LABORATORY OF INFORMATION TECHNOLOGIES

In 2001, the Laboratory of Information Technologies concentrated its activities on the fulfillment of the tasks formulated at the 88th session of the JINR Scientific Council: the maintenance of operation and the development of the computing and networking infrastructure of JINR.

The JINR computing and networking infrastructure as a basic facility includes:

— External computer communication channels, distributed information systems, and telecommunication service;
— JINR Local Area Network (LAN) and High-Performance Computer Centre (HPCC);
— Support and development of standard software and modern tools of computational physics for users.

In 2001, the scientific programme of LIT covered two first-priority topics of the Topical Plan for JINR Research and International Cooperation in 2001. The Laboratory participated in 11 more topics of the Topical Plan in collaboration with other JINR Laboratories on the project level and in other 14 topics on the level of cooperation.

During the year, LIT participated in organizing a number of international conferences:

- 21–22 February — workshop «Role of the Operating System Linux in the Computing Infrastructure of the Future», organized in cooperation with the Hewlett Packard company;
- 28–30 June — International workshop «Computer Algebra and Its Applications to Physics» (CAAP-2001);
- 3–4 July — the first conference in Russia on data storage systems «Solutions on Data Management in Scientific Research», organized together with the TechnoServ A/C company;
- 12–18 September — XVIII International Symposium on Nuclear Electronics and Computing (NEC-2001).

The reports delivered by LIT scientists demonstrated a high level of investigations performed at LIT.

A series of works «Detection and Research of Exotic Hadron States $N(3520)$ and $K(1630)$ with Similar Peculiarities» performed by V. M. Karnaukhov, V. I. Moroz and C. Coca was awarded the second prize of JINR's annual competition for best research in 2001.

First «Information Bulletin of LIT» (JINR, 4-7998. Dubna, 2001) was published, containing information for users of JINR networking, computing and information resources.

EXTERNAL TELECOMMUNICATION CHANNELS

At present JINR leases 30 Mb/s channel to Moscow from the Russian Satellite Communications Company (RSCC «Dubna»); thus JINR has access to the Russian networks and information resources (up to 30 Mb/s) as well as access to the international channel through shared RBNet in the common data stream and up to 1 Mb/s granted bandwidth.

Table 1 shows the incoming JINR traffic for the year 2001 (total 4.15 TB) distribution among the JINR divisions. The University of Dubna and the modem pool (Table 2) take a noticeable share in the common traffic.

The further perspectives of the improvement of the JINR computer telecommunications are related to the development in Russia of the system of international channels for science and education, to the development of the high-speed network infrastructure, especially for nuclear physics centres, and to the extension of cooperation with RBNet and the Russian Satellite Communications Company and its branch in Dubna.

Table 1. JINR incoming traffic (> 25 GB and %)

LIT + proxy + servers	FLNR	DLNP	Univ. Dubna	Modem pool	LHE	BLTP	LPP	FLNP	Adm.	UC
1500	768.45	369	302	249	237	228	222	121	74	26
36 %	18 %	8.7 %	7.1 %	5.8 %	5.6 %	5.4 %	5.2 %	2.8 %	1.7 %	0.6 %

Table 2. JINR modem pool statistics (hours and %)

FLNP	DLNP	Adm.	FLNR	LHE	LIT	LPP	Others	BLTP
12930	10778	9236	7930	7337	6552	3965	1096	216
20.88 %	17.41 %	14.92 %	12.81 %	11.85 %	10.58 %	6.40 %	1.77 %	0.35 %

