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Joint Institute for Nuclear Research

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INTRODUCTION

March 2001 marked the 45th anniversary of the foundation of the Joint Institute for Nuclear Research. Dubna's scientists have accomplished high-class theoretical and experimental research, which widened the boundaries of perception of fundamental questions in the structure of matter. Many scientific and technical achievements at JINR have found their application in the creation and development of novel technologies. The Institute keeps the traditions aimed at the development of the international scientific and technical cooperation and bringing scientists and nations together. The experience of JINR as a school of scientific staff and a union of fundamental science and education deserves a special mention.

A series of bright scientific results mark the year of 2001. Considerable success was achieved in the experiments on the synthesis of superheavy elements at the U400 accelerator at the Flerov Laboratory of Nuclear Reactions, where two events of the $^{292}116$ isotope decay were registered. Thus, in the period of 1998–2001 one isotope of element 116, three isotopes of element 114 were registered, and the heaviest isotopes of elements 112, 110 and 108 were identified in the products of their decay. The research of the reported year concluded the first series of experiments on the synthesis of superheavy elements in the region of closed spherical proton $Z \approx 114$ and neutron $N \approx 184$ shells. The information about the discovery of elements 112, 114 and 116 was submitted for discussion to the International Union of Pure Applied Chemistry (IUPAC).

The experiments at the Synchrophasotron continued the study of spin-dependent difference of total cross-sections of neutron-proton interactions at various values of the kinetic energy of the neutron beam. The quasimonochromatic neutron beam was obtained from the extracted vector-polarized deuterons. Neutrons went through a big polarized proton target. The values $\Delta\sigma_L(np)$ were measured as the difference between total cross-sections for parallel and antiparallel polarizations of the beam and the target oriented along the beam pulse. New data have been obtained and the research is being conducted.

Experiments on superconducting materials brought results in crystal and magnetic structure of new lamellar complex Mn oxides. Analogously to the classical system in brownmillerites the ferromagnetic metallic state may be expected at intermediate Mn valence. A few facts were determined which were of fundamental importance for the model construction.

Measurements of the neutron reflection from the bilayer of iron-vanadium at temperatures higher and lower than the critical value brought about results which point to the existence of a superconducting state at the temperature higher than the critical one or to the existence of temperature-reversal conductivity. The study of the new for bilayer systems effect will be continued.

The model «Quantum Relativistic Toda Chain at Root of Unity» was formulated and investigated in detail. This model is the simplest «hybrid» one: the space of the dynamic variables is a bundle, whose layer is the local Weyl algebra — the quantum algebra of the observables, and the base is a space of centres. The «hybrid» formulation allowed the researchers to derive the Baxter equation on a quantum curve covering the classical high genus hyperelliptic one and also to obtain the quantum separation of variables explicitly as a consequence of the classical separation.

The basic JINR facilities were used in 2001 according to schedule. As a result of a successful effort to improve the Nuclotron, the intensity and quality of extracted beams were increased, the range of accelerated particles types widened. To study reactions with radioactive beams (DRIBs project) at the U400M–U400 cyclotron complex, special separating channels were developed. The modernization of the IBR-2 reactor was conducted according to the schedule stated in the Agreement between JINR and the Ministry for Atomic Energy of the Russian Federation.

The work in the framework of the BAPHYS project was continued. The aim of the project is the development

of a unified scientific-information space for physics research centres of Russia on the basis of the distributed data base system and knowledge in fundamental properties of matter and applied nuclear physics.

JINR specialists were deeply involved in the research conducted in the largest world scientific centres: CERN, DESY, BNL, FNAL, KEK, and others. Of special note are fundamental results in CP violation, which were obtained in the NA48 (CERN) experiment, as well as the results of Dubna theorists in the development of scientific programmes for the CDF, D0 and STAR (USA) experiments.

A noticeable event in the education activities of JINR was the summer school «Nuclear Physics Methods and Accelerators in Biology and Medicine», held on 27 June – 11 July 2001 in Ratmino. Ninety students and postgraduates from JINR Member States had a chance to learn about most progressive methods of research in these fields.

Wide international activities of the Institute were marked by the working meetings of the JINR Directorate with President of Kazakhstan N. Nazarbaev, President of Romania I. Iliescu, President of Slovakia R. Schuster, the first President of Russia M. Gorbachev and other politicians and state figures. Agreements on cooperation were prolonged with Hungary, Germany and Italy, scientific contacts widened considerably with Greece, India, the USA and France. Greece and India, particularly, declared their intention to become Associate Members of JINR.

Important events of the year were also the round-table discussion on JINR–Polish institutions and universities cooperation, held in the framework of the Scientific Council session, and the photo exhibition «Poland at JINR», which was displayed in Dubna and then in Moscow in the Cultural Centre of Poland. The big JINR–CERN poster exhibition «Science Bringing Nations Together» continued the series of exhibitions, being held this time at the State Duma of the Russian Federation.

On 20 December 2001, President of Russia V. Putin signed an Order «On Conferring the Status of the City of Science, RF, to Dubna, Moscow Region». Dubna has become actually the first international town of science because specialists from many countries of the world work at JINR Laboratories.

V. G. Kadyshevsky
Director
Joint Institute for Nuclear Research

GOVERNING AND ADVISORY BODIES OF JINR

ACTIVITIES OF JINR GOVERNING AND ADVISORY BODIES

CEREMONIAL MEETING DEDICATED TO THE JINR 45TH ANNIVERSARY

On 26 March 2001 the Joint Institute for Nuclear Research — an international intergovernmental organization — celebrated its 45th anniversary.

On the same date the annual session of the Committee of Plenipotentiaries of the Governments of the JINR Member States opened in the International Conference Hall. The agenda of the session included a ceremonial meeting of the Committee with a report «JINR at 45», presented by JINR Director Academician V. G. Kadyshevsky.

Ambassadors Extraordinary and Counsellors of Embassies of Armenia, Belarus, Cuba, Czech Republic, Georgia, Germany, Hungary, Italy, Kazakhstan, Mongolia, Poland, Slovak Republic, the Ukraine and the Socialist Republic of Vietnam represented their countries at the meeting as guests of honour.

The ceremonial meeting was also attended by Governor of the Moscow Region B. Gromov, Deputy of the State Duma of the Russian Federation V. Galchenko, Director of the Institute of Nuclear Research, RAS, Member of the RAS Presidium V. Matveev, President of the Academy of Sciences of Georgia A.Tavkhelidze, Counsellor of the RF Ministry for Foreign Affairs Yu. Ustyugov, Head of JINR Representatives at the RF Ministry for Atomic Energy A. Zhakovsky, President of the RF Union for the Development of Science Cities A. Dolgolaptev, First Deputy of the Chairman of the Moscow Region Government A. Panteleev, Minister for Industry and Science of the Moscow Region V. Kozyrev, Mayor of Dubna V. Prokh, Chairman of the City Deputy Council A. Beklemishchev, leading scientists and specialists of JINR.

Representatives of JINR Member States, B. Gromov, V. Galchenko, A. Dolgolaptev and other guests addressed the meeting with their greetings and congratulations on the anniversary of JINR. Numerous telegrammes from the collaboration partners of JINR were read to the audience. A festive performance for guests and JINR staff was held in the evening at the Cultural Centre «Mir».

The agenda of the festive events included a press conference «International Physics Centre in Dubna, to the 45th Anniversary of the Joint Institute for Nuclear Research» at the Central House of Journalists in Moscow, a seminar dedicated to the 10th anniversary of the JINR University Centre, a seminar in memory of Professor V. A. Sviridov (LPP, JINR), a scientific seminar «Fundamental Scientific Problems at the Frank Laboratory of Neutron Physics» and a wide leisure-and-sport programme.

MEETING OF THE JINR COMMITTEE OF PLENIPOTENTIARIES

A regular meeting of the Committee of Plenipotentiaries of the Governments of the JINR Member States was held in Dubna on 26–27 March 2001.

Academician M. P. Kirpichnikov (Russian Federation) was elected Chairman of the Committee of Plenipotentiaries (CP) until the next meeting.

The CP took note of the report, presented by JINR Director V. G. Kadyshevsky, on implementation of the recommendations of the Scientific Council and the decisions of the CP concerning JINR activities in 2000 and plans for 2001–2003.

The CP approved the JINR Directorate's activities on implementation of the research programme in 2000, approved the recommendations of the 88th and 89th sessions of the JINR Scientific Council, and the plan of scientific research and international cooperation for 2001.

In line with the recommendations of the 89th session of the JINR Scientific Council (18–19 January 2001), the CP commissioned the JINR Directorate to give priority to funding the following activities in 2001:

— improvement of the Nuclotron beam extraction system and of external beam lines, operation and development of the Nuclotron, further reduction of electric power consumption for the operation of the Nuclotron accelerator complex;

— modernization of the IBR-2 reactor according to the schedule approved by the Agreement between JINR and the Russian Ministry for Atomic Energy;

— completion of the first stage of the Dubna Radioactive Ion Beams (DRIBs) project, implementation of work on the realization of the second stage of the project;

— construction of IREN, with a realistic schedule and an agreed financial envelope, with a view to completing its first stage in 2002;

— further development of JINR's telecommunication links and of JINR's computing and networking infrastructure;

— 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;

— 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, CLIC);

— continuation of relativistic nuclear interaction studies aimed at searching for manifestations of quark and gluon degrees of freedom in nuclei and asymptotic laws for nuclear matter at high energies, as well as studies of the spin structure of lightest nuclei; experiments at the Synchrophasotron–Nuclotron accelerator complex and also at accelerators of other centres: CERN (SPS, LHC), BNL (RHIC), GSI (SIS), at Uppsala (CELSIUS) and at RIKEN (Japan);

— physical and chemical studies of heavy nuclei in the vicinity of the «stability island» $Z = 114–116$ using the Gas-Filled Recoil and VASSILISSA separators, study of the fusion-fission reactions of weakly excited compound nuclei with the CORSET+DEMON facility, study of the structure of light exotic nuclei and neutron correlations in them using the ACCULINNA, COMBAS and MULTI set-ups, study of the mechanism of nuclear reactions with radioactive ion beams using the FOBOS detector and the high-resolution beam lines;

— development of instrumentation and data acquisition equipment for spectrometers at the IBR-2 reactor; exploitation of the spectrometers for experimental studies of complex structures in biology, pharmacology, materials science, etc.;

— development of the JINR Education Programme, including special-purpose training of specialists for the Member States.

The CP confirmed that, to realize its functions as an international intergovernmental organization, JINR is competent to carry out the following activities in accordance with its aims stated in the JINR Charter, Chapter 4:

— telematic services: electronic mail, access to information resources, information service, data processing, vocal message service, oral information transmission service;

— data transmission service.

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 execution of the JINR budget in 2000, and approved the JINR budget for 2001 with a total expenditure of US$ 37.5 million and the Member States' contribution scale for 2001 proportional to the UN scale. The provisional estimate of the JINR budget for 2002 in income and expenditure was set by the CP to be US$ 37.5 million.

The activities of the CP Working Group in 2000 were approved. The CP commissioned the JINR Directorate to continue improving the procedure of determining contributions to the JINR budget for subsequent years based on comparable basic indices. The CP took note of the information about the work on restructuring of debts, conducted by the JINR Directorate with the Member States on bilateral basis.

Taking into account that after the adoption of the law «On 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 the Joint Institute for Nuclear Research in the Russian Federation» JINR had fully proved its international status as an intergovernmental organization, the CP asked the Plenipotentiaries to undertake measures with a view to including contributions to JINR in the national budgets of the Member States as international obligations.

Upon proposal presented by Plenipotentiary of the Russian Federation M. P. Kirpichnikov and after due discussion, the CP extended the term of office of JINR Director V. G. Kadyshevsky until 1 January 2006.

Upon proposal by Director V. G. Kadyshevsky, the CP extended the terms of office of JINR Vice-Director A. N. Sissakian, JINR Vice-Director Ts. Vylov, and JINR Chief Scientific Secretary V. M. Zhabitsky until 1 January 2006.

According to the JINR Staff Regulations, the term of office of JINR Chief Engineer I. N. Meshkov completes on 1 January 2003.

Based on the reports presented by N. M. Shumeiko and S. Dubnička, the CP approved the protocols of the Finance Committee meetings held on 19 October 2000 and 23 March 2001 as well as the Directorate's report on the execution of the JINR budget in 1999.

The CP took note of the report presented by Vice-Director A. N. Sissakian on JINR's participation in the programme of the development of Dubna as a science city, also on implementation of the measures towards 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». The CP agreed with JINR's participation in the Russian federal programme of the development of Dubna as a science city based on the Agreement of 11 January 2000 between the Administration of Dubna and JINR. According to Article 5, Chapter 21 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», the CP considers it expedient if the privileges and immunities stipulated by this Agreement would be extended also to the persons invited to JINR officially from Germany and other countries upon official presentations from these countries and after coordination of this matter with the Russian Government.

Upon proposal by the JINR Directorate, presented by Chief Scientific Secretary V. M. Zhabitsky, the CP elected I. Antoniou, Deputy Director of the International Solvay Institutes for Physics and Chemistry (ISIPC, Brussels, Belgium), and G. van Middelkoop, Director of the National Institute for Nuclear Physics and High Energy Physics (NIKHEF, Amsterdam, the Netherlands), members of the JINR Scientific Council until the completion of the term of duties of the present Scientific Council members elected by the CP in 1998, i. e. until March 2003.

SESSIONS OF THE JINR SCIENTIFIC COUNCIL

The 89th session of the JINR Scientific Council, chaired by JINR Director V. G. Kadyshevsky, took place in Dubna on 18–20 January 2001.

At the session, Academician V. G. Kadyshevsky presented a report on implementation of the recommendations of the 87th and 88th sessions of the Scientific Council concerning the reform programme of JINR, gave comments on the proposed JINR Scientific Programme for the years 2001–2003, as well as information on the preparation for the celebration of JINR's 45th anniversary.

Scientific progress reports were presented by the JINR Laboratories, Division of Radiation and Radiobiological Research, and University Centre. Recommendations of the JINR Programme Advisory Committees were presented by H. Lauter, Chairperson of the PAC for Condensed Matter Physics, P. Spillantini, a member of the PAC for Particle Physics, and by N. K. Skobelev, Scientific Secretary of the PAC for Nuclear Physics. The Council was informed by JINR Chief Engineer I. N. Meshkov on the status of the operation of the JINR basic facilities and on the construction of the IREN facility, and by FLNR Director M. G. Itkis on the status of the DRIBs project. The Council was also informed by H. Schopper about the Expert Committee's recommendations concerning DELSY and by V. Nikogosyan about the ongoing activities concerning the SESAME project. The research programme and structure of the Laboratory of Information Technologies were presented by LIT Director I. V. Puzynin.

Elections were held for the position of a Deputy Director of BLTP. The Council also approved the Jury's recommendations on the JINR prizes for 2000 and the Directorate's proposals on the awarding of the title «Honorary Doctor of JINR». The awarding of the 2000 B. Pontecorvo Prize took place at the session. One of the laureates delivered a talk on the subject of his research. A highlight scientific report «Synthesis of Superheavy Elements» was presented by FLNR Scientific Leader Yu. Ts. Oganessian.

The session included a round-table discussion «Poland at JINR», whose participants were the Scientific Council members and representatives of Polish research centres, universities and state institutions. A dedicated photo exhibition was also organized.

The Scientific Council took note of the report, presented by JINR Director V. G. Kadyshevsky, on the implementation of the Scientific Council's recommendations concerning the reform programme of JINR. At this session the Scientific Council was informed about the JINR Directorate's final proposals concerning the future activities and structure of the Frank Laboratory of Neutron Physics:

- To maintain FLNP as one Laboratory, with the scientific departments and fundamental and applied research activities in nuclear physics with neutrons and condensed matter studies using various physical methods.
- To maintain at FLNP the units for the facilities IBR-2 and IBR-30 (for two years) and allied departments and services, which must afford technically the modernization of IBR-2 and the development of the IREN installation, as well as the exploitation of the existing neutron sources until their dismounting for reconstruction. To improve the organization of work for the construction of the IREN facility with a view to completing its first stage in 2002. Construction of the IREN linac and multiplying target will be provided by FLNP and LPP's accelerator department.

- To elect the FLNP Directorate at the 90th session of the Scientific Council in June 2001 and to appoint Dr A. V. Belushkin as Acting Director of FLNP.

The Scientific Council endorsed these proposals, which were also supported by the PACs for Condensed Matter Physics and Nuclear Physics. The Scientific Council requested to be informed at the next sessions about the progress of the reform programme and about the Directorate's new scientific proposals aimed at further optimization of JINR's research programme through concentration of the available human, financial and material resources.

Since the establishment of JINR, Poland and the Polish members of the Scientific Council have been playing an important role in the formation of JINR's scientific policy. Their ideas, proposals, critical remarks and positive attitude are highly appreciated. In particular, the extensive and fruitful collaboration of JINR with Polish research centres was highlighted by the round-table discussion at this session and by the dedicated photo exhibition. The Scientific Council thanked the representatives of Polish research centres, universities and other institutions for taking part in the round-table discussion.

The Scientific Council took note of the «Status Report on the Operation of the JINR Basic Facilities and on the Construction of the IREN Facility», presented by Chief Engineer I. N. Meshkov. The recommendation of the Scientific Council to concentrate manpower and resources on the most urgent activities, in particular those which concern modernizing and establishing stable operation of the JINR basic facilities, is being implemented by the JINR Directorate.

The Scientific Council noted that the programme of the IBR-2 reactor refurbishment was pursued in 2000 according to schedule and looks forward to the successful continuation of this activity in 2001. The Scientific Council agreed with the decision of the JINR Directorate to complete the construction of the first stage of IREN in 2002. It is 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 in the middle of 2001.

The Scientific Council was pleased to note the running performance of the Phasotron in 2000 and the extensive research programme with its beams. The ongoing work on cancer treatment using beams of this facility is of special importance.

The Scientific Council took note of the report «Status of the DRIBs Project», presented by FLNR Director M. G. Itkis. The Scientific Council was impressed with the fast realization of the DRIBs project and stressed that it should be actively pursued. In view of the upcoming ISOL facilities worldwide, the first stage of DRIBs — production of the light radioactive ion beams — should be realized in 2001, and the second stage — acceleration of fission fragments — in 2002.

The Scientific Council urged the JINR Directorate and the Directorates of JINR Laboratories to actively recruit young scientific and technical staff, with highest priority for the operation, maintenance and development of the Institute's facilities.

The Scientific Council took note of the report prepared by the «Committee of Three» concerning DELSY as presented by Professor H. Schopper and of the response made by JINR Director V. G. Kadyshevsky. The Scientific Council recommended that the DELSY project be presented within the shortest possible time providing the following information:

— A complete cost estimate including the cost of the machine complex, buildings, beam lines, instrumentation and auxiliary facilities. It would be valuable to compare the DELSY implementation and cost with similar projects currently finished or planned in Europe and in the Middle East. The Scientific Council noted the JINR Directorate's commitment to implement the DELSY project from non-budgetary sources only.

— Commitments from the users' community including contributions in cash, in kind or manpower. The forthcoming 2nd Workshop «JINR Synchrotron Radiation Source: Prospects of Research» (2–5 April 2001) could be used for that purpose.

— The integration of the DELSY project in the JINR long-term scientific programme, in particular in view of its operation. Since the DELSY programme is intended to keep JINR attractive in the long term, it would be useful to know the opinion of the PACs and the JINR staff concerned if any alternative project fulfilling this objective could be considered.

The Scientific Council took note of the report «Research Programme and Structure of the Laboratory of Information Technologies», presented by LIT Director I. V. Puzynin. From the point of view of the present-day scientific and technical cooperation, the Scientific Council recommended considering as important: the necessary development of remote access to the experimental facilities, data processing and transfer; participation in collaborations on the «Data Grid» and «Grid» projects in Europe and America; establishment of a high-quality connection between the JINR network and the scientific networks of the Member States. The Scientific Council considers the JINR Computing and Networking Infrastructure as a permanently operating basic facility and recommends that the JINR Directorate provide it with adequate special-purpose funding.

The Scientific Council took note of the proposals, presented in written form by the Directors of the JINR Laboratories, concerning the JINR Scientific Programme based on a three-year plan of activities. Taking into account these proposals and the recommendations of the PACs, the Scientific Council endorsed the following priority activities in 2001:

— improvement of the Nuclotron beam extraction system and of external beam lines, operation and development of the Nuclotron, further reduction of electric power consumption for the operation of the Nuclotron accelerator complex;
— modernization of the IBR-2 reactor according to the schedule approved by the Agreement between JINR and the Russian Ministry for Atomic Energy;
— completion of the first stage of the Dubna Radioactive Ion Beams (DRIBs) project, implementation of work on the realization of the second stage of the project;
— construction of IREN, with a realistic schedule and an agreed financial envelope, with a view to completing its first stage in 2002;
— further development of JINR's telecommunication links and of JINR's computing and networking infrastructure;
— 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;
— 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, CLIC);
— continuation of relativistic nuclear interaction studies aimed at searching for manifestations of quark and gluon degrees of freedom in nuclei and asymptotic laws for nuclear matter at high energies, as well as studies of the spin structure of lightest nuclei; experiments at the Synchrophasotron–Nuclotron accelerator complex, also at accelerators of other centres: CERN (SPS, LHC), BNL (RHIC), GSI (SIS), at Uppsala (CELSIUS) and at RIKEN (Japan);
— physical and chemical studies of heavy nuclei in the vicinity of the «stability island» $Z = 114$–116 using the Gas-Filled Recoil and VASSILISSA separators, study of the fusion-fission reactions of weakly excited compound nuclei with the CORSET+DEMON facility, study of the structure of light exotic nuclei and neutron correlations in them using the ACCULINNA, COMBAS and MULTI set-ups, study of the mechanism of nuclear reactions with radioactive ion beams using the FOBOS detector and the high-resolution beam lines;
— development of instrumentation and data acquisition equipment for spectrometers at the IBR-2 reactor; exploitation of the spectrometers for experimental studies of complex structures in biology, pharmacology, materials science, etc.;
— development of the JINR Education Programme, including special-purpose training of specialists for the Member States.

The Scientific Council asked the LHE Directorate to present at the next session a detailed plan of the Nuclotron development and of the Synchrophasotron outphasing. The Scientific Council recommended that the JINR Directorate outline a long-term scientific programme of JINR for the next 10–15 years, including the lines of research and the corresponding new facilities.

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

Condensed matter physics issues. The Scientific Council noted with satisfaction the agreement between the Russian Ministry for Atomic Energy and JINR allowing for the refurbishment of the IBR-2 reactor. The Scientific Council supported the demand to urgently renew the cooling system guaranteeing a reliable supply of cold neutrons and the construction of three spectrometers: a small-angle scattering spectrometer, a reflectometer and a quasielastic spectrometer on the cold source, and also asked the JINR Directorate to support this instrumentation programme. The situation of the reactor staff, in particular in the context of the refurbishment programme, should be reviewed by the JINR Directorate.

Particle physics issues. The Scientific Council strongly supported the LHE efforts towards the establishment of the Nuclotron as a «user friendly» facility which is operating routinely and the need for improved coordination of all experiments utilizing polarized beams and targets to make optimal use of the Nuclotron beams. The Scientific Council supported the PAC recommendations on new scientific projects (STRELA, DELTA–SIGMA, HARP/PS214, *PP*-singlet). The Scientific Council agreed with the list of the activities suggested for implementation with first priority in 2001–2003 and with the closure of a number of research projects.

Nuclear physics issues. The Scientific Council 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 2001. 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 Scientific Council appreciated the very satisfactory running of the FLNR cyclotrons in 2000. The focusing of the future programme on the synthesis of superheavy nuclei and on the structure of light exotic nuclei was strongly endorsed. The Scientific Council welcomed the beam-line upgrading programme of the Phasotron, which would improve significantly the secondary beam quality by the end of 2001.

In line with the previous appointments, Ch. Briançon, S. Dubnička and H. Lauter continue to be Chairpersons of the JINR PACs until June 2001. Upon proposal by the JINR Directorate, the Scientific Council appointed the following new members of the PACs:

PAC for Nuclear Physics:

- A. A. Goverdovski (IPPE, Obninsk, Russia),
- C. Petitjean (PSI, Villigen, Switzerland);

PAC for Condensed Matter Physics:

- H. Tietze-Jaensch (FZ, Jülich, Germany).

GOVERNING AND ADVISORY BODIES OF THE JOINT INSTITUTE FOR NUCLEAR RESEARCH

COMMITTEE OF PLENIPOTENTIARIES OF THE JINR MEMBER STATES

Armenia	H. A. Vartapetian	Moldova	V. A. Moskalenko
Azerbaijan	N. A. Guliev	Mongolia	Ts. Ganzog
Belarus	A. I. Lesnikovich	Poland	A. Hrynkiewicz
Bulgaria	G. Kaschiev	Romania	I. Vâță
Cuba	D. Codorniu	Russia	M. P. Kirpichnikov
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Georgia	N. S. Amaglobeli	Ukraine	I. I. Zalyubovsky
Kazakhstan	V. N. Okolovich	Uzbekistan	B. S. Yuldashev
D. P. Republic of Korea	Li Je Sen	Vietnam	Nguen Van Hieu

Finance Committee

One delegate
from each Member State

SCIENTIFIC COUNCIL

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Scientific Secretary: V. M. Zhabitsky

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A. Budzanowski	Poland	M. Mateev	Bulgaria	H. Schopper	Switzerland
N. A. Chernoplekov	Russia	V. A. Matveev	Russia	N. M. Shumeiko	Belarus
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J. Ganzorig	Mongolia	Nguyen Van Hieu	Vietnam	A. N. Tavkhelidze	Georgia
A. Hrynkiewicz	Poland	V. N. Okolovich	Kazakhstan	I. N. Vishnevsky	Ukraine
J. Janik	Poland	Yu. A. Osipian	Russia	I. Wilhelm	Czech Republic
D. Karadzhov	Bulgaria	V. V. Papoyan	Armenia	B. S. Yuldashev	Uzbekistan
N. Kroo	Hungary	M. Petrovici	Romania	G. M. Zinovjev	Ukraine
F. Lehar	France	B. Peyaud	France		

Programme Advisory Committee for Particle Physics

Chairperson: T. Hallman (USA)
Scientific Secretary: Yu. A. Gornushkin

Programme Advisory Committee for Nuclear Physics

Chairperson: N. Rowley (France)
Scientific Secretary: N. K. Skobelev

Programme Advisory Committee for Condensed Matter Physics

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

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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
A. V. Belushkin

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

- 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

The Scientific Council extended the mandates of the PACs with their present memberships for three more years and looks forward to a rotation of PAC members as stipulated by the Regulation for the JINR PACs.

The Scientific Council elected by ballot D. Blaschke Deputy Director of the Bogoliubov Laboratory of Theoretical Physics until the completion of the term of office of the BLTP Director. The Scientific Council agreed with the JINR Directorate's proposal to postpone the election of Deputy Director of the Laboratory of Particle Physics. The Scientific Council confirmed the vacancies of the Director and two Deputy Directors of the Frank Laboratory of Neutron Physics.

The Scientific Council congratulated Professor G. T. Zatsepin and Dr V. N. Gavrin (INR, Moscow) on the awarding of the 2000 B. Pontecorvo Prize, in recognition of their outstanding contribution to the solar neutrino studies by the gallium-germanium method at the Baksan Neutrino Observatory. The Scientific Council approved the Jury's recommendations on the JINR prizes for 2000. The Scientific Council congratulated Professors S. Hofmann, A. M. Petrosyants and G. Piragino 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 followed with interest the scientific reports presented at this session and thanked the speakers V. N. Gavrin and Yu. Ts. Oganessian. The Scientific Council congratulated Professor Yu. Ts. Oganessian and his colleagues Professors P. Armbruster and G. Münzenberg (GSI, Darmstadt, Germany) on the awarding of the L. Meitner Prize of the European Physical Society for their unique and long-standing work on the synthesis of superheavy elements.

The 90th session of the JINR Scientific Council, chaired by JINR Director V. G. Kadyshevsky, took place in Dubna on 7–8 June 2001.

At the session, Academician V. G. Kadyshevsky informed the Council about the decisions taken by the JINR Committee of Plenipotentiaries at its meeting held on 26–27 March 2001. The recommendations of the JINR Programme Advisory Committees were presented by their Chairpersons: S. Dubnička (PAC for Particle Physics), Ch. Briançon (PAC for Nuclear Physics), and H. Lauter (PAC for Condensed Matter Physics). The status of development of the JINR basic facilities was reported by JINR Chief Engineer I. N. Meshkov, the status of the DRIBs project — by FLNR Scientific Leader Yu. Ts. Oganessian, the plan of the Nuclotron development and of the Synchrophasotron outphasing — by LHE Chief Researcher I. B. Issinsky.

V. G. Kadyshevsky presented the Directorate's new proposals on the awarding of the title «Honorary Doctor of JINR». The session also included elections of the Director of the Frank Laboratory of Neutron Physics and of a Deputy Director of the Laboratory of Particle Physics.

The Scientific Council took note of the information, presented by JINR Director V. G. Kadyshevsky, concerning the decisions taken by the JINR Committee of Plenipotentiaries (CP) at its March 2001 meeting. On 26 March 2001 the Joint Institute for Nuclear Research celebrated its 45th birthday. The Scientific Council congratulated the international staff of JINR on their outstanding scientific achievements and wished them much success in the future.

The Scientific Council took note of the report «Status of Development of the JINR Basic Facilities», presented by JINR Chief Engineer I. N. Meshkov, and of the report «Status of the DRIBs Project», presented by FLNR Scientific Leader Yu. Ts. Oganessian. The Scientific Council was pleased with the completion of the production target, the separator, the ECR-source for radioactive beams, and of the successful transport of ^{6}He ions into the transport gallery at FLNR, which is an important milestone in the realization of the DRIBs project.

The Scientific Council took note of the «Plan of the Nuclotron Development and of the Synchrophasotron Outphasing», presented by LHE Chief Researcher I. B. Issinsky. The Scientific Council recognized the significant progress which was achieved in 1999–2001 in the improvement of the Nuclotron's performance and beam parameters. The first stage of the work on beam extraction from the Nuclotron has been accomplished and experiments with extracted beam have started. The upgraded cryogenic supply system has provided the conditions necessary for long-duration runs of this facility. Considering the progress in reaching the operational modes for some of the Nuclotron systems, the Scientific Council recommended that the LHE Directorate provide the users with at least 2000 hours of running time per year for physics experiments. The Scientific Council endorsed the LHE plan for development of the Nuclotron accelerator complex for the years 2002–2008, including the production of polarized beams, and recommended that the JINR Directorate secure the necessary funding for this activity. The Scientific Council endorsed phasing out the Synchrophasotron in 2003 and asked the JINR Directorate to consider this plan.

The Scientific Council noted the progress in the IBR-2 refurbishment, but at the same time expressed concern about the lack of planned funding for this project. The Scientific Council considers the exploitation of cold neutrons to be of great interest to JINR. It requests the PAC for Condensed Matter Physics to follow up this issue as a priority matter, and to work with the users community and the FLNP Directorate towards the implementation of a realistic cold neutron programme. The Scientific Council considers the significant progress of the IREN project as a result of the effort made by the JINR Directorate to concentrate manpower on this important activity. The new department organized at LPP for the IREN pro-

ject is working efficiently, and the involvement of the LPP infrastructure in this activity is essential in the realization of the IREN linac LUE-200.

The Scientific Council was informed by Chief Engineer I. N. Meshkov about the new concept for the DELSY project, which is proposed to be realized in three phases. As a partial response to the recommendations of the 89th session of the Scientific Council, the Conceptual Design Report of Phase 1 (Free-Electron Lasers) was distributed at this session. The Scientific Council took note of this Report.

The Scientific Council took note of and concurred with the recommendations made by the PACs at their April 2001 meetings and presented by their Chairpersons.

Particle physics issues. The Scientific Council noted the progress in establishing the Nuclotron as a «user-friendly» facility, which is operating routinely. The Scientific Council endorsed the recommendations of the PAC for Particle Physics on the execution of the new scientific projects, as detailed in the PAC Minutes. The Scientific Council highly appreciated the activity of BLTP scientists towards giving theoretical support to the ALICE, ATLAS, and CMS experiments.

Nuclear physics issues. The Scientific Council applauded the recent results on the synthesis of element 116 at FLNR. These are the first and direct experimental evidence of the existence of the «island of stability» of superheavy elements. The Scientific Council noted that the successful production, separation, and injection of ^{6}He into the beam-transport gallery are decisive steps in Phase I of the DRIBs project. The timely realization of Phases I and II of this project is essential for the competitiveness of the Flerov Laboratory in this field. To ensure the continuation and rapid progress of DRIBs, adequate resources should be provided immediately. The Scientific Council took note of the JINR–Kurchatov Institute joint project of separation of rare stable isotopes in large amount, using the Ion Cyclotron Resonance method. The Scientific Council welcomes the further study of this interesting project in view of its implementation at JINR.

The Scientific Council was pleased to note that, since the previous session, progress had been achieved in the implementation of the IREN project, despite continuing financial difficulties.

The Scientific Council noted that the steps presented by the Laboratory of Information Technologies to the PAC for Nuclear Physics should improve the external connection to the Russian network considerably. As the internal JINR network situation is also becoming critical, urgent measures are needed to preserve its proper operation.

Condensed matter physics issues. The Scientific Council strongly supported the ongoing project to refurbish the IBR-2 reactor, the cold moderator, and the instrumentation on the cold source: JINR's obligations to fulfil the agreement with the Russian Ministry for Atomic Energy must be respected to guarantee that the refurbishment of the IBR-2 reactor itself progresses according to schedule. The finite lifetime of the reactor's essential components does not allow a delay in the schedule. The performance of the actual cold moderator leads to the project of the construction of a new cold moderator system, whose temperature can be optimized for specific spectrometers. The gain at a spectrometer is an optimization of intensity, enhanced resolution, the shift to low-momentum transfer or the shift to low-energy transfer. Due to the near end of the lifetime of the actual cold source it is necessary to investigate urgently when a new cold source or cold source system can be installed. It was again noted that the reactor refurbishment programme also requires measures concerning the reactor staff to ensure successful refurbishment and successful performance of the IBR-2 reactor after the restart as advised in previous recommendations of the PAC for Condensed Matter Physics.

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

- T. Hallman (BNL, Upton, USA) — PAC for Particle Physics;
- N. Rowley (IReS, Strasbourg, France) — PAC for Nuclear Physics.

The Council also re-appointed H. Lauter as Chairperson of the PAC for Condensed Matter Physics for a term of one year.

The Scientific Council conferred the title «Honorary Doctor of JINR» on Professors G. J. Deutsch, S. Ozaki, and G. Trilling, in recognition of their outstanding contributions to the advancement of science and the education of young scientists.

The Scientific Council followed with interest the scientific reports: «Phenomenon of Direct CP Violation» presented by V. D. Kekelidze, «Results of the DELPHI Experiment at LEP» presented by A. G. Olshevski, «Current Experiments Using Polarized Beams of the JINR LHE Accelerator Complex» presented by F. Lehar.

The Scientific Council unanimously elected by ballot A. V. Belushkin Director of the Frank Laboratory of Neutron Physics for a term of five years, and R. Lednický Deputy Director of the Laboratory of Particle Physics for a term of five years.

According to the Regulation in force, the Scientific Council announced the vacancies of Directors at LHE, FLNR, and LPP.

MEETING OF THE JINR FINANCE COMMITTEE

A regular meeting of the JINR Finance Committee took place in Dubna on 23 March 2001. It was chaired by Professor S. Dubnička (Slovak Republic).

Note was taken of the report presented by the JINR Directorate on the implementation of the Finance Committee's recommendations of 17–18 February 2000 and 19 October 2000 and of the Control Commission's recommendations of 9 June 2000.

Based on the report «On Execution of the JINR Budget in 2000 and on the Draft Budget for 2001» presented by JINR Assistant Director for Economic and Financial Issues V. V. Katrasev, the Finance Committee recommended that the Committee of Plenipotentiaries (CP):

- take note of the information on the execution of the JINR budget in 2000;
- approve the JINR budget for 2001 with the total expenditure US$ 37.5 million;
- approve the contribution scale for 2001;
- fix the 2002 JINR budget estimate of income and expenditure amounting to US$ 37.5 million;
- approve the activity of the CP Working Group in 2000; charge the Directorate to continue improving the existing procedure of determining contributions for the subsequent years based on the comparable basic indices;
- charge the JINR Directorate and Plenipotentiaries to cooperate in developing in the course of the year a procedure of restructuring the debts of JINR Member States to the JINR budget, including the possibility of a differentiated approach.

MEETINGS OF THE JINR PROGRAMME ADVISORY COMMITTEES

The 15th meeting of the Programme Advisory Committee for Particle Physics was held on 9–10 April 2001. It was chaired by Professor S. Dubnička.

The Programme Advisory Committee for Particle Physics took note of the information, presented by Vice-Director A. N. Sissakian, on the recommendations of the 89th session of the JINR Scientific Council (January 2001) and the decisions of the Committee of Plenipotentiaries (March 2001). The PAC noted with satisfaction the outstanding scientific results obtained at JINR over the last few years, despite continued serious problems with financing of the Institute by its Member States.

The PAC took note of the report, presented by JINR Chief Engineer I. N. Meshkov, on the successful operation of the JINR basic facilities in the first quarter of 2001 and noted that the process of the establishment of the Nuclotron as a «user-friendly» facility must be accelerated to make this facility fully operational for the international community waiting to use it.

The PAC reviewed the proposals of new projects and themes and recommended their approval:

— «Study of nucleus fragmentation into two cumulative hadrons at the Nuclotron» (SCAN-2);

— «Measurement of branching ratio of the $K_l^0 \to \pi^0 \nu\tilde{\nu}$ decay» (JINR's participation in the E391a experiment at KEK-PS);

— «Search for effects of nucleon polarized hidden strangeness in nucleon-nucleon interactions at the Nuclotron» (NIS);

— «Measurement of spin observable in nucleon-nucleon interactions and in decay of nuclei» (SPIN project);

— «Study of physical aspects of the electronuclear method of energy production and of radioactive waste transmutation using beams of the JINR Synchrophasotron/Nuclotron» (Energy + Transmutation project);

— «Movable polarized target» (MPT);

— «Measurement of the analyzing power for the $p+CH_2$ reaction at proton momentum range 3–6 GeV/c».

The PAC also reviewed the amended proposals on opening the new theme «Computer Physics for Theoretical and Experimental Studies» and recommended approval of this activity.

The ongoing activities connected with LHC experiments were considered at this meeting. The PAC recognized the valuable contribution of the JINR team to software development and simulation of the ALICE Inner Tracking System and the dimuon spectrometer. The PAC congratulated the JINR ALICE magnet team on the achievements in the design of the dipole magnet for the ALICE dimuon spectrometer and construction of the prototype. The PAC also supported JINR's participation in

the ALICE photon spectrometer in collaboration with the Ukraine and Russia.

The PAC noted with satisfaction the important progress made in ATLAS: completing the R&D programme and beginning the production phase. In compliance with JINR's responsibilities in ATLAS, production sites were set up at JINR to make modules of the barrel tile and liquid-argon end-cap calorimeters, to produce and assemble muon chambers, and to prepare and assemble TRT straw tubes.

The PAC took note of JINR's participation in the CMS project and was pleased to learn that JINR Member States' participation in CMS through JINR as part of the RDMS (Russia and Dubna Member States) collaboration had allowed them to take a leading position and to accept full responsibility for creating the hadron calorimeter and part of the muon system (ME1). They will also make a valuable contribution to preparing the electromagnetic calorimeter.

The PAC noted with interest the scientific reports from BLTP on elaboration of the physics programmes of the ALICE, ATLAS and CMS experiments and recommended that the JINR Directorate support these important high-quality studies.

The PAC recognized the LIT Directorate's activities on reforming the Laboratory, which is carried out in accordance with the recommendations of the JINR Scientific Council. The PAC recommended that a task force be formed to examine the present and future needs of the scientific programme and help identify a solution to this problem.

The PAC took note of the report on JINR's participation in the DIRAC experiment and noted the high scientific significance of the experiment for exploring the nature of chiral symmetry breaking, as well as the seminal contribution of JINR to this experiment.

The PAC expressed its gratitude to Professor S. Dubnička for his most valuable work as Chairperson of the PAC for Particle Physics and recommended that the JINR Scientific Council appoint Professor T. Hallman as Chairperson of this PAC for the period of one year.

The 14th meeting of the Programme Advisory Committee for Nuclear Physics was held on 23–25 April 2001. It was chaired by Professor Ch. Briançon.

The PAC was informed about the presentation to the Scientific Council of the previous PAC recommendations and about their implementation, also about the Resolution of the 89th session of the JINR Scientific Council (January 2001) and the decisions of the JINR Committee of Plenipotentiaries (March 2001).

Nuclear physics with neutrons. The PAC was pleased to note that progress in the implementation of the IREN project had been achieved since the previous meeting, despite continuing financial difficulties. Future advances will be helped by the Directorate's decision to create a new structure from the FLNP IREN group and the LPP accelerator division. However, the PAC expressed deep concern about the fact that the funds provided up to now are not even sufficient to achieve the partial decommissioning of IBR-30 necessary in 2001 and the purchase of urgent components of LUE-200.

The PAC heard a report on the KaTRiN experiment on a search for triple correlation in interaction of polarized neutrons and targets, which is aimed to test CP symmetry, and recommended its active preparation with high priority.

Heavy-ion physics. The PAC noted that the production, separation, and injection of ^{6}He into the beam-transport gallery is a decisive step in Phase I of the DRIBs project. To ensure the continuation and rapid progress of DRIBs, adequate resources should be provided. The PAC supported DRIBs as a project of highest priority and recommended that the equipment for experiments with accelerated radioactive beams should be discussed at the next PAC meeting in more detail.

The PAC considered the programme of the synthesis of superheavy elements to be of highest priority, in particular the continuation of the investigation of element 116 and the development of a method for a direct mass identification of superheavy nuclei. The successful modernization of VASSILISSA is a first important step along this line. Further possibilities presented with the MASHA project were proposed to be discussed in more detail at the next PAC meeting. The programme on the investigation of chemical properties of heavy and superheavy elements was recommended to be continued with high priority.

The combined spectrometer CORSET + DEMON allowed FLNR to observe correlations between fission fragments and secondary radiation such as prompt neutrons and γ rays, which showed strong similarities between fission process mechanisms for heavy and superheavy nuclei. The role of multi-valley structures of the potential barrier of cold fissioning nuclei was underlined. The PAC recommended continuation of the above studies, improving statistical accuracy in order to get information not only qualitatively but also quantitatively.

The PAC is aware of the unique possibilities of JINR to use a tritium target in combination with accelerated tritium beams, allowing the study of extremely neutron-rich light nuclei. The first results on ^{4}H and ^{5}H were very interesting and promising. This research should be continued with high priority.

Low- and intermediate-energy physics. The PAC heard a report on the improvement work of the Phasotron beams and was hopeful of learning in due time about the results of this work. It was also proposed to discuss the H^- injection scheme once the plans are sufficiently advanced.

The PAC followed the joint proposal (JINR and IMP of the Kurchatov Institute) to produce rare stable isotopes using the Ion-Cyclotron Resonance (ICR) method. The PAC encouraged this important project and recommended that the JINR Directorate study the conditions of its implementation at JINR. For the next meeting the PAC invited a report on the results of this analysis and the scientific motivations of the programme.

The PAC received a status report on the preparation of the first tests to be performed within the FAMILON project at the Phasotron in 2001. The PAC expressed hope to learn in due course about the development of this interesting experiment.

Information technologies and computational physics. The PAC appreciated the restructuring of LIT, aimed at fulfilling the Laboratory's main task — reliable operation and development of the JINR computing and networking infrastructure. The PAC noted that the connection abroad is not yet at the level needed for an institute of JINR's size and importance and that the internal JINR network is getting into a critical situation. The reliable and efficient operation of the JINR basic facility — networking and computing infrastructure — needs adequate financing with highest priority.

The PAC appreciated the research activities of LIT and invited a more detailed report on computational activities directly connected with JINR's nuclear physics programme to be presented at its next meeting.

Scientific reports. The PAC heard two theoretical reports of great interest to the JINR experimental programmes: «Supersymmetric Dark Matter — Status and Prospects» by V. A. Bednyakov and «Time Scales in Fusion and Fission» by I. N. Mikhailov. The PAC highly appreciated the results presented in these reports.

The PAC was informed about the current preparation of the International Summer School «Nuclear Methods and Accelerators in Biology and Medicine», which took place in Dubna on 27 June – 11 July 2001. The PAC appreciated once again the wide diversity of subjects covered by the JINR Education Programme as well as its growing international recognition.

The PAC members were also informed about the forthcoming European East–West Collaboration Meeting on Nuclear Science, which would take place in Sandanski (Bulgaria) on 5–9 May 2001.

The 14th meeting of the PAC for Condensed Matter Physics was held on 27–28 April 2001. It was chaired by Dr H. Lauter.

The PAC took note of the information, presented by JINR Chief Scientific Secretary V. M. Zhabitsky, about the recommendations of the 89th session of the JINR Scientific Council (January 2001) and the decisions of the Committee of Plenipotentiaries (March 2001 meeting), in which the modernization of the IBR-2 reactor and the development of instrumentation at the reactor were among the priority activities for funding in 2001.

The PAC took note of the report presented by V. D. Ananiev and was gratified to hear that the IBR-2 refurbishment programme for the year 2000 was completely fulfilled. However, the 2001 situation gives rise to concern because of lack of funding of JINR and consequently the absence of support by the Ministry for Atomic Energy. Due to the limited lifetime of the reactor's central components, no delay with respect to schedule of the reactor refurbishment is acceptable.

The PAC took note of the report by E. A. Krasavin about the setting up a «consultative board for life science», which coordinates research activities in the following fields: study of mechanisms of induced mutagenesis, development of new radiopharmaceuticals, improvement of methods for cancer treatment, ecological investigations, development of new types of nuclear filters and new methods of radionuclide production in biomedicine.

The PAC noted that the «Spectrometer Development Programme», supported by the PAC at its 12th session, should be reinstated on the list for priority funding to ensure that essential instrument components will be available.

The PAC took note of the reports by V. Pomjakushkin (HRFD–FSD), D. P. Kozlenko (DN-12) and K. Ullemayer (Skat–Epsilon), which showed the high scientific output and the actual performance of the spectrometers. Propositions for further improvements were supported. The PAC took note of the reports by V. I. Gordely about the fruitful collaboration for studies performed at the small-angle spectrometer YuMO and suggested steps to minimize the background and to optimize the spectrometer for the cold source.

The PAC was impressed by the report of V. V. Sumin about the use of IBR-2 neutron beams for applied research and expressed a wish to support and enlarge this activity. The PAC appreciated the excellent presentation by T. Rekveldt, who reviewed the application of spin echo to small-angle scattering, reflectometry and diffraction. The PAC was interested to receive an outline showing the advantage of this technique at an IBR-2 spectrometer. The PAC appreciated the expose of N. M. Plakida on

the theoretical background of a novel superconducting substance MgB_2. The PAC strongly supported the presence of theoretical physicists who are directly interested in current problems of condensed matter physics, including local relevance.

The PAC took note of «LIT's Proposals for Development of Computational Physics Research», presented by A. Polanski. The PAC encouraged development of collaboration between LIT and FLNP, in particular in the area of neutron instrumental simulation.

The PAC was very satisfied with the successful Second Meeting of the German–Russian Collaboration at the IBR-2 Reactor, which took place at FLNP on 23–25 April 2001. Further user meetings were strongly recommended. V. L. Aksenov reported about the results of the School on the Use of Neutron Scattering and Synchrotron Radiation (March 2001). The PAC appreciated this initiative and was impressed by the practical content of the course.

The PAC took note of the short report by JINR Chief Engineer I. N. Meshkov about activities in connection with DELSY, and reiterated its statement that a synchrotron source together with the IBR-2 reactor is a wanted combination for condensed matter research. However, the «Recommendations Concerning the DELSY Initiative» of the 89th session of the JINR Scientific Council should be respected.

The 16th meeting of the Programme Advisory Committee for Particle Physics was held on 19–20 November 2001. It was chaired by Professor T. Hallman.

The PAC for Particle Physics took note of the information, presented by Vice-Director A. N. Sissakian, on the preparation of the JINR Scientific Programme for the years 2002–2004 and on the recommendations of the 90th session of the JINR Scientific Council. The PAC appreciated the activity of the JINR and CERN Directorates on the popularization of the international cooperation in particle physics and noted the successful series of poster exhibitions «Science Bringing Nations Together», organized since 1996.

The PAC took note of the reports presented by LHE Director A. I. Malakhov, BLTP Director A. T. Filippov, LPP Director V. D. Kekelidze, DLNP Director N. A. Russakovich and LIT Director I. V. Puzynin, and endorsed the proposed main lines of the JINR research programme in the field of particle physics and relativistic nuclear physics for the period 2002–2004.

In view of JINR's involvement in many large experiments at CERN, DESY, and the USA, the PAC particularly recommended continuation of the efforts to ensure fast computing links between JINR and outside laboratories and to create adequate computing power on site.

The PAC took note of the report presented by JINR Chief Engineer I. N. Meshkov on the operation of the JINR basic facilities in 2001 and noted with satisfaction that the operation of almost all the JINR basic facilities was performed in accordance with the plan despite continued problems with financing. The PAC encouraged further strengthening of the diagnostic systems at the Nuclotron and continued commissioning of this accelerator to meet its full design specifications.

After considering new proposals the PAC recommended approval of the projects «Measurement of Polarization Transfer from *d* to *p* in the Reaction ^{12}C (**d**, **p**)*X* at Internal Momenta of 0.6–0.8 GeV/c» and «Search for Effects of Polarized Hidden Strangeness in Nucleons» (NIS project) for execution with first priority in 2002. The PAC also welcomed JINR's initiative to participate in astrophysical investigations on space satellites and gave a provisional approval to the TUS project, which, however, has to be confirmed at the next PAC meeting, when the presentation of a well-documented proposal is expected.

The PAC recommended that the JINR Directorate open two new themes «Lifetime Measurement of $\pi^+\pi^-$ Atoms to Test Low-Energy QCD Predictions» (DIRAC project) and «Study of Rare Processes » (project «Measurement of Branching Ratio of the $K_l^0 \to \pi^0\nu\tilde{\nu}$ Decay», JINR's participation in the E391a experiment at the KEK-PS) instead of the theme «Investigation of Hadron-Hadron and Lepton-Hadron Interactions».

Concerning the ongoing experiments, the PAC noted with satisfaction the progress in commissioning of the COMPASS spectrometer as well as in fulfilling JINR's obligations for this experiment. At the same time the PAC expressed its concern about the fact that the COMPASS programme may not be completed if CERN decides to cut short the SPS fixed target programme, and urged the JINR Directorate to protect the interest of COMPASS in the JINR–CERN discussions.

The PAC was impressed by the status report on the D0 project, and noted that the large work on the upgrade of the D0 muon detector had been successfully accomplished. The PAC supported the involvement of JINR physicists in the Tevatron research programme.

The PAC congratulated JINR physicists taking part in the STAR experiment on the commissioning of the RHIC accelerator complex and on the successful start of the STAR scientific programme, noting the valuable contribution of JINR to the construction of the electromagnetic calorimeter (EMC) of STAR as well as to the EMC software development.

The PAC noted with interest the reports presented by A. V. Gladyshev and O. V. Teryaev and appreciated the participation of BLTP physicists in theoretical studies rel-

evant to CDF, D0 and STAR research programmes. The PAC recommended that the JINR Directorate support these high-quality important studies.

The PAC noted the significant progress in the development of the Nuclotron accelerator complex achieved during last few years and proposed that a strategic coordinated plan for the scientific and technical programme of the Nuclotron facility up to the end of 2005 should be presented at the PAC meeting in November 2002.

The PAC recommended continuation of the SPHERE and GIBS projects with first priority until the end of 2004, noting that the SPHERE set-up is a very useful detector for experiments using the Nuclotron slow extraction beams. Also the PAC recommended the formation of an active international collaboration which would present a scientific proposal utilizing the excellent potential of the SPHERE experiment.

The PAC recommended a list of first-priority activities in the JINR Programme of Particle Physics and Relativistic Nuclear Physics for the years 2002–2004, and also made recommendations on some second-priority experiments.

The PAC thanked Professor V. D. Kekelidze for the interesting scientific report «Phenomenon of Direct CP Violation» on the fundamental results of the NA48 experiment, noting that these results were obtained with active participation of LPP physicists at all stages of the experiment.

The 15th meeting of the PAC for Condensed Matter Physics was held on 22–23 November 2001. It was chaired by Dr H. Lauter.

JINR Chief Scientific Secretary V. M. Zhabitsky reported the recommendations and considerations of the 90th session of the JINR Scientific Council which are given in its Resolution under the chapter «Recommendations in Connection with the PACs», paragraph «Condensed Matter Physics Issues». The discussions at this PAC meeting focused on these issues.

The IBR-2 reactor. The PAC took note of the progress of the IBR-2 reactor refurbishment programme, presented in the report by FLNP Chief Engineer V. D. Ananiev. The PAC appreciated the timely contributed Minatom's financial support, but expressed concern about the delay of payment from the JINR budget.

The PAC emphasized that the shortfall in the general funding and in the schedule should be fully recovered in the next financial period. The apparent over-aging of the reactor staff should be taken seriously as a danger of the completion of the reactor refurbishment programme and timely efforts should be made to avoid a forthcoming crisis. A timetable should be established showing when actions become necessary, e. g., vacancies should be filled up.

Cryogenic moderator. Head of an FLNP sector E. P. Shabalin presented an outlook of the existing cold source and the possibilities for the optimized new broad-band source assembly around the new reactor core. It is the combination of the high-flux IBR-2 reactor together with its broad-band source that leads to unique properties to be exploited by the instrumentation. The PAC recognized that the run time of 350 hours per year is too short for the full scientific benefit of the existing broad-band source. The PAC proposed the implementation of the broad-band source renewal programme, which should begin with the broad-band source development programme, including the review and optimization of the specific instrument parameters in respect to the broad-band source; the parameter optimization of the broad-band source itself should be supported by numerical calculations.

Instrumentation. The small-angle scattering spectrometer and the Fourier diffractometer are already viewing the existing broad-band source and a third beam line is vacant. The PAC recommended the optimization of these two spectrometers (SANS and HRFD) for the use of the broad-band source. It also supported further developments in view of the future ESS.

DELSY. The PAC took note of the project «DELSY Phase 1: Linac-800 and Free-Electron Lasers» presented by M. V. Yurkov. The PAC expressed its opinion to the JINR Directorate and the JINR Scientific Council that DELSY- related activities would not be welcomed unless the appropriate funding for the IBR-2 reactor refurbishment with its cryogenic moderators is secured and grants for the instrumentation development are assured. The PAC recommended that the scientific programme of «Phase 1» together with a description of the experimental set-up of interested research groups be presented at the next PAC meeting. This presentation should be preceded by a distribution of the information material to the PAC members.

Users' policy. FLNP Scientific Secretary V. V. Sikolenko presented an overview of the Users' policy at FLNP. The PAC recommended that announcements by the Scientific Secretary be distributed more user-friendly and that two dead-lines a year be reintroduced for the submission of proposals.

Presentation of research programmes and scientific reports. The PAC appreciated all the reports presented at this meeting. In many scientific reports collaborations were wanted and proposed. The PAC definitely supports all collaborations which lead to an improved scientific output.

The PAC took note of the information, presented by UC Director S. P. Ivanova, about the International School «Nuclear Methods and Accelerators in Biology and Medicine», which took place in Dubna on 27 June – 11 July 2001. The PAC highly appreciated the results of this School, held with a large representation of students and lecturers from JINR Member States, and recommended its regular continuation in the future.

