example, BINP (Novosibirsk) was one of the main suppliers for the LHC magnets. Not only Russian institutes but also Russian industry was largely involved in the construction of almost all parts of the LHC detectors.

The contribution of other CIS and SEE countries is also highly appreciated. JINR (Dubna) played an important role creating the LHC collaborations with CIS countries (Armenia, Azerbaijan, Belarus, Georgia, Ukraine) and other JINR Members. Within the CMS experiment Russia-Dubna Member States organized a collaboration RDMS which consolidated the participation of small countries in the big experiment making it more visible. Altogether, the number of the RDMS participants in CMS averages to a quarter of all CMS

physicists. Now the almost all parts of the CMS detector are built and these huge parts have been lowering to the pit, which is a complicated engineering task – a real challenge, and all members of the RDMS collaboration actively participated in this work.

There are some brilliant examples of contribution of small countries to the LHC experiments. Within RDMS collaboration Armenia made the design, prototyping and production of ceramics PCB of the CMS Endcap Preshower. The Armenian participation in the ALICE Grid project started from the very beginning and several young Armenian physicists have been involved in it. Belarus played an important role in the construction of the Endcap Hadron Calorimenter of CMS. For the production of the HE structure RDMS proposed an uncommon resource for raw materials – naval shell from St-Petersburg port. In this project Dubna was a leader of the mechanical design of HE and the Belarus plant MZOR produced the machining work on the HCal absorber which weighed 300 t.

The political and economics situation of Georgia and Azerbaijan as of Armenia has been too difficult after disintegration of the Soviet Union. However, these countries participated as far as possible in the LHC construction: Georgia worked on the preparation of the muon drift chamber and the TRT detector for the ATLAS set-up, Azerbaijan – in the Hadron ECal assembling for ATLAS. The most visible and important of the Ukrainian participation was in the ALICE experiment, they produced Hybrids, Al-kapton microcables.

The economics situations in Romania and Bulgaria, a Member State of CERN, have been also difficult; however, Romania participated in the construction of ALICE, LHCb and ATLAS experiments (the structure of the ATLAS Tile Hadronic Calorimeter produced by the Romanian colleagues is shown in the picture). The participation of Bulgaria was mostly concentrated on the CMS HCAL but also the Bulgarian physicists work in the other CERN experiments as for NA48.

4. CERN programme for the future

The CERN Council Strategy Group for the development of the European strategy for particle physics in Europe was set up in 2006. Its aim was consolidation of the collaboration between the European laboratories and coordination of the European participation in the world projects. The Strategy Group worked out a list of the prioritised activities in which it was mentioned that the CERN Council (by its very Convention) has the necessary authority to assume a role of coordinator of this strategy.

The highest priority in the document was given to the operation of the LHC with full capacity, with the R&D for a luminosity upgrade of LHC. After, the priorities were given as follows:

- development of the technology for high-performance magnets for future accelerators;
- design and technical preparation towards the construction decision on ILC (by 2010) in order to complement the results of the LHC with measurements at a linear collider;
- the neutrino programme and non-accelerator physics with a continuing coordinating role of CERN;
- low-energy physics led by national and regional collaborations;
- fixed target experiments at CERN;
- strong support of theoretical physics in view of forthcoming LHC results.

In July 2007 CERN Council accepted a "White Paper" – a programme of the additional activities and of the associated additional budget resources for the period from 2008 to 2011. The programme consists, by order of priority, of four main themes:

•   completion of the LHC machine and running of the experiments at the design luminosity;

•   renewal of the injector complex: the existing Linac2 should be replaced by a higher energy Linac4 as soon as possible; replacement of the Booster by SPL, and then the replacement of the PS (built in 1959) by a new PS2;

•   a minimum R&D programme on detector components and on super-conducting accelerator magnets in preparation for an increase in the LHC luminosity. Also, enhancement of the CLIC programme with CLIC Test Facilities (CTF3);

•   various activities to be partly funded by CERN (SC cavities test facilities, R&D for neutrino production, electron cooler for the antiproton ring, NA48, new ISOLDE etc.).

5. Non-Member States in the future CERN programme

The priorities in CERN's non-Member-State relations are now including:

1. facilitating the completion of the LHC and its experiments and assuring a sustainable framework for their exploitation;
2. encouraging cooperation on R&D in support of the LHC upgrade; seeking collaboration on the improvements of the CERN's proton accelerator complex;
3. expanding non-Member-State participation in the accelerated CLIC R&D programme,
4. laying a basis for collaboration on CERN's future projects.

The layout of the new LHC injectors was accepted in 2006, but Russia started participation in the R&D work for the upgrade of the CERN accelerator complex earlier in 2005 with the three ISTC projects for the Linac4. Two of them have a chance to transform into a CERN order for the production of parts of the future Linac4. The first project is for the development of the CCDTL prototype, carried out by VNIITF (Snejinsk) and BINP (Novosibirsk). The prototype has been already delivered to CERN and successfully tested. If ISTC accepts the partial financing of this project, these two institutes will be responsible for the production of the CCDTL part of the Linac4 the delivery of which is planed for 2010. The second project is for the design and development of Alvarez type structures for energy ranges up to 40 MeV which has been carrying out by VNIIEF (Sarov) and ITEP (Moscow). The prototype drift tube of this structure is finished and has been delivered to CERN and tested. This project is under consideration by ISTC for the financing of the production of the Alvarez type structures for the Linac4.

6. Conclusions

The CIS and SEE countries have been playing an important role in the LHC construction. This role should not be decreased while a physics programme on the LHC starts, on the contrary, these countries should take full benefit from the investment they made in this programme. Development of computing and Grid should be important tool in the realization of this programme.

Naturally, for the realization of its "White Paper" programme CERN is strongly counting on further support from these countries.

DNA-based electronic devices

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The paper gives a review of theoretical and practical approaches to the development of an element base of nanobioelectronics, i.e. DNA-based electron logic elements and nanosensors.

The possibility of the development of an electronic biochip based on the idea of measuring the olignucleotide conductance is considered. The operation principle of such a nanobiochip is based on the fact that the conductance of a single-stranded oligonucleotide changes if it hybridizes to the complementary chain.

The possibility of the development of the XOR (EXCLUSIVE OR) logic element on the basis of a double-stranded oligonucleotide with control electrodes is considered. It is shown that suitable properties are offered by DNA duplexes where the interferention pattern of electron waves determining the duplex conductance will lead to a logical table corresponding to XOR element.

The qubit element based on guanine quadruplex is also considered.

Keywords: oligonucleotide, logic gate, conductance, mobility, biochip, Green function

Although the DNA structure was discovered by Watson and Crick more than 50 years ago, investigation of its functional properties is one of the most pressing problems of the 21st century. Simple and clear principles of arrangement and stacking of a DNA molecule, its fundamental role in molecular biology have changed this science into a quantitative natural discipline. The use of these principles has made molecular biology an engineering science with extremely rich potentialities of application in medicine and living systems construction. Quite a new and unexpected for molecular biologists stage of DNA investigations started at the turn of the century. It was triggered by the discovery of DNA conducting properties which proved to be quite surprising. They were unlike those of metals, dielectrics, conductors or superconductors individually, but resembled the characteristics of all these groups in combination [1-5]. Understanding of the phenomenon presents a real challenge and opens up new lines of inquiry in the theory of condensed matter, biopolymers, quasi-one-dimensional systems, etc. Though the phenomena of charge transfer in DNA have not been fully described in the framework of a complete theory as yet, their potential practical applications promise revolutionary changes in nanotechnologies. For example, an electronic device has been developed in which tetramers G4 stacked into a quadrupole DNA helix (G4 - DNA) are used as building blocks [6]. G4 - DNA electronic nanodevices can carry out computations and be used in information procession operations. A field electronic transistor (FET) using CMOS technology on the basis of A-DNA has been constructed in [7]. Experimentally measured FET characteristics have demonstrated that poly A – poly T DNA chains exhibit the properties of n-type semiconductors while poly G – poly T chains demonstrate the properties of p-type semiconductors. DNA molecules can be assembled by a self-assembly method and arranged into nodes, stacks and layers which can be bound to some surfaces or molecules to form a conduction electronic circuit. In this paper we discuss how the DNA conducting capacity can be used in nanoelectronics.

Electronic nanobiochip

In this section we shall discuss the possibility to utilize the DNA conducting properties for realizing the electronic nanobiochip.

DNA-based microchips, also known as biochips and genechips, have appeared only recently and are used in most efficient devices for simultaneous analysis of thousands of genes. Their potential applications are countless, including gene expression analysis, studies of genetic disorders, drug development, even the solution of mathematical problems. Development of their technology is concerned with further miniaturization, i.e. increase in the number of spots on a biochip. Progress in this field goes on at about the same rate as which miniaturization in computer technology advances (Moore's law).

The methods for processing information read out from biochips will probably come up against the limits of miniaturization still earlier than the production of modern electronic circuits for computers (where the circuits of 0.1 μm size are presently used) will do, since readings from biochips are currently taken by measuring the intensity of a signal from an individual spot and analyzing changes in its intensity or color. This places a fundamental limitation on the accuracy of the measurements which is determined by the wavelength of the light emitted by a fluorescent marker used in the biochip technology, i.e. $\cong 1$ μm. At present, a technically attainable size of a spot is about 20 μm.

One way to overcome this limitation is to develop electronic biochips from which one could read out detailed information by measuring the conductance of an individual fragment of a DNA molecule used in biochips (Fig.2c). This would enable the biochip technology to break through into the nanometer region since in this case the resolution of the readings would be determined by the characteristic size comparable with the diameter of a DNA molecule, i. e. $\cong 2$ nm.

The model of a nanobiochip considered here is a single-stranded DNA fragment whose ends are attached to electrodes as shown in Fig.1a. Fig.1b presents a nucleotide sequence in which charge transfer is determined by matrix elements of the transitions between neighboring nucleotides. The values of matrix elements and site energies in the case when a charge is carried by holes are given in works [8, 9].
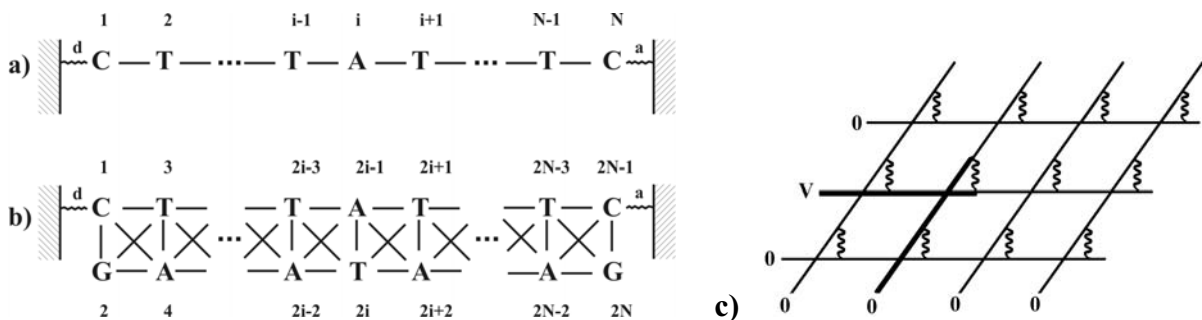
Fig.1. a) single-stranded DNA; b) double-stranded DNA with all nearest interactions; c) electronic biochip

The charge transfer can be calculated with an effective tight-binding Hamiltonian $\hat{H}$ with diagonal elements determined by relevant oxidation potentials and off-diagonal elements

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equal to the integrals of overlapping of electron wave functions of neighboring nucleotides [8, 9]:

$$H = H^\circ + V,$$

$$H^\circ = E_d|d\rangle\langle d| + \sum_{i=1}^{2N} E_i|i\rangle\langle i| + E_a|a\rangle\langle a|,$$

$$V = V_{d,1}|d\rangle\langle 1| + V_{a,2N-1}|2N-1\rangle\langle a| + V_M,$$

$$V_M = \sum_{i\neq j} v_{ij}|i\rangle\langle j|,$$

where $v_{d,1}$, $v_{a,2N-1}$ are matrix elements of the transition between donor (d) and nucleotide (1) and acceptor (a) and nucleotide (2N-1) respectively; V_M is a bridge DNA Hamiltonian, where v_{ij} are matrix elements between neighboring nucleotides; E_d, E_a and E_i are hole energies on a donor, an acceptor and the i- th nucleotide respectively.

To compare the conductances of the single-stranded DNA fragment and the double-stranded one presented in Fig.1, in [8] we considered their ratio f, determined by the formula:

$$f = \frac{R_{1N}^2}{R_{1,\,2N-1}^2}$$

where $\hat{R} = \left(E - \hat{H}\right)^{-1}$ is a resolvent corresponding to $\hat{H}$ and R_{ij} is an appropriate Green's function, E is a complex variable, the real part of which is interpreted as a hole energy.

It is shown in [8] that an electronic biochip containing ten nucleotide pairs will recognize $\approx 96\%$ sequences with the accuracy of measurements making up 10%. It is also demonstrated that the percentage of identifiable sequences will grow with the sequence length.

DNA-based electronic memory

DNA-based electronic memory is arranged in the same fashion as ferrite memory of early computers was. However the density of data in it can be $10^6 \div 10^9$ times higher than that in modern integrated circuits. In [10] it was suggested to construct this memory relying on hysteresis properties of DNA, by analogy with ferrite memory. However, as distinct from ferrites which exhibit hysteresis of magnetization, DNA demonstrates hysteresis of conducting properties depending on the value of the electric field. Adress encoding and decoding of information is carried out by matrix method. Unlike a biochip, the storage unit is constructed from oligonucleotide duplexes rather than from single-stranded oligonucleotides shown in Fig.1.

DNA-based logic elements

Apart from memory, a digital nanocomputer needs logic gates which are involved in the computational process. A theoretical consideration of a DNA-based logic gate, in particular, a logic gate carrying out XOR (EXCLUSIVE OR) operation is given in [11]. The principle of operation of such a gate is based on interference properties of electron waves in DNA.
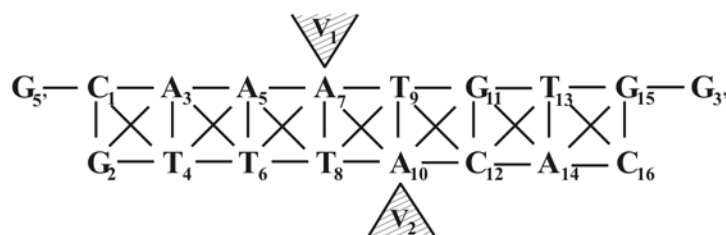
Fig.2. DNA duplex with control potentials V_1 and V_2

Fig. 2 presents a design of a XOR logic gate on an oligonycleotide depicted in Fig. 2. Voltages V_1 and V_2 between the control electrodes regulate electric current I along the oligonucleotide, so that a logic element with the properties presented in the following table is realized:

Table I

V_1	V_2	I
1	1	0
1	0	1
0	1	1
0	0	0

Another way of realizing logic gates is the employment of guanine quadruplexes. Guanine quadruplexes can be used to code binary information and perform Boolean operations. The basic idea is to use the charge configuration which is the most optimal for a nanostructure under consideration. Divalent metals Zn^{+2}, Co^{+2}, Ni^{+2} can be used as donors, and molecules of oxygen, iodine, or dye molecules as acceptors [12] – [16]. The nanostructure shown in Fig.3a) represents the scheme of the quantum cell automate from Fig.3b) in which black circles indicate possible positions of electrons (holes) in polarized states P1 and P2 [17, 18]. The bistable character of the quadruplex-quadruplex interaction makes possible quantum-functional devices. Fig.3c) presents an example of a logic element which contains three input majority gates.

As was shown in [17, 18] this scheme realizes the majority Boolean logic represented by Table II.

Table II

A	B	C	output
0	0	0	0
0	0	1	0
0	1	0	0
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	1
1	1	1	1
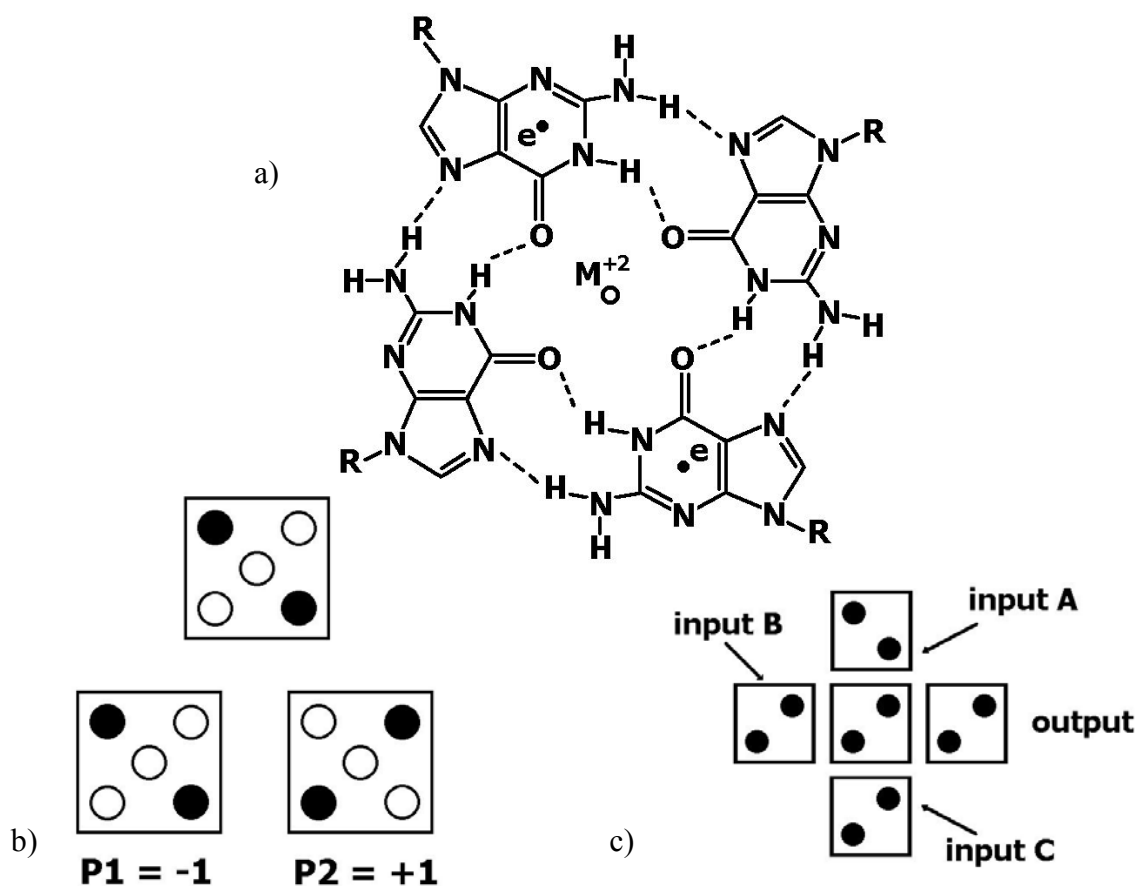
Fig. 3.

Since the quantum state of a guanine quadruplex is determined by a superposition of electron (hole) states on all four guanines, the polarization of such a nanostructure becomes an oscillating value. In principle, one can manage this superposition by changing the potential barrier separating the guanines, or by exposing them to a local electric field. Such a superposition of the quadruplex states, which can be described in terms of a pseudospin, can be considered similarly to a qubit in a quantum computer. The principle of functioning of a quadruplex computer will be similar to that of a quantum computer on quantum dots.

Comparison with other approaches

By now a lot of DNA-based devices have been developed. It makes sense to discuss their advantages and disadvantages. By way of illustration let us consider a DNA-nanosensor, whose principle of operation is based on the difference between the physical properties of single-stranded and double-stranded DNA. Such a nanosensor could determine with high accuracy agents of diseases from a known DNA sequence. Thus, according to [19], from a 15 nucleotide pair length DNA fragment of botulism or scarlet fever agents one can identify the disease with the probability of error $\sim 10^{-19}$ with the use of a single-stranded oligonucleotide. For this purpose one binds gold nanoparticles to oligonucleotides complementary to the sequence to be detected. Optical properties of these nanoparticles vary in the course of hybridization of the oligonucleotides with the complementary strands. An electron analog of such a sensor could be the same oligonucleotide occurring between nanoelectrodes whose conducting properties change in the course of its hybridization to the

complementary chain. Unlike a sensor with nanoparticles, an electronic sensor does not require a lot of similar oligonucleotides which makes it much more compact. What is more important, an electronic nanosensor has a virtually inexhaustible variability of conductances, while in an optical variant the spectrum of different frequencies is limited and considerably overlapped. Combining various oligonucleotide sensors into a set we could get a nanobiochip which could identify as many disease agents at a time as there are nanosensors in it. This would $10^6 \div 10^9$ times exceed the efficiency of modern optical microbiochips.

The main difficulties encountered in developing the above described nanoelectronic devices are those associated with construction of contacts with monitored inputs and outputs. The key problem of measuring the DNA conductance is that of attaching an individual DNA to two electrodes. This procedure has become possible due to progress in nanotechnologies. At present electrodes are produced with the use of Electron-beam lithography, Atomic-force microscopy, and low-energy point electronic sources. To attach an individual DNA molecule to a metal electrode a technique of gluing DNA oligomers has been developed. In this method sticky ends of DNA hybridize with short oligomers attached to the surface [20], [21].

These examples suggest that nanobioelectronics is a very wide discipline in which fundamental investigations and solutions of theoretical problems can quickly become applications. Our short review has had little concern with particular technical details of the design of DNA-based devices, since in view of rapid development of the science they quickly get out of date. For this reason, the main attention has been given to fundamental ideas. This, in particular, refers to the examples considered in the paper, the aim of which was to demonstrate the conceptual aspect of the subjects arising in this fast progressing discipline.

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"Mathematical Cell" - the next step forward in the development of GRID applications in computational biology

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IMPB RAS is evolving the project "MATHEMATICAL CELL" (www.mathcell.ru) as a multipurpose resource for obtaining of fundamental knowledge in cell biology. The intended objectives are achieved by integration of various information and computational resources. This environment is based on modern information technologies and makes use of the accumulated experience of mathematical modeling of complex systems. The present state of the resource is impressive.

Mathematical modeling of a living cell is a great challenge for modern science. The creation of integrated model of eukaryotic cell is the aim of the Mathematical Cell (MathCell) project (http://www.mathcell.ru) realized at the Institute of Mathematical Problems of Biology RAS during the EGEE, EGEE2 Projects. The portal includes 3D interactive living cell model, encyclopedia on mathematical modeling of cell and software for modeling of basic processes in living cell. Architecture and realization of the information component of the portal are described in detail [1, 2].

Within the limits of the project the interactive environment was developed, which allows to perform calculations of some mathematical models on GRID infrastructure. At the present three calculable models are deployed in GRID infrastructure:

- software for modeling the electron transfer in a DNA molecule;
- simulation model of electron transfer on inner photosynthetic membrane in chloroplasts;
- software for calculation of Dissolution Energy of Biomolecules in Water by Monte Carlo Method.

The applications were made available through a web portal. This web portal enables login on our system, studying the mathematical model details, searching for the most appropriate parameters of model, calculating the model in the GRID infrastructure, viewing the results. Actions are performed through a self-explicating graphical user interface and results are presented in numerical and graphical forms. The graphical presentation is realized in the form of static image and in the dynamic form and has the possibility of changing parameters of presentation. This part of the interface is realized by scripts on PHP and JavaScript.

A special middleware is produced that maintain the interaction of the application with GRID.

The processes of queuing of the job in the GRID infrastructure, of its status monitoring and of results obtaining are realized by a special middleware that is making invisible for Windows experienced user all Linux operations. This middleware assembles jobs for GRID by organizing its own queues, sends the jobs to Resource Broker and, if the RB can't allocate the job right now, automatically repeats its attempts until the successful allocation. Then the middleware monitors the status of allocated jobs and automatically receives files with results.

All jobs of the user are collected in the internal database, where for successfully computed tasks both sets of input data and obtained results are presented. Jobs waiting for

GRID resources or waiting for results with appropriate status marks are presented too. Our middleware make the GRID computing comfortable and transparent for user, independent of its Linux experience and of the quality of internet communication. The middleware is written in Shell Unix.

The middleware is invariant for all applications; it was testified on the task of modelling of charge transfers along biomolecular structures. It will make the deployment of another application in GRID infrastructure very easy and quick procedure.

Model of Charge Transfer Along a DNA Fragment

Quantum-classical model of excitation transfer along a <u>DNA</u> fragment is computed. This DNA fragment is considered to be a chain of N sites. Each of these sites behaves as a harmonic oscillator. It is conventional, that the base planes of nucleotides are parallel to one another, and the distance between base planes of neighboring sites is constant; this corresponds to the B-form of DNA.

$$\begin{cases} i\hbar \dot{b}_n = (\alpha_n^0 + \sum_k \alpha_{kn}' \tilde{u}_n) b_n + \sum_{j=n} v_{n,j} b_j \\ M_n \ddot{\tilde{u}}_n = -\gamma_n \dot{\tilde{u}}_n - K_n \tilde{u}_n - \sum_k \alpha_{kn}' |b_n|^2 , n = 1,...,N \end{cases} ,$$

where

b_n is the probability amplitude of the <u>electron</u> localization at the n-th site,
α_n^0 is the excitation energy at the n-th site,
α_n' is coupling constant between the charge with nucleotides,
$\tilde{u}_n$ are displacements of sites from their equilibrium positions,
$v_{i,j}$ are matrix elements of transition from the i-th to the j-th site,
M_k is the mass of the k-th site,
γ_k is the friction coefficient,
K_k is the elastic constant.
All derivatives are differentiated here with time $\tilde{t}$.

Let $\tau = 10^{-14}$ sec is the characteristic time, U_n is the characteristic size of fluctuation of the n-th site, that is $\tilde{u}_n = U_n u_n$, $\tilde{t} = \tau \cdot t$. The corresponding system in proximity of the nearest neighbors in non-dimensional variables has the following form:

$$\begin{cases} i\dot{b}_n = \eta_n b_n + \eta_{n,n+1} b_{n+1} + \eta_{n-1,n} b_{n-1} + \kappa_n \omega_n^2 u_n b_n \\ \ddot{u}_n = -\omega_n^2 u_n - \omega_n' \dot{u}_n - |b_n|^2 , n = 1,...N \end{cases} ,$$

where

ω_n is the oscillation frequency of the n-th site,

$\eta_n = \tau \alpha_n^0 / \hbar$, $\eta_{n,n\pm1} = \tau v_{n,j} / \hbar$,

$\omega_n^2 = \tau^2 K_n / M_n$, $\omega_n' = \tau \gamma_n / M_n$,

$\kappa_n = \alpha_n' U_n T / \hbar$.

All derivatives are differentiated here with the non-dimensional variable t.

The effective mass of all sites is considered to be the same, and it is equal to $M_n = 10^{-21}$ g. High frequency intramolecular oscillations in DNA, which correspond to oscillations of bases in a separate site, have frequencies of picosecond order. Frequencies and friction coefficients on sites are considered to be the same; the corresponding non-dimensional values lay in the range $\omega^2_n \approx 10^{-4} - 10^{-6}$, $\omega'_n \approx 10^{-2} - 10^{-5}$. The system is solved by the fourth-order Runge-Kutta method with constant step.

Simulation Model of Electron Transfer on Inner Photosynthetic Membrane

The simulative platform is represented as a region in three-dimensional space. The region includes several compartments, which are: a section of a twofold photosynthetic membrane, intermembranous space (lumen), and the area outside the membrane (stroma). The model contains mobile electron transmitters (plastocyanin in lumen, ferredoxyne in stroma, and plastoquinone in the membrane), as well as protein complexes of photosystems I and II and a cytochrome b_6f complex, which are built in the membrane.

The parameters of the model are geometrical dimensions of the section of the photosynthetic membrane being modeled and quantity (density) of complexes.

Movement of the mobile transmitters is described by the Brownian dynamics. Diffusion coefficients of the transmitters are prescribed. The model takes into account collisions of transmitters and protein complexes.

Reactions of transmitters and complexes are described through interaction radius d and reaction probability p. If an electron transmitter approaches a landing site on a complex closer than for distance d, then a coupling and the reaction of electron transfer are possible with probability p.

Calculation of Dissolution Energy of Biomolecules in Water by Monte Carlo Method

The software package was developed to study energetic aspects of small (of several dozens of atoms) biologically active molecules hydration.

Computer simulation by Monte Carlo method allows calculating of average energy of the molecular system under investigation from a statistically significant sample of its configurations at a prescribed temperature. Generation (sample group) of molecular configuration is completed *via* Metropolis sampling procedure [3], which executes stochastic process (Markov chain) of wandering in the coordinate space of the model under investigation [3, 4, 5]. The energy of intermolecular interactions is calculated by means of atom-atom potential functions [4, 5].

The system being modeled represents a cell in the shape of rectangular parallelepiped filled with water molecules and containing the molecule under study in the central part of the simulation unit. Dimensions of the cell and the number of water molecules are set (automatically) in such a way that interaction energy between the solute molecule and a peripheral water molecule is small enough to be neglected. To eliminate surface effects, periodic boundary conditions are imposed upon the cell.

Dissolution energy (for infinite dilution) will be calculated as difference between the average energy of the system being modeled (a molecule having been dissolved + N water molecules) and average energy of the water system without the molecule under study (the same N water molecules in a somewhat less cell).

A user should set absolute temperature (by Kelvin scale) and prepare a molecule description file in ASCII-text format (resembling PDB, see examples of input files). The last column in the molecule file is an atom type (1- H-(O,N), 2- H-(C aromatic), 3- H-(C aliphatic), 4- aliphatic C, 5- aromatic C, 6- amino-group N, 7- pyrrol N,

8- pyridine N, 9- ester O, 10- carbonyl O, 11- "charged" carboxyl or phosphate O, 12 - phosphorus). The last but one column is partial atomic charge (for example, charge for water O is -0.680, and for water H it is 0.340).

If the molecule being investigated is not electrically neutral, then the value of dissolution energy having been calculated for it can differ greatly from the real one (to speed up computations interaction cutoff is implemented).

To accelerate calculations and to obtain more reliable results, partition of large molecules into small and, where it is possible, electrically neutral fragments is recommended. In the file being prepared, atoms of one fragment should be separated from atoms of the next fragment and the terminal line (END) by the line TERM. Calculation for a large molecule can continue for dozens of hours, that is why the given version of the programs has quantitative limitations on the number of atoms (maximum number of fragments is 20, maximum number of atoms in a fragment is 30, and no more than 2000 water molecules).

The software under review can be used for various purposes, which are fundamental research or applied development of pharmaceuticals. For example, it allows obtaining of relative data for estimation of dissolution energy of molecules from homologous sequences, or, estimation of enthalpic or entropic effects of dissolution from temperature dependences.

Further development of the MathCell project implies integration of individual components of the model into an integrated program system which would simulate cell processes at different levels – from microscopic to macroscopic scales and from picoseconds to the cell lifetimes. Such modeling will allow ones to solve a number of practical problems, for example, acceleration of development of novel drugs and of prediction of their direct and mediated action, development of thin biochemical agents which will influence on metabolic reactions in the organism. Besides, such model will be useful by development various nanostructures and nanomaterials - in the most advanced researches which are having for an object creation nanorobots which at a cellular level will work with a view of medicine and preventive maintenance of illnesses. This work will naturally require combining of resources provided by EGEE-II Project and their merging into an integrated computational environment.

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The LHC Computing Grid and HEP experience extended to other scientific fields

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Abstract

This article gives concrete examples of the collaboration between the High-Energy Physics and other sciences in the field of grid technology. We show how original developments in the field of job management, monitor and data management have been beneficial outside the initial scope of the LHC physics and have been used in fields as diverse as theoretical physics or biomedical applications.

Introduction

In this article I will discuss the role of High-Energy Physics (HEP) and of the LCG (LHC Computing Grid [1]) project from an non-conventional point of view, namely trying to evaluate the impact in other fields of applied computing. In particular I will refer to the experience supported and developed in the EGEE (Enabling Grids for E-sciencE [2]) project (phase 1 and 2, April 2004-April 2008).

In the case of HEP, a specific effort was set up (jointly between the EGEE and the LCG project), to investigate the usage of the grid for the so-called end-user analysis. With the word *analysis*, in HEP we mean all computing activities performed, almost independently, by individual physicists, sometimes organised in small teams. In general, they share a common software foundation, but each individual/team has a set of different executables, in general tailored for a specific scientific task. All analyses share part of the input data (experimental data, both raw and reconstructed plus simulated data) but often rely on private copies of "derived data". Frequent multiple passes on subsets of the data are the rule. The impact of this activity on the grid computing is relevant at least in three areas.

On one side, the size of potential user community (in the case of the LHC experiments, several thousands physicists) is a call for a robust system, which should be relatively user friendly and transparent. Analysis is therefore very different from the organised activities (detector simulation, raw data reconstruction, etc...) where all the activity is performed by an expert team in a coordinated way.

Realistically, if a large community has to use the grid, this should not force unnecessary changes in the way of working (analysis is a day-by-day activity). Being grid technologies still in a fast-evolution phase, the users should be shielded at least by non-essential changes in the internal components of the infrastructure.

The second area is again intimately connected to users expectations. Users are interested to perform analysis on the grid only if they can get a faster turn-around time or have access to larger or more complex data sets. The potential benefit of having larger resources could be reduced (or even disappear) if one needs continuous expert support in particular in troubleshooting activities. This observation translates in the requirement of a system which should not only provide sheer power, but should be reliable and efficient. In this case, the users can rely to have the results back within dependable time limits. High efficiency means that users do not need too many time-consuming operations, like resubmitting jobs to failures of the system in accepting jobs, in accessing the data, in returning the results. The availability of simple access to monitor information is clearly the key.

The last area is data access. Data access on the grid is a field of research in itself. In the analysis use case, users should be empowered with simple but performing tools to access the data and perform data location functions. As an important example, here we mention the metadata catalogues, i.e. those systems that, in their simplest usage, should help the users to preselect input data sets to be analysed.

The LHC and the Grid Projects

The Large Hadron Collider (LHC) will start to operate in 2008. Four major LHC experiments (ALICE, ATLAS, CMS and LHCb) will collect roughly 15 PB of data per year, which should be processed, calibrated and analyzed multiple times. Seamless access to the LHC data should be provided for 5,000 scientists in about 500 research institutions worldwide. The lifetime of the project is estimated to be around 15 years of data taking.

The goal of the LHC Computing Grid Project (LCG also called Worldwide LCG or WLCG) is to prepare and deploy the computing environment indispensable to perform the physics programme of the LHC project. This includes the detector simulation studies to push the detectors' performance to their limit, the calibration and the monitor of the detectors during the data taking periods, the reconstruction of the raw data and other selection stages. All relevant data should be accessible to all the physicists worldwide participating into the experiment.

The LCG project was approved by the CERN Council in September 2001. Two major phases of the project were defined. The goal of the first phase (2002-2005) was to develop software and services, to build the prototypes and to accumulate first experience operating the new infrastructure. The second phase (2006 onward) is bringing into operation the production quality system for storing and analyzing of the LHC data.

The LCG Technical Design Report [3] estimates the computing power required for the LHC data analysis to be of the order of 100,000 CPUs (CPU available in 2004). A globally distributed model for data storage and analysis was chosen. Originally the MONARC [4] project (Models of Networked Analysis at Regional Centers for LHC Experiments) suggested a hierarchical structure of distributed computing resources (partially modified due to the emerging grid technologies). CERN and multiple computing centers worldwide are providing resources for constructing of the LCG infrastructure.

The LCG infrastructure is built out of a collaborative effort on top of other projects and organizations like EGEE (Enabling Grids for E-sciencE), OSG (Open Science Grid [5]) and NDGF (Nordic Data Grid Facility [6]). All these projects have a multiscience character, particularly prominent in the case of EGEE. In all cases, the HEP community is one of the major drivers. In this article, I will use the experience matured in EGEE (in a set of activities globally labeled as ARDA, "A Realisation of Distributed Analysis"; http://cern.ch/arda) jointly funded by EGEE and by CERN and with substantial contributions of several institutes as the Russian institutes in LCG and the Taipei Academia Sinica Grid Centre).

In this article I will give three examples corresponding to the three areas mentioned in the introduction. The three examples correspond to three lines of activity of the ARDA team at CERN over the last four years.

Ganga

Ganga is a job-management system, developed as an ATLAS- LHCb common project. ARDA started to collaborate with the Ganga team already in 2004 and progressively increased

its contribution due to the interest and the potential of this system [7].

The basic idea is to offer a simple, efficient and consistent user experience in a variety of heterogeneous environments: from local clusters to global grid systems. It is natural that a user develops an application on his or her own laptop, move to a local batch system for optimising the analysis algorithm onto a reacher data sets and eventually perform full-statistics runs on the grid. Moving from one stage to another applies also in the reverse order (from the grid to the laptop), for example when a bug-fix or an algorithm improvement should be developed and tested.

Ganga shields users completely from the job submission details (basically the execution back-end is selected by the users by a software switch and Ganga generates the appropriate stubs to execute user code on the available resources).

It is interesting to note that this approach also shields the users from the evolution of the middleware, hence it fully responds to the first area mentioned in the introduction.

Ganga is written in Python. Current versions are available under the GNU Public Licence. Ganga acts as a front-end to submission of computational intensive jobs to a variety of submission back-ends:

- Several batch system including LSF, PBS and Condor;
- Grid middleware like different flavours of the LCG/EGEE middleware or NorduGrid (NDGF);
- Specialised workload management systems for the grid such as Dirac (LHCb experiment) and Panda (ATLAS experiment).

Since Ganga scripts are Python scripts, the entire power of Python is available for creating complex tasks, yet the user is not obliged to be a Python expert. In tutorials new users typically learn the necessary syntax within the first 30 minutes. In Figure 1, we show a basic example which is used in most of our tutorial sessions.

Finally, Ganga keeps a record of of the jobs created and submitted by the user, which are recorded in a job repository. This allows the user to manipulate Ganga jobs in between sessions. Manipulations include being able to submit, kill, resubmit, copy and delete jobs. The repository is updated by a monitoring loop which queries all used back-ends for the status of the jobs and updates the status or triggers actions based on the state transition. For example, a job that changes into a completed state triggers the retrieval of the registered outputs from the submission back-end.

Figure 2 accounts for the very large user basis which has been built around Ganga. In the context of this paper, it is important to note that around 25% of the user community (over 50 regular users each month) comes from non-HEP communities.
As an example of usage of Ganga outside the ATLAS and LHCb, I chose the calculation from theoretical physics. QCD describes the interaction of the constituents of the hadronic matter (quark and gluons) and ultimately the structure of nuclei. When QCD is studied on discrete systems (Lattice QCD) it requires non-trivial computing resources. The application that we use as an example is a study of phase transitions in a quark-gluon plasma [9].

The interest of the example from the computing point of view sits mainly in the fact that Ganga allowed a very fast porting of an application onto the grid. The clear scientific advantage is that, with an investment of about 1 week for porting and running on the EGEE infrastructure, the available statistics has been multiplied by 4 (compared to the one collected over several months on existing resources).

```
#
# Ganga example
# submit 3 jobs, one local, one on batch, one to the grid
#

j=Job(backend=Interactive(),application=Executable())
j.application.exe="/bin/echo"
j.application.args=["Hello world"]
j.submit()

j2=j.copy() # make a copy of the last job
j2.backend=LSF(queue=?8nm?) # submit to LSF
j2.submit()

j3=j.copy()
j3.backend=LCG() # run on the Grid
j3.submit()
```

Fig. 1. A simple example where the same job ("Hello world") is submitted to the local machine, a batch system (LSF) and the LCG grid.

Fig. 2. Ganga usage as reported by MonALISA [8]. In 2007 over 1,000 distinct users (unique users) tried out Ganga. Each month, over 100 ATLAS users and about 50 LHCb users use Ganga for their activities. Additional 50 users (25% of the total) are coming from other communities (mainly outside HEP).

The workflow of the application is outlined in Figure 3. The application binary (~700 kB) reads a file containing the description of the space-time lattice (~1,200 kB) to be investigated. Of these lattices 21 different versions exist, all describing slightly different physical conditions.

Since the result improves with the number of iteration performed and since the result is saved in the space-time lattice, it makes sense to run the application for as long as possible (ideally until the batch queue time is reached). Therefore the decision was taken to run in an infinite loop and to regularly send back results to a simple server. This allows the script which runs on the worker-node to be very simple and to make sure that if a job crashes or gets killed, the latest result is still available. Since results where sent back every hour, on average a job would waste one hour at most (out of several days of running).
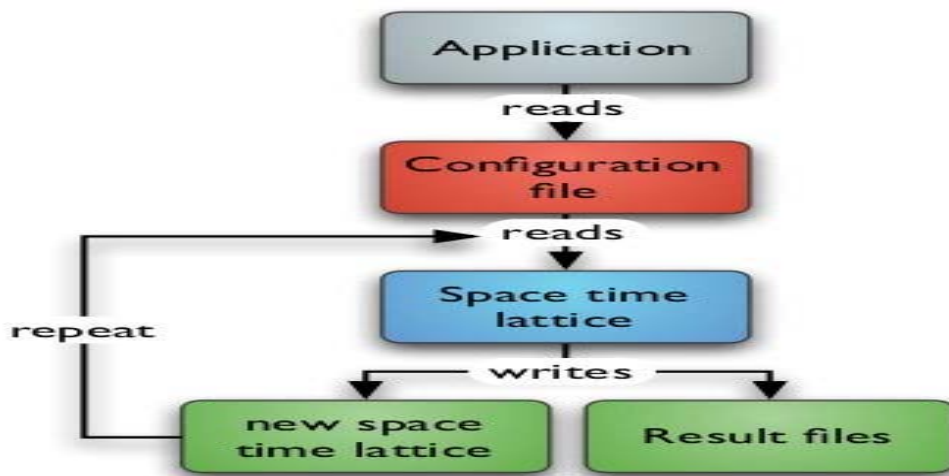
Fig. 3. The workflow of the Lattice QCD application. The binary reads one space-time lattice and a configuration file. After a cycle has been performed, the new improved space-time lattice is written out. The new lattice then acts as input for the next cycle.

We have exploited the natural parallelism (the 21 space-time lattice files), together with the free parameters in the configuration file. With this strategy around 450 jobs were submitted using Ganga to both the EGEE Grid and to the CERN LSF batch system. This resulted in about 9,500 CPU cores to be used. The jobs ran for about one week, after which they were killed (via Ganga). Within this week the results from more than 30 CPU-years could be harvested. A subset of these results have been used for presentation in conferences, as Lattice 2007. The jobs ran on more than 50 sites, with a majority of jobs running on fast Intel Xeon processors (see Figure 4).

This example is a neat demonstration of the power of Ganga as a tool to facilitate the usage of the grid. The original goal to isolate the HEP users from the details of the execution back-end led to the development of a tool, Ganga, which is attiring users from different activities. Often new users discover the tool by themselves and then start using it.
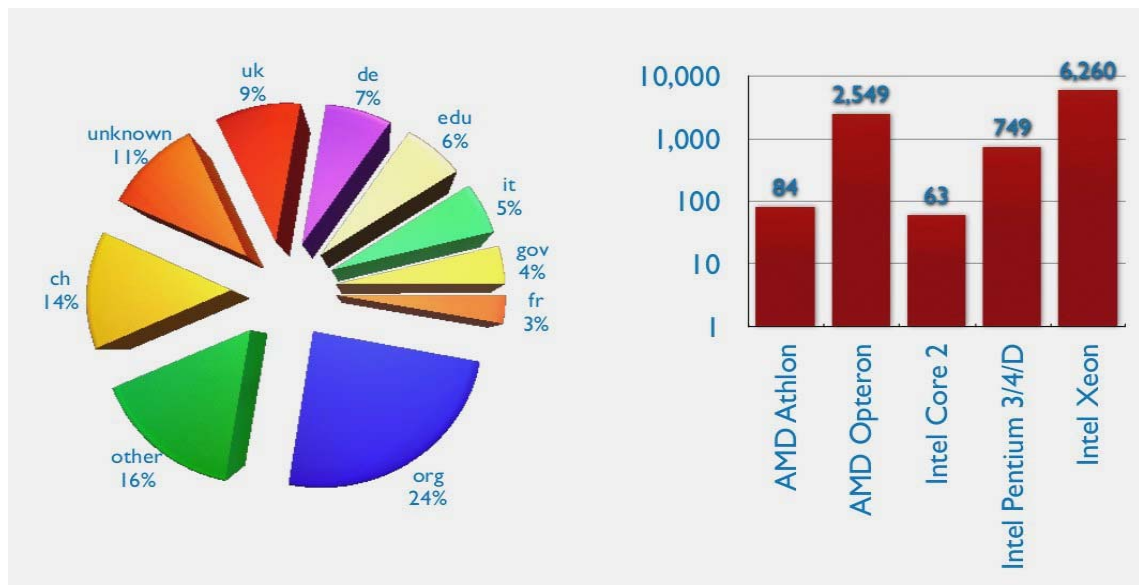
Fig. 4. Distribution of top level domains of the sites and the distribution of processors used for the lattice QCD application. Note the log scale in the processor distribution plot.

Within the EGEE context, we have observed the value of Ganga also as a tutorial tool. The choice of the Python language (its flexibility and the availability of powerful extension modules), helps to guide the new users into realistic scenarios without unnecessary technicalities. The final result is that users end a 3-hour tutorial and are in the position to continue experimenting and preparing to use the EGEE production infrastructure without further dedicated effort.

The Dashboard and the Grid Reliability Tools

In the previous section I have illustrated the link between the requirement of a tool for easing the day-by-day activities of the HEP community and the indirect benefit for other communities. In the introduction, we discussed a second requirement, connected to the need of easy access to monitor information.

It is clear that a tool like Ganga does not prevent execution problems if these are connected, for example, to a misconfigured site or to a failure in the middleware stack. Such investigations need monitor information. As a matter of fact, all the different actors in the grid world (operation support, middleware developers, individual users, application managers) need easy access and correlation tools on the available information. The combination of the experience of the monitor system of CDF (FNAL) and the user monitor of an early ARDA analysis prototype were used to start the CMS Dashboard project (later renamed (*Experiment) Dashboard* since the same foundation is used by all 4 LHC experiments [10]).

The strategy was to give to all grid actors the right tool to manipulate and display the available data. The grid operation support, for example, could use the Dashboard to isolate site-specific troubles and use the statistics of error message to fix the problem. Middleware development teams could collect large statistics of error conditions, concentrating on the most common (hence most annoying for the users) factoring out site or application problems. Users are clearly interested to follow the execution (including error conditions) of their own jobs while the activity managers are interested to global figures like resources usages.

In the development of the project, the emphasis was given to combine existing

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information and no effort was devoted in the development of new sensors or protocols. The main components of the Dashboard are information collectors, data storage, currently implemented for an Oracle backend, and the services responsible for data retrieval and information presentation (command-line tools, web pages etc...).

The Dashboard is using multiple sources of information, among them other grid monitoring systems like R-GMA (Relational Grid Monitoring Architecture) [11], GridIce (Monitoring tool for Grid Systems) [12], SAM (Service Availability Monitoring) [13] or IMRTM (Imperial College Real Time Monitoring of the Resource Brokers) [14].

In addition, information from experiment-specific services (like the ATLAS Data Management), central databases (as the ATLAS Production database) and servers of the MonALISA [8] monitoring system. Information is transported to the Dashboard via various protocols. Data collectors are implemented in either push or pull modes.

The collection of input information implies regular access to the information sources. They are retrieved and stored in the Dashboard database. To provide a reliable monitoring system, data collectors should run permanently to recover any missing data in case of failures (and restart the necessary components). The Dashboard framework provides all the necessary tools to manage and monitor these agents, each focusing on a specific subset of the required tasks.
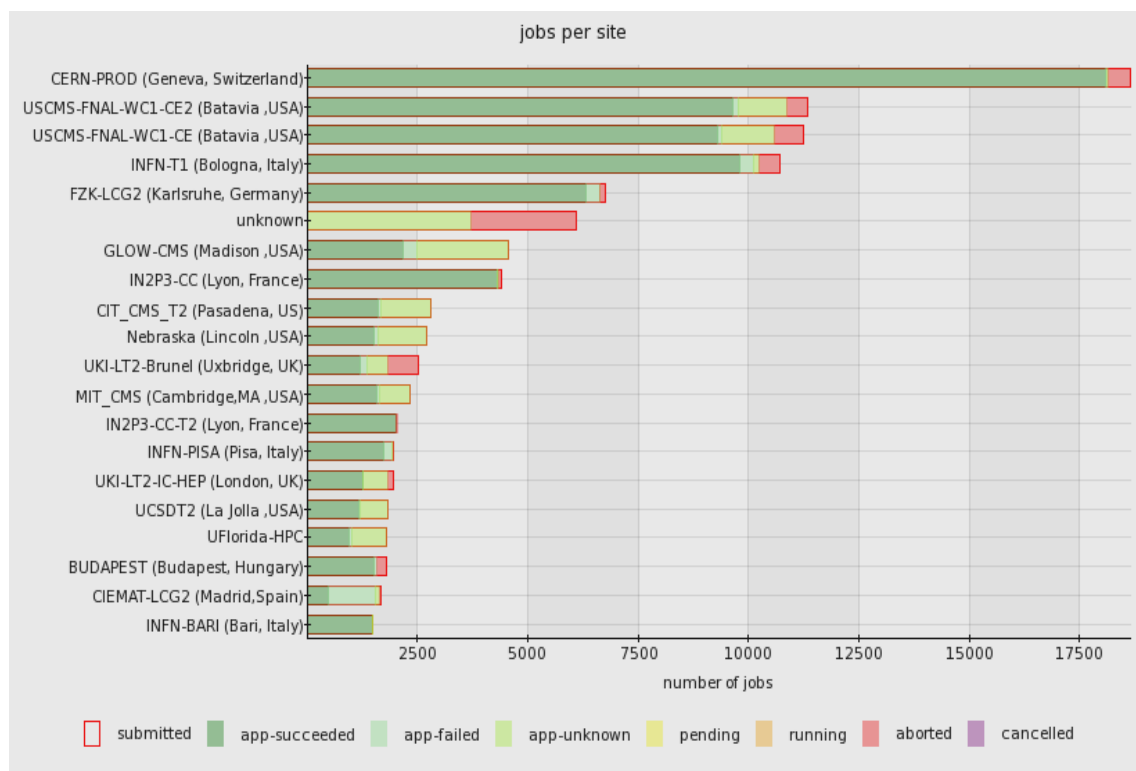
Fig. 5. Dashboard Job Monitor. Summary of CMS production jobs (1 week at the beginning of 2008). The Experiment Dashboard accounts for all CMS jobs, on both the infrastructures used by the experiment (EGEE and OSG).

In Figure 5, we present one of the main views of the Dashboard, namely the Job Monitor. We display as an example, the summary of CMS production jobs (1 week at the beginning of 2008). It is worth noting that, since the LHC experiments use as a rule more than one grid infrastructure, the Dashboard has been designed in order to collect information from

all used resources. The centres listed in the display belong to EGEE with the exception of the US site (belonging to OSG).

The importance of an activity like the Dashboard is clear and documented by the interest in the HEP community (usage by the 4 LHC experiments): the Dashboard provides unbiased views of the delivered performances to specific user communities by measuring the efficiency of the users application by monitoring directly the activity of all the users. All the project (and the Job Monitor in particular) has generated interest in several applications in EGEE. Biomedical applications (VL-eMed) have adopted it and Diligent (Digital Libraries) are considering to evaluate it on their infrastructure.

In Figure 6, we show another Dashboard application: the Site Efficiency. In this case, the Dashboard is the installation in use for VL-eMed . In this application, job attempts are identified and the grid failures are categorized and associated to a given grid resource in a site. In case a job is resubmitted multiple times due to failures, each job attempt is taken into account to test all available grid sites. The main difference with the Job Monitor application (Figure 5) is that in that case only the final execution of a job is considered. Site Efficiency permits to very quickly identify error patterns, typically connected to a site misconfiguration. In the case of common errors, the tool points to a list of explanations/solutions, which are accessible via the drill-down functionality of the tool.

SiteName (click on any site)	Successful jobs	Failed jobs	Efficiency
unknown	0	4	0.00%
SARA-MATRIX	8660	9908	46.64%
ce.gina.sara.nl:2119/jobmanager-pbs-express	4	0	100.00%
mu6.matrix.sara.nl:2119/jobmanager-pbs-long	1	0	100.00%
ce.gina.sara.nl:2119/jobmanager-pbs-medium	3878	4678	45.32%
mu6.matrix.sara.nl:2119/jobmanager-pbs-express	13	6	68.42%

JobIds	# jobs	Successful?	Error message
See all the jobids...	6	No	Failure while executing job wrapper
See all the jobids...	7	Yes	user retrieved output sandbox
See all the jobids...	3	Yes	Job terminated successfully
See all the jobids...	1	Yes	unknown
See all the jobids...	1	Yes	unknown
See all the jobids...	1	Yes	unknown

mu6.matrix.sara.nl:2119/jobmanager-pbs-medium	7	4	63.64%
ce.gina.sara.nl:2119/jobmanager-pbs-short	4748	5216	47.65%
mu6.matrix.sara.nl:2119/jobmanager-pbs-short	9	4	69.23%
NIKHEF-ELPROD	11250	1967	85.12%
tbn20.nikhef.nl:2119/jobmanager-pbs-qshort	6333	994	86.43%
tbn20.nikhef.nl:2119/jobmanager-pbs-qlong	4917	973	83.48%
LSG-AMC	18368	2058	89.92%

Fig. 6. The Site Efficiency Dashboard application at work for VL-eMed . Job attempts are identified and the grid failures are categorized and associated to computing resources of the sites. The application permits to very quickly identify a specific error pattern.

Data management

Data management is a particularly interesting in the case of HEP. In this case the quantity of data (every year several PB of data have to be added to the data store), the replication strategies (multiple complete copies should coexist over the LCG infrastructure to provide redundant storage) and the complex access patterns (especially at the level of end-user analysis), make data management a very interesting problem. ARDA invested a lot in this field, starting from middleware tests to monitor activities. A very important part of the Dashboard monitors data transfers at the level of the infrastructure services (the FTS system) and at the level of experiment-specific steering systems).

In Figure 7 we show the data transfer of one of the first tests of the full chain of data acquisition in the late 2007. During a week, the ATLAS detector collected cosmic-rays events and distributed them in the computing infrastructure as expected in LHC operations (namely distribution of the raw and centrally reconstructed data, access to the data by end-users after distribution to remote sites).
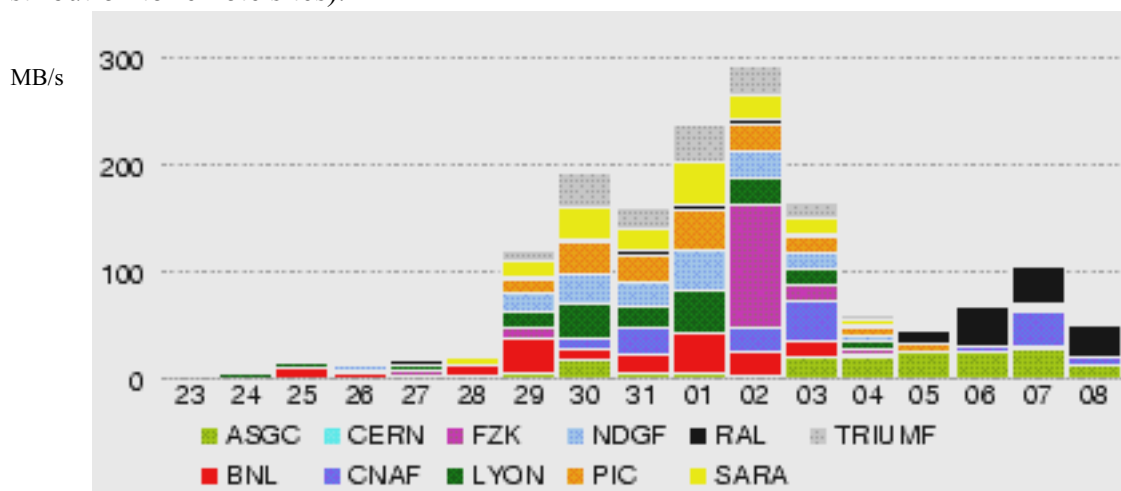
Fig. 7. ATLAS cosmics data acquisition (August 23-September 8, 2007). The snapshot of the Dashboard shows the data distribution from CERN to the main regional centres supporting the ATLAS experiments.

As an example of the fruitful collaboration between HEP and other sciences, one of the best example is the AMGA metadata catalogue (AMGA stands for ARDA Metadata Grid Access [15]). This system, originally developed by ARDA as a tool to validate the metadata interface in the EGEE middleware, was used as a laboratory to investigate efficient techniques to provide robust and efficient access to database in a grid context. AMGA is at the basis of a few systems in the HEP world (most notably the LHCb bookkeeping catalogue).

The AMGA system has been adopted by several applications in completely different domains (see for example the Book of Abstract of the 2nd User Forum organised by EGEE in 2007 [16]). Applications ranges from Climatology to Multimedia. The application we use here as an example is High-Throughput Screening in Drug Discovery. The first application in this field is WISDOM [17] active on the EGEE infrastructure since 2005. In 2006, a new phase was started with the arrival of new collaborators (most notably by Academia Sinica Taipei [18]) and with the start of a set of campaigns against the H5N1 virus (Bird Flu).

The basic idea is to use the grid to perform collaborative screening of potentially

active chemical compounds (called ligands). This activity, called docking, can be executed on the grid by assigning single combinations of proteins and ligands to independent execution units. In order to scale up this activity, a central repository is needed (to assign the protein-ligand pairs, to store and display the results and to implement more complex workflows). The choice for this system has been AMGA (Figure 7). The decisive arguments in the choice were the performance and robustness in supporting multiple concurrent clients and its support for grid security.

Especially in the case of H5N1, one of the leading ideas is to prepare for a fast-response system. In 2007, the system has been demonstrated to perform as expected (delivering interesting candidate to be validated in the laboratory). A typical challenge scans several millions ligands using hundred of CPU-year in a month time. The result is an handful of promising preselected candidates for validation in the laboratory.
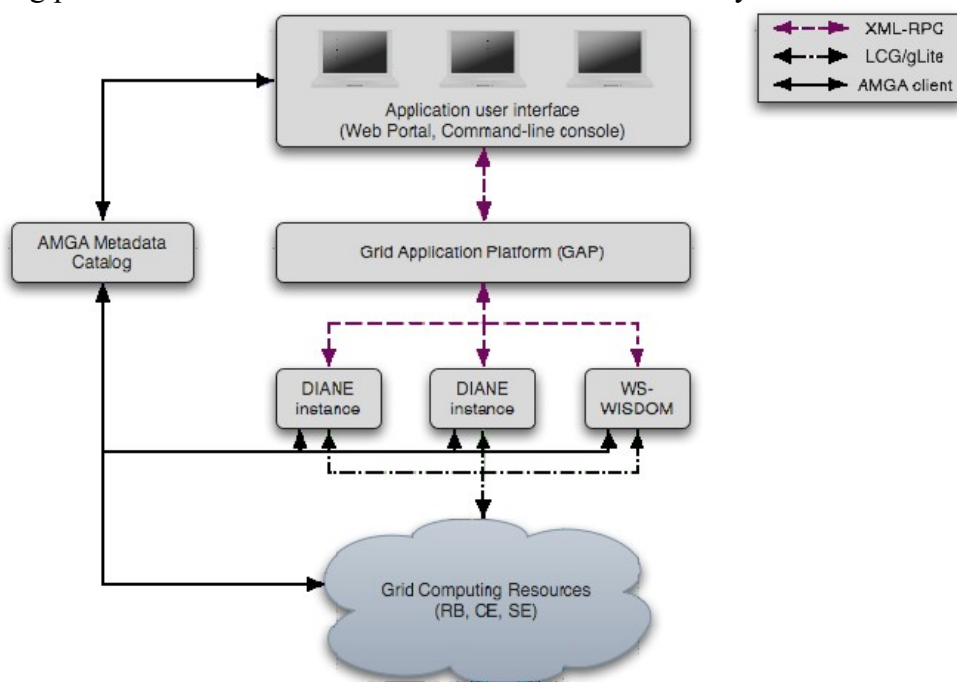
Fig. 8. The system in use in the most recent challenges against H5N1 (Bird Flu) showing the integration of the AMGA system. The layer with the DIANE and WS-WISDOM is the component which controls the execution of the jobs on the grid. DIANE is actually a component of the Ganga system.

Conclusions

The collaboration of the ARDA team with other sciences in the last several years has been fruitful and stimulating. Using the three examples of this article, I demonstrate a concrete form of collaboration across different scientific domains.

On one side, projects like EGEE have the virtue to generate contacts and ideas exchanges across communities. On the other, the HEP community keeps maintaining its leading role in innovating computing and grid technology in particular.