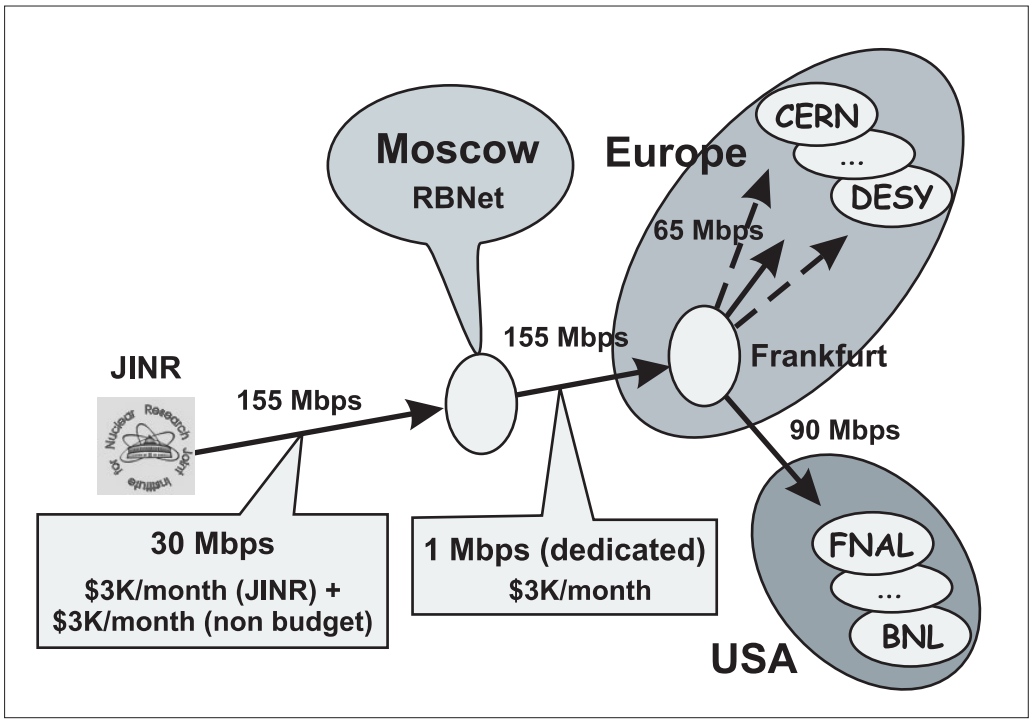

Fig. 1. JINR telecommunication channels

By order of the JINR Director, a committee has been set up to learn the needs of the scientific programme for particle physics in computer communications and to work out recommendations on improving the operation of the computer communication links. The construction of dedicated channels to CERN and DESY is an urgent task (Fig. 1).

Systematic work on the LAN management was performed by the Network Operation Centre (http://noc.jinr.ru/). To make operation of the central mail server @jinr.ru more comfortable and reliable, a number of new services have been provided for its users: e-mail stream antivirus check-up, mail pseudonyms, protection from commercial and undesired messages (SPAM). One can use the www-interface https://webmail.jinr.ru/ for fast access to mailboxes. The interface is a multi-language one (Russian, English, etc.). The access through the webmail seems more preferable for the users outside the JINR network.

In 2001, JINR received the License on data transfer services and now the Reglament and the Rules on user connection to JINR data transfer links are in preparation.

JINR LOCAL AREA NETWORK

At present IP-addresses database contains 3451 registered JINR LAN elements (3105 in the year 2000).

Currently the JINR network operates in a non-standard configuration in a critical, temporary mode using Fast Ethernet technology as a result of ATM-backbone destruction.

A project on modernization of the network topology and choosing an adequate technology of its design is in development stage now, and LAN backbone construction will be the main task for future years. The basis for the work on the project is the recommendation of the 89th session of the JINR Scientific Council on the further development of remote access to experimental installations, data processing and data transfer, participation in the collaborations under the projects Data Grid and Grid in Europe and America. The high-performance network will allow one to organize distributed computations, effectively using large computer complexes at the JINR Laboratories. It is of particular importance for data processing for the LHC experiments at CERN, where JINR takes an active part.

There were a number of discussions on the future Local Area Network backbone. It was reported at several Institute's forums that during the year the JINR backbone used two technologies: the unreliable ATM and Fast Ethernet at three Laboratories, and since 30 October 2001, the whole JINR backbone has been using Fast Ethernet (Fig. 2) due to central ATM-backbone equipment crash.

Two information technology dealers from Moscow (JetinfoSystems and TechnoServ A/C) and the telecommunication faculty of the Russian University of Peoples' Friendship were invited to take part in the discussions. All external experts and network specialists from the Institute's Laboratories have come to the conclusion that the Institute scientific programmes and participation in the international research programmes demand creation of a high-speed reliable backbone, which can be realized through the transfer to Gigabit Ethernet technology. All information about the LIT projects on computing and networking are available at http://noc.jinr.ru/projects.htm.

The LIT Directorate together with SCAR organized training for fourteen network specialists with the help of lecturers invited from Moscow. Ten of them have passed the examination and received certificates.

A department of information technologies of computing systems in the Moscow Technical University of Radio Engineering, Electronics and Automation was or-

