ANNUAL REPORT

JOINT INSTITUTE FOR NUCLEAR RESEARCH

Joint Institute for Nuclear Research

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INTRODUCTION

The year 1998, which marked the beginning of reforms at JINR, has ended. Summing up the experiences of the year, we can say that the Institute continues working despite the August crisis in Russia.

A variety of non-standard measures had to be undertaken for survival of JINR. The JINR Directorate, Scientific Council, leading experts of the world's largest scientific centres appealed to the President and Prime Minister of Russia seeking their support. The Directorate members had meetings with high-ranking governmental and political officials of the Russian Federation and other JINR Member States, with the leaders of EC Directorate-General XII and the Executive Secretariat of CIS.

In 1998, the JINR scientists demonstrated again that despite all difficulties they are carrying out investigations that are important and competitive at the world level.

Among the most remarkable and significant scientific results of the past year is synthesis of a new long-lived superheavy element with number 114. This important discovery, made at the Flerov Laboratory of Nuclear Reactions by a team headed by Prof. Yu.Ts.Oganessian in collaboration with the Lawrence Livermore National Laboratory (USA), crowns the 35-year work of scientists from JINR, USA, Germany on the search for the «stability island» of superheavy nuclei. Now FLNR and other research centres continue experiments to confirm the result.

The «stability island» of superheavy nuclei could have been discovered owing to the unique parameters of the set-up that detects extremely rare events of formation and decay of nuclei and the record intensities of accelerated ion beams from the cyclotron U-400.

At the Rochester Conference in Vancouver (Canada, July 1998) they reported a scientific result to which Dubna theorists had made a direct contribution. It concerns the mass of a Higgs boson, the only Standard-Model particle that has not been experimentally observed so far. One of the programmes, ZFITTER, which accumulates all theoretical data on this model, was being developed during 15 years by an international team headed by D.Yu.Bardin. The Higgs boson mass is predicted to be below 262 GeV (95% C.L.).

The set-up DIRAC has been put into operation at the Proton Synchrotron (PS) beam line at CERN, and the first experimental run was carried out in October–November. This experiment on precision measurement of the lifetime of the $\pi - \pi^+$ atom for model-independent check of QCD was proposed by Prof. L.L.Nemenov, who was elected spokesperson of the experiment by the Collaboration.

A group of JINR scientists headed by Prof. A.A.Tyapkin proposed a new experiment to study properties of the near-threshold Cherenkov radiation. In October scientists from Comenius University (Bratislava), CERN, and JINR observed Cherenkov radiation in a biaxial triglycine sulphate crystal exposed to the beam of lead nuclei from the SPS (CERN). The first results indicate an increasing intensity of the Cherenkov light near the threshold, which is the main goal of the study.

The XVIIth International Conference on High Energy Accelerators (HEACC'98) has become an important event in the scientific life of Dubna. Summing up its results, Chairman of the International Committee for Future Accelerators (ICFA) B.Wiik said: «We in ICFA are grateful to JINR which showed willingness to hold the Conference. I heard only good opinions from all participants in HEACC'98. The Conference programme was nice and the atmosphere of friendship was fantastic.»

A year ago, at the 83rd session of the Scientific Council, the JINR Directorate presented a plan of reforming the Institute. Backed by the Scientific Council and the Committee of Plenipotentiaries of the Member States, we made practical steps in its implementation. This is the first stage of the reforms, which includes strict economy of budgetary expenditure, all-Institute status for all basic facilities, and reduction of JINR staff.

The pivot of this stage was centralized management of the facilities (Nuclotron, accelerators U-400–U-400M, reactor IBR-2), including the IREN construction project. Despite the extremely difficult financial situation, the JINR Directorate agreed to increase the duration of exper-

imental runs at the facilities understanding that operating facilities make the Institute attractive both for the Member States and for other countries interested in nuclear-physics investigations.

Particular emphasis is placed on development of telecommunication links and of computing and networking infrastructure at the Institute. A High-Performance Supercomputer Centre has been established for providing a full-scale network and informatics support of the research under way at JINR and for increasing efficiency of its scientific collaboration.

Starting the reforms, the JINR Directorate tries to keep all the essentials developed through the history of the Institute: facilities, scientific structure, and rich scientific traditions. The reforms of JINR aimed at making its activity more rational and efficient are extremely important for preserving and developing the Institute.

V.G.Kadyshevsky
Director
Joint Institute for Nuclear Research

GOVERNING AND ADVISORY BODIES OF JINR

ACTIVITIES OF JINR GOVERNING AND ADVISORY BODIES

MEETING OF THE JINR COMMITTEE OF PLENIPOTENTIARIES

A regular meeting of the Committee of Plenipotentiaries (CP) of the governments of the JINR Member States was held in Dubna on 12–13 March 1998. It was chaired by Professor S.Dubnička (Slovak Republic).

Based on the report on JINR's activity in 1997 and the Directorate's proposals of reforms for JINR, presented by JINR Director V.G.Kadyshevsky, the Committee of Plenipotentiaries decided:

1. To approve the Institute's activities on implementing the JINR programme of research and international cooperation in 1997 as well as the concept and plan of reforming JINR in the years 1998–2000, presented by the Directorate.

2. To approve the recommendations of the 82nd and 83rd sessions of the JINR Scientific Council and the Topical Plan of Research and International Cooperation for 1998.

3. To approve the «Scientific Programme of JINR for the years 1998–2000».

4. Taking into account the recommendations of the 83rd session of the Scientific Council, to commission the JINR Directorate to give first-priority financing in 1998 to:

– construction of the Nuclotron beam extraction system and of external beam lines; continuation of the Nuclotron exploitation; experimental studies of spin degrees and colour degrees of freedom in nuclear matter at the Nuclotron, at CERN and BNL;
– realization of the work for the IREN project, with a realistic schedule, approved by the JINR Directorate, and an agreed financial envelope, with a view to its completion as rapidly as possible;
– upgrade of the IBR-2 reactor, with a view to securing the long-term future of this facility; completion of the cryogenic moderator; development of instrumentation and data acquisition equipment for spectrometers at the reactor; continuation of the spectrometers' exploitation;
– synthesis of heavy nuclei near the region $Z = 114$, study of the fusion-fission reaction for weakly excited superheavy nuclei, study of the structure of light exotic nuclei and neutron correlations in them, and research with beams of stable and radioactive ions using the FOBOS and MULTI detectors and the High Resolution Beam Line;
– continued participation in frontier particle physics experiments, amongst others at accelerators of IHEP (Protvino), CERN, DESY, BNL and FNAL; accelerator system R&D for U-600 (IHEP), LHC (CERN) and linear colliders (TESLA);
– theoretical studies in particle physics, nuclear physics, and condensed matter physics, also with a view to supporting experimental work in these fields;
– development of JINR's and JINR member-state institutes' computing and networking infrastructure, and of communication links.

Based on the report presented by JINR Administrative Director A.I.Lebedev the CP decided:

1. To take note of the information on the implementation of the JINR budget in 1997.

2. To approve the JINR budget for 1998 with a total sum of expenditure amounting to US$37,5 million and the scale of the Member State's contributions to the 1998 budget proportional to the UN scale.

3. To fix the 1999 budget estimate amounting to US$37.5 million.

The CP requested the Directorate to submit to the Plenipotentiaries of all Member States by 1 September 1998 a draft of a new budget structure of JINR with account of the objectives of the first stage of reforms to be accomplished at the Institute, in particular transition to centralized management of the basic facilities.

4. To approve the Protocol of the Finance Committee meeting held on 12–13 February 1998.

The CP asked the Plenipotentiary of Russia to inspect the financial and management activity of JINR in 1997. For examining the inspection results, it was decided to set up a control commission consisting of representatives of Armenia, the Czech Republic, Poland, and Russia. The CP requested the Directorate to consider the issue of pension provision for the Member-State personnel of JINR. It also asked the Directorate to address the corresponding governmental agencies of the Russian Federation with a request to confirm the validity of Resolution of the USSR Council of Ministers No. 1523-764 of 22 November 1956, according to which the sums of taxes raised from the JINR staff members — citizens of the JINR Member States — should be considered as part of the Member States' contributions for the maintenance of the Institute.

The CP took note of the information presented at the meeting by A.Hrynkiewicz (Poland), Chairman of the CP Standing Commission for improvement of the scientific and financial policy of JINR and its structure. The CP approved the recommendations of the Commission and asked it to assist the Directorate in their implementation.

In view of the extremely difficult financial situation being faced by the Institute due to incomplete budgetary inflows in 1997, the CP considered it necessary to limit the rights of those Member States whose debts exceed the sum of contributions for two years. Specifically, the following sanctions may be applied: such Member States shall not have the right to vote at meetings of the Finance Committee and at meetings of the CP when financial issues are considered; the scientific missions (with full or partial covering of travel expenses by JINR) by JINR staff members from such Member States shall be authorized by the JINR Director only by way of exception subject to his subsequent informing the CP Chairman (at least once every four months) about the justification of these missions; the number of JINR staff members from such Member States shall not exceed the level recorded at the moment of application of the sanctions.

Upon proposal by the JINR Directorate, followed by voting, the CP approved a new list of members of the JINR Scientific Council, composed of 44 persons, for a term of five years. Taking into account that some re-elected members expressed their wish to stay on the Council for two years, the CP asked the Directorate to submit a corresponding proposal for rotation of the Council members.

Following a personal application received from N.A.Golovkov, the CP relieved him of the post of the JINR Chief Engineer. Upon proposal by the Directorate, followed by ballot, the CP appointed Professor I.N.Meshkov, Corresponding Member of the Russian Academy of Sciences, as JINR Chief Engineer until the completion of the term of office of the JINR Director (1 January 2003).

The CP followed with interest the scientific report «Hot nuclei and phase transitions in nuclear matter» made at the meeting by Professor V.A.Karnaukhov and thanked the speaker.

SESSIONS OF THE JINR SCIENTIFIC COUNCIL

The 83rd session of the JINR Scientific Council, chaired by JINR Director V.G.Kadyshevsky, took place in Dubna on 15–16 January 1998.

At the session, Professor V.G.Kadyshevsky presented a report on the results of the Scientific Council's activity over the last five years and a report «JINR on the threshold of the 21st century: the Directorate's proposals of reforms for JINR».

Information from the CP Standing Commission for improvement of the scientific and financial policy of JINR and its structure was presented by the Commission's Chairman A.Hrynkiewicz.

Implementation of the Council recommendations for the priority fields of research in 1997 was reported by JINR Vice-Director A.N.Sissakian and Chief Scientific Secretary V.M.Zhabitsky. They also gave comments to the proposed Scientific Programme of JINR for the years 1998–2000.

At this session, the Council continued consideration of JINR's longer-range plans of research, which had been started at the 81st session. Three reports were offered: «Search for antimatter in cosmic rays using a satellite-based track calorimeter» (by L.G.Tkatchev), «Ionization Neutron CAlorimeter on a satellite to study cosmic rays (project INCA)» (by G.B.Zhdanov and G.T.Zatsepin), and «JINR facilities and radiation and space biology» (by V.M.Petrov).

Recommendations of the JINR Programme Advisory Committees were presented by their Chairpersons Prof. G.Pepy (PAC for Condensed Matter Physics), Prof. G.J.Deutsch (PAC for Nuclear Physics), and Prof. P.Spillantini (PAC for Particle Physics). The Council also appointed the members of the Programme Advisory Committees for a new term.

The following scientific reports were included in the agenda: «Asymptotics in relativistic nuclear physics» by A.I.Malakhov and «Experimental observation of the «dineutron» configuration in the exotic halo nucleus ^{6}He » by G.M.Ter-Akopian.

The Council approved the Jury's recommendations on the JINR Prizes for 1997.

The awarding of two prizes took place at the session. The B.Pontecorvo Prize went to Prof. K.Winter (Germany) for his experimental research in the field of neutrino physics using accelerators. The Ya.Smorodinsky Prize went to the editors of the weekly «Dubna» for their achievements in popularization of science and international cooperation.

The Council adopted the following Resolution, which states, in particlular:

«Established by the Committee of Plenipotentiaries in 1993 with the aim

– to evaluate the results of the scientific activities of the Institute,
– to draw conclusions on the plans of the scientific research of the Institute submitted by its Director and on the reports on their implementation,
– to work out recommendations on the improvement of the scientific activities,

the Scientific Council, basing on its five-year experience of work, considers that its area of activity has been properly defined.

Perhaps two recommendations for the future operation of the Scientific Council should be made here. First, closer ties to the work of the Committee of Plenipotentiaries may be appropriate, as all decisions made by JINR's superior governing body are of utmost importance for the scientific life of the Institute. Second, a «rolling membership» mode of the Scientific Council should be considered instead of exchanging all members at once, with a view to promoting greater continuity.

The Scientific Council takes note of the concept and plan of reforms for JINR in the area of the basic facilities and infrastructure presented by Director V.G.Kadyshevsky and strongly supports this important initiative taken by the Directorate.

The Scientific Council takes note of the information presented by the Plenipotentiary of the Republic of Poland A.Hrynkiewicz, Chairman of the CP Standing Commission for improvement of the scientific and financial policy of JINR and its structure.

In view of the unstable financing of JINR, the Scientific Council urges the Chairman of the JINR Committee of Plenipotentiaries and the Director of JINR to send a letter to the Prime Minister of the Russian Federation V.S.Chernomyrdin asking for his assistance to resolve the serious problem of the payment of the Russian Federation's debt to JINR for 1996–1997 and to ensure normal financing in 1998.

The Scientific Council acknowledges the continued active efforts made by the JINR Directorate to develop international cooperation. It takes note of the importance of the Cooperation Agreement between UNESCO and JINR, signed in September 1997, which opens wide possibilities for cooperation between the two international organizations in joint scientific and educational programmes.

The Scientific Council takes note, with satisfaction, of the progress in the implementation of the 1997–1999 Scientific Programme, based on a rolling three-year plan of activities and approves the general lines of the «JINR Scientific Programme for the years 1998–2000».

Taking into account the proposals of the Directorate and the recommendations of the PACs, the Scientific Council endorses the following priority fields of activity in 1998:

– construction of the Nuclotron beam extraction system and of external beam lines; continuation of the Nuclotron exploitation; experimental studies of spin degrees of freedom at the Nuclotron, and studies of colour degrees of freedom in nuclear matter at the Nuclotron, at CERN and BNL;
– realization of the work for the IREN project, with a realistic schedule and an agreed financial envelope, with a view to its completion as rapidly as possible;
– upgrade of the IBR-2 reactor, with a view to securing the long-term future of this facility; completion of the cryogenic moderator; development of instrumentation and data acquisition equipment for spectrometers at the reactor; continuation of the spectrometers' exploitation;,
– synthesis of heavy nuclei near the region $Z = 114$, study of the fusion-fission reaction for weakly excited superheavy nuclei, study of the structure of light exotic nuclei and neutron correlations in them, and research with beams of stable and radioactive ions using the FOBOS and MULTI detectors and the High Resolution Beam Line;
– continued participation in frontier particle physics experiments, amongst others at accelerators of IHEP (Protvino), CERN, DESY, BNL, and FNAL; accelerator system R&D for U-600 (IHEP), LHC (CERN) and linear colliders (TESLA);
– theoretical studies in particle physics, nuclear physics, and condensed matter physics, also with a view to supporting experimental work in these fields;
– development of JINR's and JINR member-state institutes' computing and networking infrastructure, and of communication links.

The Scientific Council takes note of the interest expressed by external research groups in the radiobiological studies using the basic facilities of JINR and recommends that the activities in this field of research be pursued.

The Scientific Council concurs with the concerns and assessments of the PAC for Condensed Matter Physics, and endorses its recommendations, in particular its address to the CP Standing Commission to confirm that funding will be found for the IBR-2 reactor modernization plan.

The Scientific Council endorses the recommendations made by the PAC for Nuclear Physics and recommends that the JINR Directorate:

– consider all possibilities for a rapid accomplishment of the IREN project. As a first-priority measure, a guaran-

teed funding of this project in 1998 from the JINR Directorate grant and the FLNP budget should be provided for construction of vital systems of IREN;
– consider the problems caused by the outphasing of IBR-30;
– solve the problems raised by the difficulty to provide the required beam time (about 8000 hrs) to the users of the heavy ion accelerator complex.

The Scientific Council endorses the recommendations made by the PAC for Particle Physics on the approval of newly proposed experimental activities and on the closure of a number of other activities, as detailed in the minutes of their November 1997 meeting.

The Scientific Council supports the active efforts of the directorates of JINR and LCTA to establish a high-performance computing centre at the Laboratory for providing a full-scale network and informatics support of the research under way at JINR.

The Scientific Council supports the Directorate's proposal concerning regular rotation of the PAC members and suggests that the Regulations for the JINR PACs be reviewed at the next session of the Scientific Council.

In view of this the Scientific Council appoints upon proposal by the Directorate the members of the Programme Advisory Committees for a term of 1 year only and the Chairpersons of the PACs:
for half a year –

G.-J.Deutsch — PAC for Nuclear Physics,

P.Spillantini — PAC for Particle Physics,

for 1 year –

H.Lauter — PAC for Condensed Matter Physics.»

The Scientific Council elected by ballot A.T.Filippov as Director of the Bogoliubov Laboratory of Theoretical Physics (BLTP) for a term of 5 years and confirmed the vacancies of 2 Deputy Directors of BLTP.

The 84th session of the JINR Scientific Council, chaired by JINR Director V.G. Kadyshevsky, took place in Dubna on 4–5 June 1998.

At the session, Director V.G. Kadyshevsky informed the Council about the decisions taken by the JINR Committee of Plenipotentiaries at its March 1998 meeting and about the implementation of the plan of reforms for JINR.

The recommendations of the JINR Programme Advisory Committees were reported by their Chairpersons: H.Lauter (PAC for Condensed Matter Physics), P.Spillantini (PAC for Particle Physics), and G.J.Deutsch (PAC for Nuclear Physics).

A proposal for amendment of «The Regulation for the JINR PACs» concerning rotation of the PAC members was presented by JINR Chief Scientific Secretary V.M.Zhabitsky.

JINR Vice-Director A.N.Sissakian reported on the progress of the JINR Educational Programme and on the situation at the Institute with the staffing of young scientists.

In view of the intention of JINR and the Latin-American Centre for Physics (CLAF) to conclude a cooperation agreement, information about the activities of CLAF was given by its Director L.Masperi.

The Scientific Council continued consideration of JINR's longer-range plans of research. The following reports were presented at this session: «Possibilities for the use by JINR of the Synchrotron Radiation Source at the RRC «Kurchatov Institute» by S.M.Belyaev and «Prospects of condensed matter research with neutrons and synchrotron radiation» by V.L.Aksenov.

Other agenda reports invited by the Council included: «Status and future development of the JINR basic facilities» by JINR Chief Engineer I.N.Meshkov, «Review of the IREN project» by V.I.Furman, and «Radiobiological research with radionuclides at JINR» by E.A.Krasavin.

Following the successful work accomplished at JINR to establish a high-performance computer centre, three reports concerned this activity: «Supercomputer centres in Russia and JINR» by V.V.Boiko, «Hewlett Packard's strategy for equipping Russia with modern computer facilities. JINR's place in this strategy» by H.Lorentz, and «JINR High-Performance Computer Centre» by V.V.Korenkov. On the same day the Scientific Council members attended the inauguration of the Computer Centre at the Laboratory of Computing Techniques and Automation.

The session also included the awarding of diplomas to the 1997 JINR prizewinners.

The Scientific Council adopted the following Resolution, which states, in particular:

«The Scientific Council takes note of the information presented by the Director of JINR about the decisions taken by the JINR Committee of Plenipotentiaries (CP) at its March 1998 meeting:
– of the approval of the concept and plan of the first stage of reforms proposed by the JINR Directorate and endorsed by the Scientific Council at its previous session;
– of the approval of the «JINR Scientific Programme for the years 1998–2000» based on the recommendations of this Council and the PACs;
– of the appointment of the Scientific Council members for a new term of 5 years;
– of the appointment of I.N.Meshkov as Chief Engineer of JINR.

The Scientific Council appreciates the steps taken so far by the JINR Directorate within the reform programme in the areas of basic facilities and infrastructure.

The Scientific Council reiterates its strong support of this important initiative and looks forward to being informed at its next sessions about the progress of these reforms and about the Directorate's proposal in the field of scientific research in view of the deep reforms under way.

The Scientific Council also reiterates its earlier recommendations to the JINR Directorate about a comprehensive review of the present Laboratory structure to determine whether it adequately meets the needs and goals of the JINR scientific programme.

The Scientific Council stresses the primary importance of JINR as the place where common scientific work is to be done by scientists from the Member States in collaboration with scientists working permanently at JINR. It recommends that the JINR Directorate balance this very important point with interests asking for JINR's participation in research projects outside the Institute area.

The Scientific Council wishes again to express its concern that the high intellectual and technological potential of JINR is not matched by adequate financial resources in the real JINR budget. The Council therefore urges the JINR Member States to make available their nominal contributions in due time.

In view of the extremely difficult financial situation at JINR, the Scientific Council addresses a letter to the President of the Russian Federation B.Yeltsin.

The Scientific Council recommends that the JINR Directorate address similar letters to the governmental authorities of those Member States which have debts to JINR.

The Scientific Council supports the decision of the JINR Directorate, approved by the CP, concerning the centralized management of the JINR facilities: the Nuclotron, U-400–U-400M cyclotrons, IBR-2 reactor, and the IREN construction project.

The Scientific Council welcomes the decision taken by the JINR Directorate to allocate in 1998 a special-purpose grant for construction of IREN's vital systems. It recommends that further efforts be made by the Directorate to find the funds needed for rapid completion of this major project.

The Scientific Council reiterates its standing recommendations about the priority development of the JINR basic facilities, namely:

– construction of the Nuclotron slow beam extraction system;
– modernization of the IBR-2 reactor, with a view to securing the long-term future of this facility;
– upgrading of the cyclotron complex at the Flerov Laboratory of Nuclear Reactions in line with forthcoming PAC-recommendations.

The Scientific Council takes note of the information about the activities of the Latin-American Centre for Physics (Centro Latinoamericano de Fisica, CLAF) presented by Professor L.Masperi, Director of CLAF, and endorses the intention of the JINR Directorate to conclude an agreement with this international intergovernmental organization. The Scientific Council cautions, however, that concrete further steps should be commensurate with JINR's budget provisions.

The Scientific Council takes note of the impressive progress in the field of education achieved at the University Centre since its establishment in 1991, in particular, the increasing number of the subjects offered for training graduate and post-graduate students.

The Scientific Council recommends that this activity, aimed at a higher inflow of young scientists to JINR, be continued as a vital strategic objective of JINR.

The Scientific Council invites the Directorate to include highlight scientific reports by JINR young researchers in the agenda of its future sessions.

The Scientific Council takes note of and concurs, after due discussion, with the recommendations made by the PACs at their April 1998 meetings and presented by their Chairpersons.

The Scientific Council agrees with the Directorate's proposal that the PACs review during the remainder of the year the priority assignment of the experimental programme in the light of the forthcoming reforms.

Based on the proposal of the JINR Directorate, the Scientific Council approves the revised text of the «Regulation for the JINR Programme Advisory Committees» which envisages regular rotation of the PAC members with a view to ensuring both change and continuity in the membership of the PACs.

The Scientific Council congratulates the directorates of JINR and LCTA on the successful work accomplished since its previous session to establish a high-performance computer centre for providing a full-scale network and informatics support of the research under way at the Institute and for promoting a more efficient cooperation with member-state and non-member-state institutions.

The Scientific Council takes note of the report presented on the radiobiological studies with radionuclides and their use in clinical medicine, purposed for diagnostics and treatment of various diseases, including cancer.»

The Scientific Council elected by ballot N.A.Russakovich as Director of the Laboratory of Nuclear Problems for a term of 5 years.

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

H.Lauter — PAC for Condensed Matter Physics,

P.Spillantini — PAC for Particle Physics,

and appointed C.Briançon as Chairperson of the PAC for Nuclear Physics for a term of one year.

MEETING OF THE FINANCE COMMITTEE

A regular meeting of the JINR Finance Committee was held in Dubna on 12–13 February 1998. It was chaired by A.I.Volodin (Russia).

The Finance Committee heard a report presented by JINR Director V.G.Kadyshevsky «JINR on the threshold of the 21st century: the Directorate's proposals of reforms for JINR». The Committee approved the JINR Directorate's activity on implementation of the scientific programme in 1997. It recommended that the JINR Committee of Plenipotentiaries approve the concept of reforms to be accomplished at JINR in the years 1998–2000.

Based on the information given by V.G.Drozhenko, the Finance Committee approved the work of the Control Commission, which met on 16–17 July 1997, and recommended that the Committee of Plenipotentiaries (CP) approve the report on the implementation of the JINR budget in 1996.

The Finance Committee asked the Plenipotentiary of Russia to inspect the financial and management activity of JINR in 1997. For examining the inspection results, it is recommended to set up a control commission consisting of representatives of Armenia, the Czech Republic, Poland, and Russia.

Note was taken of the report presented by the JINR Directorate on implementing the Finance Committee's decisions of 20–21 February 1997 and the Control Commission's recommendations of 16–17 July 1997.

A report on the implementation of the JINR budget in 1997, on the draft budget for 1998, and on the budget estimates for 1999 was presented by JINR Administrative Director A.I.Lebedev. The Finance Committee recommended that the CP take note of the information on the implementation of the JINR budget in 1997, approve the budget for 1998 with a total sum of expenditure amounting to US$37.5 million, and ask the JINR Directorate to introduce corrections in the budget with regard to the recommendations of the 83rd session of the Scientific Council and the current meeting of the Finance Committee. It is also recommended to allow the JINR Directorate in 1998 to correct budget distribution over items of expenses, including salaries, in accordance with variation in the level of remuneration of labour, prices, and tariffs in the JINR host country.

The Finance Committee recommended that the CP request the Directorate to submit to the Plenipotentiaries of all Member States by 1 September 1998 a draft of a new budget structure of JINR with account of the objectives of the first stage of reforms to be accomplished at the Institute, in particular transition to centralized management of the basic facilities.

The Finance Committee recommended that the Committee of Plenipotentiaries approve the main part of the Member States' contributions for 1998 to be proportional to the UN scale, and fix the 1999 budget estimate amounting to US$37.5 million, which may be corrected with account of inflation and US$/rouble exchange rate fluctuations.

Having considered the proposals of the CP Standing Commission for improvement of the scientific and financial policy of JINR and its structure, the Finance Committee recommended that the CP apply sanctions against those Member States whose debts exceed the sum of contributions for two years. Specifically, the following sanctions should be applied: such Member States shall not have the right to vote at meetings of the Finance Committee and at meetings of the CP when financial issues are considered; the scientific missions (with full or partial covering of travel expenses by JINR) by JINR staff members from such Member States shall be authorized by the JINR Director only by way of exception subject to his subsequent informing the CP Chairman (at least once every four months) about justification of these missions; the number of JINR staff members from such Member States shall not exceed the level recorded at the moment of application of the sanctions.

MEETINGS OF THE JINR PROGRAMME ADVISORY COMMITTEES

8th meeting of the PAC for Condensed Matter Physics, 6–7 April 1998. Chairperson: Dr H.Lauter.

The PAC for Condensed Matter Physics was informed by its Chairperson about implementation of the recommendations made at the PAC's previous meeting and by the JINR Chief Scientific Secretary about the recommendations of the 83rd session of the JINR Scientific Council (January 1998) and the decisions of the JINR Committee of Plenipotentiaries (March 1998 meeting).

In its recommendations to the JINR Directorate, the PAC noted the great importance of the IBR-2 reactor for the present and future research at JINR in condensed matter physics, which is confirmed by all JINR governing bodies, on the one hand, but expressed its concern about the inadequate funding of the maintenance and development of the IBR-2, on the other hand. The PAC reiterated its standing recommendation about the highest priority to be given to the IBR-2 reactor refurbishment.

The PAC also reiterated a number of its previous recommendations for the years 1998–1999 concerning the IBR-2 instruments. These included the feasibility study to be made for the refurbishment of the YuMO spectrometer, upgrades of neutron optics, modernization of the SPN-1 and REFLEX-N spectrometers, implementation of the cold source and a detailed study of the instrumentation around it.

The PAC took note of the work carried out at LPP on the construction of the EXAFS-spectrosopy station to be installed on the synchrotron radiation beam line of the RRC «Kurchatov Institute».

The PAC took note of the high quality of the research «Radiation processes and modification of materials, radioanalytical and radioisotope investigations» carried out at the FLNR accelerators and recommended extension of this activity.

The PAC confirmed its support for a new project in radiobiological research and its use in nuclear medicine.

The PAC was impressed by the scientific reports in the field of solid state physics made at the meeting by Prof. N.Plakida and Dr V.Priezzhev (BLTP).

9th meeting of the Programme Advisory Committee for Particle Physics, 16–17 April 1998. Chairperson: Prof. P.Spillantini.

The PAC was informed by its Chairperson about implementation of the recommendations made at the previous PAC's meeting, by its coordinator, Vice-Director A.N.Sissakian, about the recommendations of the 83rd session of the JINR Scientific Council (January 1998), the decisions of the JINR Committee of Plenipotentiaries (March 1998 meeting), and further steps of the JINR Directorate towards reforming the Institute, as well as by JINR Chief Engineer I.N.Meshkov about the future development of the JINR basic facilities.

The PAC supported the concept and plan of reforms proposed by the Directorate in the areas of basic facilities, infrastructure, and staff policy, as well as the first positive steps made to realize this important initiative, and the main directions of the JINR programme of particle-physics research according to the approved projects with their corresponding priorities.

The PAC took note of the intention of the JINR Directorate to make a comprehensive review of the projects taking into account the real budget as a major input in planning the next stage of reforms at JINR in the field of scientific research.

The PAC supported the decision of the JINR Directorate concerning the centralized management of the JINR facilities: the Nuclotron, U-400–U-400M cyclotrons, IBR-2 reactor, and the IREN construction project.

The PAC considers it important that the construction of the Nuclotron slow beam extraction system be completed by the end of this year and that this activity be provided with adequate running time. The PAC invited the Directorate to present at the next meeting a comprehensive report on the development of the Nuclotron and the long-range plan for research at this unique facility.

The PAC took note of the status and positive results of the HERMES experiment. It recommended merging of this activity with the COMPASS experiment in a dedicated spin structure functions programme. The PAC recommended that the LPP Directorate submit a proposal at the next meeting for closing the activities concerning the experiments TNF and NA47.

The PAC supported opening of the activity «Fields and Particles» and recommended extension of the project «Study of K decays with the HYPERON spectrometer.»

The PAC members agreed with the proposal of the JINR Directorate that Professor P.Spillantini be re-appointed as Chairperson of this PAC for a term of one year.

8th meeting of the PAC for Nuclear Physics, 20–22 April 1998. Chairperson: Prof. G.-J.Deutsch.

The PAC for Nuclear Physics heard a report about implementation of the recommendations of its 7th meeting and was informed about the resolution of the 83rd session of the JINR Scientific Council and the decisions of the JINR Committee of Plenipotentiaries (March 1998 meeting).

The PAC fully endorsed the proposal of reforms for JINR presented by JINR Director V.G.Kadyshevsky to the Scientific Council, the 1st stage of which is to guarantee intensive operation and the development of the JINR basic facilities.

The PAC was informed about a recommendation of the JINR Scientific-Technical Council to allocate 500 kUSD to the IREN project in 1998 for this goal. (The sum includes 200 kUSD from FLNP and 300 kUSD as a Directorate grant).

JINR Vice-Director Ts.Vylov briefed the PAC members about the activities under way at the Institute, and asked the PAC to proceed at its next session to the re-appraisal of the relative priorities of the projects within the first-priority research themes and to estimate the status and outlook of the Phasotron.

Nuclear physics with neutrons. Considering the financial needs of the project IREN, the PAC wished to see these funds from the FLNP budget and the Directorate grant effectively attributed in 1998 for the construction of IREN's vital systems. This would allow a hope for this project to be achieved by 2001.

In order to ensure the continuity of the high-quality activities in nuclear physics with neutrons, the PAC would consider it useful to continue some limited research programme at IBR-30.

Heavy ion physics. The PAC members were informed about the structural changes in the scientific and technical departments of FLNR. Concerning the scientific programme of FLNR, the PAC acknowledged the high quality and importance of the results obtained in the re-

search within the projects of the theme «Synthesis of new nuclei and study of nuclear properties and heavy-ion reaction mechanisms», recommending the extension of the activity on this theme for two years.

The PAC appreciated the interesting physical results obtained with the FOBOS detector system and stressed the importance of good communication among theorists and experimental groups from JINR and other research centres in order to provide for an optimal exploitation of this detector system.

The PAC was pleased to note that a total running time of 6,000 hrs, recommended at its 7th meeting, was foreseen in 1998 for the U-400 and U-400M accelerators and expressed its hope that this would continue in the following years.

The PAC was impressed by the high-intensity and low material consumption achieved in producing ^{48}Ca beams, placing this result among the best in the world.

The PAC supported the idea of further developing radioactive beams and invited a detailed technical proposal as well as the physics programme for the cyclotron-tandem U-400 + U-400M and storing-cooler projects to be presented at the meeting, taking into account the competitiveness and the cost.

The PAC was impressed by rich information obtained in the study of the ^{252}CF spontaneous-fission decay using the GAMMASPHERE array.

Low- and intermediate-energy physics. The PAC heard a report on the progress of the LESI project, and looks forward to the results expected at more powerful accelerators.

The PAC was pleased to emphasize the progress in the AnCor experiments at PSI and Orsay and strongly supported the beta-neutrino correlation measurements in super allowed ($0^+ \rightarrow 0^+$) beta decays.

The PAC took note of the respectable progress in the preparation of experiments to be performed with the ANKE spectrometer at COSY. The PAC members heard with interest about the letter of intent to measure the polarization transfer with the TOF facility at COSY.

Nuclear theory. The PAC supported the intention of BLTP to open a new theme on nuclear theory starting from 1999 for 5 years and expected to hear a detailed report on this important topic at the next meeting.

The PAC listened to a scientific report on metallic clusters and quantum dots and highly appreciated the results obtained.

9th meeting of the PAC for Condensed Matter Physics, 13–14 November 1998. Chairperson: Dr H.Lauter.

The PAC was presented with reports on implementation of the recommendations made at the PAC's previous meeting and with information about the recommendations of the 84th session of the JINR Scientific Council (June 1998).

The PAC appreciated the efforts of the JINR and FLNP Directorates which allowed the fulfilment of the IBR-2 current maintenance programme. At the same time, the PAC expressed its very serious concern that the IBR-2 modernization plan for 1998 failed.

The PAC confirmed its principal position concerning the refurbishment of the IBR-2 reactor as a leading basic facility which can ensure the condensed matter physics research at JINR at a high level.

The PAC took note of and approved the report about the recommendations of the 84th session of the JINR Scientific Council presented by Chief Scientific Secretary V.M.Zhabitsky. The PAC supports the JINR Directorate's efforts to reduce a number of minor-importance research projects in order to achieve a more rational distribution of resources.

The PAC took note of the report «Operation and development of the JINR basic facilities in 1998» presented by Chief Engineer I.N.Meshkov. The PAC agreed with the proposed reduction in the number of reactor cycles from 10 to 8 a year and its power reduction from 2 to 1.5 MW to ensure the longer life of the reactor.

Concerning the information presented by I.N.Meshkov on preparation of JINR's project of an Electron Accelerator Complex based on NIKHEF's AmPS, the PAC noted that the long-term possibility of the creation of a synchrotron radiation source at JINR was of course welcomed by this Committee. However the PAC could not comment further on this idea until it was satisfied with a detailed examination of the technical, financial, operational and manpower content of such a proposal.

The PAC highly appreciated the scientific reports considered at the meeting:

– «Photoelectron spectroscopy investigations of condensed matter with SR-beams» presented by M.N.Mikheeva. These activities in the collaboration between JINR and the Kurchatov Institute are supported by the PAC.
– «Current state and plans for the IBR-2 performance» presented by V.D.Ananiev. Thanks to his careful study, he could find a solution in the reactor operation for a prolonged period of time.
– «New intelligent porous structure» presented by P.Yu.Appel. The PAC recommended that the FLNR support this activity.

The PAC supports the widening of scientific contacts with non-member-state institutions and took note of the interesting report by Prof. A.Sternberg about the investigations in the field of condensed matter physics in the Latvian University (Riga).

The PAC supported the opening of a new research activity «Neutron investigations of structure and dynamics of condensed matter» reported by FLNP Director V.L.Aksenov, the revised proposal for activity «Modernization of the IBR-2 spectrometer complex and information-computation infrastructure», and the opening of a

new project «Fourier spectrometer for applied investigations».

The PAC appreciated the efforts of FLNP aimed at increasing the professional skills of young scientists from the Member States of JINR in the field of condensed matter physics research.

10th meeting of the PAC for Particle Physics, 18–19 November 1998. Chairperson: Prof. P. Spillantini.

The PAC for Particle Physics heard a report presented by the Chairperson P.Spillantini about implementation of the recommendations of its 9th meeting and was informed by JINR Vice-Director A.N.Sissakian about the resolution of the 84th session of the JINR Scientific Council, also about the current preparation of the JINR Scientific Programme for the years 1999–2001 in the light of the reforms under way at the Institute.

The PAC appreciated the efforts of the JINR Directorate and the JINR Internal Board for Review of Research Activities in developing a plan for optimization of the JINR scientific programme in particle and relativistic nuclear physics. The PAC acknowledged the strenuous efforts undertaken by the JINR Directorate and the staff to implement the scientific programme of JINR under extremely difficult financial conditions.

The PAC took note of the reports presented by the directors of LHE, LPP and LNP and their proposals towards developing a balanced programme of forefront scientific research in particle physics for the years 1999–2001.

The PAC appreciated the efforts made by the JINR Directorate in the current difficult situation to ensure the operation of the JINR basic facilities as a high-priority task.

The Committee took note of the feasibility study presented by Chief Engineer I.N.Meshkov on the possible establishment of an Electron Accelerator Complex at JINR, and of the new lines of research that such a facility would potentially open up.

The PAC endorsed the analysis done by the JINR Internal Board for Review of Research Activities in Particle Physics and Relativistic Nuclear Physics (JINR Internal Board), established by the JINR Directorate to re-examine all the projects in these fields. The Committee considers that the list of the projects proposed for execution by the JINR Internal Board is sufficiently sound and can be accomplished within the nominal budget of the Institute. In accordance with the conclusions of the JINR Internal Board, the PAC recommended that the JINR Directorate close 18 activities and projects with a view to further streamlining the scientific programmes of LHE, LPP, and LNP in particle and nuclear physics and achieving an optimal distribution of financial and human resources.

The PAC gave its recommendations concerning the first-priority activities and projects in the JINR Programme of Particle Physics and Relativistic Nuclear Physics for the years 1999–2001.

The Committee acknowledged the high-quality research done by Dubna theorists and recommended to open the theme «Fields and Particles» for a period of five years. The PAC recommended that decisions on ALICE, NA49, and TCAL projects be made at the next meeting of the PAC. The same recommendation was made on the accelerator themes «R&D of elements for future colliders» and «Accelerator physics and engineering», inviting the authors to present at the next meeting a revised proposals for these activities.

9th meeting of the PAC for Nuclear Physics, 23–25 November 1998. Chairperson: Prof. Ch. Briançon.

The PAC was informed about the recommendations of the previous PAC meeting and their implementation, also about the Resolution of the 84th session of the JINR Scientific Council (June 1998). The PAC took note of the current preparation of the JINR Scientific Programme in light of the reforms undertaken at JINR since the beginning of 1998. The PAC appreciated the efforts undertaken by the JINR Directorate towards finding optimum solutions of this task. The PAC learned with satisfaction that the Scientific Council had endorsed its recommendations and highly appreciated that the necessary beam time of 6000 hours forseen in 1998 for heavy-ion physics had been provided.

At its meeting the PAC considered written reports on first-priority themes approved till 1998, heard a report about the operation of the JINR basic facilities in 1998 and the status of their development. The PAC discussed the JINR scientific programme in nuclear physics for the years 1999–2001 and proposals for extension of the activities and opening of new themes. The PAC also heard with interest three scientific reports presented.

The PAC made the following recommendations to the JINR Directorate concerning the fields of research and the facilities.

Heavy-ion physics. The PAC recommended the extension of the activity on the theme «Synthesis of New Nuclei and Study of Nuclear Properties and Heavy-Ion Reactions» for two years with allocation of 6000 hours of running time of U-400 and U-400M per year. The PAC was impressed by the unique efficiency in producing high-intensity ^{48}Ca beams which opened exciting perspectives for the Super Heavy Element programme. The VASSILISSA separator has already given interesting preliminary results on the synthesis of elements 110 and 112. This work should clearly continue with the highest priority. The PAC appreciated the successful completion of the ACCULINA and COMBAS fragment separators.The separator ACCULINA used with the beams of ^{6}He and ^{8}He allowed one to perform first experiments on correlated two- and four-neutron transfers, thus providing inter-

GOVERNING AND ADVISORY BODIES OF THE JOINT INSTITUTE FOR NUCLEAR RESEARCH

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Azerbaijan	N.A.Guliev	Mongolia	Ts.Ganzog
Belarus	V.A.Gaisenok	Poland	A.Hrynkiewicz
Bulgaria	G.Kaschiev	Romania	I.Vâță
Cuba	D.Codorniu	Russia	V.E.Fortov, V.B.Bulgak
Czech Republic	R.Mach	Slovak Republic	S.Dubnička
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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F.Dydak	Switzerland	Yu.A.Osipian	Russia	G.Trilling	USA
J.Ganzorig	Mongolia	V.V.Papoyan	Armenia	I.N.Vishnevsky	Ukraine
A.Hrynkiewicz	Poland	M.Petrovici	Romania	I.Wilhelm	Czech Republic
J.Janik	Poland	B.Peyaud	France	B.S.Yuldashev	Uzbekistan
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F.Lehar	France				

Programme Advisory Committee for Particle Physics

Chairperson: P.Spillantini (Italy)
Scientific Secretary: R.Ya.Zulkarneev

Programme Advisory Committee for Nuclear Physics

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

Programme Advisory Committee for Condensed Matter Physics

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

INTERNAL ORGANIZATION OF THE JOINT INSTITUTE FOR NUCLEAR RESEARCH

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Vice-Director A.N.Sissakian

Vice-Director Ts.Vylov

Administrative Director A.I.Lebedev

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

Laboratory of Nuclear Problems

Director N.A.Russakovich

Research in

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

Flerov Laboratory of Nuclear Reactions

Director M.G.Itkis

Research in

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

Frank Laboratory of Neutron Physics

Director V.L.Aksenov

Research in

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

Laboratory of Computing Techniques and Automation

Director R.Pose

Research in

- development of information and computation infrastructure of JINR
- development of interfaces with international computer networks and information systems
- nonlinear problems of computing and mathematical physics for development of methods, algorithms and software
- automation of experimental facilities
- film data processing

Laboratory of Particle Physics

Director V.D.Kekelidze

Research in

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

Division of Radiation and Radiobiological Research

Leader E.A.Krasavin

Research in

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

University Centre

Director S.P.Ivanova

Central services

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

esting results on neutron correlation in halo nuclei. The PAC considered this programme of top level and supported its continuation with high priority.

The PAC recognized the effort made to attract young physicists around the FOBOS spectrometer and looks forward to seeing, before the end of 1999, first experimental results and a more detailed scientific programme planned with the use of this device.

The Committee supported an idea of developing the basis for the radioactive ion beams and highly appreciated, in particular, the perspectives to produce neutron-rich exotic beams from photo-fission fragments using the existing Microtron accelerator. The PAC recommended to support performing additional investigations and the necessary tests. The PAC invited a detailed proposal to be presented in 1999 according to the standard procedure. The PAC also recognized the urgency of further modification of the VASSILISSA separator to enable transmission of ion beams heavier than ^{48}Ca.

Nuclear physics with neutrons. In view of its earlier recommendations, endorsed and amplified by the Scientific Council at its 84th session, the PAC insists again on the imperative necessity to provide, in the nearest future, the funds required to avoid a cancellation of the IREN project . The cancellation of the project, in which about 1 MUSD has been already invested, would be highly detrimental to the credibility of JINR. The Directorate should provide the community with a clear time-table of financing the achievement of the project. In parallel, FLNP is invited to actualize the scientific programme of IREN for the next meeting of the PAC.

The PAC appreciated the interesting physical results obtained with limited beam time at the IBR-30 facility, in particular, in fundamental symmetry violation, nuclear fission induced by resonance neutrons, and two-step gamma cascades. Considering the delay in the implementation of the IREN project, the PAC strongly recommended the running of IBR-30 with budgetary funds and the extension of the research programme at this facility into 1999.

Low- and intermediate-energy physics. Considering the world-level quality of the experiments in the field of nuclear and weak interaction physics at LNP, the PAC recommended that the highest priority be given to the experiments AnCor, ANKE, LESI, NEMO, PIBETA, TGV and looks forward to the final results of the experiments OBELIX and DISTO within two years. The PAC also recommended supporting, with high priority, the R&D work in detectors (DETECTOR Project) and electronics related to the accepted experiments. The outstanding contribution of many JINR groups is based on these activities.

As to the successful completion of the muonium-antimuonium conversion investigation in 1998, the PAC recommended discussing the final results of this work at its next meeting. The PAC underlined that the construction of the TRITON set-up had provided essential progress in the work with $dt\mu$-molecular mixtures and recommended realizing the next stage of the experiments at the Phasotron. The PAC recommended that necessary beam time be allocated to the Phasotron experiments DUBTO, CATALYSIS, DIBARYON to complete them under good conditions and to pursue limited activity of YASNAPP on the horizon of the year 2000.

Nuclear theory. The PAC appreciated the activity and high scientific quality of nuclear theory research performed by BLTP scientists in the wide cooperation with famous centres of nuclear physics of the world and with the experimental groups of other JINR Laboratories. It also recognized the important role of the Laboratory in the education programme for young scientists.

The PAC strongly supported the opening of the new theme «Theory of Nuclear and Other Finite Systems», which includes all modern directions in nuclear physics. The PAC expressed its deep concern about the lack of funding BLTP in 1998. There is an urgent need for renewal of old personal computers and also a need for adequate funds to ensure a daily functioning of the Laboratory.

JINR basic facilities. The PAC endorsed the continuation of the first-priority activities «Upgrading of the IBR-2 complex» and «Development of the cyclotron complex of the Flerov Laboratory of Nuclear Reactions for producing intense beams of accelerated ions of stable and radioactive isotopes».

As for the H^--project and the idea of Dubna Electron Accelerator Complex, the PAC needs more information to evaluate their interest in nuclear physics research and to identify a potential user community.

JINR networking. The PAC appreciated the progress made within the CONET project in creating a unified networking, information and computing environment for JINR, and recommended the extension of this project for three more years. The expected completion of the ATM Backbone and the connection to the RBNet and to other communication channels are important steps in order to provide the connection to the European network. The PAC considers that close contacts of LCTA with the other JINR Laboratories and regular work of the JINR Expert Group for Networks and Computing as well as a wide discussion of the further development in data handling and computing are necessary.

The PAC heard with interest a presentation about the observation of a new mechanism of ultra-cold neutron losses in traps and a report about the newest results concerning synthesis of heaviest isotopes of elements 110 and 112. The PAC members appreciated the high scientific value of these research efforts. The PAC also heard a report on the studies of the environment pollution by toxic heavy metals. The PAC recommended that this activity should be supported as JINR's contribution to the important issues faced by the industrial society.

PRIZES AND GRANTS

The 1998 V.G.Khlopin Prize of the Presidium of the Russian Academy of Sciences was awarded to Doctors of Chemical Sciences Yuri V.Norseev and Vladimir A.Khalkin (JINR) for a series of investigations «Discovery and study of the properties of new inorganic and organic astatine compounds.»

The 1998 B.Pontecorvo Prize was awarded to Professor V.M.Lobashev (Institute for Nuclear Research, Moscow) for his experimental research in the field of weak-interaction physics.

The P.L.Kapitsa Silver Medal «To Author of Scientific Discoveries» was awarded to A.N.Sissakian, Vice-Director of JINR, Vice-President of the University «Dubna» and member of the Russian Academy of Natural Sciences (RANS). Professor A.N.Sissakian was given this award by the decision of the RANS Presidium for his contribution to the development of elementary particle physics and to the establishment and formation of the University «Dubna».

PRIZEWINNERS OF JINR's ANNUAL COMPETITION FOR BEST RESEARCH — 1998

Theoretical physics research

First Prize

«Electron spectrum and superconductivity in models of high-temperature superconductors».
Authors: N.M.Plakida, V.S.Oudovenko, R.Hayn, V.Yu.Yushankhai.

Second Prize

«Relativistic and nuclear effects in processes of leptonic and hadronic scattering off the deuteron».
Authors: L.P.Kaptari, A.Yu.Umnikov, S.M.Dorkin, K.Yu.Kazakov.

Encouraging Prize

«Physics beyond the Standard Model in rare processes and cosmology».
Authors: V.A.Bednyakov, S.G.Kovalenko, A.Faessler, H.V.Klapdor-Kleingrothaus.

Experimental physics research

First Prizes

1. «Structure of ^{6}He: a bound dineutron in the field of the ^{4}He core».
Authors: A.S.Fomichev, V.A.Gorshkov, A.N.Lebedev, Yu.Ts.Oganessian, A.M.Rodin, S.I.Sidorchuk, S.V.Stepantsov, G.M.Ter-Akopian, R.Wolski, V.I.Zagrebaev.
2. «Thermal multifragmentation — a new decay mode of hot nuclei».
Authors: S.P.Avdeev, V.A.Karnaukhov, L.A.Petrov, V.K.Rodionov, V.Karcz, M.Janicki, H.Oeschler, O.V.Bochkarev, E.A.Kuzmin, L.V.Chulkov.