The 15th meeting of the Programme Advisory Committee for Nuclear Physics was held on 26–28 November 2001. It was chaired by Professor N. Rowley.

The PAC was informed on the implementation of the recommendations of the previous PAC meeting and on the Resolution of the 90th session of the JINR Scientific Council (June 2001). The PAC noted the subsequent successful completion of DRIBs Phase I on time and the closure of IBR-30, which will permit the timely implementation of IREN. The PAC members applauded the new results obtained by FLNR in the synthesis of superheavy element $Z = 116$, which confirmed the earlier identification of elements having $Z = 114$, 112 and 110.

Nuclear physics with neutrons. The PAC appreciated the progress in the implementation of the IREN project but noted that further delays had been accumulated due to financial problems. The proposal of the project management to ensure the realization of different parts of the project by carrying them out in parallel was supported. In particular, this concerned the start-up of the first stage of the linac LUE-200 by mid 2003. Regular financing and continuous support of the JINR technical services are needed to complete these projects on schedule and to ensure that the IREN project enters into its decisive final stage on time.

The PAC heard with interest a report on the FLNP Research Programme on Neutron Physics for 2002–2004 and noted that this forms a solid basis for further research, which will be continued with IREN. The PAC recommended that FLNP make every effort to encourage young scientists into these projects.

Heavy-ion physics. The PAC heard report about successful completion of the first series of experiments on the synthesis of superheavy isotopes in reactions between ^{48}Ca ions and U, Pu and Cm targets. The PAC strongly recommended the continuation of these efforts with the initial aim being the $Z = 118$ element and supported further efforts to investigate chemical properties of superheavy elements. It also strongly encouraged the development of the MASHA mass separator, which will allow precise mass identification ($\Delta A \approx 0.3$) for superheavy isotopes.

The PAC noted that the assembly of Phase I of the DRIBs project had been completed within the planned period of time and expressed hope that similar progress be achieved in the development of Phase II, which is based on a pioneering technique for producing radioactive beams. The PAC supported rapid development of Phase II to preserve the leading position of FLNR in this important new field.

The PAC paid attention to the first observations of resonant states of ^{4}H and ^{5}H in experiments with a cryogenic tritium target at the separator ACCULINNA and stressed the importance of the results obtained in the study of the fission of weakly excited superheavy nuclei achieved by coupling the CORSET (fission fragment) and DEMON (neutron) detector systems. The PAC approved the FLNR Programme of Scientific Research for 2002–2004, including the synthesis and study of the physical and chemical properties of superheavy nuclei, the study of fusion reactions leading to the formation of compound nuclei with $Z = 120 \div 122$ and the study of their fission modes, as well as experiments with accelerated ^{6}He, ^{8}He ions to study elastic and inelastic scattering. It noted that these must all be accorded high priority. The PAC recommended appropriate financing for the timely realization of Phase II of the DRIBs project in 2002 and speedy preparation of experimental equipment for work with accelerated radioactive ion beams.

Low- and intermediate-energy physics. Prior to the PAC meeting, a tour of the proton therapy facilities was given to the Committee members. They were impressed by the various sites, all being in a successful operating state. The PAC noted the variety of fundamental investigations in the DLNP Research Programme for 2002–2004 within experiments such as NEMO, TGV, GENIUS, MAJORANA, FAMILON, PIBETA, MUON, ANCOR, ACMuC, CATALYSIS, LESI, DUBTO, ANKE–COSY, PP2γ, YASNAPP. The PAC recommended general support of these activities, but requested more information on each of these projects.

The PAC strongly supported Dubna's continued participation in the ANKE–COSY programme, which is expected to yield a rich harvest of results in particle physics, e. g., ω-meson production in $p+n$ reactions, a_0 production in $p+p$ reactions, subthreshold K^+ and K^- production.

The PAC heard plans for a Phasotron upgrade and invited the presentation of this improvement programme and corresponding benefits for the experimental programmes at a future PAC meeting.

BLTP research programme. The PAC approved the research programme of BLTP for the years 2002–2004 and stressed the importance of theoretical research for the

general activities of JINR. The existing balance between young and experienced researchers gives a good basis for fulfilling this programme. To do this, however, it is important to provide BLTP with some increase of travel funds for collaborations.

Information technologies and computational physics. The PAC again pointed out the basic-facility character of the JINR local area network (LAN) and external networking, and stressed the importance of their proper funding. Considering the present critical situation (damage of the central ATM equipment), the PAC underlined the absolute need for urgent recovery of the LAN and also recommended the realization of the proposed steps to improve LAN security.

The PAC recommended that the JINR Directorate open a new theme «Computer Physics for Theoretical and Experimental Studies» with first priority for three years until the end of 2004. The PAC expressed a wish to be informed about the activities of the JINR Expert Group for Networks and Computing and invited short reports/comments of the other JINR Laboratories on the important and urgent tasks to be solved in the field of information technologies and computational physics, as well as on their contacts with LIT.

Scientific reports. The PAC heard three scientific reports relating to the JINR nuclear physics programme: «$^{10}_{\Lambda}$Be and $^{10}_{\Lambda}$B Hypernuclei: a Clue to Some Puzzles in Nonleptonic Interaction» (by L. Mailing), «Investigation of the ^{4}H and ^{5}H Superheavy Hydrogen Isotopes in $t+d$ and $t+t$ reactions» (G. M. Ter-Akopian) and «Fission and Quasi-Fission of Superheavy Nuclei» (M. G. Itkis) and highly appreciated the new results presented in them.

JINR education programme. The PAC was informed on the outcome of the International Summer School «Nuclear Physics Methods and Accelerators in Biology and Medicine» (Dubna, June–July 2001). The PAC supported the UC's activities on the organization of international student schools and considered positively the suggestion made by the UC Director concerning joint supervision of PhD students at Dubna by scientists of their home countries and JINR.

Sandanski-2 meeting. The PAC noted the written report on the 2nd East–West Collaboration Meeting on Nuclear Physics (Sandanski, Bulgaria, May 2001). The PAC supported the conclusions of this meeting and recommended that the JINR Directorate take them into account in the context of its international collaborations.

PRIZES AND GRANTS

The 2001 B. Pontecorvo Prize was awarded to Dr N. Samios (BNL, Brookhaven, USA), in recognition of his outstanding contribution to particle physics.

The N. O. Myklestad Award of the American Society of Mechanical Engineers (ASME) was awarded to Leading Researcher of the JINR Bogoliubov Laboratory of Theoretical Physics V. K. Melnikov for the development of the global method of chaos prediction, known as the Melnikov method.

PRIZEWINNERS OF JINR'S ANNUAL COMPETITION FOR BEST RESEARCH — 2001

Theoretical Physics Research

First Prize

«Lie Algebra Contractions and Separation of Variables».
Authors: P. Winternitz, A. Izmestev, G. Pogosyan, A. Sissakian.

Second Prize

«Radial Excited Meson Nonets and Glueball in the Chiral Quark Model».
Authors: C. Weiss, M. Volkov, M. Nagy, D. Ebert, V. Yudichev.

Experimental Physics Research

First Prizes

«Synthesis of Element 116 in the Reaction ^{248}Cm + ^{48}Ca».
Authors: Yu. Oganessian, Yu. Lobanov, A. Polyakov, I. Shirokovsky, Yu.Tsyganov, A. Mezentsev, A. Sukhov, M. Itkis, K. J. Moody, E. Karelin.

«Synthesis of Element 114 Isotopes in the Reactions ^{242}Pu + ^{48}Ca, ^{244}Pu + ^{48}Ca».
Authors: F. Abdullin, G. Buklanov, V. Gorshkov, A. Yeremin, S. Iliev, O. Malyshev, A. Popeko, J. F. Wild, V. Utyonkov, D. Hofmann.

Second Prize

«Measurement of Polarization of Λ and $\overline{\Lambda}$ Hyperons and a Study of Strange Particle Production in ν_μ Charged Current Interactions in the NOMAD Experiment».
Authors: S. Bunyatov, D. Kustov, Yu. Merekov, D. Naumov, B. Popov, A. Chukanov.

Physics Instruments and Methods

First Prize

«Production of High-Intensity Beam of ^{48}Ca Ion at the U-400 Cyclotron».
Authors: V. Kutner, V. Bekhterev, B. Gikal, I. Ivanenko, I. Kalagin, V. Lebedev, V. Loginov, S. Pashchenko, M. Khabarov, A. Shamanin.

Second Prizes

«Semi-Automatic Line for Assembly and Testing of Detectors for the Muon System of the ATLAS Experiment».
Authors: G. Chelkov, D. Dedovitch, P. Evtoukhovich, A. Gongadze, M. Gostkin, D. Khartchenko, S. Kotov, I. Potrap, N. Russakovich, E. Tskhadadze.

«Observation and Investigation of the Exotic Hadronic States *N* (3520) and *K* (1630) with Similar Features».
Authors: V. Karnaukhov, V. Moroz, C. Coca.

Applied Physics Research

First Prize

«Operation of the Nuclotron Cryogenic Supply System Without Liquid Nitrogen: Feasibility Study, Development of Instrumentation and Experimental Investigation During the Accelerator Runs».

Authors: N. Agapov, V. Batin, B. Vasilishin, B. Volkov, A. Kovalenko, I. Kulikov, P. Piatibratov, L. Spasov, H. Khodzhibagian.

Second Prize

«Neutronography in Geology and Geophysics».
Authors: K. Walter, T. Ivankina, A. Nikitin, K. Ullemeyer, Ch. Szeffzük.

Special Prize

«Low-Energy Neutrons and Their Interaction with Nuclei and Matter».
Authors: Yu. Alexandrov, Yu. Zamyatnin, A. Ignatyuk, M. Kazarnovsky, V. Konovalov, N. Kornilov, L. Pikelner, V. Plyaskin, Yu. Popov, W. Furman.

Encouraging Prizes

«SANS Investigations of Self-Assembling Aggregates».

Authors: N. Gorski, J. Kalus, Yu. Ostanevich .

«R&D of Cathod Strip Chambers».

Authors: I. Golutvin, Yu. Ershov, A. Zarubin, V. Karzhavin, Yu. Kiryushin, S. Movchan, P. Moissenz, V. Perelygin, D. Smolin, V. Khabarov.

«Experimental and Model Investigations of IBR-2 Pulsed Reactor Dynamics Peculiarities».

Authors: E. Bondarchenko, Yu. Pepelyshev, A. Popov.

GRANTS

In 2001, a number of scientific projects by JINR staff members received grants of the international foundations ISTC, INTAS, INTAS–RFBR, DFG, DFG–RFBR, CNRS, CNRS–RFBR, CRDF and foundations of the RF Ministry for Industry, Science and Technology.

Four grants «Leading Scientific Schools» rendered by the President of RF were financed by the RF Ministry for Industry, Science and Technology and RFPR. RFPR financed 80 projects in the competition «Initiative Projects», nine projects in the competition «Projects of Creation and Development of Information, Computing and Telecommunication Resources», a project in the competition «Software of Supercomputers and Supercomputer Centres», two projects in the competition «Regional Competition 2001': Moscow Region». Seven grants were received by JINR staff members in the competition «Programme of Support of Young Scientists».

Thirty-seven staff members of JINR were awarded state grants by the Presidium of the Russian Academy of Sciences.

JINR • 2001

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 2001 is described by the following facts:

- Joint investigations on 39 first-priority and 7 second-priority research topics were carried out with scientific centres of the Member States, with international and national institutions of other countries.
- 2,868 JINR scientists and engineers went on various missions within collaborative projects and for participation in external scientific meetings and conferences.
- 1,354 scientists and engineers came to JINR for joint work and consultations and for participation in workshops, conferences and schools.
- 21 international conferences, 22 workshops and 12 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 20 January the Steering Committee on Collaboration of the Joint Institute for Nuclear Research with scientific centres of the Republic of Poland adopted and signed the Résumé, which declares the following: «The Meeting confirms that the collaboration between JINR and Polish scientific centres, based on the membership of Poland to JINR, is important for scientific research. JINR affords Polish scientists additional opportunities to use the achievements in scientific research in Russia. It is through JINR that important ties with scientific centres in all the Member States of the Institute can be kept. The collaboration between JINR and Polish scientific centres should be widened, so that the researchers from Dubna could participate in the projects at Polish centres and benefit more effectively from the joint scientific programmes».

On 20 January CERN Research Director C. Détraz visited the Flerov Laboratory of Nuclear Reactions and the Laboratory of Particle Physics, where he was informed about the progress in research in superheavy elements synthesis and joint studies for the COMPASS experiment. He had discussions with JINR Vice-Director A. N. Sissakian, FLNR Scientific Leader Yu. Ts. Oganessian, FLNR Director M. G. Itkis, LPP Director V. D. Kekelidze, LPP Honorary Director I. A. Savin and other scientists.

The XI annual meeting of the Joint Steering Committee for the Implementation of the BMBF–JINR Agreement on Cooperation and Use of JINR Facilities was held in Leipzig on 5–6 February. JINR Director V. G. Kadyshevsky headed the delegation of JINR. The sittings of the Committee were co-chaired by its Chairmen Doctor H.-F. Wagner (BMBF) and Professor A. N. Sissakian (JINR).

The JINR Directorate informed the Committee about the most important scientific results obtained at JINR in 2000, the implementation of the reform programme at the Institute, reorganizations in scientific activities and realization of the education programme. The German colleagues expressed their appreciation of the research activities and congratulated JINR on the achievement of outstanding results in the experiments in the superheavy elements synthesis and the development of time-of-flight methods in structural neutron diffraction at pulsed and stationary reactors. Both sides marked progress in the realization of joint projects.

It was suggested by BMBF to render JINR in 2001 a credit of 2 million German marks as the German contribution. The Committee approved the distribution of the contribution in the traditional fields of cooperation: theoretical physics, neutron physics, heavy-ion physics and high-energy physics (experiments at DESY, Hamburg). Besides, means are directed to projects for the computer

infrastructure at JINR and other aspects of the Institute's activities.

Taking into account the mutual request of German and Dubna physicists to increase the number of joint projects, the BMBF Administration decided for the first time to render 160 thousand German marks for new projects in addition to the German contribution for 2001. The status of the German specialists at JINR who work in Dubna under the BMBF–JINR Agreement was discussed. The JINR participants of the meeting were also informed about the long-term scientific programmes at largest German research centres.

On 7–9 February JINR Director V. G. Kadyshevsky and Vice-Director A. N. Sissakian went on a working visit to Florida University (Gainsville, USA). They discussed aspects of cooperation in theoretical and experimental particle physics, information technologies and other research with the leading professors of the university P. Ramon, G. Mitselmakher and other scientists. An agreement was concluded on the cooperation between JINR and the university, which specified joint participation in research and educational projects and an exchange of information and researchers.

On 10–12 February the JINR leaders visited the Fermi National Accelerator Laboratory (Batavia, USA), where the modernized D0 and CDF installations were adjusted to the start-up at the Tevatron. Meeting V. G. Kadyshevsky and A. N. Sissakian, FNAL Director M. Witherell expressed his gratitude to the JINR specialists for their timely and high-qualified work. The JINR leaders met with the experiments' spokespersons and leading FNAL scientists, and with the group of JINR staff involved in experiments at FNAL. A. N. Sissakian made a report «VHM Physics» at the CDF collaboration seminar.

On 13–15 February V. G. Kadyshevsky and A. N. Sissakian visited the Brookhaven National Laboratory, where they were acquainted with the results of the first experimental run at the new accelerator of relativistic nuclei (RHIC), commissioned into operation in 2000. JINR researchers from the Laboratory of High Energies and the Laboratory of Particle Physics had participated in the preparatory work and conduction of the STAR experiments. The JINR leaders had talks with BNL Director J. Marburger, discussing a wide range of cooperation aspects. A Protocol was signed to the Agreement on cooperation between JINR and BNL. Along with the traditional topics of cooperation, medical research and ecology were proposed for the further collaboration with BNL.

On 26–27 February a delegation of JINR representatives, headed by JINR Vice-Director Ts. Vylov, visited Budapest. Two meetings were held with the Secretary-General of the Hungarian Academy of Sciences Academician N. Kroo. In the negotiations Hungary was represented by Academician Z. Bor, Academician B. Kardon, Academician D. Kiss and other Hungarian scientists. A wide rage of questions of mutual interest was under discussion. The sides marked the successful implementation of the research programme in the framework of the bilateral Agreement between JINR and HAS and agreed upon the list of the joint projects planned for the year 2001. It was decided to propose bilaterally new joint projects with the implementation period up to three years. The JINR delegation met with Hungarian scientists at the Central Research Institute for Physics, HAS (Budapest), who work under the JINR–HAS Agreement contract. They discussed different questions concerning the efficiency of the joint research.

On 28 February Plenipotentiary of the Russian Federation to JINR, First Deputy Minister Academician M. P. Kirpichnikov and JINR Vice-Director A. N. Sissakian had a meeting at the Ministry for Industry, Science and Technology. They had a detailed discussion of the status of research held at JINR. Special attention was paid to the issues related to the preparatory activities for the JINR Finance Committee meeting (23 March) and the session of the Committee of Plenipotentiaries of the JINR Member States (26–27 March 2001). M. P. Kirpichnikov charged the staff of the Ministry with a number of commissions. Deputy Director of a department of the Ministry V. G. Drozhenko took part in the meeting.

A meeting of the JINR–Czech Republic Committee was held on 5–7 March in Prague, where grants for the joint scientific projects were considered. JINR Vice-Director Ts. Vylov and FLNR Director M. G. Itkis represented the Joint Institute in the Committee, while Professor Č. Šimane, Professor M. Suk, Professor J. Dobeš and Plenipotentiery of the Czech Republic to JINR Professor R. Mach represented the Czech Republic. The Czech scientists made reports on the results of the previous projects. Twenty-one projects were proposed and 17 of them were approved.

On 13 March JINR Chief Scientific Secretary V. M. Zhabitsky had a meeting in Tashkent with President of the Republic of Uzbekistan, Plenipotentiary of the Republic of Uzbekistan to JINR Academician B. S. Yuldashev. A wide range of cooperation issues was discussed. B. S. Yuldashev spoke about the plans in the nearest future to stabilize the participation of Uzbekistan in the JINR activities. Different aspects of scientific cooperation between physicists of Uzbekistan and the Joint Institute were discussed with Director of RIAP (Tashkent)

Academician T. M. Muminov and Deputy Director of INP, UAS Professor U. S. Salikhbaev.

On 4 April in the Ministry for Industry, Science and Technology, Deputy Minister Academician M. P. Kirpichnikov, Plenipotentiary of the RF Government to JINR, had a working meeting with JINR Director Academician V. G. Kadyshevsky, Vice-Director Professor A. N. Sissakian, and with Assistant Director for Financial and Economic Issues V. V. Katrasev. The results of the meeting of the Committee of Plenipotentiaries (CP), held in March, were discussed, as well as the status of activities to fulfil the Government's commissions by the address of the JINR Directorate, State Duma deputy V. V. Galchenko and Governor of the Moscow Region B. G. Gromov on the RF fulfilment of financial obligations to JINR. During the meeting, M. P. Kirpichnikov gave a number of instructions to the executives of the Ministry for Industry, Science and Technology.

On 5 April Plenipotentiary of the President of the Russian Federation in the Central Federal District G. S. Poltavchenko arrived in Dubna with a working visit. He had a meeting with the Director of the Joint Institute for Nuclear Research, visited the Flerov Laboratory of Nuclear Reactions and a number of local industrial enterprises. As a result of the visit a press conference was held, attended by the local mass media staff.

An Agreement on cooperation between the JINR University Centre and the international postgraduate courses at the H. Niewodniczanski Institute for Nuclear Physics (Cracow, Poland) was signed in Dubna on 11 April 2001. The Agreement is aimed at widening of different forms of the educational process and scientific activities in Dubna and Cracow. The cooperating sides will exchange students, postgraduates, teachers and researchers in order to conduct mutual work, popularize the idea of mutual studies and Diploma preparation and coordinate plans for future cooperation.

On 11 April by the decision of the Ministry for Industry, Science and Technology, the Joint Institute for Nuclear Research was accredited as a scientific organization. This state act grants the Institute the right, apart from receiving the RF contribution to the JINR budget, to take part in RF grant competitions and federal purpose-oriented programmes, as well as to receive financing for scientific investigations and experimental design work alongside with other organizations accredited in Russia. The state accreditation certificate grants a scientific organization facilities to pay taxes stipulated by the Russian legislation.

The II Russian–German Meeting of the IBR-2 Users was held at the Frank Laboratory of Neutron Physics on 21–25 April. Its aims were to sum up the results of cooperation, discuss problems and outcomes of the mutual exploitation of the equipment at IBR-2 and to plan further activities and new projects. BMBF representatives and scientists from research institutions and universities of Berlin, Darmstadt, Dortmund, Leipzig, Munich, Potsdam, Freiburg, Jülich and other cities took part in the Meeting from the German side.

The cooperation between physicists of the Frank Laboratory of Neutron Physics and German scientists has been kept for 30 years. As early as when IBR-2 was under construction, German physicists took part in the manufacturing of the equipment base. In 1987 Germany concluded an agreement on cooperation with JINR. Due to monetary support by the German side, the opportunities of modernization at IBR-2 have been sufficiently widened, together with conditions to construct new facilities.

The reports delivered at the Meeting were devoted both to the set-ups at IBR-2, which are partially financed by Germany, and to the latest results of research. Aspects of further development of the experimental equipment were discussed.

JINR Vice-Director Professor A. N. Sissakian was at CERN on 22–25 April, where he took part, as a JINR representative, in the meetings of the Resource Review Board concerning experiments at LHC. Results and prospects of mutual collaboration were discussed at the meetings, such as preparatory activities for experiments at ALICE, ATLAS, CMS and LHC-B. I. A. Galutvin, A. S. Vodopianov and G. A. Shelkov also participated in the meetings as JINR experts.

A. N. Sissakian had talks with CERN Director-General L. Maiani, Research Director R. Cashmore and other CERN authorities.

On 26–29 April JINR Director Academician V. G. Kadyshevsky and Vice-Director Professor A. N. Sissakian were on a working visit at the International Solvay Institutes for Physics and Chemistry. Negotiations on the results and plans for further cooperation were held. ISIPC Deputy Director Professor I. Antoniou highly estimated the contribution rendered by JINR scientists into the realization of mutual projects. Deputy Director of the JINR Laboratory of Information Technologies V. V. Ivanov took part in the negotiations. As a conclusion, a general agreement was signed on the cooperation between JINR and ISIPC for five years.

In the European Commission a meeting of the JINR leaders with Doctor Y. Capouet, a member of the Commissioner Cabinet on research, and other members of the Secretariat was held. A project of a JINR–EC agreement was discussed. The JINR leaders also met with R.Vardapetyan, acting director of the ADONIS project.

In April JINR Director Academician V. G. Kadyshevsky and Assistant Director for International Contacts Professor P. N. Bogolyubov visited Tajikistan. They took part in the meeting of the Council of the International Association of Academies of Sciences (IAAS) and in the celebration ceremony of the 50th anniversary of the Tajik Academy of Sciences. One of the main results of the visit was the signing of a triple agreement among the Joint Institute for Nuclear Research, the Academy of Sciences of Tajikistan and the Tajik State University (Dushanbe). The agreement stipulates the exchange of scientists, postgraduates and students. It will make it possible to restore scientific ties, which have been weakened lately as Tajikistan is not a JINR Member State. It was marked during the visit that JINR played an outstanding role in the training of scientific staff for the Republic of Tajikistan. The work at JINR was useful and fruitful for them, and many of them hope that Tajikistan will become a full Member State of JINR. V. G. Kadyshevsky had a talk with the President of Tajikistan, Eh. Rakhmonov, and invited him to visit Dubna. The invitation was accepted with gratitude.

From 4 to 9 May a Meeting of East–West Collaboration on Nuclear Physics («Sandanski-2») was held in Sandanski (Bulgaria). It was organized by the Committee on Nuclear Physics of the European Physical Society, JINR, the Institute of Nuclear Research and Nuclear Energy of the Bulgarian Academy of Sciences (Sofia) and the Committee for Peaceful Use of Atomic Energy of Bulgaria. Scientists from 18 European countries, the USA, Japan and JINR took part in the Meeting. The main purpose of the Meeting was to strengthen and widen the cooperation between institutes and laboratories of Eastern and Western Europe. Much attention was rendered to young European physicists. The Meeting adopted a number of documents, which contain the analysis of the achievements and prospects for the already existing and new collaborations.

A delegation from Belarus visited the Joint Institute for Nuclear Research on 15–16 May. It was represented by Plenipotentiary of the Government of the Republic of Belarus to JINR Academician A. I. Lesnikovich, Vice-President of the NAS of Belarus Academician P. A. Vityaz, First Deputy Director of the Department of Social and Cultural Policy at the Belarus Council of Ministers A. V. Kukharev, General Director of the Academic Scientific and Technical Complex «Sosny» S. E. Chigrinov, Director of the National Centre of Particle Physics and High-Energy Physics of the State University of Belarus Professor N. M. Shumejko and Dean of the physics department of BSU V. M. Anishchik. The guests were acquainted with JINR's main research trends, they were shown around the Laboratories and met with members of the JINR Directorate and Belarusian colleagues.

On 17–18 May a delegation of German scientists from Darmstadt visited the Joint Institute for Nuclear Research — Director of the Society of Heavy Ion Research Professor W.-F. Henning, Deputy Director Professor H. Gutbrod and Chief of Department G. Münzenberg. The guests were acquainted with the research activities and facilities of the Flerov Laboratory of Nuclear Reactions. Professor W.-F. Henning held a seminar «Society of Heavy Ion Research. Future Plans». In the framework of the visit a meeting with the Laboratory Directorate was conducted, where current aspects of mutual research and future plans were discussed. A wide range of activities at the Joint Institute was demonstrated to the guests. They expressed their interest in many of them — from pure science and theoretical problems to applied research.

From 29 to 31 May JINR was visited by Professor Jean Tran Tan Van (Orsay, France). He is well known as the establisher of a series of conferences «Rencontres de Moriond», «Rencontres de Blois», and «Rencontres du Vietnam». For 30 years, many physicists from JINR have participated in them. Professor Tran Tan Van visited the Laboratory of Theoretical Physics and the Laboratory of Nuclear Reactions and was received by the JINR Directorate. The plans of collaboration and participation of Vietnamese physicists in JINR activities were discussed. Plenipotentiary of Vietnam at JINR, President of the National Academy of Sciences of Vietnam Professor Nguen Van Hieu took part at the meeting. Professor Tran Tan Van was accompanied by journalists from the Vietnamese TV.

JINR Vice-Director Professor A. N. Sissakian met with CERN Director-General Professor L. Maiani on 11 July in Geneva. Multiple emphatic items of cooperation between the two large international organizations were discussed during the meeting. Principal accord was achieved on the prolongation of the General Agreement on CERN–JINR cooperation. A joint exhibition «Science Bringing Nations Together», dedicated to the contribution of CERN and JINR to the development of science, international cooperation and closer relations between nations, was planned to be held in Moscow. JINR group leader at CERN A. G. Olshevsky took part in the meeting.

A. N. Sissakian also had meetings with CERN Research Director Professor R. Cashmore, coordinators for cooperation with CERN nonmember countries Professor J. Allaby and N. Koulberg, collaboration spokespersons P. Jenni, M. Della Negra and many other leading scientists and specialists. Questions of cooperation in scientific and education programmes were widely discussed during the meetings.

On 24 August Vice-Chairman of the National Scientific Council of Taiwan Doctor Chin-Ju-Tshe and senior researcher of the Nuclear Institute of Taiwan Doctor Hen-Tuk-Huan visited the Joint Institute for Nuclear Research. The guests met with JINR Vice-Director Professor A. N. Sissakian and visited the Flerov Laboratory of Nuclear Reactions.

On 28 July a monument to Academician Nikolai N. Bogoliubov, the 20th century's outstanding scientist in the field of physics, mathematics and mechanics, was unveiled in the grounds of the JINR Administration building. At the opening ceremony the following personalities were present: JINR Director Academician V. G. Kadyshevsky, Dubna Mayor V. E. Prokh, Honorary Director of the Bogoliubov Laboratory of Theoretical Physics Academician D. V. Shirkov, Academician E. M. Primakov, Academician A. A. Logunov, Professor P. N. Bogolyubov. The speakers marked the outstanding contribution of N. N. Bogoliubov to science, which will determine the development of many fields of science in future. Scientific schools established by him are vividly applied in Dubna, Moscow and Kiev. For 25 years N. N. Bogoliubov was at the head of the Joint Insititue for Nuclear Research, and his pupils became prominent scientists, physicists and mathematicians. The ceremony was attended by the author of the monument, a famous sculptor Academician M. K. Merabishvili, who managed to incarnate in the bronze statue an image of remarkable scientist and man.

On 19–22 September the leaders of the TRD/ALICE project Professor J. Stachel, Director of Physics Institute, University of Heidelberg, and Professor P. Braun-Münzinger, Assistant Director of GSI, Darmstadt, visited the Laboratory of High Energies. TRD is the largest Transition Radiation Detector in the world, constructed for the ALICE experiment on LHC. The guests were acquainted with the work on the project at LHE, in particular with new technology rooms and equipment for drift chamber production. About 90 drift chambers (as transition radiation detectors with a total area about 150 m^2) will be constructed here.

JINR Director Academician V. G. Kadyshevsky greeted the quests. They had discussions with JINR Vice-Director Professor A. N. Sissakian, Assistant Director of LHE Professor I. A. Shelaev, coordinator of the TRD/ALICE project at JINR Professor Yu. V. Zanevsky and leader of an LHE department Professor Yu. A. Panebrattsev. The main questions of the joint work under the project were discussed.

On 9 October Chairman of the ESS Council (the largest European project for creating an evaporative neutron source) Professor P. Tindemans (Jülich, Germany) was on a working visit to Dubna. Participating in a meeting at the JINR Directorate were JINR Director V. G. Kadyshevsky, Vice-Director A. N. Sissakian, Director of FLNP A. V. Belushkin, Assistant Director of JINR P. N. Bogolyubov. At the meeting, an agreement was reached on participation of JINR in this project at the stage of constructing the source as well as in scientific and applied research using the source. Professor P. Tindemans visited FLNR and FLNP, where work on calculation and simulation of the neutron moderators and target was already under way. FLNP Director Professor A. V. Belushkin is JINR's representative in the ESS Council.

«Science Bringing Nations Together» — a photo exhibition under this title was organized at the State Duma of the Russian Federation. On 10 October, Duma deputies, representatives of Ministries and Departments of Russia, heads of diplomatic missions accredited in Moscow, scientists and cultural workers were invited to attend the exhibition. The speakers at the presentation were JINR Director Academician V. G. Kadyshevsky, JINR Vice-Director Professor A. N. Sissakian, CERN Directorate representative J. Ellis, Chairman of the Foreign Affairs Board at the State Duma D. O. Rogozin, Plenipotentiary of the Russian Federation Government to JINR Academician M. P. Kirpichnikov, JINR scientist Corresponding Member of the Academy of Sciences of Czechia I. Zvara. The importance of fundamental science for the development of the world civilization, various aspects of cooperation between the two international scientific organizations — JINR and CERN — were the topics of their reports.

A delegation from the Republic of Serbia was on a visit to the Joint Institute for Nuclear Research on 14 October. The delegation included Minister for Science, Technology and Development Dragan Domazet, Deputy Minister Radojica Pesic, Director of the VINCA Institute of Nuclear Sciences Krunoslav Subotic, Head of the TESLA project Nebojsa Neskovic, Head of the Physics Laboratory of the VINCA Institute of Nuclear Sciences Alexander Dobrosavlevic.

At the JINR Directorate the guests were welcomed by the Institute's Director Academician V. G. Kadyshevsky, Vice-Directors Ts. D. Vylov and A. N. Sissakian, Assistant Director P. N. Bogolyubov, and Directorate members of the Flerov Laboratory of Nuclear Reactions. The programme of the visit included a tour around the Laboratory of Nuclear Reactions, where units of the TESLA cyclotron are being constructed for the VINCA Institute of Nuclear Sciences. This work is conducted in the framework of the Protocol on the cooperation between scientific centres of Yugoslavia and JINR, which is valid until 2004. In the course of discussions both sides stated their intention to activate the work on

constructing the cyclotron. Participating in the discussions were FLNR Director Professor M. G. Itkis, Scientific Leader of the Laboratory Corresponding Member of RAS Yu. Ts. Oganessian and other leading scientists and specialists of the Laboratory. Minister D. Domazet and JINR Vice-Director Ts. D. Vylov signed a protocol expressing a mutual wish to maintain and develop the scientific and technical cooperation between the research centres of Yugoslavia and JINR.

JINR Director Academician V. G. Kadyshevsky and JINR Vice-Director Professor A. N. Sissakian paid an official visit to Romania on 15–17 October.

On 16 October the leaders of JINR met with President of Romania Ion Iliesku. Their one-hour talk with the leader of one of the countries that founded JINR covered the tasks of fundamental science today, the international cooperation in science and education. V. G. Kadyshevsky and A. N. Sissakian informed President I. Iliesku about the latest achievements and initiatives at JINR and the participation of Romania in the Institute activities. They marked the importance of widening and deepening of the overall cooperation. I. Iliesku underlined the vital role of JINR in the development of science and staff training, particularly for Romania. He stressed the fact that Romania intends to cooperate with JINR and CERN (where he had been not long before). «The participation in both international centres is very important for the interests of the European Community», — said the President of Romania.

Mr I. Iliesku highly evaluated the initiative to hold exhibitions «Science Bringing Nations Together». «It is my strong opinion that science must bring people together and must not create and deepen the precipice between nations», — concluded the President of Romania in his speech. He was invited to visit JINR. In his answer he said that he would gladly take the nearest opportunity to come. On 15 October a warm welcome was rendered to the JINR delegates at the Academy of Sciences of Romania. The Academy President, Academician E. Simion, and other scientists welcomed the guests. A long and business-like discussion was held about the prospects of widening scientific, technological and educational contacts between the sides.

On 15–17 October business meetings took place with a number of leaders of the Ministry for Science and Education of Romania. Specific steps to stabilize the participation of Romania in JINR activities were discussed, to strengthen the cooperation in some trends of research at JINR.

V. G. Kadyshevsky and A. N. Sissakian met with scientists of the H. Hulubei National Institute for Physics and Nuclear Engineering, the Physics Department of Bucharest University and other scientific centres of Romania. They talked about the scientific programme at the international centre in Dubna.

On 18–19 October a Hungarian scientific delegation paid a visit to JINR — General Secretary of the Hungarian Academy of Sciences Norbert Kroo, Head of the Department of Nuclear Physics of the Research Institute for Particle and Nuclear Physics Professor Denes Lajos Nagy, Director of the HAS Department for International Cooperation Janos Pustai. Director of JINR Academician V. G. Kadyshevsky and Academician N. Kroo signed a protocol on the prolongation of the Agreement on the JINR cooperation with the Hungarian Academy of Sciences. At the JINR Directorate an exchange of opinions took place on the perspectives of continued cooperation, where the JINR Directorate was represented by JINR Director V. G. Kadyshevsky, Vice-Directors Ts. D. Vylov and A. N. Sissakian, Chief Scientific Secretary V. M. Zhabitsky, and Assistant Director P. N. Bogolyubov. The guests visited the Flerov Laboratory of Nuclear Reactions.

JINR Vice-Director A. N. Sissakian was at CERN on 21–24 October, where he took part in the meetings of the Resource Review Board concerning experiments at LHC (ATLAS, CMS, ALICE, LHCB). CERN Director- General L. Maiani spoke about the status of the LHC project and the Directorate's proposals on the project implementation under the conditions of increasing costs. Reports were delivered by leaders and experiment coordinators on the status of activities and plans for the future. On 22 October A. N. Sissakian had a talk with CERN Director-General L. Maiani on the issues of cooperation. L. Maiani informed him that Research Director R. Cashmore had been appointed a new Co-chairman of the CERN–JINR Cooperation Committee starting from November. A. N. Sissakian is Co-chairman from JINR. Apart from that, A. N. Sissakian participated in the meetings and consultations with staff members of the CERN Directorate as well as with leaders of the collaborative experiments. On 24 October, a meeting of the CERN–JINR Cooperation Committee took place, which examined the results of the joint work in 2001 and drafted a plan for 2002. The Committee took note of the successful collaborative work and elaborated a number of recommendations for 2002.

On 28–31 October JINR Vice-Director Professor A. N. Sissakian was on a visit to the Gran Sasso Laboratory of the National Centre for Nuclear Research in Italy and got acquainted with its experimental facilities. On 30 October he took part in a meeting with Director of the

Laboratory Professor A. Bettini, where issues of development and JINR–INFN cooperation were discussed. On 29–30 October A. N. Sissakian had a meeting with Leader of the BOREXINO experiment Professor G. Bellini, who examined the set-up to be commissioned in 2002, and had a discussion on the issues of further cooperation, including issues of prolongation of the General Agreement between JINR and INFN. Participating in the discussion was Leader of the JINR group Professor O. A. Zaimidoroga.

On 30 October A. N. Sissakian took part in a seminar at the Gran Sasso Laboratory and delivered the reports «On the Scientific Programme of JINR» and «Very High Multiplicity Physics».

A. N. Sissakian addressed a letter of congratulations from the JINR Directorate to INFN Director Professor E. Iarocci in connection with the 50th anniversary of INFN which was celebrated in 2001.

On 12 November President of the Slovak Republic R. Schuster was on an official visit to Moscow. He attended an exhibition and a conference at the Joint Exhibition Company Stankoimport devoted to the cooperation between Slovakia and Russia. In the framework of this exhibition, a JINR exposition was organized which displayed the achievements of the international scientific centre in Dubna, including the work on creating a cyclotron centre in Bratislava conducted at JINR's Flerov Laboratory of Nuclear Reactions.

JINR Vice-Director A. N. Sissakian told the President of Slovakia and the accompanying officials about JINR's latest achievements. FLNR Deputy Director J. Kliman spoke about the importance of creating a cyclotron centre in Slovakia. In the framework of this conference, head of an FLNR sector A. G. Artyukh delivered a report on the JINR activities in creating the Slovak cyclotron complex. The President of Slovakia highly appreciated JINR's contribution into the development of Slovakian science.

On 20 November a working meeting of the First Deputy Minister, Chairman of the Committee of Plenipotentiaries and Plenipotentiary of the Government of the Russian Federation at JINR Academician M. P. Kirpichnikov with JINR Director V. G. Kadyshevsky and JINR Vice-Director Professor A. N. Sissakian was held at the Ministry for Science, Industry and Technology of the Russian Federation. The JINR leaders informed M. P. Kirpichnikov about the latest results of research at JINR. Approaches to compilation of the JINR budget for 2002 and the following years, questions of the debt restructuring of the JINR Member States, acquisition of new partners to JINR, international cooperation and other questions were discussed.

The 4th working meeting on the scientific cooperation between JINR and the Federal Ministry for Education, Research and Technology of Germany (BMBF) was held in Dubna from 21–22 November. At the meeting, the results of scientific investigations conducted in the framework of both the Agreement between JINR and BMBF and two-sided Agreements between JINR and different scientific centres in Germany were discussed. A detailed analytical report on the current status of cooperation was delivered by JINR Vice-Director Professor A. N. Sissakian. In the cooperation with German scientific centres, the Bogoliubov Laboratory of Theoretical Physics takes the leading place. BLTP theorists collaborate with 58 German institutes and universities. Nine projects are being realized at the IBR-2 reactor, five projects are being carried out together with the Flerov Laboratory of Nuclear Reactions, one project at the facility COSY (Jülich), two with the GSI (Darmstadt), and four together with DESY.

On 28 November V. G. Kadyshevsky and A. N. Sissakian had a meeting with Vice-Minister of development of Greece H. Theodorou (he supervises the General Secretariat on Science and Technology of Greece). Mr H. Theodorou was informed by the JINR leaders about the scientific activities at JINR and cooperation with Greek physicists, who had brought in an initiative to develop scientific ties with Dubna scientists. On behalf of Greek physicists, Professor I. Antoniou handed the Vice-Minister a letter written by a group of physicists with a suggestion to establish an associate society of Greece at JINR, which is an international intergovernmental scientific organization.

From 30 November – 2 December JINR Director V. G. Kadyshevsky and Vice-Director A. N. Sissakian were on a short visit to CERN. Professor A. N. Sissakian, who is an Observer Member of the European Committee for Future Accelerators (ECFA), took part in a plenary meeting of the ECFA. At the meeting, main results of 2001 were considered, as well as plans for development of European accelerator centres.

On 1 December, Academician V. G. Kadyshevsky and Professor A. N. Sissakian participated as observers in the activity of the CERN–Russia Cooperation Committee. The Committee considered the results of cooperation in 2001 and drafted a plan for the future. V. G. Kadyshevsky and A. N. Sissakian discussed with Research Director Professor R. Cashmore, Professor C. Détraz and Co-ordinator of cooperation with non-member states of CERN N. Koulberg a wide range of issues concerning the JINR–CERN cooperation.

CONFERENCES AND MEETINGS HELD BY JINR

Of the scientific conferences organized by JINR in 2001 the largest were the following eleven.

The V Scientific Conference of Young Scientists and Specialists was held on 5–10 February in Dubna (Ratmino). It was organized by the JINR Society of Young Scientists and Specialists. About 120 young scientists, students and postgraduates took part in the Conference, who represented universities of Moscow, Tver, Tula, Voronezh, Samara, Ekaterinburg, Kharkov and London, along with the leading research centres of Russia. About 60 scientific reports were presented on the basic trends of theoretical and experimental research in the field of physics of elementary particles and nuclei, condensed matter, nuclear analytical methods of environmental problems solution, modern methods of charged particles acceleration, radiation and radiobiological research and information technologies.

On 21–22 February, JINR hosted a workshop «Role of the Operating System LINUX in the Computing Infrastructure of the Future», organized by JINR and the «Hewlett Packard» (HP) company.

More than hundred representatives of the scientific centres interested in the development of their computer infrastructure — CERN, CC MSU, ISP RAS, the Keldysh Institute RAS, ITEP, RINP MSU, IOCh RAS, St. Petersburg Institute of Nuclear Physics, and the Research Institute of the Public Prosecutor-General's Office — participated in the workshop. The meeting was also attended by the representatives of the Ministry for Industry, Science and Technologies and the Ministry for Economic Development and Commerce of the Russian Federation, as well as the leading companies such as HP, Oracle, Informix, Intel, etc., which deliver a computer periphery and software.

JINR Vice-Director A. N. Sissakian spoke about the history of the JINR foundation, the main directions of its activity and the JINR basic facilities. Mr Hilmar Lorens, Director of the HP Department of Corporate Computer Systems, delivered his address. His work in the particular area began in 1993 in Dubna and he highly evaluated the cooperation between HP and JINR. One of the bright reports was presented by Leanne Guy (CERN) about the role of computing in the organization of processing and analysis of data from LEP up to LHC. V. V. Korenkov, Deputy Director of LIT, informed the participants of the workshop on the prospects in the development of the JINR information infrastructure. The report «Intel and LINUX» delivered by I. A. Sysoev, a manager on strategic alliances of the Intel company, was highly appreciated by all the participants. The reports represented modern tendencies in the development of information technologies in various activities (business, science, education, state and municipal management). The questions of using the LINUX system in various fields of business and solutions of the HP company in this area, as well as sharing experience on porting large programming complexes in the LINUX environment, etc., were discussed.

The 9th International Seminar on Interaction of Neutrons with Nuclei (ISINN) was held in Dubna from 23–26 May. This seminar was traditionally attended by representatives of the largest Western scientific centres possessing neutron sources: Laue–Langevin Institute, Los Alamos National Laboratory, Hahn–Meitner Institute, Delft University of Technology and others. The latest achievements in the field of neutron physics, possibilities of their use in applied investigations, plans and results of modernization of facilities were discussed at the seminar together with Russian scientists from Obninsk, Gatchina, Troitsk and JINR.

On 29 May – 1 June the II Sissakian Readings and II International Symposium «Problems of Biochemistry, Radiation and Space Biology» were held under the auspices of UNESCO in Moscow and Dubna, dedicated to the memory of Academician Norair M. Sissakian, a great scientist-biochemist, one of the founders of space biology and medicine, an outstanding organizer of science and international scientific cooperation. The A. N. Bakh Institute of Biochemistry and the State Research Centre of the Russian Federation — the Institute for Biomedical Problems of the Russian Academy of Sciences, the National Academy of Sciences of Armenia and the Joint Institute for Nuclear Research organized the Symposium.

At the opening of the Readings, held on 29 May in Moscow at the A. N. Bakh Institute of Biochemistry of RAS, greetings and recollections were addressed to the audience. Among the speakers were First Deputy of the Minister of the RF Ministry for Industry, Science and Technology Academician M. P. Kirpichnikov, Ambassador Extraordinary and Plenipotentiary of the Republic of Armenia in the Russian Federation S. M. Saakian, Acting Director of the A. N. Bakh Institute of Biochemistry V. O. Popov, Director of the G. Kh. Bunatian Institute of Biochemistry of NAS RA A. A. Galoian, Academician of the Georgian Academy of Sciences T. G. Beridze, Professor of the Yerevan Physics Institute Ts. M. Avakian and others. Greetings to the Symposium and Readings arrived from the Armenian Academy of Sciences, UNESCO Office in Moscow, Administration of the town of Ashtarak, from Director of the International Solvay Institutes for

Physics and Chemistry, Nobel Prize winner I. Prigozhin. The scientific part of the Readings consisted of three reports on the heritage by N. M. Sissakian (RAS Corresponding Member A. N. Grechkin, Academician T. G. Beridze, Professor I. I. Filippovich). The participants of the Readings visited the tomb at the Novodevichie cemetery where the scientist is buried and brought flowers.

About 100 reports, including 14 plenary ones, were made at the Symposium. The scientific programme of the Symposium included the following topics: biochemistry, space biology and medicine, general and space radiobiology. Among the reporters were Academician O. G. Gazenko, Academician A. I. Grigoriev, astronaut S. V. Avdeev, Professor E. A. Krasavin, Professor A. A. Zamyatnin and others. A photo exhibition, dedicated to N. M. Sissakian, was organized at the opening of the Symposium and Readings.

A competition of papers presented by young scientists to the Symposium was held in three scientific areas. Twenty papers were submitted to the competition. The winners, who were awarded diplomas and bonuses, are A. N. Antipov (the A. N. Bakh Institute of Biochemistry), D. N. Butorina (the A. N. Bakh Institute of Biochemistry), Yu. I. Vasina (the Institute for Biomedical Problems of the Russian Academy of Sciences) and D. V. Zhuravel (DRRR, JINR).

The IX International Conference «Supersymmetry and Unification of Fundamental Interactions» (SUSY '01) was held in Dubna on 11–17 June. This event happened to be the first of this series in the new millennium and marked the 30th anniversary of supersymmetry. The first conferences on supersymmetry were organized in the USA and soon they transformed into wide forums devoted to physics beyond the Standard Model of fundamental interactions along one of the most urgent lines. They are now organized annually on both sides of the Atlantic Ocean. In 2000 this conference was held at CERN in anticipation of SUSY discovery at the LEP collider. And, at last, SUSY '01 has reached Russia as if paying tribute to the motherland of supersymmetry in the jubilee year.

The topics were rather diverse and included both theoretical talks and experimental reports on SUSY searches from all the world collaborations. There were 35 plenary and 75 parallel talks given by scientists from CERN, Finland, France, Georgia, Germany, Great Britain, Greece, India, Israel, Italy, Japan, JINR, Mexico, the Netherlands, Poland, Portugal, Russia, Slovakia, Slovenia, the South Korea, Spain, Sweden, Taiwan, the Ukraine and the USA. The Conference was organized under the financial support from UNESCO, RFBR, RAS, JINR and the Heisenberg–Landau and Bogoliubov–Infeld Programmes.

The 3rd International Conference «Non-Accelerator New Physics» (NANP '01) was held in Dubna on 19–23 June. The aim of the Conference was to discuss modern status of research in the field of the so-called new physics, which is expected beyond the Standard Model (SM) of the electroweak interactions. Most attention of the participants was concentrated on possible demonstrations of new physics phenomena in non-accelerator experiments. The circle of theoretical tasks bound to them overlaps various SM extensions, including supersymmetry and great unification of fundamental interactions, as well as cosmological aspects of the elementary particle physics. The main topics of the Conference were the problem of neutrino mass and mixing, neutrino oscillations, solar and atmospheric neutrinos, neutrinoless double beta decay and other rare processes, non-baryon dark matter in the Universe. The scientific programme of the Conference covered theoretical aspects of new physics and possibilities of its application, appropriate research strategies, experimental methods of the ongoing and planned studies, discussion of modern approaches to the account of nuclear and hadron structure in rare processes and the related questions of new physics effects.

On 27 June – 11 July JINR's holiday home «Ratmino» hosted the International Student School «Nuclear Physics Methods and Accelerators in Biology and Medicine», which was held within the cycle of JINR's summer student schools. The wide application of ionizing and non-ionizing radiation, radionuclides, gamma therapy units, electron and proton accelerators, and computer tomographs in medicine has turned medical physics into a kind of «strategic arms» and one of the bases of medicine in the present and future. Modern applied medical physics is concerned with radiation therapy, nuclear medicine, radiation diagnostics, non-ionizing diagnostics and therapy, computer facilities and mathematical modelling in diagnostics and therapy, radiation safety, and radioecology. The purpose of the School was to acquaint students and postgraduates with latest achievements and current problems of applied medical physics.

The School was attended by students from Belarus, the Czech Republic, Ecuador, Macedonia, Poland, Romania, Russia, Senegal, and Slovakia. The working language of the School was English. The lecturers of the School were 37 specialists of JINR, the Czech Republic, Germany, Poland, Russia, Switzerland, and the USA. The total number of the School participants was more than 120. They came from Moscow Engineering Physics Institute (MEPI), Moscow State University (MSU), Ural University, Lipetsk, Belarus, the Czech Republic (Prague Technical University), Polish universities, Romania, Slovakia, JINR's University Centre and the Oncology Centre (Moscow). Student sessions were an important feature of the School. Twenty-three papers by students from Poland,

Russia and Czechia were presented there. At the end of the School, three student reports were marked out as the best and their authors were awarded prizes.

The IX International Conference on Symmetry Methods in Physics, organized by the Bogoliubov Laboratory of Theoretical Physics of the Joint Institute for Nuclear Research and the International Centre for Advanced Studies of Yerevan State University, was held on 3–8 July in Yerevan (Armenia). Historically, a series of conferences «Symmetry Methods in Physics» is related to workshops initiated by Professor Ya. A. Smorodinsky (1917–1992), which were successfully organized on a regular basis in Obninsk at the Institute for Physics and Engineering. Since 1993 this Conference has been held in Dubna (1993, 1995 and 1997).

Opening the Yerevan Conference, Professor A. N. Sissakian, JINR Vice-Director and chairman of the International Advisory Committee of the Conference, pointed out that the choice of Yerevan as the location of the Conference was not accidental as the theoretical physics in Armenia has glorious traditions. It is generally recognized that a series of conferences «Symmetry Methods in Physics» has become one of a few conferences that are regularly held on such a wide subject as the application of mathematical methods for simulation and description of physical systems based on the properties of their symmetry. The last Conference is not an exception. It covered many trends where symmetry aspects play an important role, namely, integrable and superintegrable systems; periodic and aperiodic systems; quantum field theory and strings; gravitation, cosmology and quantum gravity; nuclear, atomic and molecular physics; condensed matter and statistical physics; quantum optics and coherent states; theory of differential and difference equations.

The Conference was attended by 80 participants from 20 countries, including 15 JINR staff members. The review talks were presented by such prominent physicists as P. Winternitz, R. Jackiw, K. Fronsdal, J. Hietarinta and others. The Conference took place in the year of celebration of the 1700th anniversary of adoption of Christianity in Armenia.

An International Symposium «Exotic Nuclei ’01 – Baikal» (EXON’2001 – Baikal) took place in a village Listvyanka near Irkutsk, Russia, on 24–29 July. Superheavy elements, properties of exotic nuclei, reactions with radioactive beams and projects of large factories for radioactive beams were the topics of the Symposium. The Flerov Laboratory of Nuclear Reactions (JINR), the nuclear centres GANIL (France) and RIKEN (Japan) were the main collaborators and organizers. The geography of the participating countries showed widespread interest in this field. Scientists from Belgium, Brazil, Finland, France, Germany, Japan, Italy, Poland, Romania, Slovakia, Switzerland, the UK, the Ukraine and the USA took part in the Symposium.

A traditional International School-Seminar «Actual Problems of Particle Physics» took place on 7–16 August in the guest house «Zolotye Peski» near Gomel (Belarus). This forum was a jubilee one — the first school for young scientists was conducted in Gomel in 1971 (Professor V. G. Kadyshevsky was the rector of the school). Owing to mutual efforts of JINR and Belorussian scientists, 4 years ago this tradition was resumed after a twenty-year break. This year’s School has been the third since 1997. It is appropriate to remind that these schools, the organization of which was launched by N. N. Bogoliubov and F. I. Fedorov, have made a remarkable contribution into the formation and development of both physics of elementary particles and high energy physics in Belarus. The famous school of Belorussian theoretical physicists founded by F. I. Fedorov within the precincts of the Belorussian Academy of Sciences served as a solid basis for that. It is to the 90th anniversary of F. I. Fedorov’s birthday that the 2001 School was dedicated to.

Deputy Plenipotentiary of the Government of Belarus at JINR N. M. Shumeiko, JINR Vice-Director A. N. Sissakian, Deputy of the National Assembly, Rector of Gomel State University M. V. Selkin, Academician D. V. Shirkov, Chairman of the Gomel Department of RB NAS Yu. M. Pleskachevsky and others took part in the opening ceremony of the School. The School was also attended by Minister of Education of the Government of Belarus V. I. Strazhev, who made a report. During seven working days of the School-Seminar, about 50 lectures were delivered. The speakers were D. V. Shirkov, A. N. Sissakian, N. A. Russakovich (JINR), W. Lohmann (Germany), B. Loehr (CERN), A. A. Bogush, L. M. Tomilchik (NAS, Belarus), I. A. Karnaukhov, L. L. Yenkovsky (NAS, Ukraine) and others.

For the first time since its inception 40 years ago, the European School of High Energy Physics was held in Switzerland at Beetenberg. Running from 26 August to 8 September, it attracted 95 students from 30 countries. This year’s event, traditionally organized by CERN and JINR, was prepared in association with the University of Bern.

The European School of High Energy Physics has become a major event in the particle physics calendar. The tradition began in 1962, and the programme first included courses on nuclear physics at bubble chambers and emulsion techniques. By 1965 the focus had switched to teaching theoretical elementary particle physics to young experimentalists, where it has remained ever since. In 1970 the school was held in Finland, in collaboration with the Joint Institute for Nuclear Research, and it was entitled the CERN–JINR School on Physics up to 1993.

PARTICIPATION OF JINR IN INTERNATIONAL AND NATIONAL CONFERENCES

In 2001, scientists and specialists of the Joint Institute for Nuclear Research took part in 231 international conferences.