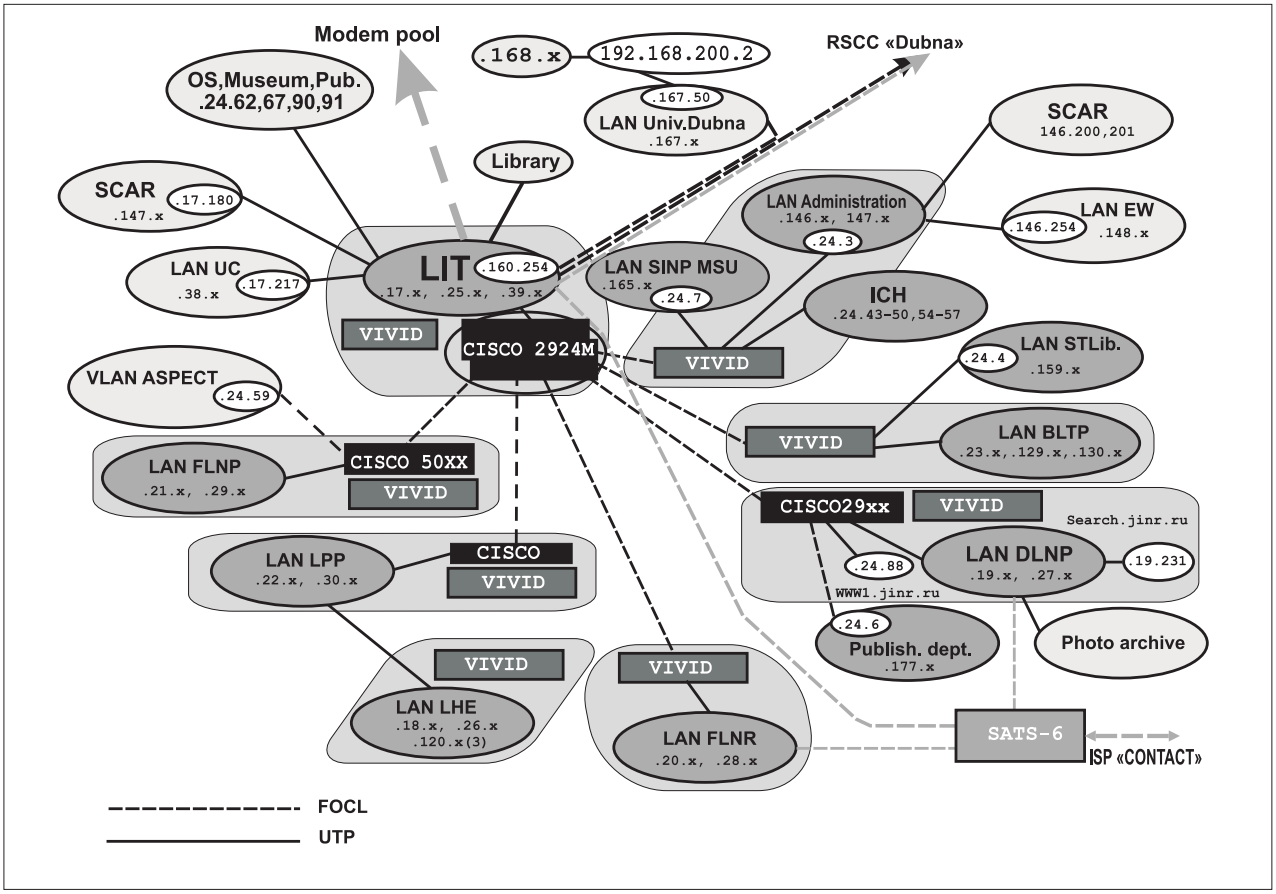

Fig. 2. JINR LAN

ganized on the LIT basis. The first enrolment of 10 students started in 2001.

Distributed Information Systems, HPCC

More than one thousand staff members of JINR and other research centres are the HPCC users. JINR HPCC (Fig. 3) is one of the ten largest Russian centres. It actively cooperates with other leading centres — Intergovernmental Supercomputer Centre, Institute of High-Performance Computations and Data Bases (St. Petersburg). In collaboration with the leading nuclear physics centres of Russia, JINR HPCC participates in creating the Russian Regional Centre for LHC Data Handling.

In 2001, the creation of the GRID segment in Russia was in progress. Ten more institutes of the Russian Federation take part in the project. The main LIT activity consists in the installation of GLOBUS toolkit, creation of common information server GRIS (Grid Resource Information Service) and GIIS (Grid Index Information Service), certification server creation, testing of metadispatcher, development of monitoring tools, data management, physical event mass generation and creation of a distributed database at the LIT PC-farm and HPCC servers.

During the year, SPP2000 server was used by 81 of 142 registered users. The CPU usage was 96 % and the total CPU time was 58500 hours. Table 3 shows the percentage of CPU time used by JINR Laboratories.

Table 3. SPP-2000 using by the JINR Laboratories

LIT	FLNR	DLNP	LPP	FLNP	BLTP	LHE
22 %	13 %	9 %	8 %	15 %	22 %	11 %

The CONVEX-220 computer was used as the computing, e-mail, and http-server by 1215 users, 1031 were active e-mail users. Table 4 shows the registered users distribution over the JINR Laboratories.

Table 4. CONVEX-220 users distribution over the JINR Laboratories

FLNR	DLNP	LPP	FLNP	BLTP	LHE	LIT	Adm.
165	166	124	57	109	129	372	93

There is a plan to replace the old CONVEX computers with a cluster of Intel-based servers.

Computing Service

Information and computer support of the JINR participation in the experiments at CERN, DESY and BNL was in progress in 2001. The further adaptation and support of current versions of Anaphe (LHC++) Library for Linux and Windows NT platforms was performed.