Second Prizes

1. «Chemical identification of element 106».
Authors: M.V.Vedeneev, I.Zvara, V.Ya.Lebedev, V.P.Perelygin, Xu Honggui, S.N.Timokhin, Yu.T.Chuburkov, A.B.Yakushev.
2. «Measurement of the spin-dependent structure functions of the neutron and proton».
Authors: A.G.Karev, V.G.Krivokhijine, V.V.Kukhtin, K.S.Medved, D.V.Peshekhonov, D.Pose, I.A.Savin, G.I.Smirnov.

Methodical and engineering research

First Prize

«Detectors on the basis of plastic scintillators».
Authors: Yu.K.Akimov, G.Bellettini, J.A.Budagov,

I.E.Chirikov-Zorin, V.E.Kovtun, O.E.Pukhov, V.P.Seminozhenko, V.G.Senchishin, S.Tokar, I.I.Zaljubovsky.

Second Prizes

1. «Production of intense beam of ^{48}Ca ions at the U-400 cyclotron».
Authors: V.B.Kutner, Yu.Ts.Oganessian, S.L.Bogomolov, A.A.Efremov, B.N.Gikal, G.G.Gulbekian, G.N.Ivanov, V.Ya.Lebedev, V.N.Loginov, S.V.Pashchenko.
2. «The 900-channel time-of-flight detector for investigations of high-energy nuclear interactions».
Authors: S.V.Afanasiev, A.M.Baldin, L.Ya.Zhiltsova, V.I.Kolesnikov, A.I.Malakhov, E.A.Matyushevsky, G.L.Melkumov, A.Yu.Semenov, Yu.I.Tyatyushkin.

Encouraging Prize

«High-efficiency narrow-band FEL-oscillator for linear electron-positron colliders».
Authors: A.A.Kaminsky, A.K.Kaminsky, E.A.Perelstein, S.B.Rubin, V.P.Sarantsev, S.N.Sedykh, A.P.Sergeev, V.L.Bratman, N.S.Ginzburg, N.Yu.Peskov.

Applied research

Second Prize

«Mechanical properties and microstructure of metals and alloys irradiated by heavy ions and neutrons».
Authors: M.A.Adawi, G.G.Bondarenko, A.Yu.Didyk, T.Kohanski, V.A.Kuzmin, V.A.Skuratov, K.Havancsak, A.Hofman, V.A.Shegolev, Yun Dyun Man.

Encouraging Prize

«JINR local area network».
Authors: B.A.Bezrukov, A.G.Dolbilov, A.T.Dorokhin, V.V.Korenkov, E.Yu.Mazepa, S.V.Medved, G.A.Sukhomlinov, V.Ya.Fariseev, V.P. Shirikov, B.G.Shchinov.

GRANTS

In 1998, a number of scientific projects by JINR staff members received grants of the Soros Foundation, INTAS Foundation, and of the International Centre for Science and Technology. 9 projects were financed by the Russian Ministry of Science and Technology, and 99 projects by the Russian Foundation for Basic Research. 35 staff members of JINR were awarded state grants by the Presidium of the Russian Academy of Sciences.

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 1998 is described by the following facts:

- Joint investigations on 37 first-priority and 17 second-priority research topics were carried out with scientific centres of the Member States, with international and national institutions of other countries.
- 2,285 JINR scientists and engineers went on various missions within collaborative projects and for participation in external scientific meetings and conferences.
- 664 scientists and engineers came to JINR for joint work and consultations.
- 631 scientists and engineers came to JINR to participate in workshops, conferences and schools.
- 18 international conferences, 15 workshops and 14 other scientific meetings were organized by JINR.
- 29 fellows worked at the Laboratories of JINR

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 21 January, in Moscow, Vice-Director A.N.Sissakian met with S.A.Zykov, First Deputy Executive Director of the International Science and Technology Centre, with whom he discussed issues of cooperation between the two international organizations. An outcome of the meeting was the signing of an Agreement, stipulating the ISTC's financial support of those research activities within the CMS Programme (LHC, CERN), which involve JINR and a number of Russian enterprises.

A meeting of the Joint Steering Committee for the implementation of the BMBF – JINR Agreement on Cooperation and Use of JINR Facilities, co-chaired by Dr. J.Arnold (the Federal Ministry for Education, Research and Technologies of Germany) and by Prof. A.N.Sissakian (JINR), was held in Dubna on 9–10 February. The following reports were presented at the meeting: on reforming JINR, by Director V.G.Kadyshevsky; on JINR's activities in 1997, plans for 1998 and the ongoing collaboration with German scientific centres, by Vice-Director A.N.Sissakian; on the implementation of the JINR budget and on the expenditure from the German contribution in 1997, by Administrative Director A.I.Lebedev.

Dr. J.Arnold and Prof. G.Schunk (BMBF) highly appreciated the fulfilment of the joint research programmes and gave their proposals for 1998. The German contribution for 1998 was defined to be DM 1.9 million. The meeting resulted in signing an official protocol. The Parties agreed to distribute the contribution for support of the collaborative programmes in theoretical physics, neutron physics, heavy-ion physics, high-energy physics (DESY, Hamburg), JINR's infrastructure, including the development of computer nets.

JINR Director V.G.Kadyshevsky and Vice-Director A.N.Sissakian met with the Head of the RF Government's Department for Science, Education and High Technologies M.P.Kirpichnikov at the Government House in Moscow on 18 February. A wide range of issues related to JINR's activity on the territory of the Russian Federation was on the meeting agenda. The JINR leaders presented information on the present situation at the Institute. Questions of JINR's financing by Russia and ratification of the Agreement between the RF Government and JINR by the State Duma were touched upon. Academician M.P.Kirpichnikov gave concrete recommendations on some of the problems raised and expressed his intention to further support JINR's activity as an intergovernmental scientific organization.

On 19–20 February Dubna was visited by a delegation of the Republic of Belarus, including the Chairman of the State Committee for Science and Technologies and New Plenipotentiary of Belarus to JINR V.A.Gaisenok. Meeting with the JINR Directorate, both parties expressed their common interests to further develop and strengthen the scientific links. JINR Vice-Director A.N.Sissakian emphasized the necessity to search for new, more efficient ways of collaboration along with deepening the traditional ones. Finance issues and prob-

lems of the forthcoming reformation of the Institute were under discussion at the meeting.

Prof. T.Necsoiu, Director-General of the Institute for Optical Electronics (Bucharest) visited JINR in April. He stayed at the Laboratory of Nuclear Problems, got acquainted with the JINR University Centre. Issues of extending the collaboration in the field of particle physics and in educational programmes were on the agenda of discussions with Prof. A.N.Sissakian on 8 April. The visit resulted in signing a Memorandum for Collaboration between the two centres.

Chairman of the Federation Council of the Federal Assembly of the Russian Federation Ye.S.Stroev had a meeting with the Directorate of the Joint Institute for Nuclear Research in Orel on 13 April. In their long talk with the leader of the upper chamber of the Assembly, JINR Director V.G.Kadyshevsky, Vice-Director A.N.Sissakian, and Administrative Director A.I.Lebedev spoke in detail about the situation at the Institute and its problems. The discussion embraced a wide range of issues related to the activities and status of the international intergovernmental scientific organization in the Russian Federation, including urgent financial, economic, and legal matters.

Ye.S.Stroev expressed his appreciation of the scientific achievements of the JINR scientists and showed understanding of the problems faced by the JINR staff and Dubna residents. The JINR Directorate invited Ye.S.Stroev to visit the Joint Institute for Nuclear Research. The invitation was accepted with gratitude.

On 21 April in Prague, JINR Vice-Director A.N.Sissakian was received at Charles University by R.Mach, Plenipotentiary of the Czech Republic to JINR, and I.Wilhelm, University Vice-Rector and a member of the JINR Scientific Council. They discussed in detail various aspects of collaboration between Czech scientific centres and the Joint Institute.

On 22–23 April A.N.Sissakian was on a visit to the Slovak Republic. There he had meetings with the Plenipotentiary of the Slovak Republic to JINR S.Dubnička, the President of the Slovak Academy of Sciences S.Luba, and a member of the Academy Presidium D.Krupa. A wide range of issues related to the collaboration in research and educational programmes was touched upon in the discussions.

Mr.Ts.Tserendashjin, Ambassador of Mongolia to the Russian Federation, and Mr.S.Urtnasangjin, Counsellor of the Embassy, stayed in Dubna on 22–23 May. Meeting with the JINR Directorate, the guests got acquainted with the Institute's ongoing research programme and with the development of its international collaboration, including links with scientific centres of Mongolia. They visited the Frank Laboratory of Neutron Physics, met with Mongolian employees of JINR, and made a tour of the town.

A delegation of the Republic of Poland headed by Prof. Z.Stachura, Director-General of the State Committee for Scientific Research, stayed at JINR through 2–3 June. The delegation included Z.Machula, Deputy Director of the State Committee, A.Ziaja, Director of «METRONEX», S.Kurek, Deputy Director of the Firm Bureau, and others. The guests visited JINR Laboratories, met with the Polish employees of the Institute. They were received by V.G.Kadyshevsky, A.N.Sissakian, and Ts.Vylov. A wide range of issues related to development of the collaboration between JINR and scientific centres of Poland was on the meeting's agenda.

On 13–21 June the Joint Institute was visited by Academician B.Sendov, Vice-President of the National Assembly of the Republic of Bulgaria. He took part in the International Conference «Modern Trends in Computational Physics», met with the JINR Directorate and visited JINR Laboratories.

On 23 June Plenipotentiary of the Russian Federation to JINR V.B.Bulgak had a meeting with JINR Director V.G.Kadyshevsky and JINR Vice-Director A.N.Sissakian in the Ministry of Science. The issues related to JINR's activity were discussed. In accordance with RF Government Decree No. 583 of 11 June signed by Prime Minister S.V.Kirienko, «The Protocol on Land Occupied by JINR» attached to «The Agreement between the Government of the Russian Federation and JINR on the Location and Terms of Activity of JINR in Russia» was signed during the meeting.

From 25 to 1 July JINR Director V.G.Kadyshevsky and Vice-Director A.N.Sissakian were on a working visit to Armenia. During their stay in this Member State of JINR they were received by the President of Armenia R.S.Kocharyan, with whom they discussed issues of development of collaboration between JINR and Armenian scientists. In the discussion, special attention was given to the participation of Armenian research centres, together with JINR, in large international programmes, including those under preparation at CERN's LHC.

In Yerevan, JINR's leaders were also received by Armenia's Prime Minister A.R.Darbinian, Minister for Foreign Affairs V.M.Oskanian, Minister of Science and Education L.O.Mkrtchyan. Their detailed discussion covered a wide range of issues of collaboration in the field of basic and applied research, and in education programmes.

In the course of their visit, V.G.Kadyshevsky and A.N.Sissakian held talks with Academician F.T.Sarkisyan, President of Armenia's National Academy of Sciences, Academician R.M.Martirosyan, Rector of Yerevan State University, and with Professor R.L.Mkrtchyan, Director of the Yerevan Physics Institute (YePI).

On 29 June in Yerevan, JINR's leaders took part in the opening of the International Workshop «Classical and Quantum Integrated Systems» co-sponsored by JINR and Yerevan State University (YeSU) with support from a number of financing and scientific organizations.

JINR Director V.G. Kadyshevsky and YeSU Rector R.M.Martirosyan signed a Cooperation Agreement which envisages, in particular, the establishment of a joint centre for advanced studies.

On 15 July in Trieste (Italy), JINR Director V.G.Kadyshevsky and the Directorate of the Research Centre, established on the basis of the new ELETTRA storage ring, signed an Agreement on joint activities in the field of accelerator engineering.

While visiting Geneva in July, JINR Vice-Director A.N.Sissakian met with CERN's Directorate, participants of the collaborative research, and with heads of some European Laboratories. A wide range of issues concerning cooperation in scientific and educational programmes was touched upon in the discussions. A Memorandum of Understanding between CERN, JINR, and Russia on the activities in the framework of the LHC project was prepared and agreed upon with CERN's Administration. A.N.Sissakian also had talks related to the forthcoming CERN-JINR joint schools for young physicists (the years 1998–1999) and the preparation of the CERN-JINR exhibition «Science Bringing Nations Together» to be held at UNESCO in Paris in October 1998. He got acquainted with the status of the preparation for the ATLAS, COMPASS, DIRAC and other experiments. The JINR Vice-Director met with the collaborators at Turin University and at the INFN Division in Turin. Joint research programmes in nuclear medicine were on the agenda of the discussion at Geneva University.

On 4–5 August JINR was visited by Professor K.Touryan, Director of the National Renewable Energy Laboratory of the US Department of Energy and one of the founders and heads of a philanthropy fund to support science in the CIS countries. He met with JINR Vice-Director A.N.Sissakian, FLNP Director V.L.Aksenov, JINR Chief Accountant A.E.Nazarenko, and leaders of the projects financed by the fund. The discussions resulted in signing a Memorandum of Understanding.

A delegation of the Republic of Korea (RK), including a member of the RK National Assembly, Chairman of the Committee for Science and Education of the Parliament of Korea, and President of the Korean Society for Nuclear Geopolitical Studies Kim Hyon-Wook, stayed in Dubna on 8 September. He was accompanied by the First Secretary of the Embassy of the Republic of Korea in Russia Rhew Choon-Geun. The guests were received by JINR Director V.G.Kadyshevsky, Vice-Director A.N.Sissakian, Chief Scientific Secretary V.M.Zhabitsky, and Assistant Director for International Relations P.N.Bogolubov. The participants of the meeting exchanged their opinions on a wide range of issues of collaboration in scientific and educational programmes. The guests got acquainted with the on-going research at JINR.

On 20 October in Moscow, JINR Director V.G.Kadyshevsky met with Yu.S.Osipov, President of the Russian Academy of Sciences and a member of the RF Government. A wide range of issues of the JINR- RAS collaboration and problems of JINR's activity in Russia were on the agenda of discussion.

Academician B.S.Yuldashev, Plenipotentiary of Uzbekistan to JINR, had a meeting with the JINR Directorate: V.G.Kadyshevsky, A.N.Sissakian, and Ts.Vylov on 21 October. Prospects of cooperation between JINR and scientific centres of Uzbekistan were the focus of attention in the discussions.

A.M.Andries, President of the Academy of Sciences of Moldova, stayed at JINR on 18 November. He got acquainted with the on-going research at the Flerov Laboratory of Nuclear Reactions and with the JINR University Centre. The President was received by JINR Vice-Director Ts.Vylov, FLNR Scientific Leader Yu.Ts.Oganessian, FLNR Director M.G.Itkis, and JINR UC Director S.P.Ivanova.

A meeting of the Russia-CERN Cooperation Committee took place in Geneva on 21 November. Russia's delegation was headed by the Minister for Science and Technologies M.P.Kirpichnikov, CERN's — by Director-General C.Llewellyn Smith. JINR Director V.G.Kadyshevsky and Vice-Director A.N.Sissakian took part in the meeting as official observers. The participants discussed in detail the results of the cooperation and outlined plans for the future.

A meeting of the CERN-JINR Cooperation Committee co-chaired by Professors J.Allaby and A.N.Sissakian was held in Geneva on 23 November. Spokespersons of all the joint experiments presented reports there. Also attending the meeting were CERN Director-General C.Llewellyn Smith and JINR Director V.G.Kadyshevsky. The participants considered the results and discussed prospects of the collaboration. Issues of finding new partners in the member-state scientific centres of both JINR and CERN for the collaborative research projects were touched upon, too.

On 30 November V.G.Kadyshevsky, A.N.Sissakian, and M.G.Itkis were received by R.Paldan, Ambassador of the Slovak Republic in Russia. They informed him on JINR's on-going activity, including that of the Slovak specialists in Dubna, and on the collaboration between JINR and Slovak scientific centres. The status of the Slovak Cyclotron Project to be realized in close cooperation with JINR was also touched upon.

Following the invitation of the President of the Korean Atomic Energy Research Institute (KAERI) Seong-Yun Kim and of some political figues of the Republic of Korea, JINR Director V.G.Kadyshevsky visited KAERI in November. He got acquainted with the Institute's activities and presented a report on the JINR research programme.

At the National Assembly in Seoul V.G.Kadyshevsky presented a lecture about the activities of JINR to the members of the Korean Society for Nuclear Geopolitical Studies. He also met with Speaker of the National Assembly Jyun Kyu Park, Minister for Science and Technologies Kang Chang Hee, Vice-President of the Academy of Sciences R.J.Kim, and with a number of statesmen of the Republic of Korea.

In Pohang the JINR Director visited the University of Science and Technology and signed with its Director Sung-Kee Chung an Agreement, stipulating joint research, students and professors' exchage, as well as an exchage of scientific papers. He also visited the Pohang Accelerator Laboratory.

On 4 December JINR Director V.G.Kadyshevsky and JINR Vice-Director A.N.Sissakian were received by Chairman of the State Duma of the Federal Assembly of the Russian Federation G.N.Seleznev and had a long talk with him at the State Duma in Moscow. The JINR leaders spoke about the state of affairs at the Institute, achievements of its scientists and specialists, problems and difficulties of the current period.

G.N.Seleznev gave his high appreciation of the activities of JINR as an international organization that effectively serves world science, on the one hand, and is very important for the prestige of Russia, on the other. He expressed his willingness to promote ratification of the Agreement between the Government of the Russian Federation and JINR, to support widening of international scientific cooperation of JINR using interparliamentary contacts, and to assist in stabilizing the financial and economic situation at JINR.

G.N.Seleznev accepted with gratitute the invitation to visit JINR at the beginning of 1999.

CONFERENCES AND MEETINGS HELD BY JINR

Of the scientific conferences organized by JINR in 1998 the largest were the following eight.

From 26–31 January JINR hosted the 5th International Conference «Mathematics. Computing. Education», attended by more than 130 scientists. This conference, pioneered by the Association «Women in Science and Education», is held annually during students' winter holidays alternately in Dubna and Puschino. The 5th Conference was organized by the Association together with the Joint Institute for Nuclear Research, Moscow State University, Puschino State University, and institutions of the Russian Academy of Sciences (RAS): Central Institute of Economics and Mathematics, Institute of Applied Mathematics, Institute of Human Being, Institute of Philosophy, and the Computing Centre of RAS.

For the second time representatives from many higher schools of Russia and CIS gathered together in Dubna to share their teaching experience, results of scientific research as well as problems and plans. A wide scope of questions was discussed at the Conference section meetings: «Computers and Education», «Computer Information Technologies», «Computational Methods and Mathematical Modeling», «Mathematical Models in Chemistry and Biology», «Mathematics and Economics», «Natural Science and Humanitarian Education».

JINR offered the Conference participants a number of reports on its main areas of activities. A number of talks were delivered by professors and lecturers of the International University «Dubna», of which JINR is a founder. Considerable interest of specialists in mathematical simulation was aroused by a lecture given by Professor S.P.Kurdyumov, Corresponding Member of RAS, who proposed a number of unexpected applications of a definite class of nonlinear systems. Most of the sessions were dedicated to educational issues. Considered in detail among others were numerous aspects related to informatization of the training process. The Conference also included a presentation of the information computer proposals from the TechnoServ Company and a demonstration of training programmes at the JINR UC computer classrooms. An important outcome of the Conference was creation of a foundation of computer training programs FOCUS.

The 6th traditional Seminar on Interaction of Neutrons with Nuclei took place in Dubna from 13–16 May. More than 100 specialists from JINR and the scientific centres of Bulgaria, France, Germany, Iran, Korea, Russia, and the USA attended this Seminar. Its programme included: fundamental interactions and symmetries in neutron reactions, gamma decay of excited states, properties of high-excited states, methodical aspects of nuclear

physics with neutrons, fundamental properties and β-decay of the neutron, physics of ultracold neutrons, and nuclear fission. For the first time the Seminar was prepared by an International Programme Committee, which united scientists of Russia, the USA, France, and Korea. In fact, it is the only annual forum on nuclear physics research with neutrons throughout the world.

The 1st International Conference «Modern Trends in Computational Physics» was held at JINR from 15–20 June. The aim was to provide a forum for the presentation of new approaches to computational modeling in physics. Scientists from JINR, Russia, CIS, America, Europe, and Asia attended the Conference. About 25 plenary and 50 original contributed talks were presented within the scope of the following Conference themes: numerical algorithms, nonlinear systems and dynamics, computer analysis of physical processes, mathematical modeling, exotic systems, and computer algebra. A number of reports were devoted to the recently established JINR High-Performance Computer Centre.

The XIth International Conference «Problems of Quantum Field Theory» dedicated to the 90th anniversary of the birth of D.I.Blokhintsev, a prominent physicist, organizer, and the first Director of JINR, was held from July 13–17 at the Bogoliubov Laboratory of Theoretical Physics. The Conference was attended by more than 150 scientists from Austria, the United Kingdom, Bulgaria, Germany, Italy, Spain, Canada, China, Poland, Romania, the USA, the Slovakia Republic, the Czech Republic, Switzerland, Yugoslavia, Japan, and JINR. About 140 reports, including 25 plenary talks, were delivered at the Conference. The programme covered important aspects of the modern quantum field theory and its applications in elementary particle physics. Much attention was given to the following problems: quantum chromodynamics, electroweak theory, Grand Unification theories, nonperturbative methods and phenomenology of strong interactions. Also, some mathematical problems were discussed related to string theories, quality, quantum symmetries, and integrable models. Among the speakers were V. de Alfaro (Turin, Italy), A.Bassetto (Padua, Italy), N.Brambilla (Vienna, Austria), M.Vasilev (Moscow), F. Jegerlehner (Zeuthen, Germany), D.Kazakov (JINR), A.Kamenshchik (Moscow), A.Logunov (Protvino), L.Lusanna (Florence, Italy), K.Stelle (London), E.Ivanov (JINR), L.Lipatov (St.Petersburg), J.Moffat (Toronto, Canada), G.Prosperi (Milan, Italy), L.Faddeev (St.Petersburg), D.Ebert (Berlin, Germany), and others. The conference included a memorial session devoted to D.I.Blokhintsev's scientific and organization activity, at which 6 plenary talks were given. Financial support was provided by the Russian Ministry of Atomic Energy, Russian Foundation for Basic Research, State Programme «Actual Problems of Condensed Matter Physics», and the Heisenberg-Landau Programme.

The 14th International Seminar on High-Energy Physics Problems was held at JINR from 17–22 August. Physicists from JINR, the JINR Member States and over 30 scientists from the USA, Germany, France and other countries took part in this Seminar. The main subject of the Seminar «Relativistic Nuclear Physics and Quantum Chromodynamics» joined theorists and experimenters working at different aspects of strong interaction physics and the nature of particles and nuclei. The programme of the International Seminar has become stable enough for a thirty-year period of its implementation. It allows one to hear the results of the latest world achievements and also the results of research traditionally developed under the aegis of JINR. Among the news, one should point out a report on the observation of neutrino oscillations. In addition to an important result of long-term search, this outcome will give a new impulse to high-energy physics.

The Seminar ended in survey reports on the construction of new experimental set-ups and accelerators at JINR and in the world. JINR physicists began to play a significant part in experiments with relativistic nuclei at CERN. This is a natural extension of the research performed in Dubna. Both R&D and physical results of these experiments were presented at the Seminar. The main result of the Seminar is that concentration on advanced trends of nuclear and strong interaction physics allows JINR to make a contribution to world scientific research not limiting it to the role of a supplier of cheap natural and intellectual resources.

The 1998 European School of High-Energy Physics, organized jointly by CERN and JINR, took place from 23 August – 5 September in St.Andrews, Scotland. Almost 100 young experimental physicists not only from Europe but also from Brazil and Kazakhstan attended the School. Its work was somehow guided by expectation of great discoveries: the LHC facility, which is under construction at CERN, may allow one to find new elementary particles. One of them is named after Prof. P.Higgs, who was an honorary guest of the School. Therefore, it is not surprising that two large lecture courses dealt with the Standard Model (V.Novikov), which explains the appearance of the Higgs particle, and with quantum chromodynamics (M.Mangano), which underlies the description of interaction among hadrons colliding in an accelerator. The subject matters of the two courses slightly overlapped, which led to a sort of stereo effect by allowing one to compare various approaches. Another large course of lectures was presented by J.Ellis. It dealt with a possibility of going beyond the firmly established part of theory, i.e., the Standard Model, and especially with realization and experimental manifestations of supersymmetry.

Smaller yet very interesting lecture courses were read on CP-violation (Y.Nir), detector physics (T.Virdee), cosmology (J.Peacock), gravitational waves (V.Kuzmin), heavy ions (J.Stachel), and neutrino oscillations (J.Hough). Traditional for these Schools were the lectures on physics at CERN (J.Ellis) and at JINR (A.N.Sissakian). The latter showed a unique potential of the science in Dubna. Participation of a large group of students from JINR and its CIS Member States in this School is an important investment in the future science.

From 30 August – 5 September in Dubna, the Joint Institute for Nuclear Research and Moscow State University held the 8th School on Neutron Physics. The School was dedicated to the 90th anniversary of the birth of the first Director of the JINR Laboratory of Neutron Physics, Nobel Prize winner Academician I.M.Frank. The School was purposed for students and post-graduates to acquaint them with the possibilities offered by neutron methods used in different fields of research. The introductory speech by Professor V.L.Aksenov was followed by a series of lectures by leading scientists in application of neutrons for investigations of fullerides (Yu.A.Ossipian, ISSP, Chernogolovka), structural and functional organization of protein (A.S.Spirin, Institute of Protein, Puschino), physics of high pressures (S.M.Stishov, IHP, RAS), neutron optics (Yu.G.Abov, ITEP), Fermi surfaces in metals (A.Yu.Rumiantsev, RRC KI), structure of inorganic materials (E.V.Antipov, MSU). Also, during morning sessions, lectures were given on the physics of ultracold neutrons (V.N.Shvetsov, JINR), symmetry of the order parameter (Yu.A.Iziumov, IPM, Ural Branch RAS, Ekaterinburg), methods of the synthesis of new materials (Yu.D.Tretiakov, MSU), and neutron activation analysis (M.V.Frontasyeva, JINR). During the afternoon sessions the School participants worked in sections of condensed matter physics and nuclear physics, where they listened to lectures and did practice at the spectrometers of the IBR-2 pulsed reactor and the IBR-30 booster at FLNP.

The XVIIth International Conference on High Energy Accelerators took place in Dubna from 7–12 September. It is the largest international accelerator conference held in the leading accelerator centres of the world every three years. Opening the plenary session, Chairman of the Organizing Committee V.Kadyshevsky read the addresses to the HEACC-98 participants from President of the Russian Federation B.Yeltsin, Chairman of the Federation Council Ye.Stroev, ministers and heads of governmental agencies of Russia. Welcome addresses also came from the governor of the Moscow region and the mayor of Dubna.

The first scientific speaker was J.Ellis (CERN), who reported on the current status of high-energy physics. His elaborated review was well supplemented by the report of A.Malakhov (JINR) on the possibilities of investigating the quark-gluon plasma at modern accelerators. As in the previous years, status reports of the leading research laboratories accounted for a major part of the scientific programme. G.Jackson spoke about the programme for increasing the luminosity of the Tevatron (Fermilab). The participation of JINR in international accelerator projects, such as the LHC and TESLA, and the most recent results of the operation of the Nuclotron, a new JINR accelerator, were reported by A.Sissakian. D.Trines (DESY) spoke about the status of the electron(positron)-proton collider HERA. An increase in the SPS CERN intensity was reported by K.-H.Kissler. J.Dorfan (SLAC) reported the results of the investigations at the Stanford Linear Collider. The status of the Relativistic Heavy-Ion Collider (RHIC), which is under construction now, was reported by S.Ozaki (BNL, USA). The high-energy accelerator investigations at the Budker Institute of Nuclear Physics (Novosibirsk) were reviewed by A.Skrinsky. The results of the DAFNE start-up were presented by M.Zobov (INFN, Italy). S.Kurokawa (KEK) spoke about the programme of physical experiments at the asymmetric electron-positron collider KEKB and about the experiment on neutrino oscillations. E.Troyanov (IHEP) reported the main results of the work at the Serpukhov proton synchrotron for the past few years. A.Temnykh (Cornell University, USA) spoke about the current status of the Cornell Electron Storage Ring (CESR).

The progress in the construction of the LHC was reported by P.Lebrun (CERN). Leading laboratories of Europe, USA, Japan, and Russia participate in this project. The project of the Electron-Nucleus Collider (ENC) was discussed in the talk by K.Blasche (GSI). The beginning of the work on the MUSES project of the Factor of Radioactive Ion Beams (RI Beam Factory) at RIKEN was reported by T.Katayama. In their talks A.Kovalenko (JINR), R.Palmer (BNL), and E.Malamud (FNAL) discussed future projects, among them the Very Large Hadron Collider (VLHC) with beam energies 2x50 TeV. Linear colliders, which are gradually replacing cyclic ones, were the subject matter of the fourth day.

Particular sessions, grouped into sections, were devoted to the main systems of high-energy accelerators. The discussions related to development of accelerator techniques included a report on providing the longitudinal parameters of the LHC beam by T.Linnecar (CERN) and reviews: feed-back systems, emittance control by I.Ivanov (JINR), methods of cooling charged particle beams (stochastic and electron) by D. Möhl (CERN) and I.N.Meshkov (JINR), respectively.

The conference ended with a round-table discussion on the organization of high-energy accelerator confer-

ences. In the opinion of the participants, the conference in Dubna will become a model for future HEACCs. It was decided to hold the conferences with a relatively small number of participants who are real leaders in their research centres, to lay emphasis on invited talks and more debates, and to invite promising young scientists. A total of 60 reports and 56 poster presentations were made at the conference.

PARTICIPATION OF JINR IN INTERNATIONAL AND NATIONAL CONFERENCES

In 1998, scientists of the Joint Institute for Nuclear Research took part in 218 international and national conferences.

The largest delegations of JINR attended the following conferences: International Winter School on Theoretical Physics (Poland, Wroclaw), XXXII PNPI Winter School on Nuclear and Particle Physics (Russia, St. Petersburg), HADES Collaboration Meeting (Poland, Cracow), XVI Nuclear Physics Divisional Conference of the European Physical Society («Structure of Nuclei under Extreme Conditions») (Italy, Padua), 5th International Conference on Charged Particle Optics (CPO-5) (Netherlands, Delft), 5th International Seminar «Neutron Scattering Investigations in Condensed Matter» (Poland, Poznan), International Seminar «Quarks'98» (Russia, Suzdal), 16th European Conference on Few-Body Problems in Physics (France, Autrans), International Workshop on Nuclear Physics (Russia, Moscow), 15th International Conference on Cyclotrons and Their Applications (France, Caen), 6th European Particle Accelerator Conference (EPAC-98), Workshop «Exotic Atoms, Molecules and μCF» (EXAT'98) (Switzerland, Ascona), 29th International Conference on High-Energy Physics (Canada, Vancouver), 6th Summer School on Neutron Scattering («Complementarity between Neutron and Synchrotron *X*-Ray Scattering») (Switzerland, Zuoz), 6th European Powder Diffraction Conference (EPDIC-6) (Hungary, Budapest), International Nuclear Physics Conference (INPC98) (France, Paris), 6th International Conference on Path-Integrals from peV to TeV (Italy, Florence), International Workshop «Symmetry and Spin» (Czech Republic, Prague), 19th International Conference on Nuclear Tracks in Solids (France, Besançon), 13th International Symposium on High-Energy Spin Physics (Russia, Protvino), Czech Physicists' National Conference «Nucleonika-98» (Czech Republic, Prague), 4th International Workshop on Quantum Field Theory under the Influence of External Conditions (Germany, Leipzig), Symposium on Modern Trends in Particle Physics (Georgia, Tbilisi), International School-Seminar on Fission Physics (Russia, Obninsk), 4th International Conference on Dynamical Aspects of Nuclear Fission (DANF'98) (Slovak Republic, Casta-Papiernicka), 16th Workshop on Charged Particle Beam Accelerators (Russia, Protvino), GANIL-DUBNA Collaboration Workshop (France, Caen), Fundamental Interactions Conference (Russia, Moscow).

Development of JINR's international collaboration and relations during the years 1965-1998

		1965	1975	1985	1990	1995	1997	1998
1.	Number of visits to JINR by specialists from its Member States (excluding participants in JINR conferences)	203	1026	1469	1050	299	268	285
2.	Number of visits by JINR specialists to Member States	171	474	600	778	682	670	626
3.	Number of conferences and meetings organized by JINR	19	42	49	44	52	58	47
4.	Number of visits to international conferences and research centres of non-Member States	69	131	119	437	1451	1465	1659
5.	Number of visits of scientists from non-Member States	27	226	144	563	1036	1039	792
6.	Number of JINR fellows		11	3	16	28	30	29

CONFERENCES AND MEETINGS ORGANIZED BY JINR IN 1998

№	Title	Site	Date
1.	Meeting on the CP Standing Commission for Improvement of the Scientific and Financial Policy of JINR and its Structure	Dubna	14 January
2.	83rd Session of the JINR Scientific Council	Dubna	15–16 January
3.	Meeting of the Polarized Target Users	Dubna	17 January
4.	Workshop on the IHEP-JINR Neutrino Detector and NOMAD Experiment	Dubna	21–23 January
5.	5th International Conference «Mathematics, Computers, Education»	Dubna	26–30 January
6.	Meeting of the Steering Committee for the BMBF-JINR Agreement Implementation	Dubna	9–10 February
7.	Meeting of the JINR Finance Committee	Dubna	12–13 February
8.	II Open Scientific Conference for Young Scientists and Specialists	Dubna	2–6 March
9.	School-Seminar «Collective Phenomena in Condensed Matter Physics»	Bulgaria Pamporovo	7–15 March
10.	Meeting of the CP Commission for Improvement of the Scientific and Financial Policy of JINR and its Structure	Dubna	11 March
11.	Meeting of the Committee of Plenipotentiaries of the JINR Member States	Dubna	12–14 March
12.	Workshoop for IBR-2 Users from Germany	Dubna	2–4 April
13.	Meeting of the Programme Advisory Committee for Condensed Matter Physics	Dubna	6–7 April
14.	Workshop «Nucleation Theory and its Application»	Dubna	6–17 April
15.	Meeting of the Programme Advisory Committee for Particle Physics	Dubna	16–18 April
16.	Meeting of the Programme Advisory Committee for Nuclear Physics	Dubna	20–22 April
17.	Workshop on Photoemulsions in Relativistic Nuclear Physics	Dubna	21–24 April
18.	VI International Seminar on Interaction of Neutrons with Nuclei	Dubna	13–16 May
19.	International School «Technology and Methods of Chemical Separation of Nuclear Waste: Application, Problems, Urgency of Further Investigations»	Dubna	18–28 May
20.	International Workshop «Deuteration of Biological Molecules for Structural and Dynamic Research. Application for Neutron Scattering and NMR»	Dubna	19–24 May
21.	Workshop of the SPHERE Collaboration	Bulgaria Varna	24–31 May
22.	Workshop «Hadronic Atoms and Positronium in the Standard Model»	Dubna	26–31 May

№	Title	Site	Date
23.	Workshop «Finite Quantum Systems»	Dubna	3–11 June
24.	84th Session of the JINR Scientific Council	Dubna	9–10 June
25.	1st International Conference «Modern Trends in Computational Physics»	Dubna	15–20 June
26.	Summer School for Young Scientists and Specialists	Dubna	19–21 June
27.	Workshop «Supersymmetries and Integrated Models»	Dubna	22–26 June
28.	II International Seminar «Relaxor Ferroelectronics»	Dubna	23–26 June
29.	Workshop «Classical and Quantum Intergrated Systems»	Armenia Yerevan	29June – 4 July
30.	Meeting of the Control Commission of the JINR Finance Committee	Dubna	2–3 July
31.	Internatonal Conference «Problems of Quantum Field Theory» (dediceted to the 90th anniversay of D.I.Blokhintsev's birth)	Dubna	13–17 July
32.	School-Seminar «Self-Similar Systems»	Dubna	30 July – 7 August
33.	Workshop on Topological and Intergrable Field Theories	Dubna	11–14 August
34.	XIV International Seminar on High-Energy Physics	Dubna	17–22 August
35.	Summer School for Students (dedicated to the 85th anniversary of B.Pontecorvo's birth)	Dubna	17 August – 1 September
36.	VI Internatonal School on High-Energy Physics	UK St. Andrews	23 August – 5 September
37.	VIII International School on Neutron Physics	Dubna	30 August – 5 September
38.	XVII International Conference on High-Energy Accelerators (HEACC'98)	Dubna	7–13 September
39.	Workshop on Medium-Energy Electron Cooling (MEEC'98)	Dubna	14–15 September
40.	Workshop «Spin Effects in QCD»	Dubna	15–26 September
41.	International Conference «Science, Philosophy, Religion»	Dubna	1–3 October
42.	Workshop on the Experiments with the EXCHARM Installation	Dubna	20–23 October
43.	Meeting of the Programme Advisory Committee for Condensed Matter Physics	Dubna	13–14 November
44.	Workshop «Collaboration of JINR with German Scientific Centres»	Dubna	16–17 November
45.	Meeting of the Programme Advisory Committee for Particle Physics	Dubna	19–21 November
46.	Meeting of the Programme Advisory Committee for Nuclear Physics	Dubna	23–25 November
47.	Workshop of the BAIKAL Collaboration	Dubna	1–4 December

The Joint Institute for Nuclear Research is an international intergovernmental sientific research organization, the activities of which are based on principles of openness for participation to all interested states and of their equal, mutually beneficil collaboration.

Dubna, 12 March. Meeting of the Committee of Plenipotentiaries of the JINR Member States

Dubna, 4 June. Participants of the 84th session of the JINR Scientific Council

Dubna, 10 February. Signing of the Protocol of the Meeting of the Joint Steering Committee for Implementation of the BMBF (Germany)–JINR Agreement on Cooperation and Use of JINR Facilities

Orel. 13 April. Meeting of Chairman of the Federation Council of Russia's Federal Assembly Ye.S. Stroev with the Directorate of JINR. In the photograph (left to right): A.I.Lebedev, A.N.Sissakian, Ye.S.Stroev, V.G.Kadyshevsky

Dubna, 19 February. A delegation, headed by the Plenipotentiary of the Republic of Belarus to JINR V.A.Gaisenok (centre), visiting the Laboratory of Nuclear Problems

Dubna, 25 February. Participants of the Commissioning of the System of Physical Protection and of Nuclear Material Control and Accounting established at JINR within the Agreement between the Russian GOSATOMNADZOR and the US Department of Energy

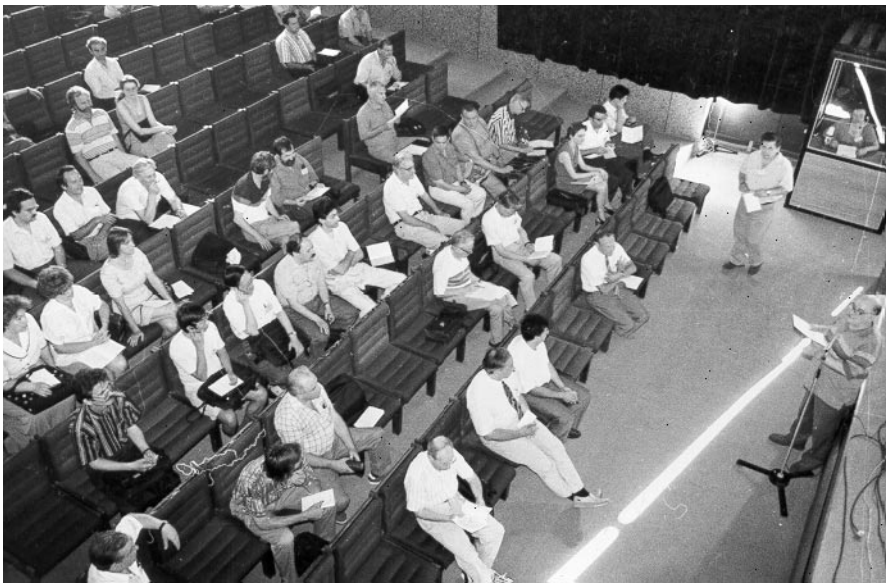
Dubna, 18 November.
Visit to JINR by the President
of the Academy of Sciences of Moldova
A.M.Andries (right)

Dubna, 8 September. Visit to JINR
of the Chairman of the Committee
for Science and Education of the
Parliament of Korea Kim Hyon-Wook
together with the First Secretary
of the Embassy of the Republic of Korea
in Russia Rhew Choon-Geun

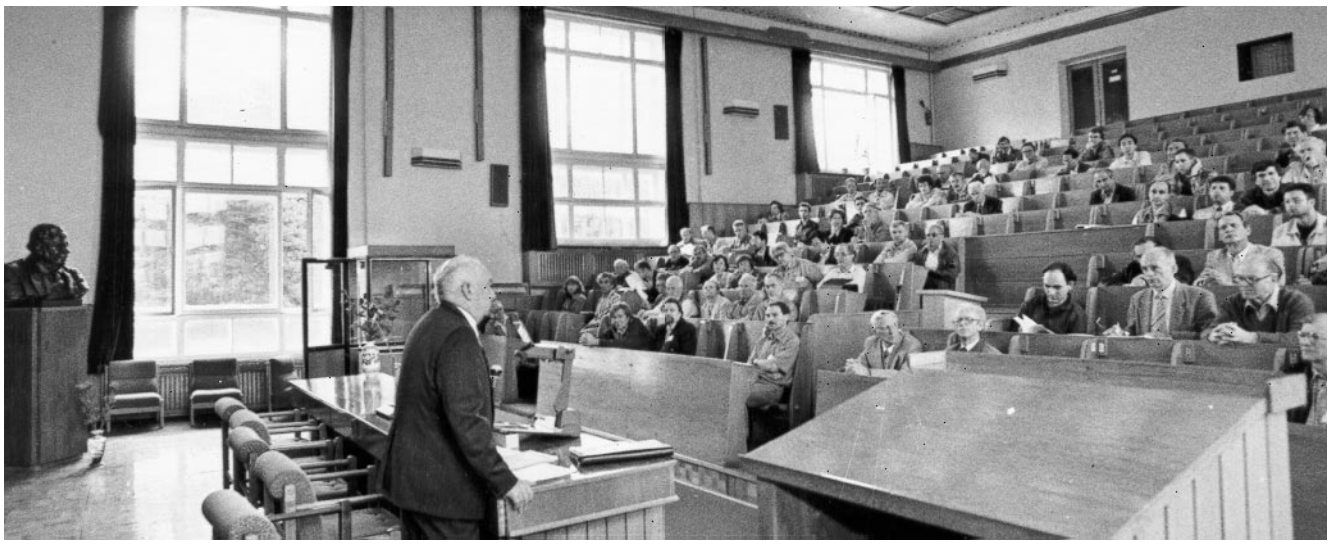
Dubna, 13–17 July. International Conference «Problems of Quantum Field Theory»
dedicated to the 90th anniversary of the birth of D.I.Blokhintsev (1908–1979), the first Director of JINR

Yerevan, Armenia, June.
In the photo (left to right):
Armenia's delegate to the JINR Finance Committee G.T.Torosyan,
President of Armenia's National Academy of Sciences F.T.Sarkisyan,
President of Armenia R.S.Kocharyan,
JINR Director V.G.Kadyshevsky,
JINR Vice-Director A.N.Sissakian,
and YeSU Rector R.M.Martirosyan

Dubna. A delegation headed by Professor Z.Stachura (third from left), Director-General of Poland's State Committee for Scientific Research, visited JINR on 2–3 June



Dubna, 15–20 June.
The 1st International Conference «Modern Trends in Computational Physics»

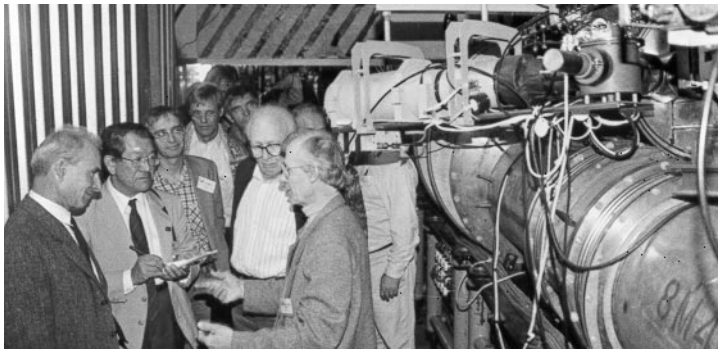


Dubna, 17–22 August. International Seminar on High-Energy Physics

Moscow, 4 December.
Meeting of the JINR Directorate
with G.N. Seleznev, Chairman
of the State Duma of the Federal
Assembly of the Russian Federation

St. Andrews (Scotland).
23 August – 5 September.
VI European School of High-Energy
Physics co-organized by CERN and JINR.
A group of students from JINR

Dubna, 7–12 September. XVII International Conference on High Energy Accelerators (HEACC’98)



RESEARCH AND EDUCATIONAL PROGRAMMES OF JINR

BOGOLIUBOV LABORATORY OF THEORETICAL PHYSICS

In 1998, the Laboratory continued studies on quantum field theory and elementary particle theory, mathematical physics, theory of nuclei and nuclear reactions, theory of condensed matter. The Laboratory's computer infrastructure was further developed. Theoretical physicists also participated in realizing a number of the JINR experimental programmes.

FIELDS AND PARTICLES

Directions of research in the Fields and Particles division are rather diverse. The main activity was concentrated on the following directions:

- Quantum symmetries, supersymmetries, and integrable models, with applications to strings, gravity, and cosmology;
- Perturbative computations in gauge theories and various approaches to nonperturbative treatment;
- Standard model and its extension;
- Heavy flavours and B-physics;
- Spectroscopy of light flavours.

Many studies were carried out in the domain of **«pure theory»**.

The construction of q-deformed Serre relations was generalized to the case of an arbitrary solution R of the quantum Yang–Baxter equations. Within this approach, q-Serre relations naturally arise from the kernel of an appropriate bilinear form generalizing the standard Killing one [1].

The low-energy effective actions of the $N = 2$ gauge multiplet and charged hypermultiplets in the Coulomb branch were computed using the $N = 2$ harmonic superspace techniques. The corresponding holomorphic contributions (chiral and harmonic-analytic) were both shown to be due to a nonzero central charge in $N = 2$ superalgebra [2].

The general superfield solution of the $N = (0|2)$ superconformal Toda lattice was constructed for the first time [3].

Partial spontaneous breaking of $N = 1$, $D = 10$ supersymmetry was described within the nonlinear realization approach, with the hypermultiplet as the only basic Goldstone superfield, and it was shown to yield a manifestly worldvolume supersymmetric form of equations of the type I super 5-brane in $D = 10$ [4]. This implies, in particular, the existence of brane extension of harmonic analyticity and off-shell hypermultiplet actions.

On the basis of the Hurwitz transformation it was shown that the eight-dimensional isotropic oscillator was dual to the five-dimensional charge-dyon bound system with the $SU(2)$ Yang monopole. The generalized Runge–Lenz vector and the $SO(6)$ group of hidden symmetry were established. It was also shown that the group of hidden symmetry made it possible to calculate the spectrum of the system by a pure algebraic method. The total wave function and degeneracy of the energy levels of a charge-dyon system were calculated [5].

It was shown that degrees of freedom responsible for the Bekenstein–Hawking entropy of a black hole in induced gravity were described by a two-dimensional quantum field theory defined on the bifurcation surface of the horizon. This result was proved for a class of induced gravity models with scalar, spinor, and vector heavy constituents [6].

A conformal-invariant unification of the theory of gravity with the standard model of strong and electroweak interactions was proposed on the basis of the Weyl geometry of similarity supplemented with the Einstein requirement for the physical time being unique and the number of derivatives being minimal. This model was applied to determine observable physical parameters [7].

Gluon propagators in the Lorentz (or Landau) gauge were simulated by the Monte Carlo method in the SU(2) lattice gauge theory. It was shown that zero-momentum modes of gauge fields played an important role in fixing the Lorentz (or Landau) gauge [8].

An effective method was developed to calculate the QED vacuum energy with boundary conditions given on a sphere and a cylinder. After incorporating the dispersion effect, it was applied, specifically, to elucidate the mechanism of sonoluminescence [9].

Studies were continued on the development of the «analytic perturbation theory in QCD». For the processes of electron-positron annihilation into hadrons and lepton-nucleon deep inelastic scattering it was shown that the analytic approach reduced the dependence of theoretical results on higher-loop contributions and on the renormalization scheme [10].

Many works were devoted to the domains close to **experimental phenomenology**.

New predictions for the Higgs boson mass in the Minimal Supersymmetric Standard Model (MSSM) were derived on the basis of the renormalization group infrared fixed points. For low (high) $\tan\beta = v_2/v_1$ scenarios the values of the lightest Higgs mass were found to be $94.3+1.4\pm5$ GeV ($\mu>0$) and $124.8-8.8\pm5$ GeV ($\mu>0$) or $120.9-5.1\pm5$ GeV ($\mu<0$), respectively, for a SUSY breaking scale of an order of 1 TeV [11]. New limits on the Higgs mass from LEP and new calculations of the radiative decay branching ratios restrict the parameter space of the Constrained MSSM. It was found that for the low $\tan\beta$ scenario only one sign of the Higgs mixing parameter was allowed while the high $\tan\beta$ scenario was practically excluded [12].

The charge and magnetic form factors of heavy charged leptons were shown, in the framework of perturbation theory, to have the imaginary part. The effects, where these imaginary parts could manifest themselves, were discussed [13].

High energy *pp* scattering at moderately large momentum transfers was studied within a QCD model in which the proton was viewed as being composed of a quark and a diquark. It was shown that this model led to single- and double-spin transverse asymmetries which were neither small nor vanish at high energies. The model results were of the same order of magnitude as those observed experimentally at the Brookhaven National Laboratory [14].

The mechanism to resolve the famous «spin crisis» in QCD was suggested in papers [15]. This mechanism is based on a large contribution of the quark zero and nonzero modes in the instanton field to the proton spin.

Some indication of a nonzero spin dependent quark fragmentation function responsible for a left-right asymmetry in fragmentation of a transversely polarized quark was obtained in the $Z \to 2$-jet decay DELPHI data. The value of asymmetry (the analyzing power), $(12.9\pm1.4)\%$, implies that this effect can be used in measuring the transverse quark polarization in other processes [16].

