

**TOPICAL PLAN  
FOR JINR RESEARCH  
AND INTERNATIONAL COOPERATION  
2022**

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All the themes in the Plan are listed by fields of research. Each theme is coded according to the JINR system of classification and contains the following information:

- the first number\* - the field of research;
- the second number\*\* - the conventional number of Laboratory or other Division of JINR;
- the third number - the theme's ordinal number;
- the fourth and the fifth numbers - the years of the activity's beginning and completion.

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| <p>* 01 – Theoretical Physics (TP)<br/>02 – Elementary Particle Physics and Relativistic Nuclear Physics (EPP&amp;RNP)<br/>03 – Nuclear Physics (NP)<br/>04 – Condensed Matter Physics and Radiation Radiobiological Research (CMP&amp;RRR)<br/>05 – Networking, Computing, Computational Physics (NCCP)<br/>06 – Educational Programme (EP)</p> | <p>** 0 – All-Institute topics<br/>1 – Veksler and Baldin Laboratory of High Energy Physics (VBLHEP)<br/>2 – Dzhelapov Laboratory of Nuclear Problems (DLNP)<br/>3 – Bogoliubov Laboratory of Theoretical Physics (BLTP)<br/>4 – Frank Laboratory of Neutron Physics (FLNP)<br/>5 – Flerov Laboratory of Nuclear Reactions (FLNR)<br/>6 – Meshcheryakov Laboratory of Information Technologies (MLIT)<br/>8 – Department of Science Organisation Activities (DSOA)<br/>9 – Laboratory of Radiation Biology (LRB)</p> |
|--|--|

Prepared by  
N.A. Boklagova  
D.S. Korobov



**Theoretical  
Physics  
(01)**

## Fundamental Interactions of Fields and Particles

**Leaders:** D.I. Kazakov  
O.V. Teryaev

### Participating Countries and International organizations:

Argentina, Armenia, Azerbaijan, Belarus, Bulgaria, Canada, CERN, Chile, China, Czech Republic, Finland, France, Georgia, Germany, Hungary, ICTP, India, Italy, Japan, Kazakhstan, Mexico, Mongolia, New Zealand, Norway, Portugal, Poland, Republic of Korea, Russia, Serbia, Slovakia, Spain, Sweden, Switzerland, Ukraine, United Kingdom, USA, Uzbekistan, Vietnam.

### Issues addressed and main goals of research:

The main aim of the research within the theme is the construction of theoretical models and their application to the description of properties of elementary particles and their interactions. This research includes the following directions of activity. The development of quantum field theory formalism in gauge and supersymmetric theories. Construction and investigation of the models of particle physics beyond the Standard Model.

Theoretical support of experiments at the Large Hadron Collider on the search of new physics and the study of the properties of the Higgs boson.

Calculation of radiative corrections to the processes of particle creation within the Standard Model and its extensions.

Investigation of neutrino properties and neutrino oscillations. Investigation of the hadron properties within quantum chromodynamics and phenomenological quark models. Study of the hadron spin structure with the help of generalized and transverse momentum dependent parton distributions and theoretical support of NICA/SPD program.

Study of heavy quark properties and exotic hadrons. Lattice simulations for obtaining nonperturbative results in gauge theories.

Investigation of dense hadronic matter and theoretical support of the MPD/NICA program.

Theoretical support of a wide range of current and future experiments at JINR, IHEP, CERN, GSI, JLab and other physics centers.

### Expected main results in the current year:

- Calculation of two-point two-loop Feynman diagrams containing an elliptic structure in the form of combinations of Goncharov and elliptic polylogarithms.

Derivation of hypergeometric functions of one and several variables in terms of iterated integrals in the frames of the fractional derivation technique. Search for an iterated integral representation of a class of special functions for Feynman diagrams.

Evaluation of the renormalon contributions to two-point correlators of composite quark currents in QCD.

Study of the  $\alpha_s^2$  contribution to the hadronic structure function of Drell-Yan processes in the framework of perturbative QCD.

Study of the critical behavior of 3-dimensional QCD and its supersymmetric generalization in the first two orders of the  $1/N_f$  expansion. Study of the critical behavior of 3-dimensional QED in the first three orders of the  $1/N_f$  expansion through the anomalous dimension of the fermion mass.

Study of the role of axion-like particles in experiments of electron-nucleon scattering. The role of New physics in anomalous magnetic moments of leptons and electric dipole moments of nucleons.

Development of a semi-analytical approach for the evolution of transverse-momentum-dependent parton densities to the next-to-leading order.

Construction of a semi-analytical approach for double parton distributions.



Establishment of the relation between effective cross sections of double parton scattering in photon-hadron and hadron-hadron collisions.

- Calculation of pion electromagnetic form factors in the low and (or) moderate energy regime, extending the domain of applicability of LCSR, in the order  $O(\alpha_s)$  for comparison with precision Jlab experiments.

Revision of distribution amplitudes (leading twist) of (pseudo)scalar and (longitudinal and transverse) vector mesons within QCD SRstaking into account new QCD corrections obtained for all of its components.

Theoretical analysis and a development of propositions for setting up an experiment for measurement of tensor electric and magnetic polarizabilities of the deuteron.

Investigation of the properties and energy dependence of new effects, which were determined in the experimental data by the TOTEM Collaboration at an energy of 13 TeV. Determination of the properties of the long-range hadron potential, which lead to peculiar properties of the differential crosssections of hadron-hadron elastic scattering.

Study of the generalized transverse momentum dependent distributions by restoring the Sivvers function in an alternative way, involving the new-found additional contribution in the inverse Radon transforms.

Investigation of the role of the gluon poles in the two-photon process producing transverse polarized hadrons with different fragmentation functions.

Investigation of the role of the twist-3 quark-gluon-quark correlation function in studying the hadron structure.

Study of the sum rules for hadron structure functions and fragmentation functions in quantum chromodynamics (QCD) with the use of the generalized truncated Mellin moments approach (TMM).

Study of the fragmentation functions in the inclusive pion and kaon production in proton-proton collisions in the NICA project.

Numerical optimization of perturbative series for observables using the renormalization group in QCD. Applications of the DIS sum rules and comparison with experimental data.

Study of Generalized Parton Distribution (GPDs) properties and GPDs effects in meson leptoproduction at modern colliders.

Study of the effects of magnetic monopoles and instantons in QCD on the hadron properties by simulations of lattice gauge theory. In particular, precise estimation of the number of instantons and anti-instantons, masses of the charm quark, eta prime and baryons, and the decay constants of mesons and baryons. Determination of the quantitative relations between the density of the number of instantons and anti-instantons and these observables. Investigation of possible detection of the monopole and instanton effects in experiments.

- Motivated by the first search for the rare charged-current B-meson decay into four-leptons,  $B \rightarrow l^+ l^- l' l'$ , it is planned to calculate the decay amplitude, the double differential distribution and branching fraction.

Elaboration of semianalytical methods for computation of bound states spectral functions in effective meson and quark-meson models by means of the nonperturbative renormalization group approach and their further implementation for calculation of decay widths and study of mass generation mechanisms for light mesons.

Study the role of leptoquarks in explanation of the flavor anomalies observed in precision experiments.

Derivation of the effective Lagrangian of the Nonrelativistic Quantum Electrodynamics (NRQED) that takes into account all interactions necessary for calculation of the bound states of Coulomb systems with a precision up to and included the order of  $m\alpha^7$ . Calculation of the hyperfine splitting of spectral lines in rho-vibrational transitions of molecular hydrogen ions with a relative accuracy of  $10^{-7}$ , which is necessary for the analysis of new precision experiments. Improvement of the values of the fundamental constants of atomic physics (Rydberg constant, the proton-to-electron mass ratio) by imposing more stringent restrictions on the interaction potentials of the "fifth" force.

Analysis of possibilities for a search for dark matter axions in spin experiments in storage rings.

- Calculation of the dependence of the critical temperatures of confinement/deconfinement and chiral symmetry breaking/restoration transitions on the angular velocity in rotating QCD within lattice simulation.

Study of the anisotropy of the static quark-antiquark potential in the presence of rotation. Calculation of the moment of inertia of rotating gluon plasma in rotating lattice QCD.

Investigation of the effect of quantum anomalies on transport phenomena in a vortical relativistic fluid containing also elementary particles with higher spins in external fields. Investigation of anomaly induced quantized vortices in mesonic superfluids and their effect on baryon polarization.

Improvement of the prediction of the global  $\Lambda$  polarization in the NICA-FAIR-HADES energy range, including its centrality and rapidity dependence. Calculation of splitting of the  $\Lambda$ -anti $\Lambda$  polarization within the thermodynamic approach including splitting induced by the meson field and the recently proposed thermal shear contribution.

Modeling of light-nuclei production in heavy-ion collisions in the SPS-RHIC energy range within the thermodynamic approach based on the three-fluid dynamical model and a comparison of the results with experimental data.

Study of a response of neutral and charged Fermi-systems with condensates of the vector fields, such as the triplet pairing, on the rotation. Special attention will be paid to the consideration of the possibility of self-rotation in nuclear systems.

Study of the influence of the effects of polarization of the dense nuclear matter on the properties of excitations with quantum numbers of the pion and on their s-p condensation in the framework of the quasiparticle approximation and beyond it. The results will be applied to describe proto-neutron stars and nucleus-nucleus collisions.

