THE JINR SCIENTIFIC PROGRAMME

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1. INTRODUCTION

1.1 General information about the Joint Institute for Nuclear Research (JINR)

The Joint Institute for Nuclear Research (JINR) in Dubna was established on the basis of the convention signed by the Plenipotentiaries of the governments of the Member States of the JINR in March 1956 in Moscow. The JINR was created in order to unify the intellectual and material potential of the Member States in order to study the fundamental properties of matter.

Dubna as a town of science was founded immediately after the end of World War II. In 1947 a group of scientists led by Academician I.V. Kurchatov initiated construction of the then largest accelerator of charged particles – the synchrocyclotron. The accelerator was commissioned already in 1949. Extensive fundamental and applied investigations into the properties of nuclear matter immediately started at the newly established Institute for Nuclear Problems (INP) with its operating 680 MeV synchrocyclotron, headed by the young physicists M.G. Meshcheryakov and V.P. Dzhelepov, later world-known scientists.

After the INP, the Electrophysical Laboratory of the USSR Academy of Sciences (EFLAN), headed by Academician V.I. Veksler, was set up in Dubna. A new accelerator, namely a synchrophasotron with record parameters for that time, was constructed at EFLAN.

In 1954 the European Organization for Nuclear Research (CERN) was established near Geneva to unite the efforts of Western European countries for studying the fundamental properties of matter.

About the same time, under the stimulus of the USSR Government, the countries then belonging to the socialist world took the decision to establish the Joint Institute for Nuclear Research in Dubna from the INP and EFLAN laboratories. The same year, specialists from 12 countries (Albania, Bulgaria, China, Czechoslovakia, East Germany, Hungary, Mongolia, N. Korea, Poland, Romania, USSR, and Vietnam) came to Dubna. The town became international, and investigations into many fields of nuclear physics of interest for research centres of the JINR Member States were launched there.

Many scientists and engineers from the Member States have been trained in the JINR scientific schools established by N.N. Bogoliubov, D.I. Blokhintsev, G.N. Flerov, I.M. Frank, B.M. Pontecorvo, V.I. Veksler, and other outstanding physicists. The development of different scientific directions at JINR is connected with the names of L. Infeld and H. Niewodniczanski (Poland), G. Nadjakov (Bulgaria), H. Hulubei (Romania), L. Janossy (Hungary), N. Sodnom (Mongolia), Wang Gangchang (China), Nguyen Van Hieu (Vietnam), V. Votruba and J. Kozesnik (Czechoslovakia), H. Pose and K. Lanius (Germany), and others.

The Charter of the JINR was adopted in 1956, the text of which was revised in 1992 and more recently in 1999. In accordance with the Charter, the activities of the Institute are achieved on the basis of its openness, and the mutual and equal co-operation of all the interested parties to participate in research.

The aim of the Institute is:

- to carry out theoretical and experimental investigations on adopted scientific topics;
- to organize the exchange of experience when carrying out research and the exchange of information obtained as a result of these investigations through publication of scientific papers, holding of conferences, symposia etc.;
- to promote the development of the intellectual and professional capabilities of the scientific personnel;
- to establish and maintain contacts with other national and international scientific organizations and institutes to ensure the stable and mutual co-operation;
- to use the results of the investigations of an applied nature to provide supplementary financial resources for fundamental research by implementing them into industrial, medical, and technological developments.

The results of investigations carried out at the Institute can be used solely for peaceful purposes for the benefit of mankind. So until the late 1980s, Dubna was a centre that unified the efforts of leading research groups of nuclear sciences from socialist countries and the Soviet Union.

After the disintegration of the USSR, membership of the JINR underwent the following changes: the majority of Eastern European countries, such as Poland, the Czech and Slovak Republics, Bulgaria, Romania, and others continue to be Member States and contribute to the budget. Germany remains as an observer and makes a substantial financial contribution. Most of the former Soviet Union republics, which became independent states, entered the JINR as new members.

I would like to recall the words of the great Russian writer A. Chekhov, who said:
“Science cannot be national, in the same way that a multiplication table cannot be national. If a science becomes national, it ceases to be a science”.

JINR is a perfect illustration of this idea.

There are different ways to participate in the activities of the Institute: on the basis of membership, or bilateral and multilateral agreements in order to perform particular scientific programmes. JINR Member States contribute financially to the Institute’s activities and have equal rights in its management.

At present the JINR has 18 Member States: Armenia, Azerbaijan, Belarus, Bulgaria, Cuba, Czech Republic, Georgia, Kazakhstan, D.P. Republic of Korea, Moldova, Mongolia, Poland, Romania, Russian Federation, Slovak Republic, Ukraine, Uzbekistan, Vietnam.

The JINR has special co-operation agreements concluded on the governmental level with:

- Germany (in the field of theoretical physics, heavy-ion physics, condensed matter physics, and high-energy physics);
- Hungary (in the field of condensed matter physics);
- Italy (in the field of intermediate and low energy physics).

Among the major partners with whom JINR has long-term co-operation agreements are:

- CERN, in the field of high-energy physics;
- IN2P3 (France), in the field of nuclear and particle physics;
- INFN (Italy), in the field of nuclear and particle physics;
- FNAL, BNL, SLAC and other research centres in the USA.

Recently, special agreements were signed with UNESCO and CLAF (Latin American Centre for Physics). The latest political changes in Eastern Europe and especially in Russia have made the JINR more and more open. New collaborating countries are welcomed to join the JINR.

Particularly, successful negotiations have been lately conducted between the JINR Directorate and Governmental bodies of Greece on the subject of Greece entering the JINR as Associate Member.

THE AGREEMENT BETWEEN THE GOVERNMENT OF THE RUSSIAN FEDERATION AND JINR HAS BEEN RATIFIED

On the 3rd December 1999 the State Duma of the Russian Federation passed a Federal Law "On Ratification of the Agreement between the Government of the Russian Federation and the Joint Institute for Nuclear Research on the Location and Terms of Activity of the Joint Institute for Nuclear Research in the Russian Federation". The Federal Law was approved by the Federation Council on 22 December 1999 and signed by the Acting President of the Russian Federation V. Putin on 2 January 2000. The Federal Law came into force from the date of its official publication – 6 January 2000.