Experiments with tagged photons, radiated from the initial state in electron-proton and electron-positron collisions, were considered in a series of papers. These radiative processes will permit one to extract information about the final states at continuously varying values of the collision energy. Events with tagged photons, which are actually seen at HERA (DESY), were described with a high theoretical precision [17].

The first estimations of enhancement of free-bound transitions for cold positron-antiproton collisions in a trap in an external laser-pulse field were given as a function of laser-pulse parameters oriented on the CERN experiment ATHENA/AD-1 [18].

Semileptonic heavy-to-light and heavy-to-heavy meson transitions were studied as a phenomenological application of a heavy-quark limit of Dyson–Schwinger equations [19].

Exclusive strong, radiative, and nonleptonic decays of charm and bottom baryons were studied within a relativistic three-quark model. The factorizing as well as nonfactorizing contributions were calculated. It was found that for heavy-to-light transitions the total contribuion of nonfactorizing diagrams amounted to ~ 60% of factorizing contributions to the amplitude, and to ~ 30% for heavy-to-heavy transitions [20].

The heavy quark limit of the Wilson loop in the presence of the (anti-)self-dual homogeneous background field was examined in the non-Abelian gauge theory. It was demonstrated that this field produced an oscillator confining potential. The way in which deconfinement can occur at finite temperature was studied in the static temporal gauge by calculating the effective potential at high temperature [21].

Studies were performed for the behaviour of the pion gas in hot and dense media. It was shown that the intermediate σ-meson played an important role in the radiation near the critical point [22].

In a model of constituent quarks and gluons with potential interactions, masses of the lowest hybrid states of charmonia and bottomonia were calculated, and mixing coefficients of the hybrid charmonium with low-lying vector states of the Ψ family were defined. Relations be-

tween the leptonic width of physical states were derived in accord with data which gave an evidence that the dominant component of the state vector of the Ψ(4.16) resonance was the hybrid configuration containing a constituent gluon and the $c\bar{c}$ component in the colour octet state[23].

The hadronic $\pi^+\pi^-$ atom was studied within the relativistic perturbative approach based on the Bethe–Salpeter equation. The general expression for the atom lifetimewas derived. Lowest-order corrections to the relativistic Deser-type formula for the atom lifetime were evaluated within the chiral perturbation theory [24].

NUCLEAR THEORY

In the field «Nuclear Theory» main efforts were focused, in 1998, on the following subjects:

- Structure of atomic nuclei under extreme conditions of isospin and spin;
- Mechanisms of nucleus-nucleus collisions;
- Application of nuclear theory methods to other Fermi systems;
- Exotic nuclei and molecules;
- Relativistic nuclear physics.

Many works were devoted to **the theory of nuclear structure**.

A formalism of describing vibrational states built on high-spin multi-quasiparticle isomers in deformed nuclei was developed. Coupling of quasiparticle and vibrational degrees of freedom and the Pauli principle influence were taken into account on a microscopical footing. Calculations were made for the $K^\pi = 16^+$ isomer in ^{178}Hf, $K^\pi = 25/2^-$ isomer in ^{179}Hf and the $K^\pi = 9^+$ isomer in ^{180}Ta. The Pauli blocking effect was shown to be very important for vibrations built on isomers. Many fast γ transitions from the isomeric states to the energy range of 5–6 MeV in ^{178}Hf and to the energy ranges of 2.6–3.0 and 3.4–3.6 MeV in ^{180}Ta were predicted [25]. A finite rank separable approximation for an effective interaction of the Skyrme type was proposed and used to study the properties of vibrations in a long chain of the Ar isotopes including ones near the proton and neutron drip lines. It was found that a low-lying dipole component at ~ 7 MeV appeared in the A = 48 – 52 isotopes due to the single-particle transitions [26]. The 2_1^+, 2_2^+, and 0_2^+ states were described in the framework of the *Q*-phonon scheme and the Interacting Boson Model. The wave vectors were written as an expansion in multiple *Q*-phonon excitations of the ground state. It was shown that the convergence of this expansion was fast and the main component already provided a good description of the wave vectors, e.g., for the whole symmetry triangle the two-Q and three-Q configurations in a sum exhaust more than 90% of the norm of the 0_2^+ state. The results were applied to the description of the E2-decay branching ratio of the 0_2^+ state in nondeformed nuclei [27]. The photon spectra and total radiative muon capture rate on nuclei ^{58,60,62}Ni were for the first time calculated using a microscopic description of the nuclear excitation function. The nuclear amplitude of radiative muon capture was treated in the framework of the standard impulse approximation and also in the modified impulse approximation which took into account the continuity equation for electromagnetic current. The calculated total rates of ordinary muon capture are close to experimental data [28].

Different approaches to description of **nucleus-nucleus collisions** were used.

Starting from the equations of motion of a system possessing the properties of elastic and plastic bodies, its Lagrangian and Hamiltonian functions as well as the Rayleigh dissipation function were constructed. The studies showed that, at the beginning of the process, an important part of the collective energy was stored in the internal collective degrees of freedom. During the time when the elastic properties of the system dominate the motion, the fluctuations in the collective channel were hindered. This analysis of fluctuations was applied to get insight into the role of nuclear elastoplasticity in the fusion of heavy nuclei. The theory explains the competition between the regular drive to the fused configuration and random rebounds resulting in the fast fission [29]. Using the dinuclear system concept, production cross sections for the heaviest nuclei were calculated. Good agreement with experimental data was obtained. The experimentally observed rapid fall-off of the cross sections of the cold fusion with increasing charge number *Z* of the compound nucleus was explained. Optimal reactions for the synthesis of superheavy nuclei were suggested [30]. Nonlinear excitations of nuclear density were considered in the framework of semiclassical nonlinear nuclear hydrodynamics. Possible types of stationary nonlinear waves in nuclear media were analyzed using the nonlinear Schrödinger equation of the fifth order and classified using a simple mechanical picture. A rich spectrum of nonlinear oscillations in a one-dimensional nuclear medium was shown to exist [31].

The nuclear theory methods were applied to study metallic clusters.

Shell structure in the single-particle spectrum of deformed harmonic-oscillator potentials, when a term proportional to L^2 is added, was analyzed for a large particle number. It was argued that, in view of the chaotic nature of the problem, thorough understanding of the classical

situation provides essential guidance in tackling the corresponding quantum-mechanical problem. A scaling law that gives a dividing line between regular and chaotic behaviour in terms of energy, deformation, and strength of the L^2 term was found. According to this law, shell structure survives for higher particle numbers only with less deformation [32].

Rigorous mathematical methods of **the few–body theory** were developed and applied to a variety of physical problems.

The non-self-adjoint operators representing operator roots of the transfer function for a 2×2 matrix Hamiltonian were constructed. On this basis, completeness and basis properties for the root vectors including those for resonances were proved [33]. The representation theory of the six-dimensional rotation operators was constructed in the three-body hyperharmonics basis. The recurrence systems of the differential and linear equations were derived for the operators and their matrix elements. The integral representation and efficient calculation algorithms were proposed [34].

The effect of screening by the bound electron in the $^7\mathrm{Be}(p,\gamma)^8\mathrm{B}$ reaction was evaluated in the framework of three-body problems. It was shown that at the temperatures, like those in the centre of Sun, this effect increased the reaction rate by 15 times, which led to essential change (about 10%) of the rate at the Gamow peak energy ~ 18 keV [35]. The existence of a new type of muonic molecules containing 3 hydrogen atoms was predicted. It was found that the fusion $(D_3\mu \rightarrow {}^6Li\mu)$ probability was considerably higher than the decay rate of molecules [36].

The following results were obtained in the field of **relativistic nuclear physics**:

Particularities of the statistical mixed phase model of describing the deconfinement phase transition were studied. The modifications proposed concern an improved treatment of hadron-hadron interactions within the nonlinear mean-field model of nuclear matter and inclusion of the one-gluon exchange correction in the quark-gluon sector of the mixed phase thermodynamic potential. Some experimental manifestation of the mixed phase formation and deconfinement transition via the so-called «softest point effect» was estimated in the fireball expansion dynamics [37]. The method of model-independent analysis of experimental form factors was applied to study the available data for 14 nuclei from ^{4}He to ^{208}Pb with the aim of constructing their experimental charge-density distributions (CDD) on the basis of a unified procedure for the entire set of nuclei. The method is distinguished from others by using the trial symmetrized Fermi-function and its derivatives having the correct exponential asymptotics. Relative changes of the obtained nuclear CDD with increasing atomic weights were found. The high-momentum-transfer region, where experimental data can be explained only by taking into account the so-called radial variations in CDD, was specified [38]. The elastic proton-deuteron backward reaction was analyzed within a covariant approach based on the Bethe–Salpeter equation with a realistic meson-exchange interaction. The Lorentz boost and other relativistic effects in the cross section and spin correlation observables were investigated in an explicit form. A complete set of polarization observables was calculated [39]. The connection between the off-mass-shell kinematics of nucleons inside the deuteron and the binding effects in deep inelastic scattering on the deuteron was investigated. It was shown that assuming a small nucleon relative momentum, one could express the deuteron structure wave function F_2^D in terms of a free nucleon structure function and its derivatives. The contribution of the P, S^{--}, D^{--} waves turned out to be suppressed as a second power of the nucleon mass excess relative to the S^{++}, D^{++} wave contribution [40].

THEORY OF CONDENSED MATTER

Theoretical investigations in the Theory of Condensed Matter were performed in the following main directions:

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

To investigate the mechanism of the high temperature superconductivity, **models with strong electron correlations** were studied.

A microscopic theory of the electron spectrum and superconductivity for the *t-J* model of CuO_2 plane was developed within the Hubbard operator technique. For the first time, a numerical solution of Eliashberg's equations for the model was given which permitted one to explain peculiarities of photoemission experiments and give a microscopic proof of the *d*-wave spin-fluctuation pairing mechanism with high T_c [41].

A theory of strong interaction of correlated electrons with phonons was formulated for the Holstein–Hubbard model. The collective mode of phonon clouds which surround polarons was proved to exist. This leads to the essential renormalization of electron Green functions and influences the phase transitions in the system [42].

To interpret recent photoemission measurements on the cuprate compound $Sr_2CuO_2Cl_2$, a multi-band effective tight-binding model for the CuO_2 plane was proposed and the hole excitation spectrum was calculated [43].

Electron-phonon interaction and the Raman linewidth in superconducting fullerides were investigated on the basis of the proposed microscopic theory. Phonon relaxation rate and frequency renormalization were calculated in good agreement with photoemission experiments [44].

In the field of the theory of **dynamic systems, mathematical physics, and self-organization** the following results should be mentioned:

Quantization of classical dynamic systems with a Poisson structure on homogeneous Köhler manifolds was considered. The quantization follows the method invented by Berezin and represents the unitary transition operator $(-i\tau H)$ as a quasiclassical path integral in the coherent-state basis. When the coherent-state manifold appears as a (degenerate) rank-one co-adjoint orbit of the symmetry group, an explicit representation of the transition amplitude in terms of classical data can be derived for large values of the highest weight, which corresponds to the quasiclassical approximation. This representation was further shown to perfectly agree, in contrast with some earlier approaches, with the known exact results and may provide nontrivial asymptotics of physical relevance [45].

Dynamics of Eulerian walkers as a model of self-organized criticality was investigated. The evolution of the system was divided into characteristic periods which can be seen as avalanches. The structure of avalanches was described and the critical exponent in the distribution of first avalanches $\tau = 2$ was determined. The mean square displacement of Eulerian walkers was obtained as a simple diffusion law in the critical state. The evolution of underlying medium from a random state to the critical one was described [46].

Some aspects of a new noncombinatorial fermionic approach to the two-dimensional dimer problem in statistical mechanics based on the integration over anticommuting Grassmann variables and factorization ideas for the dimer density matrix were discussed. The dimer partition function can be expressed as a Gaussian fermionic integral. For regular lattices, the analytic solution then follows by passing to the momentum space for fermions [47].

A principally new connection between *N*-soliton solutions of nonlinear integrable equations and one-dimensional Ising chains was found. Tau-functions of the Korteweg-de Vries equation and the *B*-type Kadomtsev–Petviashvili equation describe the partition function of a one-dimensional antiferromagnet at some fixed values of temperature [48].

Disordered structures were studied and the following results were obtained:

The problem of phonon scattering by grain boundaries was studied within the wedge disclination dipole (WDD) model. It was shown that a specific q dependence of the phonon mean free path for biaxial WDD resulted in a low-temperature crossover of the thermal conductivity, κ. The obtained results allow one to explain the experimentally observed deviation of κ from a T^3 dependence below $0.1K$ in *LiF* and *NaCl* [49].

The change of the Josephson supercurrent density j_s of a weakly-connected granular superconductor in response to an externally applied arbitrary thermal gradient ∇T (nonlinear Seebeck effect) was considered within a model of 3D Josephson junction arrays. For $\nabla T > (\nabla T)_c$, where $(\nabla T)_c$ was estimated to be of an order of $\cong 10^4\ K/m$ for *YBCO* ceramics with an average grain size $d \cong 10\,\mu m$, the weak-link-dominated thermopower S was predicted to become strongly ∇T-dependent [50].

In the field of **finite quantum systems**, several results were obtained to be relevant to modern technologies and novel materials.

A model was developed to describe the one-dimensional confinement of an exciton in a rectangular quantum-well structure. A dielectric mismatch and a mass mismatch at the interfaces of different media were taken into account as well as corrections to the interaction potential due to the charge images. Upper and lower bounds for the binding energy E_b of the exciton were derived and the dependence of E_b on the width of the confining potential was calculated with higher accuracy than in the previous reports. For a specific case of the $Ga_{1-x}Al_x\,As/Ga\,As/Ga_{1-x}Al_xAs$ heterostructure, the upper and lower bounds provide one with E_b which are similar in shape and constitute a rather small allowed channel for the exact binding energy. The peak structure of E_b was shown to exist in contrast with the previous findings [51].

The ^{4}He Bose-condensate in porous glasses, being a bulk system, showed the loss of translation symmetry similar to that in a mesoscopic system. The experimentally measured shift of condensation temperature was used to estimate theoretically the relative number n of atoms influenced by the deformation of the interatomic potential because of pores, $n \approx 10\%$. The Bogoliubov nonideal gas model combined with the path integral calculations, earlier developed by V. Yarunin , was used [52].

The dynamics of neutral atoms in quadrupole magnetic traps was studied. A novel regime of motion was described when atoms are confined from one side of a trap but not confined from the other side. This regime made it possible to create a directed beam of atoms. The cloud of emitted atoms acquired ellipsoidal shape stretched in the direction of motion. Such a semiconfining regime provided a dynamic mechanism for an atom laser [53].

Statistical-ordered optical field was investigated in terms of properties of a quantum phase shift. The results obtained provided numerical simulations and could be used for precise quantum measurements, especially in small volumes [54].

COMPUTER FACILITIES

Two new workstations Ultra 2 (the first with two 200 MHz and the second with single 300 MHz processors) were added to the cluster of Sun computers. The Laboratory's main host (thsun1.jinr.ru) was upgraded to configuration with 4 processors (SuperSPARC 85 MHz), 640 MB of RAM and total 23 GB of the disk storage. Fast Ethernet network was developed to connect Sun workstations with the file server. For user's convenience there was installed a CD recorder in one of the Sun workstations.

The principal reconstruction of the Laboratory's local network was performed. To reduce competition between computers for network resources, a large network was divided into 12 independent collision domains. In the centre of the network, the 100BaseT/10BaseT switch was installed which connects every new domain with Fast Ethernet network of the workstations.

Five personal computers with Pentium II were installed in work places. Dual Pentium II PC is under preparation to be installed in the computer hall.

Most significant software packages renewed in 1998 include REDUCE, SunSoft Fortran and C/C++, GNU C/C++, TeX/LaTeX, WWW browsers, WWW servers. A new version of the operating system with improved user interface, Solaris 2.6, was installed in all Sun workstations.

MEETINGS, SCIENTIFIC COLLABORATION

In 1998, the Laboratory participated in the organization of 11 meetings most of which were supported by UNESCO, the Russian Foundation for Basic Research (RFBR), and the Heisenberg–Landau Programme (HLP).

The XIth International Conference «*Problems of Quantum Field Theory*» dedicated to the 90th anniversary of the birth of D.I. Blokhintsev was held on July 13–17, 1998 at the BLTP. More than 150 scientists from Austria, Bulgaria, Canada, China, Czechia, Germany, Italy, Japan, Slovakia, Spain, Switzerland, Poland, Romania, Russia, the United Kingdom, the USA, Yugoslavia, and JINR participated in the Conference. The programme covered important aspects of modern quantum field theory and its applications in elementary particle physics. Much attention was given to the following problems: quantum chromodynamics, electroweak theory, Grand Unification theories, nonperturbative methods, and phenomenology of strong interactions. Also, some mathematical problems were discussed which are relevant to string theories, duality, quantum symmetries, and integrable models. The Conference included a memorial session devoted to Blokhintsev's scientific work and his activity as a science organizer. In opinion of all the participants, this Conference was an important event in scientific life. Studies on actual problems of QFT and elementary particle physics were summarized, and the most promising trends of further research were discussed.

Like in the previous years, theorists participated in organization of *the International Seminar on High Energy Physics Problems*. The 14th Seminar of this series was held at BLTP on 17–22 August. Physicists from JINR, the JINR Member States, and over 30 scientists from other countries took part in this Seminar.

The Russian–Indian workshop «*Topological and Integrable Field Theories*» was held at the BLTP on 11–14 August. The Workshop was organized in the framework of the Integrated Long Term Programme of Cooperation in Science and Technology between the Russian Federation and the Republic of India in the field of fundamental research (mathematical physics). The Workshop was attended by 15 representatives of BLTP, 20 specialists of Russian scientific centres, and 7 collaborators of leading Indian research centres. During the workshop, 20 one-hour lectures covered the present situation in string theory and quantum integrable field theories. The workshop promoted establishing new contacts between Russian, JINR, and Indian specialists actively working in modern mathematical physics.

In 1998, BLTP took part in the organization of two meetings held in the JINR Member States: *The VIIth International Colloquium «Quantum Groups and Integrable Systems»,* (June 18–20, Prague, Czechia) and *Workshop «Classical and Quantum Integrable Systems»* (Yerevan, Armenia, June 29 – July 4).

A wide scientific collaboration is continued with the scientific centres of the JINR Member States and other countries. In 1998, the collaboration was supported by grants of the plenipotentiaries of the Czech Republic, the Slovak Republic and Hungary; a new programme of collaboration with Polish theorists, the Bogoliubov–Infeld Programme, was established.

Within the Heisenberg–Landau Programme more than 70 papers were published jointly with the colleagues from German scientific centres, 38 joint projects and 8 meetings obtained financial support from the HLP.

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. Agreements between BLTP and CERN TH, ICTP are in force.

Till now, studies at our Laboratory have covered three themes approved for 5 years up to 1998. Our proposals concerning new themes «**Fields and Particles**», «**Theory of Nuclei and Other Finite Systems**», «**Theory of Condensed Matter**» for a period from 1999 to 2003 were considered at the PAC autumn sessions and approved at the 85th Session of the JINR Scientific Council.

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LABORATORY OF HIGH ENERGIES

The scientific programme of the Laboratory of High Energies (LHE) is presently concentrated on investigations of interactions of relativistic nuclei in the energy region from a few hundred MeV to a few TeV per nucleon with the aim of searching for manifestations of quark and gluon degrees of freedom in nuclei, asymptotic laws for nuclear matter in high energy collisions as well as on the studies of the spin structure of the lightest nuclei.

Experiments along these lines are being carried out using beams of the Synchrophasotron–Nuclotron accelerator complex and other accelerators: at CERN (SPS, LHC), BNL (RHIC) and also at the CELSIUS storage ring in Uppsala (Sweden). LHE takes part in preparing the HADES experiment at GSI (Darmstadt).

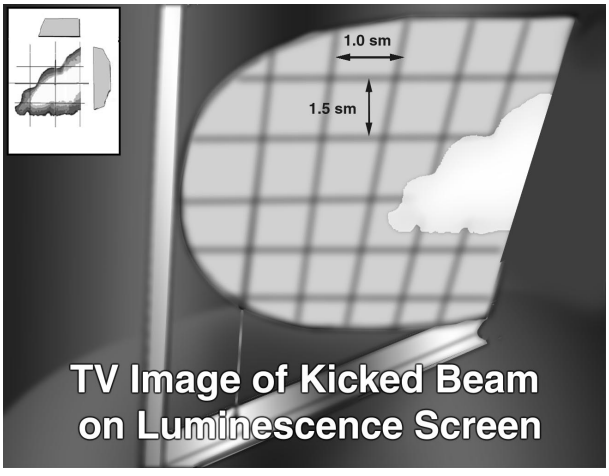
ACCELERATION COMPLEX DEVELOPMENT

Important advances in the operation of the Nuclotron were achieved in 1998. The beam energy increased up to 4.1 GeV/nucleon. The intensity of an accelerated deuteron beam reached $\sim 2 \cdot 10^{10}$ part./cycle. The first experiment on the resonance excitation of an accelerated beam, which is needed for its slow extraction, was carried out (Fig.1). The external beam system will be constructed in 1999. In accordance with the schedule approved by the JINR Directorate, two beam runs of a total duration of 558 hours were performed at the Nuclotron. The beam of He nuclei was first accelerated and used for data taking.

The total running time was limited by 250 hours. The cost of the beam time was compensated by the users. The greater part of the running time was used for the experiments with unique beams of polarized deuterons. The beams of *p, d* in the energy range of $1 \div 5$ GeV were also used. The new problem of narrow external beam formation ($\varnothing = 16 \div 18$ mm) was successfully solved.

Fig.1. Luminous track of a beam on the scintillation screen installed in the chamber of the accelerator at a distance of 2 cm from its axis

The dominant condition of the machine operation is the attraction of the users' resources. In spite of a continuous rise of the electricity cost, the number of users does increase. First of all, these are the polarized beam users. Interest in the traditional beams of light nuclei is still very great.



EXPERIMENTS ON AN INTERNAL BEAM OF THE NUCLOTRON

The studies of the transversal dimensions of the region of cumulative particle production were continued within the framework of the project **SPHERE**. The correlations of protons, emitted in the angle interval between 106÷112° in the laboratory system, were studied in the reactions $dA \to ppX$ and $\alpha A \to ppX$ at a small relative momentum of secondary protons. The measurements were made on C, Al, and W nuclei. Preliminary information on the transversal size of the proton emission region was obtained. The experiment was performed using the two-arm scintillation spectrometer on an internal 3 GeV/nucleon deuteron beam of the Nuclotron [1].

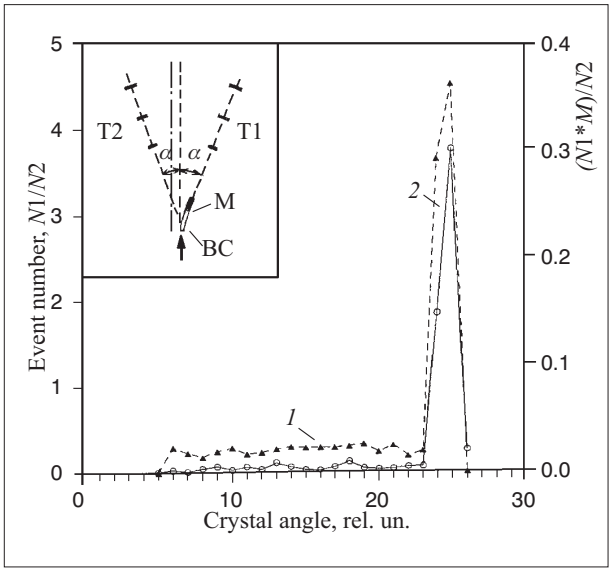


Fig.2. The dependence of the count ratio of the operating telescope to the background one on the crystal orientation angle. The arrangement of operating telescope T1 and background one T2 is shown in the figure inset. Here M is the scintillation counter placed in the Nuclotron chamber immediately behind the crystal BC

The experiments on the study of π°- and η-meson production on internal beams of the Nuclotron were continued in March and December 1998. The aim of these experiments is to study the state of hot and dense nuclear matter formed in nucleus-nucleus collisions. Above 10^7 events with two and more gammas were registered in the experiments on deuteron and α-particle beams at an energy of 3 GeV/nucleon. The ratio of the structure functions *G(X,A)* of *d* and ^{4}He nuclei in the region of $0.2 < X < 0.6$, where *X* is the cumulative number, was measured. The preliminary estimates of the probability of 6-quark cluster («flucton») production in *d* and ^{4}He nuclei were ~ 1% and ~ 5%, respectively.

The experiment aimed at testing the equipment produced for a comparative study of new tungsten and silicon crystal deflectors on the beams of accelerated nuclei with an energy of up to 6 GeV/n was performed at the Nuclotron in December 1998. Figure 2 shows the dependence of the count ratio of the operating telescope to the background one on the crystal orientation angle. Curve (2) is for the case when the operating telescope was additionally in coincidence with the counter placed in the vacuum chamber behind the exit end of the crystal. A considerable increase of the event count along the extraction direction with a sharp growth of the dependence of curve (2) over a narrow angular region can be interpreted as the effect of deviation of accelerated deuterons from the Nuclotron orbit with a bent crystal.

LHE EXTRACTED BEAM EXPERIMENTS

The new experimental set-up **DELTA (INR RAS – JINR)** was put into operation during the June 1998 Synchrophasotron run. The installation is aimed to perform the experiment at the LHE JINR Polarization Complex based on the polarized deuterons accelerated by the Synchrophasotron–Nuclotron and the ANL–Saclay–LHE Polarized Proton Target (PPT) placed at LHE. The set-up ensures a high-resolution and high-aperture detection of neutral π^0 and η mesons with an energy of 100 MeV and above and charged particles (π^+, p, d) within 40–300 MeV. There are the following main units: a 300-channel Cherenkov spectrometer consisting of two blocks (CH1 and CH2) each based on 150 prisms that are made of lead glass, a telescope of detectors (ΔE-E Arm) based on plastic scintillators and used to identify charged particles and to measure their energy by the method of measuring energy losses. The work on starting up the installation in the June 1998 run was done on a neutron beam of the Synchrophasotron with carbon and polyethylene targets. About 2,100 pair events corresponding to the $np \to \pi^0 d$ reaction on a polyethylene target and appr. 700 events on a hydrogen target were obtained on a neutron beam with an intensity of $5 \cdot 10^6$ neutrons per cycle and an energy of 1.5 GeV. The value of random background was of the order of 30% of hydrogen. As an example, Fig.3 shows the reconstructed invariant mass spectrum for the particle, decaying into two γ quanta.

In the framework of the **SPHERE** project, the tensor analyzing power A_{yy} was measured in the fragmentation reactions of tensor polarized deuterons into protons and cumulative pions of high transfer momenta $d+A \to p(130\ \text{mrad.})+X$ and $d+A \to \to \pi(135\,\text{mrad.})+X$. These measurements continue the investigations made at Saclay and LHE JINR in the preceding experiments with deuteron breakup, where significant deviations from nucleon model predictions of the deuteron based on an impulse approximation were observed in the region of high internal momenta. The description of the deuteron structure at small distances by the standard two-component wave function is apparently inconsistent. Additional components should be also introduced taking into account non-nucleonic degrees of freedom in the deuteron. To clarify the nature of these components and their relative role, an extended set of experimental data is needed including information on the dependence of spin observables on transverse momentum. The experiments carried out for high transverse momenta (up to $P_T \approx 0.8$ GeV/c) gave new unexpected results. In the reaction $d+A \to p(85\text{mrad.})+X$, one could expect the degree of agreement with IA calculations to improve with decreasing the role of pion diagrams within the framework of the hard scattering model. In fact, a sharp mismatch with the model, increasing with rising proton transverse momentum, was observed in this reaction (Fig.4a). The new data obtained in the 1998 run for a proton emission angle of 130 mrad will make it easy to

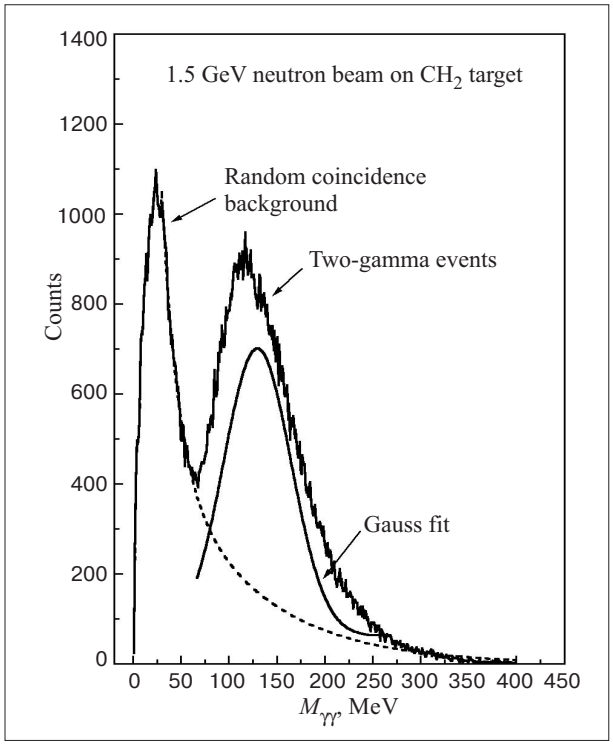


Fig.3. Invariant mass spectrum of reconstructed π^0 mesons. The solid line is the result of Gauss fitting

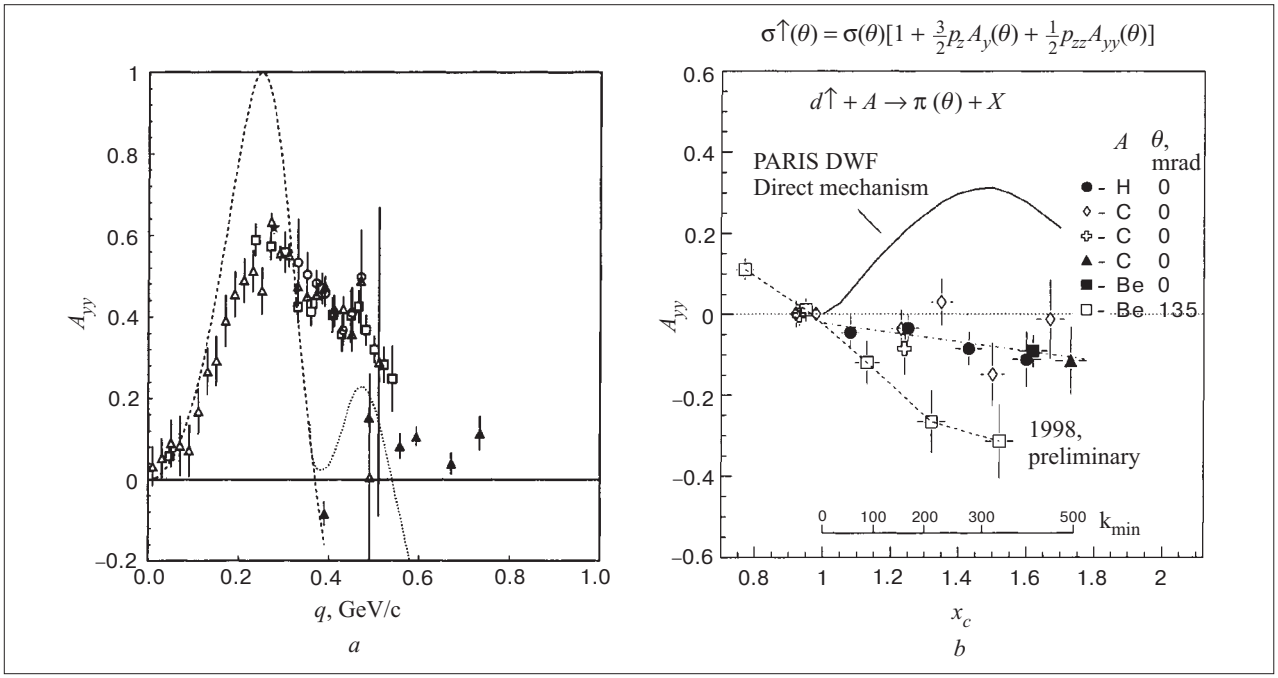


Fig.4. a) A_{yy} data for deuteron inclusive breakup from the present experiment (black triangles) as compared with the data obtained at 0° on a carbon target versus proton momentum in the rest frame of the deuteron q. The dashed and dotted lines are the calculated results using Paris DWF at 0 and 85 mrad proton emission angles, respectively. b) A_{yy} for the reaction $\vec{d}A \to \pi^-(\theta)X$ at the fragmentation of 9 GeV deuterons on H-, Be-, and C targets as compared with the direct production mechanism calculations (PARIS DWF). A_{yy} is shown vs. cumulative variable x_c and nucleon internal momentum $k_{\min}$

trace evolution A_{yy} with increasing transverse momentum. The growth of the tensor analyzing power A_{yy} with increasing cumulative pion transverse momentum was found in the reaction $d+A \to \pi(135\text{mrad.})+X$ (Fig.4b). It conflicts in sign with the prediction of the model based on a direct mechanism of cumulative pion production from the hypothesis of high momentum nucleon component in the deuteron. The research of spin effects in cumulative pion production was conducted for the first time. This unique information was obtained due to the availability of high momentum polarized beams of deuterons at LHE. The research should be continued to study evolution A_{yy} at larger pion emission angles (at higher P_T) and to obtain data on the vector analyzing power in the reaction of fragmentation of vector polarized deuterons into cumulative pions [2-5]. The observation of the growth of the analyzing power with increasing the transverse momentum of cumulative particles can be compared with the detection of significant spin effects in hard-hadron scattering at high transverse momenta, which were not predicted in the framework of the perturbative QCD.

The MARUSYA set-up. The diagnostics system of the beams of the Nuclotron based on microchannel plates was made and successfully tested in four beam runs. The prototypes of the monitoring system and the scintillator TOF system were made and tested on the beams of the Synchrophasotron. The Cherenkov threshold counter based on a silicon crystal was made and tested. A special movable vacuum stand was constructed. The scintillators for the multiplicity detector were made and polished.

Theoretical Research and Interpretation of the Experimental Data

The principles of symmetry and self-similarity were used to get an explicit analytical expression for inclusive production cross sections of particles, nuclear fragments and antinuclei in relativistic nuclear collisions in the central rapidity region ($y = 0$). The result is in agreement with the available experimental data. The effective number of nucleons involved in nuclear collisions decreases with increasing energy, and the cross section tends to a constant value equal for particles and antiparticles. The analysis of the obtained results makes it possible to conclude that hopes of obtaining dense and hot matter in heavy ultrarelativistic nuclear collisions are not justified [6].

The analysis of spin correlations in the detection of nonfactorizable two-particle states was performed. The appearance of such correlations is due to the general quantum-mechanical effect predicted by Einstein, Podolsky and Rosen. The elastic scattering of one of two unpolarized particles is shown to result in the polarization of another particle in the presence of the spin correlations. This makes it possible (in principle) to produce particle beams with controlled spin polarization without a direct force action on the particles to be polarized. The distinctive features of the correlations in the singlet and triplet states of two particles with spin 1/2 are discussed; the correlations of the scattering planes for two particles with spin 1/2 scattered on a spinless or unpolarized target are analysed. It is shown that the spins of two identical nucleons (protons, neutrons) with small relative momenta, produced in nuclear collisions, are strongly correlated. The investigation of neutron-proton correlations at deuteron peripheral breakup is performed [7].

A new dimensionless relativistic invariant variable is suggested for reactions of the type $(a,a')X$: $\Re$ can be interpreted as the ratio of the excitation energy of the system X to the total energy transferred $E_a - E_{a'}$; therefore, this variable measures the «degree of scattering inelasticity».

$$\Re = \frac{\Delta m_x}{\nu}, \quad \nu = \frac{1}{m_t} P_t (P_a - P_{a'}) = m_a u_t (u_a - u_{a'}),$$

where $P_a, P_{a'}$, and P_t are the 4 -momenta of the projectile, the projectile, and the target, respectively; $u_a, u_{a'}$, and u_t are the 4-velocities of these particles; $\Delta m_X = m_X - m_t$ is the difference between the masses of the recoiled system in the final state (missing mass, m_X) and the initial state (target mass, m_t), respectively. The data on the tensor analyzing power A_{yy} obtained at LHE JINR are analysed in terms of this variable for $(\vec{d},d')X$ inelastic scattering. A_{yy} taken as a function of $\Re$ is found out to be independent of incident energy and scattering angle (to $\theta_{cm} \approx 30°$); there is no noticeable difference between the proton and nuclear targets either (see Fig.5) [9].

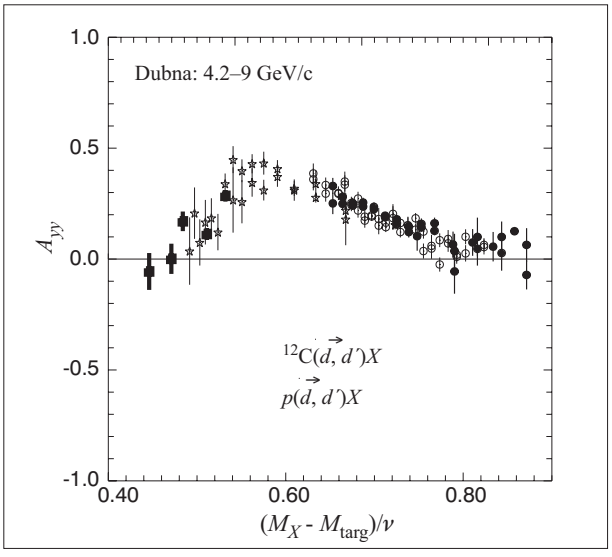


Fig.5. $A_{yy}(\Re)$ for $p(\vec{d},d')X$ and $^{12}C(\vec{d},d')X$ inelastic scattering; the data are taken from [2,8]. Open circles: 4.2–4.5 GeV/c; black circles: 5.53 GeV/c; stars: 9 GeV/c; all the data at a lab. scattering angle of 0°; black squares: 9 GeV/c at an 85 mrad lab. scattering angle (carbon target [2])

Bubble Chamber Data Analysis

The enhancement, exceeding the background by 6.12 S.D., is observed in the effective mass spectrum of $\pi^+\pi^-$ combinations at $M_{\pi^+\pi^-} = (759 \pm 5)\ \mathrm{MeV/c^2}$ for the events from the reaction $np \to np\pi^+\pi^-$ at $P_n = (5.20 \pm 0.16\ \mathrm{GeV/c})$ selected on condition that $\cos\Theta^*_p > 0$. The total experimental width of the enhancement $\Gamma = (35 \pm 12)\ \mathrm{MeV/c^2}$, the isospin J=0 and the most probable value of spin J=0. The cross section of the observed effect $\sigma = (38 \pm 9)\mu\mathrm{b}$. This enhancement can be interpreted as a σ meson with quantum numbers $I^G(J^{pc}) = 0^+(0^{++})$[10]. The obtained results are in good agreement with the data from other papers.

APPLIED RESEARCH

During the June 1998 run, the collaboration of scientists from the institutes and universities of Germany (Marburg, Julich and Torgau), Greece, France, India, China, Russia (Obninsk and Moscow), Byelorussia and physicists from JINR LHE, LNP, LCTA, the Department of Radiation Safety, and FLNR continued research on neutron generation in the extended targets made of lead and uranium and on the transmutation of radioactive wastes (iodine-129, neptunium-237 and americium-241) using the proton beams at 0.5, 1.0, and 1.5 GeV [11,12].

The space-time distribution of the temperature and heat production level inside a $50\times50\times80\,\mathrm{cm}^3$ lead target during irradiation with a 5 GeV proton beam from the Dubna Synchrophasotron was investigated using high-sensitive microthermo-couples. The space-energy distribution of neutrons inside the same lead target irradiated with 1.5 GeV protons was also investigated. Using the gold activation detectors (bare and Cd-covered), the neutron field was scanned moving off the beam line. The data obtained from the spatial distributions of fast, resonance, and thermal neutrons were useful for a safe choice of target and blanket dimensions in the U/Pb assembly, JINR [13].

The distribution of radionuclides was studied in the interactions of a proton beam with a sectional (10 cm in diameter and 5×10 cm long) Pb target. SSNTD and Pb foils were mounted between the sections; Pb-foil was simultaneously used as an activation detector and a radiator for the track detectors.

The measurements of Pb-foil activity show that more than 100 residual nuclei are produced, the cumulative and independent yields of which depend on beam penetration into the target; ^{205,206}Bi isotopes produced in the reactions Pb(*p,xn*) can serve as an «internal» monitor of primary and secondary protons.

To study the space-time distribution of heat production in the target, the calorimetric method based on a platinum resistance thermometer is used. Due to a careful isolation, success was achieved in a substantial reduction of heat losses from the whole target and heat transfer between its sections. The possibility of measuring temperature with an accuracy of 2–3 mK appeared at JINR for the first time. This method will be used in experiments on the U/Pb assembly [13].

COOPERATION AT THE ACCELERATORS OF OTHER CENTRES

The inelastic scattering of 3.73 GeV/c polarized deuterons on protons with Roper N(1440) and Δ resonance excitation was studied in the experiment on SATURNE-II (Saclay, France) using the **SPES-4π spectrometer**. First preliminary results for the tensor analyzing powers of inelastic $p(d,d')X$ scattering at $\theta_{\mathrm{lab}} \approx 0.8°$ (Fig.6) and elastic backward ($\theta_{\mathrm{c.m.}} = 180°$) scattering were obtained on part of the statistics (Fig.7). The analyzing power of the latter reaction was measured under kinematically redundant conditions when both the scattered proton and the recoil deuteron were detected in coincidence. In this case, the identification of both particles was based on the measurements of their momenta, time of flight, and energy losses in the scintillators. The data are compared with the known world data. In this experiment, both scattered particles were first registered for energies above $\approx$ 1 GeV.

The WASA project is aimed at further studies of the threshold production of light mesons and a new research of meson rare decays using the 4π-detector set-up at the CELSIUS storage ring in Uppsala.

Recently, we have given experimental evidence of anisotropy in the $pp \to pp\eta$ angular distributions near threshold [16]. This is a first indication of the effect from higher partial waves in this reaction. The sign of the angular asymmetry of η mesons is sensitive to the basic pro-

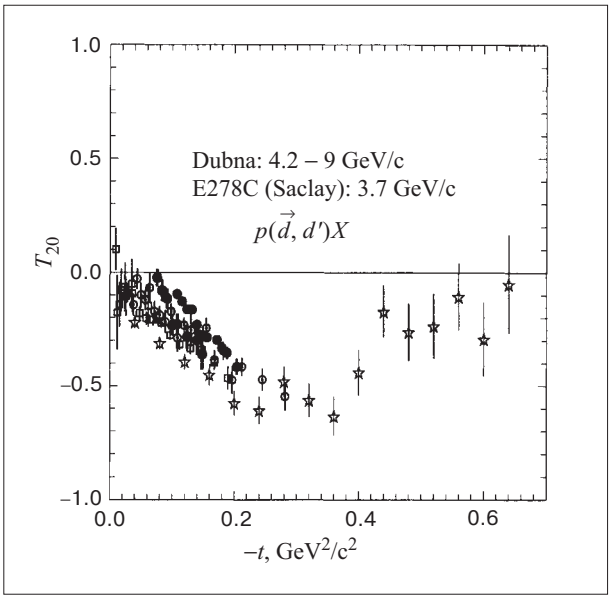


Fig.6. T_{20} data for $p(\vec{d}, d')X$ inelastic scattering at 0° from Ref. 8. Stars: 9 GeV/c; open squares: 5.532 GeV/c; open circles: 4.495 GeV/c; black circles: data from Ref. 9 for momenta of 4.24 ÷ 6.55 GeV/c

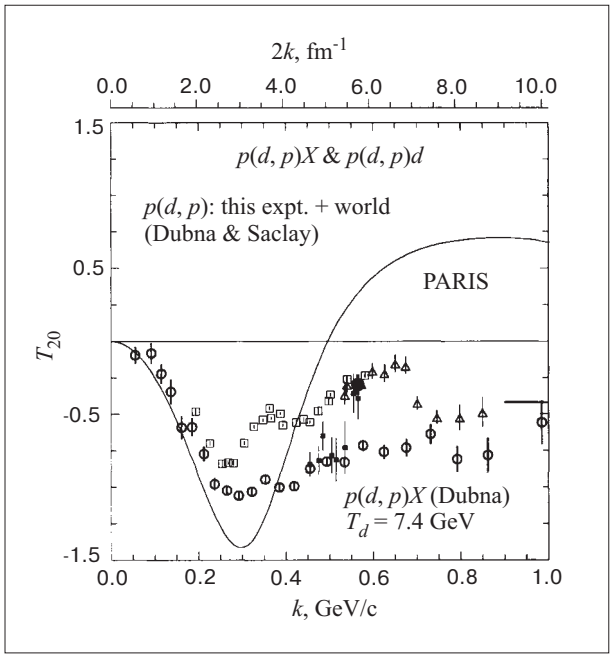


Fig.7. Data on T_{20} for $p(d,p)d$ backward (c.m.) elastic scattering (open squares and open triangles) from Refs. 9,14 and for $p(d,p)X$ breakup at 0° at T_d = 7.4 GeV/c from Ref. 15 (open circles). Black circles — data from this experiment for $p(d,p)d$ at $\theta_{c.m.} = 180°$ when both final particles are detected in coincidence. Small black squares: data from this experiment for $p(d,p)pn$ at $\theta_{c.m.} = 180°$

duction mechanism. All the existing theoretical models, describing η production in *pp* scattering, differ mainly in their choice of meson exchange in nucleon isobar excitation. Our $pp \to pp\eta$ data analysis suggests a more important contribution term of ρ exchange than that of π exchange.

The WASA/PROMICE *p-p*-bremsstrahlung data were tested for the presence of dibaryons over the mass range from 1900 to 1960 MeV [17]. The resulting upper limits (at a 95% CL) of the dibaryon cross section are 10 and 3 nb at 200 and 310 MeV, respectively. In order to have the possibilities of studying a rare process, the WASA 4π-detector facility is being prepared for experiments. The pellet-target system and such new parts of the Central Detector as a superconducting solenoid, a CsI(Na)-electromagnetic calorimeter, a mini-drift chamber and a plastic scintillator barrel were installed and tested in the set-up in 1998.

New experimental data on the multifragmentation of 10.7 *A* GeV Au nuclei were obtained in the framework of the **EMU01/12** Collaboration. A systematic comparison of the results with those of the ALADIN collaboration (Au at 600 *A* MeV) was made. A systematic discrepancy between the two sets of data was found.

It is shown that allowance for the registration efficiency of two charged fragments at the ALLADIN set-up is needed to compare Au-fragmentation data at high and intermediate energies. Considering the registration efficiency of two charged fragments, one can conclude unambiguously that the IMFs multiplicity at high energies is smaller than that observed at intermediate energies. On the average, the charge of the heaviest fragment in an event at high energies is larger than at intermediate ones.

R&D, construction and laboratory testing of the AD16-H1 amplifier-discriminator for the low-mass drift chambers of the **HADES spectrometer** (to be built at GSI, Darmstadt in the framework of the collaboration of 19 institutes from 9 European countries) was completed at LHE.

A number of stringent requirements were imposed on the device parameters: very small power dissipation, low level of electronic noises and high bandwidth to provide a spatial resolution of better than 100 μm. This development was complicated by the necessity to keep a high channel density (about 2.5 cm^2/channel). The main AD16-H1 parameters are the following: the number of channels is 16, the power dissipation is 30 mW/channel, the rise time is 8 ns, the noises are about 0.3 fC, the double pulse resolution is better than 100 ns, and the dimensions of the PCB multilayer are 9×4 cm^2. Similar octal channel electronics was used to test the full-scale drift chamber prototype (developed at LHE) on a proton beam at GSI. A high spatial resolution of 50 μm was obtained. The first samples of AD16-H1 cards were constructed at the Central Experimental Workshop, JINR.

Two low-mass multilayer drift chambers MDC-2 of the central part of the HADES spectrometer were constructed at LHE. Readout electronics and one of the

low-mass multilayer drift chambers MDC-2 will be tested in February, 1999. After a final beam test of the drift chambers with this electronics, a mass production of 27,000 channels is to start.

STAR. The participation in the construction of the 4π-detector STAR for the collider RHIC at the Brookhaven National Laboratory is the main goal of the project. The LHE group together with IUCF (Indiana) and BNL takes part in the design and construction of the Shower Maximum Detector (SMD) for the End-Cap Electro-Magnetic Calorimeter (EEMC). The EEMC is a crucial part of the STAR detector used to study polarization phenomena at RHIC.

The prototypes of a scintillator shower maximum detector with a light readout system based on Russian photomultipliers and a gaseous shower maximum detector (CDF type) with cathode pad readout were designed, manufactured and tested with a radioactive source and cosmic muons. The design of a 30° module for the gaseous shower maximum detector (CDF-type) with cathode pad readout was completed. The SMD full-scale prototype was manufactured in 1998 at the JINR Workshop and tested at the Alternating Gradient Synchrotron (AGS). The results of these tests were presented at the meeting of the STAR collaboration.

CMS Heavy Ion Program. The study (simulation) of a CMS calorimeter global response to the total transverse energy flow produced in nucleus-nucleus collisions was carried out. One can conclude that

– the CMS HF calorimeter can provide an adequate estimate of the collision impact parameter at a minimum dependence on dynamics details in the central pseudorapidity region (Fig.8) [18];
– the resolution of the CMS calorimeter system allows one to observe the manifestation of jet quenching directly in the total transverse energy differential distributions [19,20];

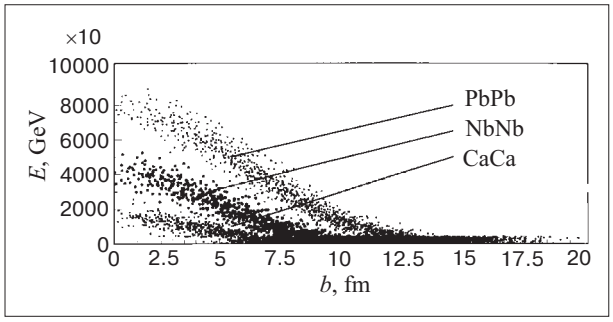


Fig.8. Correlation between the total energy flow per collision E (GeV) in a very forward calorimeter direction and collision impact parameter b (fm). From top to bottom: 10,000 minimum bias Pb-Pb, Nb-Nb and Ca-Ca collisions at a collision energy of 5 TeV/nucleon

– a fast trigger might be applied to select inelastic nucleus-nucleus collisions; the basic idea is to use a signal time coincidence from two very forward calorimeter arms.

