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JINR/RUSSIAN PROGRAMME IN HIGH ENERGY PHYSICS

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Contents

Abstract

Information about the current status of JINR and its HEP programme is presented. The HEP programme of Russia and the Former Soviet Union countries is briefly discussed.

1. General information about JINR

1.1. Historical background

The Joint Institute for Nuclear Research is situated in Dubna, a small town located about 120 km north of Moscow. This town appeared in the late 1940s in hard times after the end of World War II as part of the USSR Nuclear Defense Programme on the initiative of Igor Kurchatov, an outstanding Soviet scientist who was responsible for the Programme at that time and who also had a perfect understanding of the importance of fundamental research.

JINR was founded in March of 1956 (in Khruschev times) on mutual agreement of the governments of Albania, Bulgaria, China, Czechoslovakia, Hungary, the Socialist Republic of Vietnam, the German Democratic Republic, the Democratic People's Republic of Korea, Mongolia, Poland, Romania, and the Soviet Union. The USSR handed over to the new institution two laboratories located in Dubna. After the establishment of JINR - an international organization for fundamental research in nuclear science - Dubna became an open town.

I would like also to mention that the formation of various scientific fields of research at JINR was initiated by a number of some outstanding scientists of the Institute's Member States including the first directors Dmitri Blokhintsev and Nikolai Bogoliubov.

1.2. JINR's Charter; membership and internal organization

The Chapter of JINR was adopted in 1956, later on it was revised and newly-adopted in 1992.

In accordance with the Chapter the activity of the Institute is realized on the basis of its openess, mutual and equal cooperation for all 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 scientifists in carrying out reseacrh, of ideas and information by publishing scientific papers, organizing conferences, symposia etc.;

- to promote the development of intellectual and professional capabilities of scientific personnel;

- to maintain contacts with other national and international scientific organizations and institutions to ensure the stable and mutual cooperation;

- to use the results of investigations of applied character to provide supplementary financial sources for fundamental research by implementing them into industrial, medical and technological developments.

The results of investigations carried out at the Joint Institute for Nuclear Research can be used solely for peaceful purposes to the benefit of mankind.

So until the late 80's Dubna was as a centre which unified the efforts of leading research groups in nuclear sciences of the so- called 'socialist countries' and the Soviet Union. After the disintegration of the USSR the membership of JINR underwent the following changes: The majority of East European countries, such as Poland, the Czech and Slovak Republics, Bulgaria, Romania continue to be Member States of our Institute. Germany stays as an observer and makes a substantial financial contribution. Most of the former Soviet Union republics which became independent states of the CIS (Commonwealth of Independent States) entered JINR as new members. Even some of the former

Soviet republics - non-participants of CIS - joined JINR as well.

To my mind it somehow reflects the essence of science - its international integration. Moreover, a new process is developing now: discussions with such countries as France, Italy and the United States are under way in order to sign cooperation agreement on governmental levels.

The participation in the Institute can be realized in different forms: on the basis of membership, bilateral and multulateral agreements to perform particular scientific programmes. JINR Member States contribute financially to the Institute's activity and have equal rights in its management.

JINR has at present 18 Member States:

Armenia	Moldova
Azerbaijan	Mongolia
Belarus	Poland
Bulgaria	Romania
Cuba	Russian Federation
Czech Republic	Slovak Republic
Georgia	Ukraine
Kazakhstan	Uzbekistan
D.P.Republic of Korea	Vietnam

JINR has special cooperation agreements concluded on governamental level with Germany (in the field of theoretical physics, heavy ion physics, condensed matter physics and high energy physics) and Hungary (in the field of condensed matter physics).

Among the major partners with whom JINR has long-term cooperation 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 USA.

JINR is also an associated member of EPS, has observers in ECFA, ICFA, IUPAP and other international unions. The latest political changes in Eastern Europe and especially in Russia have been making JINR more and more open. New collaborating countries are welcomed to join JINR.

Today JINR is a large centre with a total staff close to 4000 including services and workshop. Approximately 1100 scientists work in it.

The internal organization of JINR is determined by scientific specialization. There are 7 Laboratories at the Institute:

BLTP	Bogoliubov Laboratory of Theoretical Physics
LHE	Laboratory of High Energies
LPP	Laboratory of Particle Physics
LNP	Laboratory of Nuclear Problems
FLNR	Flerov Laboratory of Nuclear Reactions
FLNP	Frank Laboratory of Neutron Physics
LCTA	Laboratory of Computing Techniques and Automation.

Each laboratory has its own design and construction divisions which develop and manufacture non-standard equipment for particle accelerators, detectors and other experimental facilities. The staff of these divisions totals about 370 engineers, technicians and workers.

A number of associate experimantal physics workshops are also part of the Institute.

The personnel of the JINR Experimental Physics Facilities Division totals about 400. It is equipped with everything necessary to manufacture large-sized non-standard facilities, electronics, and has technological lines for constructing detectors for high energy physics. It was there that the main units of JINR's heavy ion cyclotrons U-400 and U-400M were constructed in recent years, as well as the Nuclotron - a new, first in Russia, superconducting accelerator for relativistic nuclear physics.

Now, before I go to the next point of my report I would like to make the following remark.

As you certainly know well, nuclear science and in particular its frontier Particle Physics or High Energy Physics is rather an expensive field of research. Of course it is very well understood now that deep fundamental studies have always resulted in huge technological benefits. And the great discoveries of the past such as electricity, magnetism, etc have never been paid off, and all the investments to fundamental science in the whole world is still a negligible part compared to the benefit that mankind got from it. It would be fare to say that mankind is INTERNALLY INDEBTED to fundamental science.

Now I am coming to the questions of JINR's international cooperation.

Despite the present hard economic and financial situation in most of JINR's Member States, which of course has greatly affected the ongoing research programme of the Institute, many scientific groups from Dubna continue to participate in largest projects of world's major centres.

The intensity of JINR international cooperation events can be demonstrated by the following:

approximately 1200 JINR specialists participated in 1993 in joint experiments and international conferences; more than 1000 scientists from collaborating laboratories and centres visited Dubna. JINR organized 10 large conferences, 40 workshops and other meetings. Together with CERN JINR participated in the organization of the European School on HEP (formerly JINR-CERN School of Physics since 1970). JINR scientists participated in more than 150 international conferences held world-wide.

2. JINR is a major partner of world's HEP Laboratories

Broad international cooperation is one of the most important principles of the JINR activity. Almost all investigations are carried out in a close collaboration with JINR member-state scientific centres as well as international and national institutions and laboratories of the world. The most effective cooperation is realized with such institutes as IHEP (Protvino), Kurchatov Institute in Moscow, Institute of Nuclear Physics in Gatchina near St.Peterburg, ITEP (Moscow), INR (Troitsk), Lebedev Institute of Physics (Moscow).

A fruitful scientific cooperation is being held with CERN, especially in the last years, as well as with many physics laboratories in USA, France, Germany, Italy, Switzerland and other countries. Cooperation with scientific centers of China is being developed, a Protocol on collaboration has been signed between JINR and the Institute of Modern Physics of Academia Sinica. The JINR Directorate is ready to maintain constant and long-term contacts with laboratories of other countries as well.

