ANNUAL REPORT

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Joint Institute for Nuclear Research

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INTRODUCTION

The Joint Institute for Nuclear Research continues to remain one of the flagships of the world science development. The activity of JINR in 2000 was marked by important scientific achievements. Among the most remarkable are the discovery of a new element of the D.I.Mendeleev Periodic Table with $Z = 116$, the first physical results in the experiments with the extracted beam of the JINR Nuclotron, also a number of scientific results in investigations in nuclear physics, particle physics and condensed matter physics.

The experiments on the synthesis of element 116 were conducted at the Flerov Laboratory of Nuclear Reactions at the beams of the U400 cyclotron — one of the best accelerators of this type in the world. The new stage in the modernization of the U400 and U400M cyclotrons were the efforts concentrated on development of an accelerator complex for producing radioactive beams (the DRIBs project). In 2000, special separation channels were developed and constructed for realization of the physics programme to investigate reactions with radioactive beams. Using the ^{7}Li and ^{11}B ion beams extracted from the U400M cyclotron, it has been possible to produce secondary ^{6}He and ^{8}He ion beams.

New interesting results in the structural studies of high-temperature superconductors have been obtained with the high-resolution Fourier diffractometer at the IBR-2 pulsed neutron reactor. A group of researchers of the I.M.Frank Laboratory of Neutron Physics (JINR) and their colleagues from the I.V.Kurchatov Institute and B.P.Konstantinov Institute of Nuclear Physics (St. Petersburg) were awarded the 2000 State Prize of the Russian Federation in science and technology for the development and realization of new methods in structural neutron diffraction studies by the time-of-flight method using pulsed and stationary reactors.

First experiments at proton, deuteron and carbon nuclei beams, extracted from the Nuclotron, have been carried out with an energy up to 3 GeV per nucleon. Interesting results have been obtained at the extracted proton beam at the set-up STRELA, the extracted deuteron beam provided first events at the set-up SCAN-2.

In the studies of asymptotic laws in relativistic nuclear physics, the principles of symmetry and similarity were used in order to derive the analytic expression for the inclusive cross-section of particle, nuclear fragment and anti-nucleus production in relativistic nuclear interactions in the central velocity region ($\gamma = 0$). The results are in agreement with the available experimental data. It has been shown that the effective number of nucleons participating in nuclear interactions falls with the energy growth, and the cross-section tends to a constant equal for particles and antiparticles. Analysis of the obtained results gives a possibility to predict the asymptotic behaviour of particle, nuclear fragment and anti-nucleus production cross-sections.

The origin of earlier constructed boson and fermion solutions of symmetry equations corresponding to two-dimensional boson and $N = (2|2)$ supersymmetric Toda lattices has been established by JINR theorists. The algebras of corresponding symmetries were derived. A two-dimensional $N = (0|2)$ supersymmetric Toda lattice hierarchy was proposed, its $N = (0|2)$ superfield formulation was discussed. Boson and fermion solutions of symmetry equations, corresponding to the $N = (0|2)$ supersymmetric Toda lattice equation, as well as their algebras were constructed.

An Analytic Perturbation Theory (APT) has been devised that relates renorm-invariant, effective coupling functions $\tilde{\alpha}(s)$ and $\alpha_{an}(Q^2)$. Non-power perturbation expansions were constructed for observables in time-like and Euclidean domains, which are free of extra singularities and obey better convergence in the infrared region. The basic tool was the «double spectral representation», similar to the representation for the Adler function, which stems from first principles of local QFT.

The programme of scientific investigations which involves participation of JINR specialists in collaborative experiments is carried out at the largest accelerators of the world. Dubna physicists occupy the leading position in

experiments at CERN, DESY, BNL and FNAL, that signifies great contribution of JINR scientists acknowledged by the leaders and international collaborations of these centres. Our specialists work selflessly, they fulfil their tasks in due amount and time, manufacturing modules of modern new detectors. Strictly according to the schedule, modules for the ATLAS and CMS detectors for LHC are being developed. For the last two years 33 modules of the hadron calorimeter have been manufactured for CERN according to the ATLAS programme (the total number of modules to be developed in Dubna is 64). In 2000 JINR fully completed the manufacture and delivery of 607 muon counters for CDF at FNAL covering about 270 m^2 (more than 75 %) around the detector, and 6500 mini-drift tube detectors with 50 thousand electronics channels for D0. All the components of CDF and D0 are ready for a long run at the Tevatron. JINR physicists took part in Run I with the STAR detector at RHIC (BNL), and the obtained new data on gold nuclei collisions are analysed at the LHE (JINR) PC-farm.

The lifetime of the negative muon in the ^{129}Xe isotope was measured for the first time at the JINR Phasotron. Analysis of analogous results for the $^{132,136}Xe$ isotopes showed a noticeable dependence of the nuclear muon capture rate on the mass number for the isotopes in question (the isotopic effect in the nuclear capture of the negative muon in xenon).

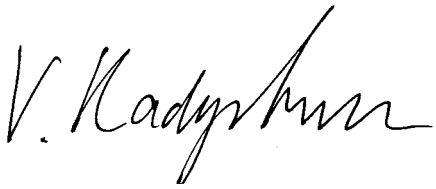
On 1 December 1999, a radiological clinic was opened in Dubna and 38 patients of the radiological clinic received treatment at the Phasotron beams in the course of 2000. It is planned to provide treatment to a doubled number of patients in 2001.

Realization of the BAPHYS project continued. The project is aimed at the establishment and development of a unified scientific and information environment for Russian nuclear research centres on the basis of a distributed network of data bases and knowledge in the sphere of fundamental properties of matter and applied nuclear physics for the purposes of science, education, socially significant applied spheres of activity.

Among the highlights of the year were the 2nd International Symposium «LHC Physics and Detectors» held in Dubna and the traditional JINR–CERN poster exhibition «Science Bringing Nations Together» held in the European Parliament (Brussels).

The active role of the Joint Institute for Nuclear Research in international cooperation was vividly demonstrated during a round-table discussion in Dubna, which was attended by representatives of Russian research centres, universities and industrial enterprises, as well as at a meeting of the Board of the International Association of Academies of Sciences, where it was noted that JINR is one of the world's most prestigious physics centres and that its activity serves as an example of scientific research integration on the international scale.

In recognition of the outstanding scientific achievements of the Joint Institute for Nuclear Research as well as to pay respect for its international status, 26 March — JINR's Foundation Day — has become a day-off for the JINR staff since 2000.



V.G.Kadyshevsky
Director
Joint Institute for Nuclear Research

JINR • 2000

GOVERNING AND ADVISORY BODIES OF JINR

ACTIVITIES OF JINR GOVERNING AND ADVISORY BODIES

MEETING OF THE JINR COMMITTEE OF PLENIPOTENTIARIES

A regular meeting of the Committee of Plenipotentiaries (CP) of the Governments of the JINR Member States was held in Dubna on 17–18 March 2000. It was chaired by Professor R.Mach (Czech Republic).

The Committee of Plenipotentiaries listened to and discussed the report presented by JINR Director V.G.Kadyshevsky on implementation of the Scientific Council's recommendations and the CP's decisions concerning the reform programme of JINR, on JINR's activity in 1999, and on plans for 2000–2002. The CP acknowledged the significant progress made within the reform programme in the areas of basic facilities, infrastructure and personnel policy, also in the centralized management of financing JINR research projects as a new element of the reform programme.

The Scientific Council hailed the ratification of the «Agreement between the Government of the Russian Federation and the Joint Institute for Nuclear Research on the Location and Terms of Activity of JINR in Russia» and adoption of the corresponding Federal Law of the Russian Federation. The CP considers that this Federal Law, as a document of key importance, will play a positive role in the future development of JINR as an international research centre.

New scientific results that greatly contributed to world science were obtained at the Joint Institute for Nuclear Research in 1999. The JINR Directorate could provide stable operation of the basic facilities according to schedule and their further development. The CP congratulated the JINR staff on the successful test of the Nuclotron slow beam extraction system, on the commissioning of the cryogenic moderator at the IBR-2 reactor, noted progress in construction and tests of the acceleration section for the IREN project, results of the experiments on the synthesis of a new isotope of the element with $Z = 114$ and $A = 288$ in addition to two isotopes with $A = 287$ and 289, earlier observed by FLNR scientists. Also noted were some other significant achievements in theoretical and experimental research at JINR facilities (Nuclotron, IBR-2, cyclotron complex U400–U400M) and in collaborating research centres (CERN, FNAL, IHEP, etc.).

The recommendations of the 86th and 87th sessions of the JINR Scientific Council, the research and international collaboration plan for 2000, and the «JINR Scientific Programme for the Years 2000–2002» were approved.

Taking into account the recommendations of the 87th session of the JINR Scientific Council, the CP commissioned the JINR Directorate to give first-priority financing to the following activities in 2000:

— completion of the Nuclotron beam extraction system and of external beam lines; operation and development of the Nuclotron; experimental studies of quark and gluon degrees of freedom in nuclei and of spin effects at the LHE accelerator complex, also at the accelerators of other centres: SPS and LHC (CERN), RHIC (BNL), SIS (Darmstadt), COSY (Jülich) and CELSIUS (Uppsala);
— construction of IREN, with a realistic schedule and an agreed financial envelope, with a view to its completion in 2002;
— upgrade of the IBR-2 reactor, with a view to securing the long-term future of this facility; development of instrumentation and data acquisition equipment for spectrometers at the reactor; continuation of the spectrometers' exploitation and of experiments with the cold neutron beam for studying complex structures in biology, pharmacology, materials science, etc.;
— physical and chemical studies of heavy nuclei in the vicinity of the «stability island» $Z = 114$–116 using the Gas-Filled Recoil separator and the upgraded VASSILISSA set-up, study of the fusion-fission reaction for weakly excited superheavy nuclei, study of the structure of light exotic nuclei and neutron corre-

lations in them, research with beams of stable and radioactive ions using the FOBOS and MULTI detectors and the High-Resolution Beam Line;
— realization in 2000–2002 of the Dubna Radioactive Ion Beams (DRIBs) project;
— continued participation in frontier particle physics experiments, amongst others at accelerators of IHEP (Protvino), CERN, DESY, BNL and FNAL; accelerator system R&D for the LHC (CERN) and linear colliders (TESLA);
— theoretical studies in particle physics and quantum field theory, nuclear physics, and condensed matter physics, also with a view to supporting experimental work in these fields;
— further development of JINR's telecommunication links and of JINR's computing and networking infrastructure;
— implementation of the JINR Educational Programme, including special-purpose training of specialists for the Member States.

Following the recommendations of the Scientific Council and of the JINR Directorate, the Committee of Plenipotentiaries decided to name the Laboratory of Nuclear Problems after Professor V.P.Dzhelepov to commemorate his outstanding contribution to the establishment and development of this Laboratory and of the whole Institute. Responding to the request of the JINR Directorate and Laboratory Directorates, the CP also decided to name two alleys on the LNP site after M.Hmitro (Czech Republic) and Yu.M.Ostanevich (Russia) — scientists who had made a large contribution to the development of JINR.

Based on the report by JINR Assistant Director for Economic and Financial Issues V.V.Katrasev, the CP took note of the information on the implementation of the JINR budget in 1999, approved the JINR budget for 2000 with a total expenditure of US$37.5 million and a member-state contribution scale for 2000 proportional to the UN scale. The tentative estimate of the JINR budget for 2001 was set to be US$37.5 million. The CP commissioned the JINR Directorate to continue improving the procedure of determining contributions to the JINR budget.

The CP agreed with the participation of JINR as a founder in the non-commercial organization «Foundation for Applied Research» and with allocation of US$2,500 from non-budgetary funds as JINR's contribution.

Based on the written information from Finance Committee Chairman J.Kolin, the CP approved the Protocol of the Finance Committee meeting held on 17–18 February 2000 and the report of the Joint Institute for Nuclear Research on implementation of the 1999 budget. The sanctions against the Member States whose debts exceeded the sum of their contributions for two years, as stipulated in paragraph 5, section IV, CP Minutes of 12–13 March 1998, were confirmed.

On listening to and discussing the information about restructuring of debts of JINR Member States, the CP took note of what had been done in this connection by the JINR Directorate in 1999 and commissioned it to continue consultations with the governments of the JINR Member States about the terms and procedure for restructuring of debts.

Based on the information by JINR Vice-Director A.N.Sissakian on realization of the Agreement between the Government of the Russian Federation and JINR, the Committee of Plenipotentiaries decided to approve the list of immediate activities proposed by the JINR Directorate for realization of the Agreement between the Government of the Russian Federation and the Joint Institute for Nuclear Research on the Location and Terms of Activity of the Joint Institute for Nuclear Research in the Russian Federation and for improvement of the normative and legal procedures of JINR.

The Committee of Plenipotentiaries prolonged the term of office of Professor R.Mach (Czech Republic) as the CP Chairman until the next meeting.

SESSIONS OF THE JINR SCIENTIFIC COUNCIL

The 87th session of the JINR Scientific Council, chaired by JINR Director V.G.Kadyshevsky, took place in Dubna on 13–14 January 2000.

At the session, Director V.G.Kadyshevsky presented a report on implementation of the recommendations of the 85th and 86th sessions of the Scientific Council concerning the reform programme of JINR and gave comments on the proposed JINR Scientific Programme for the years 2000–2002.

Scientific progress reports were presented by the JINR Laboratories, Division of Radiation and Radiobiological Research, and University Centre. JINR Chief Engineer I.N.Meshkov informed the Council on the progress of development of the JINR basic facilities.

Two highlights of 1999 were reported: «Results of the First Test of the Nuclotron Beam Slow Extraction System» by LHE Director A.I.Malakhov and «Methane Cryogenic Moderator at the IBR-2 Reactor» by FLNP leading scientist E.P.Shabalin.

Recommendations of the JINR Programme Advisory Committees were presented by their Chairpersons: H.Lauter (PAC for Condensed Matter Physics), Ch.Brianşon (PAC for Nuclear Physics) and S.Dubnička (PAC for Particle Physics).

The session included a round-table discussion «JINR–Russia Cooperation», whose participants were the Scientific Council members and invited prominent Russian scientists — leaders and representatives of major research cenres, universities and industrial enterprises. A dedicated photo exhibition was also organized during the round-table discussion, and a telebridge between JINR and Moscow State University was established via Internet communication channels.

The Council approved the Jury's recommendations on the JINR prizes for 1999. The awarding of the 1999 B.Pontecorvo prize took place at the session. The prize went to Professor R.Davis (BNL, USA) for his outstanding achievements in developing the chlorine-argon method for solar neutrino detection. The laureate gave a talk on the subject of his research. The following scientific reports were also presented by JINR prizewinners: «Integrable Systems with Extended Supersymmetry» by A.Sorin, «Fission of Heavy and Superheavy Nuclei near and below the Coulomb Barrier» by M.G.Itkis, and «Fragment Separator COMBAS» by A.G.Artyukh.

The Scientific Council took note of the report presented by JINR Director V.Kadyshevsky on the implementation of the Scientific Council's recommendations concerning the reform programme of JINR.

The Scientific Council applauded the actions twice undertaken by the Directorate in 1999 to secure salary increases for the staff.

The Scientific Council was pleased to learn about the ratification of the «Agreement between the Government of the Russian Federation and the Joint Institute for Nuclear Research on the Location and Terms of Activity of JINR in Russia» as a Federal Law of the Russian Federation, signed by the Acting President of the Russian Federation V.Putin on 2 January 2000, which came into force on 6 January 2000.

The Scientific Council appealed again to all the Member States to fulfil their financial obligations to the Institute. Timely payments would benefit the scientific mission of the Institute, including its ambitious reform programme.

The Scientific Council thanked the representatives of Russian research centres, universities and industrial enterprises for taking part in the round-table discussion. The Scientific Council acknowledged the continued efforts made by the JINR Directorate to develop international cooperation. In particular, it appreciated the extensive and fruitful cooperation of JINR with Russian research centres, universities and industrial enterprises, highlighted by the round-table discussion at this session and by the dedicated photo exhibition.

The Scientific Council took note of the report «Progress of Development of the JINR Basic Facilities» presented by Chief Engineer I.Meshkov and highly appreciated that, despite the present financial difficulties, the JINR Directorate had managed to ensure the stable operation of the basic facilities according to schedule in 1999 and their further development.

The Scientific Council congratulated JINR on the successful test in December 1999 of the Nuclotron slow beam extraction system and on the start-up of the cryogenic moderator for the IBR-2 reactor. The Scientific Council looks forward to the commissioning of the beam extraction system and of the cold source for experiments, and recommended that the JINR Directorate provide the necessary support of these priority activities.

The Scientific Council took note of the information presented by the Chief Engineer on the outcome of the International Workshop «JINR Synchrotron Radiation Source: Prospects of Research» held on 1–3 November 1999 according to the joint recommendations of the three PACs. The Scientific Council asked the JINR Directorate to prepare a detailed proposal for the DELSY project, including the technical design of machine and experimental equipment, cost evaluation for realization and future operation, research programme, needs of the users' community, and indication of all financial sources outlined within the framework of the JINR research programme implementation. The DELSY proposal should be discussed at a Scientific Council session after the panel's referee report. Upon proposal by the JINR Directorate, the Scientific Council appointed a panel to referee the DELSY project: A.Budzanowski, H.Schopper and A.Skrinsky.

The Scientific Council approved the general lines of the proposed «JINR Scientific Programme for the Years 2000–2002» and reiterated its standing recommendation that the highest emphasis should be put on the reliable operation of the Institute's present basic facilities.

Taking into account the proposals of the Directorate and the recommendations of the PACs, the Scientific Council endorsed the following priority activities in 2000:

— completion of the Nuclotron beam extraction system and of external beam lines; operation and development of the Nuclotron; experimental studies of quark and gluon degrees of freedom in nuclei and of spin effects at the LHE accelerator complex, also at the accelerators of other centres: SPS and LHC (CERN), RHIC (BNL), SIS (Darmstadt), COSY (Jülich) and CELSIUS (Uppsala);
— construction of IREN, with a realistic schedule and an agreed financial envelope, with a view to its completion in 2002;
— upgrade of the IBR-2 reactor, with a view to securing the long-term future of this facility; development of instrumentation and data acquisition equipment for spectrometers at the reactor; continuation of the spectrometers' exploitation and of experiments with the cold neutron beam for studying complex structures in biology, pharmacology, materials science, etc.;
— physical and chemical studies of heavy nuclei in the vicinity of the «stability island» $Z = 114$–116 using the Gas-Filled Recoil Separator and the upgraded

VASSILISSA set-up, study of the fusion-fission reaction for weakly excited superheavy nuclei, study of the structure of light exotic nuclei and neutron correlations in them, research with beams of stable and radioactive ions using the FOBOS and MULTI detectors and the High-Resolution Beam Line;

— realization in 2000–2002 of the Dubna Radioactive Ion Beams (DRIBs) project;
— continued participation in frontier particle physics experiments, amongst others at accelerators of IHEP (Protvino), CERN, DESY, BNL and FNAL; accelerator system R&D for the LHC (CERN) and linear colliders (TESLA);
— theoretical studies in particle physics and quantum field theory, nuclear physics, and condensed matter physics, also with a view to supporting experimental work in these fields;
— further development of JINR's telecommunication links and of JINR's computing and networking infrastructure;
— implementation of the JINR Educational Programme, including special-purpose training of specialists for the Member States.

The Scientific Council took note of and concurred with the recommendations made by the PACs at their November 1999 meetings and presented by their Chairpersons.

Particle physics issues. The Scientific Council appreciated the efforts undertaken by the JINR Directorate to provide the necessary financing of the work to construct the Nuclotron beam slow extraction system and congratulated the staff of the Laboratory of High Energies on the first successful test of this system.The Scientific Council endorsed the long-term plan of physics research at the Nuclotron and recommended that the JINR Directorate give adequate support to its implementation.

The Scientific Council took note of the new recommendations of the PAC for optimizing the JINR research programme in particle and relativistic nuclear physics. It agreed with the list of activities proposed for execution with first priority in 2000 and with the closure of a number of projects, as outlined in the minutes of the PAC meeting.

Nuclear physics issues. The Scientific Council endorsed the nuclear physics programme for the years 2000–2002 presented at the PAC meeting by the Laboratories.

The Scientific Council congratulated the Flerov Laboratory of Nuclear Reactions on the synthesis of the new isotope of element 114 with $A = 288$ in addition to the two isotopes with $A = 287$ and 289, earlier observed at this Laboratory. The Scientific Council strongly recommended continuation of this programme with high priority.

The Scientific Council agreed with the PAC for Nuclear Physics that the highest priority should be given to the completion of the IREN facility and to the development of the DRIBs project. The Scientific Council learned with satisfaction about the efforts made by the JINR Directorate to ensure the basic financing of the IREN project in 1999 and about the progress in the construction and testing of the accelerator section that are vitally important for implementation of this project in 2002. The Scientific Council recommended its funding as spelled out in the financial plan presented by the PAC's Chairperson. The Scientific Council emphasized the scientific merit of the DRIBs project. Impressed by the rapid progress of the project, the Council strongly supported this programme and looks forward to its funding in accordance with the accelerated project schedule.

The following experiments at the Laboratory of Nuclear Problems, highly ranked by the PAC, should be continued with the best financing and beam time allocation: μ-catalysis, DUBTO, LESI.

Condensed matter physics issues. The Scientific Council repeated its recommendations for adequate funding, including refurbishment, of the IBR-2 reactor to ensure its continuing operation. Due to the support of Minatom, the financing and the time schedule of the refurbishment programme have to be revised. In particular, the decisions about the reduced power of the reactor from 2 to 1.5 MW and reduced number of cycles from 10 to 8 should be re-examined.

The Scientific Council appreciated the successful tests of the new cryogenic moderator at the IBR-2 reactor and supported the demand for a cryogenic system to cool the cryogenic moderator. New areas in research using cold neutrons can only be achieved with an adequate instrumentation programme that should be urgently established and supported with high priority.

On a general note, it was supported that, due to its specific nature, accelerator R&D should be in the competence of the JINR Directorate. If deemed appropriate, on a case-by-case basis, the advice of external accelerator experts should be seeked.

The Scientific Council congratulated Professors C.Détraz, V.Dmitrievsky, S.Jullian, G.Münzenberg, H.Oeschler, D.Shirkov, A.Tavkhelidze and V.Zrelov on their being awarded the title «Honorary Doctor of JINR», in recognition of their outstanding contributions to the advancement of science and education of young scientists.

The Scientific Council congratulated the scientific and engineering staff of JINR, particularly those associated with the Laboratory of Nuclear Problems, on the 50th anniversary of the commissioning of JINR's first basic facility — the Synchrocyclotron, which opened, in 1949, the era of high-energy physics research.

The Scientific Council welcomed the decision of the JINR Directorate to name the Laboratory of Nuclear Problems after Professor V.Dzhelepov, in recognition of his outstanding contribution to the activities of this Laboratory and of the whole Institute.

The 88th session of the JINR Scientific Council, chaired by JINR Director V.G.Kadyshevsky, took place in Dubna on 8–9 June 2000.

At the session, Director V.G.Kadyshevsky informed the Council about the decisions taken by the JINR Committee of Plenipotentiaries at its March 2000 meeting, also about the Directorate's proposals of reforms in the scientific domain of JINR. On the occassion of the 30th anniversary of the journal «Physics of Elementary Particles and Atomic Nuclei», a dedicated report of activities was presented by its Editorial Board. The status of development of the JINR basic facilities was reported by JINR Chief Engineer I.N.Meshkov. The research programme at the Nuclotron was presented by LHE Director A.I.Malakhov.

A special meeting of the JINR Scientific Council to mark the 40th anniversary of scientific research at pulsed reactors was held on 8 June in the Dubna Branch of the Institute of Nuclear Physics of Moscow State University. Its programme included the dedication of a monument to Dmitry I. Blokhintsev, the scientific report «40 Years of Research at Pulsed Reactors» by FLNP Director V.L.Aksenov, and welcome addresses by representatives of JINR member-state research centres.

Further at the session on 9 June, the recommendations of the JINR Programme Advisory Committees were presented by their Chairpersons: S.Dubnička (PAC for Particle Physics), Ch.Brianşon (PAC for Nuclear Physics), and H.Lauter (PAC for Condensed Matter Physics). Two scientific talks were delivered at the session: «Polarized Nucleon Strangeness» by M.G.Sapozhnikov and «Search for Physics Beyond the Standard Model in Semi-leptonic Processes at Low Energy» by V.G.Egorov.

The session also included the awarding of diplomas to the 1999 JINR prize winners.

The Scientific Council took note of the information presented by the Director of JINR about the decisions taken by the JINR Committee of Plenipotentiaries at its March 2000 meeting, in particular:

— of the approval of the JINR Directorate's activity on implementing the reform programme of the Institute;

— of the approval of the Topical Plan of Research and International Cooperation for 2000 and the «JINR Scientific Programme for the Years 2000–2002» based on the recommendations of the Scientific Council and of the PACs;

— of the naming of the Laboratory of Nuclear Problems after Professor V.Dzhelepov.

The Scientific Council regretfully noted the amendment to the list of JINR's first-priority activities made by the CP upon the JINR Directorate's proposal concerning the project IREN: «construction of IREN, with a realistic schedule and an agreed financial envelope, with a view to completion of its first stage in 2002», that is the IREN facility as a whole without one clystron.

The Scientific Council highly appreciated the steps taken so far by the JINR Directorate within the reform programme in the areas of basic facilities, infrastructure, and personnel policy. At this session it was informed about the Directorate's first proposals of reforms in the area of scientific research, in particular on organization of research at the Frank Laboratory of Neutron Physics and at the IBR-2 reactor, as well as on reorganization of the Laboratory of Computing Techniques and Automation (LCTA) into the Laboratory of Information Technologies (LIT). The main LIT tasks will be the maintenance of operation and the development of the computing and networking infrastructure.

The Scientific Council took note of these proposals and discussed them in detail. While agreement on the proposed restructuring of LCTA into LIT was reached, no conclusion was drawn on the desirability of splitting FLNP into two units, either two laboratories, or else into a laboratory and a division. It was noted that a division, as opposed to a laboratory, still needs to be defined. The Scientific Council expects such clarifications, as well as a report on the future structures and activities at the January 2001 session. Concerning LIT, the Scientific Council would like to hear a detailed report on the future activity and structure of this new laboratory created on the basis of LCTA.

The Scientific Council took note of the report «Status of Development of the JINR Basic Facilities» presented by JINR Chief Engineer I.Meshkov.

The Scientific Council highly appreciated the stable operation of the basic facilities according to schedule in 2000 and their further development. The Scientific Council noted the successful run of the Nuclotron on 17 March 2000, when the deuteron beam was obtained. The Scientific Council looks forward to the development of the Nuclotron to the stage of a routinely operationable accelerator for the use in a wide range of studies. The Scientific Council expressed its satisfaction with the progress in the IBR-2 refurbishmen, the realization of the DRIBs and IREN projects and encouraged the JINR Directorate to focus their attention on the projects' schedule fulfilment. The Scientific Council was satisfied with the JINR Directorate's decision to fund the basic facilities' exploitation and development on the basis of the Directorate's grants. The Scientific Council asked the JINR Directorate to present for consideration at the 89th session a detailed proposal for the DELSY project after its scrutiny by the appointed «Committee of Three».

The Scientific Council took note of the report by LHE Director A.Malakhov reviewing the programme of the research planned for the extracted beam of the Nuclotron facility. The Scientific Council congratulated the Directorates of JINR and LHE, as well as the staff of the Laboratory of High Energies, on the successful accomplishment of this important milestone in developing the LHE accelerator complex — in achievements of slow beam extraction from the Nuclotron and successful ex-

GOVERNING AND ADVISORY BODIES OF THE JOINT INSTITUTE FOR NUCLEAR RESEARCH

COMMITTEE OF PLENIPOTENTIARIES OF THE JINR MEMBER STATES

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One delegate
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F.Dydak	Switzerland	V.N.Okolovich	Kazakhstan	A.N.Tavkhelidze	Georgia
J.Ganzorig	Mongolia	Yu.A.Osipian	Russia	G.Trilling	USA
A.Hrynkiewicz	Poland	V.V.Papoyan	Armenia	I.N.Vishnevsky	Ukraine
J.Janik	Poland	M.Petrovici	Romania	I.Wilhelm	Czech Republic
N.Kroo	Hungary	B.Peyaud	France	B.S.Yuldashev	Uzbekistan
F.Lehar	France	G.Piragino	Italy	G.M.Zinovjev	Ukraine

Programme Advisory Committee for Particle Physics

Chairperson: S.Dubnička (Slovak Republic)
Scientific Secretary: Yu.A.Gornushkin

Programme Advisory Committee for Nuclear Physics

Chairperson: Ch.Briançon (France)
Scientific Secretary: N.K.Skobelev

Programme Advisory Committee for Condensed Matter Physics

Chairperson: H.Lauter (France)
Scientific Secretary: S.I.Tyutyunnikov

INTERNAL ORGANIZATION OF THE JOINT INSTITUTE FOR NUCLEAR RESEARCH

DIRECTORATE
Director V.G.Kadyshevsky
Vice-Director A.N.Sissakian
Vice-Director Ts.Vylov
Chief Scientific Secretary V.M.Zhabitsky
Chief Engineer I.N.Meshkov

Bogoliubov Laboratory of Theoretical Physics

Director
A.T.Filippov

Research in

- symmetry properties of elementary particles
- field theory structures
- interactions of elementary particles
- theory of atomic nuclei
- theory of condensed matter

Laboratory of High Energies

Director
A.I.Malakhov

Research in

- structure of nucleons
- strong interactions of particles
- resonance phenomena in particle interactions
- electromagnetic interactions
- relativistic nuclear physics
- particle acceleration techniques
- interactions of multicharged ions in a wide energy range

Dzhelepov Laboratory of Nuclear Problems

Director
N.A.Russakovich

Research in

- strong, weak and electromagnetic interactions of particles, particle structure
- search for new particles
- nuclear structure
- nuclear spectroscopy
- mesoatomic and mesomolecular processes
- particle acceleration techniques
- radiobiology

Flerov Laboratory of Nuclear Reactions

Director
M.G.Itkis

Research in

- properties of heavy elements, fusion and fission of complex nuclei, cluster radioactivity, reactions on an isomer hafnium target
- reactions with beams of radioactive nuclei, structure of neutron-rich light nuclei, non-equilibrium processes
- interactions of heavy ions with condensed matter
- particle acceleration techniques

Frank Laboratory of Neutron Physics

Director
V.L.Aksenov

Research in

- nuclei by neutron spectroscopy methods
- fundamental properties of neutrons
- atomic structure and dynamics of solids and liquids
- high-temperature superconductivity
- reactions on light nuclei
- materials by neutron scattering, neutron activation analysis and neutron radiography methods
- dynamic characteristics of the pulsed reactor IBR-2

Laboratory of Information Technologies

Director
I.V.Puzynin

Research in

- provision of operation and development of the JINR computing and networking infrastructure
- optimal usage of international computer networks and information systems
- modern methods of computer physics, development of standard software

Laboratory of Particle Physics

Director
V.D.Kekelidze

Research in

- experimental investigations in elementary particle physics at external accelerators to study particle structure and interaction laws
- development of instruments and methods for investigation of elementary particles
- development of methods and systems for acceleration of particles to super-high energies

Division of Radiation and Radiobiological Research

Leader
E.A.Krasavin

Research in

- radiation fields
- genetic effect of ionizing radiation
- radiation monitoring

University Centre

Director
S.P.Ivanova

Central services

- central scientific and information departments
- administrative and economic units
- manufacturing units

traction of the deuteron beam from the Nuclotron to the experimental physics set-ups. The Scientific Council recommended continuation of the first experiments, using the Nuclotron extracted beam, including the projects STRELA and SCAN-2, and also approval of the research programme with the extracted beam of the Nuclotron at the set-ups: SPHERE, DISC, MARUSYA, GIBS, FAZA, DELTA, DELTA-SIGMA, SMS MSU, and MRS.

The Scientific Council took note of and concurred with the recommendations made by the PACs at their April 2000 meetings and presented by their Chairpersons.

Particle physics issues. The Scientific Council highly appreciated the great accomplishment of the Laboratory of High Energies in achieving slow beam extraction from the Nuclotron to the experimental hall for the physics set-ups. The PAC approved the research programme to be implemented at the Nuclotron extracted beam. The Scientific Council agreed with the PAC for Particle Physics' evaluation of the DIRAC experiment as of high scientific significance, as well as with the determining contribution to its implementation made by JINR. The Scientific Council noted with satisfaction that with an active participation of LPP physicists a new result, having a fundamental meaning for the development of particle physics, had been obtained in the NA48 experiment at CERN: the parameter of direct CP-violation was measured in the neutral kaon decays with high precision $\mathrm{Re}(\varepsilon'/\varepsilon) = (14.0 \pm 4.3) \cdot 10^{-4}$.

The Scientific Council supported the recommendation of the PAC for Particle Physics to extend first-priority themes for a term of not more than three years, considering this practice expedient from the point of view of the improvement of the scientific research planning at JINR.

Nuclear physics issues. The Scientific Council appreciated the progress of the DRIBs project, specifically the successful completion of R&D for Phase 1 of the project. In view of the fast progress of the upcoming ISOL facilities, the Scientific Council counts that Phase 1 of the DRIBs project should come into operation as soon as possible and, therefore, be financed with highest priority, according to the schedule appointed by the Scientific Council.

The Scientific Council noted with satisfaction that some success in the development of the IREN project had been achieved due to the financing efforts of the Directorate. Also, satisfactory results of testing the accelerator system LUE-200 had been obtained.

The Scientific Council stressed again the necessity of a sufficient funding of the project, appropriate to its timely implementation, following the schedule approved by the Scientific Council at its 87th session and by the JINR Directorate.

The Scientific Council appreciated the DLNP efforts to unite activities in order to optimize the support of the Phasotron improvement and instrumentation for the research programme at DLNP, and encouraged further steps in that direction.

Condensed matter physics issues. The Scientific Council supported the JINR and FLNP Directorates in the activity for the refurbishment programme of the IBR-2 reactor and was satisfied with the agreement between JINR and the Russian Ministry for Atomic Energy on the financing of the IBR-2 reactor refurbishment.

The Scientific Council strongly supported the first part of the instrumentation programme on the new cold source of the IBR-2 reactor, as recommended by the PAC for Condensed Matter Physics. In order to fulfil this programme, a cryogenic liquefier is mandatory and multidetectors as well as neutron guides have to be developed. The Scientific Council supported mutual efforts of the FLNP and JINR Directorates to satisfy these requests.

Upon proposal by the JINR Directorate, the Scientific Council re-appointed the following Chairpersons of the PACs for a term of one year:

- Ch.Briançon — PAC for Nuclear Physics,
- S.Dubnička — PAC for Particle Physics,
- H.Lauter — PAC for Condensed Matter Physics.

Upon proposal by the JINR Directorate, the Scientific Council appointed the following new members of the PACs:

PAC for Nuclear Physics —

- H.Börner (ILL, Grenoble, France),
- N.Rowley (IReS, Strasbourg, France);

PAC for Particle Physics —

- H.Gutbrod (Subatech, Nantes, France);

PAC for Condensed Matter Physics —

- D.Nagy (KFKI, Budapest, Hungary).

Concerning the report of the Editor-in-Chief of the journal «Physics of Elementary Particles and Atomic Nuclei» A.Baldin, presented by P.Isaev, the Scientific Council noted:

For thirty years the Editorial Board of the journal «Physics of Elementary Particles and Atomic Nuclei» has been maintaining a high quality of Russian and English publications, their scientific claim and importance, and appropriate selection of authors of highest qualification from both the JINR Member States and many leading centres worldwide.

The transformation of the journal «JINR Rapid Communications» into «Physics of Particles and Nuclei, Letters» will contribute to the coordination of the activities of both Editorial Boards in developing JINR's scientific policy.

The Scientific Council recommended the journals «Physics of Elementary Particles and Atomic Nuclei» and «Physics of Particles and Nuclei, Letters» to be included into the Science Citation Index (Institute of Scientific Information, USA) list.

The Scientific Council expressed its gratitude to all the members of the Editorial Board for their fruitful work in publishing the journal «Physics of Elementary Particles and Atomic Nuclei».

The Scientific Council elected by ballot:

- I.Puzynin as Director of the Laboratory of Information Technologies (LIT),
- V.Ivanov, V.Korenkov and A.Polanski as Deputy Directors of LIT

for a term not later than January 2003.

According to the Regulation in force, the Scientific Council announced the following vacancies: Deputy Director of the Bogoliubov Laboratory of Theoretical Physics, Deputy Director of the Laboratory of Particle Physics.

The Scientific Council followed with interest the reports presented at the seminar to mark the 40th anniversary of JINR's research using pulsed reactors. The Scientific Council was pleased to note that, since the commissioning of the first research reactor in 1960 under the guidance of Professor D.Blokhintsev, JINR had accomplished an impressive programme of neutron-aided research and had acquired a leading position in this field. The Scientific Council congratulated the staff of the Frank Laboratory of Neutron Physics on this occasion and wished it further successful activity. Equipped today with the IBR-2 reactor, a powerful source of neutrons with unique parameters, JINR has all the prerequisites for preserving and developing in future its scientific traditions in nuclear physics with neutrons and condensed matter physics.

MEETINGS OF THE JINR FINANCE COMMITTEE

A regular meeting of the JINR Finance Committee was held in Dubna on 17–18 February 2000. It was chaired by J.Kolin (Czech Republic).

The Finance Committee heard the report «On Implementation of the Recommendations of the JINR Scientific Council and CP Concerning the Reform Programme of JINR; Results of 1999 and Plans for 2000–2002» presented by JINR Director V.G.Kadyshevsky. The Committee approved JINR's activities within the reform programme in the areas of basic facilities, infrastructure, personnel policy, also in the centralized management of financing JINR research projects. It gave high appreciation of the actions undertaken by the Directorate in 1999 to secure salary increases for the staff. The Finance Committee considers that the adoption of the Federal Law on the Agreement between the Government of the Russian Federation and JINR will play a positive role in the future development of the Joint Institute as an international research centre.

The Committee approved JINR's activity on implementation of the research and international collaboration plan in 1999, which resulted in appreciable contributions to world science.

Based on the information given by A.S.Kurilin, the Finance Committee approved the work of the Control Commission, which met on 25 June 1999, and recommended that the Committee of Plenipotentiaries (CP) approve the report on the implementation of the JINR budget in 1999. Note was taken of the report presented by the JINR Directorate on implementing the Finance Committee's decisions of 25–26 February 1999 and the Control Commission's recommendations of 25 June 1999.

A report on the implementation of the JINR budget in 1999, on the draft budget for 2000, and on the budget estimates for 2000 was presented by JINR Assistant Director for Economic and Financial Issues V.V.Katrasev. The Finance Committee recommended that the CP

- take note of the information on the implementation of the JINR budget in 1999;
- approve the JINR budget for 2000 with the total expenditure US$37.5 million;
- approve the main part of the Member States' contributions for 2000 to be proportional to the UN scale and approve the contribution scale for 2000;
- fix the 2001 budget estimate amounting to US$37.5 million, which may be corrected for inflation and US$/rouble exchange rate fluctuations, and due to developing a new method to define contributions;
- prolong the sanctions, as stipulated in paragraph 5, section IV, CP Minutes of 12–13 March 1998, against those Member States whose debts exceed the sum of contributions for two years;
- agree with the participation of JINR as a founder of the non-commercial organization «Applied Research Support Fund» and with the financial contribution of US$2.5 thousand from non-budgetary sources, provided the CP is presented with the Fund's constituent documents.

Based on the information given by JINR Vice-Director A.N.Sissakian, the Finance Committee recommended that the Committee of Plenipotentiaries support the activity on restructuring in 1999 the debts of JINR Member States to the JINR budget and charge the Directorate to complete in 2000 the agreement with the governments of the JINR Member States of the terms and procedure for restructuring the debts.

The Finance Committee also recommended that the CP approve the list of first priority activities to realize «The Agreement between the Government of the Russian Federation and the Joint Institute for Nuclear Research on the Location and Terms of Activity of JINR in Russia» and to improve the normative and legal procedures of JINR.

An extraordinary meeting of the JINR Finance Committee was held in Dubna on 19 October 2000. It was chaired by Professor N.M.Shumeiko (Belarus).

The Finance Committee heard the report «On Implementation of the JINR Topical Plan of Research for 2000» presented by JINR Director V.G.Kadyshevsky and endorsed JINR's activity on implementation of the Topical Plan of Research during nine months of 2000.

Based on the report «On Improvement of the Technique for Determining Contributions to the JINR Budget and the Choice of a New Contribution Calculation Technique» by V.G.Drozhenko (Russian Federation), the Finance Committee recommended that the Committee of Plenipotentiaries (CP) approve the technique proposed by the CP Working Group at its session on 7 June 2000 for calculation of contributions to the 2001 JINR budget and approve the use of the average scale for 1998–2000 for calculating the contributions in proportion to the UN scale.

Based on the report given by Professor S.Dubnička (Slovak Republic), the Finance Committee approved the results of the work of the Control Commission, which met on 9 June 2000, and recommended that the CP approve the JINR report on the budget expenditure of US$14,556,300 in 1999 with the total final balance of US$79,052,000 as of 1 January 2000.

The Finance Committee took note of the information on implementation of the JINR budget during nine months of 2000 and on budget estimates for 2001 presented by JINR Assistant Director for Financial and Economic Issues V.V.Katrasev.

The JINR Directorate was charged to send the draft budget for 2001 worked out with allowance for decisions of the present meeting of the Finance Committee to the Member States by 1 January 2001.

MEETINGS OF THE JINR PROGRAMME ADVISORY COMMITTEES

The 13th meeting of the Programme Advisory Committee for Particle Physics, 7–8 April 2000. Chairperson: Prof. S.Dubnička.

The PAC for Particle Physics was informed by its Chairperson about the implementation of the previous session's recommendations. The PAC took note of the information presented by Vice-Director A.N.Sissakian on the recommendations of the 87th session of the JINR Scientific Council (January 2000) and the decisions of the Committee of Plenipotentiaries (March 2000). The PAC was pleased to learn that the hard work of the JINR Directorate concerning «The Agreement between the Government of the Russian Federation and JINR on the Location and Terms of Activity of JINR in the Russian Federation» had culminated in the ratification of this Agreement. The corresponding Federal Law of the Russian Federation came into force on 6 January 2000. It was mentioned that the Agreement between JINR and the Government of the Russian Federation is of great importance for the further development of JINR and strengthening of its status as an international centre for physics research.

As a major accomplishment of the Laboratory of High Energies, the PAC mentioned the slow beam extraction from the Nuclotron to the experimental hall. The PAC congratulated the Directorates of JINR and LHE as well as the staff of the Laboratory of High Energies on the successful accomplishment of this important milestone, as well as on the first physical results obtained with the extracted beam.

The PAC noted with satisfaction the fruitful cooperation between JINR and research centres in Germany in the field of particle physics in the framework of the Agreement between JINR and BMBF.

The PAC congratulated the JINR and DLNP Directorates and the whole staff of the Institute on the occasion of the 50th anniversary of the commissioning of the Dubna Synchrocyclotron. It was noted that launching of this accelerator had started an intensive programme of high-energy physics research in Russia and the other JINR Member States.

The PAC followed with interest the report by A.I.Malakhov reviewing the impressive programme of the research planned for the extracted beam of the Nuclotron facility. The PAC recommended proceeding with the approved first experiments with the Nuclotron extracted beam, including the projects DISK, SPHERE, MARUSYA, GIBS, FAZA, DELTA, DELTA-SIGMA, SMS, and MRS. The PAC invited the authors of the STRELA and SCAN-2 experiments to present a proposal detailing the plan of research at the next PAC meeting.

The PAC took note of the report by I.N.Meshkov on the operation of the JINR basic facilities in the first quarter of 2000 and noted with satisfaction that, as a result of the programme of reforms and modernization instituted by the JINR Directorate, the operation of all the JINR basic facilities within the stated period had met or exceeded expectations. The PAC has recommended that manpower and resources continue to be devoted to modernizing and establishing extended stable operation of the JINR basic facilities, concentrating the resources on the most urgent activities.

The PAC recommended approval of the project «Study of Hadron Structure at the HERMES Spectrometer (Continuation of Experiment)» with first priority up to the end of 2003.

The PAC noted the importance of JINR's participation in HERMES, which is a very interesting experiment studying hadron spin structure using both a polarized lepton beam and a pure gas polarized target.

The PAC recommended opening a new theme in the JINR Topical Plan and approval of Phase I of the proposal «Hadron Production Studies for the Neutrino Factory and for the Atmospheric Neutrino Flux (HARP, PS 214)».

The PAC noted with interest the report on the DIRAC experiment and appreciated the considerable progress made in this forefront experiment. The PAC noted the importance of the experiment in a world view in exploring the nature of chiral symmetry breaking, and was pleased to note the leading role played by JINR in the organization and realization of this experiment.

The PAC made recommendations on experiments approved for completion in 2000:

— on JINR's participation in the NOMAD experiment, the PAC recommended continuing this work in 2001 with first priority;
— on JINR's participation in the NA48 project, the PAC noted with satisfaction that a new result having a fundamental meaning for the development of particle physics had been obtained in the NA48 experiment at CERN with active participation of LPP physicists: the parameter of direct CP-violation was measured in the neutral kaon decays with high precision. The PAC recommended extension of this activity with first priority up to the end of 2003;
— the PAC recommended extension of JINR's participation in the H1 experiment with first priority up to the end of 2003;
— the PAC recommended extension of the EXCHARM experiment with first priority up to the end of 2003;
— the PAC recommended continuing the GAMMA-2 experiment with second priority up to the end of 2003;
— the PAC recommended extension of the WASA project with second priority up to the end of 2002;
— the PAC recommended continued support for developing the polarized target and associated equipment for the DELTA-SIGMA experiment;
— the PAC recommended that at its next session the participants of the COMPASS experiment present the status of this joint project taking into account the commitments from the LPP and DLNP groups for the experiment.

As a general remark the PAC recommended that the JINR Directorate extend first-priority themes for a term of no longer than three years, considering such a practice expedient from the point of view of improved planning of scientific research at JINR.

The PAC thanked V.P.Ladygin for his report «Investigation of the Short-Range ^{3}He Spin Structure in the $dd \rightarrow {}^3\mathrm{He}n$ Reaction at RIKEN».

The PAC expressed its gratitude to Professor S.Dubnička for his valuable work as Chairperson of the PAC for Particle Physics, and recommended that the JINR Scientific Council appoint him as Chairperson of the PAC for one more year.

The PAC expressed its gratitude to Professor J.-E.Augustin for his fruitful activity and many contributions to the work of the PAC.

The PAC recommended that the JINR Scientific Council appoint Professor T.Gutbrod as a member of the PAC for Particle Physics.

The 12th meeting of the Programme Advisory Committee for Nuclear Physics, 10–11 April 2000. Chairperson: Prof. Ch.Briançon.

The PAC was informed about the recommendations of the previous PAC meeting and about their implementation, also about the Resolution of the 87th session of the JINR Scientific Council (January 2000) and the decisions of the Committee of Plenipotentiaries (March 2000). The PAC was pleased to learn about the ratification of the «Agreement between the Government of the Russian Federation and JINR on the Location and Terms of Activity of JINR in the Russian Federation» as a Federal Law of the Russian Federation.

The PAC noted with satisfaction that the Scientific Council had concurred with its recommendations and especially appreciated its support for the completion of both IREN and DRIBs projects in 2002. From the report by JINR Chief Engineer I.N.Meshkov the PAC learned that the JINR basic facilities performed well in 1999.

Heavy-ion physics. The PAC appreciated the progress of the DRIBs project and recommended that Phase I of the DRIBs project should come into operation as soon as possible and therefore be properly financed.

The PAC was pleased to learn about the production of the third isotope of element 114 and recommended supporting the upgrade of VASSILISSA to allow the synthesis of element 116. The programme on fission, and the studies of light exotic nuclei at ACCULINNA and COMBAS should continue with high priority.

The PAC also recommended extension of the theme «Synthesis of New Nuclei and Study of Nuclear Properties and Heavy-Ion Reaction Mechanisms» for three years. In order to provide the basis for the successful research programme, the PAC also recommended extension of the theme «Development of the FLNR Cyclotron Complex for Producing Intense Beams of Accelerated Ions of Stable and Radioactive Isotopes».

Nuclear physics with neutrons. The PAC learned with satisfaction that some success in the development of the IREN project had been achieved. Particularly, satisfactory results of testing the accelerator system for the linac LUE-200 have been obtained. The PAC heard a plan for the implementation of the IREN project in the framework of the new schedule up to 2002 and strongly recommended the sufficient funding of the project appropriate to its timely implementation.

The PAC heard with satisfaction the report on the expiring theme «Investigation of the Fundamental Properties of Neutron and Nucleus». It welcomed the results achieved in different activities in the framework of this theme. The PAC supported the opening of a new theme entitled «Nuclear Physics with Neutrons» for the next five years.

Nuclear theory. The PAC recognized the high scientific level of the research performed at BLTP on the theme «Theory of Nuclei and Other Finite Systems» and appreciated the fruitful cooperation of the Laboratory with experimental groups of other JINR laboratories, as well as extensive international cooperations. The PAC strongly recommended an increase of the computing power and infrastructure at BLTP.

Low- and intermediate-energy physics. The PAC heard the report by DLNP Director N.A.Russakovich on the perspectives of this Laboratory in the near future and endorsed the following proposals: to open for the next four years a new theme replacing the expiring one, 05-2-0986-92/2000, under the title «Investigation of Fundamental Interactions at Low Energies»; to open for the same period a new theme replacing the expiring one, 05-2-0987-92/2000, under the title «Nucleus and Particle Interaction at Intermediate Energies»; to terminate theme 05-2-0918-91/2000.

The PAC confirmed its high appreciation of the activities performed within the expiring themes 05-2-0933-91/2000, 05-2-1023-97/2000, 08-2-0980-92/2000 and supported DNLP's effort to unite these activities under one new theme. The PAC appreciated in particular the radiotherapy programme and looks forward to receiving a documented report on it at its next meeting.

The PAC noted the high quality of investigations of weak and electromagnetic interactions at low energies performed in the AnCor, TGV, NEMO, LESI, and YASNAPP-2 experiments, recommending their support and looking forward to learning in more detail about the follow-up of these experiments.

The PAC also heard a presentation on the research theme «Investigations of Symmetries and Dynamics of Lepton, Hadron and Nucleus Interactions at Intermediate Energies» and noted the successful achievement of the experiments OBELIX, Muonium conversion and MESON, as well as the progress of the ANKE (COSY), PIBETA, DUBTO, μ-catalysis and MUON experiments.

JINR networking and computing. The PAC recognized LIT's activities on modernization and extension of computing systems and network structure but noted that the electronic connection abroad is not yet adequate for an international research institute. The PAC recommended supporting these activities with a proper status and financing mode of this JINR basic facility.

The PAC appreciated the activities related to the mathematical and computational support of both the theoretical and the experimental research at JINR as well as investigations on the problems of computational physics itself.

Scientific reports. The PAC heard two reportes devoted to the experimental and theoretical investigations of both neutron-induced fission and fission process in the fusion of heavy and superheavy nuclei.

Sandanski-2 meeting. The PAC took note of the information on preparation of the 2nd Coordination Meeting on Nuclear Physics in October 2000 in the town of Sandanski (Bulgaria).

The PAC warmly congratulated Professors G.Münzenberg and H.Oeschler on their being awarded the title «Honorary Doctor of JINR».

The 12th meeting of the Programme Advisory Committee for Condensed Matter Physics, 14–15 April 2000. Chairperson: Dr H.Lauter.

The PAC took note of the information about the recommendations of the 87th session of the JINR Scientific Council and on the decisions of the JINR Committee of Plenipotentiaries presented by JINR Chief Scientific Secretary V.M.Zhabitsky.

The PAC congratulated the JINR Directorate on the ratification of the «Agreement between the Government of the Russian Federation and JINR on the Location and Terms of Activity of JINR in the Russian Federation».

The PAC took note of the information on the JINR basic facilities and IBR-2 refurbishment status presented by JINR Chief Engineer I.N.Meshkov. The PAC supported the JINR and FLNP Directorates in the activity for the refurbishment programme and was satisfied with the signing of the Agreement between JINR and the Russian Ministry for Atomic Energy on the financing of the IBR-2 reactor refurbishment. According to this Agreement, the participation of the Atomic Ministry is defined.

The PAC appreciated the presentations by A.M.Balagurov and V.I.Gordely, showing the excellent performance of the new solid methane moderator through the scattering spectra obtained at the HRFD and YuMO spectrometers. The PAC took note that a helium liquefier was urgently needed for a full operation of the cryogenic moderator.

Concerning the development programme of spectrometers at the IBR-2 reactor presented by FLNP Director V.L.Aksenov, the PAC strongly recommended starting this programme with three spectrometers on the new cold moderator: a small-angle scattering spectrometer, a reflectometer and a quasi-elastic spectrometer. The PAC also recommended to formulate the request for a JINR Directorate grant for the development programme with a special view on these three spectrometers.

The PAC considered proposals for the extension of research activities and recommended that the following themes be extended:

— 07-4-1012-96/2000 for the period of three years to complete the existing projects on spectrometer development at the IBR-2 reactor with the same priority;
— «Radiation Effects and Modification of Materials, Radioanalitical and Radioisotope Investigations at the FLNP Accelerators» for the period of three years with first priority;
— «Radiation and Radiobiological Investigations at the JINR Basic Facilities and Environment» for 2001–2003 with the same priority.

Following the report presented by G.V.Mitsin, the PAC recommended opening a new theme «Radiotherapy, PET and DNA Diagnostics with JINR Hadron Beams» with second priority from 2001 to 2003.

The PAC appreciated very much the scientific reports «Mesoscopics in Superfluidity and in Bose–Einstein Condensate» presented by V.S.Yarunin and «Radioecological and Radioisotope Investigations at the MT-25 Microtron» presented by O.D.Maslov.

The PAC congratulated the organizers of the School on Modern Neutron Scattering held in Dubna on 7 February – 4 March 2000 and recommended that such schools be organized regularly for students and young scientists.

The PAC expressed its gratitude to Professors L.Czer and V.G.Petin for their fruitful activities as members of this PAC.

The 13th meeting of the PAC for Condensed Matter Physics, 10–11 November 2000. Chairperson: Dr H.Lauter.

The PAC took note of the information on the recommendations of the 88th session of the JINR Scientific Council (June 2000) presented by JINR Chief Scientific Secretary V.M.Zhabitsky. The PAC supported the announcement of the JINR Directorate, contained in this report, to preserve at FLNP the research activities in nuclear physics with neutrons and in condensed matter physics and welcomed the extension of condensed matter studies to «various physics methods».

The PAC took note that the IBR-2 refurbishment programme is presently entering its decisive stage and in connection with this underlined the importance of the agreement about nearly equal contributions from the Russian Ministry of Atomic Energy and JINR for the financial support of the IBR-2 refurbishment. The PAC recommended that the JINR Directorate make a special decision to carry out its support obligations for the IBR-2 refurbishment with highest priority for the year 2001. The PAC urged the JINR Directorate to finance fully its grant for IBR-2. The PAC recommended that the JINR Directorate encourage financially the staff involved in the refurbishment project activities and recognized the need to actively recruit additional staff for the IBR-2 operation and refurbishment. The PAC was very much impressed by the careful planning of the reactor refurbishment, as presented by V.D.Ananiev.

The PAC announced the new title for theme 08-2-0980-92/2000 to be «Further Development of Methods and Instrumentation for Radiotherapy and Associated Diagnostics with JINR Hadron Beams» and noted that the formulation of the strategy of «life science» at JINR would be presented at the next PAC meeting.

The PAC made the following recommendations to the FLNP Directorate:
— In the framework of the development programme of spectrometers at the IBR-2 reactor, at the next meeting the sector leaders will present an overview of scientific prospects of the ongoing activity, in connection with the new proposals, also in view of the accomplishment of existing projects.
— The PAC appreciated the initiative for detector development, including new detector technology and production of new neutron guides.
— The PAC recommended starting the development of the following spectrometers on the cold source: a small-angle spectrometer, a reflectometer and a quasi-elastic spectrometer.

The PAC underlined that the refurbishment of the reactor, the cold source modernization and the instrumentation development on the cold source are one complex of tasks and need a simultaneous advancing.

The PAC appreciated the status report on the SANS spectrometer by A.I.Kuklin. Concerning the status report on FSD spectrometers by E.S.Kuzmin, the PAC supported the idea of the completion of the detector system using new technology. The PAC thanked M.A.Smondyrev and M.M.Komochkov for their reports at this meeting.

The PAC strongly supports the collaboration with ESS and encourages its expansion.

The recently celebrated 40th anniversary of the research at pulsed reactors was an important event. The PAC also wishes to mark this occasion at its next meeting by a lecture «Neutron Methods of Potential Interest to Industry».

The 14th meeting of the Programme Advisory Committee for Particle Physics, 16–18 November 2000. Chairperson: Prof. S.Dubnička.

The PAC for Particle Physics took note of the information presented by JINR Vice-Director A.N.Sissakian on the preparation of the JINR Scientific Programme for the years 2001–2003 and on recommendations of the 88th session of the JINR Scientific Council (8–9 June 2000).

The PAC took note of the reports presented by V.N.Penev, Deputy Director of the Laboratory of High Energies, D.I.Kazakov, Deputy Director of the Bogoliubov Laboratory of Theoretical Physics, V.D.Kekelidze, Director of the Laboratory of Particle Physics, N.A.Russakovich, Director of the Dzhelepov Laboratory of Nuclear Problems, and by I.V.Puzynin, Director of the Laboratory of Information Technologies, and endorsed the main directions of the JINR Programme of Particle and

Relativistic Nuclear Physics Research proposed by them for the period 2001–2003. The PAC noted that there are a number of high-energy and nuclear physics research interests at JINR, which transcend traditional Laboratory boundaries, and encouraged strong collaboration of groups working in similar areas in different Laboratories to promote the best possible intellectual environment at JINR.

The PAC took note of the report presented by JINR Chief Engineer I.N.Meshkov on the operation of the JINR basic facilities in 2000 and noted with satisfaction that the operation of all the JINR basic facilities had met or exceeded expectations despite continued problems with funding. The PAC also strongly supported the LHE efforts towards the establishment of the Nuclotron as a «user friendly» facility which is operating routinely. The PAC noted the need for improved coordination of all experiments utilizing polarized beams and targets to make optimal use of the Nuclotron.

The PAC highly appreciated the progress of the JINR Educational Programme and noted that the activities carried out by the JINR Directorate and the University Centre in collaboration with the Institute's Laboratories are extremely useful and productive.

The PAC reviewed a number of the new proposals: «Investigation of Charge-Exchange Processes in Deuteron-Proton Collisions» (STRELA), «Measurements of the Energy Behaviour of Spin-Dependent Differences of the JINR LHE L/T Polarized *n* Beams and *p* Target» (DELTA-SIGMA), «Hadron Production Studies for the Neutrino Factory and for the Atmospheric Neutrino Flux» (HARP, PS 214) (JINR's participation), «Measurement of Spin-Spin Correlation in Elastic *pp*-Scattering near 90°» (*PP*-singlet), and recommended approval of these experiments for execution with first priority until the end of 2003.

The PAC reviewed the proposal «Light Nuclei Structure Investigation at JINR LHE and at RIKEN (Japan)» (LNS). It recognized the physics interest of the proposed measurements but considered that the set-up proposed for the Nuclotron experiments was suboptimal to achieve its goals with adequate accuracy and a reasonable amount of beam time. The Committee encouraged the authors to present a revised experimental plan at the next meeting of the PAC. The PAC noted the report «Computer Physics for Theoretical and Experimental Studies», made several remarks and required further elaboration of the plan of this activity before making a decision on the proposed theme. The PAC took note of the information on the preparation of the SCAN-2 project and invited the authors to present a proposal at the next PAC meeting. The PAC highly appreciated the activity on the COMPASS experiment and recommended that the JINR Directorate and the Laboratories involved in the experiment approve this activity for 2001–2003, giving it first priority for this period, and sufficient funding to meet existing JINR commitments.

The PAC decided that in future it would appoint one or two referees for each of the most important and long-duration experimental programmes. These experts will follow the development of the activities, examine the resource requirements, and periodically report to the PAC.

The PAC took note of the reports «Particle Accelerator Physics and Engineering», «Organization, Maintenance, and Development of the University-Type Educational Process at JINR», BES project, MRS project, and recommended extension of these activities with first priority until the end of 2003. JINR's participation in the BOREXINO experiment was recommended to be extended with second priority also until the end of 2003. The PAC took note of the reports on the projects PPT and SPIN and recommended that the JINR Directorate close these activities.

The PAC considered written reports on the following second-priority activities: «*NN*-scattering» (experiment in Prague), «Development of Accelerators for Radiation Technologies» and recommended continuation of these activities in 2001 with second priority, provided they are financed from non-budgetary sources. Concerning the second-priority project «Neutrino Detector», the PAC recommended that the JINR Directorate extend this activity to the end of 2001 with the same priority and that the authors of the project present a report at the next meeting on the main physics results obtained with this unique set-up.

The PAC took note of the information «About JINR's Participation in the Investigations of the Decay $K_L^0 \to \pi^0 \nu\tilde{\nu}$, under Project E391a at KEK-PS» and recommended presenting this proposal as a separate project.

The PAC followed with interest the report «Recent Results of the Higgs Boson Search at LEP» presented by A.G.Olshevsky. Concerning the information presented by N.Giokaris on the successful start of the modernized CDF-detector, the PAC noted that JINR had significantly contributed to the 1996–2000 CDF upgrading and successful completion of the November 2000 technical run.

The 13th meeting of the Programme Advisory Committee for Nuclear Physics, 20–22 November 2000. Chairperson: Prof. Ch.Briançon.

The PAC was informed about the recommendations of the previous PAC meeting and about their implementation, also about the Resolution of the 88th session of the JINR Scientific Council (June 2000).

The PAC congratulated FLNR on the synthesis of the new nuclide with $Z = 116$ and $A = 292$ nuclei and was delighted about the awarding of the first Lise Meitner Prize to Yu.Ts.Oganessian, G.Münzenberg and P.Armbruster for their contribution to the discovery of superheavy elements.

The PAC highly appreciated the efforts of the JINR Directorate to secure to the best of their possibilities the

funding for the IREN and DRIBs projects in 2000. For the former project, this is essential to maintain an internationally recognized neutron nuclear physics programme at JINR, and for the latter, it will allow the timely start of a world-class facility for radioactive ion beams.

The PAC applauded the decision of the JINR Directorate to preserve FLNP as one of the main structure units of the Institute. The PAC considers moreover the establishment of a new accelerator division issued from LPP and FLNP, with the specific aim to construct the Linac LUE-200, to be decisive for the realization of the IREN project.

The PAC highly appreciated the progress achieved in the JINR Educational Programme over a relatively short period and with a rather modest budget.

Nuclear physics with neutrons. The PAC agreed with the decision of the JINR Directorate to complete the construction of IREN by 2002 and noted that it was important to have this facility achieved by the end of 2002 to deliver beams allowing resumption of the neutron physics programme after the outphasing of the IBR-30 reactor. This implies, among others, the availability by 2002 of at least two klystrons for the Linac LUE-200. This schedule should be respected to preserve the leading role of FLNP in this field.

The PAC approved the proposed research programme. The activities in nuclear physics at FLNP will be mainly oriented towards the development and construction of new instruments for research at the IREN neutron source under construction. These projects will be completed and in the year 2003 experiments with IREN beam are expected to start.

The PAC recommended the closure of theme 06-4-0974-92/2000 and the opening of the new first-priority theme «Nuclear Physics with Neutrons — Fundamental and Applied Studies» for the period 2001–2004. The PAC endorsed the programme of environmental investigations for the project REGATA and proposed to the JINR Directorate to plan a financial support to this activity.

Heavy-ion physics. The PAC was impressed with the fast realization of the DRIBs project and recommended that the first stage of the project, production of the light radioactive ion beams, should be realized in 2001, and the second stage, acceleration of fission fragments, in 2002. The PAC noted the results of the first investigations of superheavy compound nuclei fission using beams of ^{48}Ca, ^{58}Fe and ^{86}Kr and endorsed the programmes on the synthesis of superheavy nuclei, in particular on the synthesis of elements 112, 114, 116, to be carried out with VASSILISSA and the Gas-Filled Recoil Separator, and on the structure of light exotic nuclei and supported the programme to determine chemical properties of SHE. The PAC appreciated the satisfactory running of the FLNR cyclotrons in 2000.

The PAC discussed the investigations performed within the projects of the theme «Synthesis of New Nuclei and Study of Nuclear Properties and Heavy-Ion Reaction Mechanisms» and the related theme «Development of the FLNR Cyclotron Complex for Producing Intensive Beams of Accelerated Ions of Stable and Radioactive Isotopes» and recommended the extension of the activities of these first-priority themes for the three years of 2001–2003.