More examples of collaboration could be given and I preferred to single out just three, corresponding to three systems we developed and shared with our colleagues (Ganga, Dashboard, AMGA). I am confident that in the next years more collaborations across different scientific areas (and applied technology also in the business sector) will bloom and be as fruitful as these early examples.

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Visualization and Data Treatment Software Based on PV-WAVE and IDL Packages

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Introduction

The software applications of licensed packages for visual data analysis are very popular in many neutron centers because of the lack of developers working in this field and the necessity to react on demands of users who get a very short time for their experiments at the reactor. In 1996 the FLNP purchased licensed visual data analysis software to develop neutron instrument oriented applications. At present, FLNP possesses the development licenses on the packages *PV-WAVE* by *Visual Numerics* [1] and *IDL* by *Research Systems* [2]. Both packages comprise their own programming languages, working environment, and comprehensive mathematics and graphics libraries. Specially developed at FLNP applications of *PV-WAVE* package and the **lamp** program [3], developed at the Laue-Langevin Institute (Grenoble, France) as the application of the *IDL* package, are available for the FLNP users. The report summarizes the experience with the mentioned above software packages during several years.

The program openg2

The program "openg2" [4] is designed for access, reduction, visualization and express-analysis of the data measured on different neutron instruments (mainly, the time-of-flight ones). The program provides a set of functions for general purposes and special possibilities for a few FLNP neutron instruments. Input data formats include raw data written by Sonix [5] or older DAQ software used at FLNP of JINR, ASCII (1,2 or 3 columns), NeXus data format [6], and several raw data formats for neutron instruments from ILL (Grenoble) and HMI (Berlin). Such data can be read into workspaces, which are the flexible memory structures with main components oriented on visualization tasks. Workspaces can be visualized, analyzed and saved into data files. Output data formats are two- and three-column ASCII, NeXus and Rietveld-Pruf data. The program is written in pv-wave language and uses PV-WAVE environment during its operation. All PV-WAVE functionality is available from the separate command window, which allows one to call any PV-WAVE procedure to recalculate any workspace components (as well as to browse the PV-WAVE on-line help, etc.).

Visualization options consist of several types of one-dimensional X-Y plots, images, surfaces, contours and color maps for two-dimensional spectra. Most of visualization windows of openg2 program are equipped with their own graphic user interface. The standard tools for color customization are also available. Analysis options include: automatic execution of preliminary data treatment procedures for some of the IBR-2 neutron instruments; typical operations on workspaces with automatic recalculation of statistical errors; the coordinate conversions; tools to create new workspaces (for example, background workspace); tools for easy one-dimensional fitting by mouse clicks on the plot; tools for data merging; etc.

The starting menu of the program permits one to select one or more files to read; to save and restore the whole session; to select, view and edit a text file; to download raw data files from the VME machine; to create a postscript file from the last picture or to print it. After selection of the data files a dialog appears to define the type of the data file, and, for some types, additional windows appear to define data treatment parameters. After that the WzWorkspace window appears, that is the main tool to access, view, and manipulate the workspaces (Fig. 1).
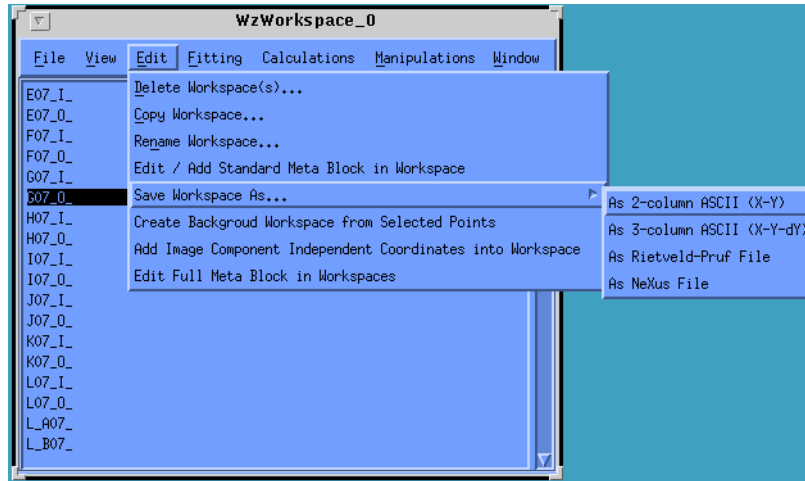
Fig. 1. WzWorkspace tool interface

The SPN-2 and YuMO are neutron instruments operating at the IBR-2 neutron reactor at FLNP. The special openg2 modules were developed for both instruments to provide the instrument oriented user interface for express-analysis of the data. Fig.2 shows a window, which appears after reading raw SPN-2 / Sonix data measured in the new small-angle mode of the instrument. Tests were carried out in May 2002. The specially developed graphic user interface permits one to select any group from 32 point detectors, for example, detectors placed at the same distance from the center (the rings are numbered from 1 to 4 at the left), or at the same radius (the azimuthal angles marked as 0, 45, 90,… 315 degrees on top). The data can be shown in TOF channels, wavelength, and wave vector transfer (**Q**) coordinates. The calculated Q-grid is not uniform and the logarithmic X-axis is selected.
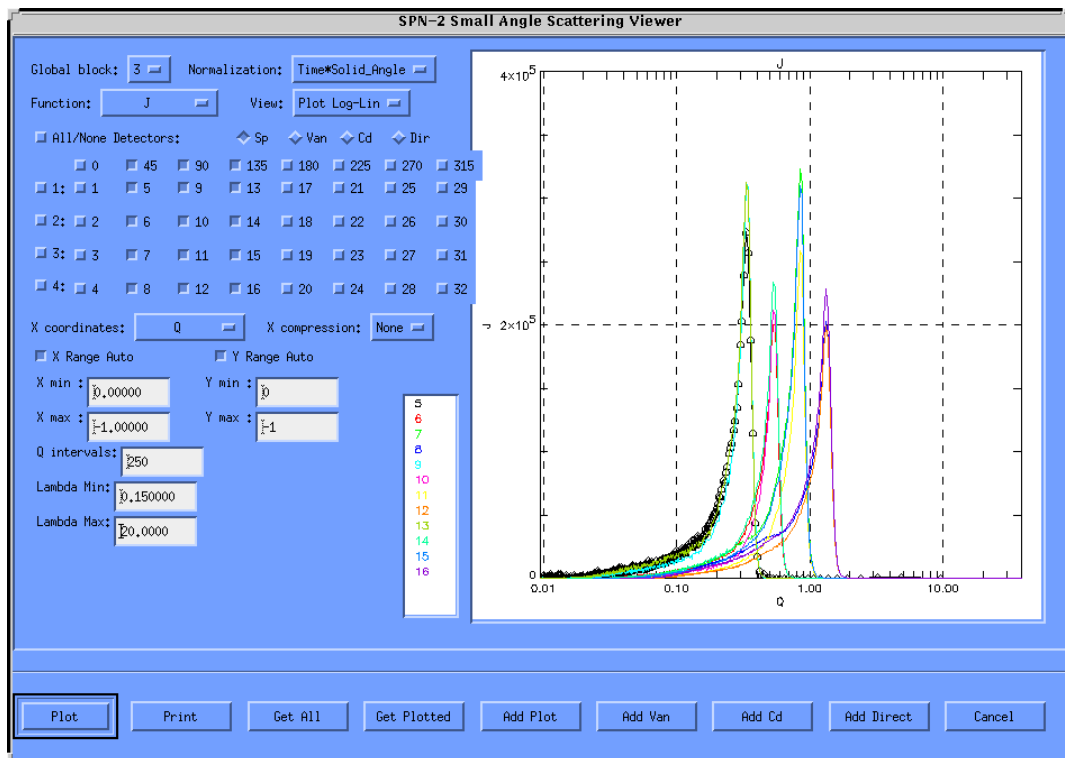
Fig. 2. SPN-2 Small Angle data viewer interface (12 point detectors selected)

In Fig. 3 all point detector data are summarized (merged) and shown in the uniform Q-grid.
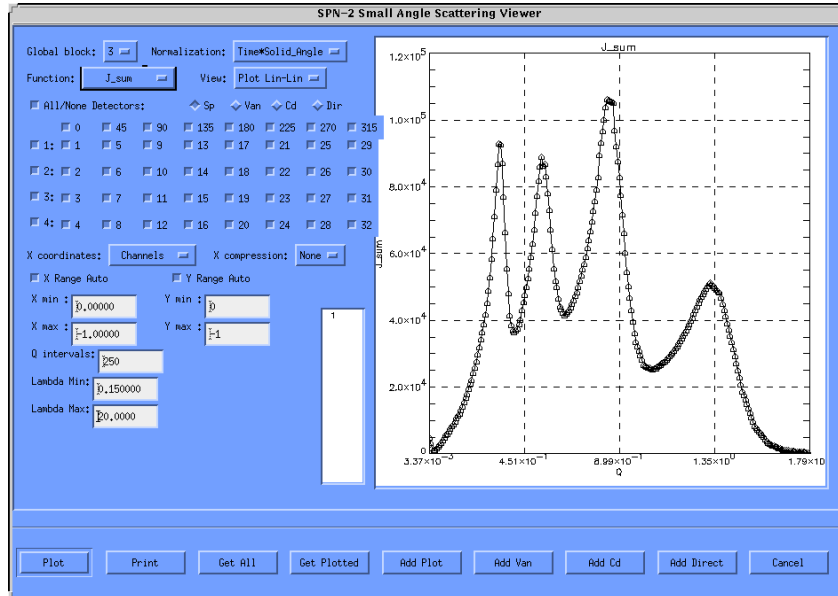
Fig. 3. SPN-2 Small Angle mode - merged data from all 32 point detectors

About 13% of program code (~60 from ~500 procedures) was specially written for the YuMO neutron instrument [8]. The YuMO module of the openg2 program permits one to access the data from the ring shaped point detectors (combined into two detector banks of 8 rings each) and from the unique ring shaped positive-sensitive detector (8 rings) of the YuMO setup. After reading and preliminary treatment of raw YuMO / Sonix data, the program creates several workspaces for each ring of point detectors: the normalized spectra in TOF channels and full cross-section in wavelength and in **Q**. For each ring of PSD the program creates similar 2D workspaces: normalized spectra in TOF channels, the intensity in wavelength, in **(Q,φ)** coordinates, and in **(Q_x,Q_y)** ones. Additionally, in the PSD case, 1D workspaces are created for every ring. They are the normalized positional spectra summed over TOF coordinates. These positional spectra are used to evaluate the scattered neutron intensity distribution in real detector space.

All created workspaces in **Q** space are automatically merged to get summarized workspace for each detector. Merging algorithms, taking into account the statistical errors for 1D and 2D data, were developed as the general purpose procedures of the OpenG2 program.
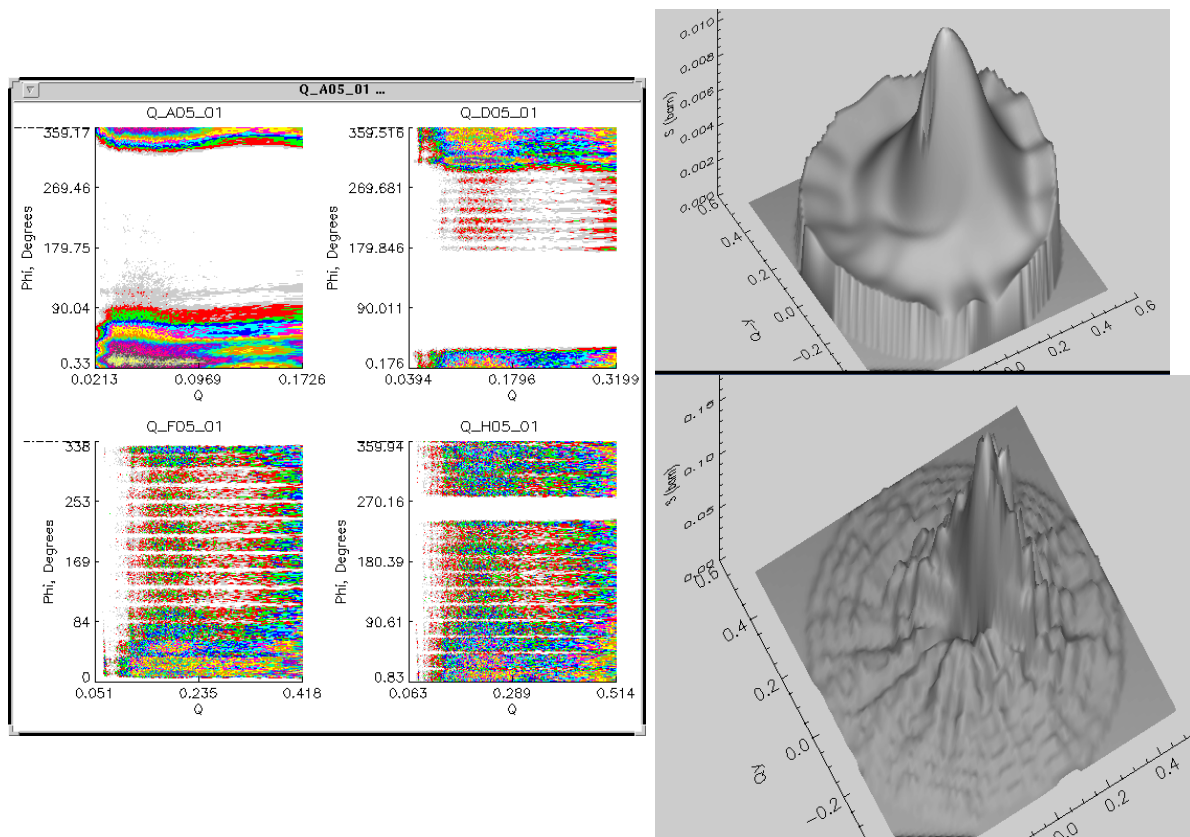
Fig. 4. YuMO ring PSD data: raw data (left) in (Q,φ) coordinates, data in (Q_x,Q_y) merged by standard gridding routine (upper right), and data in (Q_x,Q_y) merged by openg2 2D merging algorithm (lower right). Here Q is the absolute value of the wave vector transfer, Q_x and Q_y are its projections to x and y axis, and φ is the azimuthal angle.

In Fig.4 (left picture), one can see the test measurement data for 4 from 8 rings of the YuMO PSD in dependence of **Q** (absolute value of the wave vector transfer) and **φ** (azimuthal angle). The pictures in **(Q_x,Q_y)** show the merged data using standard pv-wave gridding procedure (top) and using special openg2 algorithm to merge 2D workspaces (bottom). One can see that special algorithm is more sensitive and permits one to see the real elements of the detector (linear separators along the radiuses).

The dn2_viewer program

3D data measured using two-coordinate positive-sensitive detector on the DN-2 neutron instrument of IBR-2 reactor can be viewed using the "dn2_viewer" program. Three independent coordinates of the data correspond to the time-of-flight channels, the detector X position channels, and the detector Y position channels. An iso-surface is a pseudo-surface of constant density within a volumetric data set. 3D iso-surfaces can be presented only on the uniform grid. The data in Fig.5 are plotted in wavelength, X position, and Y position coordinates.
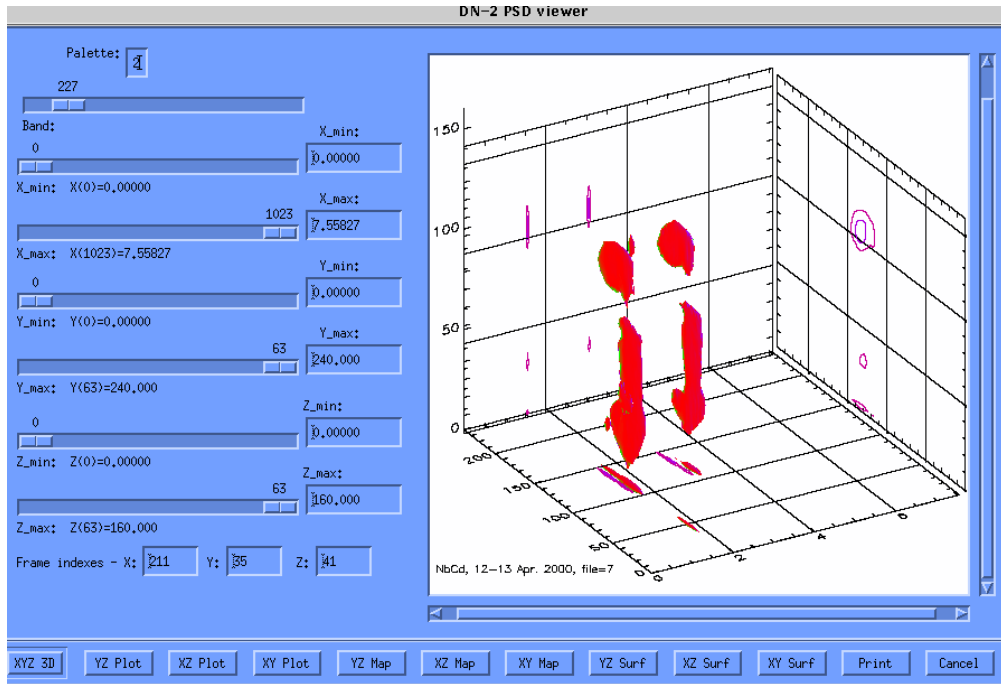
Fig. 5. 3D iso-surface with selected value of the intensity (equal to 227) of the
DN-2 PSD data

The projections to 2D plane can be shown in non-uniform grid of coordinates. In Fig.6 2D projection of measured data is plotted versus interatomic distances D and the detector X position coordinates.
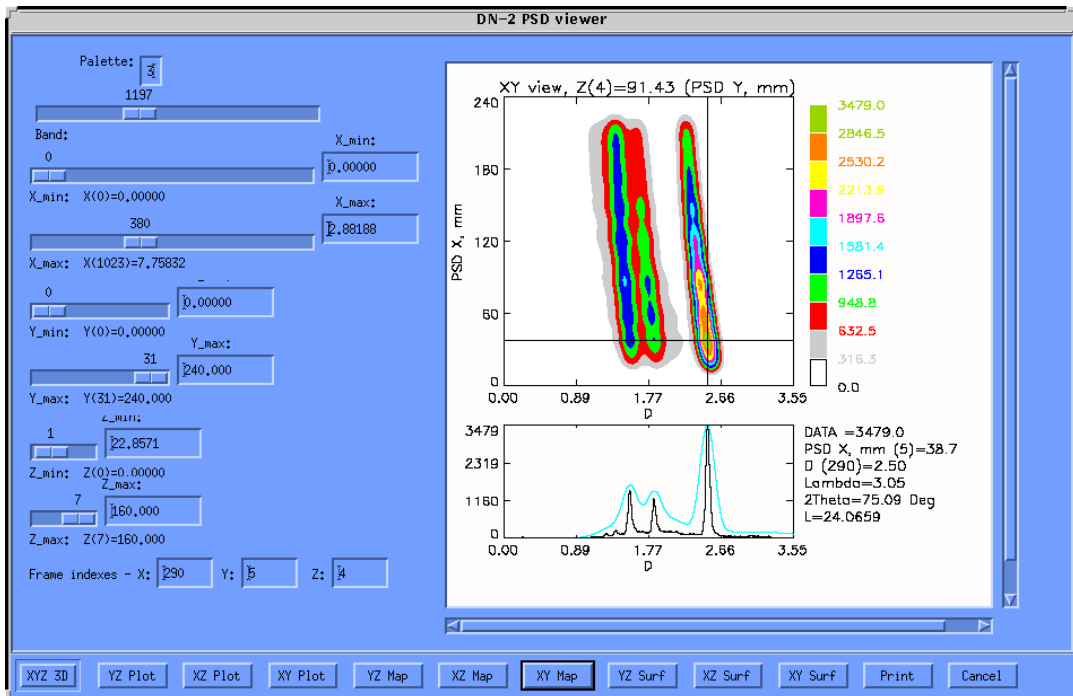
Fig. 6. 2D slice of 3D data from DN-2 PSD

The programs developed in cooperation with HMI

In the presence of the common basic programming packages for visual data analysis (PV-WAVE) the cooperation between FLNP and HMI (Berlin, Germany) on the joint development of the GUI applications was established starting from 1997. As one of the results, the Bean program (Fig. 7) was accepted as standard software for the analysis of experimental data gathered at BENSC [8].
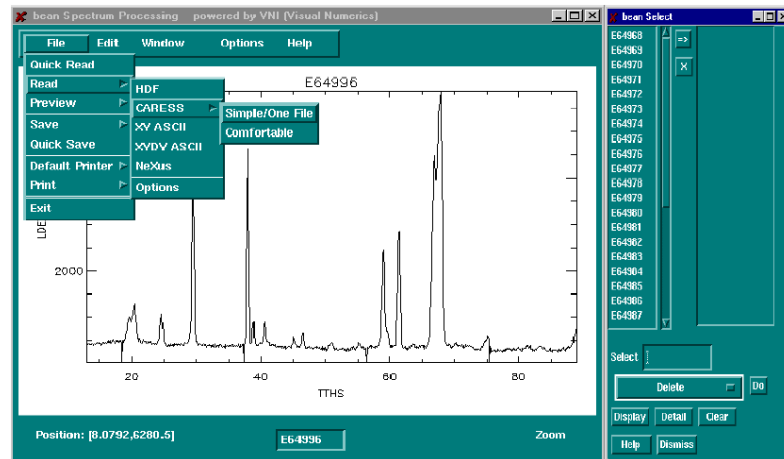
Figure 7. Bean interface

During several years the data acquisition systems for MSGC and MWPC positive-sensitive detectors are under development at HMI in collaboration with FLNP [11-12]. One of the first prototypes of the software, developed as a part of this project, was the program on the basis of PV-WAVE. The first tests of the system with this software were carried out on the BER-II reactor (HMI, Berlin) in June 2003 (Fig. 8).
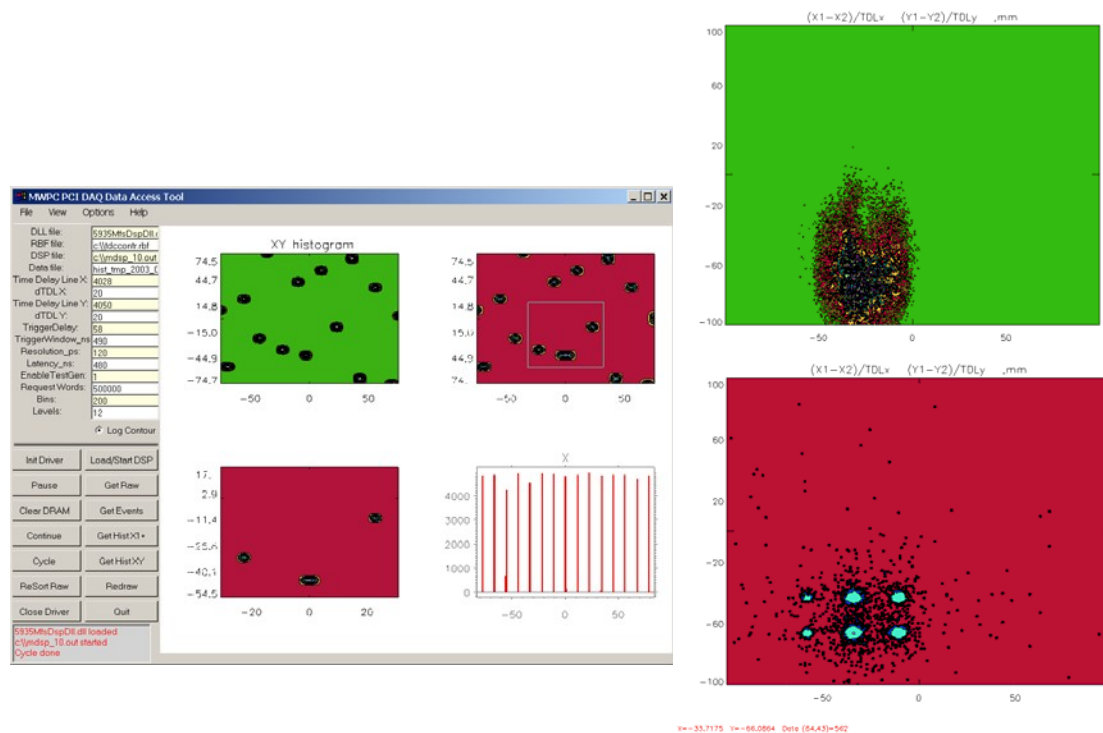
Fig. 8. MWPC DAQ PV-WAVE based program and the test results

After some time a final solution for this project was taken to use the software on the basis of the ROOT package [13-14].

IDL based software

The FLNP users can view and process ASCII, NeXus, and raw ILL data with the help of the IDL based program LAMP [3], freely available from ILL (Grenoble) and installed at FLNP. There are also procedures to read raw YuMO data into the LAMP. This popular program provides a lot of useful functions for visualization, the tools to work with 2D data in polar coordinates, etc.

In cooperation with Mark Johnson and Didier Richard from ILL (Grenoble) the special IDL based software was developed in 2002 for solving the deconvolution problem (taking into account the instrument resolution function). The program is designed to evaluate the numerical solution of the Fredholm integral equation of the first kind using the standard form and the filter factor form of the Tikhonov regularization method. The software has been tested on the quasielastic and powder diffraction data measured at ILL (Fig. 9).
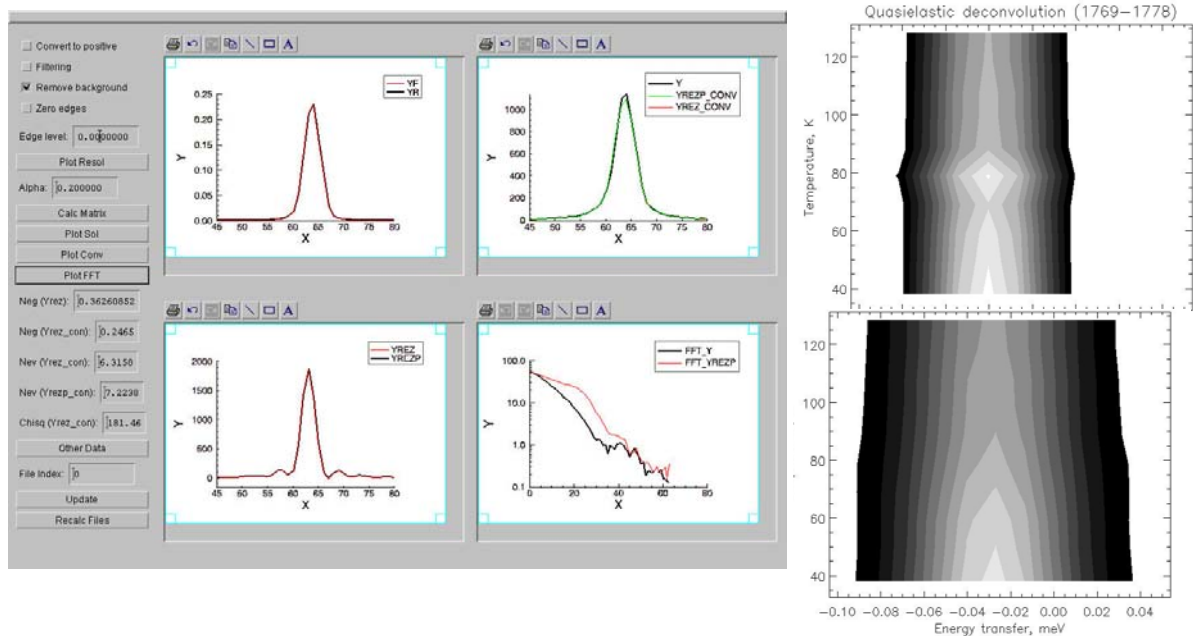
Fig. 9. IDL based deconvolution tool inteface and the test results

Conclusions

The existing experience permits the author to formulate some conclusions regarding above mentioned software packages:
1. Both packages can be used for rapid development of the software, especially in the process of investigations of different data analysis algorithms and creation of new ones. In particular, the openg2 program has been used as a basic package to compare the different types of filtering techniques on noisy small-angle data [9-10].
2. If compared with C++ possibilities regarding data acquisition software, the PV-WAVE has no reliable way to setup programmed timers and interrupts. But the PV-WAVE and IDL applications can be called directly from the C++ programs, and dynamically loadable libraries written in C++ can be called from the PV-WAVE and IDL programs.

3. Both packages comprise a big set of mathematical procedures for reliable and precise numerical analysis, but the IDL package has some additional ones (wavelet toolkit). Also, beginning in version 5.0, the IDL supports object-oriented approach and provides a set of standard object-oriented graphic classes. On the other hand, the PV-WAVE package has two very useful standard data types: associative arrays and lists which do not exist in IDL.

4. Until now the most frequently used method to create GUI applications of the both packages is the way of using basic widgets, arranging them on the window region by trying different values from the command line. Standard visualization tools with their GUI (VDA Tools in PV-WAVE and Live Tools in IDL) should be extended by application developers to present measured spectra. In particular, standard WzPlot and WzSurface VDA Tools were redesigned in the openg2 program into new WzWPlot and WzWSurface ones to provide necessary functionality for 1D and 2D workspaces. But IDL Intelligent Tools (new in IDL 6.0) promise to solve the most of the problems with ready-to-use interactive visualization utilities.

5. The version 6.0 of the IDL package provided a new distribution model for IDL applications. Starting with this version anyone with an IDL development license can freely distribute complied IDL code (with slightly restricted functionality). To execute the code, it is enough to install freely available cross-platform runtime utility (IDL VM).

The author would like to thank for the cooperation all participants of all projects briefly mentioned in this overview of software applications.

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Practical experience of deployment and management of disk storage system at ITEP

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Abstract

This work is an attempt to describe stages of development SEs (the systems of the data storage which have been included in general GRID disk space) in ITEP from Classic SE to dCache SEe.

1. Introduction

The ITEP staff members participate in all four LHC experiments. The ITEP takes part in the LCG/EGEE projects, as an element of all-Russian consortium RDIG (Russian Data Intensive Grid). At the institute is created full-function LCG/EGEE site with all necessary services (CEs, SEs, UI, WNs, LFC, WMSLB, top level BDII, VOBOX, gLite RGMA_MON).

The ITEP site has passed all stages of development MiddleWare (from LCG_1 to GLITE_3) and various version of the operation systems (from RedHat_7 to SLC_4.5 for x396 and x86_64) specified by group of software developers.

The MiddleWare on servers is installed with use YAIM tools. At present the ITEP site is submitted by servers - top level BDII, lcg CE with Torque batch system, gLite CE with Torque batch system, DPM SE for 2TB, dCache SE server together with two dCache disk pool servers for 5TB, UI, LCF, WMSLB, VOBOX, gLite RGMA with MON and E2MONIT services and 52 WNs with 146 CPUs.

The ITEP provides the resources for job submission and data storage to six experimental groups - ALICE, ATLAS, CMS, LHCB, HONE, PHOTOH VOs, and to two groups of monitoring - DTEAM, OPS VOs.

2. Stages of development and types of SE in ITEP

At the site organization in the ITEP has been created Classic SE in capacity 1TB. Further the disk space of this SE, has been increased to 2.6 TB by connection on NFS to the separate File Server.

In process of development access services and a data control at different stage of their storage, appearance new GRID services, functioning Classic SE has ceased to satisfy requirements VOs. In particular, Classic SE does not support interface of Storage Resource Management (SRM). Therefore it has been decided to deny usage Classic SE in ITEP.

3. DPM SE in the ITEP

As a result in ITEP it has been deployed DPM server with disk pools for 4TB disk memory. For the organization of file systems it starts to be used XFS.

XFS: A high-performance journaling filesystem developed by company Silicon Graphics. XFS combines advanced journaling technology with full 64-bit addressing and scalable structures and algorithms. This combination delivers the most scalable high-performance filesystem ever conceived.

The XFS filesystem provides the following major features:

- Quick Recovery
- Fast Transactions

- Massive Scalability
- Efficient Allocations
- Excellent Bandwidth

XFS allows increasing the sizes of file systems to 18000PB with the maximum size of files to 9000PB. Operating experience XFS in ITEP shows increase in safety in operation of file system. Further XFS becomes the basic and unique file system for all SE servers.

Absence of at that time working procedure of installation dCache SE through YAIM toolkit was the choice reason between DPM and dCache SE in favour of DPM. DPM server (se2.itep.ru) works at the moment. It is used VO ATLAS for Service Challenges in ATLAS DDM.

The DPM consists of:
- DPM socket client,
- SRM server (srmv1 and/or srmv2): receives the SRM requests and pass it on to the DPM server,
- DPM server: keeps track of all the requests,
- DPM name server (DPNS): handles the namespace for all the files under the DPM control,
- DPM RFIO server: handles the transfers for the RFIO protocol,
- DPM Gridftp server: handles the transfer for the Gridftp protocol.

Used ports:
- **DPM server:** port 5015/tcp must be open locally at your site at least (can be incoming access as well),
- **DPNS server:** port 5010/tcp must be open locally at your site at least (can be incoming access as well),
- **SRM servers:** ports 8443/tcp (SRMv1), 8444/tcp (SRMv2) and 8446/tcp (SRMv2.2) must be opened to the outside world (incoming access),
- **RFIO server:** port 5001/tcp and data ports 20000-25000/tcp must be open to the outside world (incoming access), in the case your site wants to allow RFIO access from outside,
- **Gridftp server:** control port 2811/tcp and data ports 20000-25000/tcp (or any range specified by GLOBUS TCP PORT RANGE) must be opened to the outside world (incoming access).

The DPM is GSI security enabled.

The YAIM configuration file has to contain the following variables for DPM:

- DPM_HOST="se2.$MY_DOMAIN"   # my-dpm.$MY_DOMAIN
- DPM_DB=dpm_db
- # The DPM pool name
- DPMPOOL=dpmpool2
- DPM_FILESYSTEMS="$DPM_HOST:/storage $DPM_HOST:/pool1"
- DPM_DB_USER=dpmdbuser
- DPM_DB_PASSWORD=My_Password
- # The DPM database host

- DPM_DB_HOST=$DPM_HOST
- DPMFSIZE=200M
- DPM_INFO_USER=dpminfo
- DPM_INFO_PASS=My_Password
- BDII_SE2_URL="ldap://$DPM_HOST:2170/mds-vo-name=resource,o=grid"

Installation of DPM server is realized by running of the commands:

```
$ yaim -i -s site-info.def -m glite-SE_dpm_mysql
$ yaim -c -s site-info.def -n SE_dpm_mysql
```

Testing the DPM:

```
$ dpns-ls –l /dpm/itep.ru/home
    drwxrwxr-x  17 root    103              0 Jul 21 10:51 alice
    drwxrwxr-x  22 root    102              0 Jun 02 00:29 atlas
    drwxrwxr-x   6 root    105             0 Jun 01 18:47 cms
    drwxrwxr-x   9 root    106             0 Jul 23 13:01 dteam
    drwxrwxr-x   1 root    104             0 May 16 16:31 lhcb
    drwxrwxr-x   1 root    108             0 Jan 17  2007 ops
    drwxrwxr-x   4 root    107             0 Apr 11 15:20 photon
```

```
$ ldapsearch -x -H ldap://se2.itep.ru:2170 -b mds-vo-name=resource,o=grid | grep Space
GlueSAStateAvailableSpace: 596530000
GlueSAStateUsedSpace: 1229833122
GlueSAStateAvailableSpace: 596530000
GlueSAStateUsedSpace: 144
GlueSAStateAvailableSpace: 596530000
GlueSAStateUsedSpace: 0
GlueSAStateAvailableSpace: 596530000
GlueSAStateUsedSpace: 25098
GlueSAStateAvailableSpace: 596530000
GlueSAStateUsedSpace: 1049573
GlueSAStateAvailableSpace: 596530000
GlueSAStateUsedSpace: 3846679
GlueSAStateAvailableSpace: 596530000
GlueSAStateUsedSpace: 1079
```

Quick Test

After this part of the install the /opt/lcg/bin/dpm-qryconf command should show the created pool with a single filesystem on it:

```
[root@se2 pool1]# dpm-qryconf
POOL dpmpool2 DEFSIZE 200.00M  GC_START_THRESH 0  GC_STOP_THRESH 0
DEF_LIFETIME 7.0d DEFPINTIME 2.0h  MAX_LIFETIME 1.0m MAXPINTIME 12.0h
FSS_POLICY  maxfreespace  GC_POLICY  lru  RS_POLICY  fifo  GIDS 0  S_TYPE -
MIG_POLICY none RET_POLICY R
                CAPACITY 1.79T FREE 596.05G ( 32.5%)
```

se2.itep.ru /pool1 CAPACITY 916.65G FREE 596.05G (65.0%)
se2.itep.ru /storage CAPACITY 916.68G FREE 2 (0.0%)

The basic deficiency of the DPM SE, in our opinion, is that:
- it is possible to create a disk pool for use only one VO, but there are no means to forbid access to a pool one or several VOs;
- at filling of file system on a server there is no automatic transition to file system of a disk pool.
- Therefore it has been decided to refuse use DPM SE and all disk resources for SE in the near future to unite them under dCache SE.

4. dCache SE in the ITEP

It is necessary to underline, that since appearance gLite versions of YAIM tools, in difference from LCG YAIM, installation of components dCache SE is carried out practically without application of manual adjustment. It is very important for system administrators. DCache SE allows distributing pools for one or several VOs   At the moment ITEP dCache SE consists of Admin Node and two Pool Nodes for 5.2 TB disk memory. For the organization of file systems it is used XFS.

4.1. dCache is a disk pools management system with a SRM interface

The dCache Layer Model:
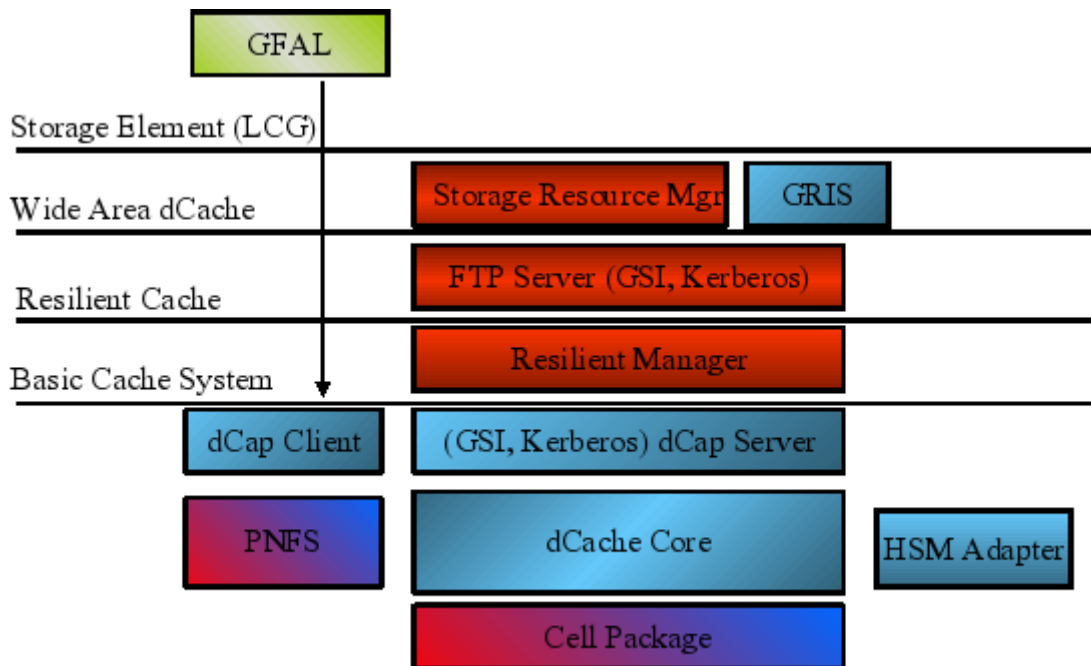
(concept by P. Fuhrmann)

The YAIM configuration file has to contain the following variables for dCache Admin Node:
- DCACHE_ADMIN="se3.itep.ru"
- DCACHE_POOLS="se3.itep.ru:/pool1   s3.itep.ru:/pool2   rrcdsk6.itep.ru:/pool_dsk6 seitep.itep.ru:/pools"

- RESET_DCACHE_CONFIGURATION=yes
- #RESET_DCACHE_CONFIGURATION=no
- RESET_DCACHE_PNFS=yes
- #RESET_DCACHE_PNFS=no
- RESET_DCACHE_RDBMS=yes
- #RESET_DCACHE_RDBMS=no

And for dCache Pool Nodes:
- DCACHE_ADMIN="se3.itep.ru"
- DCACHE_POOLS="se3.itep.ru:/pool1   s3.itep.ru:/pool2   rrcdsk6.itep.ru:/pool_dsk6 seitep.itep.ru:/pools"
- RESET_DCACHE_CONFIGURATION=yes
- #RESET_DCACHE_CONFIGURATION=no
- RESET_DCACHE_PNFS=no
- RESET_DCACHE_RDBMS=no

Installation of dCache Admin Node is realized by running of the commands:
$yaim -i -s site-info.def -m glite-SE_dcache_admin_postgres
$yaim -c -s site-info.def -n glite-SE_dcache_admin_postgres

Installation of dCache Pool Node is realized by running of the commands:
$yaim -i -s site-info.def -m glite-SE_dcache_pool
$yaim -c -s site-info.def -n glite-SE_dcache_pool

4.2. Used ports:

- Port 32768 and 32768 is used by the NFS layer within D-Cache which is based upon rpc, this service is essential for rpc.
- Port 111,1939 and 33808 is used by portmapper which is also involved in the rpc dependencies of D-Cache.
- Port 34075 is for postmaster listening to requests for the Postgres database for D-Caches SRM application.
- 33823 is used for internal D-cache communication.
- 2811 is used to Communicate to the the client.
- 8443 is the SRM port.
- 2288 is used the web interface to D-Cache.
- 22223 is used for the D-Cache admin interface.
- 22125 is used for the D-Cache Dcap Protocole.
- 22128 is used for the D-Cache GSI enabled Dcap Protocole.
- 22158 is used for the D-Cache admin interface.
- 33080, 22128, 22125 is used for D-Cache in some way but I am not sure what.

4.3. Distribution of pools between VOs:

- (PoolManager) admin > psu ls pool -a
- se3_2 (enabled=true;active=24;rdOnly=false;links=0;pgroups=4)
- linkList :

- pGroupList :
- lhcb (links=1;pools=2)
- alice (links=1;pools=2)
- default (links=1;pools=4)
- atlas (links=1;pools=2)
- rrcdsk6_1 (enabled=true;active=9;rdOnly=false;links=0;pgroups=2)
- linkList :
- pGroupList :
- cms (links=1;pools=1)
- default (links=1;pools=4)
- seitep_1 (enabled=true;active=17;rdOnly=false;links=0;pgroups=2)
- linkList :
- pGroupList :
- photon (links=1;pools=1)
- default (links=1;pools=4)
- se3_1 (enabled=true;active=24;rdOnly=false;links=0;pgroups=6)
- linkList :
- pGroupList :
- lhcb (links=1;pools=2)
- ops (links=1;pools=1)
- alice (links=1;pools=2)
- default (links=1;pools=4)
- dteam (links=1;pools=1)
- atlas (links=1;pools=2)

4.4. Distribution of disk space between VOs:

$ldapsearch -x -H ldap://se3.itep.ru:2135 -b mds-vo-name=local,o=grid | grep -i -A 2 GlueSAStateAvailableSpace
- GlueSAStateAvailableSpace: 2160305364
- GlueSAStateUsedSpace: 346881795
- GlueSAAccessControlBaseRule: atlas
- --
- GlueSAStateAvailableSpace: 2160305364
- GlueSAStateUsedSpace: 346881795
- GlueSAAccessControlBaseRule: alice
- --
- GlueSAStateAvailableSpace: 2160305364
- GlueSAStateUsedSpace: 346881795
- GlueSAAccessControlBaseRule: lhcb
- --
- GlueSAStateAvailableSpace: 1738779238
- GlueSAStateUsedSpace: 21083611
- GlueSAAccessControlBaseRule: cms
- --
- GlueSAStateAvailableSpace: 1130908105
- GlueSAStateUsedSpace: 176909437

- GlueSAAccessControlBaseRule: dteam
- --
- GlueSAStateAvailableSpace: 199550535
- GlueSAStateUsedSpace: 704540081
- GlueSAAccessControlBaseRule: photon
- --
- GlueSAStateAvailableSpace: 1130908105
- GlueSAStateUsedSpace: 176909437
- GlueSAAccessControlBaseRule: ops

dCache provides the sysadmin with a web based interface showing the status of your dCache install in terms of cell services, pool status (usage and queues) and a log of actions that have been taken. http://se3.itep.ru:2288

5. Conclusions

In the conclusion it is necessary to underline that on-line delivered toolkits of installation and updating SEs from the version to the version qualitatively improved, reducing manual adjustment of servers practically to zero.

From experience of operating DPM and dCache SEs in ITEP follows, that both types SE satisfy the general requirements at work in the environment of Grid. Nevertheless, ITEP has made decision to translate all SE servers on dCache. As principal causes of such decision it is possible to specify the following:

- convenience of management dCache servers in comparison with DPM;
- organization possibility of quota system between VOs with accuracy of one pool;
- distribution of network loading between elements dCache, redefining data flows from a server on disk pools;
- convenience of activation XROOTD protocol;
- convenience of connection HSM;
- the detailed constantly updated documentation.

References

[1]   http://www.dcache.org/
[2]   http://www.desy.de
[3]   http://www-pnfs.desy.de
[4]   http://grid-deployment.web.cern.ch/grid-deployment/documentation
[5]   http://storage.esc.rl.ac.uk/documentation/html/D-Cache-Howto/index.html
[6]   http://wiki.gsi.de/cgi-bin/view/Grid/DCacheInstallation;
        Novak Judit, dCache Guide for LCG Site Administrators, DESY

The Project on the Construction of Computational Segment at TSU HEPI

E. Magradze, Z. Modebadze
HEPI TSU

A number of Georgian research centers are involved in the international scientific collaborations that are intensively developing the high performance computing technologies and GRID infrastructures for a common work of thousands of specialists from hundreds of the institutions. Deployment of the high performance computing and GRID technologies in Caucasian region will promote a larger integration of Georgian specialists in the international community via the GRID-enabled Virtual Organizations. Scientists of Georgian research centers involved in the international collaborations are interested in implementation of modern high performance computational infrastructure and creation of a powerful base for Georgian national GRID infrastructure. In the paper we present the characteristics of a computational segment constructing now at the TSU HEPI and future plans and prospects for creating and developing Georgian national GRID infrastructure. The use of Linux clusters for scientific research at Georgian research institutions corresponds to the modern computing trends and the open source software promises to be a cost-effective way to obtain a high performance system.

Institute of High Energy Physics and Informatization of Ivane Javakhishvili Tbilisi State University (IHEPI TSU) is the leading institution of Georgia in high performance computing, networking and GRID infrastructure development. The IHEPI TSU team has a large experience in computer networking, data management and analysis. Since the 1999 year IHEPI TSU owns the Internet Service Provider server that provides internet connections for several Georgian organizations.

The researchers from E. Andronikashvili institute of physics, HEPI TSU and A. Razmadze institute of Mathematics are working on software related problems for several large international experiments. As an example we could list here the activities of researchers from HEPI TSU currently working at the Joint Institute for Nuclear Research (Dubna):

- development of offline software for the ATLAS Tile Calorimeter (GEANT4 simulation, detector description, reconstruction);
- development of Detector Control System (DCS) for Tile Calorimeter High Voltage system;
- development of data acquisition software for the Tile Calorimeter.

In the frames of the ISTC (The International Science and Technology Center) "The Search for and Study of Rare Processes Within and Beyond Standard Model ATLAS Experiment of Large Hadron Collider at CERN" project, the computing cluster (14 CPU, 800 GB HDD, 8-16MB RAM) on Linux platform (SL5) with disk RAID is now constructing at IHEPI TSU. The PBS batch system has been chosen to be installed, Ganglia software will be used for monitoring and all the nodes will be interconnected by gigabit Ethernet interfaces. The specialized ATLAS software (ATHENA) is required for physics studies (background processes generation, fast and full simulation, reconstruction and analysis).

The activities on Georgian national GRID infrastructure development are currently in a very beginning phase and it is still necessary to determine and make clear a lot of aspects. We could just list the prior steps we consider to be very important for our future work:

- the further development of the Georgian national network for science and education in the frames of different joint projects as the base for construction of a national GRID segment in Georgia;
- training and education of specialists;
- creation of the common computing and networking infrastructure for Georgian research centers;
- installation of GRID software and other application packages and creation of GRID service centers;
- integration of Georgian national GRID segments into the Caucasian GRID segment and the world wide GRID infrastructure.

State of the Internet & Challenges ahead[1]

"How is the Internet likely to evolve in the coming decade"

O.H. Martin[2]

ICTConsulting, Gingins (VD), Switzerland

Abstract

After a fairly extensive review of the state of the Commercial and Research & Education, aka Academic, Internet the problematic behind the, still hypothetic, IPv4 to IPv6 migration will be examined in detail. A short review of the ongoing efforts to re-design the Internet in a clean-slate approach will then be made. This will include the National Science Foundation (NSF) funded programs such as FIND (Future Internet Network Design) 0 and GENI (Global Environment for Network Innovations) 0, European Union (EU) Framework Program 7 (FP7), but also more specific architectural proposals such as the publish/subscribe (pub/sub) paradigm and Data Oriented Network Architecture (DONA) 0.

Key words: Internet, GEANT2, Internet2, NLR, NSF, GENI, FIND, DONA, OECD, IETF, IAB, IGF, RIPE , IPv6, EU, FP7, clean-slate, new paradigms.

1. Introduction

While there appears to be a wide consensus about the fact that the Internet has stalled or ossified, some would even say that it is in a rapid state of degeneracy, there is no agreement on a plan of action to rescue the Internet. There are two competing approaches, evolutionary or clean-slate. While a clean-slate approach has a lot of attractiveness it does not seem to be realistic given the time constraints arising from the fact that the IPv4 address space will be exhausted in a few years time, unless IANA[3] (the Internet Assigned Numbers Authority) allows an IPv4 "trading model" to be created. Therefore, the migration to IPv6 looks "almost" unavoidable, though by no means certain[4], as the widespread usage of Network Address Translators (NAT) and Application Level Gateways (ALG) is both unlikely to scale indefinitely and/or to meet the ever evolving Internet users' expectations and requirements. However, new ideas arising from more radical and innovative approaches could probably be retrofitted into the existing Internet, e.g. self-certifying names, à la "DONA[5]". The purpose of this paper is to raise awareness about the ongoing initiatives with a special emphasis on technical issues and possible remedies or solutions, it does not attempt in any way to be exhaustive as the subject of the Internet evolution including the societal, ethical and governance aspects are far too wide and complex to be addressed in a single article.

2. Main Sources

Most of the information appearing in this paper has been extracted from the following Web sites and conferences, Terena Networking Conference[6] 2007 0 and, in particular: "The latest development in NSF's GENI/FIND projects and their influence on the European Networking Community[7] 0" by Jiri Navratil (CESNET), STARPLANE: "An Application-controlled Photonic network[8] 0", by Cees de Laat (University of Amsterdam), "Is Global IPv6

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[1] http://nec2007.jinr.ru/

[2] Olivier.Martin@ictconsulting.ch

[3] http://www.iana.org

[4] the cost/benefit ratio is still far too high to build a convincing business case

[5] Data Oriented Network Architecture

[6] http://tnc2007.terena.org/programme/index.php

[7] http://tnc2007.terena.org/programme/presentations/show.php?pres_id=60

[8] http://tnc2007.terena.org/programme/people/show.php?person_id=132

Deployment on Track?[9] 0", by Carlos Friaças (FCCN), RIPE55[10] 0, NANOG41[11] 0, CCIRN[12] 2007 0, IEPG[13] 2007 0, "IPv6 Transition and Operational Reality 0", by Randy Bush (IIJ[14]), Australian IPv6 summit[15] 2007 0, OECD workshops[16] 0, IAB workshops[17] 0, "Living the Future 0" by Dirk Trossen (NOKIA), IPv4 Address Report[18] 0, CircleID[19] 0, Geoff Houston's posts[20] 0, Global IPv6 launch event[21] (2004) 0.

3. State of the Internet

Today's Internet is plagued by a number of very serious "ills" that are threatening, if not its existence, at least its long-term stability as listed below:

- o IPv4 address space exhaustion and lack of significant IPv6 rollout raising serious doubts about the operational future of IPv6!
- o Routing stability and Growth of Routing Table due to multi-homing, in particular.
- o Domain Name System (DNS) stability:
  - ✓ DNS overload, often due to misconfigured servers. Also, the DNS was designed to reference hosts not multiple objects as commonly found on many Web pages.
- o Security:
  - ✓ Spamming;
  - ✓ Phishing (fraudulent activities, e.g. stealing credit card numbers, passwords);
  - ✓ Identity theft;
  - ✓ DDoS (Distributed Denial of Service Attacks).

Furthermore, today's Internet users are "nomadic"; however, the Internet protocols were not designed with either mobility or security in mind. Internet access over mobile phones is also spreading very rapidly as well as Sensor Networks (e.g. Radio-Frequency Identification (RFID[22]), embedded), Personal Area Networks (PAN), Vehicle Area Networks (VAN), etc.

In addition, large scale deployment of new applications, e.g. Peer-to-Peer, Television on-demand (IPTV), is hampered by the lack of affordable and ubiquitous "Last Mile Broadband Access" technologies. Indeed, ADSL technology is far from being adequate even within densely populated urban areas and is, in any case, hampered by the inherent asymmetry of the up and down links. However, ADSL2, up to 10Mb/s, is already there and ADSL2+[23], up to 20Mb/s, should be ratified by the ITU this year and there are several other

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[9] http://tnc2007.terena.org/programme/people/show.php?person_id=127
[10] http://www.ripe.net/ripe/meetings/ripe-55/
[11] http://www.nanog.org/mtg-0710/agenda.html
[12] http://www.ccirn.org/
[13] http://www.iepg.org/2007-07-ietf69/index.html
[14] Internet Initiative Japan http://www.iij.ad.jp/en
[15] http://www.ipv6.org.au/summit/
[16] http://www.oecd.org/dataoecd/26/36/37422724.pdf
[17] http://www.iab.org/about/workshops/routingandaddressing/index.html
[18] http://www.potaroo.net/tools/ipv4/index.html
[19] http://www.circleid.com/posts/ipv6_extinction_evolution_or_revolution/
[20] http://www.circleid.com/members/602/
[21] http://www.global-ipv6.net/agenda.htm
[22] http://en.wikipedia/wiki/RFID
[23] http://en.wikipedia.org/wiki/ADSL

competing technologies, e.g. "Data over Cable" (DOCSYS[24]), WiMAX[25], G-PON[26] (Gigabit Passive Optical Network), VDSL[27].

Given the tremendous success of video-on-demand and video-sharing sites such as YouTube[28], DailyMotion (YouTube's French brother)[29], Joost[30] and the penetration of the Internet into many people's home, there is a tremendous growth of near real-time traffic which is putting heavy demand on the Internet infrastructure, at large. The problem is exacerbated by the fact that there is a lack of large scale 40 Gbit/s deployment in core Internet backbones, because of the high associated costs.

Regarding 40 Gigabit Ethernet and/or 100 Gigabit Ethernet, a particularly relevant technology for Internet Exchange Points (IXP) and/or high performance clusters, the IEEE 802.3ba standard[31] is not expected to be finalized before 2010-2011.

The charts below, courtesy of Internetworldstats[32], shows the penetration of the Internet by world region, with a total number of 1,24 billion users worldwide in September 2007 and an estimated yearly increase of over 300 million users.

World Internet Users
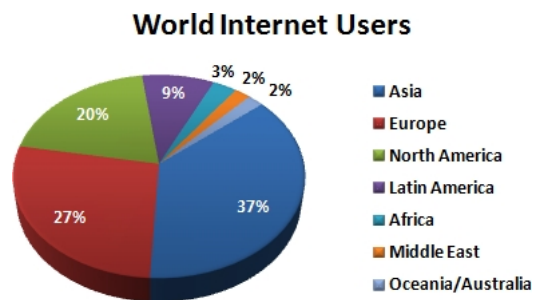
Copyright © June 2007, www.internetworldstats.com

Internet Usage by World Region
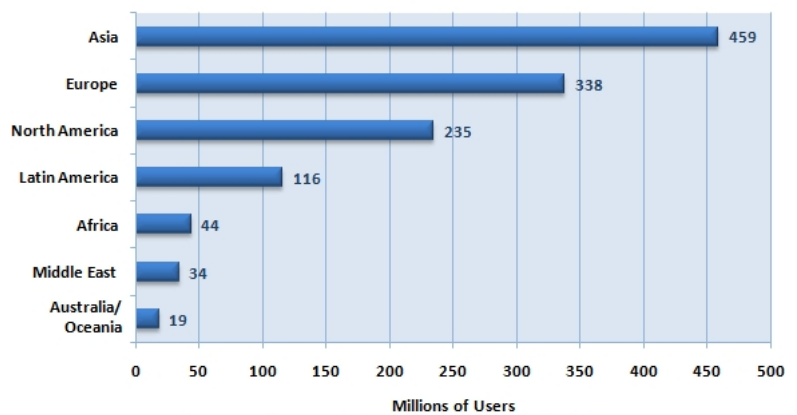
Copyright © 2007, www.internetworldstats.com

Slightly surprising is the fact that Asia and Europe are now well ahead of North America in terms of number of users and that the Internet is already fairly well developed in Africa despite the numerous difficulties that most of this continent is faced with.

However, these figures are somewhat different when one looks at the penetration of the Internet with respect to the population of the various

Internet Penetration by World Region

Copyright © 2007, www.internetworldstats.com

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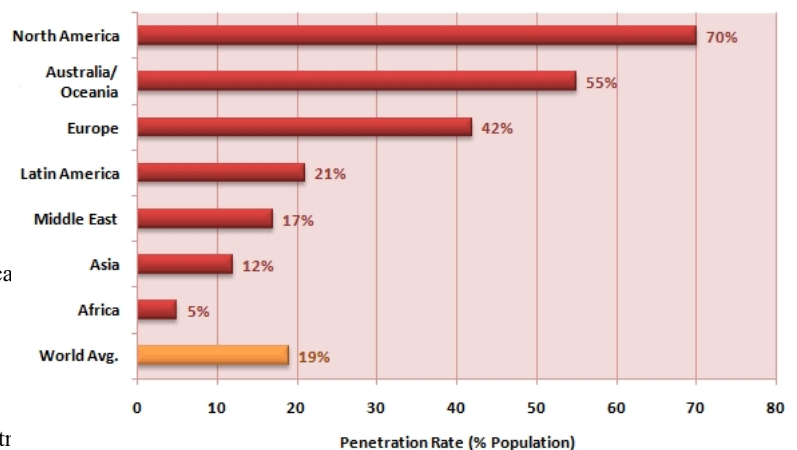
[24] http://en.wikipedia.org/wiki/DOCSIS
[25] http://en.wikipedia.org/wiki/WiMAX
[26] http://en.wikipedia.org/wiki/Passive_optica
[27] http://en.wikipedia.org/wiki/VDSL
[28] http://en.wikipedia.org/wiki/YouTube
[29] http://www.dailymotion.com
[30] http://en.wikipedia.org/wiki/Joost
[31] http://en.wikipedia.org/wiki/IEEE_802.3
[32] http://www.internetworldstats.com/stats.htr

regions with North America being still well ahead of Asia and Europe. Nonetheless, a World average Internet penetration of 19% is extremely impressive.

An unfortunate consequence of the high-penetration of the Internet into (almost) everybody's home, in particular, and, more generally, spectacular advances in Information, Communication and Computing Technologies is the impact on worldwide CO_2 emissions. According to Bill St.Arnaud's "Green Broadband" Web site[33] *"It is estimated that the CO_2 emissions of the ICT industry alone exceeds the carbon output of the entire aviation industry."* So, "green computing" has become a very fashionable topic and many conferences and reports are attempting to address the related issues and solutions.

3.1. The state of European Research & Education Networks

Prior to the European Union-wide Telecom de-regulation back in 1998, the European R&E community as well as the European commercial Internet Service Providers (ISP) suffered from the prohibitive costs telecom services. Since then, Telecom prices (i.e. Internet access, leased lines, fixed as well as mobile telephony) have been continually dropping leading to a more healthy situation regarding the relation between the incurred costs and the pricing of services to customers, but also leading to a number of bankruptcies and a narrowing of the commercial margins, thus deterring the remaining Telecom Operators, usually the incumbents, to make heavy investments in new or yet unproven technologies and services. Lack of serious IPv6 operational deployment by commercial ISPs is clearly a direct result of this situation as, even assuming near-zero Capital Expenditures (CAPEX), the Operational Expenditures[34] (OPEX) are likely to be fairly high.