2.1. JINR's international cooperation in high energy physics

JINR's Broad International Collaboration in HEP:

HEP Lab's of Member States:	Other countries:
Russia:	
(...IHEP - 9 JINR experiments	China
ITEP, Budker INP...)	Japan
Kiev	Canada
Minsk	Sweden
Tbilisi	Finland
Yerevan	Israel ...
Alma-Ata	

CERN:	**USA:**	**France:**
LEP-DELPHI	FNAL	IN2P3
SPS-SMC	BNAL	LAPP (Annecy)
NA-48	SLAC	LAL
OMEGA	CEBAF	CAE
NOMAD		...
LEAR-OBELIX		
LEP-2	**Germany:**	**Italy:**
LHC-ATLAS	DESY (Humburg)	INFN-Pisa
CMS	MPI (Max plank)	INFN-Frascati
ALICE	DESY (Zeuthen)	Universities
Accelerator Program		Milano,
		Firenca

2.2. Cooperation with IHEP (Protvino)

JINR scientists are carrying out experiments at IHEP's U-70 proton synchrotron with the help of such set-ups as MIS-2, SVD. Tagged Neutrinos, EXCHARM, DIMESOATOMS, HYPERON, Neutrino Detector, and others.

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. Cooperation: Bulgaria, Romania, Czechia, Austria, U.K., Italy, France, Switzerland,

	Belarus,, Georgia, Kazakhstan, Russia.
SVD	Investigations of processes of open charm particle production in pp-interactions. Cooperation: Bulgaria, Romania, Hungary, Georgia, Russia.
HYPERON	Investigations of rare K-meson decays. Cooperation: Bulgaria, Vietnam, Poland, Romania, Slovakia, Czechia, Hungary, Germany, Italy, USA, France, Azerbaijan, Armenia, Belarus, Georgia, Ukraine, Russia.
NEUTRINO DETECTOR	Investigations of neutrino oscillations and neutrino-nucleon interactions. Cooperation: Bulgaria, Vietnam, Poland, Romania, Slovakia, Czechia, Hungary, Germany, Italy, USA, France, Azerbaijan, Armenia, Belarus, Georgia, Ukraine, Russia.
TARGGED NEUTRINO COMPLEX	Verification of the universal features of weak interactions; search for rare decays in neutrino interactions; search for CP-violation in K-decays. Cooperation: Bulgaria, Belgium, Germany, Spain, Azerbaijian, Armenia, Belarus, Georgia, Kazakhstan, Russia, Uzbekistan.
MIS-2	Investigations of radial excitations of boson systems of light quarks. Cooperation: Russia, Italy, Switzerland.
POSITRONIUM-GLUON	Search for and investigations of meson-meson and gluon-gluon bound states. Cooperation: Bulgaria, Vietnam, Poland, Slovakia, Czechia, Hungary, Germany, Italy, USA, France, Azerbaijan, Armenia, Belarus, Georgia, Ukraine, Russia.
PROZA-DIBARYON	Measurements of polarization parameters in πN an NN interactions.

	Cooperation: Bulgaria, Vietnam, Poland, Romania, Slovakia, Czechia, Hungary, Germany, Italy, USA, France, Azerbaijan, Armenia, Belarus, Georgia, Ukraine, Russia.
ISTRA-IKS	Study of the $K^- - \pi^-\mu^-\mu^+$ decay and measurements of the structural radiation of γ -quantum in the K^- - $e^-\nu\gamma$ decay. Cooperation: Bulgaria, Russia, France.

JINR's participation in the UNK construction programme

NEPTUN	Study of spin effects in experiments with stream polarized target at the UNK internal beam.
MARS-MPS	Multi-particle spectrometer.
UNK-1 Accelerator	Development of separate systems of the UNK first stage (the system of suppression of transverse oscillation of the beam); recapture station at U-70; cryogenic systems of the UNK second stage.

2.3. Cooperation with CERN

Dubna physicists are involved in a big part of the CERN experimental programme. The general Agreement between JINR and CERN was signed in 1992, but cooperation between two international organizations has a very long history.

Figs.2.3.1 and 2.3.2 show the current experimental activities of Dubna groups at CERN. The interest in the future CERN programme is demonstrated by the involvement in the detector R&D and active participation of Dubna teams in the preparation of Letters of Intent for the LHC.

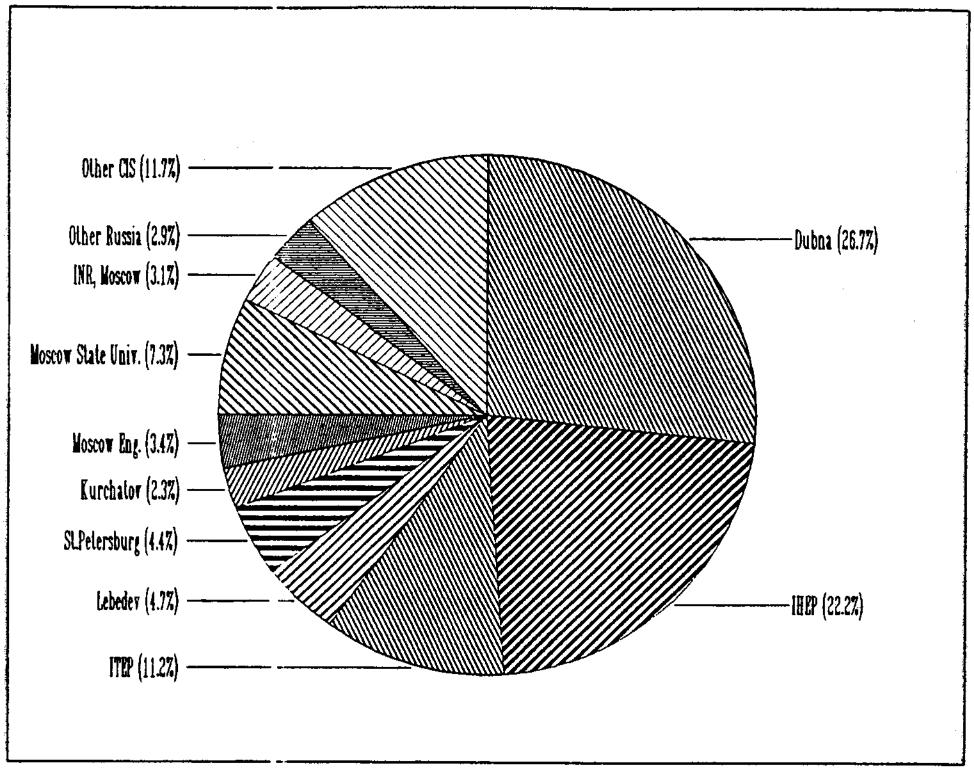

Figure 1: Distribution over Institutes of Russian physicists on LHC Letters of Intent. Total number 347