Low- and intermediate-energy physics. Having discussed extensively the entire research programme of DLNP at its 12th meeting, the PAC concentrated, this time, on the report on the perspectives of the Phasotron and on the addendum to the Familon proposal, presented according to recommendations of the 12th meeting.

The PAC took note of the Phasotron running performance in 2000 of 1060 hrs of beam time devoted to nuclear physics related topics and welcomed the beam-line upgrading programme, which would improve significantly the secondary beam quality by the end of 2001. The PAC looks forward to receiving in due time a detailed proposal for the H^--injector and intense extracted proton beam-line projects.

After the discussion of the addendum to the Familon project including the results of corresponding calculations the PAC recommended the allocation of the beam time requested for the first part of the experiment (70 hrs for tests and about 240 hrs for data-taking). Recommendations concerning a second part, with TPC, will require the corresponding additional Monte-Carlo simulations. The Familon beam time should be well identified and included within the allocation of the MUON project.

The PAC recommended the closure of the following research themes: 05-2-0986-92/2000, 05-2-0987-92/2000, 05-2-0918-91/2000, 05-2-1023-97/2000 and 05-2-0933-91/2000. It also recommended the opening of the following new first-priority themes for the years 2001–2003: «Investigation of Fundamental Interactions in Nuclei at Low Energies», «Nucleus and Particle Interactions at Intermediate Energies», «Improvement and Development of the JINR Phasotron for Fundamental and Applied Research».

Research programme of BLTP. The PAC learned with satisfaction about some details of recent research performed at BLTP in the field «Theory of Nuclei and Other Finite Systems» and approved the outline of the research programme for the years 2001–2003. It especially supported the cooperation of BLTP with experimental groups and theoretical teams at JINR and abroad.

Laboratory of Information Technologies. The PAC noted that the restructuring of the former LCTA is a good step and that the programme and structure of the new LIT should be similar to those in computer divisions of other large world institutes. There are clearly two types of activities whereby LIT provides support to JINR Laboratories. The activity in computational physics is largely appreciated. On the other hand, there are clearly serious problems with service activities. The PAC members are convinced that the most important task of LIT should be

service to JINR Laboratories. In particular, the improvement of outside network connections with cooperating countries and laboratories should be of first priority. A detailed proposal for improving the network along with its appropriate schedule and funding requirements is urgently needed. In order to monitor the situation, regular contacts between LIT and JINR Laboratories should be established and maintained. The PAC looks forward to a report on this issue at its next meeting. The PAC proposed to close the theme «Nonlinear Problems of Computational and Mathematical Physics: Software, Algorithms, and Investigations».

Educational programme of JINR. The PAC appreciated the successful implementation of the educational programme in the framework of the theme «Organization, Maintenance and Development of the University-Type Educational Process at JINR» (10-0-1026-98/2000), aimed at the professional training of students and young researchers from JINR and its Member States. The PAC encouraged further developments of this programme, in particular to intensify the in-job training at JINR in specialized fields, and recommended that the JINR Directorate increase the financial support of this programme. Further exchanges of teachers and students with European countries are also encouraged. The PAC recommended the extension of the first-priority theme 10-0-1026-98/2000 for three years until 2003.

Scientific reports. The PAC heard with great interest the scientific reports delivered at the meeting. In the first one, new results on the theory of the Λ-hyperon ${}^{7}_{\Lambda}\mathrm{He}$ nucleus, including predictions of its low-energy excitation states, were presented. The second one was devoted to new experimental results due to the up-scattering effect of ultra-cold neutrons (UCN) in traps. The PAC highly appreciated the obtained results.

Sandanski-2 meeting. The PAC was informed about the decision of the EPS Nuclear Physics Board to organize, together with JINR and the Institute for Nuclear Research and Nuclear Energy (Sofia), an East-West Collaboration Meeting on Nuclear Physics. The meeting will take place in the town of Sandanski (Bulgaria) from 5–9 May 2001. The PAC looks forward to the outcome of the meeting and will take into account its conclusions in future recommendations on the JINR international programme.

PRIZES AND GRANTS

The 2000 State Prize of the Russian Federation in the field of science and technology was awarded to V.L.Aksenov, Doctor of Sciences (Phys. and Math.), Director of the JINR Frank Laboratory of Neutron Physics (FLNP), A.M.Balagurov, Doctor of Sciences (Phys. and Math.), Head of Sector of FLNP, V.V.Nitz, Senior Researcher of FLNP, and to Y.M.Ostanevich, Doctor of Sciences (Phys. and Math.) (posthumously), for the development and realization of new methods in structural neutron diffraction studies by the time-of-flight method using pulsed and stationary reactors.

The 2000 B.Pontecorvo Prize was awarded to Academician G.T.Zatsepin and Dr V.N.Gavrin (INR, Moscow) for their outstanding contribution to the solar neutrino studies by the gallium-germanium method at the Baksan Neutrino Observatory.

The international A. von Humbolt Prize was awarded to Professor S.M.Bilenky (Bogoliubov Laboratory of Theoretical Physics) for his important contribution to the advancement of science and education and to the development of scientific cooperation.

The L.Meitner Prize for Nuclear Science of the European Physical Society was awarded to the Scientific Leader of the JINR Flerov Laboratory of Nuclear Reactions Yu.Ts.Oganessian, Corresponding Member of the Russian Academy of Sciences, in recognition of the unique and long-standing work on the synthesis of heavy elements, which has led to the discovery of elements with $Z = 105–109$.

PRIZEWINNERS OF JINR'S ANNUAL COMPETITION FOR BEST RESEARCH – 2000

Theoretical Physics Research

First Prizes

«Analytic Approach in Quantum Chromodynamics».
Authors: D.V.Shirkov, I.L.Solovtsov.

«Theoretical Support of Experiments at the Z Resonance on Precision Tests of the Standard Model (Project ZFITTER)».
Authors: D.Yu.Bardin, M.S.Bilenky, P.Christova, M.Jack, L.V.Kalinovskaya, A.G.Olshevski, S.Riemann, T.Riemann.

Experimental Physics Research

First Prizes

«Investigation of the Reactions Between Light Nuclei in the Range of Ultra-Low Energies Using Liner Plasma».
Authors: V.M.Bystritsky, V.M.Grebenyuk, S.S.Parzhitski, F.M.Penkov, V.A.Stolupin, G.A.Mesyats, V.M.Bystritskii, M.Filipowicz, J.Wozniak, N.A.Ratakhin.

«Discovery of the Dicke Superradiation of Nuclear Spins».
Authors: Yu.F.Kiselyov, V.I.Yukalov, V.K.Henner.

Second Prize

«Study of Spin Effects in Strange Particle Production and Decays».
Authors: A.I.Zinchenko, I.M.Ivanchenko, V.D.Kekelidze, D.T.Madigojin, Yu.K.Potrebenikov, G.T.Tatishvili, A.L.Tkatchev, P.Z.Hristov.

Encouraging Prizes

«Neutron Diffraction Study of the Atomic Structure and Physical Properties of High-T_c Mercury-Based Superconductors as a Function of Anion Composition and External Pressure».

Authors: V.L.Aksenov, A.M.Balagurov, D.V.Sheptyakov, E.V.Antipov, S.N.Putilin.

«Study of the Peculiarities in the Formation and Investigation of the Properties of Neutron-Rich Nuclei of Light Elements Using Sulphur Beams».
Authors: D.S.Baiborodin, Z.Dlouhy, R.Kalpakchieva, M.Lewitowicz, S.M.Lukyanov, Yu.E.Penionzhkevich, N.K.Skobelev, E.A.Sokol, O.B.Tarasov, V.D.Toneev.

Physics Instruments and Methods

First Prize

«The Internal Target Station for Experiments at the Nuclotron».
Authors: Yu.S.Anisimov, A.S.Artiomov, V.A.Krasnov, A.I.Malakhov, V.M.Slepnev, A.Yu.Starikov, J.Kliman, V.Matoušek, M.Morhač, I.Turzo.

Second Prize

«High-Efficiency Time-of-Flight Spectrometer of Fission Fragments, Neutrons and Gamma Quanta».
Authors: V.M.Voskresenski, Yu.M.Itkis, E.M.Kozulin, N.A.Kondratiev, L.Krupa, I.V.Pokrovski, E.V.Prokhorova, G.G.Chubarian, F.Hanappe, L.Stuttge.

Encouraging Prizes

«R&D of the Precise Tracking Detectors Based on Straw Drift Tubes».
Authors: V.N.Bytchkov, Yu.L.Zlobin, G.D.Kekelidze, V.V.Livinski, S.P.Lobastov, V.M.Lyssan, V.D.Peshekhonov.

«Gas-Filled Detectors for Research of Neutron-Induced Charged Particle Emission Reactions».
Authors: Yu.M.Gledenov, V.I.Salatskii, P.V.Sedyshev, M.V.Sedysheva, R.Mashrafi, G.Khuukhenkhuu, Cheng Zemin, Tang Gyouy, V.A.Vesna, P.Szalanski.

«R&D, Construction and Investigation of High-Accuracy Low-Mass Drift Chambers for the Inner Part of the HADES Spectrometer».
Authors: Yu.V.Zanevsky, G.N.Agakishiev, V.F.Chepurnov, S.P.Chernenko, O.V.Fateev, L.N.Glonti, V.N.Pechenov, A.G.Petrov, L.P.Smykov.

Applied Physics Research

First Prize

«New Ion-Implantation Methods for Nanotechnology».
Authors: V.F.Reutov, S.N.Dmitriev, A.A.Sokhatsky, V.K.Semina.

GRANTS

In 2000, a number of scientific projects by JINR staff members received grants of the Soros Foundation, INTAS Foundation, and of the International Centre for Science and Technology. Ninety one projects were financed by the Russian Foundation for Basic Research. Forty-three staff members of JINR were awarded state grants by the Presidium of the Russian Academy of Sciences.

JINR • 2000

INTERNATIONAL RELATIONS AND SCIENTIFIC COLLABORATION

COLLABORATION IN SCIENCE AND TECHNOLOGY

The international collaboration of the Joint Institute for Nuclear Research in science and technology in 2000 is described by the following facts:

- Joint investigations on 35 first-priority and 11 second-priority research topics were carried out with scientific centres of the Member States, with international and national institutions of other countries.
- 4,595 JINR scientists and engineers went on various missions within collaborative projects and for participation in external scientific meetings and conferences.
- 3,324 scientists and engineers came to JINR for joint work and consultations and for participation in workshops, conferences and schools.
- 15 international conferences, 26 workshops and 13 other scientific meetings were organized by JINR.
- 17 fellows worked at JINR Laboratories.

The international collaboration of JINR is also characterized by agreements and contracts, joint experiments at basic facilities of physics research centres, scientific results, joint publications, delivery of equipment and technologies to the interested parties, etc.

On 15 January, C.Détraz, CERN Director for Research and a member of the JINR Scientific Council, visited JINR Laboratories where he got acquainted with the ongoing preparation for the joint experiments at CERN's accelerators. After the tour he had a meeting with JINR Vice-Director A.N.Sissakian, LNP Director N.A.Russakovich, LPP Director V.D.Kekelidze, and LPP Honorary Director I.A.Savin. Professor C.Détraz noted the important contribution of JINR physicists and specialists to the experiments performed at CERN.

From 1–3 February, JINR Vice-Director A.N.Sissakian and FLNP Acting Director V.L.Aksenov were on a working visit to the Russian Federal Nuclear Centre «All-Russian Research Institute for Experimental Physics» (VNIIEF) in Sarov (former Arzamas-16). At an all-Institute seminar there, A.N.Sissakian and V.L.Aksenov delivered reports «JINR Research Programmes» and «Neutron Physics on the Verge of the XXI Century», respectively. Prospects of developing the cooperation were discussed with VNIIEF First Deputy Scientific Leader Yu.A.Trutnev, Deputy Scientific Leader and Head of the Nuclear and Radiation Research Centre V.T.Punin, and with other scientists of the Institute. The guests inspected some basic facilities and got acquainted with the status of the collaborative research. A Protocol on the research programme in physics of ultra-cold neutrons to be realized at the BIGR VNIIEF (Sarov) was signed in the course of the visit.

The X annual meeting of the Joint Steering Committee for the Implementation of the BMBF–JINR Agreement on Cooperation and Use of JINR Facilities, co-chaired by A.N.Sissakian (JINR) and H.-F.Wagner (BMBF), took place in Dubna on 7–8 February. JINR Director V.G.Kadyshevsky welcomed the participants of the meeting. He underlined the importance and mutual benefit of the collaboration between JINR and German research centres. A comprehensive presentation of JINR's activities in 1999, major results and prospects of the collaboration between the Joint Institute and German scientific centres was made by JINR Vice-Director A.N.Sissakian. JINR Assistant Director for Economic and Financial Issues V.V.Katrasev gave information on the implementation of the JINR budget in 1999, on the draft budget for 2000, as well as on the expenditures from the German contribution in 1999. H.-F.Wagner (BMBF), R.Klanner, DESY Director for Research, R.Wagner, Vice-Director of the Research Centre in Jülich, and others expressed their high appreciation of JINR's ongoing research programmes and the achievements of the collaboration. The meeting resulted in signing an official protocol. The guests toured JINR Laboratories.

Through 20–27 February JINR Director V.G.Kadyshevsky and Vice-Director A.N.Sissakian were on a short visit to the USA. At the Fermi National Accelerator Laboratory (FNAL, Batavia) they discussed issues of strengthening the collaboration between the two large research centres with FNAL Director M.Witherell, relating to the fact that JINR specialists had contributed much to provide for continuing the D0 and CDF experiments at Tevatron.

The JINR leaders met with other members of the FNAL Directorate, spokespersons of the experiments, and with the group of JINR employees involved in the preparation of experiments at FNAL.

At Brookhaven National Laboratory (BNL) V.G.Kadyshevsky and A.N.Sissakian had talks with BNL Director J.Marburger. A JINR–BNL Collaboration Agreement on the STAR Experiment for 2000 was signed during the visit. The BNL Director noted the high quality of the work being fulfilled at JINR. The JINR leaders got acquainted with some ongoing activities of BNL in the fields of particle physics and applied research. They also had meetings with other BNL leaders and with participants of the experiments.

On 26 February in New York, V.G.Kadyshevsky and A.N.Sissakian met with J.Tokhadze, President of ICC (educational centre). Collaborative projects in educational programmes were touched upon in the discussion.

Issues of possible concluding an «umbrella-type» Cooperation Agreement between the Joint Institute and U.S. governmental structures (DOE, NSF) taking into account the scientific potentials of U.S. research centres and JINR were discussed in the course of the visits to FNAL and BNL too.

While staying in Brookhaven, the JINR leaders met with a delegation of the National Natural Science Foundation of China, including Academician Wang Naiyan, Vice-President of the Foundation, Vice-Chairman of the Commission of Science and Technologies, Vice-President of the Chinese Nuclear Society. Issues of extending scientific cooperation were considered at the meeting.

JINR Chief Scientific Secretary V.M.Zhabitsky and LNP Deputy Director V.B.Brudanin stayed in Tashkent on 10 March. Issues of cooperation between the Joint Institute and scientific centres and universities of Uzbekistan were discussed with B.S.Yuldashev, Corresponding Member of the Academy of Sciences of Uzbekistan and Plenipotentiary of this Republic to JINR, Academician M.Kamilov, Vice-President of the Academy, and Professor T.Bekmuradov, Scientific Secretary. The status and prospects of the cooperation were considered in detail with Academician T.Riskiev, Counsellor for Science and Education to the President of Uzbekistan. Steps to stabilize the participation of Uzbek physicists in JINR's research programmes were outlined in the course of the visit.

In March, a delegation of JINR including Vice-Director Ts.Vylov, LHE Director A.I.Malakhov, and FLNR Scientific Leader Yu.Ts.Oganessian visited Bulgaria. The guests had meetings with the Chairman of the Committee on the Use of Atomic Energy for Peaceful Purposes of Bulgaria G.Kaschiev, Vice-Chairman R.Popits, and other officials of the Committee. Various aspects of the cooperation between scientists of JINR and Bulgaria, as well as ways of promoting its efficiency were the focus of attention in the discussions.

The JINR representatives met with the Chairman of the Bulgarian Academy of Sciences I.Yukhnovsky, Vice-Chairman N.Sabotinov, and some other officers of the Academy. They also had discussions with the Deans of the Physics Faculties at Plovdiv and Sofia Universities. Yu.Ts.Oganessian and A.I.Malakhov delivered reports at scientific seminars.

Scientists of the Philipps University's Institute of Nuclear Chemistry (Marburg, Germany) — Professor R.Brandt, a prominent radiochemist, and Professor W.Westmeier, a compiler of the famous catalogue for gamma quanta, — stayed at JINR from 20–27 March. The aim of their visit was a discussion of prospects of future cooperation between German scientific centres (in Jülich, Meln, Marburg and Hoyerswerda) and the JINR Laboratories that participate in the research programme at the Synchrophasotron and Nuclotron within the collaboration «Energy plus Transmutation».

On 28 March in Moscow, JINR Director V.G.Kadyshevsky and Vice-Director A.N.Sissakian took part in negotiations with R.Wolf, General Director of the «Siemens Business Services» Office in Russia. Issues of cooperation were discussed, and a Memorandum of Intent was signed during the meeting. The other participants of the negotiations were: from the SBS Company — G.Berger, Director of Department of Large Projects for the HERMES programme, and V.A.Kitov, Head of Department «Science and Education»; from JINR — V.V.Korenkov, Deputy Director of LCTA.

At the invitation of the JINR Directorate, the Ambassador of Romania to the Russian Federation I.Diaconu with his wife and the First Secretary of the Embassy C.Botes visited JINR on 29 March. They were welcomed by JINR Director V.G.Kadyshevsky, Vice-Director A.N.Sissakian, Assistant Directors V.V.Katrasev and P.N.Bogolyubov, and FLNR Deputy Director S.N.Dmitriev. The aim of the visit, as was stated by Ambassador I.Diakonu, was to become more closely acquainted with JINR activities and to outline the main tasks of future collaboration. In the final part of the visit the guests met with the Romanian staff members of JINR.

On 3 April JINR Director V.G.Kadyshevsky and Vice-Director A.N.Sissakian visited the International Solvay Institutes for Physics and Chemistry in Brussels, where they discussed with its Deputy Director I.Antoniou and other Institute staff members issues of cooperation in scientific and educational programmes, including those implemented within the EC 5th Framework Programme.

On 4 April, at the Headquarters of the European Commission (EC) in Brussels, V.G.Kadyshevsky and A.N.Sissakian met with Professor G.Sonnino, Assistant to the EC General Directorate for Research, with whom they discussed various issues of cooperation in the fields of fundamental science. Following mutual consultations between the directorates of JINR and CERN, it was agreed upon with EC that the exhibition «Science Bringing Nations Together», jointly organized by CERN, JINR

and the International Solvay Institutes for Physics and Chemistry, would be opened in the European Parliament on 12 September 2000. The meeting at the EC Headquarters was also attended by I.Antoniou, Deputy Director of the International Solvay Institutes, and R.Vardapetian, an INTAS manager.

On 5 April in Amsterdam, JINR Director V.G.Kadyshevsky, Vice-Director A.N.Sissakian and Chief Engineer I.N.Meshkov were received by the Directorate of the National Institute for Nuclear Physics and High Energy Physics (NIKHEF): Director G. van Middelkoop, Deputy Director A. van Rijn, and Department Heads J.Spelt, J.Engelen, R.Blockzijl. JINR's guests had a detailed visit around the scientific and engineering departments of NIKHEF. Issues of collaboration between the two centres, including activities to transport the AmPS facility to Dubna in order to establish the DELSY synchrotron source at JINR and possibilities of using non-budgetary sources for funding these activities, were under consideration during the talks.

JINR Vice-Director A.N.Sissakian visited CERN on 17–21 April 2000. As JINR's representative, on 17–18 April he took part in the meetings of the Resource Review Boards on the experiments planned for the LHC. The Boards members discussed the progress of development and manufacture of elements of the experimental facilities and the scientific programme preparation. N.A.Russakovich (ATLAS), I.A.Golutvin (CMS) and A.S.Vodopianov (ALICE) participated in the meetings as experts. A.N.Sissakian also took part in the launching of the Dubna–CERN videoconferencing telecommunication system, which had been adjusted by CERN specialists together with their colleagues from JINR's Laboratory of Computing Techniques and Automation.

On 19–20 April A.N.Sissakian had talks with CERN Director-General L.Maiani, Research Directors R.Cashmore and C.Détraz, Cooperation Coordinator N.Koulberg, Spokespersons P.Jenni (ATLAS), M.Della Negra (CMS), J.Schukraft (ALICE), S.Paul (COMPASS) and others. A wide range of cooperation aspects was under consideration, including the organization of the ATLAS Week and the International Symposium «LHC Physics and Detectors» in Dubna, of the 2000 European School of High-Energy Physics for young scientists in Portugal, and other issues.

A.N.Sissakian had meetings with Ambassador A.Kavadze, Representative of Georgia in the UN Office in Geneva, with A.Likhotal, Vice-President of the Gorbachev Foundation in Switzerland, and with representatives of Geneva University. Collaboration in scientific and educational programmes was the topic of the discussion.

Carrying out a commission of the government of Japan, a delegation of experts visited JINR on 17–18 April. Members of the delegation were K.Mishima and K.Koboyashi, Professors of Kyoto University, and S.Ueda, Deputy Executive Director of the International Science and Technology Centre (ISTC). The experts got acquainted with the current status of the international ISTC project of developing diagnostics systems for pulsed neutron sources and with new proposals of JINR that could be implemented within the framework of the ISTC. They visited FLNP, FLNR, and LHE.

The Presidium of the Russian Academy of Sciences (RAS), at its session chaired by RAS President Yu.S.Osipov on 16 May, discussed the collaboration between RAS and JINR. In his report «The Role of the Russian Academy of Sciences in the Formation and Evolution of the Joint Institute for Nuclear Research in Dubna» JINR Director V.G.Kadyshevsky spoke on the traditions of and prospects for scientific collaboration between JINR and institutes of RAS (until 1991 the USSR Academy of Sciences).

President of RAS Yu.S.Osipov, Vice-Presidents G.A.Mesyats, V.E.Fortov, A.F.Andreev, members of the Presidium and advisers Yu.A.Osipian, Yu.A.Izrael, V.I.Subbotin, N.A.Shilo and others took part in the debate on the report. Academician Yu.S.Osipov pointed out that JINR is developing as one of the world's largest scientific centres and that collaboration with this international organization occupies an important place in scientific programmes of RAS.

Other JINR representatives at the session were Vice-Directors A.N.Sissakian and Ts.Vylov, Chief Engineer I.N.Meshkov, Chief Scientific Secretary V.M.Zhabitsky, BLTP Honorary Director D.V.Shirkov, and FLNP Director V.L.Aksenov.

On 17 May Director of the Scientific Centre for Atomic Research in Teheran A.Gharib visited JINR. He was received by JINR Vice-Director A.N.Sissakian and Assistant Director for International Relations P.N.Bogolyubov, and was shown around the Institute's Laboratories.

From 15–20 June JINR Director V.G.Kadyshevsky and Vice-Director A.N.Sissakian were on a working visit to Greece. During their visit, meetings concerning JINR's collaboration with research and education institutions were held with T.Xanthopoulos, Rector of the National Technical University of Athens, M.Dermitzakis, Dean of the Physics Department of the University of Athens, C.Papanicolas, Director of the Institute of Accelerating Systems and Applications of the University of Athens, I.Antoniou, Deputy Director of the International Solvay Institutes for Physics and Chemistry (who coordinates a number of projects with participation of Greece and JINR), N.Giokaris, a member of the JINR PAC for Particle Physics, M.Floratos, Coordinator of Greece–CERN cooperation, and with other scientists.

JINR's leaders were also received by the General Secretary for Research and Technology of Greece D.Deniozos, whom they informed about the activities of JINR and its collaboration with Greek research centres. Professor D.Deniozos expressed his high appreciation of this collaboration. The negotiations resulted in mutual inten-

tions to start the formal procedures for preparation of an Agreement on Cooperation between JINR and Greece (as an associate member of JINR). At the University of Athens, V.G.Kadyshevsky delivered a lecture «The Standard Model on the Basis of Geometrical Reasoning» and A.N.Sissakian presented the JINR Research Programme.

On 21–22 June Dubna hosted the 10th meeting of the Board of the International Association of Academies of Sciences (IAAS). This international nongovernmental organization was established in 1993 to unite the efforts of national academies of sciences in dealing with major scientific problems, in keeping and developing the traditional and new creative ties between scientists. The present members of IAAS are the Academies of Sciences of all the CIS countries and of Vietnam. The Slovak Academy of Sciences has an observer status. There are also five associate members of IAAS, including JINR.

IAAS President B.E.Paton, a member of the National Academy of Sciences of Ukraine, delivered a report at the meeting. Presentations on the status of science in the CIS countries and on urgent problems faced by the Academies of Sciences (recruitment of young researchers, integration of fundamental science and higher education, equipment upgrading, and others) were made at the meeting by the heads of the IAAS delegations and by associate members. An overview of the activity of the Joint Institute for Nuclear Research was given by JINR Director V.G.Kadyshevsky, a member of the Russian Academy of Sciences. The Board members were also informed about the Declaration on Science and Scientific Knowledge Application, adopted at the World Conference «Science for the Twenty-First Century» (Budapest, 1999), and discussed other science-related matters.

On 29 June, CERN Research Director R.Cashmore and Cooperation Coordinators J.Allaby and N.Koulberg visited some JINR Laboratories, where they got acquainted with the status of activities to fulfil JINR's obligations within the ATLAS, CMS, ALICE, COMPASS and other joint experiments. Explanations were given by JINR Vice-Director A.N.Sissakian, DLNP Director N.A.Russakovich, LPP Director V.D.Kekelidze, as well as by a number of the Institute's leading specialists. The guests noted the high quality of the work being performed at JINR.

In late July, JINR Vice-Director A.N.Sissakian was on a working visit to CERN. In the course of his visit he met with CERN Director-General L.Maiani, Research Directors R.Cashmore and C.Détraz, Cooperation Coordinators J.Allaby and N.Koulberg, Spokespersons P.Jenni (ATLAS), J.Schukraft (ALICE), L.Nemenov (DIRAC), and others. A wide range of collaborative aspects was under consideration. Particular attention was paid to the fulfilment of JINR's obligations on preparation of the joint experiments at CERN and to working out scientific programmes of future experiments.

S.Evans, First Secretary of the Embassy of the United Kingdom in Russia (Department for Science, Ecology and Technologies) stayed at JINR in September. The guest had a meeting with the members of the Institute's Directorate and visited the Flerov Laboratory of Nuclear Reactions and the Laboratory of High Energies. He noted the close scientific ties between physicists of JINR and the UK, in particular of the Rutherford Appleton Laboratory.

A joint JINR–CERN poster exhibition «Science Bringing Nations Together» was held in the building of the European Parliament in Brussels on 11–15 September, continuing the series of exhibitions launched at the University of Oslo in 1997.

The ceremonial opening was attended by representatives of diplomatic missions accredited to Belgium, by JINR and CERN managing officials, scientists, Europarliament staff members, and journalists. They were addressed with greetings by Chairman of the Europarliament Commission for Industry, Foreign Trade, Science, and Power Industry K.Westendorn, CERN Director-General L.Maiani, JINR Director V.G.Kadyshevsky, and by Deputy Director of the International Solvay Institutes for Physics and Chemistry I.Antoniou. The speakers emphasized the great contributions made by JINR and CERN to world science and their humanistic role in conducting scientific research.

The exhibition was also visited by the EC Commissioner for Research Ph.Busquin and by the delegation of the Russian State Duma that took part in the meeting of a Europarliament commission.

The dominant theme of the exhibition was that joining of creative efforts and material resources by scientists from various countries has become another important way to rapprochement of peoples and mutual understanding between them.

On 19 September, JINR Director V.G.Kadyshevsky and Vice-Director A.N.Sissakian held a meeting with Rector of Moscow State University V.A.Sadovnichy, his Adviser V.V.Belokurov, and with Vice-Minister of Education and Chief Scientific Secretary of the Russian Supreme Attestation Commission V.V.Kozlov. Issues of collaboration in research and educational programmes were touched upon during the discussion.

A meeting of the joint working group for cooperation in the LHC project chaired by CERN Research Director R.Cashmore was held at CERN at the end of September. The status of the cooperation between CERN and scientific centres of Russia, including the Joint Institute for Nuclear Research, as well as plans for next year were under consideration at the meeting. JINR was represented by Vice-Director A.N.Sissakian as a permanent observer and by the group leader I.A.Golutvin. A.N.Sissakian had meetings with CERN Director-General L.Maiani, Research Director R.Cashmore, Spokespersons of the ATLAS and ALICE collaborations P.Jenni and J.Schukraft, Coordinator for cooperation with Russia N.Koulberg, member of the JINR Scientific Council

H.Schopper, and others. A wide range of collaborative issues was touched upon in the discussions.

The Ambassador of Ukraine to the Russian Federation N.P.Beloblotsky and Counsellor for Science and Technology A.A.Vasiliev stayed at the Joint Institute for Nuclear Research on 5 October. The guests met with the JINR leaders and got acquainted with several JINR Laboratories. They noted Dubna's important role in the development of fundamental and applied science and the successful cooperation between physicists of JINR and their colleagues from Kiev's and Kharkov's institutes. A delegation of Belgorod State University, including its Rector N.V.Kamyshanchenko, stayed at JINR through 27–30 October. The guests toured JINR Laboratories and visited the Institute's University Centre. Issues of developing the collaboration were discussed with JINR Vice-Director A.N.Sissakian and UC Director S.P.Ivanova.

From 8–12 November, JINR Director V.G.Kadyshevsky and Vice-Director A.N.Sissakian visited the Republic of Armenia. In Yerevan, they took part in the meeting of the International Interim Council for the SESAME project, chaired by H.Schopper (CERN). The project is expected to be realized in the countries of the Middle East and Transcaucasus under the aegis of UNESCO. The Collaboration includes Armenia, Greece, Iran, Israel, Palestine, Turkey and some other countries as participants; Germany, Russia, USA as observers. The project is considered to be a scientific and peacemaking initiative aimed to bring people together through common scientific interests and research. Together with the other participants of the meeting, V.G.Kadyshevsky and A.N.Sissakian were received by the President of Armenia R.Kocharyan.

A meeting of the Science and Technology Council of the International Centre for Advanced Studies, founded by YeSU and JINR, took place in Yerevan State University. The major results of the activity of the Centre during its first year of existence and plans for the future were on the agenda of the meeting. Talks were given by YeSU Rector R.Martirosyan, Vice-Rector E.Chubaryan, Centre Executive Director G.Pogosyan, V.G.Kadyshevsky, A.N.Sissakian and other participants.

W.Molzon, a prominent American physicist of the University of California and Spokesperson of the new research project «MECO» to be realized at the Brookhaven accelerator, spent in Dubna several days in November. He was received by the JINR Directorate, delivered a review report at an LHE–LPP seminar, discussed possibilities of cooperation in preparing the project with some leading scientists of JINR.

A meeting of the CERN–JINR Cooperation Committee, co-chaired by J.Allaby (CERN) and A.N.Sissakian (JINR), took place in Dubna on 16 November. The results of collaboration in 2000 and plans for 2001 were on the agenda of the meeting. Participating in the discussions were H.Gutbrod (France), N.Koulberg (CERN), V.D.Kekelidze, A.I.Malakhov, I.V.Puzynin, I.N.Meshkov (JINR), and others.

A delegation of JINR, including LHE Director A.I.Malakhov, JINR Assistant Director for Economic and Financial Issues V.V.Katrasev, and LHE Scientific Secretary E.B.Plekhanov, was on a working visit to Romania from 20–25 November. Following the recommendations of the meeting on cooperation between JINR and scientific centres of Romania held in Dubna in June 2000, the aim of the visit was to discuss with Romanian leaders of science the prospects of the collaboration and ways of increasing its efficiency. The JINR delegation met with the leaders of the National Agency for Science, Technology and Innovation (NASTI), ISS Director D.Hasegan, IFIN-HH Director G.Mateescu, representatives of the scientific community of Romania, and the Ambassador of the Russian Federation to Romania V.F.Kenyajkin. NASTI President S.Lanyi highlighted the importance for Romania to further develop our relations in such directions as scientific research, education, and studies in the field of new technologies and innovations.

At the session of the Presidium of the Russian Academy of Sciences on 21 November, Scientific Leader of the Flerov Laboratory of Nuclear Reactions Yu.Ts.Oganessian delivered a report on the synthesis of the new elements. The participants of the meeting gave their appreciation of the high quality of the activity presented and of the outstanding achievements of the Laboratory. Involved in the discussions were Vice-President of RAS and Executive President G.A.Mesyats, Vice-Presidents A.F.Andreev, O.M.Nefedov, Deputy Chief Scientific Secretary B.F.Myasoedov, Corresponding Members of RAS S.S.Gershtein, Yu.G.Abov, and JINR Director Academician V.G.Kadyshevsky.

From 27 November – 2 December, JINR Director V.G.Kadyshevsky stayed in Japan with an official visit. He was accompanied by DLNP Deputy Director A.S.Kurilin. The programme of the stay comprised visits to two largest Japanese nuclear centres — the High Energy Accelerator Research Organization (KEK, Tsukuba) and the Institute of Physical and Chemical Research (RIKEN, Wako). Long activities to prepare the General Agreement on JINR–KEK Scientific Cooperation preceded this visit. The signing of such an Agreement had to be coordinated at the highest governmental level in Japan, and this task was implemented during the visit (earlier, an agreement of this type had been signed between CERN and KEK).

On 27 November the General Agreement on JINR–Japan Cooperation was signed. The Agreement opened up wide prospects for collaboration in all JINR's research fields, primarily in theoretical physics and particle physics. The Agreement was signed by Professor H.Sugawara, Director-General of KEK, and V.G.Kadyshevsky, Director of JINR.

On 30 November JINR Director V.G.Kadyshevsky arrived at the Institute of Physical and Chemical Research

(RIKEN), where a group of JINR specialists, headed by JINR Chief Engineer I.N.Meshkov, was on a scientific mission. The first day of the JINR Director's visit included a meeting with Professor I.Tanihata, Director of the RIKEN Laboratory of Radioactive Ion Beams, Professor T.Katayama, Director of the RIKEN Laboratory of Physics and Charged Particle Beam Technology, and Professor Y.Yano, Director of the Accelerator Laboratory. Professor I.N.Meshkov and Dr A.S.Kurilin took part in the meeting. Issues connected with the implementation of the joint research programmes under the agreements signed by the above-mentioned RIKEN Laboratories and JINR Laboratories were discussed.

On 1 December JINR Director V.G.Kadyshevsky, JINR Chief Engineer I.N.Meshkov and DLNP Deputy Director E.M.Syresin had a meeting with RIKEN President Professor S.Kobayashi. It was agreed to conclude a General Agreement between the two institutions with a view to continuing the present collaboration and developing new areas of research. This Agreement is planned to be signed during the visit of Professor S.Kobayashi to Dubna in 2001.

At the invitation of the Department of Atomic Energy (DAE) of the Government of India, a delegation of JINR scientists, led by Vice-Director A.N.Sissakian, visited India on 11–15 December. The other members of the delegation were Professor M.G.Itkis, Director of the Flerov Laboratory of Nuclear Reactions, Professor N.A.Russakovich, Director of the Dzhelepov Laboratory of Nuclear Problems, Professor I.V.Puzynin, Director of the Laboratory of Information Technologies (LIT), and Dr M.V.Altaiski (secretary of the delegation), a LIT researcher.

The delegation was received by Professor A.Kakodkar, Chairman of India's Atomic Energy Commission, Secretary of DAE and Director of the H.Bhabha Atomic Research Centre (BARC, Mumbai). The Indian side was also represented by Professor S.S.Kapoor, DAE H.Bhabha Chair, Professor V.S.Sahni, Director of BARC's Physics Group, Professor S.K.Sikka, Director of BARC's Solid State and Spectroscopy Group. The JINR representatives informed the Indian colleagues about the activities of the Joint Institute and its intention to expand the scientific and technological cooperation with Indian research centres. Among the issues discussed at the meeting was a possibility of India's becoming an associate member of JINR. Professor A.Kakodkar expressed DAE's great interest to develop collaboration with JINR in various research and educational programmes.

The visit resulted in signing, by A.N.Sissakian and V.S.Sahni, of a Memorandum on Areas of Scientific and Technological Cooperation between JINR and BARC/DAE, which specifies twelve long-range areas of joint activities, including development and construction of accelerators and accelerator subsystems, participation in other collaborative works and in educational programmes.

CONFERENCES AND MEETINGS HELD BY JINR

Of the scientific conferences organized by JINR in 2000 the largest were the following thirteen.

The 7th International Conference «Mathematics, Computing, Education» was held in Dubna on 24–29 January. It was initiated by the association «Women in Science and Education». The Conference topics covered a wide scope of problems: from professional to philosophic and humanitarian ones. Work was organized in sections: «Computers in Science and Education», «Calculation Methods and Mathematical Modeling», «Mathematical Models in Chemistry, Biology, Ecology, Medicine», «Mathematical Models in Economics», «Ecology and Radiobiology», «Natural-Scientific and Humanitarian Education». A conference of this type was held for the second time.

The IV Scientific Conference of Young Scientists and Specialists was held in Dubna from 31 January till 4 February. It was organized by the JINR Association of Young Scientists and Specialists in cooperation with the Dubna branch of SRINP, MSU. About 150 participants from JINR and other scientific centres and universities gave their original reports. During the Conference, lectures were given by V.M.Zhabitsky (JINR), V.V.Korenkov (LIT), Yu.A.Sapozhnikov (MSU), M.P.Chavleishvili (BLTP), M.V.Frontasieva (FLNP), E.A.Krasavin (DRRR), V.P.Gerdt (LIT), A.A.Tiapkin (LPP) and O.L.Kuznetsov (IUD).

The International Conference «Nuclear Structure and Related Topics» was held in Dubna on 6–10 June. It was organized by BLTP with the financial support of UNESCO, the Russian Foundation for Basic Research, and the Heisenberg–Landau Programme.

The tradition to organize international conferences and schools on selected topics in nuclear structure was established in Dubna in the 1960s by the outstanding nuclear theorist Prof. V.G.Soloviev. Thanks to his efforts, these conferences have become popular and highly prestigious in the international scientific community. The organizers dedicated this Conference to his memory.

Among over 100 participants of the Conference were nuclear scientists from JINR and its Member States, many European countries, as well as from Iran, Japan and the USA. The Conference programme included more than 50 reports; section meetings were held in addition to

the plenary ones. A large part of the reports dealt with theoretical and experimental studies of nuclei far from stability. Lively discussions took place at the sessions devoted to the properties of superheavy nuclei as well as halo-nuclei.

An international seminar to mark the 40th anniversary of JINR's first pulsed reactor, IBR, took place in Dubna on 8–10 June. It started with the opening of a monument to the first Director of JINR and father of the first pulsed reactor D.I.Blokhintsev. A special sitting of the JINR Scientific Council was held on the occasion. Opening the seminar, Professor V.L.Aksenov, Directior of the Frank Laboratory of Neutron Physics (FLNP), spoke about the historical background of the Russian reactor-building, construction of pulsed reactors in Dubna, as well as about the highlight results obtained at IBR and new directions of JINR's research in this field.

The seminar took place in the Dubna branch of MSU SRINP and was organized by FLNP with support of the Russian Ministry of Industry, Science and Technology, the Russian Ministry for Atomic Energy and the Russian Academy of Sciences. It was attended by representatives of JINR member-state research centres, by honorary guests and outstanding scientists who had worked in Dubna.

The 3rd International Seminar «Relaxor Ferroelectrics» was held in Dubna on 14–17 June. Seventy scientists from 12 countries participated in it. Under discussion at the Seminar were the results of the experiments to study ferroelectrics with a spread phase transition (RFE) and attempts to describe their specific properties using today's theoretical concepts.

In recent years RFE investigations with neutron and X-ray techniques, as well as optic and dielectric spectroscopy methods have yielded key results that provide a new understanding of the problem of relaxor ferroelectrics and make it possible to have answers to a number of crucial questions formulated by previous Relaxor Ferroelectrics seminars.

It was for the first time in the long history of the collaboration that an ATLAS Week took place outside CERN. About 350 participants got together on 21–26 June to discuss progress of and questions arising during the detector construction. About 100 specialists came from Russia and other JINR Member States.

Prof. N.A.Russakovich, leader of JINR's activity for the ATLAS project and one of the leaders of the local Organizing Committee, introduced the participants to the events foreseen to accompany the scientific programme of the Dubna meeting. After that the meeting took its usual way. Numerous presentations during the Week covered the status of all subsystems of the detector, physics issues, electronics and DAQ. They were followed as usual by constructive discussions which helped the people concerned to find new ideas for better moving forward. The participants of the meeting visited the sites of manufacture and assembly of ATLAS detectors at JINR. One day was completely devoted to an excursion that gave the participants a chance to see the old Russian town Sergiyev Posad, located 60 km north from Moscow.

Closing the Week, ATLAS Spokesman P.Jenni expressed the opinion that the meeting in Dubna was very successful. He also pointed out that the ATLAS management announced as one of the main goals for the meeting held outside CERN the possibility to get together people from different fields of activity in ATLAS in the local area to establish better human contacts. And this goal was achieved thanks to the excellent organization of the meeting and to the social programme offered by JINR.

On 28–30 June an International Symposium «LHC Physics and Detectors» was held in Dubna, which became the scene of this impressive meeting for the second time. The Chairmen of the Symposium were CERN Director-General L.Maiani and JINR Director V.G.Kadyshevsky. The Organizing Committee was headed by CERN Director of Research R.Cashmore and JINR Vice-Director A.N.Sissakian. About 250 physicists from the leading research centres of 25 countries attended the Symposium; some 45 plenary reports were delivered.

On the first day CERN Director of Research R.Cashmore, a co-chairman of the Organizing Committee, gave a talk on the LHC programme. He comprehensively described all the work concerning the LHC project and thoroughly analysed the status of the ATLAS, CMS, ALICE, and LHCb facilities. The leaders of these projects, L.Evans, P.Jenni, T.Virdee, J.Schukraft, T.Nakada, gave a comprehensive scientific, technical, and financial analysis of the work done and spoke on the plans for the future.

The speakers from the collaborations discussed in detail all aspects of the detectors under construction and their efficiency for solving the most important physics problems and for physics research. Professors G.Bellettini, D.Green, S.Ozaka, K.Moenig and R.Cashmore vividly described the experiments at CERN, FNAL, RHIC and DESY and the long-term research plans. An interesting report «Physics Before and After the LHC» was made by Academician L.B.Okun.

A press conference was held on the first day of the Symposium. JINR Director V.G.Kadyshevsky, JINR Vice-Director A.N.Sissakian, a co-chairman of the Organizing Committee, Professors R.Cashmore, P.Jenni, N.Koulberg, G.Bellettini and V.I.Savrin answered the reporters'questions and spoke about the importance of the LHC for understanding the structure of the Universe and extending our knowledge of Nature.

Every two years Europe, Japan, Russia, the USA, CERN and JINR organize a Joint Accelerator School (JAS), giving accelerator physicists and engineers from each region an opportunity to meet experts from most of the world's accelerator laboratories. This year it was Russia's turn to host the school. It was held from 1 to 14 July on board a river boat sailing from St. Petersburg to Dubna and Moscow along the waterways that link the mouth of

the Neva with the Volga. The school attracted about 150 students from different countries.

The title of the school was «JAS 2000: High-Quality Beams». An international team of more than 20 lecturers discussed the topics of the many effects that limit the intensity and luminosity of proton and electron beams in both linear and circular machines. Parallel afternoon sessions on the accelerator design, space-charge and beam quality control for linear colliders allowed students to concentrate on the topics of their choice.

The participants had a chance to visit St. Petersburg and Moscow, passed through two large lakes — Ladoga and Onega — and could see the monastery on Valaam Island, the famous church at Kizhi and the delightful city of Yaroslavl.

On 31 July – 5 August Dubna hosted the XXIII International Colloquium on Group Theoretical Methods in Physics. The Group Theoretical Colloquium is one of the traditional conference series covering the most important topics of symmetry which are relevant to the intersection of present-day mathematics and physics with the focus on group theory, including topological, algebraic, and geometric methods that can be used to study properties of physical systems. The Colloquium organized in Dubna was not an exception; its theme covered many branches of physics in which group theoretical methods are important. While drawing up the programme of the Conference, the Dubna Organizing Committee used the experience of organizing the XXI Colloquium in Germany, where the most interesting and modern topics were discussed at mini-symposia. Alongside the topics traditional for Dubna such as Lie groups and representation theory, finite-dimensional symmetries and supersymmetries, particle physics, symmetries in molecular, atomic and nuclear physics, quantum and nonlinear optics and others, three mini-symposia on quantum groups and noncommutative geometry, integrable systems and the method of continuous integration were held in the framework of the Colloquium. The Conference programme included 15 plenary and around 160 section talks presented by more than 240 participants from 36 countries, including 10 JINR Member States. The review talks were given by L.Accardi (Italy), R.Askey (USA), Yu.Berest (USA), A.Bohm (USA), L.Bonora (Italy), H.-D.Dobner (Germany), R.Kerner (France), S.Kilin (Belarus), V.Korepin (USA), T.Miwa (Japan), M.Moshinsky (Mexico), D.Rowe (Canada), M.Semenov-Tyan-Shansky (France, Russia), I.Todorov (Bulgaria) and A.Filippov (JINR).

A ceremony of awarding the Wigner Medal for 2000 was held on the second day of the Colloquium. It went to the well-known Irish scientist Prof. L.O'Raifeartaigh for the «Spectrum Mass Theorem in Relativistic Theories and Pioneering Contribution to Particle Physics».

At the last session the participants of the Colloquium listened to a lecture by Prof. Yu.Ts.Oganesian, which was devoted to studies carried out at the Flerov Laboratory of Nuclear Reactions on the synthesis of superheavy elements and especially to the recently discovered element 116 of Mendeleev's Table.

Such a large Colloquium could not be organized without the support from IUPAP, INTAS, UNESCO, RFBR and the Heisenberg–Landau and Bogoliubov–Infeld Programmes.

The 2000 European School of High-Energy Physics, organized by JINR and CERN, took place in Caramulo (Portugal) from 20 August to 1 September. A large delegation from JINR and its Member States (more than 20 representatives) participated in the School. Among the lecturers were JINR Vice-Director Prof. A.Sissakian, who acquainted the participants with the scientific programme of JINR, and Prof. D.Kazakov (Bogoliubov Laboratory of Theoretical Physics, JINR), who presented a lecture course «Beyond the Boundaries of the Standard Model». In the course of the School the thirtieth anniversary of joint JINR–CERN schools for young scientists was marked. The first one was held in Loma Koli (Finland) in 1970.

An International Conference «Modern Problems in Radiobiology, Radioecology and Evolution» was held in Dubna on 6–9 September. It was organized by JINR, the Russian Academy of Sciences, the Russian Academy of Medical Sciences and the National Academy of Sciences of Ukraine. The Conference was dedicated to the centenary of the birth of the outstanding Russian geneticist N.W.Timofeeff-Ressovsky (1900–1981). On 7 September a memorial round-table discussion was held under the chairmanship of Academician V.A.Yablokov. The participants, who knew N.W.Timofeeff-Ressovsky personally, delivered reports at the meeting. Among them were Ts.M.Avakian, D.Ganten, N.A.Lyapunova, M.A.Reformatskaya, A.N.Tyuryukanov, P.D.Usmanov, V.A.Yablokov and others.

The XV International Seminar on High Energy Physics Problems «Relativistic Nuclear Physics and Quantum Chromodynamics» was held in Dubna on 25–29 September.

The main task of relativistic nuclear physics — the study of properties of highly excited states of nuclear matter, its behaviour at short distances — has grown into a large-scale issue in the research of relativistic multiparticle systems. Future research in this field has a direct connection to a most promising theme of strong interactions physics, i.e. long-distance quantum chromodynamics and quark confinement.

131 reports were presented at the seminar, including reports about the first results of the experiments at the extracted beam obtained at the Nuclotron, a superconducting accelerator. For the first time the results achieved at the recently launched RHIC heavy ion collider in the USA were also presented. Together with JINR scientists, delegates from Armenia, Brazil, Bulgaria, Czech Republic, France, Georgia, Germany, Iran, Mongolia, Poland, Russia, Slovak Republic, Taiwan, USA, Uzbekistan, and Yugoslavia took part in the seminar.

A memorial seminar dedicated to the 90th anniversary of the birth of Mikhail G. Mescheryakov (17.09.1910–24.05.1994), a prominent physicist and experimenter, Corresponding Member of the USSR Academy of Sciences, the organizer and first Director of the

Laboratory of Computing Techniques and Automation, a founder and honorary citizen of Dubna, was held on 27 October. The seminar was opened by LIT Director I.V.Puzynin. JINR Director V.G.Kadyshevsky noted, in his address, M.G.Mescheryakov's meritorious service to science and marked his basic role in the foundation of the Institute. O.G.Uspensky addressed the seminar on behalf of the town administration. The scientist's disciples, colleagues, friends and relatives shared their recollections about this remarkable man.

At the seminar a book «Mikhail Grigorievich Mescheryakov» was presented. This is a collection of his public presentations, memoirs and letters as well as the reminiscences of the scientists who had happened to work with him, among them V.P.Dzhelepov, D.V.Shirkov, G.D.Stoletov, V.P.Zrelov, V.P.Dmitrievsky, L.S.Azhgirey, A.N.Sissakian, R.Pose, E.P.Zhidkov, V.M.Tsupko-Sitnikov and others. A ceremonial opening of the exhibition of photographs by Yu.Tumanov devoted to M.G.Mescheryakov took place on the 3rd floor of the LIT building. The photos commemorate moments and events of the life of this outstanding scientist.

PARTICIPATION OF JINR IN INTERNATIONAL AND NATIONAL CONFERENCES

In 2000, scientists of the Joint Institute for Nuclear Research took part in 224 international and national conferences.

The largest delegations of JINR attended the following conferences: 34th Winter School of the St. Petersburg Nuclear Physics Institute (Russia, Repino), 16th International Conference on Few-Body Problems in Physics (China, Taiwan, Taipei), Euroconference on QCD and High Energy Hadronic Interactions (France, Les Arcs), International Workshop «Synthesis of Superheavy Nuclei» (Italy, Messina), 5th International Conference on Radioactive Nuclear Beams (France, Divonne), Joint Study Hallo 2000 Meeting (Belgium, Brussels), 7th International Seminar on Neutron Scattering Investigation in Condensed Matter (Poland, Poznan), XI International Seminar on High Energy Physics (Russia, Pushkino), International Workshop on Fission Dynamics of Atomic Clusters and Nuclei (Portugal, Luso), International Conference on the Structure of the Nucleus at the Dawn of the Century (Italy, Bologna), III International Symposium «Ion Implantation and Other Applications of Ions and Electrons (Poland, Kazimierz Dolny), Workshop on Target and Ion Source Technology (France, Caen), 50th Workshop on Nuclear Spectroscopy and Structure of Atomic Nucleus (Russia, St. Petersburg), International Workshop on Polarized Neutrons for Condensed Matter Investigation (Russia, Gatchina), 9th International Colloquium «Quantum Groups and Integrable Systems» (Czech Republic, Prague), 7th European Particle Accelerator Conference (Austria, Vienna), 7th International Conference on Nucleus-Nucleus Collisions (France, Strasbourg), 7th Inter-State Workshop «Plasma Electronics and New Acceleration Methods» (Ukraine, Kharkov), International Conference «Supersymmetry and Quantum Field Theory» (Ukraine, Kharkov), XXX International Conference on High Energy Physics (Japan, Osaka), 8th Summer School on Neutron Scattering (Switzerland, Suoz), 20th International Conference on Nuclear Tracks in Solids (Slovenia, Portoroz), 5th Conference on Nuclear and Radiochemistry (Switzerland, Pontresina), Workshop «Resonances in Few-Body Systems» (Hungary, Sarospatak), 5th International Symposium and Exhibition on Environmental Contamination in Central and Eastern Europe (Czech Republic, Prague), International

Development of JINR's international collaboration and relations during the years 1965–2000

		1965	1975	1985	1990	1995	1999	2000
1.	Number of visits to JINR by specialists from its Member States (excluding participants in JINR conferences)	203	1026	1469	1050	299	361	425
2.	Number of visits by JINR specialists to Member States	171	474	600	778	682	692	682
3.	Number of conferences and meetings organized by JINR	19	42	49	44	52	48	54
4.	Number of visits to international conferences and research centres of non-Member States	69	131	119	437	1451	1830	1946
5.	Number of visits of scientists from non-Member States	27	226	144	563	1036	659	990
6.	Number of JINR fellows		11	3	16	28	20	17

Computational Accelerator Physics Conference (Germany, Darmstadt), XVII European Conference on Few-Body Problems in Physics (Portugal, Evora), All-Russian Conference «Internet Service for Science» (Russia, Novorossiysk), 2000 CERN School of Computing (Greece, Maraphon), 2nd Euroconference on Atomic Physics at Accelerators: Mass Spectrometry (France, Cargese), NATO Advance Research Workshop «Dynamical Symmetries of Integrable Quantum Field Theories and Lattice Models» (Ukraine, Kiev), 15th Workshop on Fission Physics (Russia, Obninsk), Hadron Structure 2000 International Conference (Slovak Republic, Stara Lesna), 3rd International Workshop on Computer Algebra in Scientific Computing (Uzbekistan, Samarkand), All-Russian Conference on Charged Particle Beam Accelerators (Russia, Protvino), 14th International Spin Physics Symposium (Japan, Osaka), International Conference on Current Status of Nuclear Medicine and Radiopharmaceutics (Russia, Obninsk), 15th Meeting of the International Collaboration «Advanced Neutron Sources» (Japan, Tsukuba), International Conference «Problems of Radiation Genetics at the Turn of the Century» (Russia, Moscow), 3rd Russian Conference on Radiochemistry (Russia, St. Petersburg).

CONFERENCES AND MEETINGS HELD BY JINR IN 2000

Title	Site	Date
87th Session of the JINR Scientific Council	Dubna	13–15 January
XXII Workshop on Experiments with the IHEP–JINR Neutrino Detector and the NOMAD Experiment	Dubna	19–21 January
7th International Conference «Mathematics, Computing, Education»	Dubna	24–29 January
IV Scientific Conference of Young Scientists and Specialists	Dubna	31 January – 4 February
X Meeting of the Steering Committee for Implementation of the BMBF–JINR Agreement on Cooperation and Use of JINR Facilities	Dubna	7–9 February
School on Modern Neutron Scattering	Dubna	7 February – 4 March
Meeting of the JINR Finance Committee	Dubna	17–19 February
Meeting of the Committee of Plenipotentiaries of the JINR Member States	Dubna	16–18 March
Workshop «Nucleation Theory and Its Application»	Dubna	3–28 April
V International Workshop «Heavy Quark Physics»	Dubna	6–8 April
Meeting of the Programme Advisory Committee for Particle Physics	Dubna	7–8 April
Meeting of the Programme Advisory Committee for Nuclear Physics	Dubna	10–12 April
Scientific Seminar in Memory of V.P.Dzhelepov	Dubna	12 April
Meeting of the Programme Advisory Committee for Condensed Matter Physics	Dubna	14–15 April
SAD Collaboration Meeting on the Research Programme	Dubna	27–29 April
International Workshop on the Study of the Structure of Light Exotic Nuclei by the Nuclear Emulsion Method	Dubna	16–18 May
VIII International Seminar on Interactions of Neutrons with Nuclei	Dubna	17–20 May
Workshop on Problems of Nuclear Fusion Dynamics in Extreme Conditions	Dubna	25–27 May
International School-Seminar «New Trends in High-Energy Physics»	Ukraine, Miskhor	27 May – 4 June
Baikal Collaboration Workshop	Dubna	30 May – 2 June
2nd International Workshop on Data Acquisition Systems for Neutron Experimental Facilities (DANEF '2000)	Dubna	5–7 June
International Conference «Nuclear Structure and Related Topics»	Dubna	6–10 June
Meeting of the Control Commission of the JINR Finance Committee	Dubna	6–11 June
International Seminar «40 Years of the First Pulsed Reactor IBR»	Dubna	8–10 June

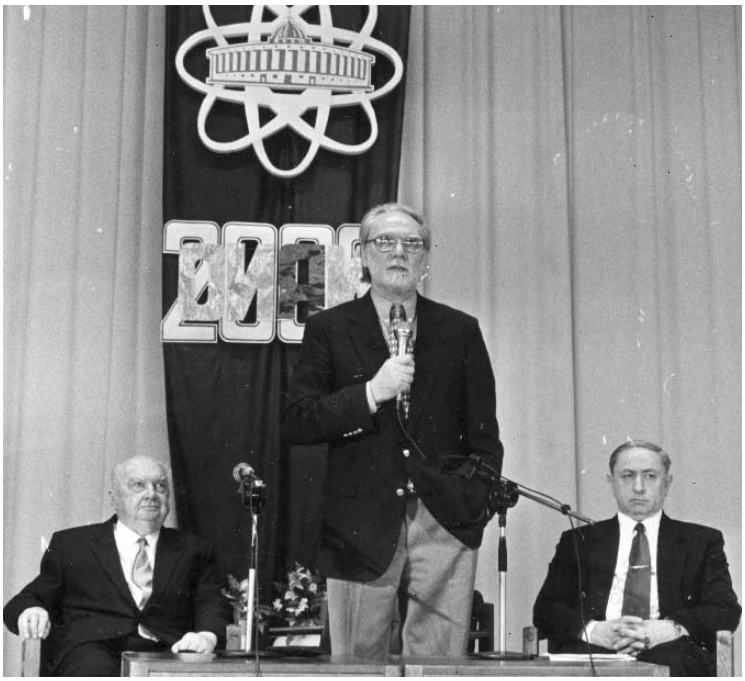
Title	Site	Date
88th Session of the JINR Scientific Council	Dubna	8–9 June
School of Young Scientists	Dubna	9–11 June
5th Topical Meeting «Heavy Ions in CMS»	Russia, Gatchina	11–14 June
III International Seminar «Relaxor Ferroelectrics»	Dubna	14–17 June
Workshop «ATLAS Week»	Dubna	21–26 June
International Workshop «Very High Multiplicity Physics»	Dubna	26–27 June
Workshop «Relativistic Nuclear Physics from Hundreds of MeV to TeV»	Slovak Republic, Stara Lesna	26 June – 1 July
International Symposium «LHC Physics and Detectors»	Dubna	28–30 June
Joint CERN–Japan–JINR–Russia–USA International Advanced Accelerator School	St.Petersburg – Dubna (on board a river boat)	1–14 July
Workshop «Calculation for Modern and Future Colliders»	Dubna	10–23 July
International Workshop «Neutrino and Physics Beyond the Standard Model»	Dubna	19–22 July
International Workshop «Symmetry and Spin»	Czech Republic, Prague	17–22 July
International Workshop «Actual Problems of Computing Physics»	Dubna	24–29 July
XXIII International Colloquium on Group Theoretical Methods	Dubna	31 July – 5 August
VIII European School of High-Energy Physics (a CERN–JINR school)	Portugal, Caramulo	20 August – 2 September
First Mongolia–JINR School-Seminar «Aspects of Applied Nuclear Physics»	Mongolia, Ulaanbaatar	20 August – 2 September
International Workshop «Hot Points in Astrophysics»	Dubna	22–26 August
Workshop «Quantum Gravity and Superstrings»	Dubna	28 August – 3 September
International Conference «Modern Problems of Radiobiology, Radioecology and Evolution»	Dubna	6–9 September
III Workshop «Internet–Russia» («Internet–Russia–2000»)	Dubna	19–22 September
XV International Seminar on High Energy Physics Problems	Dubna	25–29 September
International Workshop on Monitoring of Natural and Man-Made Radionuclides and Heavy Metals in Environment	Dubna	3–6 October
COMPASS Collaboration Workshop	Dubna	10–15 October
Meeting of the JINR Finance Committee	Dubna	19–20 October
Seminar Dedicated to the 90th birthday of M.G.Mescheryakov	Dubna	27 October
Meeting of the Programme Advisory Committee for Condensed Matter Physics	Dubna	10–11 November
Meeting of the Programme Advisory Committee for Particle Physics	Dubna	16–18 November
Meeting of the Programme Advisory Committee for Nuclear Physics	Dubna	20–22 November
Conference «Physics Programme with CMS Detector»	Russia, Moscow	22–24 November
Seminar in Honour of Professor I.A.Savin's 70th Birthday	Dubna	7 December

Dubna, 8 June. Dedication of a monument to D.I.Blokhintsev, the first Director of JINR

Dubna, 13–14 January. The 87th session of the JINR Scientific Council. Round-table discussion «JINR's cooperation with Russian research centres, universities and industrial enterprises»

Dubna, 17–18 March. Participants of the regular session of the Committee of Plenipotentiaries of the Governments of the JINR Member States visit the Laboratory of High Energies

Dubna, 8 February. The X meeting of the Joint Steering Committee for Implementation of the BMBF (Germany) – JINR Agreement on Cooperation and Use of JINR Facilities



Dubna, 26 March.
JINR Director V.G.Kadyshevsky addresses the Ceremonial meeting of the JINR scientific community on the occasion of the Institute's Foundation Day

Sarov, 1 February.
Working visit to the All-Russian Research Institute of Experimental Physics by JINR Vice-Director A.N.Sissakian (third from right) and FLNP Acting Director V.L.Aksenov (first on the right)

Dubna, 29 March. JINR's guest — Ambassador of Romania to Russia I.Diaconu (third from left)

Dubna, 19 October. Meeting of the JINR Finance Committee

Dubna, 16 May. Participants of the VIII International Seminar on Interaction of Neutrons with Nuclei

Dubna, 21–22 June.
The meeting of the Board of the International Association of Academies of Sciences

Dubna, 17 March.
Inauguration of a photo exhibition entitled «Polish Baltic Seashore» at the JINR Scientists' Club

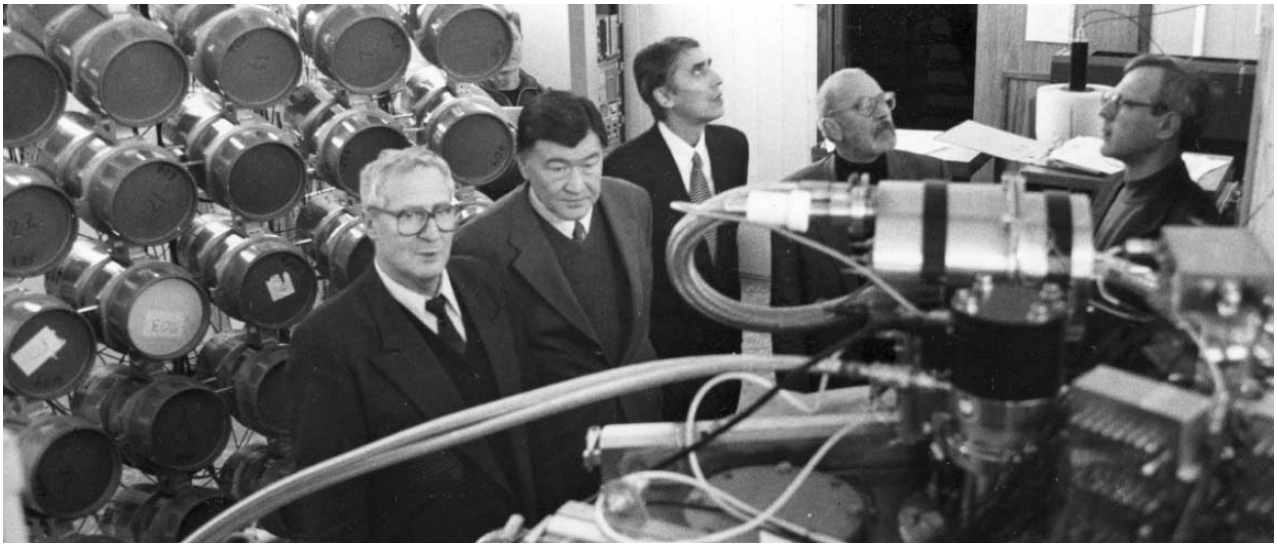
Dubna, 8 June. International Seminar «40 Years of the First Pulsed Reactor IBR»

Dubna, 21–27 June. Participants of the International meeting «ATLAS Week»

Dubna, 28–30 June. International Symposium «LHC Physics and Detectors»

St. Petersburg – Dubna, 1–14 July. The participants of the International Advanced Accelerator School visit Kizhi island

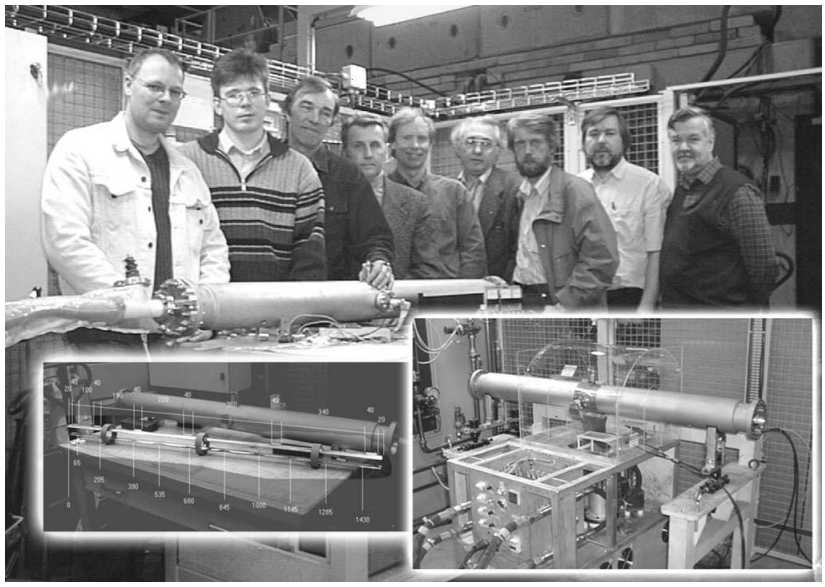
Dubna, 7 September. JINR Director V.G.Kadyshevsky welcomes the participants of the seminar «Science Towns of Russia»



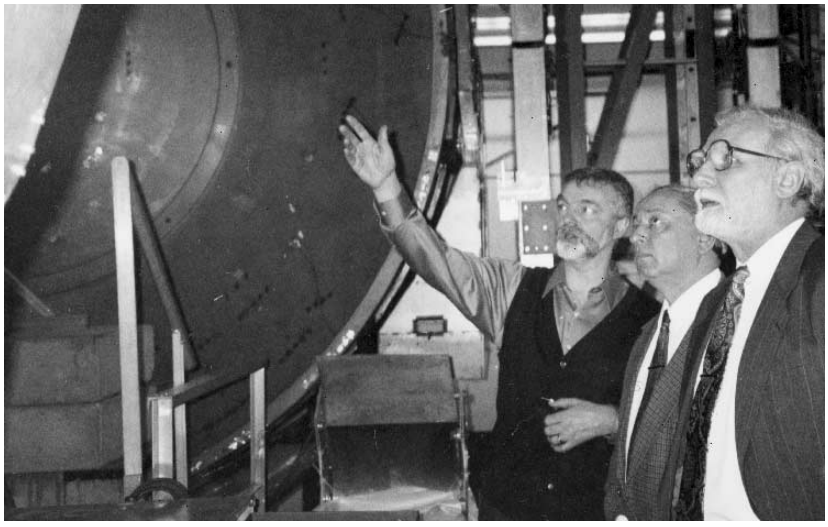
Flerov Laboratory of Nuclear Reactions. Visit to JINR of the newly appointed Plenipotentiary of the Republic of Kazakhstan to JINR Professor K.K.Kadyrzhanov (second from left)

Dubna, 5 October.
Visit to Dubna of the Ambassador of Ukraine to Russia N.P.Beloblotsky. Meeting of the Ambassador (first on the left) with Ukrainian staff members of JINR

CERN, April.
Participants of the LHC Damper development: the CERN–JINR team after the prototype tests



Fermi National Accelerator Laboratory (USA).
Visit to FNAL by JINR Director V.G.Kadyshevsky and Vice-Director A.N.Sissakian.
The Collaboration spokesperson H.Weerts (first from left) gives explanations for the D0 installation



Geneva, CERN. Construction of the tunnel for the Large Hadron Collider continues.
JINR's delegation, headed by Vice-Director A.N.Sissakian (second from left), is seen in the LHC cavern on the future site of the ATLAS detector

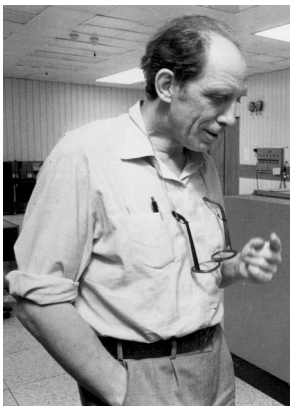
Tsukuba (Japan), 27 November. The signing of the General Agreement on JINR–KEK Scientific Cooperation.
In the photo (centre): Professor H.Sugawara, Director-General of KEK, and Academician V.G.Kadyshevsky, Director of JINR

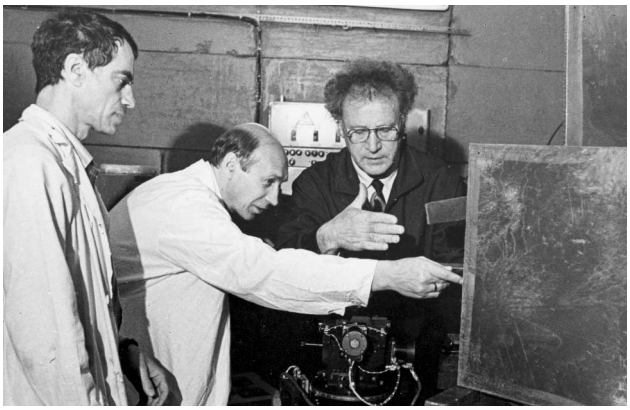
Caramulo (Portugal), August.
A group of participants of the 2000 European School of High-Energy Physics

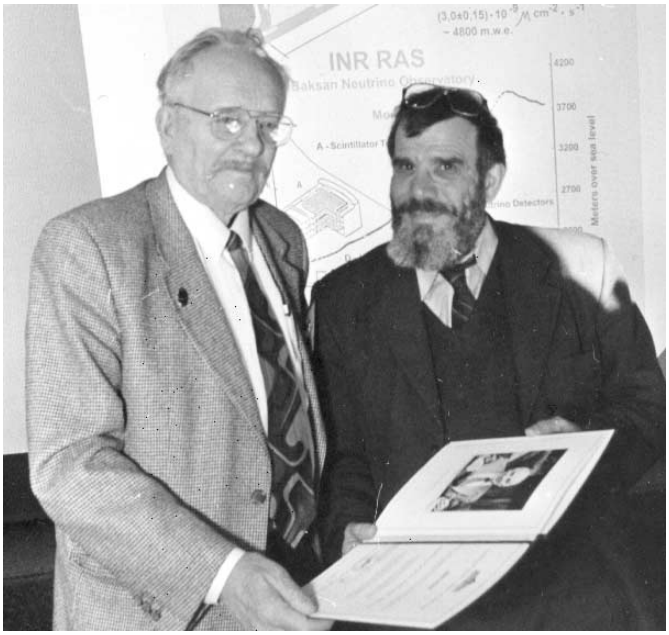
Brussels, 11–15 September. The joint JINR–CERN poster exhibition «Science Bringing Nations Together», held in the building of the European Parliament

Dubna, 22 November. Members of the Programme Advisory Committee for Nuclear Physics

Dubna, 11–15 October. Participants of the International Workshop of the COMPASS Collaboration







Laureates of the 2000 State Prize of the Russian Federation in the field of science and technology (left to right): Yu.M.Ostanevich (posthumously), A.M.Balagurov, V.L.Aksenov (JINR), V.A.Trunov (PNPI), V.V.Nitz (JINR)

Academician D.V.Shirkov, Honorary Director of the Bogoliubov Laboratory of Theoretical Physics, presents V.N.Gavrin (INP RAS, Moscow) with the 2000 B.Pontecorvo Prize

Laureates of the L.Meitner Prize for Nuclear Science of the European Physical Society (left to right): G.Münzenberg (Germany), Yu.Ts.Oganessian (JINR), P.Armbruster (Germany)

JINR • 2000

RESEARCH AND EDUCATIONAL PROGRAMMES OF JINR

BOGOLIUBOV LABORATORY OF THEORETICAL PHYSICS

In 2000 at the Laboratory, studies were continued on three first-priority themes approved at the 85th session of the Scientific Council: «Fields and Particles», «Theory of Nuclei and Other Finite Systems», and «Theory of Condensed Matter».