Calculation of the thermodynamic potential and investigation of the superfluid / superconducting phase transition and scaling in SU(N) symmetric equilibrium systems of ultracold fermions in the framework of the nonperturbative renormalization group.

Demonstration that the origin of the correlations between low and high- $p_t$  flow components in peripheral lead-lead collisions is traced to correlations of particles in jets.

Demonstration that the third eccentricity has a pure fluctuation origin and is substantially dependent on the size of the overlap area only, while the second eccentricity is mainly related to the average collision geometry.

Study of the propagation of nonlinear waves in the hot, viscous, nonextensive quark-gluon plasma.

Analytical calculation of quantum Tsallis thermodynamic variables. Derivation of the Tsallis-like quantum single particle distributions (to be used in high-energy collision physics) from nonextensive Green's functions. Comparison of them with the results obtained using the Tsallis statistical mechanics.

Preliminary magneto hydrodynamic simulation at nonzero conductivity in the context of heavy ion collisions.

- Preparation of a research program for future electron-positron colliders, including projects of the super charm-tau factory and the FCC-ee. High-precision theoretical predictions for the processes of particle interaction at these colliders and analysis of the effects associated with the polarization of the initial beams and produced tau leptons.

Calculation of the widths of tau lepton decays into hadrons and cross-sections of the electron-positron annihilation into hadrons in the framework of the Nambu-Jona-Lasinio model including rectification of the results for the tau lepton decays into hadrons obtained earlier with taking into account meson interaction in the final states.

Development of a simulation package for production of pions generated in interactions of neutrinos and charged leptons with nucleons within the framework of the GENIE neutrino generator. Implementation of a new model (the so-called MK model) of resonant production of pions and improvement of the earlier models based on the SU(6) relativistic quark model. Adjustment of the parameters of the models with inclusion of modern acceleration data.

Exploiting of the quasidirac neutrino scheme for conclusions on the potential of neutrino oscillations and double-beta decay experiments to determine absolute scale of neutrino masses.

Investigation of the corrections to the reactor antineutrino flux by considering the impact of new atomic and nuclear effects on the corresponding differential characteristics.

## List of Activities:

<b>Activity or experiment</b>	<b>Leaders</b>
Laboratory or other Division of JINR	Main researchers
<b>1. Quantum field theory and physics beyond the Standard Model</b>	<b>D.I. Kazakov</b>
BLTP	<b>A.V. Bednyakov</b> A.N. Baushev, A.T. Borlakov, Ch.R. Das, V. Gnatic, A.V. Kotikov, G.A. Kozlov, L. Mizhishin, V.A. Naumov, A.V. Nesterenko, A.I. Onishenko, A.F. Pikelner, R. Remetsky, D.M. Tolkachev, S.I. Vinitsky, A.A. Vladimirov, R.M. Yakhibbaev, 5 students
MLIT	O.V. Tarasov
DLNP	V.A. Bednyakov, E.V. Hramov, L.V. Kalinovskaya, L.G. Tkachev, E.V. Yakushev
<b>2. QCD parton distributions for modern and future colliders</b>	<b>I.V. Anikin</b>
BLTP	<b>O.V. Teryaev</b> V.V. Byt'yev, M. Deka, S.V. Goloskokov, D.B. Kotlorz, Y.A. Klopot, S.V. Mikhailov, A.G. Oganesyan, A.A. Pivovarov, G.Yu. Prokhorov, O.V. Selyugin, A.J. Silenko, N.I. Volchanskiy, 6 students
VBLHEP	Yu.I. Ivanshin, A.P. Nagaitsev, I.A. Savin, R. Tsenov
DLNP	A.V. Guskov
<b>3. Strong interactions phenomenology and precision physics</b>	<b>M.A. Ivanov</b>
BLTP	<b>V.I. Korobov</b> A.B. Arbuzov, D. Alvarez, A.K. Bekbaev, Yu.M. Bystritsky, S.M. Eliseev, C. Ganbold, S.B. Gerasimov, A.N. Isadykov, L. Martynovich, K. Nurlan, A.A. Osipov, H.-P. Pavel, A.V. Sidorov, Yu.S. Surovtsev, Zh. Tyulemisov, M.K. Volkov, S.A. Zhaugasheva, 5 students
<b>4. Theory of Hadronic Matter under extreme conditions</b>	<b>D. Blaschke</b>
BLTP	<b>V.V. Braguta</b> <b>E.E. Kolomeitsev</b> <b>S.N. Nedelko</b> D.E. Alvarez-Castillo, N.Yu. Astrakhantsev, T. Bhattacharyya, M. Deka, S. Dorkin, A.V. Friesen, A.A. Golubtsova, M. Hnatic, M. Hasegawa, Yu.B. Ivanov, E.-M. Ilgenfritz, L. Kaptari, A.S. Khvorostukhin, A.Yu. Kotov, K. Maslov, V.S. Melezhik, A.V. Nikolsky, S. Pandiat, A. Parvan, A.M. Snigirev, V.D. Tainov, O.V. Teryaev, V.D. Toneev, V.E. Voronin, D. Voskresensky, G.M. Zinoviev, 4 students
MLIT	A.S. Ayriyan, H. Grigorian, Yu.L. Kalinovsky, E.G. Nikonov
VBLHEP	O.V. Rogachevsky, V. Voronyuk

**5. Theory of electroweak interactions  
and neutrino physics**

BLTP

VBLHEP

DLNP

**A.B. Arbuzov**  
**V.A. Naumov**  
**F. Simkovic**

A. Babic, A.V. Bednyakov, Yu.M. Bystritskiy, V.V. Byt'yev,  
I.D. Kakorin, M.I. Krivoruchenko, K.S. Kuzmin, A.F. Pikel'ner,  
D.S. Shkirmanov, G. Seylkhanova, I.A. Sokal'skiy, 1 student

V.A. Zykunov

Ye.V. Dydysenko, L.V. Kalinovskaya, D.V. Naumov, O.N. Petrova,  
R.R. Sadykov, A.A. Saponov, O.Yu. Smirnov, V.I. Tretyak,  
2 students

**Collaboration**

**Country or International Organization**

**City**

**Institute or laboratory**

Argentina

Buenos Aires

CNEA

Armenia

Yerevan

Foundation ANSL

Azerbaijan

Baku

RAU

BSU

Belarus

Gomel

IP ANAS

GSTU

Minsk

GSU

BSU

INP BSU

IP NASB

JIPNR-Sosny NASB

Bulgaria

Sofia

INRNE BAS

SU

Canada

Corner Brook

MUN

Montreal

UdeM

CERN

Geneva

CERN

Chile

Valparaiso

UV

China

Beijing

PKU

Lanzhou

IMP CAS

Wuhan

WIPM CAS

Czech Republic

Prague

CTU

CU

IP CAS

Rez

NPI CAS

Finland

Helsinki

UH

France

Lyon

UCBL

Metz

UPV-M

Montpellier

UM2

Paris

UPMC

Saclay

IRFU

SPhN CEA DAPNIA

Georgia

Tbilisi

RMI TSU

TSU

Germany

Aachen

RWTH

Berlin

FU Berlin

HU Berlin

Bielefeld

Univ.

Bochum

RUB

Bonn

UniBonn

Darmstadt

GSI

		TU Darmstadt
	Dortmund	TU Dortmund
	Erlangen	FAU
	Frankfurt/Main	FIAS
	Hamburg	DESY
		Univ.
	Heidelberg	Univ.
	Jena	Univ.
	Julich	FZJ
	Kaiserslautern	TUK
	Karlsruhe	KIT
	Mainz	HIM
		JGU
	Munich	LMU
	Regensburg	UR
	Rostock	Univ.
	Tubingen	Univ.
	Wuppertal	UW
	Zeuthen	DESY
Hungary	Budapest	ELTE
		Wigner RCP
ICTP	Trieste	ICTP
India	Bhubaneswar	IOP
	Chennai	IMSc
	Kolkata	VECC
Italy	Naples	INFN
	Padua	UniPd
	Pavia	INFN
	Pisa	INFN
	Trieste	SISSA/ISAS
	Turin	UniTo
Japan	Chiba	Chiba U
	Kyoto	Kyoto Univ.
	Nagoya	Nagoya Univ.
	Osaka	Osaka Univ.
	Tokyo	Meiji Univ.
		Tokyo Tech
		UT
	Tsukuba	KEK
Kazakhstan	Almaty	FAPHI
		INP
	Nur-Sultan	BA INP
Mexico	Cuernavaca	UNAM
Mongolia	Ulaanbaatar	IPT MAS
New Zealand	Hamilton	Univ.
Norway	Trondheim	NTNU
Poland	Kielce	JKU
	Krakow	INP PAS
	Lodz	UL
	Otwock (Swierk)	NCBJ
	Wroclaw	ITP UW
Portugal	Coimbra	UC
Republic of Korea	Cheongju	CBNU
	Daegu	KNU