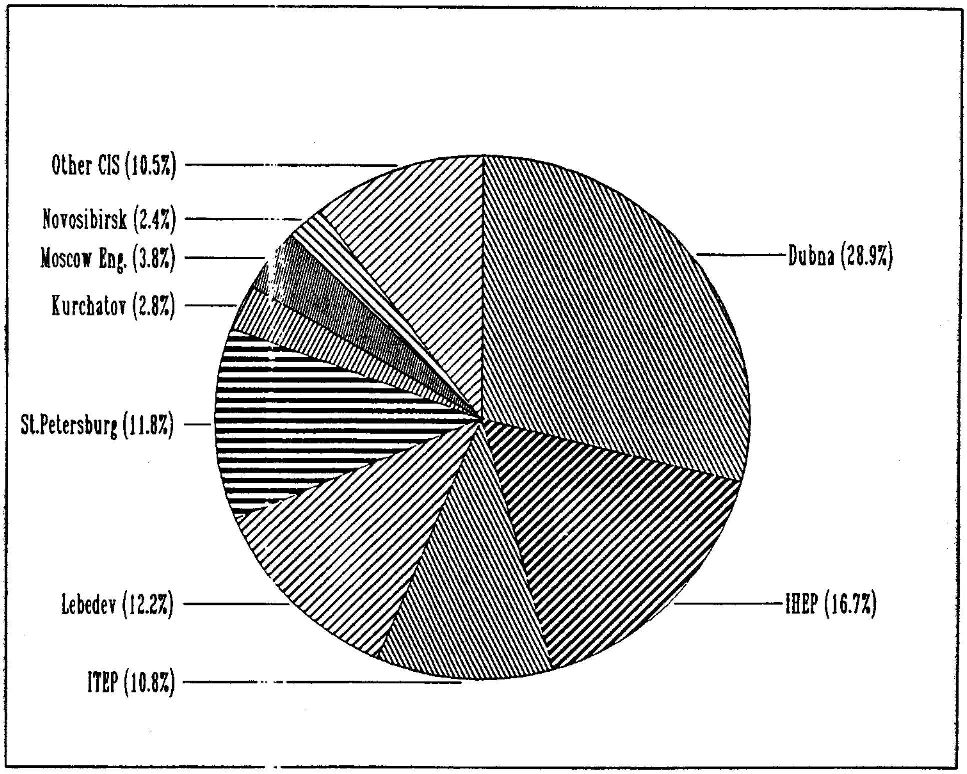

Figure 2: Distribution over Russian physicists over Institutes in current CERN programme, using Grey Book figures. Total number 287

Experiments where Dubna involved (in 1994):

LEAR	OBELIX	PS201
SPS	SMC	NA47
	CP Violation	NA48
	OMEGA GLUEBALL	WA91
	OMEGA BEATRICE	WA92
	NOMAD	WA96
LEP	DELPHI	
LHC	ATLAS	
	CMS	
	ALICE	
	TRD/RD6	
	LHC dampers	
	LHC Control architectures	

2.4. Cooperation with Italy

Scientific contacts with Italian physicists have been maintained since the very foundation of JINR in 1956. At first these were visits of Italian scientists invited to Dubna by the JINR Directorate and the exchange visits of Dubna specialists to Italy. Among the eminent Italian scientists who came with lectures on questions of experimental and theoretical physics at that time were professors G.Vatagin, T.Reggi, A.Zichichi and others.

A new stage of cooperation between JINR and Italian research centres opened in the late 1960s when the joint experiments started at the Synchrocyclotron of the Lab. of Nuclear Problems (JINR) and at the proton accelerator in Protvino. The first of these experiments began in 1968 and was aimed at the study of elastic and inelastic scattering of pions on He nuclei with the help of streamer chambers. The most active groups involved from the Italian side were from Turin, headed by Prof.G.Piragino, and from the National Laboratory of Frascati, headed by Prof. R.Scrimaglio. The JINR group was headed by Yu.Scherbakov and I.Falomkin.

Another example of this fruitful cooperation was the joint participation of Dubna, Milan and Bologna groups in the experiments using the magnetic spark spectrometer MIS developed by JINR. The research which they carried out allowed to study the spectrum of the excitation levels of the component structure of meson both in terms of the orbital and radial quantum number. The major result of that research was the discovery of two new resonance states of π -meson. Later on the work continued using the modernized spectrometer MIS-2 to investigate bosonic resonances at dissociation of mesons on nuclei. The JINR group was headed by Prof.A.Tyapkin, the Italian groups were headed by professors D.P.Bellini and G.Vegni (for MIS), and by professors F.Palombo and P.-L.Frabetti (for MIS-2).

Beginning from the 80s the both sides became jointly involved in a wider cooperation in two experiments at CERN - PS-179 and PS-201 (the study of antiproton-nuclear interactions at low and intermediate energies at the antiproton storage ring LEAR).

While work continued last year for the development of the Superconducting Super Collider in the USA, 2 protocols were signed between JINR and a group of Italian physicists headed by Prof.D.Belletini on the joint development, construction and testing of new-generation detectors and calorimeters to be used at TeV-colliders (Dubna team leader is Prof.Ju.Budagov). As you know, this project (the construction of the Super collider) has been regretfully cancelled.

Of all the 61 research topics in JINR, 20 are carried out with the participation of Italian laboratories and universities. This collaboration covers practically all the fields of research represented at JINR, except two of them, namely neutron nuclear physics and condensed matter physics.

The long-standing wide cooperation between Dubna and Italian theorists deserve special mentioning.

Much activity in this field is done at the International Cenre of Theoretical Physics in Trieste (Italy). The Centre was established in 1964 to promote fundamental science in developing countries by organizing lectures and seminars given by well-known physicists from many countries. Many scientists from JINR have visited Trieste in the past years, including JINR's former Director Prof.N.N.Bogolubov, an outstanding theoretical physicist and mathematician. The famous Pakistani scientist, Nobel Prize winner Prof. Abdus Salam, Director of the Trieste Centre for Theoretical Physics, was welcomed at JINR Dubna, too. Every year the Centre organizes many schools and meetings on various aspects of modern physics and applied mathematics, for example the School on High Energy Physics and Cosmology, held last year.

1993 was a record year in the number of visits of JINR's scientists to Italy: 80 physicists from Dubna visited Italian research centres or took part in conferences.

In conclusion I would like to emphasize that we much appreciate the assistance in this cooperation which is given to us by the Italian Embassy in Russia, in particular, by the Counsellor for Science Prof.G.Piragino. Prof. Piragino supervises our cooperation, frequently visits JINR in connection with the joint experiments and as a member of the JINR Scientific Council.

Last year Professors V.Kadyshevsky and L.Maiani signed an umbrella-type General Cooperation Agreement.

3. JINR's scientific potential

3.1. Technical possibilites of JINR Laboratories for HEP experiments

are as follows:

Lab. of Particle Physics	track detectors (drift chambers, proportional chambers, drift tubes), semiconductor detectors;
JINR Serpukhov Dept.	provision of experiments at U-70, capillary track detectors with liquid scintillator, electromagnetic and hadron calorimeters;
Lab. of High Energies	superconducting magnetic systems, polarized targets;
Lab.of Nuclear Problems	wire proportional chambers, pressurized

drift tubes, electromagnetic and hadron calorimeters, radiation-proof big-sized scintillation counters, cryogenic polarized targets, development and fabrication of big-sized magnetic systems.

3.2. The Synchrophasotron-Nuclotron complex

Nuclotron	–	superconducting synchrotron for accelerating of nuclei, 6-7 GeV/n
Synchrophasotron	–	accelerator of polarized protons and deutrons; acceleration of nuclei up to the energy of 4 GeV/n.

The new superconducting accelerator Nuclotron was put into operation in 1993. It will enable to perform a wide programme of research in relativistic nuclear physics. The injection complex is being developed consisting of a buster, linac and ion sources. This complex will allow one to accelerate nuclei from hydrogen to uranium with the intensity from 10^{13} to 10^{8} particles per pulse respectively and the energy of 6-7 Gev per nucleon. Polarized deutron beams are forseen.

3.3. Dubna accelerators and reactors

The main fields of the Institute's investigations 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 radiative medicine, experimental instruments and methods.

The major facilities of the Institute for experimental investigations are the synchrophasotron, phasotron, U-200, U-400 and U-400M cyclotrons, IBR-30 and IBR-2 neutron reactors (see tabl. 3.3.1).