The Agreement between the Russian Government and the JINR was signed in Dubna in 1995. Now it is supported by the law and confirms the international personality and legal capacity of JINR. It also grants facilities, privileges and immunities in correspondence with the established practice for international intergovernmental organizations.

GOVERNING AND ADVISORY BODIES OF THE JINR

- Committee of Plenipotentiaries of the JINR Member States
- Finance Committee (one delegate from each Member State)
- Scientific Council
- Programme Advisory Committee for Particle Physics
- Programme Advisory Committee for Nuclear Physics
- Programme Advisory Committee for Condensed Matter Physics

The main fields of the Institute's activities are theoretical physics, elementary particle physics, relativistic nuclear physics, physics of low and intermediate energies, heavy-ion physics, nuclear physics with neutrons, condensed matter physics, radiobiology and nuclear medicine, experimental instruments and methods, computing technologies.

The basic facilities of the Institute for experimental investigations are the Nuclotron, U400 and U400M cyclotrons, and IBR-2 neutron reactor. The other JINR facilities such as the synchrophasotron, phasotron, cyclotron U-200, and the IBR-30 reactor are mainly supported by resources which are outside the JINR budget.

The internal organization of the JINR is determined by scientific specialization. There are seven Laboratories in the Institute:

- Bogoliubov Laboratory of Theoretical Physics (BLTP)
- Laboratory of High Energies (LHE)
- Laboratory of Particle Physics (LPP)
- Dzhelepov Laboratory of Nuclear Problems (DLNP)
- Flerov Laboratory of Nuclear Reactions (FLNR)

- Frank Laboratory of Neutron Physics (FLNP)
- Laboratory of Information Technologies (LIT)

There are three more all-Institute subdivisions in the JINR's structure:

- Division of Condensed Matter Physics
- Division of Radiation and Radiobiological Research
- University Centre of JINR

The total number of JINR personnel is about 6,000 (including service divisions). Approximately 1,100 scientists work at the Institute. The scientific policy of the JINR is established by the Scientific Council, whose members are prominent scientists from the Member States (A.A. Logunov, V.A. Matveev, A.N. Skrinsky, R. Sosnowski, A.N. Tavkhelidze, etc.) and well-known physicists from CERN, France, Germany, Italy, the USA and other countries. M. Della Negra, C. Detraz, F. Dydak, F. Lehar, B. Peyaud, H. Schopper, P. Spillantini, G. Trilling, and others are among the members of the Scientific Council. JINR's Director, Academician V.G. Kadyshevsky, is the Chairman of the Scientific Council.

Several associate experimental physics workshops are also part of the Institute. The personnel of the Central Workshop totals about 400. It is equipped with everything necessary for manufacturing large-size non-standard facilities, electronics, and has technological lines for constructing detectors for physics. Here the main units of JINR's heavy-ion cyclotrons — U400 and U400M — were constructed in recent years, as well as the Nuclotron — a new superconducting accelerator for relativistic nuclear physics. It is an excellent result especially in view of the difficult economic situation in Russia in recent years.

2. JINR's SCIENTIFIC ACTIVITY AND BASIC FACILITIES

Let us consider the research programmes at the JINR's main facilities and a few examples of the recent results.

2.1 Nuclotron

The new superconducting accelerator, the Nuclotron (see Fig. 1) was put into operation five years ago (A.M. Baldin et al.). It will enable an extensive programme of research in relativistic nuclear physics to be performed both in asymptotic mode (an accelerated nuclei energy higher than 4 GeV/n) and transmission regime (less then 4 GeV/n). In the asymptotic mode the nucleons cannot be considered as quasiparticles of nuclear matter and the influence of quark–gluon degrees of freedom in interactions of hadrons and/or nuclei should be observed.

The Laboratory of High Energies (LHE) of the JINR was a pioneer in designing and constructing the first low-cost accelerator based on low-field iron dominated superconducting magnets. The Nuclotron was built over a period of five years. The main magnetic equipment and many other systems were fabricated by JINR workshops.

The Nuclotron ring of 251 m in perimeter is installed in the Synchrophasotron technological tunnel. The total 'cold mass' of the magnetic system is about 80 t. Cooling of the system down to 4.5 K takes about 90 h. The cooling system was designed taking into account the fast cycling mode of the Nuclotron (up to 0.5–1.0 Hz), which is a specific feature of this superconducting accelerator.

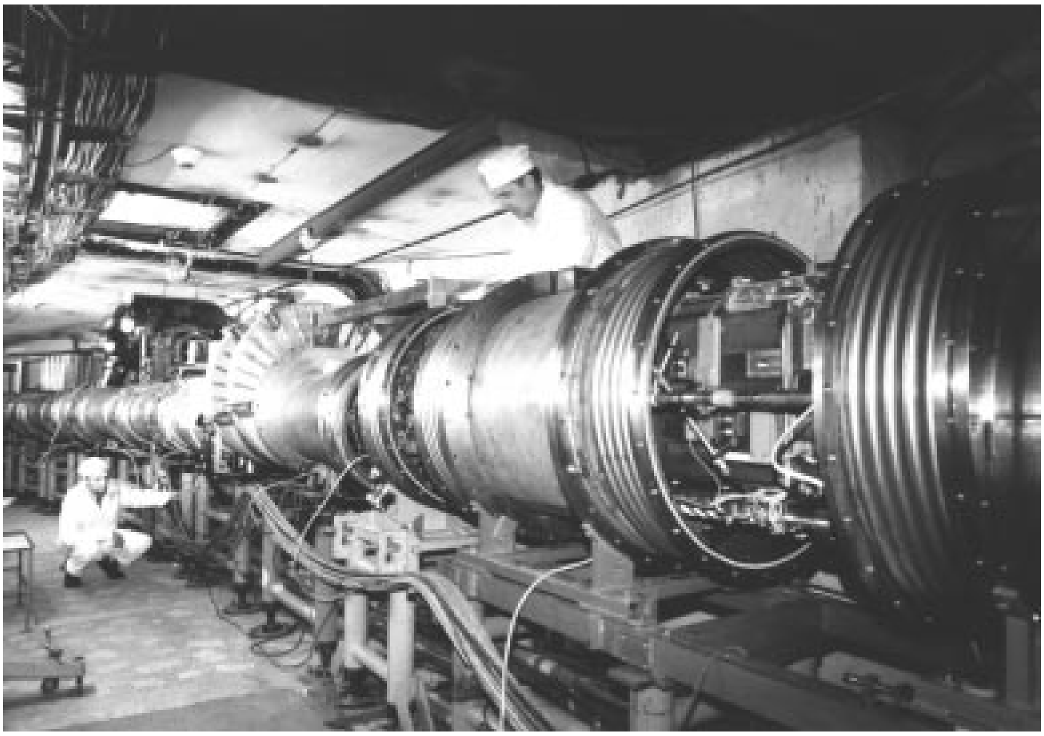

Fig. 1: The Nuclotron.
A new superconducting accelerator which permits an extensive programme of research in relativistic nuclear physics to be performed.