In 2001, new run of mass event production was performed at a PC-farm, LIT JINR (16 processor units of 500 MHz) for the CMS high-level trigger. The volumes of simulated data up to 75 GB are generated. The data pro-

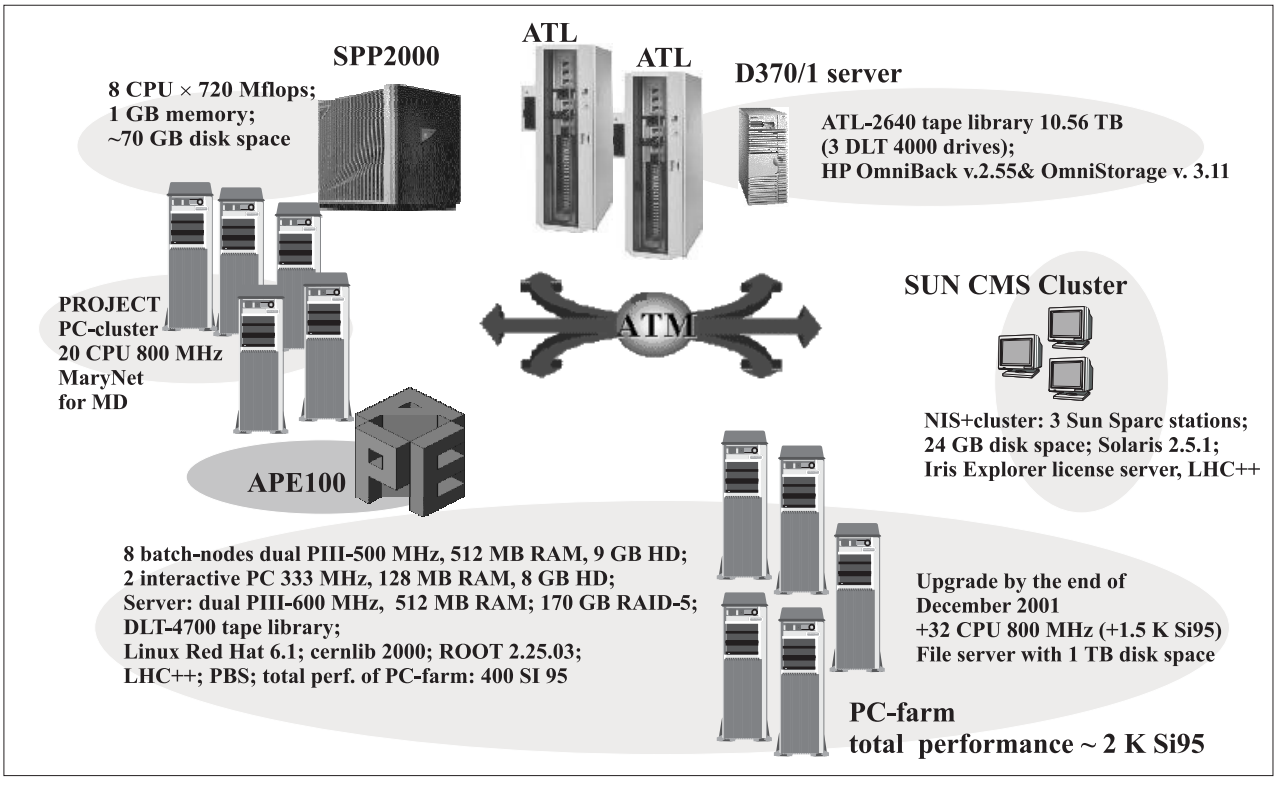

Fig. 3. The main JINR computing centre facilities

duction is performed with the use of the Pythia program and CMSIM, a program for simulation and reconstruction of events for the CMS experiment.

An investigation of the specialized computing system APE-100 based on the SIMD architecture has been performed.

DATABASE AND WWW SERVICE

A systematic supplement and maintenance of the earlier constructed databases (DB) and information systems continued taking into account the users' needs. Among these are:

- Information system IPDB — a web-interface of the JINR IP-addresses database (http://iis.jinr.ru/ipdb/).
- Accelerator Databases (http://iis.jinr.ru/acc/).
- System for accounting and statistics of operating the JINR basic facilities (http://iis.jinr.ru/basic-fac/), performed using ASP technology.
- A system for monitoring activities on preparing elements of the ATLAS detector at JINR has been put into operation and is maintained (http://wnlse50.jinr.ru/wf/new/wf.html). It was designed at St. Petersburg Institute of Nuclear Physics. In the framework of the project, application OAS (Oracle Application Server) on PL/SQL has been provided for mapping the DB status in the global network. The database has been transferred from WinNT server to the Linux Redhat server. A Perl module has been written for the weekly DB archiving in a semiautomatic mode.
- Digitizing of graphics at users' requests, preparation of bibliographic data on HEP for the PPDS database (http://www.jinr.ru/~diginfo/). Almost 150 scientific papers have been prepared for the PPDS database. More than 50 papers were coded and included into the database. The other 50 are being prepared now. The work was carried out in cooperation with IHEP, BNL and other physics centres. 148 graphics have been digitized at the requests of JINR and foreign physicists.
- Information system «JINR Topical Plan for Research» (http://dbserv.jinr.ru/~deadhead/tp/). Software has been added for automated file translation from LaTeX into DB Oracle.
- Information System «System of Accounting Between JINR and Experimental Production Plant (Access, VBA)» for the JINR Accounting Department.

Among the activities related to the main JINR and LIT servers (http://www.jinr.ru, http://lit.jinr.ru), the following work should be noted: new JINR home-page design, actualization of the divisions in accord with the main scientific results and the programmes of JINR activities; information on conferences, schools and workshops held at JINR; news; the development and maintenance of the www-JavaStation (http://dbserv.jinr.ru/js/).

