JINR / RUSSIAN PROGRAM IN HIGH ENERGY PHYSICS

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1. General information about JINR

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

The Charter of JINR was adopted in 1956, its new edition was readopted in 1992.

In accordance with the Charter 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 scientists in carrying out research, of ideas and information by publishing scientific papers, by 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 Institute can be used solely for peaceful uses to the benefit of mankind.

The participation at the Institute can be realized in different forms: on the basis of membership, bilateral and multilateral agreements to perform separate scientific programs. The 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
P.D.Rep.of Korea	Vietnam

JINR has special agreements concluded with:

- SSCL, FNAL, BNL and other research centers in USA
- Germany, in the field of theoretical physics, heavy ion physics and condensed matter physics
- 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
- Hungary, in the field of condensed matter physics

The structure of JINR is determined by scientific specialization:

BLTP	Bogolubov 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

The total number of JINR personnel is about 4,000. Approximately 1,100 scientists work at the Institute.

Each laboratory has its own design and construction divisions which develop and manufacture non-standard equipment for particle accelerators, detectors and other exper-

imental facilities. The staff of these divisions totals about 370 engineers, technicians and workers.
A number of associate experimantal physics workshops is 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 here that the main units of the following heavy ion cyclotrons were constructed in recent years:
U-400: the range of accelerated nuclei is (A/Z) =4 - 20, energy is $650Z^2/A$ MeV, beam intensity is 10^{14} - 10^{12} ions/s.
U-400M: the range of accelerated nuclei is from He to U, energy is 100 - 20 MeV per nuclei, beam intensity is 10^{14} - 10^{11} ion/s, and
the new, first in Russia, superconducting accelerator for relativistic nuclear physics NUCLOTRON.

2. JINR is a major partner of world 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 centers as well as international and national institutions and laboratories in 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.Petersburg, ITEP (Moscow), INR (Troitsk), Lebedev Institute (Moscow).

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

A fruitful scientific cooperation is being held with CERN, especially in last years, as well as with many physics laboratories in USA, France, Germany, Italy, Switzerland and other countries.

The JINR Directorate is ready to maintain constant and long-term contacts with laboratories of other countries. The cooperation with scientific centers of the P.R. China is being developed, the Protocol on collaboration has been signed between JINR and the Institute of Modern Physics of Academia Sinica.

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

approximately 1200 JINR specialists participated in 1992 in joint experiments and international conferences, symposia, more than 900 scientists from collaborating laboratories and centers visited Dubna. JINR organized 10 large conferences and 34 workshops and other meetings. Dubna scientists participated in 149 international conferences.

(a) International cooperation of JINR in HEP

40%
HEP
experimental

HEP Lab.'s		
of Member States		
(...IHEP - 9 JINR experiments (200)		
ITEP, Budker INP ...)		China
Kiev,		Japan
Minsk,		Canada
Tbilisi,		Sweden
Yerevan,		Finland
Alma-Ata		...
<u>CERN</u>	<u>USA</u>	<u>France</u>
LEP-DELPHI (50)	SSCLab	IN2P3
SPS-SMC(15)	SDC(30)	LAPP(Annecy)
NA-48 (10)	GEM (30)	LAL
OMEGA	Accelerator systems	CAE
NOMAD		...
LEAR-OBELIX (20)		<u>Italy</u>
LEP-2	FNAL	INFN-Pisa
LHC-ATLAS (50)	BNAL	INFN-Frascati
CMS (50)	CEBAF	...
Heavy ions program	...	
Accelerator program		<u>Germany</u>
		MPI (Max Planck)
		Zeuthen
		...

(b) Cooperation with IHEP (Serpukhov)

The collaboration with the Institute for High Energy Physics (IHEP) occupies a major place in the HEP activities of JINR. Over 30% of the IHEP accelerator time is taken by the joint experiments with Dubna.

– 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, Geogia, 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 Италия, США, Франция,
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
TAGGED NEUTRINO COMPLEX	Verification of the universal nature of weak interactions; search for rare decays in neutrino interactions; search for CP-violation in K decays Cooperation: Bulgaria, Belgium, Germany, Spain, Azerbaijan, 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 and 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 structural radiation in K-meson decays. Cooperation: Bulgaria, Russia, France

– JINR's participation in the UNK construction program

NEPTUN	Study of spin effects in experiments with stream polarized target at the UNK internal beam
UNK-1 Accelerator	Development of separate systems of the UNK first stage (the system of supression of transverse oscillation of the beam); recapture station at U-70; cryogenic systems of the UNK second stage
R&D for VLEPP	

(c) Cooperation with CERN

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

Experiments in 1993

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	

Fig.1 demonstrates that present experimental activities of Dubna group at CERN.