FIELDS AND PARTICLES

The theme includes a wide range of researches on modern topics in quantum field theory and particle physics. The following fields of studies are of main importance:

- Quantum symmetries, integrable models, supersymmetries with application to strings, gravity, and cosmology;
- Nonperturbative approaches to QCD;
- Standard model and its extension;
- QCD: spin effects, sum rules, and vacuum structure;
- Low-energy quark models and hadron spectroscopy.

Integrable models continue to play an essential role in present-day investigations in string and M-theories, in gauge theories, and in quantum gravity.

A new insight into the nature of symmetries and, as a consequence, into the origin of complete integrability of the supersymmetric Toda lattice equations is achieved. The conjecture concerning the possibility of a superfield formulation of the $N=(2|2)$ supersymmetric Toda lattice hierarchy, proposed earlier, is proved, and the algebras of the corresponding symmetries are exactly derived. The two-dimensional $N=(0|2)$ supersymmetric Toda lattice hierarchy is proposed and its $N=(0|2)$ superfield formulation is discussed. Bosonic and fermionic solutions to the symmetry equation corresponding to the two-dimensional $N=(0|2)$ supersymmetric Toda lattice equation and their algebra are constructed. An infinite class of new two-dimensional supersymmetric Toda-type hierarchies is discussed [1].

A universal functional equation is derived for eigenvalues of the integrals of motion for a wide class of discrete three-dimensional quantum integrable models associated with the Weyl algebra at the root of unity. In the simplest cases, this equation is equivalent to the Baxter $T-Q$ equation and, in general, to the complete «nested Bethe ansatz» chain of equations [2].

Till now **the supersymmetry** remains the most appealing idea in the theory of elementary particles. A series of interesting results were obtained in this area. The world-volume superfield equations of motion for the $N=1, D=4$ supermembrane as well as for the space-filling $D2$- and $D3$-branes are derived from nonlinear realizations of supersymmetries. A new polynomial representation for the $d=3,4$ Born–Infeld equations, with merely cubic nonlinearity, was proposed [3].

The most complete version of conformal $N=(4, 4)$, $2D$ supergravity was for the first time constructed by using the $N=(4, 4)$, $2D$ harmonic superspace. This supergravity theory is important for unambigous construction of the superstrings with the world-volume $N=(4,4)$ supersymmetry [4].

The dynamics of an $N=4$ spinning particle in a curved background is described by using the $N=4$ superfield formalism. The anti-de-Sitter spaces are shown to belong to the class of admissible manifolds [5].

Noncommutative gauge field theories play an important role in the nonperturbative string dynamics. The dynamics of excitations along brane vacuum realised by noncommutative solitons was studied. These excitations

are described by a nonlinear sigma-model for which classical solutions and statistical behaviour in the limit of small noncommutativity were found [6].

In the framework of solving an inverse problem for reducing polynomial Hamiltonians to the normal form, the method of construction of a class of integrable models is formulated on the basis of symbolic computational algebra package of REDUCE [7].

The quantum gravity remains a challenge to theoreticians. A new method of describing quantum field effects near rotating black holes and, more generally, on any stationary space-time was developed. The idea of the method is to go to an equivalent problem where the background itself is static, but there is an additional gauge connection corresponding to the rotation. This transition from one problem to another is similar to the Kaluza–Klein approach. The new method has a number of important applications. For instance, it enables one to derive the thermal part of the stress-energy tensor of quantum fields near the horizon of the Kerr–Newman black hole. Analogous derivation by other methods is extremely difficult because of complexity of the corresponding geometry [8].

The effective method was developed for constructing the spectral zeta functions in quantum field theories and quantum gravity with allowance for boundary conditions possessing spherical or cylindrical symmetries. For this purpose, the contour integration is used in the complex frequency plane as well as the uniform asymptotic expansions and the addition theorems for the Bessel functions. In this approach, the renormalization procedure is elaborated which leads to a finite value of the vacuum energy in the problems under consideration [9].

The reparametrization-invariant description of relativistic strings is developed by resolving the energy constraints. The method leads to a new continual representation of the causal Green functions and gives a new algebra of local constraints [10].

The lattice simulations remain the most powerful nonperturbative method in QCD and other gauge theories. The special effect of zero-momentum modes (ZMM) of the gauge field on the gauge dependent fermion correlators was studied. It was found that the standard Lorentz gauge fixing prescription in lattice theory provided gauge copies with ZMM. The Lorentz gauge employing nonperiodic gauge transformations for suppressing the ZMM (the ZML gauge) allows one to reach the global maximum of the Lorentz gauge functional. Furthermore, it provides reliable fermion mass determination, at least, if the hopping parameter κ is chosen not too close to the chiral critical line $\kappa_c(\beta)$ [11].

A self-consistent scheme — **Analytic Perturbation Theory** (APT) — is devised that relates renorm–invariant, effective coupling functions $\widetilde{\alpha}(s)$ and $\alpha_{\rm an}(Q^2)$. Non-power perturbation expansions are constructed for observables in Minkowskian (time-like) and Euclidean domains, that are free of extra singularities and obey better convergence in the infrared region. The basic tool is the «double spectral representation», similar to the representation for the Adler function, that stems from first principles of local QFT. A global APT scheme is constructed for the real QCD case in the whole space-like and time-like domain with various numbers of active quarks. The effect of π^2 terms in the APT expansions for the s-channel QCD effective coupling and observables, and its influence on the numerical values of $\overline{\alpha}_s$ extracted from experiments are analyzed. The main result is that the common two-loop (NLO, NLLA) approximation widely used in the five-quark ($\sqrt{s} \gtrsim 10$ GeV) region for a shape analysis contains a systematic negative 1–3 per cent error for the extracted $\overline{\alpha}_s^{(2)}$ values. The physical conclusion is that the $\overline{\alpha}_s(M_Z^2)$ value averaged over the $f=5$ data $\left\langle \alpha_s(M_Z^2) \right\rangle \simeq 0.124$ appreciably differs from the currently accepted «world average» ($=0.118$) [12].

The analytic perturbation theory was applied to describe the inclusive decay of the τ lepton. It is argued that this method gives not only a self-consistent description of the process in the time-like region (by using the initial expression for R_τ) and in the space-like domain (by using the analytic properties of the hadronic correlator), but also makes it possible to essentially reduce theoretical uncertainties associated with unknown higher-loop contributions and renormalization scheme dependence [13].

Studies were continued on **the minimal supersymmetric standard model (MSSM).** Soft supersymmetry breaking was examined in the superfield formalism. It is shown that it initiates soft masses for the auxiliary fields which enter into the renormalization group equations for scalar superpartners. Explicit solutions for masses of nonphysical particles are obtained up to three-loop order in the general case and in the MSSM. Arbitrariness in the choice of initial conditions is discussed [14].

The role of higher orders in the $b \to s\gamma$ decay rate in the MSSM was discussed. It is shown that if higher orders are taken into account, one can enlarge the allowed region in the MSSM parameter space. The range of possible values of the Higgs boson mass in the MSSM is found to be $m_{\rm h} = 115 \pm 3(\text{stop mass}) \pm 1.5(\text{stop mixing}) \pm 2(\text{theory}) \pm \pm 5(\text{top mass})$ GeV. This is valid for any value of $\tan\beta$ greater than 20. The values of $\tan\beta$ smaller than 3.3 are eliminated by the direct Higgs boson nonobservation [15].

Studies in QCD proceed to supply theoretical description of new, more subtle properties of hadronic processes. The spin azimuthal asymmetries recently observed in semi-inclusive hadron production on longitudinally (HERMES) and transversely (SMC) polarized targets were explained *without using any free parameters*. This explanation is based on preliminary experimental data from DELPHI on the left-right asymmetry in the fragmentation of transversely polarized quarks («Collins effect») and the theoretical calculation of the proton transversity distribution in the effective chiral quark soli-

ton model. On this basis, one can state that the proton transversity distribution could be successfully measured in future DIS experiments with *a longitudinally* polarized target, simultaneously with measuring the spin gluon distribution $\Delta g(x)$, for example, in the COMPASS experiment [16].

The basic hard exclusive processes: $\pi\gamma^*\gamma$ transition, pion and nucleon electromagnetic form factors were analyzed, and the analytic continuation of QCD formulas from the space-like to the time-like region of the relevant momentum transfers was performed. It was shown that for the hard perturbative QCD contribution to the hadronic form factors there were no *K*-factor-type enhancements. The soft part of the pion electromagnetic form factor was studied in a QCD sum rule inspired model, and it was shown that there existed noncanceling Sudakov double logarithms which result in a *K*-factor-type enhancement in the time-like region. Such an enhancement is supported by experimental data, thus providing another evidence that at present energies the hadronic form factors are dominated by the soft mechanism [17].

The twist-3 contribution to Deeply Virtual Compton Scattering was investigated. As a result, the manifestly gauge invariant amplitude of the order of $1/Q$ was obtained, and the respective contributions to the spin asymmetries were calculated. The result is further developed in several papers (Polyakov et al., Belitsky and Muller, Radyushkin and Weiss) and may be important for a simultaneous description of spin asymmetries recently reported by HERMES and CLAS/E1 [18].

Principles and **physics on photon-photon colliders** were reviewed. Main attention was paid to the nonlinear effects in the process of backward Compton scattering of circularly polarized laser beams focused on the bunch of high-energy longitudinally polarized electrons. The photon–photon luminosity and polarization characteristics are obtained. Also, the calibration processes were reviewed. The physical program on photon colliders is discussed in a conspective form [19].

A detailed next-to-next-to-leading order (NNLO) **QCD** analysis was performed of experimental data of the CCFR collaboration for the xF_3 structure function. It was found that the amplitude of the *x* shape of the twist-4 factor decreased in NLO and NNLO, though some remaining twist-4 structure seems to retain in NNLO in the case when statistical uncertainties are taken into account. The NNLO results for $\alpha_s(M_Z)$ values, extracted from the CCFR xF_3 data, are $\alpha_s(M_Z) = 0.118 \pm 0.002$ (stat) $\pm$ ± 0.005 (syst) ± 0.003 (theory), provided the twist-4 contributions are fixed through the infrared renormalon model, and $\alpha_s(M_Z) = 0.121^{+0.007}_{-0.010}$ (stat) ± 0.005 (syst) $\pm$ ± 0.003 (theory), provided the twist-4 terms are considered as free parameters [20].

The phenomenology approach successfully combines a rigorous formalism with additional theoretical ideas and experimental facts.

The investigation of processes with very high multiplicity when the inelasticity is close to unity and practically all incident energy is expended into the mass of produced particles is offered. We present new area of hadron physics investigations, which is beyond traditional conceptions of the hadron physics.

There is not any experimental information about processes of this kind and the phenomenology of this processes has already been formulated by introducing the formal classification of asymptotics over multiplicity. The interpretation of asymptotic classes in the perturbative QCD frame allows one to conclude that the very high multiplicity processes are mainly the central, i.e. hard, ones.

The statistical description of the inelastic processes in terms of the Schwinger–Keldysh type real-time finite-temperature field theory was developed. It was shown that this approach to the problem was rightful if the energy correlators are sufficiently small. This condition is in accordance with the criteria of N.N.Bogoliubov for the close-to-equilibrium processes and has the transparent meaning from the experimental point of view. It is shown that the perturbative QCD, with its leading-log ideology, is unable to describe the inelastic processes where the energy of created particles is comparatively small. For this purpose, a cardinally new form of the perturbation theory for the Yang–Mills field theory is developed [21].

In a chiral $U(3)\times U(3)$ quark model, if radial excitations of quarkonia are taken into account, it is shown that the experimentally observed scalar meson states in the energy interval from 0.4 to 1.7 GeV can be interpreted as members of two scalar meson nonets: the ground state and radially excited ones, and a glueball ($f_0(1500)$). In a $U(3)\times U(3)$ quark model without radially excited quarkonia, the glueball is introduced into the effective meson Lagrangian, by using the dilaton model. Masses and main strong decay modes of the scalar mesons were described in [22].

It was shown that the absolute normalization of the pion form factor asymptotics predicted by perturbative QCD was expressed in terms of the fundamental QCD vacuum parameter — the quark nonlocal condensate [23].

In the linear sigma model, the chromoelectic and chromomagnetic polarizabilities of pions by the gluon field were found, and on that basis, the $\pi J/\Psi$ cross section was estimated in the scattering length approximation to be $\sigma(\pi J/\Psi) \approx 1.9$ μb [24].

The so-called relativistic three-quark model (RTQM) was elaborated to study the properties of heavy baryons containing a single heavy quark (bottom or charm). Physical observables for the semileptonic and nonleptonic decays as well as for the one-pion and one-photon transitions were successfully described in this approach. It was found that the semileptonic decay rates were clearly affected by the choice of currents, whereas the asymmetry parameters showed only a very weak dependence on the choice of currents. The RTQM was also extended to include the effects of finite quark masses [25].

THEORY OF NUCLEI AND OTHER FINITE SYSTEMS

In 2000, investigations within the area «Theory of Nuclei and Other Finite Systems» were carried out in accordance with four projects. Namely,

— Nuclear structure under extreme conditions;
— Dynamics and manifestation of structure in nuclear and mesoscopic systems;
— Few-body physics;
— Relativistic nuclear dynamics.

The following main results were obtained in the field of **nuclear structure theory**.

A systematic microscopic study of the anharmonic properties of the double giant dipole resonance (DGDR) was carried out, for the first time, for nuclei with mass number A spanning the whole mass table. It was concluded that the corrections to the energy centroid of the $J^{\pi} = 0^{+}$ and 2^{+} components of the DGDR from its harmonic limit were negative, had a value of an order of a few hundred keV and followed an A^{-1} dependence [26]. A self-consistent random phase approximation for finite Fermi systems was extended to finite temperatures within the framework of the thermofield dynamics. A nonlinear coupling of the thermal Hartree–Fock equations with the equations of motion for the collective variables appearing due to a nonvanishing amount of thermal quasiparticles in the thermal phonon vacuum state was taken into account explicitly. The thermal occupation numbers were also calculated in a consistent way with the energies of the Hartree–Fock quasiparticles. Numerical calculations for the two-level exactly solvable Lipkin model demonstrated that within the thermal SCRPA a statistical behaviour of the system was described with appropriate accuracy at any temperature even if the Hartree–Fock field is fixed at its «spherical» configuration [27].

It is observed experimentally that an isomeric ratio (IR) for ^{137}Ba and ^{139}Ce equals about 0.13 while in ^{141}Nd and ^{143}Sm it is less than half the size. To explain this effect, the structure of the excited states in the energy region up to 6.5 MeV was calculated within the quasiparticle-phonon model. The single-particle component of the wave function is responsible for the large values of the transitions. The calculated value of IR is in very good agreement with the experimental data for all the four nuclei. A slightly different value of maximum energy with which the nuclei rest after a neutron decay of the giant dipole resonance is responsible for the reported effect of the A dependence of the IR [28].

Nuclear structure model based on the $U(6/12)$ graded algebra describes a nuclear system with collective quadrupole excitations and odd particle occupying single-particle states with angular momenta $j = 1/2, 3/2$, and $5/2$. It was shown that although in the general case the model Hamiltonian did not obey a dynamic symmetry, part of the eigenstates of even–even and odd neighboring nuclei formed supersymmetric multiplets [29].

The self-consistent harmonic oscillator model including the three-dimensional cranking term was extended to describe collective excitations in the random phase approximation. It was found that quadrupole collective excitations associated with the wobbling motion in rotating nuclei led to the appearance of two- or three-dimensional rotation [30].

Global properties of dinuclear systems treated as two touching nuclear clusters were compared with the corresponding quantities of super- and hyperdeformed nuclei. It was found that the hyperdeformed states of nuclei were close to those of nearly symmetric nuclear systems, whereas the superdeformed states could be considered as the states of asymmetric dinuclear systems. The super- and hyperdeformed states constructed from two touching clusters have large octupole deformations [31].

The nuclear theory methods were also applied in theoretical studies of metallic clusters.

An orbital quadrupole magnetic resonance (twist mode) was predicted in alkali metal clusters where it was represented by $I^{\pi} = 2^{-}$ low-energy excitations of valence electrons with strong $M2$ transitions to the ground state. The shell structure of clusters was fully exploited, which is crucial for the considered region of sizes ($8 \le N_{e} \le 1314$). In medium and heavy spherical clusters, the twist mode dominates over its spin-dipole counterpart and becomes the strongest multipole magnetic mode [32].

Various problems were investigated within the project **Few-Body Physics**.

The resonance transparency of repulsive barriers for bounded pairs of particles was studied. It was shown that a local minimum of the total potential generated metastable bound states, and their spectrum determined the positions of maxima in the penetration probability. Another conclusion is that the probability of tunnelling of two interacting particles from a false vacuum can be considerably larger than it was assumed before [33]. The mechanism of formation of the Efimov states of the helium ^{4}He trimer was studied when the force of the interatomic interaction was changed. It was shown that the Efimov levels arised from virtual levels which were in turn formed from (quasi)resonances settled on the real energy axis. The resonances including virtual levels are calculated by the method based on solving the boundary value problem, at complex energies, for the Faddeev differential equations describing the scattering processes ($2+1 \to 2+1; 1+1+1$). Moreover, it was shown that the excited state of the trimer was indeed the Efimov state [34]. Effect of a drastic change of the Auger decay rate due to the wave-function mixture was predicted for long-lived states of the antiprotonic helium. The effect takes place for the states whose energy is close to that of the specific short-lived ones. In the fall of 2000, after revival of the experimental programme in CERN, this prediction has been confirmed by the ASACUSA collabora-

tion [35]. Elastic ηd scattering was considered within the AGS formalism for various ηN input data. A three-body resonant state was found close to the ηd threshold. This resonance is sustained for different choices of the two-body ηN scattering length $a_{\eta N}$. The position of the resonance moves towards the ηd threshold when $\mathrm{Re}\, a_{\eta N}$ is increased and it turns into a quasi-bound state at $\mathrm{Re}\, a_{\eta N} = 0.733$ fm [36]. From the analysis of the recent JLab data for the reaction $p(e,e'p)\pi^0$ it was found that up to $Q^2 = 4.0$ (GeV/c)^2 the extracted $\Delta(1232)$ resonance helicity amplitudes $A_{3/2}$ and $A_{1/2}$ remained comparable with each other. This implies that the hadronic helicity is not conserved and that the pQCD limit is not yet reached at the above range of Q^2 [37].

At the end, let us enumerate the main results of the project **Relativistic Nuclear Dynamics**.

An analytic expression for the eikonal phase for the typical nuclear potential of the symmetrized Woods–Saxon shape was obtained. This expression can be widely applied in the analysis of intermediate energy nucleus– nucleus collisions at dozens of MeV/nucleon, thus permitting one to analyze the mechanism of scattering and perform fast numerical calculations [38]. A production of ϕ mesons in the near-threshold region using throughout the conventional «non-strange» dynamics was analyzed. The occurrence ϕNN interaction may show up in different unpolarized and polarization observables in the $\pi N \to N\phi$ reaction. A strong nontrivial difference between observables in the reactions $pp \to pp\phi$ and $pn \to pn\phi$ caused by the different role of the spin-singlet and triplet in the entrance channel was found. A series of predictions for the experimental study of this effect was presented [39]. A quantum statistical model of nuclear multifragmentation was proposed. The model exhibits the first order phase transition. Quantum statistics effects are clearly seen on the microscopic level of occupation numbers but are almost washed out for global thermodynamic variables and the averaged observables studied. In the latter case, the recurrence relations for multiplicity distributions of both intermediate-mass and of all fragments were derived and the specific changes in the shape of multiplicity distributions in the narrow region of the transition temperature was stressed [40].

THEORY OF CONDENSED MATTER

Theoretical investigations in the «Theory of Condensed Matter» were performed in the framework of the following projects:

— Strongly correlated systems;
— Dynamic systems: chaos, integrability and self-organization;
— Disordered structures: glasses, topological defects, nanostractures and Josephson junction;
— Mesoscopic and coherent phenomena in quantum systems.

In the studies of **strongly correlated systems**, models with strong electron correlations were investigated to elucidate physical properties of materials with complicated metal-insulator, magnetic and superconducting phase transitions like manganites, vanadates and cuprates.

An explanation of a «giant» oxygen isotope effect is suggested for the Curie temperature T_c recently observed in (La–Pr–Ca)MnO_3 manganites. The proximity of the ferromagnetic transition to the dielectric antiferromagnetic phase enables one to explain the experimental data by considering only weak electron-phonon interaction for the charge carriers [41].

The theory of magnetic superexchange is developed for a cuprate family member $Ba_3Cu_2O_4Cl_2$ and the quater-filled two-leg ladder system NaV_2O_5. By formulating the multiorbital Hubbard model and reducing it to the effective spin Hamiltonian the ground-state magnetic properties of the cuprate compound were analysed and additional noncollinear modulation of the antiferromagnetic structure was predicted [42].

Numerical evidence for the coexistence of metallic and insulating dynamical mean field theory solutions in a half-filled single-band Hubbard model in the Bethe lattice is found [43].

Superconducting pairing in the periodic Anderson model for d- and f electrons was investigated. The singlet superconductivity was suggested due to interplay of Kondo coupling, interorbital tunnelling, nonlinear correlations and on-site Coulomb repulsion [44].

A phenomenological approach determining the critical temperatures for homologous series of mercurocuprates depending on the number of copper-oxygen layers was proposed which provided a quantitative explanation of the experiments [45].

In the field of the theory of **dynamical systems: chaos, integrability and self-organization**, the following results should be mentioned.

By an inversion symmetry, it is shown that in the Abelian sandpile model the probability distribution of dissipating waves of topplings that touch the boundary of the system shows a power–law relationship with critical exponent 5/8. The probability distribution of those dissipating waves that are also last in an avalanche has an exponent of \$1\$. Extensive numerical simulations not only support these predictions, but also show that inversion symmetry is useful for the analysis of the two-wave probability distributions [46].

In the investigations of **disordered structures** the following main results were obtained.

A field-theory model was formulated to describe electronic states of a fullerene-like molecule. The existence of exactly one zero-energy mode due to a disclination was predicted. For 60° disclination the normalized electron density at zero energy was found to behave as $R^{-5/3}$, with R being the fullerene radius [47].

The asymptotical behaviour of the vortex-like solutions was studied in the framework of the gauge model of disclinations in elastic continuum. For 2π vortices, an important role of two characteristic lengths appearing in the gauge theory of defects was established [48].

The pronounced crossover in the thermal conductivity from T to T^2 due to phonon scattering by biaxial wedge disclination dipoles of finite length was found at low temperatures [49].

Low-frequency magnetic noise spectrum of a granular superconductor was calculated within the model of $3D$ random overdamped Josephson junction arrays. The existence of both white noise and flicker-like noise contributions was predicted [50].

The main topics of **mesoscopic and coherent phenomena in quantum systems** cover the expansion of basical quantum effects to the cases of finite (mesoscopic) systems.

Concerning the Bose-condensation theory, T_c for Bose-condensation of trapped atoms was found to depend on the deformation of the trap by the gravitational field due to the barrier cut-off and the redefinition of the atomic spectrum. The $2D$ Bose-condensation T_c shift caused by the gravity increases from $\sim 5\cdot10^{-7}$ K in the initial trap up to $\sim 2\cdot10^{-6}$ K in the deformed trap for the same number of atoms and the trap volume. This example predicts the probable nonstability of properties for mesoscopic devices planned to be used in the outer space [51].

The short-range particle correlations were considered for a dilute Bose gas with an arbitrary strong repulsion within the thermodynamically consistent model proposed earlier. This allowed for deriving correct values of the kinetic and interaction energies of the system involved. Found results are in agreement with the data of the Monte-Carlo calculations for the hard-sphere Bose gas [52].

The polaron energy and the effective mass are calculated for an electron confined in a symmetrical finite quantum well constructed of $GaAs/Al_xGa_{1-x}As$ layers. To simplify the study, an approximate model is developed in which parameters of a medium are averaged over the ground-state wave function. The authors obtained a rather monotonous behavior of the polaron energy as a function of the confining potential width and found a peak of the effective mass [53].

A complicated electrodynamics for strongly correlated systems of atoms, phonons and nuclei was elaborated [54].

Methods were developed for classical and quantum spin systems with toroid polarization in addition to the magnetic one. The generalized Maxwell equations for media with two toroid electric and magnetic polarizations were proposed, and patents were taken out for some mesoscopic set-ups based on the proposed theory. Dynamic description of the electromagnetics in mesoscopic, low-dimensional systems, and cyclic molecules were performed. The applications were found in the most fundamental fields of physics related to the problems of quantum gravity [55].

COMPUTER FACILITIES

For the first time at the BLTP, the server with two processors Alpha with the clock rate 750 MHz was installed (http://thsun1.jinr.ru/guide/alpha). Peak productivity of 3 GFlops and 2 GB of the RAM allows one to solve, with the new computer, the most complicated problems with the use of Fortran, C, C ++, Reduce, Form.

With the purpose of improving the performance of the computer network at BLTP, the first stage of a new cabling system based on a twisted pair (UTP) was developed. The high-speed Fast Ethernet switch was installed. The first stage of the UTP network covers about 100 rooms at BLTP and provides connection to the switches for more than 200 computers. Now, the new cabling system allows one to connect, via Fast Ethernet, all of BLTP servers and about 30 most powerful PCs (http://thsun1.jinr.ru/guide/lan/lan_2000.png).

During 2000, there were purchased and installed 13 modern personal computers based on the Pentium-III. On the cluster of workstations, the transition to the Solaris 7 operating system was completed, and some packages of the applied software were refreshed. The object-oriented system ROOT developed at CERN for the numerical calculations and graphical representations of results was installed. Creation of the guide to computer resources of BLTP was started (http://thsun1.jinr.ru/guide).

The resources of the JHEP server (http://jhep.jinr.ru), the accelerator of access to xxx.itep.ru (http://thsun1.jinr.ru:1081) and a file archive (http://thsun1.jinr.ru/file-archive.html) were extended. The search engine for the keyword-based document retrieval from the archive was installed. The caching proxy-server was started (the configuration file — http://thsun1.jinr.ru/proxy.pac). This development became possible due to funding from RFBR (The Russian Foundation for Basic Research).

MEETINGS, SCIENTIFIC COLLABORATION

In 2000, the Laboratory participated in 11 international conferences and workshops held in Dubna, Prague and Kharkov.

The International Conference «Nuclear Structure and Related Topics» was held in Dubna on 6–10 June. The tradition to organize conferences and schools on selected topics in nuclear structure was established in the 1960s by the outstanding nuclear theorist Prof. V.G. Soloviev. Thanks to his efforts, these conferences have become popular and highly prestigious in the international scientific community. The organizers dedicated this conference to the memory of Professor V.G.Soloviev who would be 75 on 12 October, 2000. Among more than 100 participants of the Conference were nuclear scientists from JINR and its Member States, many European countries, as well as from Iran, Japan and the United States. The Conference programme, which included more than 50 reports, appeared to be quite dense, so that two parallel sessions were organized. A large part of the talks dealt with theoretical and experimental studies of nuclei far from stability.

On 31 July–5 August, Dubna hosted the XXIII International Colloquium on Group Theoretical Methods in Physics. The first colloquium of this series was held in 1972 in Marseille (France) and since then it has been organized in different countries on a regular basis. On the territory of Russia it was organized only once, in 1990, in Moscow. Therefore, the decision taken by the Standing Committee of the Colloquium in 1996 to hold this meeting in Dubna was a recognition of the important role of our Institute in developing this field of mathematical physics. The programme included 15 plenary and around 160 section talks presented by more than 240 participants from 36 countries, including 10 JINR Member States.

The Laboratory participated in the organization of three conferences in the JINR Member States: IX International Colloquium «Quantum Groups and Integrable Systems» (June 22–24, Prague, Czech Republic); International Workshop «Symmetries and Spin» (July 17–22, Prague, Czech Republic); International Conference «Supersymmetry and Quantum Field Theory» (July 25–29, Kharkov, Ukraine). The Conference in Kharkov was dedicated to the memory of the outstanding theoretical physicist Dmitry Vasilevich Volkov (1925–1996). A good deal of efforts in organizing and conducting the Conference were undertaken by JINR physicists, first of all from the Bogoliubov Laboratory, which signified in favor of the long-standing and fruitful relations of the disciples with scientists of the Laboratory and the Institute.

In 2000, the regular workshops organized by the Laboratory: «Nucleation Theory and Applications» (April 3–28); «Heavy Quark Physics», (April 6–8); «Calculations for Modern and Future Colliders», (July 9–23); «Hot Points in Astrophysics», (August 22–26); «Quantum Gravity and Superstrings», (28 August – 8 September) were held; most of them were supported by UNESCO, BMBF, the Russian Foundation for Basic Research, the Heisenberg–Landau Programme, the Bogoliubov–Infeld Programme.

At the European School of High-Energy Physics (Caramulo, Portugal) organized by JINR and CERN, D.I.Kazakov presented a lecture course «Beyond the Standard Model».

In 2000, the international collaboration was supported by grants of the plenipotentiaries of Bulgaria, the Czech Republic, Poland, the Slovak Republic, Hungary, and the JINR Directorate; the collaboration with German theorists was based on the Heisenberg–Landau Programme; and with Polish theorists, on the Bogoliubov–Infeld Programme. A new programme of collaboration with Czech theorists, the Blokhintsev–Votruba Programme, was established.

Some studies were carried out in collaboration with scientists from Western Europe in the framework of the JINR–INFN, JINR–IN2P3 agreements and on the projects supported by INTAS, RFBR–DFG, RFBR–CNRS.

During his visit at CERN, A.T.Filippov met G.Altarelli and agreed to prolong the agreement between the CERN TH and the Bogoliubov Laboratory.

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LABORATORY OF HIGH ENERGIES

At present the scientific programme of the Laboratory of High Energies (LHE), Joint Institute for Nuclear Research (JINR), is concentrated on investigations of interaction of relativistic nuclei in the energy region from a few hundred MeV to a few TeV per nucleon to search for manifestations of quark and gluon degrees of freedom in nuclei, asymptotic laws for nuclear matter at high energy collisions as well as on the study of the spin structure of the lightest nuclei. Experiments along these lines are carried out with the beams of the Synchrophasotron-Nuclotron accelerator complex as well as of other accelerators at CERN (SPS, LHC), BNL (RHIC), GSI (SIS) and at CELSIUS storage ring in Uppsala (Sweden).

During several years the LHE research programme has been performed mostly on the Nuclotron, and the Synchrophasotron is used practically only for the research with polarized deuteron beams. The Nuclotron is based on the unique technology of the superconducting magnetic system, which was proposed and investigated at the Laboratory [1]. In the near future we are planning to obtain polarized beams at the Nuclotron, too.

ACCELERATION COMPLEX DEVELOPMENT

Two years ago only the internal beam of the Nuclotron was used for physics experiments. In the end 1999, the external beam of the Nuclotron was obtained by means of the beam slow extraction system constructed on the base of superconducting elements. Now the experiments at the Nuclotron external beams have started.

Scheme upgrading of the Nuclotron cryogenic helium refrigerators KGU-1600/4.5 is performed. The precooling of the compressed helium flow by liquid nitrogen has been substituted with adiabatic expansion in the turboexpanders installed additionally. As a result of the first tests, liquid nitrogen consumption in the 18th Nuclotron run (November 16 – December 10, 2000) was reduced from a usual figure of 357 tons to 236 tons (Fig. 1). At the further operational development of the system the saving of liquid nitrogen will be doubled.

This upgrading has not only reduced the cost of the accelerator operation, but it has also taken off restrictions on running time, since after modernization the liquid nitrogen consumption of the Nuclotron will be no more than the capacity of the liquid nitrogen plant of the Institute. In two runs, the total running time of the Nuclotron was limited by 949 hours.

The total running time of the Synchrophasotron was limited by 384 hours. In 2000, the users compensated the cost of the beam time. The dominant condition of the machine operation is the attraction of the users' resources. In spite of a continuous rise of the electricity cost, the number of users does increase. First of all, these are the polarized beam users. The interest to the traditional beams of light nuclei is still very big.

In the first runs of the Nuclotron with the extracted beam, two set-ups (STRELA and SCAN-2) were used for physical research. Simultaneously the Laboratory continued the experiments at the internal beams of the Nuclotron.

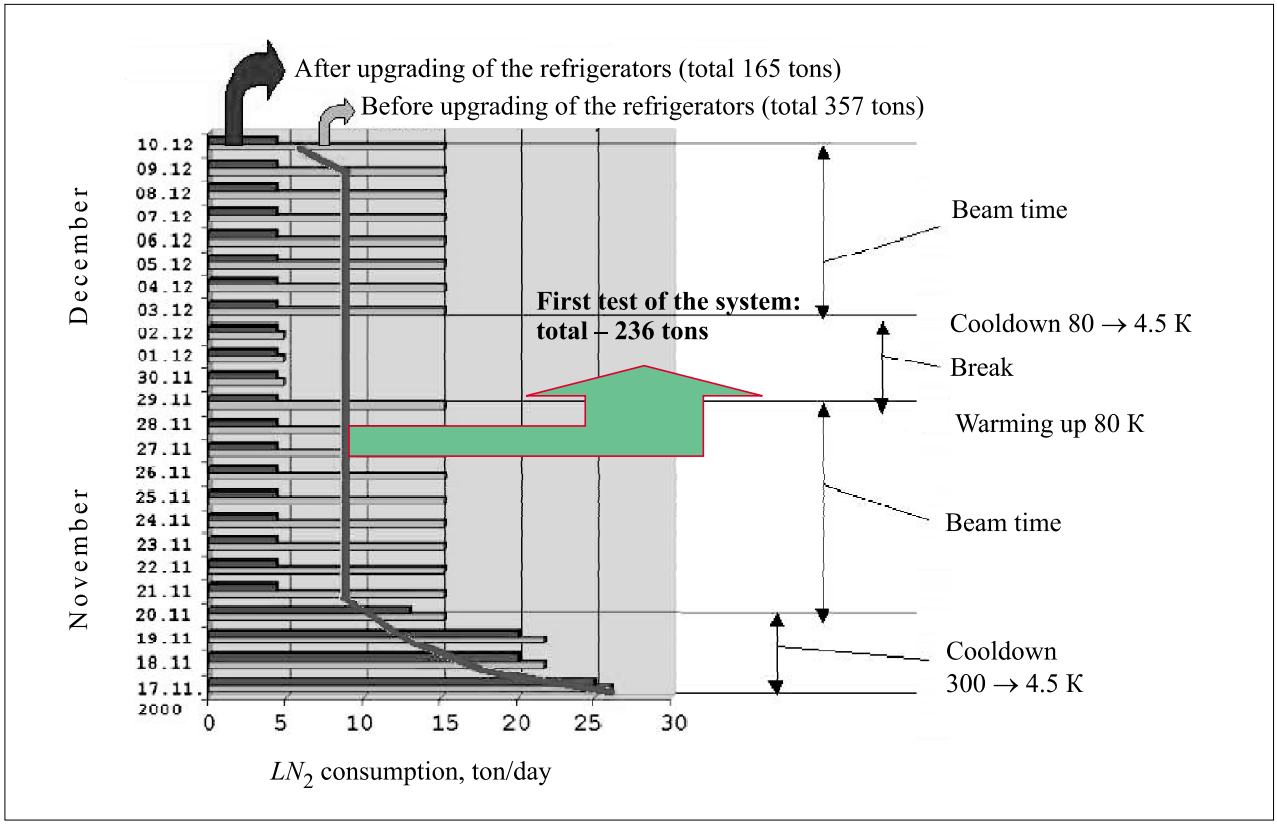

Fig. 1. The result of the first tests: liquid nitrogen consumption in the 18th Nuclotron run was reduced from a usual figure of 357 tons to 236 tons

EXPERIMENTS ON THE EXTRACTED NUCLOTRON BEAM

The **STRELA** experiment (Spokesmen: V.V.Glagolev, N.M.Piskunov). The STRELA spectrometer was prepared to use the slow extraction Nuclotron beam. It consists of a liquid hydrogen target, an analyzing magnet and the aligned 9 scintillation and Cherenkov counters. There were two beam runs in March and December in 2000. The main goal was to study charge-exchange processes in the $dp \to (pp)n$ reaction to define the spin-dependent part of the charge-exchange np elementary amplitude. Due to a bigger size of the beam spot at the target place, the polyethylene target was used instead of the liquid hydrogen one. The STRELA detectors were aligned along the direction of the break up protons at the zero angles and the half momentum of the primary deuterons.

The STRELA set-up is a magnetic spectrometer with a small angular acceptance (0.5 degree) and this allows tuning on a maximum of a stripping curve by changing the magnetic field of the analyzing magnet. The distribution of the amplitudes of the single Cherenkov counter signals is presented in Fig. 2. It is seen that even from one Cherenkov counter (at the amplitude resolution of 18.4 %) it is possible to select events with two protons at a level of $3 \cdot 10^{-3}$. There are 5 counters of that kind in the STRELA set-up.

In the December run some period of time the STRELA set-up was exposed to the beam of carbon nuclei with momenta of 1.75 GeV/c/nucleon. The distribution on charges of fragments at zero degrees has been obtained. The two-dimensional distribution of amplitudes from two Cherenkov counters is presented in Fig. 3. A good charge separation of fragments is seen and it is possible to select separate isotopes. Thus, the carried out researches have shown in principle that the STRELA set-up can be used for a wider range of investigations.

The SCAN-2 set-up is aimed to study the proton-formation length in $d + A_T \to p_1(0^\circ) + p_2(0^\circ) + X$ reaction. Also, the 2000 Nuclotron runs with the external deuteron beam have obtained the experimental information at the SCAN-2 set-ups, which is analysed now.

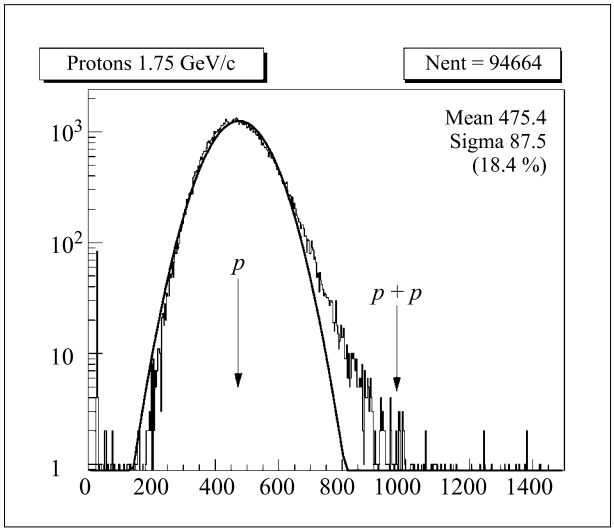

Fig. 2. The distribution of the amplitudes of the single Cherenkov counter signals

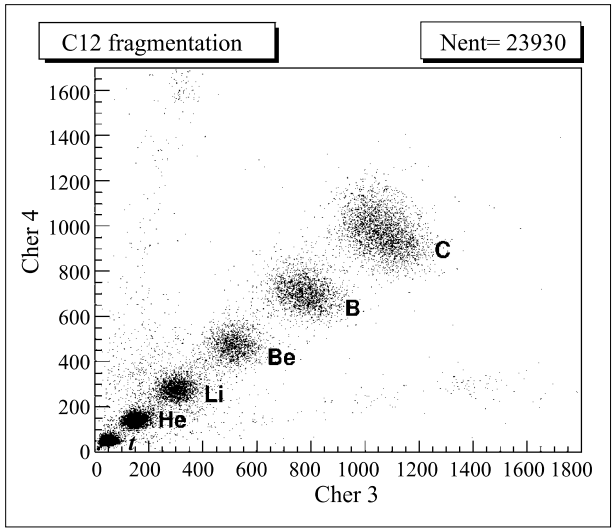

Fig. 3.The two-dimensional distribution of amplitudes from two Cherenkov counters

EXPERIMENTS ON THE INTERNAL NUCLOTRON BEAM

The target fragmentation into two cumulative protons by means of the **SKAN-1** set-up (Spokesman S.V.Afanasiev) is investigated at the internal beam of the Nuclotron. The goal of the experiment is measuring the transversal dimension of the nucleus-nucleus interaction region. The method is the measurement correlation of cumulative protons, emitted at a small relative momentum. Correlations of protons, emitted in the angle interval between 106 ÷112° in the laboratory system, are studied in the reactions $d + \mathrm{C} \rightarrow p + p + X$ and $d + \mathrm{Cu} \rightarrow p+p+X$ ($p_d = 2A \cdot$ GeV). Approximately the same transversal radius for dC and dCu interactions: $r_{d\mathrm{C}} = 3.0 \pm {}^{0.5}_{0.4}$ fm and $r_{d\mathrm{Cu}} = 2.6 \pm {}^{0.8}_{0.7}$ fm has been obtained. These investigations will be continued for other projectiles and targets.

The group of **MARUSYA** (Leader Anton Baldin) collaboration has begun investigations of the secondary fragment yield in the result of interaction of the internal Nuclotron beams with heavy targets by using a thin semiconductor detector. This group has obtained a good separation of secondary fragments with very low energies in the region from 2 up to 25 MeV in the d + Au interaction at 1.044 GeV deuteron energy (Fig. 4). These data are in the process of analysis now and will be used to study the effect of the full destruction of the nuclei because the energies of the secondary fragments are very low.

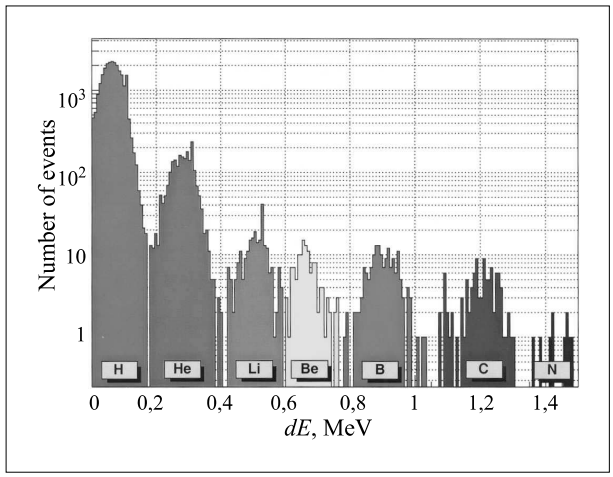

Fig. 4. Separation of the secondary fragments for d + Au reaction at 1.044 GeV deuteron energy

EXPERIMENTS ON THE LHE SYNHROPHASOTRON

Project SPHERE. The nucleon model can describe many properties of atomic nuclei. But it is clear that applicability of the nucleon model is limited because the nucleons are composite particles. It is natural to expect deviations from the nucleon model for the configuration where distances are compared with nucleon size separate nucleons. The description of nucleons at short distances is related to the following poorly studied questions as the

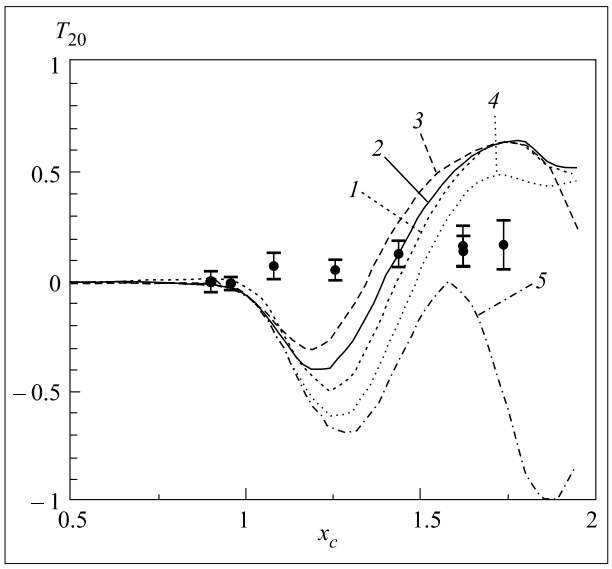

Fig. 5. Tensor analyzing power T_{20} for the reaction of deuteron fragmentation into pions. The calculation results are compared with the experimental data from [2,3] at the projectile proton momentum $P_p = 4.45$ GeV/c. Curve *1* corresponds to the calculus by neglecting the internal structure of the elementary vertex $NN \to \pi X$. The other lines correspond to the calculus by using various types of the nonrelativistic DWF: the Paris one *(2)*, the RSC *(3)* and two Bonn types: the full Bonn DWF *(4)* and the relativistic Bonn DWF *(5)*, respectively

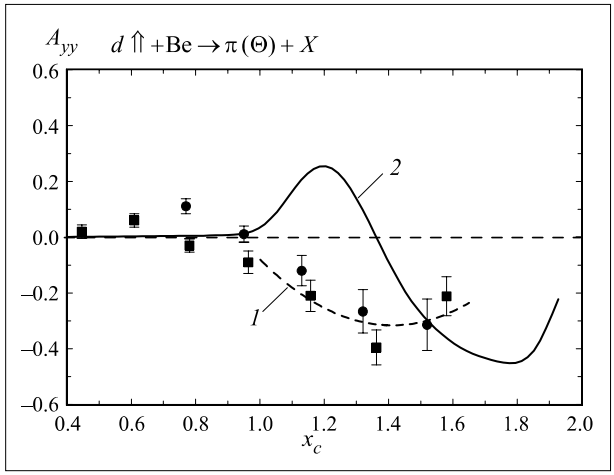

Fig. 6. Tensor analyzing power A_{yy} for the reaction of deuteron fragmentation into pions at a nonzero angle (very preliminary). *1* — approximation of experimental data by quadratic dependence; *2* — the calculation is performed in IA [4]; ■ — 180 mrad; ● —135 mrad

problem of confinement and problems of the description of the bound state of the particle (QCD for long distances) with relativistic momentum (short distances correspond to the high momentum). The deuteron, as the simplest nucleus, («hydrogen atom» for nuclei physics) is especially interesting. The nontrivial spin structure of deuteron (D wave admixture) gives a good opportunity for the reaction with the polarized deuteron. There are a lot of predictions for reactions with the polarized deuteron based on the nucleon–nucleon model. The experiments on studying the tensor analyzing power T_{20} for the polarized deuteron break-up reaction $D\uparrow + A_t = p + X$ are examples of these predictions. These experimental data obtained in Saclay and Dubna (for higher internal momentum) have shown that T_{20} has a big value and is described by calculations based on impulse approximation (IA) only for internal momentum $k \le 0.2 \div 0.3$ GeV/c. The approximation mechanism additional to IA (rescattering, FSI ...) allows one to describe experimental data up to $k \le 0.5$ GeV/c. But there are no calculations based on the nucleon model describing T_{20} for the whole measured region.

These deviations of the experimental data from calculations can be related to the manifestation of nonnucleon degrees of freedom in the deuteron wave function (DWF) for these small distances ($k \le 0.5$ GeV/c corresponds to the distances $l = 0.4$ fm). In this case it is natural to use, as a probe, hadrons with quark contents different to those of the nucleon. It was one of the reasons to study polarization observable for the reaction of deuteron fragmentation into cumulative (subthreshold) pions at zero angle $D\uparrow + A_t = \pi(0^\circ) + X$ on the beam of the polarized deuteron of the accelerator complex of LHE, JINR (this complex gives the polarized deuteron beam with a higher energy). Physicists from Bulgaria, Japan and some institutions of Russia took part in these measurements. The results for the tensor analyzing power T_{20} have been obtained and are presented in Fig. 5 [2,3]. From this Figure one can see that the value of T_{20} is small with respect to the prediction based on the nucleon model [4]. For this reaction a nonzero value of T_{20} is connected to the anisotropic part of DWF. In the framework of the nucleon it is impossible to understand why the D wave (and P wave in more sophisticated models) does not manifest itself as it happens in the deuteron break-up reaction (as a minimum for $k \le 0.2 \div 0.3$ GeV/c). It should be noted that the value of rescattering for the cumulative pions production is smaller than for the deuteron break-up reaction as a minimum because the pion–nucleon cross section is smaller than the nucleon–nucleon one.

The measurements of the tensor analyzing power A_{yy} for the same reaction at nonzero angles have been performed in 2000 in order to clarify the reaction mechanism. The physical meaning of A_{yy} is very close to T_{20} (for zero angle it is equality $A_{yy} = -\sqrt{2} \cdot T_{20}$). The preliminary data (obtained on-line) are shown in Fig. 6 and look unbelievable. From these data one can see that A_{yy} has a visible value related (as it is noted before) to the anisotropic part of DWF. But, on the other hand, these data are in a strong contradiction (even the sign is opposite) to the prediction of the nucleon model. It should be mentioned that additional to IA mechanisms (like rescattering), if it is significant, rather reduce the value of A_{yy}.

If one takes into account the data for T_{20} (Fig. 5) obtained at the zero angle and the data for A_{yy} (Fig. 6) obtained at the nonzero angle for deuteron fragmentation into cumulative pions, the following questions arise: Why does the T_{20} have a small value as it should be for a nearly isotropic source of pions, while at the same time A_{yy} has a big absolute value as it should be for a strongly anisotropic source? Why is the A_{yy} sign opposite to that predicted by calculations in the framework of the nucleon model?

One of the possible answers is that for a big internal momentum (up to $k \geq 0.5$ GeV/c, internucleon distance $l \leq 0.4$ fm) the nonnucleon degrees of freedom should be taken into consideration. In other words, to describe the deuteron core structure, more sophisticated deuteron models are necessary that would take into account the inner structure of the nucleon (like the quark cluster model including the spin structure).

From this point of view it will be interesting to make exclusive or semiexclusive measurements. It will be interesting to measure the same values for production of particles with quark contents different from the pion. Especially interesting is K^-, the particle consisting of the sea (for nuclei) quark. This possibility was studied and it was shown that for data taking with a reasonable accuracy it is necessary to have a longer beam time (about a month).

MSU-SPHERE experiment. The experiment to investigate the scattering of the polarized protons on the intranuclear nucleons started at the LHE Synchrophasotron. The physicists of the Nuclear Physics Institute of the Moscow State University and JINR, LHE carry out this work in the frame of the «Leading Particles» experimental programme. The main task of the experiment is to measure the analyzing power reduction at the scattering on the intranuclear nucleons in the ratio to the scattering on the free ones. It allows one to test critically the RIA model description of the hadron–nucleus interaction, which predicts significant effects for the spin observable in the investigated phenomena, and to obtain a new information about the nucleon clusterization. Moreover, this measurement is important for the methodical task of the construction and optimization of carbon polarimeters operating in the GeV region of energies.

The method of polarized deuteron stripping developed at the SMS MSU set-up in 1992–95 has been used for the polarized proton beam production. The beam polarization was permanently controlled by the additional beam line polarimeter. At the first run (June 2000) the analyzing power was measured for $d\uparrow + C \rightarrow p_L + X$ reaction (including the control measurement at the hydrogen (CH_2 target)) at two values of the initial energy and for a number of leading proton momenta. The obtained data were presented at the XV ISHEPP, Dubna.

The goal of the **FASA** project is to study the mechanism of the «nuclear thermal multifragmentation» induced in heavy targets by light relativistic ions. It was proved for the first time by the FASA group in 1994, by

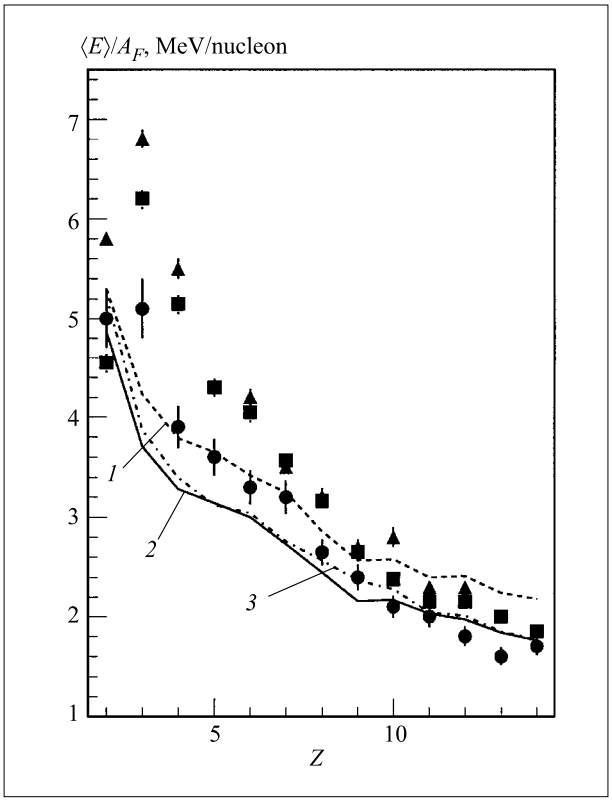

Fig. 7. The mean kinetic energies per nucleon of outgoing fragments with charge Z measured at $\theta = 89°$ for p(8.1 GeV) + Au (*1*, ●), ^{4}He(14.6 GeV) + Au (*2*, ■) and ^{12}C(22.4 GeV) + Au (*3*, ▲), collisions. The lines are calculated using INC* + SMM and assuming no flow

the fine angular correlation measurements for the intermediate mass fragments (IMF, $2 < Z < 20$), that this process is indeed a new multibody decay mode of very hot nuclei, governed mainly by the thermal excitation energy. In 2000, the FASA group concentrated on studying the IMF kinetic energy spectra, as they reflect, due to the «Coulomb law», the geometry and dynamics (expansion) of the emitting source. By comparing the data from p + Au collisions with those from the reactions induced by ^{4}He and ^{12}C beams, the research group evidenced a transition from the pure statistical process to the behaviour reflecting dynamics. It was shown that a spatial distribution of fragments at freeze out could be inferred from the observed collective component of IMF kinetic energy.

The experiments were performed using the modified 4π FASA set-up installed at the external beam of the JINR Synchrophasotron. Figure 7 shows the mean kinetic energies per nucleon of fragments emitted in collisions of p(8.1 GeV), ^{4}He (14.6 GeV) , ^{12}C (22.4 GeV) with Au. The calculated values of $\langle E \rangle / A_{\mathrm{IMF}}$ (shown by lines) were obtained with the combined approach, included the empirically modified Intranuclear Cascade Code (INC*) followed by the Statistical Multifragmentation Model (SMM) [5]. The measured energies are close to the calcu-

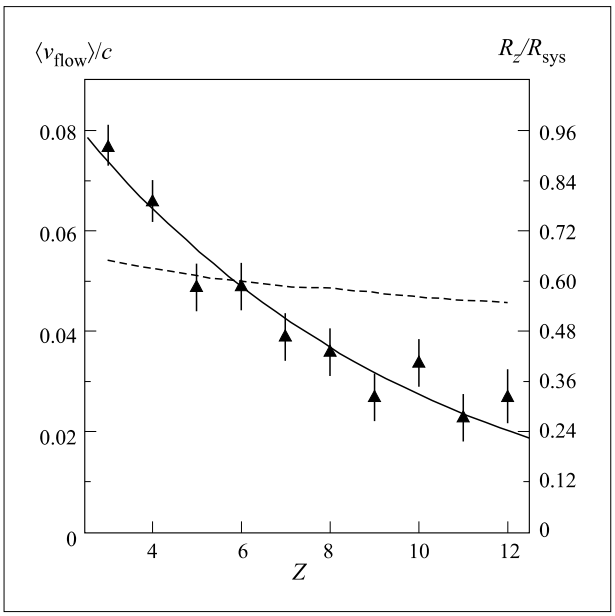

Fig. 8. Experimentally deduced mean flow velocities (▲) for $^{12}C + Au$ collisions as a function of the fragment charge (left scale), and the mean relative radial coordinates of fragments (right scale), obtained under assumption of a linear radial profile for the expansion velocity. The dashed line shows the mean radial coordinates of fragments according to the SMM code

lated ones for the proton induced reactions, but the experimental data for ^{4}He and ^{12}C beams exceed remarkably both the calculated values and the measured ones for $p + Au$ interaction. This enhancement is attributed to the radial collective flow (driven by the thermal pressure) in the systems (target spectator) which are hotter in the case of heavier projectiles. The estimation of the fragment flow energy is made as a difference between the measured IMF energies and those calculated by the model without any flow (lines in Fig. 7) [5,6]. The flow energies per nucleon are going down with the fragment charge from ~ 2 MeV for Be to ~ 0.4 MeV for Ne for C + Au collisions.

The corresponding mean flow velocities for different fragments are given in Fig. 8. The right scale gives the relative mean radial coordinates of fragments. It is obtained under assumption of a self-similar radial expansion when the local velocities are linearly dependent of the distance of the particle from the centre of mass. The dashed line shows the mean radial coordinate of fragments according to the Statistical Multifragmentataion Model. Note the significant deviation of the data from the model prediction, which may be caused by the fact that the model uses a uniform density distribution and, hence, a rather constant probability of fragment formation in any point of the available volume. The data indicate that the heavy fragments are predominantly located in the interior of the nucleus.

The present study has shown that in spite of the success of the statistical multifragmentation models, the description of the freeze-out condition might be still too simplified. The fragment energy spectra provide sensitive probes for the source configuration and emission dynamics. An additional information in that sense was obtained in paper [7] devoted to the study of the correlation between the energy spectra shape and fragment multiplicity.

THEORETICAL RESEARCH AND INTERPRETATION OF THE EXPERIMENTAL DATA

The generalization of correct KNO scaling is presented. It allows one to describe the multiplicity distributions of both π^+ and π^- mesons in different nucleon–nucleon and nonannihilation antinucleon–nucleon interactions by the same scaling function $\Psi(z)$ and the same energy dependence of the scale parameter. The multiplicity distributions in different antinucleon–nucleon annihilation reactions are described by another function $\Psi(z)$. In this case the slope of the scale parameter energy dependence is about 1.5 times greater than for nucleon–nucleon interactions [8].