Synchrophasotron [1)] is an accelerator of 10 GeV protons put into operation in 1957. In the 70's the acceleration of nuclei heavier than hydrogen, that is deuterium, lithium, carbon, fluorine and magnium, was accomplished in the broad energy spectrum from 100 MeV to 4 GeV per nucleon. Average densities of beams range from 10^{4} to 10^{11} ion/cm^{2} s depending on the atomic number of accelerated nuclei and experimental requirements.

Phasotron[1)] is an accelerator of 680 MeV protons. It was put into operation in 1949, reconstructed in 1984 and represent the oldest basic facility of JINR. 10 beam channels are available at this machine which are used to carry out experiments with pions, muons, neutrons and protons. 5 secondary beams are designed to carry out medical investigations, mainly for cancer therapy. The intensity of the extracted proton beam is 2 mkA.

U-200 is an isochronous cyclotron constructed in 1968 to accelerate heavy ions. It is designed to accelerate nuclei with $(A/Z) = 2.8 - 5$ up to 145 $Z^2/AMeV$ with the beam intensity $10^{8} - 10^{9}$ ion/s. This machine is used presently for applied studies.

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1) Since 1992 supported from Stabilization fund (under the budget of JINR), organized by users.

Table 3.3.1

Facilities	Particles Obtained	Energy of particles	Number of particles per sec	Irradiation impulse rate	Irradiation depth	Neutron flux behind sheilding	Absorption dose in the beam Gr/sec
Synchro-phasotron	protons	8–10 GeV	$4 \cdot 10^{11}$	.14 +.09	$3 + 10^4$	$2 \cdot 10^{11}$	200
	deutrons	3.6 GeV/ nucleon	10^{11}	- " -	- " -	$2 \cdot 10^10$	50
	^3He		$4 \cdot 10^8$	- " -	- " -	$2 \cdot 10^8$	0.8
	^4He	- " -	$6 \cdot 10^9$			$3 \cdot 10^9$	12
	Li	- "	$4 \cdot 10^8$			$2 \cdot 10^8$	2
	C	- " -	$2 \cdot 10^8$			10^8	4
	O	- " -	$2 \cdot 10^6$			10^6	$7 \cdot 10^{-2}$
	F	- " -	$6 \cdot 10^5$			$3 \cdot 10^5$	$2 \cdot 10^{-2}$
	Mg	- " -	10^4			$5 \cdot 10^5$	$0 \cdot 10^{-4}$
	Si	- " -	$3 \cdot 10^3$			10^3	$2 \cdot 10^{-4}$
Nuclotron	protons	12 GeV	$5 \cdot 10^{11}$ A/q^2	.5 + .09	$3 + 10^4$	10^{10}	–
	$^2H +^{238} U$	6 GeV/ nucleon	- " -	- " -	- " -	10^{10}	–
Phasotron	protons	660+680 MeV	$4 \cdot 10^{13}$	240	1.1; 140	$5 \cdot 10^9$ (E ¿ 20) $3 \cdot 10^{10}$ (E ¿ 0)	$5 \cdot 10^3$
Cyclotron U–400	ions B + Zr	20 + 5 MeV/nucl.	$10^{13} + 10^{12}$	150	3 + 6	$2 \cdot 10^9$ $2 \cdot 10^8$	–
Cyclotron U–400M	ions B + Zr	120 + 5 MeV/nucl.	$5 \cdot 10^{11}$ $+10^{12}$	- " -	- " -	$4 \cdot 10^8$	–
Reactor IBR–2	neutrons	fission spectrum	2 MBT	5	10^3	10^8	$4 \cdot 10^{-3}$
	γ -quanta		- " -	- " -	- " -		$+3 \cdot 10^{-2}$
			- " -	- " -	- " -		10^{-3}

U-400 is a heavy ion isochronous cyclotron constructed in 1978. The range of accelerated nuclei is $(A/Z) = 4 - 20$, energy is 650 $Z^2/A\ MeV$, beam intensity is 10^{12} - 10^{14} ion/s.

U-400M is an isochronous cyclotron put into operation in 1991-92 to accelerate heavy ions. It is designed to operate in the cyclotron U-400 + U-400M complex and allows to accelerate ions from hydrogen up to uranium in the range of energy 120-20 MeV per nucleon respectively with the average beam intensity of $4 \times 10^{13} - 10^{11}$ ion/s.

IBR-30 [2)] is a pulsed reactor on fast neutrons of periodic cycle constructed in 1969. The average heat power of the reactor is 25 kW, instant pulse power is 150 MW. The reactor generate pulses with frequency from 4 to 100 per second and length of 50 μ s. The pulsed density of the heat neutron beam is 5×10^{14} n/cm^{2}s. While operating in the buster mode with an electron linac, the duration of neutron flash is reduced up to 3-4 μ s.

IBR-2 was put into operation in 1984. The average power of the reactor is 2MW, the pulse power is 1500 MW, pulse length is 215 μ s, the frequency of pulse repetition is 5 per second, pulse density of the neutron flux is 10^{16} neutron/cm^2/s.

4. Dubna as an Educational Centre

JINR gradually changes now from a purely scientific research institution to an international centre, in which fundamental science, engineering and applied researches are closely connected with training. Structurally, it takes the form of a new satellite "students" laboratory. Its prototype is the currently working Training Centre (TC). This new training function of JINR is supposed to be oriented to international demand.

The JINR Directorate has also plans to establish an International University at Dubna. One of the steps taken by JINR towards this goal was the organization (in July-August 1993) of the International Summer Courses "Radiation Protection: Physical, Medicobiological and Ecological Aspects" (Chernobyl's lessons).

Status and development of the JINR Training Centre

The following topics of training are offered at present:

- *Elementary particle physics* ,on the basis of:
  Lab. of High Energies (Director: Prof.A.Baldin)
  Lab. of Particle Physics (Director: Prof.I.Savin)
  Lab. of Nuclear Problems (Director: Prof.N.Russakovich)
  Chair of Elementary Particle Physics of Moscow State Univ.
  (Head of the Chair: Prof.A.Tyapkin)
  Chairs No.40 and No.7 of Moscow Physics Engineering Inst.
  (Heads of the Chairs: Prof.B.Dolgoshein and Prof.F.Sergeev)

  The Chair of Physics of High Energy Particle Interaction
  was set up in 1993 on the decision of the Scientific Council of
  Moscow Institute of Physics and Technology (Head of the Chair:
  Dr.G.Shelkov).

- *Physics of the Atomic Nucleus*,on the basis of:
  Lab. of Nuclear Reactions (Director: Prof.Yu.Oganessian)

2) Since 1992 supported from Stabilization fund (under the budget of JINR), organized by users.

Lab. of Neutron Physics (Director: Prof.V.Aksenov)
Chair of Physics of the Atomic Nucleus of Moscow State Univ.
(Head of the Chair: Prof.V.Balashov)
Chair No.11 of Moscow Physics Engineering Institute
(Head of the Chair: Prof.V.Grigoriev)

– *Nuclear Methods in Condensed Matter Physics and High Temperature Superconductivity,* on the basis of:
Lab. of Neutron Physics (Director: Prof.V.Aksenov)
Chair No.25 of Moscow Physics Engineering Institute
(Head of the Chair: Prof.Yu.Bykovsky)

– *Engineering Physics* (formerly *Accelerator Physics),* on the basis of
Laboratories of Nuclear Problems, Particle Physics, Nuclear Reactions (Leader from JINR: Prof.E.Perelshtein)
Faculty "A" of Moscow Physics Engineering Institute

– *Radiobiology,* on the basis of:
Laboratory of Nuclear Problems
(Leader from JINR: Prof.E.Krasavin)
Chair No.1 of Moscow Physics Engineering Institute
(Head of the Chair: Prof. E.Kramer-Ageev)

The first graduates of the Training Centre presented their diploma papers in 1993. The number of students trained in the spring semester of 1993 was 98, in the autumn semester - 80.
120 students studied in the 1994 spring semester.