As observed by the author of this article, then at CERN, in "The Ongoing Evolution from Packet Based Networks to Hybrid Networks in Research & Education Networks[35] 0" there is a widespread tendency in R&E networks worldwide to transform themselves into Telecom Operators through long term lease (IRU) of dark fibers. This has been the case in Europe of GEANT2 0, the pan-European backbone interconnecting most National Research & Education Networks (NREN), and many NRENs, e.g. CESNET, SURFNET, SWITCH, but the same trend can also be observed in the USA with Internet2 0 and the National Lambda Rail[36] (NLR) 0, for example, and elsewhere. Whereas there are clear economic benefits in the short term, the mid- to long-term implications of this strategic choice are much less clear. In particular, there is a definite risk that the available effort and expertise is misused and that instead of pioneering new technologies and services together with Telecom Operators and Information & Communication Technologies suppliers, off-the shelves networks and/or new special purposes services with doubtful commercial viability are built.

This is exemplified by GEANT2, a state of the art R&E backbone running all the services and features that almost no commercial Internet Service Provider (ISP) is offering, e.g. Multicast, IPv6, Quality of Service (QoS), Bandwidth on Demand (BoD). Even worse, these very interesting services are, to the best of my knowledge, little used by the very community who claimed they needed it!

Furthermore, the overall GEANT2 infrastructure is grossly over-dimensioned due to the fact that the high bandwidth applications, e.g. Grid, would not run satisfactorily on a

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[33] Green IT/Broadband and Cyber-Infrastructure: December 2007
[34] http://en.wikipedia.org/wiki/Operating_expense
[35] http://www.jinr.ru/NEC/NEC-2005/proceeding2005/Martin.doc
[36] http://www.nlr.net

shared layer3 infrastructure given the intensive bulk data transfer applications, such as LHC[37], that cannot tolerate packet losses. Thus, in practice, GEANT2 is providing layer2 circuits (lambdas), i.e. Private or Mission Oriented Networks at very attractive prices to the communities that need it, thanks to the fact that the whole GEANT2 infrastructure is subsidized by the European Union.

David West from DANTE, the company in charge of GEANT, made an excellent presentation[38] on the state of GEANT2 and the prospect of GEANT3 during the last Coordinating Committee for Intercontinental Research Networking[39] (CCIRN) meeting in Cheju (South Korea) in August 2007. In his presentation, he provided figures on the number of point to point circuits provided by GEANT2 to four communities namely, LHC (11), DEISA (5), EXPReS/eVLBI (4) and Phosphorus (4), i.e. 14*10Gbit/s and 11*1Gbit/s. However, in terms of the aggregate capacity, i.e. 151Gbit/s, LHC alone is using 61%, DEISA 33%, and the others 5%. Even the EU funded FP6 Integrated Project Phosphorus[40] (Lambda User Controlled Infrastructure for European Research) "that aims to address some of the key technical challenges to enable on-demand, end-to-end network services across multiple domains in a seamless and efficient way" is using these links statically as the G-MPLS experiments can only be conducted at the edges.

What is slightly surprising is that, despite the fact that the need for on-demand, i.e. switched, circuits has not been clearly established, somewhat overdue efforts are spent on developing various Bandwidth on Demand (BoD) middleware in Europe and North America, e.g. Autobahn[41], DRAGON[42], ESLEA[43], JIT[44], OSCARS[45], etc. Fortunately, the DICE (DANTE, Internet2, CANARIE, and ESnet) Control Plane working group is actively developing an Inter-Domain Controller (IDC) protocol, based on ESnet's OSCARS technology. *"As a result[46] of both the DRAGON and DICE collaborations, Internet2 has recently released an early version of a turn-key dynamic networking solution, called the "DCN (Dynamic Control Network) Software Suite" which includes IDC software and a modified version of the DRAGON software. Deployed as a set of web services, IDC software ensures that networks with different equipment, network technology, and allocation models can work together seamlessly to set up optical circuits"*. UCLP[47] User Controlled Light Path) is somewhat different and is usually referred to as a "user controlled traffic engineering" tool rather than a BoD tool, which implies quasi real-time circuit provisioning. The UUCP middleware has now been transferred under the name ARGIA to INOCYBE[48], a Canadian commercial company,[49] as a network virtualization solution.

However, the R&E community would be well inspired to take a more serious look at both the economics of switched circuits and also its history. Indeed, the Telecom operators repeatedly failed to introduce switched data circuits, e.g. ISDN[50], because of the high costs to

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[37] http://lhc.web.cern.ch/lhc/
[38] https://wiki.internet2.edu/confluence/download/attachments/16835/David+West+CCIRN+Reg+net+26_8_07.ppt?version=1
[39] http://www.ccirn.org
[40] http://www.ist-phosphorus.eu/about.php
[41] http://www.geant2.net/server/show/ConWebDoc.2544
[42] http://cnl.gmu.edu/dragon/
[43] http://www.eslea.uklight.ac.uk/
[44] http://www.gridtoday.com/04/0405/102957.html
[45] http://www.es.net/oscars/
[46] https://mail.internet2.edu/wws/arc/i2-news/2008-01/msg00004.html
[47] http://www.uclpv2.ca/
[48] http://www.inocybe.ca/
[49] http://www.inocybe.ca/products/argia/
[50] http://en.wikipedia.org/wiki/Integrated_Services_Digital_Network

the customer thus making leased circuits much more attractive for regular use. ADSL is an excellent example of this trend while ISDN (Integrated Services Digital Network) has essentially become irrelevant. Furthermore, the differentiation between "fast provisioning" and "bandwidth on demand" is usually not explicitly made which creates additional confusion. As rightly pointed out by Bill St Arnaud in CAnet-news[51] back in October 2007, *"Bandwidth on Demand" smells the bad days of "circuit switched networks" and all the extensive centralized administrative processes that are required to ensure adequate capacity and support*". On the contrary "fast provisioning" is a very worthwhile goal that all the Telecom Operators are striving to reach, in order to satisfy their customers and to differentiate with their competitors; the challenge there, as always, is end-to-end inter-domain, multi-vendor, provisioning.

A major impediment to the use of switched circuits is that additional intelligence[52] needs to be added to the applications in order to make use of it which, in practice, more or less precludes the use of this technology by "conventional" applications which, for the most part, are not even IPv6 enabled yet! Videoconferencing applications, in particular, but also more generally real-time applications may be the exceptions**.** An additional problem is the real value of a layer 1/2 circuit when there is no automatic configuration of the layer 3 (routing)?

I cannot resist stating that scarcity may spur innovation whereas, in contrast, abundance of goods, e.g. bandwidth, may encourage the "status quo". The LHC applications that present enormous challenges in terms of computing and networking are a good example of this, where the way of transporting Petabytes of data per year in near real-time has been tackled with a "brute force" approach, i.e. parallel transfer of the data to the ten or so "LHC Tier1" computing centers worldwide; a technical solution which is unlikely to benefit other communities, unless the widespread belief that broadband technology will become ubiquitous turns true.

It would not be fair to forget the instrumental role of the academic community and of the funding agencies such as NSF, DoE, EU, in the development and the deployment new technologies such as, for example, Grids[53]. However, the Grid technology has not been up to the expectations of the industry analysts. What is under construction today, e.g. EGEE[54], is, without question, quite far from fulfilling the original promises of the Grid and, in particular, its potential to work in heterogeneous computing environments, i.e. mixed hardware & software. This makes today's Grids look like avatars of "Distributed Cluster Computing" to the extent that some people already start to predict "The End of Grid Computing[55]".

In the USA, Internet2 is very similar to GEANT in the sense that it is a nation-wide, instead of pan-European, layer3, i.e. routed, backbone interconnecting "regional" instead of "national" networks. The only difference is that Internet2 does not provide access to the commercial Internet whereas most, if not all, European NRENs do so, either directly or through GEANT. Like GEANT and many other networks Internet2 is also involved in the BoD race. NLR who was the precursor of a US-wide dark fiber infrastructure failed for the second time to merge with Internet2 0, and it is not clear at this stage whether is it a good or a bad thing? In any case, this is the first time that the almost universal "dogma" that a National

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[51] http://emperor.canarie.ca/pipermail/news/2007/000515.html
[52] Circuit establishment and tear-down, circuit failures, etc.
[53] http://en.wikipedia.org/wiki/Grid_computing
[54] The Enabling Grids for E-sciencE project http://www.eu-egee.org/
[55] http://telzur.blogspot.com/2007/10/end-of-grid-computing.html

Research & Education Network (NREN) is a "natural monopoly" is seriously challenged, but for how long?

The above comments are not meant to be negative as I have been extremely impressed by the spectacular advances of, for example, European academic networks that have been achieved thanks to the continued support of the European Union and the cooperation of the European NRENs through DANTE. However, I believe that a more research oriented approach could have been more appropriate that just mimicking the work of Telecom Operators using more or less "off the shelves" equipment. As far as European National Networks are concerned, the only exceptions may be SURFNET (NL) and CESNET (CZ).

- o SURFNET is engaged into building a truly all-optical backbone across the Netherlands for the benefit of the Dutch academic & research community; however, whether this work will be relevant to larger countries remains to be demonstrated.
- o CESNET is involved in developing cheap optical transmission equipment which would greatly benefit former Eastern countries (Caucasian, Central Asia as well as Africa, Middle-East, etc.).

3.2. A view on the commercial Internet

Whether or not this is a "heretic" view, I believe that, during the last decade or so, most innovations appear to have come, in the form of services, through the commercial Internet, e.g. Web 2.0, sophisticated data dissemination techniques (e.g. Akamai[56], BitTorrent[57], Google[58], Yahoo), Web caches, content engines, network appliances, Network Address Translation (NAT[59]), Application Level Gateway (ALG[60]), Firewalls, Intrusion Detection System (IDS), IP Telephony, Skype[61], Streaming media proxies, ultra sophisticated search engines like Google, Peer-to-peer[62], etc. On the contrary, the guardians of the Internet, namely the IAB and the IETF are sticking to principles like "end-to-end", native Multicast, IPSEC, DNSSEC, etc. Likewise, IPv6 is often presented by some academic "purists" as "the" solution to all the ills the Internet is suffering from, e.g. restoring the "end-to-end" principle, providing QoS, without too much effort to open their eyes to the reality!

MPLS[63] (Multi-Protocol Label Switched), IPSEC[64] and SSL[65] based VPNs[66] (Virtual Private Network) are flourishing within the commercial Internet and are a major source of revenue in a market where most profit margins, e.g. Internet access, are extremely "slim". Although VPNs are usually available inside NRENs and, in particular, across GEANT, they are little used to the best of my knowledge, as in these networks that are already sort of Private Networks, VPNs are normally not needed. There has been some exceptions, though, for example the need to access the DataTAG[67] 0 transatlantic test-bed transparently at layer2, i.e. Gigabit/s Ethernet, by some project partners.

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[56] http://www.akamai.com
[57] http://www.bittorrent.com
[58] http://www.google.com
[59] http://en.wikipedia.org/wiki/Network_address_translation
[60] http://en.wikipedia.org/wiki/Application-level_gateway
[61] http://www.skype.com
[62] http://en.wikipedia.org/wiki/Peer-to-peer
[63] http://en.wikipedia.org/wiki/MPLS
[64] http://en.wikipedia.org/wiki/IPsec
[65] http://en.wikipedia.org/wiki/Transport_Layer_Security
[66] http://en.wikipedia.org/wiki/MPLS_VPN
[67] http://www.datatag.org

3.2.1. The Evolution of the Web and the need for a new underlying network infrastructure

Few people remember what the early implementations of the Web browsers were like at its inception back in 1990-1991, i.e. a dumb-terminal oriented Web with HTTP and HTML already well-developed, with Hypertext pointers highlighted and followed by pressing the "Enter" key or scrolled over. But, an already very integrated and nicely built environment with interfaces to the most popular Internet tools and services such as Email (SMTP, UUCP/Unix), ftp, telnet, News, Archie, Gopher, etc. In 1993, Mosaic, a graphics enabled browser, the precursor of Netscape, received almost immediate acceptance from the Internet community at large, and especially the commercial Internet one. Since then, Web protocols and technologies have been under constant evolution, however, it is customary to distinguish the following phases, Web 1.0, the static Web, from 1992, Web 1.5, the dynamic Web around year 2000, then Web 2.0, since approximately 2004.

The following tables, that have been extracted from Dirk Trossen's (NOKIA) proposal to MIT's Communication Futures Program titled "Living the Future[68]", provide an excellent overview of what Web 2.0 really means in practice and how the existing network layers, dubbed Net 1.0 by analogy with Web 1.0, should evolve in future in order to support the evolving needs of the Internet users, in general, and those of the mobile Internet users, in particular.

3.2.1.1. Web1.0/2.0 Services & Functionality Comparison

Web1.0	Web2.0
Ofoto[69]	Flickr[70]
Bookmarks in browser	Social bookmarking[71] (Delicious)
Britannica Online	Wikipedia
Personal websites	Blogging[72]
Microsoft Outlook (proprietary)	Zimbra (open source)
Browsing to websites	Subscribing to and receiving RSS[73] feeds (Podcasting)
Publishing	Participation
Content created by service	Content created by the users
Read-only : All Rights Reserved	Add / Modify / Delete : Some Rights Reserved
Directories (taxonomy)	Tagging ("folksonomy"). Also TrackBacks.
One service	Mashups[74] (housingmaps.com, craigslist)
	Ruby on Rails[75]
Some API's	Open API's
The service is static	The service improves the more it is used, data added

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[68] http://cfp.mit.edu/events/slides/jan06/Dirk-Trossen.pdf
[69] Online Photos, http://en.wikipedia.org/wiki/Ofoto
[70] Sharing Photos, http://www.flickr.com/
[71] Social Bookmarking, http://en.wikipedia.org/wiki/Social_bookmarking
[72] Blog, http://en.wikipedia.org/wiki/Blog
[73] Really Simple Syndication (RSS), http://en.wikipedia.org/wiki/RSS_(file_format)
[74] Hybrid Web Application, http://en.wikipedia.org/wiki/Mashup_(web_application_hybrid)
[75] http://en.wikipedia.org/wiki/Ruby_on_Rails

Based on http://www.oreillynet.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html and Dirk Trossen's (Nokia) presentation "Living the Future" (http://cfp.mit.edu/events/slides/jan06/Dirk-Trossen.pdf).

3.2.1.2. Net 1.0/2.0 Envisioned Functionality comparison

Net 1.0	**Net 2.0**
Mobile IP add-on	Locator-identifier separation (HIP[76], M-FARA[77], ...)
Static end-user peering	Personal Broadband. i.e., BB access based on user's choice, dependent on use, location, time & other context
Licensed Spectrum and ISP mentality	Open spectrum, cognitive radios -> virtually unlimited bandwidth
Intra-domain, intra-technology access	Inter-domain & inter-technology in edge devices
Administrative IP domains	Regions based on geography, trust, administration…
Routers in the network	Mobile devices acting as (ad-hoc) routers
Management domains based on different technologies	Knowledge plane as inherent part of Internet architecture
Several competing (if at all) location techniques	Universal location support
Little network information available to edge device	Providing network-level context seen as differentiator and inherently supported
Scales to hundreds of millions	Scales to billions and more (Internet of Things, e.g. RFIDs)
Intra-domain QoS (at best)	Full E2E (inter-provider) QoS

Based on Dirk Trossen's (Nokia) presentation "Living the Future"

4. Internet Governance

This chapter is not meant to be exhaustive, as it is not really the main purpose of this article, and the number of actors is huge, so I am therefore only focusing on the respective roles of the Internet Society[78] (ISOC), the Internet Architecture Board[79] (IAB) and the Internet Engineering Task Force[80] (IETF), also mentioning the Internet Governance Forum[81] (IGF) as well as the OECD[82], as I have been quite impressed by the work of the OECD's STI (Science, Industry & Technology) department with regard to assessing the state of the Internet.

ISOC is a non-profit organization founded in 1992 to provide leadership in Internet related standards, education. ISOC is dedicated to ensuring the open development, evolution

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[76] http://www.ietf.org/html.charters/hip-charter.html
[77] http://cs.shenker.net/files/294lecture6b.pdf
[78] http://www.isoc.org/
[79] http://www.iab.org
[80] http://www.ietf.org
[81] http://www.intgovforum.org/index.htm
[82] OECD's Science Technology and Industry Directorate http://www.oecd.org/sti/

and use of the Internet for the benefit of people throughout the world. ISOC provides leadership in addressing issues that confront the future of the Internet, and is the organization home for the groups responsible for Internet infrastructure standards, including the IETF and the IAB.

4.1. The fading influence of the academic community over the evolution of the Internet

The Internet was mostly specified and developed by the academic community and it has long been an undisputed fact that the development of the Internet protocols had been led by the academic and research community; however, with the commercialization of the Internet there has been growing divergences between the commercial and the R&E Internet and it is clear that the influence of the academic community is fading out. This may be due to the fact that the consensus building model exemplified by the working style of the IETF has been eroding slowly, as there are too many conflicting commercial interests at stake; another reason is that there are many other forums, e.g. World Wide Web Consortium[83] (W3C), Global Grid Forum[84] (GGF), Optical Internetworking Forum[85] (OIF), ITU-T[86] (International Telegraphic Union), MPEG[87] (Moving Pictures Experts Group), etc.

This process is happening despite, or because of, the "heroic" efforts of the IAB to keep control of the Internet standards process and, together with the academic community, to stick to the original Internet design principles, e.g. the "end-to-end[88]" principle.

Even though this principle is architecturally clean and sound, it no longer matches the needs of the commercial Internet and its too narrow interpretation could lead to sub-optimal communications:

o First of all, "end-to-end" means different things to different people. For some purists, it means that the actual data transfer must take place between the intended hosts. Therefore, an intervening transparent Web cache, for example, as well as NATs and/or Firewalls are breaking this "intangible" Internet dogma, whereas all the redirection and caching mechanisms implemented across the Internet have been proven to be invaluable.

o However, "end-to-end" also means that the network must be kept as dumb or transparent as possible in order to keep the intelligence at the edges which, in turn, will facilitate the transition to next generation Internet protocols. A good example of this is TCP, which suffers from some well-known deficiencies in some operational environments such as long-distance very high-speed networks, where most proposed changes only affect the sender side thus making transition incremental and therefore extremely easy.

o Nonetheless, despite all the supposed advantages of a completely "dumb" network, Internet routers, if not at the core at least at the edges, have to deal with the issue of "fairness" between flows, both UDP and TCP, as well as maximum resilience against Denial of Service (DoS) attacks, port scans, etc., which can only be implemented by fairly smart and sophisticated routers.

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[83] http://www.w3c.org
[84] http://www.ggf.org/
[85] http://www.oiforum.com/
[86] http://www.itu.int
[87] http://en.wikipedia.org/wiki/MPEG
[88] http://en.wikipedia.org/wiki/End-to-end_principle

- o Although this fact does not break the "end-to-end" principle, per se, it shows the limit of academic concepts versus operational reality. Indeed, today's high-end routers are far more complex that the most complex super-computers.
- o Admittedly, the end-to-end principle is also used to differentiate the Internet, as a whole, which is completely "decentralized", some would even say "disorganized", from the classical Telephony network which is highly centralized and hierarchical, with most of the controlling and signaling functions performed in a separate network.

4.2. The Internet Activity Board (IAB)

The IAB is chartered both as a committee of the IETF and as an advisory body of the ISOC. Its responsibilities include architectural oversight of IETF activities, Internet Standards Process oversight and appeal, and the appointment of the RFC Editor. The IAB is particularly concerned by the stability and the graceful evolution of the Internet and has organized workshops on "hot subjects" such as "Routing and Addressing[89]", October 2006 (Amsterdam), and "Unwanted Traffic[90], March 2006 (UCLA).

Regarding *"Routing and Addressing"*, the key workshop findings include an analysis of the major factors that are driving routing table growth, constraints in router technology, and the limitations of today's Internet addressing architecture.

This triggered a major research effort under the auspices of the Internet Research Task Force[91] (IRTF) which is investigating a new routing architecture that would improve the Internet's ability to scale to potentially support billions of new users in developing countries. IRTF's "Routing Research Group[92]" is jointly led by Tony Li (Cisco) and Lixia Zhang (UCLA). One of the main thrust is allow multihoming[93], which has become very pervasive, without impacting the size of the global routing table which cannot grow indefinitely without some undesirable side-effects on the cost of routers and the stability of the Internet.

Regarding *"Unwanted Traffic"* the workshop came out with very alarming messages such as: "*The first important message this workshop would like to bring to the Internet community's attention is the existence of an underground economy. This underground economy provides an enormous amount of monetary fuel that drives the generation of unwanted traffic. This economic incentive feeds on an Internet that is to a large extent wide open. The open nature of the Internet fosters innovations but offers virtually no defense against abuses.*"

Back in July 1999, the IAB held an historical workshop in Utrecht on the state of the Internet network layer whose results are documented in RFC2956[94].

The main outcome was that, although the IPv4 based Internet is not on the verge of collapse, its lifetime is indeed limited; therefore, something needs to be done in order to stop its worrying level of fragmentation, restore end to end transparency, and allow easy re-numbering, in order to ensure stability of the routing system.

IPv6 may be the solution although its level of penetration, due to the lack of applications, in particular, but also to the fact that not all the necessary standards have been defined, has been rather disappointing, so far.

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[89] http://www3.tools.ietf.org/html/rfc4984
[90] http://www3.tools.ietf.org/html/draft-iab-iwout-report-03
[91] http://www.irtf.org/
[92] http://www.irtf.org/charter?gtype=rg&group=rrg
[93] http://en.wikipedia.org/wiki/Multi-homed
[94] http://tools.ietf.org/html/rfc2956

Regarding problems caused by NATs (Network Address Translator) and the embedded ALGs (Application Level Gateways) without which a number of applications would not be possible (e.g. FTP, H.323, Real Audio), RSIP[95] (Realm –Specific IP), a new proposal allowing hosts to dynamically borrow globally routable Internet addresses had very well received and it was observed that RSIP, as well as NATs, could in fact be used to facilitate the transition to IPv6.

It was also observed that "*in the original IPv4 network architecture hosts are globally, permanently and uniquely identified by an IPv4 address. IPv4 in fact mingles the semantics of node identity with the mechanism used to deliver packets to the node. The deployment of mechanisms that separate the network into multiple address spaces breaks the assumption that a host can be uniquely identified by a single IP address. Besides that, hosts may wish to move to a different location in the network but keep their identity the same. The lack of differentiation between the identity and the location of a host leads to a number of problems in the current architecture.*"

One of the most interesting, although depressing, aspect of this workshop is that nearly ten years afterwards, the problematic is essentially unchanged which shows, if need be, the extent to which the "organized" evolution of the Internet is indeed stalled!

In conclusion, IAB's positioning as the guardian of the Internet theology is lacking flexibility and appears to be unable to influence the "evolution" of the Internet in a coherent and effective manner, hence the "clean-slate" design temptation and the long term NSF initiatives to rescue the Internet.

4.3. World Summit on Information Society[96] (WSIS) follow-up

The IGF is a new forum for multi-stakeholder policy dialogue whose purpose is to support the United Nations Secretary-General in carrying out the mandate from the WSIS. The IGF meets once per year and the second meeting took place in Rio de Janeiro on 12-15 November 2007. The chairman summary[97] of the meeting is available and transcripts of the following main sessions are also available:

12 November	13 November	14 November	15 November
Opening Ceremony	Reporting Back Session I	Reporting Back Session II	Reporting Back Session III
Opening Session	Access Session	Openness Session	Taking stock and the way forward
Critical Internet Resources Session	Afternoon Reporting Back Session	Security Session	Emerging Issues
	Diversity Session		Closing Ceremony

The IGF has a rather bureaucratic setup which appears to satisfy everybody because of the, so called, "multi-stakeholder" approach. A marked improvement over ITU's or UN's top-down, government managed style of work and decision making. The IGF may prove to be an improvement over the bottom-up, IETF style which has also shown its limits because of the relative loss of influence of the academic and research community worldwide and the huge,

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[95] Since then, the RSIP proposal has been dropped and NAT have continued to proliferate to the extent that some people believe that it is "the" solution.
[96] http://www.itu.int/wsis/follow-up/index.html
[97] http://www.intgovforum.org/Rio_Meeting/Chairman%20Summary.FINAL.16.11.2007.pdf

often conflicting, commercial interests. However, the practical results, so far, have not been very impressive, to say the least, apart from the agreement on the organizational structure of such a worldwide forum which is admittedly a big achievement already!

The third meeting of the IGF will be held on 8-11 December 2008 in New Delhi and a first preparatory meeting will be held in Geneva on 26 February 2008.

4.4. OECD Workshops

A workshop[98] entitled *"Social and Economic Factors Shaping the Future of the Internet",* co-organized by the US National Science Foundation (NSF) and the Organization for Economic Co-operation and Development (OECD), was held at the US National Science Foundation in Washington D.C., on 31 January 2007. A similar workshop[99], focusing on "*the Future of the Internet"* was held in Paris in March 2006. These workshops as well as others[100] were held in preparation of the OECD Ministerial meeting on "The Future of the Internet Economy" to be held in Seoul (Korea) in June 2008.

4.4.1. Main points coming out of the Joint OECD/NSF Workshop

"Today's Internet is the sum of all the private and public investment, activities, inventions and creativity of a billion users, over 23 000 autonomous systems[101], and countless creators and innovators.

In a relatively short time, the Internet has become a fundamental infrastructure for our economies and societies and, as a result, raises increasingly important policy issues across a broad range of economic and social dimensions. Three main trends are increasingly influencing the current Internet's ability to meet the requirements of users:

- o *The openness of the Internet has been a clear factor in fostering competition and innovation, and is increasingly enabling users to develop, collaborate and distribute content and customize applications. This openness is driving a range of new social and economic opportunities and deepening the role of the Internet as a key part of our economic infrastructure.*

- o *Security threats endanger network operation and a trusted online environment at a time when an increasing number and variety of communities and businesses critically rely on the Internet.*

- o *Convergence between previously distinct networks and services towards the use of the Internet protocol generates new demands on the Internet and places strains on existing regulatory models.*

In considering the range of scenarios that relate to a future Internet, an array of choices can be made, in which technological evolutions may be partnered with social policy and regulatory discussions. To examine these choices and their potential implications, a dialogue between the technical community and the policy community is crucial, and should be informed by the work of economists, social scientists, and legal experts."

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[98] The position papers submitted by the participants as well as the summary of the workshop are available at: http://www.oecd.org/sti/ict/FutureInternet2007
[99] http://www.oecd.org/dataoecd/26/36/37422724.pdf
[100] OECD workshops
[101] An autonomous system (AS) is a collection of IP networks and routers under the control of one entity that presents a common routing policy to the Internet

"The future of the Internet is too important to be left to chance or random developments"

David Clark

"Discussants at the workshop agreed that there was a critical necessity to design future systems to be as adaptive as possible to evolving needs - whether these needs are technical, economic, social or legal in nature - as opposed to solely reflecting current requirements. They agreed on the need to draw lessons from the applications and use associated with the evolution of the current Internet and to identify the features that have been critical to the Internet's success and its openness/fostering of what several participants called "serendipity" or, as another participant called it, "generativity". At the same time, participants realized that the current Internet faces many challenges as it evolves to embrace new requirements, which are not only related to existing technical limitations but also to economic, social and regulatory issues.

At the outset of the workshop, participants were reminded that the question of whether future needs may be accommodated by incremental improvement of the current design of the Internet, and/or by a clean-slate approach, is being investigated by the research community, partly within the framework of the NSF/GENI project, which is both an effort to solve current Internet problems five years into the future, as well as a longer-term effort to define requirements for the network 10 or 15 years from now. GENI will be designed for experiments with different architectures that enable an assessment of socio-economic impacts, e.g. different architectures might lead to more or less openness."

5. Is the migration of the Internet from IPv4 to IPv6 unavoidable?

During the January 2007 NSF/OECD workshop "Social and Economic Factors Shaping the Future of the Internet" Geoff Houston, in his truly excellent presentation[102], went as far as writing:

*"The expectation with IPv6 was that the increasing scarcity of IPv4 addresses would drive service providers and their customer base to IPv6 deployment. What does not appear to be factored into this expectation is that Network Address Translators (NATs) produce a similar outcome in terms of virtually extending the IPv4 address space, and, additionally, are an externalized cost to the service provider .... **Currently it appears that the path of least resistance for the industry appears to be that of standardizing NATs, over the option of a near term migration of the entire Internet to IPv6."***

However, the above statement was made before the predictions for the exhaustion of the Unallocated IPv4 Address Pool had been revised in May 2007.

5.1. IPv4 Address Report[103]

An IPv4 Address report is auto-generated by a daily script and is available from: http://www.potaroo.net/tools/ipv4/index.html

The report generated on 13 December 2007 predicted November 2010 as the date of the exhaustion of IANA's Unallocated IPv4 Address Pool and November 2011 as the date of the exhaustion of the RIR[104] (Regional Internet Registries) Unallocated IPv4 Address Pool.

A number of people, e.g. Randy Bush, have been predicting for a long time that, pending the agreement of IANA, the RIRs could go to an IPv4 *"Trading Model"* thus

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[102] http://www.oecd.org/dataoecd/60/7/37985661.pdf
[103] http://www.potaroo.net/tools/ipv4/index.html
[104] http://en.wikipedia.org/wiki/Regional_Internet_Registry

transforming themselves into "*Title Agents*" instead of IPv4 space "*Allocators*". Given the huge amount of allocated, but unused, IPv4 space, there is a widespread belief that such a strategic move could considerably extend the life of IPv4 and also facilitate the migration to IPv6 by granting additional time.

5.2. Regional Internet Registries (RIR) Statements

Given this difficult situation most Regional Internet Registries, e.g. ARIN, RIPE, have issued warnings about the urgency to consider a graceful migration from IPv4 to IPv6 as soon as possible. According to Randy Bush *"these messages to the world have stirred up a far larger hornets' nest than they may have intended, and all sorts of folk now want to know what the real operational issues are on the way to widespread IPv6 deployment. An ongoing project has been looking at the operational speed-bumps on the road to widespread IPv6 deployment."*

5.2.1. RESOLUTION[105] OF THE BOARD OF ARIN[106] ON INTERNET PROTOCOL NUMBERING RESOURCE AVAILABILITY[107].

"WHEREAS, community access to Internet Protocol (IP) numbering Resources has proved essential to the successful growth of the Internet; and,

BE IT RESOLVED, that this Board of Trustees hereby advises the Internet community that migration to IPv6 numbering resources is necessary for any applications which require ongoing availability from ARIN of contiguous IP numbering resources; and,

5.2.2. RIPE[108] Community Resolution[109] on "IPv4 Depletion and Deployment of IPv6"

"Growth and innovation on the Internet depends on the continued availability of IP address space. The remaining pool of unallocated IPv4 address space is likely to be fully allocated within two to four years. IPv6 provides the necessary address space for future growth. We therefore need to facilitate the wider deployment of IPv6 addresses.

While the existing IPv4 Internet will continue to function as it currently does, the deployment of IPv6 is necessary for the development of future IP networks.

We recommend that service providers make their services available over IPv6. We urge those who will need significant new address resources to deploy IPv6. We encourage governments to play their part in the deployment of IPv6 and in particular to ensure that all citizens will be able to participate in the future information society. We urge that the widespread deployment of IPv6 be made a high priority by all stakeholders."

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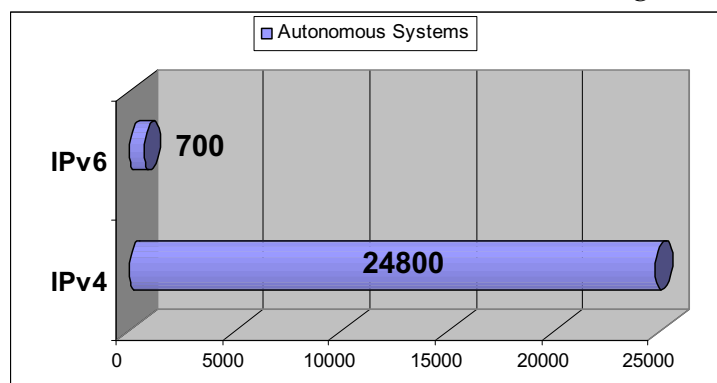
[105] Unanimously passed by the Board of Trustees on 7 May 2007.
[106] American Registry for Internet Numbers
[107] http://www.arin.net/v6/v6-resolution.html
[108] http://www.ripe.net/
[109] http://www.ripe.net/news/community-statement.html

5.3. The sad IPv6 "saga

Not surprisingly, IPv6 deployment is still in its infancy. Whereas it serves no purpose to finger-point some individuals and/or some organizations, it is a fact, however, that there has been too many counterproductive attempts to "sell" IPv6 with false arguments, e.g. built-in Quality of Service (QoS), etc. In some parts of the world and, in particular, Europe, there is still a tradition of centralism and voluntarism (wishful thinking) which can yield mixed results The Global IPv6 launch event[110] back in January 2004 is an excellent example of this ineffective approach led by theologians instead of deployment costs aware technologists and industrial companies. However, the development of the French "Minitel[111]" and "High Speed Rail[112] (TGV)" would not have been possible in a more "democratic" bottom-up process.

In any case, there is now a growing consensus, I believe, that the IPv4 to IPv6 migration strategy has not been sufficiently thought out. I also think this is indeed the case, even if this statement looks unfair more than 10 years after this strategy[113] was elaborated.

Indeed, RFC1671, the original strategy document, dates back to August 1994, however, a number of improvements have been made since then, e.g. the non-controversial 6to4 approach, as explained very well by David Preston in April 2001 "Edge Routers for IPv6 Migration" in a Network World article[114].

A bit of history may be useful here: Decnet Phase V, an OSI conformant network protocol, was proposed as a contender for IPng[115] to the IETF and was rejected for good reasons, e.g. address field of 48 bits, but bad reasons too, e.g. "not invented here" syndrome, general mistrust of the IETF community towards OSI based protocols, too visible political support of OSI protocols by the European Union[116]. In any case, the Decnet phase IV to Decnet Phase V migration strategy was then extremely urgent as the limited number of Decnet "areas[117]" was slowing down the deployment of the wide-area Decnet infrastructure which the high energy physics and space community were then heavily dependent upon, given the popularity of the VAX computers.

The "dual-stack" oriented strategy made lot of sense in a small network with a rather limited number of hosts and sites. Unfortunately, after IPv6 was specified and adopted, the people who contributed most to the IPv4 to IPv6 transition had been strongly influenced by the Decnet transition. If the IPv6 transition had been started then, it might well have worked out all right, even though this is doubtful.

At the beginning of 2008, it is rather clear that the IPv4 to IPv6 transition strategy is incomplete. As rightly pointed out by Randy Bush in his RIPE55 "IPv6 Transition & Operational Reality[118]" presentation *it is essential to avoid the fragmentation of the Internet, whereas it would be good to keep as much of the "end-to-end" principle as possible*. Undoubtedly, the IPv4 to IPv6 migration process, which is almost unavoidable, will be

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[110] http://www.global-ipv6.net/agenda.htm
[111] http://en.wikipedia.org/wiki/Minitel
[112] http://en.wikipedia.org/wiki/TGV
[113] http://www.rfc-archive.org/getrfc.php?rfc=1671
[114] http://www.networkworld.com/news/tech/2001/0423tech.html
[115] IP next generation, which became IPv6
[116] It is rather clear today that OSI standards were seen as a "weapon" against TCP/IP protocols which, in addition to being of US origin mostly, could not, by definition, be considered as standards given that the IETF definitely did not qualify as a standards making organization such as ISO or ITU. It is less clear who was at the origin of this "war", namely European governments, Telecom Operators, emerging National Research & Education Networks, such as DFN in Germany, influencing the EU or a few "visionaries" inside the EU, who knows!
[117] 256 different areas with up to 1024 hosts per area
[118] http://www.ripe.net/ripe/meetings/ripe-55/presentations/bush-ipv6-transition.pdf

incredibly more difficult that originally thought and additional mechanisms will need to be specified, e.g. IPv4 to IPv6 application level relays and/or proxies. Hexago's[119] Gateway6[120] type solutions, i.e. sort of IPv6 appliance, are likely to prosper during this very long transition period. Although the dual stack strategy should obviously be preferred if/when available, it looks unavoidable that all sort of kludges will need to be deployed in order to allow "full" connectivity between the two worlds and I do not think it is responsible attitude to condemn these, a priori.

The same type of comment applies to the "heretic" RFC2766 (NAT-PT) which was re-classified from "Operational" to "Historical" status by RFC4966 in July 2007, which, as rightly pointed out again by Randy Bush at RIPE55 *"tells you a lot about the IVTF, their level of operational clue, and how much they care about religion as opposed to ease of IPv6 deployment"*.

6. Short (incomplete) Review of ongoing Initiatives to Rescue the Internet, the "clean-slate" design temptations

Given this rather sad state of affair, some of the key players, e.g. the US National Science Foundation[121] (NSF), the European Union through its Framework programs (FP6 & FP7), but also some of the prestigious Universities that contributed the most to the Internet concepts and architectural principles, e.g. Cambridge University (UK), Stanford University, MIT have launched Internet "clean-slate" design programs.

6.1. National Science Foundation Initiatives and the "clean-slate" design temptations

6.1.1. GENI[122] (Global Environment for Network Innovations)

GENI is basically a flexible and reconfigurable network "test-bed". A good description of GENI's goals and purposes by Chip Elliott, GENI Program Director, as well as a "comics" explaining how "they" will use it and build it, can be found at the following addresses:

o http://www.geni.net/docs/GENI_Office_61907.pdf

o http://www.geni.net/docs/two_tales_geni_8807_download.pdf

6.1.2. FIND[123] (Future Internet Design) Projects

FIND is a major new long-term initiative of the NSF NeTS research program. The FIND program solicits "clean slate process" research proposals in the broad area of network architecture, principles, and design, aimed at answering these questions. The philosophy of the program is to help conceive the future by momentarily letting go of the present - freeing our collective minds from the constraints of the current.

The FIND program invites the research community to consider what the requirements should be for a global network of 15 years from now, and how we could build such a network if we are not constrained by the current Internet -- *if we could design it from scratch*. FIND solicits research across the broad area of network architecture, principles, and mechanism

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[119] http://www.hexago.com/
[120] http://www.hexago.com/4105/description.asp?product_id=164
[121] NSF
[122] NSF's GENI
[123] NSF's Future Internet Design (FIND) Program

design, aimed at answering these questions. The philosophy of the program is to help conceive the future by momentarily letting go of the present - freeing our collective minds from the constraints of the current state of networking. The intellectual scope of the FIND program is wide. FIND research might address questions such as:

- o How can we design a network that is fundamentally more secure and available than today's Internet? How would we conceive the security problem if we could start from scratch?

- o How might such functions as information dissemination, location management or identity management, best fit into a new network architecture?

- o What will be the long-term impact of new technologies such as advanced wireless and optics?

- o How will economics and technology interact to shape the overall design of a future network?

- o How do we design a network that preserves a free and open society?

6.1.3. NeTS[124] (Network Technology and Systems) Program

In addition to FIND, the NeTS program also includes the following program areas:

- o Networks of Sensor Systems (NOSS);
- o Wireless Networks (WN);
- o Networking Broadly Defined (NBD).

6.1.4. Data Oriented Network Architecture (DONA)

Following the analysis that the Internet is "sender oriented", i.e. users want to access particular data or service wherever it is located, many Internet experts, including Van Jacobson, have suggested to change the Internet service model to a more receiver-oriented one using point-to-point to publish/subscribe in a multicast like manner (i.e. session/content description protocol). A side effect of this approach is that it greatly uses Denial of Service (DoS) problems as it is the user who explicitly subscribe to the content he is interested in. DONA's proposed register/fetch mechanism are a step towards that goal.

"Publish/Subscribe[125] (or pub/sub) is an asynchronous messaging paradigm where senders (publishers) of messages are not programmed to send their messages to specific receivers (subscribers). Rather, published messages are characterized into classes, without knowledge of what (if any) subscribers there may be. Subscribers express interest in one or more classes, and only receive messages that are of interest, without knowledge of what (if any) publishers there are. This decoupling of publishers and subscribers can allow for greater scalability and a more dynamic network topology."

DONA also proposes to make extensive use of Self-certifying names[126], a well known technique using a hash of the public key to authenticate data, hosts, services, etc. The advantage of embedding it into the DONA architecture is that it alleviates the need for a Public Key Infrastructure (PKI).

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[124] NeTS
[125] http://en.wikipedia.org/wiki/Publish/subscribe
[126] Self-certifying key - Wikipedia, the free encyclopedia

6.2. EU's New Paradigms and Experimental Facilities[127] (FP7)

The FP6 Phosphorus project has already been mentioned, Lucifer[128] (Lambda User Controlled Infrastructure For European Research) is yet another "lambda on demand" type of EU funded FP6 project started at the end of 2006.

6.2.1. New Paradigms and Experimental Facilities

Excerpts from Cordis FP7 ICT Web page[129]:

Today's communication infrastructure is more and more based on the Internet, resulting from a long evolution. The large legacy of deployed infrastructures, however, limits the Internet's capacity to absorb innovation and to cope with new requirements. Within Challenge 1 "Pervasive and trusted network and service infrastructures" of the ICT theme of the Cooperation Programme under FP7, under Call 2 the Commission has called for proposals on Objective 1.6 "New paradigms and experimental facilities". 14 proposals were selected for negotiation[130].

Work under this objective has two related dimensions:

Experimentally-driven long term research on new paradigms and advanced networking approaches for the future internet: *Many networking researchers around the world have identified emerging limitations of the current Internet architecture and agree that it is time for research to take a long term view and to reconsider the basic architecture of the Internet, to see if any improvement can be identified, even if it does not appear to be backward-compatible at a first glance. To be effective and to produce applicable results, this long-term, fundamental research in new communication and networking paradigms has to be tested, at least as a proof-of-concept, in large scale environments, so as to assess the feasibility of the new concepts, verify their large scale effects (not only at technological level, but also as for their foreseeable implications on users, society and economy) and derive further requirements, orientations and inputs for the long-term research. This kind of experimentally-driven approach avoids that the long-term research will remain at the level of paperwork and will hopefully allow exploring significant improvements over the current Internet.*

Interconnected testbeds on networks and services: *In the long term, it is envisaged that the interconnected testbeds supported in Call 2 of Objective 1.6 will evolve from gradually federated testbeds towards becoming a sustainable, dynamic, and integrated large scale experimentation facility supporting academia, research centres and industry in their research on networks and services. The interconnected testbed activities under Objective 1.6 are open to any relevant European projects within other Objectives of FP7, as well as national, regional or multinational initiatives, to allow usage of the facilities or to federate their testbed within the facility.*

*Objective 1.6 on **"New paradigms and experimental facilities"** is complementary to other objectives in Challenge 1 and in particular to the third focus on **"Technologies and systems architectures for the Future Internet"** of Objective 1.1 **"The Network of the Future"**. The activities under Objective 1.6 do not start from scratch but build on the "Situated and Autonomic Communications" Initiative and other Internet-related research projects funded under Future and Emerging Technologies (FET), several testbed projects launched as Research Networking Testbeds under FP6, as well as many other research projects addressing important aspects of the future Internet under the FP6 IST Strategic Objectives "Broadband for all", and "Mobile and Wireless Systems and Platforms beyond 3G", several of them containing a testbed dimension.*

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[127] http://cordis.europa.eu/fp7/ict/fire/

[128] http://www.i2cat.net/i2cat/ImgsPortal/LUCIFER_UCLPv2%20Wokshop_Sergi.pdfhttp://www.i2cat.net/i2cat/ImgsPortal/LUCIFER_UCLPv2%20Wokshop_Sergi.pdf

[129] http://cordis.europa.eu/fp7/ict/fire/

[130] ftp://ftp.cordis.europa.eu/pub/fp7/ict/docs/fire/ictc-presentation-objectives_en.pdf

6.3. Other "Clean-Slate" programs

6.3.1. Stanford University "Clean-Slate" project[131]

Excerpts from Stanford University's clean-slate project home page:

*"We believe that the current Internet has significant deficiencies that need to be solved before it can become a unified global communication infrastructure. Further, we believe the Internet's shortcomings will not be resolved by the conventional incremental and 'backward-compatible' style of academic and industrial networking research. **The proposed program will focus on unconventional, bold, and long-term research that tries to break the network's ossification**. To this end, the research program can be characterized by two research questions: "With what we know today, if we were to start again with a clean slate, how would we design a global communications infrastructure?", and "How should the Internet look in 15 years?" We will measure our success in the long-term: We intend to look back in 15 years time and see significant impact from our program."*

6.3.2. Cambridge University (UK) "Clean-Slate" project[132]

During the kick-off meeting back in summer 2006, Jon Crowcroft restated that he doesn't believe in "top-down driven innovation" and so is instead asking for a collection of bottom-up talks and discussions, stemming from people's work and ideas, to stimulate imagination and cross-fertilization. Several novel areas discussed, especially in role based architecture, meta-routing, privacy preserving network monitoring, the split between software and hardware support for network and router virtualization, and vehicular and other novel wireless network applications.

The talks are available from: http ://www.cl.cam.ac.uk/Research/SRG/netos/cleanslate.html

6.3.3. MIT Communication Futures Program[133] (CFP)

Excerpts from MIT's CFP home page:

"Our Vision at the Communications Futures Program (CFP) is to define the roadmap for communications and its impact on adjacent industries. CFP is a new cross cutting partnership between University and Industry. Industry partners include companies across the entire communications value chain including end users."

Overview available http://cfp.mit.edu/docs/overview.pdf

7. Tentative Conclusions

The Internet has ossified. A clean-slate re-implementation is unlikely in the medium to long term (i.e. 7-10 years). However, some new ideas may find their way into the current Internet. The most urgent problem is to solve the explosion of the routing tables which is endangering the growth and the stability of the Internet, but this should be fairly easy to solve as the number of actors, i.e. suppliers of core Internet routers, is fairly small (i.e. Cisco, Juniper).

The next most urgent problem is the exhaustion of the IPv4 address space. Strangely enough, this is not seen as a high priority item by many major ISPs! however, IPv6 looks unavoidable some day, if one adopts the "conventional" view that all Internet capable devices, e.g. mobile phones, home appliances, RFIDs, etc., must be directly accessible, but, is this really desirable or even sound? NAT like solution, even so considered as "kludges", are therefore very likely to flourish and even to slow down considerably, if not prevent, the deployment of IPv6. This process should culminate with the standardization by the IETF of NATs. Last but not least, one cannot exclude the possibility that IANA, will allow the RIRs to

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[131] Stanford University "clean-slate" project
[132] http://www.cl.cam.ac.uk/research/srg/netos/cleanslate/ccr-report.pdf
[133] MIT's Communication Futures Program

go to an IPv4 "*Trading Model*", thus considerably extending the lifetime of IPv4 and also facilitating the migration to IPv6 by granting much needed additional time.

An ongoing problem is the proliferation of security threats and the associated "degeneracy" of the Internet but the time horizons of the clean-slate Internet architects and the Internet Service Providers are so different that one must be prepared to continue living with it!

More programmable network devices, e.g. routers, multiplexers, should become available, however, "Active Networks" technology is unlikely.

Last Mile, affordable, broadband access, including Campus networks will remain very challenging and fast evolving technology.

8. Acknowledgments

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Biography

Olivier Martin was the Project Leader of the DataTAG project. He received an M.Sc. degree in EE from École Supérieure d'Électricité (Supélec), Paris, France in 1962. He joined CERN in 1971, held various positions in the Software Group of the Data Handling Division, and then moved to the Communications Group of the Computing & Networks Division in 1984, where he has been Head of the External Networking Section from 1989 until 2004. Prior to the DataTAG project, he was involved in several European projects (including BETEL, BETEUS and STEN) in the framework of the RACE, ACTS and TEN programs. His research interests include next generation Internet, high-speed networking, transport protocols and Grids. Since August 2006, he is working as an independent ICT consultant.

Control program for a distributed high-voltage power supply system

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1. Introduction

This paper examines the creation of a program for local control of a distributed system of high-voltage power supply modules. Its primary goal is to allow great flexibility and dynamic change of the controlled system structure. There are also some additional requirements that determine the module parameters refresh time to be less than 1 sec. They also impose high speed code execution, easy migration to a remote control system and usage of the already available development tools.

A very suitable base for this software package development could be a *Supervisory Control And Data Acquisition* (SCADA) system, such as LabView or Winlog. For example the PVSS SCADA will be used in all slow control systems of the LHC experiments at CERN, including power supply systems. The advantages of a SCADA application are well-defined modular structure providing for good code reusability, short terms of software development, task distribution over multiple workstations and easy connection to external applications like databases or remote services. The basic disadvantage of SCADA based software is its binding to the development system and therefore strong dependence on the SCADA producer. Unfortunately the functionality of the currently available open-source SCADA systems is very limited. The network security of the selected SCADA has to be considered too.

The universal programming languages like C, BASIC and JAVA are very suitable for the development of the software. Skipping the details about each language we have to mark their advantages – optimized and/or platform independent code, large availability of libraries, reference code and compilers/interpreters. Their main disadvantage is the longer development time compared to SCADA solutions.

Considering the specific requirements to our program and the preceding speculations the final decision was to use Visual C++ language to create a program package oriented to MS Windows NT based operational systems.

2. Controlled system

The target distributed power supply system has a tree-like structure and consists of several layers (Fig. 1). The topmost layer is the controlling workstation. It connects to each of the controlled branches of devices using one of its serial interfaces (RS232, RS485, USB).
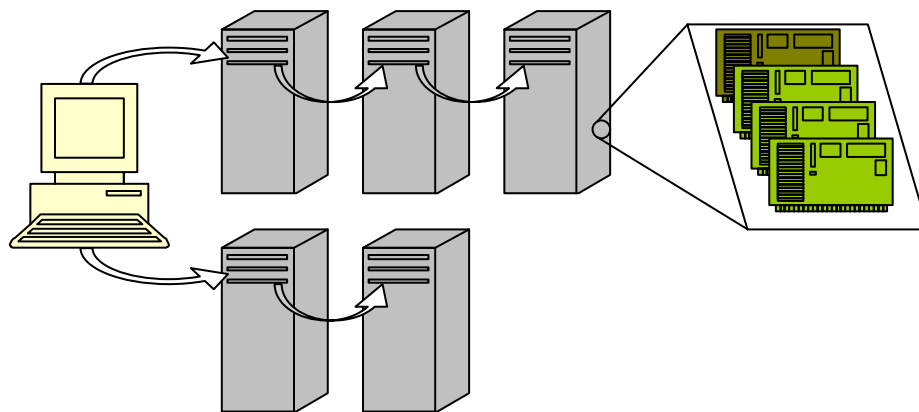
Fig. 1

Each branch consists of one or more serially connected crates. Each one of those crates has a programmable identification number, differentiating it from the rest of the chain. The crate has a power supply unit, controller and a variable number of power supply modules.

The modules consist of a defined number of power channels and the necessary control logic [1]. There are different types of power supply modules, according to the number and the parameters of the channels. Each type of modules has a unique identification number and each module has a unique address in the crate.

The communication to the crates is conveyed through a specialized master–slave type protocol, with several slave devices. The communication itself is initialized by the control station. First it sends a slave select command. The following communication is only to the selected device until a deselect command or another slave select command, addressed to a different device, is issued.

The communication protocol is package organized (Fig. 2). Each package consists of a header byte (H), a package size byte, data field and a checksum byte. The control station sends a package with a command or a data query. For each of the transmitted packages the currently selected slave device sends back a reply package, containing the requested data, or a status package for a successfully/unsuccessfully executed command.

| H | SIZE | DATA | SUM |

Fig. 2

The packages can be addressed to three different targets – to a crate, a module or a channel.

Four different types of packages can be sent to the crate – for addressing, for parameter inquiry, for assignment of new parameter values and commands for immediate execution.

There are only three types of packages that are sent to the modules and the channels – for inquiries, parameter assignments and immediate execution commands. The addressing to a specific module or channel is included in the package.

In order to examine the crate type and the installed modules the control station uses a "Request Crate Configuration" command.

A "Set Voltage" command is used to assign new output settings for the addressed module or channel. To define the voltage ramp-up and ramp-down speed parameters for the selected module a "Set Ramps" command is used.

The newly assigned parameters are kept in the volatile memory of the crate-controller, but it's still their old values that are used for control. The new values are applied only after a

"Go" command has been sent to the crate. This mechanism guarantees the simultaneous actualization of the changed parameters.

In order to preserve the changes as future default values, a special write command is implemented to save the current parameters in the nonvolatile memory of the controller.

There is a "Clear Voltage" command, which can be addressed to a module or to an individual channel, used to shut down the corresponding channel(s). The voltage goes down at a rate defined by a previous "Set Ramps" command.

An emergency power-shutdown ("Kill") command has been implemented. When it is executed, all voltage outputs of the crate are switched off, as fast as possible, without conforming to any voltage drop-down speed limitations.

A "Restore Voltages" command is used to switch on the channels after a "Clear Voltage" and "Kill" commands, or after they have been switched off by a protection circuit.

Two types of crates exist in regard to the supported specific set of instructions, and respectively there are also two versions of the communication protocol. Crates supporting different versions of the protocol but with the same interface can work together in one branch without interfering in each others' work. The differences between the two versions of the protocol are due to some differences in the way crates work – for some of them there are parameters that are defined with a single instruction for all modules at the same time, while for the others this is done separately for each module.

3. Control program

The control program is built-up following the document-view architecture. The document contains the operational data, as well as the communication subprograms. The views contain the subprograms for visual representation of the information in the document in an appropriate form and provide means for value assignment to the control variables.
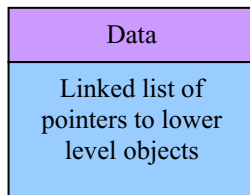
Fig. 3

The controlled system has a tree-like structure thus reflecting the same structure of the data describing it in the control station. In order to recreate this structure, in the program are used unified type of objects, holding data for the represented element and a linked list of pointers (Fig. 3). Using the list of pointers allows for the easy, dynamic adding and deleting of sub-elements to the data structure.
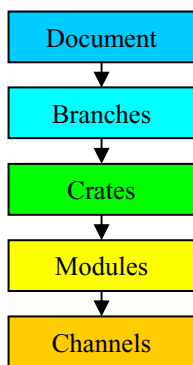
Fig. 4

The data built-up in such way is organized hierarchically on five levels (Fig. 4).

The root of the tree is the document-object of the program.

On the next level are the objects, representing the separate communication branches. They consist of data for the corresponding communication channel, like used interface, transmission speed etc.

The third hierarchical level represents the crates, connected to each branch, and every such object holds information for the number of the corresponding crate, its current state, the values of the power supply voltages and the crate temperature.

The fourth level reflects the crate modules. Each one of them is represented by its address, type, current state, voltage ramp-up and ramp-down speeds, values of the output variables and their corresponding limiting values.

On the last level of the hierarchy are the power supply channels of the module. They are represented by the address of each channel, state, up-to-date values of the output current and voltage, and output voltage assignment.

There are various algorithms that can be implemented to design the program and the good choice is crucial for the resulting parameters, like performance speed and the size of the used memory. From another point of view, there is always the problem of keeping the code as simple as possible and easy for maintenance during the period in which the software product is used.

There are two fundamental approaches that can be implemented in the design of the program – using parallel or serial task execution.

The chief advantage of the serial task execution is the simplified and clear structure of the program, which often leads also to a much simpler and fast executable code. In many cases this design approach is good enough to achieve the intended goal. Its main disadvantages show when there is a need to control a higher number of asynchronous processes, like for example a user input, a communication to a device, or waiting for the result of the execution of another program. In this case, in order to support the user interface without making the program appear blocked, it's necessary to periodically check the readiness of all such processes in cycle, which on its turn causes an additional use of processor time.

As an alternative to this exists the possibility to split the program into sub-tasks, which are executed in parallel. Usually the main task is the user interface support, and it's informed by the other work tasks when they are ready, or what are the results of their execution, in a certain way – with shared variables, interruptions etc.

Te second approach, although better in many extents, also has its shortcomings. Due to the nature of the parallel execution appears a possibility of simultaneous access to data. This might be fatal to the execution of the program and is an error, very difficult to discover, because of the random nature of the event. In order to avoid such events, special algorithms for shared data access are employed, along with additional variables granting or restricting the access. If the access to the data is restricted, the task waits until the one before it finishes its work with the data. Nevertheless, it's possible to come along a situation when two tasks wait for each other to finish work and the program stops functioning falling into a loop.

As a result the multi-task programming is considerably more complex. Usually it generates a larger executable code and creates more chances for hidden program errors, which are discovered much later during the program implementation. In some specific cases it is possible that the multi-task program is executed much slower than a single-task program, owing to the need of an additional code for synchronization and switching of all separate tasks.

In our case, despite all the described disadvantages, the multi-task programming is preferred because its use leads to higher performance when more branches are connected to the main station. And also allows for the capabilities of the modern multi-core processors and multi-processor systems to be used in a more efficient way.

The internal structure of the designed program is shown on Fig.5. It consists of a main execution thread (main task) and multiple work threads.

The main thread handles all views of the user interface and the single document in the program. Each work thread handles the communication through one of the serial interfaces, corresponding to one branch of the whole system.
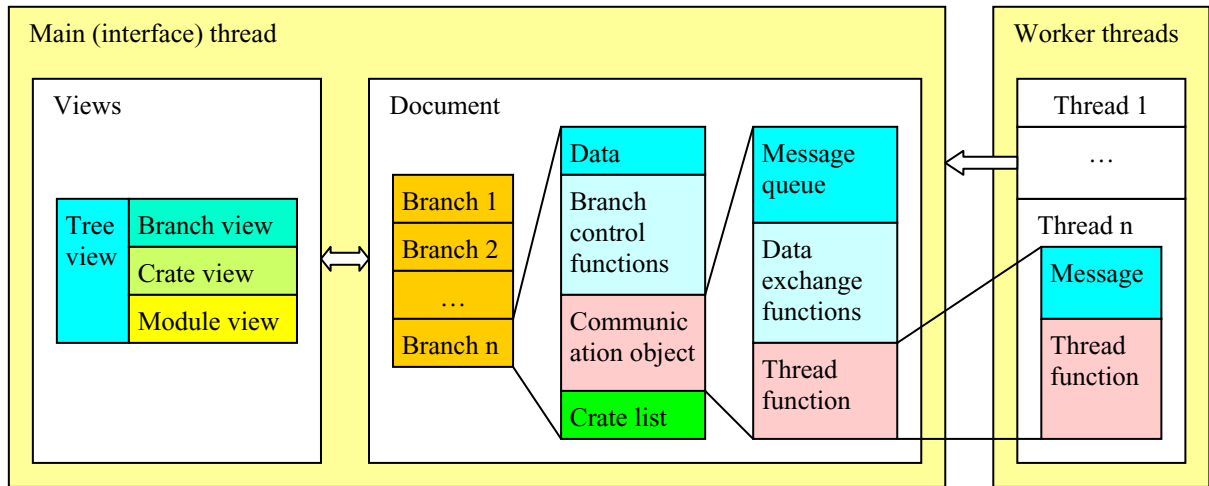
Fig. 5

The work thread function is part of a communication object. Besides this function the object contains data, shared between the main thread and the work thread, and also functions for synchronization of the access to the shared data. The shared data are organized in the form of a message queue. The messages are actually pointers to strings, containing the data to be sent or received over the communication interface. The threads add or delete messages from the queues using the access synchronization functions.

The document composes command into a message, using the branch control functions (Fig.5). Then the message is added to the end of the message queue of the corresponding thread. The thread extracts messages from the queue, sends them through the communication interface, and writes the reply of the device into a new message, which is added to a reply queue. Then it sends to the application window a user-defined windows message. The application window resends those messages to the document, where they are processed by the corresponding branch control function. The function extracts and analyses all replies present in the queue and updates the data in the document.

There are three main tasks in the control of each branch – maintenance of the data structure in the document, according to the real branch configuration, update the control parameters of the crate when a change has occurred in the corresponding parameters in the document data, and actualization of the output values in the document when there is a change of the corresponding values in the real device. Since there is only one communication channel for each branch, all those tasks need to share it among themselves. This is achieved by channel multiplexing over time. The branch control function is divided in three sub-functions. In each moment only one of them can convey any communication. The arbitration among them is realized by using prioritization. The highest priority is for the sub-program for work task modification, then follows the sub-program for actualization of the current output values, and with lowest priority is the branch structure actualization program.

The subprogram for assignment change is started only when there is a change in a control parameter in the document. The current value actualization subprogram is executed once every second. The configuration actualization subprogram is carried out once every other minute. When active, it checks all unavailable crate numbers, one at a time, on a 100 ms timeframe. After each check it releases the communication channel to higher priority tasks if necessary.

When the document data has been altered, a message is sent to the views, for the actualization of the corresponding element. If the element is visible in the moment of receiving the message, the view reads out of the document its value and updates it.

The visualization of the data is made possible through four different views (Fig. 5).