The quantum-mechanical Aharonov-Bohm effect at the diffraction of charged particles on a toroidal solenoid, incorporating the magnetic field inside, is investigated [9]. The integral and differential cross sections of elastic scattering depend on the magnetic flux inside the solenoid even in the presence of a ring-like «black» screen, not allowing the charged particles to penetrate the region of the magnetic field localization. The relations, describing the transport cross section of elastic scattering of charged particles on the toroidal solenoid, are derived in the eikonal approximation and in the frames of the unitary model of scattering with the sharp change of partial amplitudes. The transport cross section of scattering is proportional to the average transfer of the longitudinal momentum to the scattered particle, and it can be expressed through the force operator. It is shown that in the absence of the screen the transport cross section of scattering on the toroidal solenoid is really determined by that part of the incident beam only, which intersects the internal region of the toroidal solenoid, where the strength of the magnetic field and, thus, the Lorentz force are not equal to zero. Meantime, the transport cross section of scattering on the toroidal solenoid, closed by the ring-like «black» screen, does not depend on the magnetic flux in-

side the solenoid, and it coincides with the transport cross section of diffraction on the screen itself. In so doing, the contribution from the scattering on the hole in the screen, depending on the magnetic flux, is entirely compensated by the contribution from the interference of amplitudes of scattering on the hole and on the «black» screen.

The analysis of experimental data on the hadronic resonances is performed in the systems decaying into usual and strange particles (Yu.Troyan). It is shown that the law of square dependence of resonance spin on its mass has been violated in all systems. The phenomenological potential is constructed with the help of them, the universal dependence of resonance spin on its masses can be found for all investigated resonances contained *u*, *d* and *s* quarks. The universal description of the dependence is found for all systems. Also, the analysis of the spin dependence on the masses of astrophysical objects (asteroids, planets, and stars) has been done. The obtained results are compared with the results of R.M.Muradyan. The investigation has been reported at the seminar in LHE (Leader — Academician A.M.Baldin).

Investigations were carried out to search for and study resonances in the $\pi^+\pi^-$ system based on 45388 events from the reaction $np \to np\pi^+\pi^-$ in *np* interactions at $P_n = (5.20 \pm 0.16)$ GeV/*c* in 1 m HBC of LHE, JINR. Using the criteria $\cos\Theta^*_p > 0$ and $\left|X^*_{\pi^+ + \pi^-}\right| \le 0.5$, nine peculiarities were found at the masses of (350 ± 11), (405 ± 10), (505 ± 8), (609 ± 5), (665 ± 11), (754 ± 4), (878 ± 10), (1155 ± 11) and (1235 ± 23) MeV/c^2 (see Fig. 9 and [10]). The excess above the background for them was 2.3, 4.8, 4.1, 2.5, 2.9, 7.8, 2.2, 4.9, and 4.7 S.D., respectively. The experimental widths of the resonances varied within the region from 16 to 43 MeV/c^2, that is comparable with the experimental mass resolution. The comparison with the effective mass spectrum of $\pi^-\pi^0$ combinations from the reaction $np \to pp\pi^-\pi^0$ has shown that the corresponding peculiarities mentioned above were absent in this spectrum. Therefore it is necessary to attribute the value of isotopic spin $I = 0$ for the peculiarities found in the mass spectrum of the $\pi^+\pi^-$. The estimation of spin was carried out for the most statistically provided resonances at the masses of 405, 505, and 754 MeV/c^2. It has been determined with a high degree of confidence that $J = 0$ for $M_R = 754$ MeV/c^2; and the most probable value $J = 0$ for $M_R = 405$ MeV/c^2 and $M_R = 505$ MeV/c^2. Therefore it can be affirmed that there were found, at least, 3 states with quantum numbers of σ_0 meson $0^+(0^{++})$ at the masses of 405, 505, and 754 MeV/c^2. The preliminary data on the resonance with the mass equal to 754 MeV/c^2 published in 1998, were included in «Eur. Phys. Jour. C» (2000. V. 15. P. 1) (Particle Data Group), (URL: http:// pdg.lbl.gov).

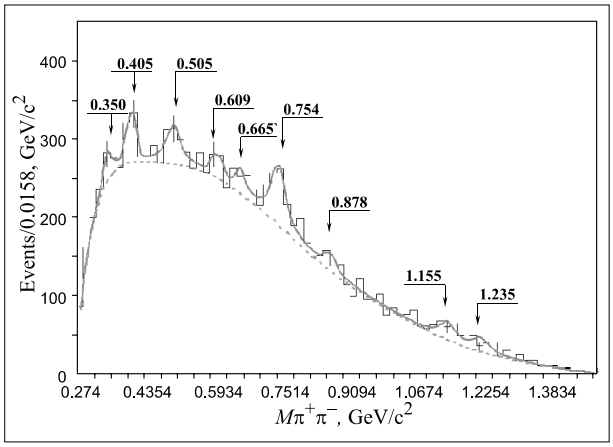

Fig. 9. Distribution of the effective masses $\pi^+\pi^-$. Amount of selected events — 11299

APPLIED RESEARCH

In 2000, the activities on designing the accelerator for electronuclear reactor proceeded. The common conceptual circuit reactor has been developed, it includes:

— Ten isochronous injector cyclotrons with the multidee by the system ensuring a mode of acceleration with separate orbits (MD CSO); every cyclotron provides acceleration of protons with a current of 10 mA up to the energy of 30 MeV;

— One booster CSO with the superconducting (SC) 10-floor magnetic system and 12 warm high-frequency (hf) resonators, accelerating the ten injected beams up to the energy of 300 MeV;

— One basic CSO with a similar SC magnetic system and 44 hf resonators informing the final energy of 1 GeV to the beams;

— 10 SC channels transporting the accelerated beams into the active zone of the reactor.

An article has been prepared (see [11]) concerning the basic parameters of the accelerator complex for the reception of the proton beam with the energy of 1 GeV and the current of 100 mA. The interface with the reactor by thermal capacity of 3 GW has been described. The associating problems related to the project, and design parameters are discussed.

«**Energy + Transmutation**». The experiments were carried out on irradiation of the lead target-converter and

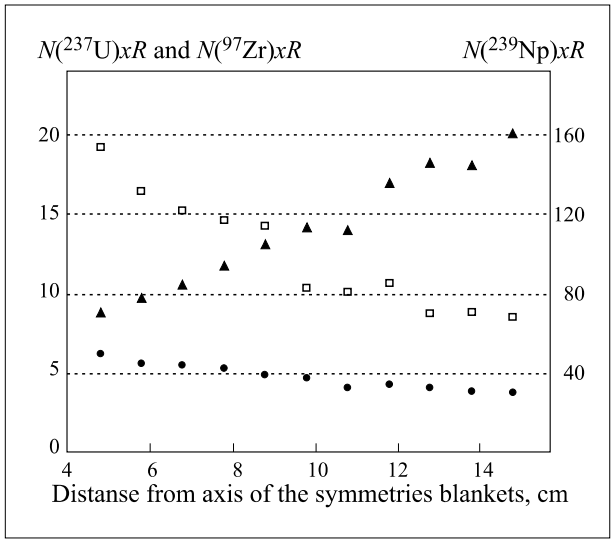

Fig. 10. Radial dependence of the (n,f)-, (n,γ)- and $(n,2n)$ reactions on uranium-238 nuclei is determined after processing the γ spectra from activation detectors (natural uranium) exposed together with the U-Pb assembly. ▲ — ^{239}Np – ^{238}U (n,γ), E_γ =277.6 keV; □ — ^{237}U – ^{238}U$(n,2n)$, E_γ =208 keV; ● — ^{97}Zr – ^{238}U (n,f), E_γ =743.3 keV

two-section uranium blanket by using the activation and track tomography and thermometric calorimetry [12] at the Synchrophasotron proton beam at 1.5 GeV. Partial fission integrals of uranium nuclei were measured by means of the original method — uranium fission integrator. A combination of cadmium screens and radiators (depleted and enriched with uranium-235) with solid state track detectors allowed one to perform separate determination of the number of fission events induced by neutrons related to different energy ranges (thermal, resonance and fast neutrons). Results of separation of these contributions depending on the distance from the symmetry axis of the U/Pb assembly in the interval from 5 to 14 cm are obtained and show the tendency of the increase of the contribution due to slow neutrons. The analysis of the obtained data indicates that the main contribution comes from the fissions of uranium-238 by fast neutrons. This conclusion is in good agreement with the result obtained in [13] considering the choice of the positions optimal for samples to study transmutation cross sections of radioactive wastes with thermal and resonance neutrons.

Computer modelling of the main characteristics of the U/Pb assembly (effective neutron multiplication coefficient, neutron spectra, energetic gain, etc.) is performed. Radial dependence of the (n, f)-, (n,γ)- and $(n,2n)$ reactions) on uranium-238 nuclei has been determined after processing the γ spectra from activation detectors (natural uranium) exposed together with the U-Pb assembly. Examples of these dependences are shown in Fig. 10. Mass distributions of fission fragments and products generated in the reactions of radiation capture allow one to obtain the data on heat generation capacity in the natural uranium blanket [13].

COOPERATION AT THE ACCELERATORS OF OTHER CENTRES

Joint activities are continued in CERN experiments NA45 (CERES), NA49, WA98, EMU01 running with SPS nuclear beams. Detector equipment of various types has become an essential contribution for these facilities. In this respect the ALICE and CMS experiments at LHC will give a new and complementary information and the LHE physicists will actively participate in preparation of these experiments.

Some results of experiments NA45, NA49, and WA98 along with the results of the other experiments at the SPS lead beam in CERN, were interpreted as signals of quark-gluon plasma.

Dr. B.Morozov was elected Spokesman of WASA collaboration at the CELSIUS storage ring in Uppsala and his LHE group actively participates in this experiment.

For 2001–2003 years, LHE has planned to continue participation in the above-mentioned experiments except WA98, which has been completed by the moment.

NA45 (CERES) collaboration (Spokesman from JINR Yu.A.Panebratsev) with a fully upgraded apparatus has planned to continue activities with Pb beams to obtain high statistics on ω- and ϕ-mesons production.

It is planned to continue activities in the **STAR** collaboration (Spokesman from JINR Yu.A.Panebratsev) at RHIC (BNL) which obtained the first experimental data in 2000.

Primary items of the **NA49** (Spokesman from JINR G.L.Melkumov) experimental programme as the follows:

— to obtain more statistics for Pb + Pb collisions at 158 A·GeV for rare processes,

— to study Pb + Pb collisions at lower beam energies (40 and 80 A·GeV) in order to establish the collision energy dependence of QGP signals,

— to study collisions of lighter ions (C + C, Si + SI and Ag + Ag) to investigate how the properties of matter depend on the size of colliding objects.

For **ALICE** experiment (Spokesman from JINR A.S.Vodopianov) a warm dipole magnet for the muon arm spectrometer will be designed and constructed at JINR as a joint effort of JINR and CERN. The LHE physicists also participate in ALICE software development and simulation.

The model 40×40 cm of **TRD (ALICE)** detector (time-projection drift chamber with a cathode strip read-out by fast Flash ADC) has been designed and constructed. The investigations with different gaseous mixture are started.

First results from the joint **JINR–RIKEN** experiment have been obtained on the study of the short range ^{3}He spin structure. The main goal of the joint JINR–Japan experiment R308n(0A) approved by RIKEN PAC in December of 1999 is to explore the short-range ^{3}He (^{3}H) spin structure at distances unreachable at the moment by using electromagnetic probes via the measurement of the angular distribution of the tensor analyzing powers A_{yy}, A_{xx} and A_{xz} in the $dd \to {}^3$Hen and $dd \to {}^3$Hp reactions.

These polarization observables are sensitive to the spin-momentum distribution of neutron (proton) in ^{3}He (^{3}H) at short distances in the framework of one nucleon exchange approximation [14,15]. The predictions of the behaviour of the tensor analyzing powers A_{yy}, A_{xx} and A_{xz} at 270 MeV of the deuteron initial energy for different three-nucleon bound state wave functions are shown in Fig. 11 [16]. One can see the strong sensitivity of these observables to the used three-nucleon bound state wave function, especially, at the forward emission angles.

On the other hand, since ^{3}He and ^{3}H are charge-symmetry mirror images, the differences in their observables can be interpreted in terms of Charge Symmetry Breaking (CSB). The measurement of the analyzing powers, which are not sensitive in the first order Coulomb corrections, in both $dd \to {}^3$Hen and $dd \to {}^3$Hp reactions, especially, at large momenta could provide an additional information on the nature of CSB.

The LHE–RIKEN collaboration performed the measurement of the tensor A_{yy}, A_{xx}, A_{xz} and vector A $_y$ analyzing powers by using the polarized deuteron beam of RIKEN cyclotron and the SMART spectrometer from November 26 until December 11 last year. These observables have been measured with the statistical error of ±0.02 at the energies of 270 and 200 MeV over full angular ranges for the $dd \to {}^3$Hp reaction. The same set of analyzing powers has been obtained for the $dd \to {}^3$Hen channel at 270 MeV between 0° and 120° in the centre of mass. Such a high precision of the experimental data will allow one to discriminate different models of the three-nucleon bound state up to the nucleon internal momenta of ≈ 600 MeV/c.

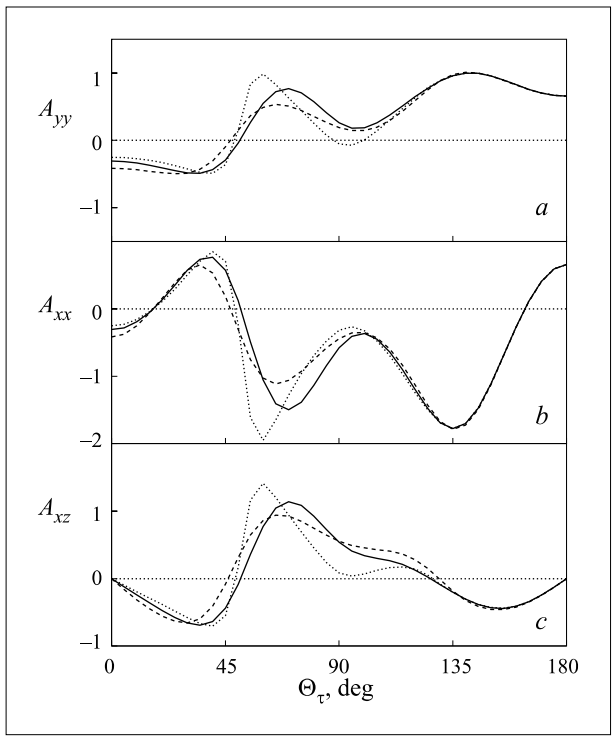

Fig. 11. Tensor analyzing powers A_{yy}, A_{xx} and A_{xz} in the $dd \to {}^3$Hen reaction at 140 MeV (*a*), 200 MeV (*b*) and 270 MeV (*c*), respectively. The solid, dashed and dotted lines are the results of one nucleon exchange calculations by using different ^{3}He wave functions

These investigations can be continued in future by using the polarized deuteron beam of the LHE Accelerator Complex [17].

For **HADES** experiment (Leader from LHE Yu.V.Zanevsky) the Laboratory has done the following:

— Seven modules of low-mass multilayer drift chambers have been constructed and tested under laboratory conditions. Six of these modules were assembled with read-out electronics and installed into the superconducting magnet of the HADES spectrometer. The modules have been used in $C + C(1.5A \cdot \mathrm{GeV})$ experiment in the commissioning beamtime of November 2000. The experimental results are in processing.

— 30 thousand channels of the analogue front-end read-out electronics for drift chambers, designed at LHE (JINR), have been constructed by the Russia industry. 14 thousand channels were tested and installed on the drift chambers before the November 2000 beamtime. To test the behavior of all the drift chambers, special cards of FEE constructed at LHE (JINR) have been used.

— The algorithm of the drift chamber efficiency estimation has been developed and the programme has been written. The programme allows one to analyse the

work of the drift chambers and readout electronics during the beamtime. The programme was used to analyse the experimental data received in 2000. The algorithm of finding the track candidates in the outer drift chambers was developed and the first version of the programme was written. The programme was tested on the experimental data received in the November beamtime.

The LHE participants contributed to the development of Heavy Ion Physics Programme in **CMS** on global characteristics of nucleus–nucleus collisions at the ultrarelativistic energy. These results will be included in the draft of the Heavy Ion TDR for CMS Collaboration and CMS Heavy Ion Meeting in St. Petersburg.

The LHE proposals have included the following advanced notions:

a) Observation of the jet quenching and parton shadowing effect (at small-x region, $x \sim 10^{-4}, 10^{-5}$) in the colliding nuclear matter by a global observable (total transverse energy and charged multiplicity) (Fig.12) [18–20].

b) The study of the impact parameter evolution of these effects [18].

c) The use of the global observable to estimate the initial conditions of nucleus-nucleus interactions at the beginning stage [16,20].

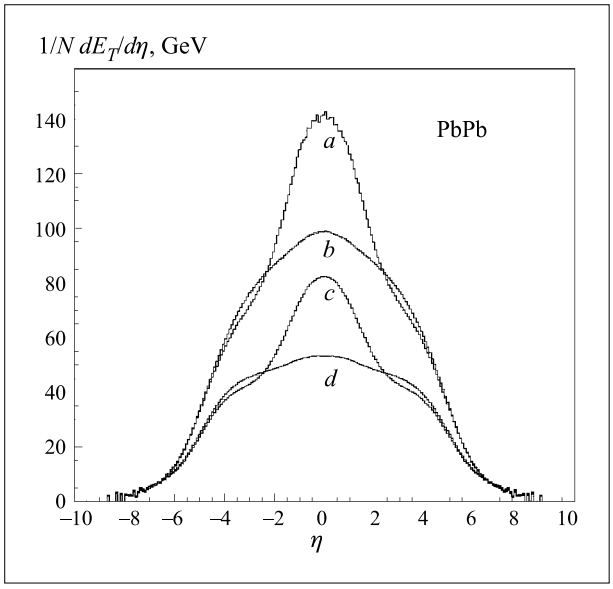

Fig. 12. The pseudorapidity total transverse energy distributions dE_T (GeV) for 10.000 PbPb collisions at LHC energy (5.5 TeV per nucleon). From the top to the bottom: no shadowing, with quenching (*a*), no shadowing, no quenching (*b*), with shadowing and quenching (*c*), with shadowing, no quenching (*d*)

CONFERENCES, MEETINGS

In 2000, some scientific conferences were organized with participation of the LHE:

On May 16–18 Dubna held a workshop devoted to the study of structure of simple exotic nuclei by using a method of nuclear emulsion. The prospects of irradiation on the acceleration complex of LHE — formation of beams of proton-superfluous isotopes of boron, carbon were also discussed. The basic question here concerns the available proton halo in nuclei for the nuclei near the border of the proton stability. This task is especially attractive for the emulsion technique because of the best observability of these interactions at the record spatial resolution. It is possible to assume that the classical emulsion technique will allow one to initiate a new chapter of researches on the structure of the nucleus already with the Nuclotron beams.

The meeting collected the most experienced experts on the emulsion technique. The plans of research of heavy nuclei interactions on the Nuclotron and at other centres were discussed. Thus, experimental method, which appeared hundred of years ago simultaneously with the discovery of radioactivity by A.Bekkerel, continues to work for perspective researches in physics of the nucleus.

From 11 to 14 June 2000 a meeting dedicated to the development of the research with heavy-ion colliding beams in the framework of the Compact Muon Solenoid Experiment at the Large Hadron Collider (LHC), CERN, was held in Gatchina, at the Petersburg Nuclear Physics Institute (PNPI).

According to theoretical approaches, the picture of particle multiple production in nucleus–nucleus collisions at LHC will be predominantly described by the language of quark–gluon interactions that leads to the minijet production. These hadron jets are not obligatory distinguished in the angular analysis, but the cross section of their production can be counted in the frames of quantum chromodynamics. The growth of collision energy at LHC will evidently lead to the dominating role of partons with small fractions of the nucleon momentum. Actually, nuclear physics at the ultrarelativistic energy scale will become the physics of hadron collisions with a nuclear «flavour». Possible radiation effects and rescattering of quarks and gluons in the formed nuclear medium, their

screening in nuclear matter may lead to bright results, still unobtainable at the energies of the contemporary accelerators.

The Workshop in PNPI was held for the fifth time. The previous workshops were in Ljons (1996), Dubna (1997), and CERN (1998, 1999). The programme of this Workshop contained the following topics:

- progress in understanding the processes of the quark-gluon plasma production and prospects of heavy-ion physics at ultrarelativistic energies; elaboration of theoretical concepts and programme generators;
- latest experimental achievements in the field, including results with beams of lead nuclei at the CERN super-proton synchrotron; status of the heavy-ion relativistic collider and experiments at the Brookhaven National Laboratory; LHC status as a nuclei collider; a review of the ALICE project as an experiment specialized in the search for quark-gluon plasma;
- physics programme for heavy-ion experiments at CMS, accounting for the spectrometer capabilities, i.e., measurement of global characteristics of nuclei collisions (particle flows), quark-gluon plasma study with solid samples — heavy quarkonia and dimuons, hard jets; physics of proton–nucleus collisions, physics of electromagnetic and diffraction interactions of nuclei;
- status of the CMS facility with an impact on aspects which are especially important for the experiments with heavy ions in the tracking system, calorimetry, muon detector, trigger and data acquisition system, developing software.

The Workshop gathered more than 65 physicists, experimentalists and theorists from the JINR Member States, France, Italy, and the USA. It was held at a high scientific and organization level and evolved new ideas in the first-priority research at LHC. The leaders of the CMS collaboration, the Russian Centre for Fundamental Research, the Directorates of JINR, PNPI and the plant «Krasnyj vyborzhets» supported the Workshop.

The traditional Workshop «Relativistic Nuclear Physics from Hundreds of MeV to TeV» was held in Stara Lesna, Slovakia, from 26 June to 1 July. It was organized by JINR and the Institute of Physics (IP) of the Slovak Academy of Sciences and was devoted to the general progress in relativistic nuclear physics research. The IP provided a significant contribution to the success of the first experiments with the Nuclotron internal target. The successful Nuclotron beam extraction made it topical to discuss prospects of further collaborative research, along with practical issues in the performance of new experiments. A detailed review of the physics research programme at the Nuclotron and of the accelerator complex development was given. Among new suggestions considered at the Workshop one should mention prospects of exotic nucleus structure investigations by means of relativistic beams. In the framework of LHE participation in CERN's nucleus–nucleus collision programmes, the results of the NA49 experiment on the production of light nuclei and antinuclei were presented, as well as prospects of global reaction characteristics measurements at the LHC (the CMS collaboration). The Workshop participants from the USA and France reviewed the first results obtained at the RHIC and CEBAF accelerators.

The XV international seminar on high-energy physics problems «Relativistic Nuclear Physics and Quantum Chromodynamics» was held in Dubna on 25–29 September. These seminars date back to 1969. The first seminar was held in the 60s as a relatively moderate event at the Nuclear Physics Department of the USSR Academy of Sciences, on the initiative of Academician M.A.Markov. The aim of those seminars, known as the Markov seminars, was to discuss the latest achievements and most topical tasks within the chosen field in a limited but authoritative community of scientists. Review reports by leading physicists, theorists and experimentalists, both home and foreign, were the basis for these meetings.

It was with one of those events that the Dubna 30-year series of conferences started, which are informally called «Baldin Autumn» (for many years the Director of the LHE (JINR) was Academician Alexander M. Baldin). Since then the seminar has been held every other year. The last conference was the fifteenth. It became famous for its high status in strong interactions physics and, especially, in modern problems of quantum chromodynamics and nuclear collisions at relativistic energies. It is evident that relativistic nuclear physics has turned into one of the basic directions of the scientific future for JINR.

This seminar moved from the Laboratory of Theoretical Physics to the LHE conference hall and the LPP conference hall. It was a good chance for theorists to see the potentials of experimentalists in practice, including the organization possibilities. The LHE site seats a lot of buildings, which can be considered historical for JINR. It was on this site where the Bogoliubov Theoretical Laboratory was established in 1958.

131 reports were presented at the XV seminar, including reports about the first results of the experiments at the extracted beam obtained from the Nuclotron. For the first time the results achieved at the recently commissioned RHIC heavy ion collider in the USA were also presented. Together with JINR people, scientists from Armenia, Brazil, Bulgaria, Czech Republic, France, Georgia, Germany, Iran, Mongolia, Poland, Russia, Slovak Republic, Taiwan, the USA, Uzbekistan, and Yugoslavia took part in its work.

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LABORATORY OF PARTICLES PHYSICS

The activity of LPP in 2000 was concentrated on the current particle physics experiments and preparation of the new ones, R&D of the particle detectors and different acceleration systems.

CURRENT EXPERIMENTS

A study of charmed baryon production in neutron–nucleus interactions is continued in the **EXCHARM** experiment in the framework of the **OSCAR** theme. The EXCHARM experiment is an extension of the scientific programme being carried out at the U-70 accelerator in Protvino and aimed at:

— searching for exotic states in hadron reactions;

— studying the strange and charmed particle hadroproduction, including polarization phenomena;

— investigating the single and double ϕ-meson production and the OZI rule violation.

The relative intensity of the vector meson $K^*(892)^{\pm}$ production with zero Z component of the spin (a spin density matrix element ρ_{00}) has been measured via the decays $K^*(892)^{\pm} \to K^0\pi^{\pm}$ in the transversity frame [1]. The obtained mean values of ρ_{00} are $0.393 \pm 0.011(\text{stat.}) \pm 0.018(\text{syst.})$ for $K^*(892)^+$, and $0.363 \pm 0.025(\text{stat.}) \pm 0.018(\text{syst.})$ for $K^*(892)^-$, respectively. A clear deviation of the obtained mean value of ρ_{00} from 1/3 for the leading meson $K^*(892)^+$ indicates the spin alignment. An indication of the spin alignment for the nonleading meson $K^*(892)^-$ is present as well, but with lower statistical significance. The values of $\rho_{00}(P_T)$ increase with P_T for both kaons as it is shown in Fig. 1. Using a linear dependence: $\rho_{00}(P_T) = bP_T$, and fixing a parameter at 1/3, the following slope parameters b have been obtained: $0.137 \pm 0.022(\text{stat.}) \pm 0.043(\text{syst.})$ for $K^*(892)^+$, and $0.085 \pm 0.059(\text{stat.}) \pm 0.039(\text{syst.})$ for $K^*(892)^-$ (both in $(\text{GeV}/c)^{-1}$).

The following cross sections of hyperon inclusive production in the neutron–carbon interactions have been measured: Λ^0 — (3370 ± 190) μb/nucleon; Ξ^- — (76 ± 5) μb/nucleon; $\Sigma(1385)^-$ — (286 ± 20) μb/nucleon;

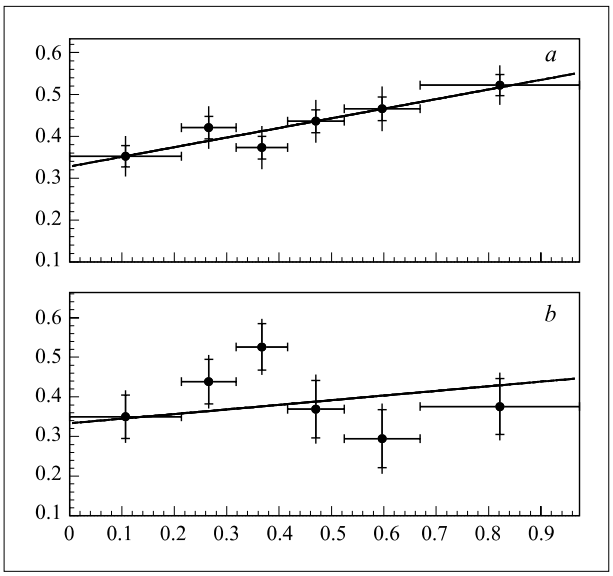

Fig. 1. P_T dependence of the spin density matrix element ρ_{00} for $K^*(892)^+$ (*a*) and $K^*(892)^-$ (*b*) in the transversity frame. The statistical errors are enlarged quadratically by the systematic ones

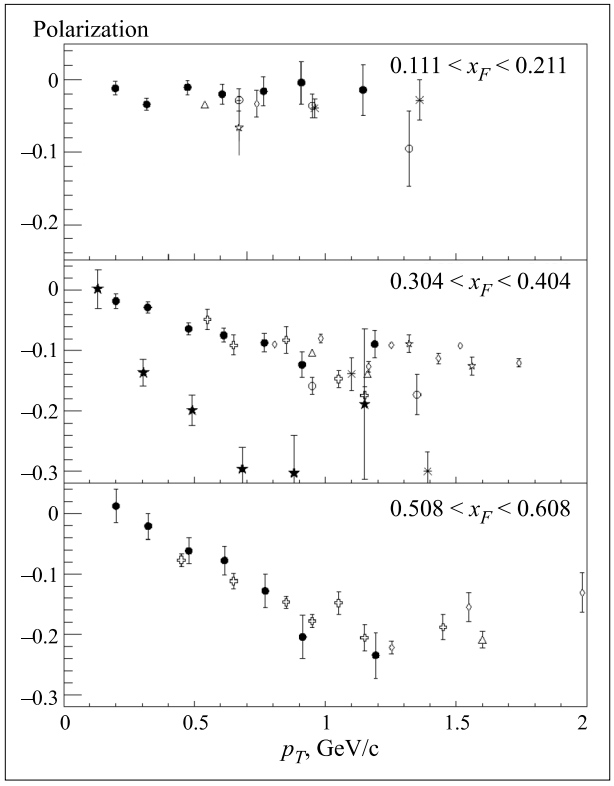

Fig. 2. Inclusive Λ^0 polarization as a function of P_T for restricted x_F. ● — this experiment, $nC \to \Lambda^0 X$, 57 GeV; ★ — Aleev-83, $n\mathrm{C} \to \Lambda^0 X$, 40 GeV; ✞ — Abe-86, $p\mathrm{Be} \to \Lambda^0 X$, 12 GeV; ◊ — Lunberg-80, $p\mathrm{Be} \to \Lambda^0 X$, 400 GeV; ☆ — Ramberg-94, $p\mathrm{Be} \to \Lambda^0 X$, 800 GeV; △ — Heller-78, $p\mathrm{Be} \to \Lambda^0 X$, 400 GeV; ✳ — Bonner-88, $p\mathrm{Be} \to \Lambda^0 X$, 185 GeV; ○ — Bonner-88, $p\mathrm{Be} \to \Lambda^0 X$, 133 GeV

$\Sigma(1385)^+$ — (252 ± 18) μb/nucleon; $\Xi(1530)^0$ — $(14.5 \pm \pm 1.4)$ μb/nucleon. Preliminary results of the antihyperon inclusive production cross section measurement were obtained as well: $\overline{\Lambda}^0$ — (175 ± 10) μb/nucleon and Ξ^+ — (6.5 ± 0.5) μb/nucleon. The studies of the associative ϕ-Λ and ϕ-kaons productions and production of $\Lambda(1520)^0$, all in the neutron–nucleus interactions, are in progress.

The polarization of Λ^0 hyperons produced inclusively in neutron–nucleus interactions at different energies and various production angles has been measured [3]. The dependence of the polarization P on the angle θ between the Λ^0-production plane and proton emission in the Λ rest system is shown in Fig. 2 for various intervals of x_F. A method of apparatus function cancellation has been used to measure this polarization. The obtained result is one of the most precise measurements of the Λ^0 polarization and is in good agreement with the data obtained in proton beams. The obtained result enlarges the covered P_T region of the measured Λ^0 polarization.

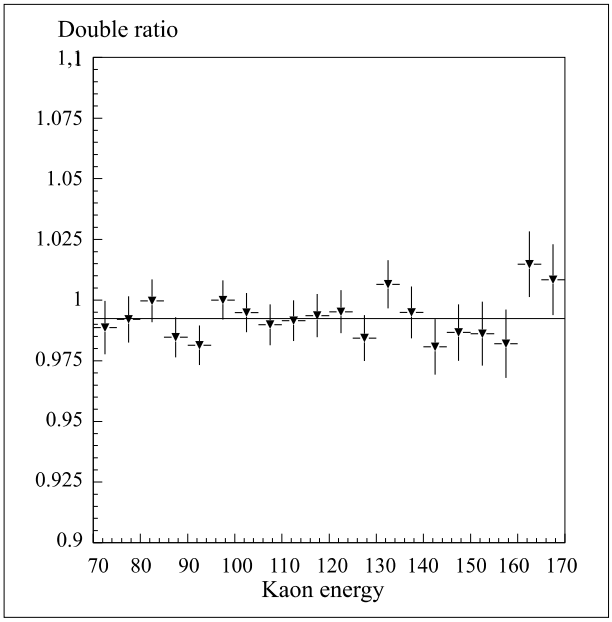

Fig. 3. Double ratio $R = \dfrac{\Gamma(K_L \to \pi^0\pi^0)/\Gamma(K_S \to \pi^0\pi^0)}{\Gamma(K_L \to \pi^+\pi^-)/\Gamma(K_S \to \pi^+\pi^-)}$ from the 1998 run data

The LPP physicists actively work in the **NA48** experiment at CERN devoted to the precision measurement of the ε'/ε ratio in CP violating decays of K^0 mesons into $\pi^+\pi^-$ and $\pi^0\pi^0$. A new preliminary result based on the 1998 run data was reported at the CERN seminar and presented at the ICHEP-2000 Conference in Osaka (Japan) [4] (see Fig. 3.): $\mathrm{Re}(\varepsilon'/\varepsilon) = (12.3 \pm 2.9(\mathrm{stat.}) \pm \pm 4.0(\mathrm{syst.})) \cdot 10^{-4}$. The combined result of the 1997 and 1998 runs (taking into account the partially correlated systematic errors) is: $\mathrm{Re}(\varepsilon'/\varepsilon) = (14.0 \pm 4.3) \cdot 10^{-4}$. This result, confirming a nonzero and positive value of $\mathrm{Re}(\varepsilon'/\varepsilon)$, is at the top margin of the Standard Model (SM) predictions. Therefore, the further improvement of the experimental precision is very important to make the conclusion about the validity of the major models calculating the direct CP-violation. New results of the neutral kaon rare decays: $K_S^0 \to \gamma\gamma$, $K_S^0 \to \pi^0 e^+ e^-$, $K_S^0 \to \pi^+\pi^- e^+ e^-$, $K_L^0 \to \pi^0\gamma\gamma$, $K_L^0 \to e^+ e^- e^+ e^-$, $K_L^0 \to e^+ e^- \mu^+ \mu^-$, $K_L^0 \to e^+ e^- \gamma\gamma$, obtained in NA48 experiment, were presented at the ICHEP-2000 Conference [5].

A new precision measurement of the Ξ^0 mass has been performed, which is $(1314.82 \pm 0.06(\mathrm{stat.}) \pm \pm 0.2(\mathrm{syst.}))$ MeV/c^2. The branching ratios of Ξ^0 radiative decays have been measured as: $\mathrm{Br}(\Xi^0 \to \Lambda\gamma) = (1.90 \pm \pm 0.34(\mathrm{stat.}) \pm 0.19(\mathrm{syst.})) \cdot 10^{-3}$ and $\mathrm{Br}(\Xi^0 \to \Sigma^0\gamma) = = (3.14 \pm 0.76(\mathrm{stat.}) \pm 0.32(\mathrm{syst.})) \cdot 10^{-3}$ [6].

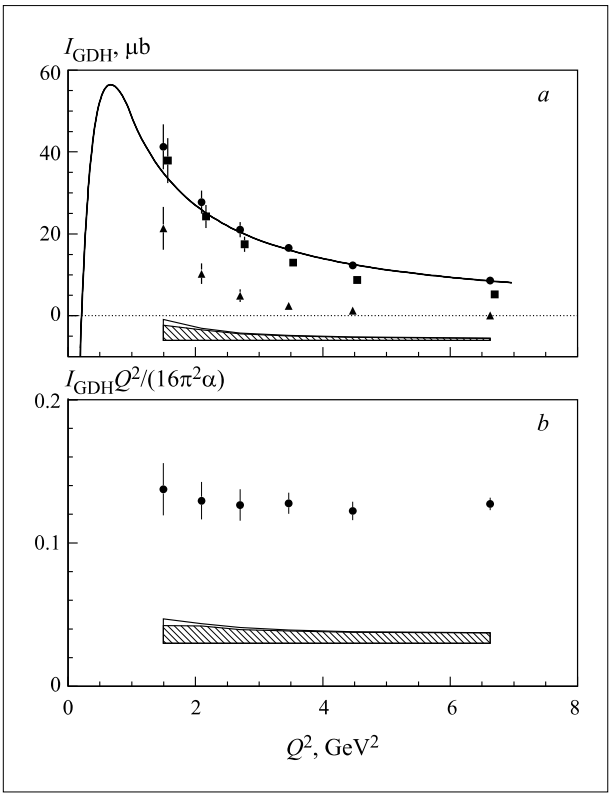

Fig. 4. *a)* The GDH integral (I_{GDH}) as a function of Q^2 for various upper limits of integration: $W^2 < 4.2$ GeV^2 (triangles), $W^2 < 45.0$ GeV^2 (squares), and the total GDH integral (circles). The curve is the Soffer–Teryaev model for the total integral. *b)* $I_{GDH}/(16\pi^2\alpha)$ as a function of Q^2. For both panels, the error bars show the statistical uncertainties, and the white and hatched bands at the bottom represent the systematic uncertainties for the total integral with the A_2 contribution and without it

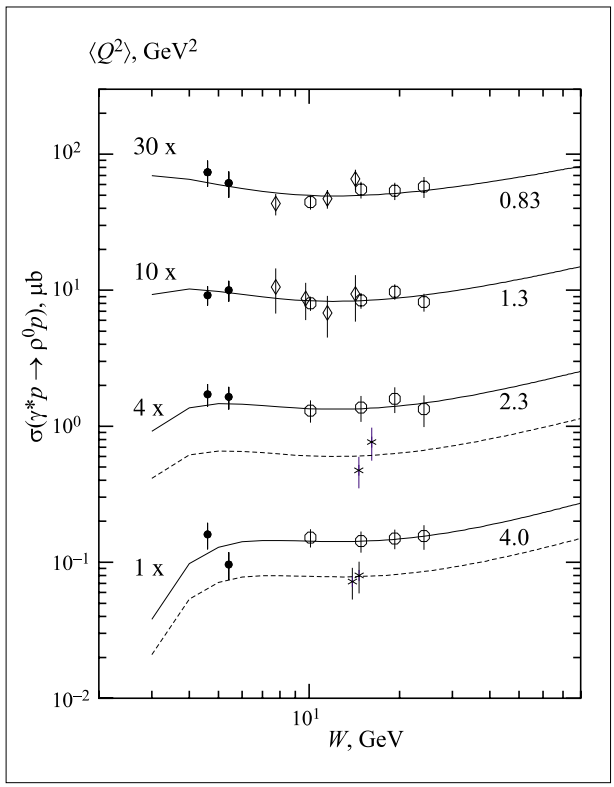

Fig. 5. The virtual-photoproduction cross section for ρ^0 production versus W at average Q^2 values of 0.83, 1.3, 2.3, and 4.0 GeV^2 (from top to bottom). The solid (and dashed) lines represent the results of calculations by L.Haakman et al. For the solid (dashed) lines the HERMES (●), CHIO (◊), E665 (○) and NMC (x) data were used to normalize the curves. Note that both the data and the calculations have been multiplied by the factors indicated on the left-hand side of the figure for plotting purposes only

The 2000 experimental run was carried out with the active participation of the JINR group. On-line physical data monitoring was developed and maintained by the JINR group during this run. The mass-production of the NA48 overlayed Monte–Carlo is running at the LPP PC-farm.

A new physics programme to investigate rare K_S and neutral hyperon decays using modified K_S beam in the NA48 experiment has been prepared. The first experimental run according to this programme has been carried out. A new physics programme for precision measurement of charged kaon decay parameters (including one related to the direct CP-violation) with an extended NA48 set-up has been prepared. An experiment according to this programme is proposed to start in 2003.

The Dubna group has taken an active part in data taking, data analysis and technical maintenance of the system of mini-Drift Vertex Chambers of **HERMES** Spectrometer Front Tracking at the HERA, DESY, Hamburg. During 2000 the HERMES has collected about $6 \cdot 10^6$ deep inelastic scattering (DIS) events with polarized deuterium target and about $15 \cdot 10^6$ DIS events with unpolarized target with various types of the nucleus.

The Gerasimov–Drell–Hearn (GDH) integral, one of the most fundamental sum rules in high-energy spin physics, has been measured in resonance and DIS regions for the first time [7,8]. It allows one to extract the Q^2 dependence of GDH integral in the range of 1.2 GeV$^2 < Q^2 <$ 12 GeV^2. The contributions of the resonance and DIS regions to this integral have been evaluated separately. The latter has been found to dominate for $Q^2 > 3$ GeV^2, while both contributions are important at low Q^2. The total integral shows no significant deviation from the $1/Q^2$ behaviour in the measured Q^2 range. There is no large effects due to either nucleon-resonance excitations or nonleading twist (see Fig. 4). The analysis of the HERMES experimental data taken with the polarized deuterium target has been started to extract the Q^2 dependence of the GDH integral for deutron and neutron.

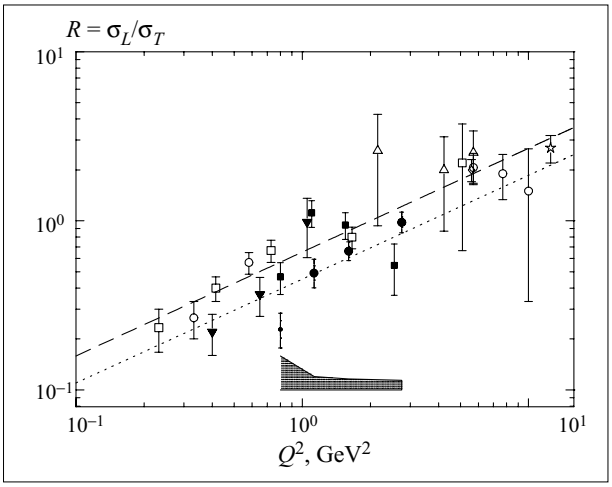

Fig. 6. The ratio $R = \sigma_L/\sigma_T$. All errors bars are only statistical. The shaded region indicates the systematical uncertainty of the present data. The dashed and dotted lines represent simultaneous fits by $R = c_0(W)(Q^2/M_p)^{c_1}$ to data with average $W > 4$ and above 7 GeV, respectively. ● — HERMES (^{3}He); ■ — Cornell; ▼ — DESY; □ — E665; ◇ — NMC (D); △ — EMC (H); ○ — ZEUS; ★ — H1

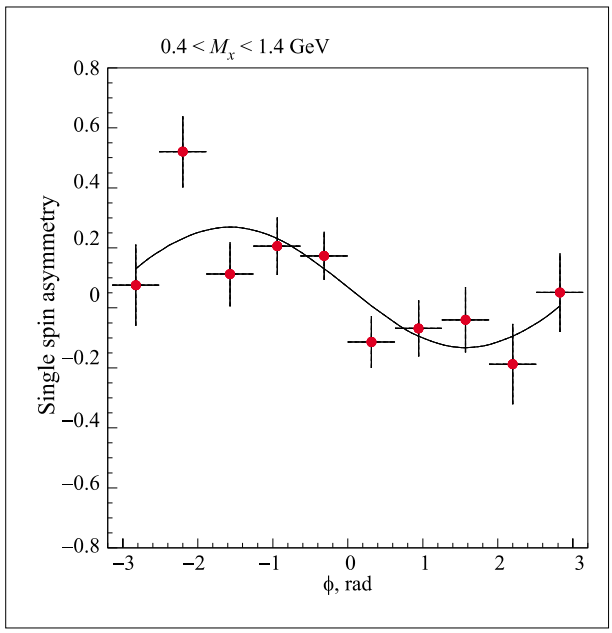

Fig. 7. The fit to the single spin azimuthal asymmetry versus the azimuthal angle

Measurements of the cross section for exclusive photoproduction of ρ^0 mesons from hydrogen are performed at HERMES [9,10]. The main aims of these measurements were a study of the W dependence of the cross section, decay angular distributions and the ratio $R = \sigma_L/\sigma_T$. The obtained results are shown in Figs. 5,6.

A study of the Deeply Virtual Compton Scattering (DVCS) [11] based on the HERMES data analysis in 2000 has started, that is one of the most interesting problems. The DVCS process can be studied through asymmetries which isolate the terms in the real photon leptoproduction cross section associated with the interference between the background. There are several asymmetries that can be studied. The initial one being investigated at HERMES is the single spin azimuthal angle asymmetry (see Fig. 7). It provides the unique possibility to get information on the skewed parton distributions related to the contribution of the total orbital momenta of quarks and gluons to the spin of the nucleon.

LPP participates in the **H1** detector upgrade to investigate deep inelastic scattering (DIS) processes at the $e-p$ collider HERA, DESY, specifically, in the software/hardware support of Forward Proton Spectrometer (FPS) [12] operation and in the upgrading of the hadron Plug calorimeter.

The JINR group has made a major contribution to the physics analysis of diffractive processes in DIS and photoproduction reactions. The total cross sections for the semi-inclusive photoproduction process with a leading proton in the final state have been measured in the kinematic range of fractional momentum of the leading proton: $0.66 < z < 0.90$ [13]. The measured cross sections are compared with semi-inclusive deep inelastic e^+p-scattering data with the leading proton in the final state. The saturation model in which the proton structure is assumed to consist of two components: vector meson dominant F_2^{VDM} contributing at low values of photon virtuality and partonic structure function F_2^{QCD} governing the region $Q^2 > 1$ GeV^2, was used to describe the photoproduction and DIS data simultaneously (see Fig. 8). It is observed that the semi-inclusive photoproduction cross section with the leading proton is suppressed more strongly with respect to the inclusive data than the semi-inclusive DIS cross section. Semi-inclusive structure function $F_2^{LP(3)}$ has been measured in DIS e^-p processes with the leading proton produced in the diffractive kinematic range ($z > 0.90$). Elastic ρ-meson photoproduction cross section and angular distributions have been measured in diffractive processes with leading proton detected by the Horizontal Roman Pots of the FPS.

The H1 experiment has measured the cross section of the reaction $e^+p \to e^+X$ and compared to the neutral current (NC) expectations of the Standard Model (SM) of strong and electroweak interactions for momentum transfer ranging between 200 and 30000 GeV [14]. The data have shown no significant deviation from the SM expectation.

The lower limit on the effective Planck scale M_s of 0.48 and 0.72 TeV for positive and negative coupling, respectively, has been found in the search for possible effects of low scale quantum gravity with gravitons coupling to SM particles and propagating into extra spatial

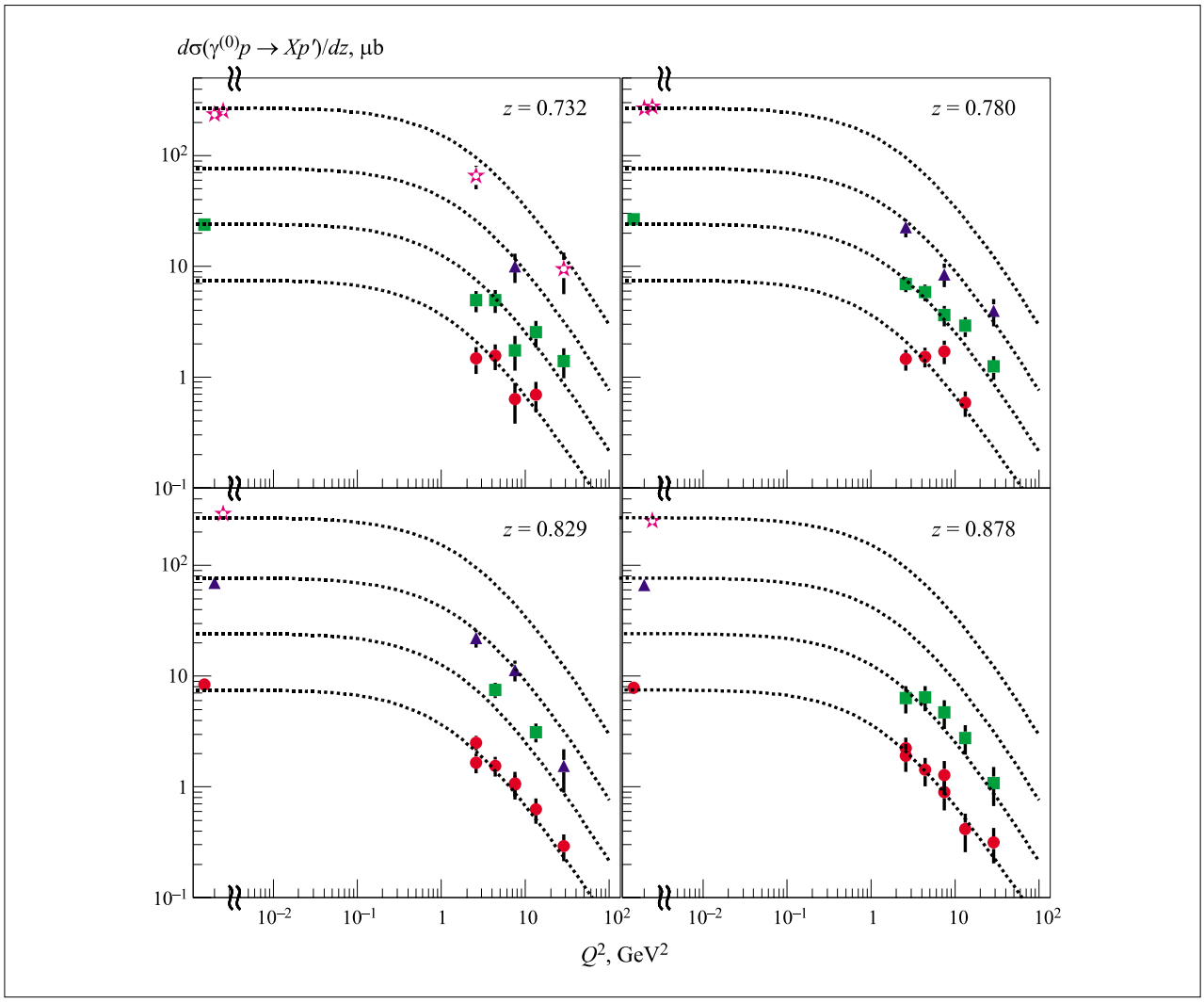

Fig. 8. The semi-inclusive photoproduction and DIS cross section for four bins of z and four bins of hadron mass M_x as a function of Q^2. The curves are the result of the fit based on the saturation model. ● — $M_x < 40$ GeV (×1); ■ — 40 GeV $< M_x <$ < 60 GeV (×3); ▲ — 60 GeV $< M_x < 80$ GeV (×9); ★ — 80 GeV $< M_x$ (×30)

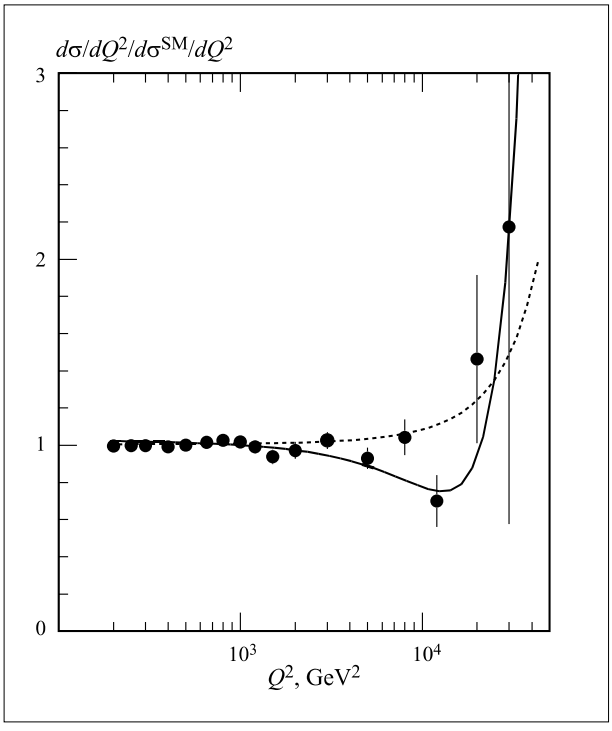

Fig. 9. Cross section of NC processes normalized to the SM expectation. The H1 data (●) are compared to the effect of graviton exchange given by the lower limits on the scale M_S for positive ($\lambda = +1$) (solid line) and negative ($\lambda = -1$) (dashed line) coupling

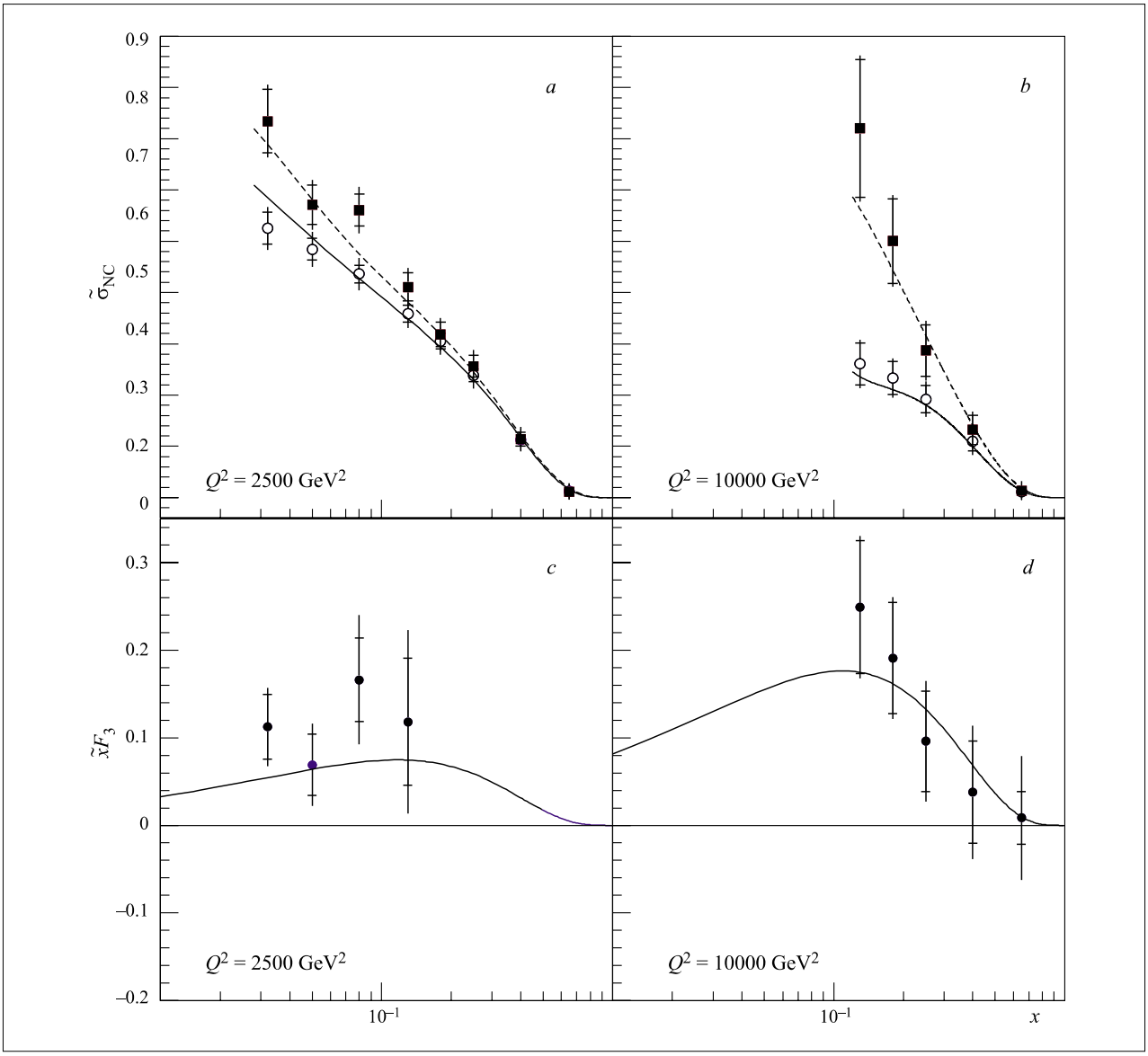

Fig. 10. The NC reduced cross section σ_{NC} and the parity violating structure function xF_3 are shown compared with the SM expectations based on the Hl e^+p QCD fit. ○ — e^+p, $\sqrt{s}$ = 300 GeV; ■ — e^-p, $\sqrt{s}$ = 320 GeV

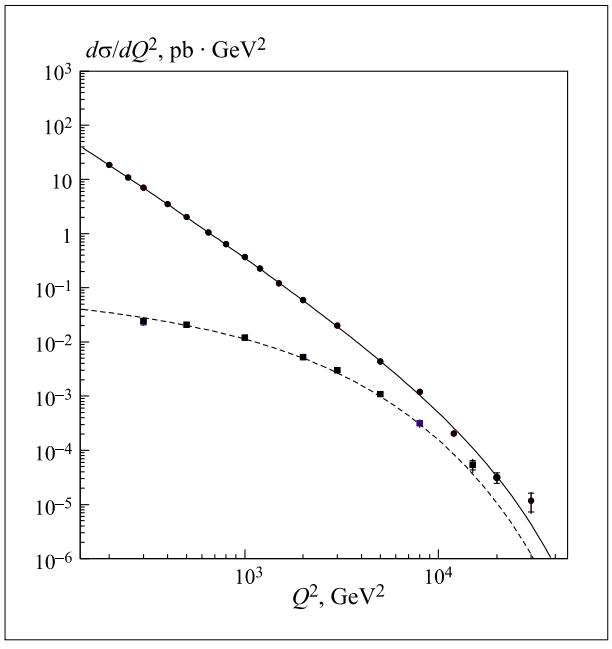

Fig. 11. The Q^2 dependence of the NC (●) and CC (■) cross sections is shown for the combined 1994–2000 H1 measurements. The data are compared to the SM expectations determined from the NLO QCD fit

dimensions. The ratio of the measurement and the SM expectations as a function of the momentum transfer squared Q^2 is presented in Fig. 9.

The inclusive $e^- p$ and $e^+ p$ differential cross sections for NC and charged current (CC) processes have been measured in the range of Q^2 between 150 and 30000 GeV^2 and Bjorken x between 0.0032 and 0.65 [15,16]. The NC $e^- p$ measurement of $d\sigma/dQ^2$ shows a clear increase with respect to the positron cross section at high Q^2, which is consistent with the SM expectation of the contribution of parity violating Z^0 exchange. As a result the parity violating structure function xF_3 is extracted (see Fig. 10.). The CC cross section is observed to be larger for electron scattering than for positron scattering by up to a factor of ten at high Q^2, because of W-boson coupling to different quark flavours. The NC cross section at low Q^2 is about 1000 times larger than the CC cross section, since the CC cross section is suppressed due to the propagator term dependence on M_W^2 (see Fig. 11). At the highest values of $Q^2 \sim M_Z^2, M_W^2$, the NC and CC cross sections are of the similar size as expected from the SM (electro-weak unification).

PREPARATION OF NEW EXPERIMENTS

The Common Muon and Proton Apparatus for Structure and Spectroscopy, **COMPASS (NA58)**, has been proposed to perform a series of experiments with the high energy muon and hadron beams at CERN. LPP has constructed and assembled the Hadron Calorimeter 1 (HCAL1) consisting of 480 modules. 160 modules were fully equipped and used in the trigger studies during the technical run in May–September 2000. LPP has participated also in the construction of the Large Area Straw Chamber Tracking Station. A specialized assembly area has been prepared and the first chambers were constructed and delivered to CERN. The COMPASS is planning to start data taking in 2001.

LPP participates in the construction of the Liquid Argon Hadronic End-Cap Calorimeter and subsystems connected to it, according to the JINR obligations in the **ATLAS** experiment which is under preparation at CERN. The absorber structure and stainless steel pieces for four serial HEC module assembly were produced at the JINR Experimental Workshop. The serial modules were assembled and checked at the CERN SPS test beam with pions, electrons, and muons and without particle beam in the cold conditions. The analysis of the experimental data shows good performance of the modules. Pollution of the liquid argon due to the irradiation of materials used in all ATLAS liquid argon calorimeters has been measured with the specially built up apparatus in the neutron fluency up to $1.5 \cdot 10^{16}$ n/cm^2 at the IBR-2 reactor. It has been shown at numerous runs that liquid argon pollution is less than 2 ppm. The preshapers, as part of the readout electronic chain, have been designed and produced. Their performance has been studied at the SPS test beam. It was shown that design and production of the preshapers were successful. About 700 temperature probes for ATLAS liquid argon calorimetry were calibrated with precision of few mK.

The main activity of LPP within **Compact Muon Solenoid Project**, **CMS**, was concentrated on the study, design, integration, and production of the CMS End-Cap detectors, where JINR takes a full responsibility in the frame of the Russia and Dubna Member States (RDMS) of the CMS Collaboration. This year opened the mass-production phase for the End-Cap hadron calorimeter (HE) and the first forward muon station (ME1/1) in accordance with the CMS construction schedule [17,18].

JINR coordinates the RDMS CMS Collaboration activity on the design and construction of the HE calorimeter and is responsible for the HE absorber. The scintillator tile production for HE-1 will be completed by the end of February 2001. A full-scale preproduction prototype of the HE calorimeter sector, PPP2, [19] has been upgraded with new 36 megatiles and ready for test at CERN.

The ME1/1 chamber assembly will start in the second half of 2001. Last year, the Cathode Strip Chamber (CSC) panel production started. Full production rate of 10 panels per week was achieved in July. Analysis of the experimental data taken with the P4 ME1/1 CSC prototype [20], instrumented with front-end electronics based on the Minsk ASICs, has confirmed that the performance of baseline CSC meets the CMS requirements.

JINR and other Dubna Member States institutes participate in Preshower subproject. 2000 resulted in the design of final specifications for silicon mass-production and design of the final technology for mass production of the Preshower silicon detector. 165 silicon detectors corresponding to 0.4 m^2 were produced. Two Preshower ladders (2×8 Si-detectors) were fabricated within required mechanical characteristics. Radiation study of the silicon strip detectors is continued.

JINR physicists participate in the RDMS CMS task on development of software and simulation of physics processes with emphasis to End-Cap and forward region [21]. The CMSIM and ORCA programmes were tested and modified for muon tracks reconstruction in the

End-Cap muon system. Computing group participates in the design of a concept of regional distributed centres. Simulation of heavy ion collisions in the CMS detector and the trigger option is in progress.

According to the JINR commitments, LPP participates in the construction of the Outer Tracker (OTR) of the **HERA-B** detector designed to search for CP-violation in exclusive B decays, mainly, in the «gold plated» decay mode $B^0 \to J/\Psi K^0_S$. The Dubna group played a major role in the preparation and installation of the OTR superlayers accomplished by the end of 1999. The LPP physicists participated in the commissioning of the OTR superlayers and detector running, control of data quality and on-line monitoring, cross-check of geometry, cabling and alignment using the real data, in 2000. Dubna group has contributed to the development of ARTE (general software package for HERA-B), readout system and the OTR data quality packages.

LPP takes part in the design and construction of the End-Cap Electro-Magnetic Calorimeter (EEMC) for the 4π-detector **STAR** for the collider RHIC at the Brookhaven National Laboratory. The experimental runs were started in 2000 with the participation of the LPP physicists. The manufacturing of the full scale prototype of the 30° EEMC module was started at the JINR Experimental Workshop.

The LPP specialists participate in construction of the low-noise neutrino detector **BOREXINO** located at the underground laboratory in Gran Sasso (Italy). The responsibilities shared by the JINR group are mainly related to the DAQ system, detector calibration, testing, cleaning and mounting of PMT.

ACCELERATION TECHNIQUES

According to the schedule of operations for the project **LHC Damper** the 2000 activities were focused on the creation and testing of a prototype system. In the course of this activity, JINR has manufactured a deflector and a wide-band amplifier for the LHC Damper. Testing of the assembled system was carried out on a special bench of LPP by JINR specialists together with colleagues from CERN. Afterwards, the prototype was transported to CERN for continued testing according to standards received for the LHC project, and also to study the stability of the kicker on possible thermal loads. As a whole, the characteristics of the prototype system were shown to meet the requirements of the project. Now the preparation for the following stage of operations — preproduction of devices — has started.

Activities within this theme continue to be focused at the creation of a technical and research basis to develop the technology for model superconducting cavities (SCC), with special emphasis towards optimizing their electrophysical parameters. A model of the cylindrical magnetron sputtering configuration based upon permanent magnets with an Nb target has been designed, manufactured, and probed. The magnetron operation is stable utilizing argon at a working gas pressure in the range from $6 \cdot 10^{-4}$ up to $5 \cdot 10^{-2}$ Torr, and with a cathode voltage at 700 to 300 V. The size of the magnetron allows one to operate the cavities of frequency 3GHz.