The largest delegations of JINR attended the following conferences: 15th International Conference on Ultra-Relativistic Nucleus-Nucleus Collisions (USA, Stony Brook), 37th Karpacz Winter School of Theoretical Physics (Poland, Karpacz), 4th Workshop on Cyclotrons and Applications (Egypt, Cairo), International Conference on Muon Catalyzed Fusion and Related Exotic Atoms (Japan, Shimoda), CAS Particle Accelerators for Medicine and Industry Course (Czech Republic, Pruhonice), International Conference «Beam Cooling and Related Topics (Germnay, Bad Honeff), Intrenational Conference on Nuclear Physics (Italy, Messina), 3rd National Conference on Application of X-Ray, Synchrotron Radiation, Neutrons and Electrons for Materials Research (Russia, Moscow), 3rd International Conference on Nuclear and Radiation Physics (Kazakhstan, Almaty), Conference «Crimea-2001» (Ukraine, Sudak), International Nuclear Physics Advisory Committee (Japan, Wako-shi), 2001' Particle Accelerator Conference (USA, Chicago), 10th Colloquium «Quantum Groups and Integrable Systems» (Czech Republic, Prague), 12th All-Russian Conference «Research Reactors for Science and Technologies» (Russia, Dimitrovgrad), International Conference «Beam Dynamics and Optimization» (Russia, Saratov), 2nd International Symposium on Quantum Theory and Symmetries (Poland, Cracow), International Nuclear Physics Conference (USA, Berkeley), 51st International Conference on Nuclear Spectroscopy and Atomic Nucleus Structure (Russia, Sarov), International Conference on Neutron Scattering (Germany, Munich), International Conference «Crystals: Growth, Properties, Real Structure and Application» (Russia, Aleksandrov), 17th International Workshop on Charged Particle Accelerators (Ukraine, Alushta), 17th International Conference on Magnet Technology (Switzerland, Geneva), International Conference «Modern Problems of Nuclear Physics» (Uzbekistan, Tashkent), 14th International School on Nuclear Physics, Neutron Physics and Nuclear Energy (Bulgaria, Varna), All-Russian Conference «Membranes 2001'» (Russia, Lianozovo), Intrenational Conference on Nuclear Data on Science and Technology (Japan, Tsukuba), International Conference «Dynamical Aspects of Nuclear Fission» (Slovak Republic, Casta Papiernicka), International Conference «Actinides 2001'» Japan, Hayama), International Seminar «Physics of Unstable Nuclei» (Japan, Kyoto), 2nd International Symposium on Advanced Science Research (Japan, Tokai).

Development of JINR's international collaboration and relations during the years 1965–2001

		1965	1975	1985	1990	1995	2000	2001
1.	Number of visits to JINR by specialists from its Member States (excluding participants in JINR conferences)	203	1026	1469	1050	299	425	348
2.	Number of visits by JINR specialists to Member States	171	474	600	778	682	682	883
3.	Number of conferences and meetings organized by JINR	19	42	49	44	52	54	55
4.	Number of visits to international conferences and research centres of non-Member States	69	131	119	437	1451	1946	1985
5.	Number of visits of scientists from non-Member States	27	226	144	563	1036	990	763
6.	Number of JINR fellows		11	3	16	28	17	17

CONFERENCES AND MEETINGS HELD BY JINR IN 2001*

Title	Site	Date	Number of participants
89th Session of the JINR Scientific Council	Dubna	18–19 January	120
23rd Workshop on Experiments with the IHEP–JINR Neutrino Detector and the NOMAD Experiment	Dubna	24–26 January	34
5th Scientific Conference of Young Scientists and Specialists	Dubna (Ratmino)	5–10 February	140
Workshop «Computing Infrastructure of the Future»	Dubna	21–22 February	120
2nd School on Application of Neutron Scattering and Synchrotron Radiation	Dubna	19 March – 27 April	80
24th EPCS Board Meeting	Dubna	21–25 March	11
Seminar in Memory of V. A. Sviridov	Dubna	22 March	90
Meeting of the JINR Finance Committee	Dubna	23 March	80
Meeting ot the Commitee of Plenipotentiaries of the JINR Member States	Dubna	26–27 March	120
2nd International Workshop «Synchrotron Radiation Source: Prospects of Research»	Dubna	2–6 April	106
Workshop «Nucleation Theory and Its Application»	Dubna	2–28 April	57
2nd International Workshop «Very High Multiplicity Physics»	Dubna	7–9 April	50
Meeting of the Programme Advisory Committee for Particle Physics	Dubna	9–10 April	100
2nd German–Russian IBR-2 Users Meeteng	Dubna	21–25 April	48
Meeting of the Programme Advisory Committee for Nuclear Physics	Dubna	23–25 April	100
Meeting of the Programme Advisory Committee for Condensed Matter Physics	Dubna	27–28 April	70
European East–West Coordination Meeting on Nuclear Physics	Bulgaria, Sandanski	4–9 May	100
Workshop «Radionuclide Methods for Diagnostics and Treament in Clinical Oncology»	Dubna	16–19 May	60
Workshop «Investigation of Relativistic Nuclei Interactions at the Nuclotron Beams by Photoemulsion Method»	Dubna	22–24 May	40
9th International Seminar on Interaction of Neutrons with Nuclei (ISINN-9)	Dubna	23–26 May	120
Workshop «IBR-2 in the 21st Century»	Dubna	24 May	150
Baikal Collaboration Workshop	Dubna	28 May – 2 June	60
International Workshop «Prospects for the Development of Laser Methods in the Study of Nuclear Matter»	Poland, Poznan	28 May – 1 June	52
2nd International Symposium «Problems of Biochemistry, Radiation and Space Biology» dedicated to the memory of Academician N. Sissakian	Russia, Moscow–Dubna	29 May – 1 June	103
90th Session of the JINR Scientific Council	Dubna	7–8 June	120
9th International Conference on Supersymmetry and Unification of Fundamental Interactions	Dubna	11–17 June	200
Workshop «Quantum Gravity and Superstrings»	Dubna	18–28 June	60
3rd International Conference on Non-Accelerator New Physics	Dubna	19–23 June	120

*A number of conferences was held in association with other organizations.

Title	Site	Date	Number of participants
Meeting of the Control Commission of the JINR Finance Committee	Dubna	21–22 June	20
International Summer Student School «Nuclear Physics Methods and Accelerators in Biology and Medicine»	Dubna (Ratmino)	27 June – 11 July	127
International Seminar «Computer Algebra and Its Application to Physics»	Dubna	28–30 June	70
5th International Summer School of Young Scientists and Specialists	Slovak Republic, Bansca Stiavnica	30 June – 9 July	31
International Symposium «Bose–Einstein Condensation of Trapped Atoms and Atom Lasers»	Russia, Moscow	2–7 July	70
International Conference «Data Management Systems»	Dubna	3–5 July	70
9th International Conference «Symmetry Methods in Physics»	Armenia, Yere-van	3–8 July	100
NEMO Collaboration Workshop	Dubna	4–8 July	34
International School-Workshop «Symmetry and Spin» (Praha-SPIN-2001)	Czech Republic, Prague	15–28 July	70
International Conference «Exotic Nuclei ’01– Baikal» (EXON’2001 – Baikal)	Russia, Listvyanka	24–29 July	120
9th Workshop on High Energy Spin Physics	Dubna	2–7 August	76
HERMES Collaboration Meeting	Dubna	7–11 August	80
9th European School of High-Energy Physics (a CERN–JINR school)	Switzerland, Beetenberg	26 August – 8 September	130
International School-Seminar on Actual Problems of Particle Physics	Belarus, Gomel	7–16 August	130
International Summer School «Dense Matter in Particle- and Astrophysics»»	Dubna	20–31 August	45
International Conference «New Trends in High-Energy Physics»	Ukraine, Yalta	8–14 September	50
Workshop «Relativistic Nuclear Physics from Hundreds of MeV to TeV»	Bulgaria, Varna	10–17 September	96
International Symposium on Nuclear Electronics and Computing (NEC ’01)	Bulgaria, Varna	13–20 September	93
16th Max Born Symposium «Supersymmetry and Quantum Symmetry III»	Poland, Karpacz	21–25 September	60
Conference «Education and Science in Russia»	Dubna	22–23 September	70
Scientific Seminar in Memory of V. P. Sarantsev	Dubna	26–28 September	60
Workshop «Investigation of Exotic Nuclei Structure at the Nuclotron Beams»	Dubna	15–16 November	45
Meeting of the Programme Advisory Committee for Particle Physics	Dubna	19–20 November	100
4th Workshop on Scientific Cooperation between JINR and German Research Centres	Dubna	21–22 November	78
Meeting of the Programme Advisory Committee for Condensed Matter Physics	Dubna	21–23 November	70
Meeting of the Programme Advisory Committee for Nuclear Physics	Dubna	26–28 November	100
Baikal Collaboration Workshop	Dubna	4–6 December	40

Dubna, 26 March. The ceremonial JINR CP meeting dedicated to the 45th anniversary of the Joint Institute for Nuclear Research. Left to right: Professor Ts. Vylov, Governor of the Moscow Region B. V. Gromov, Academician V. G. Kadyshevsky, Academician M. P. Kirpichnikov, Professor A. N. Sissakian, Corresponding Member of RAS I. N. Meshkov, V. M. Zhabitsky

Dubna, 18–20 January. The 89th session of the JINR Scientific Council, which included the round-table discussion «Poland at JINR»

Dubna, 5 April. Plenipotentiary of the President of the Russian Federation in the Central Federal District G. S. Poltavchenko (third from right) during his visit to JINR

Dubna, April.
Participants of the meetings of the Programme Advisory Committees for Particle Physics, Nuclear Physics and Condensed Matter Physics

Leipzig, 6 February.
Participants of the XI meeting
of the Joint Steering Committee
for the Implementation
of the BMBF–JINR Cooperation Agreement
after the signing of the concluding documents

Budapest, 26 February.
The visit of the JINR delegation to Hungary.
Secretary-General of the Academy of Sciences
of Hungary Academician N. Kroo (left)
and JINR Vice-Director Professor Ts. Vylov

Dubna, 23 March.
A regular meeting of the JINR Finance Committee

Dubna, 28 February. A scientific seminar dedicated to the 75th anniversary of Academician A. M. Baldin, Scientific Leader of the JINR Laboratory of High Energies

Prague, 5 March. Participants of the Steering Committee on the JINR – Czech Republic cooperation

Dubna, 2 April. Presidium of the 2nd Workshop «JINR Synchrotron Radiation Source: Prospects of Research» (DELSY-2001)

Dubna, 1 June.
Plenipotentiary of the Government
of the Socialist Republic of Vietnam
Academician Nguyen Van Hieu (centre)
meets with JINR Director Academician
V. Kadyshevsky during his visit to JINR

Sandanski (Bulgaria), 4–9 May.
The II Meeting of East–West Collaboration
on Nuclear Physics

Moscow–Dubna, 29 May – 1 June. The II International Symposium «Problems of Biochemistry, Radiation and Space Biology»,
dedicated to the memory of Academician N. M. Sissakian and held under the auspices of UNESCO

Dubna, 26 May. Participants of the 9th International Seminar on Interaction of Neutrons with Nuclei (ISINN ’01)

Dubna, 11–17 June. The 9th International Conference «Supersymmetry and Unification of Fundamental Interactions» (SUSY ’01)

Dubna, 19–23 June. The 3rd International Conference on Non-Acceleration Physics

Moscow, 10 October. The opening of the joint JINR–CERN poster photo exhibition «Science Bringing Nations Together» at the State Duma of the Russian Federation

Dubna, 18 October. The signing of the Protocol on the prolongation of the Cooperation Agreement between JINR and the Hungarian Academy of Sciences

Dubna, 8 November. The meeting of the JINR Directorate with RF State Duma Deputy V. Galchenko (second from left)

Bucharest, 16 October. JINR Director V. Kadyshevsky (left) at the meeting with the President of Romania I. Iliescu (right)

Dubna, 18 January 2002. The laureate of JINR's 2001 B. Pontecorvo Prize Dr N. Samios (USA) (right)
at the Dzhelepov Laboratory of Nuclear Problems

JINR • 2001

RESEARCH AND EDUCATION PROGRAMMES OF JINR

BOGOLIUBOV LABORATORY OF THEORETICAL PHYSICS

In 2001 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

Theoretical research in the Fields and Particles Division of BLTP covers a wide range of activity in quantum field theory (QFT) and theoretical particle physics. Following the current situation in high-energy physics, the QFT research goes far ahead of experimental grounds and is concentrated mainly in the area of mathematical physics. On the other hand, the high-energy phenomenology is developed in close contact with modern accelerator experimental data. Although these two directions seem to diverge, new interfaces between theory and experiment emerge, e. g. in astroparticle physics and cosmology.

The topics of main focus in quantum field theory are:

— Supersymmetry and superstrings;
— Integrable models, noncommutative field theories;
— Nonperturbative approaches to QCD and lattice gauge theories;
— Quantum gravity and cosmology.

Phenomenology of particle physics includes the Standard Model of fundamental interactions and its extension as well as high- and low-energy hadron physics. The main topics are:

— SUSY and Higgs boson search;
— New trends in neutrino physics;
— QCD structure functions;
— Spin and polarization phenomena;
— Chiral model and meson spectroscopy;
— Very high multiplicity physics.

During the year, a considerable progress has been achieved along several lines. Below one can find a short description of selected results obtained at BLTP in both the domains.

The integrable model called the «Quantum relativistic Toda chain at root of unity» was formulated and investigated in detail. This model is the simplest «hybrid» one: the space of the dynamic variables is a bundle, whose layer is the local Weyl algebra — the quantum algebra of the observables, and the base is a space of centres. The «hybrid» formulation allowed one to obtain the Baxter equation on a quantum curve covering the classical high genus hyperelliptic one and also to obtain the quantum separation of variables explicitly as a consequence of the classical separation. A series of papers on this subject were published, and the survey is paper [1].

Noncommutative Yang–Mills theory is known to possess a class of localized solutions that do not exist in the commutative case. The configuration consisting of a set of such objects (called lumps) is not a static solution anymore, because these objects interact. Dynamics of such interacting lump configurations corresponding to nontrivial vacua in noncommutative Yang–Mills theory was considered. It was found that this dynamics is effectively described by a matrix model, which exhibits stochastic behaviour [2]. Two-dimensional noncommutative mechanical systems in a constant magnetic field were considered. It appeared that, depending on the value of magnetic field and noncommutative parameter, the system may exist in one of two phases having different symmetries [3].

The study of nontrivial backgrounds for fermionic $N = 2$ strings in the presence of D-branes and NS–NS B-fields was initiated. Coupling a B-field with the supersymmetric $2d$ matter of the sigma model on world sheets with boundaries, the corresponding action was derived, which produced $N = 2$ supersymmetric boundary conditions. It was demonstrated that the open $N = 2$ string with a constant B-field background in the presence of $D3$- or $D2$-branes yields noncommutative self-dual Yang–Mills or a noncommutative (2+1)-dimensional modified $U(n)$ sigma model. Various classes of explicit multi-soliton configurations corresponding to $D0$-branes moving inside the $D2$-branes were constructed and studied in detail [4, 5].

For the first time, an off-shell $N = 3$ supersymmetric extension of the abelian $D = 4$ Born–Infeld action was constructed, starting from the action of supersymmetric Maxwell theory in $N = 3$ harmonic superspace [6].

Using the $N = 2$ superfield approach, full supersymmetric low-energy effective actions were constructed for $N = 4$ **SYM models**, with both $N = 2$ gauge superfield strengths and hypermultiplet superfields included. It was proved that the effective potentials of the form $\ln W \ln \overline{W}$ can be $N = 4$ completed and present the precise structure of the corresponding completions [7].

It was proved that any spherically symmetric solution of the **Einstein equations** can be generalized to a new solution that describes a space-time pierced by an arbitrary number of infinitely thin cosmic strings directed radially. Each string produces an angle deficit proportional to its tension, while the metric outside the strings is a locally spherically symmetric solution. There can be arbitrary configurations of strings provided that the directions of the strings obey a certain equilibrium condition. In general, this equilibrium condition can be written as a force-balance equation for string forces or as a constraint on the product of holonomies around strings [8].

A new class of **integrable models** of (0+1)- and (1+1)-dimensional dilaton gravity coupled to any number of scalar fields was proposed. Their solutions expressed in terms of elementary functions describe, among other things, spherical black holes and cosmologies, emerging in high-dimensional supergravity theories, and reveal nontrivial relations between these two objects [9].

Quantum field theory with nontrivial boundary conditions requires development of a new calculation technique and, first of all, of new regularization methods. The high temperature asymptotics of the thermodynamic characteristics of the electromagnetic field subjected to boundary conditions with spherical and cylindrical symmetries were constructed by making use of the relevant heat kernel coefficients. The obtained results reproduce all the asymptotics derived by other methods in the problems under consideration and involve some new high temperature expansions [10].

On the basis of recently devised global **Analytic Perturbation Theory** (APT), some QCD observables were analyzed in spacelike and timelike domains with $f = 3, 4$ and 5. All the examples demonstrate the effect of improved convergence of nonpower APT expansions as compared with ordinary power expansions (in power of $\overline{\alpha}_s(Q^2)$ or $\overline{\alpha}_s(s)$). The three-loop contribution (of order $\overline{\alpha}_s^3$) to an APT expansion is, as a rule, numerically inessential [11].

The method of nonperturbative a expansion, developed at the Laboratory, that gives a self-consistent description of both spacelike and timelike regions was applied to analyze the D functions and smearing quantities corresponding to the e^+e^- annihilation into hadrons and inclusive τ-decay data. Threshold effects were taken into account via a new relativistic Coulomb-like factor that summarizes singularities of a perturbative expansion of the type $(\alpha_s/v)^n$ and generalizes the well-known Sommerfeld–Sakharov factor. It was shown that the method proposed provides good agreement with experimental data down to the lowest energy scale [12, 13].

In the framework of the **Minimal Supersymmetric Standard Model** a global statistical χ^2 analysis of the data was performed, including the influence of higher-order corrections to $b \to s\gamma$ decay rate and new recent data on the anomalous magnetic moment of the muon. It was shown that there exists an allowed region of parameter space bounded from below by the Higgs limit and from above by the anomalous magnetic moment [14, 15]. It was shown that renormalization of the Fayet–Iliopoulos term in a softly broken SUSY gauge theory, in full analogy with all the other soft term renormalizations, is completely defined in a rigid or an unbroken theory. The four-loop renormalization proportional to the soft scalar masses and soft triple couplings was calculated [16].

Calculations of the perturbative parts of **the structure functions** F_2^c and F_L^c for a gluon target with a nonzero momentum squared were performed for the process of photon-gluon fusion. The results are quite compact in form for both the types of gluon polarization: the Feynman gauge one and BFKL-like one. The results were applied in the framework of k_T factorization approach to analyze the present data on the charm contribution to the structure function F_2 (F_2^c). The analysis was performed with several parametrizations of unintegrated gluon distributions for comparison. A good agreement of the results obtained with different parametrizations of unintegrated gluon distributions was found with experimental F_2^c HERA data, except at low Q^2 ($Q^2 \le 7\ \mathrm{GeV}^2$). Quite a large value of the charm contribution to the structure function F_L^c was also obtained at low x and high Q^2 ($Q^2 \ge 30\,\mathrm{GeV}^2$) [17].

A process of nonlinear backward Compton scattering of circularly polarized laser photons, being one of the basic processes at future high-energy photon colliders, was considered. Very high intensity of laser wave leads to a

broadening of the energy (luminosity) spectra and a shift to lower energies (invariant masses). All this is necessary for the optimization of the conversion region at photon colliders and the study of physical processes where a sharp edge of the luminosity spectrum and monochromaticity of collisions are important [18].

A single-spin asymmetry of a photon emission in deeply virtual Compton scattering was calculated. This problem is of high priority for it allows one to study generalized parton distributions within the framework of QCD (a particular case of which are parton distributions first introduced by Feynman) and, as a consequence, **the nucleon spin structure** [19].

Recently, HERMES measured **an azimuthal asymmetry** $A_{UL}^{\sin\phi}$ in electro-production of π^0 in semi-inclusive deep-inelastic scattering of unpolarized positrons off longitudinally polarized protons. It was shown that this asymmetry is well reproduced theoretically, with no free adjustable parameters, by using the calculation of the proton transversity distribution h_1^q in the effective chiral quark-soliton model of the Bochum University group, combined with experimental data (DELPHI) on the average analyzing power $\left\langle H_1^\perp / D_1 \right\rangle$ of the Collins effect, responsible for a left-right asymmetry in the fragmentation of transversely polarized quarks into nonpolarized hadrons (see the figure, *a*).

Using the *z*-dependence of the HERMES azimuthal asymmetries for π^+ and π^0 and the calculated transversity distributions, the *z*-dependence of the analyzing power was obtained for the first time (see the figure, *b*), showing the linear rise $H_1^\perp(z_h)/D_1^\perp(z_h) = 0.15 z_h$ [20].

Double-spin asymmetries for longitudinally polarized leptons and transversely polarized protons in diffractive vector meson and $Q\overline{Q}$ production in the HERMES energy range were considered. The asymmetry predicted for meson production is quite small. Large asymmetry is expected for $Q\overline{Q}$ production [21].

An interpretation of 19 **scalar meson states** with masses from 0.4 to 1.7 GeV was given for the first time [22]. It was shown that these states can be considered as two nonets: the nonet of ground states (lighter than 1 GeV) and the nonet of their first radial excitations (heavier than 1 GeV) and a scalar glueball with mass 1.5 GeV. The mixing of scalar isoscalar quarkonia and the glueball was taken into account.

A novel mechanism for the empirical $\Delta I = 1/2$ rule found in weak $\Delta S = 1$ decays was suggested [23]. This mechanism arises from **the instanton contribution** to weak decay amplitudes, and it is very important for understanding the large observed CP violation in weak decays of *K* mesons.

A description was presented of **the extremely inelastic high-energy hadron collisions** when the multiplicity of produced hadrons considerably exceeds its mean value. In a generalization of the inclusive and semi-inclusive approaches, a new method was developed that is based on the statistical picture of processes in the very high multiplicity (VHM) region. To obtain model-free predictions, a real-time finite-temperature *S*-matrix theory was built. It allows one to develop a new phenomenology approach to VHM processes and make predictions that can be useful for future experimental programs (LHC, Tevatron, etc.) [24].

Also, mention is to be made of the studies of evolution of the rotation frequency for accreting compact stars [25] and of the possibility of CP violation in the lepton sector from the data on neutrinoless double β-decay experiments [26].

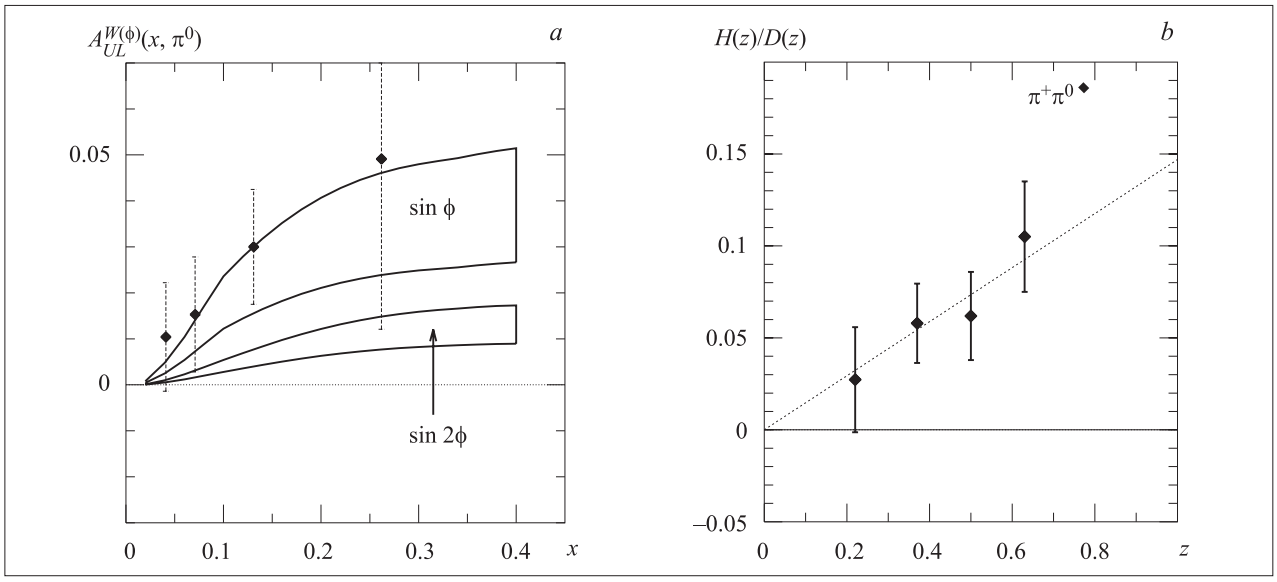

Figure. *a*) Azimuthal asymmetry A_{UL}^{w} f or π^0 as a function of *x*. The enclosed areas correspond to the statistical error in $\left\langle H_1^\perp / D_1 \right\rangle$. *b*) $H_1^\perp/D_1$ versus *z* extracted from HERMES data for π^+ and π^0 combined

In 2001, investigations within the area «Theory of Nuclei and Other Finite Systems» were carried out in accordance with the four projects:

- 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 method was developed to derive sets of relations between the experimentally observed reduced matrix elements of the quadrupole operator. This approach is based on the quadrupole shape invariants, selection rules of the Q-phonon scheme, and the fact that the corrections for noncommutativity of the components of the quadrupole moment operator are small. As an example of the general scheme, fourth-order Q-invariants of the ground state were given. A satisfactory agreement between the data and theoretical relations was obtained [27].

The magnetic dipole strength distribution in the energy range 4–10 MeV in the well-deformed ^{154}Sm nucleus was investigated. To this end, the quasiparticle-phonon model with a large basis of one- and two-phonon states was used. The strength is almost entirely due to spin excitations. It was proved that the experimentally observed two-hump structure is mostly due to separation of the proton and neutron excitations. On the contrary, the isoscalar and isovector spin strengths are spread over a rather large energy range. The calculations exclude that the two humps originate from separate $K^{\pi} = 0^{+}$ and $K^{\pi} = 1^{+}$ excitations [28]. Excitation energies, spectroscopic factors, and internal fermion structure of excited states up to 7 MeV in ^{208}Pb were calculated with a large basis of one-, two-, and three-phonon configurations. Calculations were performed in a consistent way with the ones in neighbouring odd-mass nuclei. The theoretical results were compared with recent experimental data. The calculated spectrum of 0^{+}, 2^{+}, 4^{+}, and 6^{+} states that includes mixing with the two octupole phonon multiplet was related to experimental states up to $E_x = 5230$ keV. The measured excitation strengths are consistent with the predicted fragmentation of the two octupole phonon states [29].

High-spin states of ^{32}S and ^{56}Ni were investigated by the cranking Hartree–Fock method with the Gogny interaction without imposing a restriction on the axial reflection symmetry. It was found that a non-axial octupole deformation of the Y_{31} type becomes important in the yrast states of ^{32}S. A similar effect was predicted for the nucleus ^{56}Ni [30].

In collaboration with experimenters, the implications of the fission modes in the γ-ray multiplicities from fission fragments in the reaction ^{208}Pb(^{18}O, f) were considered. The calculated shapes of the fission fragments helped to explain the observed multiplicities in the symmetric and asymmetric fission and confirmed the interpretation of each of the fission modes as going along its own fission valley. It was concluded that the concept of the valley structure of the potential energy surface is a universal tool for an explanation of properties of both a fissioning nucleus and fission fragments [31].

The problem of bosonization of physical degrees of freedom of a many-body system at finite temperature was considered in the context of the boson expansion method in the framework of the formalism of thermo-field dynamics. The importance of the bosonization of single-boson (fermion) operators in addition to the usual boson (fermion)-pair bosonization was stressed. The leading order results of the expansion for two models, the bosonic O(N) anharmonic oscillator and the fermionic Lipkin model, were derived, and the thermal excitations were shown to comply with both the symmetry and the particle statistics requirements. In the former case, it was also shown that without single-particle mapping the thermal Goldstone excitations were missing from the theoretical spectrum [32]. Hyperdeformed (HD) states were described by dinuclear quasimolecular cluster configurations. They can be formed by heavy-ion reactions. Optimum reaction partners, bombarding energies and angular momenta were selected to find these HD states. A new method to identify the populated HD states was suggested where γ transitions between the HD states are measured in coincidence with the decay of the compound nucleus into the cluster fragments. These experiments would prove whether the HD states can be considered as cluster states [33].

Various problems were investigated within the **few-body physics** project.

A solvable model designed to demonstrate the interplay of the molecular and nuclear resonance widths in a molecule was considered. The model exhibits explicitly the mechanism leading to the enhancement of fusion probability of nuclear constituents of a molecule in the case of a narrow near-threshold nuclear resonance. The case was considered where molecular Hamiltonians are arranged in the form of an infinite n-dimensional ($n \geq 1$) lattice. It was shown that, if the real part of the narrow nuclear resonance lies within a molecular band generated by the intercellular interaction, there exist molecular states which decay exponentially, with a rate inversely proportional to the nuclear width [34].

It was shown that a two-body system with a sufficiently weak inverse square interaction has a bound state with an infinitely large binding energy. To analyze a possible existence of such a collapse in a three-body system, the hyperharmonics method was applied, and three-body Schrödinger and Faddeev equations with two-body in-

verse square interactions were studied. Exact solutions of those equations were constructed as products of a hyperradial Bessel function and a finite linear combination of hyperharmonics. For these solutions, the existence criterion was proved and studied. It was found that the solutions describe the states when the collapse of all the three particles is not possible although the sufficient condition for the two-body collapse is fulfilled for any two-body subsystem [35]. A new dynamic model was developed describing most of the existing pion electromagnetic production data in threshold and resonance regions (Dubna–Mainz–Taipei model, http://www.kph.uni-mainz.de/MAID/dmt/dmt2001.html). In the case of threshold π^0 production, the effects of a final state interaction in the threshold region are nearly saturated by single charge exchange rescattering. This indicates that in ChPT it might be sufficient to carry out the calculation just up to one-loop diagrams for a threshold neutral pion production [36].

A microscopic few-body description of near-threshold coherent photoproduction of the η meson on ^{3}H and ^{3}He nuclei was given. The photoproduction cross-section was calculated with equations of the Finite Rank Approximation (FRA) by taking account of all orders of the elementary ηN interaction. Results of FRA indicate the strong final state interaction of η meson with the residual nucleus, producing fast grow of the cross-section. Sensitivity of the cross-section to the $\eta N \to \eta N$ and $\gamma N \to \eta N$ amplitudes was investigated [37].

The main results of the **relativistic nuclear dynamics** project are as follows.

The high-energy approximation was adapted for the nucleus-nucleus scattering at energies of several dozens of MeV/nucleon. It was shown that the closed form of the eikonal phase derived for the realistic Woods–Saxon type potential is hopeful for further applications. The differential elastic and total reaction cross-sections comply well with the results of corresponding numerical solutions of the wave equation. The nuclear surface plays an important role in the formation of elastic and reaction cross-sections. The origin of a continuous ambiguity in optical potential parameters was revealed in interpreting total cross-sections [38]. It was established that the isoscalar-isovector ($\rho-\omega$) interferences in the exclusive reactions $\pi^- p \to ne^+e^-$ and $\pi^+ n \to pe^+e^-$ near the ω threshold lead to an obvious difference in dielectron invariant-mass distributions depending on the beam energy. The strength of the predicted effect is determined by the coupling of resonances to the nucleon vector-meson channels and other resonance properties. Therefore, the found effect can be used as a powerful tool to study the baryon resonance dynamics. The effect can be tested by measuring the angular distribution of decay particles in reactions of the type $\pi N \to NV \to Ne^+e^-$, which are accessible with the pion beam at the HADES spectrometer at GSI, Darmstadt [39].

Dynamics of partons created through vacuum tunneling in a time-dependent spatially homogeneous field was studied for typical conditions of ultrarelativistic heavy-ion collisions. A coupled self-consistent set of equations consisting of the Vlasov-like kinetic equation with a source term, derived on the dynamic basis, and the renormalized Maxwell equation, accounting for the back-reaction mechanism, were solved numerically. Clear signals of a stochastic nature were found in temporal oscillations of the parton distribution function for phase space cells and in essential irregularity of momentum spectra at a later time. If the back reaction is neglected, these features vanish completely, and oscillation dynamics takes an ordinary regular form [40].

THEORY OF CONDENSED MATTER

Theoretical investigations in the theory of condensed matter were continued in the framework of the following projects:

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

Main results in the problem of **strongly correlated systems** were obtained in the investigation of the electronic spectrum and mechanisms of superconductivity in copper-oxide materials and in studies of magnetic properties of materials with complicated phase transitions like manganites.

A theory of superconducting pairing mediated by antiferromagnetic exchange was developed to explain a strong variation of the superconducting temperature with the lattice constant recently discovered in mercury superconductors. Calculations were performed within the two-band Hubbard model in the limit of strong correlations. Retardation effects are unimportant due to a large excitation energy at antiferromagnetic exchange of pairs of electrons from different Hubbard subbands, which results in the pairing of all electrons in the conduction band and a high superconducting temperature. The oxygen isotope effect is caused by a variation of the exchange interaction with the zero-point oxygen ion vibrations [41].

Spin dynamics was calculated in the ferromagnetic state of manganites within the generalized Kondo lattice model with taking account of strong on-site correlations

between itinerant electrons and antiferromagnetic exchange between localized spins. It was shown that spin excitations have a conventional Dq^2 spectrum in the long-wavelength limit, whereas a strong deviation from the spin-wave spectrum of the isotropic Heisenberg model is observed close to the zone boundary in accordance with recent experiments [42].

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

A new kind of integrable stochastic processes was proposed to describe one-dimensional avalanche dynamics in dissipative systems. The Bethe-ansatz method and an iterative procedure based on a detailed balance were used to obtain exact results for an asymmetric avalanche process on a ring. The average velocity of particle flow, v, was derived as a function of the toppling and the density of particles ρ. As ρ increases, the system shows a transition from the intermittent to continuous flow, and v diverges at a critical point ρ_c with exponent α. The exact phase diagram of the transition was obtained, and α was found to depend on the toppling rules [43].

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

The electronic structure of graphitic cones was investigated within the self-consistent field-theoretical model. The local and total densities of states (DOS) near the apex were calculated for cones of different opening angles. The total DOS was found to vanish at the Fermi level at any opening angles except for 60° where a local metallization of graphite occurs [44].

The problem of both the phonon and electron scattering by long-range strain fields caused by wedge disclination dipoles (WDD) was studied. The WDD-induced contribution to the residual resistivity in nanocrystalline metals was estimated. Phonon scattering due to randomly distributed WDDs was shown to result in the clear crossover from T^3 to T^2 behaviour in the thermal conductivity, κ, at low temperatures. The results are in a good agreement with the experimentally observed κ in a-SiO_2, a-GeO_2, a-Se, and polystyrene [45].

Contribution to the specific heat of crystals due to pinned twist disclinations was studied. To this end, the model of heterogeneous string was formulated for vibrating disclinations. The specific heat due to twist disclinations was found to be a linear function of the temperature and defect density. The frequency-dependent loss due to twist disclinations was studied by treating the disclination as a damped oscillating heterogeneous string. It was found that the decrement has a resonant type behaviour. The internal friction was predicted to be proportional to the fourth power of disclination length, which could be tested in experiments with rotationally disordered crystals [46].

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

Investigation of the Bose–Einstein condensation (BEC) in optical atomic traps has recently become one of the main trends in the study of quantum fluids and solids. The estimates of the balance between the kinetic and potential energies of trapped atoms at almost zero temperatures were obtained [47]. The physical reasons for positive and negative values of the scattering lengths of atoms due to the interaction between them were discussed. The conditions were formulated for each of these regimes which can be observed experimentally.

As the potential barriers of traps are very small ($\sim 10^{-9}$ eV), the atoms in traps are sensitive to the presence (or absence) of a gravity. The shift of a critical BEC temperature provided in the atomic trap by the gravitational field was estimated [48]. This result concerns the recent NASA project of new precise physical experiments in the outer space.

COMPUTER FACILITIES

For the first time at BLTP, the server with two processors Athlon with clock rate 1.2 GHz was installed (http://thsun1.jinr.ru/guide/athlon). Peak productivity of 4.8 GFlops and 1 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, and Mathematica. The server is running license manager providing up to 30 licenses for Mathematica for Windows running on PC at JINR.

In 2001, 24 modern personal computers based on Pentium-III were acquired and installed. Installation of new hard disks in the main BLTP computer (thsun1.jinr.ru) allowed one to increase the user disk space twice and to speed up the read/write operations. The system software and some applications were renewed on the Sun cluster. The user disk space on the file server TFS was doubled.

The central stack of network switches at BLTP was extended to 120 ports. Migration to Fast Ethernet on workplaces was continued. Now all the servers at BLTP and about 80 most powerful PC are connected to the Fast Ethernet.

The proxy-caching server and software archive (http://thsun1.jinr.ru/guide/web/) were moved to the new dual-processor PC server operating under Linux. This work was supported by the Russian Foundation for Basic Research (RFBR).

MEETINGS, SCIENTIFIC COLLABORATION

In 2001, the Laboratory participated in 10 international conferences, workshops and schools, held in Dubna, Karpacz, Prague, Yalta and Yerevan.

The IX international conference «Supersymmetry and Unification of Fundamental Interactions» (SUSY '01) was held in Dubna on 11–17 June. This event happened to be the first of this series in the new millennium and marked the 30th anniversary of supersymmetry. The first conferences on supersymmetry were organized in the USA and soon they transformed into wide forums devoted to physics beyond the Standard Model of fundamental interactions in one of the most urgent directions. They are now organized annually on both the sides of the Atlantic Ocean. In 2000, this conference was held at CERN in anticipation of SUSY discovery at the LEP collider. At last, SUSY '01 has reached Russia as if paying tribute to the motherland of supersymmetry in the jubilee year. Practically all the key problems of particle physics as well as related problems of mathematical physics were covered at the Conference. A high scientific level of the talks, attendance of the leading scientific centres, a wide geography of participants, and a large percentage of young people confirm the vitality of the topic of the conference demonstrating the recent achievements in theoretical and experimental areas. The next conference of this series, SUSY '02, will take place at DESY (Hamburg) in the summer of 2002. The Conference was organized under the financial support from UNESCO, RFBR, RAS, JINR and the Heisenberg–Landau and Bogoliubov–Infeld Programmes.

The International Workshop «Quantum Gravity and Superstrings» and at the same time School «Noncommutative Geometry and Field Theory» were held at the Bogoliubov Laboratory on 18–28 June. The number of participants came up to a total of about 90 from many countries, including 25 participants from JINR. Among the delegations from Germany, Poland and Russia there were students: 7, 2 and 10, respectively. The scientific programme of the Workshop and School covered the following topics: noncommutative geometry and field theory; M-theory and strings; extra dimensions and branes; integrable models in quantum gravity and gauge theories. It was organized in a way of one-hour lectures, which were either reports on the modern developments in the fields related to the above-mentioned topics or introductory lectures to some of these subjects. As a result, the programme was interesting for both the researchers working actively in these fields and the young people who only start their own work in the topics discussed during the Workshop. The organizing committee expressed hope that such a combined workshop/school would become regular. The Workshop and School were supported by BMBF (Germany), INTAS, RFBR, UNESCO, Heisenberg–Landau and Bogoliubov–Infeld Programmes.

On 20–30 August the International Summer School «Dense Matter in Particle- and Astrophysics» was held in Dubna. It was supported by the Federal Ministry for Education, Research and Technologies and Deutcher Akademischer Austauschdienst (DAAD) in the framework of the new DAAD programme «Export of German Academic Training». Participants of the School were professors and students from Argentina, Armenia, Germany, Portugal, Russia, the Ukraine, the USA, and other countries. The programme of the School included lectures and review talks on nonperturbative QCD phenomena, QCD phase structure and on nonequilibrium processes relevant to heavy-ion collisions and astrophysics. Such summer schools to be held in Dubna were initiated by professors of Rostock University. The next school within this programme will be held in Dubna in the summer of 2002 on the subject «Quantum Statistics of Many-Particle Systems».

The Laboratory participated in the organization of a number of meetings in the JINR Member States: X International Colloquium «Quantum Groups and Integrable Systems» (21–23 June, Prague, Czech Republic); International Workshop «Symmetries and Spin» (15–28 July, Prague, Czech Republic); IX International Conference «Symmetry Methods in Physics» (3–8 July, Yerevan, Armenia); International Workshop «Supersymmetries and Quantum Symmetries» (17–21 September, Karpacz, Poland); International Conference «New Trends in High Energy Physics» (22–29 September, Yalta, Crimea, the Ukraine).

In 2001, 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; with Polish theorists, on the Bogoliubov–Infeld Programme; and with Czech theorists, on the Blokhintsev–Votruba Programme.

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.

The agreements for collaboration between the Bogoliubov Laboratory and CERN TH, ICTP are functioning.

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LABORATORY OF HIGH ENERGIES

In 2001 the scientific programme of the Laboratory of High Energies (LHE), as in previous years, was concentrated on investigations of interactions of relativistic nuclei in the energy region from a few hundred MeV to a few TeV per nucleon to search for manifestation 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 [1–3]. Experiments along these lines were carried out with the beams of the LHE accelerator complex as well as of other accelerators at CERN, BNL, GSI, at CELSIUS storage ring in Uppsala (Sweden) and others.

The LHE accelerator complex includes the old machine, Synchrophasotron, and the new superconducting accelerator, Nuclotron. During several years the LHE research programme has been performed mostly at the Nuclotron, and the Synchrophasotron has been used practically only for the research with polarized particles beams. The Nuclotron is based on the unique technology of the superconducting magnetic system, which was proposed and investigated at the Laboratory [4]. In the near future it is planned to obtain polarized beams at the Nuclotron, too. During the next two years the LHE research programme will be carried out at the Nuclotron.

ACCELERATION COMPLEX DEVELOPMENT

During 2001 the Laboratory had three Nuclotron runs of 1280 hours totally. These runs obtained good external beams of boron (^{10}B, $I \approx 1 \cdot 10^5$ particles per cycle), carbon (^{12}C, $I \approx 8 \cdot 10^9$ particles per cycle) and magnesium (^{24}Mg, $I \approx 1 \cdot 10^7$ particles per cycle) ions. The profiles of the carbon and magnesium extracted beams are presented in Fig. 1. The amplitude spectrum from the scintillation counter in the boron beam is shown in Fig. 2.

A high intensity of the deuteron and proton extracted beams (up to $3.5 \cdot 10^{10}$ particles per cycle) with efficiency of the extracted beam near 100 % was also obtained. The time structure of the extracted beam was improved substantially.

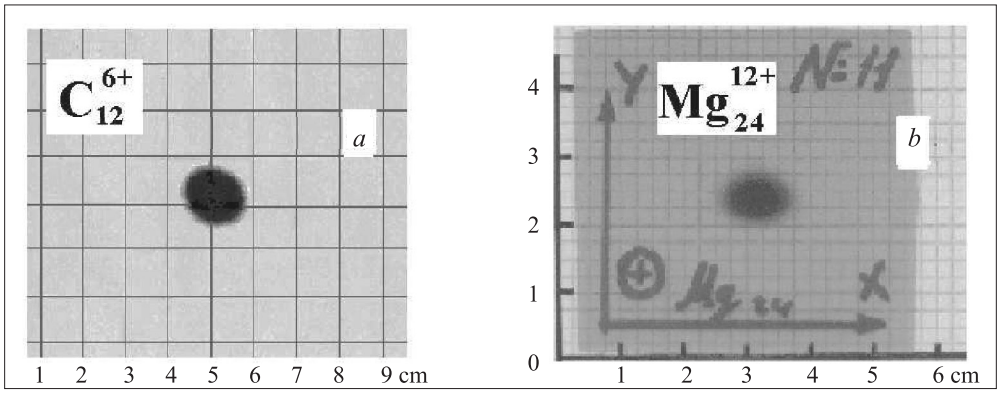


Fig. 1. The profiles of the Nuclotron extracted beams of carbon (*a*) and magnesium (*b*) ions. Run No. 19, March 2001

The Nuclotron consumption of liquid nitrogen was reduced by more than half and this achievement has given a possibility to perform long runs. Thus the last Nuclotron run in November–December 2001 lasted more than one month. Very good information for both physics and applied research was obtained during this run.

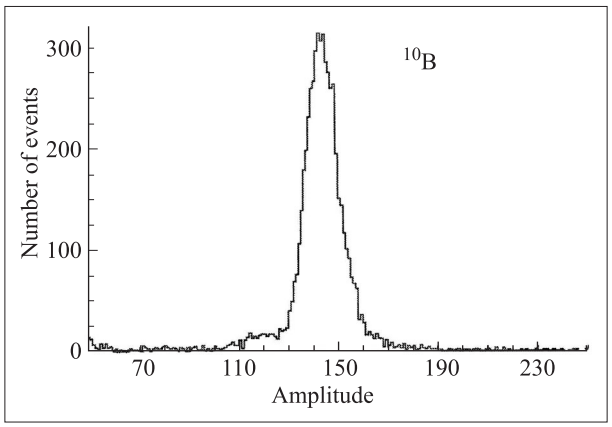


Fig. 2. The amplitude spectrum from the 8-mm scintillation counter in the ^{10}B beam of the Nuclotron. Run No. 22, December 2001

The total running time of the Synchrophasotron was limited by 580 hours. In 2001, 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 the continuous rise of the electricity cost, the number of users permanently increases. First of all, these are the polarized beam users. The interest of the users to the traditional beams of light nuclei is still great.

The development of the fast-cycling superconducting magnet technology by using the Nuclotron magnets as prototype for the GSI future accelerator was continued. In the framework of the LHE–GSI agreement, six test runs were performed with different modified magnets (a new yoke and two new superconducting coils). Tests of two prototype magnets with the yoke at 80 K temperature were also carried out.

EXPERIMENTS AT THE NUCLOTRON BEAM

In 2001 the external and internal beams of the Nuclotron were used for investigations by various physical groups. In March and December the ^{24}Mg beam was used by the Italian group for the Pamela collaboration.

Two methodical runs at the external deuteron beam of the Nuclotron were carried out at the **STRELA** set-up. The main result is a good amplitude resolution (9 %) obtained for a separate Cherenkov counter with the radiator of sapphire, which will allow selection of two-proton events at the level of 10^4 background one-proton cases. It should basically allow one to solve the project's problem of definition of a spin-dependent part of $np \rightarrow pn$ process in *dp* interactions. It is necessary to obtain the extracted beam of a small cross-section (less than 1 cm in diameter) and uniform time structure. It is also necessary to use the liquid hydrogen target and to improve the geometry of the experiment.

A lot of experimental data to study the radioactive waste transmutation were obtained by the Dubna–Marburg–Strasbourg–Jülich–Thessaloniki–Sydney collaboration at the **GAMMA-2** set-up during the November Nuclotron run.

The nuclear emulsions were irradiated with the beam of ^{10}B ions for the EMU01 collaboration during the December Nuclotron run. The laser source of ions and initial sample LaB_6 were used to obtain the beam of boron ions.

Groups of the **SCAN-1** set-up and MARUSYA collaboration continued investigations at the internal Nuclotron beams. The SCAN-1 group obtained new data on cumulative production of narrow proton pairs in interactions of accelerated *p*, *d*, He, C with heavy targets.

The polarimeter for the Nuclotron was assembled at the internal target. It consists of symmetrical left-right detector arms (Fig. 3). The set-up was tested in the course of the December Nuclotron run by using the deuteron beam with an energy of 1.2 GeV/nucleon. The primary intensity of the beam was 10^9 ions per cycle. The time spectrum was measured from the both arms for the carbon and polyethylene targets. The clear separation of the elastic *pp* scattering process was obtained.

Under the project «**Crystal-W**», work was done on preparation for research of crystalline deflectors at the extracted beam of nuclei from the Nuclotron. Test experiments with a crystal in the extracted beam's direction were carried out. It is essential that the background conditions should be improved.

The group of the **MARUSYA** set-up obtained new data on production of secondary nuclear fragments as a result of interactions of the internal Nuclotron beam with nuclear targets. These data are very important for studying such a phenomenon as full destruction of nuclei, which was discovered at the Laboratory by Professor K. D. Tolstov's group.

For the first time at the internal beam of the Nuclotron the calibration of measurement under the programme of search for η nuclei was carried out in a joint experiment of LHE and LPI, RAS.

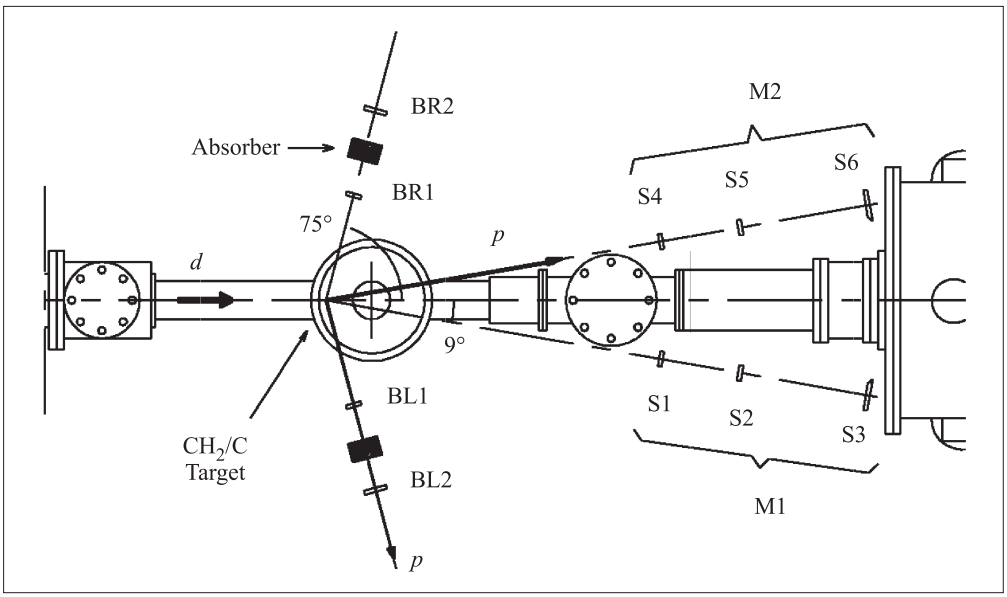


Fig. 3. The scheme of the polarimeter

EXPERIMENTS AT THE SYNCHROPHASOTRON

In 2001 two Synchrophasotron runs of about 580 hours were performed. Two main experiments were carried out.

The first experiment was related to obtaining new data of the **DELTA–SIGMA** collaboration to investigate the energy dependence of the *np* spin-dependent cross-section difference $\Delta\sigma_L(np)$ at neutron beam kinetic energies of 1.4, 1.7, 1.9 and 2.0 GeV. The DELTA–SIGMA collaboration includes physicists from Bulgaria, Czech Republic, France, Russia and the Ukraine. Specialists from the Laboratory of High Energies, the Laboratory of Nuclear Problems and the Laboratory of Neutron Physics participated in this experiment. The value of $\Delta\sigma_L(np)$ was measured as difference between the *np* total cross-sections for the parallel and antiparallel beam and target polarization, both oriented along the beam momentum in the longitudinal (L) direction.The polarized neutrons were transmitted through a large proton polarized target. The preliminary results of the DELTA–SIGMA experiment, obtained in 2000, together with the published results [5, 6], are presented in Fig. 4.

One of the participants of this experiment from France Professor F. Lehar wrote the following words about the last Synchrophasotron run: «My feeling is that the measurements of $\Delta\sigma_L(np)$ have been completed. It would have been a pity not to determine $\Delta\sigma_T(np)$ now when the coils exist at the Laboratory of High Energies».

The second experiment was devoted to measuring the analyzing power of the reaction $p\uparrow+CH_2 \rightarrow p+\ldots$ for momenta of 3.8, 4.5, 5.3 GeV/c. The **ALPOM** set-up (hybrid of the ALPHA set-up and the POMME polarimeter, brought from France) measured the analyzing power of blocks of polyethilene of different width in the beam of polarized protons obtained from stripping of accelerated vector-polarized deuterons.

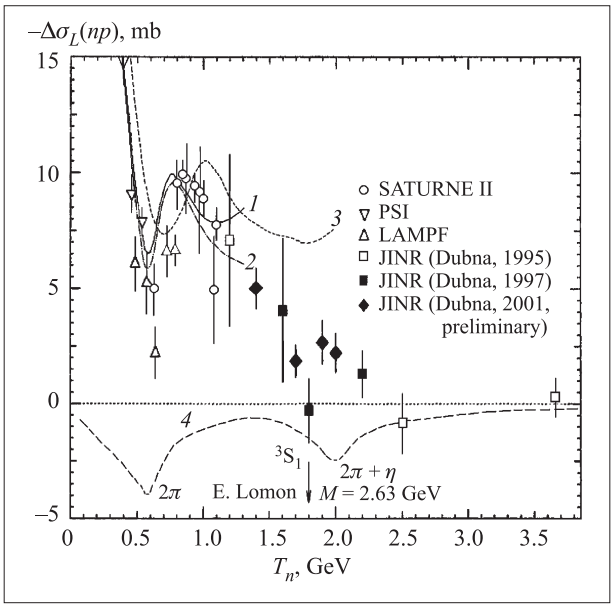


Fig. 4. Energy dependence of the $\Delta\sigma_L(np)$ observables obtained with the polarized neutron beam. The new 2001 points were measured at neutron beam kinetic energies of 1.4, 1.7, 1.9 and 2.0 GeV. Curve *1* denotes GW/VPI PSA Solution FX98, *2* — GW/VPI PSA Solution SP99, *3* — Meson Exchange, *4* — Non-perturbative QCD contribution

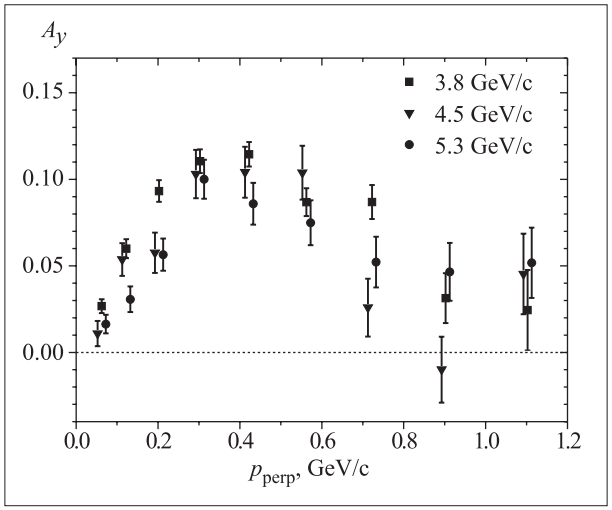


Fig. 5. The results of measuring the analyzing power of the reaction $p\uparrow + CH_2 \rightarrow p+\ldots$ for momenta of 3.8, 4.5, 5.3 GeV/c

Following the approval by the JINR PAC in April 2001, the Laboratory of High Energies began measurements of the proton analyzing powers of CH_2 for momenta of up to 5.4 GeV/c in a collaborative effort involving physicists of LHE (N. Piskunov, I. Sitnik, D. Kirillov and Y. Mushinsky), from Saclay (E. Tomasi-Gustafsson) and from the USA (V. Punjabi (Norfolk State University), M. K. Jones (Jefferson Lab/CEBAF), C. F. Perdrisat and L. Pentchev (College of William and Mary) and G. Kumbartzki (Rutgers University)).

A part of the POMME polarimeter, previously working at the Laboratoire Nationale Saturne, was tested in Saclay (France) and transported to Dubna, on the basis of the Cooperation Agreement for common studies of polarization phenomena, which was signed between the CEA/DSM (Saclay) and JINR. Within a very short time interval three proportional chambers of dimensions 50×50 cm and three large scintillators, equipped with electronics and a gas system, were incorporated into a new polarimeter located at the ALPHA set-up beam line.

Although the time was very short, in 36 hours of data taking the group of researchers obtained the analyzing power data at 3.8 and 5.4 GeV/c already in June 2001.