The user workspace is divided vertically in two panes. The left pane accommodates the navigation view, and the right field – the data of the currently selected object (Fig. 6).
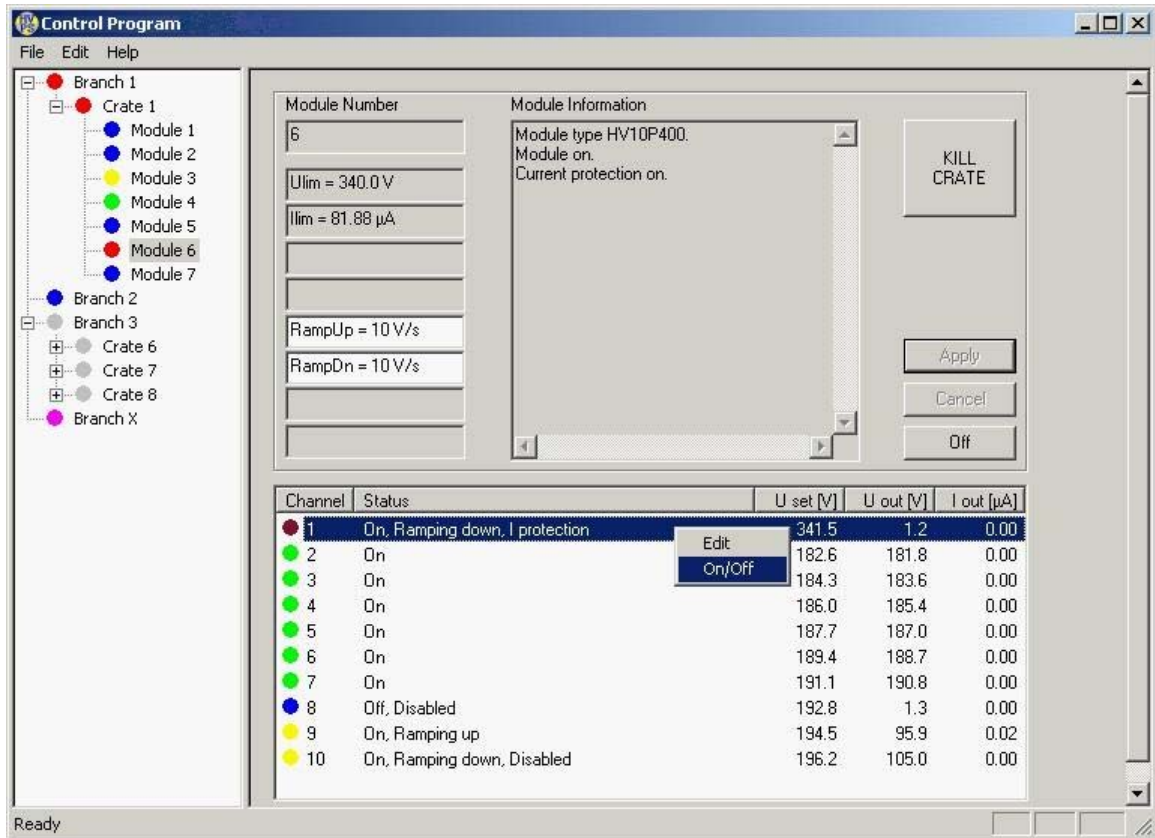
Fig. 6

The navigation pane contains a tree-view showing the structure of the document data. The objects are represented not only by their names but also by a unified status icon – a coloured dot. The colours represent the following states:
- gray – not-responding/inexistent object
- purple – unspecified control parameter
- blue – switched-off/off-line object
- green – switched-on object with normal output values
- yellow – switched-on object with still settling output values
- red – switched-on object in an emergency/break-down state

There are three views showing the object data – one for each level of the tree-view hierarchy. They switch automatically with the choice of each object. They are designed following the same scheme – on their left side there are several fields for the control parameters and the output values of the object. In the middle is situated an information field, which holds the detailed description of the currently chosen object along with its state. On the right side are placed the control buttons. In the module view, under the described elements, there is also an additional list of all the channels in the selected module (Fig. 6). In this list for each channel there is a status icon, a text field with detailed description of its current state,

output value field, and two other fields for the up-to-date output current and output voltage values. Most of the fields of the view have a context menu of the possible operations for the corresponding variable. All fields which can be filled in by the user have value validation functions. If the entered value is incorrect, a hint with the accepted value ranges is displayed.

4. Conclusion

The program has been tested in configuration with a control PC and two crates from different generations, connected through separate communication interfaces. The first crate comprises of six modules, each one of them with two groups of four channels, having voltages with different values and polarity. The second crate comprises of seven modules of four different types, according to their voltage and current, but having the same number of channels – 10 each [2].

Tested in this configuration the control program demonstrated full operability using two work threads and one main interface thread, taking insignificant amount of system resources.

In theory the system could be expanded to 127 crates on each channel (RS485). In reality this number is restricted by the loading characteristic of the used interface controllers. With a great number of crates a limitation might be also the working speed of the control computer processor and the available memory.

Based on the presented program we plan the future development of a system for remote monitoring and control of one or more control stations. As a communication medium will be used LAN or on a global scope – the Internet.

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The remote control of the spectrometers on the IBR-2M reactor

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The control over the most experiments on the IBR-2 reactor for a long time was local, i.e., from the computers inside the experimental hall only. The application of the systems based on VME computers allowed the development of software for remote control over spectrometers within FLNP network segment /1/. Nowadays, the evolution of network infrastructure in the town of Dubna enables the remote supervision and control over the experiments from any place outside the JINR network segment. The reason for such remote control and supervision is long duration of experimental data acquisition, which sometimes takes several days including weekends. The possibility to make sure that everything is functioning properly is very helpful for the user. On the other hand, the prompt response to errors or abnormal situations allows one to avoid the loss of expensive reactor time.

At the development of Sonix+ software for Windows /2/ particular attention has been given to the creation of control modules of instrument hardware and local user interface. For remote control over the experiment the Windows built-in «Remote Desktop Connection» has been suggested. This tool allows one to completely redirect the desktop of control computer to the remote one, which, in general, satisfied the user requirements at an early stage of the Sonix+ utilization. However, this approach has significant limitations. Remote desktop cannot be multiplied just with the Windows XP utilities and tools. As a result, only one remote computer can exercise control over the experiment. This is normal because it permits conflicts in control to be avoided. But it makes impossible the simultaneous supervision of the experiment from other remote computers.

There are commercial tools for multiplication of Windows Desktop and they are used on some instruments. However, the application of such tools outside the FLNP or JINR network is highly improbable.

On the other hand, Web technologies are much more popular and widely available now. Besides, for remote control over the experiment, the complete access to all control options is not necessary. If only supervision is required, access to the control functions must be forbidden.

Generally, the users can be divided into three categories:

• Team that carries out the experiment. For the members of this group the most important point is, first, the correspondence of the progress of the experiment and its conditions to the declared research program. Second, they may need remote start/stop of script execution, its correction or replacement.

• Group of users of experimental results. For the members of this group the history (log files) of the experiment and reliability of results is more important. They do not need remote control, just supervision.

• Technical personnel (programmers, etc.). They also need only supervision to make sure that software and hardware operate properly. However, they may need detailed information for analysis of the experiment progress.

Test of the supervision system prototype

Since IBR-2 was scheduled to shut down in January, 2007, for modernization, the project was carried out in an unusual way. We started from the check-up of intuitive solutions to test them in real conditions. The tests were performed in December, 2006, on the

spectrometers REMUR, NERA-PR and HRFD with position-sensitive detectors. For this reason, one of computers of the development team run Web server IIS 5.1 with PHP 5.2. Besides, FTP server IIS 5.1 was installed on data acquisition computes with Windows XP and Sonix+.

The system provided the following information for supervision:

- Screen shot of desktop with cyclic update every 1 min. as information of current state.
- Log file of current measurement.

More detailed information could not be given for lack of time and the deadline of reactor schedule.

The test has shown that:

- Supervision system is serviceable in general. Its operation does not affect the reliability of operation of data acquisition systems.
- The test version provides important information about the operation of data acquisition systems, but without details.
- The screen shot of desktop does not provide much information. What is more, it looks like a black rectangle, while the Screen Saver at the control computer is active.
- The output of the whole log file on every request is unwise. Moreover, for long-term measurements, the log file becomes large, and its transfer cannot be done within the reasonable time interval.

Review of the existing solutions

To become familiar with the current status of remote control and supervision in other research centers, we turned to our colleagues, participants of NOBUS collaboration /3/ for help. We referred to the Internet for this purpose as well. However, we have not found many examples of similar systems, as expected, though some of these systems are in service for a long time. In most cases, these systems provide remote supervision over the status of instruments and their basic parameters. Also, these systems make possible to present the accumulated data in a raw or processed form.

In servicing a set of spectrometers, an individual computer runs the Web server. The most popular OS is Linux, Web server is Apache, and programming environment is Java. The general inquiry results are shown in the Table below.

Name	Institution	Software	Specific features	Operation since
Dixie /4/	ORNL		Control and supervision	1997
BARNS /5/	ILL	PHP, IDL	Visualization of data, instrument status, log files of measurements	1998
DeepView /6/	ORNL	CGI, Perl, Java, C++	Control and supervision	1999
SICS WWW Instrument Status Display /7/	PSI, 13 spectrometers	Linux, Apache, Java	Visualization of instrument status, most important parameters, log files	2000
/8/	ANL , APS, 32ID-B USAXS	Linux (CentOS 4), Apache, PHP, JavaScript, Tcl	Static Web pages: status of current experiment, graphs of most recent data, current status of instruments	for 5 years
CIMA /9/	ANL , APS, sector 34ID-E	Fedora Core 4, Apache, PHP, JavaScript	Visualization almost in real time: raw and processed data, time of start and completion of scanning	
CBASS /10/	BNL NSLS	Linux, Windows, Java	Parameters of experiment, JPEG images of data	

Requirements to Web Sonix system

The system must satisfy the requirements of all potential user teams. It should accept not only *supervision* but *control* over the instrument as well. It should be *expandable*, i.e., the inclusion of new spectrometers should not require many and big changes in the system. Besides, the architecture of the system must be independent of specific features of spectrometers. Its architecture should avoid individual pages as much as possible, but must be easily adapted to particular spectrometer. The system must be *stable* and *protected* from unauthorized access. Besides, it should be convenient in use and have the user-friendly interface. The system must provide *detailed information* about the experiment and equipment if necessary. The operation of the system should not overload the computers, which run control software for spectrometers.

General ideas

As mentioned above, the allocation of an individual computer for Web site of the system is a common practice. This computer must be reliable and provide access 24 hours a day. The criteria of reliability and safety are the most important in deciding on a particular OS and Web server.

The control computers can be hidden for unauthorized users from outside the JINR network. This improves the safety of these computers and their protection against malicious attacks.
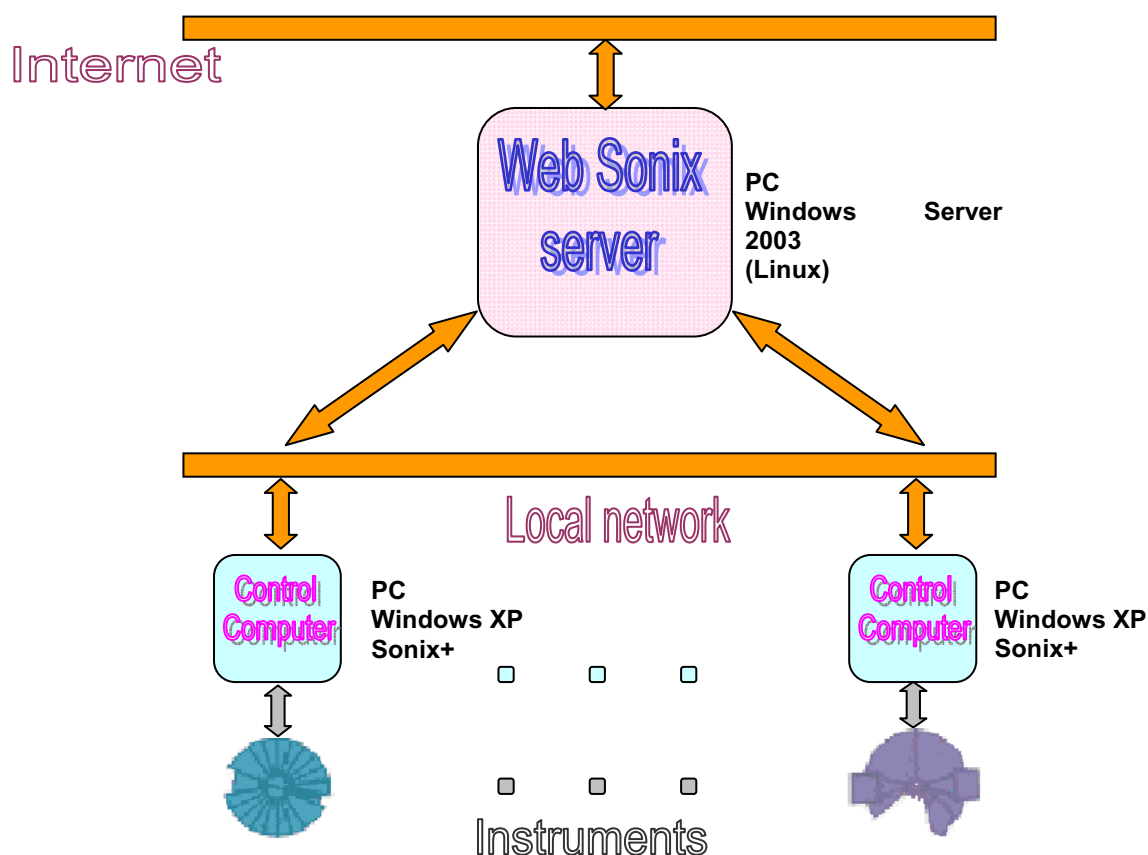

Fig.1. General layout of Web Sonix

Information contents of Web site

First of all, the contents of the Web site must reflect the current status of all components of the spectrometer (motor position, sample environment, etc.). In Sonix+ all information about the parameters of the current measurement is stored in the special database Varman. *The snapshot of database* as an individual file is best suited for this purpose. The user should have the possibility not only to look through the whole snapshot, but also to select the most important parameters (favorites) into a separate trace list.

The log files of measurements contain the detailed information about the progress of the experiment. Beside the log file of the current measurement, the user may be interested in earlier logs. Thus, the command set must contain the command for reading log file directory. As was noted above, the transfer of the whole log file is especially unreasonable, when it is large. The sorting and extraction of data portion for viewing should be performed on the control computer.

Visualization of current spectra from all detectors is also of importance. The generation of a picture on the control computer is much more reasonable than the transfer of initial data massive, especially for high-resolution position-sensitive detectors.

The control assumes that the service provided by the Web site includes tools *to read, edit* and *to manipulate scripts*.

The necessity of authorization is caused by three reasons:

- Often, the user wish to avoid "spying" upon his measurement from outside.
- Excessively frequent generation of graphs may overload the control computer.
- To restrict access to the control over the instrument.

The Web Sonix server receives information about the measurement directly from control computers. There are two ways of generation of this information: *cyclic* way at certain time intervals, and *on demand*. The second way is more complicated because it requires an individual channel to transfer commands. However, from our point of view, it is more preferable, since the total load on the control computer is less, and the presented information is more precise.

Implementation

In the Central Computation Center of FLNP a special computer is allocated to the site of the Web Sonix system. The system is a client of Apache HTTP server 2.2.4. For generation of dynamical Web pages the language PHP 5.0 has been chosen. In our opinion, functionally it compares well with Java products, but its syntax is very similar to the C language, which is the main language for Sonix+.

In deciding between various file transfer protocols, preference has been given to FTP (SFTP). This assumes the installation of FTP server on the control computer, however its load is little increased. Two directories are created on the control computer:

/tmp - for answers to commands from the server
/py_src - for user scripts

Command channel is realized at the socket level in the client-server model. The client called from the PHP program sends a command to the server as a text string, which contains the name and list of parameters. Then the client waits for an answer. The server receives the command, calls the procedure written on Python and substitutes the given list of parameters. The result of execution of the procedure consists of status and comment. Then it is returned as

a text string. This way of command interchange between the computers termed as "py_gates" was successfully used earlier for connection of position-sensitive detectors (under control of Windows, Sonix+) to VME computers (OS-9, Sonix). New version "c_channel" (command channel) is an extended copy of "py_gates".
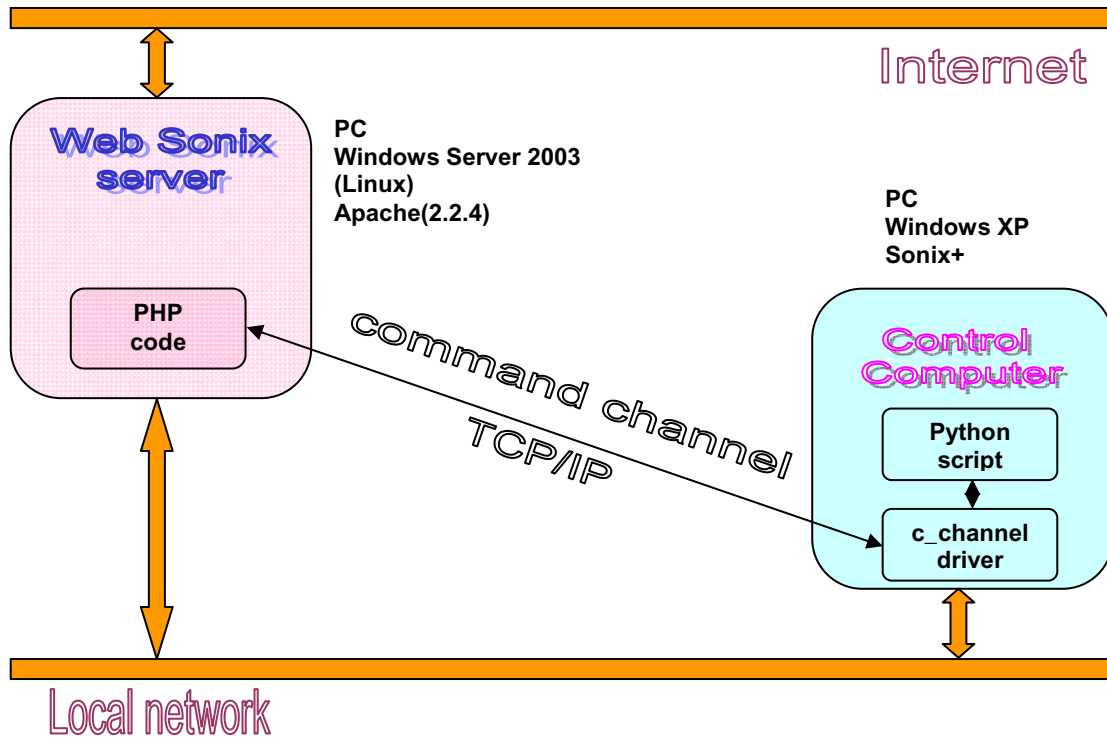

Fig.2. Layout of command channel

The command set includes the following commands:
- Saving of a shot of database and its conversion to text format
- Control over script interpretation (start and break commands)
- Reading of the current spectrum from the selected detector and plotting of its graph
- Displaying of the name of current log file
- Displaying of the list of all log files
- Reading of the selected portion of strings with a given type and level from a file

A snapshot of database is stored by the Varman server as a binary file. This file contains the values of parameters and descriptions of the data structures. This allows one to interpret database using only the contents of a shot. The transformation of database contents to human friendly text representation is performed on the control computer, which has a set of appropriate software tools. The text representation of database looks like a tree-like list to preserve its nesting structure. Each instrument may be described as a set of parameters organized as a sub-structure. This sub-structure may consist of other sub-structures, etc. Each element of the structure begins from a new line. Each embedding shifts to one column. The values of parameters are on the right side of the string. They are separated by "=" sign. Figure 3 shows an example of database in text format.

```
# snaplist.py vers. 1.13 31/05/07
#*****************************************************************
configList(list_device())
        InstrumentName=YuMO
        IbrCycle=2
        UserDataPath=e:/yumo/data/
psdList(list_device())
psd(detector_murn(DEBUG))
        status
        params
                delay=950
                range
                        range_1
                                minimum=0
                                maximum=511
                        range_3
                                minimum=0
                                maximum=255
                        range_2
                                minimum=0
                                maximum=255
                        dimention=3
                det_data_type=2
                tcwidth=128000
userList(list_device())
expo(expo())
        status
                total_time=0
                measurement_time=0
                flag=0
        params
koskas(pool_detectors_murn(DEBUG))
        status
        params
c_channel(c_channel())
        status
                iRequestNumber=2
                fWaitForRequest=0
                sInput='privet'
                sFunction='Proc'
                sResult='undefined'
        params
                iPort=8024
```

Fig.3. Representation of database as a tree-like list

Such representation allows one not only to describe the structures of instrument parameters, but also to address the value of each parameter by indicating its path. For instance, in the example given in Fig.2 the maximum TOF channel number t for psd detector is indicated as

psd/params/range/range_1/maximum.

Besides the log file of current measurement, the user may be interested in earlier logs. For this reason the command set should have a command for reading log file catalog.

Conclusion

The project is under development. The server is allocated. Now the team works on the debugging of the database and log file visualization. The completion of work is scheduled for the end of this year. The authors are grateful to V. Riabov for useful discussions and assistance.

References

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[4]   ORNL, Dixie, http://www.csm.ornl.gov/~geist/java/applets/HIFR/dixie4.html
[5]   BARNS, http://barns.ill.fr/
[6]   ORNL, DeepView, http://nobugs.dl.ac.uk/presentations/wright/MCWpaper.htm
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[11]   http://nfdfn.jinr.ru/~kirilov/Sonix_WEB/Sonix/py_gates.htm

4π detector for study of Zeno effect using
^{220}Rn → ^{216}Po α-α correlated chains

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Abstract

First test of the 4π detector for study of exponential law of radioactive decay and possibility of observation of Zeno effect [1-3], measuring the mean life of ^{216}Po is presented. This detector consists of two surface-barrier n-Si(Au) detectors placed in the close contact (<1mm) to each other. Th foil is used as a generator of Rn- gas. The foil was covered by nuclear filter with 0.4 μm pores and placed in the bottom of vacuum chamber. So, direct alpha-particles can not reach the detector active surface. The measured half-live of ^{216}Po of 143.5 (0.6) ms is in agreement with literature sources. It is shown, that for the definite source the random background correlation counts are mostly caused by the ^{220}Rn - ^{216}Po alpha activities and that it is not an easy task to decrease a background level of units of percents in the time region >$4T_{1/2}$. Both, the data acquisition system and the vacuum chamber design are presented in brief. Authors plan to perform the second set of tests at the end of 2007 and beginning of 2008 years.

1. Introduction

The consideration of general problems of decay of the unstable systems by Khalfin [1] demonstrated that decay rate of a quasi-stationary state does not obey exactly the exponential law. He demonstrated that the decay rate was slowing-down for long times. Fonda et al. [2] have analyzed a decay model and showed that in some circumstances significant deviation from the exponential law could occur at about 10 lifetimes and inverse power-law domination could occur at about 25 lifetimes.

2. 1st step in the Rn → Po α-α correlation test measurements: effect and backgrounds

To measure correlations the regions $t > T_{1/2}*n1$, and $t < T_{1/2}/n2$, ($n_{1,2} >>1$) the setup shown schematically in the fig.1 has been designed. Both silicon detectors are made from n-silicon of about 1.2 KOhm ·cm receptivity wafers with evaporated Au top electrodes. As to rear contacts, they are produced by chemical extraction of Ni onto non-etched silicon surface. Leakage current at the working bias of 20 Volts was about 0.4μA. The geometrical detection efficiency was estimated to be 80% from 4π. We use Th source when no direct alpha particle could be detected by both detectors, but only after gaseous transport of Rn single atoms onto the sensitive detector area.

3. Measured spectra for ^{220}Rn → ^{216}Po α-decays

In the fig.2 the measured spectra for both detectors are shown. Note, that he peaks under interest are located in middle, whereas left and right peaks are of 6.06 and 8.78 MeV which are used for calibration process. In the Fig. 3 two – dimensional alpha-alpha correlation spectrum for 650 ms time interval is shown. They are definitely shown an existence of backgrounds of different nature: random correlation for Rn→Po links as well as non-related counts. The acquisition time for the given spectra was about one day.
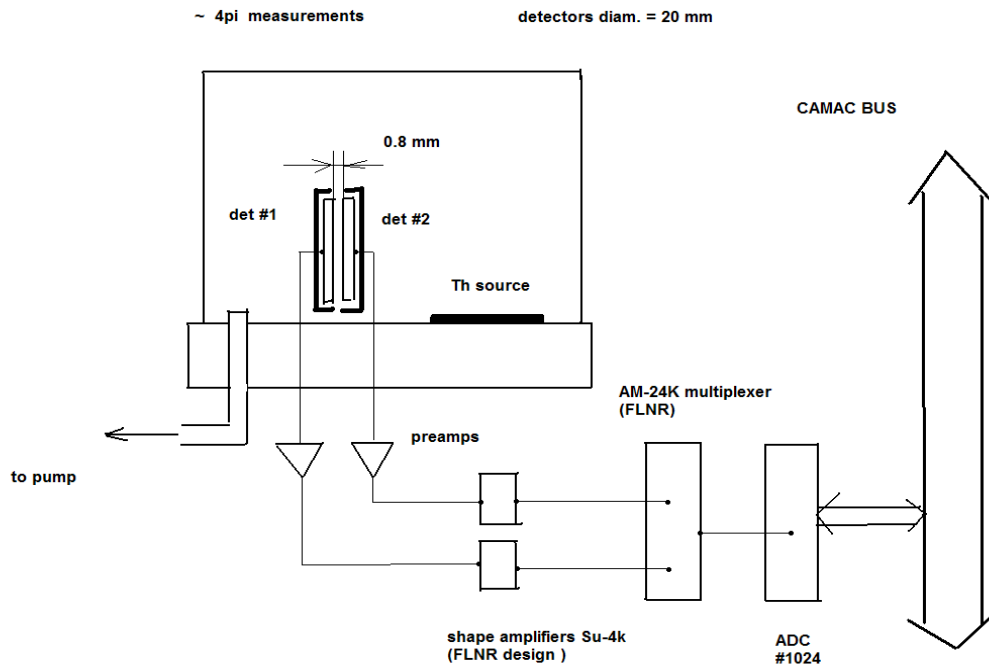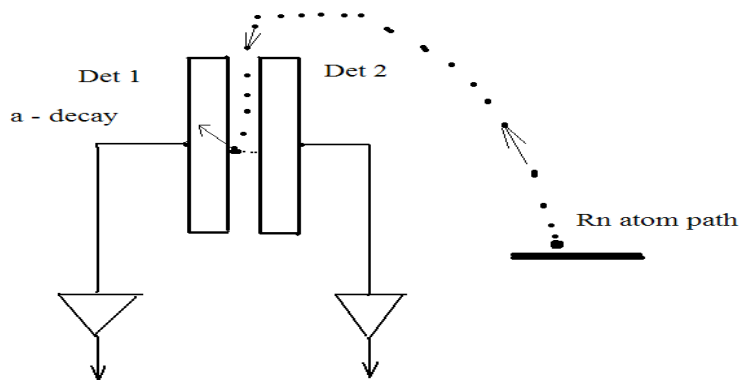
Fig.1. Schematic view of the 4π detector. No direct alpha-particles could reach to the
active surfaces of both detectors
(picture down: way of an Rn atom to detector active Au-surfase)
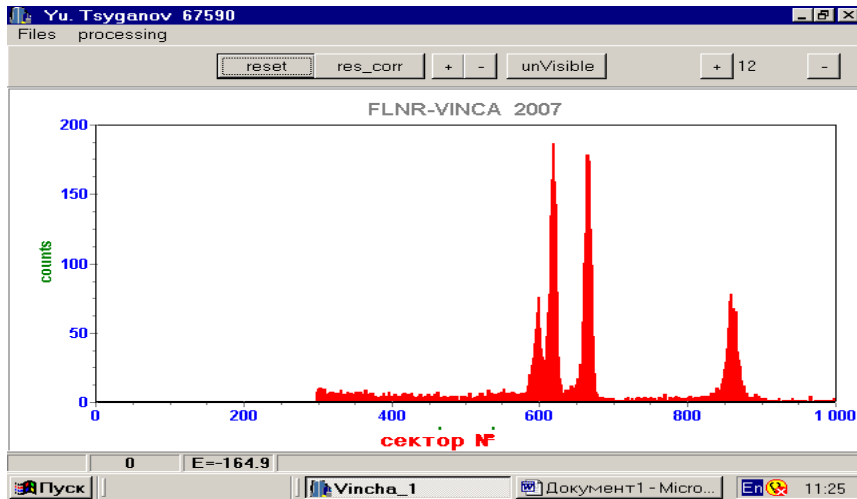
Fig. 2. Spectrum for ^{220}Rn$\rightarrow$^{216}Po correlated chains. Two intense peaks – Rn && Po. Two others 6.062 and 8.785 MeV
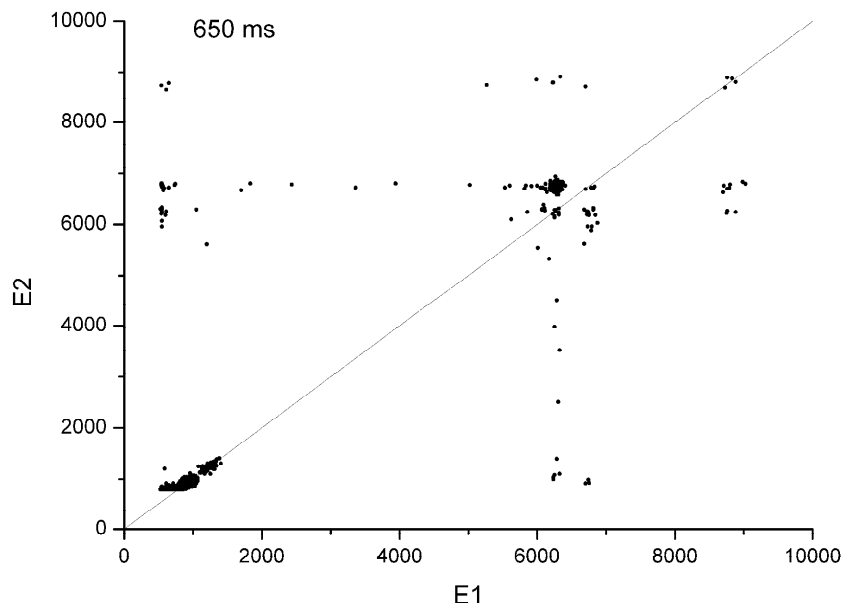
Fig. 3. *E1-E2* correlation spectrum. Time window is 650 ms. Both scales(y,x) in KeV's. Group of events symmetrical according to y=x line is in fact background is explained for Rn$\rightarrow$Po decays themselves

4. Discussion

Although units of percents of background explained itself random correlation Rn$\rightarrow$Po are existed even in the range more than four half-lives, such the effect can be described in the form of time independent constant, due to the rate of both sources (Rn & Po) are constant in the mean sense.

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So, the mathematical description of background right tail is a great of interest. Of course, the additional sources which are not related to the ^{220}Rn$\rightarrow$^{216}Po random links are also should be under consideration. From the other hands, any attempts to minimize the mentioned factor are required a lot of exposition time, like months or even years.

5. Conclusions

First test of simple 4π- detector to study Zeno effect for Rn$\rightarrow$Po correlation sequences has been performed. It is shown for times $> 4T_{1/2}$ background of random correlation is not less that of units of percents. There are three reasonable ways for prolongation of the experiment:

a) by using source with much more less activity $\rightarrow$ very long time of measurement will be required;

b) by using the same or even much more powerful source, but with exact mathematical description of background shape in the t > 10 $T_{1/2}$ region;

c) by using special design detector pair with position sensitive resistive layers, but with the slit as small as possible, to prevent Po atom to go out the region restricted by a several mm units.

Appendix1

When preparing this manuscript, measurements with larger statistics (16 days) were performed[*]. In the Fig. 4 decay curve for ^{220}Rn-^{216}Po α-α correlation chains is shown.

Measured parameters of half-life and random background are shown in the frame.

An accuracy of an elapsed time measurement was of one microsecond. Both time decay constants are correspond to each other (k- parameter in the exponential function fit).

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[*] The DGFRS spectrometer (two spectrometry channels of "veto" detector) is used
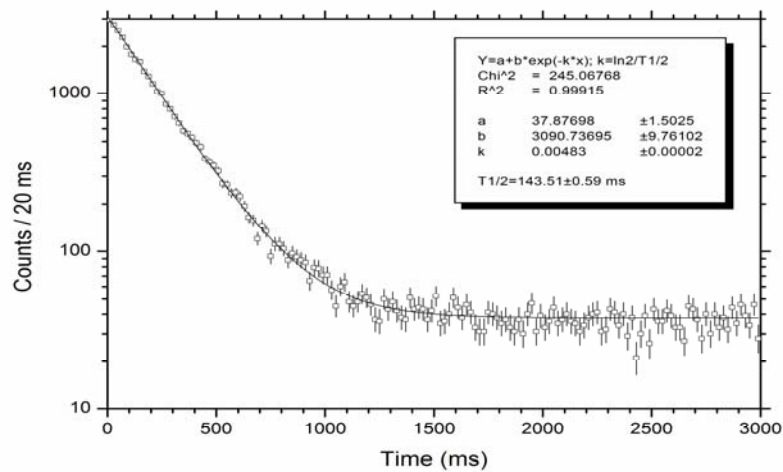
a)
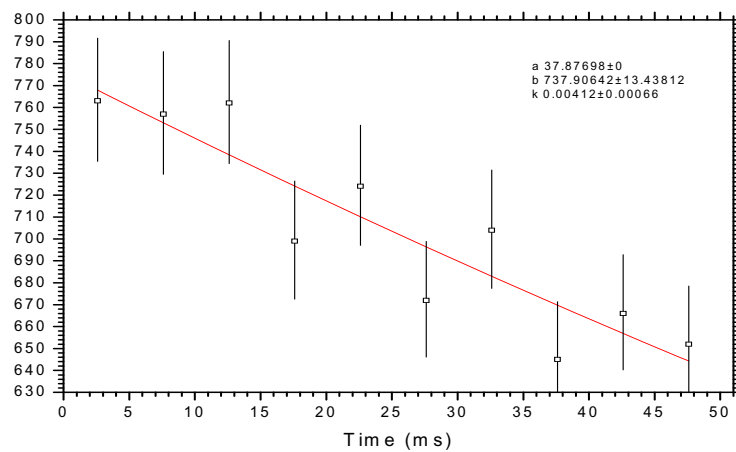
b)

Fig.4. Decay curve for ^{220}Rn $\rightarrow$ ^{216}Po α-α correlated sequences
a) Measured half-life value is equal to 143.51±0.59 ms
(The same value reported in [4] is equal to 145 ±2 ms.)
b) the same exponential decay, but for (0, 50 ms) time interval is taken into account

Modernization of the systems of control and power supply of Accelerator - Microtron MT-17 Hanoi, Vietnam

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Introduction

In 1982, Microtron MT-17 was put into operation at the National Institute of Physics, VAST. The Microtron MT-17 has seventeen trajectories and accelerates electrons up to 15MeV and works in pulse regime. It is simultaneous a source of 15 MeV bremsstrahlung photons and fission neutrons. Though very modist, Microtron MT-17 − simultaneous sources of bremsstrahlung photon flux and fission neutrons is very useful for us in both fundamental and applied physics research. During the recent year by using Microtron we have carried out different investigations. The accelerator-microtron MT-17 was constructed by institute of physical problems AS- USSR and launched in 1973, and up to dispatch in Hanoi, It has been already exploited about 10 years. This Microtron to moment of the modernization has operated for long time (more than 30 years). The all electronic blocks were made from transistors and already outdated on quality and on time! They often went out of operation. So we have solved to modernize the whole control system and power supply of the MT-17. Practically we began to be occupy with modernization of MT-17 in 2003, but only October 2005 started to check a state of all MT-17 and after this have removed all old electronic parts. After preventive maintenance completely we have put cables and conductors, to have assembled electronic blocks and checked all working state of the system of the power supply and the MT-17 control system.

On that of this we present some results about modernization of our Microtron-MT-17.

Technical parameters of the microtron:

Maximum energy of accelerated electrons, MeV	16
Range of energy change, MeV	10 - 15
Power on a fascicle, kw	0,3
Number of orbits	17
Beam intensity of electrons, μA	20
Flow of fast neutrons, 1/s	10^{11}
Fluency of thermal neutrons, 1/s. CM^2	10^8
Fluency of resonance neutrons, 1/s. CM^2	10^7
Working vacuum,	10^{-4}
Power consumption, KW	20
Frequency of high-frequency generator MHz	2790
Pulse power of the Magnetron, MW	1,6
Frequency of modulations, Hz	100,200,400
Pulse duration of modulations, μsec	3
External diameter of the chamber, mm	1200
Internal diameter of the chamber, mm	720
Cooling	Water, air.

The MT-17 microtron is exploited more than 20 years. It provides the possibility of carrying out the series of highly sensitive techniques of scientific activities:

- Research K – meson and Π-meson reactions.
- Research spontaneous division, photo fissions, fission fragment isomers.
- Activation analyses of mineral resources of ore and oils.

(Gamma and neutron activation analysis of the contents in a material. Besides, we still irradiation grain models for stimulation of green growth in agriculture and also conduct medical researches (for example the research of a radiation dose from atomic explosions).

The all systems of the power supply and control of MT-17 have been changed new elements. The new systems are made on modern compact and with low-used energy. Besides, system of the power presently does not supply from VPL-30 (the special system, which provides three-phase 380 V, 400 Hz), but straight from the network of three-phase 380 V, 50 Hz. That is much comfortable, simply and high stability, as well as economical of supply energy.

For the power supply system one should have 5 sources such as ES 035-5 which possess output powers from 0 up to 35 V and a current 5 A.2 a source such as SM 7020-D, which possess output powers from 0 up to 70 Volt and 20 Amperes. One of source such as SM 15-100-D, which possess output powers from 0 up to 15 V and a current 100 A, and One of source such as SM 15-400-D possess output powers from 0 up to 15 V and a current 400 A. Here two variants of conversions were used. Feed from 220 V for low power sources, and feed from 380 V for high power sources.

The principles of operation of these sources are following:

The 220 V AC line voltages is rectified by a bridge rectifier and smoothed by a large electrolytic capacitor.

The 50 Hz choke in the input circuit improves an waveform of the input, so that no low frequency distortion is produced on the line voltage.

Carefully designed RFI filters protect the line and the load from the high frequency interference produced inside the power supply.

When the unit is switched on, the electrolytic capacitor is charged via the resistor of the SOFT START circuit, so no large inrush current will flow. As soon as the voltage is sufficiently high the power supply starts working and the series resistor is bypassed by a triac.

The operating switching frequency of 100 kHz has many advantages like small size, light weight, low ripple and fast regulation.

The rectified 220 V (300 V DC) is chopped by the transistors and transformed to a lower voltage. This 100 kHz power converter is of the feed forward type. The regulation is achieved by pulse width modulation.

Careful design, over-rating of vital components, several built-in protections and cool operation (because of the very high efficiency) make the SM series very reliable power supplies which can be used continuously at maximum rating. Functional diagram is showing in Fig.1.
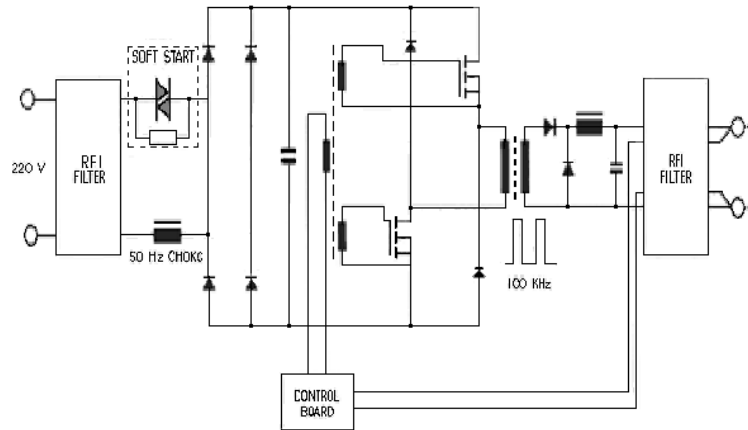
Fig. 1. Simplified functional diagram of SM 1540-D, SM 7020-D, SM 3004-D

The 380 V AC line voltages is rectified by a bridge rectifier and smoothed by a large electrolytic capacitor. The 50 Hz choke in the input circuit improves the waveform of the input, so that no low frequency distortion is produced on the line voltage.

Carefully designed RFI filters protect the line and the load from the high frequency interference produced inside the power supply.

When the unit is switched on, the electrolytic capacitor is charged via the resistor of the INRUCH CURRENT LIMITER circuit, so no large inrush current will flow. As soon as its voltage is sufficiently high the power supply starts to be work and the series resistor is bypassed by a relay contact.

The operating switching frequency of 200 kHz has many advantages like small size, reduced weight, low ripple and fast regulation.

The rectified 380 V (500 V DC) is chopped by the transistors and transformed to a lower voltage. This 200 KHz power converter is of the feed forward type. The regulation is achieved by pulse width modulation.

Careful design, over-rating of vital components, several built-in protections and cool operation (because of the very high efficiency) make the SM series very reliable power supplies which can be used continuously at maximum rating. Functional diagram is showing in Fig.2.
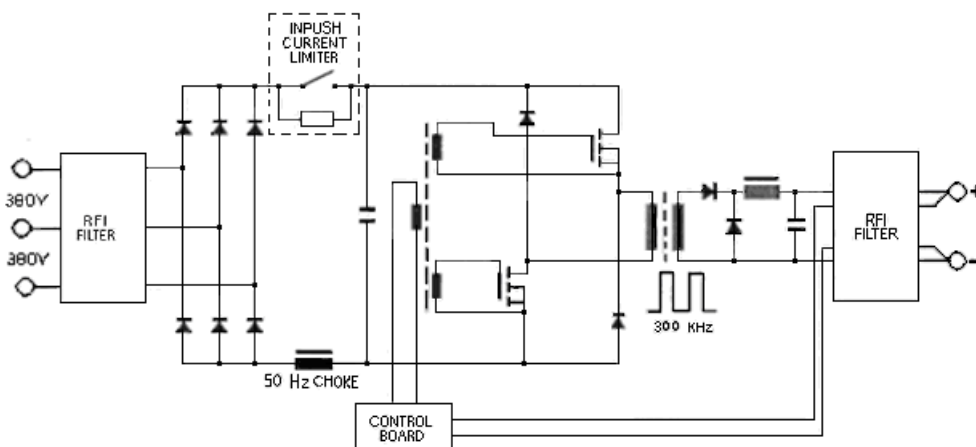

Fig. 2. Simplified functional diagram of SM 15-100-D, SM 15-400-D

For handle of the Accelerator - Microtron, there are two control modes: hand-held and automatic modes.

In the hand-held control mode all process of handle will be carried out by an operator. In the automatic control mode all process of handle will be carried out with the help of the computer, in which the program for control is installed.

Conclusion

For the conclusion, we quote a grateful letter of Director of IPE of Vietnam to the address of Director of JINR:

Hanoi, Vietnam, 23 December, 2005

Dear Prof. Alexei Norairovich,

With the great pleasure I would like to inform you that with the assistance of the scientists your Institute Mr. A.G. Belov, Mr. P.G. Bondarenko and Dr. Nguyen Manh Shat the work on renewing the system of supply sources of the Microtron MT-17 of the Institute of Physics and Electronics, VAST has been completed successfully.

At present the Microtron operates very well and our scientists are able to start their scientific research.

Using this opportunity let me send to you the most sincere thanks for your effective assistance and cooperation and warmest greeting and best wishes.

Let me also experess our sincere thanks to the above mentioned scientists for their active and effective work on the Microtron.

Sincerely yours,
Prof. Nguyen Ai Viet,
Director Institute of Physics and Electronics,

Acknowledgment

Microcomputer operating in extreme conditions for project TUS

Nguyen Manh Shat, Nguyen Minh Nam

Joint Institute for Nuclear Research, Dubna, Russia

Introduction

The TUS space experiment TUS plans to take data in most uncertain energy region $E_o \geq 5 \times 10^{19}$ eV during 3 years by measurements of fluorescent radiation caused by Extensive Air Shower(EAS), which will be initiated by different charged or neutral particles, including neutrinos. The TUS detector has been proposed to address some of one of the most important astrophysical problems: a measurement of the UHECR energy spectrum, a search for UHECR sources, possible explanation of their acceleration mechanisms. Fluorescent EAS radiation will be measured from the low space orbit (400-600 km) doing possible to measure the CR energy spectrum and composition at $E > 10^{19}$ eV.

The electronics of TUS will be designed with low energy consumption ≈ 50 Wt. The on board computer should meet requirements due to conditions in space. It will be dedicated to data acquisition; on-line filtering and 2-nd level trigger elaboration. This microcomputer will also provide for data keeping, must check whole these processes and transfer data to the general-computer, located on the Earth center. It will have to perform on-line slow control functions and receive commands for the TUS management. Thereby, Microcomputer for TUS must be small-dimensioned, compact and working in extreme conditions.

Apparatus

The TUS detector on the RESURS DK1 satellite is shown in Fig. 1. It consists of 2 main parts: the mirror-concentrator of area 1.5 m^2 with the focal distance of 1.5 m and the photo detector of 256 pixels in its focal plane. The Pixels are R1496 Hamamatsu PMTs with the light guides organizing the uniform rectangular retina. Pixel size is 13 mm (respective angle is 10 mrad). The TUS detector has a rectangular field of view (FOV) of 0.16x0.16 rad^2 that corresponds to an area in the atmosphere 56x56 km^2 and pixel resolution of 3.5 km at the orbit perigee height (350 km) and to the area 96x96 km^2 and pixel resolution 6 km at its apogee height (600 km). Optical aberrations in this narrow FOV were simulated and are small. A focal spot size is less than 0.3 of the pixel size. Signals from PMTs go to FE electronic channels which are FADC with a sampling time interval of 200 ns.

The PMT outputs are connected via multiplexer to the ADC+FIFO. The signals from the PMT are sampling with the rate 5 MHz and permanently recording in FIFO. In parallel to ADC the pixel signals come to the trigger system. The signals which are above a given threshold (the threshold value is controlled by the telescope computer program) are analyzed by the trigger system. Selection criteria are tuned to the expected background of light from the night atmosphere at the space orbit (400-600 km). Together with on board computer it will allow to tune PMT thresholds and HV amplifications according to the light background variations, to elaborate the 1-st level trigger decision and to transfer selected data to the TUS computer. Trigger logic is based on the space-time topology of EAS signals in comparison to the other atmospheric events and to PMT and FE electronic noise. The TUS electronics will be designed with low energy consumption ≈ 50 Wt. The on board computer should meet requirements due to the conditions in space. It will be dedicated to data acquisition; on-line

filtering and 2-nd level trigger elaboration. This computer will also provide for data keeping and transfer to the Earth center. It will have to perform on-line slow control functions and receive commands for the TUS management.

The TUS telescope will use UV flash lamp (LIDAR) for control of the atmosphere condition, measurements of the "reflective" Earth surface and for getting of the absolute EAS coordinates.

JINR will also participate in Monte Carlo simulation and in the off-line physical analysis of the raw data including off-line software development.
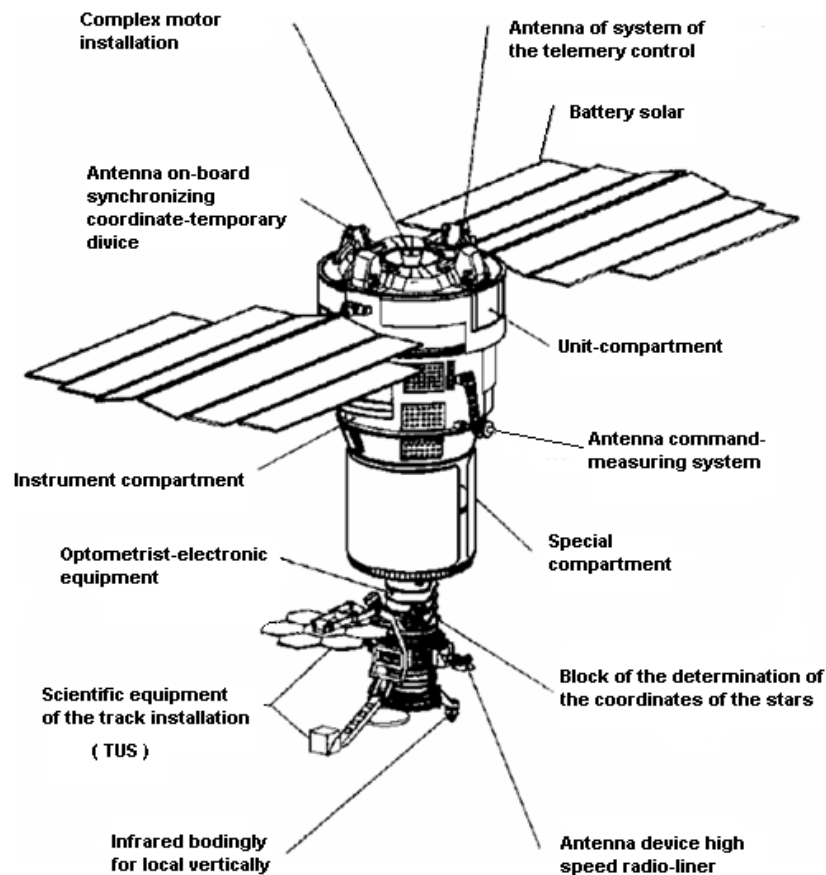

Fig.1. Disposition of the TUS detector on the RESURS DK1 satellite

In addition, JINR will participate in the development, fabrication and testing of FE and digital electronics for silicon detectors, and also in tests of the whole equipment at accelerator beams at JINR, CERN. Block-diagram of the electronic system of the TUS is shown in Fig. 2.
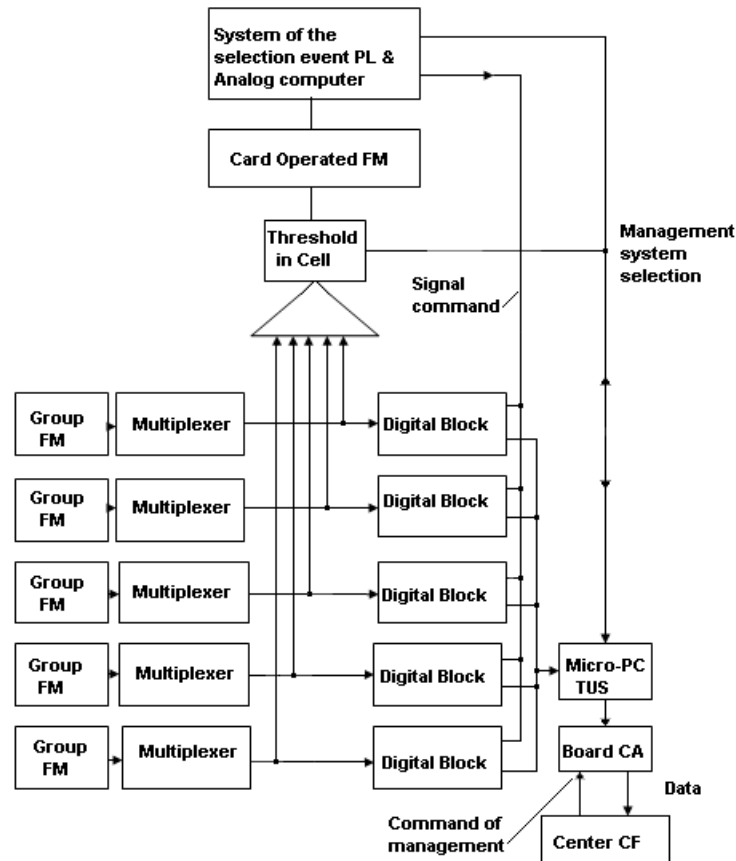
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Fig.2. Block-diagram of the electronic system of the TUS

The Separate task of the micro-computer SDG (system of data gathering) is monitoring procedure of the operation of meshes (the photo multipliers - PM)-PR. The PR (Photo Receiver) is in operating duty on a night side of the earth and is in a "sleeping" regime on a day side. Turning the power "On" and "Off" of the meshes PR is spent with the help of the control photocells having a common stream of light on surface of PR. The data on an average light background (an average current of control photocells) and the data on voltage of power supplies for PR are transferred in the micro-computer. Besides periodically (time of period will be defined during experiment) on a night side control measuring intensities of noise in cell and amplification factor of PEM of each cell are led.

The task of TUS computer is production of the command on measuring of voltage on PEM on the data on an average current of control photocells.

The control data about the operation of PR enter volume of the data transmitted to centre of registration (in an on-board computer).

For the full volume of the flow of information, entering in SDG is preliminary 50 Mb per day.

For increase of reliability micro-PC for TUS at operation in extreme conditions the following measures have been accepted:
- Duplication of operational system of the controller on an additional microcircuit of flash-memory with switching a loading microcircuit on a command, which from the Earth is entered;

- 6-fold duplication of the program of service and OS on each microcircuit is entered flash-memories (SSD0 and SSD1) with check of integrity of the loaded program and consecutive retake its copies before performance of a condition of concurrence of the program with to reference copies;
- For prevention of "lag" of system the sentry timer which automatically reloads system at absence of the response of the loaded program is used within 0.5 seconds;
- Some buffers of information interchange with a board of the satellite chosen in the casual image are reserved at everyone rerun systems.

The nucleus of the program, defining logic of job of the measuring system and the order of interrogation of TUS peripherals, is implemented by means of language Turbo-Pascal. The program unities servicing a direct access to storage, operation of input-output, processing interruptions, and also critical on execution time sites of a code are written also on Turbo-Pascal.

Micro-PC is installed in Micro-BOX shown in Fig. 3.

Fig. 3. Micro-PC is installed in Micro-BOX

Parameters of the microcomputer

1. Computer with processor National GX-1 CPU, 300 MHz, 16K write-back cache, with low energy use.
2. 128 Mbytes SDRAM on charge.
3. Flash-disk 64 Mbytes on charge.
4. Compatibility with DOS, Windows NT/CE (Microsoft), Java-TM (Sun Microsystems), QNX, Linux.
5. Farwell -TM Software BIOS in Flash-memories with standby and option of the quick boot.
6. Compact-Flash 2, 5 inch. Disk on Flash-memories 512 Mbytes (SD25B-256-100).
7. The Possibility of the connection disk Compact-Flash.
8. The Port EIDE for connection 2 NZHMD.
9. Video-adapter SVG c 2D - acceleration and video-memories to 4 Mbytes, permit before 1280x1024 fewer than 256 colors.
10. Built-in support flat ZHK-display.
11. The Built-in controller USB.
12. Universal parallel port with support mode EPP and ECP.
13. Serial ports COM1 (RS-232) and COM2 (RS-232/IR).
14. The Port of the keyboard and mouse...
15. The Watch timer.
16. The Possibility of the quick boot (the minimum 1, 5 sec.).

17. The Average time life lengths on failure less 100 thous. Hours (approximately 12 years).
18. The Operating program (Dos, Opc-FSW-PRS, Universal OPC, Linux, BeOS, QNX and others).
19. The Requirement on feeding = 10 W. (+5 V, maximum current 2 A).

Rugged environmental operation

Operating temperature	- 40º to 70º C
No operating temperature	-55º to 95º C
Relative humidity	5% to 95%
Altitude	100 to 10,000 m
Shock	40g, 3 axes
Vibration	5g, 3 axes
Size	5.75" x 8.0" x 2.0"
Weight	1, 2 kg

Acknowledgement

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Development of databases and interfaces
for CMS experiment

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CMS DB activity is carried out by the CMS sub-detectors groups. ORACLE DBMS has been chosen as a preferable database technology. Data are stored in different databases and it is very difficult to support and update such a heterogeneous system.

Our group has started work within the CMS DB development in the year 2004. At the first stage of the activities we collected information about the detector, investigated data structure and data relations and analyzed the end-user needs [1]. The subject domain considered is very extensive and complex. Informational requirements of the participants change, vary and extent permanently. It is difficult to consider all those factors in the varying conditions and create a static relational model for all the detector parts. The main task was to create an informational system which allows one to describe the changeable and unspecified subject domain.

The second stage was started in 2005 with the development of the storage system for the equipment information (equipment logs, tests results, unstructured information in the files). Usually, the application of the relational approach for the model description is a typical decision for databases creation, but in this case it is necessary to change the data structure essentially because of the new objects coming. Moreover, this approach can not be applied due to a very large quantity of different kind equipment. Thus, to design the databases structure, an abstract description method has been applied for the detector elements [2]. As a result, a new extensible database structure has been developed. Also the first realization for Endcap Muon System database and the initial filling of Endcap Hadron Calorimeter database have been done. All the activities were accomplished in the cooperation with sub-detector developers.

The informational system developed has such powerful properties as flexibility, adaptability and efficiency. The Equipment database could be considered as a core of the informational system. It is located at the basic level of the databases structure. It is independent of the equipment unit physical model. The DB supports storing of tests results and accompanying documentation, input of new data and informational search by many criterions. Information about equipment involves unstructured data like document files, images, raw data and so on [3], [4].

The DB structure considers the hierarchical relations (see Fig.1). It gives the opportunity to store information about relations between the equipment elements.
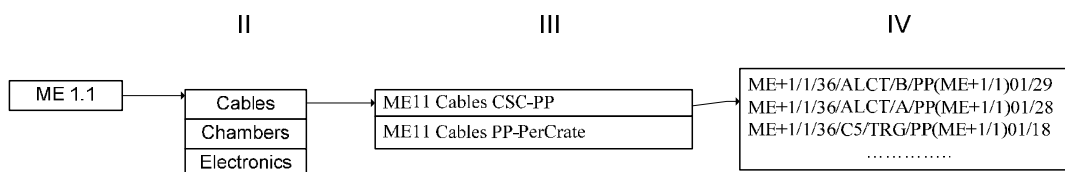

Fig.1. Equipment Hierarchy Levels

At the group level: the general parameters set and values for all equipment of the given group are defined. For example:

Cables: Chamber position [ME 1.1 position], Cable type [ALCTA, ALCTB…], Disk [YE+, YE-].

At the subgroup level: the characteristics set specific to the given subgroup is defined. For example:

Cables: ME11 CABLES CSC-PP: Start Point (CSC), End Point (Patch panel), Length.

At the equipment description level: relations to group attributes values are created, characteristics values are defined. For example:

Serial number: ME+1/1/14/LV/PP(ME+1/1)08/2,

Cable type LV,

Chamber ME+1/1/14,

Disk YE+1,

Start point (CSC) ME+1/1/14,

End Point (Patch panel) PP(ME+1/1)08/2,

Length (m) 2.25.

The analysis of the requirements and the objects of the subject domain under consideration allowed one to define a full basic entities set of the designed database. The database conceptual model was constructed as a result of these activities. Such an approach provides an opportunity to store the information on any equipment. Elements have been defined by groups and subgroups. The general parameters with a fixed value set have been revealed for the each group of elements. Specific attributes sets have been defined for each subgroup. The general DB logical model is shown on Fig.2.
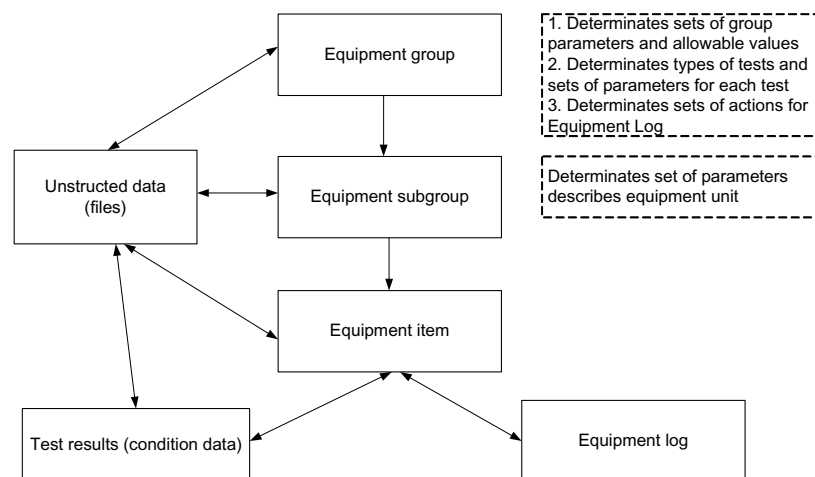
Fig.2. DB Logical Model

In the user's view, all information has a direct link to the detector equipment: unstructured files; group parameters and values; equipment unit properties; equipment logs; tests results. Fig.3 illustrates a complete Equipment DB structure. The tests results are described in the area marked by a red left large oval. The authorization part has been selected by the cyan small circle at the right top. The equipment logs are described in the area marked

by a green central oval. Unstructured information area has been selected by a blue oval in the right. The not marked area describes the equipment at all the hierarchical levels.