COMPUTATIONAL PHYSICS

The main problems of the computational physics are: the algorithmic and software support of experimental and theoretical research under way at the Institute; the provision of the effective use of JINR computing facilities.

About 80 scientific publications, reports on conferences and JINR preprints were published and presented.

Mathematical Modeling and Information Support of Experimental Investigations

Data processing support in particle physics. The main works were related to the development of basis resources (both the tool and target computing) of experiments in high-energy physics. The main gains were directed to the development and installation of the system for processing experimental and simulated (Monte-Carlo) data of the EXCHARM experiment on the new powerful server of the Linux-cluster RISK. It should be noted that in scales, entirety, comprehensive approach and level of the scope of the problems, this trend, connected with the creation and application of the Data Processing System, is very important.

The experience and methodical results obtained in the EXCHARM experiment are applied in other experiments, including those with JINR participation at CERN, etc. [1].

Development of new methods for data processing. One of perspective methods of the analysis of experimental data is a wavelet analysis based on a wavelet transformation.

A WASP (Wavelet Analysis of Secondary Particles angular distributions) package was developed. It is a C++ program aimed to analyze secondary particles angular distributions in high-energy nucleus-nucleus interactions. (WASP was designed for data analysis of the STAR and ALICE experiments.) WASP provides a user-friendly

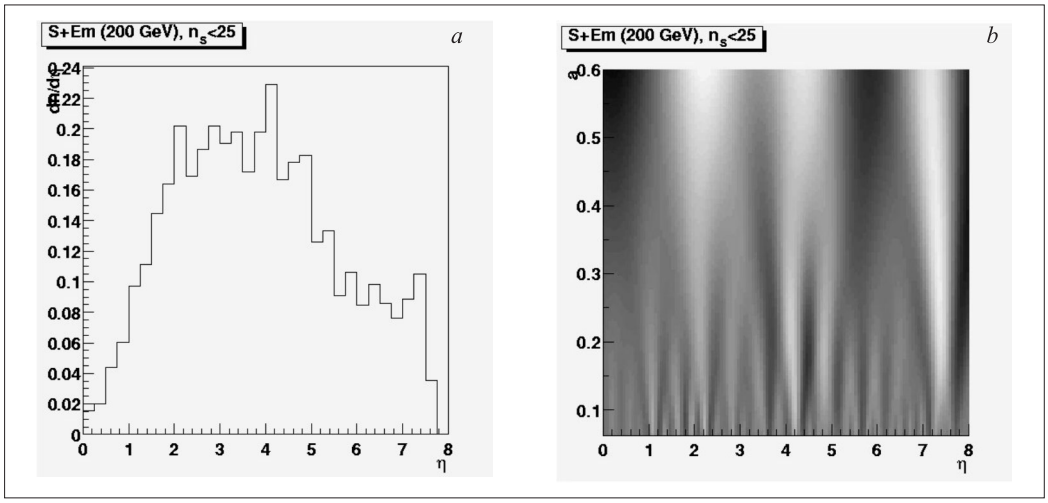

Fig. 4. Shower particles pseudorapidity distribution in events with $n_s < 25$ (*a*) and its wavelet spectrum (*b*). Three sub-structures arise at scale 0.4

Graphical User Interface (GUI) implemented by using ROOT GUI classes.

The first version of WASP was successfully applied to data analysis. Angular distributions of secondary particles produced in the interactions of sulphur and oxygen nuclei with photoemulsion nuclei at energies of 200 and 60 GeV/nucleon were analyzed. With the help of the wavelet analysis it was observed that the pseudorapidity distributions of the particles summed over all the events had three sub-structures. The distributions in separate events have more than one sub-structure in 40 % of the cases. The wavelet analysis allows one to separate events with different sub-structures (Fig. 4) [2]. New WASP version makes it possible to perform both one- and two-dimensional wavelet analysis. Thus it can be used for detecting ring-like structures [3–7].

A study of software efficiency improvements for the pattern recognition chambers (PC) of the HERA-B outer tracker (OTR) has been accomplished in framework of the planned LPP's activity in the HERA-B collaboration. A new version of the PC calibration program was developed on the basis of the consistent applying of the robust approach to both: track-finding algorithms and calibration function calculation. In addition to the improvement of the calibration accuracy, it allowed one to accelerate the calibration procedure by an order of magnitude in comparison to the conventional calibration program. The most effective was the robust fit of cubic splines directly to raw data which are the many thousands of the drift time measurements. The fit results are shown in Fig. 5.

In cooperation with LHE the experimental data on proton and π^--meson rapidity distributions in *CC* interactions at 3.36 GeV/nucleon in the events with different multiplicities of production of π^- mesons was compared with predictions of RQMD and FRITIOF models. It was shown that the RQMD model reproduces satisfactorily the π^--mesons distributions, but unsatisfactorily describes the protons characteristics. The modified FRITIOF model gives good results at tuning the free parameters of the model [8].