Following this early success, they requested and were granted four days more to do a systematic study of the analyzing power as a function of the analyzer thickness. Between the preliminary run in June and the run in October, the set-up was improved in several ways, which resulted in the data acquisition rate increased by an order of magnitude. The group also set up six planes of drift tubes chambers shipped from Virginia (the USA) to create an independent and permanent polarimeter at LHE, which will be used in several beam lines. These drift tubes chambers will stay at LHE as a contribution from the USA part of the collaboration; the required readout electronics is included in this transfer of the equipment between the Laboratories.

During the run this group carried out systematic measurements at three proton momenta, 3.8, 4.5, and 5.3 GeV/c, with different thicknesses of the CH_2 absorber. Very interesting results were obtained. They have shown two features that are important for the design of a large-size polarimeter at the Jefferson Lab/CEBAF. First, the group has demonstrated that for 3.8 GeV/c protons the analyzing power is independent of the amount of material in the analyzer, from 40 to 85 cm; this is a very important feature for the design of future high-energy polarimeters. Second, they could demonstrate that the analyzing power for 5.3 GeV/c protons had decreased only a little from its 3.8 GeV/c value for the CH_2 analyzer. This validates a proposal to build at Jefferson Lab a new polarimeter consisting of large-dimension drift chambers, which will be built at LHE. This polarimeter will be used first to measure the ratio of the electric and magnetic form factors, G_{Ep}/G_{Mp}, of the proton up to an invariant four-momentum transfer of 9 GeV^2. This proposal was approved with priority A (the highest) by the Jefferson Lab Programme Advisory Committee in July, in part on the basis of the preliminary results obtained here in June. Two previous measurements, in Hall A at the Jefferson Lab, of G_{Ep}/G_{Mp} have shown that the Q^2 dependence of the two form factors of the proton is very different, in contradiction to previous results from many different laboratories; the JLab results have triggered an intensive re-examination of various theoretical models of the proton.

The final results will be published after the completion of data processing. Physicists from France, the USA, Bulgaria participate in this run. Preliminary results of this experiment are presented in Fig. 5.

Research continued within the framework of the **SPHERE** collaboration (Dubna–Nagoya–Sofia). One of the motivations to measure analyzing powers at deuteron fragmentation into cumulative pions was a possibility to extract new information about the deuteron structure at small distances, which takes the meson and spin degrees of freedom in the deuteron into consideration.

The measurements of tensor and vector analyzing powers in the reaction $\mathbf{d}+A \rightarrow \pi(\theta)+X$ were carried out with 9 GeV polarized deuterons slowly extracted from the Synchrophasotron. At the fixed deuteron momentum $p_d = 9$ GeV/c the pion momentum p_π was varied from 3.5 to 5.3 GeV/c at $\theta_\pi = 0°$ to cover the range of the cumulative variable x_c from 1.08 to 1.76. In the framework of the DPM mechanism, x_c can be related to the minimum nucleon momentum in the deuteron, k_{min}, that is needed to produce a pion with the cumulative number x_c. The data for the tensor analyzing power A_{yy} of the reaction $\mathbf{d}+A \rightarrow \pi+X$ as a function of x_c and k_{min} are shown in

Fig. 6 (at zero angle A_{yy} is related with T_{20} defined in a spherical form as $A_{yy}(0°) = -T_{20}\sqrt{2}$).

Comparison of the 0° data and the direct mechanism calculations («PARIS DWF» curve) has shown that $A_{yy}(0°)$, contrary to IA predictions, has the negative sign and slowly increases with rise of x_c without any peculiarity near $k \cong 0.3$, where *D*-state effects are maximum in the deuteron breakup $dA \to pX$. Analyzing the $dA \to \pi X$ data obtained at H, Be, and C targets, A_{yy} was found to be independent of the mass number *A*, which confirms the fact that the behaviour of cumulative spectra is governed by the inner structure of nucleus fragments.

To study the angular dependence of A_{yy}, measurements were made at $\theta_\pi = 135$ and 180 mrad as well. The measurements were taken in the wide range of pion momenta from 2 to 5 GeV/c to cover both precumulative ($x_c < 1$) and cumulative ($x_c > 1$) regions. The sign of A_{yy} in the cumulative region is negative at all angles of $\pi^{\pm}$ emission. As the pion transverse momentum P_T increases from 0.4 to 0.8 GeV/c, the tensor analyzing power rises from a value near zero at $x_c \cong 1$ to $A_{yy} = -0.4$ at $x_c = 1.4 \div 1.6$.

The large *D*-state effect is observed at fragmentation of tensor-polarized deuterons into cumulative pions. It cannot be explained with the hypothesis of the direct mechanism of pion production by high-momentum nucleon component in the deuteron. Thus one can conclude that a meson cloud of the deuteron core cannot be reduced to superposition of meson clouds of quasi-free nucleons. So, we have got substantially new information about the features of the meson component at short internucleonic distances in nuclei. The new data of spin-dependent observables can be used for a more profound study of the structure of the meson-exchange and quark-exchange currents at short-range *NN* interactions.

The SPHERE collaboration expects to continue the study of A_{yy} in extended x_c and P_T regions, and to study the energy dependence $A_{yy}(E_d)$. Any new information on spin effects in polarized deuteron fragmentation into pions and into heavier mesons is extremely desirable be-

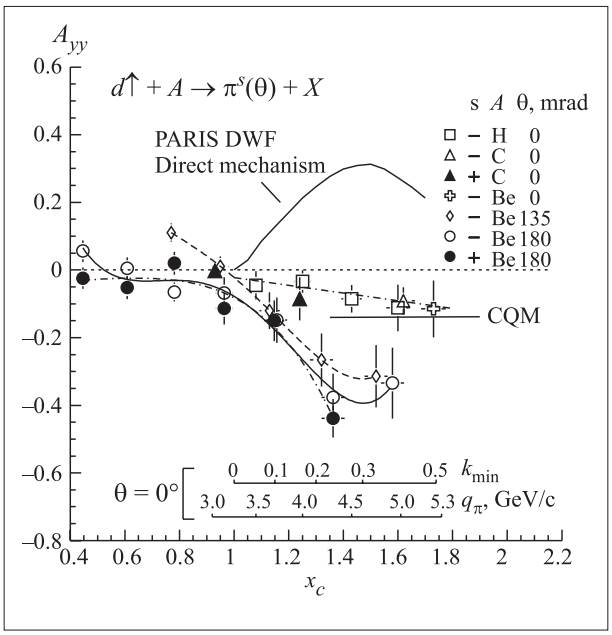


Fig. 6. A_{yy} vs x_c at fragmentation of 9 GeV deuterons at H, Be, and C targets [7]. The scales of pion momenta, q_π, and of minimum internal momenta, k_{min}, are drawn for $\theta = 0°$. CQM is the estimation of A_{yy} by the constituent quark model [8]. The non-marked curves present polynomial fits of 135 and 180 mrad points

cause it may contribute to understanding the deuteron core structure at the quark level.

Using a ^{6}Li nucleus beam extracted from the JINR Synchrophasotron at a momentum of $2.67\,A$·GeV/c, a secondary beam was produced with a composition of 1 % of ^{6}He and 99 % of ^{3}H nuclei. Preliminary results on the features of the nucleus-nucleus interactions of ^{6}He nuclei and charge exchange (CE) of ^{3}H nucleus are obtained. Interactions of ^{6}He nucleus external neutrons with emulsion nuclei as well as a coherent stripping of ^{6}He nucleus external neutrons are observed. A mean range of ^{3}He nu-

Fig. 7. Event of ^{6}He nucleus interaction with fragmentation into α particle. The α-particle track is followed until inelastic interaction

clei to inelastic interactions in emulsion is equal to 23.7 ± 3.0 cm (Fig. 7). A mean range in emulsion for a nuclear CE process ${}^3\mathrm{H} \to {}^3\mathrm{He}$ is equal to 40 ± 16 m. The CE cross-sections with a charged meson production or without it are approximately equal. The CE cross-section with excitation of a target nucleus exceeds the one without excitation. The mean transverse momentum of ^{3}He nuclei is equal to 0.16 ± 0.03 GeV/c.

Some new results obtained at the Synchrophasotron during previous runs were published in 2001 [6, 9, 10, 23, 24].

THEORETICAL RESEARCH AND INTERPRETATION OF THE EXPERIMENTAL DATA

The spin correlations at the detection of nonfactorizable two-particle spin states were analyzed for the system of two particles with spin 1/2. The appearance of these correlations is connected with the general quantum-mechanical effect predicted by Einstein, Podolsky and Rosen. In the presence of the spin correlations the scattering of one of two unpolarized final particles results in the polarization of the other (unscattered) particle, produced in the same collision event. The correlations of the scattering planes for two particles scattered on spinless or unpolarized targets after their joint production were studied [11].

Theoretical analysis has been performed of analogous spin correlations in the system of two unstable spin-1/2 particles, by using their asymmetric (violating space parity) decays [11,12]. It has been shown that the corresponding spin correlation tensor can be determined from the angular correlations of the decay analyzers, particularly, for two Λ particles both decaying into the channel $\Lambda \to p\pi^-$ — from the correlations of the momentum directions of the decay protons in the respective rest frames of two Λ particles. The difference in the properties of this tensor for factorizable and nonfactorizable two-particle states was investigated. The inequalities for linear combinations of the components of the correlation tensor were established for the case of incoherent mixtures of factorizable two-particle spin states. The spin correlations for these mixtures have the classical character. The «incoherence» inequalities include the well-known Bell inequalities and can be violated for nonfactorizable coherent superpositions of two-particle spin states. The violation of these inequalities is the result of the quantum correlations, and it can serve as a crucial test of the principles of quantum mechanics for two-particle systems. The possibility to verify the consequences of the quantum-mechanical coherence was analyzed by using the angular correlations in the parity-violating decays of the pairs of spin-1/2 particles (muons, tau-leptons, top-quarks or Λ hyperons). The two-particle coherence arises either due to the production dynamics or to the effect of quantum statistics at small relative momenta. It has been shown that in the processes e^-e^+, $q\bar{q} \to \mu^-\mu^+$, $\tau^-\tau^+$, $t\bar{t}$ the fermion pairs are produced dominantly in the nonfactorizable triplet states, in which the «incoherence» inequalities for the components of the correlation tensor are violated. The spin correlations at the emission of two Λ hyperons with small relative momenta have been considered in the framework of the model of independent one-particle sources. It was shown that the angular correlations between the proton momenta in the rest frames of two Λ particles are expressed through the fractions of the singlet and triplet states, and these fractions depend on space-time parameters of the region of the Λ-hyperon generation. When the momentum difference tends to zero, the $\Lambda\Lambda$ system is produced only in the singlet state (the total spin $S = 0$). The conditions of the violation of one of the Bell inequalities in this situation have been analyzed [11,12].

The relations for the angular correlations between the momentum directions of the decay products of two unstable particles with spin 1/2 were generalized for the decays of two resonances with arbitrary spins. The angular correlations in the decays of two identical particles with close momenta were investigated by using the model of independent one-particle sources emitting unpolarized unstable particles with a nonzero spin. These angular correlations reflect the spin correlations conditioned by the effects of the quantum statistics and the final state interaction. The general phenomenological theory of the angular correlations in the decays of any two arbitrarily polarized particles (resonances) was constructed in terms of the multipole production parameters of the system of two unstable particles and the multipole decay parameters [13].

Using the impulse approximation, studies have been made into the polarization effects and the spectrum of relative momenta of two protons at the charge-exchange breakup of the deuteron $d + p \to (pp) + n$ in the forward direction, taking into account the identity, strong and Coulomb interactions of the protons and the contribution of the D-wave state of the deuteron. It is shown that in this process the protons are produced in the singlet state.

APPLIED RESEARCH

Development of the experimental installation «**Energy plus Transmutation**» is continued along with the employment of the beams from the cryogenic accelerator, Nuclotron, increasing the size of the uranium-lead assembly and improving the methods being used in the experiment.

In 2001 the results obtained in the experiments with the 2-section blanket (Synchrophasotron, June 2000) and 4-section blanket (Nuclotron, December 2000) at a proton energy of 1.5 GeV were processed. Space-energy distributions on neutrons and fission fragments in the volume of the uranium-lead assembly, including unfolding of the neutron spectra from experimental data, are studied in these experiments by means of different experimental methods (solid-state nuclear track detectors and activation detectors) [14,15]. The research results indicate that the maximum of the neutron spectra lies above 1 MeV, i.e. fission in the uranium blanket occurs mostly from fast neutrons. The transmutation rate of neptunium-237 and plutonium-239, accumulated in nuclear reactors, is determined by means of the fission process.

Irradiation of a large lead target, surrounded by the 4-section natural uranium blanket, was performed in December 2001 by using the Nuclotron proton beam with a sufficiently high intensity. A large amount of activation (Al, La and U) detectors and threshold (Au, Bi and Co) detectors, solid-state nuclear track detectors with radiators made from uranium (depleted and enriched with uranium-235), «naked» and in combination with cadmium filters, as well as neutron spectrometers based on recoil protons in nuclear photoemulsions, have been exposed in the field of elecronuclear neutrons. Intensive work on experimental data processing has started at JINR's Laboratories, institutes and universities belonging to the Dubna–Marburg–Rez–Thessaloniki–Ulaanbaatar–Swierk–Beijing–Strasbourg–Shillong collaboration.

COOPERATION WITH OTHER SCIENTIFIC CENTRES

LHE continued its involvement in the heavy-ion programme at CERN's SPS. The physicists are involved in the **NA45** (CERES) (spokesperson of JINR Dr Yu. A. Panebratsev), **NA49** (spokesperson of JINR Dr G. L. Melkumov) and **EMU01** (spokespersons of JINR Prof. A. D. Kovalenko and Dr P. I. Zarubin) collaborations running with SPS nuclear beams.

The main results of the **NA45** experiment in 2001 are as follows:

— Analysis of 8 million Pb+Au 1999 data at 40 $A\cdot$GeV has been finished. The enhancement of the e^+e^- pair yield by a factor of 4.7 ± 1.6 in the mass range $m_{ee} > 0.2$ GeV/c^2 was observed [16].

— Analysis of the 2000 data (32 million Pb+Au events at 158 $A\cdot$GeV) is in progress.

— A new method to calculate electric field in the radial Time Projection Chamber (TPC) and alignment of detectors algorithm was developed. The calibration of detectors with a pion data sample was proposed.

The main results of the **NA49** experiment in 2001 are as follows:

— Participation in data taking at the SPS proton beam.

— Data processing and physics analysis:

- for K^+ and K^-, p_T spectra and yields at 40 and 80 $A\cdot$GeV Pb+Pb collisions were obtained [17];
- the energy dependence of K/π ratio was studied [18] (Fig. 8);
- deuteron and proton p_T spectra from central and minimum bias 158 $A\cdot$GeV Pb+Pb data were obtained [19].

In 2001 LHE continued its participation in the preparation of the **ALICE** and **CMS** experiments for LHC.

During the year LHE participated in the design and construction of the Large Dipole Magnet for the Muon Spectrometer. The largest Transition Radiation Detector (TRD) significantly expands the physics objectives of the **ALICE** experiment. The main goal of TRD is to provide electron identification in the central barrel at momenta in excess of 1 GeV/c where the pion rejection via measurement in the energy-loss TRD is no longer sufficient.

A Time Expanded Chamber (TEC) of 40×40 cm, as a small prototype of TRD, has been designed, constructed and tested in laboratory conditions at LHE. R&D work for a full-scale prototype of the TRD readout chamber is in progress (in collaboration with the Physics Institute of Heidelberg University). Specialized areas and equipment for the TRD chambers construction was scheduled to be completed in 2002.

LHE physicists participated in the development of the heavy-ion programme for the **CMS** experiment and, jointly with the Laboratory of Particle Physics of JINR, in

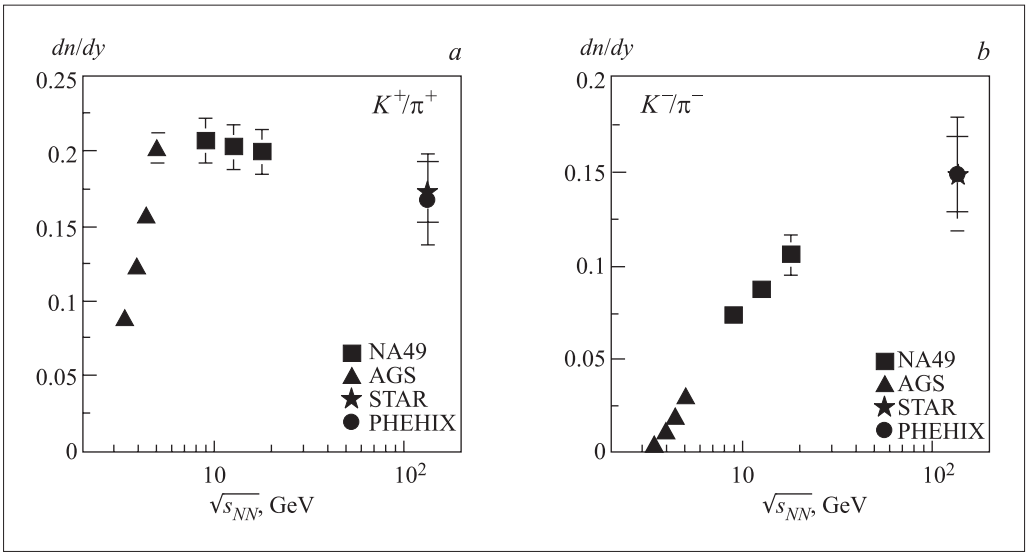


Fig. 8. Energy dependence of K/π ratio in midrapidity region: *a*) K^+/π^+, *b*) K^-/π^-

the preparation of the muon chambers tested by the CMS cosmic ray system. A method of determining the *Z*-bozon source radius production based on the interference effect between two identical muons was proposed for the CMS experiment [20].

Two LHE groups are involved in the **STAR** (spokesperson of JINR Prof. Yu. A. Panebratsev) and **PHENIX** (spokesperson of JINR Dr A. G. Litvinenko) experiments at BNL's RHIC. These groups have participated in the run preparation and data taking at a new nuclear collider RHIC at 130 $A \cdot$ GeV energy.

The main results of the **STAR** experiment in 2001 are:

— LHE group participated in the work on the construction of the Endcap Electromagnetic Calorimeter (EEMC):
  - production of the EEMC tower megatile and Shower Maximum Detector (SMD);
  - fabrication of various mechanical components;
  - production of the EEMC tower PMT and SMD/Preshower (PSD) Multi-Anode PMT «housing», including integrated magnetic shielding;
  - design of the high-voltage control system, realization of the slow control system;
  - assembly of SMD.

— LHE group participated in simulation of the double-spin asymmetry in processes with jet, dijets, prompt photon and gamma-jet production [21].

The HADES (High-Acceptance Di-Electron Spectrometer) project aims at the systematic investigation at SIS, GSI (Darmstadt), of electromagnetic and hadronic in-medium properties of vector mesons in normal and compressed nuclear matter. A strong European collaboration has been installed with GSI for the HADES experiment.

The JINR team has established experience in particle detectors, nuclear electronics and software for data analysis. The JINR group belongs to the main participants of the HADES project and essentially contributed to its design and construction. The technical expertise is on:

— multiwire gaseous detectors with a high spatial resolution;
— front-end and read-out electronics;
— software for simulation and data analysis.

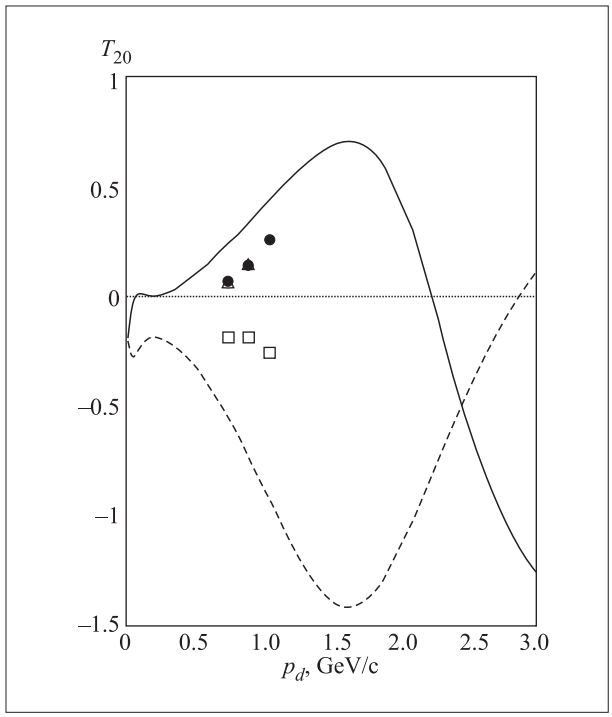
For the HADES spectrometer the group has designed and constructed 7 multilayer low-mass drift chambers for plane 2 (with a spatial resolution of about 70 μm) and front-end analogue electronics. Tracking software for data analysis is under development as well. First experiments for dilepton production in the *CC* (1.5–2.0 $A \cdot$ GeV) reaction were in November 2001. The obtained data is being analyzed.

A 1-D linear detector of thermal neutrons, developed at LHE, is used in the polarized-neutron spectrometer of the IBR-2 reactor [25]. The data are acquired in the multiframe mode of operation. The detection efficiency ($\lambda \sim 2$Å) is better than 70 %, the spatial resolution is ~1.5 mm. A successful three-year operation as part of the SPN spectrometer has demonstrated high suitability of this detector for reflectometry investigations as well as for a small-angle scattering.

A one-dimensional X-ray linear detector has been designed, tested and installed at the Institute of Crystallography, RAS (Moscow). The detector is being used at small-angle X-ray scattering experiments (**SAXS**) in X-ray diffractometer.

The first results from the joint **JINR–RIKEN R308n** experiment (spokesperson of LHE Dr V. P. Ladygin) were obtained in 2001. In this experiment the tensor

Fig. 9. Tensor analyzing power T_{20} in the $d + d \to {}^3\mathrm{H} + p$ (open symbols) and $d + d \to {}^3\mathrm{He} + n$ (solid circles) reactions. The solid and dashed curves show the results of the ONE calculations [22] for the forward and backward emission of ${}^3\mathrm{He}({}^3\mathrm{He})$ in the c.m.s.



analyzing power T_{20} was measured in the $d+d \to {}^3\mathrm{H}+p$ and $d+d \to {}^3\mathrm{He}+n$ reactions (Fig. 9). The sign of T_{20} is positive and negative, when ${}^3\mathrm{He}({}^3\mathrm{He})$ is emitted in the forward and backward directions in the c.m.s., respectively. This fact reflects the sensitivity of the data to the D/S-wave function ratio in the ${}^3\mathrm{He}({}^3\mathrm{He})$ and deuteron. The data obtained for both channels $d+d \to {}^3\mathrm{H}(0°)+p$ and $d+d \to {}^3\mathrm{He}(0°)+n$ within the achieved experimental accuracy are in good agreement. In this experiment the measurements of the tensor analyzing powers A_{yy}, A_{xx} and A_{xz} at 200 and 270 MeV over the full angular range for the $d+d \to {}^3\mathrm{H}+p$ and in the forward hemisphere for the $d+d \to {}^3\mathrm{He}+n$ reactions have also been performed. The data analysis on the angular dependence of these analyzing powers is in progress.

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LABORATORY OF PARTICLE PHYSICS

The activity of LPP in 2001 was concentrated on current particle physics experiments and preparation of new ones, R&D of particle detectors and different acceleration systems.

CURRENT EXPERIMENTS

The **EXCHARM** experiment is devoted to the study of the charmed and strange particle production in neutron-nucleon interactions at the Serpukhov U-70 accelerator. The final results on measuring the cross-sections of the hyperon inclusive production in neutron-carbon interactions have been published [1]:

$$\Lambda^0 \text{ — } (3330 \pm 280)\,\mu\text{b/nucleon},$$

$$\Xi^- \text{ — } (95 \pm 6)\,\mu\text{b/nucleon},$$

$$\Sigma(1385)^- \text{ — } (337 \pm 33)\,\mu\text{b/nucleon},$$

$$\Sigma(1385)^+ \text{ — } (277 \pm 18)\,\mu\text{b/nucleon},$$

$$\Xi(1530)^0 \text{ — } (17 \pm 3)\,\mu\text{b/nucleon}.$$

Preliminary results of measuring the inclusive production cross-sections of anti-hyperons were obtained as well [2]:

$$\bar{\Lambda}^0 \text{ — } (184.3 \pm 11.2)\,\mu\text{b/nucleon},$$

$$\bar{\Xi}^+ \text{ — } (6.04 \pm 0.51)\,\mu\text{b/nucleon},$$

$$\bar{\Sigma}(1385)^- \text{ — } (11.9 \pm 1.3\,(\text{stat.}) \pm 0.9\,(\text{syst.}))\,\mu\text{b/nucleon},$$

$$\bar{\Sigma}(1385)^+ \text{ — } (10.4 \pm 1.9\,(\text{stat.}) \pm 0.7\,(\text{syst.}))\,\mu\text{b/nucleon}.$$

An indication of the destructive correlations of the Λ^0's pairs in the region of small four-momentum has been observed [3].The fist results on the associative $\phi-\Lambda$ and ϕ-kaon production have been obtained [4].

A group of LPP physicists actively participates in the **NA48** experiment at CERN, devoted to the precision measurement of the ratio ε'/ε in CP-violating decays $K_L^0 \to \pi\pi$. The value of the parameter $\mathrm{Re}\,(\varepsilon'/\varepsilon)$ has been measured [5] on the basis of the data recorded during 1997–1999 runs, which is $(15.3 \pm 2.6)\cdot 10^{-4}$ (Fig.1).Thus, the existence of the direct CP violation predicted by the Standard Model (SM) has been confirmed.The LPP group significantly contributed to this analysis. A quadratic slope parameter in the $K_L^0 \to 3\pi^0$ decay Dalitz plot has been measured to be equal to $(-6.1 \pm 0.9\,(\text{stat.}) \pm \pm 0.5\,(\text{syst.}))\cdot 10^{-3}$ [6]. This is the most precise measurement of this slope parameter based on $14.7\cdot 10^6$ fully reconstructed $K_L^0 \to 3\pi^0 \to 6\gamma$ decays. The decay $K_S^0 \to \pi^0 e^+ e^-$ has been searched for by using the data collected in the course of the run with high-intensity K_S^0 beam in 1999. An upper limit for the branching ratio has been obtained as $\mathrm{Br}(K_S^0 \to \pi^0 e^+ e^-) < 1.4\cdot 10^{-7}$ at 90 % C.L. [7]. The test runs to investigate various triggers for charged kaon decays have been carried out in the framework of the preparation for the new, NA48/2, experiment.

A Dubna group has taken an active part in data taking, data analysis and technical maintenance of the system of mini-Drift Vertex Chambers (DVC) of **HERMES** Spectrometer Front Tracking at HERA, DESY, Hamburg.

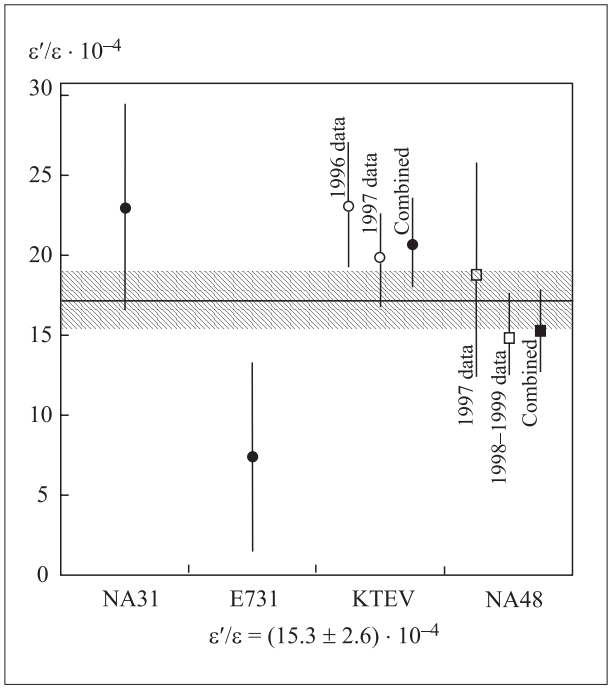

Fig. 1. Experimental measurements of the ratio Re (ε′/ε). The shaded region bounds the world average value with corresponding experimental errors

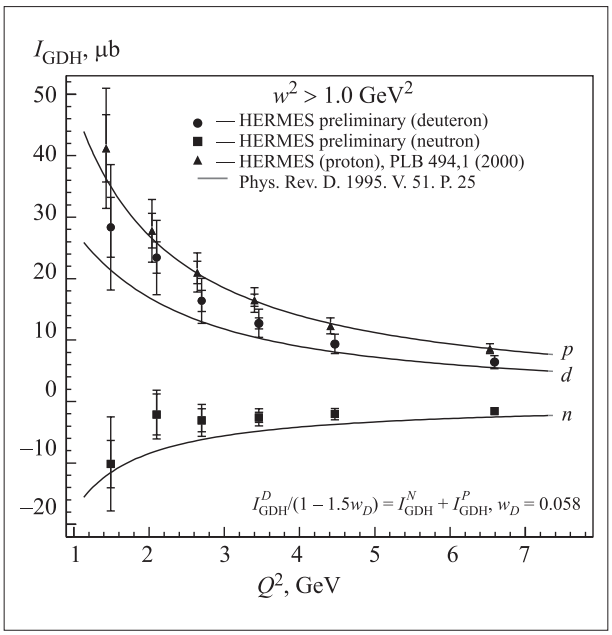

Fig. 2. The GDH integral for proton, deuteron and neutron versus Q^2. The inner (outer) error bars show the statistical (systematic) uncertainties. The curves are predictions based on Q^2 evolution of the structure functions g_1 and g_2 without explicit nucleon-resonance contribution, Soffer-Teryaev model

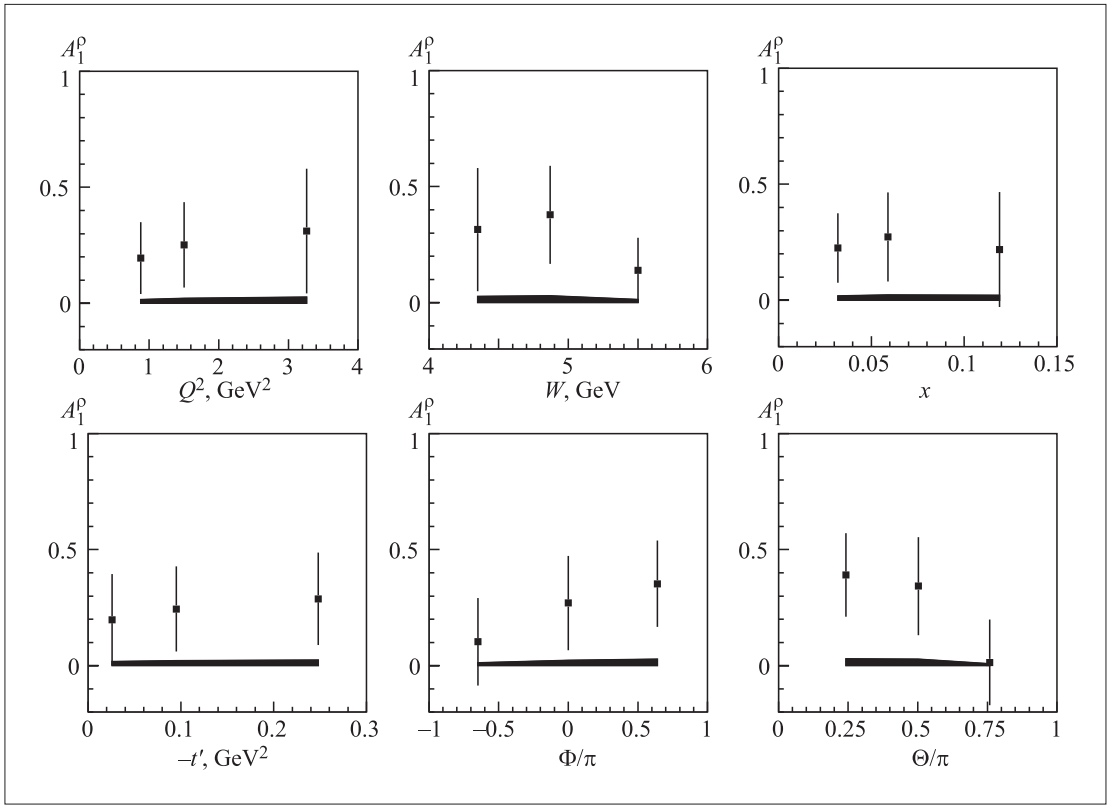

Fig. 3. Photon-nucleon asymmetry A_1 in exclusive ρ^0 production versus Q^2, W, x, $-t$, Φ, and Θ (scattering angles). Error bars and error bands denote the statistical and experimental systematic uncertainties, respectively

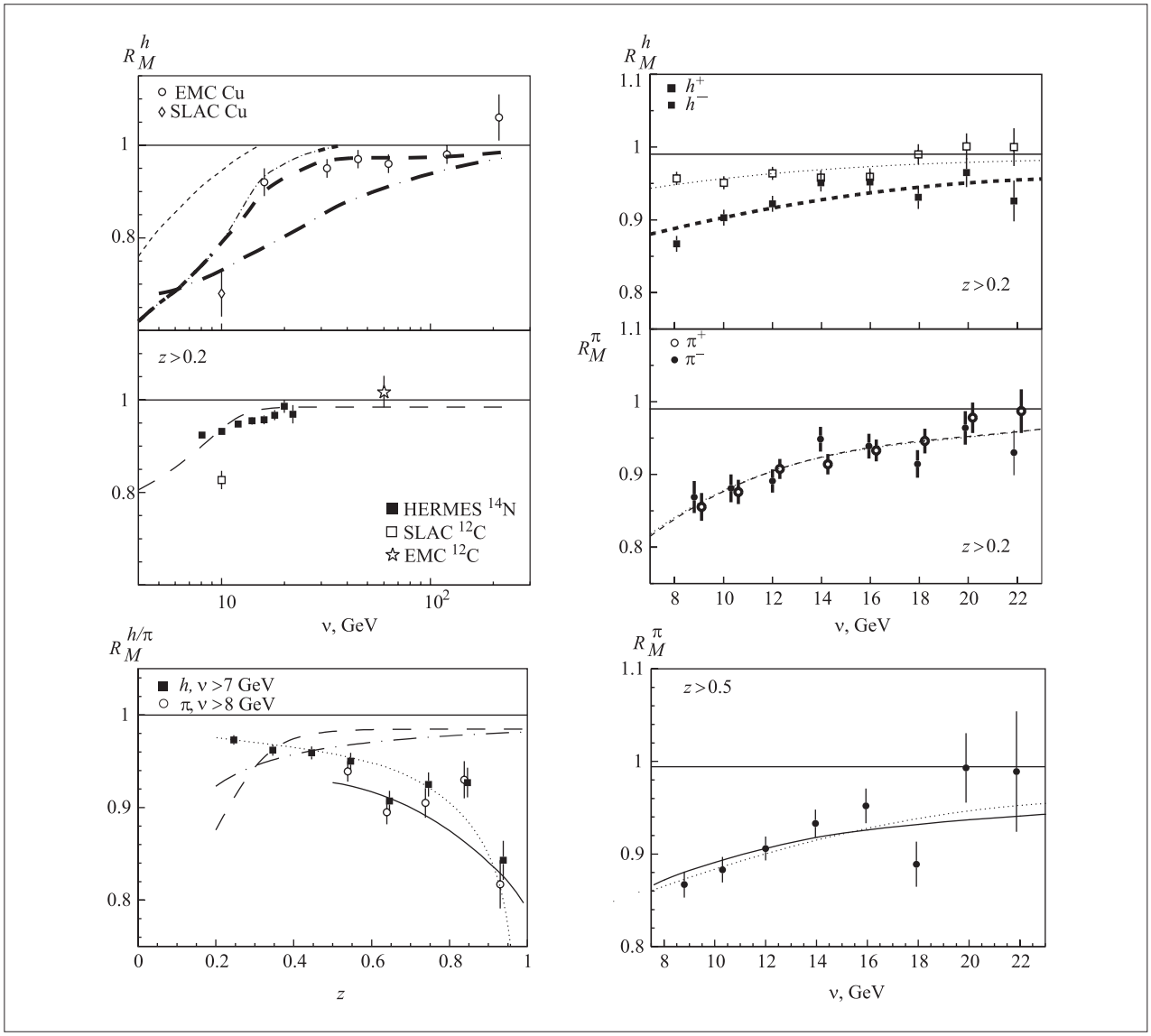

Fig. 4. The multiplicity ratio R_M^I as a function of ν and z for all charged pions (open circles) and all charged hadrons including pions (closed squares). The full curve represents a gluon-bremsstrahlung model calculation for pions. The dotted, dashed and dot-dashed curves represent phenomenological formation-time calculations

During the HERA luminosity upgrade shutdown, the JINR group has started the production of the new DVC.

They also continued the analysis of the HERMES polarized data taken in 1998–2000 to get the Q^2 dependence of the generalized Gerasimov–Drell–Hearn (GDH) integral for the deuteron and neutron [8]. The generalization of the GDH integral to non-zero photon virtuality Q^2 allows one to study the transition from the polarized real photon absorption on the nucleon to the polarized lepton scattering on quarks. The preliminary data are shown in Fig. 2.

The evidence for the positive longitudinal double-spin asymmetry has been observed in the cross-section for exclusive diffractive ρ^0 production in polarized lepton-proton scattering [9] (Fig. 3). The averaged value of the double-spin asymmetry was found to be 0.24 ± 0.11(stat.)± 0.02(syst.). The ratio of this result to the corresponding spin asymmetry in inclusive deep-inelastic scattering (DIS) is in agreement with the theoretical prediction based on the generalized vector meson dominance model.

The hadron formation in DIS of positron in the nuclear environment has been also studied in the HERMES experiment [10].The results are shown in Fig. 4. The differential multiplicity of charged hadrons and identified charged pions from nitrogen relative to that from deuterium has been measured as a function of the virtual photon

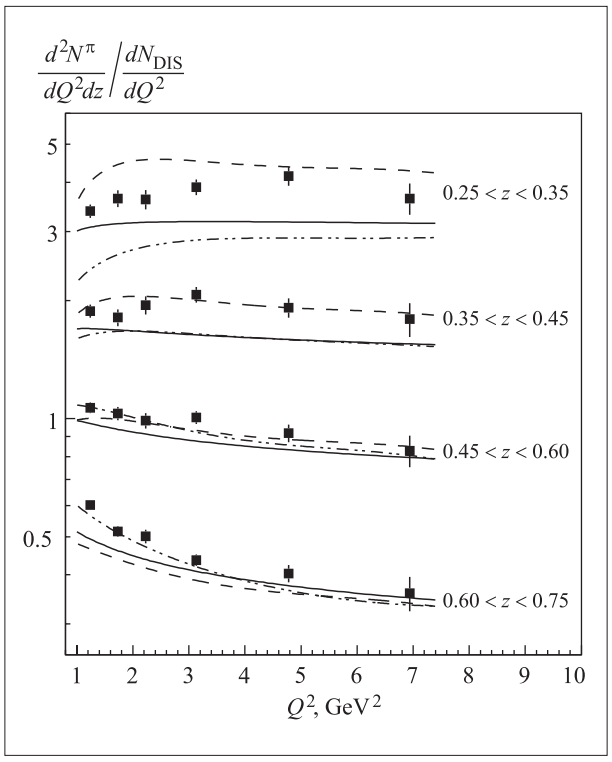

Fig. 5. Total (neutral plus charged) pion multiplicity as a function of Q^2 for various z bins. The systematic uncertainty on the data is 8.5 %. The three curves shown are NLO QCD calculations of fragmentation functions

energy ν and the fraction z of this energy transferred to the hadron. Substantial reductions of the multiplicity ratio R_M^h are observed at low ν and at high z, both of which are well described by a gluon-bremsstrahlung model of hadronization. A significant difference of the ν-dependence of R_M^h is found between positive and negative hadrons. This is interpreted in terms of the difference between the formation time of protons and pions, using a phenomenological model to describe the ν- and z-dependence of R_M^h.

The HERMES result on multiplicity of charged and neutral pions in DIS of 27.5 GeV positrons on hydrogen is shown in Fig. 5 [11]. The average charged pion multiplicity is the same as for neutral pions, in the region of z up to 0.7. This result is consistent with the isospin invariance. The observed dependence on the squared momentum transfer Q^2 agrees qualitatively with the expected behaviour based on the NLO QCD evolution, while the dependence on the Bjorken variable x is consistent with that of the previous data after correction made for the expected Q^2-dependence.

The result on single-spin azimuthal asymmetry in electroproduction of neutral pions in semi-inclusive DIS of positrons on longitudinally polarized protons is shown in Fig. 6 [12]. The asymmetry is described by a phenomenological calculation based on a fragmentation function that represents sensitivity to the transverse polarization of the struck quark. The final result on the beam-spin azimuthal asymmetry associated with Deeply Virtual

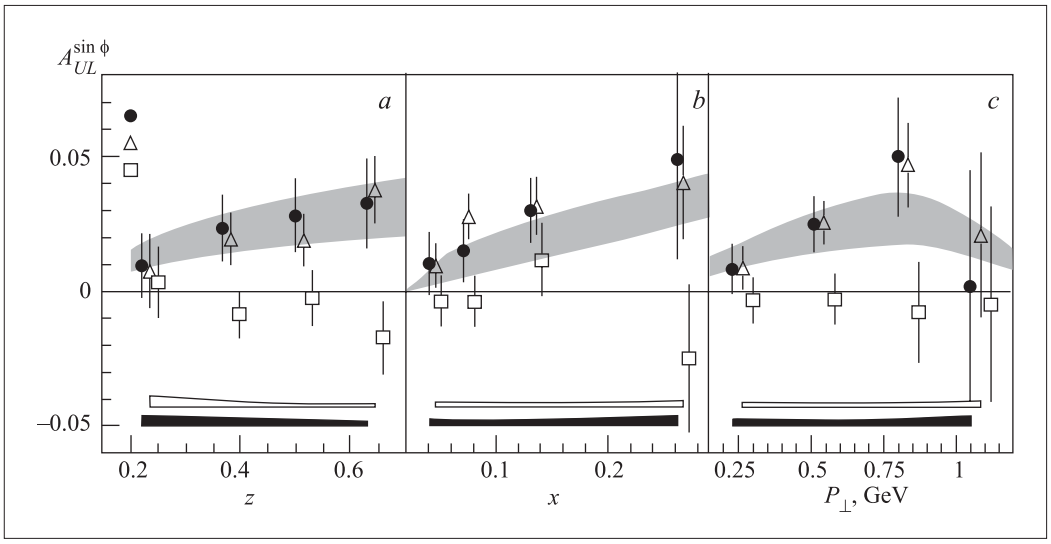

Fig. 6. Analyzing power ($A_{UL}^{\sin\phi}$) in the $\sin\phi$ moment for π^0 (circles) compared to previous results for π^+ (triangles) and π^- (squares) as a function of: *a*) the pion fractional energy z, *b*) the Bjorken variable x, and *c*) the pion transverse momentum $P_\perp$. Error bars include the statistical uncertainties only. The filled and open bands at the bottom of the panels represent the systematic uncertainties for neutral and charged pions, respectively. The shaded areas show a range of predictions of a model calculation applied to the case of π_0 electroproduction

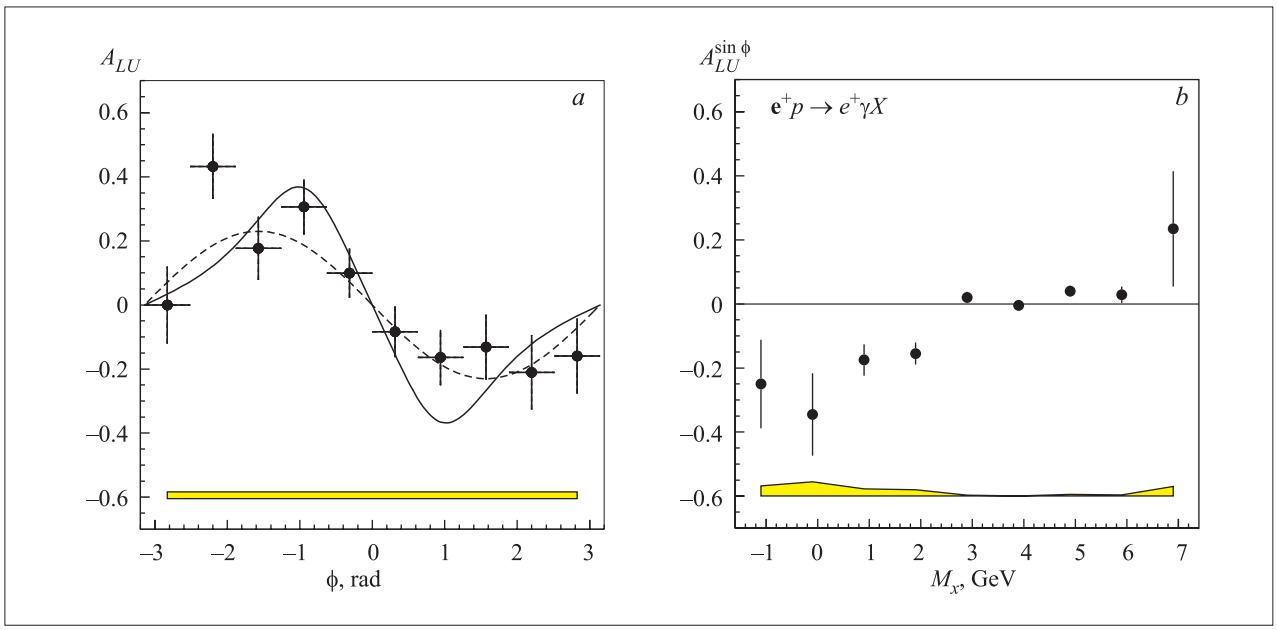

Fig. 7. *a*) Beam-spin asymmetry A_{LU} for hard electroproduction of photons as a function of the azimuthal angle ϕ. The data correspond to the missing mass region between −1.5 and +1.7 GeV. The dashed curve represents a sin ϕ dependence with an amplitude of 0.23, while the solid curve represents the result of an SPD calculation. The error band below represents the systematic uncertainty. *b*) The beam-spin analyzing power $A_{LU}^{\sin\phi}$ for hard electroproduction of photons on hydrogen as a function of the missing mass

Compton Scattering (DVCS) is presented in Fig. 7 [13]. The observed asymmetry is attributed to the interference of the Bethe–Heitler and DVCS processes.

LPP participates in the **H1** detector upgrade to investigate DIS processes at the *ep* collider HERA, DESY, specifically, in the software/hardware support of the Forward Proton Spectrometer (FPS) operation and in the upgrading of the hadron Plug calorimeter and Backward Proportional Chambers. The LPP group made a major contribution to the analysis of data on the processes with a leading proton detected in the FPS: photo-production, semi-inclusive diffractive DIS, and the elastic ρ meson photo-production.

The total cross-section for the photo-production process with a leading proton in the final state has been measured at γ*p* centre-of-mass energies *W* of 91, 181 and 231 GeV [14] (Fig. 8). The measured cross-sections apply to the kinematic range with the transverse momentum of the scattered proton restricted by $p_T < 0.2$ GeV and $0.68 < z < 0.88$, where $z = E_p^{'} / E_p$ is the scattered proton energy normalized to the beam energy. The differential cross-section $d\sigma/dt$ and the structure function $F_2^{D(3)}(x_{IP}, x, Q^2)$ have been measured in diffractive DIS processes with the leading proton in the final state [15]. The $F_2^{D(3)}$ data have been compared with the previous result obtained by H1 FPS in the non-diffractive high x_{IP} range, where x_{IP} is the fractional momentum of the

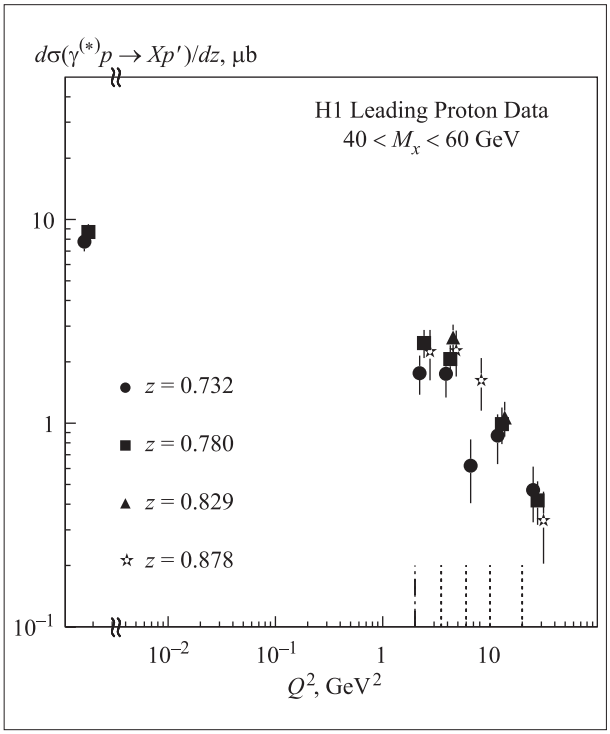

Fig. 8. Cross-section of the process $\gamma^{(*)}p \to Xp'$ with a leading proton in the final state as a function of Q^2 for different values of $z = 1 - x_{IP}$. Saturation of the cross-section is clearly visible at low Q^2 when going from DIS processes with virtual photons ($Q^2 > 0$) to photo-production processes with quasi-real photons ($Q^2 \sim 0$)

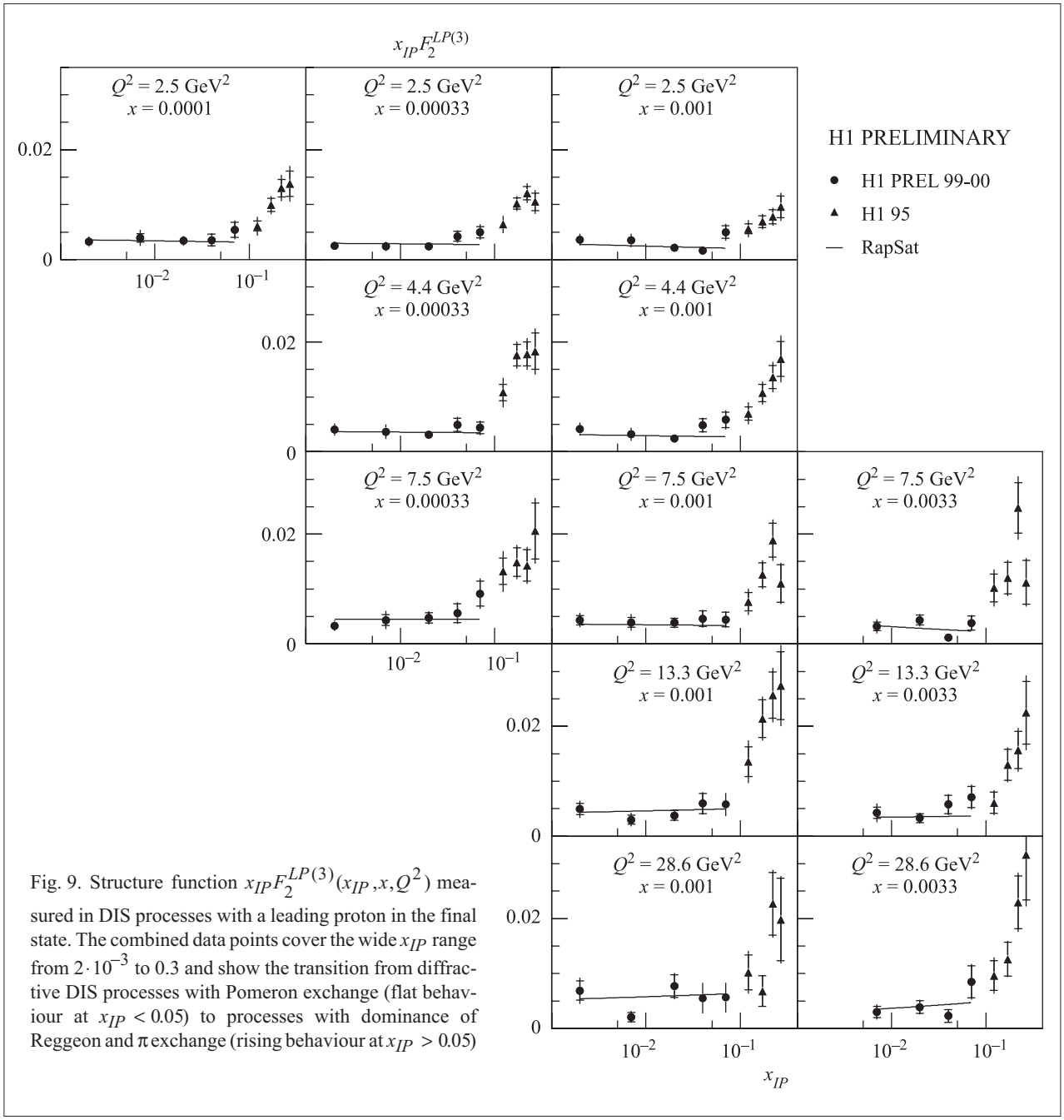

Fig. 9. Structure function $x_{IP}F_2^{LP(3)}(x_{IP},x,Q^2)$ measured in DIS processes with a leading proton in the final state. The combined data points cover the wide x_{IP} range from $2\cdot10^{-3}$ to 0.3 and show the transition from diffractive DIS processes with Pomeron exchange (flat behaviour at $x_{IP} < 0.05$) to processes with dominance of Reggeon and π exchange (rising behaviour at $x_{IP} > 0.05$)

beam proton carried by Pomeron. This comparison shows the behaviour to be consistent with the transition from Pomeron exchange at $x_{IP} < 0.05$ to the dominance of Reggeon and π exchange at at $x_{IP} > 0.05$. Comparison of the leading proton data with $F_2^{D(3)}$ [16] obtained from the presence of a large rapidity gap in the central detector has shown a good agreement between the two methods and proved a small contribution of the proton dissociation in the large rapidity gap data (Fig. 9). The saturation model based on the colour dipole approach is able to give a good description of the new $F_2^{D(3)}$ data with the leading proton.

The elastic photo-production of ρ mesons has been also studied by measuring the final-state leading proton [17]. The H1 measurement extends the centre-of-mass energy range to $25 < W < 70$ GeV, thereby further reducing the kinematic separation between the HERA and fixed target measurements. The results are in agreement with assumptions of the Vector Meson Dominance model and Regge theory.

A Common Muon and Proton Apparatus for Structure and Spectroscopy, **COMPASS (NA58)**, has been proposed to perform a series of experiments with high-energy muon and hadron beams at CERN. In 2001, 480 modules of the hadron calorimeter HCAL1 were completely mounted, tuned by means of sources and on the beam. The muon wall MW1 of the COMPASS spectrometer's first stage has been completely mounted on the beam and equipped with the analog part of the electronics. The multiwire proportional chambers of the COMPASS tracker have been installed and tuned on the beam. The «straw» chambers of the COMPASS tracker have been manufactured at LPP in the framework of a contract with the Ludwig-Maximilians University (Munich, Germany). Four double planes, with sizes of 3.5×2.5 m, have been transported to CERN.

LPP participates in the construction of the Liquid Argon Hadronic Endcap Calorimeter (LArHEC) and Transition Radiation Tracker (TRT), according to the JINR obligations in the **ATLAS** experiment, which is under preparation at CERN. The copper absorber production for LArHEC is under way at JINR and MZOR, a plant in Minsk, Belarus. The assembly of the modules is in progress at JINR. At beam channel No. 3 of the IBR-2 reactor, an investigation of the properties of materials, used for the serial modules production, was done. Electrodes of the calorimeter were placed in the cryostat, filled with liquid argon, and irradiated by fast neutrons with a total fluence being equal to $10^{16}\,\mathrm{cm}^{-2}$. The measurements of the liquid argon purity, done by the ionization chamber before and after irradiation, have shown that irradiation does not cause outgasing of electronegative components from the material surfaces to liquid argon, which decreases the charge collected in liquid argon. The studies of electrical and functional characteristics of the 64 preshapers at the full-scale chain of readout electronics for the LArHEC have been performed. The precise calibration of the temperature sensors, to be used for measuring the liquid argon temperature in the ATLAS detector cryostats, was completed.