ALICE. The design of the dipole magnet for the muon spectrometer was completed. The full-scale coil prototype is under construction. The operation of the prototype on the iron yoke started. A preliminary design of the superconducting (Meissner) magnetic shield to provide the nonmagnetic volume around the beam pipe was performed.

Intensive beam tests of the parallel plate chambers as TOF detectors were performed. A new type of gas mixture was proposed. A movable support for two-dimensional detector scanning in the beam was constructed and delivered to CERN.

WA98. The DST production for the data recorded during the 1995 Pb+Pb experiment at SPS for 158 AGeV was completed in 1998.

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LABORATORY OF PARTICLE PHYSICS

In 1998 the activity of LPP was concentrated in the following main directions:

— current experiments in the field of particle physics and preparation of new experiments;
— R&D of the particle detectors;
— R&D of different acceleration systems and accelerator theories.

RESEARCH ACTIVITIES AT IHEP (PROTVINO)

Investigations are continued in the framework of the **OSCAR** [1] using the **EXCHARM** set-up. The EXCHARM experiment is an extension of the scientific programme carried out at the U-70 accelerator in Protvino and aimed at:

— searching for exotic states in hadron reactions;
— studying of strange and charmed particles hadroproduction, including polarization phenomena;
— investigating of ϕ- and double ϕ-meson production characteristics and OZI rule violation.

In total, more than $5 \cdot 10^8$ neutron-carbon, neutron-aluminium, neutron-copper, and neutron-tungsten interactions have been recorded. Up to now, approximately 80 % of all experimental information has been processed by a reconstruction program. The main physical results obtained in 1998 are based on about 40% of the recorded events and presented bellow:

- A signal of double ϕ-meson production (124 ± 20 events) has been observed (see Fig.1). It leads to the following cross section of the inclusive double ϕ-meson production:

$$\sigma = (12.9 \pm 2.5(\text{stat.}) \pm 1.3(\text{syst.}))\ \mu\text{b/nucl.}$$

- The correlation strength λ and the radius of the K_S^0 emitting source R have been measured from the analysis of $K_S^0 K_S^0$-pair production (9500 events):

$$\lambda = 1.13 \pm 0.34(\text{stat.}) \pm 0.34(\text{syst.}),$$

$$R = (1.01 \pm 0.13(\text{stat.}) \pm 0.18(\text{syst.}))\ \text{fm}.$$

- The helicity matrix element ρ_{00} has been measured using the vector meson $K^*(892)$. The following values based on the unique statistics have been obtained: $\rho_{00} = 0.42 \pm 0.02$ for $K^*(892)^+$ and $\rho_{00} = 0.35 \pm 0.04$ for $K^*(892)^-$. Up to now analogous measurements have been performed with the corresponding precision in $e^+ e^-$ annihilation at the OPAL and DELPHI experiments only.

- Clear signals of hyperons and antihyperons have been observed in the following decay modes:
$\Lambda \to p\pi^- \approx 3.1 \cdot 10^6$ events;
$\Xi^- \to \Lambda\pi^- \approx 2.7 \cdot 10^4$ events;
$\Sigma(1385)^- \to \Lambda\pi^- \approx 1.0 \cdot 10^5$ events;
$\Sigma(1385)^+ \to \Lambda\pi^+ \approx 7.5 \cdot 10^4$ events;
$\Xi(1530)^0 \to \Xi^-\pi^+ \approx 1.0 \cdot 10^3$ events;
$\Omega^- \to \Lambda K^- \approx 200$ events;
$\overline{\Lambda} \to \bar{p}\pi^+ \approx 8.3 \cdot 10^4$ events;
$\overline{\Xi}^+ \to \overline{\Lambda}\pi^+ \approx 1.2 \cdot 10^3$ events;
$\overline{\Sigma}(1385)^+ \to \overline{\Lambda}\pi^+ \approx 1.6 \cdot 10^3$ events;
$\overline{\Sigma}(1385)^- \to \overline{\Lambda}\pi^- \approx 1.2 \cdot 10^3$ events;
$\overline{\Xi}(1530)^- \to \overline{\Xi}^+\pi^- \approx 45$ events; $\overline{\Omega}^+ \to \overline{\Lambda}K^+ \approx 70$ events.
The following values of hyperon inclusive production cross sections in the kinematical region $-1 < X_f < 1$ have been obtained:

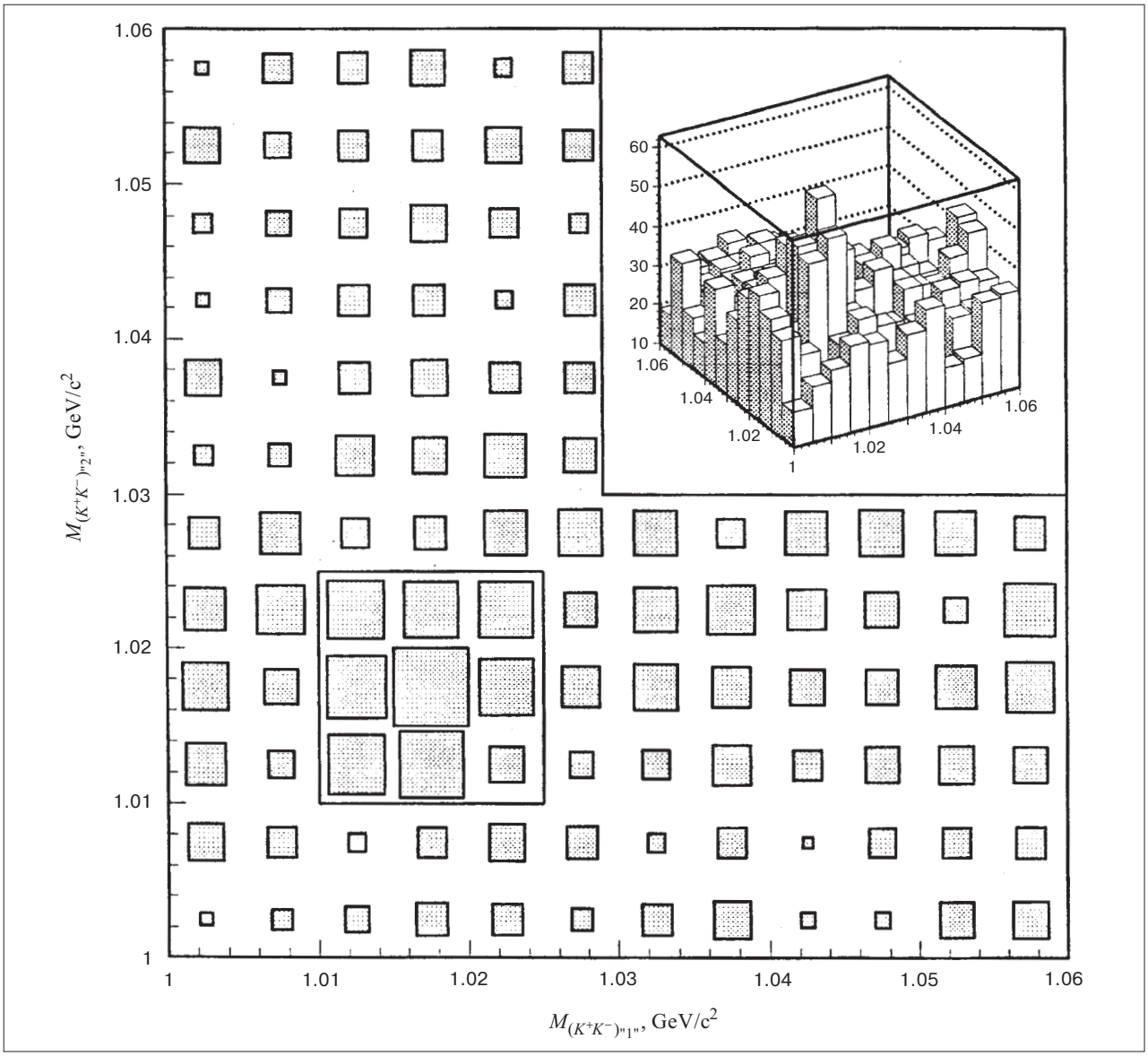

Fig.1. Observation of $\phi\phi$ production signal

$\sigma(\Sigma(1385)^-) = (405 \pm 37)$ μb/nucl.,

$\sigma(\Sigma(1385)^+) = (230 \pm 20)$ μb/nucl.,

$\sigma(\Xi^-) = (83 \pm 7)$ μb/nucl.,

$\sigma(\Xi(1530)^0) = (17 \pm 2)$ μb/nucl.

The main results of the EXCHARM experiment on the measurement of mass difference between Σ_c^0 and Λ_c^+ and partial widths ratio of Λ_c^+ decays into $K^0 p\pi^+\pi^-$ and $\Lambda^0\pi^+\pi^+\pi^-$ have been included into the Review of Particle Physics [2].

The experiment on the search for direct CP-violation in $K \to 3\pi$ decays at the Tagged Neutrino Facility (**TNF**) has been completed [3]. Processing of the obtained data on $K^+ \to \pi^0\pi^0\pi^+$ is in progress.

COOPERATION WITH CERN

The experiment **NA-47 (SMC)** has been completed. During 1998 the SMC finalized the analysis of the virtual photon-proton and virtual photon-deuteron spin asymmetries, $A_1^p(x,Q^2)$ and $A_1^d(x,Q^2)$, measured in the deep inelastic scattering of polarized muons on polarized protons and polarized deuterons at incident muon energies of

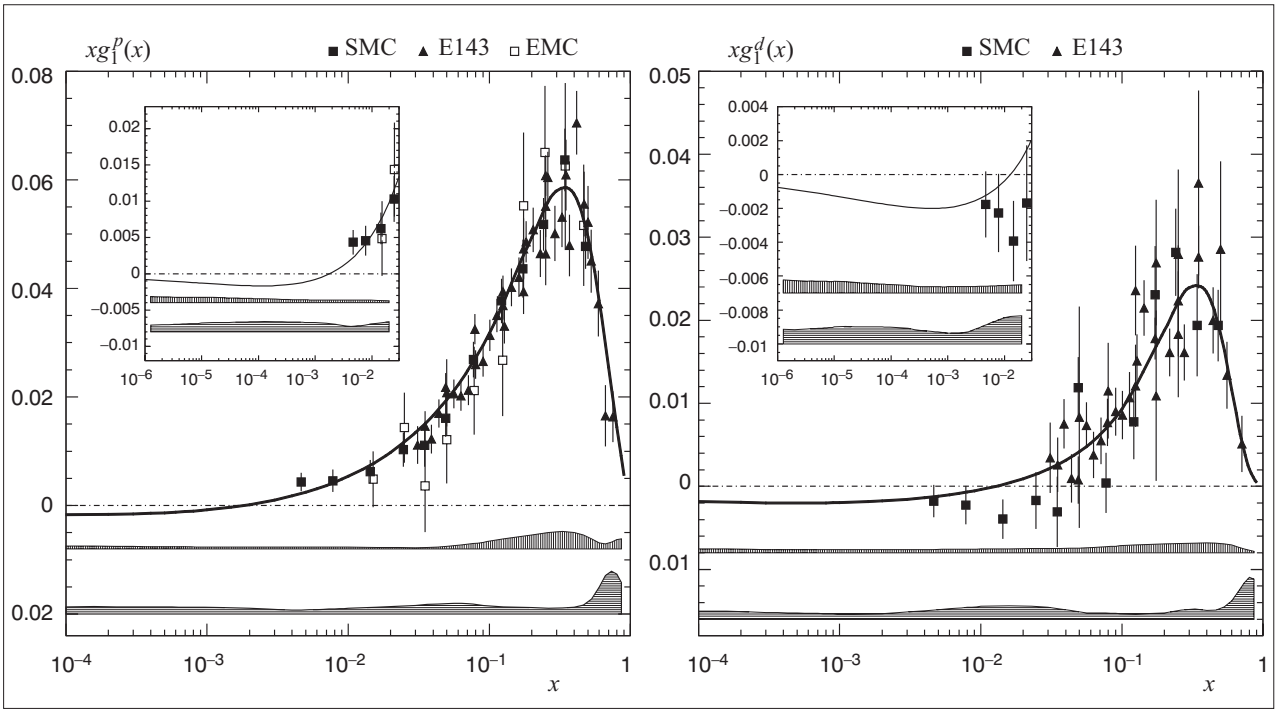

Fig.2. xg_1^p vs. x and xg_1^d vs. x for the world data with QCD fit at $Q^2=5\,\mathrm{GeV}^2$. The low x region is emphasized in the inset. The data points are shown with their statistical errors. The uncertainties of the fit due to experimental systematics and theoretical sources are shown by the vertical and horizontal bands, respectively

100 and 190 GeV. The data samples have been increased to 15.6 million events for A_1^p and 19.0 million events for A_1^d in the extended kinematic range of measurements down to $x=8\cdot10^{-4}$ [4]. The evaluated proton and deuteron spin-dependent structure functions are displayed in Fig.2 after integration over Q^2. The first moments of the spin-dependent structure functions g_1^p, g_1^d, and g_1^n have been evaluated from the SMC results at $Q_0^2=10\ \mathrm{GeV}^2$ and the following values have been obtained:

$$\Gamma_1^p=0.120\pm0.005\pm0.006\pm0.014,$$

$$\Gamma_1^d=0.019\pm0.006\pm0.003\pm0.013,$$

$$\Gamma_1^n=-0.078\pm0.013\pm0.008\pm0.014.$$

The SMC data have been used for a next-to-leading order QCD analysis, which also included data from other experiments [5].

The Bjorken Sum Rule has been tested at $Q_0^2=5\,\mathrm{GeV}^2$ in two different ways: in a global perturbative QCD analysis

$$(\Gamma_1^p-\Gamma_1^n)_{\mathrm{global}}=0.174^{+0.024}_{-0.012}$$

and in the analysis restricted to the non-singlet part of g_1

$$(\Gamma_1^p-\Gamma_1^n)_{\text{non-singlet}}=0.181^{+0.026}_{-0.021}$$

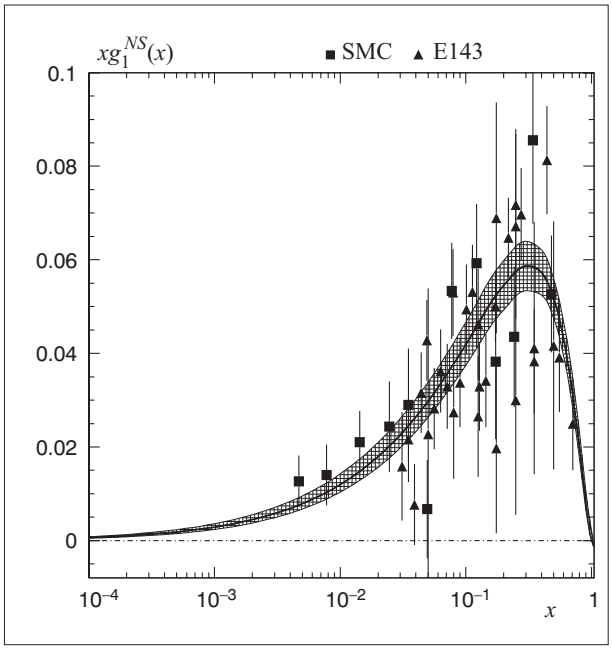

Fig.3. The result of the best fit to xg_1^{NS} together with the data points used in the fit evolved to $Q^2=5\,\mathrm{GeV}^2$. The error bars on the data points show statistical errors only, while the error band around the curve (cross hatch) represents the systematic uncertainty of the fit, including contributions from the experimental systematic and theoretical sources

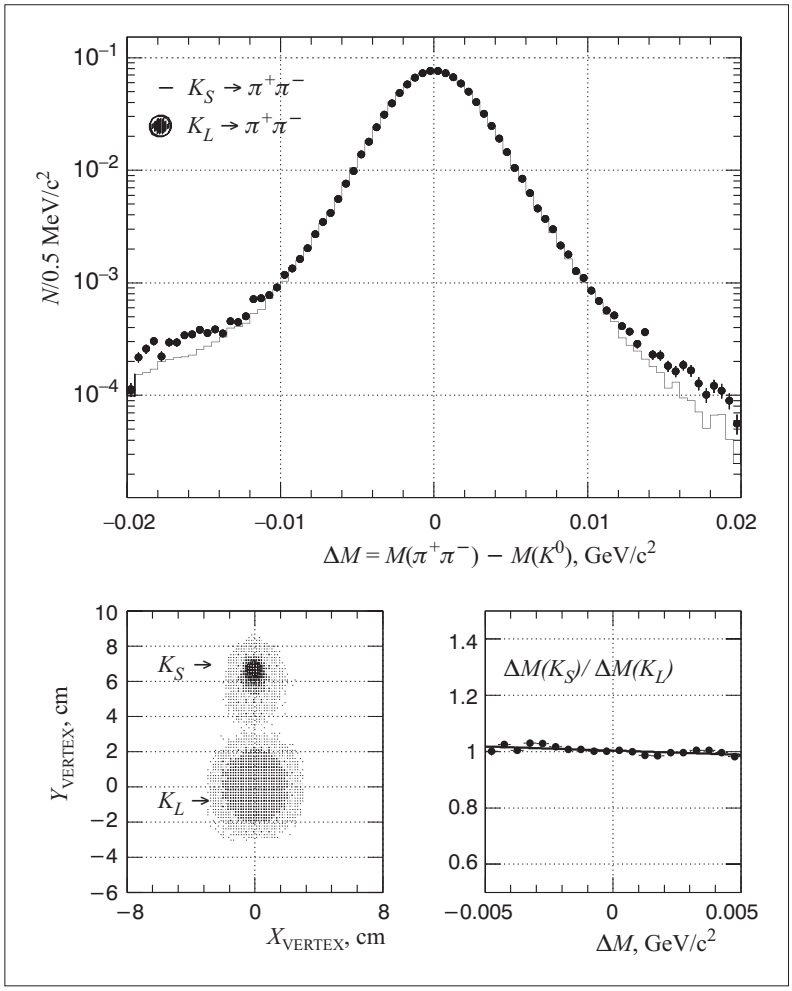

Fig.4. $\pi^+\pi^-$ invariant mass comparison for K_S^0 and K_L^0 decays

performed using a subset of the SMC data. The results are found to be in excellent agreement with the theoretically estimated value

$$(\Gamma_1^p - \Gamma_1^n)_{\mathrm{theor}} = 0.181 \pm 0.003.$$

It was shown that the Ellis–Jaffe sum-rule violation for the proton spin-dependent structure function is confirmed by new data at the level of more than 2σ. The effect of violation is even higher when studied with the deuteron spin-dependent structure function measured by the SMC and reaches 3.7σ. The non-singlet parton distribution function xg_1^{NS} by fitting the data on difference $(g_1^p(x,Q^2) - g_1^n(x,Q^2))$ has been also determined (see Fig.3).

The construction of the **NA-48** detector has been completed for the precision measurement of the ε'/ε ratio in CP-violating decays of K^0 mesons into $\pi^+\pi^-$ and $\pi^0\pi^0$. The expected precision is equal to $2.1 \cdot 10^{-4}$ which exceeds the actually measured precision value by a few times and should clarify the existence of the direct CP-violation. An experimental run has been carried out in 1998 with the participation of a JINR group (440 shifts). Around $2.2 \cdot 10^6$ CP-violating K_L^0 decays into $\pi^0\pi^0$ have been accumulated. The $\pi^+\pi^-$ invariant mass comparison for K_S^0 and K_L^0 decays is shown in Fig.4. The JINR group has contributed to the development of the experiment monitoring: on-line trigger monitoring, level-3 trigger output monitoring, monitoring of various detectors. As a result, this system has become efficiently writing and accessible through the Internet to provide a remote real-time monitoring from the collaborating institutions including JINR. The computing infrastructure has been developed in LPP which enabled the JINR group to perform the complete data analysis at Dubna.

The JINR group has significantly contributed to the analysis of the data recorded in 1997. The collaboration highly appreciated the JINR contribution to the analysis: the results obtained by the JINR group have been included into the presentation on the XXIX International Conference on High Energy Physics (Vancouver, Canada). The JINR group initiated a study of the Λ polarizations and significantly contributed to the obtained results, presented on the International Conference in Genoa (Italy) and sent for publication to the European Physics Journal.

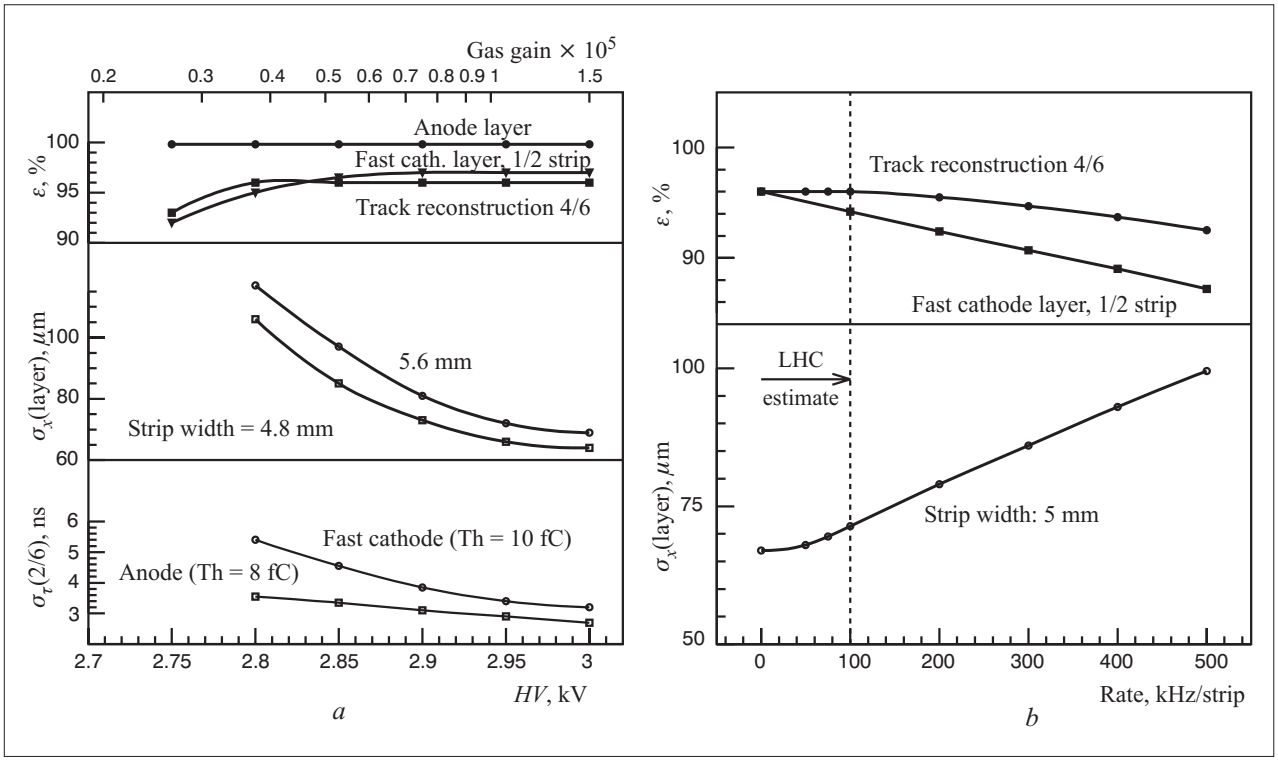

Fig.5. Performance of the ME1/1 CMS (*a*) and rate capability (*b*)

The JINR group also initiated and carried out a special K_{e3}-run to search for the deviation from the $V-A$ theory in K_{e3} decays. A study of rare decays $K_{L\to\mu\mu\gamma}$ and $K_{L\to\pi\mu\nu\gamma}$ [6] has been performed and the results have been published. The obtained value of the ratio $\Gamma(\mu\mu\gamma)/\Gamma(\text{tot.}) = 3.4 \pm 0.6 \pm 0.4$ is included into the Review of Particle Physics [7].

According to the JINR obligations concerning the **ATLAS** set-up, LPP participates in construction of the Liquid Argon Hadronic End-Cap Calorimeter (LArHEC) and subsystems connected to it. The production of the full scale prototype and the module «0» of the front wheel hadronic calorimeter has been completed and shipped to CERN. Having been wired and tested in warm conditions in Dubna, the module was put into the liquid argon cryostat for further investigations at CERN. The properties of the module as the detector for experimental particle physics were investigated using beams of pions, electrons, and muons [8]. Preliminary results of the experimental data analysis have shown the detector performance to satisfy the expectations from the design simulation.

A new approach to the jet reconstruction in LArHEC has been developed by the LPP physicists [9]. The algorithm efficiency in 2 jet reconstruction process exceeds 80 %. In the frame of the ATLAS physics performance TDR preparation, the JINR team has selected the issues of $t\bar{t}$ pair production and single top-quark production for the top-quark physics study. The full simulation of the processes in the ATLAS detector has to be done, and their topology should be carefully studied.

LPP is responsible for the Transition Radiation Tracker (TRT) which is a part of the ATLAS Inner Detector. Its concept entails both a straw tracker of charged particles and a transition radiation detector for electron identification. Different types of the small-scale straw prototypes were studied and developed for the detailed investigation of the straw operation parameters. Some TRT prototype modules were used in the test beam. The test beam study has shown good electron identification and tracking properties.

JINR is participating in the **CMS** Project in the framework of the Russia and Dubna Member States, RDMS CMS Collaboration. The main activity was concentrated on design and integration of the CMS End-Caps. JINR takes the full responsibility for the First Forward Muon Station ME1/1 [10]. The main task was the geometry optimization of the Cathode Strip Chambers (CSC) suitable for mass-production.

The P4 prototype of ME1/1 with the optimized geometry was designed and fabricated in Dubna. This prototype, instrumented with a new front-end electronics, fast cathode trigger and anode readout, was tested at H2 beam at CERN in a strong magnetic field and with differ-

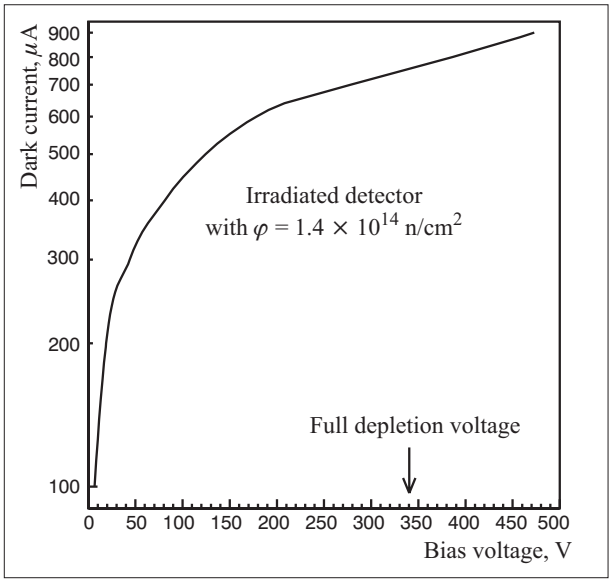

Fig.6. Typical I/V curve for the irradiated detector

ent gas mixtures. The performance of the ME1/1 CSC is summarized in Fig.5a. The CSC can operate at a low gas gain in the range of $(5\div 7)\cdot 10^4$ to avoid the aging effect with sufficient track reconstruction efficiency, spatial resolution and bunch-crossing identification. Summary of ME1/1 CSC rate capability is presented in Fig.5b which shows that for estimated LHC background rate up to 100 kHz per strip the degradation of CSC parameters is quite small.

JINR coordinates the RDMS CMS Collaboration activity on the design and construction of the End-Cap Hadron Calorimeter (ECHC) and is responsible for ECHC absorber. The main result in 1998 of ECHC groups is manufacturing of the preproduction prototype calorimeter. The influence of zero layer on the energy resolution of the combined system (hadron + electromagnetic calorimeters) was studied. Performance of the hadron calorimeter (with and without electromagnetic calorimeter) has been studied on H2 beam. The new Si-detector topology for the CMS preshower has been developed in collaboration with RIMST (Zelenograd) and CERN. Results of the test of many prototypes have confirmed that performance of the ECHC will meet the CMS requirements. The radiation investigations (proton and fast neutron irradiation) of the full-scale detector with a new topology have been performed. A typical detector I/V curve after neutron irradiation with flux of 1.4 $\cdot 10^{14}$ n/cm^2 is shown in Fig.6. The Preshower prototype with a new readout electronics was manufactured and tested at the CERN H4 beam.

Application of QCD and electroweak processes $pp \to \text{jet} + Z(\to \mu^+ \mu^-)$ and $pp \to \text{jet} + \gamma$ for the calibration procedure ''in situ'' of the hadron calorimeters has been studied. The selection criteria for suppression of the main source of misbalance of the transverse momenta of a jet and a direct photon (or Z boson), namely, processes with a large contribution of the initial state gluon radiation were found. It is shown that already during the first year of CMS operation at low luminosity a sufficient calibration of HCAL towers in Barrel, Forward, and End-Cap can be done. The JINR participants have contributed in the development of CMS Heavy Ion Programme [11]. The application of global energy flow distributions to observation of the jet quenching effect in a colliding nuclear matter is simulated. The option of triggering for heavy ion collisions in the CMS is suggested. An overload of the CMS Calorimeters in a heavy ion mode is studied.

The Common Muon and Proton Apparatus for Structure and Spectroscopy, **COMPASS (NA-58)**, has been proposed to perform a series of experiments using the high energy muon and hadron beams. From 1998, COMPASS is included in the JINR topical plan. The main LPP obligations on the construction of the apparatus include: the Hadron Calorimeter (HCAL1) consisting of 500 modules covering the area of 3×4 m^2, participation in construction of the straw tracker and RICH counters. About one half of the modules for the HCAL1 has been transported from JINR to CERN. The Munich University and LPP have been constructing a prototype of the straw tube chamber whose technology has resulted from the R&D performed for the ATLAS Inner Detector. These chambers are needed for the initial set up of COMPASS and will be installed between the SM1 magnet and RICH1 counters.

An important contribution to the COMPASS experiment is expected from the LPP physicists who have a wide experience in studies of deep inelastic scattering of muons from unpolarized and polarized targets in BCDMS, SMC, and HERMES experiments which have made an essential contribution to the contemporary understanding of the quark structure of nucleons. Particularly, the LPP physicists have been working on the software preparation to study the gluon content of the nucleon, for the first time to be measured by COMPASS, on the analysis of the spin-dependent structure functions $g_1(x,Q^2)$ and $g_2(x,Q^2)$ to be measured by COMPASS with a high precision at the highest accessible Q_2, on the development of QCD methods for $g_1(x,Q_2)$, on measurements of Λ polarization produced in deep inelastic scattering, and others. On the technical side, LPP activities include participation in the pattern recognition and reconstruction, RICH simulations, MC-simulations of detectors and processes.

COOPERATION WITH DESY

The Dubna group took part in **HERMES** data taking and is in charge of the Drift Vertex Chambers (DVC) construction and operation. Participation of the Dubna group in HERMES data analysis includes inclusive analysis (measurement of the proton spin structure functions through asymmetry using a new method — cross section separation) and the development of a special MC-simulation of the RICH detector. The measurement of the proton spin structure function $g_1^p\ (x,Q^2)$ in deep-inelastic scattering was performed with the 27.6 GeV longitudinally polarized positron beam at HERA incident on the longitudinally polarized pure hydrogen gas target internal to the storage ring [12]. The kinematic range is $0.021 < x < 0.85$ and $0.8\ \text{GeV}^2 < Q^2 < 20\ \text{GeV}^2$. The HERMES data in comparison with the recent results of other collaborations are shown in Fig.7.

The flavour asymmetry of the light quark sea of the nucleon is determined in the kinematic range $0.02 < x < 0.3$ and $1\ \text{GeV}^2 < Q^2 < 10\ \text{GeV}^2$, for the first time from semi-inclusive deep inelastic scattering [13]. The quantity $(\bar{d}(x) - \bar{u}(x))/(u(x) - d(x))$ is derived from the relationship between the yields of positive and negative pions from unpolarized hydrogen and deuterium targets. The flavor asymmetry $\bar{d} - \bar{u}$ is found to be non-zero and x-dependent, showing an excess of $\bar{d}$ over $\bar{u}$ quarks in the proton (see Fig.8).

The virtual photon absorption cross section differences $(\sigma_{1/2} - \sigma_{3/2})$ for the proton and neutron have been

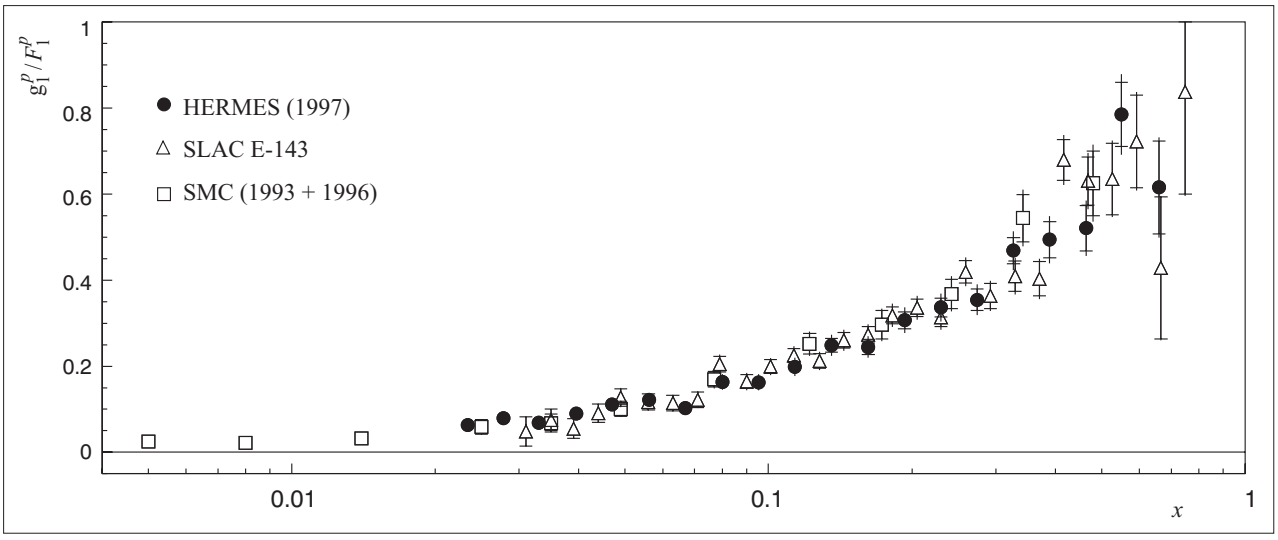

Fig.7. Comparison of the HERMES data with recent results for g_1^p / F_1^p obtained at SLAC (E-143) and CERN (SMC) for $Q^2 > 1\ \text{GeV}^2$

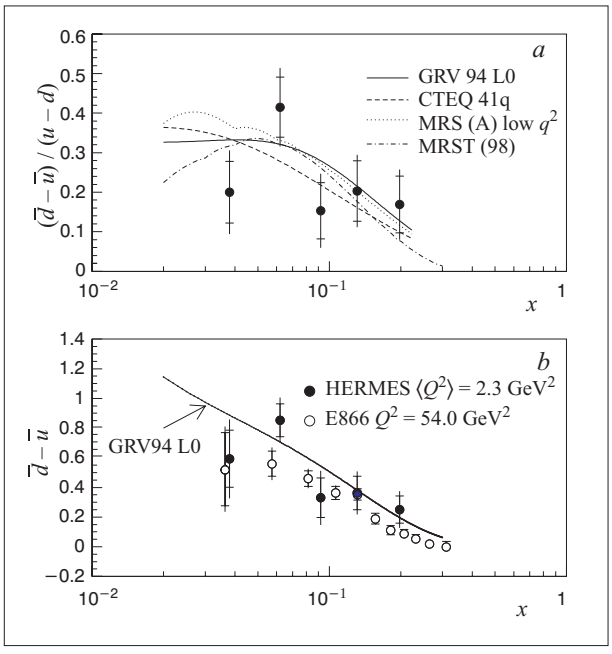

Fig.8. Flavour assymetries as a function of x. Also included are the theoretical parametrizations calculated at the appropriate Q^2 for each x-bin. The open circles represent the E-866 results

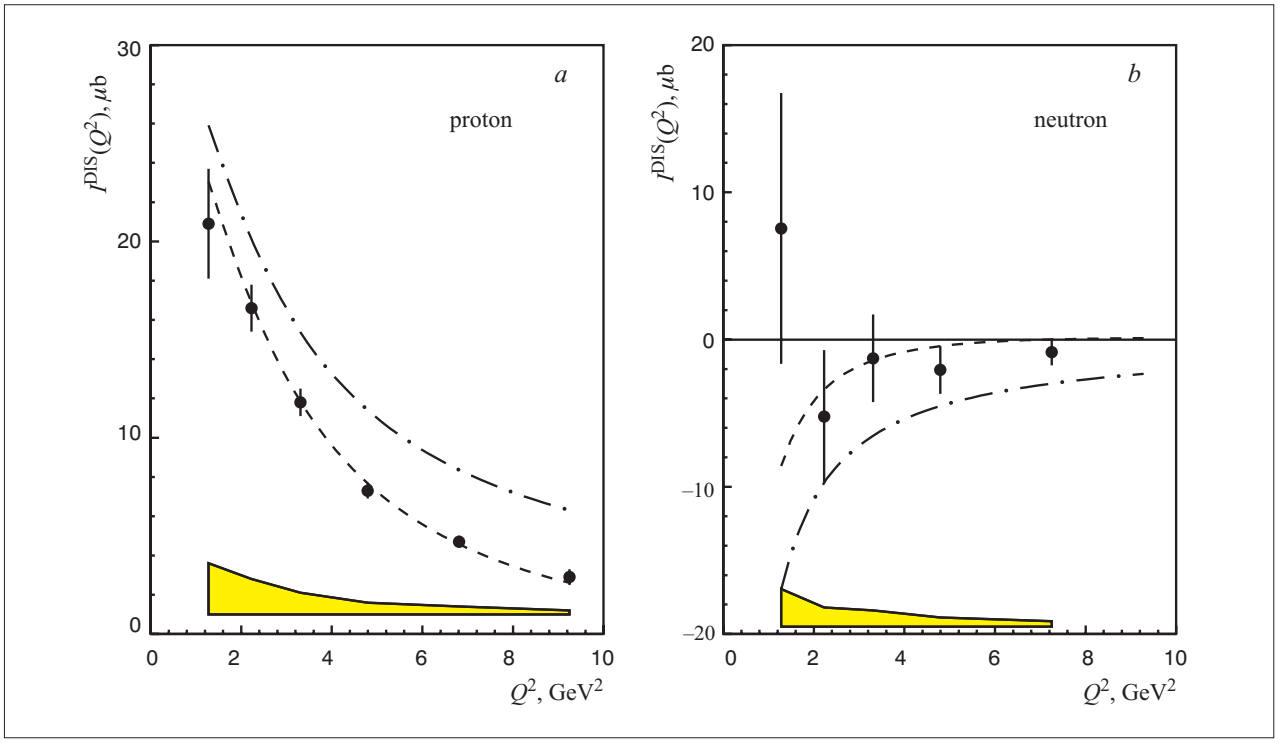

Fig.9. The generalized GDH integral as a function of Q^2 in the deep inelastic region. The points are as measured for the HERMES data in the range $\nu_0 \le \nu \le 23.5$ GeV for proton (a) and neutron (b). The error bars show the statistical uncertainties and the bands represent the systematic uncertainties

determined from measurements of polarized cross section asymmetries in deep-inelastic scattering of 27.5 GeV longitudinally polarized positrons from polarized ^{1}H and ^{3}He internal gas targets. The data were collected in the region above the nucleon resonances in the kinematic range $\nu < 23.5$ GeV and $0.8\ \text{GeV}^2 < Q^2 < 12\ \text{GeV}^2$. For the proton the contribution to the generalized Gerasimov–Drell–Hearn integral was found to be substantial and it must be included for an accurate determination of the full integral [14]. Furthermore, the data are consistent with a QCD next-to-leading order fit based on the previous deep-inelastic scattering data. Therefore the higher twist effects do not appear to be significant (see Figs.9 and 10).

According to the JINR commitments, LPP participates in the construction of the Outer Tracker (OTR) of the **HERA-B** detector designed to search for CP-violation in exclusive B decays, mainly, in the «gold plated» decay mode $B^0 \to J/\Psi K_S^0$. The OTR consists of large area modules of drift tube detectors with cell sizes of 5 and 10 mm and tubes 1 to 4 m long. There are two technologies available for the construction of such modules: honeycomb drift tubes with the cells of hexagonal form and straw drift tubes. LPP participates in manufacturing the modules of the honeycomb drift chambers made of pokalon and in R&D of straw tube chambers made of kapton.

A specialized mass production line has been made at LPP for manufacturing the honeycomb modules from the materials and details supplied from Germany. There are 6 working places on the assembly line to manufacture 6 modules per week. The following specialized testing facilities have been arranged:

– set-up for the radioactive source ^{106}Ru to control the chamber capacity [15];
– set-up for cosmic tests to measure cell efficiency, drift distance-time relation $r(t)$, and spatial resolution [16].

The straw tube modules represent an alternative technology of the OTR [17]. Similarly to the honeycomb modules MC1 and PC, the straw modules 1 and 3 m long have been built. Both modules have been tested in Dubna with the radioactive source. The modules have shown the stable work with a low noise level, negligibly small dark current, and a high efficiency. Along with the module prototypes manufacturing, 5 rolling machines have been fabricated. These machines can provide 200 km of straw tubes production per year.

The LPP physicists also participate in the software development for simulation and data processing in the experiments at HERA-B and, first of all, in geometry description, simulation, digitizing, and reconstruction of the OTR. The detailed study of the reconstruction of muon tracks generated by J/Ψ decays has been performed for different scenarios of the incomplete OTR configuration and full geometry of the muon detector [18]. It has been

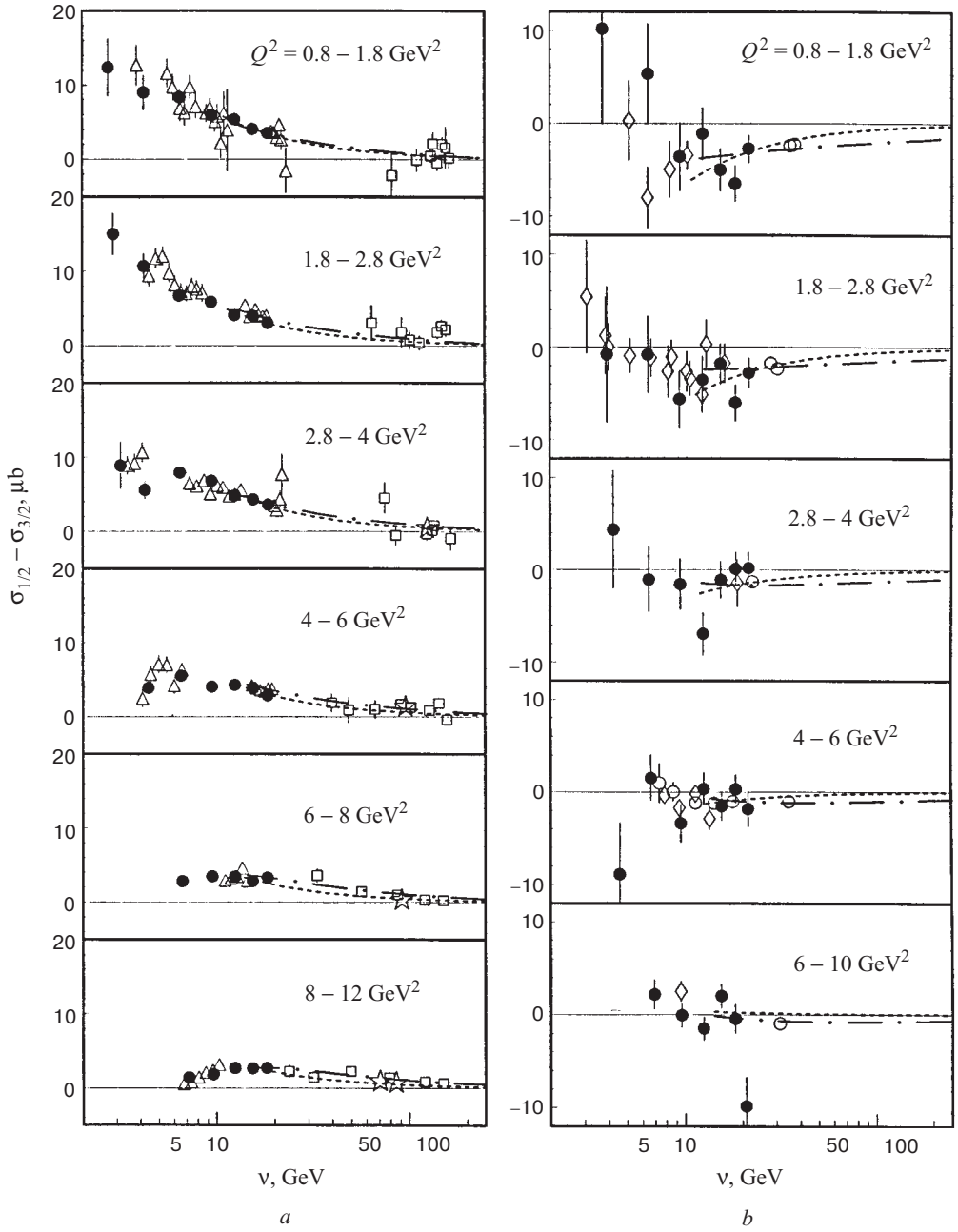

Fig.10. Cross section differences as a function of ν measured in different bins of Q^2 for proton (a) and neutron (b). Filled circles are data from HERMES experiment. Open symbols are values derived from other experiments: stars are for EMC, triangles are for E-154. Only statistical uncertainties are given. The dashed curves are ν^{-1} Regge fits to the HERMES data with $W > 4.5$ GeV. The dash-dotted curves show the next-to-leading order QCD parametrization

shown that even in the case of the OTR incomplete geometry, the reconstruction efficiency for the segments generated by muon seeds in the OTR reaches, at least, 85 % when the «upstream propagation» algorithm gets employed.

The LPP participates in the upgrading of detectors for the **H1** experiment to investigate deep inelastic scattering of electrons on protons, specifically, in the development of Forward Proton Spectrometer (FPS) and the construction of the plug calorimeter. The FPS upgrading includes development, production, and tests of the position-sensitive photomultipliers as readout devices for scintillating fiber hodoscopes at the pair of new horizon-

tal detection stations. The LPP contribution to the forward hadron plug calorimeter consists of:
– construction and tests of the plug calorimeter prototype (copper-scintillator sandwich) in electron and π-meson beams at the Serpukhov accelerator;
– selection and tests of the plug calorimeter readout scheme in the positron beam at the DESY synchrotron;
– production and tests of fine mesh photo-multipliers resistive to magnetic field as readout devices for scintillator layers in the plug calorimeter.

OTHER EXPERIMENTS

LPP takes part in the design and construction of the End-Cap Electro-Magnetic Calorimeter (EEMC) for the 4π-detector STAR for the collider RHIC at the Brookhaven National Laboratory. With this detector JINR will participate in investigations of various asymmetries in polarized *pp* and *pA* collisions in the energy range of $S = 50 - 600$ GeV per nucleon. The durability characteristics of the EEMC design have been studied using analytical methods of calculations which have shown that the construction has a rather high safety margin in terms of the static and short-term dynamic loading. The detailed calculations and analysis of the tension in the lead plates of the calorimeter passive zone have clearly shown that the «slow» deformation processes of the «creeping» type will not affect the EEMC operation and stability during the first 10 years, at least.

The laser optical control system of EEMC has been developed to control the constant operational characteristics of the calorimeter, specifically, the calibration parameters. A special procedure has been developed on the basis of MC-simulation and tested under stand laboratory conditions. It has been shown that the calibration coefficients of the calorimeter are reconstructed with the precision of a few percent. An automized control stand has been manufactured to control the size and shape of the plates.

The most important contribution to the development of the future physics programme at the detector STAR has been made in the field of spin physics, one of the traditional research directions at LPP. The LPP physicists have shown that, under the operation conditions of the detector STAR, an essentially new opportunity is revealed to measure polarization of the particles produced in the multiparticle processes. In this direction, MC-simulations of certain reactions arising from *pp* interactions at 200 GeV have been performed.

The LPP specialists participate in construction of the low-noise neutrino detector **BOREXINO** located at the underground laboratory in Gran Sasso (Italy). The facility prototype has been made to carry out the BOREXINO experiment and necessary tests. The LPP physicists have fulfilled the following works:
— selection of the type of the photo-electron multiplier (PEM) using measurements of the photo-cathode quantum efficiency, one-electron signal time spread out, and amplitude-time characteristics of impulses;
— development and realization of long-term condensing of PEM to operate in the demineralized water;
— calculations, design, and construction of a system to protect the photo-multipliers of the facility prototype against the magnetic field of the Earth;
— development of the vacuum distillation system for a liquid scintillator;
— development of radioactive contamination removal methods which depend on physical and chemical forms of radio-nuclide impurities: extraction by water, vacuum distillation, ion-exchange cleaning, diffusion and microfiltration of dust and bacteria.