Processing of experimental data for determination of exotic states of hadron structures has been completed. Experimental observations of the anomalous-narrow resonant hadronic structures $K(1630)$, $N(3520)$, $\Sigma(3170)$ are discussed. These supposed exotic states are produced in the processes with large 4-momentum transfers. The special feature of the decay points out a space clusterization of colourless decay products of $K(1630)$ and $N(3520)$, their angular separation in two parts [9].

Application of the method of volume and boundary integral equations in models of magnet systems with superconducting shields. The modeling of magnet systems with superconducting shields has been considered. Nonlinear volume and boundary integral equations are derived that govern the magnetization distribution over a nonlinear medium and the current distribution over the superconductor boundary. Methods for discretization of the continuous equations and for iterative solving of the nonlinear systems thus obtained are suggested. The

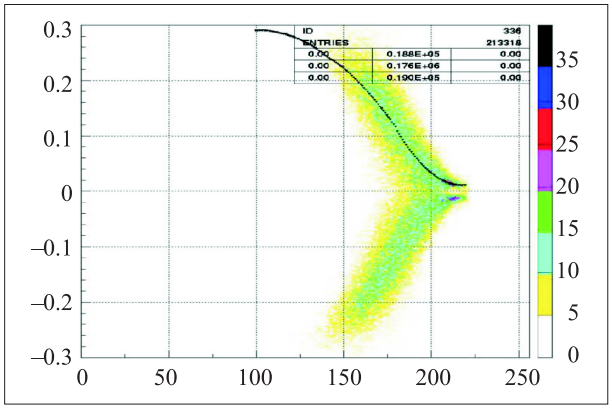

Fig. 5. Results of the cubic spline fit to 5 mm PC drift data

results of a simulation of the magnet system employed in the ALICE experiment (CERN) are presented [10].

Application of the mathematical modeling in low- and intermediate-energy physics. Using the model of a temperature peak as well as the measured radii of tracks in a high-temperature superconductor $YBa_2Cu_3O_{7-\delta}$ and its thermal characteristics, an effective electron-phonon relaxation time has been calculated for this material. It was in a good agreement with experimentally measured (by methods of laser technique) values of this magnitude. Thus, for the first time, a self-consistent description of the process of track formation in the high-temperature superconductor, not containing any matching parameters, has been constructed [11].

A new approach to the local curve approximation and the smoothing has been proposed. A very simple in computing and stable to random errors cubic smoother in an adaptation mode (LOCUS) is constructed. The efficiency and the noise stability of the algorithm are confirmed by examples and by comparison with other known non-parametric smoothers [12].

Parameters of a subcritical cascade reactor driven by a proton accelerator and based on a primary lead-bismuth target, main reactor constructed analogously to the molten salt breeder reactor (MSBR) core and a booster-reactor analogous to the core of the BN-350 liquid metal cooled fast breeder reactor (LMFBR) have been estimated. It is shown by means of Monte-Carlo modeling that the reactor under study provides safe operation modes ($k_{\text{eff}} = 0.94$–0.98), is capable of transmuting effectively radioactive nuclear waste and reduces by an order of magnitude the requirements on the accelerator beam current. Calculations show that the maximal neutron flux in the thermal zone is 10^{14} cm$^{2}\cdot$s^{-1}, in the fast booster zone is $5.12\cdot10^{15}$ cm$^{2}\cdot$s^{-1} at $k_{\text{eff}} = 0.98$ and proton beam current I = 2.1 mA [13].

Algorithmic and Software Support of Theoretical Investigations

Computational molecular dynamics methods and software. An optimized version of the DL_POLY molecular dynamics (MD) simulation code has been used to study the cluster-surface impact processes for metallic phases. The characteristics of the cluster-surface collisions were studied in a wide range of the cluster impact energies ($E_{\text{inc}} = 0.035$–3.5 eV/atom). Modification of the surface, exposed to the cluster beams, was studied by monitoring the molecular dynamics configurations of the system in real time. The density and temperature distributions in the system under the energetic irradiation have been investigated in detail. The three major channels of the impact yield (viz., soft landing, droplet spreading and implantation) were distinguished and estimated. Based on the density and temperature distributions data the low-energy cluster-surface impact has been analyzed and a novel interpretation of droplet spreading process given [14]. Figure 6 shows the results of the MD simulation for the claster incident energy $E_{\text{inc}} = 0.56$ eV/atom.

Thermoelastic computational approach to beam-surface interaction modeling. A method of numerical analysis of Stefan's problem for a metal sample exposed to a high-current pulse ion beam has been developed [15]. In supposition that the lateral areas of the sample are thermo-isolated, the dynamics of moving the interphase separating the melted and firm parts of the sample was investigated. It has been found that the form of the source influences the form of the interphase. Therefore, choosing the characteristics of the source, one can control the evolution of the interphase.