The analysis of the new experimental data, taken at CERN during the modules tests, is continued. Spin effects in the processes of the single and pair production of t quarks in pp collisions at LHC are studied.

The main activity of LPP within the Compact Muon Solenoid Project, CMS, was concentrated on the study, design, integration, and production of the CMS Endcap detectors, where JINR takes a full responsibility in the framework of the Russia and Dubna Member States (RDMS) of the CMS collaboration. The JINR group participates in the following projects: Endcap Hadron Calorimetry (HE), First Forward Muon Station (ME1/1), Endcap Preshower (SE), and Physics Task Force.

JINR co-ordinates the RDMS CMS collaboration activity on the design and construction of the HE, and is responsible for the HE absorber. The full chain of mechanics and optics mass-production is well going on. The first HE-1 absorber has been manufactured at the MZOR plant in Minsk and delivered to CERN. All tiles for HE-1 were manufactured and delivered. The first set of 38 mass-produced megatiles was tested and calibrated by pions and muons at CERN.

ME1/1 Cathode Strip Chambers (CSC) production in Dubna is going on [18]. About 90 % of CSC panels have been manufactured. Production of CSC parts and chamber assembly have been started. The ME1/1 anode electronics is in the production stage. The first set of the electronics cooling system has been produced. The test of the cooling system has started. Prototyping of the low-voltage system and mass production of the high-voltage system is going on in Bulgaria.

The preshower project is well in progress. Mass-production of silicon detectors in cooperation with RIMST, Zelenograd, is going on. In 2001, 215 radiation hard detectors were produced, and 2 % of these detectors were irradiated by fast neutrons.

JINR physicists participate in the RDMS CMS task force on development of software and simulation of physics processes with emphasis on the endcap and forward region. The study of direct gamma production is continued. The CMS hadron calorimeter response of the combined HE/HF system was simulated to investigate the «γ + jet» calibration of the hadron calorimeter. The CMSIM and ORCA programmes were tested and modified for muon track reconstruction in the endcap muon system. Computing group participates in the design of the concept of regional distributed centres. Development of the CMS Heavy-Ion Physics Programme on a topic of Global Characteristics of ultrarelativistic nucleus-nucleus collisions is in progress [19]. The package SIMUB for simulation of the B-meson production and decays is developed at Dubna for B-physics studies at CMS. The mass production of the «golden mode» $B_s^0 \to J/\psi\phi$ is in progress for the exclusive B trigger.

According to the JINR commitments, LPP participates in the commissioning of the Outer Tracker (OTR) of the **HERA-B** detector, which is a large-aperture spectrometer built for studies of collisions of 920 GeV protons with the nuclei of target wires positioned in the halo of the HERA proton beam. JINR physicists participate in soft-

ware development, HERA-B running and data analysis. In 2001, the Dubna group played a major role in the upgrading of the OTR during the HERA luminosity shutdown. Further development of the OTR software as well as the study of the OTR performance have been continued with the experimental data collected during the run 2000 [20].

LPP takes part in the design and construction of both Barrel and Endcap Electro-Magnetic Calorimeter systems for the 4π-detector **STAR** for the RHIC collider at the Brookhaven National Laboratory (BNL). In 2001, an LPP group participated in the first measurement of inclusive antiproton production in Au–Au collisions at 130 GeV by the STAR experiment [21].

LPP specialists participate in the 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 and mounting of PMT. A prototype of the BOREXINO detector, CTF2, has been installed, which is aimed at studying a new type of liquid scintillator, the efficiency of radiopurification as well as the methods of low-radioactivity control. The prototype CTF2 has been used for studies of the stability of electron. The new lower limit of the mean lifetime defined by the data is $\tau(e \to \gamma\nu) > 4.6 \cdot 10^{26}$ years at 90 % C.L. [22].

ACCELERATION TECHNIQUES

In accordance with the schedule of operations for the project **LHC Damper**, the 2001 activities were focused on the design and manufacturing of the electrostatic kickers and power amplifiers of the Transverse Oscillation Damping System (TODS) for LHC as well as on the investigations of the power amplifier circuit and damping regimes for future upgrade of TODS. Test of the power amplifier (classical variant) at CERN has shown the full conformity of its parameters to the project requirements. The technique of vacuum tubes simulation has been gradually improved. A cascade amplifier of a power of up to 16 kW has been built and tested at JINR. The development of the resistive coating of the ceramic insulators is in progress.

During 2001 the Free Electron Laser (FEL) group continued the experimental and theoretical investigations of the millimeter-wave Free Electron Maser (FEM) oscillators as possible microwave power sources for the linear collider **CLIC** at CERN. Two new techniques for frequency measurements have been put into operation: the precise mechanical wavemeter and the heterodyne spectrum meter. A new technology of Bragg resonators manufacturing — by pressing out from a stainless steel tube — has been introduced. The stability of the FEM operation has been investigated experimentally. The processes of oscillation building-up in the FEM with various Bragg resonators were simulated numerically.

The year 2001 saw the completion of the **TESLA** Technical Design Report, which provides the conceptual basis for a future collider. Main fields of contributions from JINR are X-ray Free Electron Lasers (FEL) and $\gamma\gamma$-collider option.

Since first lasing of the VUV SASE FEL at DESY (February 2000) its operation has been gradually improved. The radiation wavelength is continuously tunable in a wide range from 80 to 180 nm. At present the SASE FEL gain is tuned to a value of about 10^6, pulse duration is 0.5–1 ps, the peak and the average radiation powers are about 20 MW and 0.2–0.3 mW, respectively [23]. The peak brilliance is about 10^{27} photon/s/mrad^2/mm^2/(0.1 % BW). Equipment for Regenerative FEL Amplifier (RAFEL) has been installed and tested at the TESLA Test Facility (TTF). The experiment is in progress [24]. Success of the RAFEL experiment would allow one to reach extra high peak brilliance of about 10^{30} photon/s/mrad^2/mm^2/(0.1 % BW).

Theoretical and design studies involve the following topics: FEL physics, optimization of the user facility at TTF FEL, FEL schemes providing femtosecond-scale pulse duration [25], analysis of perspective industrial applications [26].

The experimental and theoretical investigations on the **multi-charged ion sources** continued in 2001 [27]. The biased-disk effect in the Electron Cyclotron Resonance Ion Sources (ECRIS) has been studied by using special double-electrode structure. The relative contributions of the secondary electron emission from the electrode and of the reflection of lost electrons back to ECR plasma have been determined. The measurements of the plasma potential by using the Langmuir probe have been made. The scheme of laser ablation plasma injection into ECRIS has been tested at Frankfurt University. The LPP group also participates in the laser ablation experiments at INFN LNS, Catania, Italy.

A new version of computer codes based on balance equations for all ionic charge states and on the theory of the electron and ion confinement in the open magnetic trap of ECRIS has been used for the numerical simulation of the ion or neutral injection into the ECR plasma. A modified programme library based on the macro particle method was applied to optimize the ion beam line at RIKEN.

A new, non-traditional direction in technique of the **electron accelerators for radiation technologies** is being worked out at LPP. In the developed multi-beam high-repetition rate accelerators, the average ratio of the repetition period to the pulse duration is equal to 10, so the possibility to apply a very cheap direct current (DC) electric field has appeared to accelerate the secondary electrons. The adaptation of the 200 keV accelerator was carried out to perform the experiments with electron multi-beam injected into DC field of the irradiation vessel. The design and construction of the experimental irradiation vessel with DC electric field as well as the development and construction of units of the 500–700 keV, 30 kW accelerator for electron beam processing have been performed.

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DZHELEPOV LABORATORY OF NUCLEAR PROBLEMS

The Dzhelepov Laboratory of Nuclear Problems (DLNP) covers experimental investigation in particle physics, investigation of nuclear structure, study of condensed matter properties; theoretical support of the experimental research; medico-biological investigations; development of new detectors and accelerators as well as new experimental methods and facilities. DNLP 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 at DLNP.

In 2001 DLNP took a decisive part in the organization of three very important scientific meetings, the NANP-01 conference on non-accelerator new physics, a very famous conference in supersymmetry SUSY-01 and the Gomel school-seminar on actual problems of particle physics.

Traditionally the NANP-01 conference traces a new modern trend in particle physics connected with physics beyond the Standard Model of electro-weak interactions with a certain emphasis on the non-accelerator searches. The extremely high level of the NANP conferences was confirmed, for example, by the decision of the SNO collaboration to present for the first time their evidence of the solar neutrino oscillations. This was especially remarkable in the light of the very idea of neutrino oscillations which was put forward by Bruno Pontecorvo in Dubna. It was decided to devote the next, NANP-03, conference to the 90th birthday of Bruno Pontecorvo.

The famous SUSY-01 conference «Supersymmetry and Unification of Fundamental Interactions» was held in Dubna in the summer of 2001. For the first time the 9th SUSY conference reached Russia, where 30 years ago the Supersymmetry was discovered. Practically all the key problems of modern particle physics, astrophysics as well as other related problems of mathematical physics have found their reflection at the conference. A very high scientific level of the talks and wide representation of the leading experiments and centres, large percentage of young people from all over the world and Russia have confirmed huge scientific importance of the SUSY as a theory that is able to connect tightly high-energy accelerator physics with non-accelerator particle physics together with astroparticle phenomena of extremely high energy.

In August 2001 the Gomel school-seminar on actual problems of particle physics was held. A holiday centre in the Gomel Region traditionally hosted seminars on micro-world physics in 1971, 1973, 1977, 1997 and 1999. The initiative to hold all these meetings belongs to the outstanding scientists such as N. Bogoliubov, F. Fedorov, V. Kadyshevsky, V. Bely, and B. Bokut. The agenda was packed with lectures and reports on physics and collider technologies, experimental and theoretical problems in particle physics. For the first time the new modern topic of neutrino, non-accelerator particle physics and astrophysics was included and discussed at the Gomel school. Lectures and reports were delivered by scientists from the institutes-organizers and world-known scientific centres.

ELEMENTARY PARTICLE PHYSICS

The goal of the **NOMAD** experiment is the search for neutrino oscillations in a wide-band neutrino beam from CERN's SPS. It aims at detecting ν_τ charged current (CC) interactions in a predominantly ν_μ neutrino beam by observing the production of the τ^- through its various decay modes. The analysis of a full [1] NOMAD data sample of 1.3 million ν_μ CC interactions yields no evidence for the oscillation signal in the range of $1 < \Delta m^2 < 1000$ eV^2/c^4. The final limits (Fig. 1, *a*) for the

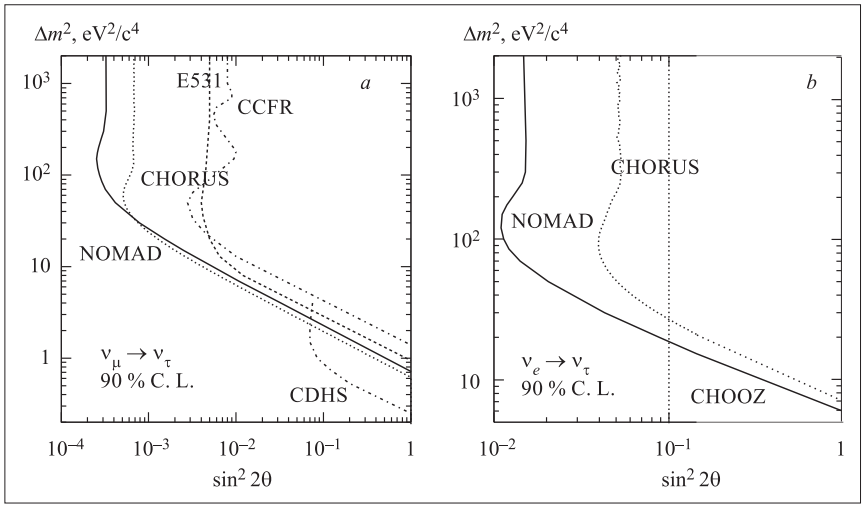

Fig. 1. The $\Delta m^2 - \sin^2 2\theta$ plane for $\nu_\mu \to \nu_\tau$ (*a*) and $\nu_e \to \nu_\tau$ (*b*) oscillations. The regions excluded by NOMAD at 90 % C.L. are shown (solid lines) together with the limits published by other experiments. The regions to the right of the curves are excluded

$\nu_\mu \to \nu_\tau$ oscillation probability and for the oscillation amplitude ($\sin^2 2\theta_{\nu_\mu \nu_\tau}$) at 90 % C.L. for large $\Delta m^2 > 50$ eV^2/c^4 are $P_{\nu_\mu \nu_\tau} < 1.63 \cdot 10^{-4}$, $\sin^2 2\theta_{\nu_\mu \nu_\tau} < 3.3 \cdot 10^{-4}$. The NOMAD limit is an order of magnitude better (lower) than the previous best result (FNAL CCFR-1995). The upper limit on the probability of the $\nu_e \to \nu_\tau$ oscillation is set to $P_{\nu_e \nu_\tau} < 0.74 \cdot 10^{-2}$, which corresponds to $\sin^2 2\theta_{\nu_e \nu_\tau} < 1.5 \cdot 10^{-2}$ at large Δm^2 (Fig. 1, *b*). The current NOMAD limits for the $\nu_\mu \to \nu_e$ oscillation probability at 90 % C.L. for the large Δm^2 and for the oscillation amplitude are $P_{\nu_\mu \nu_e} < 0.6 \cdot 10^{-3}$, $\sin^2 2\theta_{\nu_\mu \nu_e} < 1.2 \cdot 10^{-3}$. This result excludes the LSND-allowed region of oscillation parameters with $\Delta m^2 > 10$ eV^2/c^4.

The NOMAD programme also includes the non-oscillation physics investigations [2–4]. The Λ^0 polarization in ν_μ CC interactions has been measured [3]. These results provide a test of different models describing the nucleon spin composition and the spin transfer mechanisms. The first measurement of the $\overline{\Lambda}^0$ polarization in ν interactions has been performed [4]. The polarization vector is found to be compatible with zero. Both integral and differential production rates of neutral strange particles (K^0_S, Λ^0, $\overline{\Lambda}^0$) in ν_μ CC interactions have been measured. Decays of resonances and heavy hyperons with identified K^0_S and Λ^0 in the final state have been analyzed (Fig. 2). Clear signals corresponding to $K^{*\pm}$, $\Sigma^{*\pm}$, Ξ^- and Σ^0 have been observed [3].

The **DELPHI** collaboration has studied the muon pair production in the process $e^+e^- \to e^+e^-\mu^+\mu^-$ on the basis of the data taken at LEP1 ($\sqrt{s} \cong m_Z$) with the DELPHI detector [5]. The study of the process $e^+e^- \to e^+e^-\mu^+\mu^-$ provides a good way to test QED up to the fourth order of the QED coupling constant α. The QED predictions have been tested over the Q^2 range from several GeV^2/c^4 to several hundred GeV^2/c^4 by comparing experimental distributions with distributions resulting from Monte Carlo simulations. Selected events were used to extract the leptonic photon structure function F_2^γ. Azimuthal correlations were used to obtain information on additional structure functions, F_A^γ and F_B^γ, which originate from interference terms of the scattering amplitudes. The measured ratios F_A^γ / F_2^γ and F_B^γ / F_2^γ are significantly different from zero and consistent with QED predictions (Fig. 3). In 2001 the Dubna group of DELPHI within the common LEP collaboration community presented in [7] a combination of preliminary electroweak measurements and constraints on the Standard Model. The parameters of the Standard Model are evaluated, first using the combined LEP electroweak measurements, and then using the full set of electroweak results (see, for example, Fig. 4).

The **DIRAC** experiment at CERN aims to measure the lifetime of $\pi^+\pi^-$ atoms ($A_{2\pi}$) in the ground state with 10 % precision and to subject the understanding of chiral symmetry breaking of QCD to a crucial test. In 2001 the processor «DC track-analyzer» was produced and implemented in the trigger system of the DIRAC set-up; a new 4-layer forward scintillation hodoscope for an energy lost measurement was produced and implemented in the set-up; a second stage of the neural network trigger was also implemented [8]. For further development of the set-up a microdrift chamber has been designed, produced and tested with the beam. In 2001 the total number of events taken with the nickel target was about 1100 million (Fig. 5) and with the titanium target about 550 million. About 5500 $\pi^+\pi^-$ atoms have been identified with the data obtained with the nickel, titanium and platinum targets.

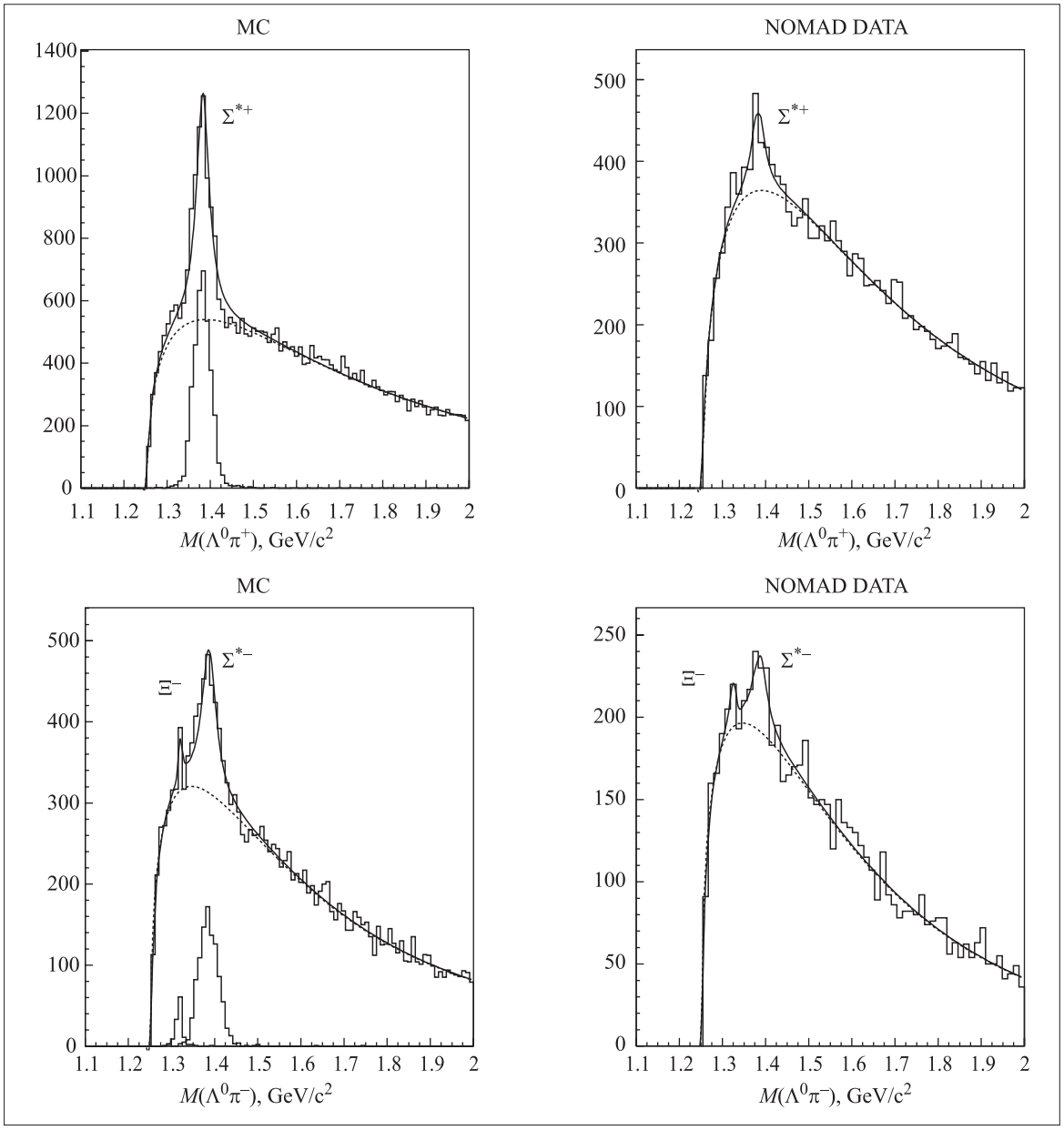

Fig. 2. $\Lambda\pi^+$ (top) and $\Lambda\pi^-$ (bottom) invariant mass distributions for both the MC (left) and NOMAD (right) data. Clear peaks corresponding to $\Sigma^{*\pm}$ and Ξ^- are visible. The solid lines are the results of the fit, while the dotted lines describe the background term. In the MC plots the additional histograms refer to the reconstructed true heavy strange particles

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 responsibility of DLNP within the ATLAS collaboration includes production of muon chambers; production and assembly of the absorber of the Barrel part of the tile calorimeter; calculations of magnetic fields and forces; software development, etc.

In 2001 the ATLAS Muon Group produced drift tubes for BOS chambers (11800 units) and for BMS chambers (2500 units). All detectors have been tested for signal wire position deviation from the tube centre. The amount of rejected tubes does not exceed 1 %. The set-up for Monitored Drift Tube (MDT) Chamber assembly is mastered. The system for comb-line adjustment on a granite table and semiautomatic machine for glue drawing during drift tube gluing were tested and entered into full operation. Machining of aluminium profiles for chamber spacers is organized at the MZOR plant (Minsk) [9].

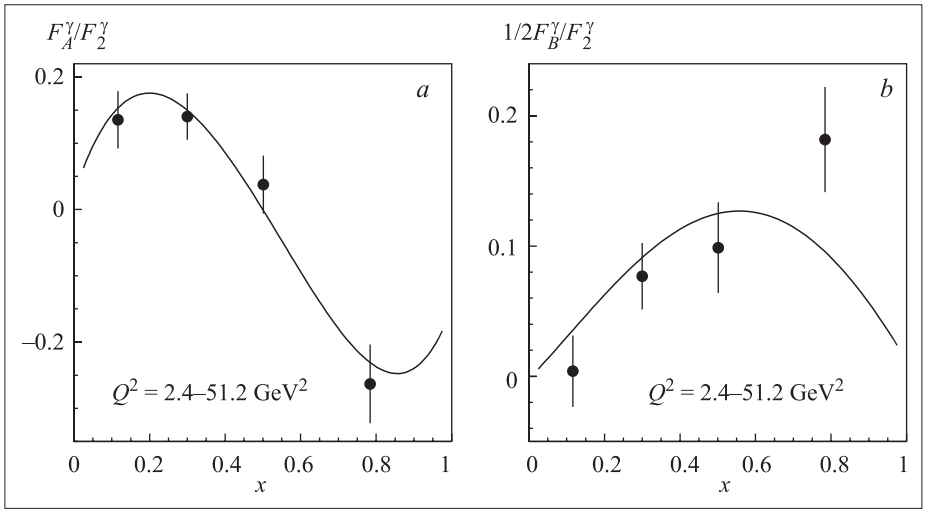

Fig. 3. Ratios of leptonic structure functions $F_A^\gamma \big/ F_2^\gamma$ (*a*) and $\frac{1}{2}F_B^\gamma \big/ F_2^\gamma$ (*b*) averaged in the Q^2 range from 2.4 to 51.2 GeV^2 as functions of *x*. The lines show the QED predictions from [6]

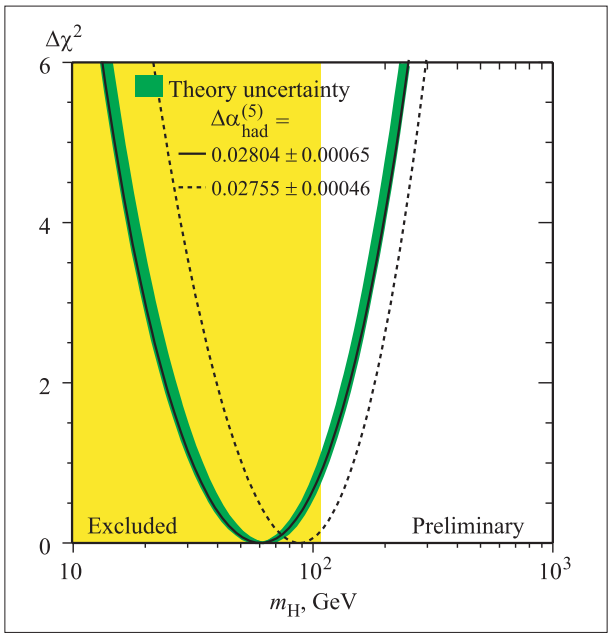

Fig. 4. $\Delta\chi^2 = \chi^2 - \chi^2_{min}$ versus the Higgs boson mass m_H.The line is the result of the fit using all data; the band represents an estimate of the theoretical error due to missing higher-order corrections.The vertical band shows the 95 % C.L. exclusion limit on m_H from the direct search. The 95 % confidence level upper limit on m_H (taking the band into account) is 165 GeV. The fit results in $m_H = 88^{+60}_{-37}$ GeV and an upper limit on m_H of approximately 206 GeV

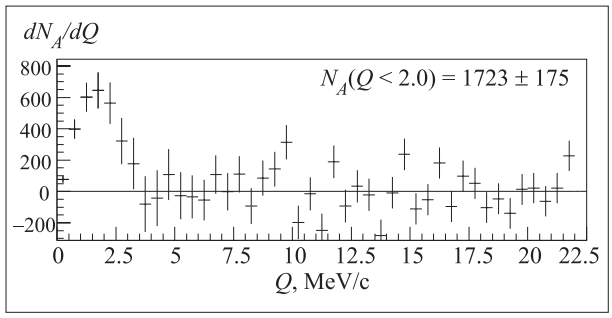

Fig. 5. Difference between the detected number of $\pi^+\pi^-$ pairs and the number of the pairs produced in the free state versus the pair relative momentum *Q*. The excess of events in the range of small *Q* is due to the pairs from the $\pi^+\pi^-$-atom breakup in the target. The number of the detected «atomic» pairs in the interval of $Q < 2$ MeV/c is 1723 ± 175. Only the events with the Ni target are shown

The modules and submodules production for the ATLAS **Hadron Tile Calorimeter** was organized at DLNP. In 2001 full production of submodules was finished, 55 modules were constructed and delivered to CERN. The modules are precision (within 3 mm) constructions of length 6 m and weight 20 t.

The performance of the ATLAS Calorimetry is being investigated in Dubna. Hadron energy reconstruction for the ATLAS barrel prototype combined calorimeter, consisting of the lead-liquid argon electromagnetic part and the iron-scintillator hadronic part, has been accomplished by the new non-parametrical method. This method utilizes only the known *e*/*h* ratios and the electron calibration constants and does not require determination of any parameters by a minimization technique [10]. The energy loss spectrum of 180-GeV muons has been measured with the 5.6-m-long finely segmented Module 0 of the ATLAS hadron calorimeter in the H8 beam of CERN's SPS [11]. The deconvolution method for analysis of single photoelectron spectra of the new types of ultra-compact PMTs R 5600 and R 5900 with the metal channel dynode system was presented [12].

On 1 March 2001 the commissioning of the **D0** equipment started with the beginning of Tevatron operation. The JINR responsibility in the collaboration is the muon tracker of the forward-angle muon system. Dubna scientists took an active part in the development of the software for this subsystem. The muon tracking efficien-

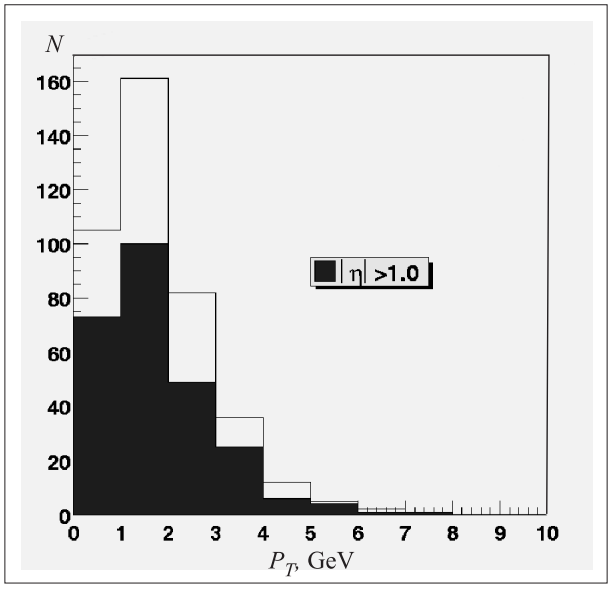

Fig. 6. Transverse momentum spectrum of muons from cascade decay of Ξ_b^- baryons produced in $\bar{p}p$ interactions at 2.0 TeV (Monte Carlo): $\Xi_b^- \to \Xi^- + J/\psi \to \mu^+\mu^-$. The dark area covers muons with pseudorapidity $|\eta| > 1.0$ GeV/c (acceptance region of JINR monitored drift tubes)

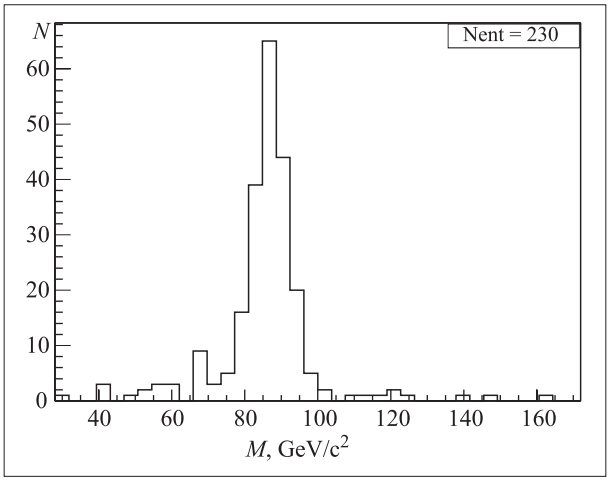

Fig. 7. Mass distribution of the selected $Z \to e^+e^-$ candidates (very preliminary)

cy is 99.5 %. The Dubna group developed new selection criteria for events with associated production of hadronic jets, direct photons and Z^0 bosons, which essentially improves the precision of setting the absolute jet energy scale for the conditions of the D0 experiment.

The Dubna group plans to investigate non-leptonic decays of beauty baryons to fully reconstructable final states (Fig. 6): $\Lambda_b \to J/\psi + \Lambda$ and $\Xi_b \to J/\psi + \Xi$ with $J/\psi \to \mu + \mu$, $e + e$ (and the same for antiparticles). It is expected that with 2 fb^{-1} of data it will be possible to fully reconstruct 15000 Λ_b baryons and several hundred Ξ_b baryons in the strange baryon $+J/\psi \to$ leptons decay mode, where a remarkable number of muons enter the forward-backward region and are registered by MDT chambers.

The **CDF** upgrade programme was successfully completed by the international collaboration at the beginning of 2001. The JINR group, in collaboration with the INFN (Pisa, Italy) team, contributed to the on-line Silicon Vertex Tracker (SVT) and to the scintillating counters of the Muon Detector. The **SVT** is a unique new trigger processor for the two-dimensional reconstruction of charged particle trajectories at Level 2 of the CDF trigger. The SVT will be used to tag events containing secondary vertices from the *b* decay. One of the main SVT parts is the Associative Memory bank, which is essentially a very fast library of track images. Design, construction and investigation of the Associative Memory board prototype were performed.

The CDF-II **muon system** (wire chambers and scintillating counters) is of key importance for broad physics programmes ($t\bar{t}$ events, search for rare *B* decays, asymmetry in *W* decays and others). In 2001 JINR constructed, delivered to FNAL and installed on the CDF more than 600 scintillating counters 1.6–3.2 m long. About 3.6 pb^{-1} of data were collected in 2001. Preliminary analysis demonstrates the high quality of the collected data (Fig. 7).

The main goal of the **COMPASS** experiment (NA58, CERN) is the investigation of hadron structure and hadron spectroscopy, which are both manifestations of non-perturbative QCD. In the COMPASS project, the Dubna–Torino collaboration is responsible for construction of a system of Multiwire Proportional Chambers (MWPC). In 2001 a total of 13 MWPCs (active size 1780×1200 mm^2 and 1780×800 mm^2) were installed in the COMPASS set-up together with more than 18000 channels of electronics. During the first run of COMPASS this equipment successfully operated at a beam intensity of $2 \cdot 10^8$ particles per spill.

The responsibility of DLNP is construction of the muon filter of the first COMPASS spectrometer (μ-wall 1) — 16 chamber planes consisting of 1200 proportional tubes equipped with front-end electronics. In 2001 the **Muon Wall-1** (MW1) group fulfilled production of the rest of hardware components of the system and delivered this equipment to CERN. Mechanical assembly of the MW1 system at CERN on the M2 beam line was completed.

New measurements of the spin-dependent total **cross-section differences** ($\Delta\sigma_T$ and $\Delta\sigma_L$) 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). For this experiment the polarized target was modernized and successfully tested, a new polarization measurement system for deuterium and lithium nuclei was created. In 2001development of containers for liquid-scintillator and moni-

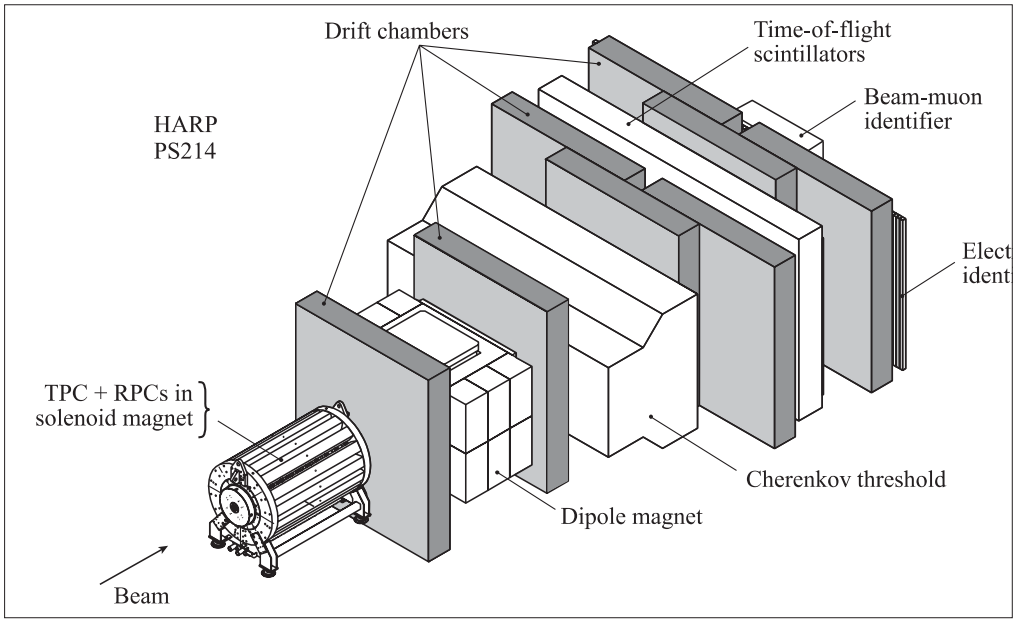

Fig. 8. Layout of the HARP experiment

tor counters was completed and their production was organized at the workshop of the Institute of Particle and Nuclear Physics, Charles University, in Prague. The prototype of the pulse shape discriminator (PSD) was fabricated at the Institute of Nuclear Problems (Minsk State University) and tested at the Van de Graaff laboratory of Charles University. The PSD prototype is capable of separating pulses induced by γ's and neutrons in the neutron detectors.

In the **HARP** experiment it is planned to measure comprehensively secondary hadrons by beams of protons and pions with a momentum of 2–15 GeV/c. For an optimal design of the intense neutrino source based on muon decay in a muon storage ring (neutrino factory) one needs to know pion yields. The yields are also needed to improve the calculation of the atmospheric neutrino flux, which is required for a correct interpretation of the evidence for atmospheric neutrino oscillations.

One of the elements of the HARP set-up (Fig. 8) is a set of large drift chambers from the NOMAD experiment used for tracking and momentum measurements. The responsibility of the JINR group in the HARP experiment is refurbishing, installation, commissioning and operation of the NOMAD drift chambers (NDC); assembling, testing and putting into operation the electromagnetic calorimeter, the muon identifier, etc.

In 2001 all the 23 NOMAD drift chambers required for the HARP experiment were modified, tested and were ready for operation. A new DAQ system for the NDC readout was developed in the framework of the general HARP data acquisition software. The electromagnetic calorimeter, the muon identifier, the cosmic wall and the beam TOF system were assembled, tested and put into operation.

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 for precise measurement of the pion beta-decay rate was continued in 2001 and the statistics obtained allows the decay rate to be determined with an accuracy of about 0.5 %.

The work on precise measurement of radiative pion decay ($\pi \to e\nu\gamma$) was started. There are indications 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. This increases the sensitivity of the experiment to possible tensor interaction by a factor of 10. Data taking for radiative pion decay is under way. A full set of new anode wire electronics for the PIBETA propor-

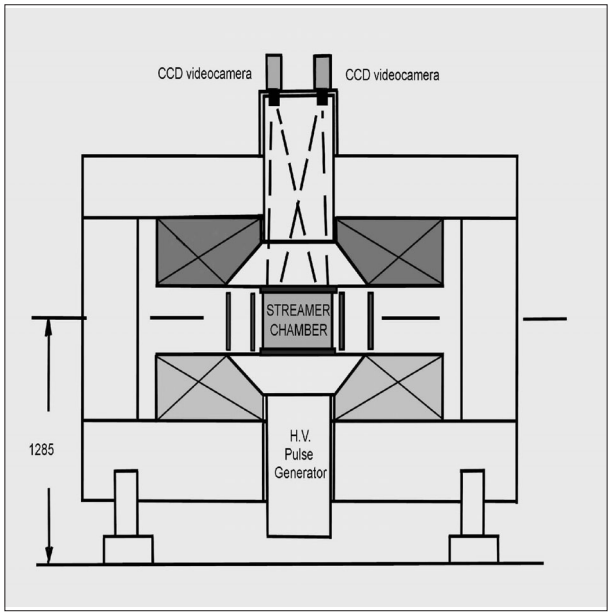

Fig. 9. Sketch of the DUBTO streamer chamber ($47\times60\times16\,\mathrm{cm}^3$) in the magnet MC-4A ($B = 0.690 \pm 0.005\,\mathrm{T}$)

tional chambers (576 channels) have been manufactured in Dubna and installed into the PIBETA set-up. An important feature of the new electronics is that both analogue (preamplifiers) and digital (data readout) parts are combined into a single module. This allows one to exclude numerous connecting cables which were necessary in all previous experiments.

The joint INFN–JINR **DUBTO** project is aimed at studying pion-nucleus interactions at energies below the Δ-resonance. The experimental set-up **STREAMER** is a self-shunted helium-filled streamer chamber in a magnetic field, equipped with two CCD videocameras for videorecording of nuclear events occurring in the chamber volume. The chamber (Fig. 9) serves simultaneously as a thin target and a triggerable track detector and permits obtaining measureable track images of very-low-energy secondary charged particles produced in nuclear reactions. The final identification of the heavy secondaries is based both on the determination of ionization losses and on complete reconstruction of the event kinematics, in which the technique of artificial neural networks is also applied.

In 2001 an experimental set-up was installed at beam channel XIII of the JINR Phasotron. Preliminary on-line data processing is performed which includes scaling, storage, compression, and creation of a database of images. About 2500 videoimages of $\pi^+ {}^4\mathrm{He}$-interaction events were collected and transformed for further processing. Much effort was spent to create dedicated software for reading, measuring and analyzing the videoimages. For event identification, i. e. distinguishing the following $\pi^+ {}^4\mathrm{He}$ events with a scattered pion recorded: $\pi^+ {}^4\mathrm{He} \to \pi^+ 2p2n$ and $\pi^+ {}^4\mathrm{He} \to \pi^+ p\, {}^3\mathrm{H}$, the technique of artificial neural networks (a layered feed-forward ANN from the JETNET3 package) was applied. Figure 10 shows the test distributions of output signals from the ANN corresponding to the reaction $\pi^+ {}^4\mathrm{He} \to \pi^+ 2p2n$ (shaded histogram) and the reaction $\pi^+ {}^4\mathrm{He} \to \pi^+ p\, {}^3\mathrm{H}$ (empty histogram) for simulated events. Figure 11 shows the same distribution for real events. It turns out that over 50 % of the recorded three-prong events represent the breakup reaction $\pi^+ {}^4\mathrm{He} \to \pi^+ 2p2n$.

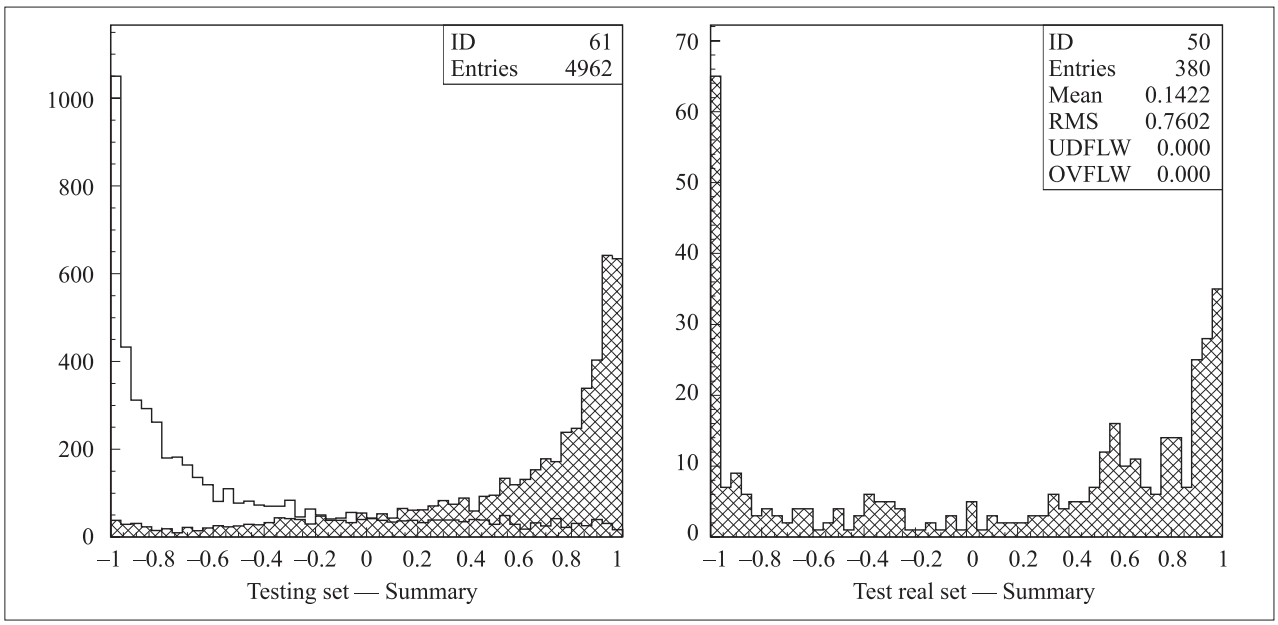

Fig. 10. Distribution of the output signals from processing the set of test patterns: events corresponding to the reaction $\pi^+ {}^4\mathrm{He} \to \pi^+ 2p2n$ are presented by the shaded histogram

Fig. 11. Distribution of the output signals resulting from processing of 212 real events

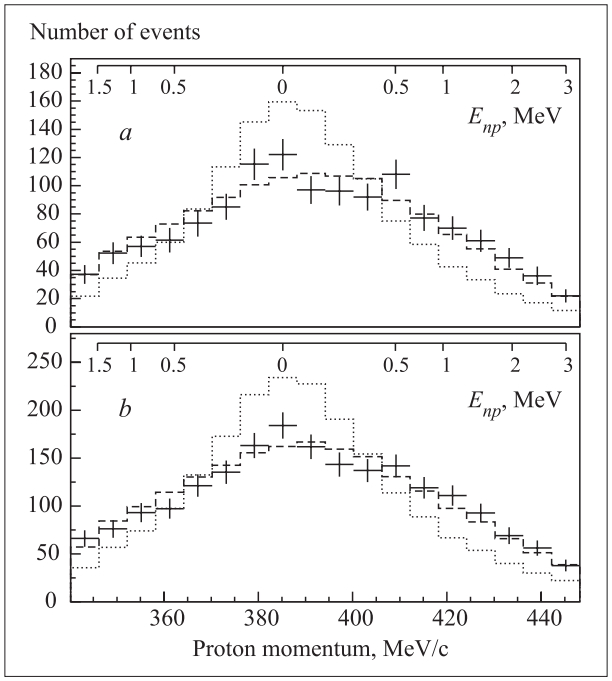

Fig. 12. Proton momentum spectra of the $pp \to pn\pi^+$ reaction for the events with $\theta_\pi < 2°$ and $\theta_p < 2°$ (*a*) and $\theta_p < 2.5°$ (*b*). The dashed histogram shows the simulation with a pure spin-triplet final state. A statistical mixture of spin states leads to the dotted histogram inconsistent with the experiment

In 2001 the near-forward cross-section for the $pp \to pn\pi^+$ reaction was measured at 492 MeV with the large-acceptance magnetic spectrometer **ANKE**, placed at an internal target position of the storage ring COSY, Jülich [13]. The shape of the peak (Fig. 12) allows one to conclude that the fraction of final spin-singlet *np* pairs is below 10 % [14]. The smallness of the singlet contribution is consistent with trends seen in lower-energy data. *A*-dependence of the forward K^+ production in *pA* collisions has been studied at energies from 1.2 to 2.3 GeV to extend investigation started at ANKE at 1.0 GeV [15].

Study of the deuteron breakup process $p+d \to (pp)_S + n$ with forward production of the *S*-wave proton pair $(pp)_S$ has been performed at energies from 0.5 to 2.0 GeV. Missing-mass distributions reveal clear evidence for a peak at the neutron mass value. The events selected at this peak show a distinct concentration at energies less than about 3 MeV, that is, in an *S*-wave state of the produced proton pair. The deuteron breakup at such cumulative conditions is observed for the first time. At such specific kinematics it should be dominated by the one-nucleon-exchange mechanism, providing information on the short-range *NN* interaction [16].

The **CATALYSIS** project is aimed at studying physical problems of muon-catalyzed nuclear fusion reactions. The **TRITON** installation is mounted in the muon channel of the JINR Phasotron and is used in the experiments. The measurements of the temperature dependence of the cycle rate of muon-catalyzed fusion reactions in a deuterium-tritium mixture (temperature 300–800 K, tritium concentration 15–65 %, density 0.2–0.8 LHD) were performed using the Tritium High-Pressure Target (1500 bar, 800 K). Experiments aimed at searching for muon-catalyzed fusion parameters in a triple H/D/T mixture were fulfilled. In 2001 the measurements of the formation rate of the $dd\mu$ molecule in the temperature range 80–800 K were finished with the Deuterium High-Pressure Target (DHPT, 1500 bar, 800 K). The results in the temperature range 350–800 K have been obtained for the first time. The experimental search for the suppressed reaction $d+d \to {}^4\mathrm{He}+\gamma$ from the state of a muonic molecule has been performed with the same target. The upper limit of the gamma yield at a level of $2\cdot10^{-5}$ is reached [17].

The joint JINR–PINP **FAMILON** project with the surface muon beam of the JINR Phasotron is aimed at measururing the branching ratio of the two-particle (neutrinoless) decay of a muon into an electron and a massless Goldstone boson (familon). This decay, $\mu \to \alpha e$, can proceed only with violation of the lepton number conservation law and it is forbidden in the Standard Model. The expected energy resolution for muon-decay positrons (at a level of 10^{-3}) allows a factor of 3 improvement of the previous result (obtained at TRIUMF). In 2001 the first μSR spectra were obtained with the magnetic spectrometer. At 10^5 muon stops per second the data acquisition rate was about 10^2 events per second.

Under the **MUON** project, aimed at investigating the muon properties and the muon interactions with matter, the following research was performed in 2001. The measurements of the magnetic moment of the negative muon in the $1S$ state of different atoms were made [18]. The study of condensed matter by the μSR technique was continued. The μSR experiments with silicon were aimed at investigating the effect of impurities on the relaxation rate of the magnetic moment of the shallow acceptor centre. The temperature dependence of the relaxation rate and the residual polarization of the negative muon gave information about the shallow acceptor centre in silicon [19]. The change in the temperature dependence and a many times increase in the relaxation rate of the magnetic moment of the electron shell of the muonic atom are found at an impurity concentration of above 10^{18} cm^{-3} [20]. The study of the compound $Ce_3Pd_{20}Ge_6$ as a system with «heavy electrons» was continued.

With the proton beam from the JINR Phasotron, the energy spectrum for high-energy γ rays from the process $pp \to \gamma\gamma X$ has been measured at 216 MeV for the first time (Fig. 13). The resulting photon energy spectrum extracted from γ–γ coincidence events consists of a narrow peak (5.3σ) at a photon energy of about 24 MeV and a relatively broad peak (3.5σ) in the energy range of 50–70 MeV. This behaviour of the photon energy spectrum is interpreted as a signature of the exotic dibary-

on resonance d_1^* with a mass of about 1956 MeV, which is assumed to be formed in the radiative process $pp \to \gamma d_1^*$ followed by its electromagnetic decay via the $d_1^* \to pp\gamma$ mode [21].

The **NEMO** project is aimed at searching for neutrinoless 2β decay in ^{100}Mo. In 2001 the construction of the NEMO-3 spectrometer was completed [22]. The chemical and physical purification of the sources was totally fulfilled. All the 20 sectors of the detector were mounted at the LSM (Modane, France) underground laboratory. The NEMO-3 spectrometer was fully assembled for the longtime measurement with the following double-beta-decay samples installed: ^{100}Mo (7.2 kg), ^{82}Se (1 kg), ^{116}Cd (0.6 kg), ^{130}Te (1.3 kg), ^{150}Nd (48 g), ^{96}Zr (20 g) and ^{48}Ca (10 g). Most of the mechanical parts of the NEMO-3 spectrometer as well as most of the plastic scintillators (6 t), front-end electronics, cables were made at JINR. Some enriched isotopes were also provided by JINR. The first three NEMO-3 sectors operated during 2000–2001.

The **AnCor** project is aimed at measuring angular correlations with neutrinos in the processes of nuclear β decay and μ capture sensitive to the Scalar, Pseudoscalar and/or Tensor Weak interactions.

Data analysis of the ^{14}O experiment was completed in 2001 [23]. Studying β decay of this specific nucleus, one stroked with unexpectedly strong (10–15 % of the effect observed) interatomic interaction of recoiling daughters. This effect introduces large systematic error that is problematic to take into account precisely. One can conclude that the β–ν angular correlation in the β decay is very sensitive to interatomic interaction in matter.

New search for scalar coupling in beta-neutrino correlations in the β decay of ^{32}Ar was started in 2001. To this end, a new experimental set-up is under development JINR. It includes 14 cooled planar HPGe detectors, which will detect 3.35 MeV monoenergetic protons and positrons ($E \leq 5.1$ MeV) emitted in the pure Fermi β decay of short-lived ^{32}Ar nuclei.

The aim of the **AC**/μ**C** project is measurement of the Doppler broadening of γ rays following muon capture and search for scalar weak couplings. In 2001 the data analysis of the ^{16}O experiment was completed. The 277 keV γ rays following ordinary muon capture (OMC) on ^{16}O were measured with high-precision HPGe detectors. The Doppler-broadened shape of this γ line is determined by the gamma-neutrino correlation which is sensitive to the sum of induced and genuine scalar couplings $C_S + g_S$ as well as nuclear matrix elements (NME) of OMC transitions [24]. It was realized that ^{20}Ne is the best candidate from the experimental point of view.

The **TGV** project is aimed at searching for double β decay of ^{48}Ca and double *e* capture of ^{106}Cd with the low-background and high-sensitivity Ge multidetector spectrometer TGV (Telescope Germanium Vertical). In 2001 the first stage of the experiment was finished, and the TGV-1 spectrometer was dismounted. A new spectrometer, TGV-2, was developed and built in Dubna. It includes 32 HPGe planar detectors mounted in the same low-background cryostat, an acquisition and data-selection system with the corresponding high-precision spectroscopic electronics, etc. Twenty grams of enriched ^{48}Ca were chemically purified from radioactive Co and Ra and converted into the CaF_2 form. Sixteen thin disk samples containing 10 g of ^{48}Ca are being prepared with a pressing procedure developed at JINR.

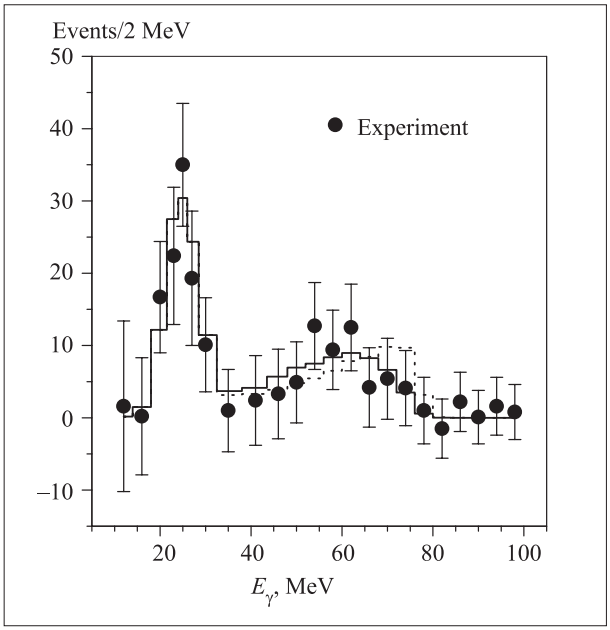

Fig. 13. Experimentally observed energy spectrum for photons from the $pp\gamma\gamma$ process and energy spectra for photons from the process $pp \to \gamma d_1^* \to \gamma\gamma pp$ calculated with the help of Monte Carlo simulations for two d_1^* decay scenarios: without the final state interaction (solid line) and with the final state interaction (dashed line)

In 2001 under the **LESI** project, devoted to investigation of interaction between light nuclei at ultralow energies, experiments aimed at measuring the energy distribution of ions on the basis of registration of optical radiation of the expanding deuterium liner were performed with the high-current ion accelerator at the Institute of High-Current Electronics, RAS (Tomsk). The experiments allowed the conclusion that the proposed approach showed high potential for reconstruction of the ion flow energy distribution in the expanding liner in the inverse *Z*-pinch geometry [25]. Two ^{3}He detectors for measurement of the neutron yield from the *dd* reaction are designed and built. Measurements of the neutron recording efficiency and neutron lifetimes in the above detector ex-

posed to a neutron flux from the *dt* reaction and from the ^{252}Cf and Pu–Be sources are taken [26].

In the framework of the **YASNAPP-2** project the radiochemical investigations, investigations of short-lived nuclides and radioactive decays of long-lived nuclides as well as atomic-nuclear processes are under way. The nuclear spectroscopy methods are used for studying transmutation of radioactive nuclides, processes initiated by electronuclear neutrons, and other reactions.