With the usage of C++ to Oracle API it is possible to add, update, delete and select information. Selection can be done by several parameters: Tile code; Date; Date interval; Data processing operator name.

Web-interface provides the initial filling of database, different access levels for users, information search on different criterions, adding and updating data (Fig.4).

The opportunity to support equipment logs (traveler lists) is realized. The events occurring with equipment elements are fixed in the traveler lists. The equipment log provides a possibility of event registration like installation, maintenance, etc. The lists of events are defined for each the equipment group.

A lot of information is provided in an unstructured form: *Special raw data; Images; Files.*

Such data sets as files can be connected with each the equipment element, group or subgroup. Files can be united into the folders. The tests results storage has been realized. The tests techniques can be defined for the each equipment group. There are tested parameters sets for the each technique. Testing results are grouped in the revisions. The files group can be connected to the test in the revision.

Fig.3. DB Structure

To manipulate this kind of data, a special subsystem connected with the mass storage system has been developed (see Fig.5).

Different types of interfaces to DB were realized:
- – WEB interface;
- – API interface to conditions data;
- – O2O interface.

Due to specificity of the DB scheme, API interfaces for different sub-detectors have been organized in different ways. Now the API interface to HE calibration data is fully realized. API is based on OCCI.

O2O (online to offline) — data transmission procedure from online (relational) DB to offline (POOL) database. Current realization of O2O code has been done in the frames of CMSSW package. The OCCI interface is used for accessing to OnlineDB (Oracle) and access to OfflineDB is provided by PoolDBOutputService.
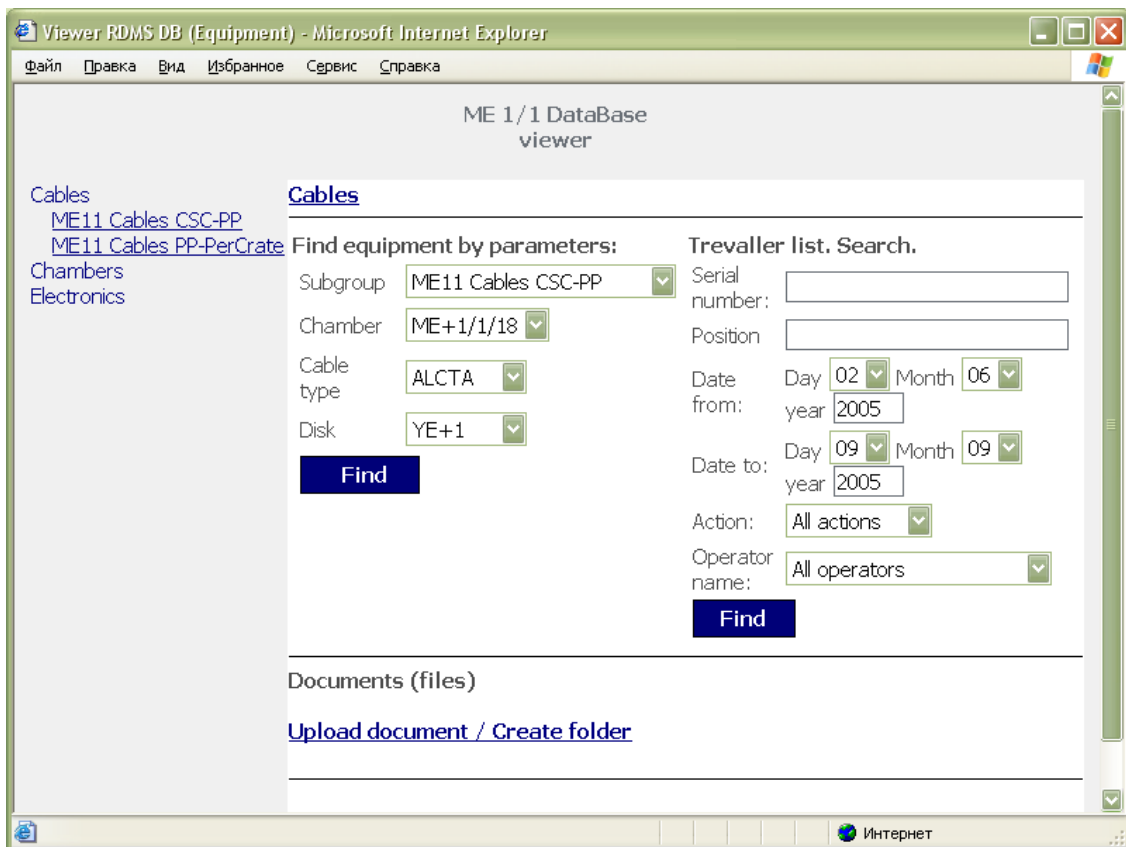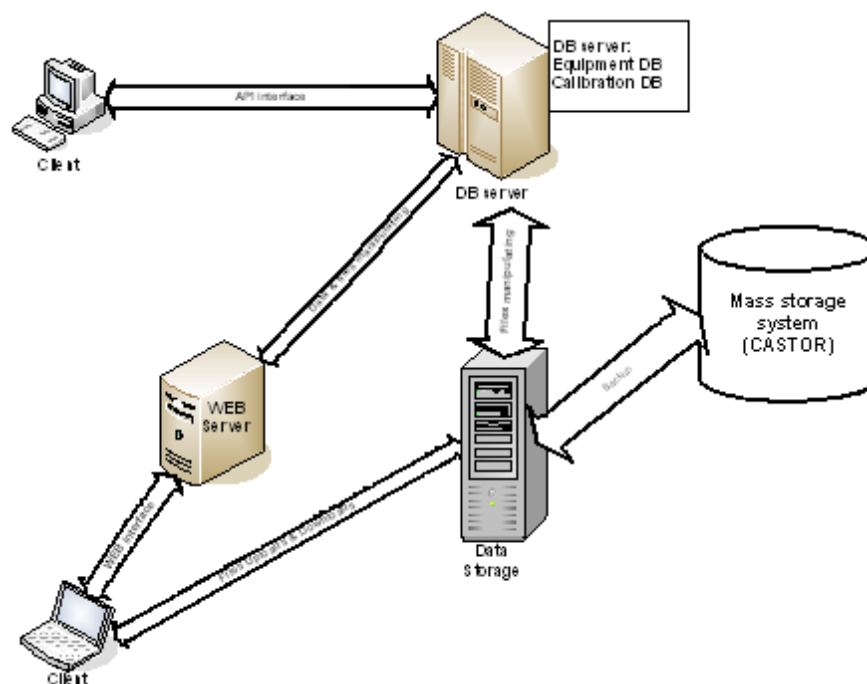

Fig.4. Equipment DB Web-interface

Fig.5. Information System Scheme

It allows one to be connected to DB both by API interfaces and Web-interfaces. The reserve copy system is in operation.

A current statistics on database capacity, available disk storage and data volumes is shown in Table 1.

Table 1. Statistics

Database	Current capacity: 1.2 GB
Disk storage	Capacity: 42 TB disk massive at JINR (dCache)
	0.4 TB buffer storage at CERN + CASTOR resources
Data volumes	Database: 30,000 records (~ 500 MB)
	Raw files: 600 GB

Currently we work at unification of the Muon CSC equipment and construction DB. Database will contain all the information about chambers, electronics, cables and other equipment; relations between equipment (tracking) and tests results.

The nearest plans are the following:
✓ Positive feedback to the constructed pre-production operations database to deploy it into production;
✓ Software development for the updating of chambers test results from files;
✓ Structure creation for the additional electronics information storing;
✓ API development for access to the initial electronics calibration constants;
✓ Continuation of DB filling;
✓ User interfaces improvement.

An expected growth of data volumes:
- up to half million of the records (5 GB) in DB;
- up to 6 TB in raw files.

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Analog electronics for measurement and control

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Some new CAMAC standard–based modules for analog electronics of detectors are presented. The modules have been designed to provide registration of analog signals from detectors and, vice versa, to produce analog signals for control functions. A set of such modules, performing fast conversion of analog information to a digital code (ADC), as well as generation of analog signals from a digital code (DAC), is considered with a list of parameters.

The modular set includes:

- 8-channel 14-bit ADC (8ADC-14)
- The Flash 100 MHz 2-channel 8-bit ADC (2ADC-100)
- 8-channel 10-bit 20 MHz ADC (8ADC-339)
- 16-channel 10-bit Charge Integrating ADC (16QDC-398)
- 8-channel 12-bit Digital to Analog Converter (8DAC-12)
- 48-channel 8-bit Digital to Analog Converter (48DAC-348)
- 16-bit Digital to Analog Converter with internal memory (DAC-349)

All appliances have been designed and used for a series of experiments at Nuclotron (the beam diagnostics, DELTA, LNS) in the Laboratory of High Energies (LHE JINR) and in other setups.

The **8ADC-14** is a 14-bit, 8-channel Analog to Digital Converter to sample analog signals, applied to the input connectors. Measurements start on GATE, initiated by an external pulse from the front panel or by the CAMAC instruction, that cause the signals to be stored into the "Track and Hold" circuits and converted by the ADCs. The obtained digital data codes, written down to output registers, can be read out from the CAMAC R1-R14 bus lines (Fig.1). The module is implemented as a single width CAMAC unit.
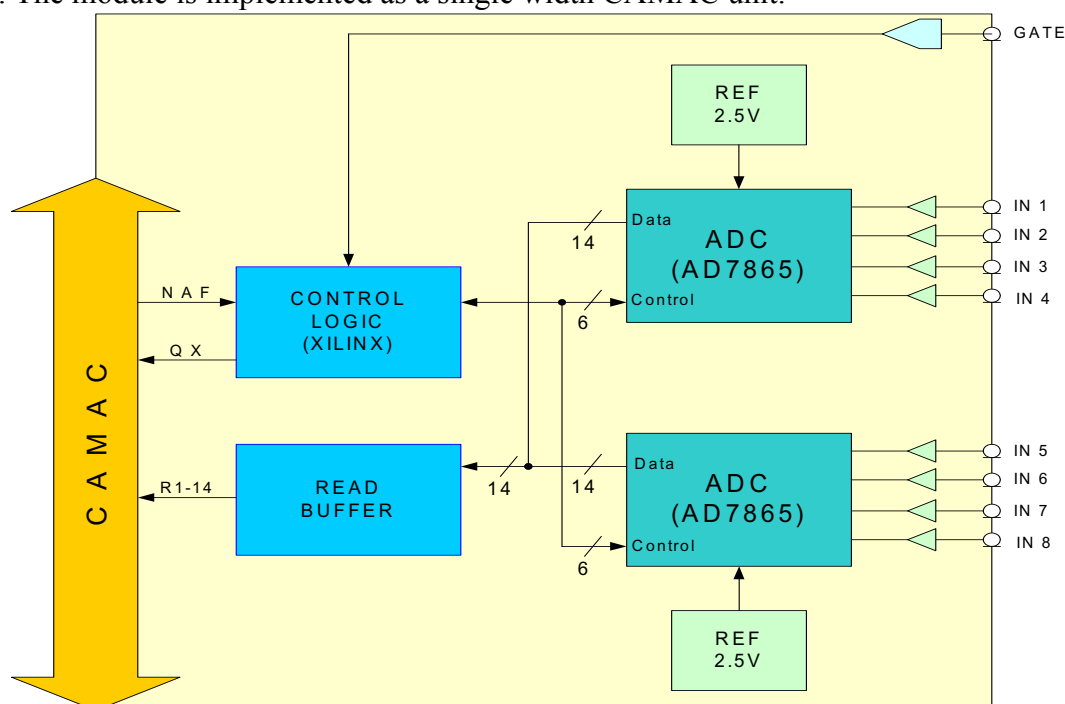

Fig.1. Block diagram of the 8ADC-14 module

General Technical Parameters of the 8ADC-14:
Analog Inputs: 8 Channels
Resolution: 14 bits
Input Voltage Range: $\pm$ 5,0V
Integral Non-linearity: $\pm$ 1 LSB
Differential Non-linearity: $\pm$ 1 LSB
Conversion Time: 10 us
Maximum Voltage Drift: 1,5ppm/C of F.S.

The **2ADC-100** is a Flash ADC, housed in a 1-unit wide CAMAC module, which implements the functions of 2-channel 8-bit voltage sampling Analog-to-Digital Converter (a functional block diagram is shown in Fig. 2). The 2ADC-100 converts an analog voltage within a range from -0.5 V to +0.5 V. Each channel is equipped with a memory, holding the 32 Kbytes of data samples. The module operates by an external CLOCK signal, at a frequency of 20 - 100 MHz, through the LEMO connector, housed on the front panel. Each input signal is converted to an 8-bit word and stored in the memory buffer after receiving of a START pulse. The conversion stops when the memory was overfull and the LAM signal was generated. This module is able to work at the 200MHz rate (when it uses both rise and fall edges of the Clock) [1, 2].
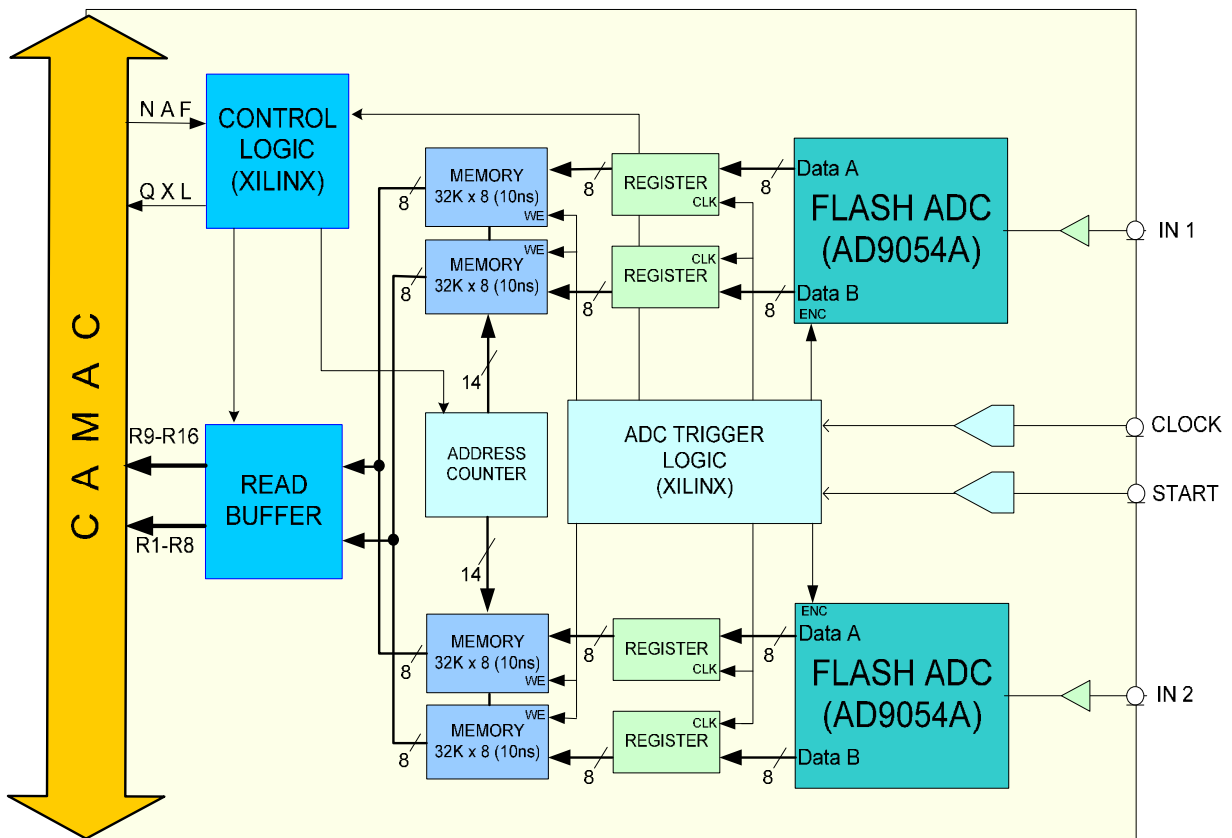

Fig.2. Block diagram of the 2ADC-100 module

General Technical Parameters of the 2ADC-100:
Analog Inputs: 2 Channels
Input Impedance: 50 Ohm
Input Range: $\pm$ 0,5V

Resolution: 8 bits
Integral Non-linearity: $\pm$ 0,5 LSB
Differential Non-linearity: $\pm$1 LSB
Conversion Rate: 100 MHz
Memory Depth: 32Kbyte per channel
Start: External (NIM)
Clock: External (NIM) 25 – 100 MHz

The **8ADC-339** is a single width CAMAC module with the 8 Flash ADC channels, those are suitable for pulse analysis. Each channel includes the 20MHz 10-bit ADC chip and the 32Kword memory [3]. The module operates by an external CLOCK at a frequency up to 20MHz. On a START pulse received, the input signals are converted by the ADCs into 10-bit words and stored in the memory by each CLOCK signal. The conversion stops when the memory was overfull, with the LAM generated, or after the STOP signal has come. The block diagram is shown in Fig. 3.

General Technical Parameters of the 8ADC-339:
Analog Inputs: 8 Channels
Input Impedance: 1 kOhm (or 50 Ohm)

Input Range: 0 to +2V

Resolution: 10 bits
Integral Non-linearity: $\pm$1 LSB
Differential Non-linearity: $\pm$0,5 LSB

Conversion Rate: 20 MHz

Memory Depth: 32Kword per channel
Start: External (NIM)
Stop: External (NIM)
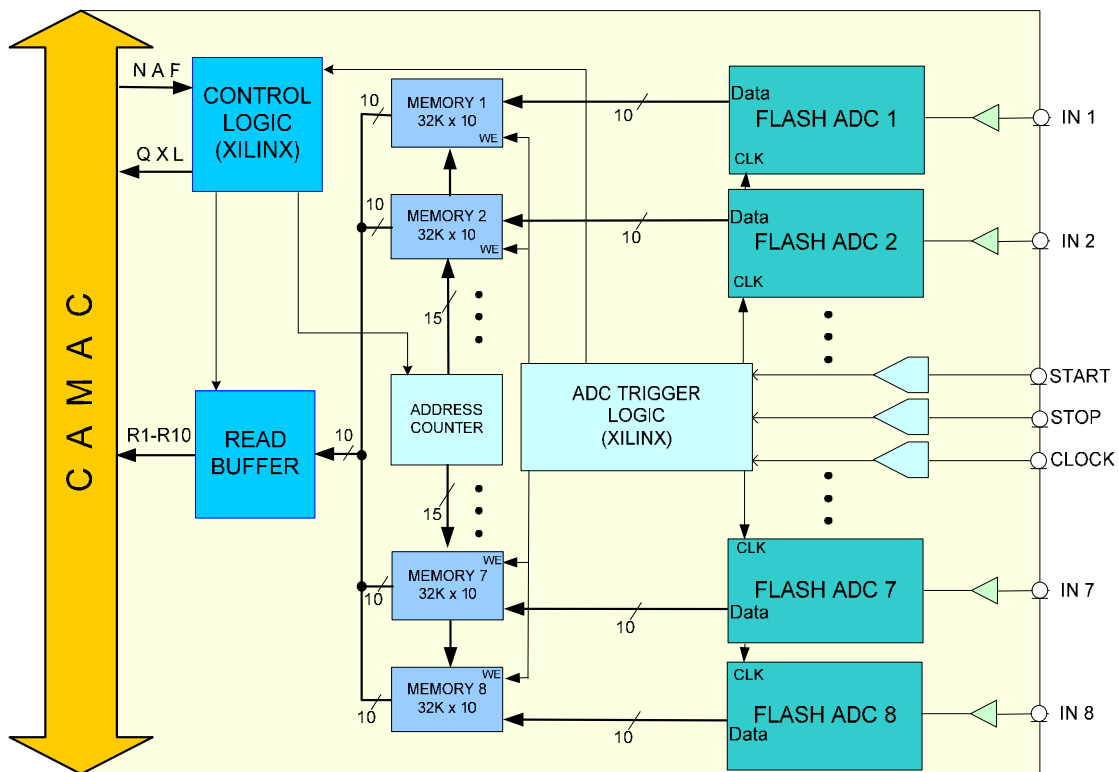Clock: External (NIM) 1 - 20 MHz

Fig.3. Block diagram of the 8ADC-339 module

The **16QDC-398** contains sixteen complete 10-bit integrating ADCs (QDCs) in a single width CAMAC module. Each ADC has a resolution of 10 bits to provide 0.1% resolution over a whole 1024-channel dynamic range. The input sensitivity of the 16QDC-398 is 0.5 pC/count for a full scale range of 512 pC. This is compatible with the most available signal sources. No additional buffering or reshaping of any kind is required to digitize nanosecond pulses. An input charge is integrated during the Gate interval and the result is stored by a fast integrator. The Gate duration can be ranged from 10ns to 500ns. At the end of the Gate an amplitude from the integrator is converted by the fast ADC, and the result is stored into the Register or into the 16-word 11-bit FIFO. At the end of conversion (or when FIFO is overfull), a LAM signal is generated. A block diagram of the 16QDC-398 is shown in Figure 4 [4].
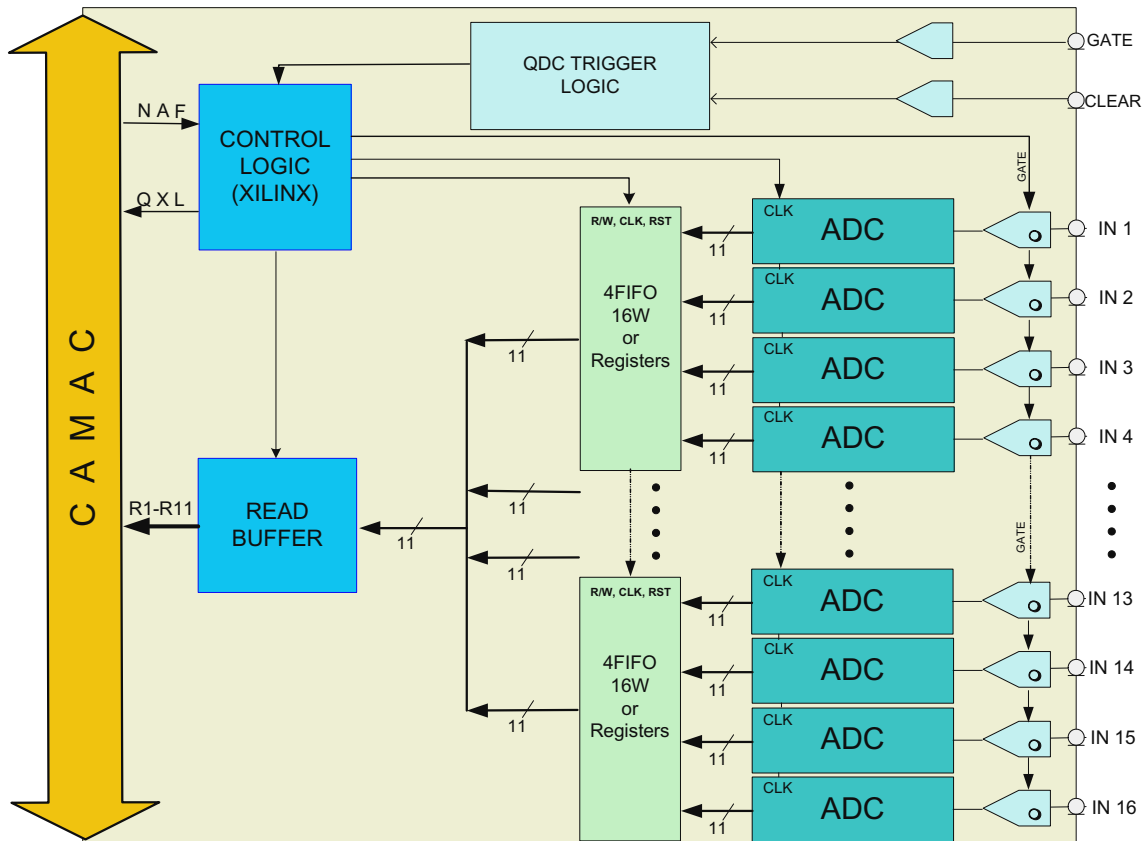

Fig.4. Block diagram of the 16QDC-398 module

General Technical Parameters of the 16QDC-398:

Analog Inputs: 16 Channels;
                        Impedance - 50 Ohm;
                        Linear range 0 to –2V
Full-Scale Range: 512 pC $\pm$ 5%
ADC Resolution: 10 bits +1 bit overflow
Integral Non-linearity: $\pm$0,5 LSB
GATE Input**:**   One gate common to all ADCs Integrators (LEMO type connector);
                        Impedance -   50 Ohm,
                        Levels   -   NIM
                        Duration   -   10 nsec - 500 nsec
CLEAR: Clear registers; common to all ADCs (LEMO type connector);

Impedance -   50 Ohm,
              Levels   -   NIM
              Duration   -   min 30 nsec
Digitizing Time: 700 nsec after the end of the Gate
Readout Time: Readout may proceed at the fastest rate permitted by the CAMAC
                       standard after digitization is complete.

The **8DAC-12** is an 8 channel 12-bit Digital to Analog Converter, where the outputs are digitally programmable through CAMAC bus. The CAMAC W-lines are used to set a voltage value to be stored in one of eight DACs, selected by the subaddress A-lines. The values, stored in the DACs internal registers, could be read out back to the 12 CAMAC R-lines. Powering on, or CAMAC resetting, lead to all output voltages go to zero until the corresponding channels were written by CAMAC functions. The module is implemented in a single width CAMAC unit. A block diagram of the 8DAC-12 is shown in Figure 5.

General Technical Parameters of the 8DAC-12:

Analog Outputs: 8 Channels
Resolution: 12 bits
Output Voltage: 0…+4,096V or 0…+5,0V (depends on Vref and adjustable via trimmer)
Maximum Output Current: 20mA
Short circuit protection
Integral Non-linearity: ± 1 LSB
Differential Non-linearity: ± 1 LSB
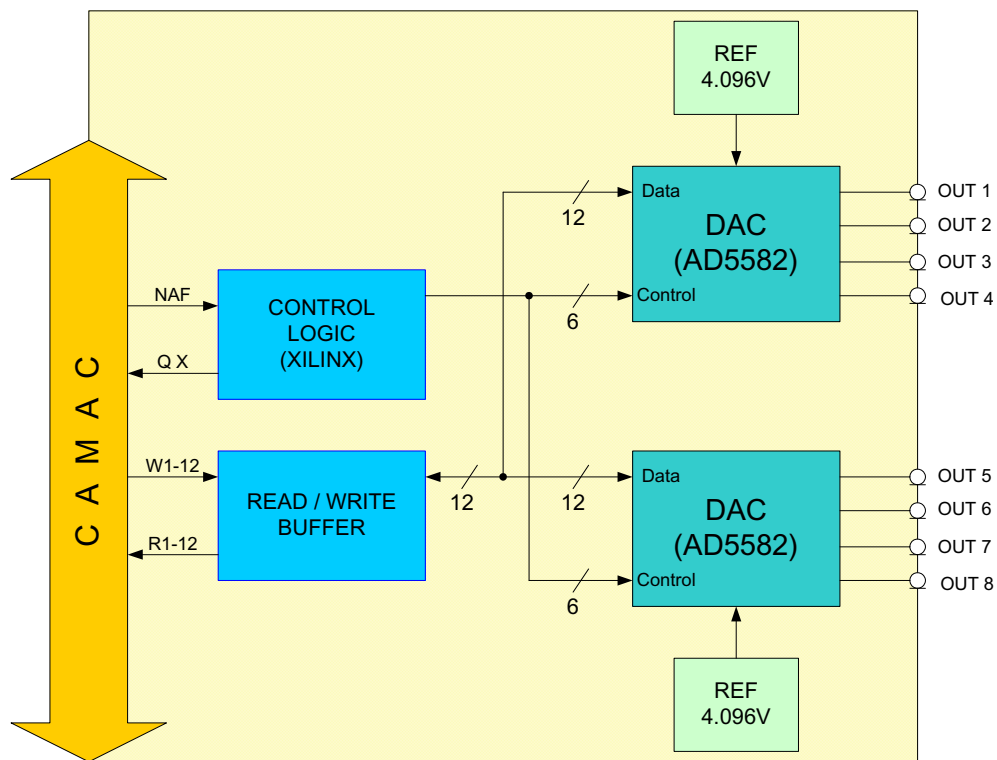Settling Time: 6 us
Maximum Voltage Drift: 1,5ppm/C of F.S.

Fig.5. Block diagram of the 8DAC-12 module

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The **48DAC-348** is a single width CAMAC module to generate current (voltage) signals thru 48 outputs (see Fig.6). The standard output range is from 0 to 10mA per channel. An 8-bit register is provided for each channel. The output settling time is less than 4us. The values, stored into the DACs internal registers, might be read back thru the 8 CAMAC R-lines. Powering on, or CAMAC resetting, clear all outputs down to zero. A number of these modules has been used at the DELTA spectrometer and applied to control HV power supplies of the photomultipliers [4].

General Technical Parameters of the 48DAC-348:

Analog Outputs: 48 Channels
Resolution: 8 bits
Output Current: 0…10 mA
Integral Non-linearity: $\pm$ 0,5 LSB
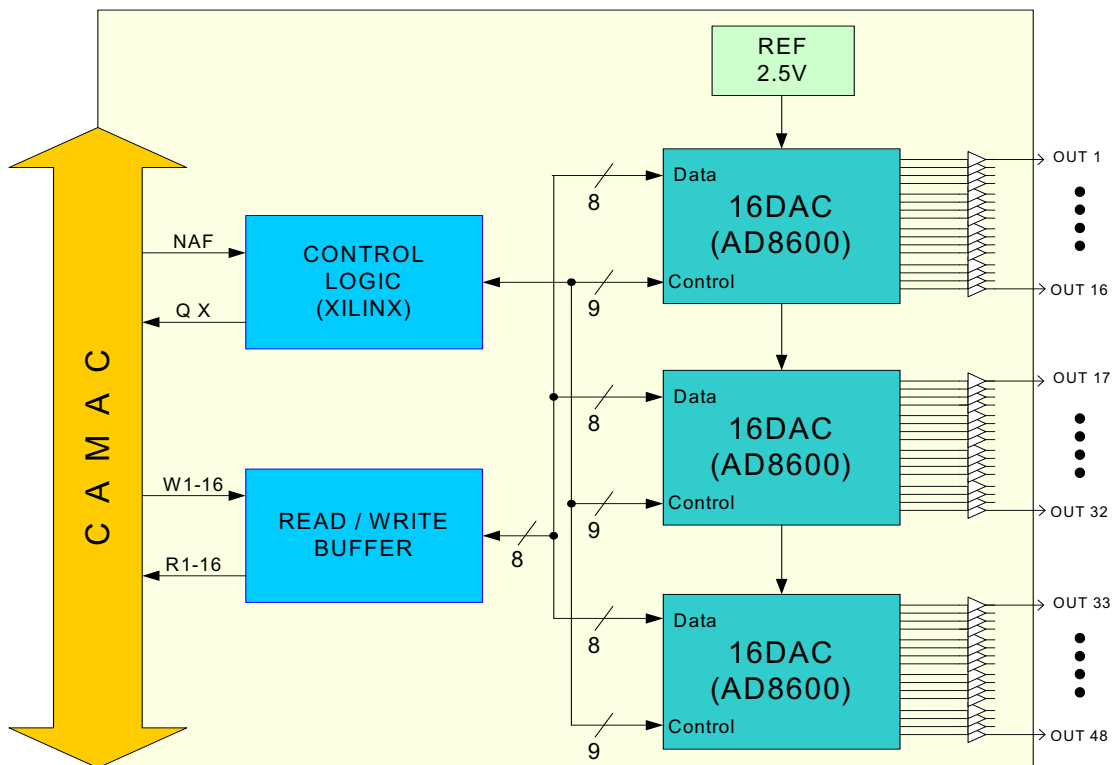Settling Time: 4 us
Short circuit protection

Fig.6. Block diagram of the 48DAC-348 module

The **DAC-349** is a single width CAMAC module, which contains 16-bit Digital to Analog Converter with a Buffer Memory. It includes the multiplying DAC, allowing one to operate with an external reference voltage of the $\pm$ 9V range. The standard output range is from –9V to +9V at maximum 10mA. The output settling time is less than 16us. The conversions are triggered from the CAMAC Dataway or from the front-panel inputs (STROBE, RESET). A block diagram of the DAC-349 is shown in Figure 7. This module is used as a precision function generator, producing the accurate voltages to control of the Nuclotron accelerator frequency [3].

General Technical Parameters of the DAC-349:

Analog Output: Multiplying DAC
Resolution: 16 bits

Input Reference: -9V to +9V (or internal reference)
Output Voltage: -9V to +9V (depends on VREF IN)
Maximum Output Current: 10mA
Short circuit protection
Memory Depth: 256 words (or 1024 words)
Integral Non-linearity: $\pm$ 2 LSB
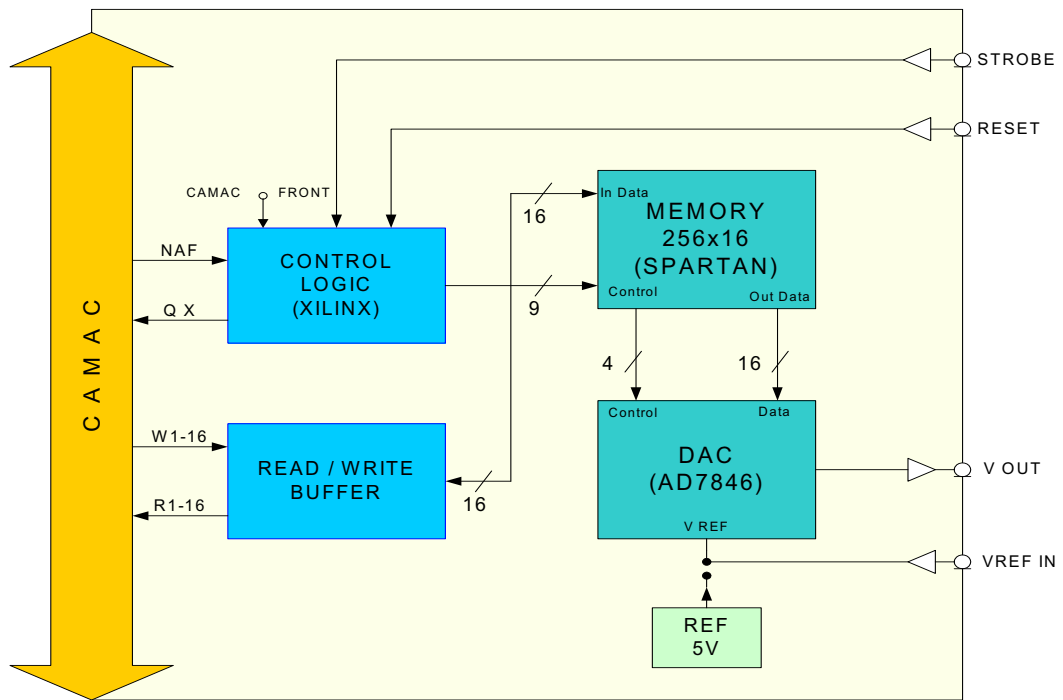Differential Non-linearity: $\pm$ 0,5 LSB
Settling Time: 16 us

Fig.7. Block diagram of the DAC-349 module

Fig.8. View of the ADC and DAC CAMAC modules reported

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On-line monitoring system of the Dubna Gas Filled Recoil Separator

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Abstract

An integrated system of on-line monitoring of the main parameters of the experiments aimed at the synthesis of the superheavy elements is presented. The experiments with the heavy transuranic targets were carried out employing the Dubna Gas-filled Recoil Separator (DGFRS), with the beams delivered by the U400 cyclotron at Flerov Laboratory of Nuclear Reactions (FLNR, JINR, Dubna). The system includes three components, i.e., the visualization system of the spectrometric information of the DGFRS detection system, the control system of the parameters of the DGFRS detection module, and the system to monitor the parameters of cyclotron beam, as well as the other technical systems (partially being under development). In particular, an algorithm of the real-time search of the correlated events is discussed.

1. Introduction

Since the end of the last century the DGFRS control system is in use[1]. It allows measuring a definite number of parameters associated with the separator, detection module and the intense heavy-ion beam provided by the U-400 cyclotron. The goal of the present paper is to present some modifications of an upgraded system, which is under development now. Some tests of subsystems and modules are in progress now.

2. Main technological parameters in the long-term experiments at the DGFRS

During long term experiments at the DGFRS the present system will measure a set of parameters and generate some "alarm indication/forthcoming actions", like:

- Dipole magnet current and external temperature at the magnet pole;
- Current values in both quadrupole lenses;
- Rotation speed of the entrance window (1.5 μm Ti foil);
- Rotation speed of the target;
- Pentane pressure in the TOF module[2];
- Temperature of oil-free VARIAN vacuum pump;
- Temperature in the spectrometer room;
- Energy of ions from cyclotron (time-of–flight measurement);
- Vacuum at the position close to the DGFRS rotating entrance widow;
- Vacuum in the separator during evacuation;
- Cyclotron beam intensity;
- Some others parameters.

The block-diagram of the CAMAC/PC based system is shown in Fig.1.

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[1] Designed by V.G. Subbotin, A.M. Sukhov and I.M. Sedykh (not published)
[2] With autonomous alarm device to prevent the destruction of the Mylar foil separating the module from the separator.
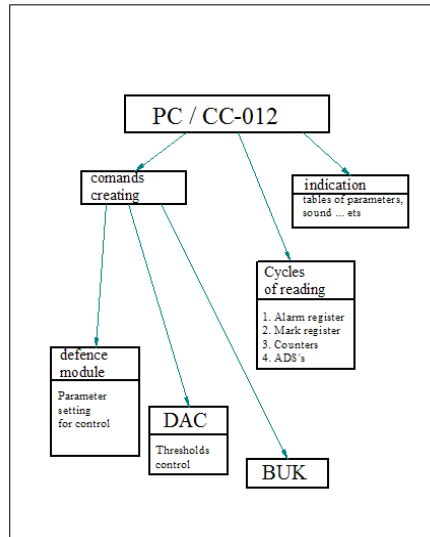
Fig. 1. Block-scheme of the CAMAC based DGFRS monitoring system

As concerning the operating code, it will be written in C++ (Builder 3 or/and 6). Some fragments of the code are already and tested in the experiments with heavy ion beams at U-400 cyclotron. As an example of its application, in Fig.2 the long term behavior of ^{48}Ca ions TOF value is shown against the elapsed time value. In Fig.3 the parameters both separator hydrogen pressure and pentane pressure in TOF detection module are shown.
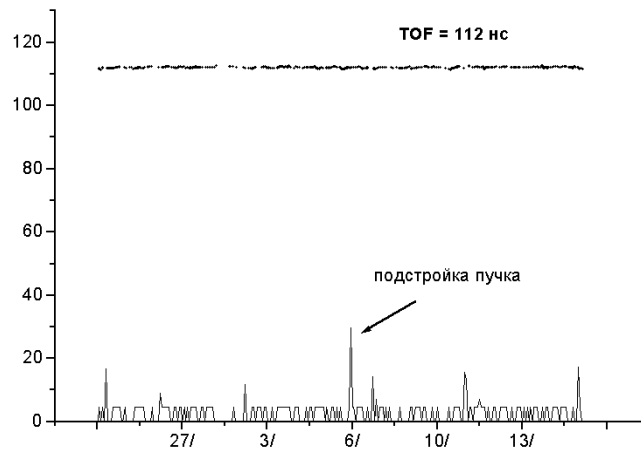

Fig. 2. Long-term measurement of ^{48}Ca ion time-of-flight value. X-axe, days; Y-axe, ns. Bottom graph: U-400 cyclotron tuning is shown by peaks (is taken from protocol text file)
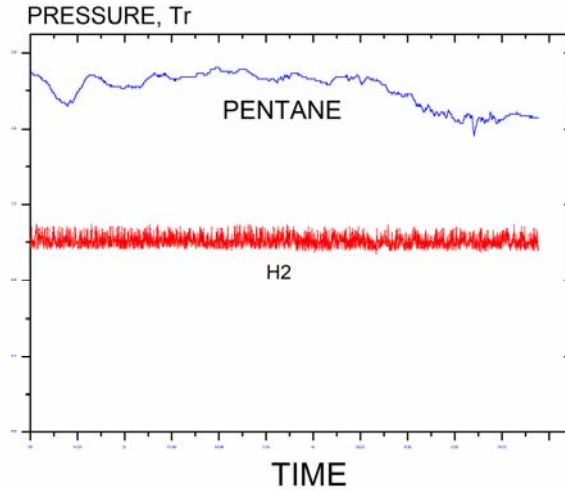
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Fig. 3. Low pressure (pentane and hydrogen) measurements. Full time scale is about one month. One vertical axe division is equal to 0.2 Torr

3. Summary

The upgraded on-line monitoring system of the main parameters of the DGFRS is presented. Some units, both electronics and C++ code are tested in the experiments with heavy ion. We plan to finish the upgrade during 2008, including beam tests. Authors do not exclude that the list of parameters under control will be extended after the beam tests.

4. Acknowledgements

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Magnetic-field meter based on Field Hall Sensor

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Abstract
  A magnetometer prototype operating in a wide range of magnetic induction under extremely high radiation and temperature conditions, is presented. The magnetic sensitive element combining properties of a usual Hall sensor and of a specific two-gate MOS unipolar transistor, is used as the magnetic field sensor.

Field Hall Sensor (SOI MSE)

Activities on project[1] "Controllable magneto sensitive sensors intended for operation in extreme physical fields" are now carried out at JINR LPP by the collaboration of RIPT (Moscow) and IMT RAS (Chernogolovka). The purpose of the given project is to design prototypes of magneto metric equipment with an increased magneto sensitivity and operational reliability under conditions of high radiation and/or temperature fields intended to operate in a wide range of magnetic induction. Making such instrumentation is of interest for different branches of science, technique, medicine, and, in particular, for magnetic field monitoring in a wide range of induction density at the world largest research centers. This magneto metric equipment should operate not only under conditions of high radiation (up to 1 MRAD and more) at different (including cryogenic) temperatures, but also in a wide range of induction density (up to several Tesla).

Now magneto resistors and Hall sensors are commonly used as magneto sensitive elements (MSEs) for magnetic fields detection. However, these traditional MSEs are characterized by a number of demerits that essentially limit their use in detecting magnetic fields of a wide dynamic range under the above extreme conditions. A narrow dynamic range of the magneto resistor sensitivity and a poor temperature range of Hall sensors operation, are some of these demerits or limitations.

In this connection, within the framework of the project it is necessary to design a new magneto sensitive element, which should combine high magneto sensitivity in a wide dynamic range with operational reliability under extreme radiation/temperature external conditions. Preliminary researches carried out by one of the participants of the project (IMT the Russian Academy of Science) have shown, that this problem can be solved by making a new MSE combining properties of a traditional Hall sensor and of a specific two-gate unipolar transistor of the MOS type. The magneto sensitive element will be fabricated on the basis of the «silicon on insulator» (SOI) structure (1,2,3,4) where a thin silicon layer is separated from a silicon substrate by the embedded insulator layer. The construction of the developed element will be a four-pole variable silicon resistor with a two-gate multilayer (metal-insulator-silicon-insulator-metal) control system, which responses to the magnetic field as the Hall effect. In this case the upper gate, which is similar to a usual MOS transistor, is formed on the insulating film located on the outer surface of the silicon layer of the SOI structure. The embedded insulator layer of the SOI structure and the silicon substrate are operating as the lower gate. Preliminary studies of the SOI Field Hall Sensor have shown that the field control of MSE performances can provide the following:

- Widening of the dynamic range of the SOI MSE magneto sensitivity up to 10^{-7} … 1,5 T, which is inaccessible for conventional silicon magneto sensors and magneto resistors;

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[1] International Science and Technology Center (ISTC), Project №2881.

- Operating in the temperature range unavailable for traditional MSEs (from cryogenic up to $150\,^0$C and more);
- Field controlling of the magneto sensitivity temperature dependence coefficient;
- Minimization of power consumption (the operating current of the SOI MSE is by 10 … 1000 times smaller, than any of other semiconductor Hall sensors or magneto resistors);
- Improvement of the SOI MSE radiation hardness due to various versions of electronic circuits of output signals processing, ensured by the two-gate system.

Electronics

On the basis of MSE a maket of a three-channel magnetometer has been developed which operates in one line with a computer. The range of the magnetic field under measuring is from 3x10-6Tl till 1.5Tl. A structural scheme is shown in Fig.1. The magnetometer has been manufactured as a movable device, which has three identical channels to control SOI MSE and measure the Hall voltage, a microcontroller and a supply source.

Each channel includes the following:

- a movable measuring hand with SOI MSE;
- an input differential amplifier;
- an analogous-digital transformer (ADC);
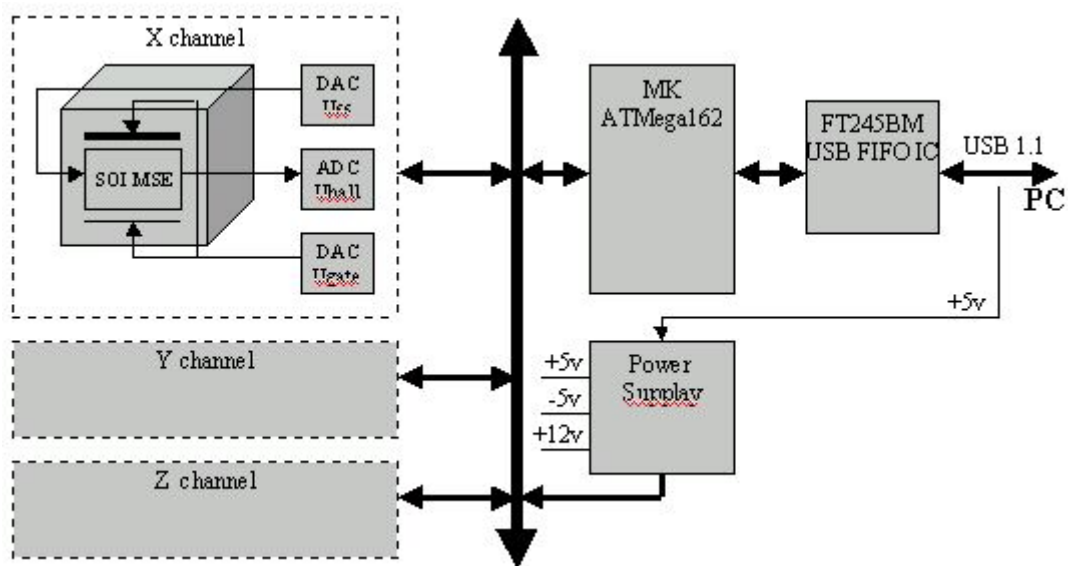- a voltage supply source SOI MSE.

Fig.1. Block-scheme of three-channel magnetic-field meter prototype on Field Hall Sensor

The input differential amplifier was made on the doubled precision OY (AD 8552). The amplification coefficient is equal to 10 and 100 and switched on/off by means of a rele. The sinphase noise damping coefficient is equal to 130dB. The measured Hall voltage is transformed into a digital type by using a 14-bits ADC (AD 7894-3). The total time of transformation and transmission of the data in the consequent code into the controller, is 10mcS. The controlling voltage onto the MSE shut for each channel is given from the 16-bits DAC (AD 5541). The supply voltage for all the three MSE forms a 12-bits DAC (AD 8300)

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to reduce the temperature drift of the measuring track, all the ADCs and DACs of the magnetometer are supplied from one and the same support voltage (REF192).

The microcontroller forms the controlling voltage for each of the channel, takes the data from the ADC in the consequent code, accommodates the data and their mathematical processing, carries out the computer connections. A microscheme ATMega162 made by firm Atmel is used as controller and is a RISK processor optimized for work with high level languages. The program memory volume is 16Kb, the operational memory is 2Kb. The program is provided for the microcontroller by the language "C". The connection between the controller and personal computer is carried out by interface USB. The interface microscheme of the type FT245BM by firm FTDI is used to provide the USB version 1.1.

All the devices of the magnetometer are supplied from the ordinal voltage of the USB interface supply that makes the magnetometer energy independent.

The SOI MSE of each channel is tuned in the reference magnetic field on the magneto metrical stand at the Laboratory of Particle Physics, JINR by using the YMR-Magnetometer. The transmission characteristic of the SOI MSE is linearized by means of the second degree polynomial approximation on the least square method. The sight of the polynomial is as follows:

$$\kappa = A*x^2 + B*x + C,$$

where k - the magnetic field volume; x - the voltage value at the MSE output, given in quantum of the DAC; A,B,C - polynomial coefficients.

The coefficients of each channel are calculated by the service program and stored in the energy independent memory of the microcontroller.

Magnetic-field meter software

An application MAGMETR was made in Delphi7 for Win XP/NT/2000/98 to exchange with a magnetic-field meter on USB 1.1 protocol (12Mbit/sec), to tune the pick-up mode and the measurement process. Program USB interface is realized by FTDIs 'D2XX Direct Driver' by firm FTDI, original class with methods for exchange with the device and two threads for asynchronous read/write on USB. Architecture of D2XX drivers consists of a Windows WDM driver that communicates with the device via Windows USB stack and a DLL which interfaces the application software to the WDM driver.

The main application form allows one to select the following:
- the device mode (channels calibration or field measurement);
- the Field Hall Sensor mode;
- the timing conditions;
- the active registration and visualization channels number.

Field Hall Sensor control is carried out on the auxiliary form by setting every of 4 DAC voltages (0 - 9,99V), the power supply voltage and the X, Y, Z measurement channel gate voltages.

Beginning the measurement you must press button 'Connect USB' to select one of FTDI devices on USB bus. Then you should set up Field Hall Sensor mode controlling 4 DAC voltages on the auxiliary form. After pressing button 'Initialization' the prepared 4 ASCII bytes sequence (DAC address + 3 significant digits of voltage) will be written into every DAC and sent the echo. Initialization activates other application control buttons.
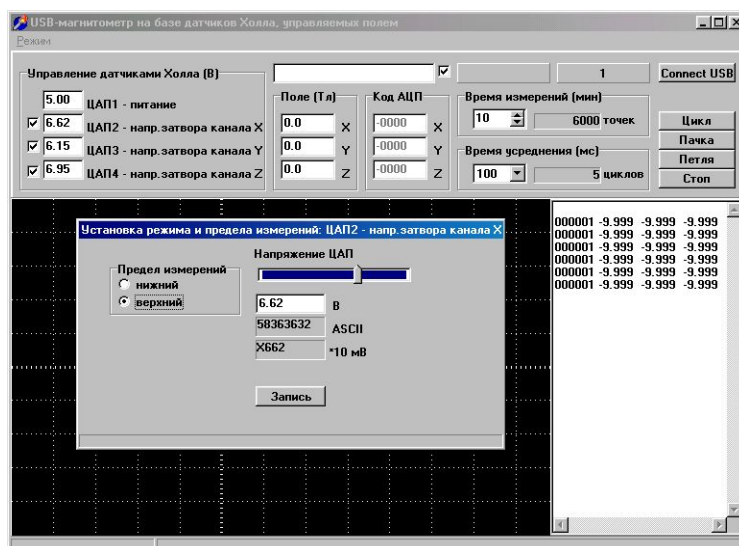
Fig. 2. The main window of application MAGMETR

The measurement results are represented in text fields named 'ADC code', 'Magnetic field', the common list and graphs. Also they are stored in the files. The magnetometer gives a signal every 20 ms. A number of measurement points are defined by correlation between the total time of the measurement and the selected time to calculate the mean quantity in the X, Y, Z channels. The measurement launching may be single (button 'Cycle') or multiple (buttons 'Batch', 'Loop') with a possibility to pause by button 'Stop'. The magnetometer is launched after the start command "S"(53hex) from the computer. After 20ms it sends 19 bytes in response: the start command echo and 6 data bytes per every measurement channel X, Y, Z (address, sign, 4 significant digits of voltage).

The measurement status is reflected on the bottom of the main application form. The current regime parameters and calibration coefficients are stored automatically in files.

Conclusion

The experience of work with this magnetometer has shown that the use of the SOI MSE jointly with the modern electronic elementary base and software can provide a universal, mobile high- sensitivity magneto-metric apparatus resistive to extreme external conditions that can be hardly overestimated for the performance of the physical experiment.

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Control system for electromagnets of LUE-200 accelerator

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Abstract

The control system for electromagnets of LUE-200 accelerator electron beam line is described in this article. The system is based on power supplies specially developed in the Budker Institute for Nuclear Physics and high current power sources from Bruker Company. The system is controlled by means of the CAN-bus. The control software is realized in Labview graphical development environment.

Hardware

For electromagnetic focusing and correction of beam position in LUE-200 [1] accelerator electron beam line a set of electromagnets were constructed. These elements are mounted now at their regular places. Our system consists of 24 elements: solenoid magnetic lenses (ML1, ML2, ML3), quadruple lenses (Q1-Q9), low current correctors (KIE, KS1, KS2, K3, K4). Some magnet parameters and corresponding technical requirements to power supplies are presented in Table1.

Table1. Some magnet parameters and corresponding technical requirements to power supplies

N	Element of System.	Inom A	Imax A	R Om	DU. (max) V	P W	Power supply
1	ML1	3	3	8	24	78	PA10
2	ML2	3	3	5.5	16.5	55	PA10
3	ML3	3	3	3	9	32.5	PA10
4	KIE_x	±3	±4.5	0.03	0.135	14	PA10
5	KIE_y	±3	±4.5	0.03	0.135	14	PA10
6	KS1x	±2	±3	4	12	42	PA10
7	KS1y	±2	±3	4	12	42	PA10
8	KS2x	±2	±3	4	12	42	PA10
9	KS2y	±2	±3	4	12	42	PA10
10	K3x	±2	±3	0.25	0.75	7.65	PA10
11	K3y	±2	±3	0.25	0.75	7.65	PA10
12	Q1	2.3	3.5	0.5	1.5	13.5	PA10
13	K4x	4	±6	1	6	58	PA10
14	K4y	4	±6	1	6	58	PA10
15	Q2	200	300	0.06	18	6.6 кВт	Vch300/6
16	Q3	200	300	0.06	18	6.6 кВт	Vch300/6
17	Q4	200	300	0.06	18	6.6 кВт	Vch300/6
18	Q5	200	300	0.06	18	6.6 кВт	Vch300/6
19	Q6	25	100	0.08	8	92 Вт	PA25
20	Q7	25	100	0.08	8	92 Вт	PA25
21	Q8	25	100	0.08	8	92 Вт	PA25
22	Q9	25	100	0.08	8	92 Вт	PA25
23	SB	250	300				BRUKER
24	S	300	450				BRUKER

Program calculation [2] for beam transport system with magnets from Table 1 gives a good accordance with project demands (75% of 200MEV electrons must be on the target of 4 mm diameter).

Location of electromagnets at the basic scheme of linac and required power supplies are shown in Fig.1.
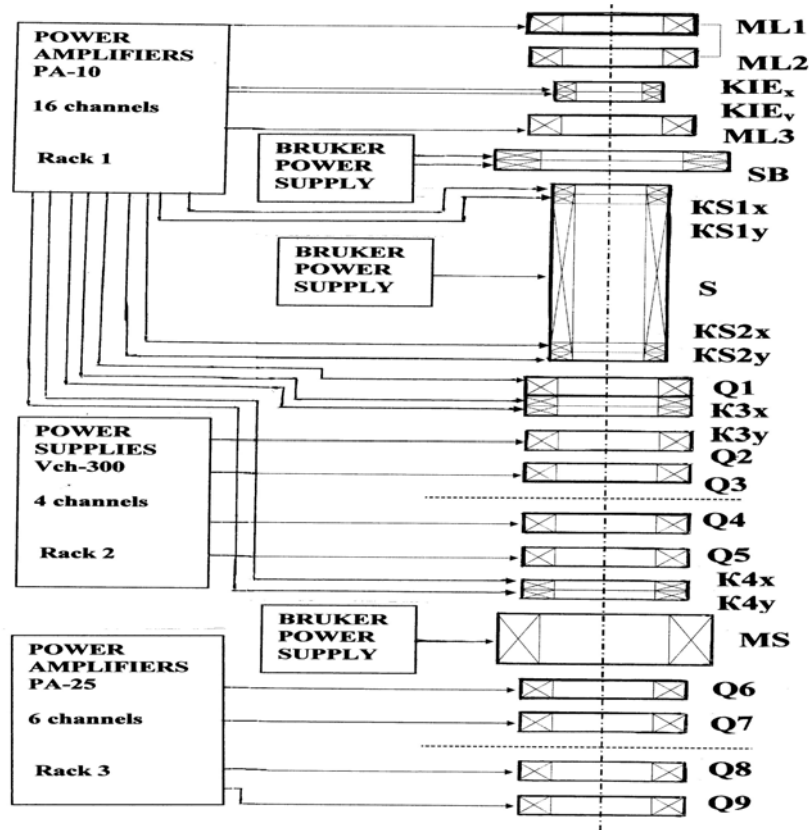

Fig. 1. Electromagnets of LUE-200 linac and required power supplies

Power supplies PA10, PA25, Vch300/6 were developed and manufactured at Budker institute of nuclear physics (BINP, Novosibirsk). Also we used old high current power supplies BMN90/750 and BMN90/500 from Bruker company.

All power supplies are controlled from main control room under CANBUS protocol.

Each of magnetic lenses and correctors are powered from current source (bipolar power amplifier) of the PA10. The output current of each channel is regulated in the range of ±3 A, the output voltage up to 20V, the current accuracy better then 0.2%.

The quadruple lenses Q6-Q9 (In<25A) are powered from the bipolar power amplifier PA25.

The power amplifiers PA10 and PA25 are made under standard "Vishnya". There are 16 of the PA10 and 6 of the PA25 channels in power supply racks with air fans, respectively.

More information about familiar power supply systems from BINP one can find in [3].

To control PA10 and PA25 power amplifiers a set of embedded devices [4,5] (multi-channel ADC and DAC) with CANBUS interface from BINP are used.

Quadruples Q2-Q5 (200A) will be powered by Vch300/6 [6] power supplies. These systems will be manufactured in BINP and must be installed in JINR (Dubna) at the end of 2007.

Wires of the s-band buncher, magnet to produce the solenoid magnetic field for indemnify the influence of beam space charge in the buncher and at the initial stage of acceleration and magnet for the broadband magnetic spectrometer are powered by high current supplies from Bruker. These supplies were used earlier at the MEA facility (NIKHEF, Holland). CANBUS interface was added [7] to each of the Bruker supplies.
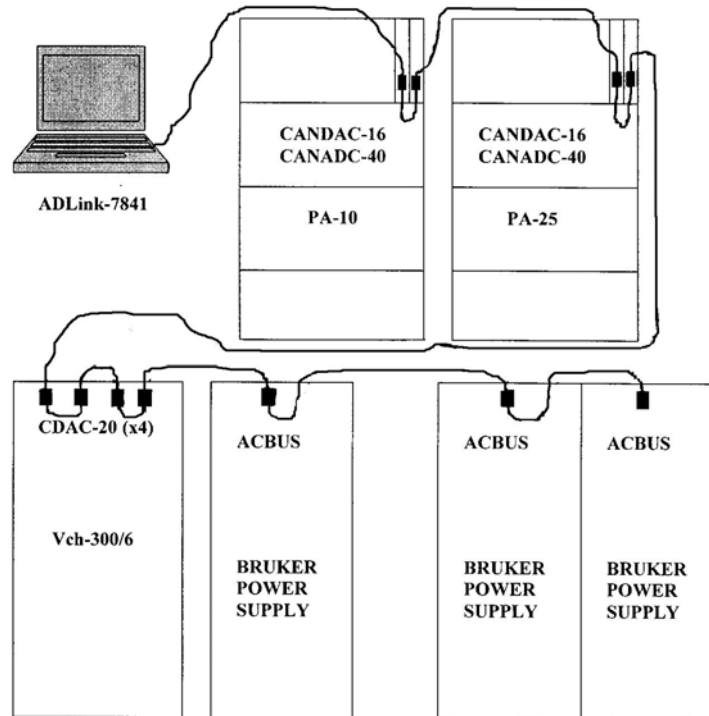

Fig. 2. CANBUS segment for LUE-200 linac power system

The CANBUS segment for LUE-200 is shown in Fig.2. PCI-CAN interface card type ADLink-7841 is placed into personal computer. All modules CANDAC16, CANADC40, CANDAC20 and CANBRUKER are connected as one continuous chain, terminated at the both ends.

Software

Magnets control system is included in general slow processes monitoring control system at LUE-200 accelerator, which is realized in LabVIEW environment (v. 7.0) and additional module Datalogging and Supervisory Control (DSC) of National Instruments company.