International contacts

A group of students did their diploma papers at the University of Dallas (USA), 6 students continue training there. Cooperation goes on with CERN and TU (Darmstadt, FRG). Contacts are developing with the European Physical Society and the EC Moscow Office in the sphere of exchange of students-physicists.

Further steps

Plans for 1994/1995 in the educational domain include: widening of the students' exchange (Poland, Czechia), cooperation with new universities (Denmark), preparation of documents for establishing in Dubna of a UNESCO-IAEA Chair of Radiation Protection.

The next step in the development of the JINR TC will be establishment of Economics Faculty in a joint effort with Moscow State University.

The signing of the inauguration documents of the "Dubna International University" is expected in autumn 1994.

5. Plans for future

JINR has the following projects for the development of new basic facilities:

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

The facility will comprise a modern 150 MeV electron linac and a subcritical uranium booster having neutron multiplication coefficient 14. This project started of realization from 1994. It will be put into operation in 1997.

$c\tau$ – Factory is a project of a new accelerator complex to comprise an electron-positron collider with an energy of 1.7 – 3 GeV in each beam and an injection system.

The research programme for this complex will include the study of Tau-lepton and τ-neutrino physics, τ-charmonium spectroscopy, CP violation, charmed baryon physics and meson spectroscopy. The desing of specialized synchrotron radiation source (8 – 10 GeV, NK – 10) is under consideration.

Dubna specialists continue to develop systems of the Storage Rings Complex (UNK)in Protvino. Experimental set-ups to carry out the first investigations are under construction.

K4-K10: The design of the Heavy Ion Storage Ring Complex K4–K10 has been performed in order to provide precise stable and exotic beams. It combines a pair of the coupled storage rings K4 and K10, both equipped with electron cooling, an injection channel to transport beams from the U-400M cyclotron to the K4 ring and separation channel designed for isolation of radiactive ion beams produced by nuclear interactions. Due to unique properties of ion beams one can study nuclear matter in the extreme state, the structure of the nucleus and mechanism of nuclear reactions, the synthesis of superheavy and exotic nuclei and many other problems.

JINR's plans for the nearest future:

- Development of methodical and computing possibilities for participation in experimental programmes of the world's largest HEP laboratories (CERN, IHEP and others).
- IREN construction.
- Development of the injector complex of the Nuclotron.
- R&D of $c\tau$ – Factory, NK-10 (together with BINP-Novosibirsk and others).
- Further development of the JINR Training Centre
- The use of JINR's advanced infrastructure for holding international conferences, meetings and schools.

In conclusion of this part of my talk I would like to express the following opinion:

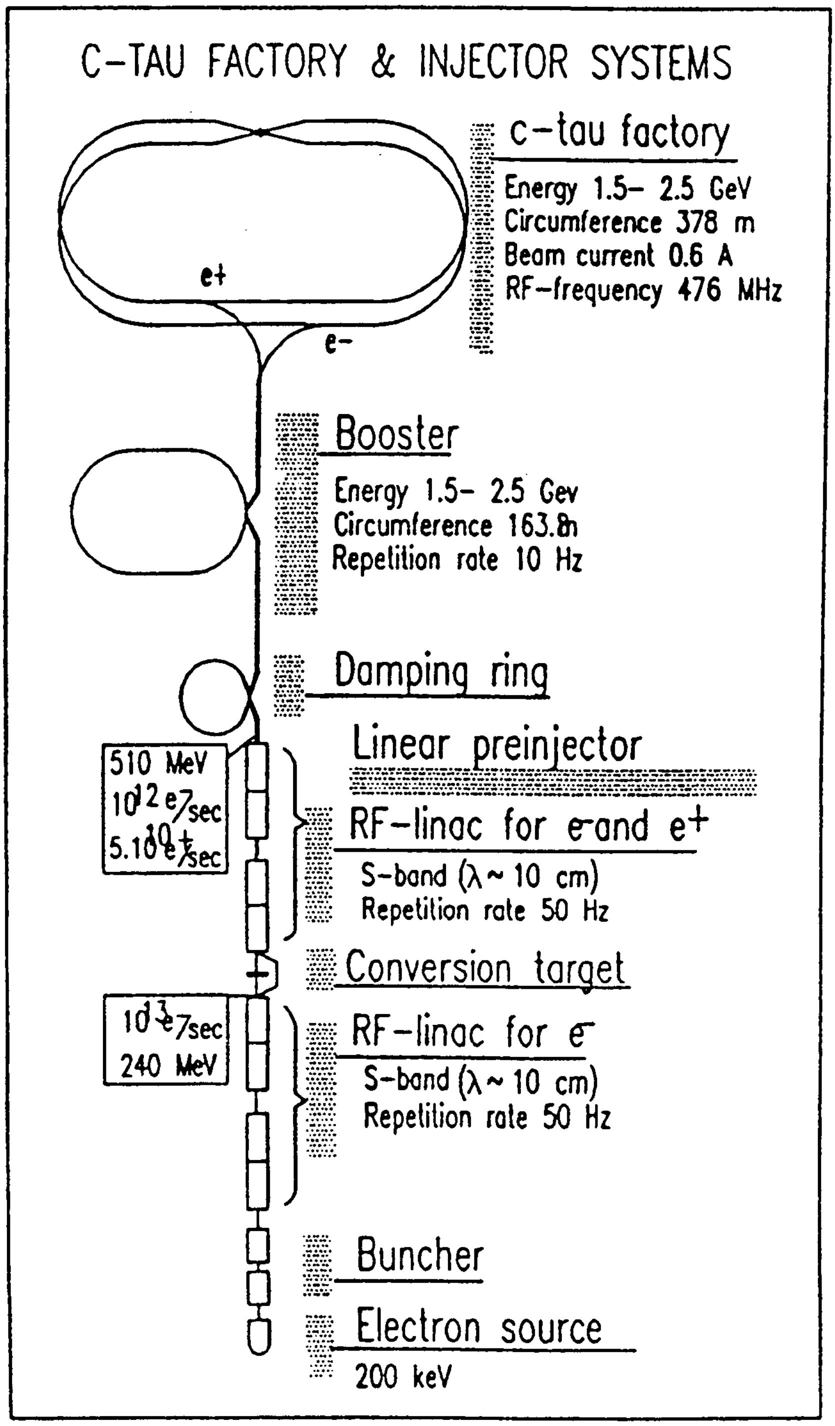
The combination of JINR's attractive scientific programme, development of new technologies and our recent initiatives in the educational field make our Institute an interesting and promising partner.

JINR continues to be an active international centre of world importance.

JINR is also a bridge between East and West.

6. The status of HEP in Russia and FSU-countries

Speaking of the programme in high energy physics in the territory of the former Soviet Union, one has to note the existence of serious economic difficulties. Yet we believe that they are temporary. This region has a rich background of applied and fundamental sciences. The world's largest proton accelerator in operation in the late 60's was in Protvino, Russia. The prestige of our HEP physicists in theoretical investigations, in accelerator and detector technologies was always very high.