In 1999, a special system for extraction of a nuclear beam from the Nuclotron to external set-ups was completed. The system is a complex structure based on superconducting magnetic elements, which does not have an analogue in the world. In December 1999, the system was successfully tested and the first extraction of the proton beam from the Nuclotron was carried out. In March 2000, an experiment was conducted to optimize the modes of the slow extraction beam and research activity was started at the extracted beam in the LHE experimental hall.

Two experiments at the STRELA and SCAN-2 set-ups have been started this year with the extracted beam. The first test measurements with the slow extracted deuteron beam of the Nuclotron were carried out within the framework of research on the charge-exchange process in deuteron–proton interactions: **dp → (pp)n**. The goal of the measurements is to register two protons moving forward in a narrow cone at the large background of single protons from the deuteron fragmentation process. The two-proton events are distinguished by measuring the Cherenkov radiation amplitude (see Fig. 2).

The SCAN-2 set-up is constructed to study the proton-formation length in
$\mathbf{d + A_T \rightarrow p_1(\sim 0^o) + p_2 (\sim 0^o) + \ldots}$

The injection complex under development will consist of a booster, linac, and ion sources. This complex will allow one to accelerate nuclei from hydrogen to uranium with an intensity of 10^{13} to 10^8 particles per pulse, respectively (see Table 1), in the energy range of 6–7 GeV per nucleon. Polarized deuteron beams are foreseen.

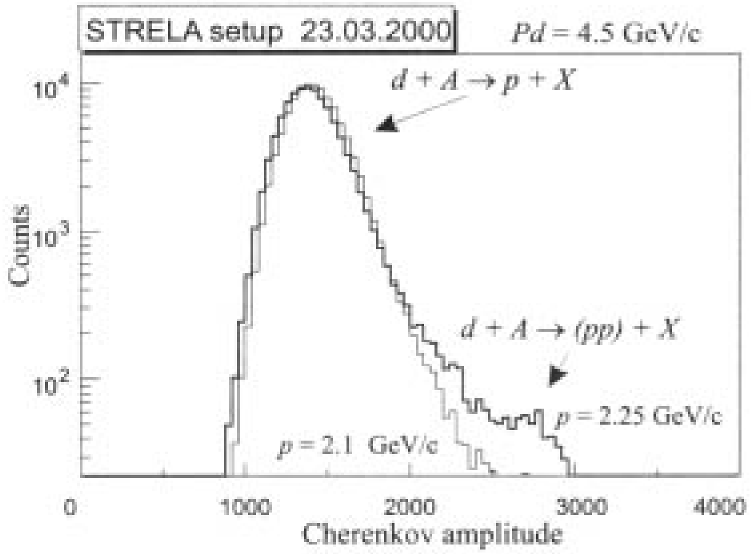

Fig. 2: The amplitude distribution of signals from the Cherenkov counter at the zero-angle scattering of deuterons with a momentum of 4.5 GeV/c from a polyethelene target

Table 1: **The NUCLOTRON beams**

Beam	INTENSITY (Particles per cycle)		
	Nuclotron *(available)*	**Nuclotron + Ion sources development**	**Nuclotron + Booster**
p	$2{\cdot}10^{10}$	$1{\cdot}10^{11}$	$1{\cdot}10^{13}$
d	$2{\cdot}10^{10}$	$5{\cdot}10^{10}$	$1{\cdot}10^{13}$
^{3}He		$2{\cdot}10^{9}$	$\sim10^{12}$
^{4}He	$8{\cdot}10^{8}$	$5{\cdot}10^{9}$	$2{\cdot}10^{12}$
^{7}Li		$2{\cdot}10^{10}$	$5{\cdot}10^{12}$
^{12}C	$1{\cdot}10^{8}$	$7{\cdot}10^{9}$	$2{\cdot}10^{12}$
^{20}Ne		$1{\cdot}10^{8}$	$5{\cdot}10^{9}$
^{24}Mg		$3{\cdot}10^{8}$	$5{\cdot}10^{11}$
^{40}Ar		$3{\cdot}10^{7}$	$2{\cdot}10^{9}$
^{56}Fe		$5{\cdot}10^{7}$	$1{\cdot}10^{11}$
^{84}Kr	$1{\cdot}10^{3}$	$2{\cdot}10^{7}$	$5{\cdot}10^{8}$
^{96}Mo			$1{\cdot}10^{10}$
^{131}Xe		$1{\cdot}10^{7}$	$2{\cdot}10^{8}$
^{181}Ta			$1{\cdot}10^{8}$
^{209}Bi		$3{\cdot}10^{6}$	$1{\cdot}10^{8}$
^{238}U			$1{\cdot}10^{8}$

2.2 Synchrophasotron

The Synchrophasotron (see Fig. 3) is an accelerator of 10 GeV protons commissioned in 1957 (V.I. Veksler, A.L. Mints et al.). In the 1970s the acceleration of nuclei heavier than hydrogen was accomplished in the broad energy spectrum from a few hundred MeV to 4.5 GeV per nucleon. The average densities of the beams range from 10^4 to 10^{11} ions per cm^2s depending on the atomic number of the accelerated nuclei and the experimental requirements.

Synchrophasotron beams attract physicists from many laboratories in the world. The collaboration SPHERE (JINR+Nagoya University) performed a study of nuclear matter at short distances.

Fig. 3: Synchrophasotron

In order to clarify the mechanism of the reactions and the structure of the non-nucleon degrees of freedom, an experiment with polarized deuteron fragmentation into cumulative hadrons was performed. The observed difference between the model and the experimental data is especially large for K = 0.2 GeV/c, where it would be natural to expect the manifestation of non-nucleon degrees of freedom in the deuteron wave function (see Fig. 4).