Theoretical investigations of the amplitude dependence on the surface resistance, SCC, of type Nb/Cu are going on. It has been shown that the limit of nonquadratic losses which appear in Nb/Cu type cavities may be shifted substantially by means of decreasing the working layer roughness until the layer can be considered smooth. The analysis of quantum fluxon behavior near the superconducting smooth surface is carried out. It has been shown that this surface creates a barrier for fluxon penetration into the superconductor which exceeds the first critical field by a factor of 2 to 3. The obtained results are in agreement with the known experiments on magnetization of smooth superconducting samples.

During 2000, the **Free Electron Laser** (FEL) group carried out investigations on microwave generation utilizing the FEL and travelling wave tube (TWT) for the project CLIC at CERN. In accordance with the long term plan of LPP, the following tasks have been resolved by investigations using the LIA-3000 accelerator: registration of the electron beam bunching at the base frequency of 30 GHz, and the experimental observation of smooth frequency tuning in the FEL scheme [22]. The electron beam bunching was registered in experiments with the FEL oscillator where for the first time a Bragg resonator of a new type was used in the feedback circuit. The generation of microwave radiation in the mode H_{11} at a frequency of 30.7 GHz with very high efficiency (greater than 30 %) was realized in this scheme of the FEL oscillator. The electron beam bunching was registered at this frequency. In addition, electron beam bunching was registered in these experiments in the mode E_{01}, with a frequency of 36.4 GHz.

Year 2000 saw the completion of the **TESLA** Technical Design Report, which provides the technical basis for a future collider at DESY. The specialists of LPP designed and manufactured the equipment of the Regenerative FEL (the so-called RAFEL), which should increase the power and narrow the band of radiation in the X ray and vacuum ultraviolet spectra [23]. Now, the equipment of RAFEL is installed on the TESLA Test Facility (TTF), and preparation for experiments with RAFEL at the TTF are continued. TTF is scheduled to run in December of 2000 and March of 2001 for final adjustments.

A novel variant of an RF sensor with a round cross section and inner diameter of 72 mm has been produced. This is a sensor with a highly uniform electric field within the measuring volume. The sensor and measuring system have been designed, manufactured, tested, and calibrated, and are intended for the TTF. This is the only system to measure a void fraction of the two-phase superfluid helium flow. The design, manufacturing, and certification of devices, and the metrological systems to control the thermodynamic state of two- and single-phase cryogens have been finished. These systems, and the developed methodology, provide an accuracy of calibration of not more than pm ±5 mK for resistive temperature sensors in the range from 1.5 to 300 K and ± 1.5 % or less for radio frequency void fraction sensors intended for helium, hydrogen, nitrogen, and others. The total rate of the system to calibrate temperature sensors is about 100 pieces per month, and can be increased by 75 % if necessary.

Within the framework of the TESLA activity, commercially available cryogenic temperature sensors were irradiated by a Cs γ-source up to an enormous total dose of 1 MGy ($E_\gamma \approx 0.661$ MeV) at 77.3 and 293 K. Afterwards, the post-radiation behavior of the sensors was estimated. The platinum, PRT, and carbon resistive temperature sensors have demonstrated high radiation resistance. In accordance with the agreement between DESY and JINR, 50 TVO temperature sensors were delivered to DESY to be used in the TTF. There were continued investigations of the TVO temperature sensors under magnetic fields in the temperature range from 1.6 to 4.2 K, and up to 9 T.

A new, nontraditional direction in technique of the **electron accelerators for radiation technologies** is performed at LPP. To verify new technical solutions, a scaled model of the accelerator has been manufactured. Parameters of the model are as follows: electron beam energy — 200 keV, beam peak current — 1 A, pulse duration — 10 μ*s*, repetition rate of the current pulses — 18 kHz, average beam power — 20 kW. The experimental experience obtained with the accelerator model was used as the basis to construct a full scale multi-beam accelerator with energy 500–700 keV and output power 25–35 kW at an extremely low cost. Electron beam parameters of the accelerator are the following: total peak beam current — 0.5 A, pulse duration — 10–20 μ*s*, repetition rate — 10–20 kHz. At present the development of the design of the accelerating voltage source — the vacuum spiral coaxial resonator — is completed and its manufacture has been started.

A work has been done to study a possibility of increasing the efficiency of the radiation technology by means of using secondary electrons to excite molecules of the gaseous mixture. At the accelerators developed at LPP the pulsed electron beam current is generated by RF electric field. An average ratio of the repetition period to the pulse duration is equal to 10, so there is a possibility of applying the DC electric field for acceleration of secondary particles. At 10 μ*s* pulse duration and 100 μ*s* repetition period the electrical discharge cannot evolve and the electric field strength can be increased up to the value enough to excite molecules. The obtained tentative results have shown that there is a principal possibility of enhancing significantly the efficiency of the molecule excitation by the electron beam and the output power of the radiation stimulated processes on the harmful admixture removal from flue gasses.

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DZHELEPOV LABORATORY OF NUCLEAR PROBLEMS

The field of scientific activities of the Dzhelepov Laboratory of Nuclear Problems is unique. It covers experimental investigation in modern particle physics (at high, intermediate and low energies); investigation of nuclear structure (including relativistic nuclear physics and nuclear spectroscopy); study of condensed matter properties; theoretical support of the experimental research; medicobiological investigations; development of new accelerators and experimental facilities.

The Dzhelepov Laboratory of Nuclear Problems (DLNP) is nowadays the only laboratory at JINR where modern rare-decay experiments and new physics searches, like neutrinoless double beta decay, are under way. The thorough study of neutrino properties is also performed only in this Laboratory. In 2000, three neutrino meetings, a workshop on neutrino oscillation experiments (NOMAD week), a workshop of the NEMO collaboration and an international conference on nonaccelerator new physics in neutrino observations (NANPino), were held at DLNP. The latter conference traces a new modern direction in particle physics connected with physics beyond the standard model of electroweak interactions with a certain emphasis on the nonaccelerator searches.

On the other hand, modern and future investigations of phenomena at high energies are also an area of constant interest and care for the DLNP scientists. It was for the first time in the history of the ATLAS collaboration that the ATLAS week took place (Dubna, 21–26 June 2000) outside CERN. Another large conference «LHC Physics and Detectors» was held in Dubna right after the ATLAS week. The Laboratory was greatly involved in preparation of the meetings.

In the time being the JINR phasotron is still considered to be a useful facility which provides a possibility of doing good physics (e.g., μ-catalyzed fusion, DUBTO project) and performing medicobiological and clinical research on treatment of tumour patients on the basis of the medicotechnical complex and medical hadron beams.

ELEMENTARY PARTICLE PHYSICS

The **NOMAD** experiment in the CERN SPS neutrino channel yielded new data for the search for $\nu_\mu \to \nu_\tau$ oscillations. Greater statistics and improved kinematic analysis used to identify ν_τ interaction acts made the experiment much more sensitive to oscillation parameters. Fifty-eight candidates for τ-neutrino interaction in the $\nu_\tau N \to \tau^- X$ reaction and 55 ± 5.4 background events in all τ-lepton decay modes considered were found. This number of candidates agrees with the number of background events. No $\nu_\mu \to \nu_\tau$ oscillations are found, which yields the upper limits for the oscillation amplitude in the mass squared difference interval $1 < \Delta m^2_{12} < 1000\ \text{eV}^2$ within the hypothesis of two types of neutrinos.

In the region of large Δm^2_{12} ($\Delta^2_{12} > 50\ \text{eV}^2$) the limits (90 % C.L.) for the amplitude and probability of $\nu_\mu \to \nu_\tau$ oscillations (Fig. 1,*a*) are [1]:

$$\sin^2 2\theta_{\nu_\mu \nu_\tau} < 4.0 \cdot 10^{-4},\ P_{\nu_\mu \nu_\tau}(\nu_\mu \to \nu_\tau) < 2 \cdot 10^{-4}.$$

This value of $P_{\nu_\mu \nu_\tau}(\nu_\mu \to \nu_\tau)$ is more than 10 times better than the previous best limit in the region of large masses $P_{\nu_\mu \nu_\tau}(\nu_\mu \to \nu_\tau) < 2.5 \cdot 10^{-3}$ (FNAL, E531–1986). Similarly, the limits for the amplitude and probability of $\nu_e \to \nu_\tau$ oscillations for $\Delta m^2_{12} > 50\ \text{eV}^2$ (Fig. 1,*b*) are [1]:

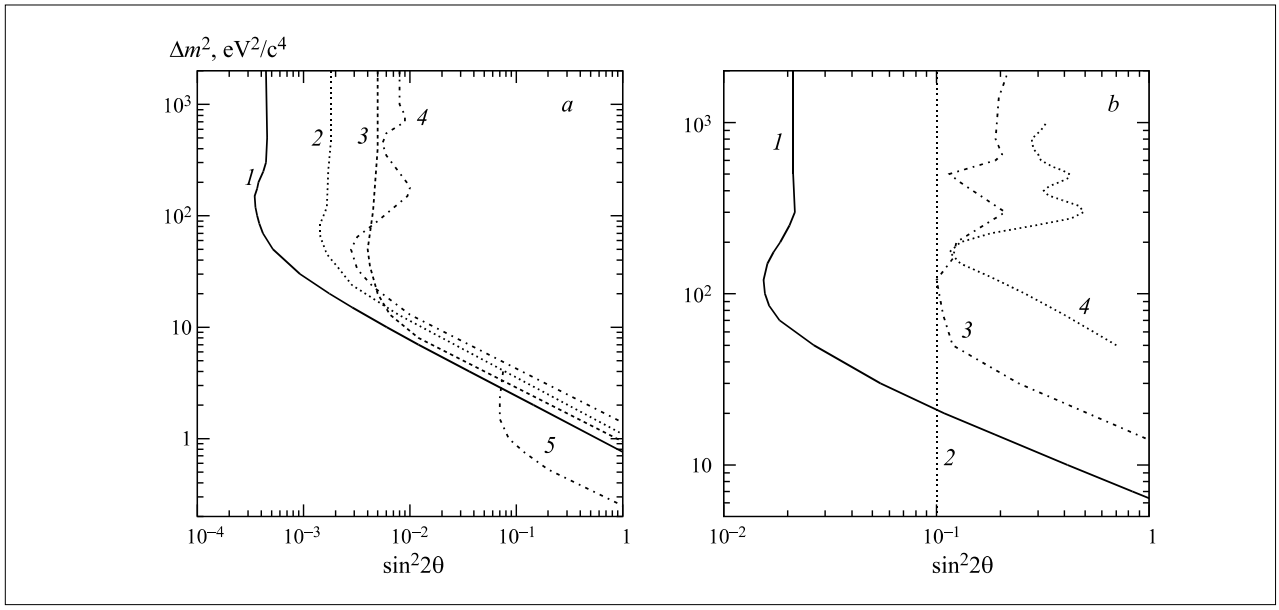


Fig. 1. NOMAD 90 % exclusion plot for $\nu_\mu \to \nu_\tau$ *(a)* and $\nu_e \to \nu_\tau$ *(b)* oscillations. Results of the experiments are presented as curves: *a) 1* — NOMAD, *2* — CHORUS, *3* — E531, *4* — CCFR, *5* —CDHS; *b) 1* —NOMAD, *2* — CHOOZ, *3* — CCFR, *4* — IHEP/JINR

$$\sin^2 2\theta_{\nu_\mu \nu_\tau} < 2.0 \cdot 10^{-2}, P_{\nu_e \nu_\tau}(\nu_\mu \to \nu_\tau) < 1.0 \cdot 10^{-2},$$

also 10 times better than the previous limits for the $\nu_e \to \nu_\tau$ oscillation parameters (FNAL, CCFR–1994).

The experiment NOMAD [2] yielded new data on polarization of Λ^0 hyperons in the charged-current neutrino interactions $\nu_\mu N \to \mu^- \Lambda^0 X$. As many as 8087 events with Λ^0 hyperons were analysed, which is 30 times more than in all previous neutrino experiments. Longitudinal polarization of Λ^0 hyperons was measured (Fig. 2) both in the target fragmentation region

$$P_x(x_F < 0) = -0.21 \pm 0.04\,(\text{stat.}) \pm 0.02\,(\text{syst.}),$$

and in the current fragmentation region

$$P_x(x_F > 0) = -0.09 \pm 0.06\,(\text{stat.}) \pm 0.03\,(\text{syst.}).$$

By measuring longitudinal polarization in the current fragmentation region it is possible to estimate the coefficient of spin transfer from the *u* quark to the Λ^0 hyperon $C_u^\Lambda = -P_x = 0.09 \pm 0.06\,(\text{stat.}) \pm 0.03\,(\text{syst.})$. It was the first time in neutrino experiments that considerable transverse polarization perpendicular to the Λ^0 hyperon production plane was observed

$$P_y = -0.22 \pm 0.03\,(\text{stat.}) \pm 0.01\,(\text{syst.}).$$

The new and more accurate experimental data make it possible to verify various models allowing for polarized strangeness in a nucleon in the region $x_F < 0$ and the mechanism for polarization transfer from the quark to the Λ^0 hyperon in the region $x_F > 0$.

In 2000, the data collected in the $e^+e^- \to e^+e^-(\gamma)$, $\mu^+\mu^-(\gamma)$, $\tau^+\tau^-(\gamma)$ and inclusive $e^+e^- \to q\bar{q}(\gamma)$ channels with the **DELPHI** detector at energies close to 183 and 189 GeV were analysed in order to extract the hadronic and leptonic fermion-pair cross sections, as well as the leptonic forward-backward asymmetries and angular distributions. No evidence for physics beyond the Standard Model was found and limits were set on contact interactions between fermions, the exchange of *R*-parity violating SUSY sneutrinos, *Z'* bosons and the existence of gravity in extra dimensions.

For sneutrino exchange in *R*-parity violating supersymmetry, the genetic coupling in the purely leptonic part of the superpotential, $\lambda > 0.1$ can be excluded for $m_{\tilde{\nu}}$ in the range 130–190 GeV for all leptonic states at the 95 % confidence level or above. Extra *Z'* bosons lighter than 300 GeV/c^2 can be excluded at the 95 % C.L. The 95 % C.L. lower limits of 542 and 680 GeV on the string scale, M_S, in models of gravity involving extra dimensions are obtained for a combinations of $\mu^+\mu^-$ and $\tau^+\tau^-$ final states [3].

The reaction $e^+e^- \to \gamma\gamma(\gamma)$ was studied using the LEP high-energy data collected with the DELPHI detector at the centre-of-mass energies of 188.6–201.6 GeV, corresponding to integrated luminosities of 151.9–40.1 pb^{-1}, respectively. The differential and total cross sections for the process $e^+e^- \to \gamma\gamma$ were measured (Fig. 3). Good agreement between the data and the QED prediction for this process was found. Lower limits on possible deviations from QED were derived. The 95 % C.L. lower limits on the QED cut-off parameters $\Lambda_+ > 330$ GeV and $\Lambda_- > 320$ GeV were obtained. In the framework of composite models, a 95 % C.L. lower limit for the mass of an excited electron, $M_{e^*} > 311$ GeV/c^2, was obtained considering an effective coupling value

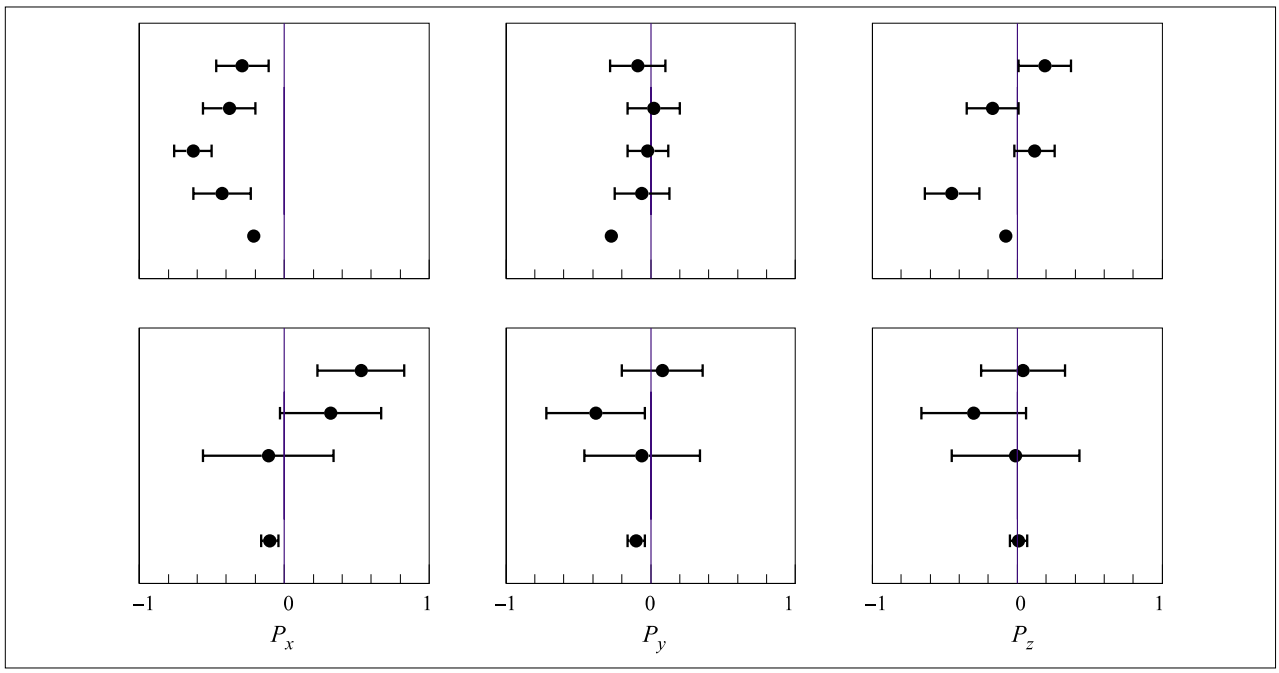


Fig. 2. Λ^0-polarization in the target fragmentation ($x_F < 0$, upper panel) and current fragmentation ($x_F > 0$, lower panel) regions in the WA 21 ($\nu_\mu - p$), WA 21 ($\bar{\nu}_\mu - p$), WA 59 ($\bar{\nu}_\mu$ – Ne), E632 (ν_μ – Ne, only upper panel) and NOMAD experiments (from top to bottom)

$\lambda_\gamma = 1$. The possible contribution of virtual gravitons to the process $e^+e^- \to \gamma\gamma$ was probed, resulting in 95 % C.L. lower limits on the string mass scale $M_S > 713$ GeV/c^2 and $M_S = 691$ GeV/c^2 for $\lambda = +1$ and $\lambda = -1$, respectively (where λ is a $O(1)$ parameter of quantum gravity models) [4].

From the data sample of integrated luminosity 155 pb^{-1} collected by DELPHI in collisions at a centre-of-mass energy of 188.63 GeV the individual leptonic branching fractions were found to be in agreement with lepton universality and the W hadronic branching fraction was measured to be $BR(W \to q\bar{q}) = 0.680 \pm 0.008(\text{stat.}) \pm \pm 0.004(\text{syst.})$, in agreement with the Standard Model prediction 0.675 and compatible with measurements at lower energies by other LEP experiments [5]. The total cross section for the doubly resonant WW process was measured to be $\sigma_{WW}^{\text{total}} = 15.83 \pm 0.38(\text{stat.}) \pm 0.20(\text{syst.})$ pb, assuming Standard Model branching fractions (Fig. 4).

The **DIRAC** experiment at CERN aims to measure the lifetime of $\pi^+\pi^-$ atoms ($A_{2\pi}$) in the ground state with a 10 % precision, to obtain the difference $|a_0 - a_2|$ of $\pi\pi$ scattering lengths in the S state with the isotope spin 0 and 2 with an accuracy of 5 %, and to put the understanding of chiral symmetry breaking of QCD to a crucial test.

The experimental set-up is located at the CERN PS extracted proton beam with the energy of 24 GeV. The set-up is a magnetic spectrometer with coordinate detectors aligned upstream of the spectrometer magnet near the target and with two telescope arms for positively and negatively charged particles downstream of the magnet. The coordinate detectors are microstrip gas chambers, scintillation fibre detectors, and scintillation ionization hodoscopes. Each telescope is equipped with drift chambers, horizontal and vertical hodoscopes, a gas Cherenkov counter, a preshower and a muon detector.

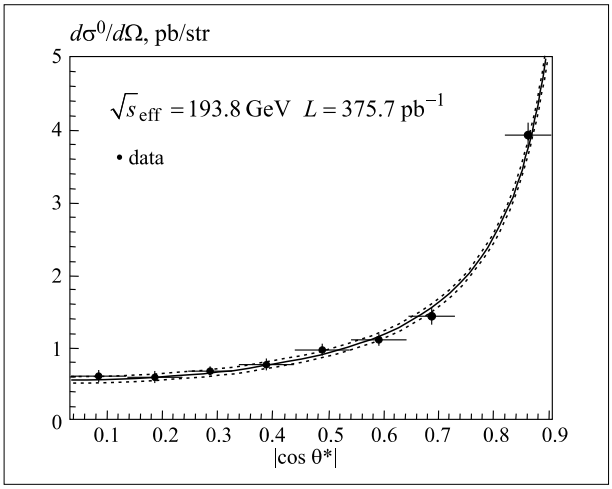


Fig. 3. Born differential cross section obtained by combining all data sets at an effective centre-of-mass enrgy of 193.8 GeV (dots), compared to the QED theoretical distribution (full line). The dotted lines represent the allowed 95 % C.L. deviations from the QED differential cross section, which correspond to the 95 % C.L. lower limits on Λ_+ and Λ_- 330 and 320 GeV, respectively, to the 95 % C.L. lower limit on excited electron mass 311 GeV/c^2 and to excited electron mass 311 GeV/c^2 and to the 95 % C.L. lower limits on the string mass scale 713 GeV/c^2 (for $\lambda = +1$) and 691 GeV/c^2 (for $\lambda = -1$)

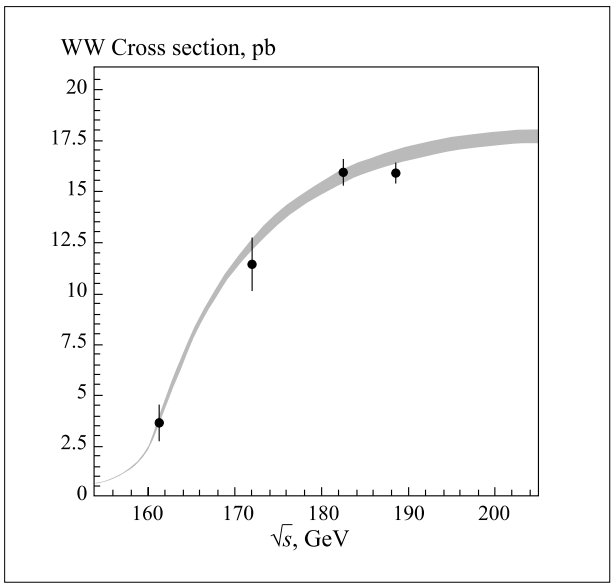


Fig. 4. Measurments of the W^+W^- cross section compared with the standard model prediction (chosen by gray colour area) using $M_W = 80.41\,\text{GeV}/c^2$ with a possible uncertainty of ±2 % on the computation

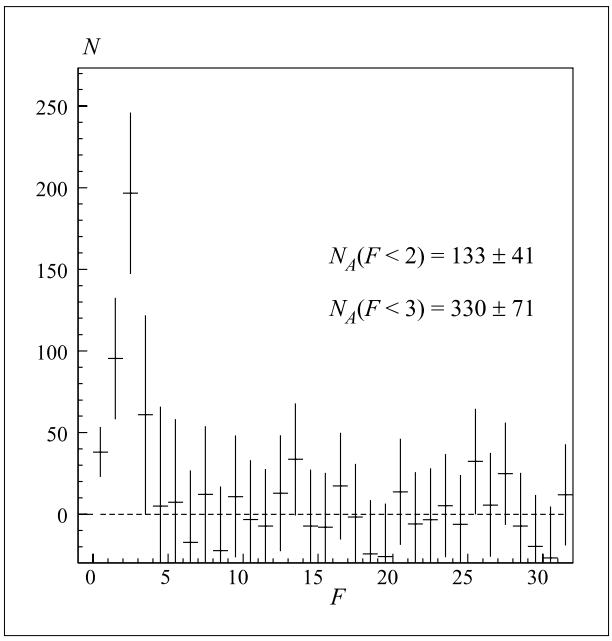


Fig. 5. The difference N between the experimental distribution of $\pi^+\pi^-$ pairs and the approximating function, which describes the contribution of pion pairs produced in free states. The variable $F = \sqrt{Q_X^2/\sigma_{Q_X}^2 + Q_Y^2/\sigma_{Q_Y}^2 + Q_L^2/\sigma_{Q_L}^2}$ is related to the relative momentum Q of pions in c.m.s. Here $Q_{X,Y,L}$ are the components of the relative momentum and $\sigma_{Q_{X,Y,L}}$ are the set-up resolutions over the corresponding components: $\sigma_{Q_X} = \sigma_{Q_Y} = 1\,\text{MeV}/c$ and $\sigma_{Q_L} = 0.65\,\text{MeV}/c$

The last three detectors are used to suppress detection of electrons and muons, respectively. The relative momentum resolution of the set-up σ_Q is about 1 MeV/c. The required accuracy of the set-up for the relative momentum is provided by a high resolution of the coordinate detectors and a small quantity of materials in the way of a particle.

The first signal of $A_{2\pi}$ observation in the DIRAC experiment was obtained after processing a part of the experimental data taken with a platinum target in 1999. The difference between the experimental distribution of $\pi^+\pi^-$ pairs and the approximating function, which describes the contribution of pion pairs produced in free states, is shown in Fig. 5. The peak in the range $F \le 3$ is caused by the additional pion pairs with a low relative momentum produced at the breakup (ionization) of $\pi^+\pi^-$ atoms inside the target.

At the beginning of 2000, the DIRAC set-up was upgraded. Firstly, the dedicated hardware processor for selecting tracks in the drift chambers was developed and manufactured. The rejection factor is about 1.5. Secondly, the software part of the data acquisition was improved to provide a twice higher effective rate of accepting data. In 2000, the set-up was running during 6 months and about 10^9 triggers were recorded. The data processing is in progress.

The **ATLAS** detector is designed to obtain new experimental results on the most acute problems of elementary particle physics (discovery and investigation of Higgs bosons, study of production dynamics and decay modes of top-quarks, *B*-physics, discovery of SUSY-particles) at the Large Hadron Collider (LHC) . The ATLAS apparatus consists of an inner detector (tracker), an electromagnetic calorimeter (ECAL), a hadron calorimeter (HCAL) and a muon spectrometer.

The inner tracker on the basis of the Transition Radiation Detector (TRT) serves to identify electrons by recording transition radiation photons and to reconstruct particle tracks by a large number of recorded points. Highly granular Liquid Argon (LiAr) electromagnetic calorimetry with excellent performance in terms of energy and position resolutions covers the pseudorapidity range $|\eta| < 3.2$. The bulk of the hadronic calorimetry is provided by a novel scintillator tile calorimeter. The main purpose of the barrel hadron tile calorimeter is to measure electron, gamma, jet and missing energies (E_e, E_γ, E_{jet}, E_{mis}). The whole calorimeter system contributes to the very good jet and E_T^{mis} performance of the detector. The calorimetry is surrounded by the muon spectrometer. The ATLAS collaboration approved the use of the Monitored Drift Tube Chamber (MDT) detectors (planes of pressurized drift tubes with an advanced system of monitoring of the detector spatial position) in the muon system for precise determination of coordinates of tracks.

The responsibility of DLNP within the ATLAS collaboration includes production of 84 muon chambers (20 % of the total area of the ATLAS muon spectrometer); production and assembly of the absorber of the barrel part

of the tile calorimeter; calculations of magnetic fields and forces; software development, etc.

In 2000, twenty-four modules (about 6 m long, 20 tons each) of the ATLAS hadron calorimeter were assembled at JINR. A total of 33 modules (250 submodules) out of required 65 (308) were assembled and 30 modules were delivered to CERN. In 2001, twenty-four new modules and 58 submodules will be produsedand delivered to CERN. The quality of the module assembling is controlled by measurments with a specially developed laser system. All produsedmodules are within tolerance (the deviation from the ideal «envelope» is than 0.3 mm when the maximum deviation is 0.6 mm).

In 2000, hadron energy reconstruction for the prototype ATLAS barrel combined calorimeter, consisting of lead-liquid argon electromagnetic and iron-scintillator hadronic parts, with a new nonparametrical method («e/h method») was performed [8]. The method utilizes only the known e/h ratios and the electron calibration constants, it does not require determination of any parameters by the minimization technique.

The lateral and longitudinal profiles of hadronic showers detected by the prototype ATLAS iron-scintillator tile hadron calorimeter were investigated [9]. This calorimeter uses a unique longitudinal configuration of scintillator tiles. With a fine-grained pion beam scan at 100 GeV, a detailed picture of the transverse shower behaviour is obtained. The underlying radial energy densities for four depth segments and for the entire calorimeter are reconstructed. Three-dimensional hadronic shower parametrization is developed. The intrinsic performance of the ATLAS barrel and extended barrel calorimeters for the measurement of charged pions is studied [10].

In 2000, the ATLAS Muon Group has done the following amount of work within the framework of the muon part of the project ATLAS:

1. Equipment of the work bay for assembly and test of muon detectors is manufactured, installed and adjusted. The equipment includes: (i) a facility to measure (accuracy 2 μm) outer diameters and ellipticity of aluminium tubes before assembling detectors; (ii) a semiautomatic detector assembly line with a capacity up to 20 detectors an hour; (iii) a tension meter for the anode wire in an assembled detector (accuracy 1 %); (iv) a meter based on X-ray tubes and X-ray-sensitive CCD to measure the position of the wire in relation to the tube axis with an accuracy of 3 μm (Fig. 6); (v) a fast meter (measuring time 5 min) to measure the leakage of the assembled detector to within 10^{-8} bar·l/s.

2. Mounting and adjustment of machining attachments are accomplished in the work bay for assembly of BMS-type muon chambers. The attachments include: (i) a highly accurately cut granite table $2.7\times3.6\times0.6$ m^3 in size; (ii) a set of seven highly accurate reference «rulers» 2.2 m long each for precisely placing the horizontal layer of detectors; (iii) an optical system for adjustment of the «rulers» on the granite table to within 0.3 mrad; (iv) a set

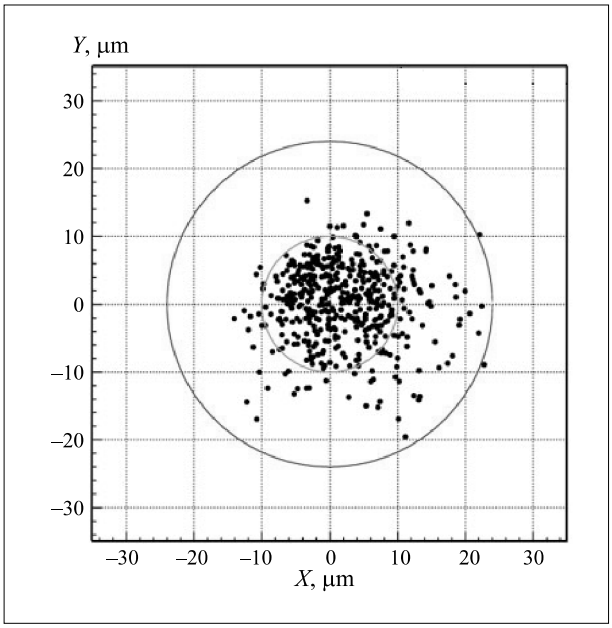


Fig. 6. The results of measuring the coordinates (position) of the anode wire in the assembled detector

of devices (towers) for vertical and horizontal positioning of glued detector layers; (v) a pneumatic feed-back system to accommodate sagging of the chamber in the course of assembly; (vi) an electron-optical system to check accuracy (within 5 μm) of mutual arrangement of chamber elements in the course of assembly; (vii) an automaton to apply epoxy glue during the assembly of detector layers.

3. Both work bays (for detector assembly and test and for chamber assembly) were accepted by the collaboration acceptance commission in June 2000. Mass production and tests of detectors began. The design work bay capacity of 500 detectors was attained in two weeks. Over 2700 detectors were produced up to November 2000 inclusive.

The **D0** experiment is located at the high-energy accelerator, the Tevatron Collider, at the Fermi National Accelerator Laboratory (USA). The research is focused on precise studies of interactions of protons and antiprotons at the highest available energies.

The basic JINR commitments in the D0 project — design and mass production of Mini-Drift Tubes (MDTs) and the corresponding front-end electronics based on ASIC chips for the D0 forward muon system — were completely executed.

The main purpose of the forward muon system, which comprises about 6500 MDTs and 50000 electronic channels in total, is to measure the muon track with a high accuracy and to provide coordinate information for the trigger system. In 2000, the JINR D0 group finished mass tests of 6500 MDTs in FNAL. Full assembly of forward muon tracker modules (48 octants in total) and their tests with cosmic rays were carried out. Commissioning of the entire system started. On-line, off-line and trigger soft-

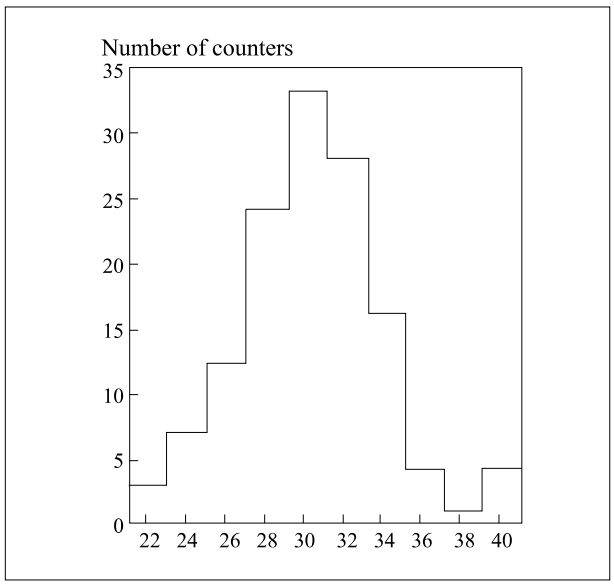


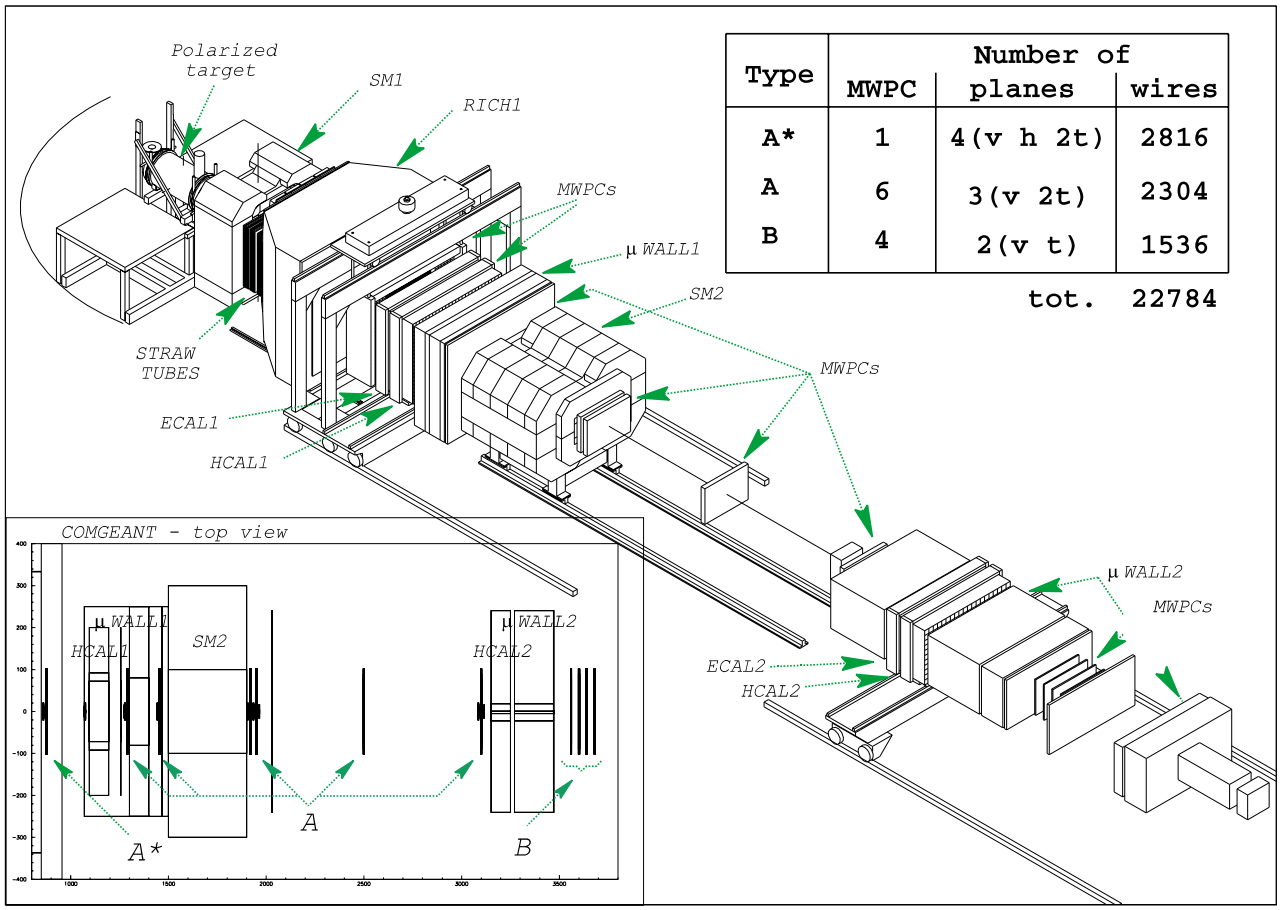
Fig. 7. Yield of photoelectrons from scintillator counters for the new muon trigger of the Upgraded CDF

ware for the forward muon system is developed. The JINR group started participating in development of software for the physical analysis of future data.

In 2000, the **CDF** group of JINR contributed both to software and hardware development of the Silicon Vertex Tracker (SVT), aimed at efficiently tagging *b*-flavoured events at the trigger level with the Collider detector at Fermilab (CDF). The SVT gives access to physics phenomena where the bottom quark is involved (heavy flavour parameter measurements, CP-violation, top quark related measurements) and possible new physics can be observed. In 2000, the Dubna group participated in:

— software development for data «patterns» to download into the Associative Memory (AM) of the SVT and for generation of the optimal pattern set for the AM;
— estimation of the execution time of the track finding and fitting process;
— development of software tools for testing AM and Hit Buffer boards during the commissioning run on the CDF. Participation in the start of the SVT at FNAL;
— development of the software and hardware tools for testing AM boards during mass production.

In 2000, a set of long (1.6–3.2 m) Scintillator Counters (607 units) for the new muon trigger of the Upgraded CDF were assembled, tested and delivered to FNAL. The counters weigh 5285 kg and cover an area of 271 m^2 around the CDF. These counters were tested with cosmic muons and radioactive sources. The yield of photoelec-



Type	Number of MWPC	planes	wires
A*	1	4(v h 2t)	2816
A	6	3(v 2t)	2304
B	4	2(v t)	1536
		tot.	22784

Fig. 8. Multiwire proportional chambers in the COMPASS initial set-up

trons (Fig. 7) is sufficient for CDF needs (30 on average) and guarantees a high efficiency of the μ trigger for the long Run II data taking period.

The main goal of the **COMPASS** experiment (NA58, CERN) is investigation of the hadron structure and hadron spectroscopy, which are both manifestations of nonperturbative QCD.

To perform these measurements a new state-of-the-art spectrometer with excellent particle identification and calorimetry is proposed.

The first runs for physics with the COMPASS spectrometer are scheduled for 2001–2002 at CERN.

The common responsibility of DLNP (chambers) and Torino (electronics) in the COMPASS collaboration is construction of a system of miltiwire proportional chambers (MWPC). A total of 13 chambers are to be installed (Fig. 8) in the initial set-up (25000 channels of electronics). Another DLNP responsibility is construction of the muon filter of the first spectrometer (μ-wall 1) — 16 chamber planes consisting of 1200 Proportional Tubes equipped with front-end electronics. The DLNP group is also participating in development of the reconstruction programme for the COMPASS apparatus and simulation of physics processes for optimization of triggers and detector design.

In 2000, the first COMPASS test beam run was completed with the impressive results obtained by the joint Dubna-Torino group: 6 proportional chambers (provided by Dubna) and instrumented with 1500 channels of front-end electronics (Torino) were successfully brought into operation complying with the nominal COMPASS spectrometer running conditions (high beam rate up to $2 \cdot 10^8$ muons per spill); above 50 million events were recorded with the Dubna-Torino system of MWPCs serving as the basis system to fulfill two main COMPASS collaboration obligations in 2000: the COMPASS muon trigger test and the test of the First spectrometer.

In 2000, the COMPASS Muon Wall-1 group obtained the following main results. All MW1 detectors (about 1100 proportional tubes, 8 wires per each tube) are produced in JINR, shipped to CERN and tested there. All analog front-end electronics (300 Amplifier-Discriminator Boards comprising about 10000 channels) is made and tested in JINR. Detector support frames are designed, the workshop for their production is prepared in DLNP, and the first two real-size frames are produced and shipped to CERN for tests. The MW1 prototype was investigated with the M2 test beam at CERN and the working gas mixture was fixed (Fig. 9).

New measurements of the spin-dependent total cross section differences (Δ_{σ_T} and Δ_{σ_L}) in neutron–proton scattering at 16 MeV were proposed by the JINR-Prague collaboration at the Institute of Particle and Nuclear Physics, Charles University (Prague). The goal of the experiment is to study nucleon–nucleon interactions and in particular their tensor component, which reveal the nature of the triton binding energy. To this end, in 1998 the polar-

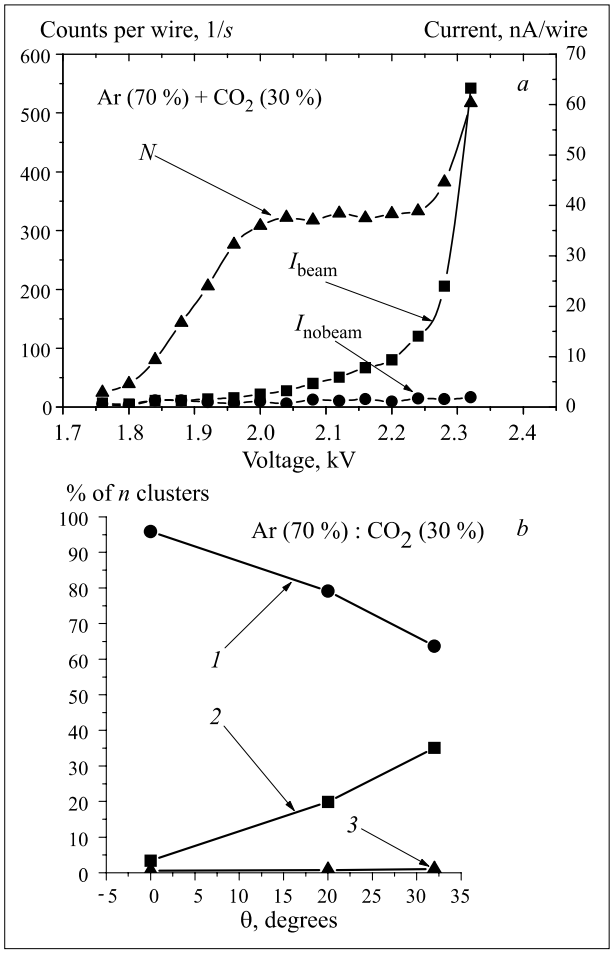


Fig. 9. The characteristics of COMPASS proportional tubes for a working gas mixture: *a*) single counting rate with beam «on» (*N*) and currents though the detector (*I*) with beam «on» and «off» versus high voltage at the detector; the stable performance plateau equals 250 V (starts at 2.0 kV, when the detector is fully efficient and stops at 2.25 kV at abruptcurrent rise); *b*) hit clusterization versus particle incoming angle — average number of fired wires (*1,2* and *3* respectively) per detector plane at the working voltage 2.1 kV

ized target was modernized and the first test run was successfully carried out. In 2000, a new device for ultralow temperature measurements based on a 4-wire automatic bridge was constructed [15]. This polarized target is also supposed to be used (as a test set-up) for the study of irradiated samples during the realization of the project «Development of the Polarized Target with ^{6}Lid and its Use for Physics Experiments (PoLiD)».

In 2000, the containers for liquid scintillator and monitor counters were developed and their production is organized at the workshops of the Institute of Particle and Nuclear Physics (Prague). All registration systems were tested with fast neutrons and the coefficient of the background suppression was in the range 300–400.

In 2000, the analysis of the data on K-meson decays earlier obtained at the Serpukhov accelerator with the **HYPERON** spectrometer (SERP-167) was continued.

The very accurate investigations of the charged and neutral decays of kaons provide important fundamental information about violation of the CP-symmetry, properties of the effective (chiral) QCD Lagrangian and new physics phenomena (supersymmentry, technicolour, extra dimensions, etc.).

At the end of 1999, a tentative value of the vector form factor slope parameter $\lambda_+ = 0.0277 \pm 0.040$ was obtained for the $K^+ \to \pi^o e^+ \nu$ (K_{e3} decay). It is based on 14000 events, which account for only 1/4 of all experimental data selected on processing. This result was obtained at the HYPERON-2 set-up with the analysing magnet, which was absent in the preceding set-up. The result is in good agreement with the world average value $\lambda_+ = 0.0286 \pm 0.0022$. The data analysis is continued to check the presence of nonzero values of the scalar and tensor terms in the K_{e3} matrix element, which were found by the HYPERON collaboration a few years ago.

In 2000, the analysis of the K_{e3} decay was carried out with the same set-up but with a new trigger condition (the so-called «soft» trigger) to exclude the possible «bias» for the earlier data. The result is $\lambda_+ = 0.0295 \pm \pm 0.0045$ for 7000 events. This result shows that the old trigger condition does not bring in any bias and therefore all collected data samples can be summarized in the new data analysis [16].

LOW AND INTERMEDIATE ENERGY PHYSICS

Precise measurement of the probability of the pion β decay allows a rigorous test of charged quark-lepton current universality, unitarity of the Cabbibo–Kobayashi–Maskawa mixing matrix and search for a possible manifestation of «new physics». The goal of the **PIBETA** experiment is to improve the accuracy from 4 % to 0.5 % at the first stage.

Data taking to accumulate statistics for precise measurement of the pion beta-decay rate was continued in 2000. Statistics obtained allows the decay rate to be determined with an accuracy of about 0.7 %. All current parameters and operation of the set-up are remotely controlled via Internet. Full information about data taking (counting rates, detector histograms, event display, etc.) is available in real time via Internet. During the whole year 2000 filtering and analysis of the experimental data were continued [17].

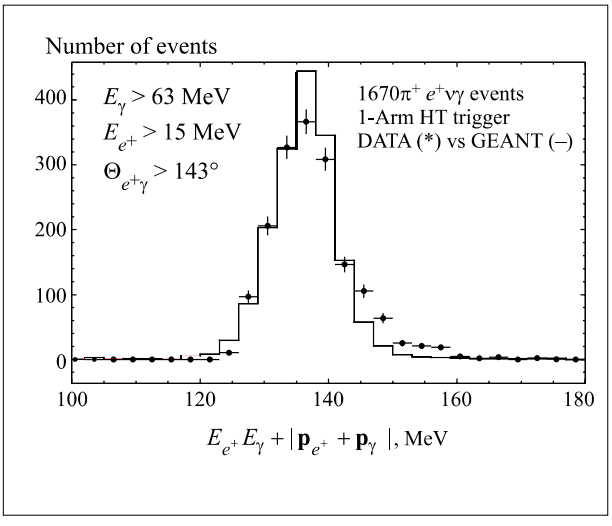


Fig. 10. Pion invariant mass of the decay $\pi \to e\nu\gamma$

The preparation to a precise measurement of radiative pion decay ($\pi \to e\nu\gamma$) was started. It was noticed [18] that a tensor interaction (forbidden in the standard model) could contribute to this decay. A new trigger was suggested which allows the $\pi \to e\nu\gamma$ events to be collected simultaneously with the data taking for the study of the pion beta-decay. A Monte-Carlo simulation performed at DLNP shows a good efficiency for $\pi \to e\nu\gamma$ decay registration with the new trigger. This allows one to increase the sensitivity of the experiment to possible tensor interaction by a factor of 10 in comparison with the earlier experiment. This new trigger was accepted by the collaboration and included in the combined trigger of the set-up. Data filtering of the available statistics for radiative pion decay study is started (Fig. 10).

The muon-catalyzed fusion is an interesting and unique process having neutron yield of nuclear fusion dependent on the macroscopic parameters of a medium (temperature, density and medium content). In particular, the study of the processes of the muon-catalyzed fusion allows one to solve the fundamental three-body problem with the Coulomb interaction with relativistic corrections.

The investigations of the parameters of muon-catalyzed fusion in double (Deuteruim/Tritium) and triple (Protium/Deuterium/Tritium) mixtures of hydrogen isotopes at high temperature and density are under way at DLNP. The study is being conducted with the **TRITON** set-up at the muon beam channel of the JINR phasotron. Measurement of the so-called effective parameters (cycling rate λ_c, neutron yield Y_n and muon loss ω) of the muon-catalyzed processes in the mixtures of hydrogen isotopes is the main aim of the experiment. The unique Tritium High Pressure Target (THPT) (Fig. 11) with the volume 16.5 cm^3, working temperature range

$300 \div 800$ K and pressure $P \leq 1600$ atm was designed, constructed and used in the experiments. The purity of hydrogen isotopes at a level of 10^{-7} was provided by the original Gas Mix Preparation System. The molecular composition of the mixtures was checked with the aid of chromatography.

In 2000, with the Tritium High Pressure Target the above-mentioned effective parameters (cycling rate λ_c, neutron yield Y_n and muon loss ω) were measured [19] in the double D/T mixture (at temperature 300–800 K and density $(1.275–2.55)\cdot 10^{22}$ nuclei/cm^3) and in the triple H/D/T mixture of hydrogen isotopes (with dependence on protium concentration at temperature 300 K and fixed density of D/T fraction in H/D/T mixture). The preliminary analysis of the dependence of the cycling rate λ_c on the tritium concentration C_t was performed. The results for the $dt\mu$-mesomolecule formation rates on DD and DT molecules were obtained. Considering the results for the dependence of cycling rates on the tritium concentration one should conclude that the theoretical resonant mesomolecule formation rates (see Fig. 12) are far greater than the experimental ones. The same conclusion was made in [20].

In 2000, the **DUBTO** self-shunted streamer chamber in a magnetic field, equipped with two CCD videocameras for studying pion interactions with light nuclei at the JINR phasotron, operated during several runs of data taking. The chamber was filled with ^{4}He at the atmospheric pressure. The technique of CCD videocameras has never been applied in experiments for visualization of particle tracks, so special software was developed for measuring digitized CCD images of nuclear events in the streamer chamber volume and for reconstruction of the reactions in space.

Particle identification is based on kinematic relationships and on analysis of the luminosity of particle tracks, which is proportional to the ionization losses in the gas target. The brightness of the CCD image of a particle track is proportional to the actual amount of light reaching the pixels of the CCD matrix, unlike the case in photographic registration, where the track brightness is logarithmically proportional to the light incident upon the film. Figure 13 shows the CCD stereo-images of a ^{4}He breakup event, in which the pion, proton and tritium tracks in the reaction $\pi^+ + {}^4\mathrm{He} \rightarrow \pi^+ + p + {}^3\mathrm{H}$ are clearly identifiable. Unambiguous identification of the charged particles and measurement of invariant masses involving strongly ionizing particles seems to make possible an analysis of the energy spectrum of excited nuclear states of the ^{4}He nucleus, and also of other quantities involving heavy secondary particles produced in the pion-helium reactions.

With the spectrometer **ANKE** at the proton synchrotron COSY (Jülich) the A dependence of the double differential cross section of the K^+-meson production in proton-nucleus collisions was measured at the proton energy above the threshold of the kaon production in proton-nucleon collisions (1.58 GeV) and in the subthreshold region [21]. At 2.3 GeV the dependence is close to $A^{2/3}$, which corresponds to the mechanism of direct production by the projectile on a nucleus proton. At the subthreshold energy a considerable deviation from $A^{2/3}$ dependence is observed, which indicates the cumulative nature (two-step mechanism) of the process.

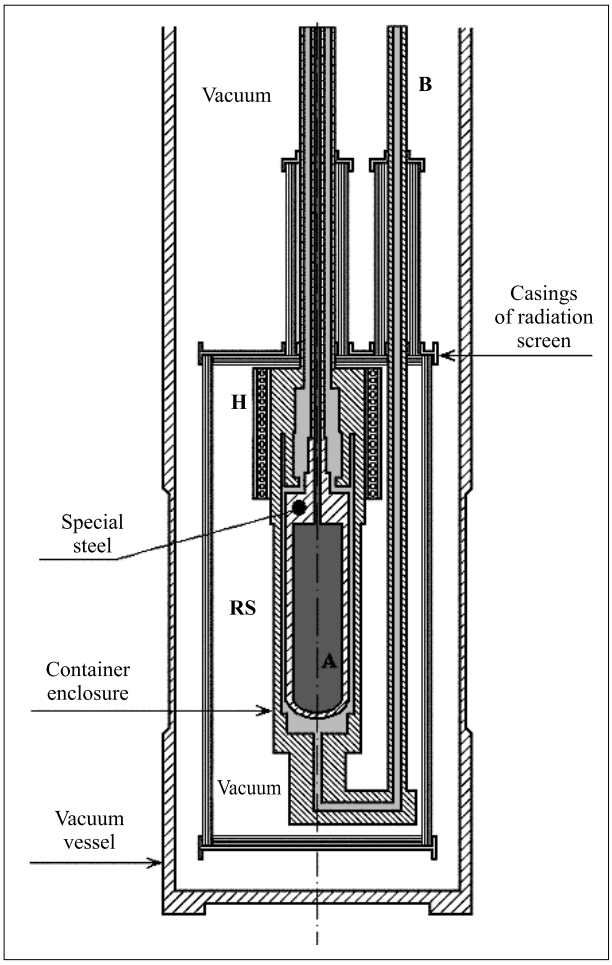


Fig. 11. Schematic view of the Tritium High Pressure Target. A — target container, B — tube for the cooling agent (hydrogen)and the path for pumping the diffusing tritium, H — heater, RS — radiation screen

The ANKE detector systems for studying the cumulative break-up of the deuteron by the proton are commissioned at the beam. The knockout of proton pairs with a small relative momentum at very small angles $p + d \rightarrow (pp)(0^\circ) + n(180^\circ)$ [22] was observed in exposure of the deuterium cluster target to a 0.5 GeV proton beam.

The lifetime of the negative muon in the ^{129}Xe isotope was measured for the first time at the DLNP JINR phasotron under the project **MUON** (investigation of the muon properties and the muon interactions with matter). This value was compared with that obtained for the

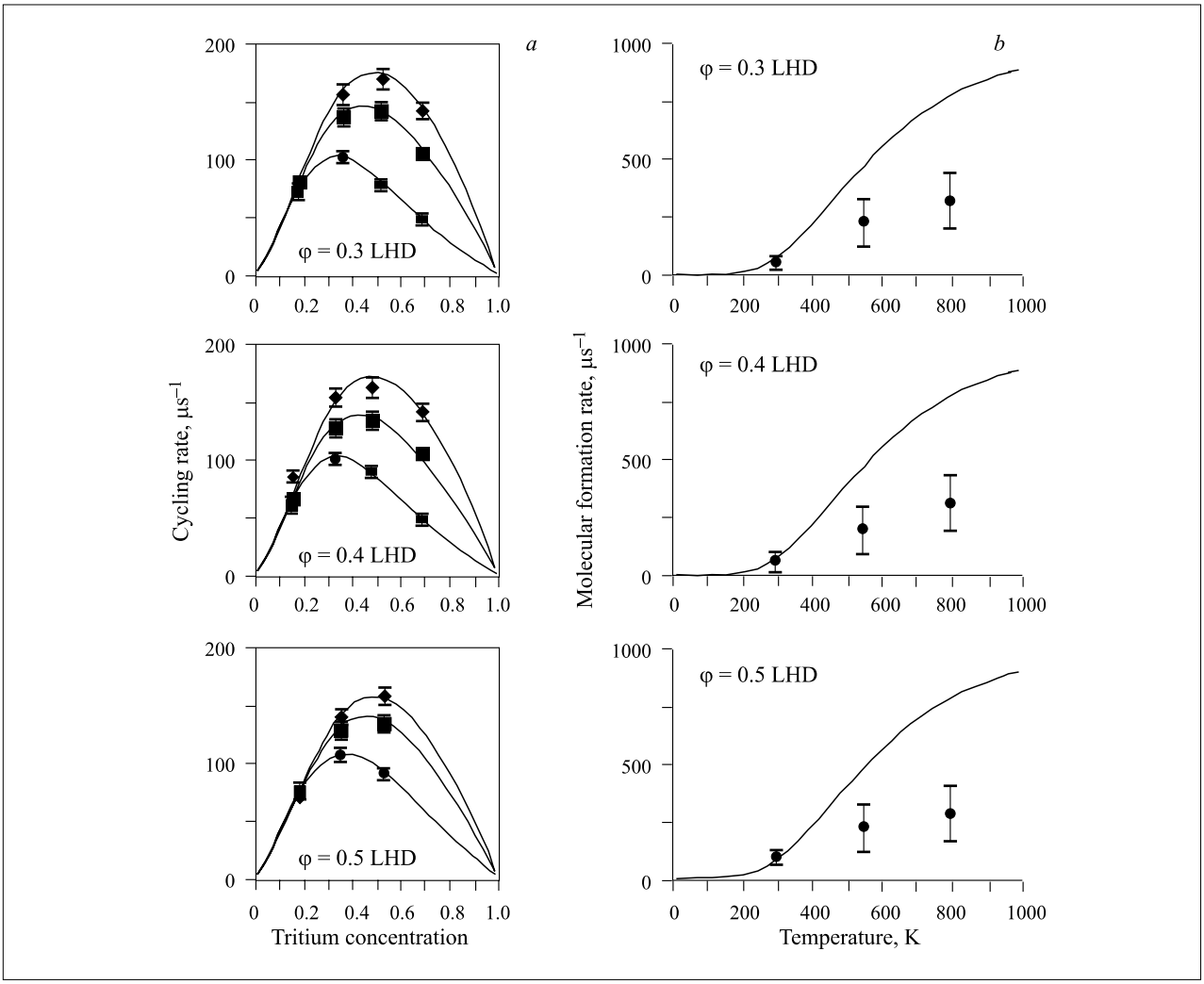


Fig. 12. Dependence of the cycling rate on the tritium concentration $\lambda_c(C_t)$. *a)* Experimental data (points) and the best fit (curves) for $\lambda_c(C_t)$ at the density of the mixture 0.3–0.5 LHD (1 LHD = $4.25 \cdot 10^{22}$ nuclei/cm^3): circles — 300 K; squares — 550 K; rhombuses — 800 K. *b)* $dt\mu$-mesomolecule formation rates $\lambda_{dt\mu-t}$ versus temperature (points) and theoretical expectations for the temperature dependence of $\lambda_{dt\mu-t}$ (curves, from *P.Ackerbauer et al.*, Hyp. Int. 101/102 (1996) 67; *M.P.Faifman et al.*, ibid., 179)

^{132,136}Xe isotopes. The noticeable dependence of the nuclear muon capture rate on the mass number for the isotopes in question is observed [23].

Preliminary measurements of the magnetic moment of the negative muon in the 1*S* state of different atoms were performed at the μ*E*4 beamline of the Paul Sherrer Institute accelerator (Switzerland). The negative muon in the bound state should possess a magnetic moment different from that of the free muon due to relativistic motion. Up to now there have only been three measurements of the magnetic moment of the negative muon in the 1*S* state of different atoms and for light atoms there is a discrepancy in the results for Mg, Si and S atoms. The measurements of the muon magnetic moment in carbon, oxygen, magnesium, and silicon confirm that the magnetic moment of the negative muon bound in the Coulomb field of the nucleus differs from the one of the free muon [24].

In 2000, the study of condensed matter by the μ*SR* technique was continued under the project MUON. The μ*SR* experiments with silicon carried out in 2000 were aimed at investigating the effect of impurities on the relaxation rate of the magnetic moment of the shallow acceptor centre. The measurements were carried out on several silicon samples with phosphorous and aluminium impurities of different concentrations. The temperature dependence of the relaxation rate of the Al shallow acceptor centre in undeformed silicon is determined for the first time. The constant of the hyperfine interaction between the magnetic moment of the muon and that of the electron shell of the muonic atom and the coefficient for capture of free electrons by a neutral aluminium atom in silicon are estimated [25].

The study of the $Ce_3Pd_{20}Si_6$ compound, one of the heaviest electron systems, was carried out in 2000. Below 0.4 K the increase of the muon spin depolarization rate

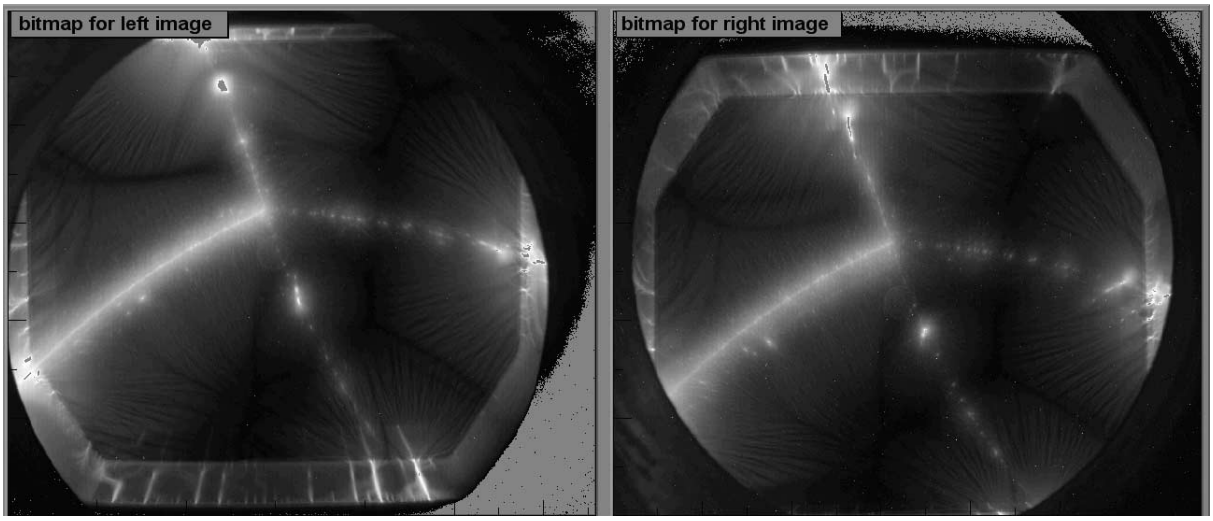


Fig. 13. The CCD stereo-images of a ^{4}He breakup event

represents development of quasi-static ordering of magnetic moments of electronic origin supposedly randomly oriented. The clear frequency shift of muon spin precession at the external transverse field was seen. This fact may be attributed to the increasing total moments of the superparamagnetic cube containing 8 Ce atoms and their ferromagnetic ordering with decreasing temperature [26].

The feasibility experiments were performed to investigate the properties of a liquid crystal whose molecule contains iron atoms. The compounds of this type are of interest from the point of view of obtaining liquid crystals with magnetic properties. The results obtained do not contradict the assumption that the iron ions form an antiferromagnetically ordered structure in this liquid crystal at the temperature below 80 K [27].

The JINR-PNPI collaboration prepares a set-up for searching for the two-particle muon decay on an electron and Goldstone's massless boson (**FAMILON** porject). This decay violates the lepton number conservation law and therefore is forbidden in the standard model.

In 2000, the assembling of the proportional chambers for the spectrometer was finished and the methodological tests were performed in PNPI. The new data acquisition system was also tested. The equipment was transported to Dubna and was assembled on the surface muon beam of the JINR phasotron. The adjustment of the chambers was performed. The data acquisition was tested in the actual conditions, the tests with radioactive sources were performed. The Monte-Carlo calculations demonstrated that with the present configuration of the FAMILON set-up the energy resolution for the muon decay positrons at a level of 10^{-3} can be reached. The resolution allows one to achieve 3-fold improvement of the TRIUMF results. In the present experimental conditions (when 10^5 muons stop per second in the target and the angle aperture is equal to ±5°) the resolution can be obtained during 300 hours of data taking.