Including magnet elements in control system is reduced to – first of all – binding these objects with DSC module, i.e. to creation of tags reflecting the function and maintanance of electromagnets.

For this purpose, on the basis of a driver of Adlink firm, LabVIEW functions library was created to maintain the CAN interface, as well as a communication program with magnetic system supply sources.

The interaction with CAN modules is realized by means of protocol [4, 5] developed at BINP. All units used in control system have unified function sets and data representation formats, which substantially simplifies development of programs from the point of view of the maintenance.

The communication program with supply sources with a periodicity ones once a second resumes information about parameters and states of magnets in real time database of DSC module, where they are accessible for any client applications.

Elements for all magnets for setting the current required and indicators of the following parameters are output on the operators screen:

- some parameters of elements (full name, nominal current, maximal permitted current, maximal permitted voltage, load resistance, address of power source);
- current value of current set by the operator;
- measured value of load current;
- measured value of receiver voltage;
- calculated value of load resistance;
- information about the state (connection, exceeding limits, warning about load resistance change).

For some types of sources, the interface contains additional diagnostic information about the source state (state of protection, water cooling, interlock systems, etc.), as well as control signals of the on/off type.

The user can save in a file values of set currents of all elements (mode) for a given moment of time as well as download data from file. At that, currents required. in power sources are set automatically.

When developing the interface program, we broadly used the adjustment tools built-in in the DSC module, which monitor and represent alarms. When necessary, this allows to organize archiving changes of system parameters and viewing these trends.

It is planned to realize, in service mode, a possibility to check sources for stability, which reveals voltage and current ripples, as well as to execute demagnetization procedure of some magnets.

Conclusion

Now PA-10 and PA-25 power amplifiers for LUE-200 are tested and mounted at their regular places. High current Bruker modules are also prepared for operation. Precision current sources Vch-300/6 are manufactured by now and must be shipped to Dubna at the end of 2007.

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"Dead-time" reduction of the detection system of the Dubna Gas-filled Recoil Separator

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1. Introduction

The Dubna Gas-filled Recoil Separator (DGFRS) [1], operated at the U400 cyclotron of the Flerov Laboratory of Nuclear Reactions, is designed for the experiments on the synthesis of the new isotopes of the superheavy elements and the study of the properties of the heaviest isotopes near predicted island of stability of the elements in the vicinity of Z=114 and N=184. An original system was designed for the detection of the reaction products in heavy-ion-induced nuclear reactions, measurement of their parameters and for data acquisition [2, 3].

The system previously employed for the registration of the complete-fusion reaction products did not satisfy the demands of the new experiment aimed to synthesis a new isotope of element 118 because of the long "dead time" (85 μs). According to the theoretical predictions [4], ^{294}118 should undergo α-decay with T_α=58 μs; thus, its decays, most probably, would occur within our system's "dead time" without being registered. Therefore, in the course of preparing the experiment with the ^{48}Ca(^{249}Cf, 3-4n)$^{293-294}$118 reaction we have modernized the registration system in order to reduce the "dead time".

2. Electronics and circuits

Layout of the DGFRS and its detection system is shown in Fig. 1. The separation method and the description of the detection system and the electronics have been widely presented in literature previously [1-3, 5-7].

Signals of the charged particles (evaporation residues, α-particles, fission fragments) from the array of semiconductor detectors were used to form the signals of the logic of registration (see Fig. 2). Time needed for the ADCs [8] to convert a signal and for the controller [9] to pass data to the PC gave the "dead time" of this system equal to 85 μs.

In order to reduce the system's "dead time" we added another CAMAC crate with the needed ADCs, counters and buffer memory which should work only when the main registration system is busy.
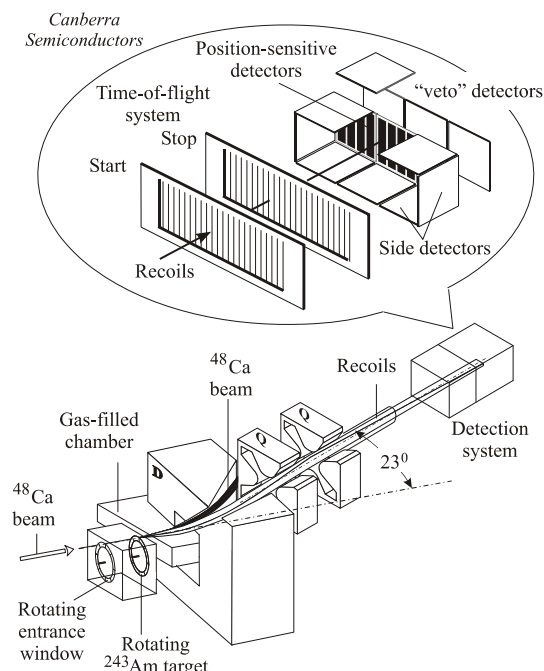

Fig. 1. Layout of the Dubna Gas-filed Recoil Separator

6 — 7	E_{ff} position	
6 — 7	E_a и E_{recoil} position	
6 — 7	E_a и E_{ff} energy	
8 — 9	Logic of registration	
6 — 7	E_{ff} energy	

1 - position-sensitive strips of Si detector.
2 - charge-sensitive preamplifier micro Catsa.
3 - sum-invert-amplifier SU-206K.
4 - amplifier SU-4K [10].
5 - amplifier ORTEC575.
6 - analog multiplexer AM-206K [11].
7 - ADC PA-24K [8].

8 - analog discriminator of energies DF-202.
9 - logical block KL-202 (to control all ADCs).
10 - charge-sensitive preamplifier PA-201.
11 - timing filter amplifier Polon 1501.
12 - nanosecond delay Polon 1506.
13 - constant fraction discriminator.
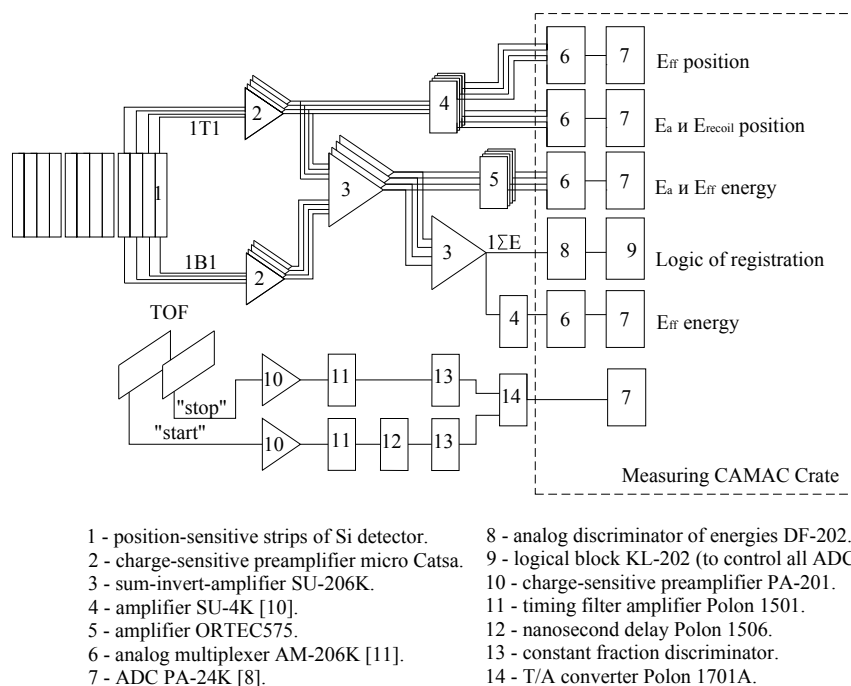14 - T/A converter Polon 1701A.

Fig.2. Block diagram of the measuring electronics
(only one detector circuit is

Thus, our task was to design a new electronic device which would manage the work of the ADCs and counters of main and additional crates. Fig. 3 shows the diagram of the logic of registration.

The principle of work of the logical block KL-203 is as follows:

- signals from the detector array (with $E_{recoil} > E_{threshold}$) allow the main ADCs to start conversion and start counter KC-011 [12] for measuring of the event time;

- unlocking of the additional ADCs is possible when there appear the following signals: signal "BLOCK" (main ADC is busy with recoil signal) from the crate controller KK-202 [13], signal from the buffer memory KL-033 [14], signal "DECAY" (i.e., presence of the signal from the Si detectors and absence of that from the TOF module) and signal of absence of the "dead-time" of the additional ADC. Blocking of "TOFselect" signal starts the measuring of the second particle in additional counter KC-011 and points "+1" in counter KC-002 that marks the recoil after which the second signal occurred;

- coincidence of detectors' signals (n>2) in KP-005 [15] marks the parasite signal. We do not take into account such events.

Circuits of KL-202 and "TOFselected" block were manufactured using integral circuits of SN74ALS(…) series. All blocks are made as CAMAC modules.

An original PC-based code was designed for singling out the short correlation sequences such as recoil-alpha or alpha-alpha in a real-time mode [16].
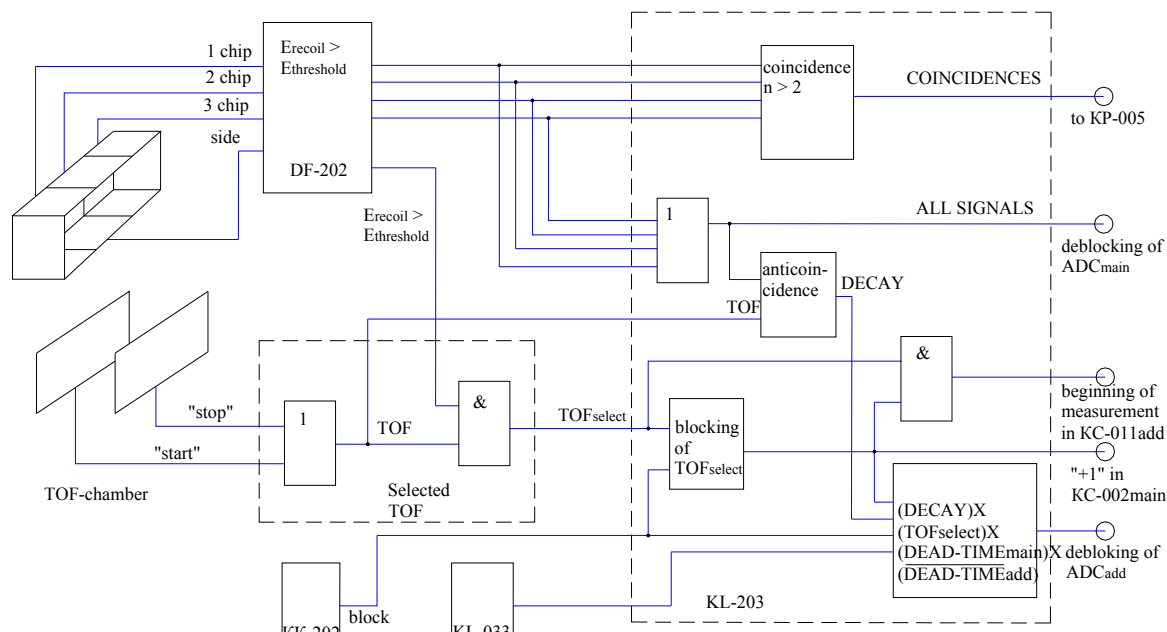
Fig. 3. Diagram of the logic of the registration of nuclear reaction products at DGFRS

3. Summary

The registration system of the DGFRS with the new logical circuit was tested by pulses from the generator of spectroscopic impulses of stable amplitude [17] and with short-lived products in the test reaction ^{nat}Yb+^{48}Ca (for example, ^{220}Th with $T_\alpha \approx 10$ μs). So, we have got the "dead-time" of the modern registration system equal to the 8 μs. In the experiment aimed at the synthesis of the new element 118 in the reaction ^{249}Cf+^{48}Ca, the half-lives of all the nuclei in the three detected decay chains originating from the parent isotope ^{294}118 (viz, ^{294}118, ^{290}116, ^{286}114, and ^{282}112) were measured to be longer than about 1 ms and therefore decays of these nuclei were registered by the ADCs of the main crate [18]. However, further investigation of the region of superheavy nuclei, e.g, nuclides with Z=120 in the reaction ^{244}Pu+^{58}Fe, that were started this year [19] and will be continued in the nearest future definitely requires applying of the ADCs and counters of both the main and the additional crates because of the short half-lives ($\sim$10-50 μs) expected for the isotopes ^{298,299}120.

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On using Ice middleware in the IARnet framework[1]

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The paper presents a new version of IARnet, a general framework for porting scientific tools to a distributed computing environment. While providing an easy-to-use development model IARnet lacks some fundamental functionality, such as security, interface definition language, advanced configuration and deployment models. The proposed IARnet2 framework addresses these issues by using Ice, a modern object middleware technology. The paper discusses architecture of IARnet2 and its current prototype implementation.

1. Introduction

IARnet [1, 2] is a general framework for integration of distributed software resources into a grid-like computing environment enabling sharing and coordinated use of these resources. It primarily focuses on transforming scientific tools, such as mathematical packages, various solvers, and simulation models, into remotely accessible services with well-defined interfaces.

By promoting sharing and collaborative use of existing tools IARnet complements modern grid computing efforts. While the first generation grid computing was about on-demand access and batch computing, the second generation paves the way for "service-oriented science" [3, 4]. The widespread adoption of service-oriented science among researchers is impeded by the difficulty of developing grid services and implementing grid-enabled applications. The main goal of IARnet is to provide high-level tools, which simplify service and application development and do not require deep knowledge of middleware technologies.

The original version of IARnet provides high-level tools for porting software components written in Java and C++ to a distributed computing environment and accessing them from Java applications, namely:

- Java Client API, which hides details of remote invocation implementation from an application developer, i.e. is neutral to underlying middleware technology;
- Service development tools for Java and C++, also neutral to middleware used for service invocation;
- Several remote invocation plug-ins based on different middleware technologies (CORBA, Web Services and Ice) and corresponding service hosting environments (containers);
- A few services, such as information service and workflow management service.

The major advantages of IARnet are simple, easy-to use service and application programming models, as well as ability to plug in different remote invocation implementations. At the same time, IARnet lacks some fundamental functionality such as full-featured interface definition language supporting user-defined complex types; security mechanism supporting encryption, message integrity, authentication and authorization; advanced configuration and deployment models.

The new version of the framework called IARnet2 is designed to eliminate these drawbacks and extend functionality of the framework without sacrificing simplicity and ease of use. The implementation of missed functionality in a middleware-neutral way in compliance with the original IARnet architecture would require considerable efforts. This put a question of whether to abandon middleware-neutrality and use a single middleware technology, or to limit supported languages to only Java. Since the tools to be exposed as services can be written in a variety of languages, for the development of IARnet2 the first approach has been taken. Among the three middleware technologies used originally in IARnet, Ice was chosen as a foundation for IARnet2.

2. Ice Overview

Ice, the Internet Communications Engine, [5] is a modern object middleware technology developed by ZeroC, Inc and available under the GNU General Public License (GPL). Ice supports development of clients and servers on many popular programming languages and is supported on various operating systems.

Ice includes a full-featured interface definition language, Slice, with support for user-defined complex types, inheritance, exceptions, etc. Slice specifications are compiled into various programming languages. Ice supports C++, Java, C#, Visual Basic, Python, PHP, and Ruby. Ice clients and servers work together, regardless of the programming language.

The Ice core library manages all the communication tasks using a highly efficient protocol (including protocol compression and support for both TCP and UDP), provides a flexible thread pool for multi-threaded servers, and additional functionality that supports extreme scalability.

Ice includes rich set of tools, services and plug-ins, among which the following are most relevant to the requirements of IARnet2:

-   IceSSL, a dynamic SSL transport plug-in for the Ice core, which provides authentication, encryption, and message integrity;
-   IceBox, an easy-to-use container for Ice services that are dynamically loaded as a DLL, shared library, or Java class;
-   IceGrid, a sophisticated server configuration, deployment and activation tool for management of complex server infrastructure;
-   Glacier, the firewall solution for Ice, which authenticates and filters client requests and allows callbacks to the client in a secure fashion.

The choice of Ice instead of CORBA or Web services was motivated by reasons discussed below.

Ice is created by a team of professionals with strong CORBA background. It borrows many good ideas from CORBA, while eliminating drawbacks inherent in CORBA specifications. This resulted in both highly efficient and simple to use middleware superior to CORBA and its implementations [6].

The most widely used middleware in a grid computing area is Web Services, promoted by all major vendors and claimed to be a key technology for implementing service-oriented architecture (SOA). While this could be true for business-to-business integration, we argue that it is not the best platform for service-oriented science and IARnet specifically for following reasons [7]:

-   SOA is an architectural style that can be implemented with Ice or CORBA as well;

- Web Services do not support object-oriented development of distributed applications. The lack of support for services with internal state resulted in OGSI and WSRF specifications, which introduce object-oriented patterns like factory for Web Services;
- The Web Services interface definition language, WSDL, is too complex to write service interfaces manually. This resulted in tools that assist in authoring WSDL or even generate it automatically from an annotated code, which generally contradict a contract-first approach advocated by SOA experts. In contrast to WSDL, Slice is much easier to write and read.
- SOAP protocol is very slow and wasteful of bandwidth in comparison to a binary protocol of Ice, which has typically hundreds of times better latency and throughput;
- The large number of partially overlapping WS-* specifications, some of which are still immature, complicate learning and using of Web Services. In contrast, Ice has stable, well-documented API and protocol.
- There are no defined language mappings for Web Services, and each vendor uses its own proprietary API and tools, making clients and services not portable. In contrast, Ice has well-documented language mappings and includes rich set of tools unavailable in a single Web Service product.

3. IARnet2 Architecture

IARnet2 architecture represents a refactoring of the original IARnet architecture and introduces several new concepts, which align it with a modern grid environment.

Grid Environment Model

The distributed computing environment based on IARnet2 conforms to the structure of modern grid systems. Such systems support *virtual organizations* (VO) - dynamic groups of individual users and organizations, which share their resources for accomplishing common goals, collaborative problem-solving, etc. The resources are provided to grid users as services. Each resource has an access policy defined by its owner. The policies are usually based on a membership in a particular VO. Each grid user holds membership in one or more virtual organizations.

G*rid site* is an administrative concept used to aggregate a set of services and resources that are installed and managed by the same set of persons. The grid system is composed of two or more sites. Each site consists of a set of servers with deployed services and resources. Grid users and services access site resources via unified interfaces.

Basic Concepts

In accordance with the grid environment model described above, the concepts of IARnet2 service and site are introduced.

IARnet2 service is an Ice object, which provides access to some scientific tool or application. Each service is described by means of Slice and implemented as an Ice servant. Service implementation acts as a mediator between clients and provided resource, delegating incoming calls to resource implementation.

IARnet2 site is a collection of IARnet2 services that are installed and managed by some organization or person. Each site implements a unified interface, which is used by clients to authenticate itself with the site and obtain proxies to services. While site can span multiple servers as a typical grid site, it can also be deployed on a researcher's desktop. This

is a distinguishing feature of IARnet2. While typical grid sites are hard to install and are usually managed by an organization, IARnet2 site is designed to be easily installed on a desktop and managed by a single person.

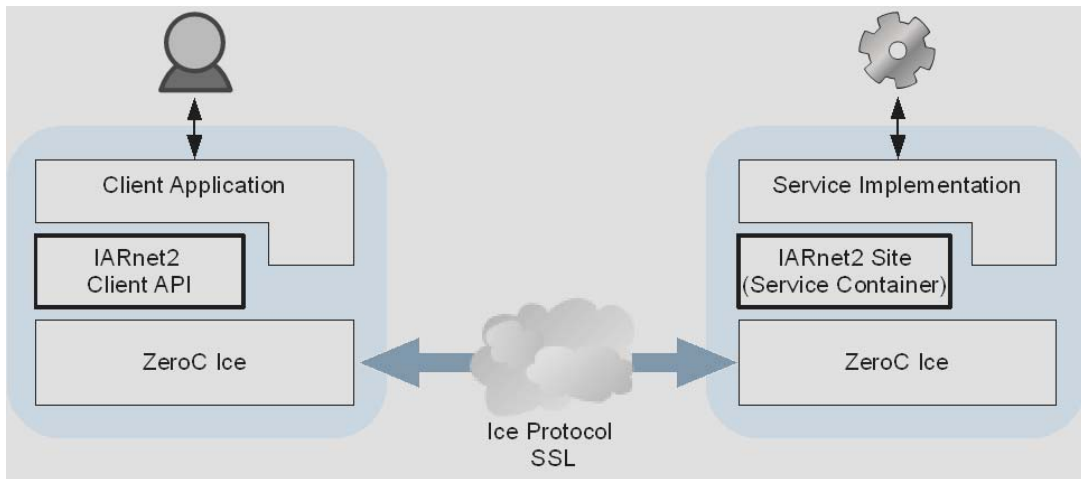*IARnet2 client* is an Ice application, which accesses IARnet2 services on behalf of a user or another service.

Fig. 1. Basic IARnet2 components

IARnet2 architecture consists of two parts (Fig. 1): *IARnet2 Site* on a server side and *IARnet2 Client API* on a client side. IARnet2 Site implements a unified site interface and provides a secure container for hosting services. IARnet2 Client API provides a simple-to-use API for accessing sites and services from client applications.

While working on top of Ice, IARnet2 does not hide Ice completely from a developer, nor does it modify Ice programming model. It means that, in contrast to original version of IARnet, IARnet2 user needs to be acquainted with at least basic Ice programming. Thanks to Ice design and extensive documentation, this can be done in a few hours.

Site and Session Interfaces

Before a client can invoke a service it must authenticate itself with a corresponding site and create a session. The Slice definition of the IARnet2 site interface is shown below:

```
interface Site {

   Session* createSession(string userId, string password)
      throws PermissionDeniedException, CannotCreateSessionException;

   Session* createSessionFromSecureConnection()
      throws PermissionDeniedException, CannotCreateSessionException;

   idempotent long getSessionTimeout();

};
```

The Site interface has two operations for session creation, depending on whether the client provides a username and password or a digital certificate over SSL connection. Upon successful authentication the site returns to the client a proxy to session object, which implements a facade for accessing site services. The Slice definition of the session interface is shown below:

```
interface Session {

   Object* getService(string serviceId)
      throws ServiceNotFoundException, PermissionDeniedException;

   idempotent void keepAlive();

   void destroy();

};
```

The client can request a proxy for a service by invoking `getService` operation on the Session interface. The site can perform additional authorization and reject the request if the client is not allowed to access this particular service. After the client received the service proxy it can invoke the service as an ordinary Ice object.

The client must keep session alive by periodically invoking its `keepAlive` operation. The session expires if the client does not invoke `keepAlive` within the certain period, which can be obtained by calling the `getSessionTimeout` operation on the Site interface. The client can also explicitly terminate the session by invoking its `destroy` operation.

Site Architecture

To be able to scale to multiple servers, the site architecture is split into two distributable parts – frontend and backend servers (Fig. 2).
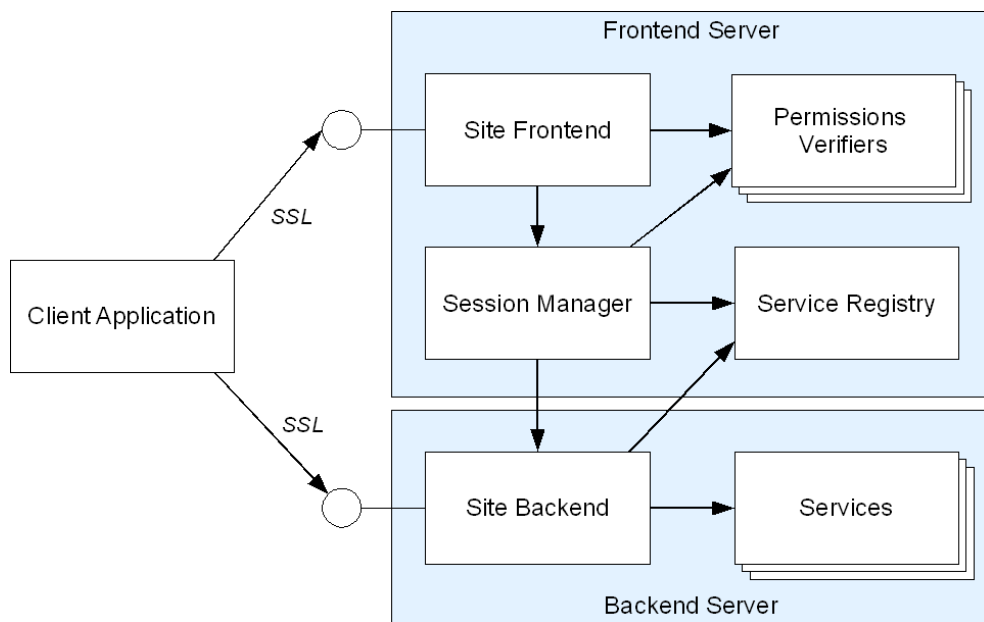

Fig. 2. IARnet2 site architecture

Frontend server is a gateway to site. It performs client authentication, authorization and session management. It also keeps track of services hosted by site. Frontend server consists of following components:

- Site Frontend, a servant that implements the Site interface;
- Permissions Verifiers, pluggable authentication and authorization modules implemented as Ice objects (inspired by Glacier2 and IceGrid verifiers);

- Session Manager, which creates and terminates client sessions;
- Service Registry, which maintains information about services hosted by site, including service metadata and backend server proxies.

Backend server is dedicated solely for hosting services. It implements a service container, which registers deployed services in Service Registry. After a client obtained a service proxy from its session, all service invocations are sent directly to a corresponding backend server. Backend server does not perform client authorization but instead uses information provided by Session Manager, which notifies backend about sessions allowed to access particular service and session termination.

The described site architecture supports two deployment modes – standalone and distributed. In the *standalone mode* the site is deployed on a single machine and runs one backend server. Frontend and backend servers communicate with each other using Ice collocated invocations, which are almost as fast as local function calls. In the *distributed mode* the site can include one or more backend servers deployed on separate machines. In this case, the site servers can be deployed and managed with IceGrid.

4. Current Implementation

The described IARnet2 architecture was implemented as a prototype in Java.

The site implementation is based on IceBox, which provides a good foundation for the IARnet2 service container, including file-based configuration, service loading and remote administration. The site components are loaded with a single IceBox service, which performs server initialization depending on configured mode (standalone, frontend or backend). Each service is loaded with another standard IceBox service, which performs servant initialization and registers service on a local backend.

Two Permission Verifiers were implemented: `MD5PermissionsVerifier`, which uses a file with MD5-hashed passwords for username-password authentication, and `SimpleSSLPermissionsVerifier`, which uses a file with distinguished names of trusted peers for SSL authentication.

The existing Ice services do not provide a session management solution that meets all IARnet2 requirements. Glacier2 router provides a good authentication and session management framework, but it is not suitable for all situations and is overkill in a standalone mode. IceGrid supports client authentication and sessions only for allocating objects for exclusive use. For that reason the Session Manager component was implemented from scratch. In the future we plan to investigate the use of Glacier2 in the distributed mode.

IARnet2 client uses Ice context feature to send its session identifier with each service invocation. The backend server is implemented using a servant locator mechanism, which allows developer to perform any actions before a request is dispatched to an Ice servant. In this particular case the backend server extracts session identifier from the client request and checks whether this session is allowed to access the service. If yes, it dispatches the request to the service implementation. If not, it returns an exception.

The service programming model is basically the same as for an ordinary Ice object. Service developer writes Slice definitions, compiles them to Java, and implements the servant. Then he deploys the service on a site by editing server configuration file and copying jar file into a dedicated server directory. In contrast to IceBox services, the developer does not

need to implement a service launcher code with `start` and `stop` methods. IARnet2 server supports passing service configuration options to the servant constructor, as well as callbacks upon session termination and service shutdown.

The distributed site mode was implemented to support deployment with IceGrid. Frontend and backend servers, including the services they host, can be deployed and managed as IceGrid applications via convenient graphical user interface.

The IARnet2 Client API was implemented to simplify the client session management and obtaining service proxies from client applications in Java. Basically it does all the routine work of session creation, keeping the sessions alive, obtaining service proxies and populating their contexts with session identifiers. After the developer obtained a service proxy, it uses a standard Ice programming model for accessing the service.

The last noticeable feature of the current implementation is its backward compatibility with the original IARnet version. It means that IARnet services can be deployed in IARnet2 server and can be accessed from unmodified IARnet clients.

5. Conclusion and Future Work

In this paper a new version of the IARnet framework, which is built on top of the Ice middleware, has been presented. The use of Ice made it possible to provide with a minimal effort all the needed functionality, such as security, session management, advanced configuration and deployment models. IARnet2 services can be described in a full-featured and simple to read interface definition language. IARnet2 site, based on a grid site model, can scale from a single desktop to a server pool. Through the pluggable permissions verifiers IARnet2 supports simple virtual organization setup with VO sites using a common set of permissions verifiers installed on a central server.

The future work on IARnet2 will be focused on extending functionality of the current Java prototype, providing implementations in other programming languages, and development of key components of the service-oriented architecture, such as discovery service and interface repository.

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IARnet: a general framework for porting scientific applications into a distributed computing environment[1]

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Abstract

Report presents an overview of basic notions, principles and software architecture of IARnet framework. IARnet unifies and simplifies porting of scientific applications (including legacy ones) into a distributed computing environment by converting them into, so called, information-algorithmic resources. The framework supports remote discovery, collaborative use and mutual interactions between those resources in various scenarios of "collaborative computing". IARnet complements the existing Grid infrastructure by focusing on integration of high-level application services, thus, widening the use of collaborative computing in new application areas.

Introduction

The concept of Grid-computing has become very popular since its introducing at the beginning of century [0, 0, 0, 0]. After a few years, Grid-computing has become "tightly coupled" with Web-services technologies, which has their "up raise" just at the same time. As a result current understanding of Grid-computing became a synonym of the Open Grid Service Architecture (OGSA) concept with Globus Toolkit (GT) as a reference implementation [0].

In parallel, the Grid, emerged from the relatively narrow problem of wide-area access to high-performance computing resources is transforming now into a general-purpose infrastructure for coordinated resource sharing within dynamic virtual organizations. Resources being "plugged" to Grid are no more limited to computing facilities, but include any resources that can be used in collaborative scientific applications: knowledge bases, software libraries and applications, instruments, etc. This extends the scope of Grid applications from high-performance computing and large-data processing to a wider class of complex problems which may be decomposed into a number of sub-problems which might be solved by already existing programmatic resources. Next-generation Grid applications will involve dynamic composition and orchestration of various types of distributed resources and services forming an application workflow.

At the same time there is a substantial gap between existing Grid framework (standards and toolkits) and the practice of their usage in day-to-day research computing activity. We do not touch here on a number of successfully used Grid-project such as EGGE, EuroGrid, CERN DataGrid etc. Regardless of a really huge data flows and "teraflops" computations, all the systems solve rather limited scope of distributed computing application algorithms: data transmission and job management mostly.

The following situation remains typical: some complex application problem requires collaborative usage of a number of computing resources, but each taken separately exists and available only in some organization, where it has been designed, implemented and deployed. There are a lot of unique (in computational efficiency) resources which can not be neither "bought on CD" nor even "moved" to another organization just because their proper functioning requires specific maintenance from their authors having enough skill and experience. Obvious decision might be to provide remote secure (controllable by owners) access to these resources over network. In other words, to reach collaboration and resource sharing, researchers have to "convert" their applications into *remote services*.

Here we get another problem. *The process of extension of an existing application to enable its usage remotely must be simple enough.* We believe that simplicity of remote service design, implementation and deployment is one of the key features effecting on choosing one or another distributed computing technology (including standards and toolkits) to integrate heterogeneous resources. Rapid development of distributed computing during the recent decade of years (e.g., see survey in [0]) makes that choice rather difficult: temporary fall of interest to Object Oriented middleware (OOM), such as CORBA, but appearing new ones OOM at the same time, e.g. Ice [0]; rise of interest to Service Oriented Architecture (SOA) and entering a number of WS-development toolkits; permanent redesign of GT (from GT 2 to GT 3, based on Grid Services, then from GT 3 to GT 4, based on "pure" Web-services) etc.

The concept of IARnet [0, 0, 0] has been introduced in attempt to promote usage of distributed computing in practice of scientific researches. IARnet (that means Network of Information-Algorithmic Resources) is both a framework and a toolkit (a set of tools and services) simplifying deployment of existing software resources (applications and software libraries) as remote services, as well as dynamic discovery and composition of resources into workflows. General view on levels of distributed systems covered by IARnet is presented in the Fig. 1.

This introductory paper presents IARnet as it has been implemented in its first version (IARnet1) in recent two years. We are working now on the next version whose description may be found in [0].
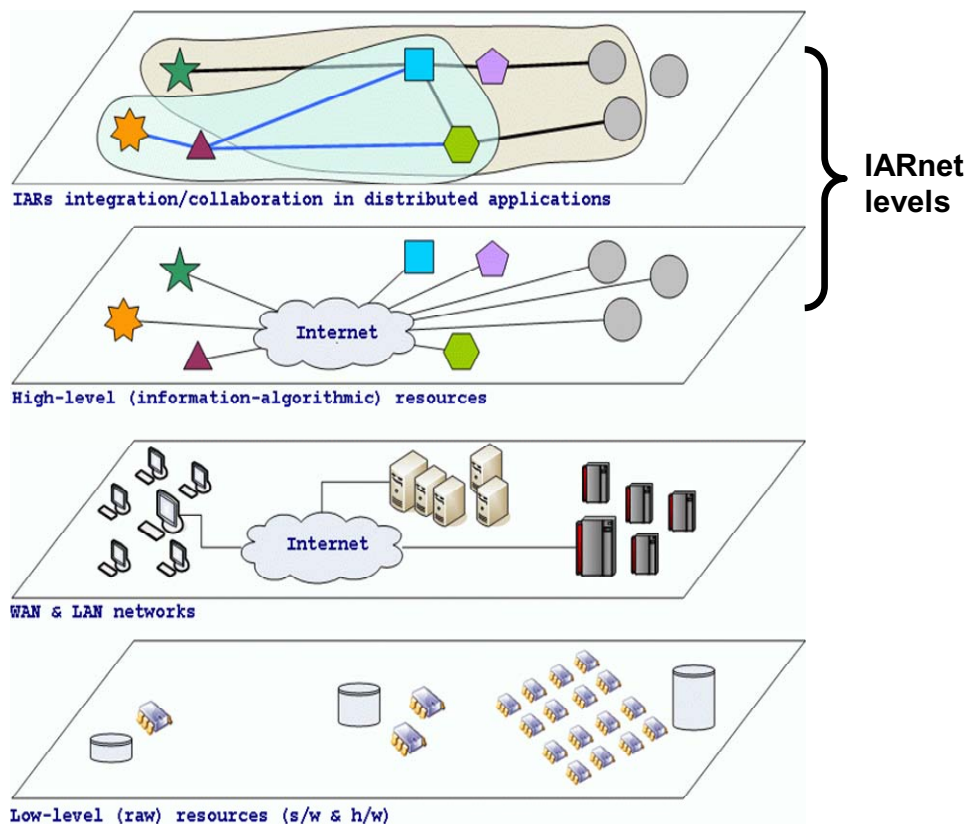

Fig. 1. Levels of distributed systems covered by IARnet

1. IARnet framework

At the core of IARnet is the notion of *information-algorithmic resource (IAR)*, which, in general, means any software component with certain specified capabilities and features intended for solving a well-defined range of applied problems. For example: special-purpose library of numerical algorithms (e.g., mathematical programming, linear algebra, symbolic computing); mathematical and simulation models, etc. IARnet provides a set of high-level tools for development, publishing, discovering and accessing various IARs required in distributed scientific applications. The IARnet architecture is composed of resource agents, special IARnet services and IARnet API (Fig. 2).
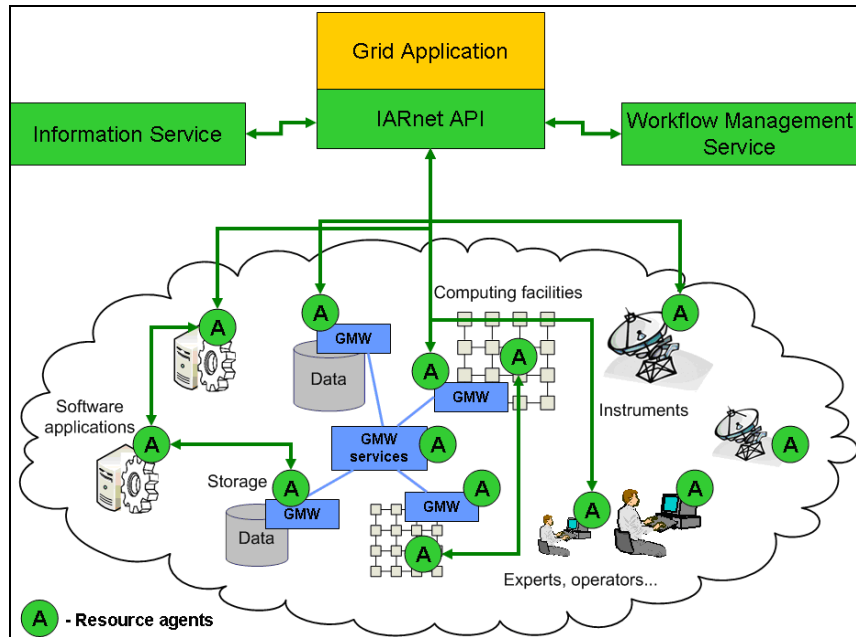
Fig. 2. General view of IARnet architecture

Resource agents are software components acting as mediators between resources and client applications. An agent provides unified access to a resource in accordance with its type, integrates it into the system, and controls user's access to it. In terms of SOA, agents expose resources to applications as standard services.

IARnet services are general-purpose components which provide basic mechanisms required by applications, such as resource discovery. Current version of IARnet contains two services – Information Service and Workflow Management Service. It is important to note that IARnet services are considered as special types of IARs, so they are implemented and accessed using the same tools as resources.

IARnet API defines a high-level application programming interface for development of applications on top of IARnet. Current version of IARnet API is implemented in Java and represents a library used by applications to discover and access resources and services. IARnet API is also used by resources and services for interactions between each other.

As shown in Fig. 2, unified access to "typical" Grid resources such as computing and data storage facilities can be provided for IARnet applications by special agents which interact with these resources indirectly via existing Grid middleware (GMW), basic Grid services, or simple Grid APIs.

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2. IARnet Resource Agents, Connectors and Containers

The problem of resource integration can be stated as how to expose a given software resource as a remote-accessible service with standard interface expected by clients. This requires one to provide a remote access to a resource, as well as implement mapping between unified and implementation-specific interfaces. These two tasks are separated and accomplished by different components of IARnet: connectors and containers (see below).

One of the main goals of IARnet was to make the development of distributed applications easy for people unfamiliar with distributed programming and middleware. To save developers from details of underlying middleware the transport level of IARnet1 is completely hidden from them by IARnet API. This also means that agent and application developers don't have to manually generate or use any stubs and skeletons/servants.

Resource Agent. The different resource implementations providing same functionality are highly heterogeneous, so there's a strong need in unified interfaces for different types of IARs which hide this heterogeneity from user and provide transparent access to dynamic collections of resources. The basic functionality of resource agent conforms to adapter design pattern where agent implements mapping between the unified interface for a given resource type and the native interface of resource implementation (Fig. 3). Current version of IARnet supports development of resource agents in Java and C++.
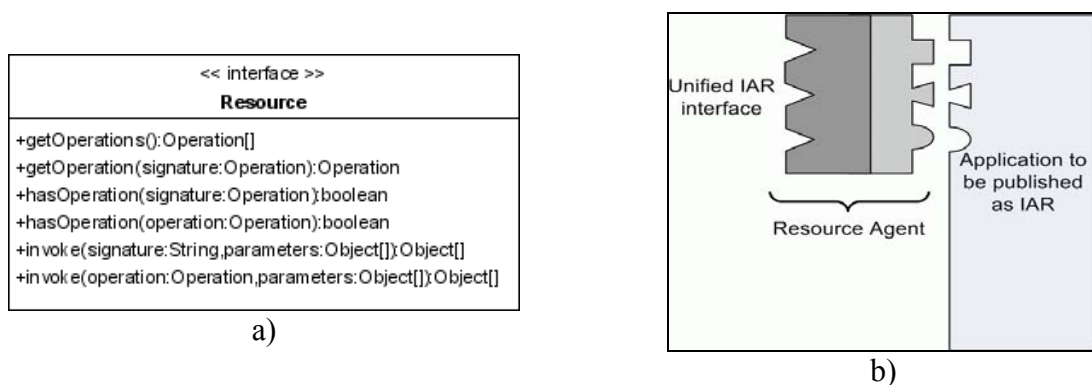

Fig. 3. Resource Agent unified interface connected with legacy application
a) Resource Agent unified interface (IARnet1); b) Resource Agent connected with resource

Container. Resource agents don't provide remote access to resources. To ensure flexibility and extensibility of IARnet this task is isolated in another component called container. *Container* is a hosting environment for resource agents which provide remote access to agents by means of some middleware technology. IARnet1 supports multiple implementations of transport level, called *middleware profiles*. The first version of IARnet includes three middleware profiles based on CORBA GIOP (JacORB [0] for Java and ACE ORB (TAO) for C++ [0]), Web services (Apache Axis [0]) and Ice [0], accompanied with corresponding container implementations. Upon deployment of agent container returns a *resource reference* string which is used to access the resource from client applications as discussed in the next section.

Client API. An application developer uses IARnet API to access resources via *proxy* objects instantiated from resource references. Each proxy implements a standard interface *Resource* (Fig. 4) of resource agent and contains methods for inspection and invocation of resource operations.

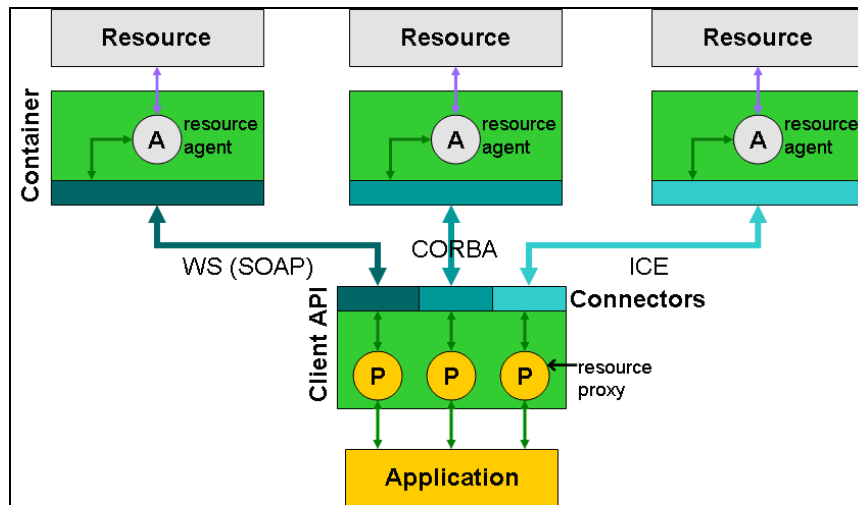General scheme of IARnet components interactions are presented in the following figure.

Fig. 4. IARnet1 components interaction

3. Some details of programmatic implementation

The first version of IARnet toolkit consists of the following components:

- IARnet Java API presented as a JAR library;
- three variants of Java connectors (for IARnet "client" programming) implementing IARnet network transport layer by the following middleware/protocol: CORBA/IIOP (based on JacORB pack); WS/SOAP (based on Apache Axis pack); Ice/ICEP; all the connectors are also provided as JAR libraries;
- three variants of Java containers (corresponding to three kinds of middleware mentioned above) for resources deploying and templates of start scripts;
- IARnet C++ resource development pack (for CORBA/IIOP based on ACETAO pack) including special IARnet annotating comments preprocessor and container application providing a number of remote resource control features (building/deploying, start/stop resources' agents etc.); there are three versions of C++ pack for different OS and C++-compilers: Windows 2000/XP and MinGW/MSYS; Linux and GCC; MacOS and GCC.

IARnet1 toolkit also contains implementations of Information and Workflow Control services. Details of these services may be found in [0].

Take a look at general scheme of IARnet resource agent programming. To reach desired simplicity of development so called "annotating/metadata" approach has been chosen to declare that "usual" function (Java or C++) can be invoked remotely. In brief, programmer must start declaration of a function with special comment and this function will be added to resource agent "remote" interface. In IARnet1 for Java this feature is provided by standard (in Java 5) "annotation mechanism". In IARnet1 C++ special precompiler has been implemented and is available as a part of IARnet1 C++ toolkit.

The following fragment of code gives an example of simple IARnet resource programming in Java (appropriate example in C++ looks almost the same).

```
// Any Java IARnet resource class must inherit from special DefaultResource type
public class DemoResource extends DefaultResource
{
/**
 * This method will be available remotely due to @Remote annotation
 * namespace parameter defines IARnet namespace semantic
 */
@Remote (namespace = "iarnet/demoResource")
public String[] foo(int i, String s) {
       // Method body
}

@Remote (namespace = "iarnet/demoResource")
public void bar(double[] arrInt, String[] arrStr) {
       // Method body
}

/**
 * This method will NOT be available remotely
 */
public void someOther() {
       // Method body
}
}
```

Fig. 5. IARnet1 resource code example

Reflection of user data type (used in function declaration) on "underlying" transport middleware will be performed automatically by IARnet software. The only restriction is that programmer must inherit his resource class from basic IARnet API "DefaultResource" type.

The first version of IARnet API supports rather wide range of parameters' types which may be used in declaration of resource agent's operation. All basic types: *boolean, byte, short, int, long, float, double,* and *string*. There is also special *void* type for return value. Multi-dimensional *arrays*, *collections* (lists and sets) and *dictionaries* (map) are supported as well. Due to some reasons structure type is not allowed in IARnet1. IARnet API has a number of standard IARnet exceptions to handle various runtime problems.

For Java programming, after compilation, user deploys his resource in container (that is available as standard part of IARnet toolkit) just by passing name of resource class as a container startup command line parameter.

For C++ programming standard make script compiles resource as dynamic library (*.dll in Windows, *.so in Linux, *.dylib in MacOS) that may be also passed to standard IARnet C++ container application as startup parameter.

On deployment completion container generates unique IARnet reference (as "human readable" string) and publish it on Information Service. This reference may be used in IARnet client application to locate resource instance.

Let's describe what IARnet Java client code looks like. General code template is: 1) get string representation of IARnet resource agent (may be from Information Service); 2) resolve the reference and convert it to resource agent proxy; 3) get list of operations supported by the agent, then you can call any operation via unified interface (see a) Fig. 3). Example of code is presented below (operation signatures correspond to example in Fig. 5).

```
public class DemoClient {
import ru.isa.dcs.iarnet.*; // Import IARnet API types
    public static void main(String[] args) {
            // Generate resource reference from command line argument
            ResourceReference rr = ArgsParser.getResourceReference();
            // Try to resolve reference to Resource proxy instance
            Resource r = null;
            try { r = LocateResource.getResource(rr);
            } catch (UnsupportedProfileException e) {
                    // Handle exception
            } catch (InvalidResourceReferenceException e) {
                    // Handle exception
            }

            // Get array of operations supported by resource
            Operation[] ops = r.getOperations();
            /** Sample of "iarnet/demoResource#foo(int,string):string[]" call
             *   Note that parameters' list is Object[] regardless of types
             */
            Object[] params = new Object[] {10, "hello"};
            // Abstract <Operation> type of IARnet API is used
            Object retVal = r.invoke(ops[0], params);
            // Get result and cast it to array
            retVal = (Object[])retVal;
            // Sample of the second operation invocation via its string signature
            params = new Object[] {new double[]{1.1, 2.2, 3.3}, new String[]{"s1", "s2"}}
            r.invoke("iarnet/demoResource#bar(double[],string[]):void", params);
            // Some other code here
    }
```

Both above resource operation invocations are performed in "synchronous call" mode that blocks client thread until remote operation will be completed and its result will be returned back. This behavior may be too restrictive for distributed applications. IARnet1 Java API supports asynchronous call as well (via special *InvokeResultHolder* type). "In context" of the above example, asynchronous call of the "foo" operation may look like the following code.

```
            // "iarnet/demoResource#foo(int,string):string[]" operation asynchronous call
            // use the same DemoResource proxy
            InvokeResultHolder h = r.ami_invoke(ops[0], params);
            // To check whether result is ready use isReady() non-blocking method
            if (h.isReady()) {
                    // get returned value by blocking getValue() method
                    retVal = h.getValue();
            }
```

4. Compare of CORBA, WS and Ice middleware performance

First version of IARnet toolkit has special *TestSuite* pack which has been implemented to check mutual compliance of different IARnet network transport layers, namely, connectors (see Fig. 4). The pack contains special *TestResource* implementing a number of operations with various parameters data types (basic ones, arrays, collections and dictionaries; altogether there about 200 operations). This resource had been deployed in different IARnet containers and special test client application called all these operations over network by different IARnet connectors. In particular, total spent time of all the tests has been logged.

Multiple running of this test IARnet1 application showed that CORBA, Web-services and Ice middlewares may be arranged as follows (according to performance which is inversely related to duration of the test): Ice, CORBA, WS. Numerical relations are 1:3:10 which mean that Ice Java middleware is 3 times faster than CORBA (JacORB), and 10 times faster than Web-services (Apache Axis Java). Of course, this "rule" corresponds to particular

choice of CORBA and WS development pack, but both JacORB and Apache Axis packs are often considered as "reference" noncommercial implementations of CORBA and WS.

5. Conclusion

IARnet framework principles are quite simple and do not require almost no extra experience in Grid computing technologies (standards and middleware) from potential user who is presumed to be skilled enough to use "usual" Java or C++ programming in his day-to-day practice. Even the first version of IARnet toolkit enabled to develop distributed computing system involving parallel implementation of branch-and-bound optimization algorithms [0] as information-algorithmic resource. Already existent library (C++ MPI, designed for high-performance multi-processor systems) has been supplied with special IARnet agent. Test distributed system performs intensive collaborative computations involving two supercomputers and a number of desktop workstations (for control and monitoring).

Another direction of our work is development of IARnet resource agent to special resources which are required to our researches on distributed solving of various mathematical problems. For example, intensive symbolic calculations are required in solving of ordinary differential equations by expansion of solution in Taylor serias. For this purpose, special IARnet agent has been developed for Maxima computer algebra system [0] on the base of IARnet C++ container.

At the same time we do not proclaim that IARnet is an alternative to existing Grid-computing frameworks and toolkits. We believe that IARnet framework have to facilitate further processing of data passing over "global" Grid-systems within a kind of "local" IARnet sites where various computing algorithms should be collaboratively applied.

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Basic non-linear effects in silicon radiation detector in detection of highly ionizing particles: registration of ultra rare events of superheavy nuclei in the long-term experiments.

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Abstract

Sources of non-linear response of PIPS detector, when detecting highly ionizing particles like recoils (EVR), fission fragments and heavy ions, including formation of large pulse-height defect (PHD) are considered. An analytical formula to calculate the recombination component of EVR's PHD is proposed on the base of surface recombination model with some empirical correction. PC-based simulation code for generating the spectrum of the measured recoil signal amplitudes of the heavy implanted nuclei is presented. The simulated spectra are compared with the experimental ones for the different facilities: the Dubna Gas Filled Recoil Separator (DGFRS), SHIP and RIKEN gas-filled separator. After the short reviewing of the detection system of the DGFRS, is considered the real-time matrix algorithm application aimed to the radical background suppression in the complete-fusion heavy-ion induced nuclear reactions. Typical examples of application in the long term experiments aimed to the synthesis of superheavy elements Z=112-118 are presented [1-9].

1. Introduction

Recently, more than 30 new nuclides with atomic numbers Z between 104 and 118 have been synthesized at the Dubna Gas-filled Recoil Separator (DGFRS) [1-7]. It should be noted that some of these experimental results have been clearly confirmed in independent experiments [7-9] involving the study of the chemical properties of the synthesized atoms. In order to succeed in detecting the synthesis of super heavy nuclides one has to pay attention to the following:

• an electromagnetic recoil separator design has to provide not only an acceptable value of the nuclide transportation efficiency (tens of percent), but also a significant suppression of the background products;

• the heavy-ion beam intensity has to be high enough to overcome the limited cross section for fusion followed by the evaporation of neutrons;

• a detection system has to provide a sufficient number of parameters in order to identify a nuclide. In additional, the design of the detection assembly has to provide for the suppression of the background products [10-12].

2. Pulse amplitudes corresponding to evaporation residues (EVR) formed in heavy-ion induced complete-fusion nuclear reactions

The multi-parameter events corresponding to production and decays of the super heavy elements (SHE) usually consist of the time-tagged recoil signal amplitudes and the alpha decay signal amplitudes. The amplitudes of the signals associated with one or two fission fragments (FF) arising in spontaneous fission (SF) might be present as well. The largest part of every detected multi-chain event consists of α-decays because of the following two reasons: 1) the possibility of measuring the energies of α-particles with a high accuracy provides sufficient information to define the atomic numbers of the original nuclides [13]; 2) the pulse amplitudes of EVRs and FF are observed with a significant pulse height defect value (PHD[1]); nevertheless, they are also of great interest since their presence at the beginning and end of each decay chain makes the identification process complete. F.P. Heßberger was the first who recognized the importance of such analysis and demonstrated its validity using the

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[1] PHD = $\Delta_W + \Delta_R + \Delta_N$, dead layer, recombination and nuclear stopping components, respectively

Monte Carlo simulation of SF decays of [256]Rf nuclei implanted into a silicon radiation detector [15]. A simulation method for modeling the EVR spectra obtained from DGFRS is reported in [16, 17] in detail. A detailed description of a simulation approach for SF events can be found in [18, 19]. The successful application of these techniques to the data generated in an experiment which was carried out to investigate nuclides with atomic number Z=112 has been reported [14, 20]. The pulse amplitude of the EVR associated with one of three events in this particular case was anomalous.
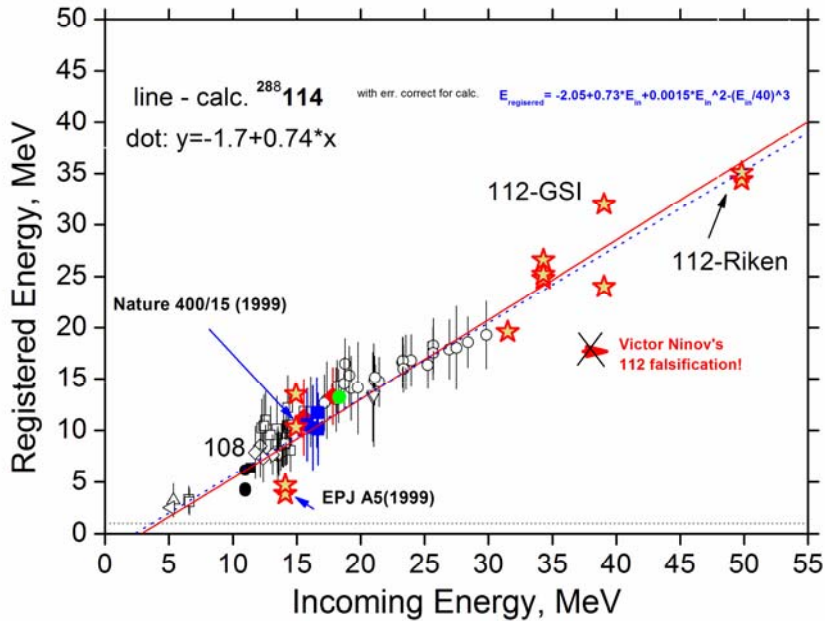
Fig.1. The measured and calculated dependences of the values of the recoil energy signal amplitudes on actual incoming energies. For more details see the text.

$$E_{Reg}(Z,A) = E_{Reg}(^{252}No) - k_1 E_{Inc}(A - 252) - k_2 E_{Inc}(Z - 102), \quad k_1 \approx 0.0169; \quad k_2 \approx 0.058.$$
$$(S_{Eff} \approx 10^3, \ \langle F \rangle \leq 0.1 \ V/\mu m)$$

The calculated and experimentally measured dependence of EVR energy signal amplitudes on the actual incoming energy for a DGFRS PIPS[2] detector is shown in Fig. 1. The solid curve is obtained by calculation [17]. The dotted line is an empirical calibration [18] measured with DGFRS for different heavy recoils. The experimental data obtained in SHIP, RIKEN [25] and VASILISSA [21] experiments are shown by stars. The experimental data corresponding to the nuclides with Z=112 measured in GSI [8, 20] and RIKEN experiments are in good agreement with the calculation. We would like to note here that, in the case of the GSI experiments, the following two nuclear reactions were used: $^{238}U + ^{48}Ca$ and $^{68}Ni + ^{206}Pb$. An EVR amplitude which deviated significantly from the expectations of theory [14] was eliminated by the authors [20] after reanalysis. In order to produce the experimental data for ^{252}No recoils, the nuclear reaction $^{206}Pb + ^{48}Ca \rightarrow ^{252}No + 2n$ was used. For this case, a Mylar degrader was utilized, with thicknesses of 1 μm. The corresponding comparison between the calculated EVR energy spectra and the experimental data are presented in Fig.2a-b. The theoretical values demonstrate a good agreement with the measured ones, with the centroids

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[2] SHIP and Vasilissa detectors are manufactured by CANBERRA Semiconductors NV, Belgium.

deviating by 1.75 MeV which corresponds to 11%. Figure 2b shows the same comparison for the production of Z=112 nuclides in the reaction of ^{48}Ca+^{238}U, where there is less experimental data; nevertheless, the deviation between experiment and simulation is only about 15% on the average.
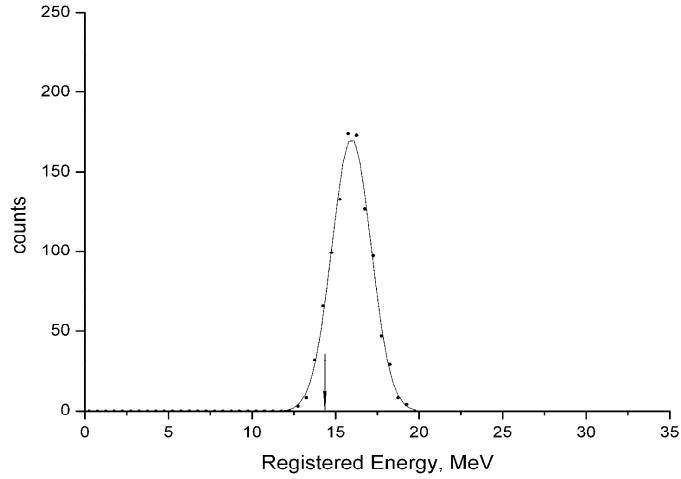
a)
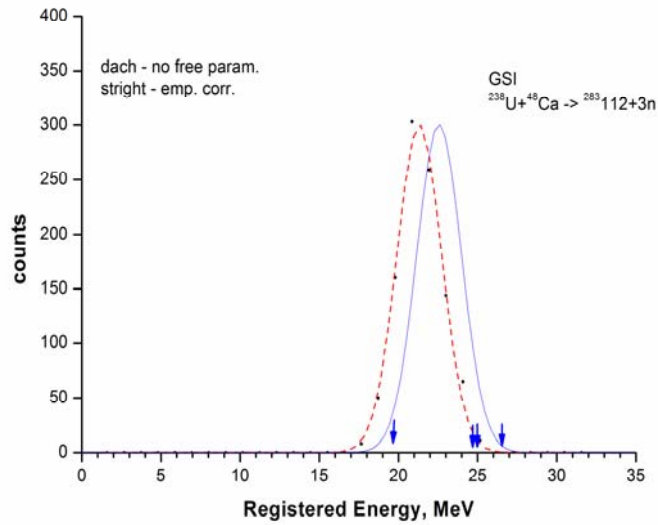
b)
Fig.2.

Simulated [present work] and experimental [8] EVR energy spectra for a) ^{252}No nuclide, with 1 μm mylar degrader, ^{206}Pb+^{48}Ca→^{252}No+2n. Centers of gravity are: 15.9 MeV (calc.) and 14.2 MeV (measured, see arrow); and b) Z=112 nuclide, no degrader, ^{238}U+^{48}Ca → 112+3n. Calculated center of gravity is equal to 21.3 MeV. Since the experimental data in 2c is limited, no Gaussian is fit to these data. (dot line - closed parameters of the simulation; line- with empirical corrections $y=a+b_1x + b_2x^2$; a=-1.22, b_1=0.3, b_2=-0.0062;) Relative recombination loss λ under simulation is equal to $\lambda=gsT_P/R$, where g-form-factor, s-effective recombination constant ($\sim10^3$ cm/s; g$\sim$0.5), R- particle range in silicon. Wilkins formula for stopping component of PHD is used.