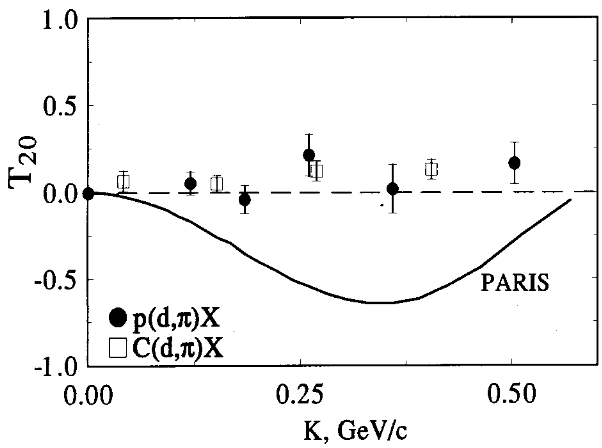

Fig. 4: SPHERE Collaboration. Measurement of the tensor analyzing power T_{20} in inclusive polarized deuteron fragmentation into pion at zero angle.

2.3 Phasotron

The Phasotron is an accelerator of 680 MeV protons (M.G. Mesheryakov, V.P. Dzhelepov et al.). It commenced operation in 1949, was reconstructed in 1984, and is the oldest basic facility of the JINR (see Fig. 5). In December 1999 the staff of the JINR's Laboratory of Nuclear Problems has celebrated the 50^{th} anniversary of commissioning the Dubna Synchrocyclotron (from 1984 – Phasotron). The person who immensely contributed to the creation, development, and subsequent upgrading of the Synchrocyclotron for applied nuclear physics and medico-biological research was Professor V.P. Dzhelepov, an outstanding scientist and one of the founders of the JINR. At its 87 session (January 2000), the JINR Scientific Council welcomed the decision of the JINR Directorate to name the Laboratory of Nuclear Problems after Professor V.P. Dzhelepov, in recognition of his great contribution to the activities of this Laboratory and of the whole Institute.

It is owing to his enthusiasm that an onco-radiological department on the basis of the Phasotron was opened in Dubna on 1 December 1999. Twenty-four patients having serious forms of cancer (4th stage) have already undergone a course of treatment in the onco-radiological department; 18 of them received a gamma–proton treatment, and 6 were exposed to gamma-rays. The results of the treatment were positive.

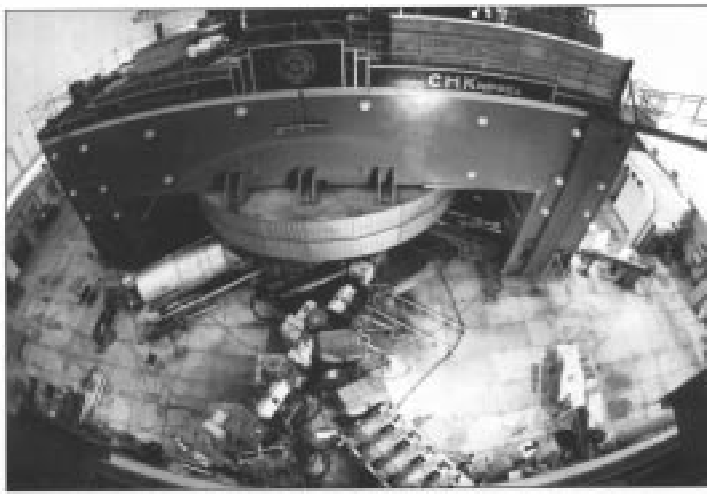

Fig. 5: Phasotron with space variation of the magnetic field, proton energy (660+3.1)MeV, extracted beam intensity $3x10^{13}$ p/s, duty cycle - 85%

Ten beam channels are available at this machine and are used to carry out experiments with pions, muons, neutrons and protons. Five secondary beams are designed to carry out medical investigations. The intensity of the extracted proton beam is 4 μA.

The scientific activities of the Laboratory cover experimental research in particle physics (at high, low and intermediate energies); investigation of nuclear structure (including relativistic nuclear physics and nuclear spectroscopy); study of condensed matter properties; biological and medico-biological investigations; applied research including cancer therapy.

There is a proposal to construct the external injection of the beam into the accelerator's centre in order to increase the intensity of the Phasotron accelerated proton beam 10–20 times.

2.4 U400 and U400M

At present the complex of two heavy ion cyclotrons — U400 and U400M (G.N. Flerov, Yu.Ts. Oganessian et al.) — is the main experimental base of the Flerov Laboratory of Nuclear Reactions. As you know, element 105 discovered at this laboratory was named Dubnium in honour of Dubna.

The Laboratory's research programme involves investigations in a wide region of low- and intermediate-energy heavy-ion physics. Intense heavy ion beams open up new vistas for the synthesis and study of radioactive and chemical properties of heavy elements, studies of nuclei far from the line of beta-stability. Research is under way in the field of reactions with exotic nuclei and the mechanism of fusion and fission processes.

The isochronous U400 cyclotron was constructed in 1978 and produces ion beams of atomic masses from 4 to 100 and maximum energy up to 25 MeV/nucleon. The maximum ion beam intensity is presently $2x10^{14}$ ion/s for Ne, and drops to $2x10^{13}$ ion/s for Ca. The experimental set-ups are located at 12 extracted beam channels.

The U400M is an isochronous cyclotron (see Fig. 6) which commenced operation in 1991-92 to accelerate heavy ions. At the U400M cyclotron, internal ion beams of light elements from He to Ar with energies up to 50 MeV/nucleon (the maximum energy is 100 MeV/nucleon) have been obtained. A system of channels for extracted beam transportation is being developed.