Precision measurment of the 277-keV γ-ray produced by capturing muons in gaseous oxygen $\mu^- + {}^{16}\mathrm{O} \to \nu + {}^{16}\mathrm{N}^{**} \to {}^{16}\mathrm{N}^{*} + \gamma$ was performed with high-resolution HPGe detectors at the PSI $\mu E4$ channel (AC /μC project). The Doppler-broadened shape of this line is sensitive to the admixture of genuine scalar interaction to muon capture. Although $V\!-\!A$ interaction is postulated in the standard model, the modern extensions of this model (like R-parity violating supersymmetry, leptoquarks, etc.) allow a possible admixture of fundamental Scoupling. The genuine scalar interaction C_S would contribute to various observable quantities in ordinary muon capture summed with the induced scalar coupling g_S which is expected to be small. A fit (Fig. 14) to the experimental line shape allowed one to obtain the recoil-gamma correlation coefficient value $a_2^1 = 0.096 \pm 0.041$ (95 % C.L.). In evaluation of the contributing nuclear matrix elements this value constrains the range of the scalar coupling constants to $-0.25 < C_S < -0.07$ (95 % C.L.). The inaccurcy is dominated by the range of possible variations of the nuclear matrix elements and thus could be reduced in the future. This constraint is independent of the PCAC-prediction for the induced pseudoscalar coupling questioned recently in radiative muon-capture [29].

The β decay of ^{32}Ar accompanied by proton emission is the goal of the next experiment under the **AnCor** project (Investigation of beta-neutrino angular correlation in superallowed beta-decay of short-lived nuclei). The fundamental aim of the project is accurate measurement of the couplings of scalar and tensor weak interactions, forbidden in the standard model. The $\beta\!-\!p$ coincidence technique used in the experiment allows one to measure a shift rather than a spread of protons following the β decay. As the Doppler effect in $\beta\!-\!p$ correlations ($\sim 1/v_p$) is essentially larger than in β−γ correlations ($\sim 1/c$), one should expect a greater sensitivity of the ^{32}Ar

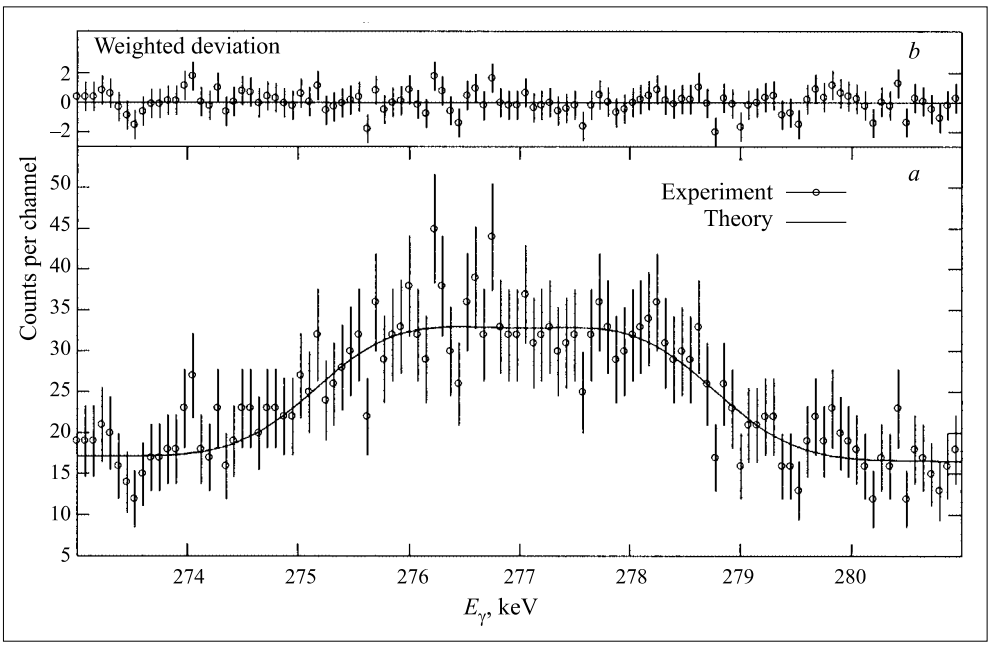


Fig. 14. Result of the elementary fit: experimental and adjusted line shapes

experiment in comparison with the previous ^{18}Ne measurements of the AnCor collaboration.

A successful test run was carried out at GANIL (Caen, France) in 2000. The quality of the ^{32}Ar beam, the experimental conditions and the characteristics of the detector prototypes were found to meet the requirements. The main experiment is scheduled for 2001–2002. The experimental set-up is under construction.

The experiment **NEMO-3** is aimed at studying nuclear double beta decays with the potential to measure a Majorana neutrino mass at the level of 0.1 eV. A total of 10 kg of isotopically enriched samples (^{100}Mo, ^{130}Te, ^{82}Se, ^{150}Nd, ^{96}Zr, ^{48}Ca) will be measured simultaneously with the NEMO-3 set-up to investigate both neutrinoless and two-neutrino modes of double beta decay.

During 2000, the main part of the NEMO-3 detector was assembled in the Frejus underground laboratory (France) at the depth of 4800 metres of water equivalent. The detector consists of 6180 Geiger counters and 1940 plastic scintillators assembled into 20 segmented sectors. In 2000, eight sectors were mounted with isotopically enriched ^{100}Mo, ^{130}Te and nonenriched control samples. The first test runs were carried out with three totally equipped sectors. The test runs showed perfect capability of the set-up with the expected background counting rate. Several calibration measurements with the ^{60}Co and ^{207}Bi sources were performed and gave the first useful information about the real energy and time resolution of the detector [30].

In 2000, the **TGV** collaboration studied the double beta decay of ^{48}Ca with a low-background and high-sensitivity Ge multidetector spectrometer TGV (Telescope Germanium Vertical). The results $T_{1/2}^{2\nu\beta\beta} = (4.2^{+3.3}_{-1.3}) \cdot 10^{19}$ years and $T_{1/2}^{0\nu\beta\beta} > 1.5 \cdot 10^{21}$ years (90 % C.L.) for double beta decay of ^{48}Ca were obtained after the processing of the experimental data collected within 8700 hours of measurement with approximately 1 gramme of ^{48}Ca [31].

In 2000, the International Germanium EXperiment (**IGEX**) on investigation of the double beta decay modes of germanium analysed about 10 kg-years of data from isotopically enriched (86 % ^{76}Ge) germanium detectors. During 2000, the experiment was conducted simultaneously in Canfranc (Spain) and Baksan (Russia) for collection of data for double beta decay with three 2-kg detectors at Canfranc (2450 metres of water equivalent) and with four 1-kg detectors in the underground laboratory (660 m w.e.) at Baksan. The average background level of about 0.15 counts per keV×kg×yr was achieved for all detectors. With Pulse Shape Discrimination applied to the recent data, the lower bound on the half-life for neutrinoless double beta decay of ^{76}Ge was deduced: $1.57 \cdot 10^{25}$ yr (90 % C.L.). This corresponds to the upper bound on the Majorana neutrino mass between 0.33 and 1.35 eV depending on the choice of theoretical nuclear matrix elements used in the analysis.

The behaviour of the characteristics of the silicon and germanium detectors in the temperature range 1–77 K is thoroughly studied [33]. Limits of using the most popular types of semiconductor detectors as spectrometric instruments at ultralow temperatures are investigated with a view to requirements of some physical problems, such as search for dark matter, study of oriented radioactive nuclei, etc. It is shown that silicon and germanium detectors can retain spectrometric properties down to 1 K under certain conditions. The investigated detectors of each type (surface-barrier, implanted, and lithium-drift ones) have specific features of their own to be taken into account under cryogenic conditions. It is shown for the first time that Si(Li) detectors of secondary

particles can be used in the temperature range 1–10 K (that the effect of their «polarizations» can be eliminated) if high (over 12500 V/cm) electric fields are generated (Fig. 15).

Contribution of the *R*-party violating supersymmetry to the muon-to-electron conversion is studied, new stringent constraints on the *R*-party violating parameters are obtained from the experimental data. A significant contribution from the strange nucleon sea is found. The effect of resonant enhancement of the Majorana neutrino contribution to the semileptonic *K*-meson decays is predicted and studied. Stringent constraints on masses and mixings of heavy neutrinos are derived. Generic properties of lepton number violating processes and their relation to different entries of the Majorana neutrino mass matrix are studied. New phenomenological, astrophysical and cosmological issues of sterile neutrinos are investigated. Their impact on the accelerator neutrino counting experiments, big bang nuclear synthesis and supernova explosion are analysed [34]. New single spin CP-odd asymmetries in polarized proton-proton scattering are proposed. Mechanisms beyond the standard model generating these asymmetries are found and possible magnitude of CP-violating effects is predicted [35].

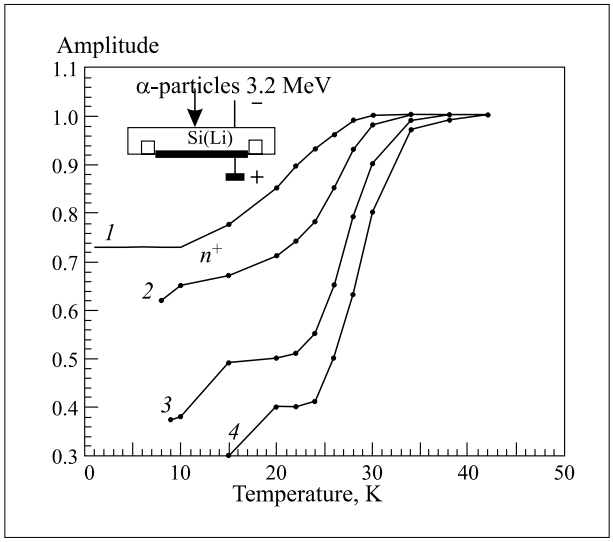


Fig. 15. Signal amplitude as a function of the temperature for various bias voltages applied to the detector. *1* — $E = 12500$ V/cm; *2* — $E = 6000$ V/cm; *3* — $E = 3000$ V/cm; *4* — $E = 1500$ V/cm

RELATIVISTIC NUCLEAR PHYSICS

The **FASA** project studies the mechanism of the «nuclear thermal multifragmentation» induced in heavy targets by light relativistic ions. In 1994, the FASA group proved for the first time through fine angular correlation measurements for the intermediate mass fragments (IMF, $2 < Z < 20$) that this process is a new multibody decay of very hot nuclei, governed mainly by the thermal excitation energy.

In 2000, the IMF energy spectra were studied. These spectra reflect geometry and dynamics of the expansion of sources of the emitted IMF. By comparing the data from p + Au collisions with the data from reactions induced by heavier projectiles (^{4}He and ^{12}C) a transition from a pure statistical process to a more complex (dynamical) process with a collective IMF flow was observed. The spatial distribution of the fragments can be deduced from the observed collective component of the IMF kinetic energy. The experiments were performed with the modified 4π-set-up FASA installed at the external beam of the JINR Synchrophasotron (Nuclotron). Figure 16 shows the mean kinetic energies per nucleon of fragments emitted in collisions of p (8.1 GeV), ^{4}He (14.6 GeV) and ^{12}C (22.4 GeV) with Au. For the proton-induced reactions the measured energies are close to the calculated energies, but the experimental data for ^{4}He and ^{12}C exceed remarkably both the calculated and measured values for pAu interaction. This enhancement is connected with the radial collective flow (due to the thermal pressure) in the system of the target spectator which is hotter in the case of heavier projectiles. The flow energy of fragments is estimated [36, 37] as a difference between the measured IMF energy and the energy calculated without any flow (Fig. 16). The corresponding mean flow velocities for different fragments are given in Fig. 17. The remarkable deviation of the data from the model prediction can be caused by the uniform density distribution used and therefore by a rather constant probability of fragment formation at any point of the available volume. The data indicate that heavy fragments are predominantely located in the interior of a nucleus. The present study shows that in spite of the success of the statistical multifragmentation models, the description of the break-up condition might be still too simplified. The fragment energy spectra (and their correlations with the fragment multiplicity [38]) provide sensitive probes for the source configuration and emission dynamics.

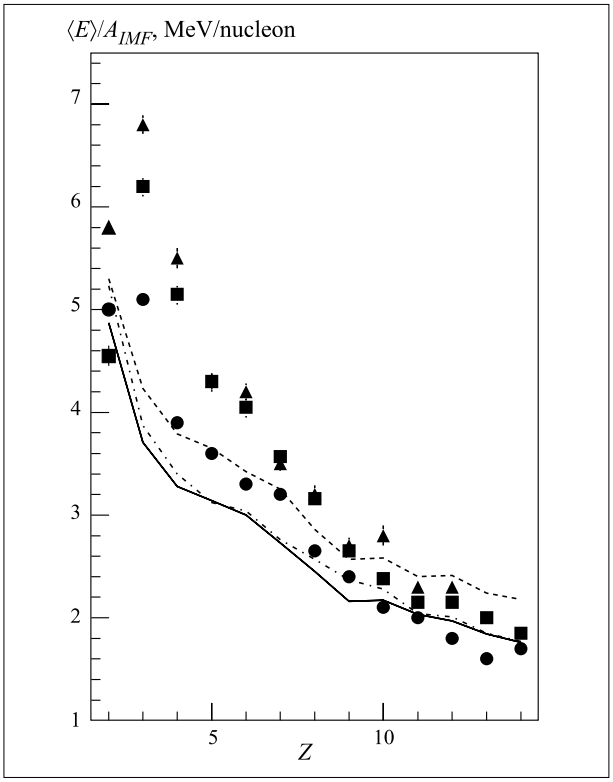


Fig. 16. Mean kinetic energies per nucleon of outgoing fragments with charge Z measured at $\theta = 89°$ for p(8.1 GeV) (dotted line and circles), ^{4}He (14.6 GeV) (solid line and squares) and ^{12}C (22.4 GeV) (dash-dotted line and triangles) collisions with Au. The lines are calculated within a combined approach which includes the Intranuclear Cascade Code followed by the Statistical Multifragmentation Model (INC* + CMM), assuming no flow

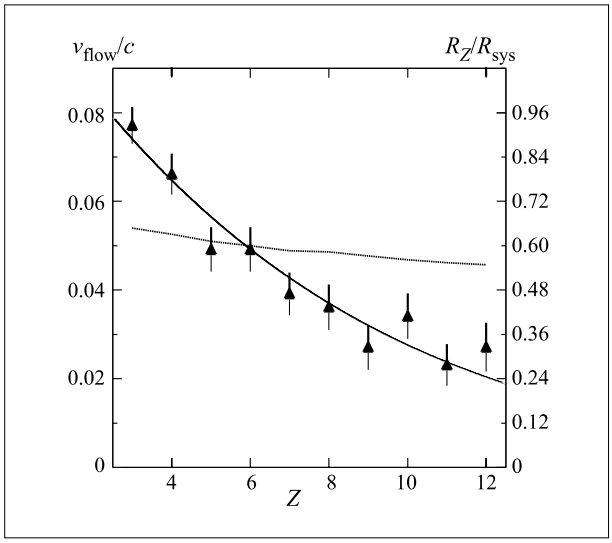


Fig. 17. Experimentally deduced mean flow velocities (trangles) for ^{12}C + Au collisions as a function of the fragment charge (left scale), and the mean relative radial coordinates of fragments (right scale), under the assumption of a linear radial profile for the expansion velocity. The dashed line shows the mean radial coordinates of fragments according to the Statistical Multifragmentation Model

APPLIED SCIENTIFIC RESEARCH

The project Low-Energy Particle Toroidal Accumulator (**LEPTA**) (Fig. 18) is aimed at constructing a small positron storage ring with electron cooling of circulating positrons. The goal of this device is generation of intense streams of electron-positron bound states (positronium) and (together with low-energy antiprotons) synthesis of antihydrogen atoms.

Design of the storage ring elements is accomplished. The solenoid of the electron cooling section is constructed, tested and adjusted. The magnetic field inhomogeneity is less than 10^{-3}, which corresponds to the design value. The vacuum chamber of the ring is designed, constructed and tested. The minimum residual gas pressure obtained is 10^{-7} Torr. The conceptual design of the positron injector is ready. The positron injector based on radioactive isotopes and the intermediate penning-type trap provides an injected beam intensity of 108 positrons, which permits an ortho-positronium flux of about 104 s^{-1}. Elements of the electron cooling system are designed on the basis of the DLNP test bench. A method of the cooling process investigation is elaborated and required diagnostics is designed.

The conceptual design of the first experiments with positronia in flight is ready. It includes direct comparison of the electron and positron electric charges and ortho-positronium lifetime measurements. The expected experimental resolution is $5 \cdot 10^{-10}$ for the charge difference and 10^{-5} for the positronium lifetime, which exceeds the present level by two and one order of magnitude respectively.

Based on the Medicotechnical complex and medical hadron beams from the JINR Phasotron, medicobiological and clinical research on treatment of tumour patients, improvement of equipment, and development of new radiotherapy methods and accompanying diagnosis are carried out at the Dzhelepov Laboratory of Nuclear Problems.

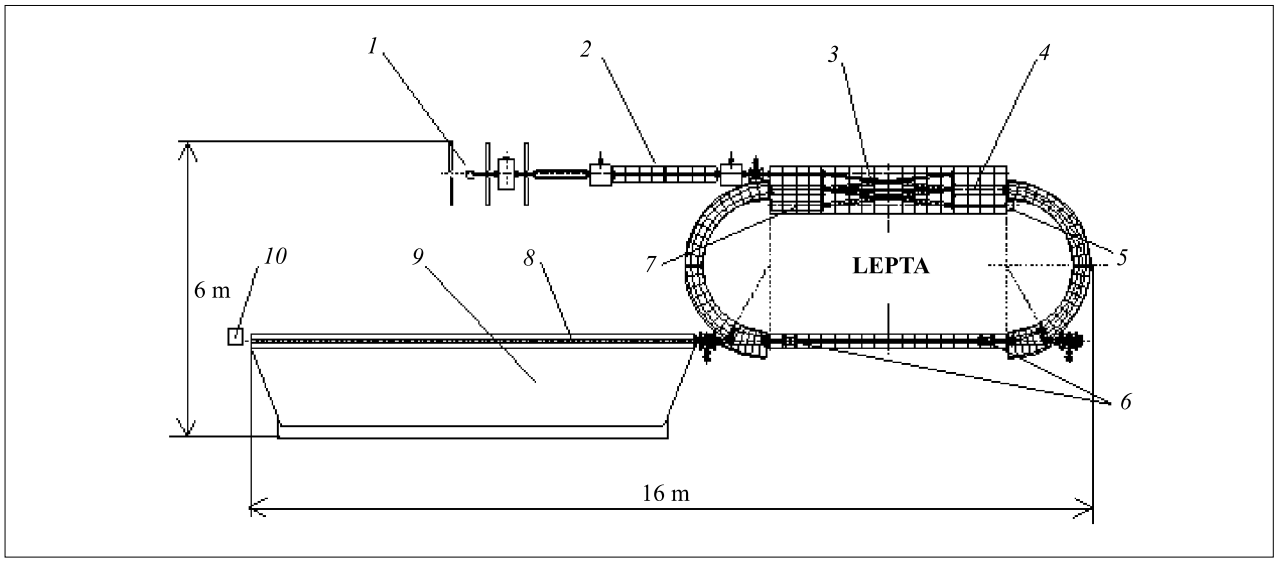


Fig. 18. LEPTA layout: *1* — positron source; *2* — positron trap; *3* — septum coils; *4* — kicker; *5* — electron collector; *6* — pick-up stations; *7* — electron gun; *8* — decay channel; *9* — dipole magnet; *10* — Ps detector

In 2000, the clinical investigations on proton treatment of tumour patients at the Phasotron were extended. A total of 36 patients were given a course of fractionated radiation treatment with the medical 150 MeV proton beam (together with subsequent gamma therapy). The total number of proton sessions was 409. Another 17 tumour patients were geven radiation treatment only on the Rokus-M gamma facility.

Special devices for modification of the Bragg peak of the proton beam have been developed, manufactured and tested. They allow a beam with a flat-top Bragg peak 2.5, 3.5, and 4.5 g / cm ^{2} long to be formed in treatment room 1, which makes radiation treatment of malignant tumours more effective.

In 2000, thermoluminescent and track detectors were exposed to the medical proton beam from the JINR Phasotron to determine their radiotherapeutic proton beam characteristics and to measure LET spectra and thus to find the contribution to the dose from secondary particles. Dosimetric calibration of the therapeutic gamma facility Rokus-M and clinical dosimeters used for dose supply in proton therapy sessions was carried out together with the specialists from the Institute of Nuclear Physics (Prague) [39].

The molecular and radiation genetics group continued experimental investigation of the nature of inherited radiation-induced recessive multations and their locations on the gene map using the polymerase chain reaction (PCR) method [40].

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FLEROV LABORATORY OF NUCLEAR REACTIONS

The fields of activity, traditional for the Flerov Laboratory of Nuclear Reactions, are experiments with heavy-ion beams of stable and radioactive isotopes, synthesis of heavy and exotic nuclei, the study of nuclear reactions, acceleration technology and heavy-ion interaction with matter, and applied research.

These lines of investigation will be realized within a wide international collaboration using the accelerators of the Laboratory and other scientific centres.

The beam time provided by the FLNR U-400 and U-400M cyclotrons in 2000 was nearly 9000 hours (the amount planned for that year). The above-mentioned factors made it possible to perform new experiments in low and medium energy ranges.

EXPERIMENTS WITH ION BEAMS OF STABLE AND RADIOACTIVE ISOTOPES ON THE HEAVY AND EXOTIC NUCLEI SYNTHESIS, THE NUCLEAR REACTIONS STUDY

Synthesis of New Elements

An important achievement of the Laboratory is the experimental proof of the macro-microscopic theory predictions concerning the existence of spherical shells with $Z \approx 114$ and $N \approx 184$. This achievement inspires hopes that approaching the boundaries of this unknown region where the influence of the $N = 184$ spherical shell becomes noticeable has become a reality in fusion reactions using the heaviest isotopes of U, Pu, Cm as targets and a ^{48}Ca ion beam.

In contrast to «cold» fusion reactions, dynamical limitations on the fusion of interacting nuclei are not expected due to the high asymmetry in the entrance channel ($A_p/A_t \approx 0.2$; $Z_p \cdot Z_t \approx 1880$). On the other hand, the excitation energy of a compound nucleus at the Coulomb barrier amounts to only about 30 MeV as a result of a significant mass excess of the doubly magic ^{48}Ca nucleus. This circumstance should increase the survival probability of the evaporation residues (EVRs) as compared with the case of «hot» fusion reactions.

Since the production cross section of a superheavy element even at the maximum of the excitation function is expected to be in the range of 1 pb, the cornerstone of our experiments was the production of a stable and intense ion beam of a ^{48}Ca isotope at the minimal material consumption. Due to the high efficiency of the ^{48}Ca beam production a world-level competitive programme on the synthesis of superheavy elements has been launched.

The experiments were carried out at the FLNR (Dubna) heavy-ion cyclotron U-400 using the electrostatic separator VASSILISSA and the Dubna Gas-Filled Recoil Separator (DGFRS) in the framework of a large collaboration with GSI (Darmstadt), LLNL (Livermore), RIKEN (Wako-shi, Saitama) and the Comenius University (Bratislava). The experimental results are summarized in Table 1.

The first positive result was obtained at the separator VASSILISSA in the spring of 1998 after irradiating the ^{238}U target with a total ^{48}Ca beam dose of $3.5 \cdot 10^{18}$ ions [1]. In the experiment two spontaneous fission events with the TKE values of 190 and 212 MeV were observed. They were assigned to the decay of a new isotope of element 112 produced in the reaction ^{238}U(^{48}Ca, $3n$)^{283}112 (see Fig. 1,*b*) with a cross section of $\sigma_{3n} \approx 5$ pb.

In March – April 1999 the ^{242}Pu target was bombarded with $7.5 \cdot 10^{18}$ ions of ^{48}Ca at the separator VASSILISSA [2]. Two decay chains were assigned to the α decay of the parent nucleus ^{287}114 (see Fig. 1,*a*). Both

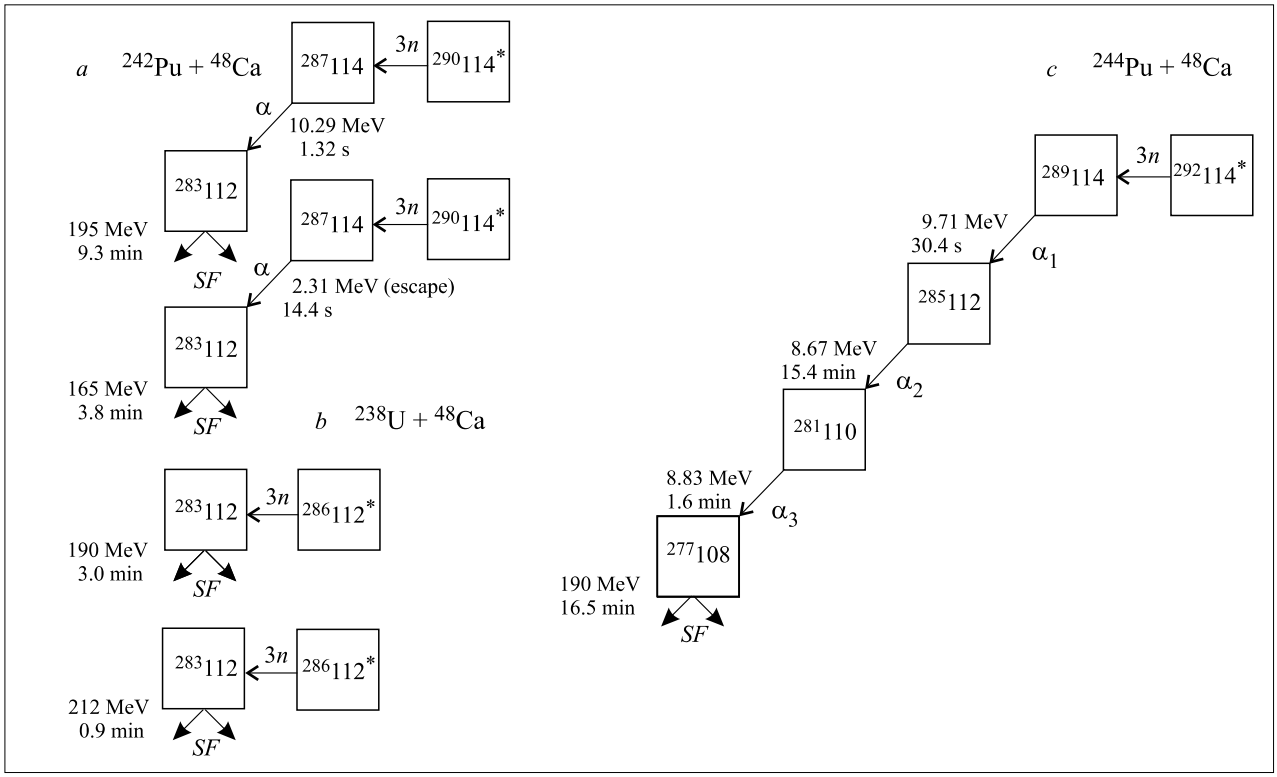


Fig. 1. Position-correlated decay chains: *a*) of $^{287}114$, produced in the reaction $^{242}Pu + ^{48}Ca$; *b*) of $^{283}112$, produced in the reaction $^{238}U + ^{48}Ca$ and *c*) of $^{289}114$, produced in the reaction $^{244}Pu + ^{48}Ca$

decay chains were terminated after the first α decays by spontaneous fission of the previously observed daughter nucleus $^{283}112$.

In the $^{244}Pu + ^{48}Ca$ and ^{48}Cm fusion reaction the isotopes of elements 114 and 116 which most closely approach the peak of the «island of stability» can be synthesized. The experiments with the ^{244}Pu target were performed at the DGFRS during November 1998 – December 1999.

After the irradiation of the ^{244}Pu target with a beam dose of $5.2 \cdot 10^{18}$ ions an α-decay sequence terminated by spontaneous fission was observed [3]. In this decay chain, all 5 signals — the recoil nucleus, α_1, α_2, α_3, and *SF* (see Fig. 1,*c*) — appeared within a position interval of ≈ 1 mm, which is a strong indication that there is a correlation between the observed decays. Considering the experimental conditions and the observed decay characteristics, it was found with most certainty that the decay chain originated in the isotope $^{289}114$ produced in the 3*n*-evaporation channel.

In the subsequent irradiation with a projectile energy, corresponding to the excitation energy of the compound nucleus $^{292}114$ equal to $E^* = (33 \div 40)$ MeV, at a beam dose of 10^{19} ions two identical α-decay chains terminated by spontaneous fission were registered [4]. All 4 signals from EVR, α_1, α_2, and *SF* (see Fig. 2,*a*) appeared within a position interval of 0.5 mm and were assigned to the α-decay of the parent nucleus $^{288}114$.

Table 1

Date		Target	Excitation energy *E**, MeV	Beam dose 10^{18}	Nuclide detected	Cross section, pb
March,	1998	^{238}U	31.0	3.5	$^{283}112$	5
Nov.–Dec.,	1998	^{244}Pu	35.0	5.2	$^{289}114$	1
March,	1999	^{242}Pu	33.5	7.5	$^{287}114$	2.5
Jun.–Oct.,	1999	^{244}Pu	35.3	10	$^{288}114$	1
Jun.–Dec.,*	2000	^{248}Cm	33.1	18*	$^{292}116$	0.5*

*The experiment is in progress.

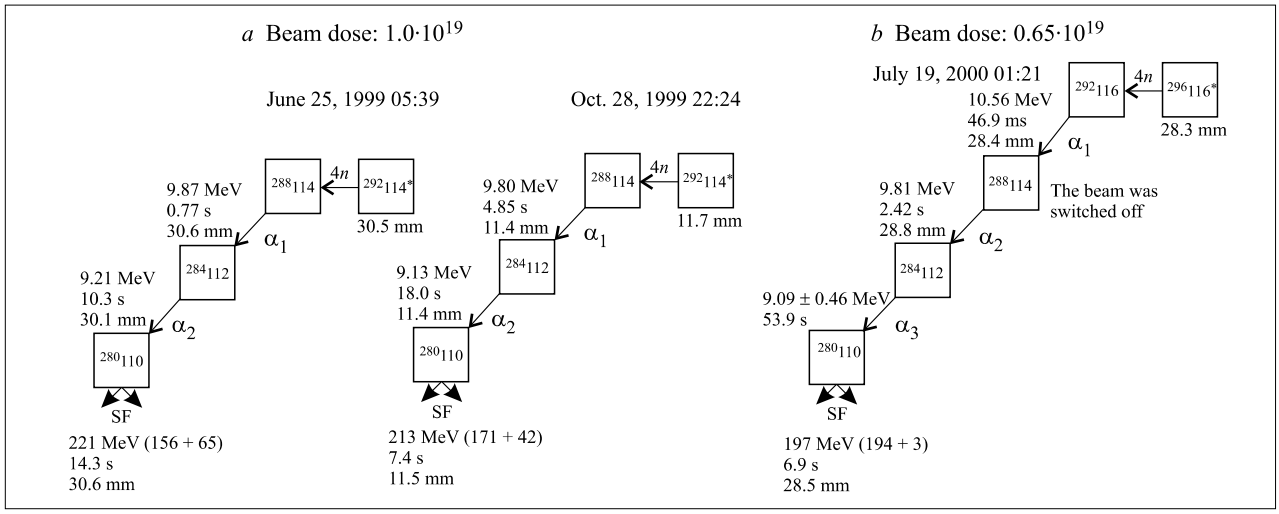


Fig. 2. *a*) Two decay sequences of $^{288}114$ observed in the $^{244}Pu(^{48}Ca,4n)$ reaction; *b*) the time sequence in the observed $^{292}116$ decay chain

The experiment aimed at the synthesis of the precursor of the isotopes $^{288}114$ and $^{289}114$ by the irradiation of the ^{248}Cm target started in June 2000. On the 35th day of the irradiation with an accumulated beam dose of $6.6 \cdot 10^{18}$ ions the first event sequence was observed [5], which could be assigned to the implantation and decay of the isotope $^{292}116$ (see Fig. 2,*b*). After the implantation of the heavy recoil followed in 46.9 ms by an α particle with $E_\alpha = 10.56$ MeV the ion beam was switched off and α_2, α_3, and *SF* were detected under low background conditions. The decay properties of the heaviest Hs – $^{292}116$ isotopes are presented in Table 2.

Future investigations at FLNR will be aimed at the synthesis of nuclei with $Z = 110 \div 118$ in the ^{232}Th, $^{236,238}U$, ^{237}Np, $^{242,244}Pu$, $^{241,243}Am$, $^{246,248}Cm$, $^{249}Cf + ^{48}Ca$ reactions. The use of ^{36}S, ^{50}Ti, ^{58}Fe and radioactive beams in these reactions is now discussed.

Table 2

Isotope	Decay mode	E_α, MeV	TKE_{mes}, MeV	$T_{1/2}$
^{277}Hs	*SF*		170	11 min
$^{280}110$	*SF*		210	6.6 s
$^{281}110$	α	8.83		1.1 min
$^{283}112$	*SF*		190	3 min
$^{284}112$	α	9.17		19 s
$^{285}112$	α	8.67		11 min
$^{287}114$	α	10.29		5 s
$^{288}114$	α	9.83		1.8 s
$^{289}114$	α	9.71		21 s
$^{292}116$	α	10.56		33 ms

In 2000, the first stage of modernization of DGFRS (electronic and detector systems) and VASSILISSA (installation of a new bending dipole, electronic and detector systems) was completed. All necessary tests were performed in December 2000, and at the end of January 2001 it is planned to start experiments aimed at the determination of mass of the superheavy nuclides, produced in the reactions $^{48}Ca + ^{236,238}U \rightarrow ^{284,286}112^*$.

Chemistry of Transactinides

The isotopes of SHE, produced in ^{48}Ca induced reactions, make it possible to study chemical properties of elements. Chemical identification of the proton number is of great importance, since the members of the decay chains are not known. The 3-min $^{283}112$ can be produced with a cross section of about 5 pb. Element 112 (E112) must belong to the IIB group Zn–Cd–Hg and have some unique chemical properties. As the first step we developed a separation and detection method for Hg.

For the experiments with short-lived Hg isotopes at the U-400 cyclotron a flow-through detection chamber was constructed (Fig. 3) which had a pair of square (2×2 cm) PIPS (passivated ion-implanted planar silicon) detectors. The deposition efficiency in each detection chamber depended on the gas composition and the flow rate.

First attempts of chemical identification of element 112 were performed at the Dubna U-400 cyclotron in January 2000 [6]. A 2-mg/cm^2 $^{238}U_3O_8$ target also contained 100 μg of natural Nd. It was deposited onto a 2 μm HAVAR. After 10 days of irradiation with ^{48}Ca ions an integral beam dose of $6.9 \cdot 10^{17}$ was accumulated. Recoils were thermalized in pure helium and transported through a 25 m long capillary to the detection apparatus. There

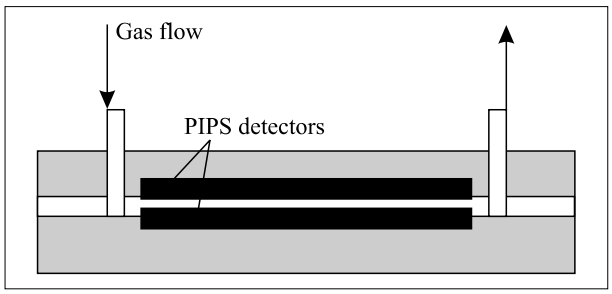


Fig. 3. Schematic view of the detector chamber

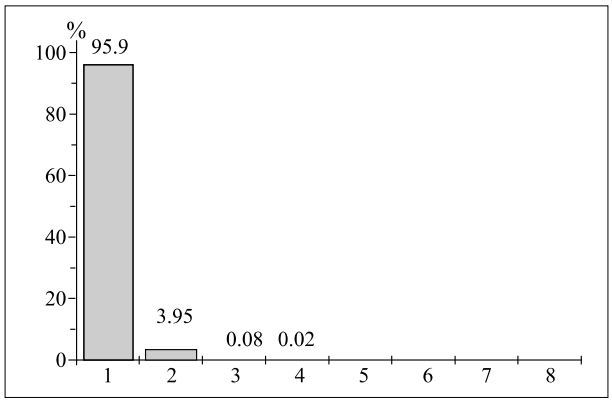


Fig. 4. The distribution of adsorbed mercury in detection chambers

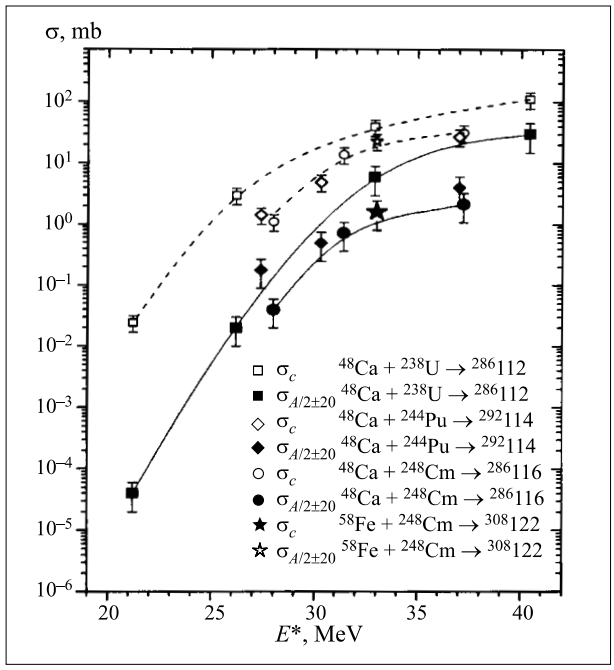


Fig. 5. The capture cross section σ_c and the fusion-fission cross section σ_{ff} for the reactions $^{48}Ca + ^{238}U$, ^{244}Pu, ^{248}Cm, and $^{58}Fe + ^{248}Cm$ as a function of the excitation energy

were 8 detection chambers in series. The detectors number 1– 6 were covered with Au, the last two chambers contained detectors with Pd. The chambers were positioned inside an assemblage of the ^{3}He-filled neutron counters. The adsorption of the Hg atoms formed in the reaction Nd(^{48}Ca; *xn*) was measured through the 5.65-MeV α particles of ^{185}Hg. A typical distribution of Hg over the detectors is shown in Fig. 4.

During this bombardment, no SF events were observed. This experiment unambiguously showed that chemical identification of nuclei produced with picobarn cross sections was feasible. The experiment does not provide any certain answer concerning physical and chemical properties of element 112. As the next stage of this work we plan to increase the beam dose twice or more and to upgrade our detector system for measuring α decays and SF events in gas exciting the chambers with the PIPS detectors using a special ionization chamber.

A series of collaborative experiments were conducted together with scientists from Switzerland, Germany and USA. New results on the properties of Bh ($Z = 107$) were obtained [7].

Nuclear Fission

In 2000, the time-of-flight spectrometer CORSET designed at the Flerov Laboratory was modernized. It is intended for the registration of fission fragments in correlation with emission of pre- and postscission neutrons and γ quanta. The modernization was performed in view of using the CORSET set-up in tandem with the multidetector neutron spectrometer DEMON. An important peculiarity of the work was the use of the «neutron clock» method for the study of time characteristics of the process of formation and decay of superheavy nuclei formed in reactions with heavy ions [8]. For the detection of neutrons 24 DEMON modules were used.

At the FLNR U-400 accelerator, experiments were carried out devoted to the study of fusion-fission of superheavy nuclei with $Z = 102 \div 122$ in reactions with ^{48}Ca and ^{58}Fe ions using ^{208}Pb, ^{238}U, ^{244}Pu, and ^{248}Cm targets; as well as with ^{86}Kr ions using a ^{208}Pb target at E*-15, 28 MeV. Figure 5 shows the results of measurements of the capture cross section σ_c and the fusion–fission cross section σ_{ff}.

In the study of the regularities of the process of the superheavy element fusion–fission a novel and important result was obtained. The obtained mass-energy distributions point to a clear evolution from the symmetric fission of the compound nucleus of ^{256}No to the situation of the ^{286}112 and ^{292}114 nuclei in which a more asymmetric process, which is caused by nucleon shells of the light fragment, becomes predominant. In the case of ^{294}118 the process of quasi-fission seems to be dominating even in the region of symmetric fission [9].

Emission of neutrons and γ quanta in correlation with fission fragments in the decay of superheavy compound

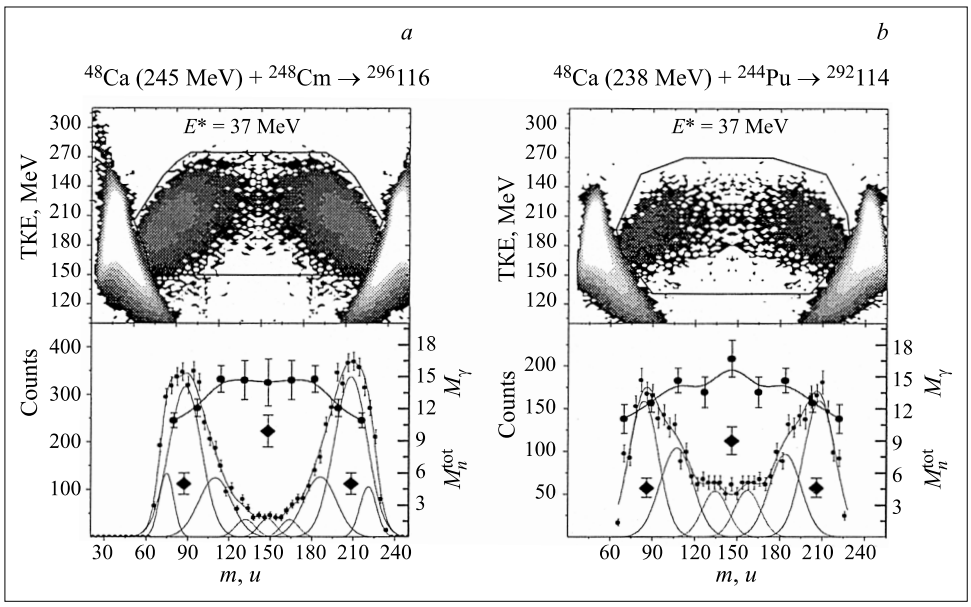


Fig. 6. Two-dimensional TKE-mass matrices (top panels) and the mass yields and neutron and γ multiplicities in dependence on the fission fragment mass (bottom panels) for the reactions ^{48}Ca + ^{248}Cm → ^{296}116 and ^{48}Ca + ^{244}Pu → ^{292}114

systems at excitation energies of near or below the Coulomb barrier had not been properly studied before. At the same time such investigations may be extremely useful for an additional identification of fusion–fission and quasi-fission processes and thus a more precise determination of the cross sections of the above-mentioned processes in the total yield of fragments. On the other hand, the knowledge of the value of the fission fragment neutron multiplicity may be used in the identification of SHE in the experiments aimed at their synthesis. The first results of such investigation are presented in Fig. 6.

Physicists from the Institute of Subatomic Research (Strasbourg), Freedom University (Brussels, Belguim), Texas A & M University (USA), the Institute of Corpuscular Physics (Caen, France), University of Messina (Italy) took part in the investigations.

Using a 4π-multidetector neutron spectrometer DEMON and a fission fragment trigger CORSET it is planned to measure at subbarrier energies the differential characteristics of mass and energy distributions of fission fragments in coincidence with neutrons and γ quanta in reactions induced by ^{22}Ne, ^{40}Ar, ^{48}Ca, ^{50}Ti, ^{58}Fe, and ^{86}Kr ions and leading to formation of compound nuclei in the region of $Z = 102–122$.

Fragment Separator COMBAS

A number of experiments devoted to the study of reaction mechanisms in nucleus–nucleus collisions at intermediate energies were carried out at a fragment-separator COMBAS. The production of isotopes with mass numbers $4 \le A \le 30$ and atomic numbers $2 \le Z \le 13$ in the reaction ^{22}Ne + ^{9}Be (^{181}Ta) at the Fermi energy domain (45 A MeV) was studied in zero-angle measurements (Fig. 7). No evidence was found for dramatic change in the reaction mechanism in the Fermi energy domain as

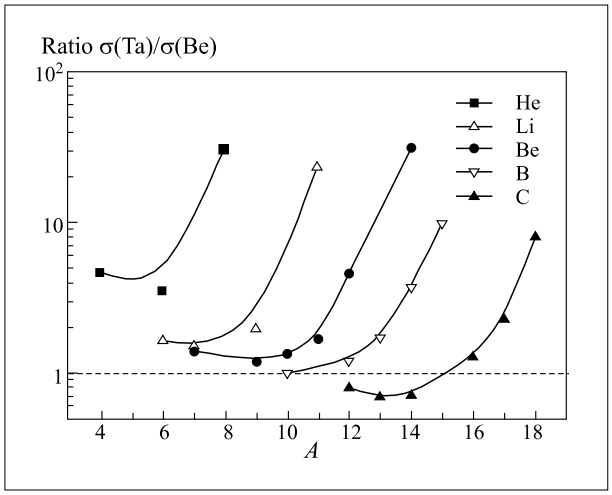


Fig. 7. Comparison of production cross sections of neutron-rich isotopes of He, Li, Be, B and C in the reactions between ^{18}O (35 A MeV) and heavy (^{181}Ta) and light (^{9}Be) targets

compared with that in the low energy range (lower than 20 $A \cdot$ MeV) [10].

It was shown that in the interaction of a light projectile (^{22}Ne) and light and heavy targets (^{9}Be and ^{181}Ta), nuclear reactions of stripping, pick-up and exchange are dominant in the Fermi energy domain. For the isotopes close to the stability line a considerable contribution from the de-excitation process was registered. The exponential approximation of isotopic distributions for all detected elements using the Q_{gg} systematics confirms a binary type of the reactions. The simple exponential approximation realized with the use of the Q_{gg} systematics is a powerful tool for predicting correctly the expected yields of unknown drip-line nuclei.

High-Resolution Beam Line ACCULINNA

The separator ACCULINNA was upgraded for the installation of a liquid tritium target. The beam line was extended beyond the 2-meter concrete wall to a newly built hall housing the reaction chamber of ACCULINNA (Fig. 8). The beam monitoring and detector arrays were upgraded in order to fit experiments aimed at the study of

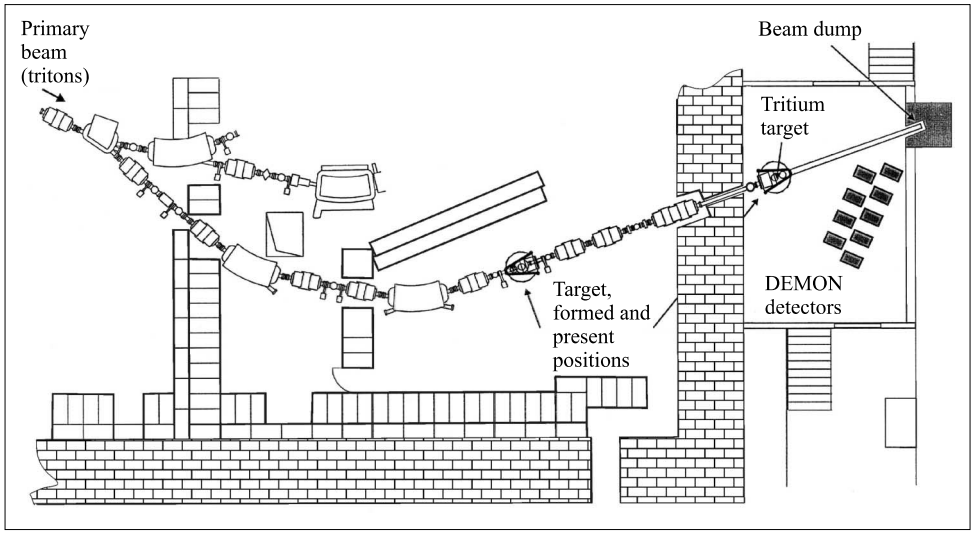
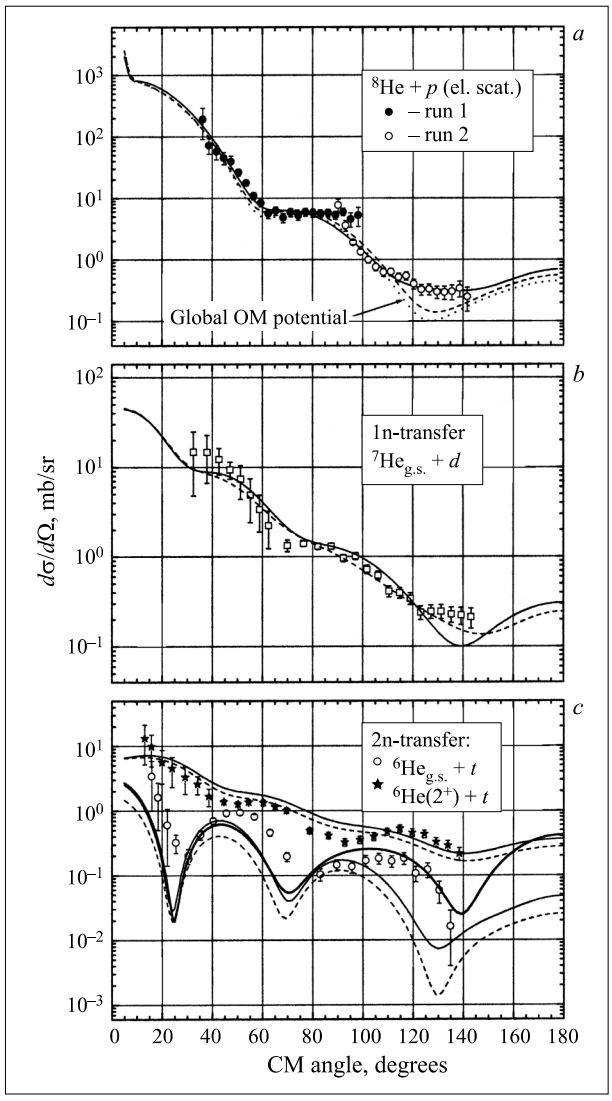


Fig. 8. The ACCULINNA set-up upgraded for experiments with the cryogenic tritium target



^{5}H produced in the $t + t$ reaction with a 51-MeV primary triton beam. New improved particle telescopes were installed in the reaction chamber. Neutrons will be detected with the DEMON detector array.

Direct reactions occurring with a 26-A MeV ^{8}He beam of bombarding hydrogen were investigated [11]. The cross sections for the elastic scattering, the 1n transfer, the 2n transfer to the ^{6}He ground-state, and the 2n transfer to 6He in the 2^+ state, respectively, were measured in angular ranges of 35–42°, 33–143°, 15–135°, and 13–138° (Fig. 9). Unlike other weakly bound nuclei, the elastic scattering of ^{8}He is relatively well described by the global OM without any adjustment. The transfer reaction data were analyzed with the finite range DWBA. Spectroscopic amplitudes (SA) for the ^{7}He(3/2–) + n, ^{6}He(0+) + 2n and ^{6}He(2+) + 2n clustering of ^{8}He predicted by the translation invariant shell model (TISM) were tested. The OM potentials for different exit channels were found. Data for the 2n transfer are leading to ^{6}He(2+) point to a large rms radius for the two-body ^{8}He = ^{6}He(2+) + 2n wave function and exceed those following from the COSMA model. The calculations consistent with a minimal number of free parameters and SA from TISM underestimate the experimental ^{6}He(0+) + t exit-channel cross section. The data suggest that the ^{5}H + t clustering is large in ^{8}He.

Angular distribution of ^{8}He ions elastically scattered from a gaseous helium target was measured in a CM

Fig. 9. Cross sections for the ^{8}He elastic scattering, the 1n transfer, the 2n transfer to the ^{6}He ground-state, and the 2n transfer to ^{6}He in the 2 + state

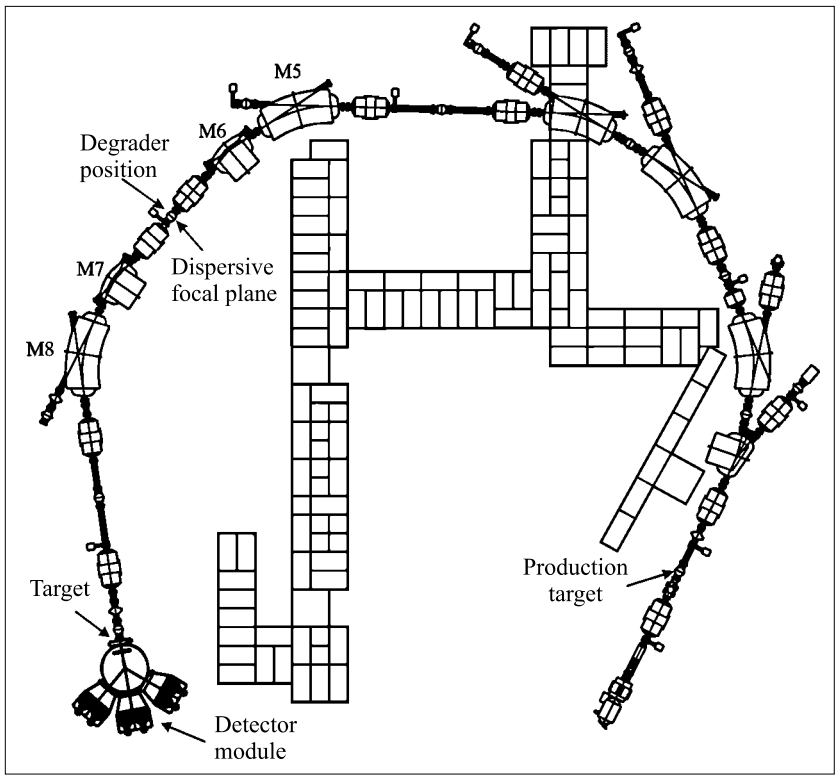


Fig. 10. Q4DQ spectrometer for secondary beam production

angular range of 20–70°at a beam energy of 26 *A* MeV [12]. The cross section limits of 5 to 0.8 μb/sr were obtained in a range of CM angles 130–165°. The forward-angle data were analyzed in terms of microscopic and phenomenological OM. The large value of the obtained total reaction cross section suggests an anomaly in the ^{8}He structure. In spite of the low cross section limits attained at the backward angles any enhancement pointing to a one-step 4*n* transfer was not observed. Finite range DWBA calculations of one- and two-step transfer reactions predict even lower values for this cross section. These calculations show that the two-step 2*n* transfer is more important than the one-step 4*n* transfer.

MULTI Project

Within the framework of the project MULTI, the U-400M accelerator's beam transportation channel was modernized and a Q4DQ spectrometer was created around it (Fig. 10).

In the ^{7}Li + Be reaction (^{7}Li beam intensity — 1μA), a $10^{5}\cdot s^{-1}$ beam of ^{6}He nuclei was produced. For the purification from other nuclear reaction products a degree of 98 % was achieved. Using this spectrometer and secondary ^{6}He beams, experiments were carried out aimed at measuring the energy dependence of the fission cross section for the compound nucleus ^{215}At produced in the ^{6}He + ^{209}Bi reaction.

The excitation function was also measured for the channel of the compound nucleus break-up accompanied by the 4 neutron emission — ^{209}Bi(^{6}He,4*n*)^{211}At. Figure 11 shows the excitation functions measured in these experiments for the channel of the ^{215}At compound nucleus fission and the 4 neutron emission.

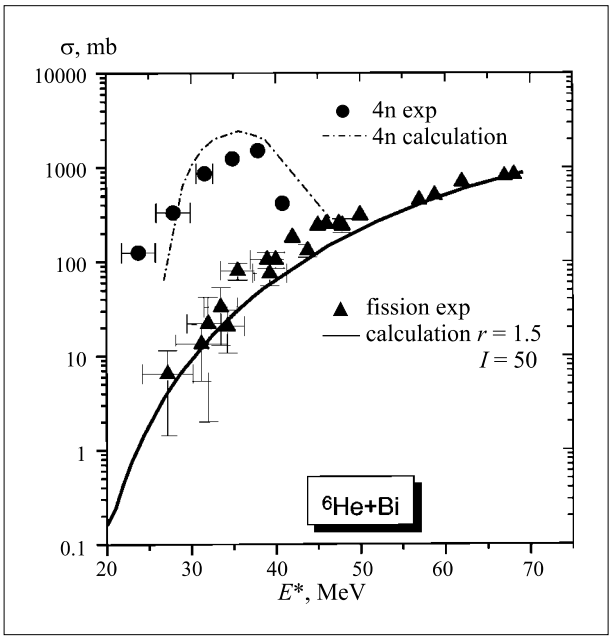


Fig. 11. Excitation functions of the ^{209}Bi(^{6}He,*f*), ^{209}Bi(^{6}He,4*n*)^{211}At reactions, measured at the Q4DQ spectrometer, and results of calculations

The results obtained for the ^{6}He beam were compared with those obtained with ^{4}He beams in the same experiments for the same fusion and fission channels. The

measurements were carried out in a wide range of bombarding energies $20 \le E_b(^6\mathrm{He}) \le 170$ MeV. A marked increase in the fission cross section was observed throughout the entire energy region for the ^{4}He beam as compared with the ^{4}He beam. The obtained results were compared with the results of calculations made with the use of an ALICE-MP-based statistical model with variable parameters of the radius r_0 and the critical angular momentum L. The same method was used in analyzing the data on the excitation functions for the $^{209}\mathrm{Bi} + ^4\mathrm{He}$ reaction, for which $r_0 = 1.29$ fm and $L_{cr} = 35$ were obtained. To achieve a good fit to the experimental data for the $^{209}\mathrm{Bi} + ^6\mathrm{He}$ reaction, $r_0 = 1.5$ and $L_{cr} = 50$–60 were required. Such a change in the parameters for ^{6}He could be explained by the influence of other reaction channels on the fission process.

The study of properties of light neutron-rich nuclei was continued within the framework of the collaboration JINR (Russia)–GANIL (France)–Hahn-Meitner Institute (Germany). The deformation and γ transitions of nuclei were experimentally measured in the $N = 20$-shell region [13]. It was found that there was a strong deformation ($\beta \approx 0.3$) in that region. In a collaborative Dubna–GANIL experiment, the masses were measured for 31 neutron-rich nuclei with $A = 27$–29, the masses of 12 of them were measured for the first time. It was shown that in the $N = 28$ shell region, Cl, S and P nuclei change their properties described by shell models. These nuclei can occur in two forms — spherical and deformed ones. In a collaborative Dubna–Hahn-Meitner Institute experiment, data was obtained on the structure of neutron-rich isotopes ^{13,14,15,16}B [14].

In the laser group, the hyperfine splitting of optical lines in the atomic spectra of the Eu isotopes with $A = 151$–155 were measured [15]. Resonance laser fluorescence in the parallel beam of Eu atoms was used. From these measurements, the hyperfine splitting constants were determined; from the constants — the values of the magnetic dipole and electric quadruple momentum were deduced. These momentum values allow one to judge about the nucleonic configuration and quadruple deformation of the indicated Eu isotopes.

In the optical spectra of Eu isotopes, a hyperfine magnetic anomaly was observed — a deviation of the ratio of the hyperfine splitting constants from the ratio of the magnetic momenta for the compared isotopes. The largest deviation (~ 5 %) was observed for the pair of the isotopes ^{151}Eu and ^{152}Eu, which points to the fact that nucleonic structure changes drastically in going from spherical nuclei (^{151}Eu) to deformed nuclei (^{152}Eu).

APPLIED RESEARCH

Interaction of Accelerated Heavy-Ions with Polymers. New methods of production of track membranes with profiled pore channels ensuring high selectivity and high efficiency of filtering dispersible species of various natures were developed. The feasibility of producing thick «blotting» membranes and membranes of the «wells with porous bottom» type was investigated. The membranes of this structure are promising as permeable substrates for immobilization of cells and the study of cellular activity.

Research and development of thermosensitive membranes was undertaken. Response of membranes to a change in temperature and their electrosurface properties were investigated (together with IPC, Moscow, and TRCRE, Takasaki, Japan). It allows creation of «intelligent» membranes with controlled properties.

The influence of plasma processing on the properties of track membranes was studied. Research was made on the applicability of the «ion transmission technique» method in the TM structure investigation (in cooperation with NPI, Rez, and HMI, Berlin). The optical properties of thick (60–100 microns) porous systems produced by the method of ion tracks were studied. New approaches to the creation of metal nanometric wires and submicrometric pipes of strictly specified sizes were proposed. It allows creation of objects with nanostructures and using them in microengineering technology, microelectronics, optoelectronics, etc.

Interaction of Accelerated Heavy Ions with Metals and Monocrystals. A change in the properties of crystalline silicon was investigated in the process of implantation of B, P, Ga, In and Bi ions with energies from 100 to 300 keV. At a fluence in the range of 10^{13}–10^{14} ion/cm^2, an increase in the diffusion coefficients of dopants was detected. These results can be applied to the development of new technologies for semiconductor industry.

The sputtering of metals and alloys, exposed to heavy-ions with high specific energy losses, was investigated. Using the SEM method, the sputtering yields were estimated: for Ni — ~ 500 atoms/ion, for chromium-nickel steel — ~ 100 atoms/ion, for W — ~ 1260 atoms /ion. The surface structure of Al_2O_3 and silicon monocrystals, and pyrolytic graphite after the irradiation with the ^{86}Kr (305, 440 and 750 MeV), ^{136}Xe (605 MeV) and ^{209}Bi (705 MeV) ions was studied using the scanning tunnel microscopy (STM) and atomic force microscopy (AFM).

The results are important for selecting the materials for the first wall of thermonuclear reactors and for understanding the physics of interaction between high-energy ions and condensed matter.

In cooperation with the Oak Ridge Laboratory (USA) and the Institute of Transuranium Elements (Karlsruhe, Germany), research on the microstructure of spinel $MgAl_2O_4$ irradiated with Kr, I and Xe ions with energies from 70 to 600 MeV was made. For the first time it was shown that when selecting the candidate materials - inert matrix fuel hosts in fission reactors — it is necessary to take into account high density ionization effects.

With the help of transmission electron microscopy (TEM) the ordering of helium pores in ion-irradiated amorphous silicon was observed. Creation of tracks in silicon by means of successive irradiation with the 17 keV He and 210 MeV Kr ions was detected. As a result of the postirradiation annealing at 500–1000 °C, recrystallization of the amorphous Si layer created by irradiation with the 17 keV He ions was studied. The obtained results are important for understanding the mechanisms of defect formation in semiconducting materials.

Ultrapure Radioisotopes and Radioanalytical Research.

1. Methods of production of radioisotopes ^{99m}Tc(^{99}Mo), ^{225}Ac and some others employing the (γ, n) reaction at the microtron MT25 were developed.

2. A technique of radiochemical extraction of ^{149}Tb was developed. The dependence of the ^{149}Tb yield on the ^{12}C ion energy was determined.

3. A combined effect of radionuclides and chemical pollution in Saratov region was estimated. Natural radionuclides were determined; the geochemistry of microelements in seismically active regions (France, Tadjikistan, Krasnodar) was investigated.

PHYSICS AND HEAVY-ION ACCELERATOR TECHNIQUES

Reliable performance of the FLNR accelerators is the prerequisite for successful carrying out the experiments and technical developments.

In 2000, the emphasis was made on the optimization of the U-400 cyclotron and the ECR-4M ion source in view of performing experiments on the superheavy element synthesis. Optimizing the beam capture system increased the efficiency of the source material consumption. The routine beam intensity of ^{48}Ca on the target was typically close to $4 \cdot 10^{12}$ s^{-1} [16].

Formation of the magnetic field in the central region of the U-400M cyclotron for the optimization of the acceleration regime and the installation of a buncher resulted in a considerable increase in the light ion beam intensities on physical targets of up to $2 \div 3 \cdot 10^{13}$ s^{-1}.

Further development of the accelerator technique was connected with the realization of the project DRIBs (production of radioactive ion beams at Dubna cyclotrons). In 2000, R & D was made for many systems: the target unit, low energy ion separator, beam channels, vacuum pumping system, beam diagnostics and control systems. The 2.45-GHz ECR ion source for the production of ^{6}He and ^{8}He radioactive beams was manufactured and tested.

A full scale modeling of the DRIBs production module was performed with a 3-mm (550 mg/cm^2) Be target bombarded with a 34 A MeV Li ion beam and with a TiC_n (porous graphite containing 6.25 % of Ti) installed behind the target [17]. At the temperature of the stopper of 1700 K, nearly 100 % of ^{6}He nuclei that left the target and were stopped in the porous graphite were vaporized and detected in the vacuum chamber containing the stopper. Separate experiments involving the detection of ^{8}He showed that the release time of He nuclei from the catcher was of the order of 50–100 ms. Energy and angular distributions and the absolute yield values were measured for ^{6}He nuclei emerging from thick Be targets bombarded with beams of ^{7}Li, ^{11}Be and ^{15}N ions with energies of 34, 32 and 48 A MeV, respectively.

During December 2000 – February 2001 the assembling and adjustment of low energy ^{6,8}He beam systems are to be completed. The first stage of DRIBs — production of light radioactive ion beams — should be realized in 2001.