The interest in the future CERN program is demonstrated by the involvement in the detector R&A activities and strong participation of Dubna teams in Letters of Intent for the LHC (see Fig.2).

(d) Cooperation with research centers of USA

JINR-USA Collaboration in High Energy Physics has a long history. The first joint experiment was carried out at Fermi National Laboratory with the help of a gas target to measure differential cross sections. In 1992 two interlaboratory Agreements were signed between the Joint Institute and SSC Laboratory concerning physics program and accelerator development. JINR is also developing a fruitful collaboration with Brookhaven National Laboratory in the field of relativistic nuclear physics.

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

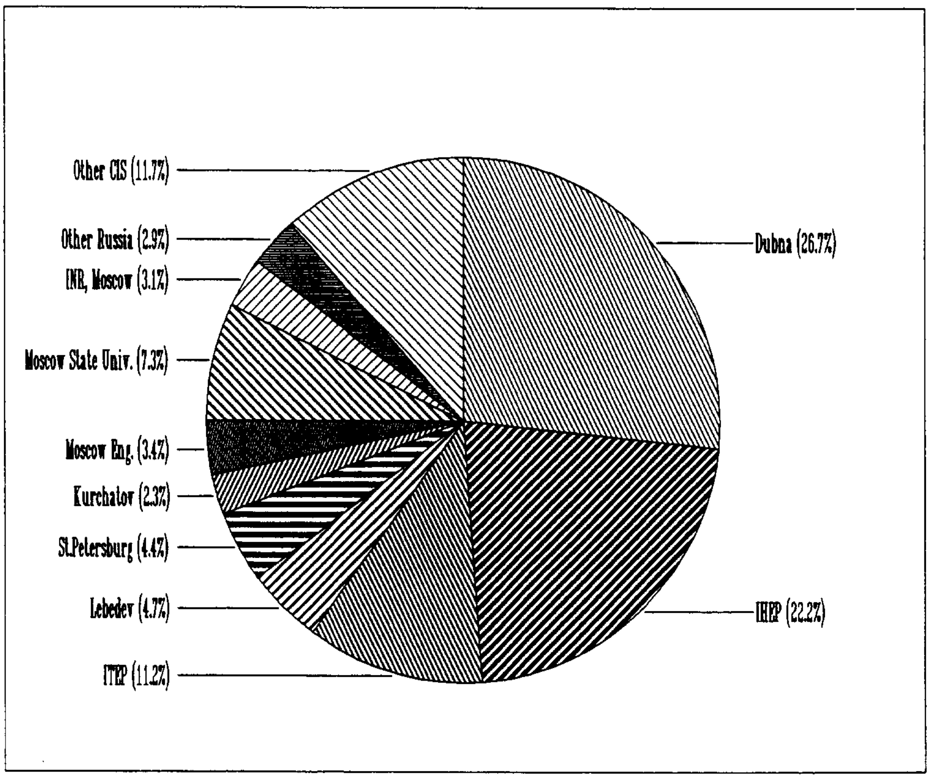

Figure 1: Distribution over Institutes of Russian physicists on LHC Letters of Intent. Total number 347