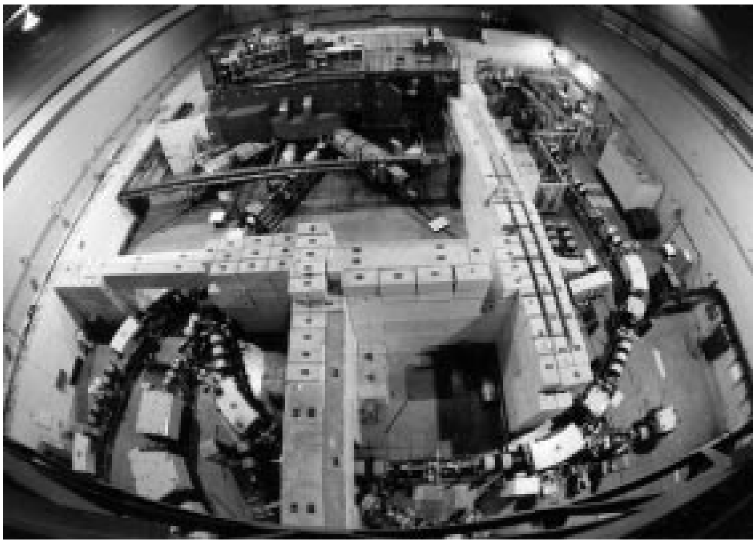

Fig. 6: U400M

To widen the range of accelerated ions at the U400M and to increase the energy, the ECR-source DECRIS has been constructed at the Laboratory. Also, a more powerful ECR-source is being developed in collaboration with the GANIL Centre (France). The use of the ECR-type heavy-ion sources will allow the Laboratory to use less expensive separated isotopes in research on the synthesis of heavy elements or exotic nuclei. In order to obtain and transport secondary beams of radioactive nuclei, the COMBAS fragment separator with a large acceptance and high resolution is being created. The project of the future development of the Laboratory accelerator complex is linked with the production of radioactive nuclear beams in the tandem mode of operation of the U400M and U400 accelerators, and with the creation of a storage ring, acting as the third stage.

The most spectacular result obtained at U400 in late 1998 was the synthesis of a new long-lived (30s) superheavy element with atomic number 114 and mass 289 and thus the discovery of an island of nuclear stability for superheavy elements. This discovery has crowned the 35-year efforts of physicists from JINR, USA and Germany in search for this stability island.

During 1999, three isotopes of the new element, 114, having masses A=287, 288 and 289 were synthesized. Among their decay products there were identified the heaviest isotopes of the elements: 112 with A=283, 284 and 285, element 110 with A=280 and 281, and element 108 with A=277.

Fig. 7 shows the decay chains of the new isotopes, including the energy values, the alpha-decay periods, and spontaneous fission.

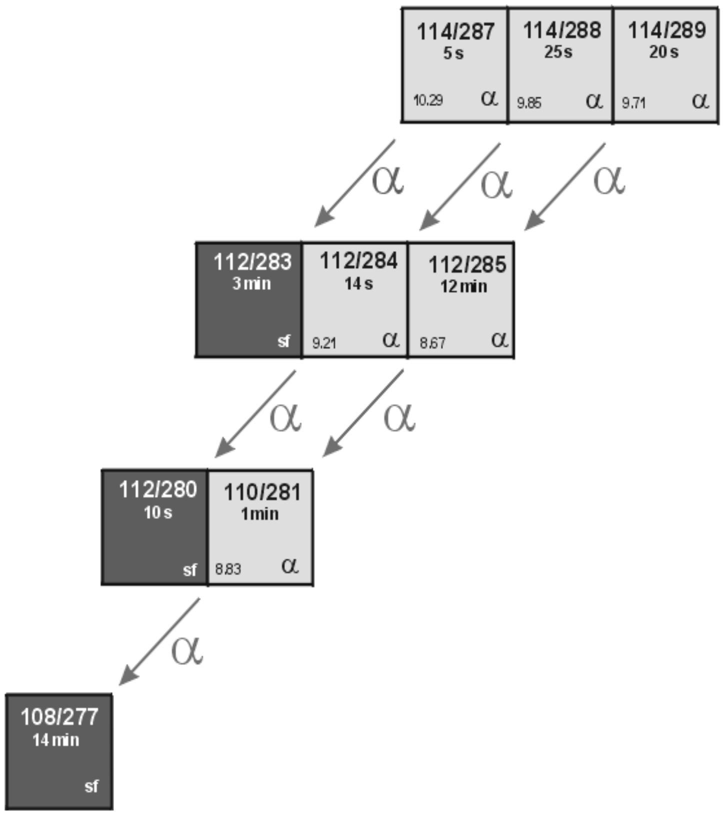

Fig. 7: Decay chains of isotopes of element 114

On 24 May 2000 an experiment on element 116 synthesis was started. The unique curium target is created with the support of the Ministry for Atomic Energy of the Russian Federation.

The other intensively developing direction at FLNR is a research programme with radioactive nuclear beams, namely the Dubna Radioactive Ion Beams (DRIBs) project. Realization of the DRIBs project assumes some modernization of U400, U400M and Microtron accelerators and construction of new beam channels between these three accelerators. The new complex will provide generation and acceleration of secondary beams of lightest nuclei ^{4}He – ^{14}O with the energy from 4 to 20 MeV per nucleon and radioactive ion beams of heavier elements generated from the products of fission fragments. It will be the first source of intense radioactive ions with unique parameters in the JINR Member States for experiments with exotic nuclei.

2.5 The IBR-2 fast neutron reactor

The main basic facility of the Frank Laboratory of Neutron Physics (FLNP) is the fast neutron pulsed reactor IBR-2 used for condensed matter research (D.I. Blochintsev, I.M. Frank et al.), see Fig. 8. Neutron scattering investigations in the field of condensed matter physics are conducted at IBR-2 using four main experimental techniques: diffraction, small-angle scattering, inelastic scattering, and polarized neutron optics.

IBR-2 is a pulsed reactor with an average thermal power 2 MW, peak power in pulse of 1,500 MW, half width of the pulse 215 μs, pulse repetition rate 5 Hz, thermal neutron flux density in moderator at maximum of the pulse – $2x10^{16}$ n/cm^2s.

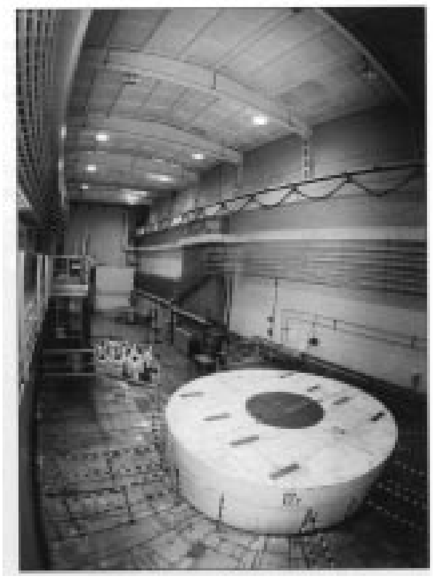

Fig. 8: IBR-2

In December 1999 the staff of FLNP completed the tests of the unique cryogenic moderator on solid methane at the IBR-2 reactor. Thus, the cold neutron flux turned out to be 3–4 times higher than the flux from the best for the moment cold neutron source ISIS in Britain. Now there are new opportunities for experimental research of complex structures in biology, physics of polymers, materials science, pharmacology, etc.