Russia	Seoul	SNU
	Belgorod	BelSU
	Chernogolovka	LITP RAS
	Gatchina	NRC KI PNPI
	Irkutsk	ISDCT SB RAS
	Ivanovo	ICS RAS
		ISU
	Kazan	KFU
	Moscow	IBRAE
		IMM RAS
		ITEP
		LPI RAS
		MI RAS
		MISiS
		MSU
		PFUR
		SCC RAS
		SINP MSU
	Moscow, Troitsk	INR RAS
	Novosibirsk	BINP SB RAS
		IM SB RAS
	Omsk	OmSU
	Perm	PSNRU
Protvino	IHEP	
Rostov-on-Don	SFedU	
Samara	SSU	
	SU	
Saratov	SSU	
Sarov	VNIIEF	
St. Petersburg	SPbSPU	
	SPbSU	
Tomsk	IHCE SB RAS	
	TSU	
Tver	TvSU	
Yoshkar-Ola	VSUT	
Serbia	Belgrade	Univ.
Slovakia	Bratislava	CU
		IP SAS
	Kosice	IEP SAS
Spain	Santiago de Compostela	USC
	Valencia	UV
Sweden	Lund	LU
Switzerland	Bern	Uni Bern
Ukraine	Dnipro	DNU
	Kharkov	NSC KIPT
	Kiev	BITP NASU
	Lutsk	EENU
	Lviv	IAPMM NASU
		IFNU
	Sumy	SumSU
United Kingdom	Canterbury	Univ.
	London	Imperial College
		QMUL

USA	College Park, MD	UMD
	East Lansing, MI	MSU
	Lemont, IL	ANL
	Long Beach, CA	CSULB
	Minneapolis, MN	U of M
	New York, NY	CUNY
		RU
	Newport News, VA	JLab
	Norman, OK	OU
	Philadelphia, PA	Penn
	San Diego, CA	SDSU
	University Park, PA	Penn State
Uzbekistan	Tashkent	IAP NUU
		NUU
Vietnam	Hanoi	IOP VAST

## Theory of Nuclear Systems

**Leaders:** N.V. Antonenko  
S.N. Ershov  
A.A. Dzhioev

### Participating Countries and International organizations:

Armenia, Austria, Belarus, Belgium, Brazil, Bulgaria, Canada, China, Czech Republic, Egypt, France, Germany, Greece, Hungary, India, Iran, Italy, Japan, Kazakhstan, Lithuania, Moldova, Norway, Poland, Republic of Korea, Romania, Russia, Serbia, Slovakia, South Africa, Spain, Sweden, Taiwan, Ukraine, United Kingdom, USA, Uzbekistan.

### Issues addressed and main goals of research:

Suggestion of new theoretical approaches for description and prediction of properties of superheavy, unstable nuclei and exotic nuclear systems, calculation of their characteristics; improvement of models for explanation of mechanisms of reactions of nuclei with particles and nuclei at low and intermediate energies; establishment of universal laws in low-dimensional small-particle systems and small-particle systems at ultra-low energies; development of the two-stage hybrid model of nuclear collisions at relativistic energies; study of nonlinear quantum processes in the interaction of photons with ultrashort high-frequency laser pulses.

### Expected main results in the current year:

- Calculations of  $\beta$ -decay and electron capture half-lives for superheavy deformed nuclei.  
Development of the formalism of the coupling with complex configurations within self-consistent nuclear models.  
Investigation of Coriolis mixing in dipole states of light deformed nuclei.  
Study of the beta-delayed gamma-spectroscopy of the cadmium isotope  $^{126}\text{Cd}$ .  
Study of the properties of isoscalar giant monopole resonance with using elements of random matrix theory.  
Estimation of the influence of pair correlation strength on the formation of nuclear scissors states within the framework of the Wigner function moments method.  
Study of the spin-flip resonance and  $2+$  collective excitations by the Wigner function moments method.  
Analysis of isomeric states in heavy nuclei and their influence on the  $\alpha$ -decay spectrum.
- Calculation and analysis of cross sections of the formation of superheavy nuclei in different evaporation channels.  
Comparative analysis of cross sections of the formation of nuclei with  $Z=119$  and  $120$  in reactions with the use of  $^{50}\text{Ti}$  and  $^{54}\text{Cr}$  beams.  
Study of the mass and energy distributions of transactinide fission fragments.  
Analysis of the cross section of fusion reactions of interest in astrophysics.  
Study of qubits in external fields.  
Calculation of spontaneous fission inhibiting factors for odd nuclei in the cluster approach.  
Analysis of the contribution of various n-particle n-hole configurations in the formation of the spreading width of giant nuclear resonances.  
Description of the decay widths of giant monopole and quadrupole resonances in heavy nuclei within random matrix theory. Study of the evolution of mirror-asymmetric deformation in isotopic chains of actinides and rare-earth nuclei.



- Investigation of the early stage tunneling dynamics of ultracold two-atom systems.
  - Investigation of a highly excited state of the 1p shell nuclei.
  - Calculation of bound states and scattering processes in two- and three-atom systems formed of the rare gas atoms.
  - Analysis of the three-body energy spectra of two-component systems with zero-range interactions in one and two dimensions.
  - Study of the spectra of low-lying states for a chain of zirconium isotopes within the geometric collective model.
  - Development of computational schemes based on two-dimensional discrete-variable representations in application to few-body quantum systems.
  - Proof of bounds for the maximal possible speed of subspace time evolution generated by unbounded Hamiltonians.
  - Justification of the use of single and double Compton ionization of atoms as a new method for dynamical spectroscopy of the electron momentum distribution.
  - Analysis of the quasi-two-dimensional motion of two interacting hydrogen atoms on a liquid helium film.
  - Study of the analytic structure of the multi-channel R-matrix.
  - Study of dynamics of a hydrogen atom in a strong elliptically polarized laser field within the time-dependent numerical approach.
  - Study of total reflection induced by the super-interference phenomenon
  - Analysis of the effect of deformation on the breakup of the  $^{11}\text{Be}$  halo nucleus within the time-dependent approach.
  - Correct formulation of the entangled exit channels in the model of incoming wave boundary conditions in sub-barrier heavy-ion fusion reactions.
- Theoretical analysis of the proton- and nucleus-nucleus scattering cross-sections over some target-nuclei in the energy range from 30 MeV to 1 GeV/nucleon basing on the development of the respective microscopic model of optical potential.
  - Study of essentially multiphoton quantum processes expected in reactions induced by intense short and ultrashort laser pulses with arbitrary polarization.
  - Application of non-extensive statistical methods to describe the particle production and transverse momentum distributions of hadrons in heavy ion-proton and proton-proton collisions.
  - Study of proton-deuteron elastic scattering in the framework of the relativistic Bethe-Salpeter-Faddeev formalism with a separable kernel. Investigation of the polarization characteristics in this reaction.
  - Investigation of the properties of baryon and pseudo-scalar mesons at finite temperature and density in the framework of three-flavour Polyakov-Nambu-Jona-Lasinio model.
  - Investigation of the cross sections of  $\Upsilon$  absorption and  $\Upsilon$  production in BB-collision in the framework of the covariant quark model with SU(5) Lagrangian including anomalous interactions.
  - Analysis of the Bethe-Salpeter solutions in coordinate space, establishment of some patterns and investigation of abnormal solutions.
  - Study of the short-range deuteron structure and of the color transparency effect in proton-deuteron interactions at relativistic energies within the generalized eikonal approximation.

## List of Activities:

<b>Activity or experiment</b>	<b>Leaders</b>
Laboratory or other Division of JINR	Main researchers
<b>1. Microscopic models for exotic nuclei and nuclear astrophysics</b>	<b>V.V. Voronov</b> <b>A.A. Dzhioev</b> <b>J. Kvasil</b>
BLTP	N.N. Arsenyev, E.B. Balbutsev, H. Ganev, V.A. Kuz'min, L.A. Malov, I.V. Molodtsova, V.O. Nesterenko, A.P. Severyukhin, V.M. Shilov, S.V. Sidorov, A.V. Sushkov, A.I. Vdovin, 3 students
MLIT	N.Yu. Shirikova
FLNP	A.M. Sukhvoi
<b>2. Low-energy nuclear dynamics and properties of nuclear systems</b>	<b>S.N. Ershov</b> <b>N.V. Antonenko</b> <b>R.V. Jolos</b>
BLTP	G.G. Adamian, A.V. Andreev, A.N. Bezbakh, Sh. Kalandarov, V.G. Kartavenko, R.G. Nazmitdinov, A.K. Nasirov, H. Pasca, A. Rahmatinedzhad, I.S. Rogov, T.M. Shneidman, B. Urazbekov, 3 students
FLNR	L.V. Grigorenko, Yu.E. Penionzhkevich, A.I. Svirikhin
DLNP	A.S. Zhemchugov
<b>3. Quantum few-body systems</b>	<b>A.K. Motovilov</b> <b>A.S. Melezhik</b>
BLTP	Ishmukhamedov, D. Janseitov, E.A. Kolganova, V.N. Kondratyev, E.A. Koval, A.V. Malykh, E.V. Mardyban, Yu.V. Popov, V.V. Pupishev, S.A. Rakityanskiy, S.A. Shadmehri, E.A. Solov'ev, D. Valiolda, S.I. Vinitsky, 3 students
DLNP	O.I. Kartavtsev
MLIT	O. Chulunbaatar, A.A. Gusev
<b>4. Relativistic nuclear dynamics and nonlinear quantum processes</b>	<b>V.V. Burov</b> <b>M. Gaidarov</b> <b>S.G. Bondarenko</b>
BLTP	M. Baznat, S.M. Dorkin, A.V. Frisen, L.P. Kaptari, A.B. Larionov, V.K. Lukyanov, A.S. Parvan, A.I. Titov, V.D. Toneev, S.A. Yur'ev, 1 student
MLIT	Yu.L. Kalinovskiy, K.V. Lukyanov, E.V. Zemlyanaya
VBLHEP	V.P. Ladygin, N.B. Ladygina, A.I. Malakhov, N.M. Piskunov, Yu.A. Panebratsev, E.P. Rogochaya