For the second stage of the DRIBs project the yields of Xe isotopes with $A = 137 - 143$ were measured in the photofission of ^{232}Th, ^{238}U, and ^{244}Pu. The experiments were carried out on the bremsstrahlung of the FLNR microtron MT-25. The fission fragments that escaped from the target were retarded in an inert gas and transported by a gas flow along a capillary to a cryostat where xenon condensed. A filter at the capillary inlet trapped all the other fragments. The mass numbers of Xe isotopes were identified by their γ spectra and half-lives. The distribution of the independent yields of Xe fragments as a function of their mass numbers was obtained. The average mass number for this distribution is 139, the dispersion increased from 1.48 for the 232Th photofission up to 1.60 for ^{244}Pu. These results point to the fact that photofission reactions are promising for the production of neutron-rich Xe isotopes intended for further acceleration at the cyclotron.

The second stage — acceleration of fission fragments — should be realized in 2002.

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FRANK LABORATORY OF NEUTRON PHYSICS

In 2000, the FLNP scientific programme was realized under the auspices of five research themes of the JINR Plan of Scientific Research and International Scientific and Technical Cooperation (PSRISTC) and it was aimed at obtaining new results in condensed matter physics (theme: «Neutron Investigations of Structure and Dynamics of Condensed Matter», headed by V.L.Aksenov and A.M.Balagurov) and neutron nuclear physics (theme: «Study of the Fundamental Characteristics of Neutrons and Nuclei», headed by W.I.Furman and V.N.Shvetsov). To effect scientific research, work to develop, modernize, and construct the FLNP basic facilities, IBR-2 (theme: «Development and Upgrading of the IBR-2 Complex», headed by V.D.Ananiev) and IREN (theme: «IREN Project», headed by W.I.Furman and I.N.Meshkov) as well as the IBR-2 computation and spectrometry complex (theme: «Development of the IBR-2 Spectrometers Complex and Computation Infrastructure», headed by A.V.Belushkin and V.I.Prihodko) continued. Also, FLNP took part in the JINR themes: «ATLAS. General-Purpose *pp* Experiment at the Large Hadron Collider in CERN» (headed by N.A.Russakovich), «Theoretical and Experimental Investigations of the Electronuclear Method of Energy Production and Radioactive Waste Transmutation» (headed by A.N.Sissakian, I.V.Puzynin and A.Baldin).

This report contains a brief account of 2000 scientific results of the Laboratory reflected in the JINR Plan of Scientific Research (PSRISTC) submitted for approval to the present session of the JINR Scientific Council. The FLNP annual report for 2000 will give a more detailed account of 2000 results.

CONDENSED MATTER PHYSICS

Experimental investigations. Diffraction. Initiated in 1997 investigations of doped manganese oxides of the type $La_{1-x}Ca_xMnO_3$, $0 \le x \le 1$ in which the Colossal MagnetoResistance (CMR) effect arises at certain levels of doping continued. The effect consists of a dramatic decrease in the electric resistance of material if an external magnetic field is applied to it. The reason for the decrease of the resistance is the phase transition from dielectric to magnetic state. The CMR effect may reach a value of 10^7 or higher. Potential technological uses of such compounds may appear to be diverse and extremely effective. In the year 2000 the main directions of research in CMR materials were experiments directed towards obtaining information about the extent of inhomogeneity of states arising at transition from dielectric to metallic state. To this end, the behavior of samples in the external magnetic field up to 4 T at 4 K temperature was investigated [1]. The experiments made it possible to build a diagram of one of the canonical CMR compounds $(La_{1-y}Pr_y)_{0.7}Ca_{0.3}MnO_3$ (LPCM) and determine its basic states. It is found that for large mean radii of the A-cation ($r_A > 1.190$ Å) the basic state in LPCM is homogeneous metallic with a ferromagnetic ordering. If $r_A < 1.185$ Å, the basic LPCM state is mainly homogeneous as well but the type of conductivity turns into semiconducting and the magnetic moments of manganese mainly form a noncollinear antiferromagnetic structure. For the intermediate region of r_A values there appears a mixed state with spatially separated regions of a mesoscopic size (~ 1000 Å) having different types of conductivity and magnetic structure forms (Fig. 1). The physical reasons for the formation of a two-phase state in magnetic

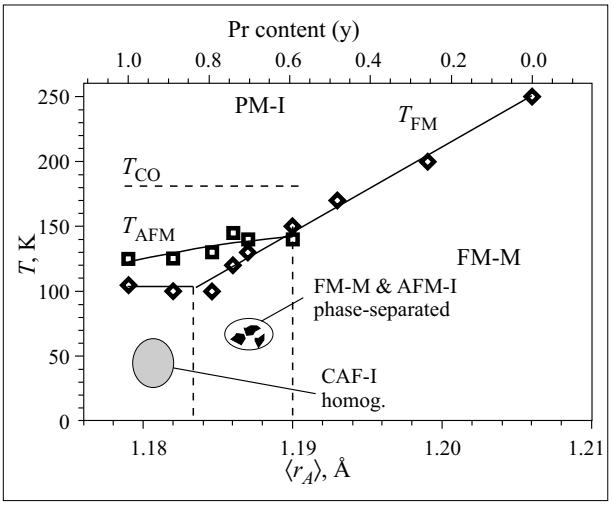

Fig. 1. Phase diagram of the $(La_{1-y}Pr_y)_{0.7}Ca_{0.3}MnO_3$ shows temperatures of magnetic ordering of Mn ions. The bottom x axis shows average A-cation radius $\langle r_A \rangle$. The low temperature state is homogeneous for $y > 0.8$ (canted antiferromagnetic insulator CAF-I) and for $y < 0.6$ (ferromagnetic metal FM-M). Between the homogeneous states the compound is spatially separated onto the regions of a mesoscopic size (~ 1000 Å) having different types of conductivity and magnetic structure

manganese oxides is the objective of further experimental and theoretical investigations.

Structural investigations of triple compounds of mercury chalcogenid $HgSe_{1-x}S_x$ were conducted at external pressures up to 3.5 GPa. At $P \approx 1$ GPa, the phase transition from sphalerite-like cubic to hexagonal cinnabar-like structure was discovered. Curves of the dependence of the structural parameters of the hexagonal phase on the pressure are obtained.

Studying the texture of marble rocks we found out that it is noticeably more expressed than the structure arising at recrystallization of carbonate rocks [2]. Calculations and further experiments show that in this case, thermal expansion has an expressed anisotropy. It is concluded that it is necessary in considering the texture of marbles to take into account correctly their behaviour at changes of temperature.

Small angle scattering. The scientific programme of investigations with YuMO comprised many research directions in the physics of condensed matter, biophysics and molecular biology, physics and chemistry of surfactants, colloids, polymers, etc. The dependence of the structure and properties of TTABr micelles on the pressure and temperature was studied. It is found that in self-organizing systems of TTABr increasing of the concentration of salt leads to the phase transition from ball-like to cylindrical form of micelles and growth of the radius and length of the cylinder. Increasing of the temperature produces the reverse effect on the system — the radius and length of cylindrical micelles decrease.

The structure of monoglycerides intensely used in food industry as emulsifiers and initiators of the crystallization of fats dissolved in water is studied. We determined the conditions of the «solidification» of monoglycerides in water, that is, of the gel-phase formation, and how the homogeneous medium monoglyceride–water is formed when adding charged amphifiles to the water.

Small-angle scattering was used to investigate gels and water solutions of poly(N-vinylcaprolactam) in heavy water in the presence of ionogen surface-active substances and pyragollole at different temperatures. It is shown that adding of a thermosensitive polymer of a low-molecular substance to the solution may influence significantly the temperature behavior and the conformation state of molecules in the polymer.

Polarized neutrons and neutron optics. On the SPN spectrometer, experiments to investigate the formation of the neutron field of standing waves in layered nanostructures and the effect of neutron waves channeling in a layered structure continued. Possible applications of the new effects are the creation of a neutron beam with a supernarrow cross section (100 nm in diameter), obtaining of extramonochromatic and extracollimated neutron beams, and the use of neutron layered resonators as phase-shifting elements in spin-echo spectrometers. The channeling effect of neutron waves is observed in the structure Cu(30 nm)/Ti(150 nm)/Cu(100 nm) deposited on glass. For the neutron scattering vectors 0.997, 0.0134 or 0.0182 $Å^{-1}$ intensity peaks corresponding to an increase of the neutron density due to coherent summation of waves with different reflection multiplicities from the copper layers are observed. Thus, it is experimentally shown that the channeling of the neutron wave occurs at distances larger than 30 mm.

Polarized neutron reflection and polarized neutron off-specular scattering together with a complete data-analysis have been employed to verify atomic spin correlations in Fe/Cr multilayers — a typical system showing the GMR effect [3]. Polarization analysis yields an important result indicating that in-plane magnetization breaks into rather small column-like domains. For increasing external magnetic fields, within the domains, spins in successive Fe layers have an antiferromagnetic component which tends to zero along with the coupling angle. At the same time, the domain size increases. Within each domain correlations extend through the entire depth of the multilayer. No detectable off-specular scattering due to interface roughness is registered for samples with «atomic flat» interfaces. Thus, magnetic pure spin-flip off-specular scattering can be attributed to the structure of magnetic correlations. These data are quantitatively described within the supermatrix formalism developed for the model of column-like antiferromagnetic domains (Fig. 2).

Inelastic neutron scattering. The dynamic properties and phase transitions of metallic, molecular, and ion-molecular compounds were investigated with the spectrometers DIN-2PI, KDSOG-M, and NERA-PR. The use of the NERA-PR spectrometer yielded most interesting results in the study of a dynamic disorder and glass-like phases in solids and compounds containing molecular groups of the type CH_3, CH_4, H_2O or OH. These investigations are traditionally conducted in cooperation with specialists from different research institutions in Poland and Russia. In the year 2000 within the framework of the theme, partial spectra of vibrational states of crystalline and glassy methanols were determined, the experiments being carried out using selectively doped samples of CD_3OH and CH_3OD. The obtained data were used to verify models of the dynamics of the crystalline and glassy phases in methanol and to determine the microscopic mechanism underlying the origin of the «boson peak» in the low-frequency vibrational spectrum of molecular glasses.

Investigations of water solutions with DIN-2PI were conducted to determine the effect of dissolved particles on the microdynamics of water molecules entering into their hydrate spheres. The effects of hydrophobic hydration, their influence on the diffusion mobility of the water of hydration and the rotation-oscillation dynamics of the molecules were investigated. A comparative analysis of two types of hydration reveals the fact that large apolar particles do not destroy the grid of hydrogen bonds in their surrounding water.

Methodical results. As in a few previous years, in the year 2000 in the framework of theme 1031, neutron scattering investigations in the physics of condensed matter were mainly carried out at the IBR-2 reactor. In addition to IBR-2-aided experiments, physicists of the Division of Neutron Investigations of Condensed Matter in FLNP working on theme 1031 conducted experiments with the electrostatic generator EG-5 and X-ray diffractometers of FLNP and also, did measurements in some neutron laboratories of Europe under accepted proposals.

During the reported year IBR-2 had eight working sessions. The IBR-2 spectrometer time was distributed in accordance with experts recommendations based on submitted proposals and taking into account the existing long-term agreements for cooperation. Ten instruments were included in the list of spectrometers to operate in the user mode in the year 2000. They are HRFD, DN-2, DN-12, SKAT, YuMO, SPN, REFLEX-P, KDSOG, NERA, and DIN.

The main methodological achievement of the year is the startup of the first stage of the new Fourier diffractometer FSD devoted for investigations of internal stresses in materials and engineering details. By the spring 2000, the principal elements of FSD, including the biological shielding, mirror neutron guide, fast Fourier chopper, beam control systems, table for the sample, and the goniometric devices, had been installed and tested on beam 11 of IBR-2. In the reactor cycle in May the first measurements in the high resolution mode with an element of the 90-degree detector MultiCon were made on FSD. The resolution of $\Delta d/d \approx 0.004$ was obtained as expected.

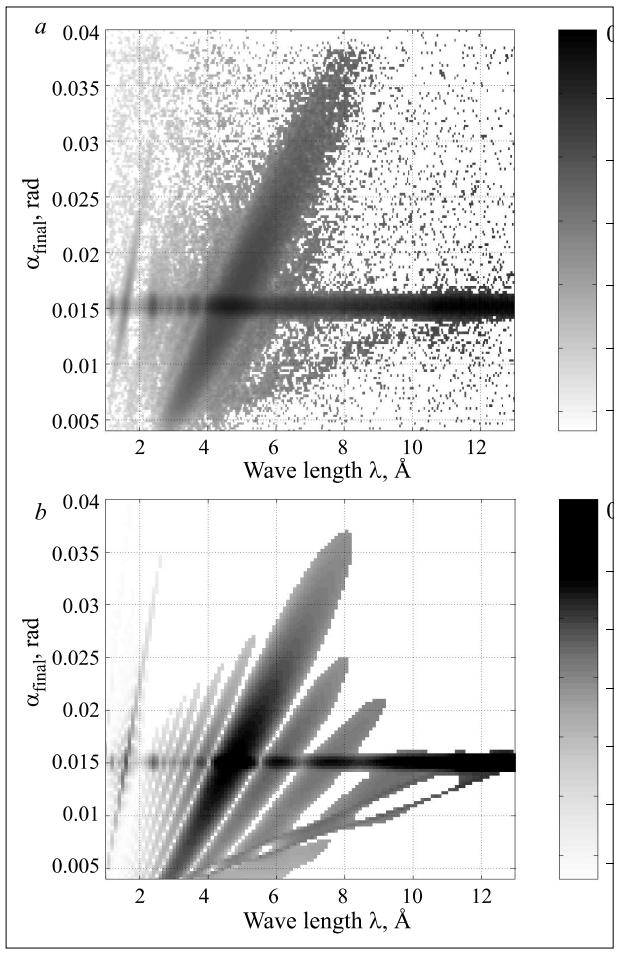

Fig. 2. *a)* Intensity map of specular and off-specular scattered neutrons (spin-down) from the Fe/Cr multilayer at $H = 0.428$ kG as a function of λ and α_f, the neutron wavelength and outgoing scattering angles, respectively; incident angle $\alpha_i = 1.5$ mrad; *b)* result of the supermatrix calculation with the model of non-collinear domains

A second detector was installed and tested in the small-angle spectrometer YuMO, which increased essentially the momentum transfer range in which the scattered neutron spectrum is also measured simultaneously (Fig. 3).

On the spectrometer REFLEX-P, the new ZnS-screen-based low-background detector was commissioned and started to operate for physical experiment. An about 50 time decrease in the background has allowed unique experiments on registration of surface phonons and magnons in thin films on the level of $2 \cdot 10^{-7}$ of the primary elastic scattering process to be conducted.

Executing the modernization project for the SPN spectrometer a supermirror neutron polarizer is manufactured and tested. In comparison with the existing regular polarizer it has a wider wavelength width for which the polarization efficiency exceeds 95 %. The application of the new polarizer will give an essential rise to the polarization efficiency of measurements at larger wavelengths (by a factor of 10 in the interval $3 \div 7$ Å) and will also increase the luminosity of the spectrometer.

On some of the IBR-2 spectrometers (HRFD, DN-2, DN-12, YuMO) a change of control electronics to VME standard has been completed thus enabling a new level of experiment automation.

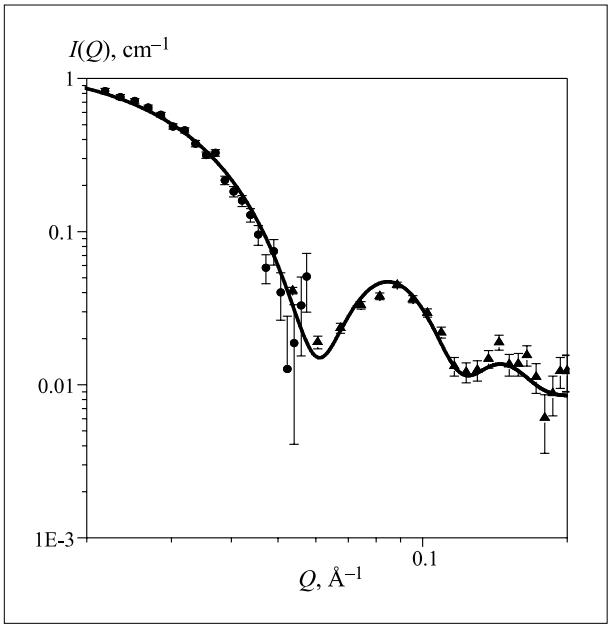

Fig. 3. Small-angle scattering from diluted solution of apoferritin, protein consisting of the spherical shell with well-known sizes ($R_{out} = 62$ Å and $R_{in} = 41$ Å) as a function of scattering vector Q. Experimental points measured by two detectors, placed at 11.95 and 5.27 m from the sample position, and calculated curve are shown

NEUTRON NUCLEAR PHYSICS

The 2000 experimental programme in neutron nuclear physics of FLNP traditionally included the following researches: experimental and theoretical investigations of the electromagnetic properties of the neutron and the beta decay of the neutron, studies of parity violation processes in nuclear fission; investigations of high-excited states of nuclei in the reactions of thermal or resonance neutron capture, obtaining of new data for the purposes of nuclear astrophysics; experiments with ultracold neutrons.

Experimental investigations. The UGRA spectrometer [5] was used to investigate the influence of the Doppler effect on the angular dependence of neutron scattering in *s* resonances. A noticeable anisotropy was observed and the data processing is under way. The neutron scattering cross sections are also measured in the region of interference dips of ^{238}U *s*-resonances. These extremely small cross sections are largely determined by the Doppler broadening of the resonances. They have practically never been measured while interest to them is due to investigations of the electromagnetic interaction of neutrons with atoms in the region of minimums of nuclear cross sections. We managed to obtain reliable results for the first three resonances.

In the framework of a Dubna–Kiev–Garching collaboration precision measurements of the total neutron cross section of ^{208}Pb were performed on the ~ 24 keV filtered beam in Garching. The result allows us to refine slightly the estimate of the neutron polarizability α_n. At the same time, it has become clear that an acceptable accuracy of $\Delta\alpha_n \cong 0.2 \cdot 10^{-3}$ fm^3 can be obtained by adding at least three points of a similar accuracy situated at ~ 20–100 keV from 24 keV to the existing cross section points. Plans of such experiments are under development.

With the POLYANA facility on the beam of polarized resonance neutrons measurements of the left-right asymmetry and parity violation effects in the resonance neutron-induced fission of ^{239}Pu nuclei continued. An exact knowledge of the coefficient of asymmetry, α_{nf}^{lr}, and of the coefficient of *P*-odd effect, α_{nf}, will make it possible to determine the parameters of unknown p resonances and extract matrix elements of the weak interaction from the experiment [6].

To complete the cycle of investigations in the angular anisotropy of fragments from the resonance neutron-induced fission of aligned ^{235}U nuclei, it appears necessary to know more precisely the constant of the electric quadrupole superfine interaction that determines the alignment coefficient of spins of uranium nuclei. To this end, the temperature dependence of the angular anisotropy of alpha-particles on the radioactivity of the investigated samples was measured over the temperature interval 0.4–290 K and preliminary data processing was done.

The first stage of precision measurements of the mass and kinetic energy distributions of fragments from the fission of ^{235}U induced by neutrons with the energy $0 < E_n < 20$ eV aimed at obtaining information on contribution variations of different fission modes and channels in this energy region, completed. Analysis of the experimental data employing the results obtained from an

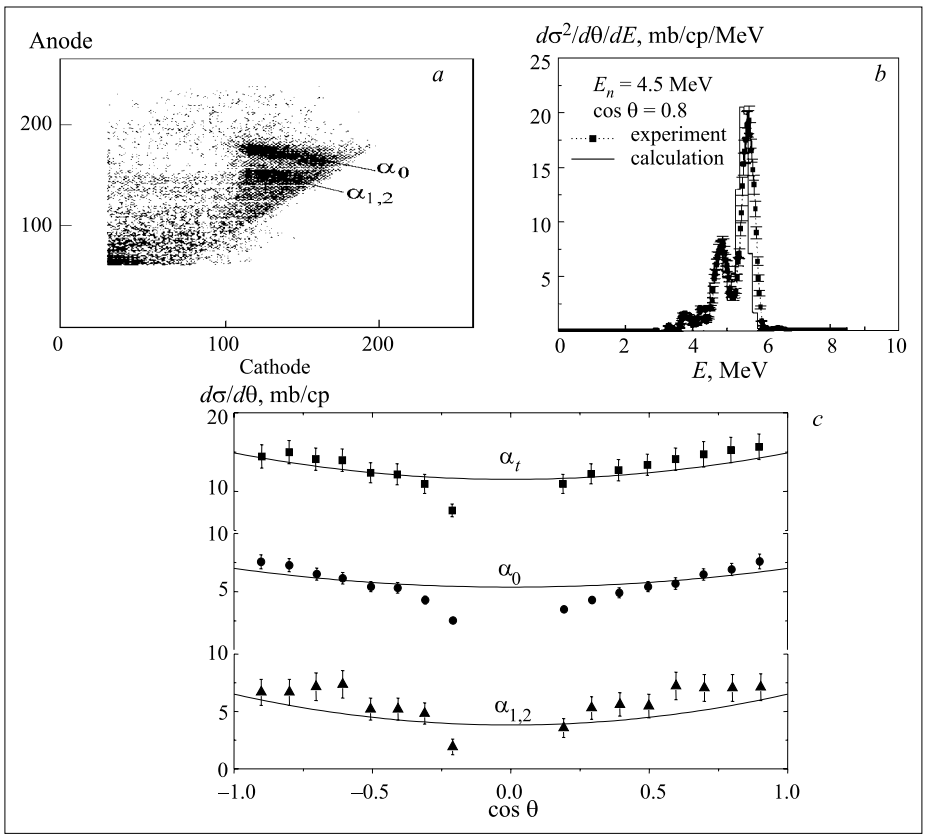

Fig. 4. ^{39}K(n,α) reaction at E_n = 5.5 MeV: *a)* two-dimensional spectrum; *b)* double differential cross section; *c)* the angular distributions

analysis of the anisotropy of ^{235}U fission fragments for a coinciding neutron energy region is nearing its completion.

The intensity of two-step gamma-cascades arising after radiative neutron capture is investigated as a function of the energy of the intermediate level of the compound nuclei ^{185,187}W, and ^{191,193}Os in joint Dubna–Rez experiments with a measuring error of not larger than 10–20 %. The experimental data are analyzed using original techniques of nonmodel determination of the density of excited states in nuclei developed in Dubna.

The obtained data are of much importance for the verification of the existing and development of the new models of the excited states density that would take into account realistically the co-existence of the ordinary and superfluid phase of nuclear matter over the whole range of excitations below the neutron binding energy.

In cooperation with Beijing and Tsinkhau Universities (China) experiments to measure the cross sections and angular distributions for the reactions ^{6}Li(n,α)T, ^{10}B(n,α)^{7}Li, ^{39}K(n,α)^{36}Cl, ^{40}Ca(n,α)^{37}Ar, ^{58}Ni(n,α)^{55}Fe, and ^{64}Zn(n,α)^{61}Ni were conducted at neutron energies from 1 to 7 MeV (see for example Fig. 4) [6,7].

The experiments were made at the Van de Graaf accelerator in the Institute of Heavy Ions of the Beijing University using the two-section ionization chamber with removable samples constructed in FLNP (JINR). The objectives of the investigation are the study of the contributions of different reaction mechanisms (compound nucleus, pre-equilibrium and direct processes) and verification of nuclear models.

On beam 5 of IBR-30, spectra of the radiative capture of neutrons with energies up to 100 eV by nuclei of the isotopes ^{181}Ta, ^{121}Sb, and ^{123}Sb were measured in cooperation with Prof. M. Psitula's group (Lodz, Poland). For antimony isotopes, correlation between the excited level population and spins of resonances was observed, which allows the use of precision gamma-spectroscopy to study the resonance structure of the investigated nucleus.

At the ILL reactor in Grenoble investigations of the mechanism of weak UCN heating continued. The temperature dependence of inelastic UCN scattering with a small energy transfer (~ 10^{-7} eV) on the surface of beryllium or copper was observed. The intensity of neutron detection on the surface of these materials decreased 2.5 times as the temperature decreased from the room to liquid nitrogen temperature. The upper limits are established and the lower limits are refined for the value of UCN heating with a small energy transfer.

The experimental upper limit of UCN under-barrier transmission through a vacuum-tight beryllium foil with the thickness 14 μm is improved by two orders of magnitude, which is $(-1.2 \pm 1.0)\cdot 10^{-8}$ per bounce.

Applied researches. In the year 2000, applied and methodological investigations were intensively conduct-

ed. The IBR-2 reactor-based instrumental neutron activation analysis (INAA) was used to solve problems concerned with environmental protection in the framework of the REGATA project. Biomonitoring of working places in a number of industrial establishments in Russia and other JINR Member States and of heavy metal depositions in some regions of Russia, including the Moscow region and Dubna outskirts, and of other countries, was performed. The study of ecological safety of construction materials was conducted by investigating kinescope glass breakage. Investigations of materials used in vitrification of liquid and solid radioactive wastes were performed in cooperation with the scientific and industrial enterprise RODON. FLNP together with the E.Andronikashvili Institute of Physics (Tbilisi, Georgia) are preparing an application for a patent on the development and creation of a selenium-containing medicine on the basis of Cyanophycea Spirulina Platensis. The analytical part of the work was made in Dubna by epithermal neutron activation. The publication of Tables for Identification of Nuclides Formed in Nuclear Reactors, which are widely used in carrying out INAA experiments at the IBR-2 reactor, must be specifically emphasized.

Original techniques were mastered and flight samples of the fast neutron detector (HEND) for the next American mission to Mars «Mars Surveyor Orbiter 2001» were calibrated with the help of the reaction $^{7}\mathrm{Li}(p,n)$ and the radioisotope sources ($^{252}\mathrm{Cf}$, Pu–Be) at the Van de Graaf accelerator.

The development of the method of a combined correlation gamma-spectroscopy of neutron–nucleus interactions was under way. The method was tested on an IBR-30 beam by carrying out the gamma-radiation spectroscopy of fragments of the resonance-neutron-induced fission of $^{239}\mathrm{Pu}$, which demonstrated the efficiency of the method. Work to build sixteen BGO-scintillation blocks for the multidetector HPGe-BGO in the gamma-spectrometer COCOS has been completed.

Experimental investigations of samples of the plastic scintillator with B and Gd neutron converters made in RChL of LNP were carried out to assess the effectiveness of their application as neutron detectors.

NEUTRON SOURCES

The IBR-2 Pulsed Reactor

In 2000, the IBR-2 reactor operated in accordance with the approved working schedule. It has operated eight cycles for the power W = 1.5 MW, three of which were carried out with a cryogenic moderator. During the reported period there were only seven emergency shutdowns. The maintenance plan for the period from June to September 2000, was fulfilled on time. It involved a removal of the movable reflector PO-1 decommissioned in 1987 from an operative store-room. This has freed storage room for the PO-3 movable reflector to be removed in the stage of modernization.

Modernization project. The PO-3 working project is completed. Manufacturing of PO-3 started in the JINR Central Workshops and NIKIET. A complete set of fuel element components for a new fuel loading is manufactured. The necessary amount of PuO_2 is processed and trials started in the industrial enterprise «Mayak». The fuel assembly project is completed in NIKIET. In the framework of the technical project of modernization the neutron-physical calculation of the active zone is carried out. Designing of the executive mechanisms of the control and emergency system started. Development of technical requirements for the electronic equipment of the control and emergency system started in the Institute of Atomic Energy in Swierk, Poland.

The IREN Project

The working schedule of the IREN project corrected in accordance with the recommendations of the JINR directorate formulated at the 87th Session of the Scientific Council is implemented in the main points during the year 2000.

The BINP in Novosibirsk completed the construction and tests of the accelerating tubes, buncher and the SLED system for the linac LUE-200 on time. In two test runs conducted with an accelerating tube prototype an acceleration of about 30 MeV/m was obtained, which is sufficiently close to the rated value. The final stage of test measurements carried out in October with participation of JINR experts showed that the shape of the electron energy spectrum differs from the expected. The achieved beam power is only 60 % of the rated value. Regular financing enabled the shipment of two accelerating tubes to JINR in September. The buncher and the SLED system are due at the end of February 2001. The design and construction of a powerful RF load and beam diagnostic elements have started in BINP in accordance with the terms of a recently signed contract. Copper tubes for the construction of a solenoid for the magnetic focusing system of the linac were partly ordered or produced. By the end of the first quarter of the year 2001 they will be delivered to JINR.

Designing and manufacturing of a set of high-voltage supplies for this system started in BINP in October 2000. Certain success is achieved in designing and modeling of a pulsed electron gun. By the end of this year a thermo-stabilization and a vacuum systems will be mounted on a full scale RF stand that FLNP assigned for testing of the accelerating tubes of LUE-200.

The contract with a known German firm, PPT, for designing and construction of two modulators for feeding of klystrons 5045 SLAC in LUE-200 is concluded and the designing will be completed in December 2000. It is financed from a long term German loan to the Russian Federation. The conditions of supply of two 5045 SLAC klystrons are agreed upon with the DOE of the USA in the respective agreement signed by JINR and DOE in 1993.

The «Mayak» plant completed the construction and received a license for the fuel elements of the multiplying target of IREN. They will remain at the plant until everything is ready for assembling of the new active zone in the reactor hall of the former IBR-30.

Specialized Moscow institutes, RINM and NIKIET, in close collaboration with JINR developed the technical project of the assembly of IREN in 2000. However, a short delay in financing as well as the necessity to do extra calculations of IREN safety caused by recently introduced stricter requirements for nuclear hazardous facilities in the Russian Federation resulted in a four-month shift of the completion date of the first stage of the technical project. This will obviously lead to a delay in receiving of the license for the decommissioning of the IBR-30 reactor and the construction of the IREN facility. However, there is still a possibility to have this license by the date of the final shutdown of IBR-30 at the end of June 2001.

DEVELOPMENT OF THE IBR-2 SPECTROMETER COMPLEX AND COMPUTATION INFRASTRUCTURE

Local area network and computing infrastructure. In the year 2000, the following work aimed at further development of the information and computer infrastructure of the IBR-2 complex was carried out:

- data traffic in the FLNP local network was optimized and the data transfer rate increased significantly (Internet);
- two segments of the network were changed over to twisted pairs (central segment in building 119 and Nuclear Physics Department segment);
- the number of X-terminals and the disk space of the SUN-cluster were increased.

In 2000, the VME data acquisition and control systems on the YuMO, DN-2, FSD and DN-12 spectrometers were put into test operation. Positive results were achieved on all the spectrometers, however, at the YuMO and DN-2 spectrometers some problem involving data accumulation from PSD arose. In the course of the first autumn cycles several nontrivial errors in electronics were found, which revealed themselves only when working with high count rates on the beam. During these cycles the errors were corrected and we hope that they were last ones.

The new generation detector electronics for gas linear and PSD detectors as well as for point detectors has been constructed and installed on the YuMO, DN-2, SPN and DN-12 spectrometers.

At JINR FLNP in collaboration with HMI, Berlin, the development of the main DAQ board for MSGC detector was completed as far as possible with simulation and routing programmes as well as the CPLD programming and the development and debagging software. A prototype of the board is ready. FLNP is presently continuing the adjustment and testing of the DAQ board by means of a software event generator. HMI is preparing the testing of the DAQ hardware and software with the MSGC detector prototype in 2000/2001.

The reliable operation with all temperature devices, close cycle refrigerators, cryostats and other sample environment devices has been provided.

The work on improvement of existing VME systems on the spectrometers HRFD, NERA-PR, SCAT and EPSYLON was continued.

Development of the IBR spectrometer complex. The main effort on the development of IBR-2 spectrometers were concentrated on the following instruments: SPN, YuMO, FSD and DN-12.

The full polarization analysis system of SPN was tested and put into operation. Two first elements of the MultiCon detectors based on a ZnS scintillator were assembled and installed at FSD. In 2000, the assembly and adjustment of the laser spectrometric system for pressure measurement in high-pressure cells were completed at DN-12 spectrometer.

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LABORATORY OF INFORMATION TECHNOLOGIES

The Laboratory of Information Technologies (LIT) of JINR was established in 2000 in frames of reorganization of the Laboratory of Computing Techniques and Automation. The main tasks of the Laboratory were formulated at the 88th session of the JINR Scientific Council. They consist in the maintenance of operation and the development of the computing and networking infrastructure.

The computing and networking infrastructure (JINR CoNet) as a JINR BASIC FACILITY includes:

1. Telecommunications Services and Channels (External Networking);
2. Local Area Network (LAN) & High Performance Computing Centre (HPCC);
3. Support and development of standard software and modern tools of Computer Physics for users.

To support these activities, a new structure of the Laboratory has been worked out. The main part of the problems on the JINR LAN technical support is solved by the LIT chief engineer's staff.

In 2000, the scientific programme of the Laboratory of Information Technologies covered three first-priority topics of the «Topical Plan for JINR Research and International Cooperation in 2000». The Laboratory staff also participated in 9 more topics of the Topical Plan in collaboration with other JINR Laboratories at the project level and in other 16 topics at the level of cooperation. The main results of the investigations performed within these topics in 2000 have been published in more than 100 articles of the well-known journals, proceedings of the scientific conferences, JINR preprints and communications.

The indication of the top-level investigations performed at the LCTA/LIT Computational Physics Department was the successful holding of the Second International Conference «Modern Trends in Computational Physics» in 2000. The scientific programme of the Conference covered various fields of research under way at LIT in the field of mathematical modelling and computational methods for research in complex physical processes, using modern vector-parallel computing systems, computer communications and distributed computations for enormous data processing, numerical methods and algorithms of computer algebra methods, computational tools for modelling and analysis of experimental data. The conference enabled one for the first time of holding conferences at JINR to provide real-time access to the plenary meetings through the Internet.

TELECOMMUNICATION SYSTEMS

In 2000, the throughput of the JINR telecommunication channel was 2Mb/s and remained at the level of the year 1999. The main Internet Provider for JINR was ROSNIIROS (the Russian Institute for Public Networks) which by the end of 2000 provided for JINR a paid access to international computer networks of 1 MB/s in the common traffic as an RBNet user and access to the Russian networks in the frames of the interdepartmental programme of creation of networks and telecommunications for science and higher school. The channel of the CONTACT-DEMOS company was used as BACKUP for

Table 1. Incoming JINR traffic distribution (in Gbyte) over the JINR subdivisions and laboratories (> 4 Gbyte)

LIT + proxy + servers	LHE	Univ.Dubna	FLNR	DLNP	BLTP	Modem pool	LPP	FLNP	UC	JINR Board	Other
695.2	235.6	177.8	199.3	160.2	123.1	112.8	106.6	84.7	49.9	47.6	16.1

the reliable operation of the JINR's network with 256 Kb/s at 5 % load.

However, such a throughput of the channel is inadequate to satisfy the JINR's needs. Figure 1 shows the peak load of the link to Moscow at daytime since October 2000 at the average week load of 65.4 % (http://noc.jinr.ru/stats/).

Table 1 shows the incoming JINR traffic from the May to December 2000 (total 2 Tbyte) distribution among the JINR subdivisions and laboratories. It should be noted that the University of Dubna and the modem pool take a noticeable share in the common traffic. The software allowing one to obtain quickly the information on the most active users of the JINR external channels has been developed at LIT. It allows one to control the correct use of telecommunication resources.

The perspectives of the development for the JINR external telecommunications were discussed at a workshop «Strategy for the Development of the JINR External Computer Communication Links» in June 2000. The proceedings of the workshop and the projects presented at the workshop are available at the web-page http://noc.jinr.ru/LCTA/E_Publications /Workshop/.

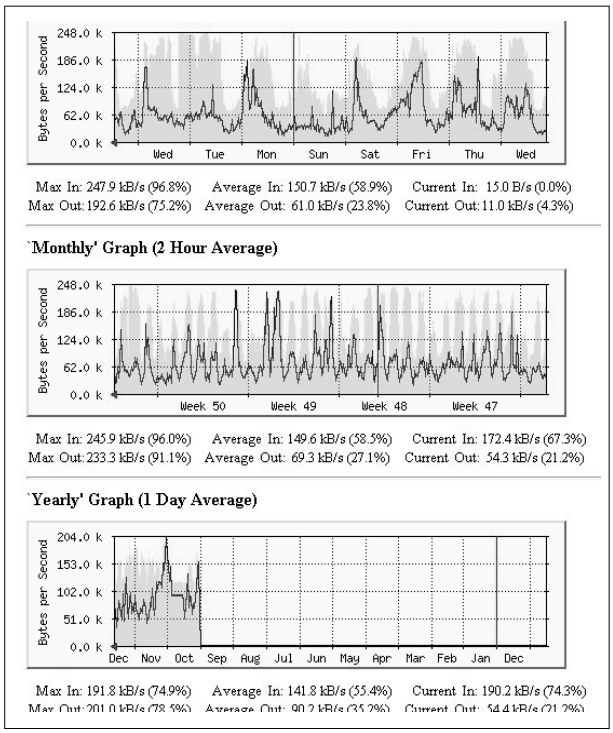

Fig. 1. Statistics of the load of the link to Moscow

JINR LOCAL AREA NETWORK

The resources of the JINR LAN were used within the bounds of possibility. The increase in the network load resulting from the growing number of the elements connected to the network (at present the IP addresses database contains 3188 registered network elements) and from breaking down part of the equipment of the ATM BackBone has set the task of re-organizing the JINR LAN and changing to present-day technologies. A project on modernization of the network topology and on selection of an adequate technology of its design is in development stage now. Figure 2 shows a modern JINR LAN topology. As a temporal decision, the broken ATM switches can be replaced by Catalyst switches from CISCO.

Systematic work on the LAN management was performed by the Network Operation Centre (http://noc.jinr.ru/). The rules for users of JINR Computing & Networking Infrastructure have been worked out and approved by the JINR Directorate. The new NOC homepage was designed using modern Internet technologies.

COMPUTING SERVICE

The JINR High-Performance Computer Centre comprises high-performance computing systems of various architecture (vector-scalar, multiprocessor, farms, clusters with bulk memory). More than one thousand staff members of JINR and other research centres are the HPCC users. JINR HPCC is one of the five largest Russian centres. It actively cooperates with other leading centres — Intergovernmental Supercomputer Centre, In-

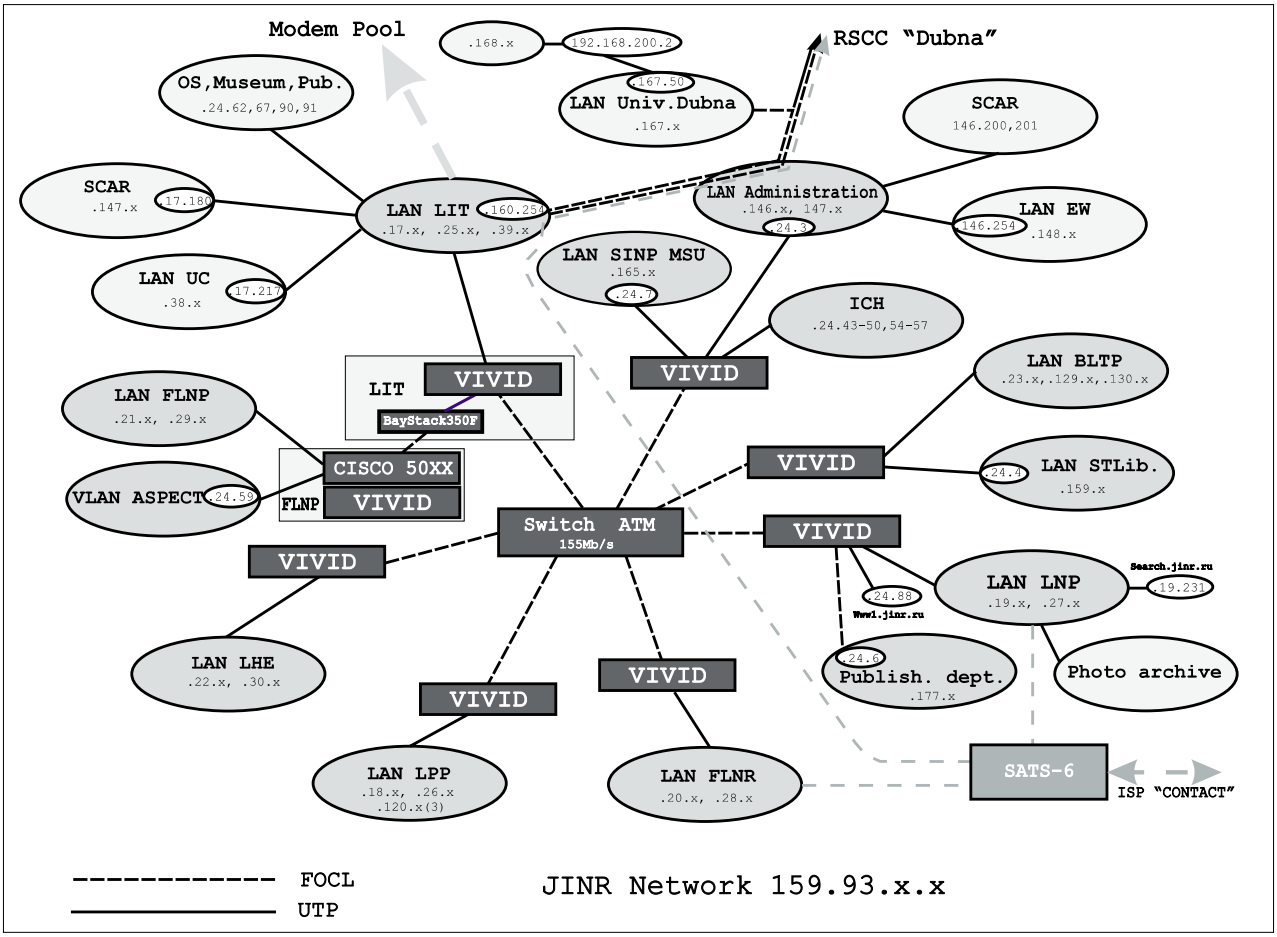

Fig. 2. Present-day JINR LAN topology

Table 2. JINR High Performance Computing Centre (HPCC) main components

	Peak perfomance, Mflops
HP Exemplar S-Class (SPP -2000)	5760
CONVEX C-3840	960
APE-100	1600
PC Farm	9200
Total:	17520

stitute of high-performance computations and data bases (St. Petersburg). In collaboration with the leading nuclear physics centres of Russia, JINR participates in creating the Russian Regional Centre for LHC Data Handling (RRC-LHC) on the basis of JINR HPCC resources.

ATL 2640 Integrated Library System

Library Capacity	10.56 TByte
Cartridge Capacity	20/40 GByte
Drive Transfer Rate	1.5 MByte/s
Library Throughput	16.2 GByte/hr

In 2000, the JINR HPCC computing machine SPP2000 was used by a 161st user and was 97 % load at 58000 hours of the CPU useful time. CONVEX-220 was used by 1140 users as a computer, a mail- and http-server (Table 3) .

Table 3. A relative use of the computing power and the modem pool by the JINR laboratories

	LIT, %	BLTP, %	DLNP, %	FLNR, %	FLNP, %	LPP, %	LHE, %	Board, %
SPP-2000	5	18	17	8	17	23	12	–
CONVEX-220	26	9	13	15	5	–	15	7
Modem pool	16.1	0.1	19.3	12.4	16.4	4.6	13.5	17.6

SOFTWARE DEVELOPMENT

Information and computer support of the JINR participation in the experiments at CERN, DESY and BNL was in progress in 2000. The technology of designing object-oriented applications and databases (GEANT4, Objectivity/DB, ROOT) was under study. A new version of the LHC++ Library has been installed on the LIT/JINR computing PC farm.

LHC Computing Support

For the last few years JINR has been involved in three projects on LHC: ALICE, ATLAS and CMS. The cooperation of Russian institutes in the LHC projects after starting up the accelerator (in the year 2005) and the experimental installations is connected directly with the necessity of providing a way for processing and analysis of experimental information directly in Russia. For this reason, by the end of 1999 a joint project «Russian Regional Centre for LHC Data Handling» (RRC-LHC) was worked out. JINR and nine leading Russian physics institutes participating in LHC are involved in the project. For the period of less than a year, LHC-oriented PC farms have been created in ITEP, IHEP, SINP MSU, LIT and LNP of JINR. The program environment of these farms is completely unified and corresponds to the current state of the specialized software used at CERN. Thus, a beginning in the improvement of the prototype of the Russian regional centre has been made.

In September–October, a run of a mass production of physical events was started 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 20 GByte are generated at the LIT PC-farm within a day. The data production is performed with the use of the pythia (v.6136) program and CMSIM (v.120), a program for simulation and reconstruction of events for the CMS experiment; the data are written in a zebra-format (fz) in blocks of an order of 1 GByte — approximately 500 events in a file. The data obtained will be transferred to CERN for inclusion into the object-oriented database (Objectivity/DB) that will be used for the definition of the Basic Units of Information, optimization of algorithms of the trigger and event reconstruction. The availability of the mass memory system at JINR HPCC provides a way of testing various models of work with enormous data volumes as well as improving the technology of a common use of the mass memory together with Moscow institutes.

Investigations for Paralleling Computations

A 32-processor APE100 complex of the $2 \times 2 \times 8$ configuration was installed at HPCC of JINR in the last year. The project APE has been worked out and is being developed by a group of Italian theoretical physicists involved in QCD. The LIT group made central contributions in the present reworking of the TAO compiler kernel, such that the performance on APEmille can be improved. This rework also takes into account the specific architectural modifications necessary for porting the compiler to apeNEXT. This development has to be completed in order to obtain a reliable prototype of a stand-alone TAO-compiler for apeNEXT and in order to allow the combination of the TAO compiler with a C compiler.

Maintenance of the JINR Program Library

New documents were prepared and introduced in WWW concerning program libraries in 2000. They include realization at JINR of electronic access to the texts of the program library CPCLIB (Belfast, Northern Ireland) and the CPC (Computer Physics Communications) journal as well as maintenance of the NAG Library and CERNLIB on the JINR computer platforms. Filling the JINRLIB with the new codes was in progress.

DATABASE AND WWW SERVICE

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

- Information system «JINR Topical Plan for Research» (http://dbserv.jinr.ru/~deadhead/tp/);
- Information system «Consolidated Financial Report of the JINR Subdivisions» for the JINR Accounts Department;
- System for accounting and statistics of operating the JINR basic facilities (http://wnct132.jinr.ru/basic-fac/);
- Information system for the interactive monitoring of the installation and taking data of the experiment COMBAS (http://noc.jinr.ru/ LCTA/ E_Publications/ A-D_Presentation_files/ frame.htm) [1];
- Publications registration server (http://wnct132.jinr.ru/student/marina/). The client-server system with an interface in the «Internet-Intranet» environment allows the users to register data on their publications;
- Digitizing of graphics at users' requests, preparation of bibliographic data on HEP for the PPDS database (http://www.jinr.dubna.su/~diginfo/).

A wide scope of problems has been solved in the field of information management, namely:

- access to specialized international data bases and information systems via the Internet (INIS, PPDS);

- development and maintenance of the main information centre established at JINR for organizations of applied nuclear physics and fundamental properties of matter (project BAPHYS). A programme Htdig has been started up. It allows a quick key word search for documents at the servers of the BAPHYS environment. This service (http://dbserv.jinr.ru:8008/htdig/baphys.html) provides a search within 14 servers;
- creation of a specialized program server («Java Station») for the JINR users studying the programming techniques with using the Java language, possibilities in applying a new XML technology and tools of organizing distributed computations based on the object-oriented CORBA standard, WWW, languages of Java and C++ type , HTML, XML, MathML, VML (http://dbserv.jinr.ru/js/).

In order to maintain and develop a specialized WWW/FTP server FAXE (http://faxe.jinr.ru and ftp://faxe.jinr.ru) with program products for the JINR users, its hard- and software facilities have been modernized.

The XML (eXtensible Mark-up Language) technology has been studied. It is a new industrial standard that specifies the architecture of the Internet programming tools of the next generation [2].

A converter xcvt has been developed in the Java language for processing XML documents. The program comprises style tables for transforming XML documents into HTML and LaTeX. A practical investigation of the Internet applications designed under the aegis of the W3C consortium and applied in WWW has been undertaken: Mathematical Mark-up Language, Vector Mark-up Language, and XHTML. These investigations can be effectively applied to

- visualization of mathematical formulas by using MathML and Amaya in combination with the package of analytical computations «Mathematica»;
- graphics (diagram) construction directly in a Web-site by using the VML tools in the standard browser MSIE5.0.

A program WDK (Web Development Kit) has been designed in the Java language as an instrumental package for designers of the Internet applications in languages HTML, JavaScript, Java, XML.

SOFTWARE FOR DATA VISUALIZATION

Scientific visualization is an effective tool for deep insight and analysis of the objects or processes under study. LIT supports and utilizes several advanced visualization systems. The most powerful of them, the so-called modular visualization systems, are Convex AVS and Iris Explorer.

Special codes for data visualization have been developed at LIT. For example, the PICASSO code was developed for visualization and interactive analysis of the results obtained by the GEANT-DIRAC simulation program. It is needed for debugging the program and investigation of processes in the DIRAC set-up. Another example is the JUNO programme (Fig. 3).

JUNO is a tool for handling, conversion and statistical analysis of large experimental data bulks. It has the unique features enabling a nonprogrammer user to perform complex manipulations on data, to build one- and two-dimensional statistical distributions, to accomplish rare events recognition by applying filters and additional criteria. JUNO needs no special settings. It is implemented in Visual C++ environment and runs under Windows 9X/NT. The program is used to handle data gained at experimental installations for heavy ions physics research.

COMPUTATIONAL PHYSICS

The main tasks for Computer Physics at JINR are:

- creation and development of methods for mathematical simulation of physical processes and analysis of data for theoretical and experimental research;
- algorithmic and software support of the computer modelling on the basis of present-day programming technologies by using and optimizing the modern architecture computing systems and high-speed networks;
- user support for the effective functioning of the JINR High Performance Computer Centre.

Mathematical Modelling for Experimental Investigations

The properties of the projected experimental facility, a sub-critical assembly in Dubna (SAD) driven with the existing 660 MeV JINR protons accelerator, have been investigated by using the particle transport codes LCS, MCNP4B/DLC189, CASCADE [3]. The assembly consists of a central cylindrical lead target surrounded by a mixed-oxide (MOX) fuel ($PuO_2 + UO_2$) and a leader reflector (Fig. 4). A dependence of the energetic gain on the proton energy, the neutron multiplication coefficient, and the neutron energetic spectra have been calculated.

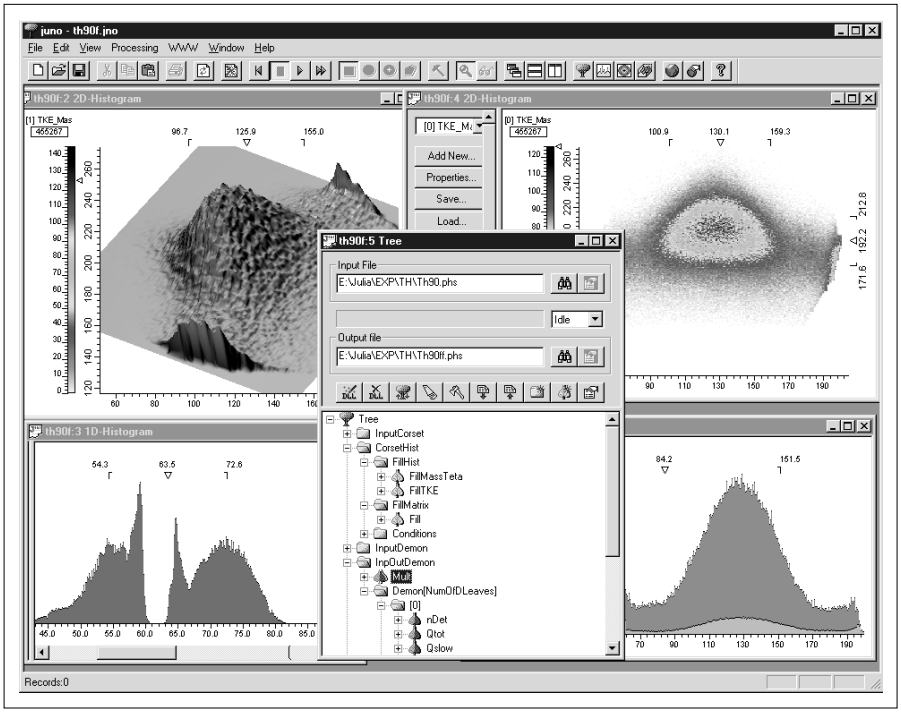

Fig. 3. JUNO application screenshot

The calculations show that for the subcritical assembly with a mixed-oxide (MOX) BOR-60 fuel (29 % PuO_2+71 % UO_2) the multiplication coefficient k_{eff} is equal to 0.947, the energetic gain is equal to 30, and the neutron flux density is 10^{12} cm$^{-2}\cdot$s^{-1}.

A mathematical processing of experimental data obtained in frames of the first experiment carried out at the LNP phasotron within the project SAD has been performed. The main goal of the experiment was to study the differential characteristics of the secondary radiation field around the thick lead target irradiated by protons. Such experimental data are needed for verification of the calculations of the internuclear cascade of secondary particles generated by primary protons within the target. Figure 5 demonstrates the comparison of the calculated and experimental neutron spectra from Pb target at 75° [4].

One of the important problems of particle physics is the question of existence of abnormal narrow multiquark states predicted in a series of theoretical studies. An experimental solution to the question about the existence of exotic hadrons and study of their internal properties and the character of the processes with their formation are of particular importance for obtaining basic ideas about the nature of hadron matter. With the help of the techniques developed at LIT, the analysis of events was carried out on the basis of experimental data with a two-meter hydrogen bubble chamber CERN in $\pi^- p$ interactions at 16 GeV/c. The width of the structure is comparable with the experimental resolution [5]. When analyzing the structure $K(1630) \to K_s^0\pi^+\pi^-$, kinematics features of its formation and decay were found which distinguish the group of events from the structure's interval and other intervals of the mass spectrum. The probability of a casual manifestation of these features is less than 10^{-7}. Conclusion has been made about the observation of the physical effect. The results have been accepted by the Particle Data Group for the Review of Particle Physics [6].

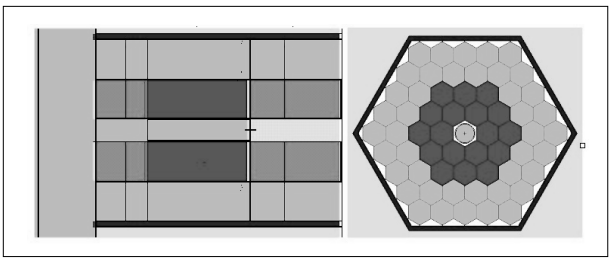

Fig. 4. SAD scheme

Methods and Software for Complex Physics System Calculations

In collaboration with the Computational Science Division, Advanced Computing Centre of the Institute of Physical and Chemical Research (RIKEN), Japan, research on the molecular dynamics simulation of clusters-beam-surface impact processes for metallic phases was performed. An optimised version of the DL_POLY molecular dynamics simulation code [7] has been used. The interaction of energetic clusters of atoms with solid surfaces is investigated with the use of the Finnis–Sinclair many-body potential. The characteristics of the collision range from a soft landing (< 0.1 eV/atom) up to higher impact energies (>1eV/atom). The penetration of the cluster into the solid substrate results in such dynamic processes as a plastic deformation of the material and shock waves. Shock waves or thermo elastic effects generated in materials are the essential factors for the analysis of new nontrivial structures on the surface and may be used to explain the structural-phase changes of the surface treated.

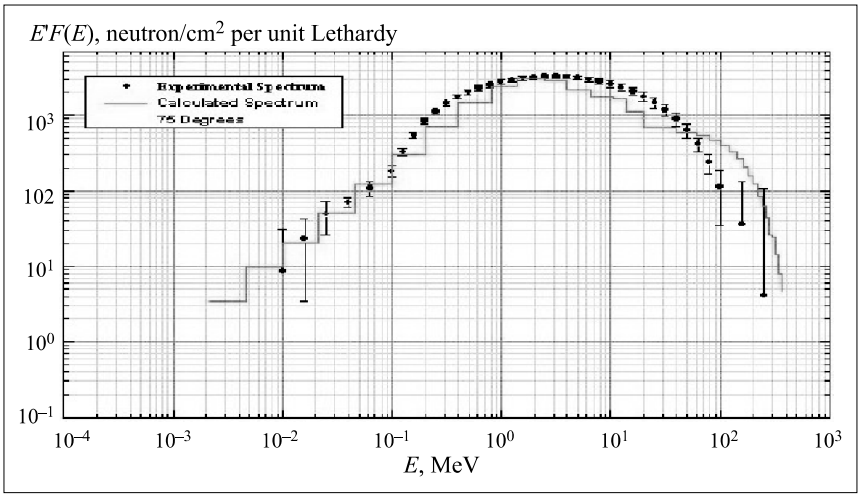

Fig. 5. Comparison of the calculated and experimental neutron spectra from Pb-target at 75°

Modification of the surface exposed to high-energy cluster-beams, is studied by monitoring the molecular dynamics configurations of the system in real time and defining the critical impact energies, necessary to produce implantation (Fig. 6) [8].

A mathematical model of the evolution of the thermo-elastic momentum arising in metal exposed to an ion source is investigated. On the basis of the numerical calculation, a relation between the thermo-elastic wave form and the form and location of the source as well as a condition of extension and putting out of the thermo-elastic waves were studied. A temperature influence on the velocity of the thermo-elastic waves was established [9].

An effective algorithm for calculation of wave functions of the continuous spectrum in a two-centre problem is proposed. To solve this problem, a finite-differential scheme of 4th-order and the continuous analogue of Newton method are applied. The wave functions of the continuous spectrum of the two-centre problem of positive molecular ion of hydrogen together with the phase shifts and with matrix elements between the continuous and discrete spectrum were calculated. The absolute accuracy of the calculated phase shift is of the order of 10^{-6} for the electron momentum $k \geq 1$ and 10^{-4} for $k \sim 0.1$ [10].

Software for computer modelling of relativistic heavy ion collisions in the framework of the fluid-dynamic model for various equations of states was developed. The mathematical methods include a PIC-method (Particle-in-Cell) for modelling of nuclear matter moving, Newton and other iteration methods for solving the equation of state and numerical integration methods for calculation of observablies. The Fortran and C++ codes were used for computations, and IDL (the Interface Definition Language) was used for visualization of the computation results.

The development of the elastodynamic method and software in the theory of nuclear matter and its application to nuclear fission physics continued. The model constructed predicts a two-mode character of fission: a spheroid mode (*S*-mode) and a torsion one (*T*-mode). It should be noted that the barriers of nuclei fission for the *T*-mode lay higher than for the *S*-mode. Since the *T*-mode is characterized by a compact fission configuration, one can expect that the total kinetic energy (TKE) of the flying apart fragments will be higher than TKE for the *S*-mode. Data on such a TKE behaviour have been received in experiments (Obninsk) on uranium isotopes fission induced by fast 8–10 MeV neutrons. A comparison of the fission barriers calculated in the elastodynamical model (*S*-mode and *T*-mode) with the experimental data allow one to conclude that the rotating mechanism of fission covers well the region of fission of middle nuclei (with the mass numbers of $170 < A < 210$) [11].

A proof has been completed of the invariance with respect of replacement of coordinates of the Feynman integral in paths (of a conversion amplitude — in quantum mechanics, a partial function — in statistical mechanics, a generating function — in the field theory) in a functional approach (i.e., without using a finitely multiple approximation) on the perturbation theory in 2 loops started in 1999. All the problems related to the determining of the integrating measure and to the existence of the contraterms arising at a quantum level have been completely solved [12].The main application of the investigations consists in the fact that their result allows one to apply a standard method of the perturbation theory for a functional integral to the problems with (topologically) nontrivial boundary conditions.

Modern Computational Tools in Experimental Data Processing

In frames of software development for the HERA-B Outer tracker, a new fast seeding algorithm for the tracking programme RANGER was developed on the basis of Radon–Hough transformation method. It was implemented as a C++ program. An algorithm of the very fast robust fit of a circle arc to drift radia in *XoZ* plane of Magnet Chamber was developed, implemented and tested on real data of MC superlayers.

A multifractal analysis of atomic Force Microscope (AFM) images of Nb thin film surfaces has been performed. The analysis allows one to propose a model of a new mechanism of the order parameter suppression on a 'superconductor-vacuum' boundary [13].

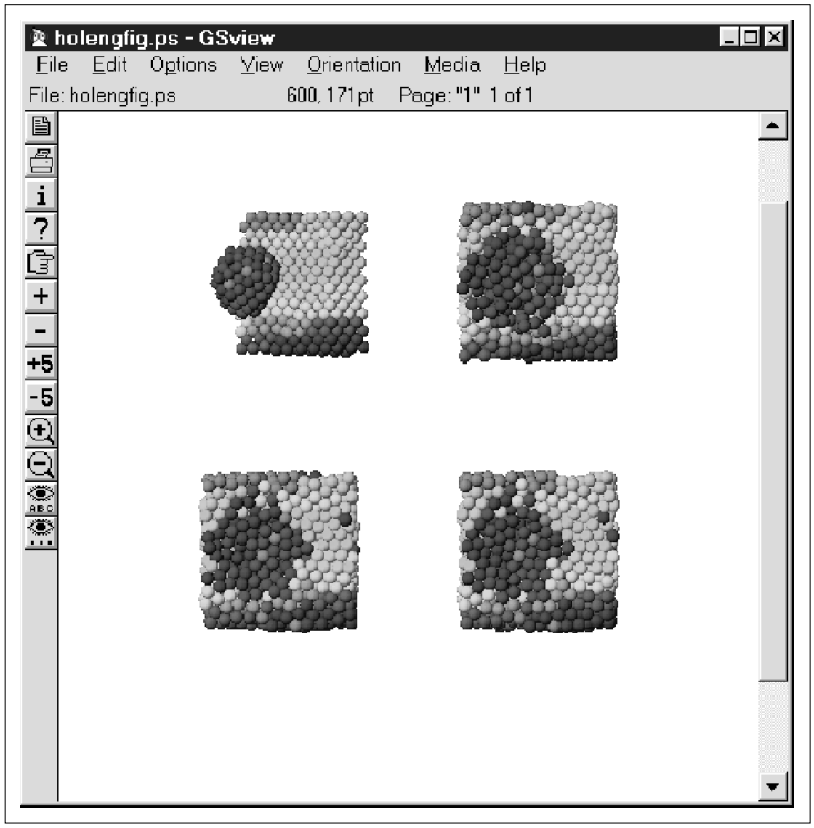

Fig. 6. Four sequential snapshots of the Molecular Dynamics simulation

Physics Fields and Particles Transport Calculations

In frames of the engineering work within the ALICE experiment (CERN), 3-dimensional calculations were performed for the magnetic system comprising a L3 magnet, a muonic filter and a dipole magnet (Fig. 7).

Three-dimensional calculations of the electric field for the NA45 experiment (CERN) also were performed. The results of the computations have been reported at a meeting of the NA45 collaboration in Darmstadt. For the project worked out at ITEP for the experiment with a polarized target, 3-dimensional calculations of the forces acting on the winding, poles and the forces polarizing the tips of the magnetic system have been performed [14].

Mathematical Processing of Experimental Data in Particle Physics

Research, development, and integration of soft- and hardware platforms have been realized for modelling and processing a number of experiments in particle physics. One of the basic properties of the local cluster is its reconfiguration and scaling. The local cluster RISC is applied as an effective tool for solving the problems of physical data processing. The mathematical processing of the experimental data obtained at the EXCHARM installation is carried out at this cluster. The data banks — the results of mathematical processing of initial experimental information (almost 200 GByte) for the experiment EXCHARM — have been generated and prepared for a further physical analysis.

The cluster RISC is also used for modelling the experiments on research of the processes with charmed and strange particles at the U-70 accelerator in Serpukhov. A new system for data processing has been created and put into operation. Its peculiar feature is the integration of the local linux cluster RISK and the computing facilities of the JINR computer centre. By means of integration of the local cluster and the robotized bulk memory, a distributed soft- and hardware platform has been synthesized for data processing in particle physics.

In frames of the CMS/LHC software activities testing and modifying CMSIM (ftn) and ORCA (C++) programes for muon tracks reconstruction in the end-cap muon system were performed [15].