C-TAU FACTORY & INJECTOR SYSTEMS
c-tau factory
Energy 1.5- 2.5 GeV
Circumference 378 m
Beam current 0.6 A
RF-frequency 476 MHz
e+
e-
Booster
Energy 1.5- 2.5 Gev
Circumference 163.8m
Repetition rate 10 Hz
Damping ring
Linear preinjector
510 MeV
10^12 e-/sec
5.10^10 e+/sec
RF-linac for e- and e+
S-band (λ ~ 10 cm)
Repetition rate 50 Hz
Conversion target
10^13 e-/sec
240 MeV
RF-linac for e-
S-band (λ ~ 10 cm)
Repetition rate 50 Hz
Buncher
Electron source
200 keV

Among the participants of European and world collaborations one can often see such research centres as

Institute for High Energy Physics (Protvino),
Institute of Theoretical and Experimental Physics (Moscow),
St. Petersburg Institute of Nuclear Physics (Gatchina),
Budker Institute for Nuclear Physics (Novosibirsk),
Institute for Nuclear Research (Troitsk, Moscow),
Moscow State university,
Lebedev Institute of Physics (Moscow),
Kurchatov Institute (Moscow),
Moscow Engineering Physics Institute,
Yerevan Institute of Physics and Yerevan University (Armenia),
Institute of Physics (Azerbaijan),
Belarus State University,
Institute for High Energy Physics (Alma-Ata, Kazakhstan),
Kharkov and Kiev institutes (Ukraine),
Institute of Nuclear Physics (Tashkent, Uzbekistan)

and others.

Let me describe in brief the experimental capabilities for HEP in Russia.

The main accelerating facilities used for research in high energy physics in Russia are

the 76 GeV proton synchrotron (IHEP, Protvino, near Serpukhov) (see Fig. 6.3 - 6.6),

the 7 x 7 GeV positron-electron storage rings VEPP-4 (Institute for Nuclear Physics of the Siberian branch of the Russian Academy of Sciences, Novosibirsk),

the synchrophasotron for acceleration of protons (10 GeV) and atomic nuclei (Joint institute for Nuclear Research, Dubna),

the proton synchrotron of the Institute for Theoretical and Experimental Physics (Moscow) accelerating protons up to 9,3 GeV,

and others (see table 6.1).

Besides, a number of proton accelerators with energies up to hundreds of MeV, phasotrons are also available operating in Russia:

at the Joint institute for Nuclear Research (Dubna) and

St.Petersburg Institute of Nuclear Physics.

An intensive linear proton accelerator is also constructed at the Institute for nuclear research (Troitsk). The first stage of the accelerator has been completed.

Table 6.1

MAIN OPERATING ACCELERATORS WITH ENERGIES MORE THAN 1 GeV

Location	Type of accelerator	Particle energy, GeV	Particle intensity or luminosity
Protvino	proton synchrotron	76	1,6 x 10^{13}
Dubna	synchrophasotron	10	4 x 10^{12} (proton acceleration)
		4 GeV/n	5 x 10^{10} (^{4} He) 5 x 10^{7} (^{16} O) 3 x 10^{4} (^{28} Si)
	nuclotron	6 GeV/n	
Moscow	proton synchrotron	9.3	1 x 10^{8}
Novosibirsk	e^-e^+ storage ring	7 x 7	3 x 10^{31} (cm^{-2} s^{-1})
Yerevan	electron synchrotron	6	7 x 10^{10}
Kharkov	linear electron synchrotron	2	1,7 x 10^{10}

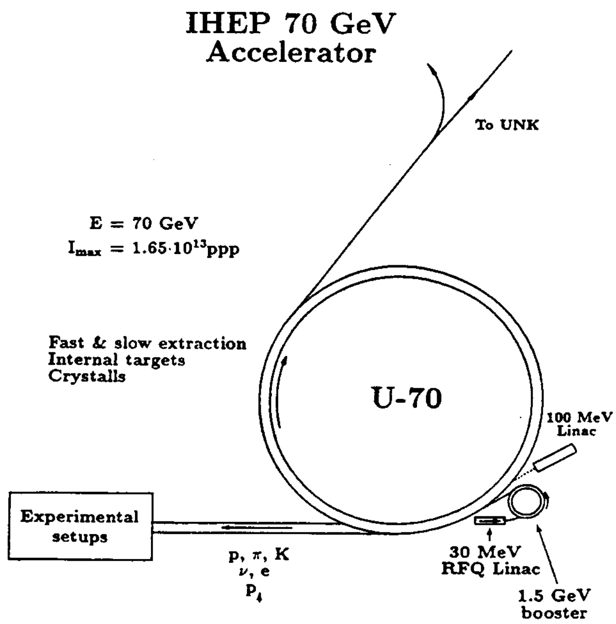
Table 6.2

ACCELERATORS UNDER CONSTRUCTION OR DEVELOPMENT

Location	Type of accelerator	Energy	Intensity
	<u>under construction</u>		
IHEP Protvino	accelerating-storage complex for proton acceleration (UNK)	i. 3.000 ii.3.000x 3.000*)	6 x 10^{14} 4 x 10^{32}
	UNK–1	600	5 x 10^{12}
BINP	e^- e Linear collider	1.000x 1.000	{R & D stage}
	<u>projects under development</u>		
Novosibirsk	(b-factory) φ -, Cτ - factories		
Dubna	Cτ - factory, NK-10		

*) The first version of the UNK–project.

Fig. 6.3



IHEP 70 GeV
Accelerator
To UNK
E = 70 GeV
I_max = 1.65·10^13 ppp
Fast & slow extraction
Internal targets
Crystalls
U-70
100 MeV
Linac
Experimental
setups
p, π, K
ν, e
P_4
30 MeV
RFQ Linac
1.5 GeV
booster

The parameters of U-70 accelerator

Parameter	Design	Achieved
Proton energy, *GeV*	70	76
Circumference, *m*	1483.7	
Beam intensity per cycle:		
- with 100 MeV linac (I-100)	$1 \cdot 10^{12}$	$5.6 \cdot 10^{12}$
- with 1.5 GeV booster	$5 \cdot 10^{13}$	$1.7 \cdot 10^{13}$
Magnetic field:		
- with injection from I-100, *G*	76	
- with injection from booster, *G*	386	350
– maximum, *kG*	12	13
Magnetic cycle duration, *s*	8.5	
Flat-top time, *s*	1	2
Number of magnets	120	
Number of periods (superperiods)	60 (12)	
Length of long stright sect., *m*	4.8	
Focusing order	FODO *(combined function)*	
Betatron frequency	9.75 - 9.85	
Accelerating RF, *MHz*:		
– with injection from I-100	2.6	
– with injection from booster	5.5	
– at the end of acceleration	6.1	
Harmonic number	30	
Transition energy, *GeV*	8	
Aperture of vacuum chamber (r x z, cm):		
– goffered chamber	19.5 x 11.5	
– chamber after upgrading (smooth)	20 x 10	