By 2002, the principal parts of the reactor IBR-2 will have their radiation resource exhausted and will have to be replaced. The programme for upgrading the IBR-2 reactor will be accomplished over a period of 10 years (1996–2005). This programme includes:

- improvement of the reactor parameters,
- increase in nuclear safety and reliability of the reactor,
- updating of the reactor systems.

2.6 IBR-30 + LUE-40

The IBR-30+LUE-40 is a pulsed neutron source consisting of the old pulsed reactor IBR-30 and the electron 40 MeV linac LUE-40 (D.I.Blochintsev, I.M.Frank et al.). The average heat power of the reactor is 10 kW, and the instant pulse power is 150 MW. It generates neutron pulses with a frequency of about or less than 100 Hz and a duration of 4.5μs. The total neutron yield is $5x10^{14}$ n/s, the flux of fast neutrons is about 10^{12} n/cm^2s.

A developed set of time-of-flight neutron spectrometers allow a wide spectrum of investigations to be carried out including the study of P- and T-symmetry violation of fundamental interactions in nuclei, the electromagnetic structure of the neutron, and some problems related to fundamental nuclear physics.

2.7 IREN

IREN (Intense Resonance Neutron Source) is a project aimed at constructing a high-flux pulsed neutron source to carry out investigations with resonance neutrons (Fig. 9).

The facility will comprise a modern 200 MeV electron linac and subcritical plutonium booster with a neutron multiplication coefficient 30. The pulse rate is 150 Hz, duration 0.4 μs, and the total neutron yield ~ 10^{15} n/s. This project was started in 1994 and the IREN facility will commence operation in 2002.

IREN (Intense **RE**sonant **N**eutron source**)**
A sketch of the project

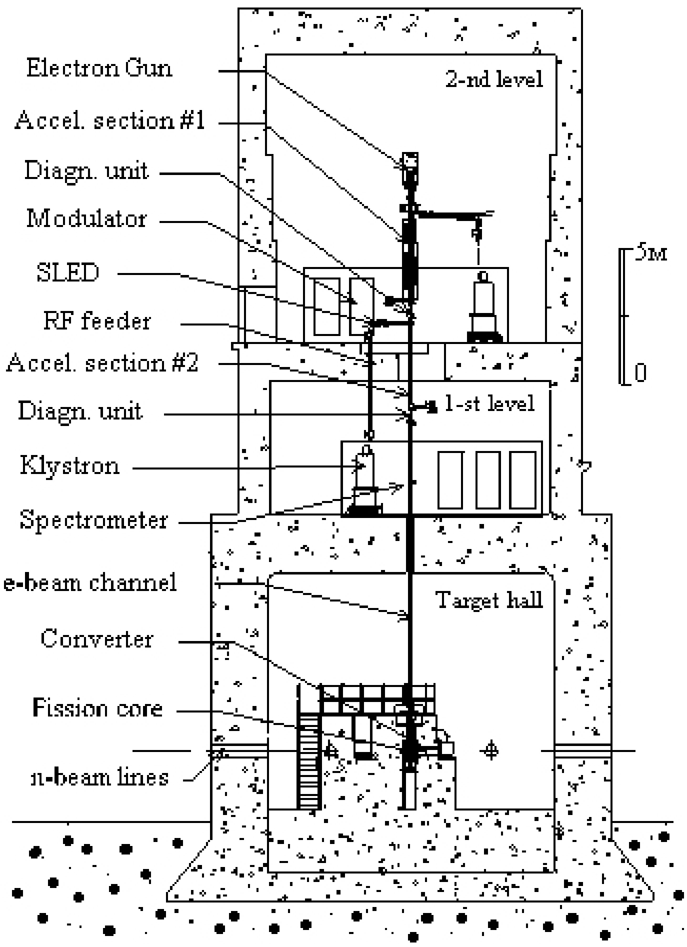

Fig. 9: The research programme for the IREN includes investigation of P- and CP - violations in slow neutron interactions with nuclei and other fundamental nuclear physics topics.

2.8 The JINR computing and networking infrastructure

According to the recommendation made by the JINR Scientific Council at its 85th session in January 1999, the Institute's telecommunication links, computing and networking infrastructure are considered to be a basic facility, too.

In 2000 the JINR Directorate took a decision to reorganize the Laboratory of Computing Techniques and Automation, which was responsible for this infrastructure, into the Laboratory of Information Technologies (LIT).

The efforts of the Laboratory of Information Technologies are directed at providing adequate networking, information, computing and software support of the research under way at JINR. The main activities of this laboratory are shown in Fig. 10.

➢ **Telecommunication systems:**
- **External communication channels (INTERNET)**
- **High-speed JINR Backbone**

➢ **Systems for powerful computations and mass data processing:**
- **General high-performance server**
- **Clusters of workstations of JINR laboratories and experiments**
- **Computing farms (PC-farms)**

➢ **Data storage system:**
- **File servers system based on AFS**
- **Mass storage system**
- **Information servers and database servers**

➢ **Software support systems:**
- **Visualization systems**

= **Computational physics**

Fig. 10: The main activities of the Laboratory of Information Technologies

3. THE JINR: A MAJOR PARTNER OF WORLD HEP LABORATORIES

3.1 International collaboration

Broad international co-operation is one of the most important principles of the JINR's activities. Almost all investigations are carried out in close collaboration with the JINR member-state scientific centres, as well as international and national institutions and laboratories of the world. Effective co-operation is achieved with institutes in Russia such as IHEP (Protvino), Kurchatov Institute (Moscow), Institute of Nuclear Physics (Gatchina near St. Petersburg), ITEP (Moscow), INR (Troitsk), Lebedev Institute of Physics (Moscow), Moscow State University, Budker Institute of Nuclear Physics (Novosibirsk), and others.

Very fruitful scientific co-operation has been achieved with CERN, especially in recent years, as well as with many physics laboratories in the USA, France, Germany, Italy, and other countries.