ACCELERATION TECHNIQUES

According to the Addendum of 1997 on JINR-CERN collaboration in LHC project, the contribution of JINR is defined to supply electrostatic kickers and amplifiers for LHC transverse oscillation damping systems. At present, based upon calculations and experimental results, the physical motivation for the system has been made, and the general concept to realize this system has been accepted. On this ground, a technical specification of the kicker and amplifier prototypes has been prepared, and amplifier model investigations have been done at the power scale of 1:10. The kicker prototype construction has been developed. Technological experiments with different knots of

the kicker prototype are performed. A full-size stand has been built and equipped to study and adjust the amplifier prototypes. A high voltage source (12 kW/6 A) has been tested with the nominal load. The amplifier prototype has been assembled, and is currently tested at the radial tetrode RS2048 according to the classical scheme version.

In the framework of the project **TESLA**, LPP participates in construction of the vacuum ultra-violet (VUV) free electron laser (FEL) and development and fabrication of bunch-compressors for the test equipment of the TESLA Test Facility (TTF) at DESY. The conceptual designs both for an X-ray FEL and for the second interaction region for γ–γ and γ–e collisions [19] at a Linear Collider have been elaborated. Parameter studies of the VUV FEL at TTF were performed using the time-dependent approach. The FEL schemes providing the complete coherence of radiation from VUV and X-ray FELs have been investigated.

The development of **FEL of the millimetre range** for linear colliders has been continued [20]. An extremely high efficiency of the generator (26 %) has been reached. When optimizing the spectral characteristics of the generator, a single mode generation regime with the bind width of about 0.25 % has been realized. These results have enabled one to conclude that this generator can be used for supplying the high-gradient accelerating structures of the colliders, for instance, the accelerating structure CLIC.

A lot of work has been done on **multicharged ion sources** for hadron accelerators of JINR and CERN [21]. The construction of a chamber designed for studying the methods of intensive-flow particles production under the laser radiation impact on solid targets has been completed. As a part of the ablative laser plasma, the flows of neutral and charged particles have been studied. A new method to define the neutrals concentration by ion beam probing has been worked out. The impact of the external flow injection has been studied on the characteristics of the plasma produced by a discharge in the bottle-neck shaped magnetic field.

A library of computer programs to calculate and optimize the beam transportation lines of the multicharged ions by the full moment method of the distribution function has been set up. The «warm» Low Energy Beam Transportation Line (LEBT) optimization has been done. The maximum of the ion beam conducted current reaches 40-50 mA. Based on superconducting solenoids, a new LEBT version has been proposed to increase the conducted current up to 100 mA and higher. Theoretical models and mathematical methods to storage and generate multicharged ions from ECR sources have been further developed, particularly, in the regime of ion and gas mixtures. For the first time, numerical simulation and experimental data interpretation on the ECR ion sources have been done to estimate the parameters of the ECR plasma electron components jointly with KVI (Groningen, Holland), RIKEN (Japan), and INFN-LNS (Catania).

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LABORATORY OF NUCLEAR PROBLEMS

ELEMENTARY PARTICLE PHYSICS

The **DELPHI** collaboration obtained constraints on the mass of the Higgs boson $M_H = 76^{+85}_{-47}$ GeV [1] on the basis of the full list of electroweak measurements, including direct measurement of the top-quark mass. While electroweak measurements provide indirect constraints on the mass of the Higgs boson, direct searches performed at LEP pushed the lower limit of the Standard-Model Higgs boson mass. At present, the best limit $M_H > 94.1$GeV was obtained from the preliminary analysis of the 1998 DELPHI data collected at 189 GeV [2].

One of the main goals of LEP2 is to perform a precision measurement of the W mass, down to ~ 40 MeV, which requires the use of all possible W-decay channels in the analysis. The distribution of the reconstructed W mass in the $WW \to q\bar{q}q\bar{q}$ channel is shown in Fig.1 [3]. This channel is statistically the most powerful but the mass reconstruction in it is likely to be affected by the final state interaction between the hadrons from different W's — Bose–Einstein correlations and colour reconnection. Potentially, those effects can be large, because the typical separation between the W^+ and W^- in $e^+e^- \to W^+W^-$ events at LEP2 energies is small, ~ 0.1 fm.

At the present level of statistics, however, the experimental data show no evidence for Bose–Einstein correlations for like-sign particles arising from different W's measured at 172 and 183 GeV [4].

One of the main interests in the $\gamma\gamma$ physics is an understanding of the photon structure function behaviour in the wide region of Q^2 and x. Such study will throw light on the parton distributions in the photon, which should be determined experimentally as an input to the perturbative QCD and soft nonperturbative interactions.

The photon structure functions, $F_2^\gamma(x,Q^2)$ and $F_L(x,Q^2)$, can be measured in the reaction $e^+e^- \to e^+e^-\gamma\gamma^* \to e^+e^-X$, where X is a multihadronic system and one of the scattered leptons is observed at a large scattering angle. At present, the main goal is to extend the study to a wider Q^2 region on the basis of LEP2 data. The latest results for $F_2^\gamma(x,Q^2)$ [5] are shown in Figs.2, 3.

In 1998, data taking was accomplished at the facility **NOMAD** (SPS, CERN) built to search for $\nu_\mu \to \nu_\tau$ and $\nu_\mu \to \nu_e$ oscillations. Over the period of four years (1995–1998) about 1.2 million charged-current $\nu_\mu N$ interactions were recorded.

The analysis of ~ 70% of these data allowed new limitations on the oscillation parameters $\sin^2 2\theta_{\mu\tau} < 1.2\cdot10^{-3}$ at 90% C.L. to be established in the region of large Δm^2 ($\Delta m^2 > 1000\,\text{eV}^2$) [6]. The region of Δm^2 and $\sin^2 2\theta_{\mu\tau}$ values where oscillations were not found experimentally is to the right of and above the curve in Fig.4. It is seen that the most rigorous limit ($\sin^2 2\theta_{\mu\tau} < 5\cdot10^{-3}$), earlier established in the E531 ex-

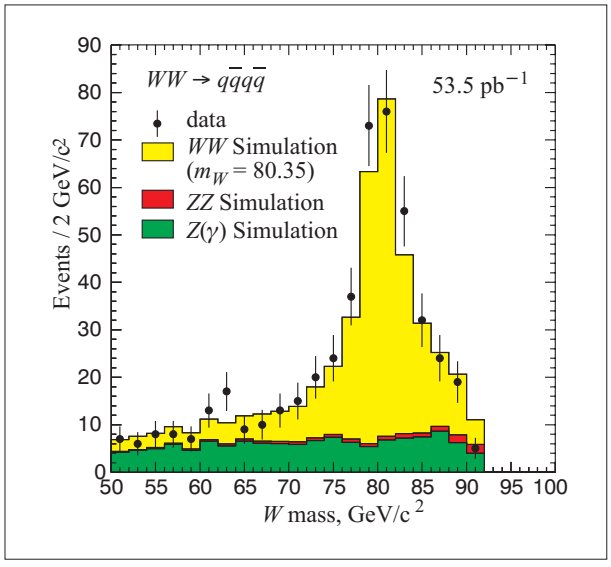

Fig.1. Reconstructed W mass for the $WW \to q\bar{q}q\bar{q}$ candidates (only one mass per event)

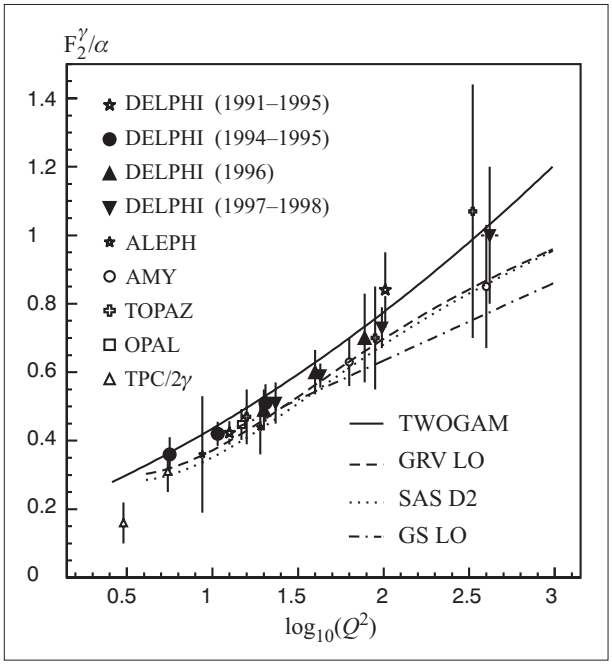

Fig.2. F_2^γ for $0.3 < x < 0.8$

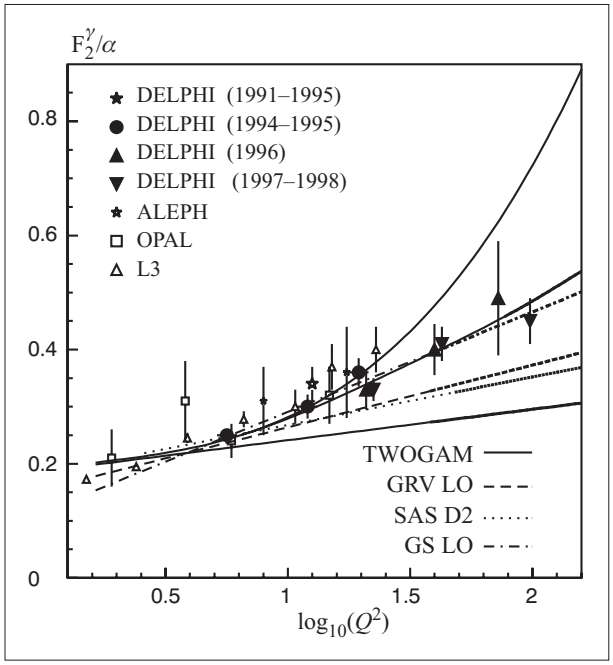

Fig.3. F_2^γ for $0.01 < x < 0.1$

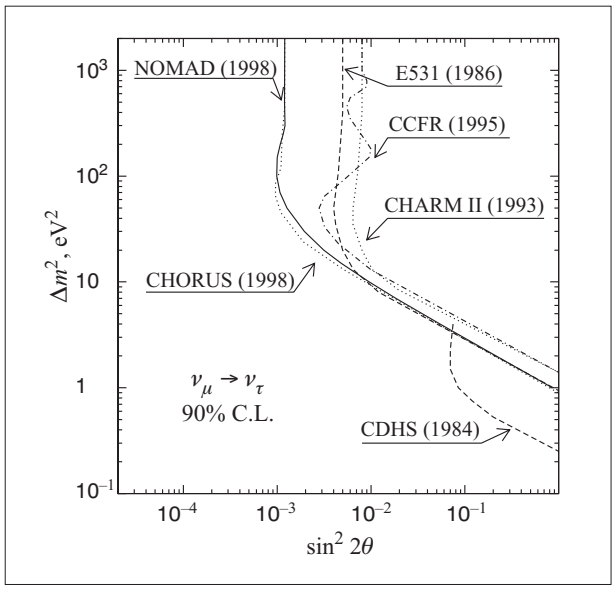

Fig.4. Results from the NOMAD and other experiments in the variables $\Delta m^2 = |m^2_{\nu_\mu} - m^2_{\nu_\tau}|$ and $\sin^2 2\theta$, where θ is the mixing angle. The regions where the oscillations are not found experimentally lie to the right of and above the curves

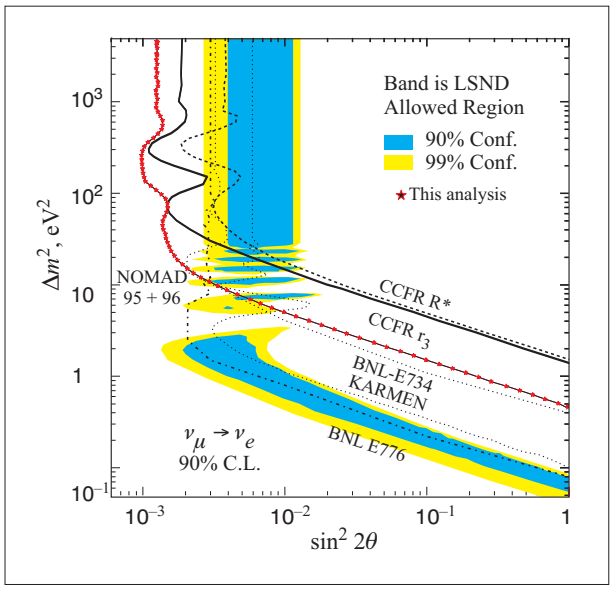

Fig.5. Results from the NOMAD and other experiments in the variables $\Delta m^2 = |m^2_{\nu_\mu} - m^2_{\nu_e}|$ and $\sin^2 2\theta$. The regions where the oscillations are not found experimentally lie to the right of and above the curves

periment at Fermilab, is improved by a factor of more than 4 in the NOMAD experiment.

In the investigation of $\nu_\mu \to \nu_e$ oscillations the processing and analysis of ~ 2700 charged-current $\nu_e N$ interactions (1995–1996 data) are accomplished. A new upper limit on the amplitude of $\nu_\mu \to \nu_e$ oscillations $\sin^2 2\theta_{\mu e} < 1.3 \cdot 10^{-3}$ (90% C.L.) is established in the region $\Delta m^2 > 15\,\text{eV}^2$. Now it is the best result for $\sin^2 2\theta_{\mu e}$ in the world [7].

The values of Δm^2 and $\sin^2 2\theta_{\mu e}$ (according to the data of various experiments) excluded for oscillations lie to the right of and above the curves in Fig.5.

The dashed area shows the region which has been known since 1996 as the region of observation of $\bar{\nu}_\mu \to \bar{\nu}_e$ and $\nu_\mu \to \nu_e$ oscillations in the LSND experiment. As is evident from Fig. 5, the NOMAD results fully overlap the LSND region for $\Delta m^2 > 15\,\mathrm{eV}^2$ and thus disprove the LSND results in this region.

Radical upgrade of the experimental facility constructed by Czech and Dubna specialists for investigation of interactions of polarized neutrons with polarized protons at 16 MeV (project «***NN* scattering**») is nearing completion at the Nuclear Centre of Charles University (Prague).

The purpose of the upgrade is to switch to experiments with polarized deuterons. In 1998 a universal system for target polarization measurement was constructed, a new DAQ system was developed, the data from the experiments with the polarized proton target were fully processed and published [8].

The Project **DIRAC** is aimed at measuring lifetimes of $\pi^+\pi^-$ atoms with an accuracy of 10%, which will allow the model-independent check of the chiral perturbation theory (low-energy limit of QCD) to within 5%.

In 1998 assembly of DIRAC detectors in the beam was accomplished. The first test run was carried out. With the data obtained, the background conditions and performance of the detectors were investigated.

The main goal of the JINR muon group activities in the **ATLAS** project in 1998/99 is completion of the *Muon Chamber* mass-production area at LNP JINR and production of module No. 0. To this end

– a major part of the work for rebuilding the hall, including installation of two cranes, is done;
– a special precise granite table for muon chamber assembling $3.5\times2.5\cdot0.5\ \mathrm{m}^3$ in size with flatness not worse than 8μm over the entire area is constructed in France, delivered to Dubna and installed in the hall;
– in close cooperation with the experts from INOEL (Bucharest, Romania) a modern leak test device based on a radio-frequency mass spectrometer is designed, constructed in Bucharest and installed and tested in LNP JINR;
– on agreement with the authorities of MPI and LMU (Munich, Germany), the common drift tube production and test area will be constructed in LNP JINR;
– as the first step under the above agreement, a $14\times4.5\ \mathrm{m}^2$ clean room is being constructed in the hall.

According to the schedule, the mass production of absorber plates for the *Tile Calorimeter* has been finished by the end of November 1998. To produce absorbers, the effective collaboration with the JINR Member States (Belarus, Slovakia, Czech Republic) has been established. The software for the Slow Control system of Tilecal has been developed and used in the test runs. The assembly areas are prepared for the construction of the 64 modules of Tilecal at JINR, and the mass production of the modules started in December 1998. The algorithm of the hadronic shower reconstruction in the Tilecal has been developed on the basis of test beam results. The achieved performance of the Tilecal meets all requirements of the project.

In the framework of the **COMPASS** project the following results have been obtained. Modification of the present (for the D0 experiment) technology of drift tubes (for the first muon wall) was done to meet CERN safety requirements. For future beam tests 16 tubes (final prototype) were produced. Conceptual design of detector support frames was performed. Multi-Wire Proportional Chambers were inspected for their current condition. Study of new Front-End electronics and measurements of such parameters as drift velocity, signal jitter, efficiency, amplitude characteristics for the proposed gas mixture was performed on a small prototype of the chamber.

The cellular automaton algorithm was implemented in the reconstruction program and was successfully tested. It gives the same or higher efficiency and speed 10 times faster than the standard algorithm used in the program.

One of the main tasks of the LNP group participating in the upgrading of the **CDF** set-up (Tevatron, FNAL) is development of a new system of muon scintillation trigger counters (Muon Scintillator counters Upgrade, MSU).

In 1998 the prototypes of scintillator counters for four subsystems of MSU (with 4 typical sizes 180–310 sm long) were produced. A new light collection system, proposed and developed at JINR together with colleagues from Pisa, Kharkov, Bratislava and Udine, was implemented in the counters. Tests with cosmic muons show that the counter characteristics meet all the project requirements.

The main goal of the JINR group participation in the **D0** (FNAL, Tevatron) upgrade project is design and construction of the muon track detector, based on mini-drift tubes (MDT), together with appropriate front-end electronics. The detector includes 6300 tubes and 48000 channels of front-end electronics.

In 1998 the optimal detector design was found and mass production of the MDT started in the JINR Workshop. The 8-channel amplifier and 8-channel discriminator for the D0 were designed together with NIINP BSU (Minsk) and Production Firm «Integral» (Minsk). The mass production of the electronics also started in 1998.

RELATIVISTIC NUCLEAR PHYSICS

The understanding of the copious emission of the intermediate-mass fragments (IMF) from highly excited nuclei is a major topic in the current nuclear physics research under the **FASA** project. This process gives access to the behaviour of nuclear matter at low densities and nuclear liquid-gas phase transition.

In 1998, the efforts were focused on the detailed study of IMF energy spectra. For thermal multifragmen-

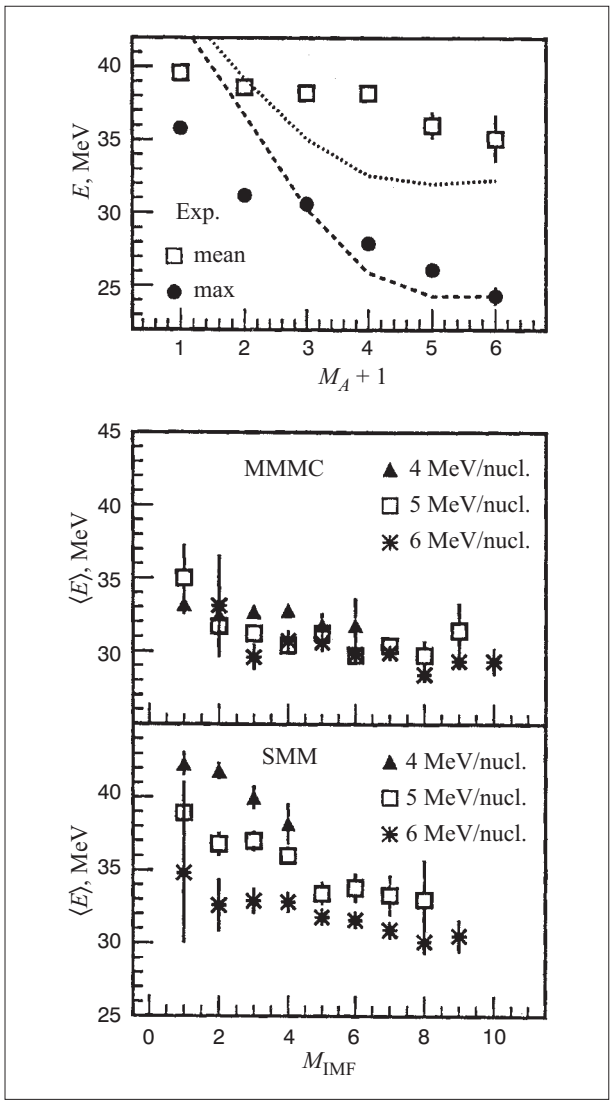

Fig. 6. Mean energy (and E_{max}) of carbon isotopes, emitted in p(8.1 GeV)+Au collisions, as a function of the IMF multiplicity. The upper part gives the experimental results (symbols). The lines exhibit the results of the INC+Expansion+SMM calculation for E_{max} (dashed) and $\langle E \rangle$ (dotted), folded with the experimental filter. The middle and lower parts show the results of the MMMC and SMM calculations of decaying A=160 nuclei at *fixed* excitation energies with values as indicated

tion. It allows one to trace back the geometry and the time evolution at break-up. In collisions of 8.1 GeV protons with gold, it is found that for a given fragment (carbon in Fig.6) the maxima of the energy spectra (as well as the mean energy) decrease with increasing number of emitted fragments. This could indicate a variation in density at break-up. But the observed behaviour of the energy spectra has a natural explanation in the kinematic redistribution of the fragment energy with increasing disintegration of the system as predicted by the statistical models at fixed density [9].

The upgrading of the FASA set-up is now in progress; the new triggering system consisting of 25 ΔE(gas)– E(SiAu) telescopes considerably increases the set-up efficiency. It also improves the conditions for measuring the small-angle correlations coincident fragments, which is important for detailed study of the process time scale.

tation they are mainly determined by Coulomb interac-

LOW AND INTERMEDIATE ENERGY PHYSICS

A precise measurement of the probability of the pion β decay, $\pi^+ \to \pi^0 e^+ \nu_e$, allows a rigorous test of charged quark-lepton current universality, unitarity of Cabbibo–Kobayashi–Maskawa mixing matrix and search for the possible manifestation of «new physics» phenomena beyond the Standard Model. The goal of the **PIBETA** experiment is to improve the accuracy from 4% to 0.5% at the first stage.

In 1998, the thin-walled cylindrical proportional chambers and low-noise cathode strip electronics were developed and manufactured at LNP with a new original technology, which ensures higher reliability and precision of the chambers.

The whole PIBETA set-up was completely assembled and successfully tested on the pion beam at PSI. The statistics obtained during these tests already allows the accuracy of the pion beta-decay rate to be improved.

The **Muonium-Antimuonium** international collaboration has finished an experiment on the search for the $M\overline{M}$ conversion. This process violates the lepton flavour conservation law and is forbidden in the Standard Model (SM) but takes place in many theories beyond the SM.

In the experiment $5.7 \cdot 10^{10}$ muonium atoms were observed in the fiducial volume. There was one event which passed all required criteria. The expected background is 1.7 events. The data obtained result in an upper limit for the $M\overline{M}$ conversion probability $P_{M\overline{M}} \le 2.3 \cdot 10^{-10}$. The corresponding upper limit for the $M\overline{M}$ conversion coupling constant is $G_{M\overline{M}} \le 3 \cdot 10^{-3} G_F$, where G_F is the Fermi constant (Fig.7).

This new $G_{M\overline{M}}$ value allows one to rule out certain models and to set new limits on the parameters of several other ones.

The present set-up has come close to its limit and the collaboration decided to stop the experiment.

The $(\pi^+, \pi^\pm p)$ reactions on ^{3}H, ^{4}He, ^{6}Li, and ^{7}Li and the $(n,2p)$ reaction on ^{3}He and ^{4}He in quasi-free kinematics have been studied (project **Meson**). A signature attributable to pre-existing Δ components of the ground state wave function is observed. The experiments were performed at LANL, Los Alamos, USA. To continue this research a new two-arm magnetic spectrometer with permanent magnets was built.

Inclusive energy spectra of p, d, t and multiplicities from the reaction ^{14}N(Ag, X), $X = p,d,t$ at E/A = 52 MeV were measured. The experimental data are compared with the Dubna version of the Cascade Model and are analyzed

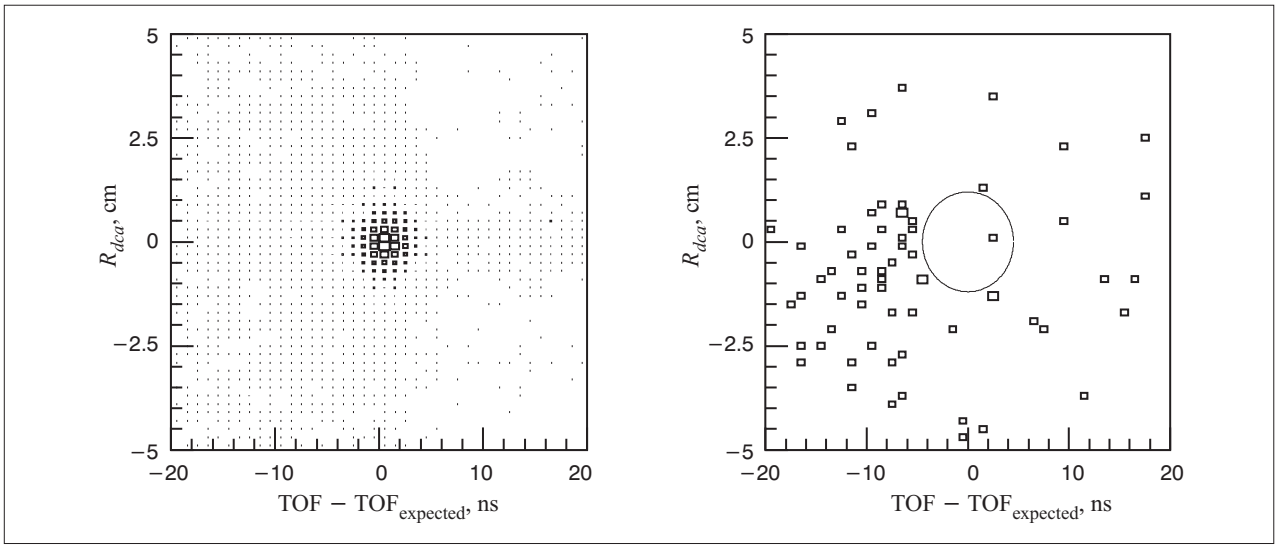

Fig.7. The distribution of the distance of the closest approach (R_{dca}) between the track from an energetic particle in the magnetic spectrometer and the back projection of the position on the MCP detector versus the time of flight (TOF) of the atomic shell particle for a muonium measurement (left) and for all data recorded in 1996 while searching for antimuonium (right). One single event falls within 3σ-region of the expected TOF and R_{dca} which is indicated by the ellipse. The events concentrated at early times and small R_{dca} correspond to a background signal from the allowed decay $\mu \to 3e + 2\nu$

in the framework of the moving source model. The experiment was performed at U-400M at JINR FLNR.

In 1998, the spectrometer **ANKE** started its physical operation at the internal proton beam of the synchrotron COSY (Jülich, BRD). The calibration of the spectrometer was performed by means of registration (in the side detector) of pions from the processes $pp \to \pi^+ + d$ and $pp \to \pi^+ + p + n$ in coincidence with deuterons and protons measured in the forward detector. The data allow investigation of the probability of the pion production in definite isospin states of the nucleon pair with small relative momenta. The measurement of the double differential cross sections of subthreshold K^+ production in pC interactions was started. All the measurements were carried out with carbon and polyethylene targets in a form of thin films inserted in the synchrotron beam.

The collaboration **DUBTO** is completing the experimental apparatus for studying pion interactions with light nuclei at low energies. The experimental set-up is based on the JINR streamer spectrometer STREAMER, serving both as a vertex detector and a track detector, and is equipped with CCD telecameras for recording the images of nuclear events occurring inside the gas volume of the streamer chamber. With the exception of the streamer chamber, no available apparatus can be used for measuring energies down to ~ 1 MeV of charged secondaries, such as protons and light nuclei, produced in reactions occurring inside gas targets.

STREAMER has been upgraded and will be completed when certain modifications of the triggering system and the chamber geometry are implemented. Runs have been performed and video-images of nuclear events have been obtained; first simulation programs based on the GEANT package of CERN have been created.

The measurements of the muon capture rates in ^{84}Kr and ^{136}Xe (project **MUON**) were carried out at PNPI (Gatchina) with LNP instrumentation and isotopes [10]. The measurements of the muon capture rates in ^{40}Ar and ^{132}Xe were performed with the JINR Phasotron. The lifetime of the negative muon in the 1S-state in the ^{132}Xe isotope was measured for the first time ($\tau(^{132}\mathrm{Xe}) = 101.7 \pm 1.7$ ns).

A more precise value for the lifetime of μ^- in the isotope ^{40}Ar was obtained: $\tau(^{40}\mathrm{Ar}) = 568 \pm 6$ ns.

In investigations of the depolarization of negative muons in silicon the following phenomena were first observed with the μSR-technique: a) at temperatures below 50 K the temperature dependence of the muon spin relaxation rate is well approximated by the power function $\lambda = C \cdot T^q$ irrespective of the type and concentration of doping impurity; b) a shift in the frequency of the muon spin precession in the external magnetic field transverse to the muon spin is observed for the silicon samples doped with phosphorus, aluminium and antimony, the value of the shift is about $(7 \div 8) \cdot 10^{-3}$ at 15 K; c) for the *n*-type silicon samples with impurity concentrations about $2 \cdot 10^{18}$ cm^{-3} a damped and undamped components of the residual polarization are observed. The frequency of the muon spin precession on the undamped component corresponds to the free muon spin one, i.e., the acceptor centre is in the ionized (diamagnetic) state.

Based on the experimental results the relaxation rate of the magnetic moment of the electron shell of the acceptor and the rate of the transition of the acceptor centre from the neutral (paramagnetic) to the ionized (diamagnetic) state are found. Unlike other methods, the

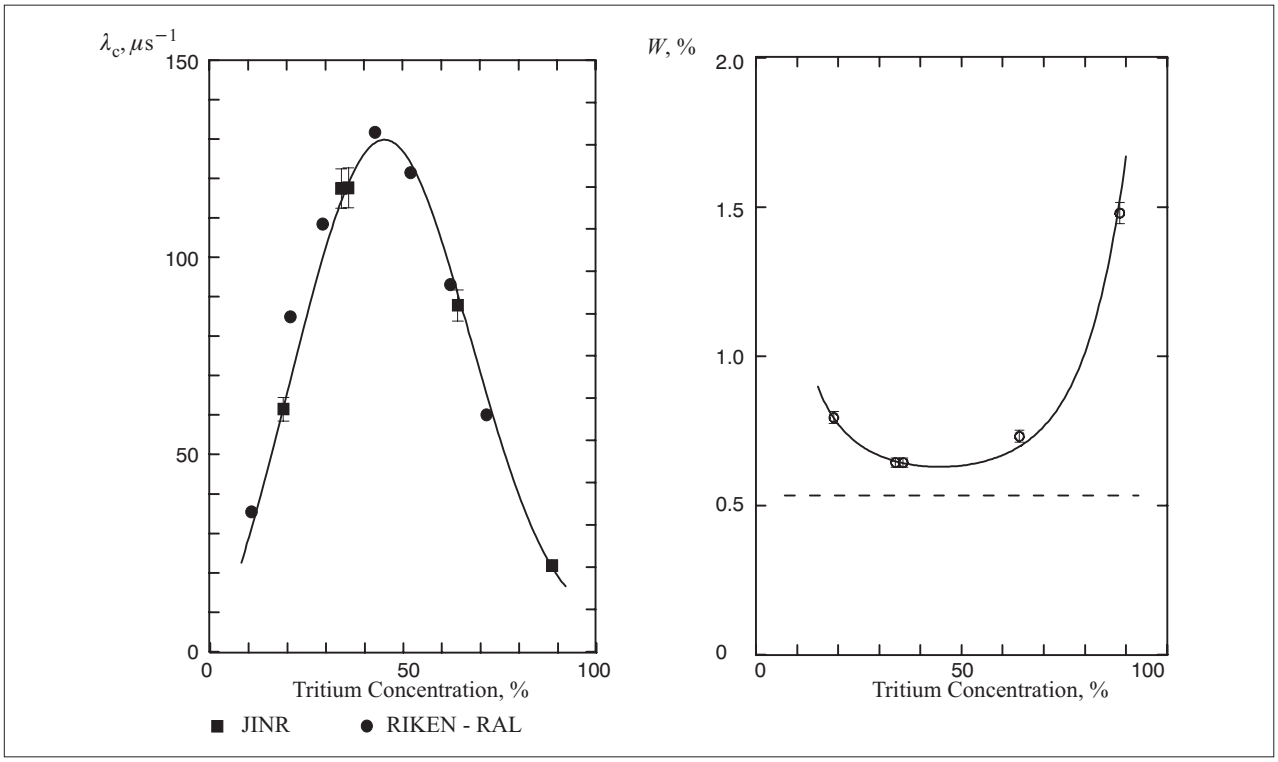

Fig.8. Normalized cycling rates and effective muon loss factors as functions of tritium concentration. Data obtianed are shown by squares

μ^- SR-technique allows one to observe acceptor centres both in ionized and in neutral states.

The study of the systems with «heavy electrons» was continued. The $Ce_3Pd_{20}Si_6$ compound is one of the heaviest electron systems. At PSI the measurements were performed to gain information about magnetic ordering at low temperatures. Strong longitudinal fields applied at 0.04 K did not reveal any field dependence of the depolarization rate parameter σ above 0.5T: $\sigma(0.5\text{T}) \approx \sigma(2.5\text{T}) = 0.18\,\mu s^{-1}$. Below 0.4 K the increase of the depolarization rate represents the development of quasi-static ordering of magnetic moments of electronic origin supposedly random oriented.

The theoretical calculations show that in this compound, Ce moments may undergo frustration, which could explain such «spin-glass» behaviour. The absence of the recovery is usually caused by fluctuations of the magnetic moments. In 1998, an investigation of the OZI rule violation in the ϕ and $f_2'(1525)$ meson production in antiproton annihilation at rest was completed within the framework of the **OBELIX** experiment.

The analysis of the $\bar{p}p \to K^+K^-\eta$ reaction for annihilation in the liquid and gaseous targets has demonstrated that the yield of the $\phi\eta$ channel decreases with increasing hydrogen pressure [11]. This dependence is just opposite to the $\phi\pi^0$ one. There is no theoretical explanation of this peculiar property of the $\phi\eta$ channel so far. The spin-parity analysis of the $\bar{p}p \to K^+K^-\pi^0$ reaction in antiproton annihilations at rest for three hydrogen target densities demonstrates strong dependence of the $\phi\pi^0$ production on the initial $\bar{p}p$ quantum numbers [12]. Significant violation of the OZI rule for tensor meson production from *P*-wave annihilation was also observed.

The purpose of the experiment **DISTO** is to measure the differential cross sections, and the spin observables P_Λ, p_{Σ^0}, A_Y, and D_{YY} for the reactions $pp \to pK^+\Lambda$, $pp \to pK^+\Sigma^0$, and $pp \to pK^+Y^*$ at energies between the reaction thresholds and the maximum attainable energy at SATURNE (about 2.9 GeV) [13]. The measurement of spin observables at SATURNE provides a way to investigate the relationship between the fundamental QCD approach and the boson-exchange theories.

The experimental set-up was placed in the proton beam of the accelerator SATURNE and included a liquid-hydrogen target and various detectors: plastic scintillating fiber chambers, multiwire chambers, a two-layer scintillation hodoscope, and a Cherenkov counter.

An essential part of the DISTO apparatus comprises 4 multiwire proportional chambers that were made in Dubna and transported to Saclay. Runs at the accelerator SATURNE were initiated in 1996 and completed in 1997, while data processing started in 1998.

In Dubna, in 1996–1998, development of data processing based on utilization of cellular automata and neural networks was under way at the same time as preparation of the equipment.

A novel and effective method of the experimental Muon Catalyzed Fusion (MCF) investigations was realized. The collaboration has created the set-up **TRITON** to carry out a wide range of investigations on MCF in mixtures of hydrogen isotopes. A high efficiency of the

installation, a low level of the neutron background in the laboratory, stable operation of the JINR Phasotron provided favourable conditions for the investigations. In 1998, with the set-up, the direct measurements of the coefficient of sticking of muons to helium and of the neutron yield in dense double and triple hydrogen isotopes mixtures were carried out for the first time. The first measurements of the dependence of the cycling rate (neutron yield) upon the temperature, pressure (density) and concentration of isotopes have been also performed (Fig. 8).

Another «Beyond-the-Standard-Model» project is **NEMO-3**. This spectrometer, being under construction now, is a next generation detector of the double beta decay. In 1998, significant part of the NEMO-3 spectrometer was built and equipped with tracking and calorimeter detectors (14 of the required 20 sectors). All the mechanical components (high-purity copper and iron walls, carrying steel frame and passive iron shielding), as well as 6-ton plastic scintillators, part of readout electronics, and cabling were produced at JINR during 1997–1998.

At the end of 1998, the first sector was completely finished and transported to the Modane Underground Laboratory (Frejus tunnel, France), where the experiment will take place. In 1999, the work will be continued. In parallel, the JINR software group designed a new tracking algorithm based on the «elastic net» method and «neural networks». In order to visualize tracking information, the corresponding software packages are also under development.

According to the current schedule, mounting of the whole NEMO-3 spectrometer will be finished in January 2000. Then it is planned to start measurements with 7 kg of enriched ^{100}Mo, 1 kg of ^{82}Se, ^{116}Cd and some other isotopes, as well as with the corresponding amounts of natural samples in order to investigate different modes of the double beta decay and background simultaneously.

The low-background, high-sensitivity multidetector spectrometer **TGV** is used to study the double beta decay of ^{48}Ca. An additional decrease in the background is achieved with the neutron shielding.

The preliminary processing of the experimental data accumulated for 7070 hours was performed which permits one to distinguish β particles from γ rays by means of measuring the rise time of the detector pulses. The value $T_{1/2} = 4(2)\cdot 10^{19}$ years for the two-neutrino double beta decay of ^{48}Ca was obtained from the analysis of the high-energy region of the final spectrum and the Monte Carlo simulations.

The final results for this decay mode will be obtained after completion of the background measurements (with and without sources with natural Ca) and test measurements (with sources of a mixture of natural Ca and a traced amount of the known α-, β- and γ activities).

The preliminary half-life estimation $T_{1/2} > 1.1\cdot 10^{21}$ years (90% C.L.) for the neutrinoless double beta decay mode of ^{48}Ca was obtained.

Radioactive decay radiation spectra of some short-lived nuclei have been investigated with modern spectrometers at the ISOL complex **YASNAPP-2**. The data allowed us to propose for the first time or to refine the excitation state schemes of daughter nuclei that are transition (from spherical to strongly deformed) ones in the deformation jump region ($N \approx 88$).

The structure of the strength function β^+ (EC) of the decay of the near-magic nucleus ^{147g}Tb has been studied experimentally and theoretically [14]. The strength function has a resonance character with the principal maximum at 2.0 MeV and allows a satisfactory description by the model (s.p.+core). Evidence is found for the F-forbidden 45.6-MeV transition between the $^{152m}\mathrm{Eu}(0^-, 9.3\,\mathrm{h})$ and $^{152g}\mathrm{Eu}(3^-)$ states with noticeably different nuclear shapes. The study of the decay of short-lived isobaric nuclei with A=157 and 159 and long-lived ^{155,157}Dy nuclei resulted in an appreciably refined behaviour pattern for single-particle and collective levels of the daughter nuclei of thulium (Z=69), holmium (Z=67), terbium (Z=65) with the neutron number around N=88–90. Some levels of these nuclei are fragmented even at low energies. Their rotational bands are strongly mixed. Earlier unknown isomers ^{156m}Ho (6 min) and ^{157m}Tm (1.6 s) are identified.

Investigation of the ^{221}Fr decay is finished. More accurate and reliable data on the ^{221}Fr gamma spectra are obtained. It is established the nine gamma transitions were earlier ascribed to the ^{221}Fr decay by mistake. Five new gamma transitions are found. The data on intensities of gamma rays are refined. Populations of the ^{217}At levels at the ^{221}Fr decay are found from the quantitative analysis of alpha-gamma coincidences. The total intensities of the 96.3-, 117.8-, 150.2-, and 171.8-keV gamma transitions, used to calculate total internal conversion coefficients, are measured and multipolarities are established.

A highly effective technique of searching for short-lived isomers (from a few nanoseconds to tens of microseconds) with the use of a single-crystal scintillation time spectrometer is developed. Based on this technique, a two-detector four-dimensional (E1–E2–E3–T) spectrometer of triple coincidences is built. Investigation of proton-nucleus reactions on separated tin isotopes by the induced activity method is being carried out in cooperation with Yerevan State University (Armenia) [15]. The purpose is to reveal the effect of the nucleon composition of target product nuclei on the yields of residual nuclei. Experiments [15] on transmutation of radioactive wastes are being continued in cooperation with the scientists from LHE and Marburg University (FRG).

The neutrino oscillations within the minimal supersymmetric standard model with R-parity violation were considered. The Super-Kamiokande atmospheric neutrino data are used to set limits on the bilinear R-parity violating terms. These very stringent limits are out of reach of the other experiments at present and in the near future [17].

APPLIED SCIENTIFIC RESEARCH

In 1998, under the development of the technology for production of small silicon dioxide **aerogel** samples with a 1-litre autoclave, a high transparency of the samples was reached. The optimization of the drying of the samples reduced the drying time and increased the quality of the samples. The yield of light from the samples increased by 25%.

The 37-litre autoclave was put into operation. The autoclave allows production of large (up to 200 mm in diameter) samples of silicon dioxide aerogel and creation of Cherenkov aerogel counters with a working surface up to several squared meters.

Under project the **Cyclotron** work on preparion and commissioning of the Electron Model of Ring Cyclotron was done in order to study the closed orbit expansion effect. Preliminary design of the high-current injector cyclotron was fulfilled. The elements of the injection system were computed. The design work related to the magnetic and radiofrequency systems of the isotope cyclotron is being finished.

In 1998, the layout and parameters of the extraction system for the cyclotron VINČY (Belgrade, Yugoslavia) were computed. Calculations of internal beam dynamics were performed. With the magnetic field measurements the distributions of magnetic fields intended for various types of ions and their energies were created. A computer model of the cyclotron magnetic field was built.

Computations related to the cyclotron U-120M (Prague) were fulfilled. Influence of the magnetic and electric field on particle dynamics in the centre of the cyclotron was studied for two variants of the centre geometry. Theoretical and experimental investigations intended to increase a negative-ion current in the central region of the cyclotron were performed.

Work related to production of the *C*-electrode with an increased aperture was continuing. Two vacuum chambers with pole tips for meson channels of the STREAMER set-up were made.

In 1998, under the project of physical and technical maintenance of biomedical and clinical investigations on **radiation therapy** with beams of the JINR Phasotron, the development of the apparatus on-line with a computer were carried out for simultaneous scanning of a tumour with a wide proton beam. To improve the accuracy of the clinical dosimetry of the medical proton beams investigations of the sensitivity of different types of detectors were carried out [18].

The method of forming of a spread Bragg peak is developed with the automatic system for simultaneous scanning irradiation. Electronic units for measurement and control of doze distribution are developed and implemented.

The most important achievement in the organization of wide treatment of oncological patients — a conversion of one of the Dubna hospital buildings to a radiological department for 30 patients — was completed owing to the grant of Russian Ministry for Atomic Energy. The department will work under the authority of the Dubna hospital, and the scientific accompaniment of the hadron radiotherapy with the JINR Phasotron medical beams will be carried out by the Medical Radiological Scientific Centre (Obninsk) according to the agreement between JINR, MRSC and the Dubna hospital.

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FLEROV LABORATORY OF NUCLEAR REACTIONS

During past 5 years a unique investigation base with modern set-ups (kinematic separators, 4π spectrometers of charged particles, detectors of neutrons and γ quanta) has been developed at the Flerov Laboratory of Nuclear Reactions on the basis of the U-400 and U-400M isochronous cyclotrons equipped with ECR-ion sources. Due to the high efficiency in producing ^{48}Ca beams a world-level competitive programme on the superheavy elements synthesis has been started.

The U-400 and U-400M cyclotrons running time in 1998 is close to 6,000 hours foreseen for this year. All this opened wide possibilities for performing new experiments in the low- and medium-energy range.

FLNR carries out research in heavy ion physics in three main directions. They include experiments with ion beams of stable and radioactive isotopes on the heavy and exotic nuclei synthesis, the nuclear reactions study, acceleration technology, as well as heavy ion interaction with matter and applied research.

The research activities were represented by three themes, grouped in 14 projects, and were performed in a wide international collaboration using both the accelerators of the Laboratory and other scientific centres.

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

Synthesis of New Elements

An important achievement of the Laboratory is the experimental confirmation of a sharp increase in the superheavy nuclei stability to spontaneous fission near the neutron shell $N=162$.

Within the framework of the Dubna–Livermore (USA) collaboration there have been synthesized on the U-400 cyclotron two new isotopes of element Sg ($Z=106$) in the ^{22}Ne+ ^{248}Cm reaction and a new isotope of element Hs ($Z=108$) with $A=267$ in the ^{34}S+^{238}U reaction. An experiment on the synthesis of element 110 in the ^{34}S+ ^{244}Pu reaction resulted in the synthesis of the element 110 with a number of neutrons $N=163$.

Experiments carried out in 1994–1998 by the GSI (Germany) – FLNR collaboration at the UNILAC accelerator, resulted in discovery of new elements with $Z=110$, 111 and 112 in ^{62,64}Ni+ ^{208}Pb, ^{64}Ni+ ^{209}Bi, and ^{70}Zn+ ^{208}Pb cold fusion reactions.

These investigations quantitatively confirm the predictions of the macro-microscopic theory about a significant stabilizing effect of the deformed shells in the heavy deformed nuclei $Z=108$, $N=162$ region, and the existence of a spherical shell with $Z\approx 114$ and $N\approx 180$ seems to be realistic.

The use of ^{48}Ca ions as projectiles in production of the heaviest elements is of special interest. Their neutron-excess makes it possible to gain access to compound nuclei whose neutron numbers are close to the predicted magic neutron numbers of $N=178$–184. The doubly magic structure ($Z=20$, $N=28$) of ^{48}Ca allows one to form relatively cold compound nuclei at energies close to the fusion barrier.

First experiment aimed at the synthesis of the superheavy nuclei with $Z=114$ has been carried out in ^{48}Ca+ ^{244}Pu reaction within the framework of the Dubna – Livermore (USA) collaboration.

In the bombardment of a ^{244}Pu target with ^{48}Ca ions, a decay sequence consisting of an implanted heavy

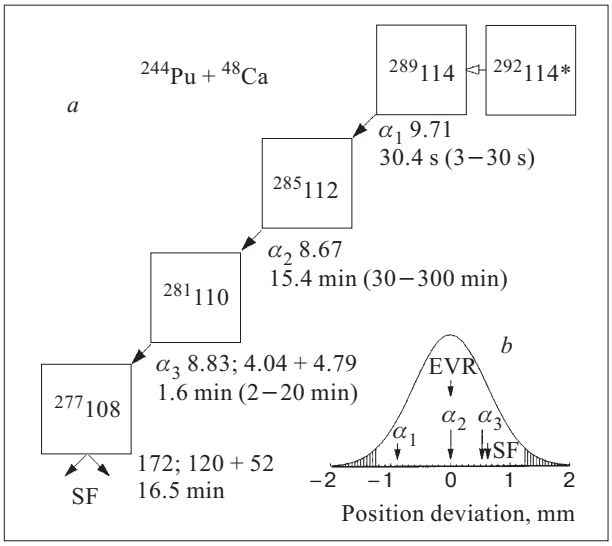

Fig.1. *a*) Time sequence in the observed decay chain. The expected half-lives corresponding to the measured Q_α values for the given isotopes are shown in parentheses. Hindrance factors between 1 and 10 were assumed for α decay of nuclei with an odd neutron number. *b*) Position deviations, in mm, of the observed decay events from the recoil nucleus. The curve shows the position distribution for correlated signals; open area corresponds to 95% confidence level

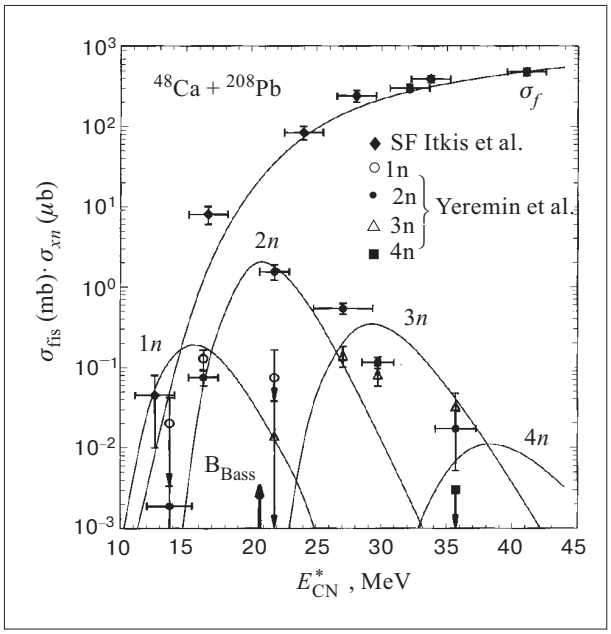

Fig.2. Production cross sections of No isotopes measured in ^{206}Pb(^{48}Ca,*xn*) reaction

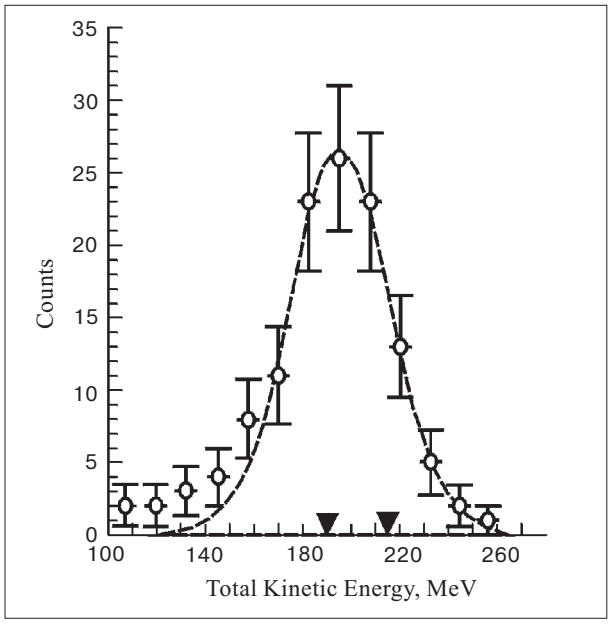

Fig.3. TKE distribution of ^{252}No spontaneous fission fragments

atom, three subsequent α decays, and a spontaneous fission, all correlated in time and position, has been observed. The measured α energies and corresponding time intervals were: E_α = 9.71 MeV (Δt = 30.4 s), 8.67 MeV (Δt = 15.4 min), and 8.83 MeV (Δt = 1.6 min); for the spontaneous fission (Δt = 16.5 min), the total energy release was approximately 190 MeV. The large alpha-particle energies together with the long decay times and spontaneous fission terminating the chain offer evidence of the decay of nuclei with high atomic numbers. They are good candidates for originating from the α decay of the parent nucleus ^{289}114, produced in the 3*n*-evaporation channel with a cross section of about 1 pb. The half-lives for all the observed new α emitters are in agreement with the theoretical T_α predictions for the nuclides with Z = 110, 112, and 114. The significant increase in the lifetimes of the new Z = 112, and 110 daughters of the Z = 114 nuclide (by more than a factor of 10^6) with respect to the known heaviest isotopes of elements 112 and 110 can be considered a direct proof of the existence of the «island of stability» of superheavy elements [1].