## Collaboration

<b>Country or International Organization</b>	<b>City</b>	<b>Institute or laboratory</b>
Armenia	Yerevan	RAU YSU
Austria	Innsbruck	Univ.
Belarus	Minsk	IP NASB

Belgium	Brussels	ULB VUB
Brazil	Louvain-la-Neuve Florianopolis, SC Niteroi, RJ Sao Jose dos Campos, SP Sao Paulo, SP	UCL UFSC UFF ITA UEP
Bulgaria	Sofia	INRNE BAS NBU
Canada	Hamilton, ON Saskatoon Waterloo	McMaster U of S WLU
China	Beijing	CIAE ITP CAS PKU
Czech Republic	Prague	CU
Egypt	Giza	CU
France	Bordeaux Caen Orsay	UB GANIL CSNSM IJCLab
Germany	Berlin Bielefeld Bonn Cologne Darmstadt  Dresden Erlangen Frankfurt/Main Giessen Hamburg Leipzig Mainz Regensburg Rostock Siegen	HZB Univ. UniBonn Univ. GSI TU Darmstadt HZDR FAU Univ. JLU Univ. UoC JGU UR Univ. Univ.
Greece	Athens	INP NCSR "Demokritos"
Hungary	Budapest Debrecen	Wigner RCP Atomki
India	Chandigarh Kasaragod New Delhi	PU CUK IUAC
Iran	Zanjan	IASBS
Italy	Bologna Catania Messina Naples Perugia Turin	BRC ENEA INFN LNS UniMe INFN INFN UniTo
Japan	Kobe Morioka Osaka	Kobe Univ. Iwate Univ. Osaka Univ. RCNP

Kazakhstan	Almaty	INP KazNU
Lithuania	Kaunas	VMU
Mexico	Mexico City	UNAM
Moldova	Chisinau	IAP
Norway	Bergen	UiB
	Oslo	UiO
Poland	Krakow	INP PAS
	Lublin	UMCS
	Otwock (Swierk)	NCBJ
	Warsaw	UW
Republic of Korea	Daegu	KNU
	Daejeon	IBS
	Jeonju	JBNU
	Seoul	SNU
Romania	Bucharest	IFIN-HH
		UB
Russia	Dolgoprudny	MIPT
	Gatchina	NRC KI PNPI
	Khabarovsk	PNU
	Moscow	MSU
		NNRU "MEPhI"
		NRC KI
		PFUR
		SINP MSU
	Moscow, Troitsk	INR RAS
	Omsk	OmSU
	Saratov	SSU
	St. Petersburg	SPbSU
	Vladivostok	FEFU
Serbia	Belgrade	IPB
Slovakia	Bratislava	CU
		IP SAS
South Africa	Johannesburg	WITS
	Pretoria	UP
	Somerset West	iThemba LABS
	Stellenbosch	SU
Spain	Palma	UiB
Sweden	Goteborg	Chalmers
	Lund	LU
Taiwan	Taipei	NTU
Ukraine	Kiev	BITP NASU
		KINR NASU
		NUK
United Kingdom	Guildford	Univ.
USA	Lemont, IL	ANL
	Los Alamos, NM	LANL
	Notre Dame, IN	ND
	Raleigh, NC	NCCU
	University Park, PA	Penn State
Uzbekistan	Namangan	NamMTI
	Tashkent	Assoc. P.-S. PTI
		IAP NUU
		INP AS RUz

## Theory of Complex Systems and Advanced Materials

### Leaders:

V.A. Osipov  
A.M. Povolotskii

### Participating Countries and International organizations:

Armenia, Australia, Austria, Azerbaijan, Belarus, Belgium, Brazil, Bulgaria, Canada, Czech Republic, Denmark, Ecuador, Egypt, Finland, France, Germany, Hungary, India, Iran, Italy, Japan, Mongolia, New Zealand, Poland, Republic of Korea, Romania, Russia, Serbia, Slovakia, Slovenia, South Africa, Spain, Switzerland, Taiwan, Ukraine, United Kingdom, USA, Uzbekistan, Vietnam.

### Issues addressed and main goals of research:

Development of analytical and numerical methods for studying complex many-body systems that are of current interest in modern condensed matter physics, the development of mathematical models of these systems and the identification of universal laws on the example of studied models. Analysis of both lattice and field-theory models of equilibrium and non-equilibrium statistical systems and modeling of a wide class of new materials, including nanostructured materials, which are of great practical importance. The concepts of scaling and universality allow one to go beyond the model approach and to apply the results obtained to broad classes of phenomena studied in the physics of condensed matter. Study of a wide range of universal phenomena in complex systems - phase transitions in condensed media and high-energy physics, scaling in (magneto)hydrodynamic turbulence, chemical reactions, percolation, etc. by the methods of quantum field theory including the functional renormalization group. The results obtained will be used in carrying out experimental studies of condensed matter at JINR. It is important to note the markedly growing interdisciplinary nature of research, where condensed matter physics and statistical physics closely intersect with atomic and nuclear physics, particle physics, mathematical physics, astrophysics, and biology.

### Expected main results in the current year:

- Development of new theoretical models and methods for studying fractal systems using the small-angle scattering technique.

Investigation of magnetocapacitive, magnetoresistive and magneto-piezoelectric effects in smart composite materials.

Development of a theory of the optical Stark effect in monolayer transition metal dichalcogenides with intervalley biexciton involvement and valley selectivity of the effect taken into account.

Modeling of carbon(silicon)-tungsten-hydrogen potentials for the use in numerical molecular dynamics investigation of graphene(silicone)-tungsten layered structures to obtain results for comparison with the proton beam irradiation experiments.

Modeling of a linear spin chain with three-body spin interactions with a density matrix renormalization group numerical method in order to obtain a phase diagram as a function of the interaction parameters.

Ab initio estimation of exchange parameters of a Co-based honeycomb Kitaev magnet  $\text{BaCo}_2(\text{AsO}_4)_2$ , and calculation of the corresponding spin-wave spectrum.

Calculation of magnon spectral line broadening in a honeycomb ferromagnet with Dzyaloshinskii-Moriya interactions.

Development of a microscopic theory of spin excitations in the electron-doped cuprates within the t-J model by considering the antiferromagnetic (AF) order as a function of doping and comparison of the obtained results with available experiments.

Development of a statistical theory for describing the properties of condensed matter systems with extended defects.

Development of the theory of quantum nets accomplishing quantum information processing.

Development of an approach to self-similar extrapolation of asymptotic series, with applications to condensed matter systems and quantum field theory.

- Investigation of the manifestation of nonlinear phenomena in the dynamics and IV-characteristics of Josephson junction stacks and Josephson nanostructures with ferromagnetic layers.

Investigation of the possibility of enhancing the efficiency of detecting current signals by using the Josephson junction stack.

Investigation of the conductivity and mobility of charge carriers in modified graphene structures through a combination of molecular dynamics and Landauer approaches.

Investigation of the temperature behaviour of resistivity of nanostructural metallic films based on the disclination concept of grain boundary. Calculation of the Hall mobility as a function of temperature and thickness in these materials.

Investigation within the model of strongly correlated electrons of the influence of short-range nonlocal Coulomb repulsion, experimentally observed in doped cuprates, on the structure of pair correlations and on the superconductivity.

Investigation of electronic properties of transition metal dichalcogenides and other types of 2D materials in the presence of 0D and 1D randomly distributed defects with a focus on the influence of the edge and bound states of defects on the transport properties in the hopping and resonant transport regimes.

- Construction of integrable models connected to complex hypergeometric functions. Construction of mixed recurrence and difference equations for the corresponding functions appearing in the limiting regime of key deformation parameter  $b \rightarrow i$  for hyperbolic hypergeometric functions.

Systematic investigation of the degeneration of multidimensional elliptic hypergeometric integrals to the hyperbolic level with a subsequent reduction to the level of complex hypergeometric functions, which corresponds to the degeneration of 4d superconformal indices to 3d and 2d supersymmetric partition functions.

Description of the finite-dimensional behavior of the dimer model on lattices with different geometries under different boundary conditions. Investigation of the entangled states of a complex quantum system with single-ion anisotropy.

Construction of the Cayley-Hamilton identities and investigation of the characteristic subalgebras for the Quantum Matrix algebras of orthogonal type.

Investigation of a family of stochastic processes on the one-dimensional chains with two states in the local vertex by the use of the Hecke type stochastic R-matrix.

Construction of a new quasi-oscillator generating set for the quantum groups  $U_q(\mathfrak{gl}_n)$  and investigation with its help of a series of Gelfand-Zetlin representations.

Calculation of exact cluster densities in the percolation model and loop densities in  $O(1)$  dense loop model on lattices with various boundary conditions.

Construction and solution of the lattice model of lattice paths with partial annihilation.

Description of particle flow statistics in an asymmetric avalanche process.

Determination of non-local correlation functions in the models of branching polymers on the lattice with boundary.