In 1999, approximately 1,200 JINR specialists participated in joint experiments and international conferences and symposia, and more than 1000 scientists from collaborating laboratories and centres visited Dubna. The JINR also organizes about 50 conferences, workshops and other meetings annually. Scientists from Dubna participated in more than 150 international conferences in 1999.

3.2. Co-operation with CERN

For more than 40 years the co-operation between JINR and CERN has been very fruitful and mutually beneficial. A general agreement between the JINR and CERN was signed in 1992, but co-operation between the two international organizations has a very long and rich history. The JINR Directorate attends much attention to the CERN–JINR collaboration in research programmes, including theoretical studies and education of a new generation of young scientists, particularly JINR–CERN Schools.

Dubna physicists are involved in a large part of the CERN experimental programme (see Table 2). Dubna has made progress in fulfilling its obligations with respect to the LHC Programme (ATLAS, CMS and ALICE experiments, as well as the LHC machine).

ATLAS project

A great amount of work for the ATLAS Barrel Hadron Tile Calorimeter has been performed: in co-operation with Belarusian and Slovak Institutes and industry about 300,000 units of steel absorber plates with very high mechanical tolerance (50 microns) were manufactured. All of them have been delivered to calorimeter submodule producers (Dubna, Prague, Protvino, Pisa).

CMS project

The JINR is participating in the CMS project in the framework of the Russia and Dubna Member States Collaboration (RDMS). The involvement of the Member States in this activity through RDMS has given them an opportunity to play leading roles and to contribute significantly to the preparation of the hadron calorimeter, electromagnetic calorimeter and the muon detector.

Belarusian scientists and industry have developed and manufactured a special electronics scheme (for proportional chambers) which successfully passed radiation tests at CERN. Belarus and Bulgaria are responsible for CMS end-cap calorimetry. They assembled the very first full-scale prototype of h-cal sector (2x2x1 m^3 in dimensions and weighing 30 t).

ALICE project

The JINR contributes to the warm dipole magnet, the production of large-scale Pestov counters, detector assembly, data taking runs, and data processing & analysis.

Table 2: Experiments at CERN in which Dubna is involved

Project	Location	a) main goals b) JINR contribution
NA45	SPS	a) Study of electron–positron pair production in relativistic nuclear collisions. b) Design & manufacture of a new magnet system for precise spectroscopy. Design & construction of the trigger system. Data analysis.
NA48	SPS	a) Highest precision direct CP violation searching in neutral kaons decays. b) Subsystems design & construction, data taking runs. Data analysis.
NA49	SPS	a) Search for the predicted phase transition from hadrons to deconfined quarks and gluons in Pb+Pb collisions at SPS. b) 900-channel time-of-flight detector for identification of $h^{\pm}$, $K^{\pm}$, p, p, d and d. Data analysis.
NOMAD	SPS	a) Search for $\nu_\mu \to \nu_\tau$ and $\nu_\mu \to \nu_e$ oscillations. b) Data taking & analysis, new proposal preparation.
COMPASS	SPS	a) Hadron structure and hadron spectrometry on high rate hadron and muon beams; q&g contribution to nucleon spin; polarization of nucleon sea q's etc. Glueballs search for exotics. b) Hadron Cal, muon detector, large area track chambers.
DIRAC	PS	a) 5% accuracy test of low energy QCD by 10% precision ($\pi^+\pi^-$) atom life time measurement. b) Experiment proposed by JINR, drift chambers, secondary particles channel, trigger development, MC simulation & software. Data taking runs, data processing & analysis.
DELPHI	LEP	a) Precision measurements of m (W), search for new particles, etc. b) Maintenance of Hadron Calorimeter and Surround Muon Chambers, physics analysis.
ATLAS	LHC	a) General purpose *pp*-experiment. b) Subsystems: calorimeters, muon, transition rad. det., rad. Hard. tests, phys. Software & simulation, trigger and data acquisition
CMS	LHC	a) General purpose *pp*-experiment. b) Subsystems: forward μ-station, hadron end cap cal., e/m cal preshower; simulation.
ALICE	LHC	a) Heavy-ion relativistic beams. Study of q-g plasma and phase transition. b) Warm dipole magnet, large-scale Pestov counters production. Detector assembly. Data taking runs. Data processing & analysis.
R&D for LHC Accel. Complex elements	LHC	a) Development & construction of LHC beams formation & control system elements. b) Design & construction of transverse oscillation damping system. Simulation & prototypes study.

LHC damper

One of the main goals of the JINR's participation in the LHC Project is to manufacture a powerful amplifier and a kicker for the Transverse Feed-back System for the LHC.

At the JINR the design of a special power device was proposed. It allows different types of damping to be used and investigated (including non-linear "bang-bang" and "logical" ones). Joint CERN–JINR experiments at the SPS (SL RF) have shown the effectiveness of this solution.

I would like also to comment some new scientific results obtained in CERN experiments in co-operation with JINR scientists. You already know about an impressive result connected with the discovery of a new state of matter – the so-called 'quark–gluon plasma'. CERN Director General Luciano Maiani mentioned that this is a result of combined data coming from the seven experiments ongoing in the frame of CERN's Heavy-Ion Programme. It is remarkable that physicists from the JINR Laboratory of High Energies participate in three of them, namely NA49, NA45 and WA98, and have significantly contributed to obtaining of this result that pertains to relativistic nuclear physics. Let me remind you that this field of research was first suggested and developed at the JINR by Academician A. Baldin – the author of the idea of Dubna's accelerator Nuclotron created to study phenomena in which particles are moving with relativistic velocities. The interpretation of the CERN experiment is still not completely clear and definite. The future experiments at RHIC (BNL, USA), in which Dubna physicists also participate, might clarify this phenomena.

One more example of our fruitful co-operation with CERN is connected with the NA48 experiment. On 29 February 2000, the NA48 collaboration presented a new result on direct CP violation. You know that this experiment is carried out at the SPS beam-line, which takes data to study direct CP violation in the neutral kaon system. The Spokesman of this experiment is Prof. V. Kekelidze, Director of the JINR Laboratory of Particle Physics. The measured parameter $(14{,}0 \pm 4{,}3)\cdot 10^{-4}$ has been obtained by analysing a big amount of experimental data accumulated in 1997–1998.