3. Recoil-FF signal amplitudes

The present analysis for SHE nuclides does not always give a satisfactory agreement with measured values; for instance, in the synthesis of two recoil atoms with Z=114, see Ref. [21]. The experimental data obtained for an extended set of FF registered energy signals are shown in Fig. 3.
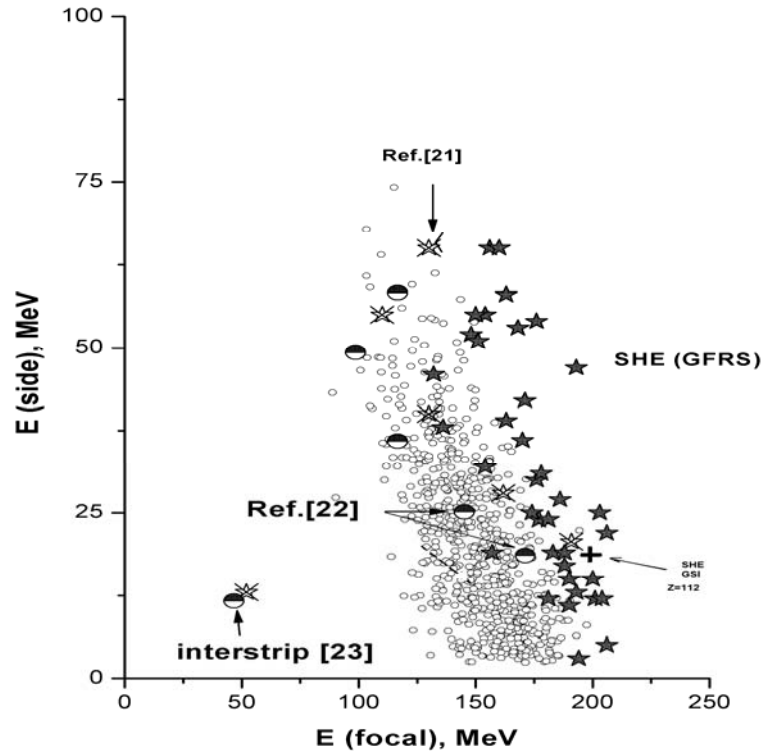
Fig.3.

Two-dimensional energy plot, SF events: the x axis corresponds to the energies of events detected by the main detector; the y axis corresponds to energies of the same events seen in the side detector. Open circles – ^{252}No events; stars – SHE SF events measured with DGFRS; half-filled circles – data from a VASILISSA experiment with a SF energy calibration extrapolated from an α-calibration; open star with a cross on top of it – original data [21-23]; cross alone – Z=112 (GSI) [8].

The systematic shift of the groups of data points with respect to each other can be explained, in part, by systematic errors in the FF registered-energy scale which are caused by different experimental conditions. For this reason, let us consider a dimensionless energy value k equal to the ratio $E_{esc} / (E_{esc} + E_{main})$, where esc and $main$ subscripts denote the energies detected by the side and main detectors, respectively. Use of the ratio diminishes the systematic shift of scales caused by different calibrations and can be introduced as a specific parameter for comparing the data. For complete-fusion reaction products, for which the implantation depth into the main silicon detector can be easily estimated, the k-parameter should decrease with an increase in the implantation depth. In Fig.4, the dependence of the k-parameter on implantation depth observed experimentally is compared with a simulation. It is

seen that the values arising in the experiment described in [21] are well outside of the main trend obtained from theory[3]. In Fig.5, the calculated recoil spectrum corresponding to the experiment described in [21] is shown. The measured amplitudes for the two reported events are shown by arrows.
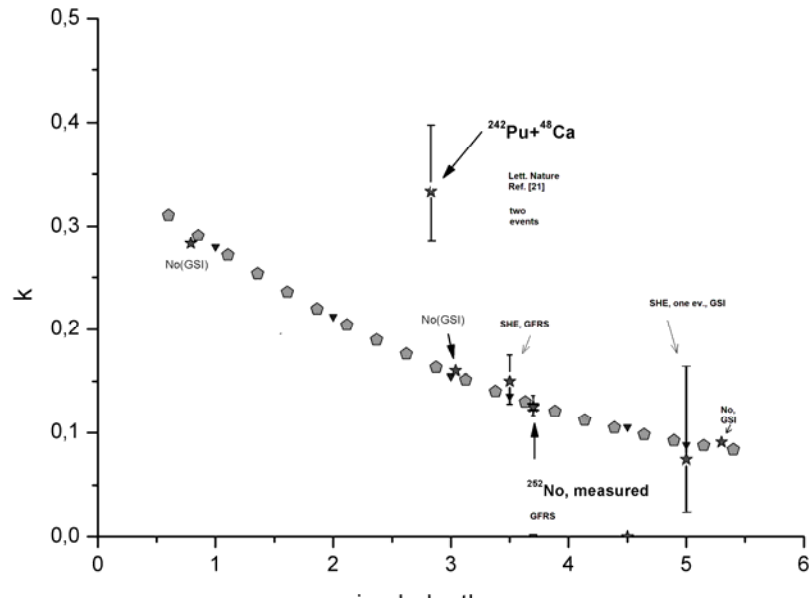

Fig.4.

Dependence of the *k*-parameter against EVR implantation depth in Si (μm). Pentagons correspond to the results of a theoretical simulation. Stars denote the values extracted from measurements at different facilities, as indicated in the figure.

4. **Detection of rare decays of SHE: "active correlations" technique**

To detect ultra rare decays of SHE in the heavy-ion induced complete fusion nuclear reactions the "active correlations" technique has been designed and successfully applied during last six years. Namely with this technique it has became possible to provide a deep suppression of background products associated with the cyclotron. The idea of method is aimed at searching in real-time mode of energy-time-position recoil (EVR)-alpha links, using the discrete representation of the resistive layer of the position sensitive PIPS detector separately for events like "recoil" and 'alpha". Of course, preset parameters for "recoil" signals are calculated according to the reported above. More details of the present method are described in the Ref.'s [10-12]. PIPS detector and it's PC memory representation are shown in the Fig.5 a,b.

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[3] Nuclear properties reported in [21] are not supported at this time by independent confirmation
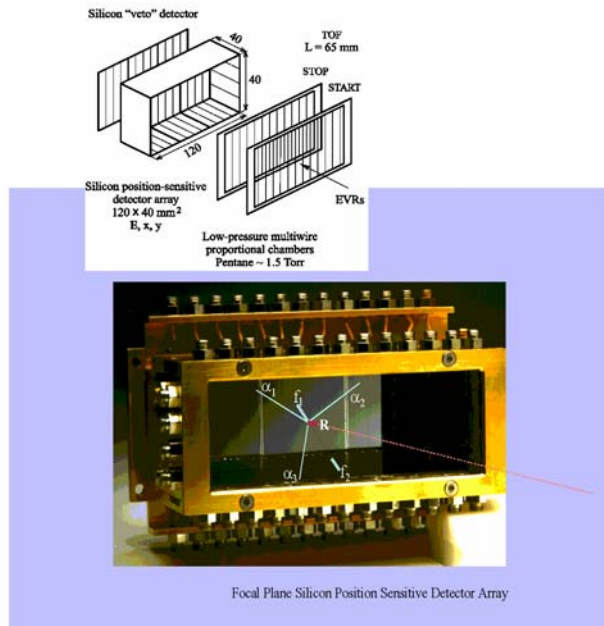
a)
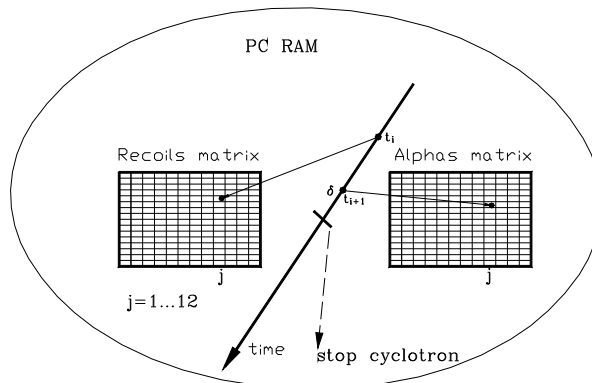
b)

Fig.5.

PIPS focal plane detector of the DGFRS (a) and PC representation for EVR-alpha quick search (b). Detection module of the DGFRS consists of PIPS 12 strip position sensitive detector, eight side detectors fog higher geometric efficiency of particles detection, escaping the focal plane one, VETO detector to suppress long-path charged particles coming from cyclotron and creating no signal in TOF detector, and gaseous low pressure pentane filled TOF detector to detect EVR's and to suppress background particles. The second (vertical) matrix index sell number is specified as: $j = \text{int}\{N_{max} * [\frac{a_{iy}N_{yi} + b_{iy}}{a_i N_i + b_i} * (\frac{R0_i}{R_i} + 1) - \frac{R0_i}{R_i} + \delta_i^{a,esc,EVR}]\}$,

where N_{max}- maximum number (130-170), R_i- resistance value for a strip number #i (first index), $R0_i$ – additional (#i) resistor, δ – small corrections parameter which is different for some different particles(alpha-escaping alpha-EVR), (a,b) – set of calibration constants are obtained from test nuclear reactions, $N_{i, yi}$ – ADC's channels for main and coordinate scales, respectively.

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In the Fig.6 the result of application is shown for ^{249}Am + ^{48}Ca $\rightarrow$ 115 + 3n complete fusion reaction and in the Tab.1 the parameters of radical backgrounds suppression factor are shown in the column 2.
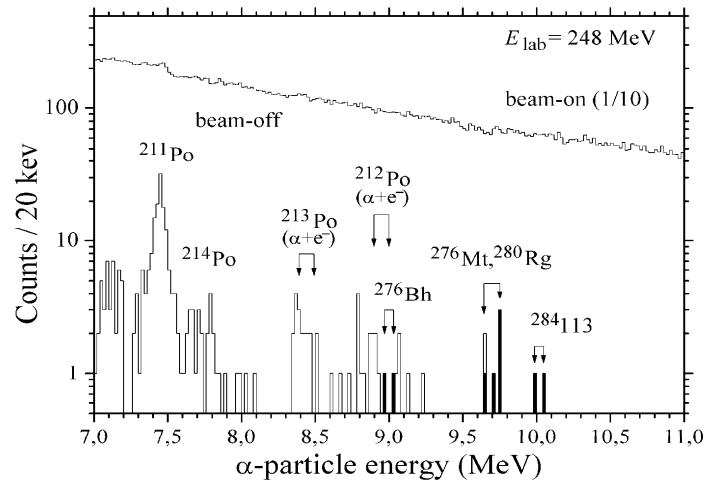

Fig.6. Spectrum of alpha decays measured in the beam-OFF intervals

Table 1. Typical suppression factors when "active correlations" technique is applied

Reaction	*An integral suppression factor (9-11 MeV)*	Energy correlation interval (Eα, MeV)	Correlation time, s EVR - α	Beam pause, min
^{238}U+ ^{48}Ca$\rightarrow$ 112	*9,5 e+03*	9,43 – 9,63/ 10,3-11,8	12/0,3	1
^{242}Pu+^{48}Ca$\rightarrow$114	*4 e +03*	9,9 – 10,35	4	1
^{245}Cm+^{48}Ca$\rightarrow$116	*1,5 e+04*	9,9 - 11	1	1
^{243}Am+^{48}Ca$\rightarrow$115	*2.0 e+04*	9,6 - 11	8	2
^{249}Cf+^{48}Ca$\rightarrow$118	*1,1 e+04*	9,9 - 12	1	1

5. Summary

1. based on:
- theoretical models, EVR spectra simulations and empirical relations obtained from test reactions ,
- Real-time matrix algorithm to search for pointer for potential forthcoming correlated sequence ,
- DGFRS detection system,
- U-400 cyclotron complex,

a new radical technique of "active correlations" is designed, tested and successfully applied in the heavy ion-induced complete fusion nuclear reactions during last six years.

- Detection of recoil-alpha correlated sequences in a real-time mode provides a deep suppression of beam associated backgrounds, when ultra rare alpha decays are detected. It provides more clear event detection and identification in long-term experiments aimed to the synthesis of SHE.

- A loss in the value of a total experiment efficiency is negligible, whereas an additional integral background suppression factor of about 10^4 in the vicinity of 10 MeV energy interval has been achieved.

2. Model calculations for EVR and SF events spectra are performed and compared with the different experimental data. This provides a framework for the criticism of the interpretation of the experimental results in the work [21]. This criticism is supported by the results of independent experiments, basing on the measurement of Z=112 nuclide decay properties (see also [26]).

3. For the case of lower PIPS detector over-depletion ratio, the formula for calculation of EVR registered energy signal amplitude in for the incoming energy interval of 5 - 50 MeV is proposed with the Z,A-depending correction coefficients (Fig.1 and it's caption).

4. A dimension-less energy parameter $k(r) = E_{esc}/(E_{main}+E_{esc})$ is proposed for critical amplitude analysis of spontaneous fission decays of implanted nuclei for the case of both fragments are detected by focal plane and side detectors.
(r – calculated implantation depths in silicon).

Acknowledgements

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On the common solution within a framework of single matrix algorithm for radical suppression of background products in heavy-ion induced nuclear reactions

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Abstract

Application of real-time matrix algorithm in heavy ion induced complete fusion nuclear reactions of super heavy elements synthesis is reviewed in brief. An extended algorithm, for the case of the recoil detection efficiency is not close to 100% has been proposed.

1. Introduction

Recently, at the Dubna Gas-filled Recoil Separator (DGFRS, [1]) more than 30 new nuclides with Z=110 to 118 have been synthesized [2]. It should be noted that some of these experimental results were clearly confirmed by the independent experiments [3-4], involving studying of chemical properties the synthesized atoms. To concentrate the reader's attention three major components of the success may be listed, namely:

• an electromagnetic recoil separator design must provide not only acceptable value of the nuclide transportation efficiency (tens of percent), but also a significant suppression of background products;

• a heavy-ion beam intensity should be high enough to provide nuclide under investigation formation;

• a radioactive rotating target design should be quite reliable, to provide a very long-term non-destructive operation

• a detection system must be not only quite informative to provide identification of the nuclide, but it should contribute to the process of deep suppression of backgrounds products .
Following the above points, the author formulated that an algorithm design, the goal of the present paper, is in fact can be considered as a supplement to the third point.

• if possible, the detection system can compensate drawbacks of the facility design.

2. Radical suppression of the backgrounds in experiments aimed to the synthesis of super heavy elements (SHE)

Usually, to reach high total SHE experiment efficiency, one use extremely high ($n*10^{12}$ to 10^{13} pps, n > 1) heavy ion beam intensities. It means, that not only irradiated target, sometimes (frequently) made on highly radioactive actinide material, should not be destroyed during long term experiment, but the in-flight recoil separator and its detection system should provide backgrounds suppression in order to extract one-two events from the whole data flow. Typically, the DGFRS provides suppression of the beam-like and target-like backgrounds by the factors of[1] $~10^{15}$-10^{17} and 10^4-$5*10^4$, respectively. Nevertheless, under real circumstances, total counting rate above approximately one MeV threshold is about tens to one-three hundreds[2] events per second. Therefore, during, for example one month of irradiation about $30*10^5*100 = 3e+08$ multi - parameter events are written to the hard disk during a typical SHE experiment at the DGFRS.

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[1] Depending on the reaction asymmetry (projectile to target mass ratio)
[2] Including events having only TOF signal and zero energy (below energy threshold)

To avoid a scenario that result of the SHE experiment (one-two-three decay chains per month) can be represented as a set of random signals real-time search technique to suppress the probability for detected event to be a random has been designed and successfully applied.

Note, that in the reactions with ^{48}Ca as a projectile, the efficiency of SHE recoiling products detection both by silicon and TOF detector is close to 100%. Namely recoil-first (second) correlated alpha decay signal was used as a triggering signal to switch off the cyclotron beam for a definite (seconds-minutes) and, therefore, detection of forthcoming alpha decays were in fact "background-free". The basic idea to apply such detection mode is to transform the main data flow to the discrete form [5]. To demonstrate this technique successful application in the Fig.1 the spectrum of α-decays detected in ^{237}Np+^{48}Ca complete fusion reaction is shown [6].
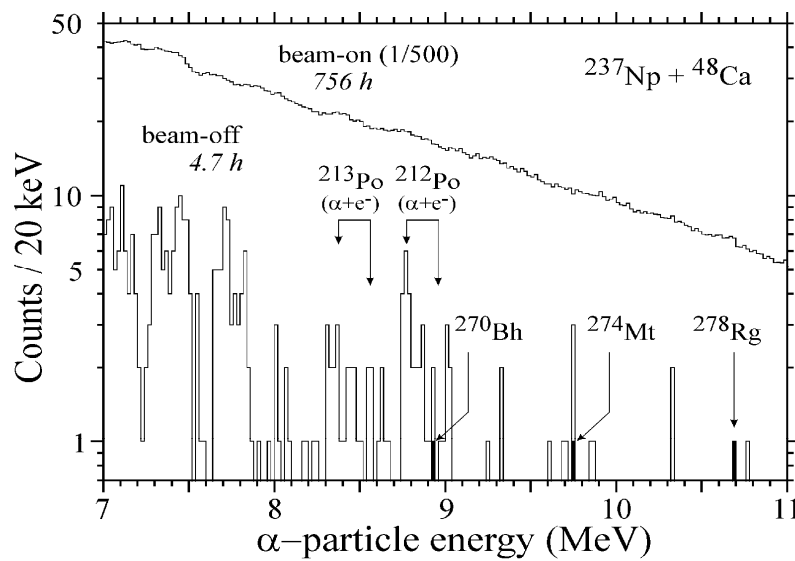
Fig. 1. Beam-OFF spectrum of alpha decays were measured in ^{237}Np+^{48}Ca complete fusion reaction [6]. Energy ranges: for EVR (7, 18) and for alpha particles (9.9, 11.4) MeV. Correlation time was 1.5 s for y-position window 2.8 mm. Beam-Off interval was of 10 s.

Note, that background suppression factor estimates as $\sim \dfrac{C_n^m}{K}$ ^{3} for the parameter of probability of the whole event to be a random [7]. Here n – the whole number of alpha decays, m- number of alpha decay, which stops the beam and K – suppression factor for single event($\sim 10^2$-10^3). It means, for instance, in the case of four alpha decay chains event, additional suppression factor is about $\sim 10^9$ if first alpha particle signal provides beam switching. Schematic of the whole process creating a background-free detection of decays is shown in the Fig. 2. It takes about 175 μs to provide full beam switching after detection a correlation recoil-alpha sequence including additional time delay ($\sim$ 60 μs) related with cyclotron operation.

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^{3} Rate difference for SF events between beam Off and beam On phase is not taken into account
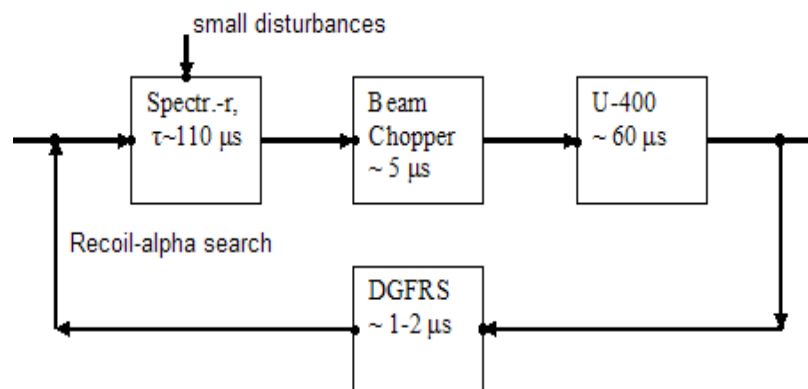
Fig. 2. Flow chart of the whole real-time process which is applied for radical suppression of background products in SHE element synthesis experiments. Delay times are shown for each component.

3. An extended algorithm

Unfortunately, in contrast to relatively high projectile, like ^{40}Ar and ^{48}Ca, when using projectiles from oxygen to magnesium, real threshold of the detection system sometimes does not allow recoil detection with close to 100% efficiency (see also Yu.S. Tsyganov, Fig.1 //this volume).

It seems more realistic in this case to use both recoil and alpha signals as a first chain of multi - chain event to provide beam switching. Of course, one assume, that the mentioned above value of the recoil detector efficiency is compatible with alpha- particle one. In the second, this value, in contrast to the one, corresponding to reactions with ^{48}Ca projectile, may be varied with varying of threshold level during an experiment. The schematic of such algorithm is represented in the Fig.4.
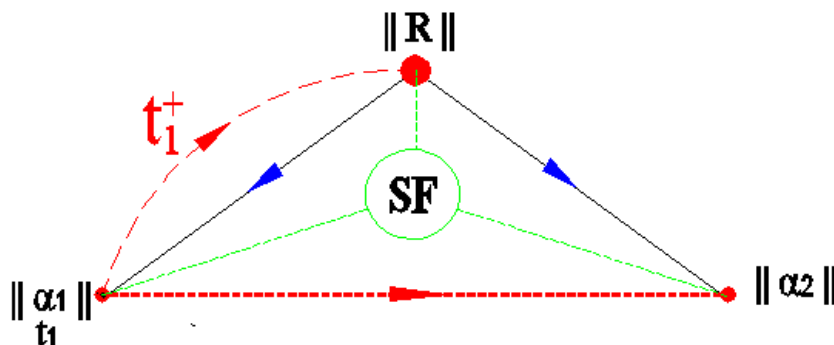

Fig. 4. The schematic of the extended algorithm of real-time search of correlated sequences. In the case of no beam stop is generated by first recoil-alpha sequence elapsed time of this alpha particle event is written to the appropriate matrix cell of the "recoil" matrix. In principle the same operation can also be provided with the second alpha decay event.

Loop t_1^+ denotes that in the case of "no success"[4], that is, if no beam stop is generated after recoil-alpha sequence detection, then the elapsed time of coming (and detected) alpha particles is written into the appropriate cell of the first ("recoil") matrix. Hence, the second alpha particle in the multi chain decay event will provide beam switching if time interval

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[4] No beam interrupt

between two alpha decays is less than pre-setting resolved time for first recoil-alpha correlation. In the case of one want to use separate pre-settings, it is necessary to use matrix cell in the form of two[5]-dimensional structure, not only write the elapsed time of the event, but also use particle identifier.

Of course, as a partial drawback of such approach one should mention, that the reported solution can be considered as "common" if all the decay life-times are of the same order. Otherwise one should use maximum preset time, and therefore, create extra break points during the process of target irradiation by intense heavy ion beam.

4. Conclusion

With a short reviewing of real-time algorithm application aimed to the radical suppression of backgrounds in heavy ion induced full fusion nuclear reaction, the most common solution based on extended algorithm version is suggested. It is estimated, that because of realistic spectrometer energy thresholds, such form of algorithm will be definitely useful in the case when the efficiency of recoil detection is far from 100%. The approximation for the recoil registered energy signal in the form $E_{reg} = -1.7 + 0.74 \cdot E_{inc}$ can be considered as an actual relation for a range of $\sim 3 \leq E\ inc \leq 50$ MeV, where E_{reg} – registered energy signal and E_{inc} – calculated incoming energy.

Acknowledgements

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[5] Or even more than two. From the viewpoint of practical realization author use C++ code and one can easily use "structure" or "class" object. To a first approximation, second component may be as an assuming number of decay chain in a multi-decay event, of course, starting from a recoil signal.

ATLAS database operations

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Abstract

ATLAS database applications require robust operational infrastructure for data replication between online and offline at Tier-0, and for the distribution of the offline data to Tier-1 and Tier-2 computing centers. We describe ATLAS experience with Oracle Streams and other technologies for coordinated replication of databases in the framework of the WLCG 3D services that are building world's largest distributed Oracle database deployment.

Introduction

The Large Hadron Collider (LHC) at the CERN Laboratory will become the largest scientific instrument in the world when it starts operations in 2008. The LHC experiments are facing an unprecedented multi-petabyte event data processing task. To address the event data processing challenge ATLAS experiment is deploying multi-grid computing technologies in the framework of the Worldwide LHC Computing Grid (WLCG) project. In addition to file-based event data, ATLAS data processing applications require access to large amounts of valuable non-event data (detector conditions, calibrations, etc.) stored in relational databases. Also, the database-resident data are critical for the event data reconstruction processing steps.

To set-up database services and facilities for relational data transfers as part of the WLCG multi-grid infrastructure, the WLCG Distributed Deployment of Databases (3D) project is coordinating database deployment and operations activity between LHC experiments and WLCG Tier-1 sites.

In preparation for LHC data taking, the focus of ATLAS database activities has shifted from development towards operations. In collaboration with the WLCG 3D project ATLAS is active in the development and deployment of the tools that allow the worldwide distribution and installation of databases and related datasets, as well as the actual operation of this system on ATLAS multi-grid infrastructure.

ATLAS Database Applications

In operations, ATLAS databases can be split in two broad applications domains: centralized and distributed. Most databases are only deployed centrally. Examples of these are many databases for online operations as well as detector construction and engineering databases. These applications are designed for interactive access or are accessed by a limited number of computers.

To increase robustness of data processing operations of petabytes of ATLAS event data ATLAS Computing split large-scale data processing tasks into smaller units: files and jobs. Several database applications keep track of numerous ATLAS jobs and files (Figure 1).

To eliminate potential access bottleneck for those database applications that serve data for numerous computers on the grid, a limited number of critical database applications - Geometry DB, Conditions DB, and Tag DB - have to be distributed world-wide. According to ATLAS Computing Model relational data are distributed to all ten ATLAS Tier-1 sites worldwide (Figure 2). This is because Tier-1 centers perform massive second-pass reconstruction and support other Conditions DB use cases.
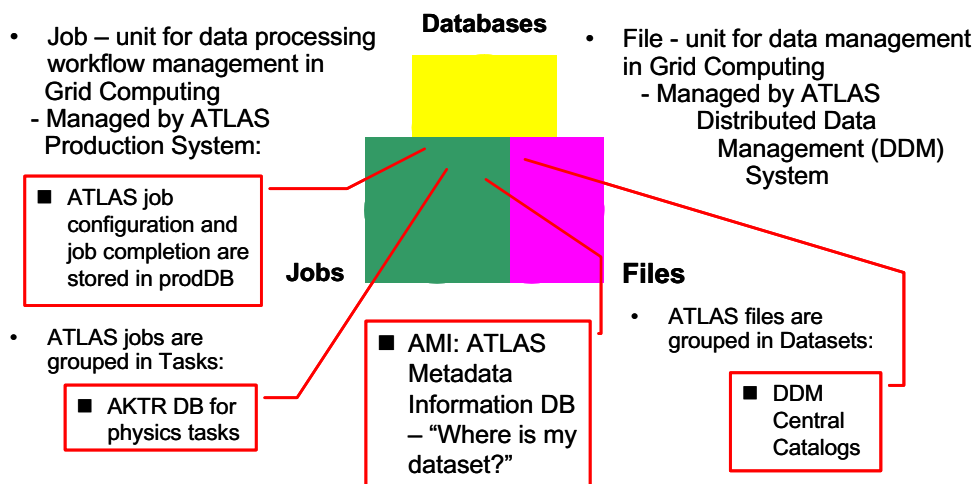
- Job – unit for data processing workflow management in Grid Computing
  - Managed by ATLAS Production System:
    - ATLAS job configuration and job completion are stored in prodDB

Databases

- File - unit for data management in Grid Computing
  - Managed by ATLAS Distributed Data Management (DDM) System

Jobs

Files

- ATLAS jobs are grouped in Tasks:
  - AKTR DB for physics tasks

- AMI: ATLAS Metadata Information DB – "Where is my dataset?"

- ATLAS files are grouped in Datasets:
  - DDM Central Catalogs

Fig. 1. Databases are critical to ATLAS data processing

Distributed Database Operations

To set-up database services and facilities for relational data transfers as part of the WLCG infrastructure the WLCG Distributed Deployment of Databases (3D) project is coordinating database deployment and operations activity between LHC experiments and WLCG sites. Because experiments applications present different challenges for distributed operations, the 3D project choose Oracle streams as baseline technology for database replication. Figure 3 shows distributed architecture of ATLAS database operations for data replication between online and offline servers at CERN Tier-0, and for the distribution of the offline data to Tier-1 sites.

Fig. 2. Worldwide distribution of relational data to all ten ATLAS Tier-1 sites
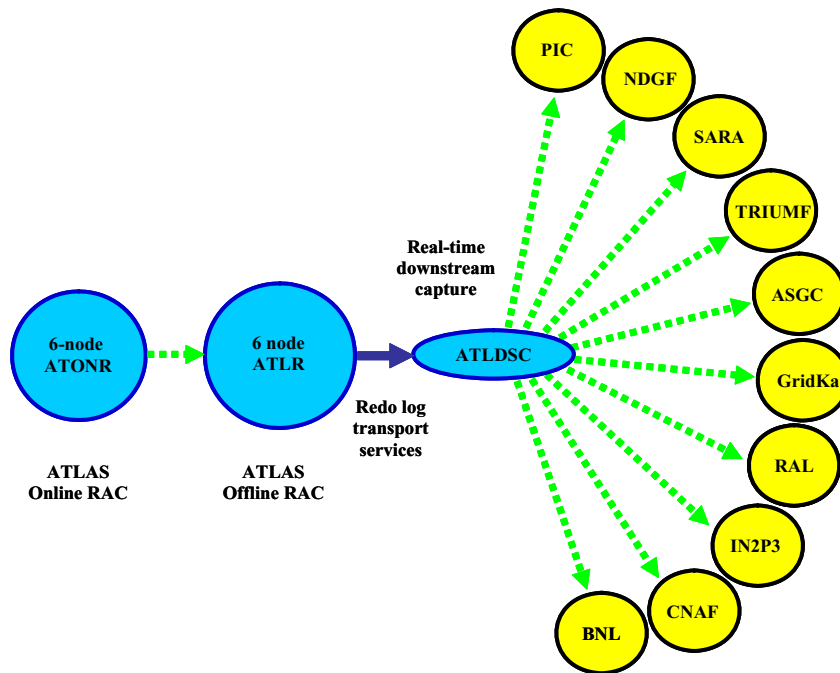
Fig. 3. Distributed architecture of ATLAS database replication via Oracle streams

In preparations for ATLAS exploitation an operational infrastructure for data replication was delivered by the WLCG 3D project on Distributed Deployment of Databases (3D). In close collaboration with 3D project and Tier-1 sites ATLAS started distribution of Conditions DB data to all ten ATLAS Tier-1 sites. Together we have accomplished a major achievement that contributed to a high-level WLCG services milestone (Figure 4).

Our next steps focus on the robustness of operations, such as the database recovery exercise. Now, we are collecting valuable production experience. Streams work reliably most of the time, however, if problems develop over weekend a backlog builds up that may take several days to recover. To avoid that planning for improved operational procedures is now in progress.

Database Scalability Tests

Because access to Conditions DB at Tier-1s is critical for that second-pass reconstruction, we studied if the deployed hardware capacities are sufficient to support massive re-processing at the Tier-1s. Since the second-pass reconstruction will process the data from tapes, our scalability studies can not rely on database data caching, therefore we tested the random access pattern to the Conditions DB data.

Fig. 4. Major WLCG milestones accomplished in database operations

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To validate Tier-1 hardware setup and to provide input to future hardware purchases Oracle scalability tests simulated realistic Conditions DB workflow. The goal of scalability tests is to overload the database cluster by launching many jobs at parallel. Initially, the more parallel jobs we launch – the more processing throughput we will get, until the server became overloaded, when it takes more time to retrieve the data, which limits the throughput.

Because of large allocation of dedicated resources, scalability tests required careful planning and coordination with Tier-1 sites, which volunteered to participate in these tests. We performed scalability testes at the French Tier-1 site IN2P3 CC at Lyon and Italian Tier-1 site CNAF in Bologna. Because Lyon and Bologna had different Oracle RAC hardware configurations the comparison of results showed the importance of doing tests at several sites. First Oracle scalability tests indicated that WLCG 3D capacities in deployment for ATLAS are in the ballpark of what ATLAS requires. Further scalability tests will allow more precise determination of the actual ATLAS requirements for distributed database capacities.

Conclusions

In preparations for data taking a coordinated shift from development towards services and operations has occurred in ATLAS database activities. The ATLAS experiment is active in the development and deployment of the tools that allow the worldwide distribution and installation of databases and related datasets, as well as the actual operation of this system on WLCG multi-grid infrastructure. In collaboration with WLCG 3D Project we was accomplished a major milestone in database deployment: a common LHC application – the Conditions DB – was deployed in ATLAS production operations. .It is now operated with real data on one of the largest distributed database systems world-wide.

Acknowledgements

ATLAS computing

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Abstract

The LHC experiments are facing an unprecedented multi-petabyte event data processing task. To address the event data processing challenge ATLAS experiment is deploying multi-grid computing technologies in the framework of the Worldwide LHC Computing Grid (WLCG) project. Recently, a full data processing chain was successfully tested with data from cosmics test run.

1. Introduction

The ATLAS computing architecture and technologies are described in detail in the ATLAS Computing Technical Design Report document [1]. Recent progress in ATLAS computing was reported in detail in many contributions at the CHEP07 conference held before the NEC2007 symposium. This overview is biased by my own opinions and presents the status based on the reports presented at the CHEP07 conference. These ATLAS CHEP contributions provide basis for a collaboration paper on ATLAS Computing to be prepared by the end of 2007.

As the exploitation phase of the ATLAS experiment nears, ATLAS computing efforts gradually transition from software development to operations. Valuable operational experience has been gathered from the detector commissioning efforts with cosmics data as well as from the computing system commissioning efforts with simulated data by grid computing operations teams. ATLAS physicists are increasing their experience in distributed analysis of these data. The M4 cosmics run in August-September successfully integrated all these separate operations in a full chain of data distribution, processing and analysis.
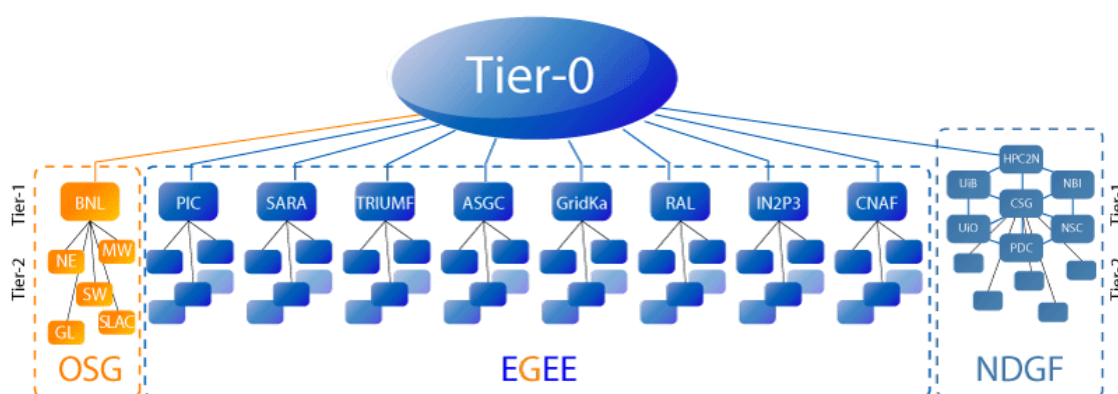

Fig. 1. ATLAS computing unified operation on grids with different interfaces

Table 1. Cooperating Roles of Distributed Tiers in ATLAS Computing Model

Tier Hierarchy	Cooperating Role
CERN Tier-0	• Prompt reconstruction on express and calibration & physics streams with old calibrations - calibration, monitoring • Calibration tasks on prompt data • 24-48 hours later, process full physics data streams with reasonable calibrations
CERN Analysis Facility	• Access to ESD and RAW/calibration data on demand • Essential for early calibration, detector optimization, and algorithmic development
10 Tier-1s worldwide	• Reprocessing of full data a few months after data taking, as soon as improved calibration and alignment constants are available
40+ Tier-2 worldwide	• On demand user physics analysis of shared datasets • Limited access to ESD and RAW datasets • Simulation (some at Tier-1s in early years)
Tier 3 Centers	• On demand physics analysis • Data private and local - summary datasets

2. ATLAS Computing Model

To cope with event data processing challenge on a petabyte scale ATLAS experiment adopted grid technologies deployed in a hierarchy of autonomous computing facilities cooperating in various roles in the framework of the Worldwide LHC Computing Grid. The roles of distributed tiers in ATLAS Computing Model have been remarkably stable (Table 1) [1]. ATLAS distributed

Fig. 2. ATLAS units for grid control

computing facilities start at the Tier-0 center at CERN and span worldwide over three computational grids EGEE, OSG, and NDGF (Figure 1). Each grid provides its set of common protocols for access to computing facilities.
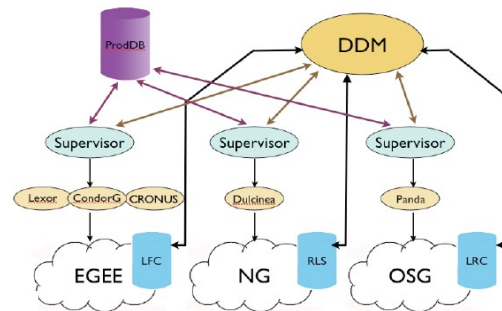
For robust handling of the unprecedented data processing and data management tasks the grid workloads are split into smaller units: jobs and files. To unify the control over the autonomous grids ATLAS developed two main control units that are specific to our computing model: ATLAS production system controls the jobs workload on the grids [1,2], ATLAS data management system controls the replication of files on the grids [1,2]. Figure 2 shows the architecture of ATLAS multi-grid operations. Underpinning the control infrastructure of ATLAS computing operations is the infrastructure of databases that keep track of jobs, files, etc. [1]. Leveraging underlying database infrastructure ATLAS Production System and ATLAS DDM successfully manage simulations workflow on three production grids: EGEE, OSG and NDGF. Figure 3 shows the statistics of success recorded in the ATLAS production database.

3. Validating Computing Model

3.1. ATLAS Computing Operations

To facilitate operational efficiency it is important to separate the development activities from ATLAS computing operations. The ongoing transition from development to operations was evidenced in numerous ATLAS contributions at CHEP07 that covered in detail both the development reports and the operational experience (Table 2). By concentrating the development on critical services such as monitoring ATLAS successfully leverages growing resources of all three computational grids (Figure 4). Table 3 presents current snapshot of ATLAS grid resources.
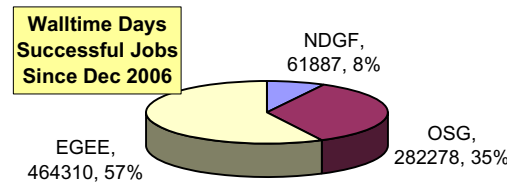

Fig. 3. Successfull ATLAS operations on three production grids

Table 2. Coverage of ATLAS CHEP07 contributions

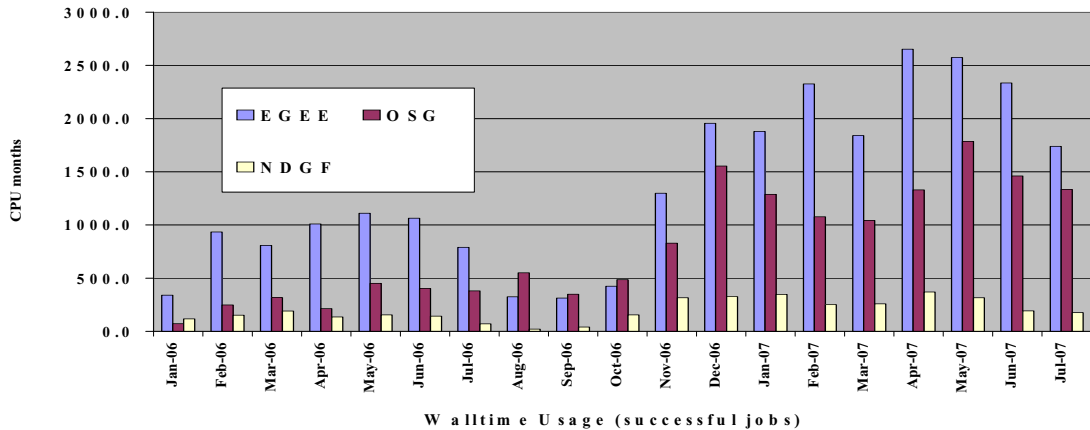| Domain		Development	Operations	
			Experience	**Monitoring**
Databases		Viegas	Vaniachine	Andreeva
Tier-0		Nairz/Goossens	Bos	Rocha
DDM		Lassnig	Klimentov	Rocha
Prod. System	EGEE	Retico	Espinal	Kennedy
	OSG	Maeno	Smirnov	Kennedy
	NDGF	Grønager	Klejst	Kennedy
Analysis		Farbin	Liko	Elmsheuser

Fig. 4. Mastering growing grid resources

3.2. ATLAS Event Data Model

The ATLAS Event Data Model is aiming to achieve equal and equal quality of access to the data for all ATLAS collaboration. There has been a considerable progress on all formats, trading size vs. flexibility (Table 4). As a result, much more will be possible with AOD than originally planned.

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Table 3. Latest snapshot of ATLAS grid resources

Grid infrastructure operated by	Resources available for ATLAS		
	Tier-1s	CPU (count)	Disk (PB)
EGEE: Enabling Grids for E-SciencE	8	3500	0.4
OSG: Open Science Grid	1	2500	0.4
NDGF: Nordic Data Grid Facility	1	500	.06

To assure redundant data storage and enable second-pass data reconstruction the raw event data will be replicated ("exported") from CERN to Tier-1 centers. With petabytes of raw data streaming from the ATLAS detector, the data export to Tier-1s presents a challenge. Since ATLAS has the largest nominal data transfer rate from CERN to Tier-1s it was important to test the data export over the Optical Private Network (OPN) that connects CERN and Tier-1s. The successful data export tests this spring reached about 75% of the nominal target, while all ten ATLAS Tier-1 centers participated in the tests.

Table 4. ATLAS Event Data Model

Data Type	Size (kB)	Accessibility
RDO: Raw Data Objects	1600	Tier-0 and Tier-1s Have to be recorded on permanent storage
ESD: Event Summary Data	500	Tier-0 and Tier-1s Output of the reconstruction Often large; difficult to analyze the full set
AOD: Analysis Object Data	100	Tier-0, Tier-1/2 - at least one complete copy per cloud, Tier-3 – subset Quantities in particular relevant for physics analysis Main input for analysis, distributed to many sites
DPD: Derived Physics Data	10	Tier-3s (e.g. your laptop)
TAG: event-level metadata	1	All Tiers

3.3. Commissioning with Cosmic Ray Data

Further validation of the computing model with realistic data rates is ongoing through the series of ATLAS cosmics runs that are gradually expanding their goals. The M3 (Milestone 3) cosmics run in mid-July of 2007 produced about 100 TB of data in two weeks. To stress-test the Tier-0 computing infrastructure M3 run acquired data at four times the nominal rate (by increasing the sampling rate of LAr calorimeter data).

The M4 run took place during August 23 - September 3. As for M3, this run included almost all of the ATLAS sub-detectors, with more detector hardware and many new features. In M4 computing operations expanded beyond the Tier-0. ATLAS exercised the full data processing chain with real data: from the detection of a real cosmic ray muon to arrival of reconstructed data at Tier-2 sites all over the world, with many steps in between. Figure 5 shows the real-time raw data transfer rates from online to Tier-0 and to all ten Tier-1s during the M4 run period. The full chain worked with all ten Tier-1s exceeding the expected target rate at the last day of the M4 run.
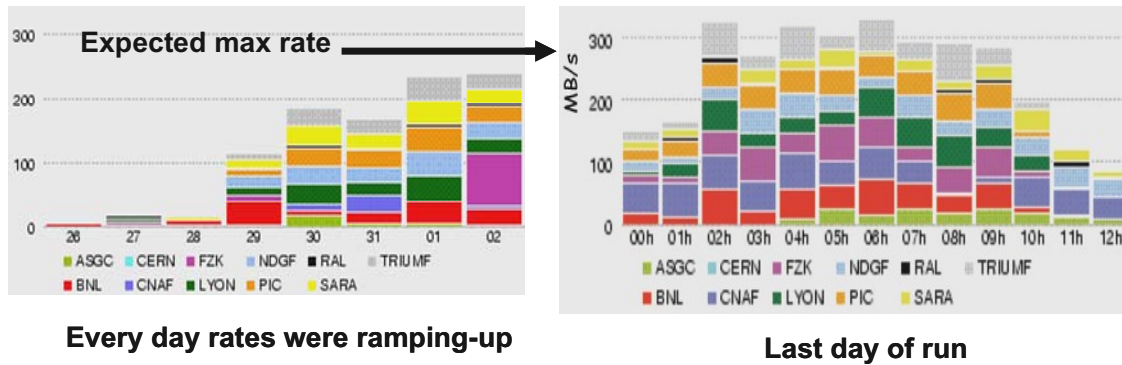
Fig. 5. Data throughput between CERN Tier-0 and Tier-1 sites during M4 period

An important milestone was that for the first time data went "end-to-end", from the detector through the data acquisition system to the Tier-0 site to all ten Tier-1 sites throughout the world, followed by the data analysis at the Tier-2 sites. The data analysis happened simultaneously at the sites across Europe and the U.S., and it happened almost in real-time. Figure 6 shows M4 cosmic event display: tracks in the Transition Radiation Tracker (TRT) and in the muon chambers.
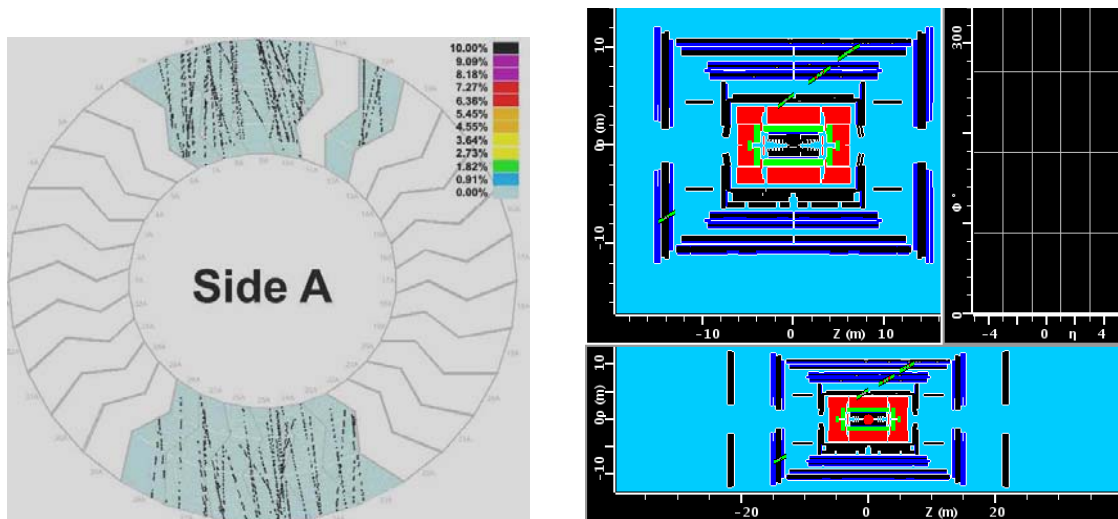

Fig. 6. Cosmic event display in TRT (left) and in the muon chambers (right)

The next M5 cosmics run is scheduled for October, 2008. It will be followed by the M6 cosmics run that will start some time in February 2008 until the start of LHC data taking. These runs will have incremental goals, with data reprocessing between the runs. The cosmics data taking will run close to the nominal rate and expect to collect up to 0.4 PB of data by the start of the LHC operations.

3.4. ATLAS Full Dress Rehearsal

To verify readiness for LHC data taking ATLAS computing is conducting a large scale Full Dress Rehearsal (FDR) exercise based on the simulated mix of physics events. The

simulated events will be injected in the ATLAS trigger and data acquisition chain to produce a realistic physics mix in the bytestream format including the "luminosity blocks" data. The resulting FDR data will have the real data file and dataset sizes, trigger tables, and will be grouped into data streams. The FDR data processing chain will include data quality analysis, with the express line and calibration production running using the Conditions DB data. The first pass reconstruction at Tier-0 will produce the ESD, AOD, TAG, and DPD data (see Table 4). The FDR data will be exported to Tier-1s and Tier-2s for remote analysis. The RAW data at Tier-1s will be reprocessed to produce the next iteration of the ESD, AOD, TAG, and DPD data, including remake of AOD from ESD and exercising group based analysis of the DPD at Tier-1s. FDR goals for the Tier-2s and Tier-3s activities includes ROOT-based analysis, trigger-aware analysis with Conditions DB and Trigger DB data, user analysis without use of the simulated "truth". In parallel, the simulations and reconstruction production will be running. Table 5 presents the loaded schedule for the ATLAS FDR activities. In addition, the first-pass production should be validated by year-end, the reprocessing will be validated months later, and the analysis roles will be validated during the FDR.

Table 5. ATLAS Full Dress Rehearsal Schedule

Round	Schedule	Activity	Status/Needs
1		Data streaming tests	***DONE***
	Sept/Oct 07	Data preparation	*STARTS SOON*
	End Oct 07	Tier-0 operations tests	
	Nov 07 - Feb 08	Reprocess at Tier-1, make group DPD's	
2	Dec 07 – Jan 08	New data production for the final round	*Needs new G4*
	Feb 08	Data preparation for the final round	
	Mar 08	Reco final round	*Needs SRM v2.2*
	Apr 08	DPD production at Tier-1s	
	Apr 08	Additional simulated data production	
	May 08	Final FDR in preparation for first data	

Also, during the WLCG workshop held before CHEP07 it was decided to have a common LHC computing centre readiness challenge (CCRC) in the first half of 2008. It will consist of two phases, the first phase in February followed by the second phase in May of 2008.

4. Ramping Up ATLAS Computing Resources for Data Taking

Figure 7 shows the planned ramp-up of ATLAS computing resources for LHC data taking. Note that changes of the LHC schedule makes little change to the resource profile. This is because the early data is for calibration and commissioning, which is needed either from collisions or cosmics.
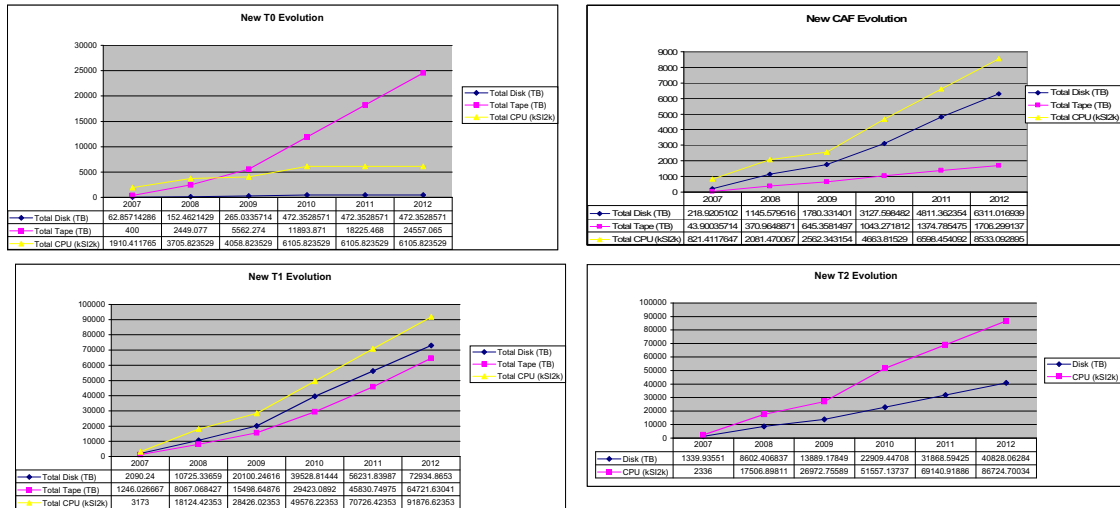
Fig. 7. Anticipated growth in ATLAS Computing Resources

5. ATLAS Analysis Model

To facilitate analysis of the first data and to support ATLAS physics program in general ATLAS Analysis Model alleviating constraints of limited computing resources by focussing software design and the requirements from physics. Recently, the Analysis Model ensured that ATLAS software framework supports the required manipulations of event data, aligned the event data design and content with foreseen calibration and physics analysis tasks, and optimized the event data in size, and access speed [1]. The Analysis Model assumes that speed is the most important factor for users. Since the smaller data can be analysed faster the Analysis Model utilize the following principles:

- Skimming- Keep interesting events;
- Thinning - Keep interesting objects in events;
- Slimming - Keep interesting info in objects;
- Reduction-Build higher-level data which encapsulates results of algorithms.

For interactive analysis the Model provides the Derived Physics Data that share the schema with objects in the AOD/ESD (Figure 8). To optimize AOD access speed close to the ROOT limit the framework implements the Transient/Persistent Separation and allows direct access to AOD in ROOT.
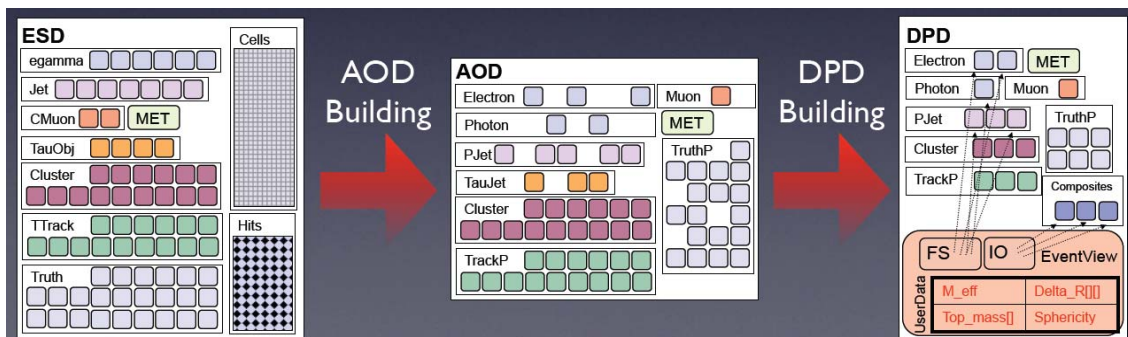

Fig. 8. Derived Physics Data share the schema with objects in the AOD/ESD [8]

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Valuable experience has been gathered in ATLAS Analysis by exposing users to various grid tools. On the EGEE and NDGF infrastructure ATLAS uses direct submission to the middleware using GANGA that hides the underlying grid-specific protocols from the users [1]. On OSG a similar functionality is provided by the pilot-based PanDA system, which is also available at some EGEE sites [1]. By exposing many users to the grid the work is getting done. Although simple user interface is essential to simplify the usage, but since experts are required to understand the problem, sometimes users get the impression that they are debugging the grid.

6. Conclusions

In the final year of preparation for LHC data taking a coordinated shift from development to operations and services is happening. ATLAS experiment mastered complex multi-grid computing infrastructure at the scale close to the expectations for running conditions, including resource utilization for simulated event production and the data transfers rates from CERN to Tier-1 sites. An increase in scale is expected in facility infrastructure and the corresponding ability to use new capacities effectively. Physics analysis activities by many users are ramping up successfully.

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Securing distributed data management with SHIELDS

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Abstract:

High-performance secure data access is vital in the distributed computing environment. However, most of database grid oriented solutions are using ineffective approach of surrounding the database with a secure middleware layer. An additional drawback of the middleware layer approach is vulnerability of the actual database access at the back-end. To eliminate this vulnerability and provide end-to-end Globus security solution for database access project "SHIELDS: Secured High-performance Infrastructure Enabling Large-scale Database Sharing" implemented secure database authorization on the transport level. The embedded security approach bridges the gap between data accessibility and the increasing power of grid computing.

SHIELDS software was designed and developed based upon open-source software, such as the MySQL database engine, OpenSSL libraries for X.509 certificate authorization, and Grid Security Infrastructure libraries for securing the distributed computing environments based on Globus. The SHIELDS software provides technology for embedding the latest GT4 security in the MySQL and PostgreSQL open-source databases. Thanks to the backward compatibility, it is also possible to use GT3 pre-RFC grid proxy certificates for the grid-enabled database authentication. The backward compatibility support is provided since most of the Grid computing solutions in deployment today are based on GT3 technologies.

SHIELDS software was tested in the distributed computing environment of Open Science Grid (OSG). The SHIELDS performance has been tested in the context of the ATLAS Distributed Data Management (DDM) software system. For that, the Python interface and a connect string protocol for the grid-enabled MySQL server connection were implemented. In the large-scale test, the SHIELDS software was used to secure data management on the OSG. On the scale of multi-millions entries which was used so far, the grid-enabled MySQL is shown to be practical. An additional benefit of using SHIELDS software was the elimination of distribution of the plain-text passwords to computing users worldwide.

Further work of the SHIELDS project has a focus on hardening of the embedded security in the production environment of ATLAS Computing Operations on OSG.

1. Introduction

Data-intensive sciences demand efficient performance in distributed computing environments, and to achieve this, we are developing the architecture and software for secure high-performance infrastructure to enable large-scale database sharing for distributed computing. This specific technical objective is represented in our software product name: SHIELDS: Secure High-performance Infrastructure Enabling Large-scale Database Sharing. Building upon a solid foundation of the Globus Security Infrastructure, we have assembled a multi-disciplinary team of researchers with strong credentials in cyber-security and data management technologies. Leveraging cross-disciplinary collaboration we are seeking to advance security mechanisms for large-scale data access within a distributed computing environment.

2. SHIELDS Architecture

The majority of database grid oriented solutions are using the traditional approach of surrounding the database with a secure middleware layer. The drawbacks of the middleware layer approach are (a) vulnerability of the actual database access at the back-end, and (b) reduced performance. Fig. 1 compares the traditional middleware layer approach and the embedded security approach. It shows that the ultimate goal of the embedded approach is to eliminate this vulnerability and provide end-to-end Globus security for database access.

Our approach is based on database architecture where the secure authorization is pushed into the database system core, eliminating inefficient data transfer bottlenecks. In

addition, to prevent use of insecure and clear-text passwords in distributed data access and data-mining applications the new technology incorporates database authentication based on time-limited X.509 proxy certificates [1, 2].
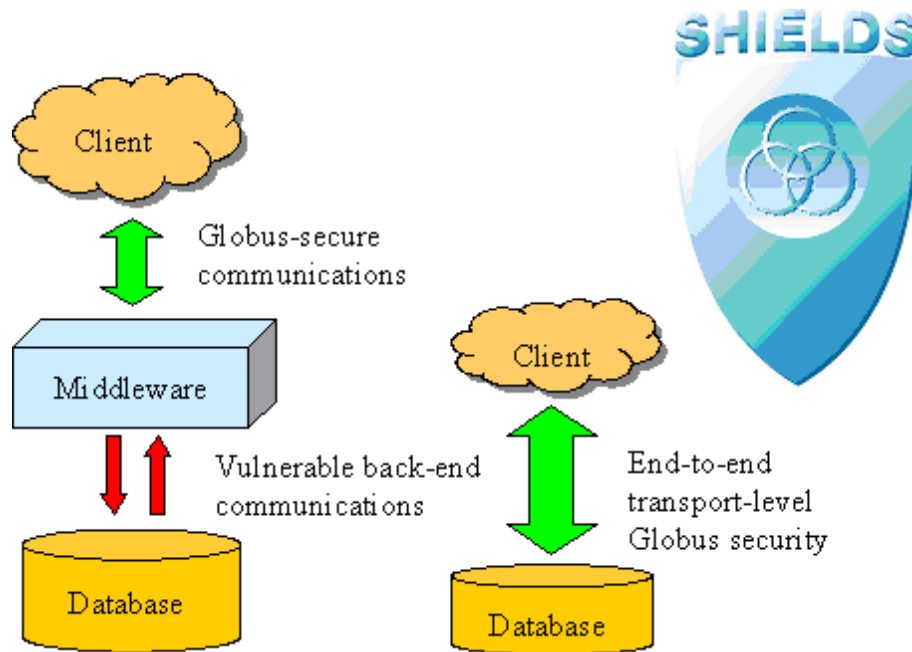

Fig. 1. End-to-end Globus security solution for database access

3. SHIELDS Software

3.1 Release Alpha

The first release of the SHIELDS software has embedded the latest Globus GT4.0 security in the MySQL. To advance SHIELDS release performance testing we posted the SHIELDS release for outside "early adopters" on the project web site [1].

SHIELDS also tested a new technology, Virtualization, which is a powerful method to protect individual computer nodes and/or computing clusters. By running independent operating environments in virtual machines, the independent system functions are isolated from the underlying hardware. This property improves detection and forensics strategies and simplifies image-based recovery.

After the first software release was built at Argonne, we tested the SHIELDS deployment and performance at Brookhaven National laboratory. The Python interface has been identified, and a connect string protocol for the grid-enabled MySQL server has been designed, e.g.:

```
mysqlx509://hbf7e4e5a:x509up_u2914@db.usatlas.bnl.gov:3306/lrc
```

The SHIELDS performance was tested in the context of the software system for large-scale Distributed Data Management of the high energy physics experiment ATLAS. At the scale of several million entries in a file catalog database, the SHIELDS software was shown to be practical.