- Study of spontaneous isotropy breaking in a generalized model of helical stochastic magnetic hydrodynamics. Calculations of critical indices and fixed RG points in the two-loop approximation.

Development of computational methods for solving equations of a non-perturbative functional renormalization group.

Study of chemical reactions kinetics in stochastic media with random fluctuations of different types. Construction of effective field models and derivation of renormalization group equations for correlation functions of the density field of chemically active molecules. Calculation of scaling exponents.

Performing three-loop calculations of fixed RG points and scaling indices in directed percolation described by some effective field-theoretic action.

Calculation of the thermodynamic potential and investigation of the superfluid/superconducting phase transition and scaling in SU(N) symmetric equilibrium systems of ultra-cold fermions in the framework of the non-perturbative renormalization group.

Study of the influence of isotropic turbulent medium modelled by the stochastic Navier-Stokes equation on the possibility of the occurrence of self-organized criticality in Hwa-Kardar anisotropic model of a moving sand pile.

Study by means of the functional renormalization group of the infrared asymptotic behaviour of the Kardar-Parisi-Zhang model with spatially quenched random noise that describes random surface growth.

Investigation of the transfer of vector impurities in an anisotropic and helical turbulent medium in the presence of a weak external magnetic field.

Study of the magnetic field effect on the transport properties of inversion symmetric Weyl semimetal heterostructures including normal superconductors and proximity induced superconductivity in Weyl semimetals.

Elaboration of semi-analytical methods for computation of bound states spectral functions in effective meson and quark-meson models by means of non-perturbative renormalization group approach and their further implementation for calculation of decay widths and the study of mass generation mechanisms for light mesons.

### List of Activities:

<b>Activity or experiment</b>	<b>Leaders</b>
Laboratory or other Division of JINR	Main researchers
<b>1. Complex materials</b>	<b>E.M. Anitas</b> <b>N.M. Plakida</b>
BLTP	A.Yu. Cherny, A.A. Donkov, A.L. Kuzemsky, P.A. Maksimov, Tung Nguen Dan, A.A. Vladimirov, V.I. Yukalov, V.Yu. Yushankhai
FLNP	V.L. Aksenov, A.M. Balagurov, A. Islamov, D.P. Kozlenko, A.I. Kuklin, E.P. Popov
MLIT	L.A. Syurakshina, E.P. Yukalova
<b>2. Nanostructures and nanomaterials</b>	<b>V.A. Osipov</b> <b>E.A. Kochetov</b>
BLTP	T. Belgibaev, Hoang Ngok Kam, I.D. Ivantsov, V.L. Katkov, D.V. Kolesnikov, S.E. Krasavin, K.V. Kulikov, A. Mazanik, I.R. Rachmonov, O.G. Sadykova, Yu.M. Shukrinov
MLIT	I. Sarhadov, S.I. Serdyukova, E.B. Zemlianaya
LRB	A.N. Bugay
FLNR	A. Olejniczak
<b>3. Mathematical models of statistical physics of complex systems</b>	<b>A.M. Povolotsky</b>
BLTP	A.E. Derbyshev, V.I. Inozemtsev, V. Papoyan, P.N. Pyatov, V.P. Spiridonov, P.E. Zhidkov
<b>4. Methods of quantum field theory in complex systems</b>	<b>M. Hnatic</b>
BLTP	G. Kalagov, N. Lebedev, M. Maiti, L. Mizisin, R. Remecki
MLIT	J. Busa

## Collaboration

Country or International Organization	City	Institute or laboratory
Armenia	Yerevan	Foundation ANSL YSU
Australia	Melbourne, VIC Sydney, NSW	Univ. Univ.
Austria	Linz	JKU
Azerbaijan	Baku	Branch MSU
Belarus	Minsk	BSTU IP NASB SPMRC NASB
Brazil	Brasilia, DF Natal, RN Sao Paulo, SP	UnB IIP UFRN USP
Bulgaria	Plovdiv Sofia	PU IMech BAS INRNE BAS ISSP BAS SU
Canada	Kingston, ON London, ON Montreal Quebec	Queen's Western Concordia UL
Czech Republic	Olomouc Rez	UP NPI CAS
Denmark	Lyngby	DTU
Ecuador	Quito	USFQ
Egypt	Giza	CU
Finland	Helsinki	UH
France	Marseille  Nice Paris Valenciennes	CPT UPC UN UPMC UVHC
Germany	Braunschweig Bremen Darmstadt  Dortmund Dresden  Jena Leipzig Magdeburg Rostock Wuppertal	TU Univ. GSI TU Darmstadt TU Dortmund IFW MPI PkS TU Dresden Univ. UoC OVGU Univ. UW
Hungary	Budapest	Wigner RCP
India	Kolkata	IACS
Iran	Zanjan	IASBS
Italy	Catania Fisciano	UniCT UNISA
Japan	Utsunomiya	UU



Mongolia	Ulaanbaatar	IPT MAS NUM
New Zealand	Auckland	Univ.
Poland	Katowice	US
	Krakow	JU
	Poznan	AMU
		IMP PAS
	Warsaw	IPC PAS
	Wroclaw	WUT
Republic of Korea	Daejeon	CTPCS IBS
	Incheon	Inha
Romania	Bucharest	IFIN-HH
	Cluj-Napoca	UTC-N
	Timisoara	UVT
Russia	Belgorod	BelSU
	Gatchina	NRC KI PNPI
	Kazan	KFU
	Moscow	ITEP
		LPI RAS
		MI RAS
		MIREA
		NNRU "MEPhI"
		NRC KI
		NRU HSE
		PFUR
		SINP MSU
	Moscow, Troitsk	HPPI RAS
	Novosibirsk	ISP SB RAS
		NIIC SB RAS
	Perm	PSNRU
	Protvino	IHEP
	Samara	SU
	Saratov	SSU
	St. Petersburg	ETU
		Ioffe Institute
		ITMO Univ.
		PDMI RAS
		SPbSPU
		SPbSU
	Voronezh	VSU
	Yekaterinburg	IMP UB RAS
Serbia	Belgrade	INS "VINCA"
Slovakia	Bratislava	CU
	Kosice	IEP SAS
		UPJS
Slovenia	Ljubljana	UL
South Africa	Pretoria	UNISA
Spain	Madrid	ICMM-CSIC
Switzerland	Villigen	PSI
	Zurich	ETH
Taiwan	Taipei	IP AS

Ukraine	Kharkov	NSC KIPT
	Kiev	IMP NASU
		NUK
	Lviv	ICMP NASU
United Kingdom	Coventry	Warwick
USA	Irvine, CA	UCI
	Louisville, KY	U of L
	New York, NY	CUNY
	Pasadena, CA	Caltech
	Piscataway, NJ	Rutgers
	Rochester, NY	UR
	Tallahassee, FL	FSU
Uzbekistan	Tashkent	Assoc. P.-S. PTI
Vietnam	Hanoi	IMS VAST

## **Modern Mathematical Physics: Gravity, Supersymmetry and Strings**

### **Leaders:**

A.P. Isaev  
S.O. Krivonos  
A.S. Sorin

### **Participating Countries and International organizations:**

Armenia, Australia, Brazil, Bulgaria, Canada, CERN, Czech Republic, Estonia, France, Germany, Greece, ICTP, India, Israel, Iran, Ireland, Italy, Japan, Lithuania, Luxembourg, Norway, Poland, Portugal, Republic of Korea, Russia, Spain, Taiwan, Ukraine, United Kingdom, USA.

### **Issues addressed and main goals of research:**

The main purpose of research in modern mathematical physics is the development of mathematical methods for solving the most important problems of modern theoretical physics: clarifying the nature of fundamental interactions and their symmetries, construction and study of effective field models arising in the theory of strings and other extended objects, uncovering of the geometric description of quantum symmetries and their spontaneous breaking in the framework of search for a unified theory of all fundamental interactions, including quantum gravity. Mathematical physics in recent years has been characterized by increasing interest in identifying and effective use of integrability in various areas, and in applying powerful mathematical methods of quantum groups, supersymmetry and non-commutative geometry to quantum theories of fundamental interactions as well as to classical models.

The main goals and tasks of the research within the theme include: development of new mathematical methods for investigation and description of a variety of classical and quantum integrable models and their exact solutions; analysis of a wide range of problems in supersymmetric theories including models of superstrings and super branes, study of non-perturbative regimes in supersymmetric gauge theories; development of cosmological models of the early Universe, primordial gravitational waves and black holes. The decisive factor in solving the above problems will be the crucial use of the mathematical methods of the theory of integrable systems, quantum groups and noncommutative geometry as well as super space techniques.

### **Expected main results in the current year:**

- Study of the interior of a black hole using random matrix ensembles holographically dual to dilaton gravity. Calculation of spectral correlators for 2d dilaton gravity, analysis using random matrix ensembles.

Investigation of the phase diagram for the thermal ensemble of  $N=4$  super-Yang-Mills theory on  $R \times S^3$  in the framework of the holographic approach. Calculation of the confinement-deconfinement phase transition temperature, calculation of the circular Wilson loop in Kerr-AdS<sub>5</sub>, and the corresponding quark-antiquark interaction potential.