Computer Algebra

In the year 2000, the following investigations were performed:

— Algorithmization of Dirac method for calculation and separation of bindings in dynamic systems of a polynomial type based on using involute polynomial bases [16];
— Effective realization in the REDUCE system as well as in the programming languages C and C++ of original algorithms of reducing the systems of nonlinear algebraic equations to a canonical Janet basis (that is the Grebner basis of a special form) which is convenient for research in the systems and their solution;
— Computation of cohomology of Lie superalgebras of the vector fields with an odd Poisson bracket was performed [17];

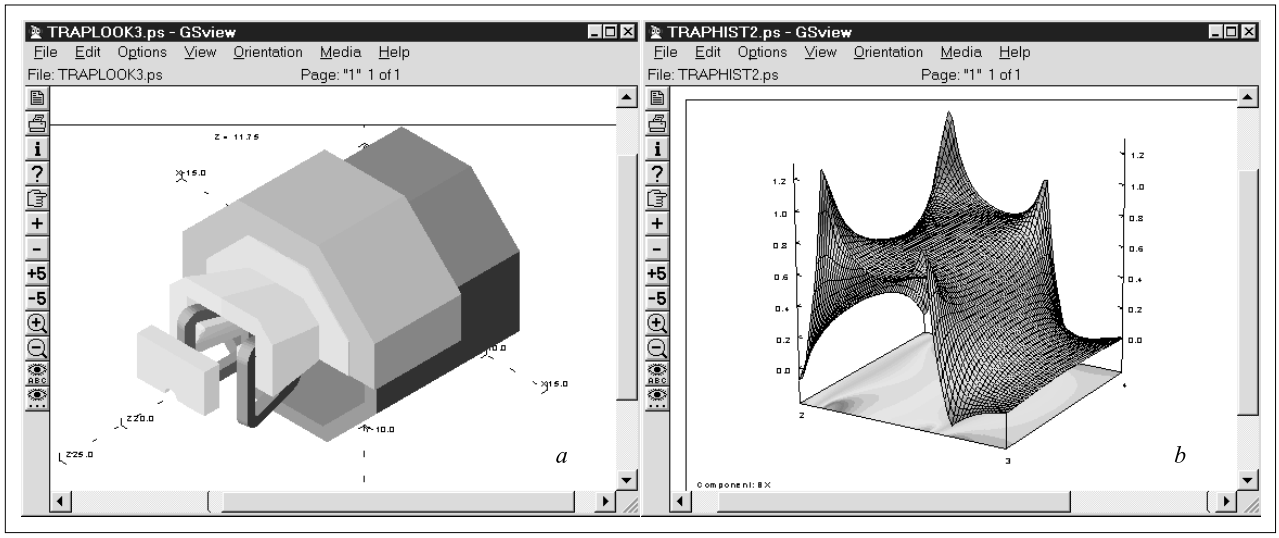

Fig. 7. Computer model *a)* and the magnetic field main component distribution *b)* for one of the variants of a dipole magnet for the ALICE experiment

— Calculation of a second coefficient in the decomposition of the core of the thermal conductivity operator for a nonminimal differential operator on the torsion curved manifold [18];
— Explicit solution to recursion relations for the Feynman integrals written with respect to the «space-time» dimension [19];
— A close relation between the Janet and Pommaret bases has been stated [20].

The algorithm and the results mentioned above are the pioneer ones. The computer programs written in the C and C++ languages , at the expense of the original algorithms embedded, exceed the best foreign programs realizing the classical Buchberger algorithm for calculation of the Grebner bases.

INTERNATIONAL COOPERATION

In accordance with the Agreement between JINR and the Research Centre Rossendorf, Germany, about a cooperation in the field of application and development of computing systems, in particular for the «Zentrale Nutzerdatenbank» project, LIT takes part in the creation of an automated system of administrating a computer complex using the WWW technology as a tool of access to the ORACLE database via the Internet. The LIT personnel provided a Java-service — the development of programs in the Java language working under the operating systems Microsoft Windows and UNIX (Linux, AIX) and controlled by the standard WWW facilities — browsers Netscape Communicator and Internet Explorer. These programs in the form of Java applets provide in a dialog mode a graphic user interface (GUI) to work with the database Oracle. The network access to the database was provided also by the Java-JDBC language.

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

— A new subsystem that provides creation of the object-oriented models of hierarchically composed data, has been introduced in the official version of the package ROOT. The subsystem includes a number of classes for creation and navigation of such objects. The subsystem represents an extra service and provides an effective input/output, an interactive monitoring and a graphical 2D and 3D representation of its results (http://root.cern.ch/root/ R2000Welcome.html). At present, the subsystem of 3D graphics allows one to obtain volume stereoimages and possesses an additional entry to the object-oriented system of 3D graphics Open Inventor that opens outstanding possibilities for integration of this system with the ROOT package (http://conferences.fnal.gov/acat2000/).

— The development of the working environment for using the object-oriented technologies for «large» experiments in nuclear physics and high energy physics has been completed. The «technological line» created on its basis for reconstructing events from the largest installation STAR has been officially put into operation in Brookhaven. In summer 2000, in the course of the first session at the largest accelerator RHIC, 10 TByte of experimental data were processed and 3.3 TByte DST were obtained with its help. It should be noted that all of the 4 experiments (STAR, PHENIX, BRAMS, PHOBOS) at the RHIC accelerator did choose the ROOT package as a main tool for

development of their subsystems for data processing and monitoring.

In cooperation with SCAR, LIT staff participated in the activities under the JINR-CERN Agreement.

— New versions of the LabVIEW software (ver.6i) and BridgeVIEW (v.3.0) were installed, tested and supported for a wide range of users in ATLAS, CMS and other experiments, as well as for the LHC test and control systems.
— LabVIEW libraries were upgraded and tested for a new version of LabVIEW for Windows-2000 and Linux (Red Hat 6.2).
— CERN LabVIEW/BridgeVIEW Users Database with a Web-based user interface has been developed and put in operation since August 2000.
— Support and upgrade of NICE in accordance with new releases of commercial software (a new version of Netscape Navigator 4.75 for all platforms, extension of Web-services, etc.).
— Start-up of integrating the operating system Windows 2000 into the NICE system at CERN and JINR.

In cooperation with Slovak scientists, qualitative and numerical research in the nonlinear ODE system describing the existence and stability of disclination vortexes in elastic matter has been started. With the help of the computer algebra system MAPLE, an asymptotic of singular and nonsingular vortexes was obtained at zero point. A behaviour of the vortexes was numerically investigated for large r for various parameters of the problem and the asymptotic.

Research on the nonlinear Schroedinger equation was performed in collaboration with the University of Capetown (SA). It has shown that the parametrically driven nonlinear Schroedinger equation has a wide class of travelling soliton solutions, some of which are stable. For small driving strengths stable nonpropagating and moving solitons co-exist while strongly forced solitons can only be stable if moving sufficiently fast [21].

The effective cooperation with the International Salvay Institute of Physics and Chemistry (Brussels, Belgium) progressed in 2000. New integral software for electrocardiogram analysis was developed [22]. Research on analysis of results of optical coherent tomography of the human skin microstructure [23] was undertaken. Resonances, correlation, stabilization and control over complex systems were studied [24].

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DIVISION OF RADIATION AND RADIOBIOLOGICAL RESEARCH

In 2000, the DRRR activity is connected with the radiation and radiobiological researches and radiation protection. The first two lines are included in the Topical Plan for Scientific Research of JINR and were concentrated on:

- neutron spectrometry and radiometry, radiation monitoring;
- investigation of radiation fields around thick targets;
- physical support of radiobiological experiments;
- shielding calculations and design;
- investigations of peculiarities and mechanisms of point and structural mutation induction in pro- and eukaryotic cells by radiation with different linear energy transfer (LET);
- problem of low doses of radiation with different LET and cell recovery;
- investigation of «methylene blue – ^{211}At» complex therapy efficiency in melanoma cells.

In 2000, the theme «Radiation and Radiobiological Investigations at the JINR Basic Facilities and in Environment» was prolonged to 2003.

RADIATION RESEARCHES

Radiation fields' calculation. The study of reference neutron spectra of the polyethylene-moderated ^{252}Cf was continued. The neutron spectra were calculated by the Monte Carlo method without and with taking into account the calibration room scatter effect and compared with experimental data. Parameters needed to test dosimeters, such as ambient and personal dose equivalent per unit neutron fluence, averaged over the neutron spectra, were defined [1].

Radiation shielding. All shields require holes or openings for cables, ventilation ducts, personnel access, etc., and considerable care has to be taken to ensure that radiation escaping through these holes does not seriously undermine the overall efficiency of the shield. The study of radiation scatter down holes in a shield was started by the Monte Carlo method.

The programme of the experimental investigation of the characteristics of secondary particles around a thick lead target irradiated with 650 MeV protons was started at the JINR Phasotron. This work is carried out in the frame of the project of MOX subcritical assembling on the accelerator and the target imitates the core of the subcritical assembling. This research programme is realized in collaboration with the LNP, FLNP and LIT. In the first stage of the programme the following characteristics were measured:

- the double differential (on angle and energy) distribution of the neutron around the target;
- the angle distributions of the hadrons (with different energy thresholds) around the target;
- the longitudinal distributions of the hadron yield (with different energy thresholds) from the target;
- the total hadron yield from the target.

The multisphere neutron spectrometer for measuring in the widest energy range and an activation detector technique were used. The neutron spectra from the thick target under 45, 75, and 105° are presented in Fig. 1 [2,3]. These results were applied for verification of the Monte-Carlo calculation of the internuclear cascade of the secondary particles generated by the primary protons within the target. The good agreement between the experimental data and the corresponding calculations was obtained. The work on the measurement of the activation

rate of the radioactive nuclides generated within the target by the protons is now in process.

The work in collaboration with the LHE for estimation of radioactive waste transmutation cross section was continued. The neutron yields from the thick lead target surrounded with the paraffin moderator irradiated by 1 and 1.5 GeV protons were studied.

The active neutron counter with activation indium detector was designed for thermonuclear neutrons' detection in specific conditions (very short duration of neutron pulse, the high level of the accompanied gamma radiation, the influence of the powerful electromagnetic field on electronic equipment and so on). The counter design was optimized for high sensitivity for fast neutrons. The experimental test showed a good agreement with the calculated neutron sensitivity [4].

For the physics support of the biological experiment the experimental run with the ^{12}C ions beam at the Nuclotron was carried out in December 2000. The purpose of the experiment was the investigation of the ion beam characteristics for the radiobiological samples' irradiation and the calibration of the monitors The irradiation of various track detectors was done also for the detectors response study. The similar work for the relativistic proton beam was finished [5].

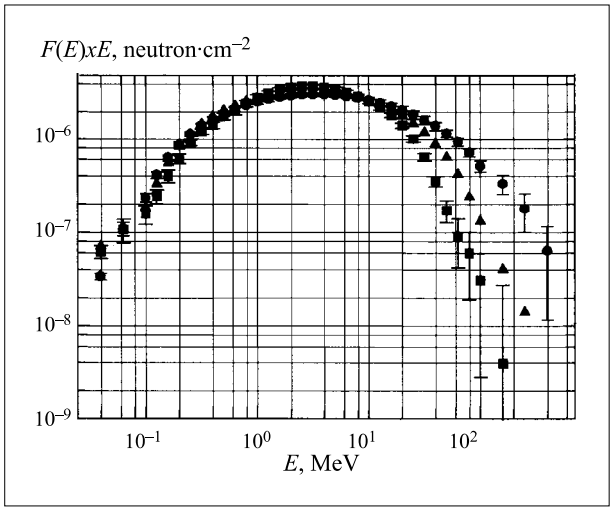

Fig. 1. The neutron spectra from the thick lead target at the angles: ● — 45°; ▲ — 75°; ■ — 105°

RADIOBIOLOGICAL RESEARCHES

The obtained data on the frequencies of stable and unstable chromosomal aberrations in *human blood lymphocytes* were summed up after proton irradiation (1 GeV), γ rays and nitrogen ions ^{14}N with energy 50 MeV/nucleon (LET ~ 77 keV/μm) [6-15]. During the investigation of their formation using conventional metaphase and FISH-methods some earlier known regularities were confirmed and the new quantitative and qualitative peculiarities of effects were revealed after action of radiation with different quality. So, the translocations prevailed in the total number of aberrations, and their frequencies had the inverse negative relationship from the LET radiation: their fractions were 40–45 % after γ and proton irradiation and ~ 25 % after nitrogen ions. In the last case high chromosome fragmentation manifested itself and, as a result, the relative decrease of stable chromosome aberration fraction was observed. Moreover, FISH-obtained data testified higher frequency of chromosomes 1 and 2 damage in the human genome after tested types of radiation. The data may confirm the supposition about different radiosensitivity of different human chromosomes. The obtained data on the induction of stable chromosome aberrations (translocations) were taken as principles of calibration curves and the basis for using such aberrations as bioindicators for estimation of absorbed doses of radiation with different quality. As the analysis shows, the exactness of γ ray and proton dose estimation was 7–15 % and it was ~ 20 % for nitrogen ions. It improves when inducing doses increased.

The obtained data were analysed for spontaneous HPRT-mutants and radiation-induced clones by different doses of radiation with different quality: γ rays, accelerated protons with energy of 1 GeV and nitrogen ions ^{14}N with LET ~ 77 keV/μm. During revealing and selection of HPRT-mutants the arising of mutants with slow growth and increasing of such mutant fraction to 80–100 % at high inducing doses of γ rays (5–7 Gy) and at all used doses of nitrogen ions (up to 3 Gy) was observed. The cytogenetic analysis of spontaneous and radiation-induced mutant subclones revealed their heterogeneity on such tests as mitotic activity, aneuploidy and chromosomal aberration level. Chromosome instability of mutant subclones decreased with increasing of ionising radiation LET. The fraction of mutants with higher chromosome aberration level as compared with intact control was: among spontaneous mutants — 71 %, γ-induced ones — 47 %, induced ones by protons — 33 % and by nitrogen ions — 16 %. The chromosome instability of spontaneous mutants was the highest one. Among the spontaneous mutants the groups of mutants were revealed which did not differ from intact control chromosome aberration level, with higher chromosome aberration level up to 2–4 times, with extremely high level of chromosome aberrations (more than 30 % of aberrant cells) and tetraploid

mutants. Also the appearance of mutants with lower chromosome aberrations level 2–4 times as compared with intact control was noted at radiation-induced mutagenesis. The fraction of such genetically stable clones with low chromosome aberration level was: amongst γ-induced mutants — 16 %, induced ones by protons — 8 % and by nitrogen ions ^{14}N — 48 %. Among the spontaneous mutants they were not observed. These data may testify that the frequency of genetically stable mutants increases at high radiation LET. The heterogeneity of HPRT-mutants, revealed in our experiments testifies that at mutagenesis a probability of infringement of chromosome integrity in mammalian cells rises and it may be regarded as a stage of corresponding genome reorganization that is adequate to changed vital conditions. Probably a degree of chromosome instability of the mutants may be conditioned by the differences of arising mutation types.

The study of the effect of *low dose irradiation* on mammalian cells was continued. One of the main aspects of this problem is the possibility of extrapolation of high dose effects to the low dose range. Nonlinear dose-effect dependence with Chinese hamster and human melanoma cells was shown earlier when the anaphase method was used. This dose dependence was characterized by hypersensitivity at low doses (below 10–20 cGy), the reverse dose-effect dependence in the range 10–30 cGy and induced radioresistance at higher doses. These «anomalous» dose curves were confirmed by synchronized Chinese hamster cells, irradiated in G1-phase of the cell cycle. Metaphase analysis of chromosome aberrations in the first postradiation mitosis, both for the number of aberrant cells and for the number of aberration per cell, showed the presence of early-absorbed regularities. Analogous dose-effect curves were observed with human melanoma cell when micronuclear test was used, which integrates the reaction of the cell population for the whole cell cycle.

It was shown also that the adaptive response of human melanoma cells estimated with micronuclear criterion was higher than that with the number of aberrant cells (0.55 and 0.8, respectively). The dose-effect dependence was changed when the preliminary irradiation at optimal doses was carried out five hours before irradiation with doses of 0.1–2 Gy; the phase of high radiosensitivity was absent in this case and a number of spontaneous aberrations were repaired. It can be concluded that the same inducible repair processes are analogous in mechanisms, and different in quantitative proportion for different cell type, underlying basically nonlinearity dose-effect curves and induction of the adaptive response.

The investigations were continued in experimental approach of *targeted radiotherapy of pigmented melanoma with radionuclide α-emitter* ^{211}At *and methylen blue (MTB)*. The selective action of ^{211}At–MTB on human melanoma cells was studied. The accumulation of radionuclide during the incubation of cells with ^{211}At-ion and 211At–MTB was used for the evaluation of the degree of selectivity; 3–4 times more effective accumulation was shown of ^{211}At–MTB in pigmented melanoma cells than in Chinese hamster cells. ^{211}At ions were accumulated by both types of cells equally and in very low quantity. These results correlate with our earlier data, which demonstrate one order higher ^{211}At–MTB-treatment efficiency on human melanoma cells in comparison with nonpigmented cells.

The induction of mutations of different nature after irradiation by ionizing radiation was studied in *yeast Saccharomyces cerevisiae* as a model system of eucaryotic cells [16-21]. Mutagenic property of ionizing radiation was characterized by using three different mutator assays. They were a forward mutation rate assay that detects mutations inactivating the arginine permease gene (Can^r mutations) and reversion assays detecting mutations that revert a 4-base insertion in the LYS2 gene or that revert a + 1T insertion in a stretch of 6 T's in the HOM3 gene. The reversion to Lys^+ and Hom^+ is due to deletion of a single nucleotide predominantly. The γ ray induced forward and frameshift mutations efficiently. Frequency of direct mutations to canavanin resistance (Can^R) is $5.8 \cdot 10^{-5}$, frameshift mutations for reversion to Lys^+ is $1 \cdot 10^{-6}$ and for reversion to Hom^+ is $1.6 \cdot 10^{-7}$ for dose 100 Gy. Dose dependence of induction of forward and frameshift mutations is linear for dose 100–1000 Gy.

Induction of base-pair substitutions by γ ray was studied earlier using special tester CYC1-system. Now we are studying induction of point mutations by heavy ions. Induction of AT–TA transversion in diploid yeast cells by ^{4}He ions was tested. The shape dose curve isn't linear for dose 100–1000 Gy. Efficiency of ^{4}He ions with LET = 80 keV/μm for induction of transversions is less than efficiencies of ^{4}He ions with LET = 20 keV/μm and γ ray.

The study of genetic control of DNA damage-induced arrest of cell cycle progression, named checkpoint-control, was continued. We intend to study interactions between the known checkpoint-genes RAD9, RAD24, RAD53 and our genes SRM5/CDC28, SRM8, SRM12 using such property as the radiosensitivity. Genetically, CDC28 and RAD9 appear to form one epistasis group, but CDC28 and RAD53 define two epistasis groups. So, CDC28 and RAD53 define two branches of the pathway controlling the radiosensitivity. We demonstrate that RAD9 and RAD24 genes act in opposition in one pathway of controlling the radiosensitivity and they interact epistatically with RAD53 gene. RAD53 is believed to function further downstream. So, the control of radiosensitivity defined a branch pathways.

Analysis of genetic characteristics of SRM1, SRM2, SRM5, SRM8, SRM12 genes was continued. We investigated effects of srm-mutations on lethal and mutagenic action of γ ray and on cell cycle progression.

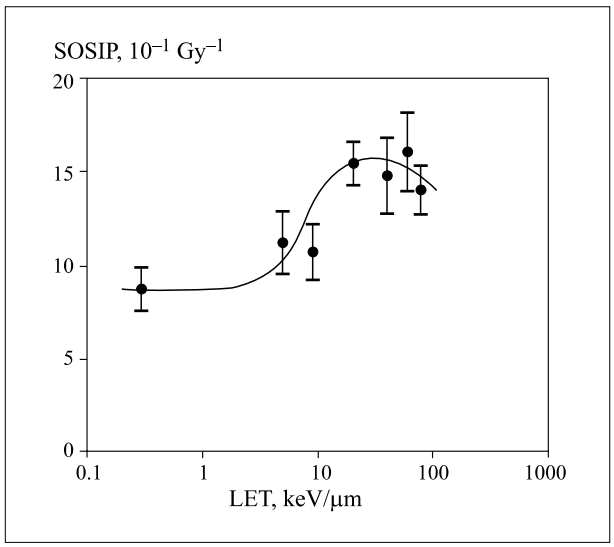

Fig. 2. The dependence of the E.coli SOS-response on the LET

The study of point (col B, ton B) and deletion mutation induction *in bacteria cells* by γ rays and heavy ions were continued [22-28]. It was shown that the frequency of col B and ton B mutations as a function of the γ-ray and heavy ion dose (helium ions with LET = 20 and 78 keV/μm and carbon ions, LET = 200 keV/μm) is described by the linear-quadratic curves. The quadratic part of these curves is parallel shifted from the dependence with γ irradiation. The relative biological effectiveness (RBE) depends on LET as a function with a local maximum. The maximal biological effect reveals after helium ion irradiation with LET = 20 keV/μm. The induction of deletion mutations by helium and carbon ions (LET = 78 and 200 keV/μm, respectively) is described by the linear function. The helium ions are more effective in induction of deletion mutations than the carbon ions.

The researches of SOS response in E.coli cells after irradiation by deuterons (LET = 5 and 9 keV/μm), helium ions (LET 20, 40 and 80 keV/μm), carbon ions (200 keV/μm) were continued. It was established that the relationship of SOS induction potency (SOSIP) on LET has a local maximum in the region of 50–60 keV/μm (Fig. 2).

The results that were obtained with bacterial cells indicate the important role of cluster DNA damages in formation of gene mutations. On the other hand, the formation of deletion mutations is connected with induction of direct and enzymatic double strands breaks of DNA.

The investigations of regularities and mechanisms of induction of precise excision of transposons by radiation with different characteristics have been started. The mobile elements are the discrete genetic structures (the segments of DNA) that are capable to be displaced from one to another position of bacterial genome.

The embedding of transposon starts with the covalent insertion of discrete genetic stable terminal sequences. A new system for monitoring and studying of the induced mutability — induction of precise excision of transposons by different types of ionizing radiation has been used in our experiments. The precise transposon excision is the specific SOS-dependent process that is connected with the formation of deletion mutations. Differing drastically from point mutations in the nature of a cellular target for inducible SOS-mutability machinery, precise excision of transposons suggests a possibility of revisiting the process of SOS-mutability via its functioning in the formation of genomic deletions.

The exponential survival curves for E.coli wild type and repair deficient mutants (recA, recN) bearing the Tn5 and Tn10 transposons were obtained. The dependence of excision transposon frequency on the dose of γ rays was determined. It was shown that the dependence for the wild type cells bearing the Tn10 transposon is described by the curve with saturation that has a maximum. The recA mutation blocks the transposon excision completely, and the recN mutation represses this process. These results enable one to conclude that rec A and rec N genes are not only involved in DNA repair but also control the induction of excision and insertion of Tn10 transposon in E.coli genome.

Low dose ionizing radiation action at laboratory experiments on peas and complex action of chemical and radionuclide pollution on plantain in Balakovo of Saratov region was studied [29-32]. The changes of parameters of physical-chemical processes (antioxidant status of the seed), cytogenetic damages (chromosomal aberrations and mitotic activity of cells of seed roots) and adaptive response were studied at the investigation of chemical and radionuclide complex action. The changes in all samples were observed in compare to control lots.

On the basis of the two-protection reaction model an analysis of *stochastic radiobiological effects of low-dose exposure* of different organisms has been carried out [33–36]. The stochastic effects are the results published in the last decade: epidemiological studies of human cancer mortality, the yield of thymocyte apoptosis of mice and different types of chromosomal aberrations. The results of the analysis show that as dependent upon the nature of biological object spontaneous effect, exposure conditions and radiation type one or another form dose–effect relationship is realized: downwards concave, near to linear and upwards concave with the effect of hormesis included. This result testifies to the incomplete conformity of studied effects of 1990 ICRP recommendations based on the linear no-threshold hypothesis about dose–effect relationship. Because of this the methodology of radiation risk estimation recommended by ICRP needs more precision and such quantity as collective dose must be defined more exactly.

RADIATION PROTECTION

The radiation monitoring for occupational exposure at JINR nuclear facilities was carried out in 2000 by the automatic systems of radiation control (ASRC) and by portable instruments. At the FLNP were done the following works with the equipment with high-level induced radioactivity:

- the disassembling and move of the IBR-2 reflector to the depository;
- the testing of the cryogenic moderator for the IBR-2.

The organization and technical measures on radiation protection ensured inexceeding of planned doses.

At FLNR in the frame of the DRIBS project (phase 1) the secondary neutron yield and the angular and energy distribution of the neutrons from the target of the U-400M were measured in the regime of the radioactive ions production. The radiation shielding of the installation was estimated and the necessary recommendations were done.

In according with the JINR-NIKHEF (Holland) agreement and the international rules the transport of radioactive equipments of the NIKHEF accelerator from Amsterdam to Dubna was carried out.

In 2000, the Individual Dosimetry Service maintained dose control to 1810 persons, including 73 visitors. The average individual doses to the JINR personnel did not exceed 1.8 mSv/yr. The highest value of the average individual dose is at FLNR — 2.8 mSv/yr. One accident of the dose exceeding was at the LNP.

The regular environmental monitoring of soil, plants (grass), water from the river basins in Dubna vicinity, water-supply system and water effluents of enterprises confirms the fact that the environmental radiation pollution around JINR area remain constant during a long time and contains the natural radioactivity and products of global fallout only. Any contribution to radioactive pollution of the environment from the JINR nuclear facilities was not found in 2000.

CONFERENCES AND EDUCATIONAL ACTIVITY

The Timofeeff-Ressovsky Centennial International Conference «Modern Problems of Radiobiology, Radioecology and Evolution» was held in JINR in September 2000. The conference was supported by UNESCO, INTAS, Ministry of Industry, Science and Technology (Russia), Genetics Society of America, Soros Foundation. More than 200 scientists from different countries took part in the conference. The memorial booklet has been published. The education process at the chair «Biophysics» of the International University «Dubna» was continued. 10 new students were admitted in 2000 to the chair on specialty «Radiation Protection of People and Environment».

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UNIVERSITY CENTRE

In 2000, the University Centre (UC) of JINR continued its activities within the first-priority topic «Organization, Maintenance, and Development of the University-Type Educational Process at JINR». The realization of this topic is entrusted mainly to the UC.

The expected results upon the completion of the topic stages or projects are the following:

- development and update of the curricula and programmes for physics students;
- support of the post-graduate studies;
- establishment of student and post-graduate exchanges between the UC and foreign universities on the basis of Agreements on Cooperation;
- creation of a system of raising the professional skills of JINR's engineering and technical staff;
- development of the computing and information technology complex for the university-type educational process, a remote instruction network, and a database of the programming courses.

Students of the fourth, fifth and sixth years complete their university education at the UC in the following areas: nuclear physics; elementary particle physics; condensed matter physics; theoretical physics; technical physics; and radiobiology.

In the spring semester (autumn semester in parentheses) of 2000, there were 76(82) students at the UC from different institutions of higher education of the JINR Member States. The curricula are worked out jointly with the institutions of higher education that have assigned their students to graduate at the UC. The table below reflects the distribution of the UC students over institutions of higher education.

The UC develops new programmes of special educational training for some student groups.

From autumn 1998, the first group of Slovak students were trained at the UC to become specialists for the Slovak cyclotron facility, which is being built with JINR's support. In 2000, they successfully defended their diploma theses. In January 2001, a second group of Slovak students are to defend their theses. Both of these groups are made up of students of Bratislava Technical University. In September 2000, a third Slovak group began their studies at the UC. This group is made up of students of Bratislava Technical University and the Komensky University.

At the UC, the Slovak students learn the specialty «Accelerator Physics and Engineering». The curriculum includes the following courses:

- Applied Mathematics;
- Dynamics of Accelerated Charged Particle Beams;
- Interaction of Radiation with Matter;
- Physics and Engineering of Heavy Ion Accelerators;

Institution	Spring 2000	Autumn 2000
Moscow State University	16	16
Moscow Engineering Physics Institute	13	15
Moscow Institute of Physics and Technology	20	17
Institutions of other JINR Member States (Armenia, Belarus, Czech Republic, Georgia, Russia , Slovakia, Ukraine)	27	34
Total	76	82

- Atomic and Plasma Physics;
- Heavy Ion Sources;
- High-Frequency Systems of Accelerators.

The lectures are given by specialists of the Flerov Laboratory of Nuclear Reactions, Laboratory of Particle Physics, Division of Radiation and Radiobiological Research, and Dzhelepov Laboratory of Nuclear Problems. This special programme requires that the students take an intensive course of Russian before attending courses in the specialty.

The UC tries to extend the range of its educational activities. It is known that actively used are medical beams at the accelerator of the Laboratory of Nuclear Problems. This has become the ground for establishing a new graduate department at Moscow Engineering Physics Institute — the Department of Physical Techniques in Applied Research and Medicine (Department No. 45). It is headed by Prof. N.A.Russakovich, Director of the Laboratory of Nuclear Problems.

The specificity of university education is its versatility. It means that the students can choose lectures and lecturers; and a wide range of additional courses, including optional subjects, are available to them.

Below follows the list of some courses given at the UC:

Elementary Particle Physics; Relativistic Nuclear Physics; Quantum Chromodynamics; Theory of Nuclear Reactions; Atomic Nucleus Structure; Introduction to the Theory of Accelerators; Experimental Nuclear Physics; Modern Techniques of Detecting Nuclear Reactions and Nuclear Radiation; Programmable Logical Units; Fundamentals of Radio Engineering; Digital Devices and Their Application; Electronic Techniques of Ionizing Radiation Detection; Radiation Safety and the Environment Protection; Mathematical Statistics; Object-Oriented Programming in C++; Programming in UNIX; Computing in High-Energy Physics; Internet Technologies; Computing Facilities in Nuclear Physics (seminar); Telecommunication Systems and World Information Resources; Computing (Visualization in Scientific Research); Operating the «Mathematica» System, English for Students, and English for Postgraduates.

During semesters, the UC offers to its students and post-graduates short lecture series on the latest developments in physics and related fields, which form the lecture cycle «Modern Problems of Natural Science». This semester, the following courses have been given:

- Dr.C.Pagliarone (Universita di Cassino and INFN Pisa) — «Modern Physics at Hadron Colliders»;
- Prof.Stephan Paul (Munich Technical University) — «Hadron Physics at High Energies — Why and How».

The UC publishes manuals for its students and post-graduates. This year, a book by Prof. Dr. R. Kragler (FH Ravensburg — Weingarten / University of Applied Sciences) «Mathematica Tutorial Course» has been published.

In 2000, the JINR post-graduate studies continued to function in ten specialties of physics and mathematics.

Since 1995, altogether 49 students have completed JINR's post-graduate programmes; 36 remained at JINR for further work. JINR's post-graduate studies have now a total enrollment of 44.

The following table reflects the distribution of the UC post-graduates over the JINR Laboratories in 2000.

	Number of post-graduates Spring 2000	Number of post-graduates Autumn 2000
Laboratory of Theoretical Physics	3	3
Laboratory of Nuclear Problems	9	15
Laboratory of Nuclear Reactions	2	4
Laboratory of Neutron Physics	7	5
Laboratory of High Energies	3	1
Laboratory of Particle Physics	5	5
Laboratory of Information Technologies	8	9
Department of Radiation and Radiobiological Research	2	1
University Centre	1	1
Total	40	44

The first-enrollment post-graduates completed their studies in 1998. Up to now, 8 defended their post-graduate theses.

Two of the UC's present post-graduates come from Egypt.

Taking into account JINR's international character, the UC actively develops international contacts.

Within the frames of the programme of the German Service of Academic Exchanges (DAAD) «Leonard Euler Scholarships» a joint project of the UC and the Institute of Theoretical Physics of the University of Giessen (Germany) has been supported for 1999–2000 and 2000–2001. Two UC post-graduates and one graduate student performing theoretical research in heavy ion

physics are paid an additional scholarship during the current academic year and will have a month's practicum in Giessen.

In July 2000, a group of 18 students of the Technical University, Prague, visited the UC. They saw JINR's Laboratories and basic installations, and were acquainted with the UC's activities.

On June 20–28, 2000, a regional forum of the European Physics Education Network (EUPEN) took place in Poznan, Poland. JINR was represented at the forum by the UC. Discussed at the forum were the cooperation within the EPS, EUPEN, and JINR; the organization of the International Student School «Nuclear Physics Techniques and Accelerators in Biology and Medicine» at JINR in 2001; and the student exchange issues.

The UC has received a grant from the European Physical Society, which will allow five UC students to spend a month at an Italian university.

The UC has traditionally friendly ties with the Polish university community.

UC and Polish students and post-graduates exchange acquaintance visits, and participate in schools and conferences held in Dubna and Poland. The Bogoliubov–Infeld programme has been established to support Polish universities' and JINR's initiatives for the development and realization of projects in education. The programme is funded by a special grant from the Polish Plenipotentiary at JINR.

The table below shows the breakdown of the number of Polish students that visited JINR during the last 3 years into the universities and years.

University	Number of students		
	1998	1999	2000
University of Lodz	-	-	9
University of Wroclaw	15	-	24
Adam Mickiewicz University (AMU) of Poznan	-	12	-
Jagellonian University of Krakow and Academy of Mining and Metallurgy	40	19	-
University of Lublin	-	10	-

In the autumn of 1998, the top officials of JINR and Moscow Institute of Radio Engineering, Electronics, and Automatics (MIREEA) established at JINR a graduate department in the specialty «Electronics and Automatics for Physics Facilities». The full-time programme for MIREEA students is given at the UC beginning with the first year of studies. The current total number of MIREEA students at the UC is 46. The UC has two auditoriums and one computer classroom for them.

All these activities require proper equipment. The UC has (Fig. 1):

- four computer classrooms, one of which is dedicated to data visualization;
- three auditoriums with multimedia-equipped lecturer's places;
- one server room with an e-mail and WWW Alpha Server (DecUNIX), and classrooms subnet and multimedia server (Windows NT);
- one student laboratory, which has been equipped at the expense of a JINR Directorate grant. A Physics Practicum has been introduced into curricula of the UC. The Practicum is made up of two laboratory exercises. One of them consists in students learning the main performances of the spectrometer, measuring gamma spectra of gauged sources, and determining the energy and intensity of characteristic lines. The other is concerned with charged particle spectrometry.

Since 1999, the UC turns out and retrains workers and raises their qualifications. The UC organizes and controls their training on the basis of JINR's Laboratories and divisions. The UC is going to broaden the scope of the technical and engineering staff training, so the arrangements are underway to obtain the licenses for educational activities in radiation safety, industrial hygiene, and information technologies.

Workers were trained in new and allied professions on an individual basis. During this year, 10 JINR staff members were trained in new specialties and 16 JINR staff members were trained in allied specialties; 84 completed the courses of training the staff for the activities supervised by the Federal Technical Inspection.

In 2000, established was the system of instructing the JINR authorities and specialists for industrial accident prevention. 229 JINR staff members were certified upon completing this course.

150 JINR staff members got essential training in fire prevention.

17 JINR staff members were sent to various training institutions of Moscow, St. Petersburg, Ivanovo, and Obninsk (Moscow Institute of Qualifications Improvement «Atomenergo», the Institute of Industrial Hygiene, etc.).

In 2000, the UC was certified by the Federal Technical Inspection to conduct training in operating industrial boilers and hoisting mechanisms. At the UC's training station, 11 staff members of Dubna's organizations were qualified in specialties supervised by the Federal Technical Inspection.

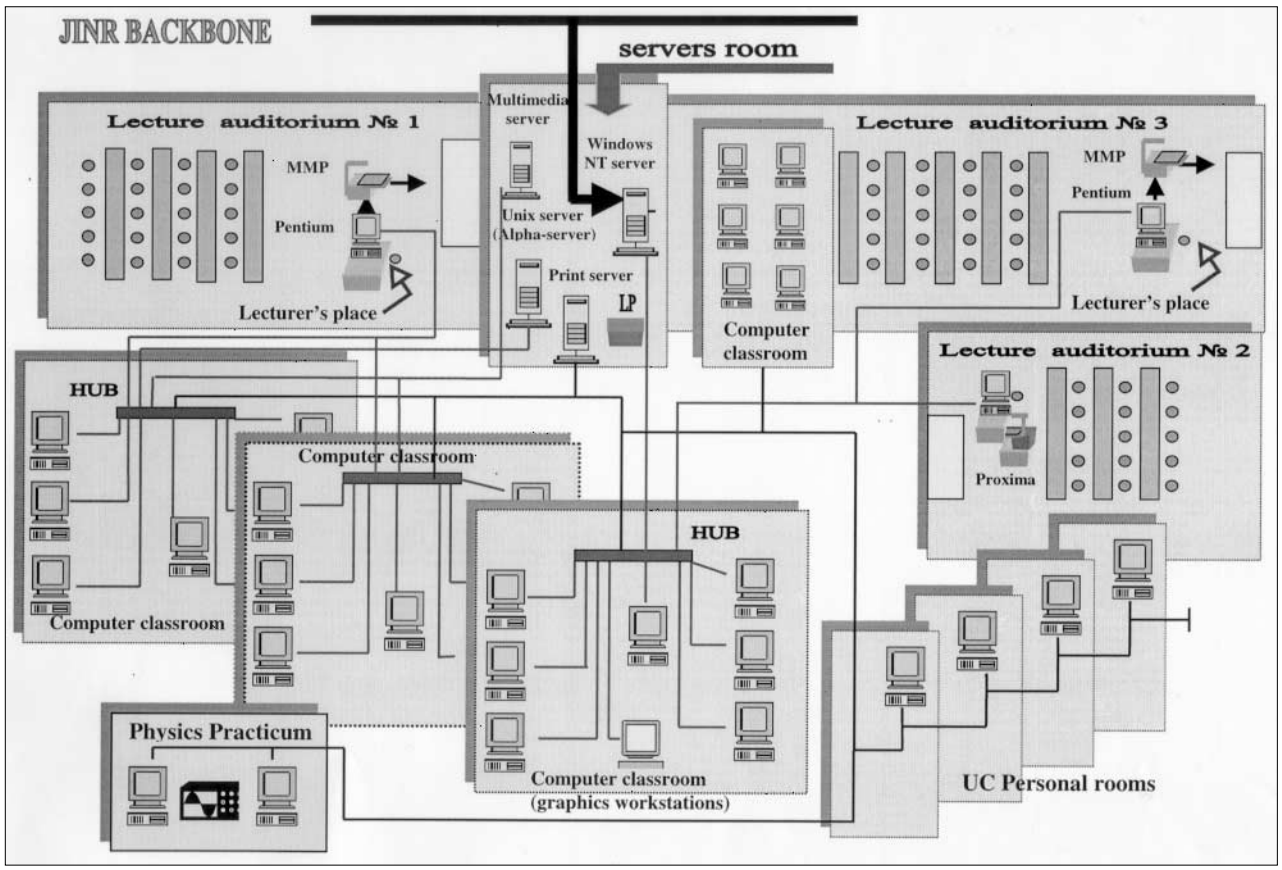

Fig. 1. Architecture of the UC JINR

At JINR's Laboratories and subdivisions, 17 students of Technical Colleges No. 67 and 95, and six students of other colleges, did practical work.

A branch of the preparatory courses training entrants to Moscow Engineering Physics Institute (MEPI) was opened. 15 Dubna's school students attend these classes in the Academic Year 2000–2001. A trip to the competitions in physics and mathematics at Moscow Engineering Physics Institute was arranged for them. A group was mustered for JINR-warranted entering MEPI, which was made up of six students who attended these courses in the Academic Year 1999–2000.

The UC Directorate gives serious consideration to the development of international student exchange. The importance of this activity has been appreciated by the participants of the past exchanges. Regular contacts will help young scientists of the JINR Member States easily join the international scientific community.

The International Student School «Nuclear Physics Techniques and Accelerators in Biology and Medicine» will be held on June 27 – July 11, 2001, in Ratmino near Dubna (Moscow Region, Russia). It will be another School in the series of the Summer Student Schools organized by JINR, Dubna.

In 2000, the reports on the JINR educational programme were presented at the:

- regional forum of the European Physics Education Network (EUPEN) in Poznan, Poland;
- international congress «Science and Education on the Threshold of the 21st Century» in Minsk, Belarus.

Within the frames of the joint project of the UC and the Institute of Theoretical Physics of the University of Giessen (Germany), theoretical research in heavy ion physics was performed at the UC [1–5].

The establishment of the UC was a timely and significant step in developing the system of the educational training of young specialists for JINR and organizations cooperating with it. JINR attaches great importance to its Educational Programme. Continuing this activity within the Topical Plan will allow the Laboratories' efforts to be united.

Regularly updated has been the UC's Web site (http://uc.jinr.ru).

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3. *Adamian G.G. et al. // Phys. Rev. C. 2000. V. 62. P. 064303–6.*
4. *Antonenko N.V. et al. // Proc. of Intern. Conf. «Nuclear Shells — 50 years», Dubna, 1999. P. 286–295.*
5. *Ivanova S.P. et al. // Proc. of Int. Conf. «Dynamical Aspects of Nuclear Fission» Singapore, 2000 (to be published).*

Dubna, 31 July. XIII International Colloquium
on Group Theoretical Methods in Physics

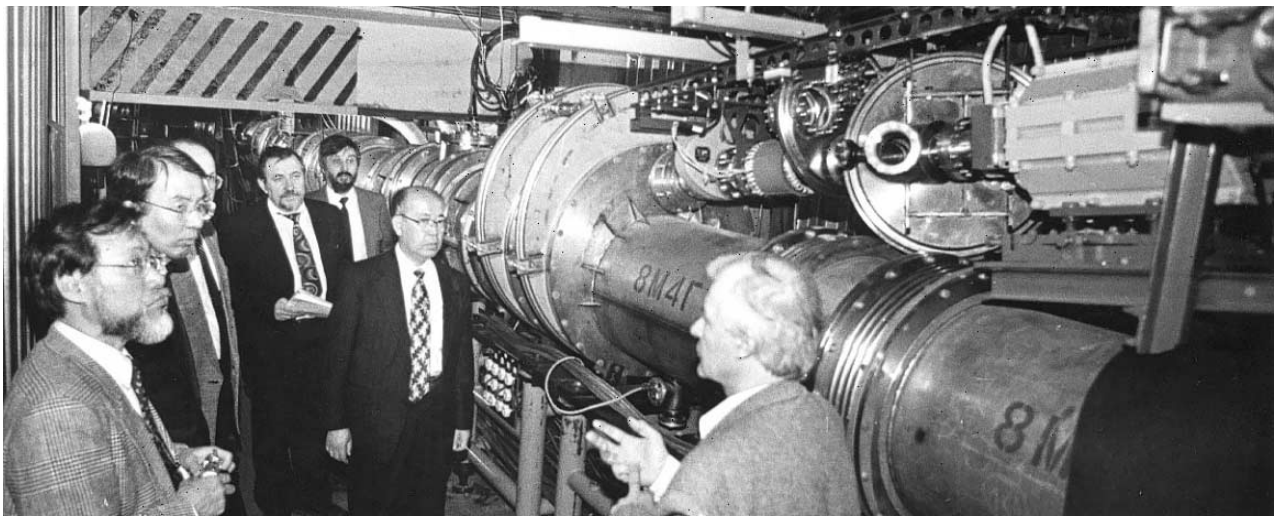
Bogoliubov Laboratory of Theoretical Physics.
Dedication of a memorial plaque to Professor V.G.Soloviev

Dubna, 22 August.
Participants of the International Workshop
«Hot Points in Astrophysics»

Dubna, 25–29 September.
XV International Seminar on High Energy Physics Problems «Relativistic Physics and Quantum Chromodynamics». A talk is delivered by Academician A.M.Baldin

Laboratory of High Energies.
The «slow extraction» beam line of charged particles from the Nuclotron

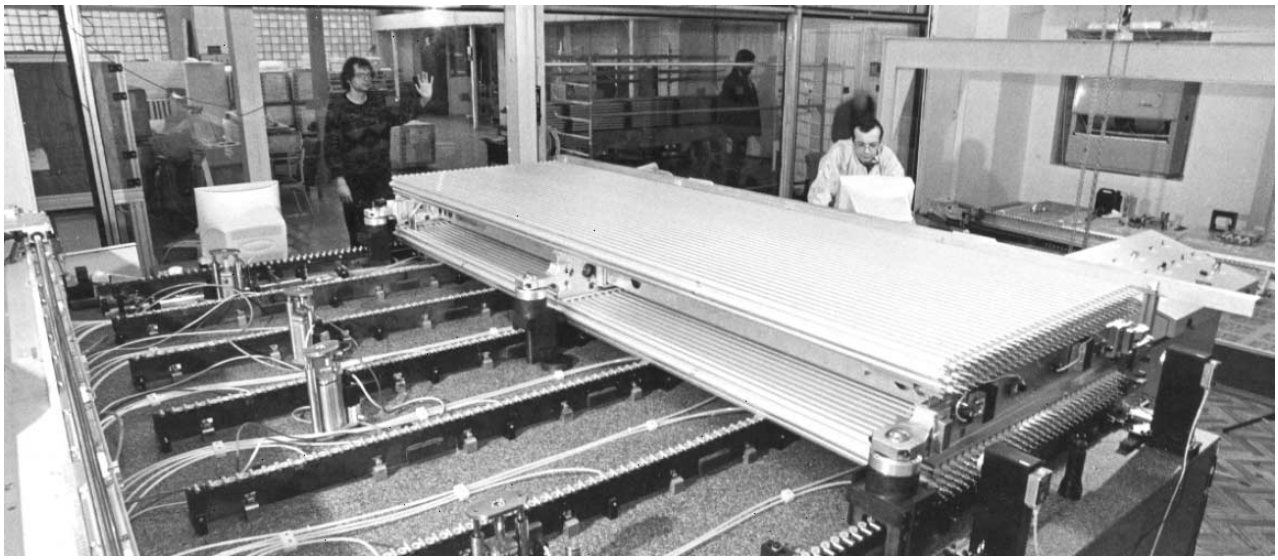
Dubna, 17 April. A delegation of experts of the Government of Japan, visiting JINR's Laboratory of High Energies



Dzhelepov Laboratory of
Nuclear Problems, 26 June.
Participants of the International
Meeting on Very High Multiplicity Physics

Dzhelepov Laboratory of Nuclear Problems. Professor S.Gershtein (IHEP, Protvino)
speaks at the seminar in memory of V.P.Dzhelepov

Dzhelepov Laboratory of Nuclear Problems. Area for assembly and tests of drift tubes for CERN's ATLAS experiments



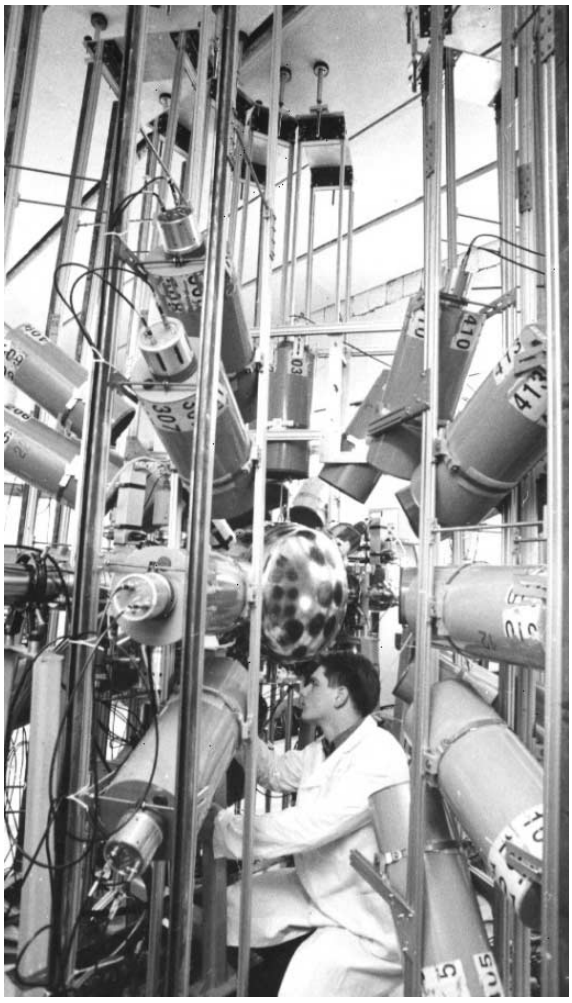
Flerov Laboratory of Nuclear Reactions. Visit to JINR by the Governor of the Moscow Region B.V.Gromov (second from right)

Flerov Laboratory of Nuclear Reactions. Pupils of the college «Dubna» — recipients of the 2000 G.N.Flerov fellowships among members of the jury and leaders of the Laboratory and JINR

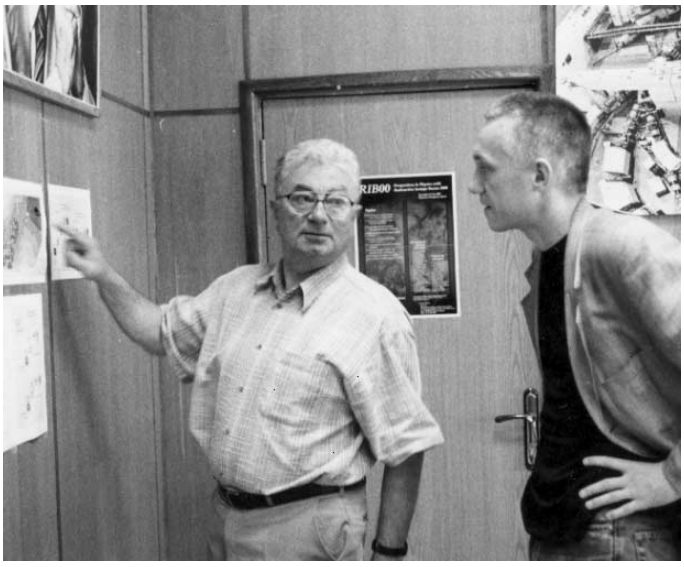
Dubna, 12 May. Meeting of the Nuclear Physics Board of the European Physical Society

Flerov Laboratory of Nuclear Reactions, 25 May.
Participants of the Workshop on Problems of Nuclear Fusion Dynamics in Extreme Conditions

Flerov Laboratory of Nuclear Reactions.
Facility for experimental studies of fusion-fission reactions
of weakly excited compound nuclei



Flerov Laboratory of Nuclear Reactions.
Professor Yu.Ts.Oganessian, Scientific Leader of the Laboratory,
gives an interview to the scientific correspondent of the
«Nezavisimaya Gazette» A.G.Vaganov about the synthesis
of an isotope of the new element with $Z = 116$

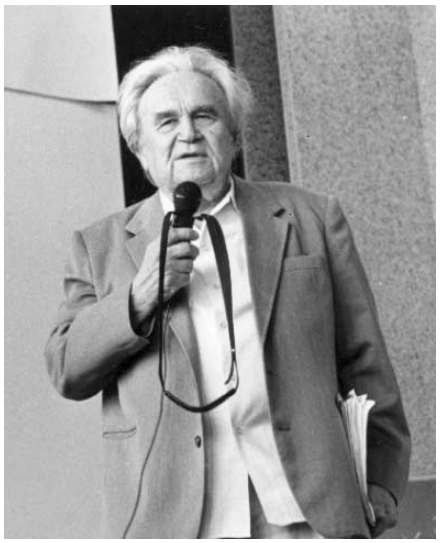


Dubna, 5 June. Participants of the 2nd International Workshop on Data Acquisition Systems for Neutron Experimental Facilities in the Frank Laboratory of Neutron Physics

Frank Laboratory of Neutron Physics.
SHF-testing of the accelerator section developed at the G.Budker INP (Novosibirsk) for the IREN facility

Dubna, 7 February – 4 March.
The students and professors of the School on Modern Neutron Scattering

Brussels, September. Long-standing collaboration links JINR with the International Solvay Institutes for Physics and Chemistry (ISIPC). In the photograph: a working seminar in the office of Professor I.R.Prigogine (centre), Nobel Prize winner and ISIPC Director

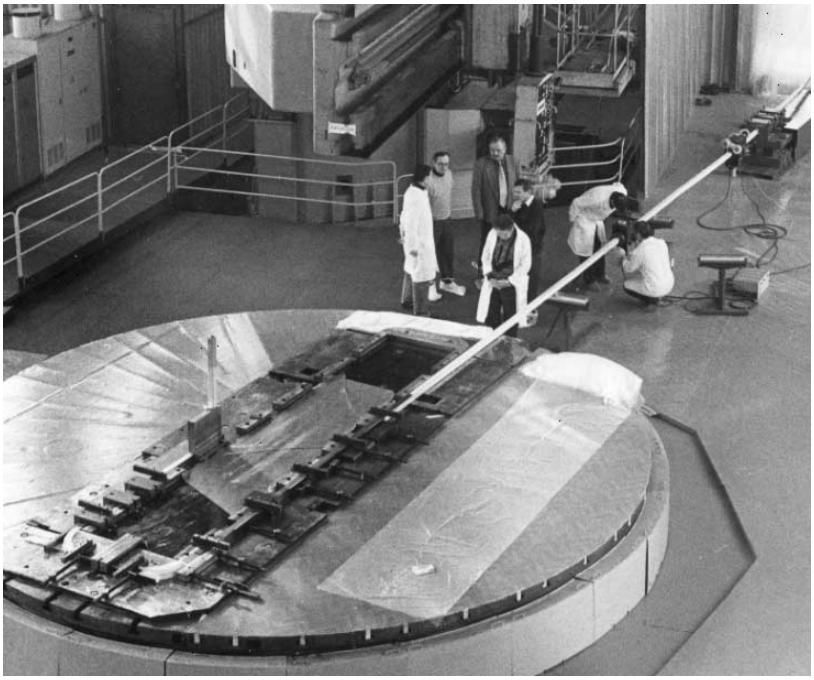


Dubna, 24 July. The 2nd International Conference «Modern Trends in Computational Physics», held in memory of N.N.Govorun. A talk is delivered by Academician A.A.Samarsky

Laboratory of Information Technologies, 27 October. Scientific seminar in memory of Professor M.G.Mescheryakov, one of the founders of JINR, of the town of Dubna, and of the Laboratory of Computing Techniques and Automation

Dubna, 31 January – 4 February.
IV Scientific Conference for Young
Scientists and Specialists

JINR Publishing Department, 5 June.
Visit by the President of the «Nauka»
International Publishing Company
A.Shustorovich and his Deputy N.G.Ovanesov



JINR's Experimental Workshop.
Ongoing work for manufacturing a prototype
winding of the large dipole magnet
of the ALICE muon spectrometer (CERN)

CENTRAL SERVICES

PUBLISHING DEPARTMENT

In 2000, the Publishing Department published JINR communications and preprints of 323 titles. Issued were 120 official publications.

A total of 36 proceedings of various conferences, schools and workshops were issued. Among them are proceedings of the XIV International Seminar on High Energy Physics Problems «Relativistic Nuclear Physics and Quantum Chromodynamics» (in two volumes), the seminar «Symmetries and Integrable Systems», the seminar «Modern Problems of Theoretical Physics», the 3rd Scientific Seminar in Memory of V.P.Sarantsev, the workshop «Supersymmetries and Quantum Symmetries». Published were also the annual reports of JINR for 1999 (in Russian and in English), the annual report of the Frank Laboratory of Neutron Physics for 1999. The proceedings of the round-table discussion held during the 87th Session of the JINR Scientific Council in January 2000 are included into a collection «Cooperation of the JINR with Russian Institutes, Universities and Industrial Enterprises».

A book «Mikhail Grigorievich Mescheryakov» was published to mark the 90th anniversary of the birth of the prominent scientist, outstanding science organizer, founder and first director of the Laboratory of Computing Technigues and Automation. A book of reminiscences «Nikolai N. Govorun» appeared, which is devoted to the 70th anniversary of the birth of the well-known scientist in the field of physics experiment automation, informatics and system programming. Published also was a booklet «N.W.Timofeeff-Ressovsky», dedicated to the centenary of the birth of one of the greatest biologists of the 20th century.

In 2000, six issues of the journal «Physics of Elementary Particles and Atomic Nucleus» with 35 reviews, and six issues of the journal «Particles and Nuclei, Letters» with 50 articles, describing original scientific, technological, and applied results, were printed. Publication of the bulletin «JINR News» in the Russian and English languages was continued.

«*Mathematica* Tutorial Course» by R.Kragler was published as a textbook of the JINR University Centre.

The Publishing Department sent more than 300 articles and reports by JINR scientists to journals and various conferences, symposia, workshops, schools, held both in the JINR Member States and in other countries. Papers by JINR scientists were published in the «Journal of Experimental and Theoretical Physics», «Theoretical and Mathematical Physics», «Instruments and Experimental Techniques», «Yadernaya Fizika», «Physics of Elementary Particles and Atomic Nucleus», «Physical Review», «Journal of Physics», «Physics Letters», «Nuclear Physics», «Nuclear Instruments and Methods», «European Physical Journal», etc.

Publications of the Joint Institute for Nuclear Research were sent to 44 countries of the world.

To keep readers of the Science and Technology Library up to date as to new publications received, there are bulletins of the Library and of the Intellectual Property, Licensing and Standardization Office printed by the Publishing Department. Traditionally, the «Bibliographic Index of Papers Published by JINR Staff Members in 1999» was issued.

The Publishing Department was also engaged in Xerox copying and book binding to fulfil numerous orders of JINR Laboratories. Over 120,000 various forms were printed for processing of experimental information and for other purposes.

SCIENCE AND TECHNOLOGY LIBRARY

In 2000, the Science and Technology Library rendered its services to 4,709 readers. 299,685 copies of books were given out. 1,395 publications, ordered by readers, were received via the interlibrary exchange system. Under the agreement with INTASS, 159 Xerox copies of scientific articles were obtained from those foreign journals which were not available at the JINR Science and Technology Library or Moscow libraries.

The Library received 7,980 books, periodicals and preprints from all compiling sources, including 5,303 books in foreign languages. All new publications were registered in the central catalogue and branch catalogues. Exhibitions of new books, preprints and periodicals were constantly up-dated, and 6,393 new titles were presented there. By 1 January 2001, the Library stock amounted to 424,842 copies, 188,253 of them in foreign languages.

Weekly express bulletins «Books», «Articles», «Preprints» (156 issues) were published with data on 17,346 titles. The bulletins were distributed among 200 JINR staff members and mailed to 50 addresses outside the Institute. Besides, the bulletins' data was included into e-mail. Information bulletins and lists of conferences appeared regularly in the WWW and INFOMAG (Moscow) systems.

The «Bibliographic Index of Papers Published by JINR Staff Members in 1999» (1,595 titles) was prepared for publication. The database on papers by JINR scientists (bibliographic descriptions of papers since 1987) is Internet accessible.

In 2000, in exchange for JINR publications printed by the JINR Publishing Department, the Library received 4,446 publications from 33 countries. Among them 469 issues were from Russia, 655 — from Germany, 306 — from Italy, 866 — from the USA, 153 — from France, 42 — from Switzerland, 346 — from Japan and 1,265 — from CERN. Additionally, scientific journals and books (125 titles) from 32 countries and organizations were received by the Library.

Intellectual Property, Licensing and Standardization Office

The acquisition of patent and technical literature, including standards, was one of the activity directions of the JINR Intellectual Property, Licensing and Standardization Office in 2000. The Office library obtained 76 more copies of standard documents. The standard database on job attestation was renovated. Twelve documents were received on diskettes. A modification was issued to the in-force standard at JINR STP-310-86 «Access Fields and Recommended Paths».

Seventy-two official patent bulletins of the Russian Federation were received in 2000. The Office stock comprised 1,732 bulletins. The publications were processed with account of the JINR research topics. Twelve issues of the bulletin «Patents» were published.

In 2000, seven applications for invention were received. The procedure of the application processing included the search for the protection subjects (means, design or substance), the assistance in methods to compile the formula and description of an invention. As an example, the Frank Laboratory of Neutron Physics applied for assistance in patenting the method of producing selenium-containing medicaments based on a blue-green alga Spirulina Plantensis matrix.

On application received earlier, Patent No. 2156328 entitled «A Method of Producing Submicrone Tube Metal Replicas from Track Membranes» was issued to the authors F.Reutov and S.N.Dmitriev.

EXPERIMENTAL WORKSHOP

In 2000, the JINR Experimental Workshop manufactured products to an amount of over 7.7 million roubles on orders of the JINR Laboratories and other departments. As in previous years, these were mainly mechanical equipment for physics experiments conducted in the framework of the JINR international cooperation:

- modules and submodules of the ATLAS Hadron Calorimeter;
- a load-bearing construction, equipment for fabrication of the prototype winding for the large dipole magnet of the ALICE muon spectrometer;
- mini-drift tubes, assembly equipment and components for the submodule COMPASS;
- a natural radioactive background shielding system for the NEMO-3 set-up.

A large amount of work was done on the upgrade of the polarized neutron spectrometer of the Frank Laboratory of Neutron Physics. Manufacturing of units of the PO-3 movable reflector for IBR-2 has started and is to finish in 2001. Mounting of equipment for the electromagnetic calorimeter of the Wayne State University (Detroit, USA) is carried out. The amount of manufactured products for the Scientific Production Centre «Aspect» was retained. Its orders allowed the radio-electronic shop to keep running at nearly full capacity.

A considerable body of work was also performed for enterprises of various industries.

ADMINISTRATIVE ACTIVITIES

FINANCIAL ACTIVITIES

The Committee of Plenipotentiaries of the Governments of the JINR Member States approved a budget of 37,500.0 thousand US dollars to cover research, construction of basic facilities, and other JINR activities in 2000.

The actual expenditures were as follows:

The actual annual incomes amounted to 16,908.0 thousand US dollars, or 45.1 % of the annual allocations.

In 2000, the actual research expenditures of the Joint Institute for Nuclear Research amounted to 18,722.6 thousand US dollars.

Item	Annual budget, kUSD	Actual expenditures in 2000, kUSD	% of budget
I. Research	14,876.9	10,378.7	69.8
II. Basic facilities	6,159.6	3,053.9	49.6
III. Infrastructure of the Laboratories	5,143.3	2,548.1	49.5
IV. Infrastructure of the Institute	5,244.0	2,741.9	52.3
V. On agreement with BMBF less JINR infrastructure and Directorate reserve fund expenditures	875.1		
VI. On agreement with the Hungarian Academy of Sciences less JINR infrastructure and Directorate reserve fund expenditures	127.5		
VII. Plenipotentiaries' grants, 8 % of Member States' contributions	2,906.1		
VIII. Directorate reserve fund, 5 % of budget	1,867.5		
IX. Savings from item IV for financing development of JINR computer network infrastructure	300.0		
Total expenditures	37,500.0	18,722.6	49.9

STAFF

As of 1 January 2001, the total number of the staff members at the Joint Institute for Nuclear Research was 5,718 (without temporary staff).

Working at JINR are: full members of the Russian Academy of Sciences (RAS) — A.M.Baldin, V.G.Kadyshevsky, D.V.Shirkov; corresponding members of RAS — I.N.Meshkov, Yu.Ts.Oganessian; full members of other academies of sciences — V.L.Aksenov, A.V.Eremin, I.A.Golutvin, V.I.Korogodin, A.M.Petrosyants, A.G.Popeko, A.N.Sissakian; corresponding members of other academies of sciences — S.P.Ivanova, V.A.Khalkin, R.M.Mir-Kasimov, A.I.Titov, A.S.Vodopianov, B.N.Zakhariev, I.Zvara; 244 doctors of science, 653 candidates of science, including 88 professors and 14 assistant professors.

In 2000, there were 499 people employed and 704 people discharged because of engagement period expiry and for other reasons.

During the year the JINR staff members were awarded the titles of professor — 3, senior researcher — 12, junior researcher — 2.

In 2000, 15 scientists received a Candidate of Science degree and 12 received a Doctor of Science degree at JINR, among them 15 from JINR, 1 from Belarus, 2 from Bulgaria, 1 from Italy, 1 from Marocco, 1 from Kazakhstan, and 6 from Russia.

AWARDS

By Decrees of the President of the Russian Federation, the following staff members of the Dzhelepov Laboratory of Nuclear Problems were awarded: K.Ya.Gromov, Chief Researcher, — the Order of Honour; L.M.Soroko, Senior Researcher, and V.A.Zhukov, Leading Researcher, — the Order of Friendship, in recognition of their meritorious services to the country, long-standing dedicated work and their outstanding contributions to the promotion of friendship and cooperation among peoples.

The title «Honoured Scientist of the Russian Federation» for outstanding scientific achievements was conferred on G.V.Efimov, Head of Sector of the Bogoliubov Laboratory of Theoretical Physics, M.K.Volkov, Head of Sector of the Bogoliubov Laboratory of Theoretical Physics, A.A.Kuznetsov, Adviser to the JINR Directorate, Yu.V.Zanevsky, Head of Sector of the Laboratory of High Energies, A.A.Smirnov, Head of Department of the Laboratory of High Energies.

The Federal Cross of Merit on the ribbon of the Order of Merit of the Federal Republic of Germany was awarded to JINR Director V.G.Kadyshevsky, in recognition of his outstanding contribution to the successful and dynamic development of cooperation between German and JINR scientists.

The title «Honorary Doctor of JINR» was awarded to Professors C.Détraz, V.Dmitrievsky, S.Jullian, G.Münzenberg, H.Oeschler, D.Shirkov, A.Tavkhelidze and V.Zrelov for their outstanding contributions to the advancement of science and education of young scientists.

For their meritorious services to JINR, long-standing and fruitful activities, 24 staff members were awarded the title «Honorary Staff Member of JINR», and 10 — «Honorary Diplomas of JINR».

291 staff members of JINR received the badge «Veteran of Nuclear Engineering and Industry» for their long-standing dedicated professional activities.

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