Radioactive decay of short-lived nuclides in the transition region (from $^{146}_{64}Cd_{82}$ to strongly deformed $N > 90$ nuclei) was investigated in the on-line mode at the ISOL facility by using modern spectrometers with solid-state detectors. Strength functions for the beta decay of odd isotopes ^{147,149,151}Tb were measured. The structure of $^{156}_{67}Ho_{89}$ was comprehensively investigated and five isomeric states with $T_{1/2} > 10$ s were observed. Off-line studies of the decay of neutron-deficient Ho isotopes with atomic masses $A = 156$, 158, 160 and ^{152}Tb were performed. The decay schemes of nuclear excited levels arising in α decay of ^{221}Fr and β decays of ^{213}Bi and ^{209}Pb were investigated by α–γ and γ–γ coincidence. New weak branches of ^{211}Po and ^{221}Fr α decays were found. The existence of the 10.6 keV low-energy nuclear transition in the ^{225}Ac decay was revealed by using the ESA-50 electrostatic spectrometer in measurements of conversion electron lines. Low-energy electron spectra from decay of ^{57}Co, ^{73}As, ^{111}In, ^{155}Eu, ^{172}Lu, ^{241}Am, ^{241}Pu and ^{225}Ac were investigated at a high instrumental resolution. Strong influence of relativistic effects on the KL_1L_2 (^{3}Po) Auger transition intensity was proved. Influence of the source support material on energies of Auger and conversion electrons was observed for the first time. An upper limit of 0.40 % (95 % C.L.) on the admixture of heavy neutrinos with masses from 14 to 17 keV/c^2 was set from the investigation of the beta spectrum of ^{241}Pu with two electrostatic spectrometers ESA-12 and ESA-50.

Transmutation rates were determined for radioactive nuclei ^{129}I, ^{237}Np, ^{239}Pu and ^{241}Am in secondary neutron fluxes generated by 1.5, 3.7, and 7.4 GeV protons from the JINR Synchrophasotron in Pb and U targets. Space distribution of the neutron fluxes was measured by radiochemistry.

The structure of nuclei near double magic ^{208}Pb was studied. A new weak ($8 \cdot 10^{-6}$ per decay) branch of the ^{211}Po alpha decay to the1633 keV ^{207}Pb level was discovered. Investigations of α–γ coincidences at the ^{225}Ac decay were finished. Many transitions earlier ascribed to the ^{225}Ac decay were not confirmed. The 10.6 keV γ transition, which was required for fulfillment of the intensity balance, was revealed [27].

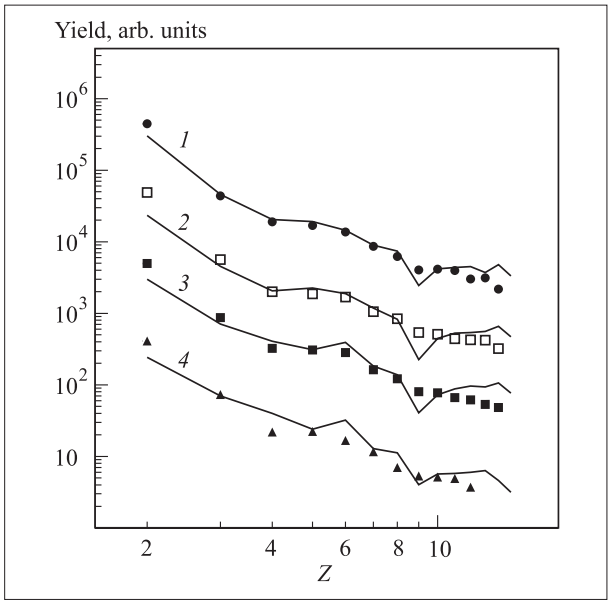

Fig. 14. Fragment charge distributions obtained for p + Au at 8.1 GeV (curve *1*), ^{4}He + Au at 4 GeV (curve *2*), ^{4}He + Au at 14.6 GeV (curve *3*) and ^{12}C + Au at 22.4 GeV (curve *4*). The curves are calculated by the statistical model

RELATIVISTIC NUCLEAR PHYSICS

The **FASA** project is devoted to the investigation of the mechanism of thermal multifragmentation, which takes place in collisions of light relativistic ions with a heavy target. This is a new, multibody decay process in which many fragments (IMF) with masses heavier than α particles and lighter than fission fragments are emitted from a very hot target spectator. A comparative study of multifragmentation of gold nuclei induced by relativistic protons, helium and carbon ions (accelerated by the JINR Synchrophasotron) has been performed [28]. The data obtained support the conclusion that in all the cases thermal multifragmentation takes place, which is a statistical break-up process governed by nuclear heating. It is illustrated with Fig. 14, which shows fragment charge distributions for different collisions. They are very similar and are well described by the combined model which includes modified intranuclear cascade calculations followed by the statistical multifragmentation model. The more detailed study demonstrates a transition from pure «thermal decay» (for p+Au collisions) to disintegration «decorated» by the onset of the radial collective flow, which is observed for ^{4}He (14.6 GeV)+Au and

^{12}C (22.4 GeV)+Au collisions. This collective flow is driven by the thermal pressure, its mean total energy is estimated to be around 115 MeV for both He and C beams, while the mean thermal excitation energy of fragmenting nuclei is 400–450 MeV.

APPLIED SCIENTIFIC RESEARCH

Under the JINR topic «Physics and Technique of Particle Accelerators», design and construction of the Low-Energy Particle Toroidal Accumulator (**LEPTA**) together with design of electron cooling systems were performed in 2001. Test of the prototype electron gun for the electron cooling system of the MUSES project (RIKEN, Japan) was conducted. Development of the electron cooling systems for the storage rings ACR (RIKEN) and NIRS (Chiba, Japan) and the electron cooling system with a circulating electron beam for the storage ring COSY (FZJ, Germany) was continued. The LEPTA project is aimed at constructing a small positron storage ring with electron cooling of circulating positrons. Main elements of the LEPTA magnetic system are constructed. The measurement of the magnetic field homogeneity was made and additional correction coils were constructed. The construction of the positron injector was started. The positron trap for storage of positrons before the injection into the LEPTA ring is under construction. The positron source on the basis of the radioactive ^{22}Na source was designed. The code for calculation of electron cooling of positrons was elaborated [29].

In 2001 the spallation product yields, angular distributions and fluxes of neutrons and charged particles from lead-vismut (Pl-Bi) target were measured with the experimental electronuclear installation **SAD** (Self-Amplifier Dubna) at the JINR Phasotron. The measurements were carried out in a wide proton energy range of up to 600 MeV.

The main goal of the JINR topic «Further Development of Methods and Instrumentation for Radiotherapy and Associated Diagnostics with JINR Hadron Beams» is to carry out medico-biological and clinical investigations on cancer treatment, etc. with medical hadron beams of the JINR Phasotron in the Medico-Technical Complex (MTC) of DLNP. In 2001 more than 50 patients were fractionally treated with the 150-MeV medical proton beam. The total number of the proton irradiation sessions exceeded 594. With the cobalt gamma unit «Rokus-M», 69 patients were irradiated (2520 irradiation sessions). A therapeutic 150-MeV uniform proton beam with a cross-section of 80×80 mm (instead of 60×60 mm used before) was delivered to room No 1. An X-ray tube and contrivances to fix X-ray sensitive plates of the commercial diagnostic device «ERGA» to the beam were installed in the same treatment room. This allowed one to make X-ray images of a patient and an autograph of a proton beam simultaneously on the same film in about 3 minutes right before the irradiation run for each direction of irradiation. This verification of the patient's position with respect to the proton beam guarantees an irradiation accuracy of 1–2 mm. It also became possible to spread out the set of localisations and to start radiotherapy and radiosurgery of intracranial targets.

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FLEROV LABORATORY OF NUCLEAR REACTIONS

In 2001, the FLNR scientific programme on heavy-ion physics included various fields of research such as experiments on the synthesis of heavy and exotic nuclei using ion beams of stable and radioactive isotopes and studies of nuclear reactions, acceleration technology, heavy-ion interaction with matter, and applied research. These lines of investigations were represented in fifteen Laboratory and all-Institute projects:

- Synthesis of new nuclei and study of nuclear properties and heavy-ion reaction mechanisms (9 projects);
- Radiation effects and modification of materials, radioanalytical and radioisotopic investigations using the FLNR accelerators (4 projects);
- Development of the FLNR cyclotron complex for producing intense beams of accelerated ions of stable and radioactive isotopes (2 projects);
- Development of the U400+U400M+MT25 cyclotron-microtron complex for the production of radioactive ion beams (the DRIBs project).

Reliable performance of the FLNR accelerators is a prerequisite for successful experiments and technical development. The first stage of DRIBs — production of light radioactive ion beams — should be realized in 2001, thus we really had to estimate how much time we had to allocate to the experimental research programmes and how much time had to be reserved for the DRIBs project.

In 2001, the operation time of the U400 and U400M FLNR cyclotrons was nearly 7000 hours, which is in accordance with the plan. Due to this, new experiments in low- and medium-energy ranges became possible. Allocation of beam time for different FLNR experimental set-ups in 2001 is shown in Tables 1 and 2.

Table 1

U400 set-up	Beam time, h
DGFRS	2100
VASSILISSA	500
CORSET	750
Chemistry	700
Applied Research	350
DRIBs	700
Others	250
Total	5350

Table 2

U400M set-up	Beam time, h
ACCULINNA	400
MULTI	300
COMBAS	250
FOBOS	50
DRIBs	700
Total	1700

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

Synthesis of New Elements

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

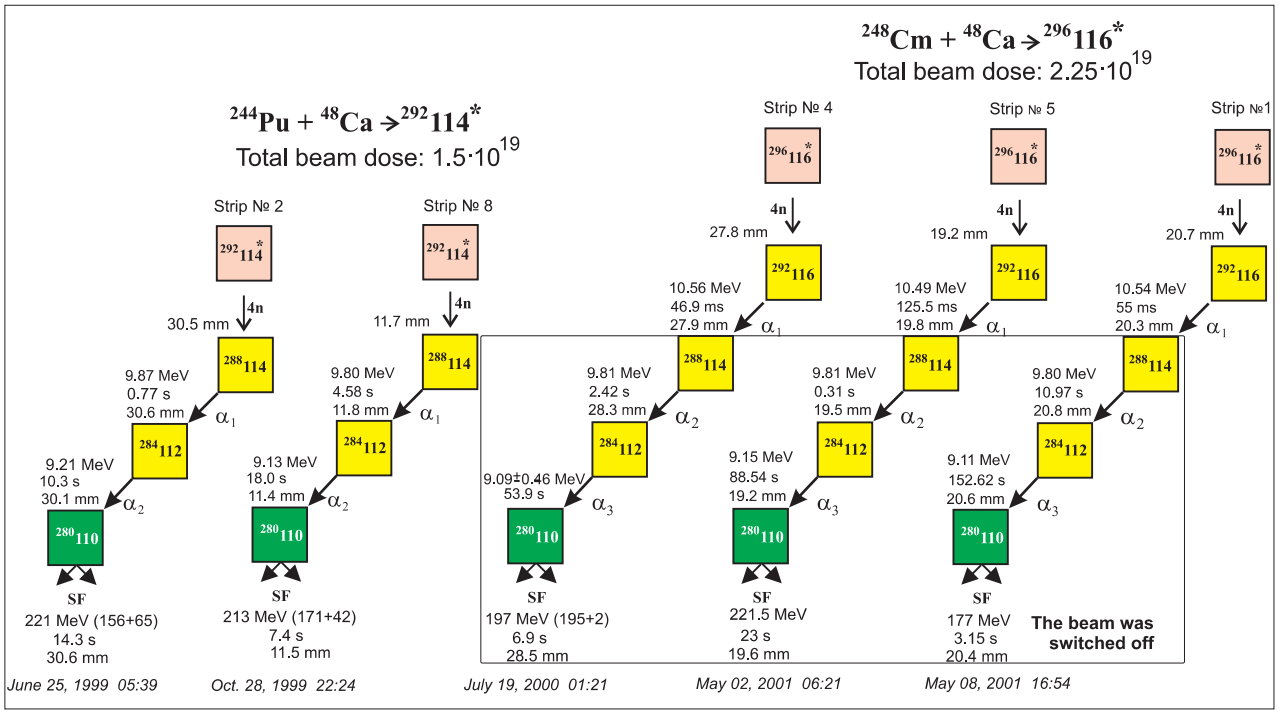

Fig. 1. Decay sequences of the nuclei observed in the reactions ^{244}Pu + ^{48}Ca and ^{248}Cm + ^{48}Ca

In January and April–July 2001, experiments were continued aimed at the synthesis of superheavy nuclei with $Z = 116$ in the complete fusion reaction ^{248}Cm + ^{48}Ca using the Dubna Gas-Filled Recoil Separator. A beam dose of $1.5 \cdot 10^{19}$ of ^{48}Ca projectiles was collected.

To improve the background conditions in view of a better detecting of long-time decay chains, a special mode of measurements was employed. The beam was switched off after a recoil signal was detected with parameters of the implantation energy and time-of-flight expected for the $Z = 116$ evaporation residues, followed by an α-like signal with the energy $10.0 \le E_\alpha \le 11.5$ MeV, in the same strip, within a position window $\Delta y = 2$ mm and time intervals of up to 5 s. The duration of the pause was determined from the observed pattern of out-of-beam α decays and was varied from 2 to 60 minutes. Thus, all the expected sequential decays of the daughter nuclides with $Z \le 114$ could be observed in the absence of the beam-associated background.

During these irradiations two more similar identical decay chains of genetically linked events were observed, each consisting of an implanted heavy atom, three subsequent α decays, terminated by spontaneous fission. These three decay chains (including the first one observed in 2000, see Fig. 1) can be assigned to the implantation and decay of the heavy nuclide with $Z = 116$. The energies and decay times of the descendant nuclei are in agreement with those observed in the decay chains of the even-even isotope ^{288}114 produced in the ^{244}Pu + ^{48}Ca reaction. Thus, the primary α decays in the chains should be attributed to the parent nuclide ^{292}116, produced via the evaporation of four neutrons. ^{292}116, ^{288}114 and ^{284}112 are the heaviest known α-decaying even-even nuclides.

As a result of these investigations, performed during 1998–2001, decays of the heaviest nuclei ^{277}Hs ($Z = 108$), ^{280,281}110, ^{283,284,285}112, ^{287,288,289}114 and ^{292}116 were observed.

The experimental results are summarized in Table 3, and decay properties of the heaviest isotopes of Hs–^{292}116 are presented in Table 4.

What can one learn from the analysis of the whole set of the data?

In reactions with ^{48}Ca at a bombarding energy close to the Coulomb barrier a maximal yield is expected for the 3*n*- and 4*n*-evaporation channels. Evaporation channels accompanied by the emission of charged particles (protons, α particles) are strongly suppressed.

For all the events of sequential α decays the energies and decay probabilities obey the basic Geiger–Nuttall rule, which connects the α-decay energy Q_α with the half-life T_α and implies decays of nuclei with large atomic numbers $Z = 110 \div 116$ (Fig. 2).

The spontaneous fission events with TKE ≈ ≈ 200 MeV are related to the decay of rather long-lived nuclei ($T_{sf} \approx 10 \div 1000$ s) with $Z \ge 106$, which are the «children» or «grandchildren» of heavier nuclei.

A significant increase in the lifetime of ^{281}110 with respect to that of ^{273}110 (by a factor of $8 \cdot 10^5$), and in the life-time of ^{285}112 with respect to that of ^{277}112 (by a

Table 3

Date	Target	Excitation energy E^*, MeV	Beam dose, $\times 10^{18}$	Nucleus detected	Number of events	Cross-section, pb
March 1998	^{238}U	31.0	3.5	^{283}112	2	5
Nov. – Dec. 1998	^{244}Pu	35.0	5.2	^{289}114	1	1
March 1999	^{242}Pu	33.5	7.5	^{287}114	2	2.5
June – Oct. 1999	^{244}Pu	35.3	10	^{288}114	2	1
June 2000 – May 2001	^{248}Cm	33.1	23	^{292}116	3	0.5
May – July 2001	^{248}Cm	30.4	8.0	^{293}116	0	< 0.5

Table 4

Isotope	Decay mode	E_α, MeV	TKE_{mes}, MeV	$T_{1/2}$
^{277}Hs	SF		170	11 min
^{280}110	SF		210	7.6 s
^{281}110	α	8.83		1.1 min
^{283}112	SF		190	3 min
^{284}112	α	9.17		44.3 s
^{285}112	α	8.67		11 min
^{287}114	α	10.29		5 s
^{288}114	α	9.83		2.6 s
^{289}114	α	9.71		21 s
^{292}116	α	10.56		52.5 ms

factor of $2.7 \cdot 10^6$), can be considered as an indication of the presence of nuclear shells at higher neutron numbers (see Fig. 3).

Comparing the half-life of ^{292}116 ($T_{1/2} = 52.5$ ms) and that of its daughter ^{288}114 ($T_{1/2} = 2.6$ s), one can suppose that $Z = 114$ is probably a proton shell. There is also an indication that this shell is a spherical one. Within the limits of the detector energy resolution and statistical uncertainty in the decay times, all the three α decays of ^{288}114 can be attributed to the decay from the ground state, which is populated after the decay of the evaporation residue or after α decay of the parent nucleus ^{292}116. This can be compared with the decay of ^{277}112, which populate different levels in the deformed ^{273}110 (due to

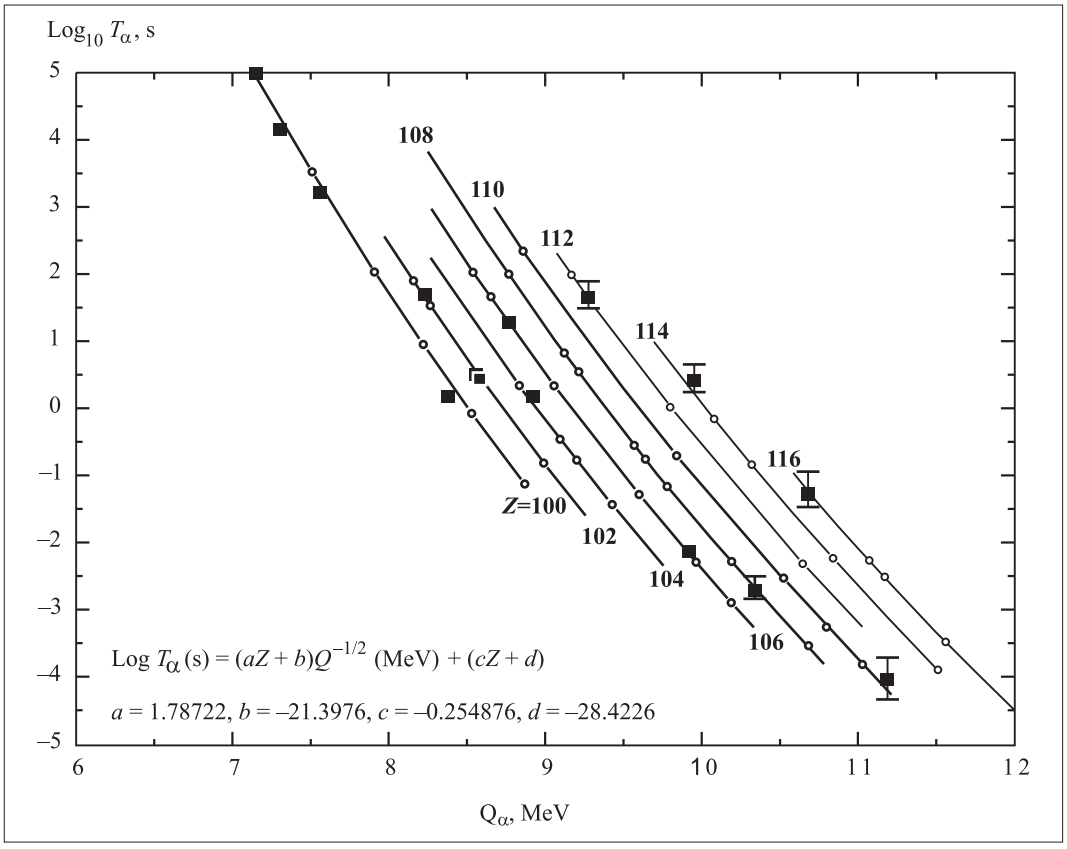

Fig. 2. A plot of Log T_α vs Q_α (the Geiger–Nuttall rule) for even-even nuclides with $Z \geq 100$

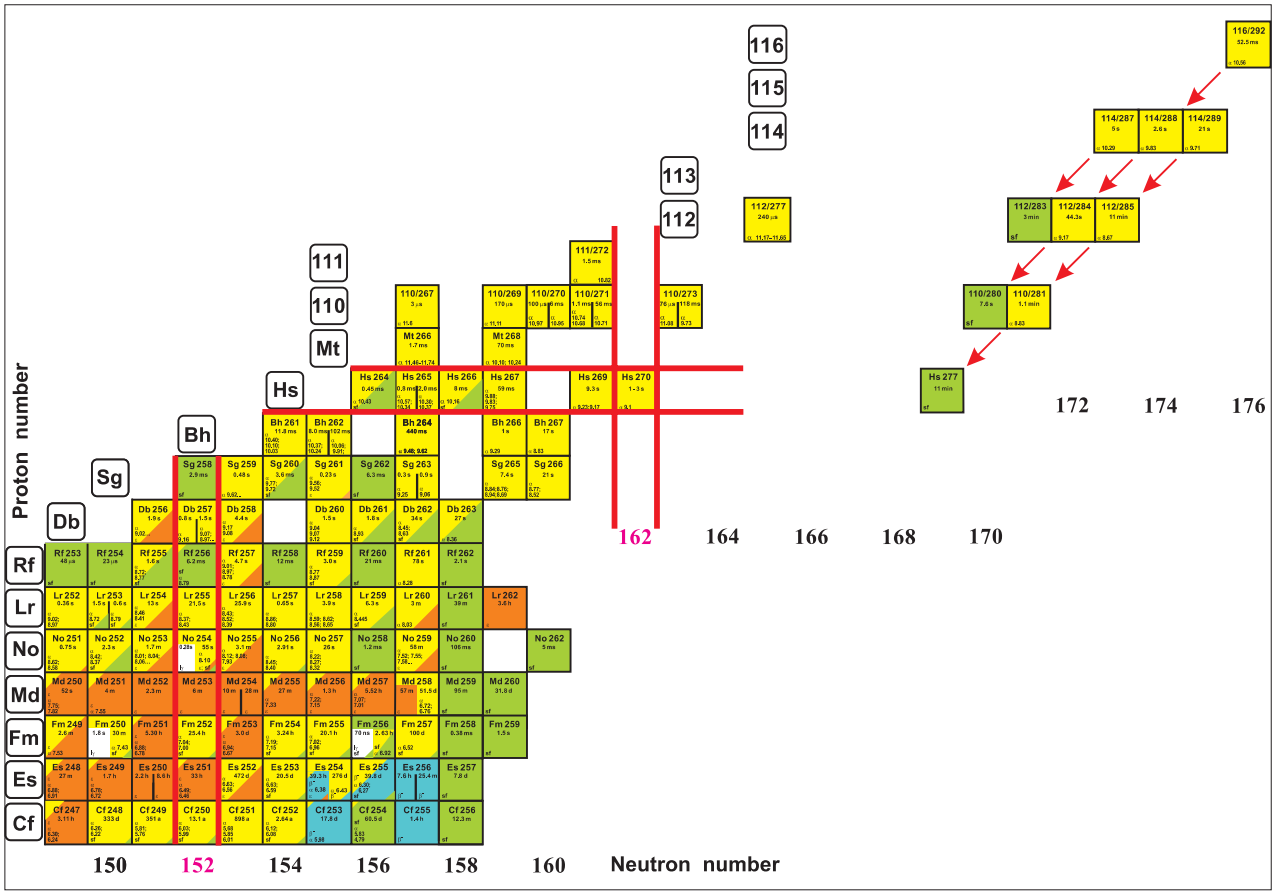

Fig. 3. Chart of the nuclides of the transfermium elements

the predicted neutron shell $N = 162$). The three observed α transitions differ by 0.5 MeV.

The experiments were carried out at the FLNR (Dubna) heavy-ion cyclotron U400 using the electrostatic separator VASSILISSA and Dubna Gas-Filled Recoil Separator (DGFRS) in the framework of a large collaboration with GSI (Darmstadt), LLNL (Livermore), RIKEN (Wako-shi, Saitama) and Comenius University (Bratislava).

The results on the synthesis of superheavy nuclides with $Z = 112$, 114 and 116 in the fusion reactions between actinide targets with ^{48}Ca ions have been submitted for the consideration by the IUPAC.

During 2002–2004, the investigations will be aimed at the synthesis of nuclei with $Z \sim 115$–118 in the ^{243}Am, ^{249}Cf + ^{48}Ca reactions. Both facilities, VASSILISSA and the Gas-Filled Recoil Separator (GFRS), will be used in these experiments, to be carried out within a wide international collaboration.

Chemistry of Transactinides

Relatively long half-lives of the isotopes with $Z = 108 \div 114$, obtained in the ^{48}Ca-induced reactions, open up new opportunities for the investigation of chemical properties of superheavy elements. Quasi-on-line mass separation or chemical separation can be employed. These methods have significant advantages in the effective target thickness (a factor of about 10) and in the beam acceptability.

The first attempt on chemical identification of element 112 was made in January 2000 using the Dubna U400 cyclotron. The 3-min ^{283}112 can be produced with a cross-section of about 5 pb in the reaction ^{238}U(^{48}Ca, 3n). Element 112 (E112) must belong to the IIB group Zn-Cd-Hg. As a first step, a method for the separation and detection of Hg was developed. After 10 days of irradiation with ^{48}Ca ions an integral beam dose of $6.9 \cdot 10^{17}$ was accumulated. During this bombardment, no SF events were observed. The experiment did not give an unambiguous answer concerning physical and chemical properties of element 112.

Another experiment on chemical isolation of element 112 was performed in November – December 2001. The detection system was extended: the ionization chamber was placed downstream behind the 8 pairs of the Au-plated PIPS detectors. The chamber and the PIPS detectors were positioned inside the neutron multiplicity

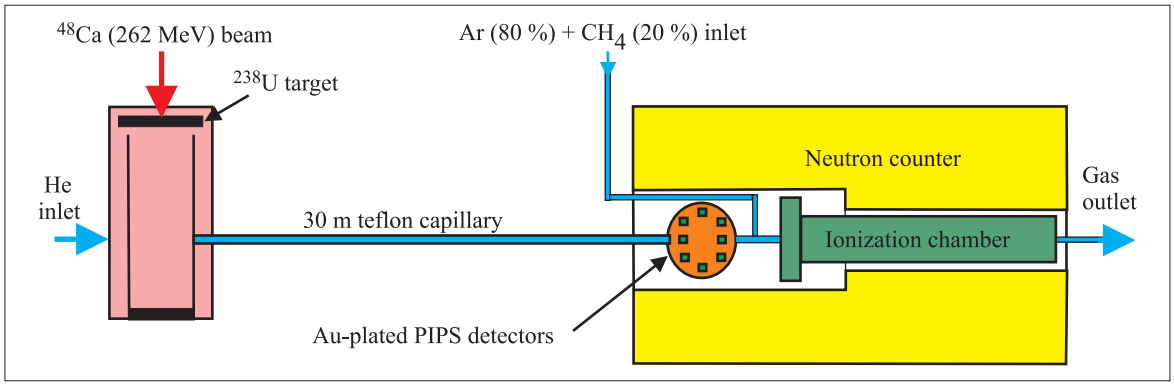

Fig. 4. Schematic view of the set-up for the isolation and identification of element 112

counter (Fig. 4). The ionization chamber was capable of detecting spontaneous fission of Rn-like reaction products in a flowing gas during 5 ÷ 10 min depending on the flow rate.

A 2-mg/cm^2 $^{238}U_3O_8$ target was deposited onto a 2 μm HAVAR foil. It contained 100 μg of natural Nd. Recoils were thermalized in pure helium and transported through a 30 m long capillary to the detection apparatus. There were 8 detection chambers placed in series. The adsorption of Hg atoms formed in the reaction Nd (^{48}Ca; *xn*) was measured through the 5.65-MeV α particles of ^{185}Hg.

After a 20-day irradiation with ^{48}Ca ions an integral beam dose of $4 \cdot 10^{18}$ was accumulated. During this bombardment, no SF events were detected by the PIPS detectors. Several spontaneous fission events with multiple neutrons were detected by the ionization chamber. Now control experiments and background measurements are in progress. The next step of this work will depend on the obtained results.

The first results on the properties of Hs ($Z = 108$) were obtained in collaboration with scientists of Switzerland, Germany and the USA.

For 2002–2004 planned is the on-line chemical isolation and identification of heavy isotopes and detection of α decay and spontaneous fission fragments in coincidence with neutrons. A series of collaborative experiments is planned at FLNR in collaboration with scientists of Germany (GSI, Darmstadt; University, Munich; University, Mainz), PSI (Villigen, Switzerland) and NINP (Cracow, Poland).

Separator MASHA

In the case of a short lifetime (micro- or milliseconds) the on-line in beam separation is needed. All existing recoil separators have similar limitations: in order to keep kinematic conditions one needs thin targets of approximately 0.3 mg/cm^2. But the recoil range in a typical target material is much wider and one could use targets with a thickness of about 2 mg/cm^2. Long lifetimes make it possible to change the approach to the synthesis of superheavy nuclei. The properties of superheavy elements are predicted to be similar to those of volatile elements Hg, Tl, Pb, Bi, Po, At or Rn, thus one can think about using an off-line separator. In that case one can get precise information on the nuclide mass. Today, R&D of the separator MASHA (Mass Analyzer of SuperHeavy Atoms) has been finished (Fig. 5).

The projectiles and recoils are stopped in a catcher with the inside temperature of as high as ≈ 2500 °C. Then volatile products diffuse to the ion source. It is planned to use the 2.4 GHz ECR-ion source at a low He pressure of 10^{-5} mbar for the production of single-charged ions. After the extraction from the ECR the ion beam will be prepared for pre-separation. In the intermediate focus, masses $A \approx 300$ are separated from masses $A \approx 250$ (target-like transfer reaction products). After the main magnetic separator at the focal plane a mass resolution is expected to be about 1000. First experiments with the use of this separator are scheduled for 2003.

Nuclear Fission

In the framework of the collaboration FLNR–IReS–LPC–ULB–Texas A&M University–INFN, the mechanisms of formation and decay of heavy and superheavy nuclei in the reactions with ^{12}C, ^{18}O, ^{22}Ne, ^{26}Mg, ^{48}Ca, ^{58}Fe, ^{86}Kr ions were investigated using the CORSET–DEMON set-up. The experiments were carried out at the accelerators of FLNR, Texas A&M University and INFN. At energies close to and below the Coulomb barrier, fission properties of the compound nuclei ^{216,218,220}Ra, ^{256}No, ^{270}Sg, ^{266,271,274}Hs, ^{286}112,

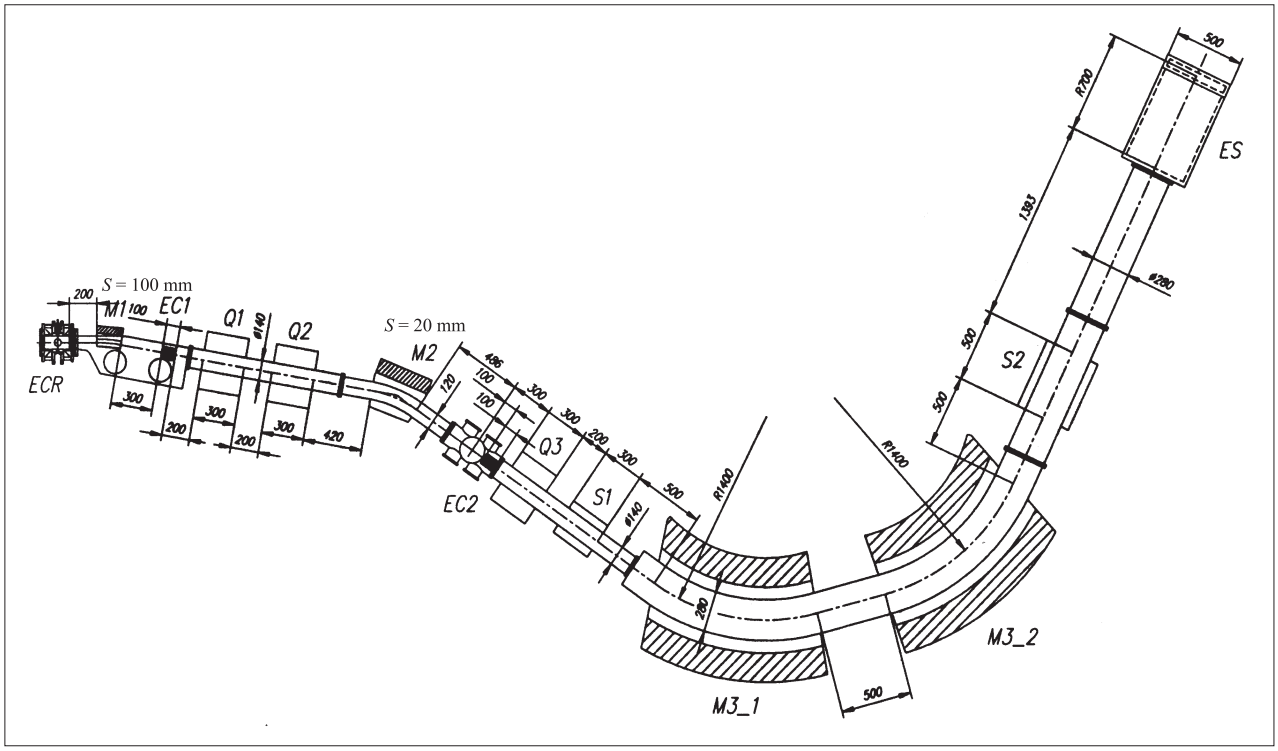

Fig. 5. Separator MASHA

^{292}114, ^{290,296}116, ^{294}118, ^{302}120 and ^{306}122 were studied for the first time.

It was found that the mass distribution of fission fragments for the compound nuclei ^{286}112, ^{292}114, ^{290,296}116, ^{302}120 and ^{306}122 is an asymmetric one,

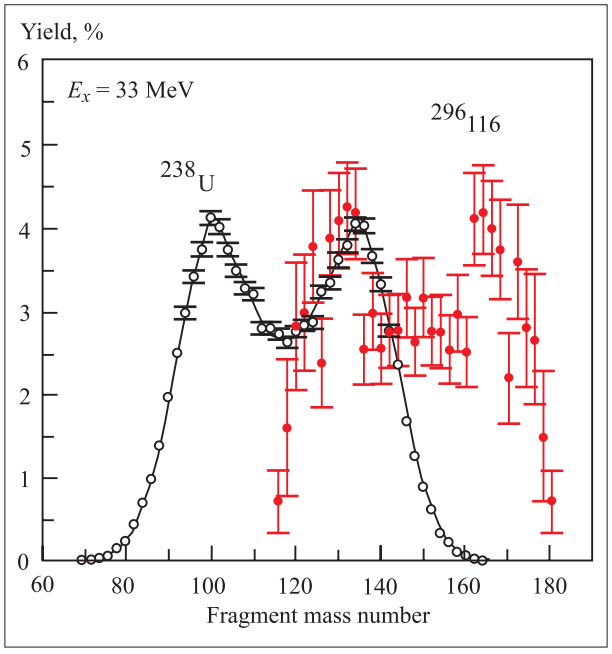

Fig. 6. Mass distribution of fission fragments of the ^{238}U and ^{296}116 compound system at a low excitation energy

whose nature, in contrast to the asymmetric fission of actinides, is determined by the shell structure of the light fragment with the average mass 132–134 (Fig. 6).

For the detection of neutrons 49 DEMON modules were used. Obtained mass-energy distributions point to a clear evolution from the symmetric fission of the compound nucleus in the case of ^{256}No to the situation of the ^{286}112 and ^{292}114 nuclei in which a more asymmetric process of quasi-fission becomes predominant. These investigations showed that the TKE, neutron and γ-ray multiplicities for the fission and those of quasi-fission of superheavy compound nuclei differ greatly.

The capture (σ_c) and fusion-fission (σ_{ff}) cross-sections for the nuclei ^{256}No, ^{266,274}Hs, ^{286}112, ^{292}114, ^{296}116, ^{294}118 and ^{306}122 were studied as a function of the excitation energy in a range of 15–60 MeV. It should be emphasized that the fusion-fission cross-section for the compound nuclei produced in the reaction with ^{48}Ca and ^{58}Fe ions at an excitation energy of about 30 MeV depends only slightly on the reaction partners, that is, as one goes from ^{286}112 to ^{306}122, the σ_{ff} changes by a factor of 4–5 and less. This property seems to be of much importance in planning and carrying out experiments on the synthesis of superheavy nuclei with $Z > 114$ in reactions with ^{48}Ca and ^{58}Fe ions.

In the case of the reaction ^{86}Kr + ^{208}Pb, leading to the production of the composite system ^{294}118, in con-

trast to the reactions with ^{48}Ca and ^{58}Fe, the contribution of quasi-fission is dominant in the region of fragment masses close to $A/2$.

In the region of heavy nuclei ^{216,218,220}Ra and ^{256}No, ^{270}Sg and ^{266,271,274}Hs the phenomenon of multi-modal fission was first observed and studied.

In 2002–2004, it is planned to investigate fusion-fission and quasi-fission cross-sections in reactions between ^{48}Ca, ^{58}Fe and ^{64}Ni ions and ^{238}U, ^{244}Pu, ^{248}Cm and ^{249}Cf targets, leading to the formation of nuclear systems with $Z = 112 \div 122$. Simultaneously, it is also planned to study neutron and γ-quanta multiplicities in the fission of superheavy nuclei with $Z = 116 \div 122$. The first experiments in the framework of the DRIBs project will be measurements of characteristics of low-energy fission of neutron-rich Th, Cm and Cf isotopes, produced in the ^{6}He and ^{8}He reactions induced on ^{226}Ra, ^{244}Pu and ^{248}Cm targets. Experiments will be carried out in collaboration with GSI (Darmstadt, Germany), INPN (Catania, Italy), IReS (Strasbourg, France), ISN (Grenoble, France), University of Brussels (Belgium), University of Texas (USA), IP (Bratislava, Slovakia) and INP (Almaty, Kazakhstan).

Separator VASSILISSA

In 2001, a new dipole magnet with a deflection angle of 37° was installed as a post-separator in tandem with VASSILISSA for determining masses of newly synthesized superheavy nuclides. A new detection system was developed. It consisted of TOF detectors, a new focal plane 32 strip detector (60×120 mm) and a corresponding data acquisition system.

Test experiments with ^{40}Ar, ^{48}Ca beams and Dy, Yb, Pb targets showed that the post-separator successfully provided an additional suppression of unwanted reaction products by a factor of about 10 and a possibility to have mass resolution at the level of 2.0 % for the heavy nuclei with masses $A \approx 300$.

During 2002–2004 it is planned to continue the experiments on the synthesis of superheavy nuclei in the reactions between ^{34}S, ^{48}Ca beams and ^{232}Th, ^{236,238}U and ^{243}Am targets using the recoil separator VASSILISSA and magnetic mass analyzer. Upgrading of the high-voltage system of VASSILISSA up to 250 kV will make it possible to investigate the influence of the shell structure in the entrance channel in a range from deep subbarrier energies to energies above the Coulomb barrier, using such reactions as ^{86}Kr + ^{124}Sn, ^{136}Xe, ^{136}Xe + ^{124}Sn, ^{136}Xe. Among the first experiments in the framework of the DRIBs project there will be experiments ^{6,8}He + ^{40,44,48}Ca, which will allow one to study the fusion process and de-excitation of compound nuclei by evaporation of neutrons, protons and α's.

It is planned to make the experiments in collaboration with GSI (Darmstadt, Germany), RIKEN (Saitama, Japan), Comenius University (Bratislava, Slovakia), GANIL (Caen, France), University of Messina (Italy).

Fragment Separator COMBAS

Production of isotopes with mass numbers $15 \le A \le 40$ and atomic numbers $6 \le Z \le 14$ induced in the inverse kinematic reaction ^{40}Ar + ^{9}Be at the Fermi energy (37.5 A·MeV) was studied in forward-angle measurements using the fragment separator COMBAS. No evidence was found of any dramatic change in the reaction mechanisms for peripheral reactions in comparison with those in a low-energy range. The dominant role of stripping, pick-up and exchange nuclear reactions was observed. The yields of isotopes produced in the stripping reactions were well approximated with a simple exponential function of Q_{gg}.

Production rates of the exotic nuclei ^{20,21}N, $^{21–24}$O, $^{23–26}$F and $^{26–30}$Ne, which can be used as secondary radioactive beams, were determined.

In 2002–2004, using intermediate-energy projectiles, the yields and cluster properties of heavy neutron-rich isotopes $^{10 \div 14}$Be, $^{14 \div 17}$B, $^{16 \div 20}$C, $^{20 \div 24}$O and $^{23 \div 26}$F will be studied using the separator COMBAS in break-up reactions on targets of hydrogen isotopes. Experiments will be carried out in collaboration with GSI (Darmstadt, Germany) and Comenius University (Bratislava, Slovakia).

High-Resolution Beam Line ACCULINNA

In order to install a liquid-tritium target the separator ACCULINNA was upgraded. The beam line was extended beyond a 2-meter concrete wall to a newly built hall housing the reaction chamber in which new, improved performance particle telescopes were installed. For the detection of neutrons 41 DEMON modules were used. The beam monitoring and detector arrays were upgraded in order to fit experiments aimed at the study of ^{4}H and ^{5}H produced in reactions with a primary triton beam (Fig. 7).

Even though the unstable nuclear systems ^{4}H and ^{5}H have been studied for over more than 40 years, the data on these nuclei remain scarce and often controversial. To further investigate the resonance states of ^{4}H and

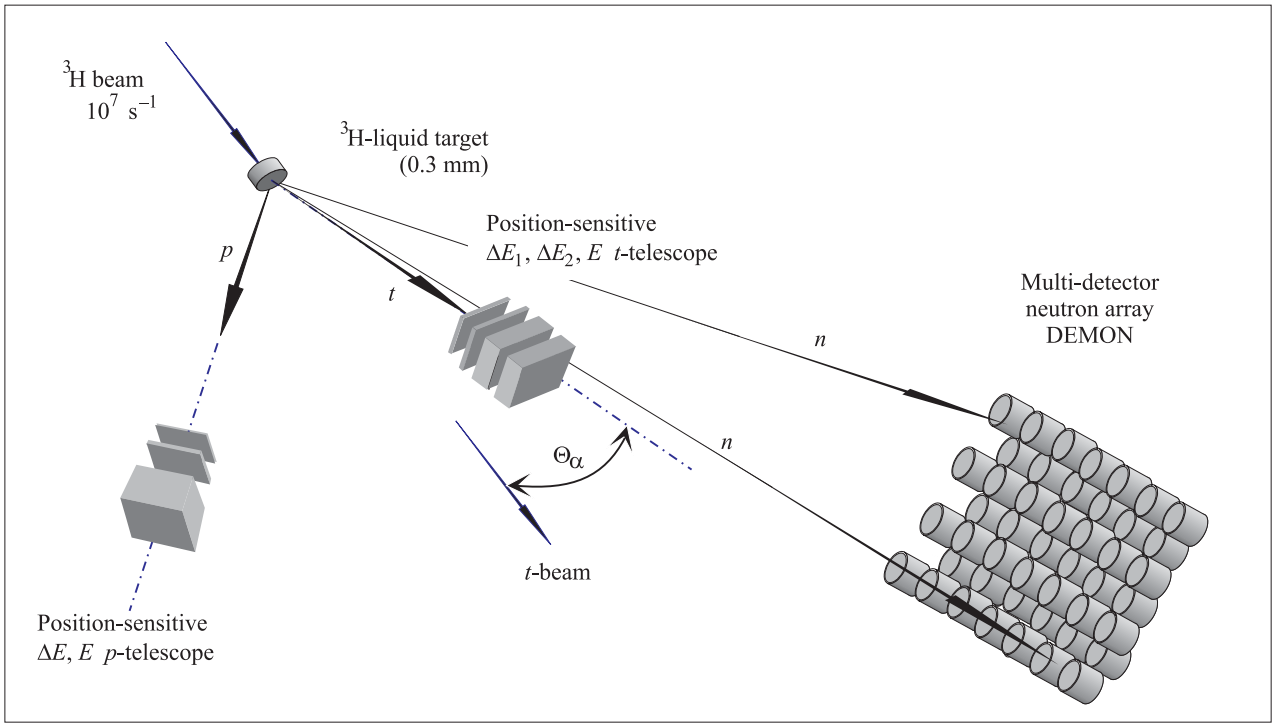

Fig. 7. Modernized detector array of ACCULINNA

^{5}H, transfer reactions were used occurring in bombardment of a liquid-tritium (deuterium) target with tritons. For this study, an environment-friendly liquid-tritium (deuterium) target was created and installed at the secondary radioactive beam line ACCULINNA, which was used in this case to deliver to the target a 57.5-MeV triton beam accelerated by the U400M cyclotron. This beam line was also used to cut the angular and energy divergence of the primary triton beam to FWHM values of 7 mrad and 0.3 MeV, respectively. The target cell had a material thickness of 0.4 mm for liquid tritium or deuterium.

Using the reactions $t+d \rightarrow p+^4$H, $t+t \rightarrow p+^5$H and $t+t \rightarrow d+^4$H there were detected protons/deuterons in coincidence with complementary tritons emitted from the target. Two highly granulated Si detector telescopes accomplished this detection. Neutrons emitted in the decay of unstable ^{4}H and ^{5}H could also be detected in coincidence with charged reaction products. A typical beam intensity on the target was $2\cdot10^7$ s^{-1}.

A state of ^{4}H with $E_{res} = 3.22 \pm 0.15$ MeV and $\Gamma_{obs} = 3.33 \pm 0.25$ MeV was obtained in the $t+d$ reaction from the spectra of protons leaving the target at $\theta_{lab} = 18$–$32°$ and detected in coincidence with tritons. A substantial fraction of protons detected in the $t+t$ reaction at $\theta_{lab} = 18$–$32°$ in *ptn* coincidence events was attributed to the states of the ^{5}H nucleus. At ≈ 2.5 MeV above the *tnn* decay threshold the ^{5}H spectrum shows a narrow maximum followed by a wide structure at 4–7 MeV (Fig. 8).

At the ACCULINNA beam line, experiments with cryogenic ^{1,2,3}H targets are planned for the period of 2002–2004 at the beams of U400M within the DRIBs project (the ISTRA set-up). Elastic scattering of ^{6}He and ^{8}He on the tritium target to the backward hemisphere will be studied in order to obtain information on the clustering configurations of ^{6}He in $t+t$ and that of ^{8}He in the ^{5}H+t clusters.

The study of transfer reactions will be extended to the study of such transfers as ^{8}He+^{3}H$\rightarrow^{10}$He+p, ^{9}Li+^{3}H$\rightarrow^{11}$Li+p, ^{6}He+^{3}H$\rightarrow^8$He+p. The aim is to investigate the halo clustering in ^{6,8}He and to search for possible structures in the tetra-neutron system. New excited states in ^{11}Li and ^{8}He populated in the reactions will also be searched for. The work will be performed in collaboration with the groups of GSI (Darmstadt, Germany), GANIL (Caen, France), YerPhI (Yerevan, Armenia), RIKEN (Saitama, Japan), Kurcharov Institute (Moscow, Russia), Comenius University (Bratislava, Slovakia).

Reactions Induced by Stable and Radioactive Ion Beams of Light Elements

At a secondary ^{6}He beam, formed with the help of a special channel (Q4DQ spectrometer) of the U400M cy-

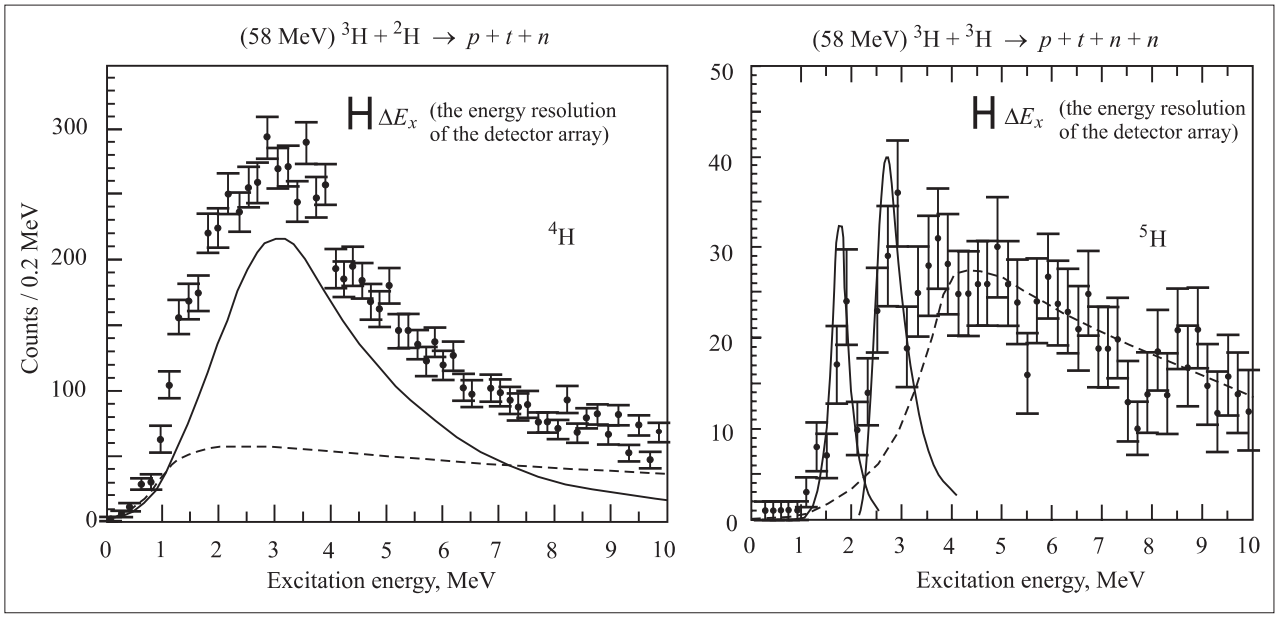

Fig. 8. ^{4}H and ^{5}H spectra

clotron, experiments were carried out devoted to measuring the excitation functions of the ^{6}He + ^{209}Bi fusion-fission reactions. The beam intensity was $5 \cdot 10^4$ pps. The excitation function was measured in an energy range of 25–70 MeV. The 4*n* evaporation decay channel of the ^{215}At compound nucleus produced in this reaction was also measured. Comparison of the experimental data with the data calculated with the use of the ALICE-MP code showed that the values of the angular momentum and radius should be increased by 15–20 % as compared to those for the ^{4}He + Bi reaction. New results were obtained for the energy dependence of the total reaction cross-sections σ_R in an energy range of 10–28 MeV/A.

In the ^{28}Si (^{6}He, ^{4}He) *X* channel the reaction cross-sections for α-particle emission were measured. In an energy range of lower than 17 MeV/A, the value of σ_R was observed to increase sharply. The energy spectra of the α particles produced in the interaction of ^{6}He with silicon are indicative of two production mechanisms, i. e., transfer reactions and a break-up of ^{6}He in the field of the ^{28}Si nucleus.

Yields of Kr and Xe isotopes were independently measured in the photofission of heavy nuclei ^{238}Th, ^{238}U and ^{244}Pu at the FLNR MT25 microtron bremsstrahlung. The produced fragments were slowed down in gas and transported with a gas flow through a capillary to a cryostat (see Fig. 9). The efficiency of the fragment transportation at a distance of 30 m within a 2 s time interval was 70 % (at a distance of 1 m, the time interval was 0.1 s). The Kr and Xe isotopes condensed in the cryostat together with all other elements were absorbed by a filter at a target chamber outlet. Xe fragments

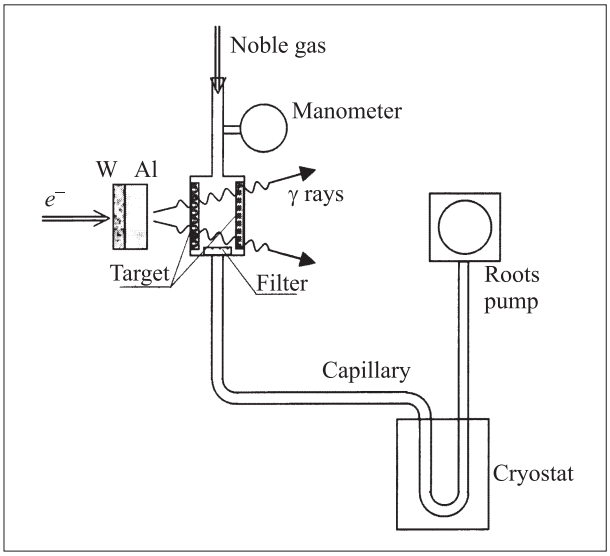

Fig. 9. Set-up for transportation of photofission fragments

were identified by the γ-radiation spectra of their daughter products.

The yields of five Xe isotopes were determined. From the obtained dependences it is seen that the yields of neutron-rich isotopes increase with an increase in the atomic number of the fissioning nucleus. The conclusion was made that the use of photofission fragments for the study of their properties and for further acceleration (within the framework of the DRIBs project) is quite promising.

The GANIL–FLNR collaborative experiments were continued. Using these experiments, the structure and

properties of nuclei with the neutron shells $N = 20 \div 28$ ($^{30-36}$Mg, $^{26-32}$Ne, $^{22-24}$O, $^{26-29}$F) in the so-called island of inversion were studied. It was shown that nuclei having neutron shells with N close to 20 are deformed. It also follows from the obtained data that in this region there are new magic numbers ($N \approx 16$) and that the stability of nuclei with extreme neutron numbers, ^{26,28}O, ^{31}F, is governed by the deformation of those nuclei.

In collaboration with Jyväskylä University, decay characteristics of the ^{228}110 compound system produced in the reaction ^{238}U + ^{40}Ar at an excitation energy of ~70 MeV were studied. It was found that the fission fragment mass distributions have a structure with peaks corresponding to mass numbers $A = 70$–80, 100 and 130, which can be accounted for by the fact that in this reaction both spherical and deformed magic nuclei (clusters) of Ni, Ge, Sn, Zr, Mo, Tl are produced.

In collaboration with teams from Manchester (UK) and Jyväskylä (Finland), the charge radii of neutron-deficient isotopes of titanium, ^{44}Ti and ^{45}Ti, were measured. The experiments were carried out using the cyclotron of Jyväskylä University. The charge radius of Ti nuclei was found to increase with a decrease in the neutron number. It is planned to continue these investigations.

Using resonance laser spectrometry, measurements were carried out of the hyperfine optical line splitting in the atomic spectra of rare-earth elements Nd, Sm, Eu, Gd and Lu. The magnetic dipole and electric quadrupole splitting constants were determined for isotopes of the indicated elements. An anomaly was discovered in the magnetic splitting, which points to the fact that the magnetic momentum of those nuclei is distributed in a spatial way.

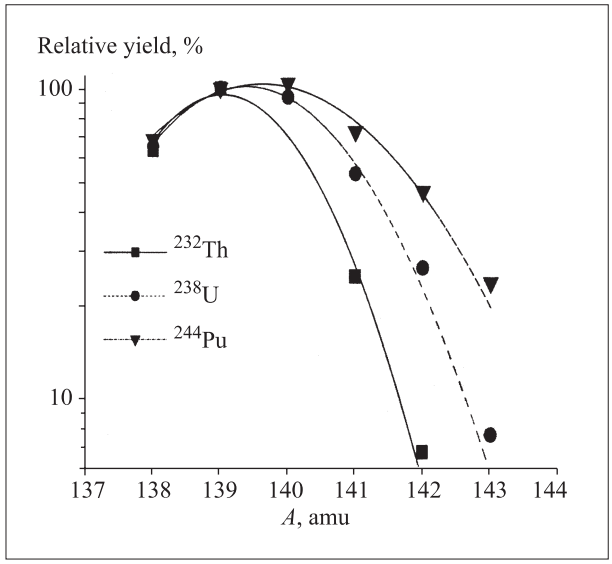

Fig. 10. Yields of Xe isotopes in photofission of ^{232}Th, ^{238}U and ^{244}Pu

APPLIED RESEARCH

Interaction of Accelerated Heavy Ions with Polymers

Research and development of thermo-sensitive membranes was undertaken. Response of membranes to a change in temperature and their electro-surface properties were investigated (in collaboration 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 an «ion transmission technique» in the TM structure investigation (in cooperation with NPI, Rez, and HMI, Berlin). 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.