Construction of a solution describing a closed bosonic (pulsating) string in the 5d space of the Kerr-AdS black hole. Calculation of the energy spectrum of a string, using the Bohr-Sommerfeld analysis, that is dual to the dispersion relations for the operators of the thermal  $N=4$  SYM on  $R \times S^3$ .

Construction of the  $N=(1,0)$ ,  $d=6$  non-abelian tensor hierarchy off the mass shell and the action of non-abelian tensor multiplet that is invariant with respect to the obtained gauge transformations.

Analysis of the spectrum of the Casimir operators for the six-dimensional Poincaré group on the subspace of states corresponding to massive particles. Construction of the field realization of massive representations of the six-dimensional Poincaré group.

Derivation of 4D and 6D covariant equations for the wave functions of particles with an infinite (continuous) spin within the framework of the generalized Wigner scheme.

Application of the Manin matrices to the theory of representations of quantum algebras on quantum linear spaces. Interpretation of the Manin matrices as generalized (co)points of some quadratic algebras. Generalization of the tensor product of representations to the quantum case. Generalization of the theory of quantum linear spaces to the infinite-dimensional case and to the case of super-algebras.

New method for construction of lagrangian cycles in algebraic varieties in the framework of Mirror Symmetry: construction of the generalized Mironov cycles in Grassmannians; germs of lagrangian cycles on divisors and their growth by the inverse flows of Liouville fields.

Construction of the trigonometric and hyperbolic Ruijsenaars-Schneider models with extended supersymmetry and analysis of their integrability.

- Computation of the two-loop divergences in the 6D,  $N=(1,1)$  supersymmetric Yang-Mills theory in the quantum harmonic 6D,  $N=(1,0)$  super field approach in the general background for checking the hypothesis that the relevant expression possesses hidden 6D,  $N=(0,1)$  supersymmetry and vanishes on the full set of the equations of motion for 6D,  $N=(1,1)$  theory.

Study of the unitary representations of the Poincaré group in six-dimensional space-time, including massless infinite spin representations, in space-time and twistor formulations.

Construction and study by various methods of the supersymmetric generalizations of many-particle integrable systems of diverse kinds, including both the nonrelativistic Calogero-Moser-Sutherland systems and their relativistic analogs – the Ruijsenaars-Schneider models.

Construction and study of new multicomponent solutions of the CP<sup>2</sup> Skyrme model with the SU(3) symmetry breaking potential.

Construction and study of new types of boson stars and hairy black holes in the U(1) gauged Einstein-Friedberg-Lee-Sirlin model.

Construction and study of compactified spin-Ruijsenaars-Schneider model as a system on phase space given by complex Grassmannian, and the study of its supersymmetric extensions.

Construction and study of an isotropic optical profiles that are dual to the two-center Coulomb problem generalizing the classical "Maxwell fish eye" refraction indices.

Construction of a new model of the  $N=4$  supersymmetric mechanics with the coordinate (1,4,3) and (2,4,2) multiplets interacting with the spin (3,4,1) multiplet, consideration of its SU(2|1) deformation and quantization in a few simple cases.

Study of various limits of the hyperbolic hypergeometric integral related to the fusion matrix of two-dimensional Liouville conformal field theory and study of limiting forms of the difference equations and symmetry relations for rarefied elliptic and hyperbolic hypergeometric integrals paying special attention to the supersymmetric case.

- Generalization of the approach to the decay of a false vacuum in 4-dimensional scalar field theory to a space with an arbitrary number of dimensions. Consideration of a wide class of unbounded potentials for which Coleman instantons do not exist. Obtaining of universal formulas for basic physical quantities related to the problem of the decay of a false vacuum in any number of dimensions. For any number of dimensions, construction of integrable potentials for which instanton equations have exact solutions.

Investigation of scalar-tensor gravity models by effective field theory methods. Derivation of a scalar field effective potential generated in a scalar-tensor gravity model with a massive scalar field admitting quartic self-interaction up to the leading gravitational corrections. Study of the effect of quantum corrections on low-energy phenomenology, especially on the ability of this model to describe slow-roll inflationary expansion.

Comprehensive study of the dynamics of null cosmic strings on physically interesting manifolds (geometries with black holes, cosmological models, and others) making use of the optical equation that takes into account the general

characteristics of the motion of a string in an arbitrary gravitational field in a coordinate-invariant and reparameterization-invariant form.

Formulation and study of quantum field theory on manifolds with holonomy, the elements of which are related to parabolic transformations of the Lorentz group (the so-called zero rotations), obtaining of Green's functions, calculation of the expectation values of the energy-momentum tensor, study of the behavior of the heat kernel, etc.

Investigation of spaces with global parabolic isometries in order to accurately describe the gravitational field of null cosmic strings. Study of the influence of null cosmic strings on the spectrum of inhomogeneities of the microwave background radiation - an analogue of the Kaiser-Stebbins effect.

Investigation of the main scenarios of the test particle and photon motion for the spherically symmetric Stephani cosmological model with accelerated expansion.

Construction of a model of a cosmological black hole in the dust-filled universe on the basis of the exact solution to the Einstein equations of the Lemaitre-Tolman-Bondi class for different types of spatial curvature. Analysis of the cosmological horizon in the Lemaitre-Tolman-Bondi metric with nonzero pressure.

Consideration of cosmological anisotropic models of Bianchi type I in the theories of teleparallel gravity  $f(T)$ . Study of the possibility of the existence in such theories of solutions with bounce and recollapse, as well as the possibility of dynamic isotropization during the expansion of the Universe. Examination of the structure of the cosmological singularity.

Development of the universal effective method for solving typical problems in the classical nonrelativistic theory of gravity, in particular, the calculation of perturbations of Kepler's ellipses.

Construction of solutions for massless cosmic strings moving in space-times containing non-trivial objects such as singularities, black holes, matter flows, fluctuations of matter density. Analysis of the possibility of extracting information from observational data related to the cosmic string about objects with which the string previously interacted and finding out whether it is possible to obtain in this way data on the physics of processes that took place on the Planck scale during the Big Bang.

Comprehensive investigation of the properties of the previously constructed solution for a dyon black hole with a dilaton field with asymptotic Minkowski space in the context of the holographic approach, which allows one to relate the parameters of solutions, such as temperature and free energy, with the parameters of dual field models.

Investigation of the properties of dynamical systems arising in models of a gravitating scalar field in five-dimensional space-time with a specific potential arising in the context of holographic duality. Interpretation of the obtained properties of dynamical systems in the context of dual field theories.

## List of Activities:

<b>Activity or experiment</b>	<b>Leaders</b>
Laboratory or other Division of JINR	Main researchers
<b>1. Quantum groups and integrable systems</b>	<b>A.P. Isaev</b> <b>S.O. Krivonos</b> <b>N.A. Tyurin</b>
BLTP	Ch. Burdik, H. Dimov, P. Fiziev, A.A. Golubtsova, N.Yu. Kozyrev, M. Podoinitsyn, G.S. Pogosyan, A.A. Provorov, A.V. Silantyev
UC	S.Z. Pakuliak
<b>2. Supersymmetry</b>	<b>E.A. Ivanov</b>
BLTP	S.A. Fedoruk, A. Nersessian, G. Sarkissyan, S.S. Sidorov, Ya.M. Shnir, A.O. Sutulin, N.M. Zaigraev
<b>3. Quantum gravity, cosmology and strings</b>	<b>I.G. Pirozhenko</b> <b>V.V. Nesterenko</b>

BLTP

I. Bormotova, E.A. Davydov, D.V. Fursaev, B. Latosh,  
A.B. Pestov, A.A. Provorov, E. Radionova, A.S. Sorin,  
E.A. Tagirov, P.V. Tretyakov

MLIT

A.M. Chervyakov

VBLHEP

E.E. Donets

## Collaboration

### Country or International Organization

### City

### Institute or laboratory

Armenia

Yerevan

Foundation ANSL

YSU

Australia

Perth, WA

UWA

Sydney, NSW

Univ.

Brazil

Juiz de Fora, MG

UFJF

Sao Paulo, SP

USP

Vitoria, ES

UFES

Bulgaria

Sofia

INRNE BAS

SU

Canada

Edmonton

U of A

Montreal

Concordia

CERN

Geneva

CERN

Czech Republic

Opava

SIU

Prague

CTU

Rez

NPI CAS

Estonia

Tartu

UT

France

Annecy-le-Vieux

LAPP

Lyon

ENS Lyon

Marseille

CPT

Nantes

SUBATECH

Paris

ENS

LUTH

Univ.

Germany

Tours

UniBonn

Bonn

LUH

Hannover

UoC

Leipzig

IPO

Oldenburg

AEI

Potsdam

UoA

Greece

Athens

AUTH

Thessaloniki

ICTP

ICTP

Trieste

IMSc

India

Chennai

BNC

Kolkata

IACS

Iran

Tehran

IPM

Ireland

Dublin

DIAS

Israel

Tel Aviv

TAU

Italy

Frascati

INFN LNF

Padua

UniPd

Pisa

INFN

Trieste

SISSA/ISAS

Turin

UniTo

Japan

Tokyo

Keio Univ.