For the Worldwide LHC Computing Grid Tier 1 site at the Brookhaven National Laboratory the SHIELDS software assures compliance with DOE facilities security guidelines

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by preventing the exposure of plain-text passwords for access to U.S. database to international distributed computing users.

In addition, we performed detailed investigation of various security scenarios [1]. The client and server used for tests were the actual patched or unpatched database client and server: mysql and mysqld for MySQL tests, psql and postmaster for PostgreSQL tests. The MySQL patch in the software release was only a proof-of-concept solution, not the production-level solution. Consequently, configurations based on that patch failed at least some test cases, as did the unpatched configurations. Several other failed configurations are documented in the table, as are two configurations that passed the tests but only by circumventing best practices. In contrast, the final configuration passed all tests by updating how the PostgreSQL client and server use openssl functions to verify certificates. However, these tests accepted only the RFC-compliant proxy certificates, not the Globus legacy proxy certificates. To overcome these limitations our next software release generalized the changes to the legacy Globus proxies.

3.2 Release Beta

The next generation SHIELDS prototype included further security enhancements. Following the guidance from our security experts the GSI security is now embedded at the core software layer – in the OpenSSL libraries. This approach provided technology for using the same SHIELDS software solution for the MySQL and PostgreSQL databases. Both databases use OpenSSL for its X.509 certificate support, so they support just the set of certificate types supported by OpenSSL. OpenSSL 0.9.8, the version used in this project, supports RFC3280 End Entity Certificates and RFC3820 Proxy Certificates. When either type of Globus proxy certificate is presented to the OpenSSL verify functions, the unknown GSI-2 and GSI-3 proxy certificate types fail the verification checks.

Ultimately we "grid-enabled" MySQL by modifying OpenSSL to support Globus proxy certificates, then making only minor changes to MySQL to take advantage of the modified OpenSSL. Table 1 summarizes added functionalities demonstrated by our test results. Our recent report [1] describes the project work to grid-enable MySQL – i.e. adding the ability to use Globus "legacy" and "pre-RFC" proxy certificates in MySQL authentication.

Table 1. Summary of the test results demonstrates new functionalities in SHIELDS

System tested	EE cert			Legacy proxy			Pre-RFC proxy			RFC3820 Proxy		
	not yet valid	*valid*	*exp*	*not yet valid*	*valid*	*exp*	*not yet valid*	*valid*	*exp*	*not yet valid*	*valid*	*exp*
Plain OpenSSL	R	A	R	-	r	-	-	r	-	R	A	R
Modified OpenSSL	R	A	R	R	A	R	R	A	R	R	A	R
Plain MySQL	R	A	a	-	r	-	-	r	-	a	A	R
Modified MySQL	R	A	R	R	A	R	R	A	R	R	A	R

Key:	A	the certificate is accepted, as expected
	a	the certificate is accepted but should be rejected
	R	the certificate is rejected, as expected
	r	the certificate is rejected but should be accepted
	–	the certificate is rejected, as expected, but for the wrong reason

In preparation for the measurement of the performance on the U.S. Open Science Grid production-level distributed computing facilities; a grid-enabled python interface was built and tested on both 32-bit and 64-bit platforms. These results were presented by our collaborators at the ATLAS Software & Computing Workshop at CERN in June of 2007 [1].

4. Conclusions

Data-intensive sciences demand efficient performance in distributed computing environments, and to achieve this, we are developing the architecture and software for secure high-performance infrastructure to enable large-scale database sharing for distributed computing. This specific technical objective is represented in our software product name – SHIELDS: Secured High-performance Infrastructure Enabling Large-scale Database Sharing. In contrast to the traditional approach that just surrounds the database with separate cryptographic middleware layers, this project is developing novel technologies that embed Globus security features inside of the database code. The resulting SHIELDS software architecture provides a solid foundation for end-to-end security for large-scale advanced computational data management and analysis. The advantages, therefore, would not only be to allow more efficient and rapid exchange of large-scale data sets but a potentially significant increase in the scalability of such exchanges within a distributed computing environment.

The embedded security approach of the SHIELDS software could have more effective security controls than the traditional middleware technology. Therefore, the project aims to provide a more effective and secure mechanism for protecting and exchanging scientific data.

The project's proposed early deployment in production support of high energy physics databases not only accomplishes this for an important and substantial scientific investment; it demonstrates the viability of doing something equivalent for scientific and other applications that rely upon distributed database access. The delivery of an infrastructure that allows use of the same credentials and supporting infrastructure for database access as are used for access to compute resources not only improves security (at least compared to current common practice), but also, by simplifying and unifying the overall security infrastructure deployment strategy for applications, greatly increases the odds that reasonably robust strategies will in fact be deployed.

Acknowledgements

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Development of protection control techniques for pulsed facility systems

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Abstract

Techniques of fast protection control for pulsed nuclear-physics facilities such as the IREN facility linac systems are developed. Now the created control tools are intended to use in duty protection systems of the LUE-200 linear accelerator. This paper describes the development of the systems for emergency control and protection of the linac electron source. It also presents recent results of the development of the protection control technique and the new multiway control unit made for the protection system of the pulsed electron gun.

Introduction

The instrumentation of the pulsed nuclear physics facility such as the IREN facility systems based on the LUE-200 linac [1, 2] should include techniques of timed data taking to diagnose and control linac cycles [3]. The offered diagnostics schemes of the cycle parameters and state transitions are applicable for fast control and functional-mode protection [4]. These schemes have been checked at the IREN test facility for a possible fast locking of the cycles [5].

Further development of the fast control and protection of the operation mode for the pulsed facilities is required along with the development of the known feedback control schemes. Now the fast control tools are advanced in protection techniques for the linac subsystems that include a pulsed electron gun and powerful klystrons with the pulse modulators, etc. The development of the protection control technique on the basis of a new control unit made for the pulsed electron source, is considered below.

Techniques of fast control and protection for pulsed facilities

The protection control technique for pulsed facilities should recognize fast transition processes whose parameters are useful to find troubleshooting and control protected subsystems, such as the linac electron source, etc. The tools for fast control and locking of cycle triggering are based on methods of data taking for each pulsed cycle and possible state transitions (Figure 1).
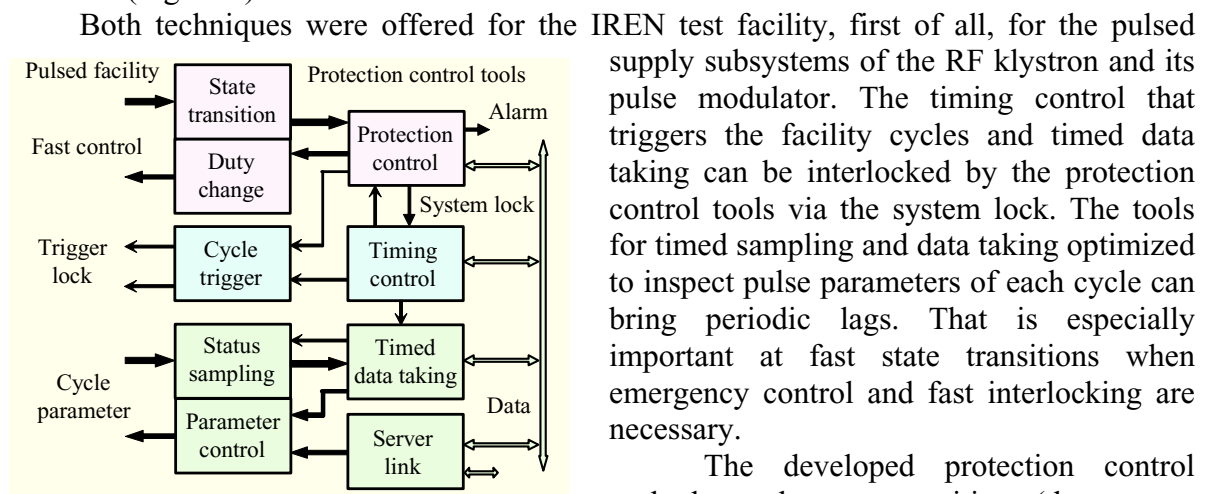
Both techniques were offered for the IREN test facility, first of all, for the pulsed supply subsystems of the RF klystron and its pulse modulator. The timing control that triggers the facility cycles and timed data taking can be interlocked by the protection control tools via the system lock. The tools for timed sampling and data taking optimized to inspect pulse parameters of each cycle can bring periodic lags. That is especially important at fast state transitions when emergency control and fast interlocking are necessary.

The developed protection control tools detect the state transitions (that are not timed with each cycle) and make duty changes faster. Both the faster signal

Fig. 1. Fast tools for the pulsed facility

diagnostics for the interlock control of the subsystems and data acquisition of status changes (for server operating) are available. The used signal processing components fulfil both sampling and recording of the deviation simultaneously. It is possible to find the state parameters at the given time intervals (to quickly identify beam issues), or at a fast state change and the facility shutdown.

The tools interacting via data link can contact the server that monitors the data for the parameter control (other industrial tools are usable to monitor static parameters and control slowly the magnets, vacuum, temperature, etc). The applied components of the own system facilitate an in-house development and maintenance. To meet the requirements of the higher data throughput, the devices fulfil roughing-out during the microseconds. The remote protection control on facility areas has required a possibly simple and robust control logic with protective interlocking.

Development of the protection control techniques

The protection control should be advanced now for state transition diagnostics and duty control of the pulsed linac subsystems. The protection control scheme for a pulsed facility (Figure 2) is composed for the pulsed supply subsystems of the linac. The subsystem protection of the pulsed gun and the klystrons with the pulsed power supply are based on the Control units (for the subsystems 1 and 2, etc) and Synch gates (programmed synchronization gates).
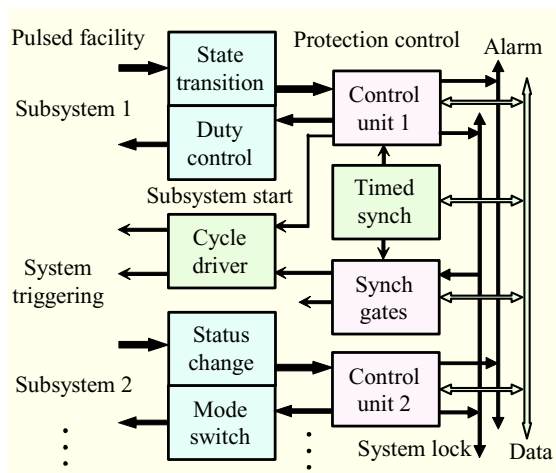

Fig. 2. Protection control of subsystems

The first created Control unit 2 is intended for alarm signaling and shutdown of faulted facilities. The unit for the test facility protection determines sudden threshold crossing of the key parameters (as pulsed voltage and currents of the klystron and a filament, a charger, the rectifier, the solenoid, and degaussing). The unit also finds a turn-on of principal sensors (for the klystron and a pulse transformer, cooling and vacuum systems, the filament and discharge). The unit can switch the modes of the protected equipment (the main HV source and selected sources for the filament or charging, or starting-up, and so on).

The signal of the system lock controls the synchronous gates of the cycle driver for system triggering. Now the technique is advanced to protect the subsystems at the linac areas. The features of deviation detection of pulsed parameters (as well as both analogue and two-stage signals) are modified to control each of the protected linac subsystems.

The second type unit having new features of the multiway diagnostics and emergency control is developed for duty protection of the gun and for interlocking of the linac subsystems. The clock pulses of the timed system synchronizer enabled in the Control unit 1 can start the gun subsystem and further the other subsystems. The system lock can be used to control other synchronous gates that allow the pulses to pass into other linac subsystems.

Thus, the new interlock devices can allow the start pulses selectively for each subsystem. The control units and the synchronous gates can be interconnected to select the timed triggering of the linac subsystems. The units also can interact while transmitting of the registered state data and obtaining the server commands. The operations of all autonomous units or linked with a computer are possible without interference of the external control.

Features of the new control unit

Functional features of the new unit for the gun protection and linac locking are displayed further (Figure 3). The unit components include the Fast lock of the Timing pulse for Start of the gun, and the Shaping for Lock control of the subsystems.
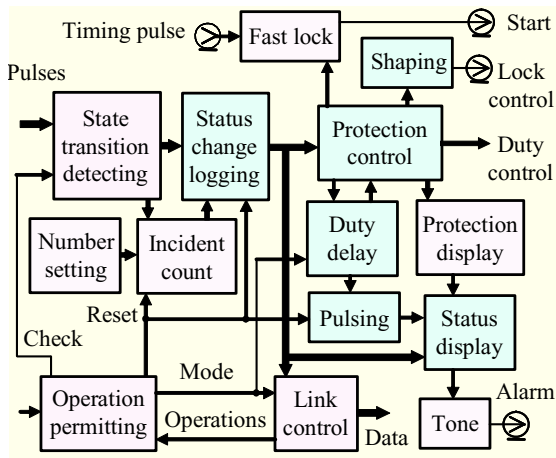

Fig. 3. Features of the new control unit

The State transition detecting and Status change logging are added with the Incident count and Number setting (to count the ignorable events). This allows one to suspend the lock when the number of omitted changes is set (up to 3 at the HV breakdowns). When the intersection of the alarm levels is defined for any input channel, then the Fast lock and Lock control, just as the Protection control (and its displays) and the Link control are initialized. After the Fast lock operation, the Duty control protects the HV devices of the gun subsystem, switching out or reducing their power.

The Status display for discovered violations is supplemented by the Protection display (for channels of the emergency control) and a controlled Tone source for the Alarm (with Pulsing during Duty delay operations or Reset). The delay timing of the Lock turn-off (and the HV subsystem turn-on) is intended to protect the gun (the cathode filament). The Operation Permitting can secure data logging and protection control. There is a choice of up to 7 control modes that include various operations (the Check, the Reset and Number setting, Modes of delay time and link). The Link control, providing Operations of a Data transmission and their reset, has also function of the Check of all channels and counting. The programmed operations include only the beforehand permitted changes of the protection mode (both the protection check and its reset, which is valid after removing the reasons of the alarm state).

The scheme of the control unit

The logic circuit of the new control unit BLG16 is displayed further (Figure 4). The unit has an input for the Clock pulse and 16 inputs for the On-off and Analog signals and Pulses. Besides there are outputs for the Start pulse, the Lock control, and the Protection control (4 channels selected from 16). The components of the Comparator and the Reference (with adjustable voltages) detect deviations of the analog signals or the pulses of various polarities. The Threshold trigger (as the Schmitt trigger with OR-logics) defines the state transitions (or contact closing) of the signals of 16 sensors. The Filter has protective components for noise filtering, interference rejection, and isolation. Additionally there is a pickup signal conditioning and the parameter range normalization.

The Register has latch logics for status change recording and additional logics of the allowed Reset of the data. The alarm data will get onto the Channel selectors, the combined Monitor of the status, and into the Interface with Selector of a Link for Data transmitting. The Main alert signal goes onto the Control logics for Protection drivers and their P-Monitor. This signal (via the OR-circuits) excites the Former for the Lock control and for the Pulse lock, the Monitor, and the Tone oscillator. Therefore, the Start pulse is locked, the Main channel (of the HV source) and other selected channels, and the N-status display are turned off, but the Lock control and the Tone of Alarm are turned on. The Monitor can display names of the normal or alarm states and of the switched channels of the protection control.
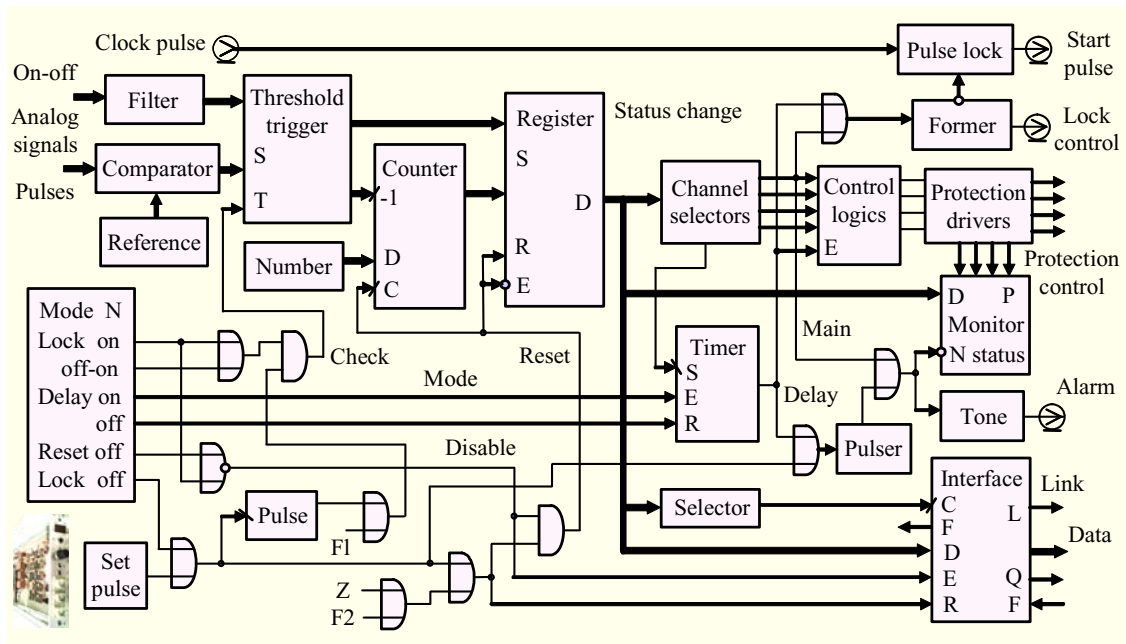
Fig. 4. The logic circuit of the multiway protection control unit

The reset of the Register, as well as the setting of the Counter and the Link (executed at the power-up) can be made by the Set pulse or by the link commands (Z or F2). At the Mode N, on default, the Register can be reset after the turn-off of alarm reasons. The Register reset (and turning-on of the fast channel selected for the delay control) can trigger the Timer. During the adjusted time of 0.1-10 minutes, the turning-on of Start pulses and other channels will be delayed. Thus the Pulser is turned on, both blinking of N-status display and pulsing of Alarm tone take place. When the timer operation is completed, the N-status is represented, and control of the Lock, Alarm and the Monitor of alarm states and protection is stopped.

There are modes allowing to disable protection or data reset and timer operations, or to switch the delay and check of all the channels with a counter preset or without it. The pulsing tone of alarm is possible at protection disabling, as well as at data resetting. The link commands (the permission, prohibition, and check of the link inquiry, and also reset of the register, the counter and link after data read-out) are supplemented by commands for the allowed check of the protection control.

Conclusion

The recent results of development of the protection control techniques for state transition detecting and on-line data taking for the operation-mode control, have been presented. The techniques are based on the control units with extended logics of protection and checking. This includes both the drive pulse interlocking and the system lock control, and also count of ignorable incidents, and modes of the counted protection and checking, the combined monitor of both the state transitions and the control operations. The created control unit is applicable for the rapid lock (the delay is less than a microsecond) of start pulses of an electron source and for selected interlocking at the pulsed linac systems. The unit also provides both faster turning-on of the protection (the driver delay is less than a millisecond) and its slowed down turning-off. The choice of stipulated modes dilates the main possibilities

of the developed protection control techniques for pulsed facility systems.

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Study of automation sources of data acquisition

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Abstract

The development of multichannel instruments of experiments at the JINR has its initial stages of solving the major problems of data acquisition and processing automation. The recent ways and automation techniques have their sources including the construction of the measuring centers and linking the instruments with computers and subsequent development of the computer-based tools and systems. The paper considers sources and steps of automation of data acquisition for multichannel instruments and control tasks as well as for monitoring of basic facilities. Some characteristics of the automation stages are presented.

Introduction

The development of multichannel experimental instruments at the JINR had its basic periods and stages in solving the problems of data acquisition and processing automation. The tasks were initiated with the advent of techniques of multichannel measuring, the analyzers accumulating data from more than 10^3 channels of the time and amplitude spectra. Developments of the both transistorized digital tools [1, 2] and numeral methods of data acquisition and processing [3, 4] have become a basis for further activity. These researches started before 1960 and later were also fulfilled at the JINR [5, 6]. References to first and other advanced researches fulfilled with participation of the author are presented here. Further instances illustrate sources of automation for studied directions and their stages of development. The study of the sources is referred to some important problems of selected 7 stages. Their performances and some development results are presented below. The automation stages within last 50 years for nuclear physics tasks will be illustrated in the conclusion Table.

1. Data acquisition and output for postprocessing

In the beginning of 60s the usage efficiency of the multichannel analyzers (as well as neutron spectrometers of the first pulsed reactor IBR at the JINR) was essentially slowed down because of duration of procedures of acquisition and an output of the stored data for postprocessing. Such operations included a select of channels and data read-out, their output on an indicator board, paper, and on punched cards, etc.

At this stage the problem was to automate both data taking and the output of accumulated data [1] and their preparation for handling [2]. And then methods of an automated output and accelerated processing of experimental data were developed [3]. Such operations as channel inquiry, the binary information conversion and outcome visualization as well as checking of data output reliability, were automated. Since 1961 the first safely operating transistorized devices have been constructed for automated output of spectra in decoded and fast printing [4, 5] and other systems with punched or magnetic tape [6, 7], and then followed with cable communications.

2. Instrument data transmission into computers

At that time the usage efficiency of measuring tools and time of experiments were still worsened because of major delays of data processing and obtaining experimental results. Both duration of preliminary preparation and reliability of the information transfer (and its input into a remote computer at the computing centre) caused major problems.

For the first time in 1961 the direct connection (a wire line) of a multichannel analyzer (the Laboratory of Neutron Physics) and a far distance remote computer (at the Computation centre of the JINR) were offered and tested [1]. The automated data transmission system from the analyzer memory into the first computers ("Kiev", "Minsk", etc) [2, 3] started to work permanently already in 1962-1963 [4]. The control consoles [5] and devices of acquisition and serial transmission of the data checking reliability [6], were applied to a long-distance communication, as well as the new equipment for incoming data into a computer and its external storage.

The first system of a bidirectional link [7] for the analyzers of LNP measuring centre with an embedded computer in 1966 became the next step of the development. Here necessary sequences of transmission-reception operations and of signals for bilateral link of the measuring instruments with a computer were formulated [8]. The tested link algorithms (they include checking of information, logic of signals of query-acknowledgement and recurring of transmission-reception cycles) further became a routine procedure. Integration of instruments and computer systems began to develop rapidly after the first probe of the automated link.

3. Centralized data acquisition and computer link

Measuring-computing centres and the centralized acquisition of the information with common tools for data read-out became a peculiarity of major systems of multiple-access. In 1963 the first centre of spectrometric measurements [1] was established with a centralized data output and their handling [2]. The measuring centre was developed further for many simultaneously on-going experiments [3] and their computer link [4].

The centralized data extraction from the spectrometers at various accesses (parallel-serial or random process) shown in [5] was used with an estimated probability of a waiting queue, an amount of common systems and required performance of their output devices. The centralized system is based on commutators of data paths [6] of the spectrometers to select output paths and to represent experimental results [7].

The unified structure of the measuring centre with BESM-4 computer and the adapted information exchange [8] in reception systems and data storage [9] allowed to combine the data acquisition and computing, and to represent outcomes of experiments [10]. Establishment of the multicomputer measuring centre with computer networks [11] has resulted in the appreciable contribution to implant computer-based tools.

4. Multichannel tools and systems based on computers

At this stage the computer-based tools were developed for the self-operational data acquisition and integrated control systems for neutron spectrometers. In 1971 the first tools on the TPA minicomputer were offered for timing analysis of ultra-cold neutrons [1] and the automated data acquisition [2], and for precise spectrometry [3] at the increased input loadings [4]. Such systems were applied to control the spectrometers [5] and conditions of experiments [6]. The data acquisition systems of the ultra-cold neutrons channel [7] and their analyses [8], data loggings [9] and the multidetector spectrometer [10], were oriented for integrated structures with microcomputers and PCs.

The measuring complexes based on the computers and their integration speeded up the development of new directions of multiway data acquisition for the surveillance of parameters and control of the experiments. That became topical problems for the systems of both the spectrometers and the basic experimental facilities.

5. Multiway monitoring and control of experiments

The automation methods of multiway data acquisition were developed to inspect assemblages of static and dynamic parameters of the equipment and to control the experiment performance. In the middle of 70s the problems of noise-resistant measurements and multiway data acquisition [1] were formulated to monitor the parameters of experimental facilities and environment of the specimen.

The modular controller subsystems of multiway data acquisition [2] are applied for centralized monitoring of various facilities. The multiplex data acquisition [3] was used to record both static and dynamic parameters [4], to sample pulse amplitudes and the time parameters [5], and the data of single signals [6] processed in the ADC [7].

Groups of the parameters could be regulated by means of control units with the microprocessor [8] and distribution units of a serial interface with a DAC demultiplexer [9]. These multiway techniques were applied to monitor and control the pulsed spectrometer facility [10] and some of the above-mentioned systems.

6. The parameter surveillance and diagnostics of basic facilities

The automation problems of data accumulation for the parameter surveillance and control of basic facilities, such as IBR reactor systems, were defined in 70s [1]. The informational-measuring systems for the surveillance of the IBR-30 pulsed reactor operation [2] and its start up control [3], were commissioned as a part of a regular management system in 1980. The authorized tools of the multiway data acquisition and on-line diagnostics were based on the CAMAC modules and PDP11 type computers. Then PC-based tools were applied for the reactor complex with the LUE-40 linac [4].

Very sensitive tools of the distant data acquisition protected from interferences (with V-F-V conversion) [5] were made to monitor reactor facilities at their start-ups. This technique was applied in the computer-based systems to carry out correlational and spectral measurements of the IBR-2 reactor parameters [6], and their fluctuations [7].

In 80s the complex system of automation of LIU-30 accelerator [8] was under construction to monitor up to 10^3 static, dynamic and pulsing parameters, and to control the electron beam [9]. The interconnected subsystems for multiplex data acquisition of each technologic task were included into the integrated multicomputer structure to control the transportation system of the accelerated beam [10]. Here the surveillance and diagnostics of the linac parameters and the shape of beam pulses were applied [11].

In 90s the multilevel computer-based data acquisition systems for the distributed control and surveillance were designed while preparation of the heavy ion accelerator complex project K4-K10 [12] and LUE-200 linac at the IREN test facility [13, 14].

7. Fast control and protection of pulsed facility systems

The present stage includes development of timed monitoring and fast control to protect the pulsed facility systems (along with the usual parameter surveillance and feedback controls for slow systems). The instrumentation and data acquisition for the pulsed systems [1] were developed in the process of the test facility construction. The data acquisition tools with timing to diagnose and control each duty cycle of the facility [2] were tested. The multiplex acquisition of pulse parameters [3] and the shape of the short signals [4] or both of them with nanosecond discrete timing [5], was developed.

The combined techniques of the timed data acquisition optimized for diagnostics of a pulsed facility, and state transition detection for fast control and duty protection [6] of the linac systems, were tested. The front-end assemblies and protection controllers [7] were

constructed for the cycle data acquisition and state transition diagnostics to control rapid linac subsystems. The multiway protection control techniques (designed for the alarm diagnostics, emergency control, and interlocking of facility systems) [8], are developed using the rapid data acquisition of state transitions.

The conclusion table

The Table illustrates the stages of the data acquisition automation.

Automation stages and years	1960	1970	1980	1990	2000
1 Data acquisition and output for postprocessing	→→→			PC-based tools and networks	
2 Instrument data transmission into computers	→→				
3 Centralized data acquisition and computer link	→→→→				
4 Multichannel tools and systems based on computers		→→→→			
5 Multiway monitoring and control of experiments		→→→			
6 Parameter surveillance and diagnostics of basic facilities		→→→→→			
7 Fast control and protection of pulsed facility systems				→→→	

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The instrumentation for monitoring power noises and vibration characteristics of the moving reflectors at the IBR-2 reactor

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Abstract

The instrumentation for monitoring power noises and vibration characteristics of the IBR-2 moving reflectors has been designed and constructed. For a pulsed reactor of periodic operation the mechanical vibrations of reflectors are the primary source of noises of external reactivity and correspondingly of uncontrolled fluctuations of energy of power pulses. The latter determines to a large measure the degree of reliability of the reactor operation. The measuring device makes it possible to study spectral and correlation characteristics of axial (in the direction of the reactor core) and torsional vibrations of reflectors simultaneously for a series of eight point induction sensors of reflector position. This allows us to identify more precisely real vibration frequencies of reflectors and to reveal their source. Along with the analysis of measured fluctuations of energy of power pulses, the device permits detecting the main sources of influence of moving reflectors on power noises and thus makes it possible to increase reliability and safety of the reactor operation.

Introduction

For a pulsed reactor of periodic operation the mechanical vibrations of moving reflector blades of reactivity modulator (RM) are the primary source of noises of reactivity and correspondingly of uncontrolled energy fluctuations of power pulses. The level of vibrations of RM to a large measure determines the service life and operational reliability of RM as a complex rotary machine, and power noises due to vibrations of RM govern the performance reliability of the reactor as a whole. Therefore for the IBR-2 reactor the investigation of mechanical vibrations of the moving reflectors along with power fluctuations is an important element of study, control and diagnostics of the reactor state. The obtaining of real spectra of axial (in the direction of the reactor core) vibrations of the reflectors is of special significance for realization of this task, since this allows more precise identification of vibration source and permits one to diagnose the reason for its occurrence. The only way to measure the real axial vibrations of the reflectors more precisely is to use not one sensor as is customary, but several sensors spaced apart along the angle of rotation of the reflectors. The paper presents a brief description of the measuring technique and a device that along with the channel of measuring the energy of power pulses makes it possible to study spectral and correlation characteristics of axial and torsional vibrations of the reflectors simultaneously for eight point eddy-current or induction sensors of reflector position. Some experimental results are given as well.

Brief description of the IBR-2 reactor and reactivity modulator

The IBR-2 reactor has been operating since February, 1984 at a pulse frequency of 5 Hz and rated average power of 2 MW [1]. The core of the reactor with a volume of 22 l is an irregular hexagonal prism. It is cooled by liquid sodium at a flow rate of 80-100 m^3/h. Plutonium dioxide enclosed in steel rods is used as a fuel. Two blades of the main and additional moving reflectors of the reactivity modulator rotate with different velocities about one axis past one of the sides of the core. Stationary reflectors whose moving blocks are the working elements of the safety control system of the reactor adjoin the other five sides. Neutron moderators are adjacent to the stationary reflectors and to the casing of the moving reflectors.

The purpose of RM is to generate short power pulses with duration of approximately 220 μs. The rate of rotation of the main and additional reflectors is 25 and 5 Hz, respectively.

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The pulse is developed at the instant of time when the main and additional reflectors simultaneously pass by the core. The pulse frequency is equal to the rotation frequency of the additional moving reflector, i.e. to 5 Hz. In the new design of the reactivity modulators PO-3 (see Fig.1) to improve reliability and safety, the rotation frequency of the main moving reflector has been reduced down to 10 Hz. The rate of rotation of the additional reflector has remained unchanged (5 Hz).

As any rotary machine, when rotating the blades of moving reflectors are subject to vibrations. Among these are forced and natural vibrations of reflectors. To the above vibrations must be added torsional (phase) vibrations, i.e. vibrations along the angle of rotation of reflectors. A part of total vibrations in the direction to the core causes reactivity noises and, correspondingly, power noises. Since the efficiency of the moving reflectors is high, axial vibrations make the main contribution to power fluctuations. Therefore the study of vibrations of reflectors and control over them is an important element in reactor diagnostics and in providing its reliable and safe operation. To reduce vibrations caused by gas-dynamic impacts when the reflectors meet, these latter are placed in a casing filled with low-pressure helium. All the above-mentioned studies are carried out using capacitive or eddy-current reflector position sensors arranged on the casing in the azimuthal direction.
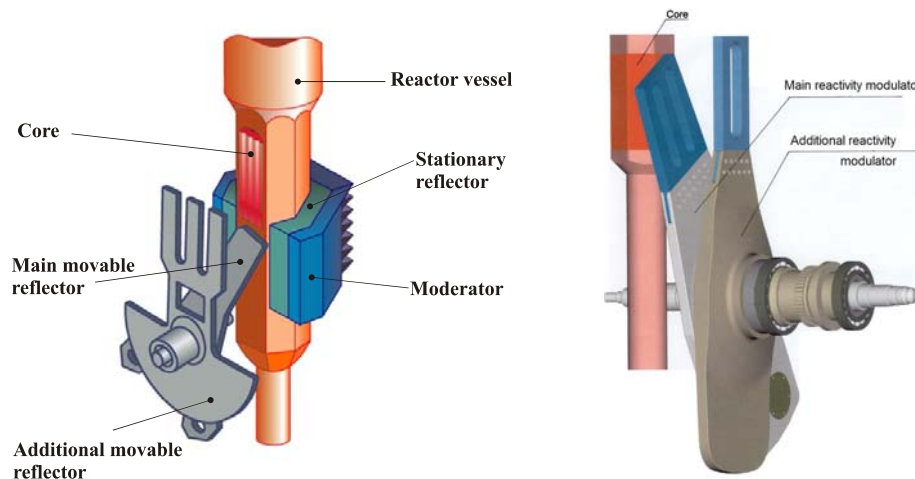
Fig. 1. Schematical view of the IBR-2 with the moving reflector PO-2M (until 2003, left) and with the moving reflector PO-3 (since 2004)

Measuring technique

The measuring technique is illustrated in Fig.2. Usually one of several sensors (n_d is the number of sensors) is used to control axial vibrations of the reflectors. Thus the frequency range of the spectrum of detected vibrations is determined by the rotation frequency of reflectors f_0, and correspondingly the critical frequency (Nyquist frequency) in this case is $f_{cr} = f_0/2$. For example, for the additional moving reflector $f_{cr} = 2.5$ Hz. In this case the analysis of spectra of the reflectors' axial vibrations has a greater degree of uncertainty since characteristic frequencies of the reflectors' vibrations are obviously higher than f_{cr} and a lot of components of the experimental spectrum f_{exp} are the disguised analogues of some real frequencies f_{real} related to f_{exp} as

$$f_{real} = 2\,f_{cr}n \pm f_{exp},\ n = 1,2,3\ldots.$$

The continuous vibrations of the blade are represented in the form of discrete time series X^j_i, where j is the number of the sensor, i is the index of the time series element registered with sampling frequency equal to rotation frequency of the main or additional reflector, i.e. 25 (10) Hz and 5 Hz, respectively. On normalization to the sensitivity of the sensor, amplifier and analog-to-digital converter, the time series can be written as $Y^j_i = k^j X^j_i$ with the spectral density S^j_X, where k^j is the normalizing factor for the j-th measuring channel. If the sampling frequency over a period of rotation of the reflectors is increased by summing the readings from all used sensors, then the critical frequency of spectral density of a new time series Z^j_i will increase by a factor of n_d — $f_{cr} = n_d f_0/2$. For technical reasons the number of sensors is limited, since the installation of each sensor on the reflector casing decreases its reliability. For the measuring purposes usually four sensors are installed. Even for four sensors it is possible to identify, for example, such an important parameter for evaluation of vibration condition of RM, as the amplitude of rotation frequency of the reflectors, which is impossible to measure by other means.

Brief description of the measuring device

The device consists of the following main parts (Fig. 3): an input signal processing circuit, memory with linear (sequential) filling and FPGA. The input signal processing circuit comprises nine identical channels, each containing a threshold circuit, high-level discriminator, DC amplifier and 10-bit ADC. The threshold circuit according to the leading edge of the input forms a signal, which if the given input is chosen as a start signal determines the starting time of sweep. Using the discriminator and the amplifier with adjustable parameters, optimum levels of input signals are set according to the ADC dynamic range. The sequential filling memory LIST MEMORY with a total capacity of 128K × 16 is divided into two independent banks (BANK A and BANK B) with 64K × 16 each. FPGA regulates the device operation according to the selected mode. The device is intended to operate in two modes: oscillographic mode (OSC Mode) and storage mode (STORAGE Mode). The oscillographic mode (OSC Mode) is intended for visualization of input signals (four signals from the sensors of the main moving reflector OPO1-OPO4, four signals from the sensors of the additional moving reflector DPO1-DPO4 and power signal PWR). Any of the above-listed signals can be selected as a start signal to start sweep (if power signal PWR is selected, the sweep is started by REACTOR ”0” signal). This signal at IBR-2 is fixed for power pulse maximum and serves to start up electronic equipment in neutron time-of-flight experiments. Interrogation rate for analog-to-digital converters is set to be 2, 16 or 64 μs. Any signal, except for a start signal, can be masked. Data from ADC sequentially fill both memory banks, first BANK A and then BANK B. On completion of filling, data are displayed on a monitor screen (the number of histograms corresponds to the number of unmasked signals). In addition, in OSC Mode for each input the time delay selection procedure (time interval between the signal leading edge and the strobe of its corresponding ADC) is performed. In the case of the PWR signal the count of delay starts from the leading edge of the REACTOR ”0” signal.
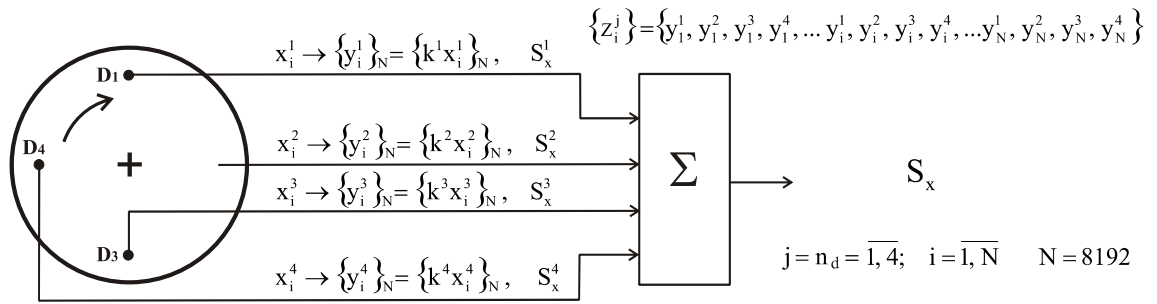
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$$x_i^1 \rightarrow \left\{y_i^1\right\}_N = \left\{k^1 x_i^1\right\}_N, \quad S_x^1$$

$$\left\{z_i^j\right\} = \left\{y_1^1, y_1^2, y_1^3, y_1^4, \ldots y_i^1, y_i^2, y_i^3, y_i^4, \ldots y_N^1, y_N^2, y_N^3, y_N^4\right\}$$

$$x_i^2 \rightarrow \left\{y_i^2\right\}_N = \left\{k^2 x_i^2\right\}_N, \quad S_x^2$$

$$x_i^3 \rightarrow \left\{y_i^3\right\}_N = \left\{k^3 x_i^3\right\}_N, \quad S_x^3$$

$$x_i^4 \rightarrow \left\{y_i^4\right\}_N = \left\{k^4 x_i^4\right\}_N, \quad S_x^4$$

$$S_x$$

$$j = n_d = \overline{1, 4}; \quad i = \overline{1, N} \qquad N = 8192$$

Fig. 2. Illustration of the measuring technique

The procedure consists of several stages. The selected signal is used as a start signal. The ADC interrogation time is set to be 2μs. On completion of filling the memory, on the signal histogram a point is chosen by a marker, which is the time delay parameter for the given signal. Thereafter in STORAGE Mode an ADC strobe will be formed in this point. The procedure is repeated in a similar way for the other input signals. It should be pointed out that the time delay parameters can be set or corrected online. On initiation of STORAGE Mode these data are recorded into corresponding registers.

In the main mode (STORAGE Mode) the memory is sequentially filled with data from ADC. In addition to nine input signals there is one more source of data. It is a time interval between any two input signals, including between one and the same. These data make it possible to judge the deviation of rotation frequency of the moving reflectors. On completion of filling of one memory bank, data start to come to another bank, and from the first one the data are readout into PC. Since data readout time is much less than filling time, the accumulation process can go on continuously.
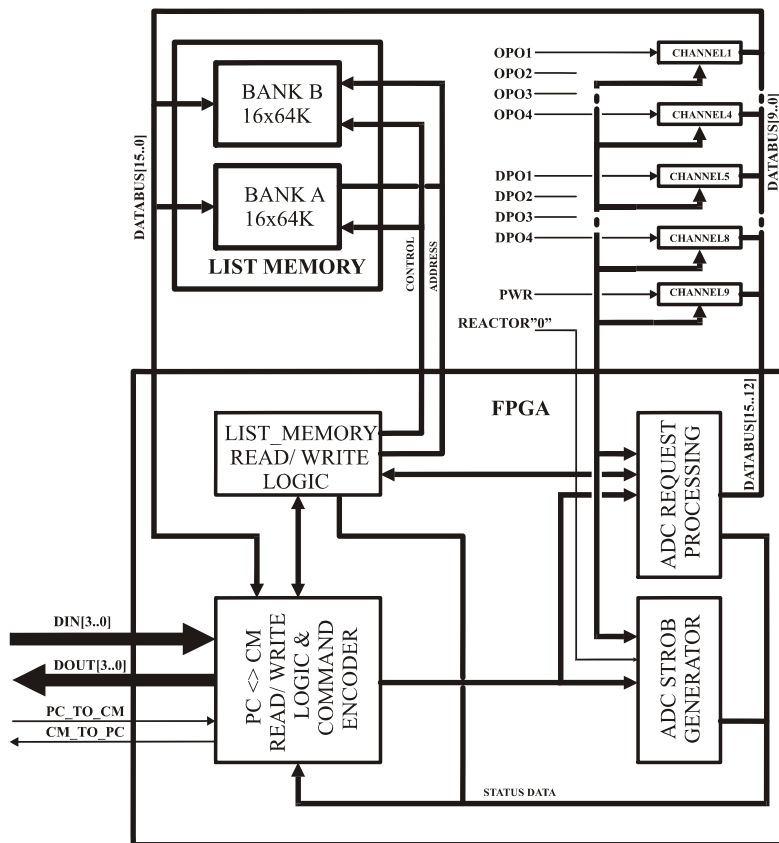
Fig. 3. Functional block diagram of the device

As an example, Figure 4 gives the oscillogram of signals from the power registration channel and from the position sensors of the main and additional reflectors. For operation of the device in the main mode a point necessary for measurement is set (using a program) on the power signal and on signals of position of reflectors' blades. Also, signals from sensors of position of reflectors' blades are selected to measure phase oscillations or period of rotation. These data are saved in a corresponding file. Upon collection of the time series of a specified length its statistical processing is carried out. On removing a linear contribution by means of the fast Fourier transform, spectral densities of vibrations for individual sensors and over all sensors are calculated. Also, spectral density of power pulse amplitude fluctuations is determined. The data are saved in a corresponding file structure and displayed on the screen as graphs.
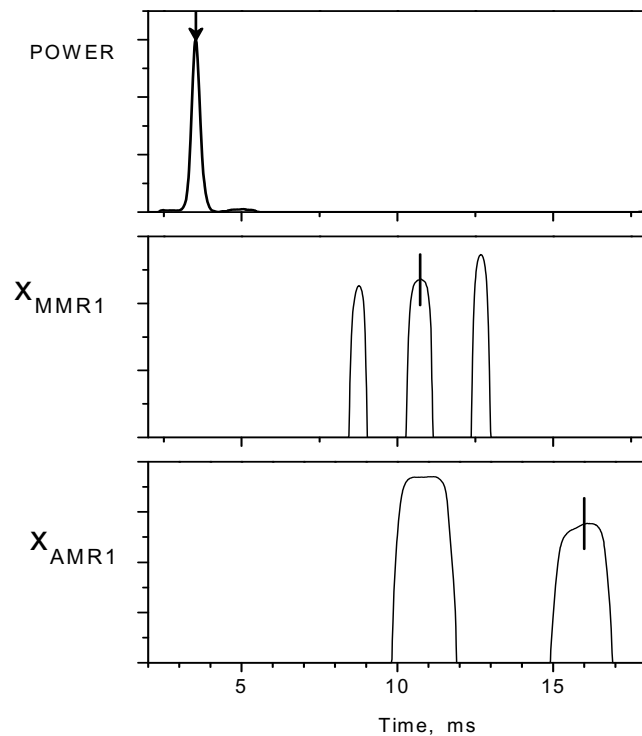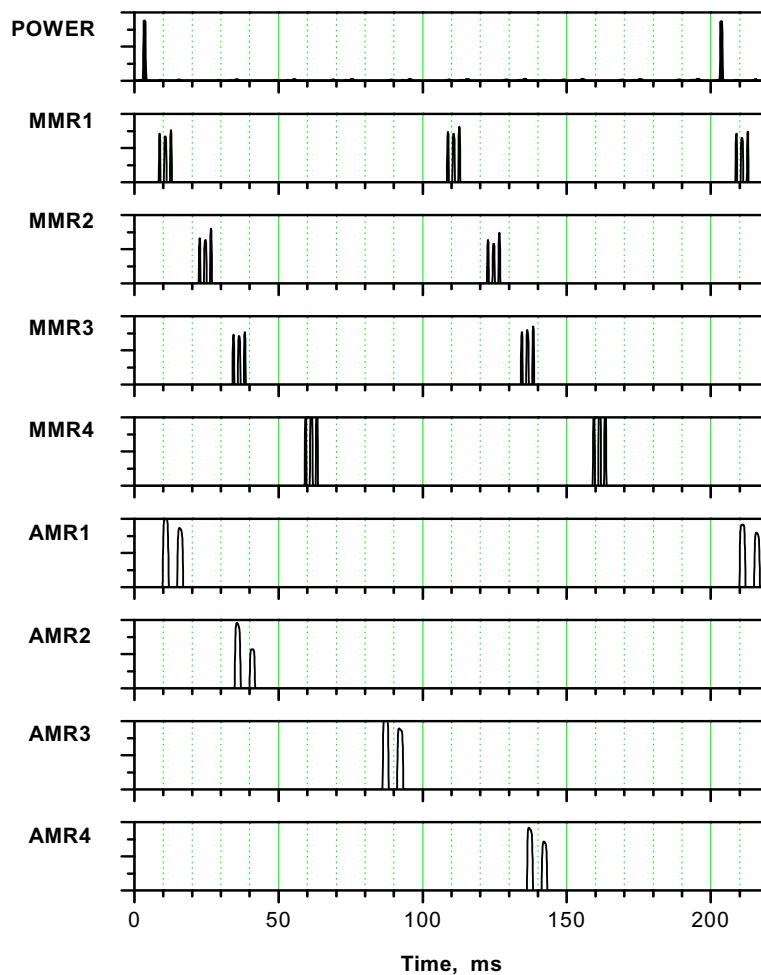

Fig. 4. Time dependence of signals from power detector and position sensors of the main and additional moving reflectors of the reactivity modulator PO-3.
Oscillographic mode of the measuring system (OSC Mode). Arrows show points on power signals and signals of position of reflectors' blades measured in the main mode

Some experimental results

Figure 5 presents oscillograms from power detector and sensors of position of the main and additional moving reflectors for the reactivity modulator PO-3. As can be seen from Fig.4, the position of moving reflectors' blades varies significantly for different sensors, as well as for different moments when the reflectors pass by the sensor. This is indicative of a complex structure of the total vibrations of the blades. In Fig.6 spectral densities of vibrations for the main reflector of PO-2M reactivity modulator are shown. In the same figure the vibration spectra of the reflectors over all four sensors are given. One can see that the

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spectrum shape and vibration amplitude in a new extended frequency range differs essentially from the vibration spectrum of the blades for one point sensor.

Conclusion

The created measuring instrumentation for spectral analysis of power pulse amplitude and vibration characteristics of the moving reflectors of the IBR-2 reactor allows one to obtain more real spectra of vibrations of the moving reflectors and thus makes it possible to diagnose more precisely the source of fluctuations of reactivity and accordingly of power.

The instrumentation has been tested at the IBR-2 reactor. In the future the instrumentation will be presumably used to carry out commissioning work on the modernized reactor IBR-2M.

References

[1]   V.D. Ananiev, V.A. Arkhipov, A.I. Babaev, etc., Power start-up of the IBR-2 reactor and first physical investigations on its beams, Atomic energy, 1984, v. 57, N 4, pp. 227 - 234.

Fig. 5. Time distribution of signals from power detector and sensors of position of the main and additional moving reflectors for the reactivity modulator PO-3 on the time interval close to the power pulse repetition period. Oscillographic mode of the measuring system

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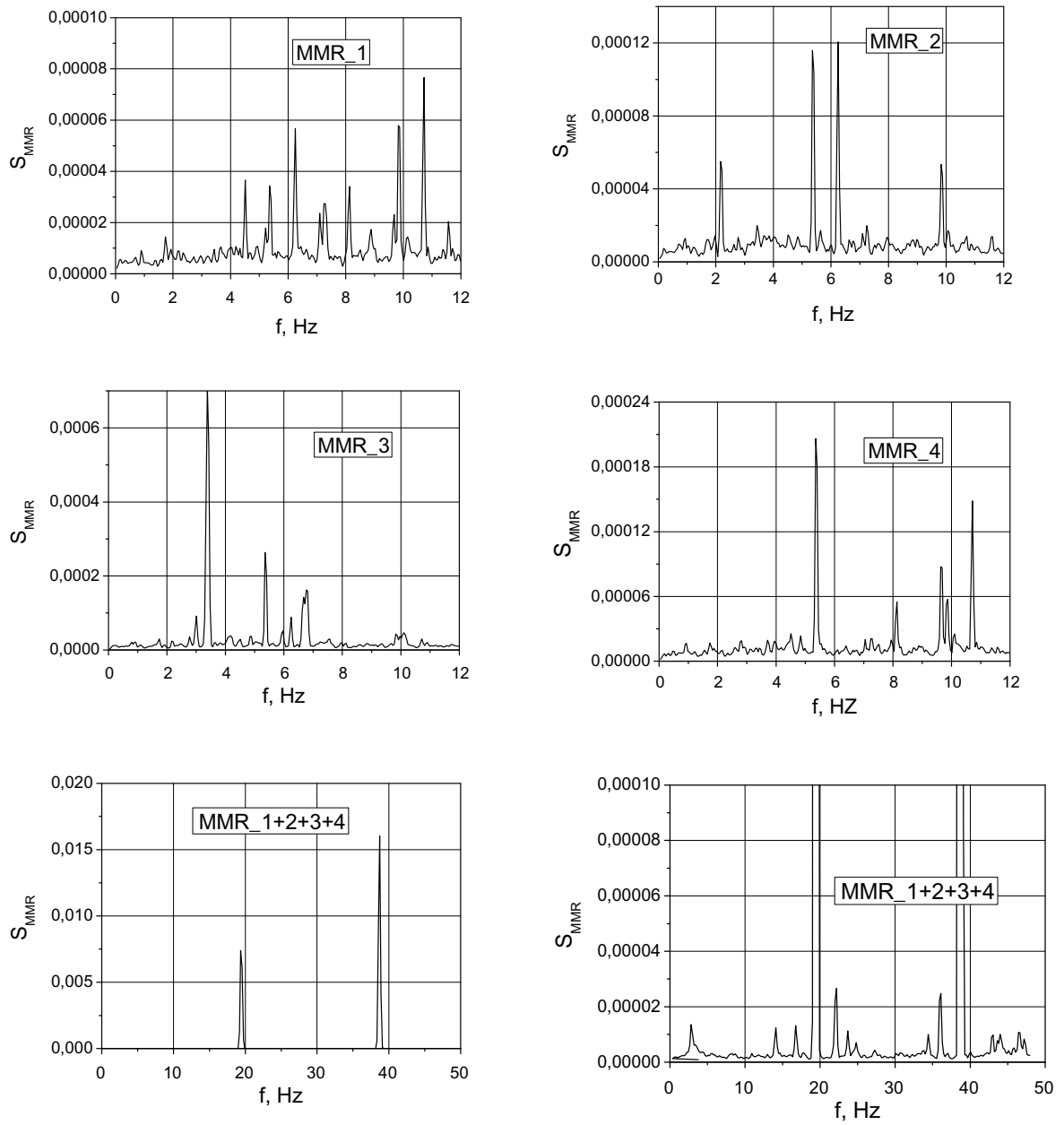
Fig. 6. Spectra of axial vibrations of the main moving reflector of the reactivity modulator PO-2M for each of all four sensors and spectrum of total vibrations of the reflector for all four sensors (at the bottom)

Method for the deconvolution of the neutron-diffraction spectra

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1. Introduction

The mathematical formalism for a large variety of problems of physical data analysis looks as follows: find a solution f(t) of an equation

$$y(x) = K(x,t)*f(t) = \int K(x,t)f(t)dt, \tag{1}$$

where y(x) is the observed experimental function, and the kernel K(x,t) is non-negative valued. In the physical literature the problem of finding the solution f(t) is called the deconvolution one, also in the case when K(x,t) # K(x-t).
It is known that such a problem is ill-posed.

Considered in the space of, e.g., continuous functions f(t) this problem has, in the general case, no stable solution for any arbitrary continuous function y(x), because, even if the equation K(x,t)*f(t) = 0 doesn't have an exact non-zero valued solution f(t), the kernel might be approximately degenerate.

In the practice, for some important problems an attempt to solve equ.(1) directly gives, as a rule, a chaotically oscillating vector, strongly increasing to the end of the interval [a,b] (because normally K(x,t) -> 0 as x -> d).

To prevent such effects one should search for a solution of equ.(1)only on a bounded set of admissible functions. This can be achieved by different methods. Here we shall consider two possible approaches.

It is often very important to derive the solution f(t) without assumptions about the concrete shape of the function f(t).

One of the approaches to dispense with a too exact parametrical description of the required solution is as follows.

To get a stable solution of (1) Tikhonov A.N. proposed regularisation methods, which transform the functional in (1) to a strongly convex form, e.g. such one

$$F(f(t)) = \|y(x) - K(x,t)*f(t)\|^2 + \alpha\, R(f(t),f'(t),f''(t)), \tag{2}$$

where the positive-definite functional R can be taken, e.g., in such a form

$$R = \int f''(t)^2/(1 + f_0'(t)^2)\, dt, \tag{3}$$

and α is positive, and $f_0(t)$ is an a priori estimate of the solution. At a proper α the solution of this problem is stable.

2. Solution in the class of non-parametrical analytical functions

The first step is the determination of the interval [a,b], (t $\in$ [a,b]), where K(x,t) # 0. Moreover, for getting a stable solution this interval should be chosen so that for any x the function K(x,t) > ε while t $\in$ [a,b].

Here ε is some positive number, depending on the required level of the stability. We have chances to restore the authentic function f(t) only for t's from this interval. Let us take a positive-definite functional R in (2) in one of the following forms:

$$R = \int f(t)^2\, dt, \; a < t < b; \tag{4}$$

$$R = \int f''(t)^2 / (1 + f'(t)^2) \, dt \, , \, a < t < b; \qquad (5)$$

here the norm is as follows

$$\int q(x) \, (y(x) - K(x,t)*f(t))^2 \, dx \, , \, c < x < d,$$

where $q(x)$ is inversely proportional to the square of the norm of the error of the given function $y(x)$.

Then the solution is a function, at which the functional (2) has a minimum. To find this minimum let us write the Euler's equation

$$\delta F(f(t)) = 0 \qquad (6)$$

The (13) is a strongly non-linear problem. To avoid the non-linearity one can proceed as follows. Let us assume that an a priori estimate $f_0(t)$ of the solution is available; as such a solution of (2) with (11) can be taken. Then we can rewrite (12)

$$R = \int f''(t)^2 /(1 + f'_0(t)^2) \, dt, \quad a < t < b;$$

It makes the equation (6) linear. The obtained solution $f_1(t)$ then can be considered as a new a priori estimate of $f(t)$, and the total procedure can be repeated in an iterative way.

The discrete analogues of the above-mentioned expressions contain sums instead of integrals.

For the discrete case two additional conditions are necessary to provide for the unique and stable solution:

1) to avoid additional errors due to a too rough discretization; the discrete distribution $y(t\_i)$ should contain enough points (t_i) to represent the contour of the continuous function $y(x)$ sufficiently exactly;

2) additional restriction on the kernel $K(x,t)$ is as follows:
$K(x,t)$'s as functions of t should be a Chebyshev system for any discrete set of x; or, the discrete set t_j, $j=1,...,m$, on which the discrete solution is defined, should be chosen so that vectors $K(x,t_j)$ are linearly independent for any discrete set of x_j.

The discrete analogue of (2) looks like this. Suppose we have a discrete set $X=(x_i, i=1,...,n)$ and chosen $T=(t_j,j=1,...,m)$; from the requirement 2 it follows that for a unique solution of (1) the relation $m < n$ should take place.

Denoting functions of the discrete variable $f(x_i)$ as f_i we get

$$F(f(t)) = \sum_j q_j \, (y_j - \sum_i K_{ji} \, f\_i)^2 + \alpha \sum_i f_i^2$$

for the case (11) and

$$F(f(t)) = \sum_j q_j \, (y_j - \sum_i K_{ji} \, f\_i)^2 + \alpha \sum_i c_i \, f_i''^2$$

for the case (5), where $c_i = 1 / (1 + f^2_0(t_i))$
and $\quad f' = (f_{i+1} - f_{i-1})/2$
$\quad\quad f''_i = f_{i+1} - 2f_i + f_{i-1}.$

The equ. (6) looks like $\partial F / \partial f_i = 0$ and its solution f_i can be obtained by, e.g., the Least Square Method.

Let us consider the case in detail. We can rewrite the above equation so:

$$(A_{kj} + R_{kj}) \, f_j = Y_k \, , \, k,j=1,...,m,$$

here the matrix A and the vector Y are

$$A_{kj} = \sum_l q_l K_{lk} K_{lj}, \quad Y = \sum_l q_l y_l K_{lk}.$$

The matrix R looks like:
1) Case (11):

$R_{ij} = \alpha$ if i=j;
0 otherwise

2) Case (12):

$\alpha c(i-1)$,   if i-2=j;
$-\alpha 2(c(i-1)+c(i))$,   if i-1=j;
$R_{ij} = \alpha c(i-1)+4c(i)+c(i+1))$, if i=j;
$-\alpha 2(c(i+1)+c(i))$,   if i+1=j;
$\alpha c(i+1)$,   if i+2=j;
0 otherwise

Let us examine what are mathematical advantages of the use of (5) over that of (4). For any analytical function f(t) we can use the following expression

$$O(f(t)) = \int f'f'^* /(1 + ff^*) \, dt, \quad a < t < b; \tag{7}$$

as an integral oscillation measure of the function f(t) (complex-valued in the general case). Applying (7) to components of an expansion of f(t) into a Fourier series in $[0,2\pi]$
$f(t) = \sum b_n(t) = \sum a_n \exp(-int), |n| = 0,1,...,\infty$, we see that

$$O(b_n(t)) = (n^4 + a_n^2) / (1+n^2 a_n^2) \sim n^2 \tag{8}$$

and it illustrates how the method works: strongly oscillating components of f(t), i.e., having large n, are suppressed first of all.

At the same time the expression (8) has a significant property: it depends only on the frequency n, but not on the amplitude a_n. Had we restricted ourselves to the second derivative in (5) our regularizer would suppress not only high-frequency components, but also large-amplitude ones, which would have lead to large distortions of the solution f(t).

3. Parametrical approach

However, this approach is too formal. It does not use the physical information about the kernel K(x,t), which is either available or, on the contrary, should be estimated too.

Let us take the following problem which plays a very important role in the analysis of the neutron diffractograms.

Within the simplest approach a powder, which subwent a distortion or is characterized by imperfection (heterogeneousness, non-isotropy,etc.) may be considered as a large family of subpowders, each of which is represented in the family according to a weight function p(s), where s is the number of the subpowder and its unit cell.

Therefore, we can describe f(x) - a diffractogram of a coherent scattering on such a powder - as a weighted averaging of y(x,s) - diffraction profiles from sth constituent subpowders

$$f(x) = \int p(s) y(x,s) \, ds, \tag{9}$$

similar to (1). The physical effect of (9) is the broadening of the diffraction peaks. Apart from above mentioned physical factors, causing this broadening, there are also instrumental factors, contributing to it. The characteristics of the instrumental factors are more or less known, and on the basis of this a priori information we can try to solve the equation (9), at least, partly, by

diminishing its instrumental contribution into the broadening. Formally this can be done by parametrization of $y(x,s)$, such that it makes the solution of (9) stable.

The parametrization of (9) is a balance between the two extremes contradicting each other:

♦ take the minimal possible number of parameters to keep the solution of (9) the most stable;

♦ take the maximum possible number of parameters to provide for an acceptable accuracy of the solution.

Under certain restrictions on $P(s)$ - fast decrease when s grows, and symmetry around s=0, the formal parametrization of (9) looks as follows:

$$f(x) \sim y(x,0) + C(x)\ y''_{ss}(x,0)s''_{aa}\delta^2 a,$$

where a are the physical and instrumental parameters.

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