Scientists from the JINR made a significant contribution also to other CERN experiments performed at LEP, the SPS, and the PS. Prof. L. Nemenov from the JINR was elected by the collaboration as a Spokesman of the DIRAC experiment, which successfully started its first run in late 1998. The main goal of this experiment is a precise measurement of $\pi^+\pi^-$ atom lifetime for the non-model check of the Quantum Chromodynamics (QCD).

3.3 Co-operation with IHEP (Protvino, Russia)

JINR scientists are carrying out experiments at the IHEP U-70 proton synchrotron using such set-ups as the EXCHARM, HYPERON, and the Neutrino Detector (Table 3).

Table 3: JINR's participation in research at U-70

EXCHARM	**Search for exotic states with strange quarks, study of processes of production and decay of particles containing heavy quarks**
HYPERON	**Investigations of rare *K*-meson decays**
NEUTRINO DETECTOR	**Investigations of neutrino oscillations and neutrino-nucleon interactions, measurement of nucleon structure functions, coupling constant of QCD at low energy**

4. DUBNA AS AN EDUCATIONAL CENTRE

The educational programme plays an important role in the JINR's activities. It should be stressed that the concept of the JINR's development is the integration of fundamental science, technological studies, and education.

To achieve this task, in 1991 we established the JINR University Centre and in 1994, together with the Russian Academy of Natural Sciences, the International University "Dubna".

The University Centre of the JINR offers graduate programmes in the fields of:

- Nuclear Physics
- Elementary Particle Physics
- Condensed Matter Physics
- Theoretical Physics
- Technical Physics
- Radiobiology

Since 1995 the University Centre of JINR has been offering post-graduate training.
Fig. 11 shows the educational contacts of the JINR University Centre.

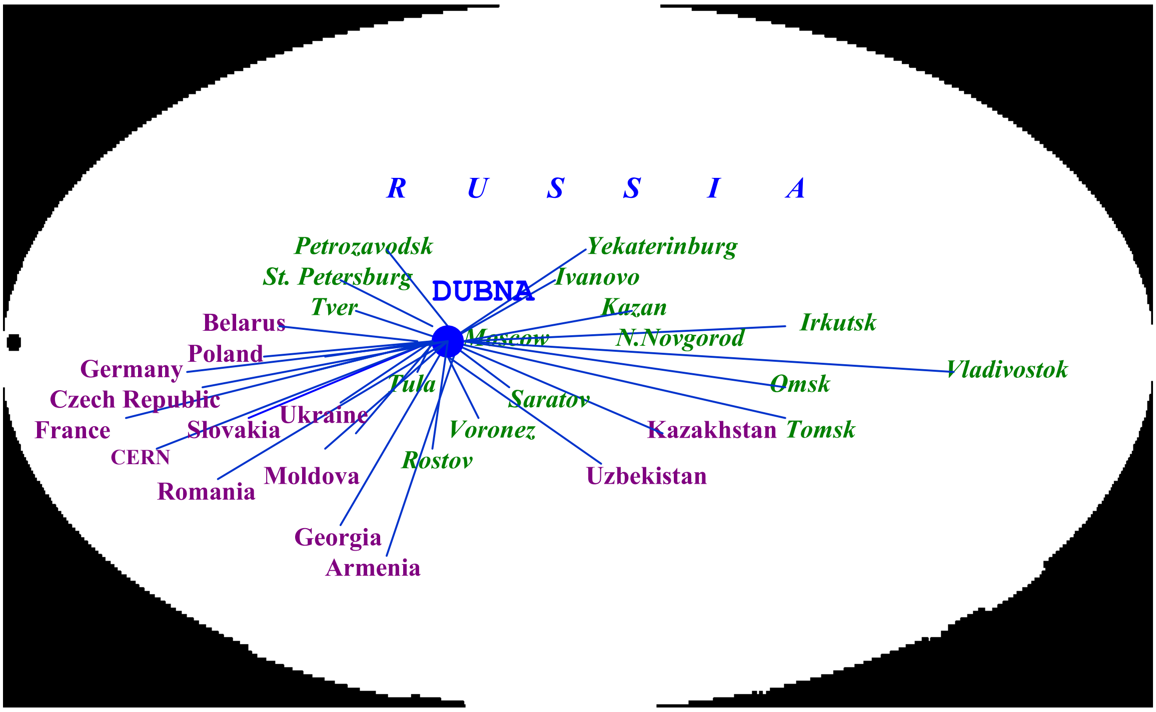

Fig. 11: Educational contacts of the JINR University Centre

5. PLANS FOR THE NEAR FUTURE

The JINR has the following plans for the near future:

- Significant broadening of the international usage of the JINR's unique research machines such as Nuclotron, cyclotron complex U400-U400M, and IBR-2.
- Development of methodical and computing possibilities for participation in experimental programmes of the world's largest HEP laboratories (CERN, FNAL, DESY, IHEP and others).
- Construction of the IREN facility.
- Development of the Nuclotron's injecton complex.
- Further development of the JINR University Centre.
- The use of the JINR's advanced infrastructure for holding international conferences, meetings and schools.
- Development of the project DRIBS dedicated to produce intense beams of unstable nuclei.
- Development of the DELSY facility — a third-generation synchrotron light source.

The JINR is continuing its programme of reforms to create better conditions for using its facilities and infrastructure.

6. CONCLUSION

This short review only presents some general information about the research centre in Dubna. It should be noted that over its 44 years of existence, the JINR has become a well-known international scientific centre, which incorporates the fundamental research of the structure of matter, the development and application of high technologies, and university education in the relevant fields of knowledge. The scientific policy pursued by the Directorate of the JINR has been developed in the context of the world's scientific trends. At the same time, recent years have been marked by a struggle for survival and the preservation of the Institute as a unified scientific centre in the time of radical political changes and serious economic difficulties in Russia and most of the Member States. Nevertheless, thanks to the joint efforts, the Institute has survived, and continues to contribute significantly to world science in the fields of particle physics, nuclear physics, and condensed matter physics.

The JINR Directorate is convinced in the further development of the Institute after the recent ratification of the Agreement between the Government of the Russian Federation and JINR.

In conclusion, I would like to stress the following: in order to preserve and multiply the achievements of JINR one should take care of its three pillars, namely:

– The international character of the Institute;
– The traditions of the Dubna scientific schools;
– The attractive experimental facilities, including the computing and networking infrastructure.

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