Reactions ^{206,208}Pb (^{48}Ca, *xn*) were chosen for a comprehensive test of the ion source, the U-400 cyclotron and separators performances in long-term experiments with an intensive beam aimed at the heaviest elements synthesis. For the first time in these experiments, the continuous beam mode was used.

At the separator VASSILISSA formation of No isotopes has been studied within the projectile energy range of 204–235 MeV. The obtained cross section values are shown in Fig.2. The spontaneous fission fragment TKE distribution of ^{252}No (SF) has been measured using the ^{206}Pb (^{48}Ca, 2*n*) reaction (Fig.3) [2].

The reaction ^{48}Ca+ ^{238}U was investigated at separator VASSILISSA in attempts to synthesize new isotopes of element 112. The experiments were performed at two beam energies. Two spontaneous fission events with the TKE values 190 and 212 MeV, respectively were observed at the lower beam energy. These events were tenta-

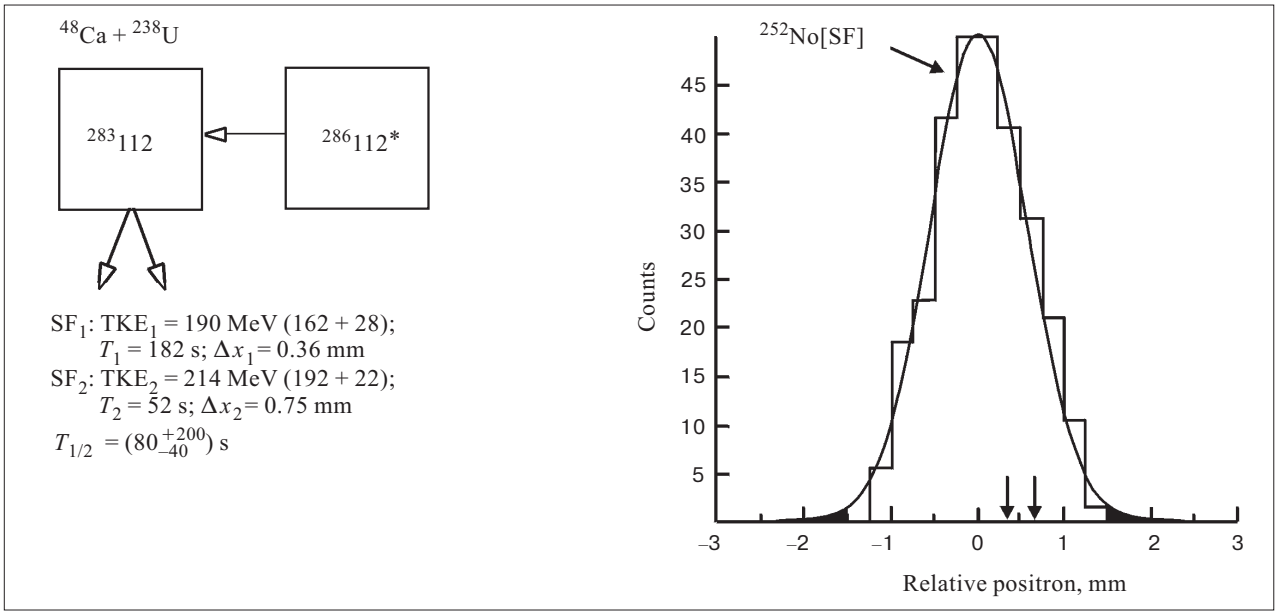

Fig.4. Time sequence in the observed decay chains and position deviations, in mm, of the observed S.F. events from the recoil nucleus

tively assigned to the new neutron rich isotope $^{283}112$ produced in the $^{206}Pb(^{48}Ca, 2n)$ reaction.

The measured cross section is $(5.0^{+6.3}_{-3.2})$ pb and the half-life is (81^{+147}_{-32}) s. The energies of the two events are shown in Fig.3. Figure 4 shows the time sequence in the observed decay chain and position deviations, in mm, of the observed S.F. events from the recoil nucleus. Open area corresponds to 98% confidence level [3].

The experiments with internal beam probe include the use of fast chemistry for extraction of the fraction containing Sg nuclei from ^{232}Th target material and the off-line measurements of the correlation chains from α decay of ^{268}Sg and SF of ^{264}Rf. These experiments will be continued in collaboration with Orsay (France) and RIKEN (Japan) [4,5].

Experiments on the superheavy nuclei synthesis in $^{48}Ca + ^{242}Pu$ reactions at the VASSILISSA in collaboration with GSI (Germany), RIKEN, and IP of UK (Slovakia) are under way.

Chemistry of Transactinides

The investigation of chemical properties of new elements is one of the traditional FLNR research programmes. A series of collaborative experiments was conducted in the FLNR at the KHIPTI set-up together with scientists from Switzerland, Germany, and Poland. New results on the properties of Rf were obtained. Comparative studies of ^{261}Rf ($T_{1/2}$ = 78 s) (oxo)chlorides and bromides, produced in $^{248}Cm(^{18}O, 5n)$ reaction, and those of ^{165}Hf ($T_{1/2}$ = 76 s) were done using isothermal chromatography technique. It was shown, that the Rf compounds are more volatile than Hf compounds [6].

The behaviour of short lived isotopes of Mo and W, analogues of Sg, was studied systematically in the gas phase. 40 atoms of element 106 were isolated as $Sg\,O_2\,Cl_2$ by thermochromatographic technique and detected by SF on quartz surface. The chemical behaviour of element 106 is similar to that of short-lived isotopes of Mo and W. The use of the comparative analysis of these results and of the data on the chemistry of Sg made it possible to define the chemical compounds formula for this element. In cooperation with the chemists from Germany, tests of the chemical identification method of Sg long-lived isotopes in aqueous solutions were continued [7,8].

A new KIT set-up (a system of 8 ionization chambers with a transporting tape) has been completely constructed. In 1999–2000 it is supposed to measure some physico-chemical properties of volatile compounds of elements with $Z \geq 106$ by gas (thermo) chromatography and to study their complexation in solutions by ion exchange and extraction techniques and upgraded set-up KIT.

Fission and Cluster Decay

New important physical results were obtained in the study of spontaneous and low-energy compound nuclei fission.

Nuclei in the vicinity of At-Th and of the superheavy nuclei with $Z \geq 100$ are of true interest in the study of the fission mode phenomenon. On the other hand, the study of the fusion-fission cross sections for heavy and, especially, superheavy nuclei at low excitation is of impor-

tance in predicting the survivability of those nuclei and in deciding on the optimum way for their synthesis.

Using a unified approach, experimental information on mass and energy distributions, pre- and post-scission neutrons, as well as on neutron angular and energy spectra in coincidence with the fragment of chosen mass and energy for the three regions of nuclei — pre-actinide, intermediate, and transfermium — was obtained using a 4π array neutron multidetector DEMON and fission fragment trigger CORSET.

A series of experiments has been carried out to investigate the fission of ^{220}Ra, ^{226}Th, ^{256}No, ^{270}Sg, and ^{286}112 compound nuclei produced in reactions with ^{12}C, ^{18}O, ^{22}Ne and ^{48}Ca ions in the excitation energy range from 12 up to 60 MeV (Fig. 5) [9.10].

The multimodal character of low energy fission of neutron-deficient nuclei of Th has been demonstrated. The transition from symmetric to asymmetric fission has been observed in the ^{220}Th $\div$ ^{233}Th region. These experiments were performed in the framework of the collaboration FLNR – INFN (Italy) – ISN (France) – University (Brussels) – University (Texas) – INP (Alma-Ata). In the latest experiments the multimodule neutron detector DEMON was used.

For the first time multiparameter correlations (mass-energy-angle for fission fragment in coincidence with neutrons and γ quanta) have been measured at sub-barrier energies in the ^{204,208}Pb(^{16}O, f) and ^{208}Pb(^{18}O, f) reactions. The excitation energy range at the saddle point for compound nuclei of ^{220,224,226}Th was $E^*_{sp} = 16 \div 40$ MeV. At the low excitation energies two different fission modes (symmetrical and asymmetric) have been observed and a time scale of nuclear collective motion for these modes has been estimated. The experimental characteristics of fission modes are proved to be in a good agreement with predictions of macro-microscopic theory.

The induced fission characteristics of nuclei with $Z \geq 100$ were measured at considerably low excitation energies, at which the shell effects play an important role

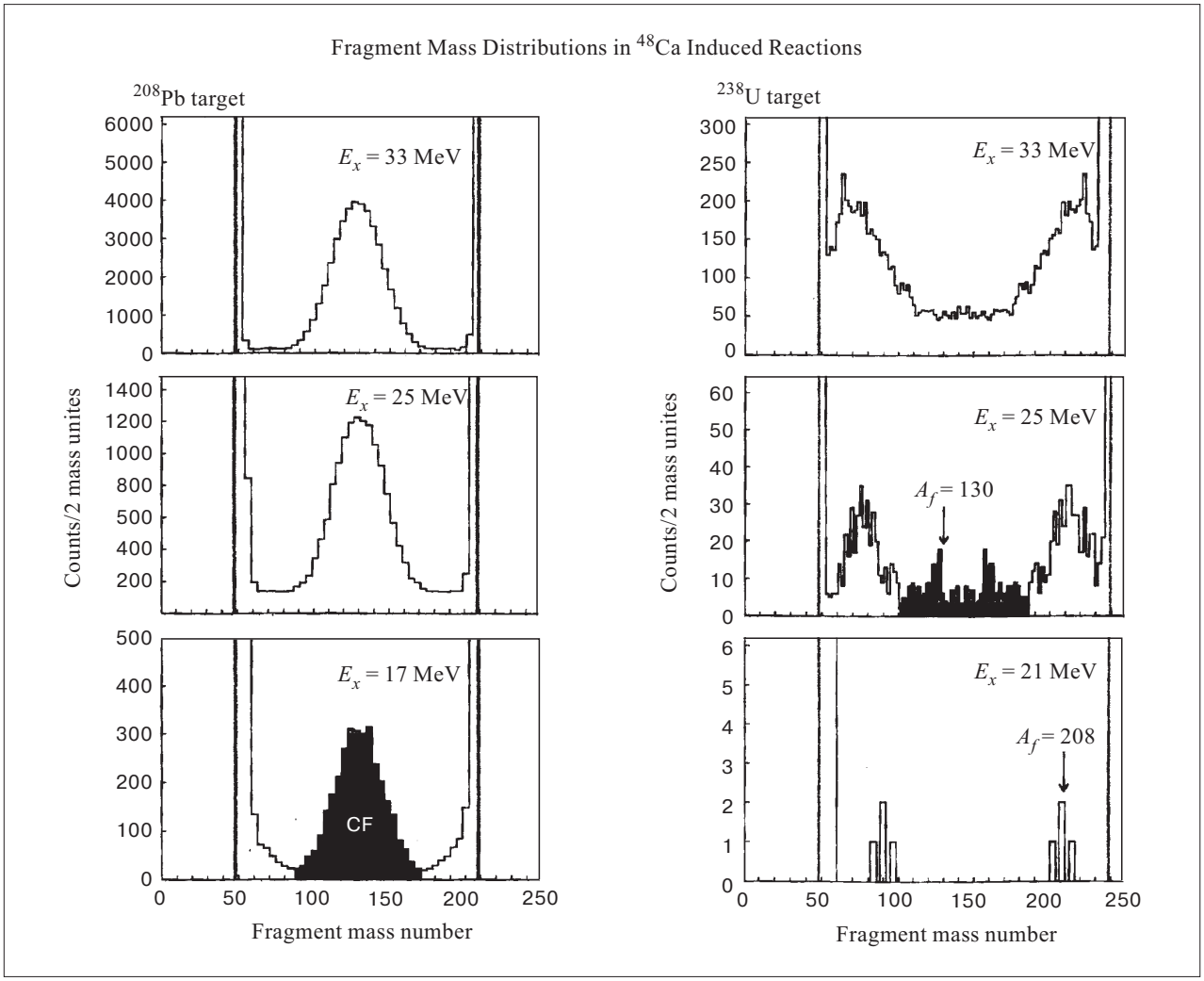

Fig.5. Fragment mass distribution of low-energy fission of ^{256}No and ^{286}112 induced by ^{48}Ca ions

and lead to new and quite unexpected properties. It is important to note that obtained results concerning the fission fragment mass and energy distribution and fusion-fission cross sections offer possibilities of predicting superheavy nuclei properties and planning future experiments.

New evidence of the shells influence on the nuclei fission dynamics has been obtained in the research of spontaneous and induced fission carried out recently at FLNR. Two independent fission modes in spontaneous fission of ^{252}Cf have been obtained by FLNR–University (Vanderbilt)–ORNL (Oak-Ridge)–IP (Bratislava) collaboration.

At the mass and energy distributions investigation of ^{244}Cm spontaneous fission fragments and of weakly excited compound nuclei $^{242m}\mathrm{Am}(n,f)$ fission fragments there were detected compact regions of increased yield in the vicinity of a fragment with a magic number of neutrons $N=50$. The observed feature may be regarded as a super short mode manifestation in the form of a three cluster chain of fragments with a nearly equal mass of $Z=31\div32$. ($2\cdot10^{-5}$ from the total fission number). An analogous structure, at small excitation energy, has been observed at the investigation of a superlong ^{252}Cf spontaneous fission mode and it is possibly determined by a different cluster configuration as well.

With polyethyleneterephtalate track detectors in the Gran Sasso underground laboratory cluster decay and spontaneous fission of ^{232}Th have been measured. The lower limit of the partial half-life for the most probable ^{26}Ne cluster decay was found: $T_{1/2\mathrm{cl}}>5\cdot10^{21}$ yr. (a 90% confidence level). Spontaneous fission with partial half-life $T_{1/2\mathrm{sf}}=(1{,}2^{+0.5}_{-0.3})\cdot10^{21}$ yr. was recorded.

Complete Fusion and Decay of Hot Nuclei

At the VASSILISSA recoil separator, de-excitation of compound nuclei with the excitation energies of up to 160 MeV and evaporation of protons, α particles and up to 15 neutrons was studied. The systematic information on the competition of different decay channels of compound nuclei at temperatures of up to 2.5 MeV was obtained.

There has been detected an increased stability to fission of high excited nuclei. Theoretical analysis has shown that particle evaporation channels $\Gamma_{n,p,\alpha}/\Gamma_{\mathrm{tot}}\approx0.8\div0.9$ dominate at excitation energies ranging from 50 to 160 MeV, and excited heavy nuclei fission starts dominating only at low excitation energies. This indicates a greater fission time for high-excited compound nuclei: $\tau\sim(3\div6)\cdot10^{-20}$ s.

High sensitivity and selectivity of the VASSILISSA separator enabled us to discover and identify a number of new neutron-deficient isotopes: ^{213,214}Pa, ^{219}U, ^{228,229}Pu and to determine the energy of the α decay and their half-lives.

For 1999–2000 it is planned to upgrade the separator VASSILISSA now operating as an energy filter to a velocity filter (Fig.6). This transformation will give possibilities for investigation of the reactions, being of great interest: $^{86}\mathrm{Kr}+{}^{208}\mathrm{Pb}\rightarrow{}^{294}118^{*}$, $^{136}\mathrm{Xe}+{}^{136}\mathrm{Xe}\rightarrow{}^{272}\mathrm{Hs}^{*}$, as well as the reactions with radioactive beams like ^{132}Sn, ^{133}Sb, ^{134}Te.

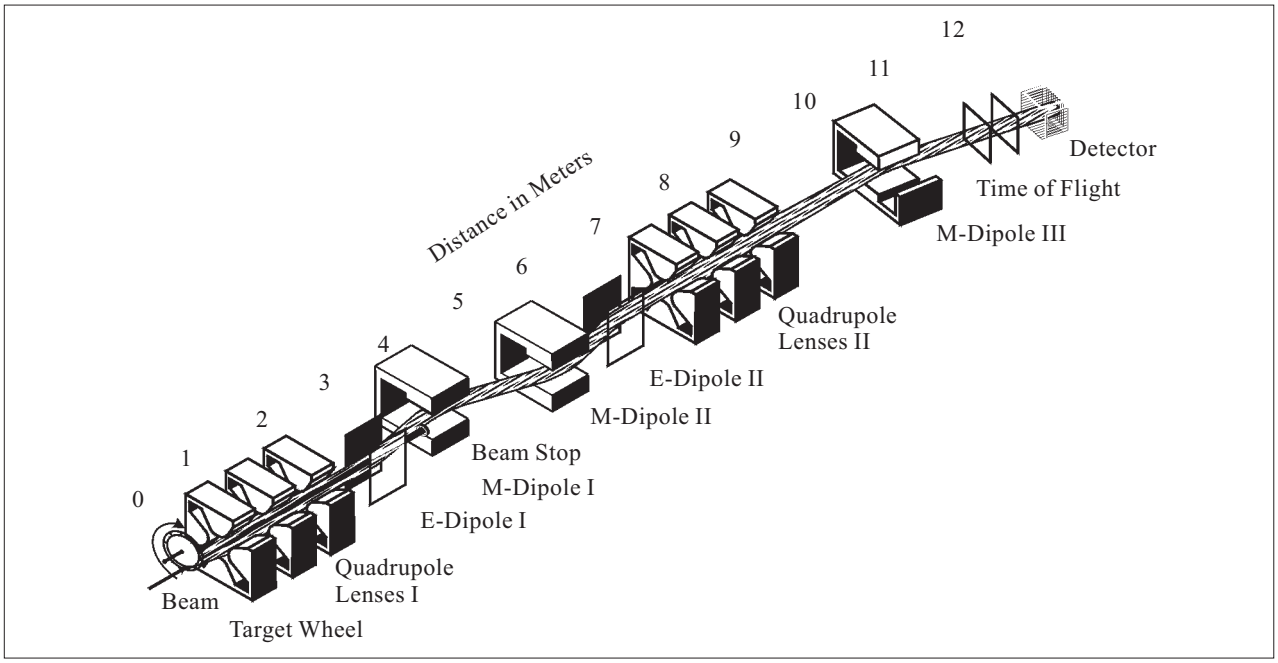

Fig.6. Proposed upgrade schema of the recoil separator VASSILISSA

Nuclear Reactions with an Exotic Target ^{178}Hf^{m2}

The research programme under the «Hafnium isomer» project which includes the production of ^{178}Hf^{m2} isomer and the study of nuclear and electromagnetic interactions using this high-spin nucleus was mainly implemented in cooperation with CSNSM and IPN (Orsay), GSI (Darmstadt), Munich and Mainz Universities (Germany), and the Kurchatov Institute (Moscow).

The reaction $^{176}\mathrm{Yb}(^{4}\mathrm{He}, 2n)^{178}\mathrm{Hf}^{m2}$ was used to produce $\approx 10^{15}$ nuclei in the isomeric state.

The radiation capture investigation of thermal and resonance neutrons by the ^{178}Hf^{m2} isomer continued on the «Osiris» reactor at Saclay (France). The achieved resonance integral for $^{178}\mathrm{Hf}^{m2}(n,\gamma)^{179}\mathrm{Hf}^{m2}$ reactions is $I_\gamma = (1060 \pm 60)$ b which does not contradict the earlier value of $I_\gamma = (800 \pm 130)$ b from the IBR-2 reactor. At the same time it was demonstrated that the yield value depends on the neutron filter type, which makes possible a conclusion that there exist at minimum two resonances with energies of 4–5 and 7–8 eV.

At the irradiation of the isomeric target with ^{208}Pb ions on the UNILAC (Darmstadt), the Coulomb excitation of the isomer was investigated. There was detected the energy of the first level of a rotation band with $K = 16$, and the momentum of inertia value for this transition was obtained.

There was obtained an unexpectedly low population probability of the five-quasiparticle isomer in $^{177}\mathrm{Hf}^{m2}$ $(I_\pi = 37/2)$ in the $^{178}\mathrm{Hf}^{m2}(\gamma, n)^{177}\mathrm{Hf}^{m2}$ photo-nuclear reaction. The upper limit with respect to the standard $^{181}\mathrm{Ta}(\gamma, n)^{180}\mathrm{Ta}^{g}$ reaction is $Y(^{177}\mathrm{Hf}^{m2})/(^{180}\mathrm{Ta}^{g}) \leq 0.2$. The laser spectroscopy method was used for measuring the electric, dipole and quadruple, moments and the charge radius of the $^{178}\mathrm{Hf}^{m2}$ nucleus.

At present a very large collaboration, including 27 institutes of Europe as well as the USA is working.

Nuclei Close to the Drip-Line

The COMBAS fragment-separator (Fig.7) with a control apparatus complex and semiconductor ΔE_1, ΔE_2, ΔE_3, ΔE_4 telescope-spectrometer was assembled, commissioned and tested at the U-400M cyclotron beam line [11].

The whole set-up was tested with the ^{12}C and ^{14}N ion beams of up to 50 MeV $\cdot A$ energy. First experiments were carried out to study the reaction mechanism of the production of heavy Be isotopes in the reaction $^{18}\mathrm{O}(35\ \mathrm{MeV} \cdot A) + {}^{9}\mathrm{Be}$ (Fig. 8).

Reactions with Radioactive Nuclei Beams

The ACCULINA set-up was fully equipped with reaction chambers, secondary beam diagnostics tools, a cryogenic gas target and detector arrays to carry out experiments with radioactive beams.

Secondary beams of 25–35 MeV/AMU ^{6,8}He, ^{9,11}Li, ^{12,14}Be, ^{8}B nuclei were produced using primary

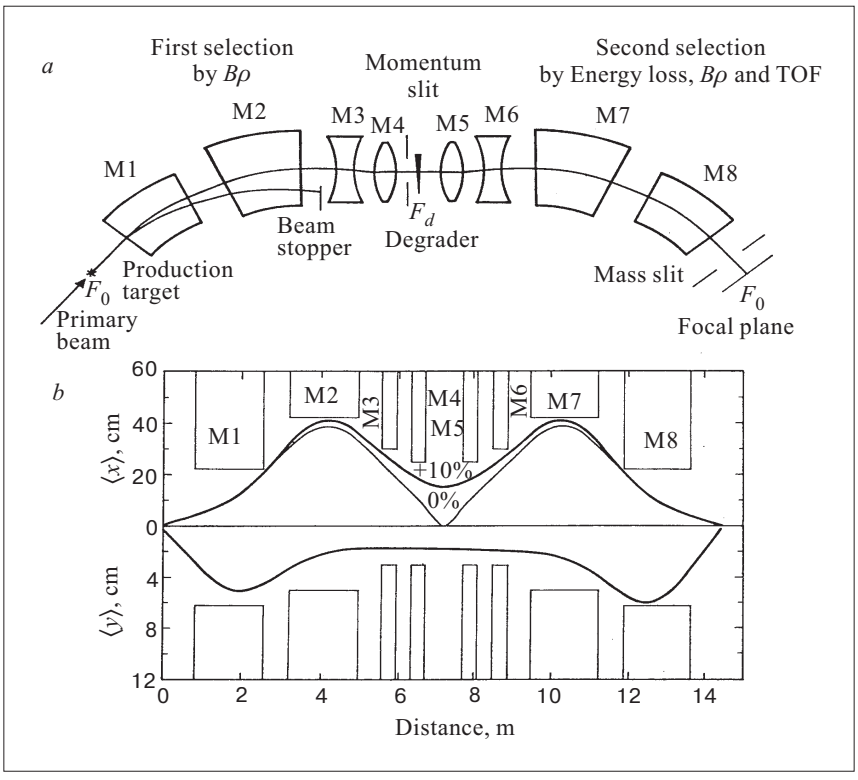

Fig.7. Schematic view of the COMBAS fragment-separator

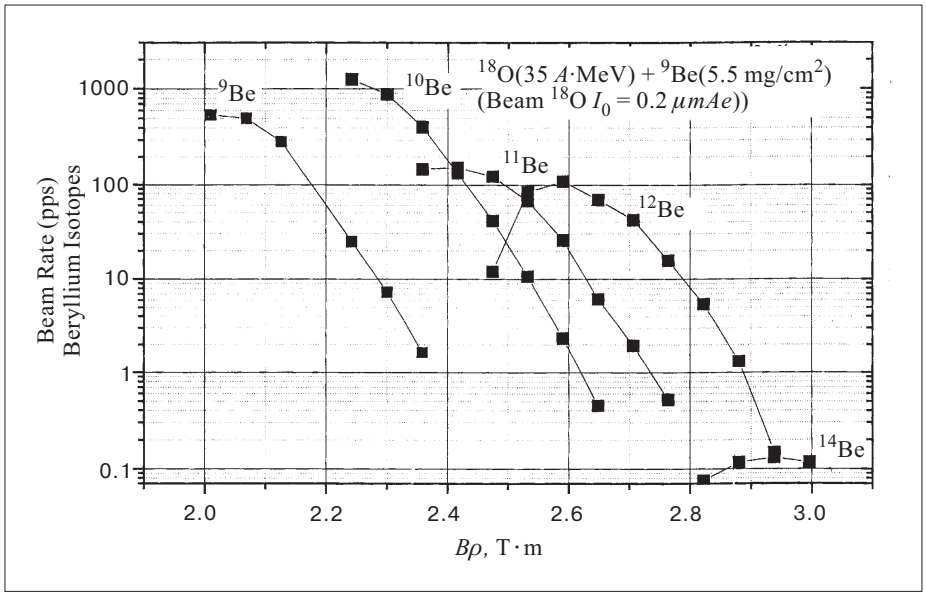

Fig.8. Measured production cross sections of heavy Be isotopes in the reaction ^{18}O(35 MeV·A) + ^{9}Be

^{7}Li, ^{11}B, ^{13}C, ^{15}N, and ^{18}O cyclotron beams. The primary beam intensities varied in these experiments between 0.5 and 2.0 pμA. Intensities of $1.5 \cdot 10^6$ and $7 \cdot 10^3$ PPS, respectively, were obtained for 25 MeV/AMU ^{6}He and ^{8}He nuclei bombarding 0.3–0.5 cm^2 targets.

The measurements of angular distributions for the transfer reaction and the elastic channels for the ^{6}He+ p system using inverse kinematics with a ^{6}He radioactive beam have been performed. This is the rarely investigated case of the transfer process with halo and non-halo nuclei being involved. Having in mind the corresponding data for the ^{6}He+ p system one could compare the influence of the structural parameters of these two nuclei on the processes studied. The angular distributions of the elastic scattering and of 1n and 2n transfer reactions were obtained by coincidence measurement of kinetic energy of both reaction partners [12].

Combined results of the three experimental runs are presented in Fig.9 (a — elastic channel, b — ^{5}He+d channel and c — α+t channel). Error bars include contributions from statistical errors and efficiency simulations inaccuracy.

Manifestations of the ^{6}He-nucleus structure in elastic scattering and transfer reactions of 150 MeV ^{6}He from hydrogen and helium nuclei have been studied. The elastic scattering differential cross section of ^{6}He from ^{4}He was measured in a CM angular range of 25–160 degrees for the first time, and the cross section rise observed at backward direction was interpreted in terms of ^{6}He wave functions given by the current theory. This study provided the first direct experimental verification for the theory predicted «dineutron» configuration of the neutron halo in ^{6}He.

For the first time the cross-section of elastic scattering and one- and two-neutron transfer reaction for the ^{6}He+ p system were measured at a 150 MeV collision

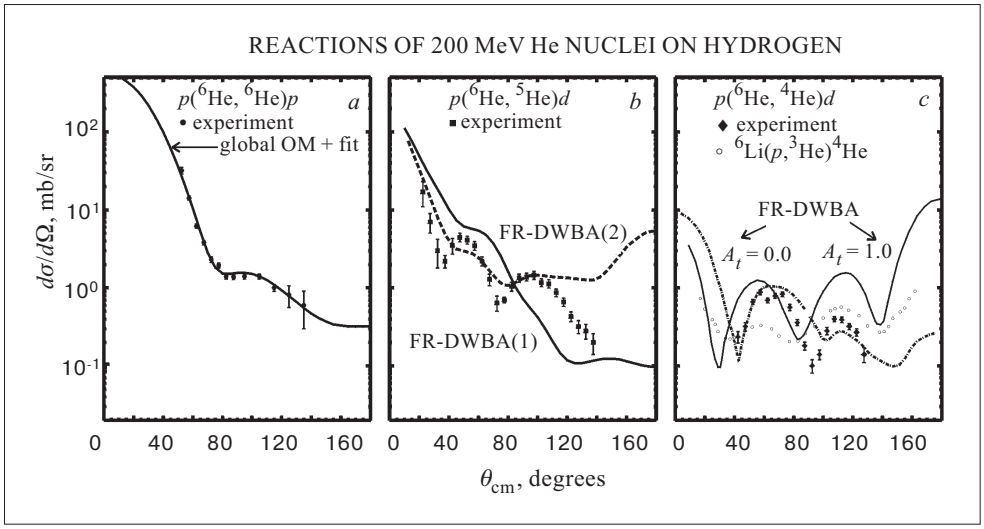

Fig.9. Angular distributions for the transfer reaction and the elastic channels for the ^{6}He+ p system: a — elastic channel, b — ^{5}He+ d channel and c — α+ t channel

energy in a CM angular range of 40–140 degrees. The results were analyzed in the framework of DWBA. The $\alpha+t$ exit channel is especially interesting since both $2n$- and t-transfer processes can contribute in its cross section. These experimental data allow one to conclude that the two-triton amplitude of ^{6}He is negligible. Their analysis confirms the high value (close to one) of the spectroscopic factor of the «dineutron» configuration in ^{6}He [13].

An experiment dedicated to the measurements of elastic scattering and one- and two-neutron transfer reactions induced by the ^{6}He beam on helium has been carried out. The data collected in this experiment are being analyzed.

The results obtained at the ACCULINNA-line are to be applied in RIB production in the U-400M main beamline in order to perform experiments at the FOBOS set-up.

Nuclear Reactions at Intermediate Energies

On the FOBOS facility using the ion beam from the U-400M cyclotron in $^{7}\mathrm{Li}\,(43\ \mathrm{MeV}/n)+{}^{232}\mathrm{Th}$ and $^{14}\mathrm{N}\,(34\mathrm{MeV}/n)+{}^{197}\mathrm{Au}$ reactions, new experimental dependences have been obtained for the cross sections of the excited nuclei ($E^{*}\sim 300$ MeV) decay into two or three fragments on the transferred momentum value. The measuring system of the FOBOS facility included the time-of-flight channel, 16 gas filled measuring modules and 80 CsI (Tl) detectors. Large statistics ($\sim 3\cdot 10^{6}$ double and $\sim 2\cdot 10^{3}$ triple correlated events) allows one to make a more detailed analysis of energy and angular dependences of the emission of fragments of intermediate mass at the decay of highly excited nuclei into three fragments.

The effect of prescission cooling in fission of hot nuclei and a steep increase of the fission fragment mass dispersion is observed for the first time at excitation energies of 100–250 and above 250 MeV.

On the basis of three-fragment events a correlation analysis was made. Simultaneous and sequential ternary breakups are clearly distinguished in these data. It has been shown that the decay into three fragments of nearly equal mass can proceed simultaneously through a collinear intermediate configuration and can be considered as a limiting case of the neck emission mechanism.

Dynamics of a Nonequilibrium Process

The structure of very neutron-rich isotopes of light elements $^{7-10}$He, ^{10,11}Li, ^{13,14}Be, ^{16}B, including the mass measurements and level structure, has been studied in collaboration with KI (Moscow) and HMI (Berlin) and on the FLNR and HMI accelerators. The structure of these nuclei is of great interest for the cluster structure, investigation of the neutron halo, investigation of the stability of neutron-rich light nuclei [14].

A new set-up «MULTI» has been constructed by the FLNR – LNP JINR – LAMPF (Los Alamos) – IPN (Rzez) – PI (Yerevan) collaboration for the study of a very excited nuclear system produced by heavy ions at intermediate energies and for the investigation of exotic nuclei provided by secondary radioactive beams. The new set-up has been sited at the U-400M cyclotron. This set-up (Fig.10) consists of 19 BGO-detectors, a multiwire position-sensitive ionization chamber, two silicon telescopes and a 4π BGO phoswich spectrometer. The first results in the study of the proton-halo structure of the ^{8}B nucleus have been obtained using this set-up and beam line of the U-400M cyclotron. In the $^{14}\mathrm{N}\,(40\ \mathrm{MeV}/n)+{}^{181}\mathrm{Ta}$ reaction with the use of the BGO-ball spectrometer new information on production of very excited fragments and subbarrier production of π mesons has been obtained. A set of experiments on production and investigation of the properties of very neutron-rich isotopes in collaborations with GANIL (Caen) and RIKEN (Saitama) has been performed.

The production rates of fragments produced by the beams of ^{32}S and ^{34}S ions with the energy up to 20 MeV/n have been measured on MSP-144 spectrometer.

The properties of very neutron-rich isotopes in the region of the neutron closures $N=20$ were investigated according to GANIL-FLNR collaboration. The evidence of particle instability of neutron-rich ^{28}O was obtained. The measurements of β-decay half-life for ^{27,29}F and ^{30}Ne were performed.

The FLNR – GANIL – Warsaw University – IPN (Orsay) – INP (Rzez) – GSI (Darmstadt) collaboration has obtained (in the fragmentation reaction of isotope ^{112}Sn on a nickel target) ~30 events of a double magic nucleus ^{100}Sn ($N=Z=50$). A number of new isotopes with $A=87\div 104$ and over 30 isomeric states with $T_{1/2}$ from 100 ns to 100 μs for nuclei from F to Cl were identified. A number of isomeric states were identified for the first time.

After this, in collaboration with the GANIL with participation of scientists from Warsaw University, INP (Orsay) and GSI (Darmstadt) on the LISE-3 spectrometer at GANIL there was measured the decay of more than 40 short-lived isomeric states ($T_{1/2}$ from 50 ns to 70 μs) including a new isomer ^{66m}As produced at quasi-fragmen-

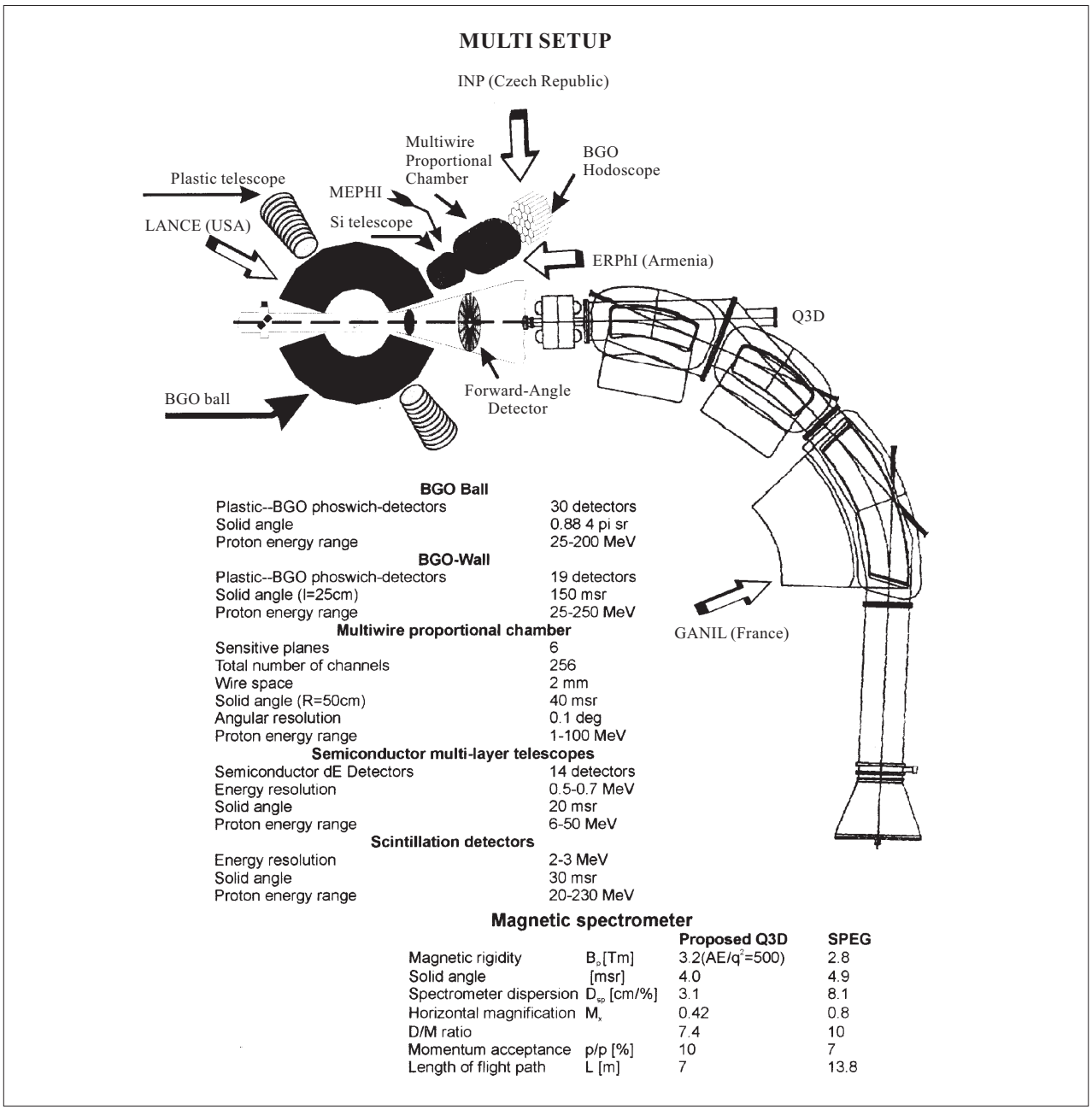

Fig.10. Schematic view of the «MULTI» set-up

tation of a beam of ions of ^{112}Sn (58MeV/u, 63 MeV/u) on a target made of ^{nat}Ni.

An experiment on production and identification of the new neutron-rich nuclei ^{38}Mg, ^{40,41}Al was carried out at RIKEN in the framework of a FLNR – RIKEN collaboration. Some clue for particle instability of ^{33}Ne was also obtained. In this experiment about 2800 events of ^{30}Ne, 90 events of ^{31}Ne and 70 events of ^{32}Ne but no events associated with ^{33}Ne were observed. Further analysis of these data sets may afford to deduce an expected yield of ^{33}Ne.

Properties of Light Nuclei

Isotopic shifts in the optical transitions of Ti atoms with mass numbers $46 \div 50$ have been measured by the highly resolving laser spectroscopy methods. For the first time the difference of charged radii for nuclei being between closed shells $20 \le Z$, $N \le 28$ has been determined. A comparison of the dependences of charged radii values on neutron number has been performed for Ti and Ca nuclei. In contrast to Ca nuclei, where at $N = 24$ the fracture is observed, in case of Ti isotopes the charged radii continuously increase with the mass number decrease.

Magnetic dipole ratio constants for isotope pairs of lanthanide and actinide elements sets were measured by the laser resonance fluorescence method. New data on the spatial distribution of electric currents were obtained. Among the studied isotopes the largest difference in the magnetic dipole ratio constants was observed for the pair of $^{233}U - ^{235}U$ (≈ 1 %). A new experimental set-up for the on-line experiments using laser radiation was constructed.

PHYSICS AND HEAVY-ION ACCELERATOR TECHNIQUES

Recently the U-400M and U-400 cyclotrons have been equipped with modern ECR sources at 14 GHz: DECRIS-14-2 and ECR-4M. Within the past three years the use of ECR ion sources at FLNR qualitatively contributed into superheavy elements synthesis, secondary beams and nuclear membrane production.

Production of the ^{48}Ca ion beam is probably the key problem in synthesizing new nuclei. The goal was to achieve the maximum intensity of the ^{48}Ca ion beam at a minimal consumption of this enriched and extremely expensive isotope. With this in view, in 1995–1997, ECR type external ion sources and axial injection systems for the U-400M and U-400 cyclotrons were created with the aim of extending possibilities for experimental investigations at both cyclotrons, see Fig. 11.

The Ion Source Development and the Acceleration of the ^{48}Ca Ion Beam

The members of the FLNR ion source group made their major effort in solving the following problems:

- stable ion beam production on a target during a long-term (few months) operation;
- increasing the $^{48}Ca^{5+,6+}$ ion beam intensity;

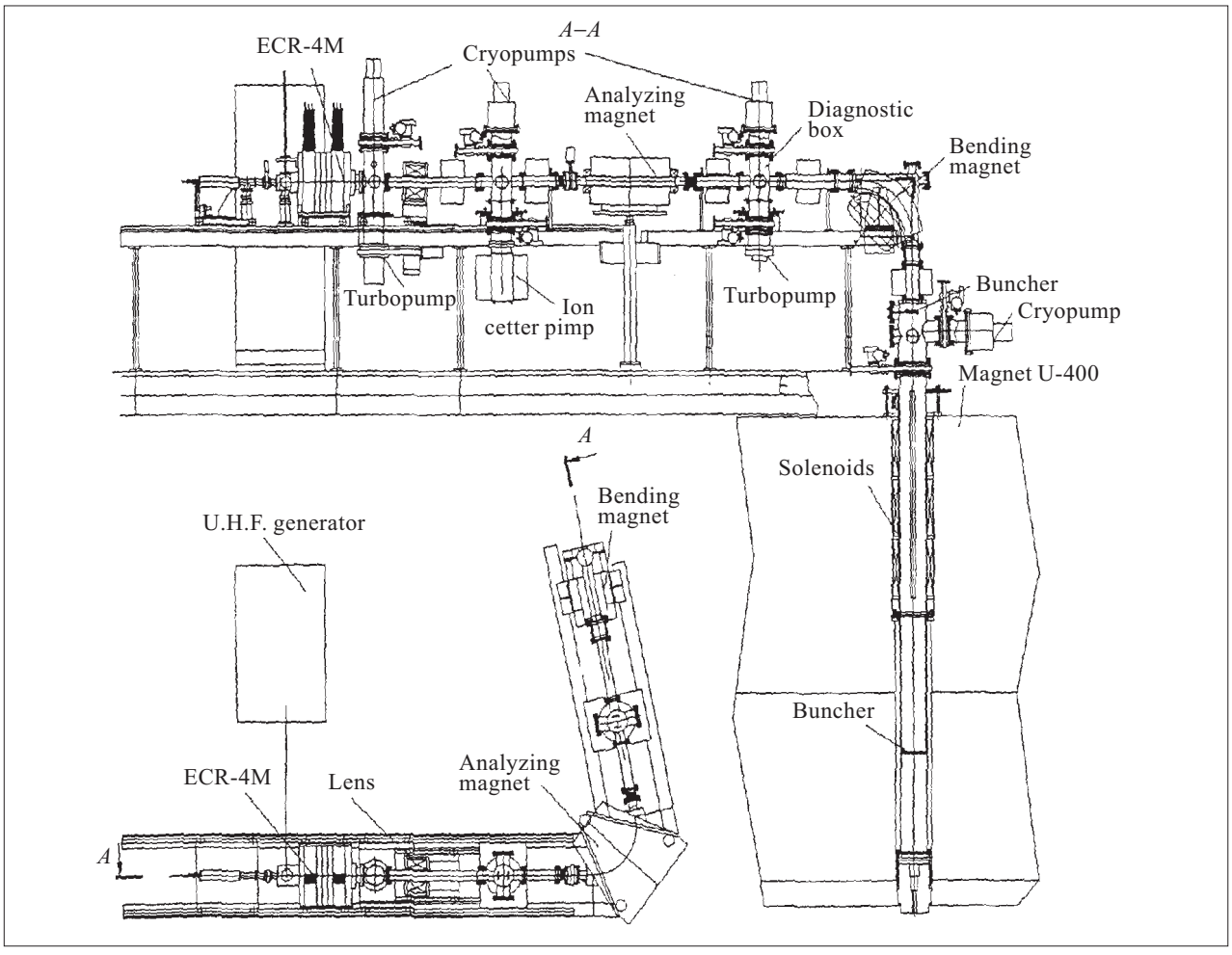

Fig.11. External ion source ECR-4M and axial injection system of the U-400 cyclotron

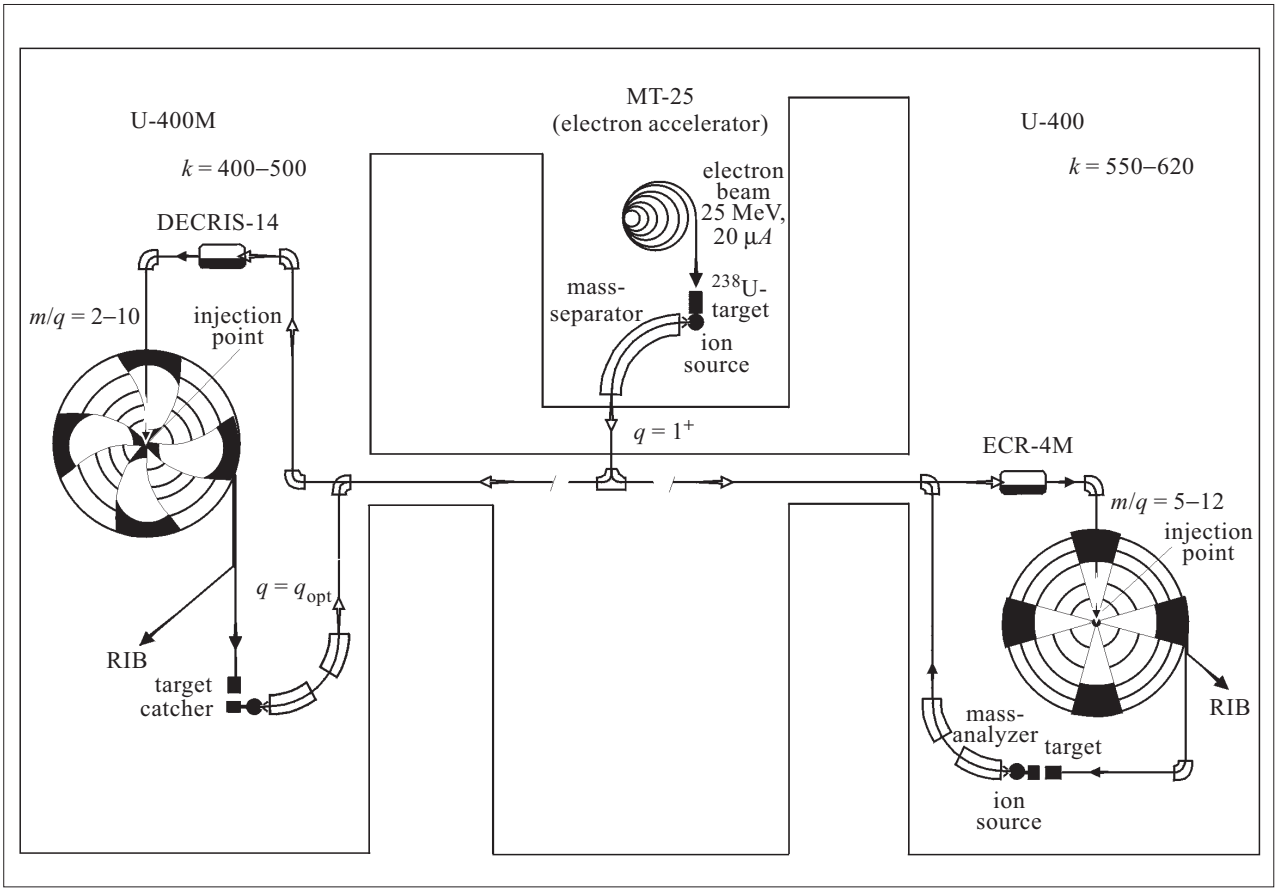

Fig.12. Concept of the RIB accelerator complex of FLNR

• optimization of the working substance consumption at the maximal beam intensity

Finally the best results concerning stable and intensive ion beams were achieved with the use of metallic calcium. In this case out of $1.4 \cdot 10^{15}$ PPS of Ca atoms fed into the source we produce about $6 \cdot 10^{13}$ PPS of $^{48}Ca^{5+}$ ions from ECR-4M. As a result, in such mode of the ion source operation it is possible to provide about 2,500 hrs of the target irradiation using one gram of ^{48}Ca. The ECR ion source at the U-400 cyclotron provides a drastic increase in the efficiency of the experiments. The total factor of the increase equals ~100 [15].

Ions of gases such as He, N_2, O_2, and Ar were successfully delivered from the DECRIS-14-2 source and accelerated at the U-400M cyclotron. The ion source showed good performances, especially for middle charge state ions (e.g., 600 eμA of Ar^{8+}), as well as high operational reliability.