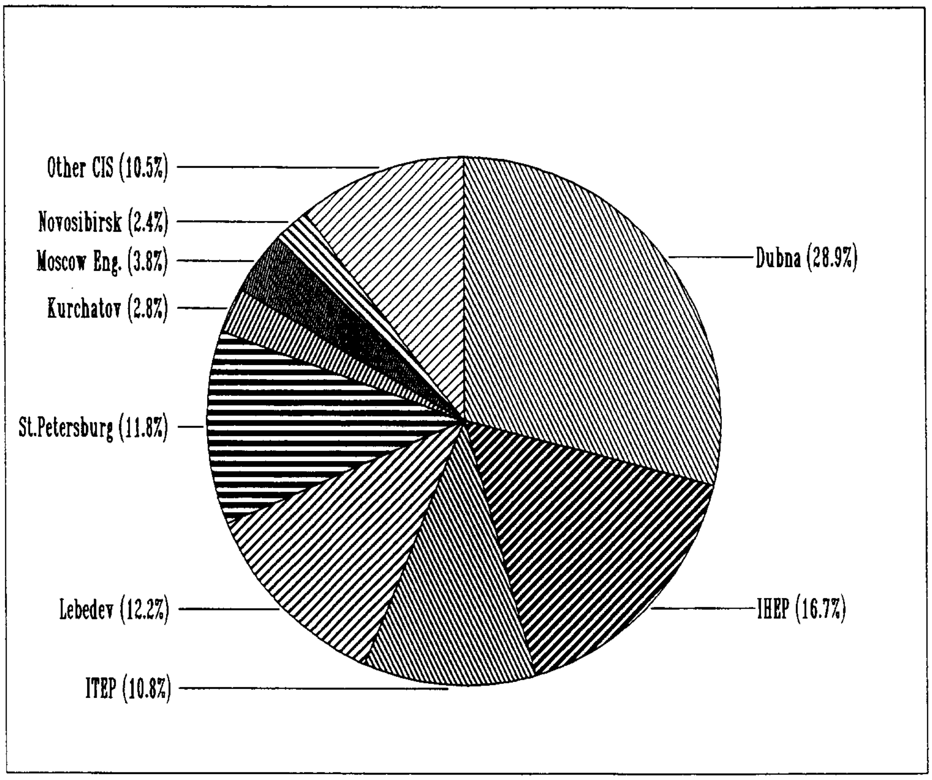

Figure 2: Distribution over Russian physicists over Institutes in current CERN programme, using Grey Book figures. Total number 287

Particle physics

SDC	End Cap Muon Barrel Toroid
GEM	Muon Chambers Muon Chambers Electronics Muon System R&D and Prototypes
SSC, HEB	Transverse Feedback System

Relativistic nuclear physics

BNL RHIC
PHENIX detector

GEM

The main focus of the JINR/GEM activity is the Muon system.
Namely, this is
A. Muon chamber
B. Muon chamber electronics
C. Muon system R&D and prototypes
To be specific:

A. JINR's available and partly being used facility for production of drift tubes, of LSDT, of proportional chambers is about 1800 M^2.

Now for GEM:

. 1 m x 4 m drift tube pprototypes were constructed

.. Cathode strip chamber prototypes are under fabrication

... New facility is under construction to fabricate 150 chambers/year (six gaps each) in order to manufucture and to test for three years the complete set of all half-barrel chambers (50 - 60 FTE at JINR).

B. JINR, together with Byelorussian National Center for Particle Physics (and industry), takes part in the assembly and tests of the on-chamber electronics.

C. For 1992-1993 period, JINR together with SSCL, BNL, ITEP, Princeton and other institutions are designing, fabricating and testing:

. 1m x 4m pressurized drift tubes prototype and

.. 1m x 1.5m cathode strip chamber prototype

Both were equipped withy JINR's electronics.

As the major effort for the post-TDR-R&D, we consider the setting up of the chamber production facility for GEM by the beginning of 1995. Considerable JINR R&D contribution is also foreseen for chamber design and prototyping.

SDC

The main (first) focus of the JINR-SDC activity is the Muon System.

The Joint Institute for Nuclear Research is participating in the design of the major magnet SDC element, the so called "Muon Magnet Barrel Toroid" (MBT). Dubna is responsible for production of the first two prototype blocks of MBT. Each weighs 80 tons.

If successful, Dubna will be responsible for full-scale MBT production (approx.16,000 tons heavy spectrometer magnet).

The first 12 slabs of continuously cast ingots are fully machined and are waiting for SSCL engineers to come for inspection, and then, block assembling, welding and final high precision machining will be started.

We have developed a solid program of quality assurance and control based on laser technology and ultrasonic yoke metal control.

We are able today to make a 3-Dimensional MBT magnetic reconstruction which is vital for understanding of the correlation between the allowed design parameter deviations and the MBT resolutions as spectrometric magnet in the process of SDC secondary particle momentum measurements.

Dubna is ready to take resoponsibility for full-scale muon magnet barrel toroid production. Dubna and the SSCL control major steps of work with the help of model ring magnetic field measurements and calculations. Besides that, Dubna-Pisa-Kharkov (Ukraine) are now constructing two 1.8m long scintillating counter prototypes for SDC muon trigger system of SDC. They will arrive at the SSCL in the autumn of 1993.

Another possible area for Dubna contribution found recently: FNAL-Dubna-Pisa-Kharkov are designing the SDC end-caps (hadronic) calorimeter. Preliminary shop drawings have arrived at Dubna Central Machine Shop to prepare the calorimeter wedges prototype fabricating. Preliminary considered FNAL-Pisa-Dubna-Kharkov collaboration for production of a part of hadron calorimeter as a fully completed device (scintillators, tiles, "pizza-pans"...). This is a new field that Dubna could possibly make an intellectual contribution to create unique SDC equipment.