Porous matrixes of a special geometry were investigated in view of using them in optoelectronic devices. A procedure of the matrix production with the use of polyimide film irradiated with krypton ions at the U400 cyclotron was elaborated. The procedure includes a two-stage chemical treatment providing formation of conical pinholes, focalizing electromagnetic radiation.

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. A feasibility of production of thick «blotting» membranes and membranes of the «wells with a porous bottom» type was investigated.

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 flu-

ence 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 the semiconductor industry.

In cooperation with the Oak Ridge Laboratory (USA) and the Institute of Transuranium Elements (Karlsruhe, Germany), the microstructure of spinel $MgAl_2O_4$ irradiated with Kr, I and Xe ions with energies from 70 to 600 MeV was studied. 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.

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, silicon monocrystals, and pyrolytic graphite irradiated with ^{86}Kr (305, 440 and 750 MeV), ^{136}Xe (605 MeV) and ^{209}Bi (705 MeV) ions was studied using 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 the interaction between high-energy ions and condensed matter.

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 post-irradiation annealing at 500–1000 °C, re-crystallization of the amorphous Si layer created by the irradiation with the 17 keV He ions was studied. The obtained results are important for understanding the mechanisms of defect formation in semi-conducting materials.

Ultrapure Radioisotopes and Radioanalytical Research

Methods of production of radioisotopes ^{99m}Tc (^{99}Mo), ^{225}Ac, ^{235}Np, ^{236}Np, ^{236}Pu and some others using (γ, n) reactions at the MT25 microtron were developed.

A technique of radiochemical extraction of ^{149}Tb was elaborated. The dependence of the ^{149}Tb yield in the reaction ^{142}Nd (^{12}C, xn)^{149}Dy 4.1 min $\rightarrow$ ^{149}Tb ($x = 5 \div 7$) on the ^{12}C ion energy was established.

The distribution of natural radionuclides in biological objects, soil, plants and water was studied in seismically active regions (France, Tadjikistan, Krasnodar). A combined effect of radionuclides and chemical pollution in the Saratov Region was estimated.

PHYSICS AND HEAVY-ION ACCELERATOR TECHNIQUES

In 2001, the emphasis was made on further optimization of the U400 and U400M cyclotrons and the ion sources in view of performing experiments on the synthesis of superheavy elements and experiments on the production of light exotic nuclei.

Development of the accelerator technique was focused on the successful realization of the DRIBs project (production of radioactive ion beams at Dubna cyclotrons).

In March 2001, according to the schedule of Stage I of the project, a complex for the generation, ionization and separation of ^{6}He and ^{8}He ions was created and tested at the ^{11}B beam of the U400M cyclotron. Assembling, adjusting and a long-term testing of the system providing transport of RIB from the U400M cyclotron hall to a distance of 120 m have been realized since July 2001.

In October 2001 the transport of ions was realized along the 1/4 of the transport line length. In October and November it is planned to transport the beam into the U400 hall. In December 2001 the beam of ^{6}He will be accelerated up to an energy of 12 MeV/n using the U400 cyclotron. The extraction of the ^{6}He beam from U400 and its delivery to a physical target is scheduled for June 2002. There will be two extraction lines from U400. One is in the direction where the main experimental set-ups are located, the other will be in an opposite way where the CORSET for fusion-fission studies and the ISTRA set-up together with DEMON modules are proposed to be installed (Fig. 11). The first experiments are scheduled for the second half of 2002.

In the experiments with the RI beams during 2002–2004 it is planned to study:

— elastic and inelastic scattering of ^{6,8}He on $^{40\div48}$Ca and Pb targets for testing the parameters of an optical model for halo nuclei (MSP-144 and VASSILISSA);

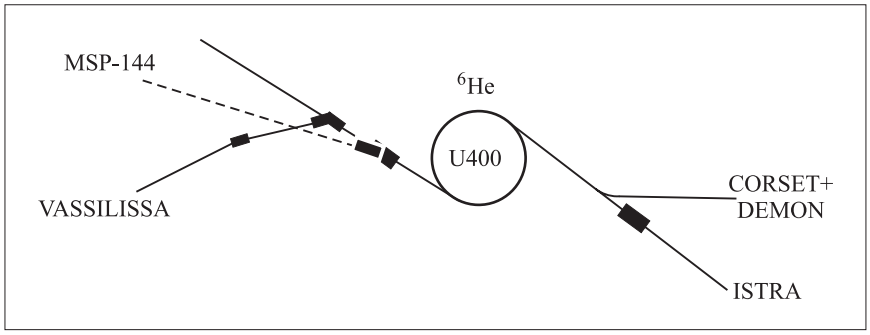

Fig. 11. Beam lines for RI in the U400 experimental hall

— fission and fusion reactions induced by ^{6}He, the probability of the full momentum transfer, fission modes of the heaviest Pu÷Cf isotopes (CORSET + DEMON);
— neutron correlations in extra neutron-rich H and He isotopes beyond the drip line (ISTRA).

To realize all the capacities of DRIBs, a further modernization of the Laboratory experimental set-ups is required.

In January 2002, it is planned to work out assignments for the R&D and manufacturing of the uranium target complex, ion source and separators in the framework of the DRIBs project (Stage II). The second stage — acceleration of fission fragments — should be realized in 2002.

FRANK LABORATORY OF NEUTRON PHYSICS

In 2001, the FLNP scientific programme was executed under five research themes included in the JINR Plan for 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 «Nuclear Physics with Neutrons — Fundamental and Applied Investigations», headed by W. I. Furman and V. N. Shvetsov). To effect scientific research, the development, modernization and construction of the FLNP basic facilities, IBR-2 (theme «Development and Upgrading of the IBR-2 Complex», headed by V. D. Ananiev and E. P. Shabalin), IREN (theme «IREN Project», headed by W. I. Furman and I. N. Meshkov) and of the IBR-2 spectrometry and computation complex (theme «Development of the IBR-2 Spectrometers Complex and Computation Infrastructure», headed by A. V. Belushkin and V. I. Prikhodko) continued.

The topical problems of research conducted in cooperation with world leading nuclear centres were discussed at an international seminar on the interaction of neutrons with nuclei and at the workshop «IBR-2 in the XXI Century».

CONDENSED MATTER PHYSICS

Experimental investigations. Diffraction. The crystalline and magnetic structures of the new complex layered manganese oxides A_2MnGaO_{5+x} (A = Sr, Ca) have been investigated. The crystalline structure which is a derivative of the perovskite structure belongs to the brownmillerite type and consists of alternating (CaO), (MnO_2), (CaO) and (GaO) or (GaO_{1+x}) layers. The valence of manganese changes from Mn^{3+} to Mn^{4+} as the oxygen index changes from 5 to 5.5. Like in the classical system (LaSr)MnO_3 in brownmillerites one may expect the appearance of a ferromagnetic metallic state at intermediate valence of Mn. Several facts of principal importance for the construction of a model have been established. It appears that, in spite of an essentially layered character of the structure (distances between the nearest Mn atoms in and perpendicular to the MnO_2 planes differ about 2 times), the magnetic structure has a 3D character. The two studied compositions, $Sr_2GaMn^{3+}O_5$ and $Sr_2GaMn^{4+}O_{5.5}$, are the antiferromagnetics with the Néel temperature $T_N = 160$ and 100 K, respectively, but their spin configurations are different: neighbouring antiferromagnetic MnO_2 planes in $Sr_2GaMn^{3+}O_5$ are coupled antiferromagnetically while in $Sr_2GaMn^{4+}O_{5.5}$ they are coupled ferromagnetically [1].

The influence of high pressure on the atomic and magnetic structures of the manganites $La_{0.67}Ca_{0.33}MnO_3$, $Pr_{0.8}Na_{0.2}MnO_3$ with a colossal magnetic resistance effect has been studied. In $La_{0.67}Ca_{0.33}MnO_3$ a transition is observed from ferromagnetic to antiferromagnetic state at a pressure of 4 GPa as the temperature decreases. In $Pr_{0.8}Na_{0.2}MnO_3$ a change in the type of the antiferromagnetic structure is observed with increasing pressure (Fig. 1).

Magnetic phase transitions in binary manganese compounds — MnAs, Mn_2Sb, have been investigated. In MnAs at a pressure of 4 GPa and a temperature below 80 K a magnetic phase transition to an earlier unknown phase has been observed. The atomic and magnetic struc-

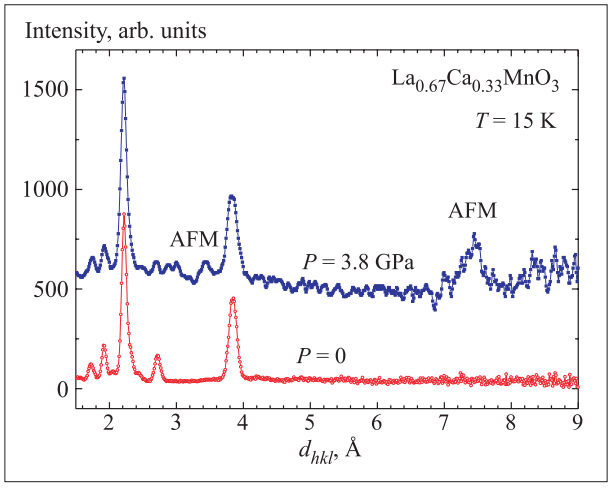

Fig. 1. The parts of $La_{0.67}Ca_{0.33}MnO_3$ diffraction spectra measured with DN-12 at pressures of 0 and 3.8 GPa and a temperature of 15 K. A ferromagnetic-antiferromagnetic phase transition takes place with increasing pressure. It is shown with new magnetic peaks (marked AFM)

ture of a high-pressure phase is determined. In Mn_2Sb at $P = 2.8$ GPa and room temperature a spin-reorientation magnetic phase transition resulting in a deviation of Mn magnetic moments from the axis *c* of the tetragonal structure has been observed.

Polarized neutrons and neutron optics. Measuring the reflection of neutrons from a Fe/V bilayer at temperatures larger or smaller than 5 K, the critical superconducting transition temperature for bulk vanadium, the results were obtained pointing to the existence of a superconducting state at a temperature above the critical one or to the existence of a temperature-reversal superconductivity. This is a new observation in the case of bilayer systems and it is necessary to be verified [2].

The interaction between neutron radiation and an ultrasonic wave-excited structure has been investigated. For this purpose, measurements of the neutron reflection coefficient as a function of the momentum transfer at total reflection from glass, diffractive reflection from a layered Fe/Cr structure, neutron wave enhancement in a wave resonator and at neutron wave channeling in a titanium layer were conducted. The measurements were carried out with longitudinal and transversal sonic waves. It is obtained that in the case of transversal waves the reflection probability is 5 times larger than that in the case of longitudinal waves. This possibly points to the fact that with longitudinal waves the reflection of neutrons is from the nodes of the standing sonic wave. The phenomenon of a sound-stimulated transition of neutrons from one to the other channeling mode is observed. The probability of such a transition is determined by the roughness of the interface, which can be used to increase the sensitivity of determination of the parameters characterizing the interface (correlation length, mean square amplitude).

Inelastic neutron scattering. The vibrational spectra of the ammonium halides NH_4Cl, NH_4Br, NH_4I were investigated at up to 8–10 GPa, which is a record pressure in the case of inelastic neutron scattering. In the area of a phase transition from disordered cubic to ordered cubic structure of the type CsCl, a breaking was observed on the pressure dependence of the librational mode of ammonium in NH_4Cl and NH_4Br. In NH_4I, at pressures higher than 6 GPa, hybridization of the transverse optical and librational modes was observed [3].

Inelastic neutron scattering investigations of crystalline electric field (CEF) effects in the systems $RAgSb_2$ (R = Er, Tm, Ho) were performed. The CEF parameters, level schemes and the wave functions of each compound were determined. The temperature dependence of magnetic susceptibility calculated along different crystallographic directions is in good agreement with the results of measurements of single crystals. An analysis of the results shows that the magnetocrystalline anysotropy in such compounds is mainly caused by CEF.

Incoherent inelastic neutron scattering investigations of the dynamics of the metal-organic compounds A_2MeX_4, where A is the organic radical ($N(CH_3)_4^+$, $N(C_2H_5)_4^+$), Me is a metal (Zn, Cu, Cl), X is a halide, were conducted over a wide range of temperatures above and below the phase transition points. Such compounds are of interest because of a strong complex effect of a complete or partial replacement of the organic group on the structure organization and different types of structural instability. As a result of the conducted investigations, the mechanism of the observed phase transitions is proposed.

Small-angle scattering. The structure and properties of tetramethylammonium bromide in aqueous solutions were studied via SANS in different conditions. It has been shown that the size of micelles decreases with temperature and the shape of the micelles is not spherical but is anisometric. The same system was studied in NaBr aqueous solutions. It was observed that the shape of micelles changes from spherical to rod-like with increasing NaBr concentration. It has been shown that gradual dehydration of micelles at increasing electrolyte concentration is the driving force of shape transformations.

A systematic study of the influence of biologically active amphiphiles with long linear hydrocarbon chains (N-Dodecyl-N,N-dimethylamine-N-Oxides), which are widely used in agriculture, food industry, pharmacy and medicine, on the structure of lipid membranes was done with SANS. It has been confirmed that these substances do influence cells on the biological membrane level. SANS real-time studies of structural changes of the lipidic cubic phase in the course of crystallization of bacteriorhodopsin (BR) from *Halobium Salinarium* led to a better understanding of the mechanism of crystallization.

Applied research. Unique experimental data on the texture of the crust and upper mantle rocks in the earth have been obtained. A collection of olivine-bearing mantle rock samples from different areas in Europe have been

investigated. Quantitative texture analysis is used to reconstruct the texture functions. The spatial distribution of elastic wave velocities in each of the investigated samples is theoretically modeled. The pole figures (PF) measured for olivine samples and the data on the condition of plastic deformation in olivine are used as a basis for the determination of systems of slipping, as well as possible thermodynamic conditions and depths of texture formation.

Samples of Archean rocks from a super deep (SD-3) borehole in Kola Peninsula have been studied. Their striking similarity in mineral composition and mineral component textures to the natural outcrop of rocks in a Kola series was discovered. Microstructural and neutronographic investigations of samples taken deep from the earth crust as well as of their analogs from the surface reveal new peculiarities in the texture of these rocks, e.g., a more perfect dominating orientation of hornblende than of plagioclase grains and of plagioclase compared to quartz grains. Complex experiments at different hydrostatic pressures showed that the anisotropy coefficients of amphibolites from different depths in an SD-3 well decrease as pressure, and correspondingly depth, grows. The results have made it possible to explain the character of rock anisotropy at different depths on the basis of the new model of the texturized inhomogeneous fractured-porous medium [4].

Investigations of the effect of one-axis compression on internal microstresses in dolomite samples were conducted using a special deformation device. Under the action of different external loads the value of residual strains and stresses in these samples was investigated. From the experimental data the Young coefficient is obtained. The results of the texture measurements performed prior to the deformation experiments indicated the existence of a weak-dominating orientation corresponding to the layered texture plane in dolomite.

Measurements of residual stresses in the elements of the VVER-1000 reactor jacket were performed in cooperation with research institutes of the RF Ministry of Atomic Energy. The investigated sample was a two-layer plate whose basic layer is made from construction ferrite steel and build-up layer is from austenite stainless steel. The component σ_y of the shell templet of the reactor jacket was investigated as a basic metal and as a melt. An analysis of diffraction peak intensities revealed a strong texture in the austenite phase of the melt.

NEUTRON NUCLEAR PHYSICS

The 2001 experimental programme in neutron nuclear physics of FLNP traditionally included the following fields of research: 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. In 2001, measurements of interference effects in the polarized neutron-induced fission of ^{239}Pu at the IBR-30 booster were completed. The emission asymmetry of light and heavy fragments in relation to the neutron momentum – neutron spin plane was measured. This so-called left-right asymmetry does not violate P parity and is due to interference between *s* and *p* resonances. The results, together with those on earlier measured forward-backward asymmetry, will make it possible to obtain yet unavailable information on *p*-wave resonances in heavy nuclei.

Another measured effect is the parity-violating asymmetry of fragments emission in and against the direction of the captured neutron spin. It is the first time that such data are obtained for plutonium resonances (Fig. 2). At present, the processing of the experimental data on both effects is nearing completion and the preparation of publications is under way.

Under the **KaTRIn** project the first tests of a neutron polarization system with laser pumping of ^{3}He were performed on beam 2 of the IBR-30 reactor. The polarization of neutrons transmitted through a cell with a low-pressure ^{3}He (5 atm) was about 23 %. Measurements with a longitudinal magnetic field off showed that the residual longitudinal field in permalloy screens is sufficient for the optical orientation of rubidium to take place. In a real experiment, this makes it possible to do without a magnetic transport channel and avoid difficulties caused by mutually perpendicular fields of the channel and the target.

Recent results from fundamental nuclear physics experiments indicate that the neutron-neutron interaction is stronger than the nuclear part of the proton-proton interaction, implying a breaking of the charge symmetry in a strong nuclear force. The best way to verify this and to stimulate further development of the isotopic-spin invariance concept is to perform a direct measurement of neutron-neutron scattering by colliding free neutrons. The proposal for such an experiment — the ISTC Project 2286, which is a joint venture of JINR, VNITF (Snezhinsk), and TUNL (Durham, NC, the USA), has been prepared and submitted to the International Science Technology Centre. Experimental study of thermal neutron fields formed by polyethylene converters inside the central channel of the aperiodic pulsed reactor Yaguar demonstrated that the reactor provides a required instantaneous thermal neutron flux density of about 10^{18} cm$^{-2}\cdot$s^{-1} during a neutron burst of 700 μs.

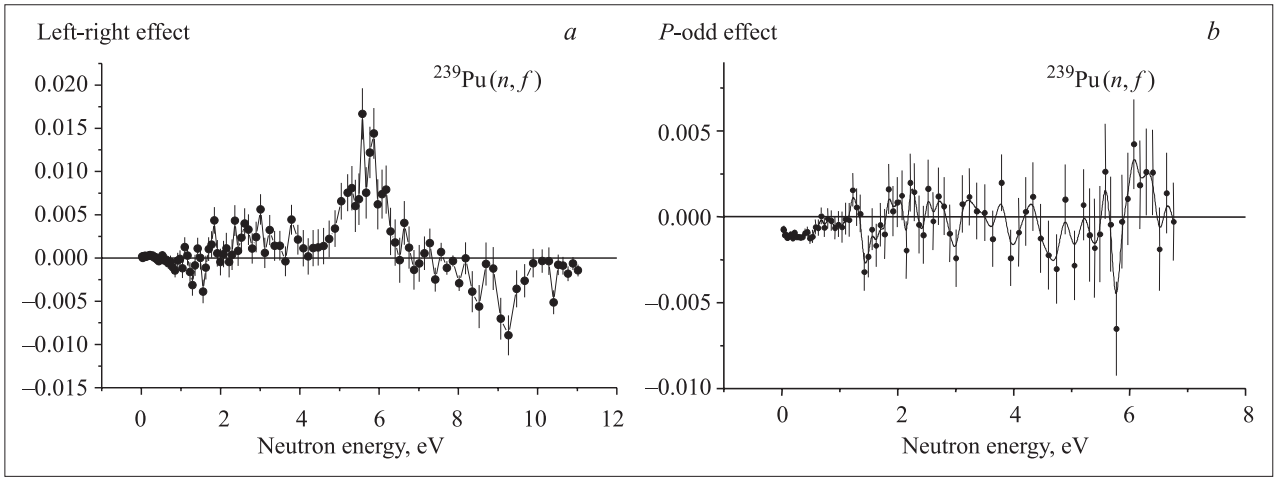

Fig. 2. The effects of the left-right (*a*) and the parity-violating (*b*) asymmetries in the resonance neutron-induced fission of ^{239}Pu

In collaboration with PINP colleagues an experiment to measure *p*-odd correlation of the type $a_\gamma \sim (\sigma_n p_\gamma)$ in the reaction $^{10}\mathrm{B}(n, \alpha)^7\mathrm{Li}^* \rightarrow {}^7\mathrm{Li}+\gamma$ was conducted. The measurements were carried out at polarized cold neutron beams at the reactor of the Institute Laue Langevin (ILL), Grenoble, France. The aim of the experiment is the determination of the contribution of neutral current to weak nucleon-nucleon interactions. By theoretical estimates, in the presence of neutral current the asymmetry is on the level of $\sim 5\cdot10^{-8}$–10^{-7}. An accuracy of $4\cdot10^{-8}$, which is an order of magnitude better than in a previous experiment with the VVRM reactor of PINP in Gatchina, has been achieved so far.

A statistical analysis of the α-widths distribution of ^{147}Sm neutron resonances obtained in a joint experiment (Dubna, Oak Ridge, Lodz) with the ORELLA facility in Oak Ridge, the USA, was carried out. Some indication was observed to a possibly nonstatistical character of mean α widths in dependence on the excitation energy of compound nuclei.

A programme for the calculation of neutron nucleosynthesis using the parameters characteristic for hydrostatic burning of helium in massive stars (weak component in the *s* process) has been created. Test calculations for the area S-Cl-Ar show good coincidence with the results of other authors.

The cross-sections and angular distributions of products from the reaction $^{64}\mathrm{Zn}(n,\alpha)$ at $E_n = 5 \div 7$ MeV were obtained in a Van-de-Graaf experiment at the Institute of Heavy Ion Physics of Peking University [5].

Systematization of the (*n*, *p*) reaction cross-sections on fast neutrons is developed on the basis of the principles of the statistical theory of nuclear reactions.

Applied research. Successful application of nuclear analytical techniques to the development of biotechnology and biochemistry, namely, to **selenium- and chromium-containing pharmaceuticals** based on blue-green algae (*Spirulina platensis*) has brought two patents in co-authorship with Georgian scientists from the Tbilisi Institute of Physics named after Andronikashvili and a number of internationally recognized papers. A combination of the above vitally important elements with protein-containing algae called the «food of the future» allows producing of pharmaceuticals with a great potential for the treatment of a wide spectrum of diseases: from ishaemic heart disease to enhancement of the immune system. Investigations on the development of a technique for elements content determination in *Spirulina platensis* are being carried out by FLNP's Neutron Activation Analysis group [6].

The calibration of the fast neutron detector HEDN (High-Energy Neutron Detector) for the American mission to Mars «Mars Surveyor Orbiter 2001» has been completed. These works have been performed in the framework of a long-term collaboration with the Institute of Cosmic Research of the Russian Academy of Sciences. The detector has been installed in a space apparatus and is successfully working on the Mars orbit.

NEUTRON SOURCES

The IBR-2 pulsed reactor. In 2001, the IBR-2 reactor operated in accordance with the approved working schedule. It has operated 2000 hours in 8 cycles with the power $W = 1.5$ MW. The maintenance plan for the period from June to September 2001 was fulfilled on time. It involved commissioning of a Diesel-electric power station

in case of failure of a standard power supply, the moving of the movable reflector PO-2 from temporary to permanent storage site.

Modernization project. The manufacturing of PO-3 is in progress. The MAYAK factory started the production of PuO_2 pellets. Two exhausted fuel assemblies (FA) from IBR-2 are being investigated. The designing of the executive mechanisms of the control and emergency system completed. Work to design a special cryogenic helium plant started.

The IREN project. In spite of serious problems with financing, some progress was made in the implementation of the IREN project and the time-tables of FLNP and LPP for the year 2001, approved in February and revised in August, were met in many points.

First of all, this concerned the creation of elements of the LUE-200 linac by LPP's new linear accelerator division and FLNP and LPP design bureaus. As a result, the construction of all elements of the electron gun completed and its mounting started. A full set of general working drawings of the linac assembly had been prepared by the end of August. It allows one to fix precisely the position and sizes of all linac elements in the accelerator halls of Bldg. 43 at FLNP. A geodesic survey of the axis of the old linac to be dismantled beginning from August was conducted. The results of this survey will be needed during the mounting of the new linac, whose beam should be directed to the centre of the multiplying target with a high precision. A technological design of the magnetic focusing system was completed. Materials necessary for its construction were partly obtained and a technological line for its mounting is presently being installed at LPP. A large volume of work was carried out on a full-scale RF stand. During the summer a vacuum system was installed and tested. A pressure of $2 \cdot 10^{-8}$ Torr was achieved. After the completion of some auxiliary systems the M-350 modulator together with the 5045 SLAC klystron was tested in the regime of enhancing RF power. Last test experiments with a long (210 ns) electron pulse and a high level (50 MW) of RF power were successfully carried out with a linac prototype at BINP, Novosibirsk, with participation of Dubna experts. It was confirmed that it is possible to achieve the rated parameters of LUE-200.

A very important stage of the IREN project began after the final shut-down of the IBR-30+LUE-40 neutron source on June 15. The technical project of the decommissioning of the IBR-30 reactor was then completed by GSPI, and after the preparation of many other necessary documents by FLNP experts the license of Russian Gosatomnadzor for decommissioning was obtained at the end of August. Since then JINR has had the right to begin technical preparation for the dismantling of IBR-30. In October the construction of new building No. 117/6 for the storing of the activated elements of IBR-30 started. The development of the technological regulation of the IBR-30 dismantling and designing of the necessary equipment started in November and are to be completed and approved by Gosatomnadzor in the third quarter of the year 2002.

A great progress was made in the working out of the modernized technical project of the multiplying target by NIKIET, Moscow, in close collaboration with JINR. As expected, the project was competed at the end of 2001. At a much lower rate the preparation of the general technical project of the IREN source was carried out by GSPI, Moscow, during the reported year. So the completion date of a partial project necessary to apply for an official approval has shifted to at least the end of February 2002.

Taking into account a large delay in the implementation of the JINR budget of the year 2001 and the respective shifts in the IREN time-table, the JINR Directorate approved the proposed project for the realization of a reduced variant of the IREN source in the next two years. Its first stage includes a full-scale multiplying target and an electron linac based on one 5045 SLAC klystron instead of previously planned two ones. Also, this stage envisages only one modulator and a reduced (to 50 Hz) repetition rate. The time-table for the years 2001–2003 was approved by the JINR Directorate in September. It foresees the startup of the first stage of the IREN source at the end of 2003.

DEVELOPMENT OF THE IBR-2 SPECTROMETER COMPLEX AND COMPUTATION INFRASTRUCTURE

Work on the theme went in keeping with the FLNP projects ICC, FSD, YuMo, Texture, PNS, Detectors, BMBF–ECS, etc. in the following main lines:

— routine operation and development of the IBR-2 spectrometer complex;
— creation of data acquisition and spectrometer control systems;
— development of the information-computation infrastructure.

Development of the IBR-2 spectrometer complex. In the reported year the spectrometer equipment was prepared and operated to serve eight IBR-2 cycles.

The development of the sample environment systems continued:

- New executive mechanisms adapted to the existing step-motor-based control systems were incorporated into the spectrometer schemes.

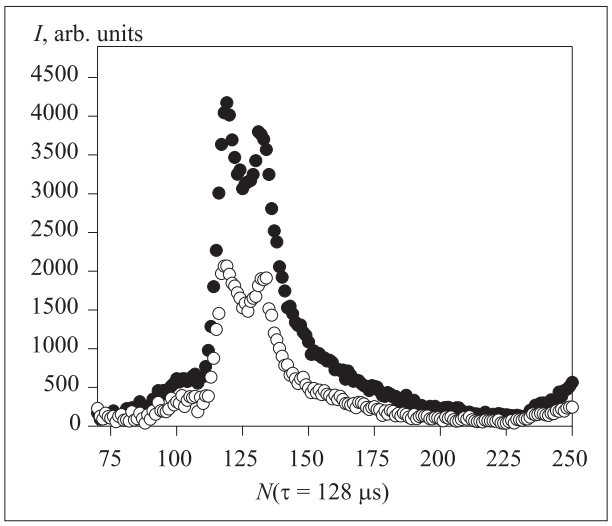

Fig. 3. The inelastic time-of-flight spectra of vanadium obtained in a period of 10 hours in equal conditions: ● — new detectors, ○ — old detectors

- Certification of the existing devices, including furnaces, refrigerator heads, etc., continued with the aim of creation of a data base on temperature control and regulation devices in the spectrometers HRFD, FSD, PNS, YuMO, DN-2 and in the X-ray diffractometer DRON.
- Research into how to connect two control elements (for the heater and refrigerator) to one Eurotherm regulator of the type 902S or 906S was carried out. The results are used in the DRON diffractometer. The precision of the control system is +/– 0.03 degrees.
- A second channel for control of the temperature of the annealing furnace in the sample preparation room is completed and put into operation.
- Work to develop an RGD-1245 refrigerator-based cryostat for 4.2 K has been carried out and the manufacturing is being completed.

The design, plans and specifications for the construction of a «clean room» and a gas rig for the assembling of gas detectors are prepared.

The main spectrometer development effort focused on SPN, YuMO, FSD, and DN-12.

Local area network and computing infrastructure. In 2001, a transition to Fast Ethernet 100 Mbit standard was accomplished in two LAN segments (bldg. 42a — NICM division, and bldg. 42 — PN devision). In bldg. 42a, the commutator Catalist 2924XL (CISCO) was installed and commissioned, which increased data transmission rates and the reliability of this transmission in the NICM-division segment.

A contract was signed to purchase a data flow router for LAN at FLNP (CISCO router 8510) and the necessary preparation work to install it was carried out. The startup of the router, expected in early 2002, will make it possible to:

- remove limits on the number of IP addresses;
- increase the actual transmission capability of network by 50–60 % without changing physical interfaces;
- perform analysis and filtration of traffic in the net;
- create virtual subnetworks for user groups irrespective of their geographical position, etc.

Data acquisition systems. In the reported year the detector systems in a number of spectrometers were modernized. In particular, new low-noise electronic blocks for the «NEW» detector in YuMO were developed, manufactured and tested, debugging of the 32-channel detector in SPN was executed, detector electronics in KDSOG was completely renewed, and a linear PSD with a resistive wire was introduced into the DN-2 scheme (Fig. 3).

In the spectrometer Epsilon a unified VME system for data acquisition was put into operation. In addition to a standard set of functions, it executes, by electronic means, the correction of the neutron time of flight (time focusing).

A second TDS/DSP data acquisition block with a PCI interface for the MSGC detector (HMI, Berlin) was manufactured and debugged using a programmable generator of events. At present, the block is being used at FLNP for the development and testing of software products.

Work continued to develop and install on the spectrometers of a SONIX unified complex of programs for data acquisition [7].

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LABORATORY OF INFORMATION TECHNOLOGIES

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

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

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

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

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

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

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

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

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

EXTERNAL TELECOMMUNICATION CHANNELS

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

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

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

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

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

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

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

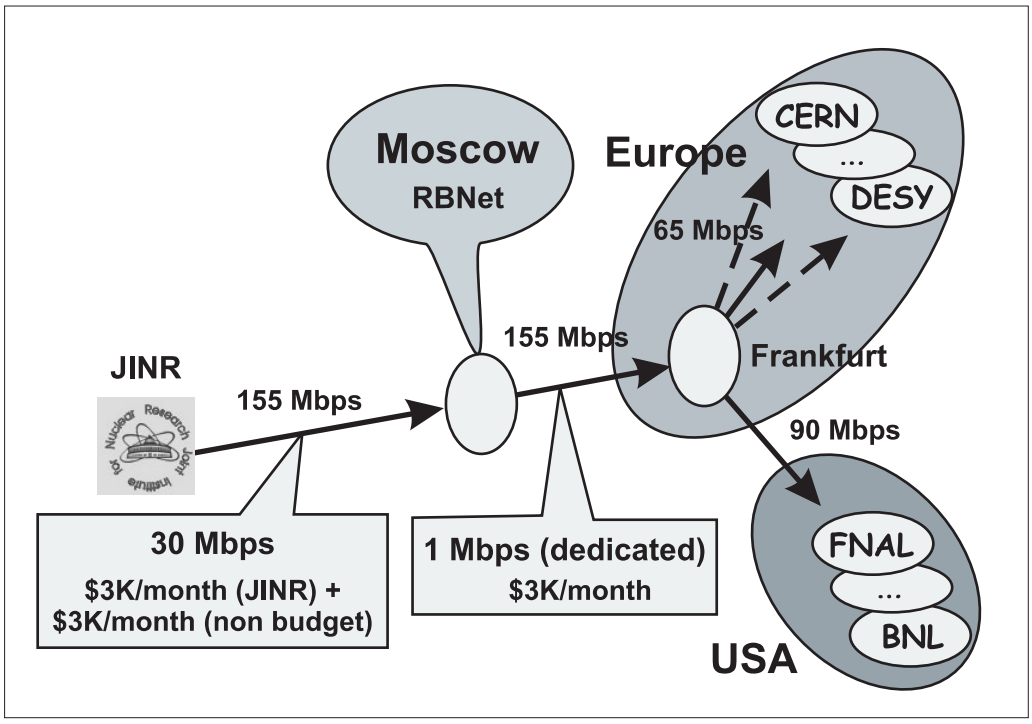

Fig. 1. JINR telecommunication channels

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

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

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

JINR LOCAL AREA NETWORK

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

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

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

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

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

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

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

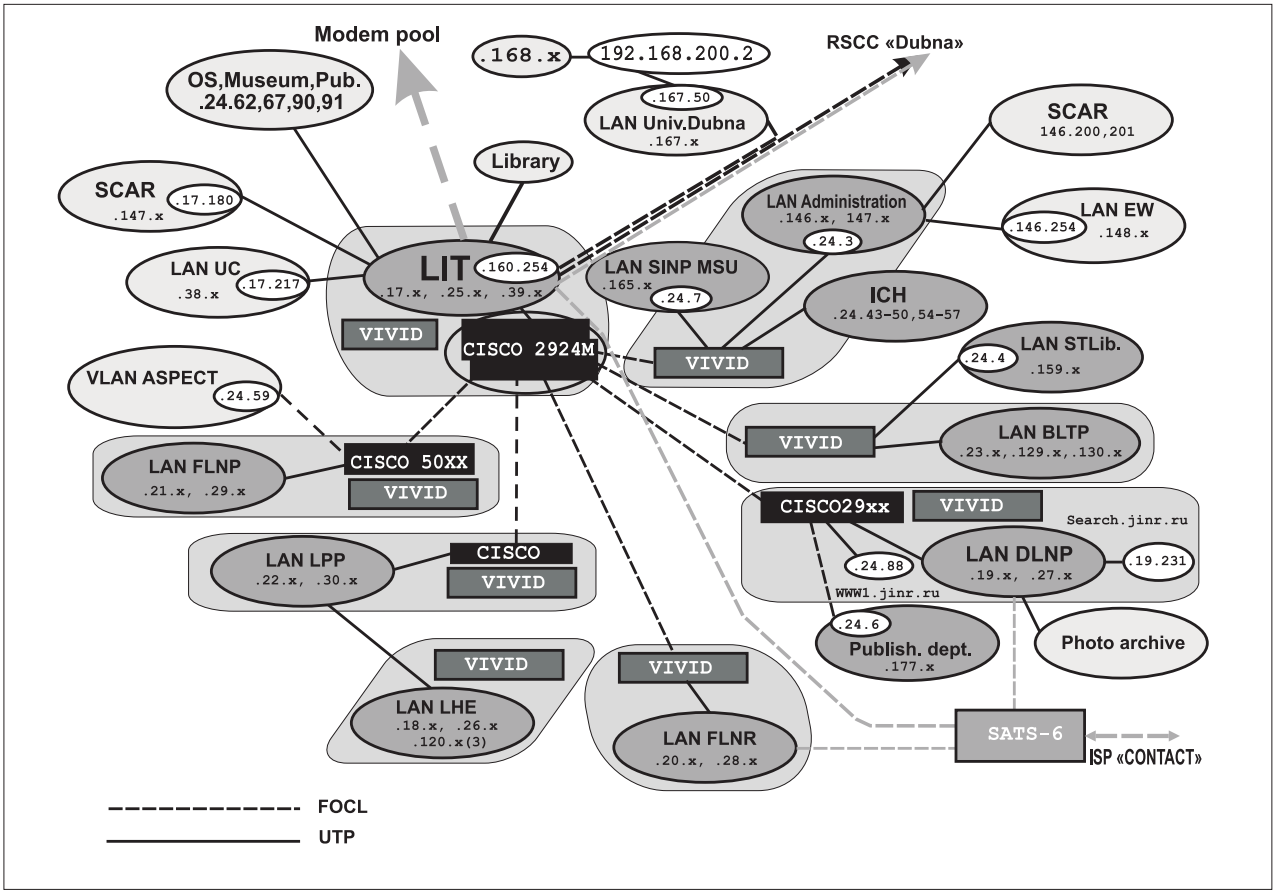

Fig. 2. JINR LAN

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

Distributed Information Systems, HPCC

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

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

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

Table 3. SPP-2000 using by the JINR Laboratories

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

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

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

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

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

Computing Service

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

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

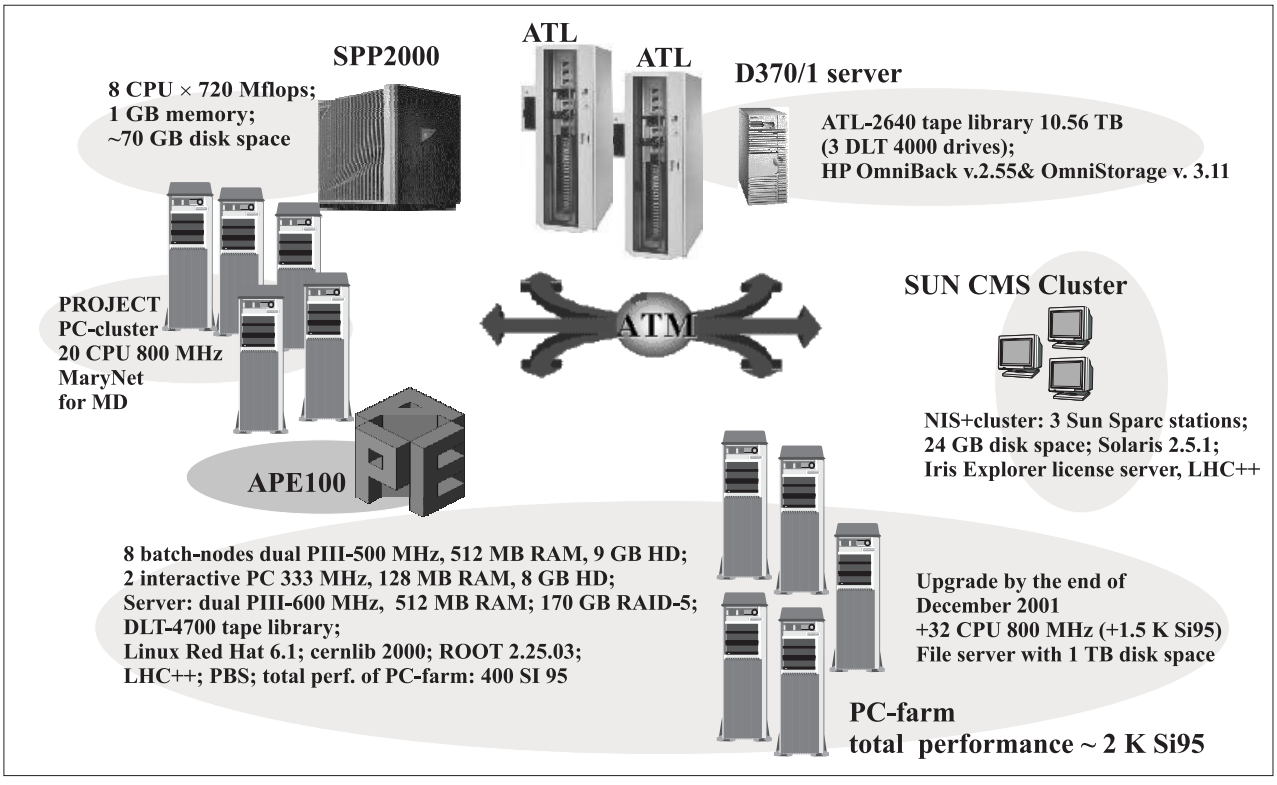

Fig. 3. The main JINR computing centre facilities

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

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

DATABASE AND WWW SERVICE

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

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

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

COMPUTATIONAL PHYSICS

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

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

Mathematical Modeling and Information Support of Experimental Investigations

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

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

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

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

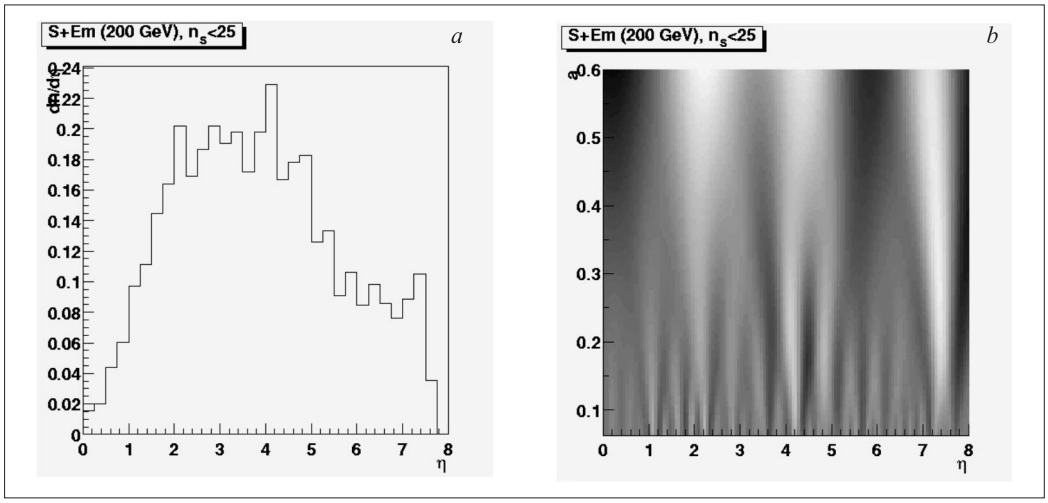

Fig. 4. Shower particles pseudorapidity distribution in events with $n_s < 25$ (*a*) and its wavelet spectrum (*b*). Three sub-structures arise at scale 0.4

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

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

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

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

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

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

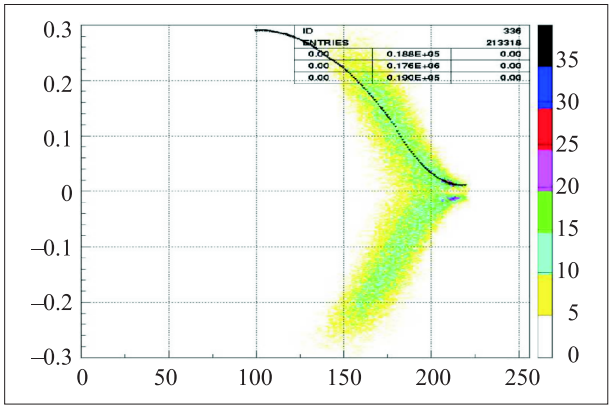

Fig. 5. Results of the cubic spline fit to 5 mm PC drift data

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

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

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

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

Algorithmic and Software Support of Theoretical Investigations

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

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

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

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

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

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

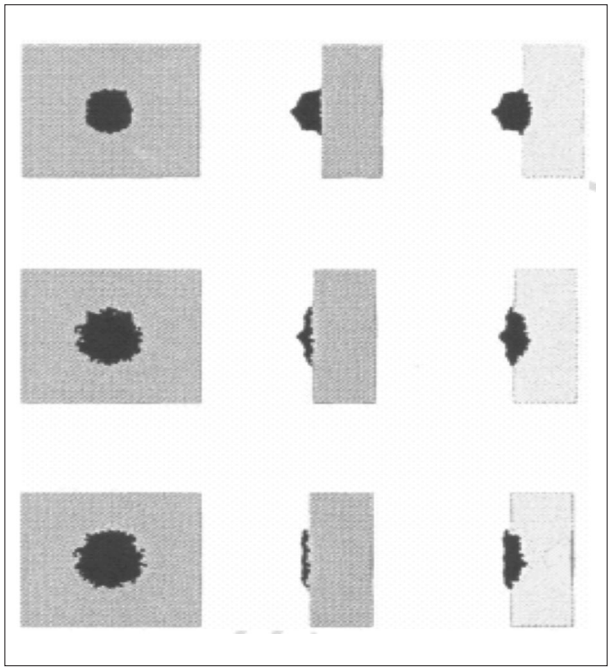

Fig. 6. Results of MD simulations for cluster. The top (left), side (middle) and cut (right) views of MD configurations at $t = 1.3$ ps (top), $t = 2.1$ ps (middle), and $t = 5.0$ ps (bottom) for the cluster incident energy $E_{\text{inc}} = 0.56$ eV/atom

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

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

INTERNATIONAL COOPERATION

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

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

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

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

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

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

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

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

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

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

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

APPLIED RESEARCH

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

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

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

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

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DIVISION OF RADIATION AND RADIOBIOLOGICAL RESEARCH

The scientific programme of DRRR is determined by a first priority theme of the Topical Plan for Scientific Research of JINR in two main lines. The radiation field is traditionally connected with radiation shielding design, dosimetry, spectrometry and radiation monitoring. The investigations of peculiarities and mechanisms of mutation in pro- and eukaryotic cells induced by different types of radiation constitute the basis of the radiobiology field at the present time. Besides, the «Mitra» project on the development of new radiopharmaceuticals for target therapy of human melanoma is being successfully realized in the framework of the theme.

RADIATION RESEARCH

The important task of radiation protection at new nuclear installation designing is to minimize the radiation influence of an installation on population and environment. There is no generally accepted method of calculation at large distances of the population exposure resulting from accelerator operations. The most reliable and detailed prediction can be obtained by the statistical modeling method. The other difficult problem is to estimate the activity of the radionuclides escaping to air from an accelerator. The techniques for prognostication of neutron and gamma doses at large distances due to «skyshine» effect and air activity resulting from accelerator operation were developed by using Monte-Carlo codes. The results were applied to the cyclotron centre project in Bratislava (Slovakia).

The data of the experimental investigation of the differential characteristics of neutrons' yield from the thick lead target simulating the core of the SAD assembly were processed and compared with the calculations by the MCNP4B + LAHET and MCNPX codes. The verification of the neutron transport codes were done for the calculation of: 1) the neutron spectra under several angles; 2) the angular and the spatial distributions of the hadron's yield at different energy thresholds. A good agreement between the calculated and experimental data in a wide energy range was obtained.

The calculations of neutron detection efficiency of the NE 213 scintillator were carried out with the modernized code. The precise calculation of the efficiencies of the gamma spectrometers at various detector-source geometry was also carried out. The responses of solid track detectors on the basis of CR-39 and PADC (with fission radiators and without them) to the ^{12}C ions with energies of 0.5 and 1.0 GeV/amu and protons with energies of 0.5 and 1.0 GeV were investigated [1].

The physics support of the biological experiment on the blood lymphocytes and mammalian cells in culture irradiation by the ^{12}C ions with an energy of 0.5 GeV/amu was done at the Nuclotron. For the biological samples irradiation with the particle beams the near uniform radiation field in the area of the samples is formed and the absorbed doses are measured with the calibrated ionizing chamber.

Area and occupational personnel radiation monitoring in the field of the JINR nuclear installation was continued.

The main goal of radiobiological research was connected with investigation of the mutagenic effect of heavy charged particles on bacteria, yeast, mammalian and human cells. The study of regularities and mechanisms of point ($fepA^-$, $tonB^-$) and deletion ($tonB^- trp^-$) mutation induction in bacteria *E. coli* by radiation with a broad region of linear energy transfer (LET) was accomplished. It was shown that the frequency of point mutations as a function of the γ-ray and heavy ion dose (helium and carbon ions with LET 20–200 keV/μm) is described by the linear-quadratic curves. The induction of deletion mutations by helium and carbon ions (LET = 20–200 keV/μm) is described by the linear function. The helium ions with LET = 50 keV/μm are more effective in induction of deletion mutations than the carbon ions (Fig. 1).

The induction of mutagenic SOS repair in *E. coli* cells after irradiation by deuterons, helium and carbon ions was studied by using the SOS lux test. A genetically controlled luminescent bacterial reporter assay was developed for detection of cell SOS response. It was shown that the relationship of SOS induction potency (SOSIP) to LET has a local maximum in a region of 50–60 keV/μm (Fig. 2). The results that were obtained with bacterial cells suggest the important role of cluster DNA damages in the formation of point mutations. On the other hand, the formation of deletion mutations is connected with induction of direct and enzymatic double strands breaks of DNA.

The important data concerning regulation of cell cycle of yeast *Saccahromyces cerevisiae* and sensitivity to DNA damage agents have been obtained in recent years. According to these data, for instance, the RAD9, RAD17, and RAD24 genes are believed to act at the initial steps of damage recognition. The RFC-Rad24 protein complex plays probably a role in loading the Rad17-Mec3-Ddc1-complexes or repair proteins on damaged DNA. The RAD53 protein kinase is involved in a signal transduction cascade, and the other kinase, CDC28, acts at the final step of cell cycle arrest regulation. Arrest is required for repair of damages. The branched system of regulation of cell cycle arrest due to DNA damage needs studies.

It is known that defects in the mechanisms that regulate cell cycle arrest due to DNA damage are believed to have some definite consequences for cell hereditary apparatus, *viz* to cause genetic instability and increased cell sensitivity to DNA-tropic agents. Indeed, enhanced sensitivity to damaging agents has been found in various checkpoint mutants affected in checkpoints. Our and some existing literature data however suggests that *post hoc* may not be completely *propter hoc* here.

Single and double strains were constructed to analyze interactions between the RAD9, RAD17, RAD24, RAD53, and CDC28 genes, and cell sensitivity to γ radiation was determined. The RAD9, RAD17, and RAD24 genes act in one and the same pathway of radiosensitivity, while the RAD9 and RAD24 genes have been classified as belonging to different groups dealing with DNA damage induced by UV light or MMS.

Protein kinases encoded by the RAD53 and CDC28 genes are epistatic to the RAD9 gene but are most probably involved in different pathways of radiation sensitivity

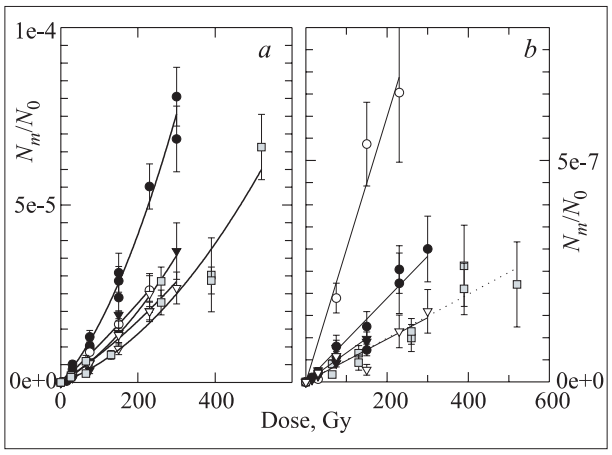

Fig. 1. Frequencies of tonB (*a*) and $tonB^- trp^-$ deletion (*b*) mutations in *E. coli* cells induced by ionizing radiation of different LET. ○ — helium ions (20 keV/μm); ● — helium ions (50 keV/μm); ▼ — helium ions (78 keV/μm); ▽ — carbon ions (200 keV/μm); ■ — γ irradiation (^{137}Cs)

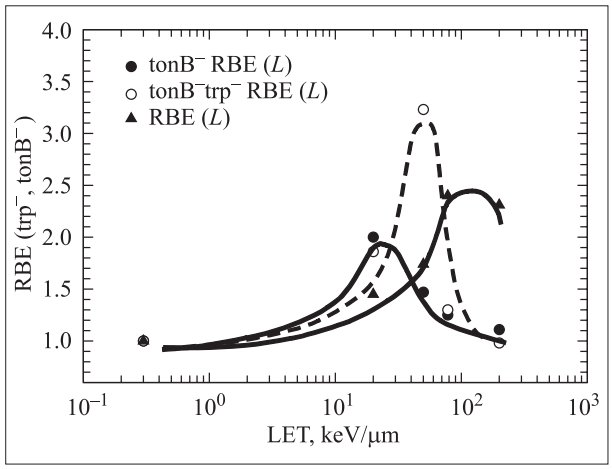

Fig. 2. Dependence of RBE induction of the $tonB^-$ and $tonB^- trp^-$ mutations on LET of radiation in *E. coli* X7026 cells

control, while CDC28 and RAD53 belong to the same branch of the regulation of cell cycle arrest.

Studies continued on induction of mutations of different nature on ionizing radiation in particular point mutations, by using a convenient tester system for 6 possible base-pair substitution diagnostic. Base-pair substitution — transversion AT–TA induced by helium and carbon ions with LET values of 80 and 200 keV/μm was characterized using the diploid strain YMH53. The mutation induction efficiency of He^{2+} (80 keV/μm) was less than the efficiency of He^{2+} (20 keV/μm). The frequency of AT–TA transversion induced by C^{6+} ions was the lowest.

Frame-shift mutations were tested in the strain RKY2672. This strain has insertions in the LYS2 and HOM3 genes, which revert to wild type as a result of only frame-shift mutations. Earlier mutation rate induced by ionizing radiation was measured. Now spontaneous reversion rate is monitored. The rate of spontaneous LYS2 reversion was 10^{-8} and HOM3 reversion — $2.5 \cdot 10^{-8}$. The results are consistent with literature data.

An extended time-course study of expression of chromosomal aberrations induced by radiation of wide LET range was finished at GSI (Darmstadt, Germany), in collaboration with GSI Biophysics Group. In these experiments the time-dependent expression of particle-induced chromosomal damage has been analyzed in 3 Chinese hamster cell lines: V79, CHO K-1 and xrs5 [2]. The cells synchronized by either centrifugal elutriation or mitotic shake-off were irradiated in G_1 phase of the cell cycle by X rays and accelerated heavy ions (Ne, Ar, Kr, Au) obtained at the UNILAC and SIS facilities (GSI, Darmstadt) with LET ranging from 360 to 3980 keV/μm. The chromosome damage has been measured at time span ranging from 10 to 34 h after exposure covering the time interval of almost 3 cell generations, so that almost all dividing cells, including very delayed, were collected. The cells were analyzed at 5–12 subsequent sampling times in 2–4 h intervals preceded by 2 h colcemid treatment. To distinguish between the metaphases of various postirradiation generations the Fluorescence-plus-Giemsa (FPG) technique was applied, and the chromosomal damage was analyzed separately in the first- and second-generation metaphases [3].

The irradiation was shown to retard the cell cycle progression and delay the entry of cells into mitosis, while the expression of chromosomal damage was markedly affected by radiation-induced cell cycle delay in dose- and LET-dependent manner. The number of aberrant cells and aberrations have been found to enhance drastically with sampling time after particle exposure, and this effect depended on LET: the most pronounced increase was observed for Ar and Kr exposure (LET: 1280 and 3980 keV/μm), reaching 100 % of aberrant cells and 10–15 aberrations per cell at later sampling times. The aberration frequency increased in *X*-ray- and Ne-irradiated samples by a factor of 2–3, while after Ar (4.6 MeV/amu, LET 1840 keV/μm) by a factor of 20.