Significant progress in the production of metal ions was achieved by introducing a new microoven with a maximal temperature of up to 900°C for evaporating metal samples. This microoven in combination with an additional tantalum sheet installed inside the discharge chamber allows one to produce $^{7}Li^{2+}$ and $^{26}Mg^{3+}$ ion beams of more than 200 eμA.

A new project (Fig.12) to accelerate in the heavy ion cyclotron complex U-400M + U-400 light radioactive nuclei like $^{6,8}He$ and fission fragments produced by photofission using the Microtron accelerator was reported and highly appreciated by PAC for Nuclear Physics [16].

SOLID STATE RADIATION PHYSICS

A new method of irradiating materials by high-energy heavy ions was offered and realized, which allowed one to study the structure of the tracks of the ions focused along the surface. Complex researches of the structure of

the surface of semiconductors (Si, GaAs, monocrystal natural and artificial diamond, pirolytic graphite) and dielectric materials (LiF, Al_2O_3, mica) irradiated with 210 MeV Kr ions were carried out with the use of scanning electronic microscopy and tunnel microscopy. It was shown that in the area where heavy ions enter the surface, craterlike structures are formed and the removed material deposit on the intact surface.

The phenomenological model of heavy ions tracks structure in semiconductors and dielectric monocrystals was advanced. On the basis of the advanced track model, investigation of the diffusion of impurities along heavy ion tracks was performed. This will permit one to create conducting multilayers in materials. Undoubtedly, the effects found have significant applied importance in creating new technology for electronic industry based on high-energy ion implantation.

The investigations with irradiated polymers permitted us to elaborate new methods of manufacturing track membranes with ultra small pores and different pore shapes.

Production of Ultra Pure Radioisotopes for Biomedical and Ecological Researches

The irradiation of highly enriched ^{235}U with α particles on the FLNR U-200 cyclotron and enrichment on JASNAPP (LNP) separator were used for monoisotope ^{237}Pu, and ^{244}Pu preparates production with isotope purity of 99,997%. These samples were used in the joint experiments with the Harwell Laboratory (Great Britain) on researching (in vivo) the plutonium metabolism in human body.

A method for producing ^{178}W in the $^{nat}Hf(^4He, xn)$ reaction at the U-200 cyclotron was developed. ^{178}W can be used as a $^{178}W/^{178}Ta$ generator, which is used in nuclear medicine for cardiac diagnostics.

A high-sensitivity track method of ^{323}Th, U, ^{237}Np, and Pu determining in earth, water, air, plants and biological objects was developed. The method uses the (γ, f)-reaction and has a limit of detection equal to 10^{-13} g, $3\cdot10^{-14}$ g, $3\cdot10^{-14}$ g, and $1.5\cdot10^{-14}$ g, respectively, which is two orders better than that of known nuclear-physical analysis methods. The given method was evaluated in more than 120 tests in the areas of northern Ukraine, Belarus and Ural.

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FRANK LABORATORY OF NEUTRON PHYSICS

In 1998, the FLNP scientific programme was covered by five research themes of the JINR Plan of Scientific Research and International Scientific and Technical Cooperation and it was aimed at obtaining new results in

– condensed matter physics (theme «Condensed Matter Investigations Using Neutron Scattering», headed by A.M.Balagurov)
– neutron nuclear physics (theme «Study of the Fundamental Characteristics of Neutrons and Nuclei», headed by W.I.Furman).

To effect scientific research, work to develop, modernize, and construct the FLNP basic facilities, IBR-2 (theme «Development and Upgrading of the IBR-2 Complex», headed by V.D.Ananiev) and IREN (theme «IREN Project», headed by W.I.Furman), as well as the FLNP measurement and computation complex (theme «Development of the FLNP Measurement and Computation Complex», headed by V.I.Prikhodko) continued.

Also, FLNP took part in the JINR themes: «ATLAS. General-Purpose pp Experiment at the Large Hadron Collider in CERN» (theme, headed by N.A.Russakovich), «Theoretical and Experimental Investigations of the Electronuclear Method of Energy Production and Radioactive Waste Transmutation)» (theme, headed by A.N.Sissakian and I.V.Puzynin).

FLNP organized International seminars on relaxor ferroelectrics, interaction of neutrons with nuclei, deuteration of biological molecules for structural and dynamic studies, VIII International school on neutron physics, dedicated to the memory of I.M.Frank .

CONDENSED MATTER PHYSICS

Experimental investigations. In 1998, at IBR-2 neutron scattering investigations in condensed matter physics were conducted using four basic experimental techniques: diffraction, small-angle scattering, inelastic scattering, and polarized neutron optics. During the reported year there were eight reactor sessions. Beam-time on the spectrometers was allocated according to experts recommendations on submitted experimental proposals taking also into account the existing long-term agreements for cooperation.

In 1998, the list of spectrometers operating in the user regime included 10 instruments: HRFD, DN-2, DN-12, SKAT, YuMO, SPN, REFLEX-P, KDSOG, NERA, and DIN. The new on the list was the texture diffractometer SKAT. It was commissioned in spring 1998 and replaced the spectrometer NSVR. The vertical geometry of the detector system in SKAT makes it possible to improve essentially the conditions of diffraction data registration from bulk geologic samples. On the diffractometer DN-2, work using a toroidal high pressure cell for the pressure up to 70 kbar developed in the Institute of High Pressure Physics started. On the spectrometer SPN, possibilities of polarized neutron scattering registration were essentially increased in particular, by introducing into its scheme an adiabatic spin-flipper, a supermirror analyzer and a position sensitive detector. In autumn 1998 work to build a neutron guide for the new Fourier diffractometer FSD began. It is expected that next year, FSD will be put into operation.

Diffraction. Data procession is completed and an article on the dependence of the structure of a $HgBa_2CuO_{4+\delta}$ compound on the applied external pressure for different doping oxygen contents is submitted for publication [1]. It is shown that the influence of pressure on interatomic distances in the structure strongly depends on the doping level: for $\delta = 0.06$ the compression of the

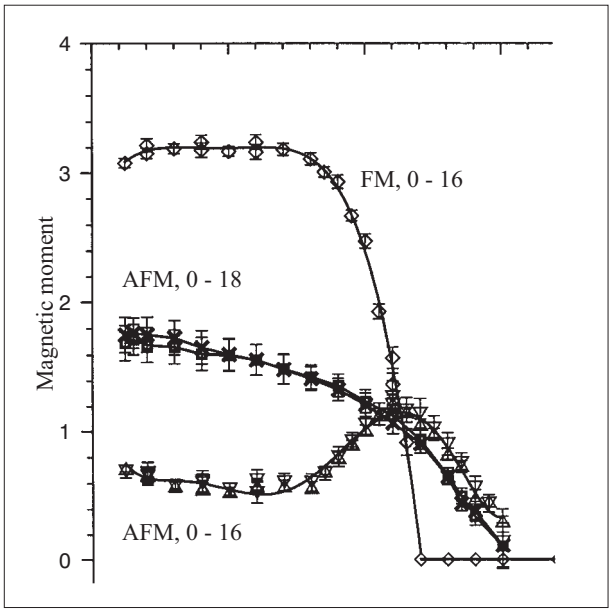

Fig.1. Temperature dependences of the Mn magnetic moments (in Bohr magnetons) for the FM- and AFM-components of the ^{16}O sample and for the AFM-components of the ^{18}O sample. For ^{16}O sample some of the points were measured twice

structure is uniform. In an overdoped state, compressibility of some distances (Hg-O2) reduces to zero and it increases 2.5 times for other distances (Ba-O3). The latter points to a considerable change in the concentration of free charge carriers in the conducting planes of CuO_2 under pressure.

Interesting results were obtained in the investigation of perovskite manganites with a CMR-effect (Colossal MagnetoResistance effect). It is shown that changes in the transport and magnetic properties of the compound $La_{0,35}\ Pr_{0,35}\ Ca_{0,30}MnO_3$ at phase transition are connected with changes in its atomic structure. Namely, at insulator to metal transition there takes place «melting» of the orbital ordering of oxygen atoms at bonds and this is accompanied with a jump in cell volume [2]. There is investigated the influence of the isotopic substitution of ^{16}O by ^{18}O oxygen on the magnetic structure and charge ordering in the manganite $(La_{0,25}Pr_{0,75})_{0,7}Ca_{0,3}MnO_3$, where strong effect of the isotopic composition on the transport properties was earlier discovered. The evolution of the magnetic structure of two samples of the compound, one with a natural mixture of oxygen isotopes (99.7% ^{16}O) and the other enriched with ^{18}O to 75 %, was studied. It is established that at room temperature such samples are identical from the structural point of view. As the temperature decreases the sample with ^{16}O experiences the antiferro-(T_{AFM}=150 K) and then the ferromagnetic (T_{FM}=110 K) transition leading to the establishment of a noncollinear ferromagnetic structure while in the sample with ^{18}O there arises a pure antiferromagnetic order (T_{AFM}=150 K) (Fig. 1). The temperature dependence of diffraction peaks connected with charge ordering is essentially different for samples with ^{16}O and ^{18}O and it also correlates with the electric resistance behavior. These experimental results are the evidence of the fact that the low temperature state of $(La_{0,25}Pr_{0,75})_{0,7}Ca_{0,3}MnO_3$ is indeed governed by strong dynamical electron-phonon interaction because of which the isotopic substitution of ^{16}O by ^{18}O results in a change of the electron state (metal-dielectric) and a completely correlated with it change of the magnetic structure (noncollinear ferromagnetic — pure antiferromagnetic) [3].

Small angle scattering. An important for applied purposes process of ethanol penetration through a model lipid membrane was studied by small-angle neutron scattering. The influence of ethanol on the thickness of a lipid bilayer and the intermembrane interaction were investigated. Decrease in the membrane thickness corresponds to the formation of a phase with interpenetrating hydrocarbon chains [4].

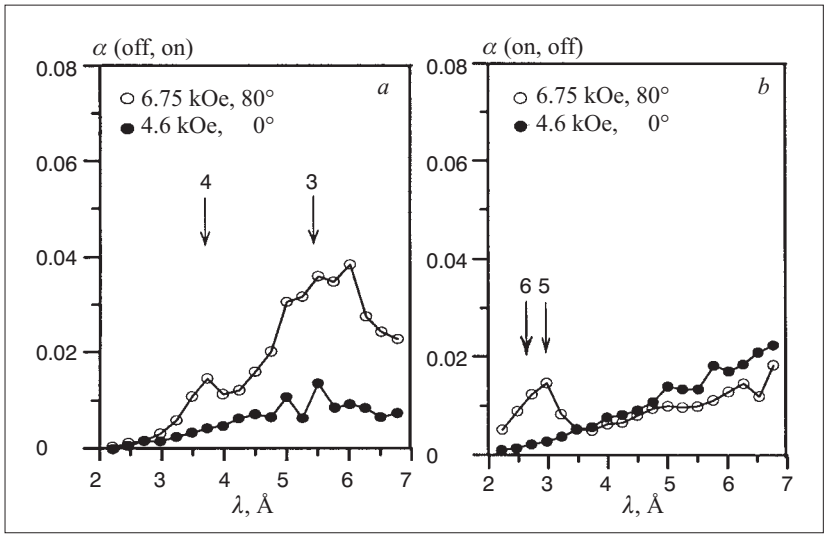

Fig.2. The dependence of the counts α(off, on) and α(on, off) on the wavelengths of the reflected incident beam of 3.2 mrad. The sample to detector distance is 3 m

Polarized neutron optics investigations. New possibilities of the spectrometer SPN allowed experiments of the observation of a complex and interesting phenomenon of neutron standing waves at neutron transmission through thin layers to be started. In the first experiments, the regime of total reflection and several registration channels of the effect (by measuring capture γ quanta or α particles, spin-flip neutrons) were used (Fig.2). Neutron standing waves with the period from 250 to 500 Å were reliably detected and it was shown that registering neutron standing waves it is possible to determine displacements of a magnetic noncollinear layer in a medium with an accuracy on the level of 0.1 Å [5].

Inelastic neutron scattering. In the recent time on the inverted geometry spectrometer NERA, a large cycle of experiments to study the density of vibrational states of methyl groups in organic molecules adsorbed on different amorphous silica samples, which are of great interest for modern nanotechnologies, were conducted. A large volume of factual information on vibrational spectra is obtained and, in addition, the results of the experiments are used to verify the calculation of such systems by quantum chemical methods [6].

NEUTRON NUCLEAR PHYSICS

According to the recommendations of the 8th session of the JINR Programme Advisory Committee for nuclear physics a limited research program was realized in 1998 on the basis of the IBR-30 and other neutron sources, e.g., in ILL, LANL, FZK Karlsruhe, Peking and Kyoto Universities. The following main results were obtained.

Methodological investigations. Essential results were obtained in the creation of the new set-up KATRIN [7] for investigation of time invariance violation (TIV) in neutron induced reactions. The first polarization in a ^{3}He-based neutron polarizer with optical pumping was carried out in collaboration with a Lebedev institute group. Work to design and construct a prototype of the installation for investigations of fundamental symmetry violations (PNC and TIV) started in the frame of the new ISTC project (JINR–ITEP–Pulse Technique Institute collaboration). The aim of the project is the creation of a neutron polarizer and analyzer with superconducting magnets and a large volume polarized nuclear target of the new type.

In 1998, in the first test of the new polarizer the neutron polarization about 45% was obtained (the rated value is 95 %).

A complex test of the KOLHIDA set-up was carried out on neutron beam No.1 of the IBR-2 reactor. The first experiments confirmed the expected characteristics of the polarized neutron beam. These were verified by polarized neutron diffraction from a crystalline sample.

The first section (7m) of the new vacuum mirror neutron guide was assembled on beam No.11 of IBR-2. After completion, this neutron guide is expected to increase the thermal neutron beam intensity over one order of magnitude.

Experimental investigations. At UGRA there were two experimental runs:

– the first measurements of the anisotropy of the elastic scattering of neutrons on a ^{238}U target in the keV energy range to estimate the possibilities of the extraction of information on the electric polarizability of the neutron;
– an investigation of a unique doublet of neutron resonances in 89Y at the neutron energy 11.6 keV with strong interference effects.

In the framework of the TRIPLE collaboration (Los Alamos) new important results were obtained for the mass dependence of the weak interaction spreading width (Fig.3):

$$\Gamma = 2\pi\, M/D.$$

Significant PNC effects were observed for ~ 70 *p*-wave neutron resonances in isotopic Nb, Rh, Ag, Pd, Cd, In, Sn, Sb, I, Cs, Xe, Th, and U targets.

The program of investigations of nuclear fission by resonance neutrons continued with the aim to study the process in the conditions when the spin and parity of a fissioning system are known. The realization is to conduct the most complete study of the investigated target nucleus. A typical example is a ^{235}U nucleus (spins of s-wave resonances are known from previous experiments with

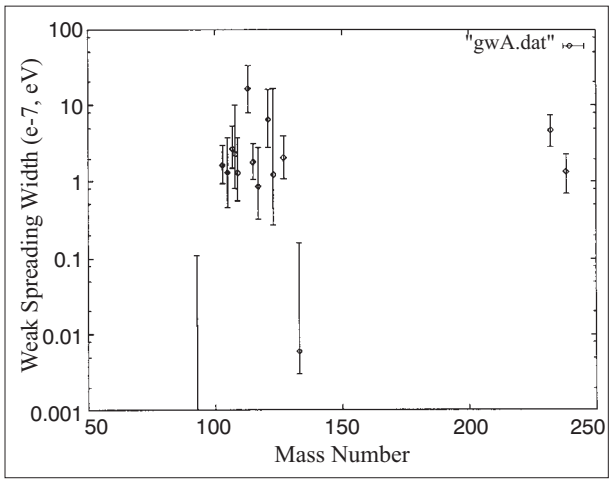

Fig.3. Mass dependence of the weak interaction spreading width

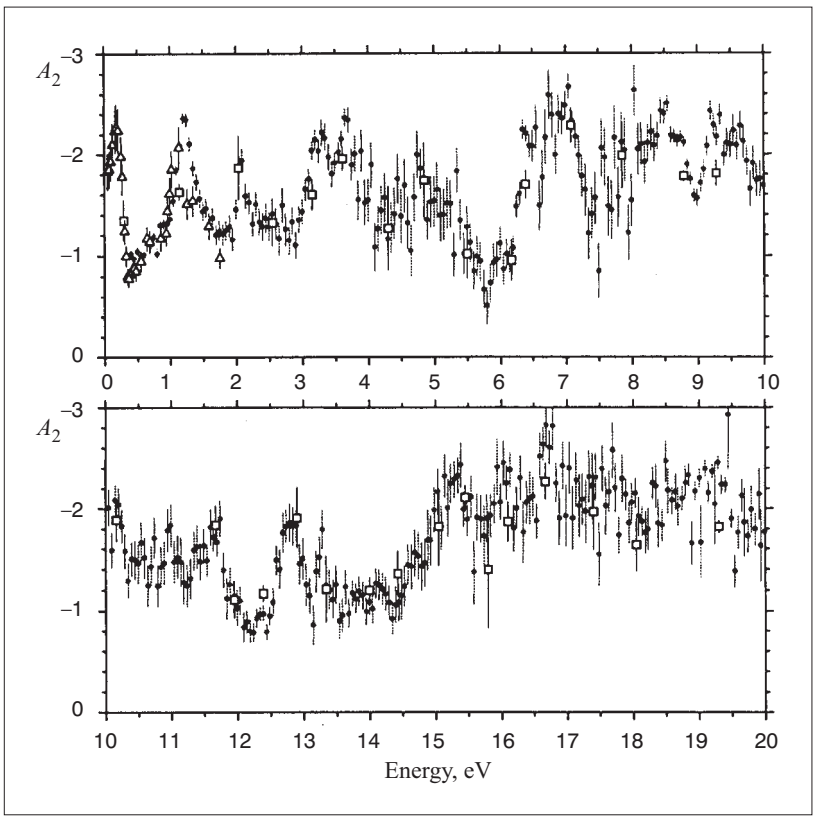

Fig.4. Energy dependence of the anisotropy coefficient A_2. Squares and triangles — data of Pattenden and Postma

polarized neutrons and target nuclei). The measurements conducted at IBR-30 (in collaboration with Gatchina, Obninsk, Bratislava and Delft University) are:

– *P*-even angular correlations of fission fragments — forward-backward, left-right (with polarized neutrons) and A_2 anisotropy (with aligned target nuclei) (Fig.4);
– *P*-odd angular correlations of fission fragments;
– Mass & TKE distributions of f.fr. as functions of the neutron energy.

The quantitative analysis was completed of the results (doubled in statistics during 1998) of measurements of the fission fragment anisotropy of the *s*-wave resonance neutron induced fission of a ^{235}U aligned target. The basic fission amplitudes described by parity π, spin J, and its projection K onto the fission axis were extracted for all neutron resonances in the neutron energy range $0 \div 20$ eV. It allows one to estimate, for the first time, in a direct and consistent way the

– K-dependence of fission barriers for $J\pi = 3^-$ states of the fissioning system ^{236}U and the degree of openness of different JK fission channels [8].

With the POLYANA set-up parity violating effects in the neutron induced fission of a ^{233}U target (neutron spin-fission fragment momentum correlation) were first observed for some *p*-wave neutron resonances as well as the first reliable results on the right-left asymmetry of fission fragments (with respect to the plane formed by the neutron momentum and the spin directions) as a function of the neutron energy in the range $0 \div 70$ eV were obtained for the investigated ^{233}U(n, f)–reaction.

The results of the first measurements carried out in 1997 to investigate the mass and total kinetic energy distributions of fission fragments from the ^{235}U(n, f)-reaction as a function of the neutron energy were analyzed for the major part of statistics (over $3 \cdot 10^7$ events). The analysis shows that some effects of fission modes in the investigated process need new measurements with a better mass and TKE resolution, which will be done in the nearest future.

The measurements of the cross sections for the resonance neutron induced fission of a ^{243}Am target in the neutron energy range $0 \div 50$ eV were completed. A good accuracy was achieved in spite of a very high alpha-particle background ($N_\alpha / N_f \sim 1010$).

In a Dubna–Rzez joint experiment, two-step gamma cascades following thermal neutron radiative capture in ^{190}Os and ^{192}Os targets were studied and it broke the record of completeness. Over 90% of the total intensity of primary gamma-transitions were measured and analyzed. It allows one to extract, with a low uncertainty, the radiative strength function of such transitions and the energy dependence of the level density over a wide energy range. The previous conclusion about the anomaly in the energy dependence of the level density of heavy deformed nuclei for the excitation energy higher than 3 MeV was confirmed with a high level of confidence.

New nuclear data for astrophysics were obtained by a Dubna–TU (Vienna)–FZK (Karlsruhe)–University Tuebingen collaboration for very small 46 and 48 Ca samples delivered from Dubna.

The total neutron transmission through thick ^{232}Th and ^{237}Np samples was measured in the neutron energy range 2 eV ÷ 100 keV. These are important for solving the problem of nuclear waste transmutation

A more accurate result was obtained for delayed neutron yields from the thermal neutron induced fission of ^{327}Np.

The first measurement of the fission cross-section of a ^{234}U target nucleus induced by thermal neutrons was carried out [9].

A series of multielement neutron activation analysis studies of ecological samples from some regions of Russia, Romania, Poland and Egypt continued successfully.

Three cycles of new experiments were conducted at ILL by a FLNP–PINP–ILL group to study the mechanism and properties of extremely small heating of ultracold neutrons (UCN) stored in material traps. This very group discovered the phenomenon in 1997 and it excited great interest in connection with the so-called anomaly of UCN storage observed earlier by Dr. A. Strelkov and colleagues.

Precision tests of the UCN dispersion law were continued in ILL by a FLNP– RRC KI–Melbourne University–ILL collaboration. Possible small deviations from the standard dispersion law were confirmed but some new systematic errors must be studied and eliminated to make the final quantitative conclusion.

APPLIED RESEARCH

Neutron diffraction. As in previous years, IBR-2 applied investigations were mainly in the field of internal stress studies in volumous industrial products and texture investigations of rocks. The texture of model calcite samples was determined and the velocity of ultrasound waves was measured with the spectrometer SKAT. The consequent calculation based on models accounting for the dependence of the wave velocity on the texturization of the sample lead to results very different from the measured data. This urges further improvement of methods for taking into account the texture as a characteristic of building substances, which is of great importance for applied purposes.

NEUTRON SOURCES

The IBR-2 Pulsed Reactor

In 1998, the IBR-2 reactor operated for physical experiments for 2043 hours in 8 cycles.

Modernization project. In connection with lack of financing the planned modernization work was not carried out. The IBR-2 resource is investigated and suggestions are elaborated for its use in 1999 and next years. As a result the decision to operate 8 cycles per year at the average power 1.5 MW was made. This forced decision significantly decreases the IBR-2 attraction for external users. The additional problem is unregular and low salary of the reactor stuff.

All these facts imperial IBR-2 perspectives not only in the period after 2005, but in the nearest future.

Cryogenic moderator. Lack of financing will delay the ultimate date of its manufacturing till mid-1999.

The IREN Project

The project status. Following the recommendations of the JINR Plenipotentiary Committee (March 1993) the JINR Directorate adopted the decision, approved at the 76th Session of the JINR Scientific Council (June 1994), to construct the new modern source of resonance neutrons for investigations in fundamental and applied nuclear physics. The completion date (physical start-up date) was the end of 1997. The IBR-30 analogous scheme, i.e., the combination of a powerful linear electron accelerator and a subcritical multiplying target, was chosen for the new neutron source. The new IREN facility will permit the neutron energy resolution to be increased an order of magnitude at a double increase in luminosity.

In 1998, financing of the work on the IREN project was lower than in 1997 and only extreme efforts of the project management made it possible for the project to survive. The problem of the IREN project implementation was re-examined in detail at the 84th session of the JINR Scientific Council. It was strongly recommended to accelerate the creation of IREN. As a result, the IREN completion date will be, at best, the end of the year 2001 on the condition of complete financing in the period 1999–2001. The IBR-30 shutdown and disassembly is respectively delayed till the middle of the year 2000.

THE FLNP MEASUREMENT AND COMPUTATION COMPLEX

The network and computer infrastructure. In 1998, under the auspices of the MCC project the server Enterprise 3000 with two Ultra Sparc II/250MHz processors, the operation memory 512 Mb and the disk space 40 Gb was put into operation. In the SUN-cluster, old workstations SUN2 were replaced by new Ultra 5/10 stations and the transition to the new operation system Solaris 2.6 was accomplished. The distinguishing feature of the processors Ultra Sparc II is 64 bit words and addresses, superscalar ability (the possibility of simultaneous execution of several instructions by independent devices) and an additional set of commands for graphical applications.

Also, the ATM/Ethernet network switch Orange Ridge was put into operation and it provides access to centralized computational and information resources of JINR at the rate up to 155 Mb/s. In the FLNP local area network (LAN) installing of fast switches (in 1998 in the CMD building and IBR-2 reactor service buildings) is completed and on their basis, local segmets are organized, which makes the data transmission possible between the segments (buildings) via fibre at the rate of 100 Mb/s as well as optimizes the local traffic of data. All of the IBR-2 experimental facilities and the new computers are switched via twisted pairs (UTP) to LAN.

As a result, for the IBR-2 complex there is created an up-to-date information infrastructure with characteristics and possibilities close to those of information infrastructures in European neutron centres.

Development of electronic equipment. In 1998, VME-data acquisition systems were put into operation at the spectrometer EPSYLON and the *X*-ray diffractometer SAX. Beam test measurements of the VME-system for HRFD are in process. Complex adjustment of the source for the spectrometer of polarized neutrons SPN (20 step motors) was carried out. Detector electronics for He-counters in the spectrometer NERA-PR (20 channels) and DN-12 (128 channels) was manufactured and tested with a neutron source. Electronics and software for the KOLKHIDA facility are commissioned. Two sets of unified VME-electronics for the position sensitive detectors of the spectrometers YUMO and DN-2 were tested. VME-electronics for the control of executive mechanisms was manufactured and adjusted and work to create/modernize electronic equipment for the spectrometers KDSOG, UGRA, REFLEX and DN-2 continued.

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LABORATORY OF COMPUTING TECHNIQUES AND AUTOMATION

In 1998, the scientific programme of the Laboratory of Computing Techniques and Automation covered two first- and two second-priority topics of the «Topical Plan for JINR Research and International Cooperation». The main aim of the Laboratory is to obtain new results in the field of «Development and Maintenance of the Networking, Information and Computing Infrastructure at JINR (Project CONET)» (leaders R.Pose and V.V.Korenkov) and on «Nonlinear Problems of Computing and Mathematical Physics: Investigation and Software» (headed by I.V.Puzynin).

The main directions of the CONET project are as follows:

- JINR Local Area Network (LAN) development (INTRANET),
- telecommunication systems (INTERNET),
- high performance computing systems and massive data processing,
- software development,
- information support and data storage systems.

The top-level investigations performed at the LCTA Computational Physics Department allowed organizing the First International Conference «Modern Trends in Computational Physics» in 1998. The scientific programme of the Conference covered various fields of research in computational methods and tools for simulation and analysis of physical processes, mathematical modelling, numerical methods and algorithms, computer algebra methods, software for physics experiments, etc.

NETWORKING, INFORMATION AND COMPUTING INFRASTRUCTURE AT JINR

JINR Local Area Network

In 1998, three JINR Laboratories — LCTA, LNP, and FLNP — put into operation the network equipment for the high-speed JINR backbone based on the ATM technology. Thus the first stage of the ATM project has been realized. The central servers segment also provides a way for the 100 Mbps and 155 Mbps connection. The JINR computing-networking infrastructure is shown schematically on Fig.1 (its status at the end of 1998).

Systematic work on the LAN management was performed by the Network Operation Centre (NOC) *(http://jicom.jinr.ru/)*. A database for the IP address registration *(http://jicom.jinr.ru/bin/faria/ip/ip_koi8.cgi)* and for automatic DNS-files construction has been developed for the proper LAN operation.

Telecommunication Systems

Since 1997, JINR has served as a RBNet node and uses for external telecommunications RADIO-MSU and DEMOS providers. The financial situation and the problems with the RADIO-MSU connectivity as well as the increasing number of computers and servers connected to JINR LAN are the main problems which lead to the unsatisfactory work of the external links to Internet. The main task to be accomplished in 1998 and in the future is to increase the telecommunication channel capacity and throughput by using new providers within the programme «Creation of a National Computer Telecommunications Network for Science and Higher School» and other programmes.

For the JINR traffic control, a specialized service has been organized. It provides an everyday monitoring of data transferred from each computer connected to JINR

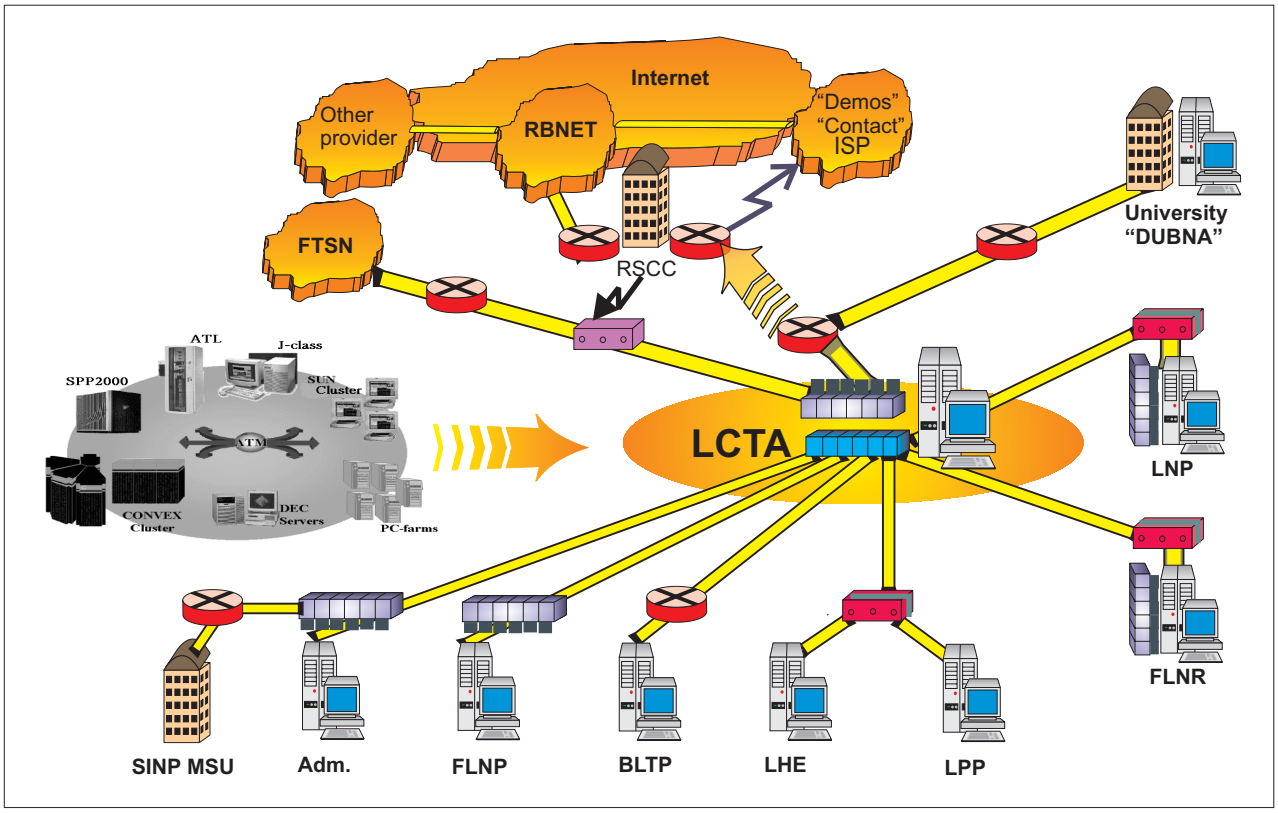

Fig.1. JINR basic computing-networking infrastructure scheme

LAN. The JINR traffic distribution for a sample period from 23.11.98 to 9.12.98 is illustrated by Fig.2.

Computing Service

In LCTA, a number of high-performance computing and file systems were established and started up this year:

- massive parallel system Hewlett Packard Exemplar S-class SPP2000,
- file server HP D370/1,
- application server HP J282,
- vector-parallel computing system CONVEX C3840,
- 10.56 Tbyte ATL 2640 — automated library on DLT tapes.

The equipment listed above became a basis of the High-Performance Computing Centre (HPCC) in JINR/LCTA [1]. A presentation of HPCC took place within the programme of the 84th session of the JINR Scientific Council. The local computer network connects in a uniform complex a massive parallel system Exemplar SPP2000, a vector-parallel system C3840, and an ATL2640 system of the information storage and migration controlled by a file server D370/1. Two technological

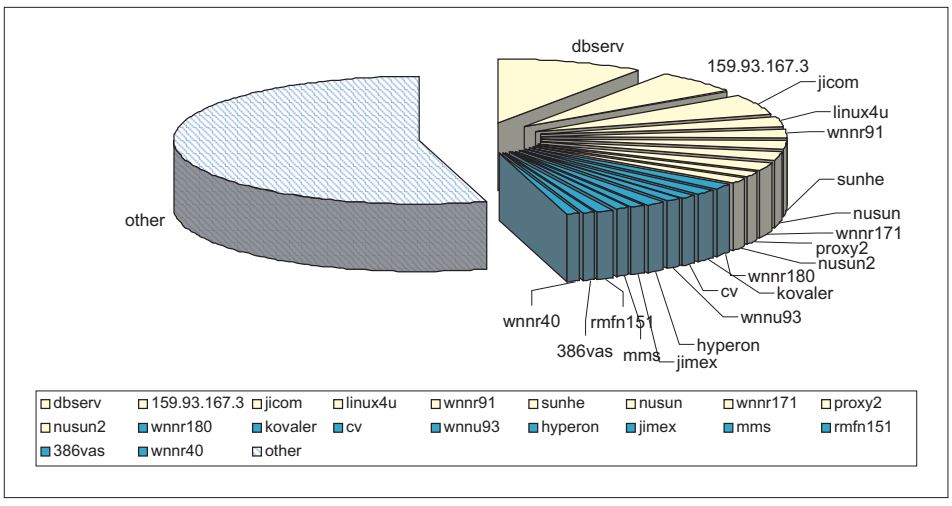

Fig.2. External channel usage statistic from 22.11.98 to 9.12.98 (total). Summary = 75666,18M

circuits for data management are realized with the help of the systems HP OpenView OmniBackup and HP OpenView OmniStorage. In order to provide a reliable storage, a reserve copying is used. It is performed with the help of the program Omniback intended for automatic creation of reserve copies of the files of the library ATL2640 and operates at the D370/1 server. This allows one to carry out a reserve copying of contents of any server connected to the local network. It enables one to restore its contents and backup a copy from ATL in case of a server failure. The software HP OpenView OmniStorage is intended for the organization of a system for file migration. Now the users of remote workstations, PCs, and X-terminals may have very large virtual working directories.

The relative intensity of the SPP2000 and CONVEX computing servers usage by the Institute laboratories over the last 11 months is given on Fig.3.

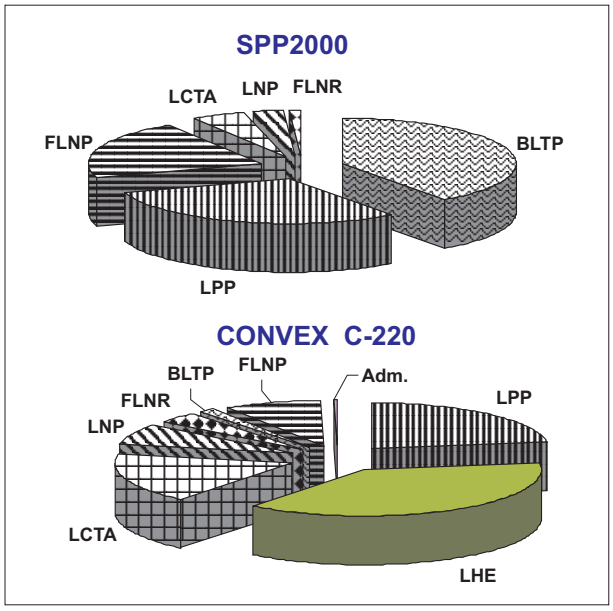

Fig.3. SPP2000 and CONVEX computing servers usage by the Institute laboratories

Software development

In 1998, for the newly established SPP2000 massive parallel system the following special arrangements were made:

– Some additional OS checkout has been performed for the JINR networking environment due to its peculiarities;
– an ATM-based connection between the SPP and D-server robot has been installed and debugged;
– A large amount of additional software has been installed to make user's work easier (more than 50 utilities and libraries were put into operation). For example, a multi-purpose program intended for modelling a molecular structure of matter has been successfully installed at SPP. The program is capable of using all available SPP processors simultaneously. This is the first experience of converting very large programs to parallel ones at JINR.

The support of the JINR program library JINRLIB was continued. The main node of the library consisting of almost 85 programs was debugged. The results of the test operation on the IBM, VAX, SPP, Convex, and PC platforms were compared. All the programs have been transferred to double accuracy. The descriptions of the programs have been prepared in a unified format for the WWW. The support of CERNLIB on JINR computer platforms was provided.

In 1998, the following arrangements were made for the NICE95/NT system within the adaptation at JINR:

- modification of the installing procedure DIANE95 for network cards used at JINR,
- modification of the base software for the NICE maintenance,
- correction of some parameters in the registry due to the peculiarities of the network and server structure of the JINR NICE,
- installation of Cyrillic system fonts for Windows-95/NT,
- selection, installation, and test of a NFS client for Windows-95.

A full-scale maintenance of NICE servers (NICE_LCTA1 under Novell NetWare and NICE_LCTA0 under WindowsNT) were provided for JINR users.

A specialized UNIX environment was created on the basis of the WWW server http://linux4u.jinr.ru, that comprised:

- The archives are brought up to date taking into account new versions of various Linux distributions;
- A procedure for simplifying the installation of Linux at JINR has been worked out;
- Two versions of the CERN software for Linux have been introduced and debugged.

In the context of JINR activities in the CMS Project, some hardware and software resources have been provided for the full participation of JINR specialists in the CMS experiment. The JINR's SUN-CMS cluster was made closer to the CERN one. LCTA also continues the information support for the CMS experiment (http://sunct2.jinr.dubna.su) [2].

According to the schedule of the development of the project on triggering and data acquisition T/DAQ of the ATLAS detector, in 1998 some proposals were worked out on a prototype of the Back-end software for T/DAQ [3]. A complete kit of the resource manager has been elaborated. The work has been performed according to the PSS05 standard and the StP/OMT application. It is in good agreement with the standards and rules of the program-oriented approach to software design stated at CERN.

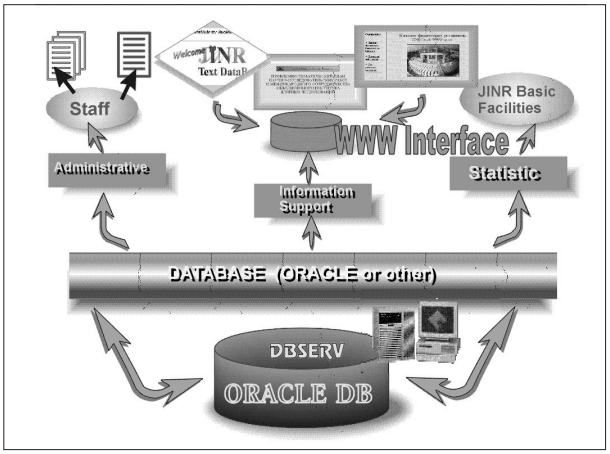

Fig.4. A general technological scheme of development and use of the databases at JINR

The local RISK cluster is used as an effective instrument and a special-purpose tool for solving problems related to physical data processing. All processing of the experimental data obtained at the EXCHARM [4] is performed at this cluster using the BISON program. The RISK cluster is also used for modelling the experiments in the research of charmed and strange quarks at the Serpukhov accelerator.

Databases and WWW Service

The activities under the CONET project in 1998 have resulted in:

- Installation and support of the software for work with international bibliographic databases. Preparation of bibliographic information on high energy and elementary particle physics for entering into the international base PPDS.
- Development and use of databases (DB) and program interfaces to them to support the JINR administrative activity (together with STD AMS JINR):
  - JINR staff DB,
  - JINR Basic facilities usage statistic,
  - JINR Topical Plan (http://www.jinr.ru/info.html),
  - subsystem for the workplace certification.
- Development of the project «Electronic Library of JINR» [5].
- Creation, introduction and usage of interactive DB for the FIBR project(LHE) (http://wnct132.jinr.ru/ nuclear/).
- Maintenance of the HRT–JINR system (JINR staff system) created with the help of a CERN used technology. Design and installation of the BHT–JINR finance management system at JINR on the basis of the technologies elaborated together with CERN. The system provides a method for the prompt analysis of financial information.
- Development and support of the main WWW/FTP-servers at JINR and LCTA, base information Web-server under the BAPHYS project, and a special proxy-server for the JINR LAN.
- Creation and development of a special program and information server (JAVA-station http://dbserv.jinr.ru/js/) for the JINR users that masters JAVA programming technique and means of the organization of distributed calculations on the basis of object-oriented CORBA technologies.

Figure 4 gives a general technological scheme of development and use of the databases at JINR.

COMPUTATIONAL PHYSICS

In 1998, work progressed on the development of new mathematical methods based on cellular automata, artificial neural networks, fractals, wavelets and their application in experiments DISTO, ATLAS, CERES/NA-45, DIRAC, STAR and in other fields for solving the problems arising in data processing [6]. In collaboration with the Torino department of INFN work has been started on the processing and statistical analysis of experimental data obtained in the DISTO experiment. The charged particle tracks recognition algorithm based on the Denby–Peterson segment model for a Hopfield-type full-connected artificial network has been developed for the EXCHARM experimental data processing [7].

A local accuracy estimation procedure for the evaluation of 3D magnetic fields with the help of the finite element method has been developed. The offered algorithms are used for designing the dipole magnets of the VULKAN series for the ALICE experiment [8]. The calculations of magnetic fields for the EXCHARM experiment and the magnet for the proposed experiments with a polarized proton target on the ITEP accelerator have been carried out [9]. The problem of synthesis of passive focusing magnetic channels for the system of beam extraction from the U-400M cyclotron was considered for lower magnetic fields. For the wide range of external magnetic fields and sizes of ferromagnetic elements, a technique of an approximate calculation of a magnetic field was offered [10].

To provide a theoretical basis for the DIRAC experiment at CERN, some investigations have been performed. The effect of strong interaction on a dimesoatomic wave function at small distances has been investigated both analytically (perturbatively) and numerically [11].

The development of new numerical methods and computational schemes has been progressing. Methods increasing the accuracy of an approximate solution to the nonstationary Schroedinger equation have been developed. Effective schemes of the high order accuracy have been obtained [12].

Research of thermoelastic processes originating in metals and metal compounds at pulsed high-energy electron and ion irradiation has been carried out [13]. A numerical solution of the nonlinear equation of thermoconductivity has been performed to simulate the evolution of thermal processes induced on the metallic surface after its irradiation by a high-current ion beam [14].

The calculations and the half-microscopic analysis of experimental data on quasi-elastic scattering and full section have been performed for a plenty of systems. The densities constructed in nuclear-structural models and effective nucleon-nucleon forces were used [15].

A program for construction on Lie superalgebras, superior in its parameters to other similar developments has been worked out [16]. The developed new universal involute algorithms for the analysis and solution of the systems of nonlinear algebraic equations are realized in the «Mathematics» system [17].

Mathematical simulation has shown that the use of 200÷300 MeV proton accelerators in subcritical electronuclear installations seems more promising in comparison with the complicated and expensive 1 GeV machines operating currently [18].

An elastodynamic method has been suggested that provides a proper account of the elastic properties of macroscopic nuclear matter revealed in recent data both on the collective nuclear dynamics and on the activity of neutron stars. The method is currently applied for the description of macroscopic dynamics of nuclear fission and for the analysis of gravitational-elastic stability of neutron stars [19].

New algorithms for the digital image filtering of both smooth images and images with sharp changes of intensity have been considered. The first results of their application (see Fig.5) to images of the human skin micro-structure obtained by optical coherence tomography have been presented at the First International Conference «Modern Trends in Computational Physics» [20].

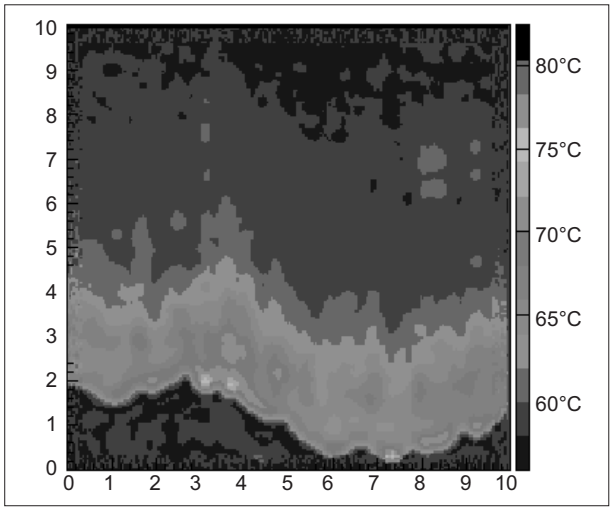

Fig.5. A result of filtering the image of a size of 200× 200 points at a 81 point working window

A method of the control and design of unstable dynamics based on a probabilistic coupling of distinct dynamical laws of evolution was presented and applied to the chaotic logistic map and to a model of interacting agents. As a result, the stabilization and control of the unstable orbits of the logistic map and the design of robust collective behavior of agents in 2 dimensions were obtained [21].

A new approach to reconstructing and predicting discrete chaotic maps has been developed. It is based on the feed-forward neural network which decomposes the analyzed map in orthogonal Chebyshev polynomials. It was shown that the Chebyshev neural network significantly exceeds the traditional multi-layer perceptron in learning rate and in accuracy of approximating an unknown map [22].

INTERNATIONAL COOPERATION

A number of joint investigations and developments were performed within the JINR programme for international cooperation in 1998. In particular, on an agreement with CERN

- a new version of the LabVIEW system (5.01) has been installed and tested; applications and libraries LabVIEW have been adapted to this version for operating systems Windows 95 and Windows/NT;
- software BridgeVIEW has been installed, tested and is being maintained for a wide range of users ATLAS, CMS, other large-scale experiments and for the management system LHC as well;
- integration of the servers and the systems Windows/NT and Windows 95 was provided for the system NICE;
- Novell NetWare servers were changed for Microsoft Windows/NT servers;
- joint research started on the issues of integrating the new operating system Windows 98 into NICE;
- in frames of the NICE development, file servers and print servers controlled by Novell NetWare were changed for Windows/NT controlled servers;
- new commercial program products were integrated in NICE95 and NICE/NT;
- a Java and WWW-based finance management system BHT has been designed at CERN. The system is used at

CERN and applied to the issues solved jointly with JINR.

Cooperation started with the research centre FZK Karlsruhe (Germany) in a research field called «Modern Control & Visualization Systems for Real-Time Data Acquisition». Work has been scheduled on the development of prototypes of the control & datamation system (KaDub). The technological basis of the project development has been agreed, and the GUI development started.

Within the agreement with the research centre Rossendorf (Germany), joint research work was carried out on preparing the introduction of a Windows/NT based hard- and software environment allowing a unified approach to installation, maintenance, development and usage of the PC software.

Within the agreement with the University of Capetown (South Africa), research in modern magnetic materials for optical fiber communication links were carried out [23].

The effective cooperation with the International Salvay Institute of Physics and Chemistry (Brussels, Belgium) progressed in 1998 within a project «Computational Tools and Industrial Application of Complexity» . The project covers theoretical and numerical investigations that have found technological industrial use. Within the theoretical research, analytical and numerical algorithms are developed for study, predetermination of a behaviour, design and control over complex systems of various types. Corresponding software is developed, and promotion of these developments for industrial use is under way. Besides JINR, research institutes of Japan, North and South America, Europe as well as five Russian institutes participate in the project. LCTA takes part in three of seven subprojects:

- «Development of new integral software for electrocardiogram analysis»;
- «Optical coherent tomography of the human skin microstucture»;
- «Resonances, correlation, stabilization and control over complex systems».

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DIVISION OF RADIATION AND RADIOBIOLOGICAL RESEARCH

In 1998, the main directions of DRRR activity were concentraded on:

- radiation researches;
- radiobiological researches;
- radiation protection.

The first two directions were included in the Topical Plan for Scientific Research of JINR as a theme of first priority. Major tasks of the DRRR scientific programme in 1998 were:

– development of the experimental methods and radiation measuring techniques;
– development of the technique of radiobiological experiments and their carrying out by the charged particle beams;
– modelling of ionizing radiation interaction with matter and shielding calculations;
– radiation detector response study;
– radiobiological investigation of the regularities and the mechanisms of the mutagenic action of ionizing radiation with different LET on pro- and eukaryotic cells;
– investigation of biological effect of low doses of radiation with different LET and cells' recovery;
– development of the methods of target radiotherapy and diagnostics.

RADIATION RESEARCHES

Radiation investigations in 1998 were connected mainly with neutron detectors' study, the radiation environment prognostication at CyLab complex in Bratislava (Slovak Republic) and shielding calculations, physical support of the radiobiological experiments at JINR facilities.

The work for systematic study and optimization of parameters of neutron detector assemblies for the nuclear materials safeguards unattended radiation monitoring was prolonged. The prototype of neutron monitor on the basis of corona type gas filled counters, suitable for using in mixed fields with high dose rate gamma-radiation, was developed and tested.

The collaboration between DRRR and the Radiation Biophysics Lab of the US National Aeronautic and Space Administration (NASA) was continued. The system of monitoring instruments for physical support of radiobiological experiments at particle beams was designed. The second run of human peripheral blood lymphocytes irradiation was carried out at the LHE Synchrophasotron at the end of June 1998. The samples irradiated by the 1 GeV protons with absorbed doses 0.5-7.0 Gy, were tested at DRRR and mailed to NASA.