Fig. 6.5

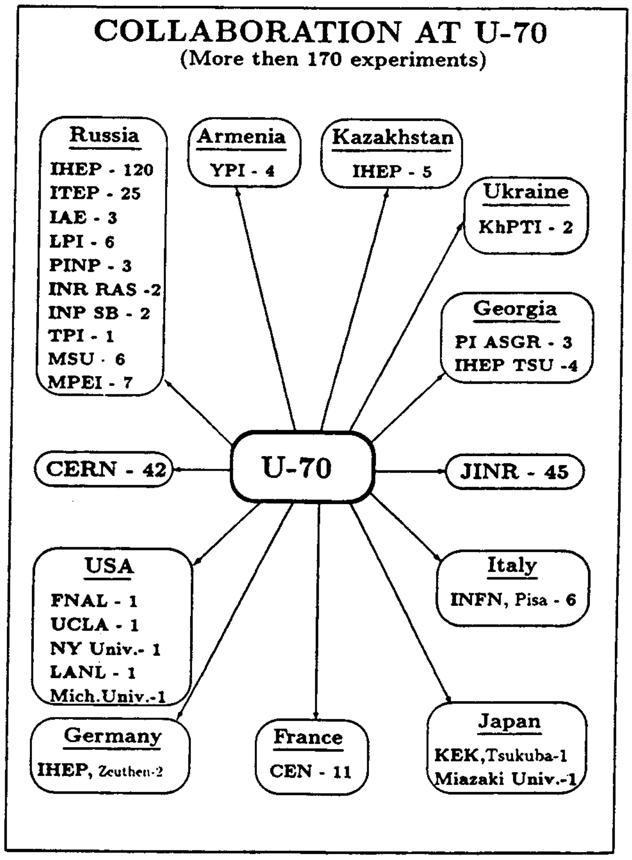

COLLABORATION AT U-70
(More then 170 experiments)
Russia
IHEP - 120
ITEP - 25
IAE - 3
LPI - 6
PINP - 3
INR RAS -2
INP SB - 2
TPI - 1
MSU - 6
MPEI - 7
Armenia
YPI - 4
Kazakhstan
IHEP - 5
Ukraine
KhPTI - 2
Georgia
PI ASGR - 3
IHEP TSU -4
CERN - 42
U-70
JINR - 45
USA
FNAL - 1
UCLA - 1
NY Univ.- 1
LANL - 1
Mich.Univ.-1
Italy
INFN, Pisa - 6
Germany
IHEP, Zeuthen-2
France
CEN - 11
Japan
KEK,Tsukuba-1
Miazaki Univ.-1

Fig. 6.6

EXPERIMENTAL PROGRAMME
AT IHEP U-70 ACCELERATOR

- **MESON SPECTROSCOPY**

  Setups: GAMS-2000, GAMS-$\widetilde{4\pi}$, VES, SPHINX, SVD, MIS-JINR
  Results: h(2050), r(2510), g(1590), g(1810), X(1814), $\pi'(1300)$, $\pi''(1770)$, etc.

- **EXOTIC BARYONS**

  Setups: CHARM, SPHINX
  Results: X(3100), X(3250), X(2050)$\rightarrow \Sigma^0(1385)$ K^+, etc.

- **RARE DECAYS**

  Setups: HYPERON, ISTRA
  Results: $K^+ \rightarrow \pi^+\pi^0\pi^0$ (g=0.637±0.020), BR($\pi^- \rightarrow e^-\bar{\nu}\gamma$) = (1.61 ± 0.23)$\cdot 10^{-7}$, BR($K^- \rightarrow \pi^0\gamma e^-\bar{\nu}$) = (2.7 ± 0.2)$\cdot 10^{-4}$, etc.

- **SPIN EFFECTS**

  Setups: PROZA (polarized target), FODS-2 ($p_{-}\uparrow$ - beam) - under preparation
  Results: Asymmetry of the inclusivly produced π, ω, η, f at high p_t

- **NEUTRINO EXPERIMENTS**

  Setup: IHEP-JINR Neutrino Detector
  Results: deep inelastic scattering, di-muons, beam-dump, etc.
  Setup: Tagged Neutrino Facility – ready for first physical run.

Figs. 6.7, 6.8, 6.9, 6.10, 6.11, 6.12 demonstrate main information about present status of UNK–1.

UNK – 600

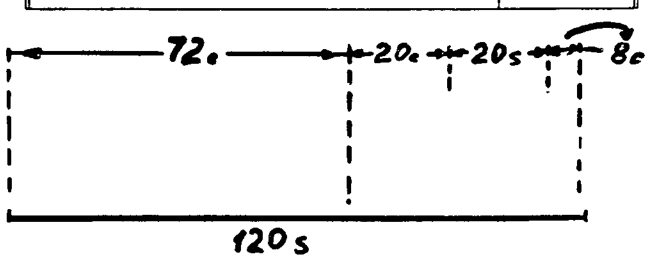
- **600 GeV Fixed Target Machine**
  ($\langle I \rangle = 5 \cdot 10^{12}$ p/s)

- **Experimental Facilities**
  - **NEPTUN (polarized jet target)**
  - **Experimental Hall № 3**
    ($\pi^{\pm}$, $K^{\pm}$, p, e^{-})
  - **Experimental Hall № 2**
    (ν, μ, $\pi^{\pm}$, $K^{\pm}$)

Fig. 6.8

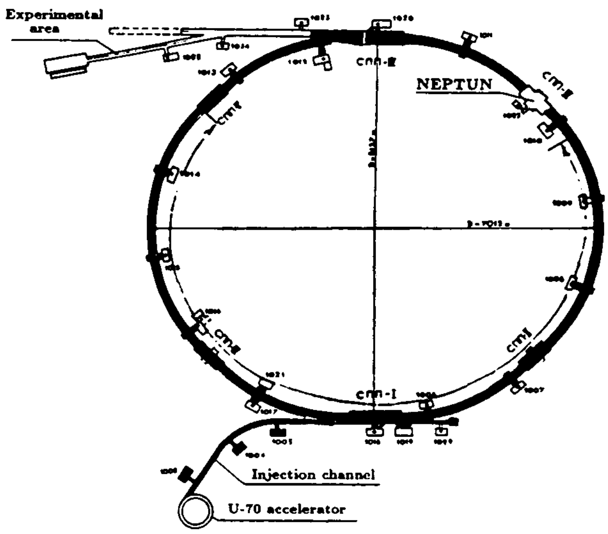
The main parameters of UNK-600

Parameter	UNK-600
Maximum energy, *GeV*	600
Injection energy, *GeV*	65
Orbit length, *m*	20771.9
Peak magnetic field, *T*	1
Injection magnetic field, *T*	0.108
Magnetic cycle duration, *s*	120
Acceleration time, *s*	20
Harmonic number	13860
RF-voltage, *MV*	7
Maximum energy gain per turn, *MeV*	2.1
Transition energy, *GeV*	42
Betatron frequency (without straight sections)	36.7
Maximum beam intensity per cycle	$6 \cdot 10^{14}$
Average beam intensity, s^{-1}	$5 \cdot 10^{12}$
Normalized transverse emittance of beam, $mm \cdot mrad$	< 150
Normalized longitudinal emittance of bunch, $MeV \cdot m/c$	< 100



U-600 Magnetic Cycle

ACCELERATING AND STORAGE COMPLEX (UNK)



STATUS

- Injection channel: has been commissioned with proton beam (March 1994)
- Tunnel boreing: 21 km
- Readiness for infrastructure installation: 14 km
- Hall for american-russian experiment NEPTUN: civil engineering finished

Table 6.10

PRODUCTION OF UNK-600 EQUIPMENT
(status)

NN	ITEM	Total number	Delivered by Jan. 1,1994	%
1.	Dipoles	2226	1500	67%
2.	Quadrupoles	522	506	97%
3.	Correction magnets	1180	1180	100%
4.	Power supplies for ring magnets	25	13	52%
5.	Power supplies for correction magnets	1180	132	11%
6.	Vacuum system:			
	- vacuum chamber	23,7 km	18 km	76%
	- vacuum pumps	3570	2500	70%
7.	Accelerating RF system:			
	- generator stations	8	4	50%
	- accelerating cavities	16	4	25%
	- power supplies	8	8	100%

Table 6.11

U-600 PHYSICS GOALS

- light and charmed meson spectroscopy;

- search for neutrino oscillations,
observation of – neutrino;
long distance ν -exp. UNK / Baikal
UNK / Gran Sasso

- polarization experiments (polarized jet target);

- study of the charged K-meson decays;

- deep inelastic lepton-hadron scattering with
muon and neutrino beams.