The observed differences in the cell cycle progression and in time course of aberrant cells after exposure of G_1 cells to densely and sparsely ionizing radiation are obviously related to different spatial energy deposition of both radiation types. The applied dose of X rays is homogeneously distributed over the cells. Thus, only small fluctuations in the amount of damage within target cell are induced and synchrony of population is at least partially maintained. In contrast, the particle exposure results in high inhomogeneity of energy deposition both in terms of dose distribution inside the track and in the number of particle traversals per cell nucleus. One of the biological consequences of this non-uniformity of energy deposition by particle exposure is the affected time course of the appearance of chromosomal damage: cells with a low number of particle traversals and correspondingly low chromosomal damage enter mitosis earlier than the cells with a high number of hits and severe chromosomal damage. The distribution of particle-induced aberrations among the cells was fitted by Neyman type A distribution that takes into account the stochastic distribution of particle traversals over the cells as well as the stochastic distribution of aberrations per single traversal. The fit parameters clearly reflected the damage-dependent cell cycle delay: the number of particle traversals per cell appears to increase with sampling time, i. e. highly hit cells are delayed for a longer time and carry correspondingly more aberrations than the cells with low number of particle traversal, less damaged which reach mitosis earlier.

Thus, the RBE (relative biological efficiency) values of high-LET particles obtained for single sampling time were shown to be strongly dependent on time: for example, after Ar ion exposure they varied from 0 at 14 h (standard fixation time) to 4.0 at 22 h postirradiation and could thus be misleading. It became clear that for the correct determination of significant RBE values multiple fixation regimes should be used. To account for the time-dependent expression of chromosomal damage, a novel mathematical approach has been developed [4–7]. This approach allowed one to quantify the amount of damage within the whole cell population. The method was shown to be more adequate for the comparison of experimental data obtained for different radiation qualities which caused different cell cycle perturbations compared with the conventional methods based on single sampling time data. It yielded for Ne (LET 460 keV/μm), Ar (1226 and 1840 keV/μm) and Kr (3980 keV/μm) ions values of 3.2,

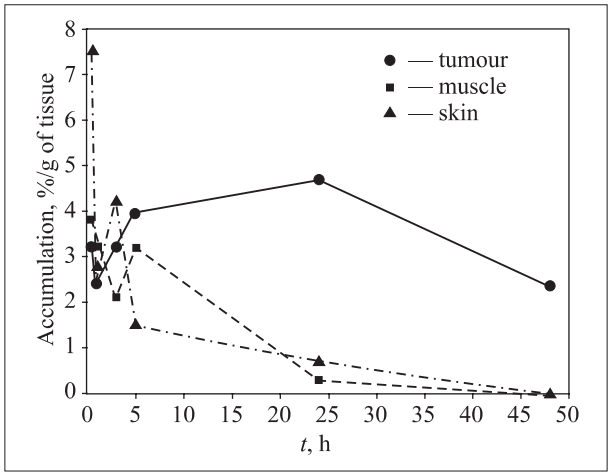

Fig. 3. Accumulation of ^{131}I-MTB in tissues of tumour-bearing animals

1.9, 1.4, 1.3, respectively, which were much higher than all previously published RBE values obtained routinely at single fixation regime in this region of very high LET [6].

The mathematical method was also applied to reconstruct the growth curves and to evaluate the amount of aberrant cells, which reached mitosis during the course of experiment as well as the number of lost cells due to the incomplete sampling or interphase death. It was demonstrated that in case of Chinese hamster cells used here the vast majority of exposed cells were able to reach their first postirradiated mitosis despite pronounced cell cycle delay.

Finally, LET-dependent alterations in aberration spectrum were demonstrated in line with the general view that the quality of lesions underlying chromosomal aberrations changed with LET. First, it was shown that after high LET radiation the chromosomal breaks were preferentially formed, while after sparsely ionizing radiation the aberration spectrum was dominated by exchange-type aberrations like dicentrics: the fraction of chromosomal breaks increased from 40 % after X-ray exposure to 55–65 % for particles with LET in the range 1000–4000 keV/μm. A further characteristic feature of densely ionizing radiation was the occurrence of a high number of chromatid-type aberrations despite cell irradiation in G_1 phase of the cell cycle. While after X irradiation the chromatid-type aberrations accounted for about 10–15 % of aberration yield, this amount gradually increased with LET being 30 % for Ne (LET 460 keV/μm), 35–40 % for Ar (1226 and 1840 keV/μm) and 45 % for Kr (3980 keV/μm) ion exposure. This is a consequence of higher complexity and lower reparability of DNA lesions produced by high LET radiation. As an extension of these studies, the time-course of chromosomal damage induced by radiation of different quality in normal healthy human fibroblast cell lines as well as in human peripheral blood lymphocytes is currently investigated [7].

The investigation of low-dose radiation effects was continued. The induction of cytogenetic damage after irradiation of Chinese hamster cells and human melanoma cells within a dose range 1–200 cGy was studied [8–10]. The anaphase and metaphase analyses of chromosome damage and micronuclei test were applied in asynchronic and synchronic populations. The hypersensitivity (HRS) at doses below 20 cGy and the increased radioresistence (IR) at higher doses were shown for all cytogenetic criteria in both cell lines. The phenomenon of HRS/IR was reproduced in synchronic as well as in asynchronic population of Chinese hamster cells. This reflects that HRS was caused by high radiosensitivity of all cells and cannot be explained by changes of radiosensitivity of cells in different phases of the cell cycle. So it was supposed that the increasing radioresistence is determined by the inclusion of the inducible repair processes in all cells. This conclusion consents with the fact that there was no evidence of HRS on dose-effect curves and that some parts of pre-existent damage were repaired after preliminary irradiation with low doses (1–20 cGy) which induced repair processes. It can be concluded that the same inducible repair processes underlie either the HRS/IR phenomenon or adaptive response [11].

Comparison of radiobiological effective depths with 150-MeV unmodulated proton beams (FLNP) was conducted. Cell survival curves were generated with the *in vitro* colony-forming assay. With ^{60}Co gamma rays as the reference irradiation, the relative biological effectiveness values for a survival fraction level of 0.1 at Bragg peak and plateau are 1.17 and 1.03, respectively. So, to maintain uniformity of radiobiological effectiveness for a target volume, careful attention should be paid to the influence of the depth of beam and irradiation dose.

As an extension of the previous studies on the genotoxic effects of low doses of radiation and formation of stable and unstable chromosomal aberrations, an experiment was performed on mammalian cultured cells and human lymphocytes exposed by ^{12}C ions (480 MeV/amu) obtained at the Nuclotron (LHE).

Studies on targeted therapy of human pigmented melanoma with radiolabeled methylene blue (MTB) were continued. Experiments were carried out with MTB labeled with ^{131}I or ^{211}At *in vitro* and *in vivo*. Accumulation of ^{131}I-MTB in human pigmented melanoma cells *in vitro* is about 4–5 times higher than that in non-pigmented cells (Fig. 3). The maximum of accumulation occurs in 2 h after injection [12]. The obtained data stay in accordance with the previous results on ^{211}At-MTB accumulation *in vitro*.

Experiments *in vivo* show rapid excretion of ^{131}I-MTB from all organs of tumour-bearing mice during first 24 h. Accumulation of the compound in tumour has maximum (5 %/g of injected activity) in 24 h and remains at a high level during at least first 2 days after injection. Tumour to normal tissues ratios for ^{131}I-MTB accumulation were 36:1 for blood, 47:1 for muscles, 7.8:1 for skin at 24 h after i. v. injection [13, 14]. Preliminary data on ^{211}At-MTB biodistribution shows high accumulation of the compound in melanoma (6 %/g of injected activity) at 5 h after injection and its slow excretion from the other organs.

The analysis and comparison of different models for describing radiobiological effects at low-dose exposure have been done [15]. All the models are presented by linear nonthreshold term of damage yields, which is resulting for the linear nonthreshold model. This fact reflects the regularity that primary reason for all stochastic radiobiological effects (perhaps DNA breaks) is linearly and nonthreshold-dependent on dose. However, the linear term of effect is necessary but insufficient for adequacy of the model, in general case, to the observation result. The linear-quadratic model can be adequate to any data on a cell level to a dose of more than 1 Gy, however at less doses the adequacy often breaks. The inducible repair model is adequate to the data on a cell level. The confidence level of the model of two cell populations is selectively adequate to the data on a cell level. The confidence level of the model of two protection reactions on totality of data is the highest one of the compared models and suitable for all the levels of an organism. On the basis of this model the estimation of radiation risk for population of the most contaminated regions of Belarus has been done [16].

CONFERENCES

The II International Symposium under the auspices of UNESCO «Problems of Biochemistry, Radiation and Space Biology» dedicated to the memory of Academician N. Sissakian and the II N. Sissakian Readings were held at the A. Bakh Institute of Biochemistry (Moscow) and at JINR on 29 May – 1 June 2001. About 120 participants from Russia and other European countries attended the Symposium. The Symposium Scientific Programme included 16 plenary reports and more than 80 reports were distributed among three special sessions on: biochemistry; space biology and medicine; general and space radiobiology.

A competition of the reports among the young scientists was organized in the framework of the Symposium. The winners were awarded diplomas and premiums.

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UNIVERSITY CENTRE

Ten years ago, in January 1991, joint Order of the Ministries of Education and Atomic Energy No. 28/33 of January 16, 1991, was signed. It was titled «On Providing Staff for Research and Applied Work in Nuclear Physics, Elementary Particle Physics, Condensed Matter Physics, and High-Temperature Superconductivity.» This Order initiated the specialized training, on the basis of JINR, of graduate students from Moscow State University (MSU), Moscow Engineering Physics Institute (MEPI), and, a little later, Moscow Institute of Physics and Technology (MIPT). On the grounds of this Order, the University Centre (UC) has been established, whose 10th anniversary was celebrated on March 21, 2001. JINR Director Academician V. G. Kadyshevsky addressed the UC students, postgraduates, faculty, and founders with a congratulatory speech and wished them further achievements in their activities, which are ultimately aimed at maintaining and developing science. The ceremony was attended by representatives of MEPI, MIPT, and MSU.

By 1991, JINR already had a system of training young specialists. The system was founded upon the Dubna-based Departments of the Physics Faculty of MSU (the Dubna branch of MSU's Institute of Nuclear Physics was opened in 1961). However, JINR's demand for the scientific staff of different specialties was growing; so the establishment of the UC was a natural addition to, and extension of, JINR's unique scientific potentialities for training young specialists. Since 1995, postgraduate studies have been successfully proceeding at the UC, now comprising 10 specialties in physics and mathematics.

The development of JINR's educational activities required amendments to the Institute's official documents. Thus Paragraph 2 was included in Article 4 of the JINR Charter: «[JINR] ...develops educational activities, including graduate and postgraduate programmes in the Institute's main fields of research, to provide highly skilled staff for the JINR Member States.» The «Educational Activities» section has been included in the JINR Topical Plan for Research and International Cooperation.

In 2001, the UC continued its activities within the first-priority topic «Organization, Maintenance, and Development of the University-Type Educational Process at JINR.»

Students of the fourth, fifth and sixth years traditionally 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 2001, there were 167 students at the UC from higher education institutions of JINR Member States. The curricula have been worked out jointly with the institutions that have assigned their students to graduate at the UC. Table 1 shows the distribution of the UC students over higher education institutions in 2001.

Table 1

Higher education institution	Number of UC students
Moscow State University	11
Moscow Engineering Physics Institute	10
Moscow Institute of Physics and Technology	30
Institutions of other JINR Member States (Armenia, Belarus, the Czech Republic, Georgia, Russia, Slovakia, and Ukraine)	37
Altogether	88

The UC total enrolment also includes 79 undergraduates of Moscow Institute of Radio Engineering, Electronics, and Automation, of whom 26 are first-year students.

The UC develops its own programmes for separate student groups.

Within the framework of training specialists for the Slovak Cyclotron Complex, which is being built with the help of JINR, Solvak students continued to attend full-time programmes at the UC. In January 2001, a sec-

ond group of Bratislava Technical University (BTU) students successfully defended their theses. A third group, which is made up of students from BTU and the Komensky University (Bratislava), continued to study at the UC the specialty «Accelerator Physics and Engineering.» The specialized curriculum includes the following courses: Applied Mathematics, Charged Particle Beam Dynamics, Interaction of Radiation with Matter, Physics and Engineering of Heavy Ion Accelerators, Atomic and Plasma Physics, Heavy Ion Sources, and High-Frequency Systems of Accelerators. The lectures in these subjects are given by scientists of the Laboratory of Nuclear Reactions, Laboratory of Particle Physics, Division of Radiation and Radiobiological Research, and Laboratory of Nuclear Problems. The lectures have been preceded by an intensive course of Russian.

In 2001, the UC Physics Practicum was supplemented by a new exercise. Within the laboratory exercise «Two-Dimensional *X*-Ray Detector for Medical and Biological Research,» which has been prepared at the Laboratory of High Energies under the supervision of Yu. V. Zanevsky, students will be studying the fundamentals of multi-strip chamber operation and the specifics of their application in medical and biological research.

In addition to the standard set of courses, the UC offers optional lectures on the following subjects: Elementary Particle Physics, Relativistic Nuclear Physics, Theory of Fundamental Interactions, Quantum Chromodynamics, Theory of Nuclear Reactions, Atomic Nucleus Structure, Introduction to Accelerator Theory, Experimental Nuclear Physics, Modern Methods of Detecting Nuclear Reactions and Nuclear Radiation, Programmable Logical Units, Fundamentals of Radio Engineering, Digital Devices and Their Application, Electronic Methods of Detecting Ionizing Radiation, Radiation Safety and Environment Protection, Mathematical Statistics, Object-Oriented Programming in C++, Programming in UNIX, Computing in High Energy Physics, Internet Technologies, Computing in Nuclear Physics (seminars), Telecommunication Systems and World Information Resources, Visualization in Scientific Research, Operating the «Mathematica» System, English for Students, and English for Postgraduates.

In the spring semester of 2001, the following courses besides the regular lectures were given to the UC students and postgraduates, as well as to all those interested:

— N. B. Skachkov. Computing in High Energy Physics. The course provided the detailed study of modern software for processing large data arrays, in particular, the widespread package ROOT, which was designed at CERN. The course included hands-on classes.

— D. Yu. Bardin. Introduction to CalcPHEP (Calculus of Precision High Energy Physics). The lectures and seminars have been supplemented by demonstrating the capabilities of CalcPHEP at the Internet site http://brg.jinr.ru.

— M. V. Savina, S. V. Shmatov. Computer-Modelled Study of Elementary Particle Interaction Using the Software Packages PYTHIA and JETSET.

— A.A.Smolnikov. Neutrino Physics and Non-Accelerator Experiments. The course provided an overview of neutrino physics based on research in nuclear physics, elementary particle physics, astrophysics, and cosmology. Modern techniques of non-accelerator physics were considered using the examples of operating and planned underground, deep-sea, and under-the-ice experimental installations. The hands-on classes were held at the research departments of JINR's Laboratory of Nuclear Problems.

Within the lecture cycle «Modern Problems of Natural Sciences,» the following courses were given in 2001:

— Yu. P. Pytyev (Moscow State University). Lecture Cycle on Mathematical, Computer, and Information Technologies in Experimental Research.

— R. Kragler (Fachhochschule Ravensburg–Weingarten/University of Applied Sciences, Germany). Mathematica Tutorial Course, Part II.

The list of textbooks published by the UC for its students and postgraduates has been supplemented with the following publications:

— V. V. Papoyan. Lectures on Classical Mechanics. УНЦ-2001-9.

— V. V. Papoyan. Lectures on Vector and Tensor Analysis. УНЦ-2001-10.

— N. V. Antonenko, S. P. Ivanova, O. V. Fotina. Statistical Approach to the Analysis of Nuclear Reactions. УНЦ-2001-11.

The JINR postgraduate programmes in 10 specialties in physics and mathematics have continued into 2001. In 2001, the UC had a total postgraduate enrolment of 60. Table 2 shows the distribution of the UC postgraduates over the JINR Laboratories in 2001.

Table 2

JINR's Laboratories and subdivisions	Number of UC postgraduates
Laboratory of Theoretical Physics	7
Laboratory of Nuclear Problems	15
Laboratory of Nuclear Reactions	5
Laboratory of High Energies	4
Laboratory of Neutron Physics	8
Laboratory of Particle Physics	6
Laboratory of Information Technologies	12
Division of Radiation and Radiobiological Research	1
University Centre	2
Altogether	60

The UC held its first postgraduate commencement in 1998. Ten of these alumni have already defended their Candidate's dissertations.

In 2001, the UC was actively developing its well-established ties with foreign institutions of higher education. Within 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 the academic year 2000–2001. Thanks to this support, two UC postgraduates and one graduate student performing theoretical research in heavy ion physics are paid an additional scholarship during the academic year; they had a month's study in Giessen.

During a month, four UC students attended courses of lectures on high energy physics at Pavia University (Italy). These studies were supported by a grant from the European Physical Society (EPS) that the UC received in 2000. For 2001, the EPS has allotted another grant to the UC, which will allow a UC postgraduate to study at one of the German universities during half a year. DAAD has prolonged its grant to the UC into 2001–2002.

The UC actively cooperates with Belarus. Among those completing their education at the UC, as well as among participants of student schools held in Dubna, regularly are students from Belarus State University (the city of Minsk).

In 2001, the UC continued to retrain technical staff members and raise their professional skills, as well as to organize and coordinate the training system on the basis of JINR's Laboratories and subdivisions.

Twelve JINR's new staff members have qualified for their second (allied) professions; 28 JINR's employees have been trained in their second professions. At the JINR Training Division, 13 employees of Dubna's organizations have qualified for professions supervised by the Federal Technical Inspection.

In 2001, training and certification according to the new Regulations on the Design and Safe Operation of Hoisting Mechanisms was arranged for JINR's managerial staff and specialists (40 people altogether).

Twenty-one members of JINR's managerial staff have been trained and certified in industrial hygiene and accident prevention at Moscow Institute of Qualifications Improvement «Atomenergo.»

In 2001, 20 students of Professional Lyceum No. 67 and Professional Technical School No. 95, and three students of Dmitrov Polytechnic had a probation at JINR.

The UC-based branch of the preparatory courses training entrants into Moscow Engineering Physics Institute (MEPI) continues to function. Fifteen Dubna's school students are attending these classes in the academic year 2001–2002. Two of those who completed the courses in the academic year 2000–2001 have entered MEPI within the system of special enrolment for training specialists for specific institutions.

A special laboratory is being created at the UC for the demonstration of secondary school experiments in physics. The laboratory is being completed with equipment and materials. The secondary school practicum in physics is to be broadened. It is also planned to arrange the demonstration of the laboratory exercises to Dubna's physics teachers.

The cycle of JINR's summer student schools was continued with the International Student School «Nuclear Physics Methods and Accelerators in Biology and Medicine,» which was held on June 27 – July 11, 2001, on the basis of JINR's holiday home «Ratmino.»

The purpose of the School was to acquaint students and postgraduates with latest achievements and current problems of applied medical physics. The wide application of ionizing and non-ionizing radiation, radionuclides, gamma therapy units, electron and proton accelerators, and computer tomographs in medicine has turned medical physics into the present and future of medicine. Modern applied medical physics is concerned with radiation therapy, nuclear medicine, radiation diagnostics, non-ionizing diagnostics and therapy, computer facilities and mathematical modelling in diagnostics and therapy, radiation safety, and radioecology.

The School was attended by students from Belarus, the Czech Republic, Ecuador, Macedonia, Poland, Romania, Russia, Senegal, and Slovakia. The working language of the School was English.

The lecturers of the School were 37 specialists of JINR, the Czech Republic, Germany, Poland, Russia, Switzerland, and the U.S.

The total number of the School students and lecturers was 127, of whom 80 were students. The audience also included 10 postgraduates of Moscow State University (MSU), the Oncology Centre (Moscow), Prague Technical University, Slovakia, and JINR.

The Organizing Committee included representatives of JINR Member States. Notably active were the Committee members of JINR, Moscow Engineering Physics Institute, the Czech Republic, and Poland. The Organizing Committee was headed by Vice-Director of JINR Prof. A. N. Sissakian. Prof. S. P. Ivanova was Co-Chairperson of the Organizing Committee.

Among those invited to the official opening of the School were the Vice-Director of JINR Prof. Ts. Vylov, Director of the Dzhelepov Laboratory of Nuclear Problems Prof. N. A. Russakovich, Head of a MEPI Department Prof. V. A. Klimanov, and Assoc. Prof. A. P. Chernyayev of MSU. First Deputy Minister of Education of the Russian Federation Prof. V. M. Zhurakovsky sent a message of greetings to the School.

The School programme was diverse. The lecturers were very well prepared; most of them had comput-

er-based presentations. They were all pleased to note the good technical and software support of the School, which provided excellent conditions for lecturing.

Separately mentioned should be the lectures by Prof. G.-J. Beyer (Switzerland), which got the audience's highest appraisal. Interesting results were presented by V. A. Klimanov (MEPI, Russia), G. I. Klenov (Moscow Institute of Radio Engineering), G. Yu. Gorlachyov (MEPI), P. Nizin and P. Heintz (the U.S.), I. A. Gulidov (Obninsk, Russia), and T. Beyer and G. Kuehnel (Germany). A scientific excursion to the Cardiology Centre (Moscow), which included a special lecture by Prof. Ye. L. Shcherbakova, was an excellent addition to the lectures given at the School.

The School's lecturer staff included a wide representation of JINR scientists, who gave the following lectures: V. Aleinikov, «Fundamental Concepts of Ionizing Radiation Dosimetry»; E. Krasavin, «Radiobiological Research at JINR»; S. Chernenko, «Multi-Strip Detectors Designed in Medical and Biological Research at JINR»; G. Mitsyn, «Hadron Therapy Complex at the Laboratory of Nuclear Problems»; G. Ososkov and V. Ivanov (Senior Scientists at the Laboratory of Information Technologies), «Artificial Neural Networks and Their Applications in Medicine»; and A. Molodozhyontsev (Laboratory of Particle Physics), «Medical Applications of Accelerator Technique in Japan.»

Student sessions were an important feature of the School. Students from the Czech Republic, Poland, and Russia presented 23 reports. At the end of the School, determined were three best student reports, and their authors were awarded prizes.

The students who actively participated in the School were given the School certificates. Attendance throughout the School was quite high — about 85 %.

The location of the School in Ratmino made for close communication between the participants. Not only did the students attend the lectures and participate in the seminars, but they also enjoyed various sport and culture activities.

Almost all the lecturers have left their lecture presentations with the School organizers. With the lecturers' permission, these materials have been put up at the Internet pages of the University Centre (http://uc.jinr.ru/SummerSchool).

It is planned to issue the proceedings of the School, which will include both lectures and students' reports.

The organizers of the School have received letters from many of its participants with high appraisals of the organization, conduction, and programme of the School and suggestions that more schools on these topics be arranged. Polish representatives proposed that the next school be held in Poznan in 2003; Czech representatives proposed that another school be held in Prague in 2005.

The School was conducted successfully thanks to the support from the JINR Directorate. The School was financed from Topic 10-0-1026-98/2003, Organization, Maintenance, and Development of the University-Type Educational Process at JINR. The School was also supported by the Plenipotentiaries of the following JINR Member States: the Czech Republic, Poland (the Bogoliubov–Infeld Programme), Romania, and Slovakia. Other sources of support were the Czech Technical University, Centre of Applied Nuclear Physics of JINR's Flerov Laboratory of Nuclear Reactions, Russian Federal Programme «Integration,» Soros Foundation, and companies Siemens Medical Solutions and HWM-Dresden GmbH.

Jointly with the regional public organization «Soros Professor Club,» the UC participated in the organization and conduction of the conference «Education and Science in Russia,» which took place in Dubna on September 22–23, 2001.

In 2001, reports on the fulfilment of the JINR Education Programme, as well as on the preparation and results of the International Student School «Nuclear Physics Methods and Accelerators in Biology and Medicine» (June 27 – July 11, 2001, Dubna), were presented —

- in the electronic journal RUPHYS NEWS of the Joint Physical Society of the Russian Federation, No. IV, 2001 (a report on JINR's educational activities; http://www.uniphys.ru/journal/N4-01/JINR/jinr.htm);
- at the EUPEN jubilee conference in Cologne in September 2001 (a report on the cooperation between the UC and Bratislava Technical University, Solvakia);
- at the 14th session of the Programme Advisory Committee on Nuclear Physics, April 23–25, 2001;
- at the 14th session of the Programme Advisory Committee on Condensed Matter Physics, April 27–28, 2001;
- at the 15th session of the Programme Advisory Committee on Condensed Matter Physics, November 22–23, 2001;
- at the 15th session of the Programme Advisory Committee on Nuclear Physics, November 26–28, 2001.

Within the joint project of the UC and the Institute of Theoretical Physics of the University of Giessen (Germany), theoretical research in heavy ion physics has been conducted at the UC [1–6].

T. M. Shneidman et al. // Symp. on Nuclear Structure Physics, ed. R.Casten, J.Jolie, U.Kneissl, and P.Lieb. Singapore, 2001.

The UC's Internet site (http://uc.jinr.ru) is regularly updated.

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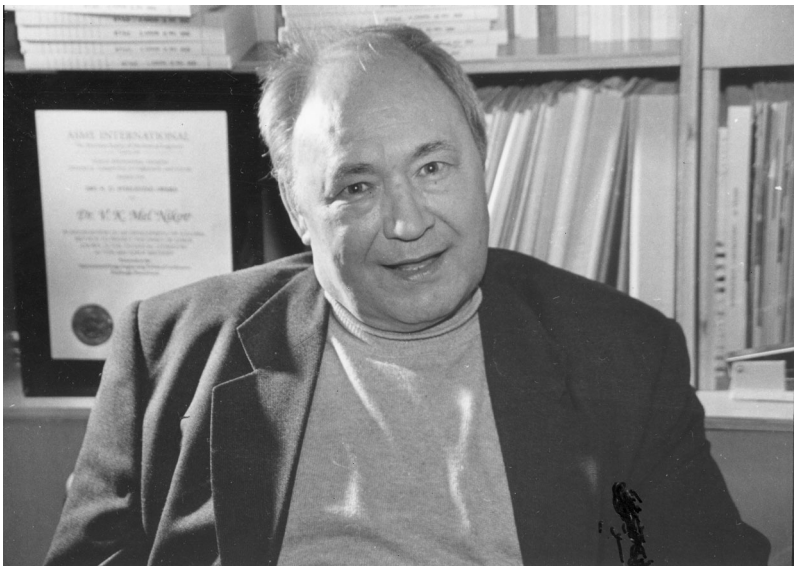
The Laureate of the N. O. Myklestad
Award of the American Society
of Mechanics Engineers (ASME)
BLTP Leading Researcher V. K. Melnikov



Bogoliubov Laboratory
of Theoretical Physics, 17 January.
Academician A. A. Logunov is making a report
«Gravitational Field Theory (Black Holes
and Big Bang)» at a Laboratory seminar

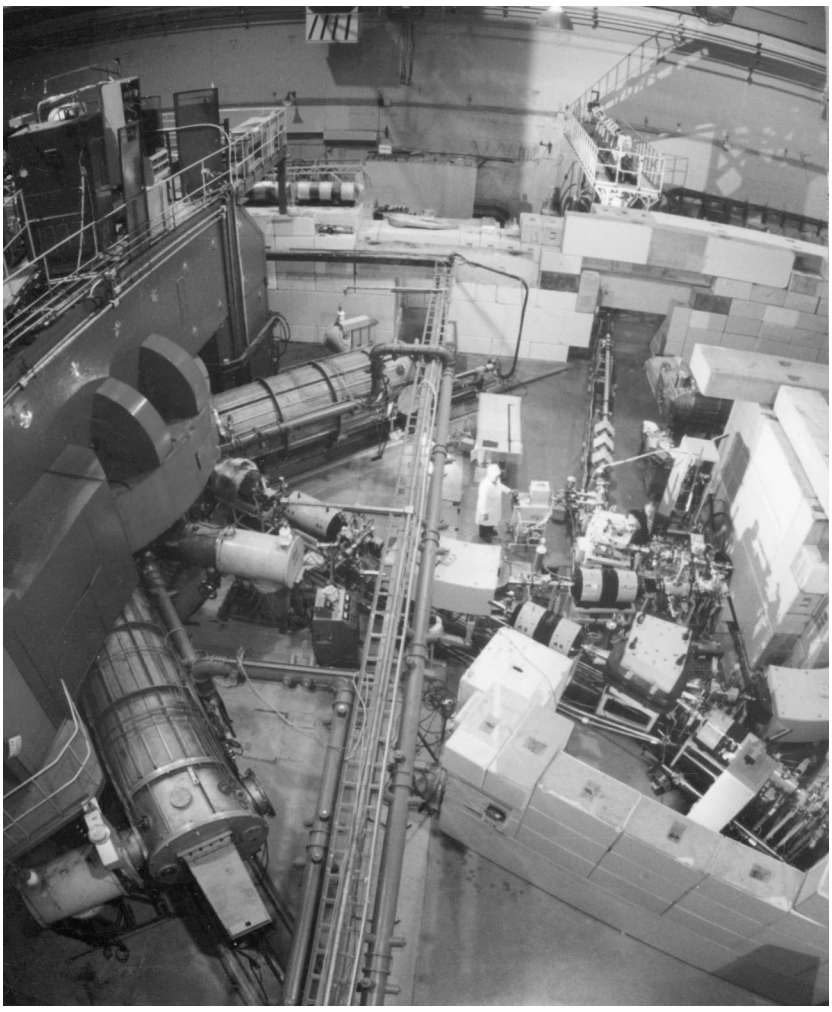
Dubna, 18 June. Participants of the 3rd International Workshop «Quantum Gravity and Superstrings»

Dubna, 17 May. JINR's guests — a delegation of German scientists (Darmstadt) — at the Flerov Laboratory of Nuclear Reactions. Left to right: Chief of GSI department Professor G. Münzenberg, Director of the Society of Heavy Ion Research Professor W.-F. Henning, Deputy Director Professor H. Gutbrod, FLNR Director Professor M. Itkis, FLNR Scientific Leader Professor Yu. Oganessian

Dubna, 14 October. The delegation of Serbia at the Flerov Laboratory of Nuclear Reactions

Flerov Laboratory of Nuclear Reactions.
Ambassador Extraordinary and
Plenipotentiary of the Czech Republic
in the Russian Federation J. Bašta (centre)
observes the equipment produced
by the firm «Vacuum Prague»
for the DRIBs project

Flerov Laboratory of Nuclear Reactions.
The mounting of the equipment
for the first part of the DRIBs project



Frank Laboratory of Neutron Physics. 15 June — one of the first basic JINR facilities, the IBR-30 reactor, is stopped

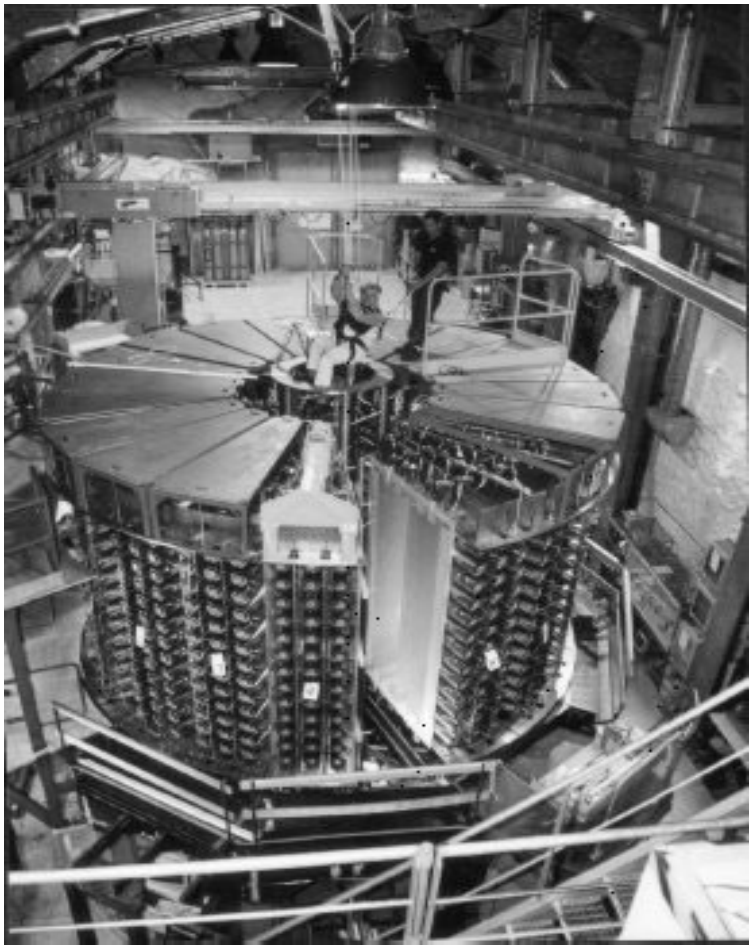
Dubna, 25 May. Participants of the Workshop «IBR-2 Reactor in the 21st Century»

Frank Laboratory of Neutron Physics.
A group of the IREN project specialists

Frank Laboratory of Neutron Physics.
Assembling of the magnet channel
of the SPN-2 spectrometer

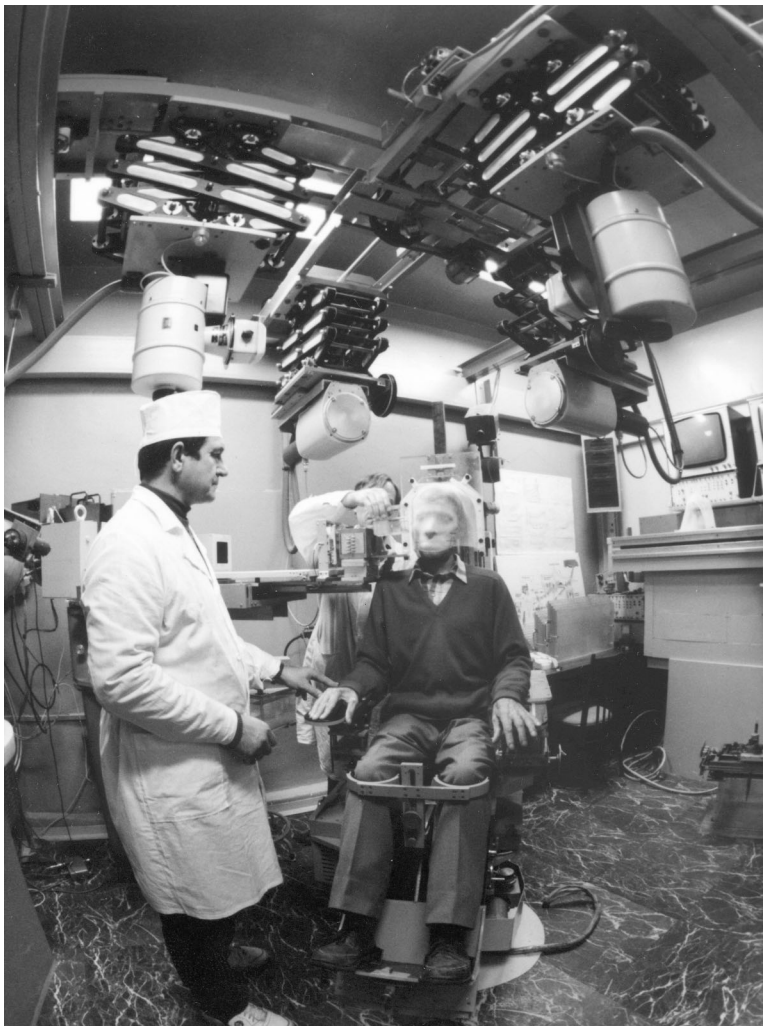
Dubna, 19 March.
The Second School on Modern
Neutron Diffractometry

Dubna, 15–16 May. A visit to JINR of a delegation of scientists from Belarus, headed by Plenipotentiary of the Government of the Republic of Belarus Academician A. I. Lesnikovich



Spectrometer NEMO-3 at the end of its construction:
the 19th sector is being mounted

Dzhelepov Laboratory of Nuclear Problems. The site of drift tubes production for the ATLAS experiment



Dzhelepov Laboratory of Nuclear Problems.
Radiotherapy session with medical beams
of the Dubna phasotron

Laboratory of High Energies.
The JINR Directorate meet with the participants of the experiments on polarized deuteron beam at the Synchrophasotron

Laboratory of High Energies.
The polarized proton target used in the DELTA–SIGMA experiment

Varna, 10–17 September.
The VI International Meeting «Relativistic Nuclear Physics: from Hundreds of MeV to TeV»

Laboratory of Information Technologies, 19 September. The inauguration of a sculptural portrait to M. G. Meshcheryakov in the hall of the Laboratory. The portrait was created by People's artist of Armenia M. Sagatelian

Varna (Bulgaria), 13 September. The 18th International Symposium «Nuclear Electronics and Computing»

Dubna, 29 June. Participants of the seminar «Computer Algebra and its Application in Physics»

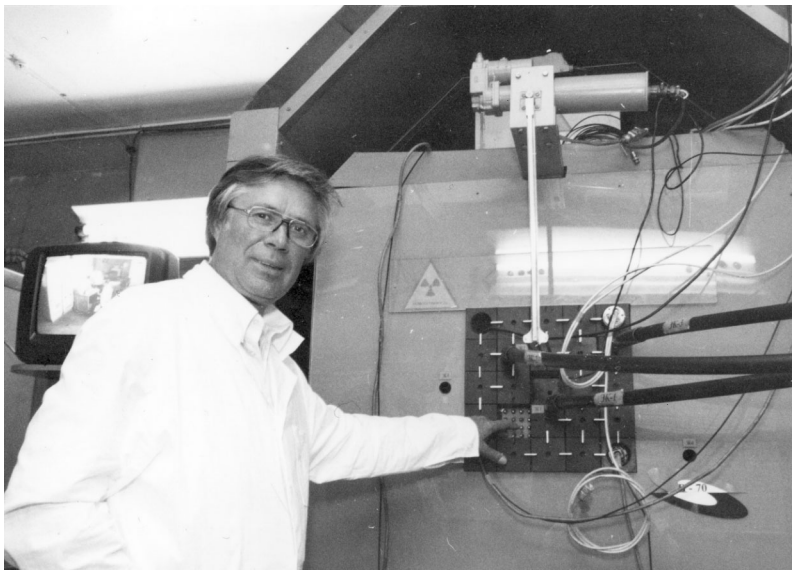
Laboratory of Particle Physics. The test bench for the straw chamber (coordinate detectors based on thin-wall drift tubes) for the COMPASS set-up

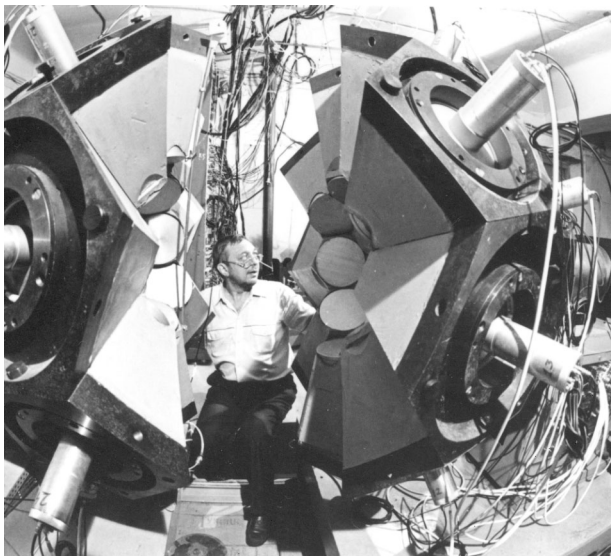
Laboratory of Particle Physics. The first ring in the mass production line of the inner detector for the ATLAS facility

Gomel (Belarus), 7–16 August. The VI International School-Seminar «Actual Problems in Particle Physics». Speaking is Chairman of the Organizing Committee and JINR Vice-Director A. N. Sissakian

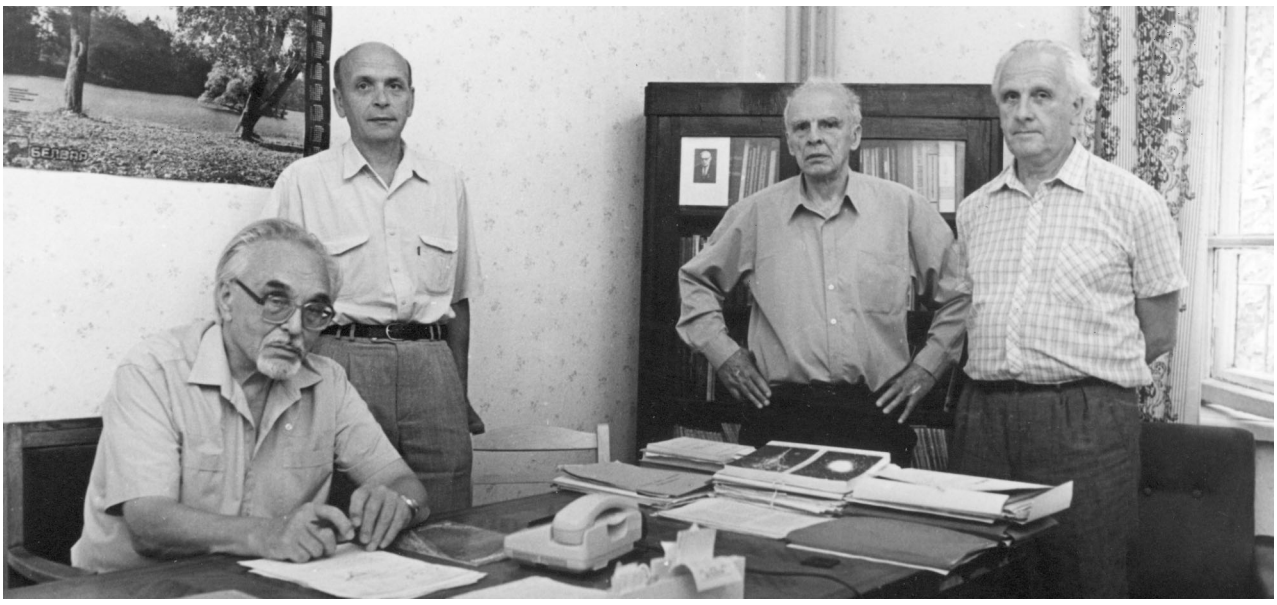
Dubna, 27 June –11 July. International Student School «Nuclear Methods in Radiobiology and Medicine»

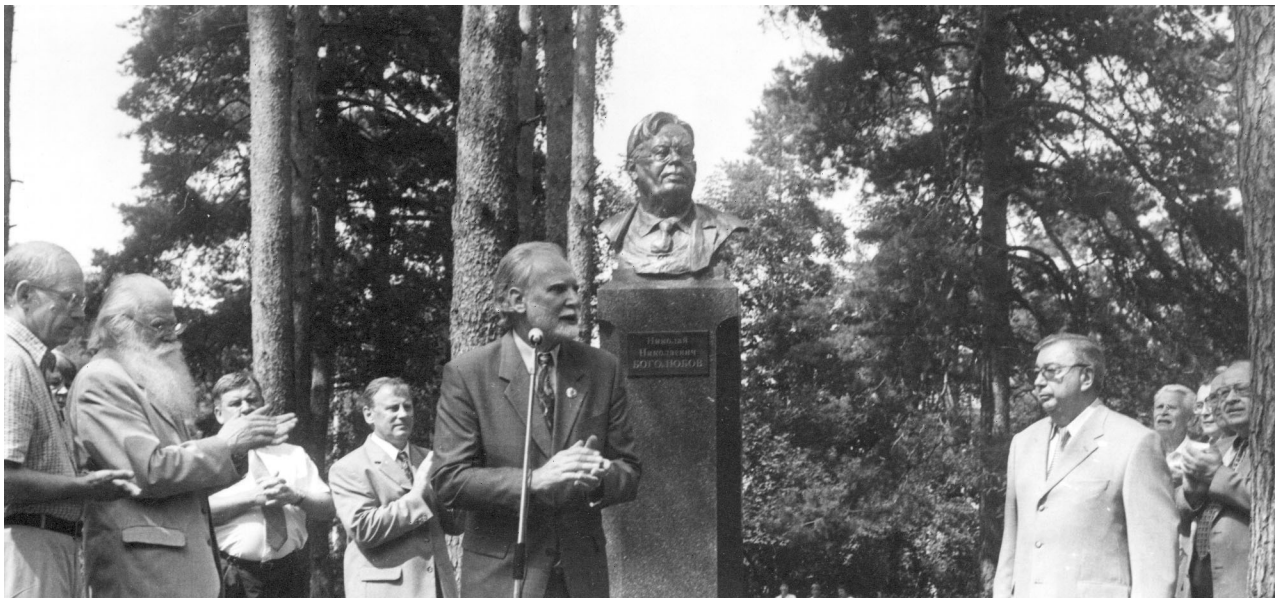
Dubna, 21 March. The seminar dedicated to the 10th anniversary of the JINR University Centre





Belarus, August.
Many years of fruitful cooperation
bond JINR with institutes,
universities and enterprises
of the Republic of Belarus





Dubna, 28 July. The inauguration of a monument to the prominent scientist in the field of mathematics, mechanics and physics Academician N. N. Bogoliubov. The opening ceremony was attended by Corresponding Member of RAS N. N. Bogoliubov (jr.), Academician A. A. Logunov, President of the Science Towns Development Union A. V. Dolgolaptev, Dubna Mayor V. E. Prokh, Academicians V. G. Kadyshevsky, E. M. Primakov, M. N. Bogoliubov, V. A. Matveev, V. S. Vladimirov and others

Dubna, 23 September. The 32nd traditional race dedicated to the memory of Academician V. I. Veksler

CENTRAL SERVICES

PUBLISHING DEPARTMENT

In 2001, the Publishing Department published JINR communications and preprints of 292 titles. Issued were 125 official publications.

A total of 41 proceedings of various conferences, schools and workshops were issued. Among them are proceedings of the international symposium «LHC Physics and Detectors» (in three volumes), the international workshop «Reletivistic Nuclear Physics: from Hundreds of MeV to TeV», the international workshop «Hot Points in Astrophysics», the international school for young scientists «Problems of Charged Particles' Acceleration». Published were also the annual reports of JINR for 2000 (in Russian and in English), the annual report of the Frank Laboratory of Neutron Physics for 2000, the annual report of the Bogoliubov Laboratory of Theoretical Physics for 1999–2000 and the annual report of the Flerov Laboratory of Nuclear Reactions for 1999–2000. The proceedings of the round-table discussion held during the 89th Session of the JINR Scientific Council in January 2001 are included into a collection «Cooperation of JINR with Institutes and Universities of Poland».

A book «Vladimir Pavlovich Sarantsev: the Life Devoted to Science» is dedicated to the memory of the noted Russian scientist, the leading specialist in the field of accelerator technology. The book includes V. P. Sarantsev's articles published in popular science editions, recollections of his friends, collegues and pupils, the full bibliographic list of publications.

In 2001, seven issues of the journal «Physics of Elementary Particles and Atomic Nucleus» with 60 reviews. The editorial board of the journal included in the additional issue No. 7, devoted to the 45th anniversary of JINR, part of reviews on the most important results obtained recently at JINR in the field of fundamental research. The second part will be published in Issue No. 3, Volume 33 in 2002. Six issues of the journal «Particles and Nuclei, Letters» with 54 articles, describing original scientific, technological, and applied results, were printed. Four issues of the journal (Nos. 1, 3, 5, 6) contains the proceedings of the internation conference «Non-Accelerator New Physics in Neutrino Observables» — NANPino-2000. Publication of the bulletin «JINR News» in the Russian and English languages was continued.

Four textbooks of the JINR University Centre were published.

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 2000» was issued.

The Publishing Department was also engaged in Xerox copying and book binding to fulfil numerous orders of JINR Laboratories. Over 150,000 various forms were printed for processing of experimental information and for other purposes.

SCIENCE AND TECHNOLOGY LIBRARY

In 2001, the Science and Technology Library rendered its services to 4,711 readers. 360,000 copies of books were given out.

846 publications, ordered by readers, were received via the interlibrary exchange system.

Weekly express bulletins «Books», «Articles», «Preprints» (156 issues) were published with data on 17,248 titles. The bulletins were distributed among 200 JINR staff members and mailed to 50 addresses outside the Institute. Information bulletins and lists of conferences appeared regularly in the WWW and INFOMAG (Moscow) systems, as well as in tele-conferences. The database on papers and preprints is accessible at the Internet address http:/lib.jinr.ru.

The Library received 8,736 books, periodicals and preprints from all compiling sources, including 6,164 books in foreign languages. All the new publications were registered in the central catalogue and branch catalogues.

Exhibitions of new books, preprints and periodicals were weekly up-dated, and 6,403 titles were presented. Five thematic exhibitions were held. By 1 January 2002, the Library stock amounted to 426,470 copies, 190,873 of them in foreign languages. The «Bibliographic Index of Papers Published by JINR Staff Members in 2000» (1,335 titles) was prepared for publication. The database on papers by JINR scientists (bibliographic descriptions of papers since 1987) is Internet accessible.

In 2001, in exchange for JINR publications printed by the JINR Publishing Department, the Library received 3,507 publications from 30 countries. Among them 487 issues were from Russia, 556 from Germany, 222 from Italy, 803 from the USA, 154 from France, 32 from Switzerland, 411 from Japan and 653 from CERN.

In 2001 the automated library information system Liber Media was put into operation at the JINR Science and Technology Library. The titles of all the new books and periodicals obtained by the Library have been entered into the system database since 2000.

ITELLECTUAL PROPERTY, LICENSING AND STANDARDIZATION OFFICE

In 2001 the activities of the Office were conducted in several areas.

Licensing. Licenses were produced for the following departments and Laboratories: for the Department of Energy Supplies to exploit gas stations; for DLNP to conduct experiments on fundamental properties of particles and space radiation with nuclear physics methods; for the Department of Reconstruction and Building to lead construction and installation work; for FLNP to use vessels under pressure and noisting cranes. The licenses were issued by the Bureau of labour protection, insurance and civil responsibility of the organizations which include dangerous industrial sites.

The JINR license library was established. The Office took part in the work of the JINR Board on Economic Safety.

Standardization. Changes on the GOST and TU information were inserted into the register, standards and guides, consultations were held and assistance was rendered in the work-out and description of the scientific and technical data, documents were compiled on themes, GOST values in the divisions were checked according to their validity and changes.

The following documentation was issued and went through the state registering: changes to «Track Membrane» and «Deonized Water»; the collection of standards «Ferrous and Nonferrous Metals» was rewritten and changed.

Seventy-two official patent bulletins of the Russian Federation were received in 2001. The Office stock comprised 1,804 bulletins. The publications were processed with account to the JINR research topics. Twelve issues of the bulletin «Patents» were published.

In 2001, three applications for invention were received. They were «Method of Obtaining Selenium-Containing Medicaments Based on Spirulina Biomass», «Method to Diagnose Accelerator Beams» and «Method of Multielement Ion Implantation».

Five invention applications received earlier were processed for defense.

EXPERIMENTAL WORKSHOP

In 2001, the JINR Experimental Workshop manufactured products to an amount of 14 million roubles on the orders of the JINR Laboratories and other departments. In the framework of the JINR international cooperation these were modules and submodules of the ATLAS Hadron Calorimeter (CERN), submodule parts of the COMPASS facility (CERN). Parts of the STAR facility were produced for BNL (Brookhaven, USA). On the order by Munich Technical University chambers of the cold neutron spectrometer for neutron studies were manufactured. Work was started to fulfil the order by CERN to produce equipment for eight Barrel Toroid windings and two End-Cap Toroids. Equipment was produced for the electromagnetic calorimeter at Wayne University (Detroit, USA).

The work on upgrading of the polarized neutron spectrometer and on manufacturing of parts of the flexible reflector for the IBR-2 reactor (FLNP) was continued.

A considerable amount of orders was still obtained from the ASPECT Scientific Production Centre in the sphere of control of the radioactive materials transport. Work was also done 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's activities in 2001.

Actual expenditures were as follows:

The actual annual receipts amounted to 19287,0 thousand US dollars, or 51.4 % of the annual allocations.

In 2001, the actual research expenditures of the Joint Institute for Nuclear Research amounted to 21321,5 thousand US dollars.

Item	Annual budget, thous US dollars	Actual expenditures in 2001, thous. US dollars	% of budget
I. Research	14,710.9	11,301.8	76.8
II. Basic facilities	6,268.1	2,781.5	44.4
III. Infrastructure of the Laboratories	5,287.4	3,551.0	67.2
IV. Infrastructure of the Institute	5,581.6	3,687.2	66.1
V. On agreement with BMBF less JINR infrastructure and Directorate reserve fund expenditures	738.5		
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	2,918.5		
VIII. Directorate reserve fund, 5 % of budget	1,867.5		
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 5,511 (without temporary staff).

Working at JINR are: full members of the Russian Academy of Sciences (RAS) — A. M. Baldin (posthumously), 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. A. Kuznetsov, 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; 239 doctors of science, 634 candidates of science, including 86 professors and 14 assistant professors.

In 2001, there were 599 people employed and 806 people discharged because of engagement period expiry and for other reasons.

During the year the JINR staff members were awarded the titles of professor — 1, senior researcher — 4.

In 2001, 28 scientists received a Candidate of Science degree and 8 received a Doctor of Science degree at JINR, among them 23 from JINR, 1 from the Republic of Armenia, 1 from Belarus, 1 from Bulgaria, 7 from the Russian Federation, 2 from Slovakia and 1 from the Republic of Uzbekistan.

AWARDS

By the Decree of the Moscow Region Governor the title «Honoured Citizen of the Moscow Region» was conferred to *Vladimir Kadyshevsky* Director of the Joint Institute for Nuclear Research, in recognition of his long-standing dedicated scientific work to the benefit of the Moscow Region and its prestige in Russia and abroad.

By the Decree of the Moscow Region Governor the badge «For the Service for the Moscow Region», in recognition of their long-standing dedicated scientific work to the benefit of the Moscow Region and its prestige in Russia and abroad, is awarded to:

Alexander Baldin (posthumously), Scientific Leader of the Laboratory of High Energies, the Joint Institute for Nuclear Research;

YuriOganessian, Scientific Leader of the Flerov Laboratory of Nuclear Reactions, the Joint Institute for Nuclear Research;

Alexei Sissakian, Vice-Director of the Joint Institute for Nuclear Research;

Dmitri Shirkov, Honorary Director of the Bogoliubov Laboratory of Theoretical Physics, the Joint Institute for Nuclear Research.

By the Decree of the Moscow Region Governor the title «Honoured Scientist of the Moscow Region» in recognition of their long-standing dedicated scientific work to the benefit of the Moscow Region and its prestige in Russia and abroad, is awarded to:

Yuri Zamyatnin, Directorate Advisor of the Frank Laboratory of Neutron Physics, the Joint Institute for Nuclear Research;

Eugeni Krasavin, Chief of the Department of Radiation and Radiobiological Research, the Joint Institute for Nuclear Research;

Igor Meshkov, Chief Engineer, the Joint Institute for Nuclear Research;

Igor Savin, Honorary Director of the Laboratory of Particle Physics, the Joint Institute for Nuclear Research;

Alexander Filippov, Director of the Bogoliubov Laboratory of Theoretical Physics, the Joint Institute for Nuclear Research.

The title «Honorary Doctor of JINR» was awarded to Professor *A. Petrosiants* (Russia), Professor *G. Piragino* (Italy), Professor *Z. Hofmann* (Germany), Professor *G. J. Deutsch* (Belgium), Professor *G. Trilling* (USA) and Professor *S. Ozaki* (USA) for their outstanding contributions to the advancement of priority branches of science and technology, and education of young scientists.

For their meritorious services to JINR, long-standing and fruitful activities, and on the occasion of the 45th anniversary of JINR, 30 staff members were awarded the title «Honorary Staff Member of JINR», and 8 — «Honorary Diplomas of JINR».