Unfortunately, the recent decision to terminate the SSC affects negatively this large collaboration. JINR is currently considering possibilities of regrouping its forces to participate in other research programs (LHC, FNAL, etc).

Summarizing numerous discussions with my colleagues in the US, Russia, Dubna and JINR member countries, I must state here that the Joint Institute for Nuclear Research at Dubna is designated to play a key mediating role in scientific contacts between western countries and the whole region of eastern Europe, of the former Soviet Union, and the Far East member countries of JINR.

3. Scientific potential of JINR

(a) Techniques possibilities

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 beam stream 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

(b) JINR synchrophasotron - nuclotron complex

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

(c) plans for future

JINR Future Facilities

IREN	resonance neutron source
K4-K10	heavy ion storage ring complex
C-Tau factory	electron-positron beams
NK-10	synchrotron radiation source, 10 GeV electron storage ring

plans for near future:

- Development of methodical, theoretical and computer possibilities for participation in experimental program of the world's largest HEP laboratories.
- Development of the injector complex of the Nuclotron.
- R&D of C-tau Factory
- Development of possibilities for training at the JINR (Educational Training Centre, University).
- The use of the advanced infrastructure of JINR for holding international conferences and schools.

"JINR is a bridge between East and West".

4. JINR as an Educational Center

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

Next step: organization of an INTERNATIONAL UNIVERSITY.

5. The Status of high energy physics in Russia and countries of the former USSR

Speaking of the program in high energy physics (HEP) on 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. By the late 60's there was the world's largest proton accelerator in operation in Serpukhov, Russia. The prestige of our HEP physicists in theoretical investigations, in accelerator and detector technologies has been very high.

Among the participants of European and world collaborations one can often see such research centers as the Institute for High Energy Physics (Serpukhov), Institute of

Theoretical and Experimental Physics (Moscow), St. Petersburg Nuclear Physics Institute (Gatchina), Budker Institute for Nuclear Physics (Novosibirsk), Institute for Nuclear Research (Troitsk, Moscow), Moscow Engineering Physics Institute, Lebedev institute of Physics (Moscow), Kurchatov Institute (Moscow), Moscow State University, and also Yerevan Institute of Physics and Yerevan University (Armenia), Institute of physics (Azerbaijan), Belarus State University, IHEP Tbilisi State University, Institute for High Energy Physics (Alma-Ata, Kazakhstan), Kharkov and Kiev Institutes (Uukraine), 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),

the 7 x 7 GeV positron-electron storage rings VEPP-4 (Institute for Nuclear physics of the Siberian branch of 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 5.1).

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 Nuclear Physics Institute.

An intensive linear proton accelerator is also being constructed at the Institute for Nuclear Research (Troitsk). The first stage of the accelerator has been completed this year.

The central problems of today's high energy physics are the search for the universal nature of different interactions and also investigations of the origin of particles' masses, the composition of physical vacuum, the existence of exotic particles, the relation between elementary particle physics and cosmology.

For this purpose, the Institute for High Energy Physics (Director - A.A.Logunov) started in 1983 the construction of UNK, an accelerating-storage complex for proton energy of 600 MeV (at final stages, possibly, up to 3000 GeV). It is expected that the UNK will enable one to perform the search for heavy scalar bosons with masses up to 500 GeV, heavy quarks, excited quark states, new intermediate bosons, supersymmetrical particles. The UNK beams will also allow to study the dimensions of quarks and leptons up to 10^{-17}cm.

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.

Table 5.1

Main operating accelerators with energies more than 1 GeV

Location	Type of accelerator	Particle energy,GeV	Particle intensity or luminosity
Serpukhov (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^{28}($cm^{-2}s^{-1}$)
Yerevan	electron synchrotron	6	7 x 10^{10}
Kharkov	linear electron synchrotron	2	1,7 x 10^{10}

Table 5.2

Accelerators under construction or development

Location	Type of accelerator	Energy	Intensity
	under construction		
Serpukhov	accelerating-	i. 3.000	6 x 10^{14}
	storage complex	ii.3.000x	
	for proton	3.000	4 x 10^{32}
	acceleration (UNK)		
	e^- e^+ linear	1.000x	
	collider	1.000	
	projects under development		
Novosibirsk	b-factory		
Dubna	$c\tau$-factory		

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, hidrogen 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.

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.