High level accuracy computational schemes for quantum systems investigations. An uncoupled correlated variational method for the calculation of helium isoelectronic bound states has been proposed. New projective coordinates $s = r1 + r2$, $v = r12/(r1 + r2)$, $w = (r1 - r2)/r12$ are introduced instead of the conventional ones $s = r1 + r2$, $t = r1 - r2$, $u = r12$. All matrix elements of the total Hamiltonian and the weight function are expressed as simple products of three one-dimensional integrals. The variational basis is formed by a set of Laguerre polynomials with a single nonlinear parameter and two sets of Jacobi polynomials for the projective coordinates s, v, w, respectively. It provides a reasonable rate of convergence of the energy, $E = E(N)$, with respect to a number N of the basis components of the eigenvector. The proposed method yields the best available energies for the isoelectronic ground states of the helium atom. New estimations of the isotope helium ground states were also presented [16].

A Newtonian iteration scheme has been constructed in framework of research on computational physics for solving a scattering problem using the Schwinger variational functional. The scattering problem is formulated as an eigenvalue problem with respect to a pair of unknowns: a phase shift and a wave function. The efficiency of the proposed iteration scheme and its accuracy are demonstrated by exact-solvable examples of the elastic scattering problem with Morze and spherical potentials [17].

Numerical calculations for nuclear models. The problem of production and survival of the very-long-lived isomeric state of ^{180}Ta nuclide is a real challenge for a theory of nucleosynthesis. Numerical calculations were performed within the Quasiparticle-Phonon Nuclear Model (QPNM) using the formalism developed in works of V. G. Soloviev. The calculations performed allowed one to make a conclusion about mechanisms of transitions of intermediate states of de-excitation of $^{180}\text{Ta}^{m}$ in the (γ,γ') reaction [18].

Computer algebra. The original highly efficient algorithms for computation of Janet bases were designed and implemented in Reduce, C and C++. These algorithms exploit a very useful data structure called Janet

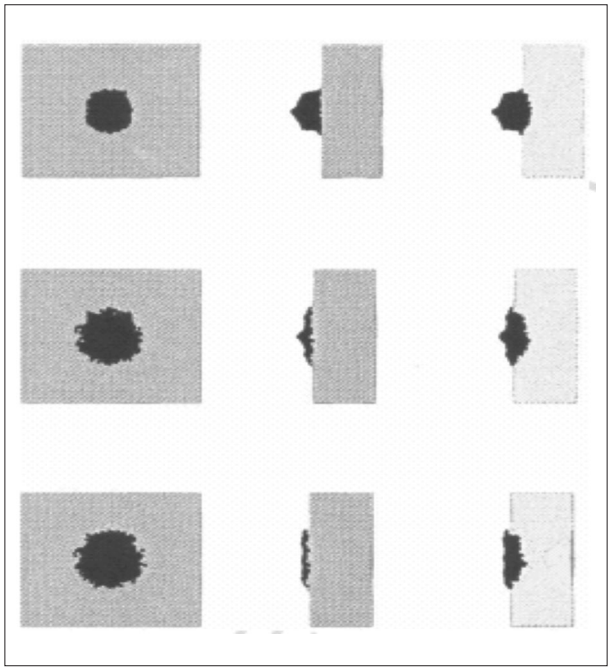

Fig. 6. Results of MD simulations for cluster. The top (left), side (middle) and cut (right) views of MD configurations at $t = 1.3$ ps (top), $t = 2.1$ ps (middle), and $t = 5.0$ ps (bottom) for the cluster incident energy $E_{\text{inc}} = 0.56$ eV/atom

tree for representing the multiplicative variables with respect to the Janet division of a given monomial set. Based on this data structure the completion to involution of both monomial and polynomial sets can be performed extremely fast. The new algorithms admit further optimization. Extensive benchmarking was performed in comparison with the special-purpose computer algebra system SINGULAR. This is a system dedicated to polynomial computations and is considered as very fast for Groebner basis computations. In most examples, the implementations of the new algorithms turned out to be faster. Moreover, the new algorithms unlike classical Buchberger algorithm for computation Groebner bases admit effective parallelization, what was explicitly demonstrated on a two-processor Pentium-based computer. Modeling multi-processor computations on this machine reveals a behaviour of the computing time which is close to inversely proportional with respect to the number of processors. General involutive algorithms for polynomial as well as linear systems of partial differential equations were also implemented in Mathematica [19–21].

Computation of cohomologies for Lie algebras and superalgebras explicit computation of Lie (super)algebra cohomologies is of great importance for studying modern models of theoretical and mathematical physics. A new algorithm has been designed. The new algorithm splits cochain complexes containing spaces of very high dimension into smaller ones. In many applications this strategy leads to significantly faster computations. The algorithm has been implemented in C and applied to some concrete examples of physical interest. This approach can also be applied to explicitly determine the Spencer cohomology of Z-graded Lie (super)algebras [22].

INTERNATIONAL COOPERATION

In accordance with the Agreement between JINR and the Research Centre FZR (Rossendorf, Germany) about a cooperation in the field of application and development of computing systems, LIT specialists took part in the realization of the project «Zentrale Nutzerdatenbank» for administration of the computer complex FZR with the use of WWW technology. Work on creation of the automated system of administrating the computer complex with application of WWW technology was carried out. A number of Java programs were developed. An opportunity was investigated of using software on base of LDAP (Lightweight Directory Access Protocol) for automated remote administrating of personal computers with different operational systems (W2000 and Linux) .