Table 6.12

MILESTONES

The injection transfer line	1994
The experimental string of UNK-600	1995
The beam injection system for UNK-600	1996
Commissioning of the 1st octant of UNK-600	1996
Operation of UNK-600	1997
Start of physics research	1998

Another direction of HEP research is connected with plans of the Institute for Nuclear Physics (Novosibirsk, Director - A.N.Skrinsky) to create colliding electron-positron beams on the basis of linear electron accelerators (VLEPP). The project's first stage is expected to provide electron-positron colliding beams with energies 500 x 500 Gev. The further development of the complex will enable one to achieve the colliding energy of 1000 x 1000 Gev.

It is believed that already the first stage of VLEPP will make it possible to verify the theory of electroweak interaction, to search and study the resonance production of neutral vector and scalar particles, double-charged boson, excited electrons and heavy exotic particles.

The international experience in dealing with heavy-current accelerators shows that a meson factory is a generator of high-intensity secondary beams of pions, muons, neutrons, neutrinos, polarized nucleons, hydrogen neutral atoms and is a unique tool for investigations in nuclear and elementary particle physics. That is why the construction of Moscow meson factory by the Institute for Nuclear Research (scientific leader - A.N.Tavkhelidze, director - V.A.Matveev) is another important direction for fundamental studies in physics in Russia (Fig. 6.12).

In terms of its parameters, every large accelerator is a unique physical installation. The high cost and sophistication of experimental apparatus urges the necessity of a wide international scientific and technical cooperation. Such cooperation in operating huge accelerating machines makes it possible to develop faster and more efficiently complicated experimental facilities comprising numerous detectors, electronic equipment and control systems.

Final remarks

This short review presents only some general information about the accelerator research centres of Russia and CIS. It should be noted that the scientific and technological potential in this area of research is determined not only by a wide variety of academic, university and civil atomic energy science but also the powerful industry of these countries and a wide net of military defence nuclear Institutions, actively involved nowadays in conversion programmes.

On the whole, this potential is rather high. This optimistic statement allows one to state that Russian scientists may and will be active participants of world's various largest projects such as LHC. The industry of the FSU-countries may be involved in implementation of scientific orders. At the same time these countries are facing another important task, that is how to maintain and develop their own scientific potential and facilities in their own regions. In my opinion, this is the only prerequisite for preserving the "quality" of science and counteracting the "brain drain".

Acknowledgements

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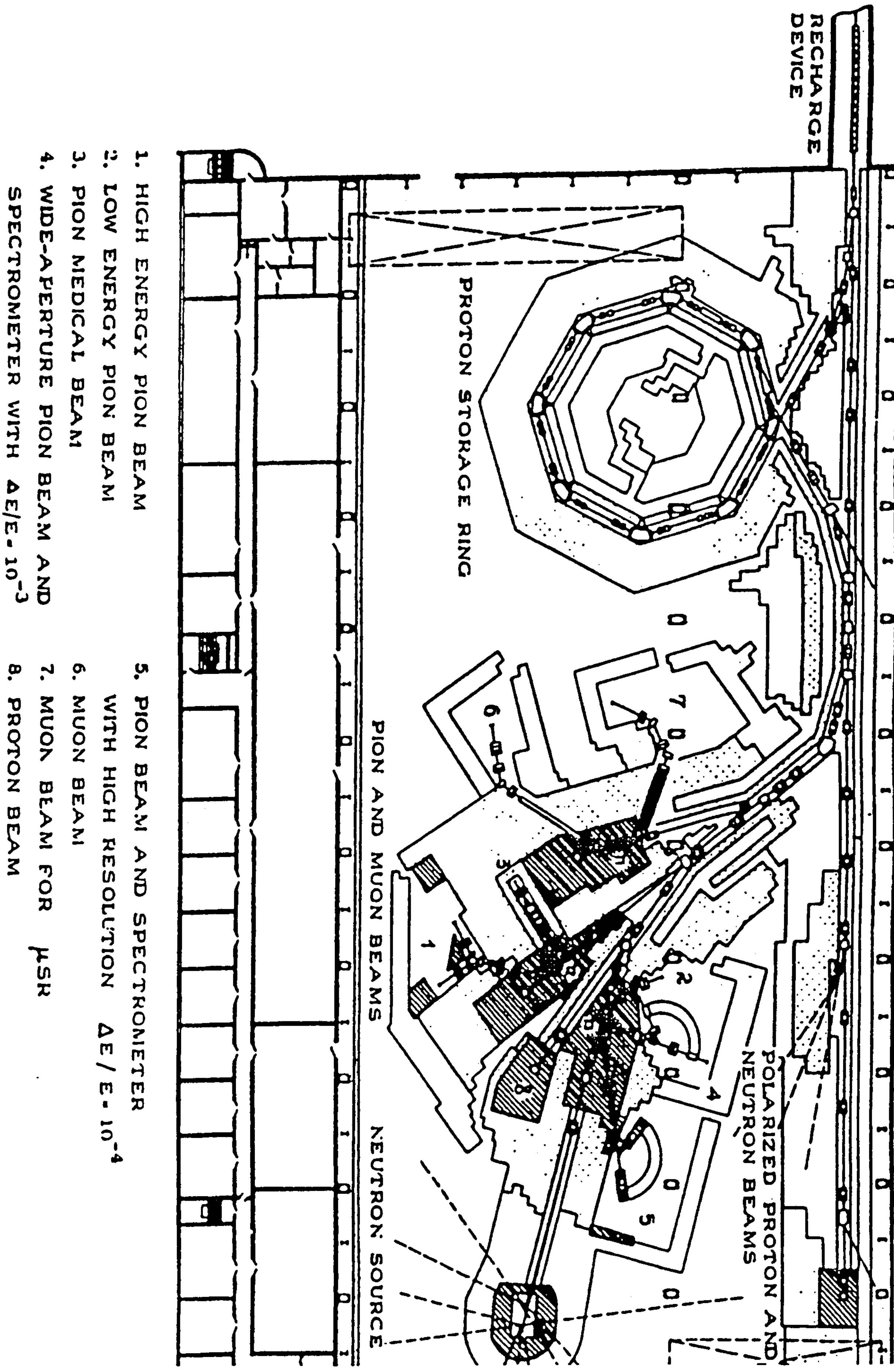
Fig. 6.13


RECHARGE DEVICE
PROTON STORAGE RING
PION AND MUON BEAMS
NEUTRON SOURCE
POLARIZED PROTON AND NEUTRON BEAMS
1. HIGH ENERGY PION BEAM
2. LOW ENERGY PION BEAM
3. PION MEDICAL BEAM
4. WIDE-APERTURE PION BEAM AND SPECTROMETER WITH ΔE/E ~ 10^-3
5. PION BEAM AND SPECTROMETER WITH HIGH RESOLUTION ΔE/E ~ 10^-4
6. MUON BEAM
7. MUON BEAM FOR μSR
8. PROTON BEAM