Radiation protection system design and shielding calculations of *CyLab cyclotron complex* were carried out.

Measurements of the double energy-angle distributions of the neutrons (in the energy range from thermal to several hundred MeV) emitted from thick targets irradiated with high-energy protons were continued [1]. The spectra and total neutron yields measurements were performed by the multisphere neutron spectrometer and activation detectors technique. The neutron spectra were unfolded by the statistical regularization method.

The *detectors responce study* was continued by the proton and carbon ion beams [2].

The code for prompt processing of activation detector data was developed.

Radiobiological investigations were performed on *mammalian cells in culture, human lymphocytes, haploid and diploid yeast, bacteria and plant cells.*

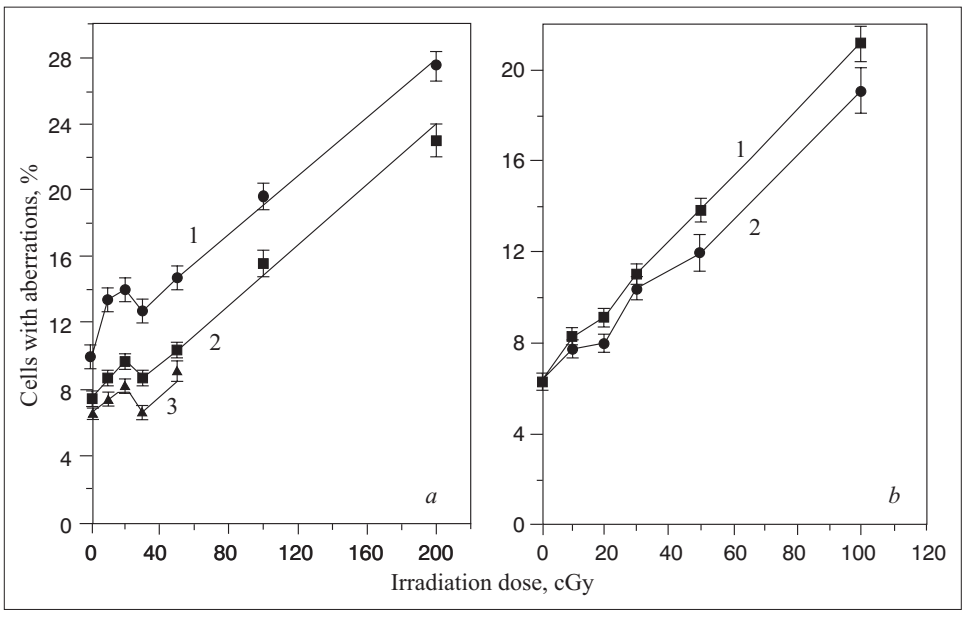
The study of stable and unstable chromosomal aberrations in human lymphocytes was continued [3]. The experiment on irradiation of human lymphocytes by the protons with the energy of 1 GeV was performed. Biotinylate- and digoxigenin-labelled total chromosomal probes were used to stain the chromosome-1 and -2 by FISH technique in spreads, fixed on microscopic slides. The stable and unstable chromosomal aberrations were analysed by FISH- and metaphase methods. The obtained data have shown that the efficiency of the protons with the energy of 1 GeV is similar to the influence of γ rays.

The study of genomic instability of HPRT-mutant clones in Chinese hamster cells (line V-79) was continued. The cells were irradiated by the protons with the energy of 1 GeV. The mutant cells were revealed and the HPRT-mutant subclones were obtained. The analysis of genomic and chromosomal instability of these mutants is being carried out. The provisional data testify the heterogeneity of mutant subclones for cytogenetical criteria. The chromosomal instability of mutant subclones is observed.

In experiments with *haploid and diploid yeast the study of induction of point mutations in eukaryotic cells* has been continued [4]. The dose-dependence of mutation induction and nature of point mutations induced by ionizing radiation was investigated. A tester system, specifically diagnosed for the six possible base-pair substitutions, was used. These strains reversed spontaneously at very low frequencies and were induced efficiently by gamma rays. The dose-response dependence features a linear-quadratic function for each base-pair substitution in diploid and haploid strains. Gamma-induced mutagenesis showed a preference for GC-AT transitions and GC-AT and AT-TA transverses in diploid strains.

The next task of this research was connected with the study of the genetic control of cell cycle arrest on mutagenesis. All living cells are exposed to a wide variety of DNA-damaging agents. When DNA is damaged, an adaptive response is triggered leading to cell cycle arrest to allow time for repair and to minimise the potentially lethal or mutagenic consequences. Cell cycle arrests are imposed by negative controls termed checkpoints that can act at various stages of cell cycle in mammalian cells as well as in yeast. Defects in checkpoint regulation can result in accumulation of mutations leading to genomic changes and neoplastic transformation. This is well examplified in the cancer-prone human disease ataxia-telangiectasia (AT). AT cells are very sensitive to gamma-rays and are also defective in post-irradiation inhibition of DNA replication and checkpoints in G1 and G2. In response to damaged DNA the tumour suppresser gene p53 activates the transcription of several genes and triggers cell cycle delay at G1 and G2 phases. The highly conserved mechanisms of DNA repair and cell cycle regulation among eukaryotes suggest the use of the yeast as a model for exploring the molecular mechanism and physiological significance in cells exposed to DNA damage. Many checkpoint genes have been identified in yeast. We identified at least three additional checkpoint genes [5,6]. Analysis of interactions between them showed that checkpoint genes don't belong to three known epistasis groups of genes of radiosensitivity. These genes are placed in two additional groups and consequently they are involved in sequential steps of different multistep biochemical pathways.

The study of spontaneous and induced deletion mutations in *bacterial cells* after irradiation was continued in



Yield dependence of Chinese hamster cells with chromosome aberrations on irradiation dose. *a* – fixing time 10 hours after irradiation (3 experiments); *b* – fixing time 3 hours after irradiation (2 experiments)

the reported period. The special test-system, used for this purpose, is based on the definition of mutations in both flanking genes: *tonB* (the stability of cells to infection by the *p80vir* phage and to the action of colicins) and *trp* (auxotroph on tryptophane). Dynamics of phenotype display of the mutations was investigated. The frequencies of occurrence of spontaneous and induced deletions (trp^--$tonB^-$) were measured. The factors affecting the SOS induction in E.coli cells such as the kind of radiation, repair genotype and cultivation conditions, were investigated. Concerning UV radiation, the molecular events leading to the SOS induction can be different at small and high doses. Particularly, the SOS-inducing lesions generated in DNA at high doses cannot be removed by constitutive repair systems as it was shown by photorectivating treatment and starvation of the irradiated suspension in buffer after exposure. It was shown that SOS induction strictly depends on the repair genotype of the cells. SOS response in the cells exposed to ionizing radiation depends on LET of the radiation. The maximum of the SOS induction corresponds to LET=20 keV/μm (Helium ions). The influence of the repair genotype on the SOS response was very similar to that observed after UV radiation.

The mathematical modelling of the SOS regulation in *Escherichia coli* cells was continued. Chromosome damage in *E.coli* bacteria or interference with DNA replication caused by ultraviolet or ionizing radiation or some chemicals results in induction of a set of physiological reactions called collectively the SOS-response. Regulation of the SOS-response induction, triggered by an inducing signal appearing after the damaging treatment, involves as its central event the interplay of the two regulator proteins, LexA (negative regulator) and RecA (positive regulator). Based on our model for SOS-response regulation, we have studied induction and turn-off of the SOS response, by simulating variations in cellular levels of the two master SOS regulators, LexA and RecA proteins. Analyses of LexA and RecA dynamics in wild-type and mutant strains, deficient in nucleotide excision repair (major cellular system for removal of ultraviolet light-induced DNA damage) help to reveal functional roles of the two regulators in the SOS-response induction. We were able to calculate dose-response curves for SOS regulatory proteins and analyse timing of the SOS regulation, which appears to be organised as a cascade of information flow through the SOS-regulatory circuit.

The study of *genetic effects of low doses of ionizing radiation* was continued in experiments with mammalian cells [7,8]. It was established that preliminary irradiation of the cells at doses of 1–20 cGy reduces the efficiency of higher consequent doses about 1.5–2 times (see the Figure). The highest values of the adaptive response were observed when the cells were irradiated by the adaptive dose in the G1 phase and by tested doses in S phase of the cell cycle.

The study of low-dose irradiation and low-dose rates of gamma radiation was also continued on yeast cells and plant cells. Earlier it had been shown that radiosensitivity of chronic irradiated cells increased when following acute irradiation and decreased at termination of the irradiation after culturing cells for 16–22 hours. We have performed investigation of the dynamics of the radiosensitivity increase. It has been shown that the cells' sensibilization does not depend on time after chronic irradiation but depends on the number of the cells' divisions occurred after the termination. The analysis of the recent investigation allows one to conclude that low-dose rate radiation does not kill cells but damages them. The damaged cells are characterized by lower speed of proliferation. The studies will be continued.

The research of gamma-ray effect at low dose rates on plant cells was aimed at the problem of linking the anomalous cell mitosis and cells' adaptive response. The result of the study shows [9] that the irradiation at low dose rates as well as at high doses leads to the increase of the amount of «rejected» seeds and causes a delay in the first mitosis. The authors observed a decrease of the chromosomal aberrations' yield and growing mitotic activity. At the same time the authors observed the response disappearance and even growth of cell radiosensitivity in the range 0÷2 cGy/h. It testifies that in the region of radiation hormesis adaptive compensation functions either disappear or are depressed. At high dose rates (about 20 cGy/h) a new adaptive cell reaction appears.

An analysis of results of epidemiological surveys of irradiated human cohorts is realised on the basis of a constructed and well-proved model of two-defence reactions. The analysis has shown [10] that the irradiation impact evaluations can differ considerably when the irradiation dose is the same, as the dose-effect dependence is determined by the radiosensitivity of an individual, or a cohort (population), by their defensive reaction reserve which in its turn depends on the medium and conditions of irradiation. A vivid example of the above-said is fully contrary to effects of Radon irradiation depending on irradiation conditions: the worst impact is for miners combining many other unfavourable factors, while the irradiation effects are favourable for house inhabitants (USA), as well as for several categories of patients who take radon baths.

The analysis of the results of the stochastic effect investigations on the cell level using the TDR model makes it possible to picture some regularities in accordance with the dose-effect dependence in the low-dose region. Growth, recession and then growth again in the aberration yield depending on the dose can be seen in the range of 10÷50 cGy, no matter what biological object it is (root meristem of barley seedlings, the HT29 cell lines of human tumour, or Chinese Hamster cells irradiated by photons). Possibly, it is the consequence of a defensive adaptive reaction, which starts at the dose of about 20 cGy.

The investigation of the application of the complex ^{211}At-Methylene Blue for *targeted radiation therapy* of pigmented melanoma was continued. This kind of therapy is founded on high affinity of MTB to melanin tumour

cells and is directed against the metastatic process, which is very characteristic of this tumour type. The degree of normal and melanoma cells damage was estimated after the application of ^{211}At in ionic form or the ^{211}At-MTB complex. The equal action efficiency of ionic ^{211}At was shown for normal Chinese Hamster cells V-79 as well as for human melanoma cells of BRO line. At the same time the efficiency of the ^{211}At-MTB action on melanoma cells is one order higher than on normal cells. This means that ^{211}At-MTB is selectively accumulated in melanin containing cells and can be used in targeted therapy of disseminated melanoma with minimal damage on normal tissues.

At the end of 1998 these investigations were separated by the project «MITRA» (within the existed scientific theme of DRRR) owing to their importance and perspective.

RADIATION PROTECTION

The radiation monitoring for occupational exposure at JINR nuclear facilities was carried out in 1998 by the automatic systems of radiation control (ASRC) and by portable instruments. The radiation field investigations in dwellings around the cyclotron U-400M were continued. The works on reconstruction of specialized ventilation of FLNR radiochemistry facilities were carried out. The modernization of the neutron measuring channels of FLNR cyclotron's complex ASRC was performed as well.

The regular environmental monitoring of soil, plants (grass), water from the river basins in Dubna vicinity, water-supply system and water effluents of enterprises allows one to assert that the environmental radiation pollution around JINR area remains constant during a long time and contains the natural radioactivity and products of global fallout only. Any contribution to radioactive pollution of the environment from the JINR nuclear facilities was not found in 1998.

In 1998, the Individual Dosimetry Service maintained dose control to 1898 persons, including 72 visitors, under individual monitoring. Their number decreased by 70 persons as compared with 1997. The yearly individual doses to the personnel did not exceed 15 mSv/yr. The highest value of the average individual dose per year among the JINR Laboratories is, as before, at FLNP and FLNR — 1.4 mSv/yr. The exceeding of the control levels of doses in Laboratories and the dose limits was not observed in 1998 as well.

EDUCATION ACTIVITY

In 1998, the process of student training at the University Center in the speciality «Radiobiology» (holder of the chair Prof. E.A.Krasavin) was successful. Three graduates and three postgraduates completed their courses at the faculty in the early 1998.

The new «Biophysics» chair was organized at Dubna International University in 1998. The chair will graduate the physical engineers in the specialty «Radiation protection of man and environment».

The work on preparation of the IAEA Regional Post-Graduated Course on Radiation Protection (the second run of which is planned to be held on the basis of JINR in autumn 1999 for states — members of the Agency from Europe and CIS) was begun.

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UNIVERSITY CENTRE

In 1998, the JINR's Educational Programme received a new status.

In connection with its successful realization and increased role, the first-priority topic «Organization, Maintenance and Development of the University-Type Educational Process at JINR» was started by the resolution of the 83rd session of the Scientific Council. The opening of the topic allowed the efforts of all the Institute Laboratories aimed at perfecting the JINR's educational system to be united and the field of the cooperation between the JINR Member States in educational programmes to be enlarged.

In the autumn semester (spring semester in parenthesis) of 1998, there were 75(66) students from different higher- education institutions of the JINR Member States at the University Centre (UC) including 6 (6) of Moscow State University, 27 (26) of Moscow Engineering Physics Institute, 18 (18) of Moscow Institute of Physics and Technology, and 24 (16) of other higher-education institutions of Armenia, Georgia, Germany, Russia, and other countries.

Early in June 1998, the first defence of Bachelor's theses by fourth-year students of Moscow Institute of Physics and Technology was held at the UC.

The UC performs its first specific goal training of specialists from a JINR Member State: since autumn 1998, 5 fifth-year students of the University of Bratislava (Slovakia) are studying within a special programme to become specialists for the cyclotron complex to be built in Slovakia with the JINR's support.

In autumn 1998, the top officials of JINR and Moscow Institute of Radio Engineering, Electronics, and Automatics (MIREEA) decided to establish at JINR a graduate department in the specialty «Electronics and Automatics of Physics Installations». To fulfil this decision, in the autumn semester of 1998 the UC began for the first time the training of MIREEA's first-year students attending the full-time diurnal programme.

JINR scientists participate actively in the educational process. The UC's teaching staff totals 47. In recent years there appeared young lecturers, which is especially important in rapidly developing areas like modern computing and microprocessor systems. The following courses in these fields were given to the students: «Databases», «Visualization of Scientific Research», «Microprocessor Systems», «Object-Oriented Programming in C++», «Fundamentals of Computing», «Internet Technologies», «Applied Computer Algebra», and «Computing in High-Energy Physics».

Four of the JINR scientists giving lectures at the UC won the 1998 competitions for the titles of Soros Professor and Soros Docent.

The educational process was expanded in 1998 by the introduction of a special practical course for the students on the basis of JINR Laboratories.

The UC's infrastructure continues to develop. A third lecture auditorium with the multimedia-equipped lecturer's place was put in operation in 1998.

The UC's computer infrastructure was modernized and maintained by the joint efforts of the staff of the UC and the Laboratory of Computing Techniques and Automation. The following tasks were accomplished:

– modernization of the UC's software and hardware complex on the basis of the Unix and Windows NT servers;
– organization of studies in the computer auditoriums;
– technical, system and information support of the educational process, including multimedia means of presentation, on the basis of computer auditoriums.

A library for students and post-graduates functions at the UC.

Further development of JINR's educational activity must make for the reinforcement of the JINR's staff with young specialists. The incorporation of the Bureau of Technical Training of JINR into the UC will allow highly qualified specialists of the Institute to be involved in the training and retraining of the engineering and technical personnel on the basis of JINR's technical divisions and will extend the list of the fields of training.

POST-GRADUATE PROFESSIONAL EDUCATION

In 1998, JINR was certified by the Ministry of General and Professional Education to conduct educational activity in post-graduate professional education.

The list of six specialties of the JINR post-graduate studies at the UC (nuclear and elementary particle physics; theoretical physics; charged particle beam physics and accelerator techniques; computational mathematics; solid state physics; physics experiment techniques, instrument physics, and physics research automation) was added in 1998 by another four specialties:

- 05.13.11 – mathematical and software support of computers, computational complexes, systems, and networks;
- 05.13.16 – computer facilities, mathematical modeling, and mathematical methods in scientific research;
- 01.04.23 – high energy physics;
- 03.00.01 – radiobiology.

There were 62 post-graduate students in 1998 at the JINR post-graduate studies; besides, 25 post-graduates affiliated to other higher-education institutions work at JINR. The distribution of JINR's post-graduates over the laboratories is as follows: 12 at the Laboratory of Theoretical Physics, 10 at the Laboratory of Nuclear Problems, 5 at the Laboratory of Nuclear Reactions, 14 at the Laboratory of Neutron Physics, 6 at the Laboratory of High Energies, 5 at the Laboratory of Particle Physics, 6 at the Laboratory of Computing Techniques and Automation, 3 at the Division of Radiation and Radiobiological Research, and 1 at the University Centre.

In 1997, a lecture cycle for post-graduates under the general title «Modern Problems of Natural Science» was started at the UC which continued in 1998. The following lecture courses were given: «Beam Dynamics in the Presence of Synchrotron Radiation» by Prof. J. Le Duff (Orsay, France), «Hot Nuclei and the Liquid-Gas Phase Transition in the Nuclear Matter» by Prof. V.A.Karnaukhov (Laboratory of Nuclear Problems, JINR), and «*Mathematica* Tutorial Course» by Prof. R. Kragler (Germany).

On December 24, 1998, a ceremony was held to mark the completion of the post-graduate studies of the first enrollment (1995). Certificates of completing the JINR post-graduate studies have been delivered to the young scientists. They all have remained to work at JINR.

UC'S INTERNATIONAL COOPERATION

One of the UC's activities is the organization and conduction of international schools and instructional courses.

In 1998, JINR signed an Agreement on Partnership with the European Physics Education Network (EUPEN), which will allow the UC's students and lecturers to be involved in the exchange programmes organized by the European Physical Society (EPS). The UC is one of the Russian Federation's coordinators in the European Mobility Scheme for Physics Students (EMSPS) and is included in the EMSPS database, where the information on the UC is available since 1995.

The agreement with the EUPEN has already brought the first result: a UC's post-graduate student was awarded one of the six grants assigned by the EPS for the study year 1998-1999 to support the practical experience of students and post-graduates of Eastern Europe within the EMSPS. This grant will support his half-year on-the-job training at the University of Giessen (Germany).

According to the JINR's Plan for International Cooperation, the UC hold in August the two-week International Summer Student School on High Energy Physics marking the 85th anniversary of Bruno Pontecorvo's birth. The School was supported by the UNESCO and the Ministry of Science and Technology of Russia. It was intended for graduate students of physics faculties, post-graduate students, and young scientists specializing in high energy physics.

About 60 students and post-graduates of Belarus, Bulgaria, Columbia, Germany, Italy, Republic of Korea, Portugal, Romania, Russia, and Sweden participated in the School. The lectures were given by known scientists of JINR, Moscow, Protvino, universities of Napoli and Florida, and CERN who had closely known Bruno Pontecorvo and collaborated with him.

The first day of the School was marked by the opening of the photo exhibition in memory of Bruno Pontecorvo and presentation of a special WWW page dedicated to him **(http://pontecorvo.jinr.ru)** which was put up by a UC's post-graduate student.

The following topics were considered in the lectures at the School: neutrino masses and lepton mixing; precise measurement of electroweak interactions; neutrino in astrophysics and cosmology; beyond the standard model; hadronic interactions at very high energies and small-x physics; meson spectroscopy; heavy ion physics; production of super-heavy elements; future detectors for hadron colliders.

Two weeks of the School were filled with various interesting lectures, seminars, and excursions. All the lectures had been promptly placed in the WWW page of the School.

The information on the School is available on the WWW at **http://uc.jinr.ru/iss98**

In March 1998, the UC and the Association of Young Scientists and Specialists (AYSS) of JINR conducted the Second Open Scientific Conference. Compared with the previous year, the Conference's subject field was extended in the sections of radiobiology and ecology. Graduate students, post-graduates, and young scientists not older than 33 participated in the Conference. The Conference attracted more than 100 participants from Dubna, Moscow, Gomel, Yekaterinburg, Minsk, Cheboksary, Voronezh, and other cities. A delegation from the Adam Mickiewicz University (Poznan, Poland) attended the Conference. JINR's leading scientists gave review lectures on the modern state and prospects for experimental and theoretical research conducted at JINR.

In June 1998, the UC and AYSS held the Second School for Young Scientists and Specialists at the holiday

The geography of the UC's international contacts

camp of the Lipnya island. About 50 participants of the School attended to the review reports of JINR's leading scientists concerned with various aspects of modern nuclear physics that are dealt with in the research conducted at the JINR Laboratories.

JINR has agreements on the joint educational activities with many universities of Russia and the JINR Member States. The UC's contacts with Polish universities are developing actively. The special Bogoliubov–Infeld programme was established in 1998, which has supported initiatives of Polish universities and JINR in the development and conduction of educational projects.

UC's students and post-graduates and their Polish colleagues exchange visits of acquaintance and participate in schools and conferences held both in Dubna and in Poland. Especially active in the exchange are the University of Lodz, University of Wroclaw, and Adam Mickiewicz University (AMU) of Poznan. One of the AMU's students had pre-diploma practice at the Experimental Department of Nuclear Physics of the Laboratory of Neutron Physics.

In February 1998, eight UC's students and post-graduates participated in the school on theoretical physics «From Quantum Mechanics to Quantum Technology» (Karpacz, Poland).

In June 1998, a group of AMU's students together with students of the Physics Faculty of Moscow State University (MSU) had summer practice in medical physics on the basis of the Division of Radiation and Radiobiological Research, UC, and the Dubna branch of the Institute of Nuclear Physics of MSU. A lecture course was given to the students, and practical classes concerned with radiation biology, radiation safety, and radioecology were conducted. During this practice, the students learned about the main fields of the JINR's activities and visited its Laboratories.

In September 1998, a group of students of Jagellonian University and the Academy of Mining and Metallurgy (Krakow, Poland) specializing in biology, chemistry, and the environment protection visited JINR. They familiarized themselves with the UC, JINR's basic facilities, and visited the Division of Radiation and Radiobiological Research, Laboratory of Neutron Physics, Laboratory of Nuclear Reactions, and Laboratory of Computing Techniques and Automation. They showed interest in continuing their education at the JINR post-graduate studies.

In December 1998, a group of students of the University of Wroclaw, Poland, paid a visit of acquaintance to JINR. A student of the University of Kiel (Germany) had on-the-job training at the Laboratory of Nuclear Reactions. Like usually in summer, one UC's student had on-the-job training at CERN.

The information on the UC was published in 1998 in «Nuclear Physics News» (vol.8, pp. 27-28) and «The Journal of the International Association of Physics Students» (Issue 5, Spring 1998, pp. 10-11).

UC's scientists conduct theoretical research of the interactions between heavy ions and nuclei [1–3].

The UC's WWW home page is at http://uc.jinr.ru

REFERENCES

1. *Antonenko N.V. et al. — Phys. Rev., 1998, v.C57, p.11832.*
2. *Adamian G. et al. — Nucl. Phys., 1999, v.A646, p.29.*
3. *Adamian G. et al. — Romanian J. Phys., 1998, in print.*

JINR is developing as a large multidisciplinary international scientific centre incorporating basic research in the field of modern nuclear physics, development and application of high technologies, and university education in the relevant fields of knowledge.

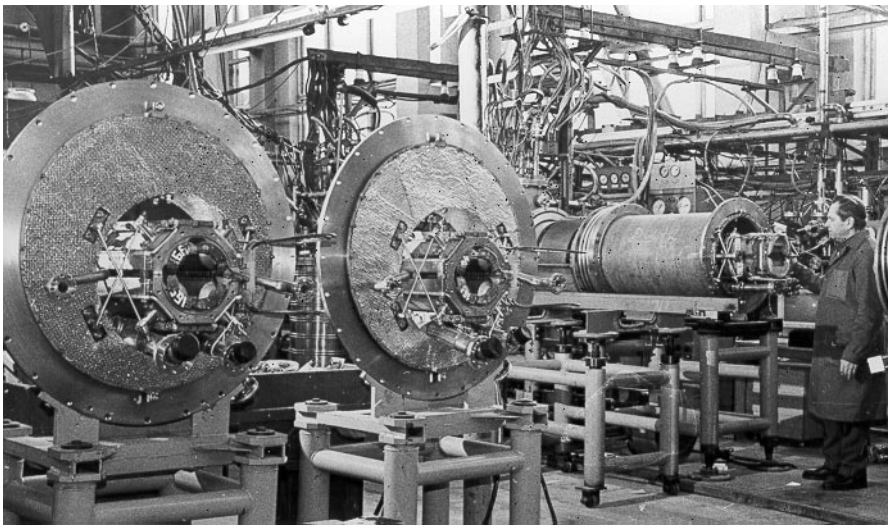
Seminar dedicated to the 85th birthday of Honorary Director of the Laboratory of Nuclear Problems V.P.Dzhelepov, one of the organizers of JINR

Flerov Laboratory of Nuclear Reactions. Seminar on the occasion of the 85th anniversary of the birth of Academician G.N. Flerov (1913–1990), an outstanding scientist and the founder of the Laboratory

Frank Laboratory of Neutron Physics. Opening of the scientific seminar dedicated to the 90th anniversary of the birth of Nobel Prize laureate Academician I.M.Frank (1908–1990)

Laboratory of Computing Techniques and Automation. Within the programme of the 84th session of the JINR Scientific Council, a presentation of the JINR High-Performance Computer Centre took place at the Laboratory on 5 June

Laboratory of Nuclear Problems. DUBTO set-up purposed for a joint Dubna–Turin (Italy) experiment using the Phasotron's pion beam

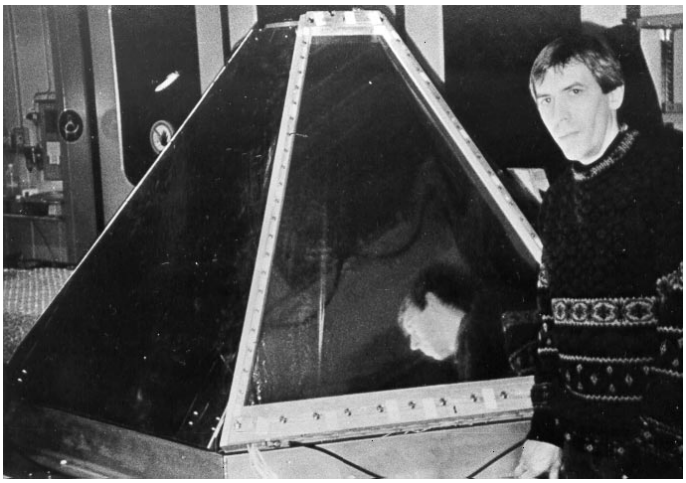


Laboratory of High Energies. Testing of elements of the Nuclotron beam slow extraction system

Flerov Laboratory of Nuclear Reactions.
International Workshop for the preparation
of a technical project for a cyclotron
laboratory to be constructed at the Slovak
Institute of Metrology (Bratislava)

Laboratory of Particle Physics.
Area for serial assembly of pokalon-C
chamber modules for the HERA-B facility
at DESY (Germany)

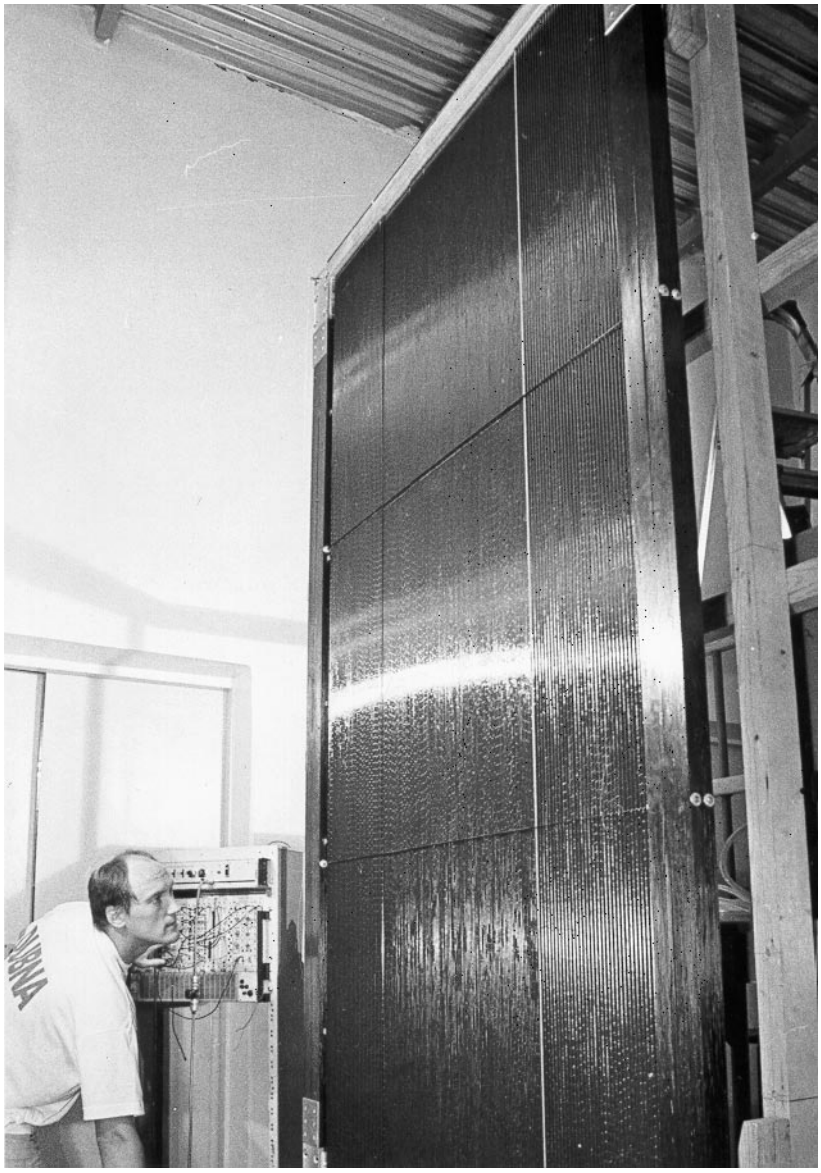
Bogoliubov Laboratory of Theoretical Physics, 14 January. Participants of a special event to mark the first publication, 40 years ago, of the monograph by N.N.Bogoliubov and D.V.Shirkov «Introduction to Quantized Field Theory»



Laboratory of High Energies.
Multilayer Drift Chamber MDC-2
with readout electronics purposed
for the HADES experiment at GSI (Darmstadt)

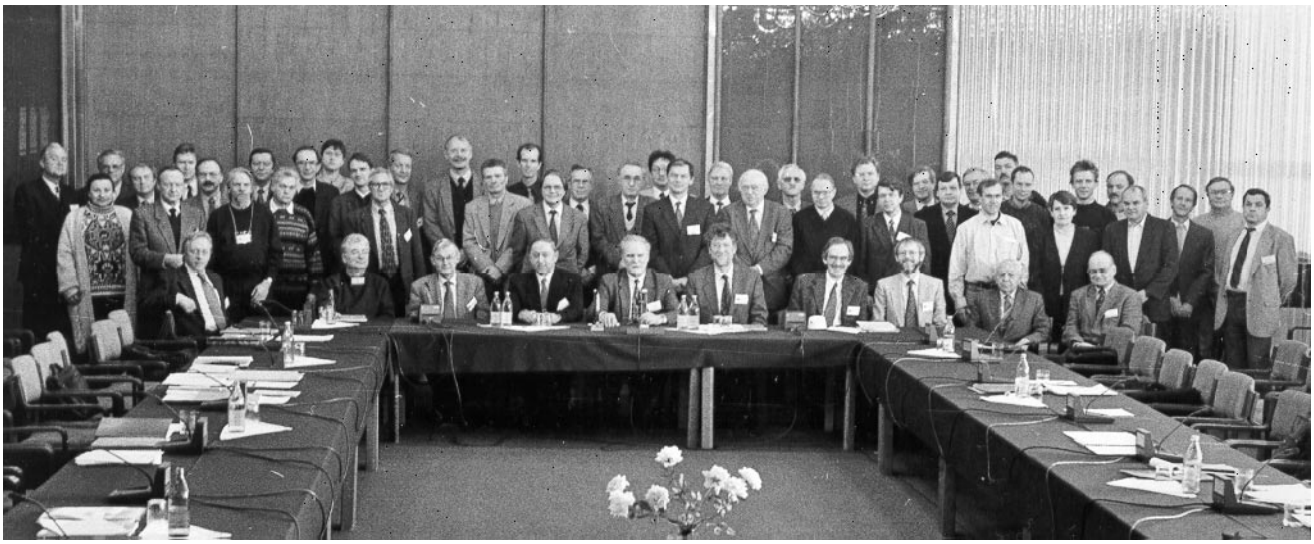
Dubna, 19–21 June. The 2nd Summer School for JINR Young Scientists and Specialists,
co-organized by the JINR Association of Young Scientists and Specialists and University Centre

JINR Experimental Workshop.
Area for testing mini-drift chambers
purposed for physics research
at the Tevatron in Fermilab (USA)
within the D0 project

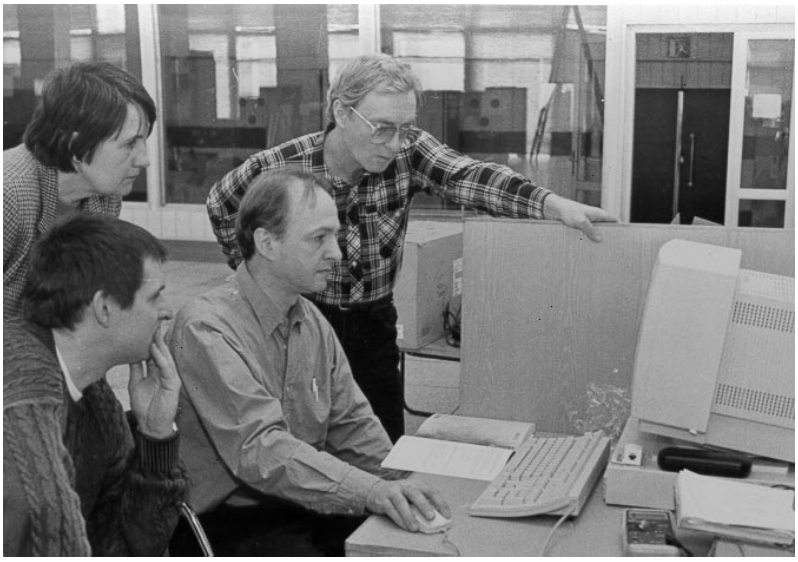


Laboratory of Particle Physics.
A high-precision straw-chamber
constructed at the Laboratory for the
COMPASS experiment at CERN

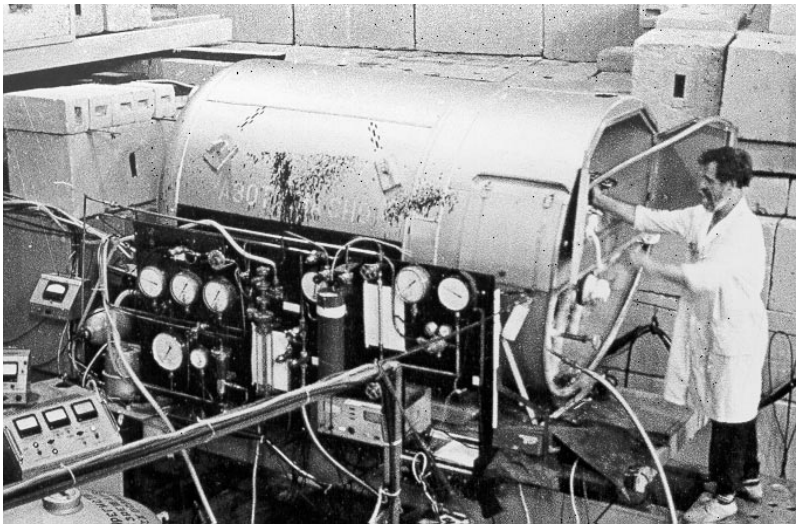
JINR Experimental Workshop.
Assembly of equipment purposed
for the cyclotron project of INS VINČA
(Belgrade, Yugoslavia)



Dubna, 16–17 November. Workshop of experts to review the progress of implementation of the joint projects carried out within the JINR–BMBF (Germany) Cooperation Agreement

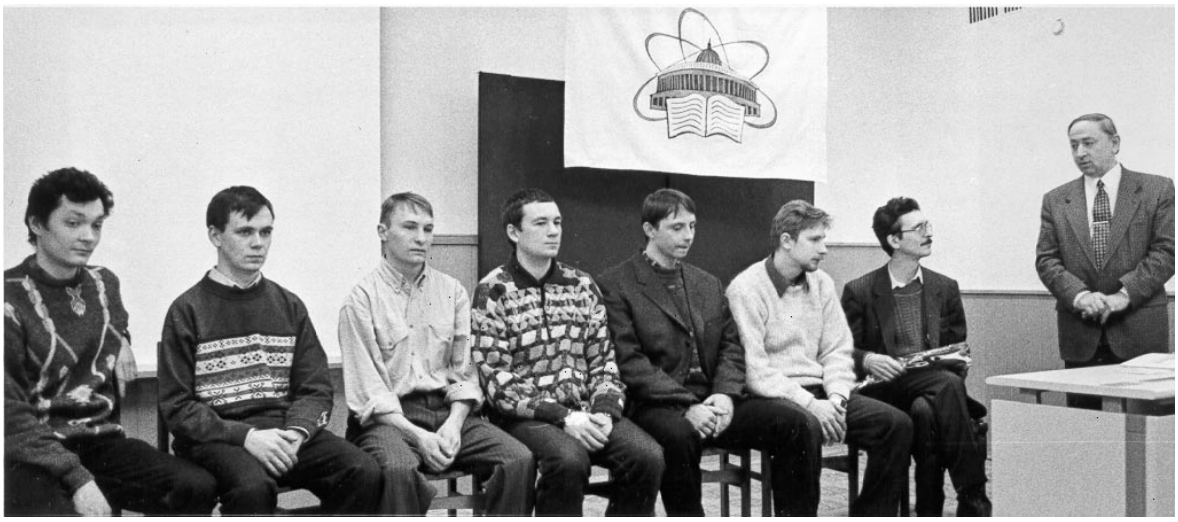


Laboratory of Computing Techniques and Automation. New equipment produced by Hewlett Packard Company installed in the Laboratory's High-Performance Computing Centre



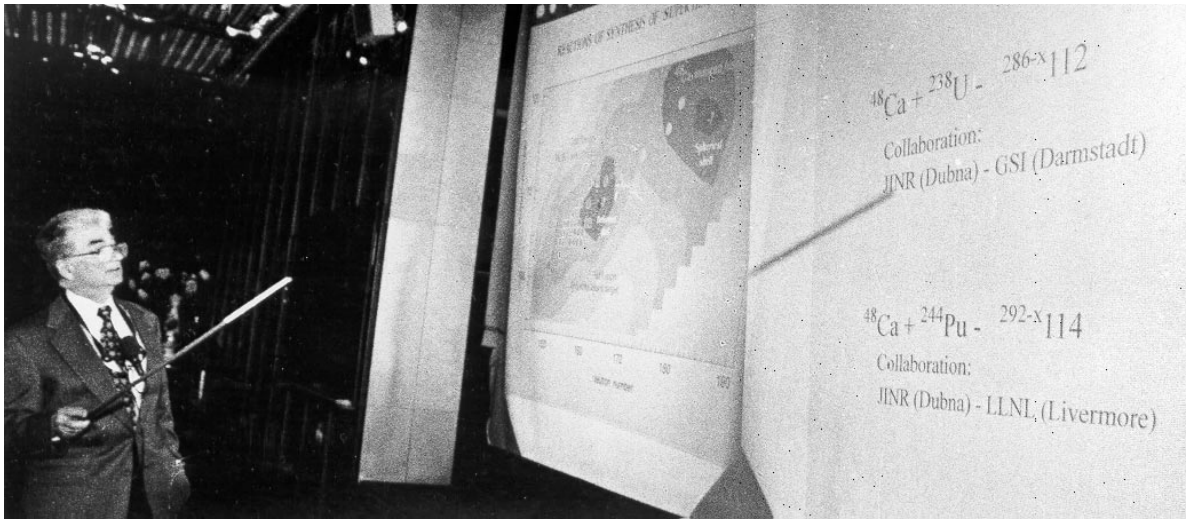
Frank Laboratory of Neutron Physics. Radiation resistance testing at the IBR-2 reactor of a prototype liquid argon chamber for the ATLAS experiment at CERN's LHC

JINR University Centre. Participants of the International Summer School on High-Energy Physics dedicated to the memory of Academician Bruno Pontecorvo



JINR University Centre. Ceremonial graduation of the first post-graduates of JINR

Laureate of the
1998 B.Pontecorvo Prize —
Professor V.M.Lobashev
(INR, Moscow) (centre)



JINR's scientific highlight of 1998 — the first experimental proof of the existence of the «stability island» of superheavy elements. In the photo: Professor Yu.Ts.Oganessian, Scientific Leader of the Flerov Laboratory of Nuclear Reactions, explains to the Scientific Council members the results of the successful experiments on the synthesis of the superheavy element with $Z = 114$

CENTRAL SERVICES

PUBLISHING DEPARTMENT

In 1998, the Publishing Department published JINR communications and preprints of 444 titles. Issued were 143 official publications.

A total of 42 proceedings of various conferences, schools and workshops were issued. Among them are proceedings of the International Conference on Nuclear Structure, the International Symposium «Problems of Biochemistry, Radiation and Space Biology» (in two volumes), the XIIIth International Seminar on High-Energy Physics Problems «Relativistic Nuclear Physics and Quantum Chromodynamics» (in two volumes), the Vth and VIth International Seminars on Interactions of Neutrons with Nuclei, the 2nd Seminar in Memory of V.P.Sarantsev. Published were also the annual reports of JINR for 1997 (in Russian and in English), the annual report of the Frank Laboratory of Neutron Physics for 1997, books dedicated to the outstanding scientists: «I.M.Frank. In Commemoration of the 90th Anniversary of Birth», «F.L.Shapiro: A Man and a Scientist. Book of Reminiscences», «N.M.Sissakian. In fond memory of the outstanding scientist». «V.P.Dzhelepov. Dedicated to the 85th Birthday», «D.V.Shirkov. Dedicated to the 70th Birthday».

Published also was the Information-Biographical Reference Book «Joint Institute for Nuclear Research» by M.G. Shafranova.

In 1998, six issues of the journal «Physics of Elementary Particles and Atomic Nucleus» with 36 reviews, and six books «JINR Rapid Communications» with 42 articles, describing original scientific, technological, and applied results, were printed. Publication of the bulletin «JINR News» in the Russian and English languages was continued.

The Publishing Department sent 354 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», «Nuclear Physics», «Physics of Elementary Particles and Atomic Nucleus», «Physical Review», «Journal of Physics», «Physics Letter», «Nuclear Physics», «Nuclear Instruments and Methods», «Modern Physics Letters», 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 Library and Patent Department bulletins printed by the Publishing Department. Traditionally, the «Bibliographic Index of Papers Published by JINR Staff Members in 1997» was issued.

The Publishing Department was also engaged in Xerox copying and book binding to fulfil numerous orders of JINR Laboratories. About 130,000 various forms were printed for processing of experimental information and for other purposes.

SCIENCE AND TECHNOLOGY LIBRARY

In 1998, the number of readers in the Science and Technology Library was 4,736. Over 250,000 copies of printed matter were borrowed from the Library during the year. Ordered by readers, 1,007 publications were received via the interlibrary loan system. Over 20 Xerox copies of articles from foreign journals not available in the JINR Library and Moscow libraries were received under the agreement with INTAS. A total of 8,815 new books, periodicals, preprints, about 6,300 of them being in foreign languages, were added to the Library from different sources in 1998. All these publications are registered in the central catalogue and in branch catalogues. As of 1 January 1998, the Library stock amounted to over 418,000 copies, 184,000 of them in foreign languages.

The bulletins «Books», «Articles», «Preprints» were published weekly. Their total of 156 issues provided information on 20,795 titles. The bulletins are distributed among about 240 JINR staff members and mailed at 77 outside addresses. The information bulletins and lists of conferences are regularly updated in the WWW and INFOMAG (Moscow).

Exhibitions of new books, preprints, periodicals were updated every week, and 7,600 titles were displayed. Three topical exhibitions were held. The «Bibliographic Index of Papers Published by JINR Staff Members in 1998» containing 1,457 titles was prepared.

In 1997, in exchange for JINR publications printed by the Publishing Department, the Library received 6,280 publications from 33 countries, among them 574 from Russia, 990 from Germany, 379 from Italy, 1,166 from the USA, 254 from France, 370 from Switzerland, 623 from Japan, and 1,862 from CERN. Besides, the Library receives scientific journals and books (144 titles) from 35 countries.

INTELLECTUAL PROPERTY PROTECTION DEPARTMENT

In 1998, ten inventor's applications were submitted for issuing patents to the authors or to JINR as patent holders. An application for a patent «Method of making submicrometer tubular metallic replicas of track membranes» (V.F.Reutov and S.N.Dmitriev, FLNR) is under consideration at the All-Russian Scientific Research Institute of State Patent Examination. The preliminary state examination was given to this application and the priority was registered on 25.12.1998.

The following patents were issued:

– «An electron-beam device for decomposition of industrial gaseous wastes» (S.A.Korenev and A.S.Korenev);
– «Method of producing a metallic replica for analysis of nanometer channels in track membranes» (S.N.Dmitriev, V.F.Reutov, and A.S.Sakhatsky).

A decision was taken to issue a patent «System for decomposition of toxic compounds» to S.A.Korenev and V.N.Samoilov.

In 1998, the Department received 72 official patent bulletins of the Russian Federation with the information on pending and issued patents. They were analysed from the standpoint of JINR research topics. Based on this analysis, 12 issues of the bulletin «Patents» were published at JINR.

In 1998, the Department continued giving methodological assistance and advice about drawing up inventor's applications for issuing patents and legal advice about the rights of patent and inventor's certificate holders.

By the end of 1998, JINR had 20 patents valid in the Russian Federation.

EXPERIMENTAL WORKSHOP

In 1998, the Experimental Workshop manufactured products to an amount of over 6.0 million roubles on the request of the JINR Laboratories and other Departments. As previously, orders for mechanical equipment dominated, including:

- units of an r.f. cavity for the heavy-ion accelerator,
- muon detectors for the experiment D0,
- a maximum shower detector for the experiment STAR,
- the NEMO spectrometer for investigation of double beta decay,
- the DIRAC facility,
- a set of neutron guides,
- polymerizers,
- copper plates for the ATLAS calorimeter.

Most of these items were manufactured in collaboration with scientific centres of the USA, France, Yugoslavia, and JINR Member States.

Among outside customers, the Scientific Production Centre «Aspect» occupied a prominent place in 1998. The production of the equipment for monitoring radioactive materials for «Aspect» increased. Its orders allowed the radioelectronic section to operate almost at full capacity. Manufacture of digital telephone exchanges continued. A large amount of work was 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 activities in 1998.

Actual expenditures were as follows:

The actual annual incomings amounted to 17,671.5 thousand US dollars, or 47.1% of the annual allocations.

The actual expenditure covering research activities of the Joint Institute for Nuclear Research in 1998 amounted to 19,973.1 thousand US dollars.

	Item	Annual budget in thous. US dollars	Expenditure in 1998 in thous. US dollars	% of budget
1.	Direct R&D expenditures in major fields of research	17,283.1	10,205.6	59.0
2.	Expenditure on infrastructure of laboratories	8,991.1	6,057.0	67.4
3.	Expenditure on JINR infrastructure	5,379.0	3,710.5	69.0
4.	On agreement with BMBF (Germany) less JINR infrastructure and Directorate reserve fund expenditure	948.6		
5.	On agreement with Hungarian Academy of Sciences less JINR infrastructure and Directorate reserve fund expenditure	127.5		
6.	Directorate reserve fund, 5% of budget	1,867.5		
7.	Plenipotentiaries' grants, 8% of Member States' contributions	2,903.2		
	Total expenditure	37,500.0	19,973.1	53.3

STAFF

As of 1 January 1999 the personnel of the Joint Institute for Nuclear Research numbered 6,037 (without temporary staff).

Working at JINR are 8 academicians: V.L.Aksenov, A.M.Baldin, I.A.Golutvin, V.G.Kadyshevsky, V.I.Korogodin, A.M.Petrosyants, A.N.Sissakian, D.V.Shirkov; 8 corresponding members of academies of sciences: V.P.Dzhelepov, V.A.Khalkin, I.N.Meshkov, R.M.Mir-Kasimov, Yu.Ts.Oganessian, A.I. Titov, A.S.Vodopianov, I.Zvara; 238 doctors of science, 676 candidates of science, including 90 professors and 14 assistant professors.

In 1998, there were 531 people engaged and 560 people discharged because of engagement period expiry and for other reasons.

During the year JINR staff members were awarded the titles of professor — 1, senior researcher — 8, junior researcher — 6.

In 1998, 14 staff members received a Candidate of Science degree and 11 received a Doctor of Science degree, among them 19 JINR staff members, 1 from the Republic of Kazakhstan, 1 from the Republic of Poland, 1 from Romania, and 3 from the Russian Federation.

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