UT

Lithuania	Vilnius	VU
Luxembourg	Luxembourg	Univ.
Norway	Trondheim	NTNU
Poland	Bialystok	UwB
	Lodz	UL
	Wroclaw	UW
Portugal	Aveiro	UA
Republic of Korea	Seoul	SKKU
Russia	Chernogolovka	LITP RAS
	Kazan	KFU
	Moscow	ITEP
		LPI RAS
		MI RAS
		MSU
		SAI MSU
	Moscow, Troitsk	INR RAS
	Novosibirsk	NSU
	Protvino	IHEP
	St. Petersburg	PDMI RAS
	Tomsk	TPU
		TSPU
Spain	Barcelona	IEEC-CSIC
	Bilbao	UPV/EHU
	Santiago de Compostela	USC
	Valencia	IFIC
	Valladolid	UVa
Taiwan	Taoyuan City	NCU
Ukraine	Kharkov	KhNU
		NSC KIPT
	Kiev	BITP NASU
United Kingdom	Cambridge	Univ.
	Canterbury	Univ.
	Durham	Univ.
	Glasgow	U of G
	Leeds	UL
	London	Imperial College
	Nottingham	Univ.
USA	Amherst, MA	UMass
	College Park, MD	UMD
	Coral Gables, FL	UM
	New York, NY	CUNY
		SUNY
	Norman, OK	OU
	Piscataway, NJ	Rutgers
	Rochester, NY	UR
	Tempe, AZ	ASU

## **Dubna International Advanced School of Theoretical Physics (DIAS-TH)**

**Leader:** V.V. Voronov

**Rector of DIAS-TH:** D.I. Kazakov

### **Participating Countries and International organizations:**

Armenia, Austria, Belarus, Brazil, Bulgaria, Canada, China, CERN, Czech Republic, France, Germany, Greece, Hungary, India, Israel, Italy, Japan, Norway, Poland, Romania, Russia, Serbia, Slovakia, South Africa, Spain, Turkey, Ukraine, United Kingdom, USA, Vietnam.

The Bogoliubov Laboratory of Theoretical Physics (BLTP) has a good record of organizing international workshops and schools in Dubna. DIAS-TH organizes and supervises all educational programs for students, postgraduates, and young scientists at BLTP. It should function continuously and the standard short schools (about 3-4 a year) should be organized coherently. Other educational programs in Dubna such as the JINR University Center may also correlate with DIAS-TH (common programs on modern theoretical physics, workshops for students and young scientists, etc.).

### **The main goals of DIAS**

- Training courses for students, graduates, and young scientists in the JINR Member States and other countries (according to special agreements and grants).
- Looking for and supporting gifted young theorists in the JINR Member States; creating databases of students and young researchers.
- Organization of schools of different levels in Dubna and coordination with similar schools in Russia, Germany, and other European countries.
- Support of the JINR experimental programs by organizing lecture courses and review lectures on new trends in modern physics.
- Cooperation with the JINR University Center in training students and postgraduates as well as in organizing schools for students.
- Coordination of the research - training programs with workshops and conferences at JINR.
- Coordination with the schools and workshops supported by the European
- Participation in nets of workshops and schools in Europe.
- Publication of lectures and discussions in different forms, in particular, with the use of modern electronic equipment, etc.
- Supporting the WEB page of DIAS-TH which should become the organizing center of the programs related to DIAS-TH.

The main topics of the DIAS activity should be centered around the most important directions of research at BLTP: Theory of Fundamental Interactions; Nuclear Theory; Theory of Condensed Matter; Modern Mathematical Physics.

### **Expected main results in the current year:**

- Organization at BLTP of winter school on theoretical physics and two international Helmholtz summer schools.
- Organization of one-day lectures/discussions and regular seminars for students and post-graduates.
- Computer processing of video records of lectures, support of digital archive of video records.
- Support of Web-site of DIAS-TH.



## List of Activities:

<b>Activity or experiment</b>	<b>Leaders</b>
Laboratory or other Division of JINR	Main researchers
<b>1. DIAS-TH</b>	<b>D.I.Kazakov</b> <b>V.V Voronov</b>
BLTP	D. Blaschke, E.A. Davydov, A.V. Frizen, D.V. Fursaev, A.P. Isaev, M.A. Ivanov, R.V. Jolos, E.A. Kolganova, V.A. Osipov, I.G. Pirozhenko, V.P. Spiridonov, A.A. Starobinsky, O.V. Teryaev, P.V. Tretyakov, V.I. Zhuravlev, 4 students
MLIT	Yu.L. Kalinovskiy, V.V. Korenkov
UC	S.Z. Pakuliak
FLNP	V.L. Aksenov
VBLHEP	V.D. Kekelidze, M.V. Savina, S.V. Shmatov
DLNP	V.A. Bednyakov
FLNR	A.S. Denikin, V. Khudoba, Yu.Ts. Oganessian

## Collaboration

<b>Country or International Organization</b>	<b>City</b>	<b>Institute or laboratory</b>
Armenia	Yerevan	YSU
Austria	Vienna	ITP TU Wien
Belarus	Gomel	GSTU
Brazil	Santo Andre, SP Sao Paulo, SP	UFABC USP
Bulgaria	Sofia	INRNE BAS SU
Canada	Edmonton Montreal	U of A UdeM
CERN	Geneva	CERN
China	Wuhan	WHU
Czech Republic	Prague	CTU
France	Rez Annecy-le-Vieux Dijon Lyon Marseille Nantes Paris	NPI CAS LAPP UB ENS Lyon CPT SUBATECH ENS LPTHE
Germany	Valenciennes Bonn Hamburg Hannover Jena Leipzig Munich Potsdam	UVHC UniBonn DESY LUH Univ. UoC MPI-P AEI

	Rostock	Univ.
	Zeuthen	DESY
Greece	Athens	UoA
Hungary	Budapest	Wigner RCP
India	Kolkata	BNC
Israel	Rehovot	WIS
Italy	Fisciano	UNISA
	Frascati	INFN LNF
	Padua	UniPd
	Pavia	INFN
	Pisa	INFN
	Trieste	SISSA/ISAS
	Turin	UniTo
Japan	Chiba	CIT
	Kyoto	KSU
		RIMS
	Tsukuba	KEK
Norway	Oslo	UiO
Poland	Warsaw	UW
	Wroclaw	UW
Romania	Bucharest	IFIN-HH
Russia	Chernogolovka	LITP RAS
	Moscow	ITEP
		LPI RAS
		MI RAS
		MSU
		NRU HSE
		SAI MSU
		SCC RAS
		SINP MSU
		VNIIMS
	Moscow, Troitsk	INR RAS
	Novosibirsk	BINP SB RAS
	Protvino	IHEP
	Saratov	SSU
	Tomsk	TPU
Serbia	Belgrade	IPB
		Univ.
Slovakia	Banska Bistrica	UMB
South Africa	Cape Town	UCT
Spain	Madrid	UAM
Turkey	Istanbul	BU
Ukraine	Kiev	BITP NASU
United Kingdom	Cambridge	Univ.
	Durham	Univ.
	London	Imperial College
	Southampton	Univ.
	York	Univ.

USA	Cincinnati, OH	UC
	College Park, MD	UMD
	Coral Gables, FL	UM
	Minneapolis, MN	U of M
	New York, NY	CUNY
		SUNY
	Newport News, VA	JLab
	Philadelphia, PA	Penn
	Piscataway, NJ	Rutgers
	Rochester, NY	UR
Vietnam	Salt Lake City, UT	U of U
	Hanoi	IOP VAST



**Elementary  
Particle Physics  
and  
Relativistic  
Nuclear Physics  
(02)**

## Study of Fundamental Interactions in $e^+e^-$ and Hadronic Collisions

**Leader:** A.S. Zhemchugov  
**Deputy:** A.V. Guskov

### Participating countries and international organizations:

Belarus, CERN, China, Germany, Italy, Poland, Russia, Sweden.

### Issues addressed and main goals of research:

The Standard Model (SM) provides the most accurate and universal description of the physics phenomena on a microscale nowadays. However, it is not free from a number of shortcomings. Some predictions of the Standard Model still have not been observed experimentally. In many cases the accuracy of the predictions is limited by the experimental knowledge of the key free parameters of the theory. At the same time, the search for New Physics beyond the Standard Model may show the way to further develop the theory and to get rid of its shortcomings. The main tool for these studies is the collider experiments using both proton-proton (LHC) and electron-positron collisions. The latter are most suitable for precision studies of elementary particles with obvious advantages from well-defined kinematics of the initial state and the absence of the large QCD background typical of hadronic colliders.

The precision test of SM predictions and search for new phenomena beyond the SM in charmonium and tau lepton decays are fulfilled in the scope of this theme using the world best facility in this energy domain - the unique electron-positron collider BEPC-II and the BES-III detector. At the same time, preparation for experiments at the future electron-positron colliders (ILC, CLIC, CEPC, FCC-ee) is under way.

An important complement to the studies in  $e^+e^-$  collisions are the planned measurements at the AMBER experiment to address fundamental issues of Quantum Chromodynamics, which are expected to lead to significant improvements in the understanding of QCD as the present theory of strong interactions. AMBER (Apparatus for Meson and Baryon Experimental Research) is a new fixed-target experimental facility at the M2 beam line of the CERN SPS. The proposed measurements cover the range from lowest-Q<sup>2</sup> physics as the determination of the proton radius by elastic muon-proton scattering, over average-Q<sup>2</sup> reactions to study hadron spectroscopy, to high-Q<sup>2</sup> hadron-structure investigations using the Drell-Yan, charmonia and prompt-photon production hard processes.