In cooperation with DESY (Zeuthen), joint work on the development and creation of applied and system software for high-performance multiprocessor computing complex APEmille as well as of apeNEXT was performed. Debugging and testing of both software and hardware for APEmille were performed. A simulation on the preliminary VHDL model of apeNEXT was done. A prototype version of a C compiler, including an interface to the TAO front-end, was developed. Testing with the functional simulator of the apeNEXT architecture running on Linux PCs was performed.

Joint work was carried out in cooperation with CERN's IT Division in the framework of the CERN–INTAS project on the creation of a system «Correlation Engine». The purpose of the system is a timely detection of anomalous states on PC-farm's nodes and failure prevention. A first prototype of the correlation system has been designed in the language Perl and statistics is being accumulated. In parallel, the possibilities of the prototype are being extended.

In cooperation with CERN and Brookhaven National Laboratory the following work has been carried out [23]:

— Development, in cooperation with CERN, of the object-oriented program environment (framework ROOT) for solving a wide class of scientific problems using workstations and PC (http://root.cern.ch).

— Elaboration, development and realization of an informational model of processors for acquisition, reconstruction and physical analysis of data for large experiments.
— Introductions of modern object-oriented technologies for the STAR experiment.
— Development of an object-oriented input/output system for the ATLAS experiment.

The investigation on joint DFG–GSI–JINR project «Nonequilibrium Strongly Dense Matter in Nucleus-Nucleus Collisions» was in progress. The aim of the project is to further develop transport schemes including off-shell effects, in particular, such as finite particle widths, and possible phase transitions in dense matter and implement these schemes into various dynamical models, i. e., to study evolution of resonance matter and dynamics of phase transitions.

Charmonium dissociation in a hot meson gas was investigated in collaboration with Rostock University (Germany). The results are applied to heavy-ion collisions within a modified Glauber model scenario and the phenomenon of anomalous J/ψ suppression is addressed [24]. The results are applicable to the case of Pb-Pb collisions at CERN.

Active collaboration was continued with Germany in the field of computer algebra. With the Technical University (RWTH) of Aachen, two Maple packages, called Involutive and Janet, implementing original algorithms designed at LIT for transformation (completion) of systems of nonlinear algebraic equations and linear systems of PDEs, respectively, into the canonical involutive form, have been developed.

With University of Greifswald, a Mathematica tool Invo for completion of nonlinear algebraic and linear differential systems to involution was created. This software tool allows a user to experiment with various involutive divisions generating different algorithmic procedures for the completion [21].

The effective cooperation with the International Solvay Institute of Physics and Chemistry (Brussels, Belgium) progressed in 2001 on the basis of developed computational tools and methods based on artificial neural networks, cellular automata. A nonlinear time series analysis was applied to the traffic measurements, obtained at the input of a medium-size local area network [25].

APPLIED RESEARCH

A graphic version of the program Progress++ for calculation and optimization of city electric supply lines has been put into operation. The program works at IBM PC under Windows environment. At present, it is exploited at all the 35 electric power supply enterprises of the Moscow Region as well as at some plants of other regions of Russia. The program is an effective tool for power loss analysis. Following the directions of the program allows one to minimize energy loss from 8–10 % down to 5–8 %. The program can create and screen schemes of various complexity. It also can determine the network graph connectivity index and detect cycles in the scheme. The solving of the system of N Kirchhoff equations is performed during the time of the order N of operations. A certificate has been received from the Ministry of Energy, registration No. 001.

A number of investigations in cooperation with the International Solvay Institute of Physics and Chemistry (Brussels, Belgium) in the field of applied research were performed in 2001:

- A review devoted to the computational methods and tools for modeling and analysis of various complex processes in physics, medicine, social dynamics and nature was published [26].
- The ability of artificial neural networks to reconstruct discrete chaotic maps with singular points was investigated [27].
- A new approach to the problem of efficient resources distribution in different types of economic systems was proposed [28].
- The use of the elastic neural nets (ENN) to find the initial estimation in automated procedures of locating seismic events was proposed. The advantages of ENN are the simplicity of the algorithm, fast convergence and high efficiency. The results were shown with simulated seismic events [29].

The cooperation of LIT with the Institute of Radiation Physics and Chemistry Problems (IRP&CP), National Academy of Sciences of Belarus, Minsk, was active. It covers the research field on computer simulation and calculations within the project on sub-critical assembly with MOX fuel for research in nuclear waste transmutation. One of the latest joint published paper [30] deals with a theoretical investigation of transmutation rates for a number of long-lived fission products and minor actinides as well as with the neutron spectra formed in the sub-critical assembly driven with the following monodirectional beams: (i) 660 meV protons; (ii) 14 MeV neutrons. The main objective is the comparison of neutron spectrum in the MOX assembly for different external driving sources.

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