### Expected results in the current year:

- BES-III data analysis.
- Development of offline software and analysis tools.
- Development of a multipurpose MC event generator to describe the main processes of  $e^+e^-$  annihilation including radiative corrections at a level of more than one loop. The generator will take into account the particle polarization for both initial and final states.
- Development of standard program codes to calculate radiation corrections at a level of 2 (for EW interactions) and 3 (for strong interactions) loops.
- Study of the research potential of the experiments at the CLIC, FCC, CEPC colliders in the domain of precision measurements and search for new physics on the basis of full detector simulation.
- Development of proposals for the physics research program of the Super c-t Factory.
- Test run to determine the proton radius by elastic muon-proton scattering.
- R&D to develop a prototype of the Micromegas chamber of 50 cm x 50 cm followed by the test-beam studies.

## List of projects:

Project	Leader	Priority (period of realisation)
1. BES-III	A.S. Zhemchugov	2 (2007-2022)

## List of Activities:

Activity or Experiment Laboratory or other Division of JINR Responsible person	Leaders Main researchers	Status
1. <b>BES-III Project</b>  DLNP	<b>A.S. Zhemchugov</b>  O.V. Bakina, I.R. Boyko, D.V. Dedovich, I.I. Denisenko, P.A. Egorov, A.V. Guskov, Yu.A. Nefedov, S.N. Pogodin, G.A. Shelkov	Realization
MLIT	V.V. Korenkov, G.A. Ososkov, I.S. Pelevanyuk	
2. <b>Theoretical support of collider experiments</b>  DLNP	<b>L.V. Kalinovskaya</b>  I.R. Boyko, E.V. Dydysenko, Yu.A. Nefedov, N.E. Pukhaeva, L.A. Rummyantsev, A. Rymbekova, A.A. Sapronov, R.R. Sadykov, V. Yermolchik, Yu. Yermolchik, A.S. Zhemchugov	Realization
BLTP	A.B. Arbuzov, C.G. Bondarenko, V.V. Byt'ev	
MLIT	I.S. Pelevanyuk	
3. <b>Exploring fundamental properties of hadrons at AMBER experiment</b>  DLNP	<b>A.V. Guskov</b>  G.D. Alexeev, Z. Chubinidze, I.I. Denisenko, V.N. Frolov, A. Gongadze, M.I. Gostkin, A.O. Gridin, N.A. Kovyazina, V.G. Kruchonok, A. Maltsev, E.O. Mitrofanov, A. Rymbekova V.A. Anosov, O.P. Gavrishchuk, R.I. Gushterski, A.Yu. Korzenev, O.M. Kouznetsov, I.A. Savin, E.V. Zemlyanichkina E.	Realization
VBLHEP		

## Collaboration

Country or International Organization	City	Institute or laboratory
Belarus	Minsk	INP BSU
CERN	Geneva	CERN
China	Beijing	IHEP CAS
Germany	Hamburg	DESY
	Hannover	LUH
Italy	Turin	UniTo
Poland	Katowice	US
	Krakow	INP PAS
Russia	Gatchina	NRC KI PNPI
	Novosibirsk	BINP SB RAS
Sweden	Lund	LU

## ATLAS.

### Upgrade of the ATLAS Detector and Physics Research at the LHC

**Leader:** V.A. Bednyakov  
**Deputies:** E.V. Khramov  
A.P. Cheplakov

#### Participating countries and international organizations:

Armenia, Azerbaijan, Belarus, Bulgaria, Canada, CERN, Czech Republic, France, Georgia, Germany, Israel, Italy, Netherlands, Russia, Slovakia, Spain, USA, Uzbekistan.

#### Issues addressed and main goals of research:

Absolutely new and unique data will be obtained in multifaceted and comprehensive research of proton-proton scattering processes. The analysis of these data will allow several fundamental physical problems to be solved. Within this Project, JINR scientists will participate in this analysis.

It is expected to obtain new results and make publications on all above-mentioned tasks where JINR scientists have responsibilities. The most important tasks are the studies of the proton structure and hadron state spectrum, probing of the Standard Model at the LHC energies, search for and investigation of supersymmetry, search for the evidence of existence of new particles and new interactions. In addition, JINR intends to obtain new results that will help specify properties of already known elementary particles such as  $W$ - and  $Z$ -bosons, top-quark, heavy baryons etc.

The implementation of this Project aimed at solving highly significant scientific problems, unique applied results which may significantly change the quality of life. Among these results the experience in operation of remote monitoring systems for technically complicated devices, big data processing, development and practical use of distributed computing systems (GRID) and database monitoring applications in long-term large-scale experiments can be noted.

#### Expected results in the current year:

- Investigation of applicability of the Standard Model and verification of SM predictions (including interactions of heavy ions), determination of the structure of the proton at ultra-high energies (PDFs), tuning and improvement of relevant computer codes and event generators etc.
- Search for the chiral  $Z^*/W^*$  bosons in the two-jet decays and in a process with more complex topology of their associative production including heavy  $b$  and  $t$  quarks.
- Search for (supersymmetric) charged Higgs bosons via their specific decay modes (3-lepton, etc).
- Analyses on associated productions of the SM Higgs with the top-antitop pair and search for production with a single top.
- Search for a valence-like nonperturbative component of heavy quarks in the proton (intrinsic heavy quarks) via specific final state topology in the  $pp$  interactions.
- Search for new hadrons and baryons containing heavy  $c$  and  $b$  quarks and study of their properties.
- Measurement of the Drell Yan triple-differential cross section and effective leptonic weak mixing angle in the  $Z$ -boson decay.
- New comprehensive study of the gluon structure of the proton, etc.
- Search for quantum black holes in the lepton+jet channel at 13 TeV.
- Participation in development of event trigger indexing infrastructure.
- Development and maintenance of the TDAQ system.
- Development of database monitoring applications.



## List of projects:

Project	Leader	Priority (period of realisation)
1. ATLAS. Physical researches at the LHC	V.A. Bednyakov Deputies: E.V. Khramov A.P. Cheplakov	1 (2010-2023)
2. Upgrade of the ATLAS Detector	A.P. Cheplakov	1 (2013-2023)

## List of Activities:

Activity or Experiment Laboratory or another Division of JINR Responsible person	Leaders Main researchers	Status
<b>1. The ATLAS experiment</b>  DLNP V.A. Bednyakov N.A. Russakovich G.P. Chelkov	<b>V.A. Bednyakov</b> <b>E.V. Khramov</b> <b>A.P. Cheplakov</b> A.M. Artikov, N.V. Atanov, V.Yu. Baranov, V.Yu. Batusov, I.R. Boyko, Z.A. Budtueva, E.A. Cherepanova, M.V. Chizhov, Z. Chubinidze, Yu.I. Davydov, D.V. Dedovich, M.A. Demichev, A.R. Didenko, A.V. Ershova, A.B. Gazzaev, V.A. Gerasimov, L.R. Gladilin, V.V. Glagolev, A. Gongadze, I. Gongadze, L. Gongadze, M.I. Gostkin, R.Z. Gurtsiev, A.V. Guskov, N. Huseinov, Yu.P. Ivanov, L.V. Kalinovskaja, S.N. Karpov, Z.M. Karpova, N.N. Kaurtsev, D.V. Kharchenko, I.A. Kochergin, D.A. Kokaev, O.A. Koval, N.A. Kovyazina, D.A. Kozhevnikov, V.G. Kruchonok, Yu.A. Kultchitsky, M.V. Lyablin, F.V. Lapkin, G.I. Lykasov, I. Lyashko, V.V. Lyubushkin, T.V. Lyubushkina, S.N. Malyukov, M. Manashova, I. Minashvili, I. Minashvili, Yu.A. Nefedov, A.A. Nozdrin, E.M. Plontikova, S.Yu. Porokhovoy, I.N. Potrap, F.V. Prokoshin, V.M. Romanov, T.O. Rudenko, R.R. Sadykov, A.A. Sapronov, A.V. Simonenko, P.I. Smolyanskiy, R.V. Sotenskii, M.M. Shiyakova, A.N. Shalyugin, V.V. Tereschenko, I.N. Troeglazov, P.V. Tereshko, S.M. Turchikhin, Yu.A. Usov, Z. Usubov, V.A. Vasiliev, A.O. Vasyukov, I.V. Yeletskikh, A.S. Zhemchugov	Technical proposal
VBLHEP A.P. Cheplakov	F.N. Ahmadov, Yu.A. Phillipov, A.V. Ivanov, V.V. Kukhtin, E.A. Ladygin, S.N. Nagorny, A.A. Soloshenko, B.G. Shaykhatdenov, T. Turtuvshin, N.I. Zimin	
MLIT V.V. Korenkov, P.V. Zrelov	E.I. Alexandrov, I.N. Aleksandrov, N.I. Gromova, A.V. Iakovlev, A.I. Kazymov, M.A. Mineev, V.N. Shigaev	
BLTP D.I. Kazakov	A.B. Arbuzov, A.V. Bednyakov, S.G. Bondarenko, N.I. Kochelev, A.F. Pikelner, O.V. Teryaev	
FLNP M.V. Bulavin		

## Collaboration

### Country or International Organization

Armenia  
Azerbaijan  
Belarus

### City

Yerevan  
Baku  
Gomel

### Institute or laboratory

Foundation ANSL  
IP ANAS  
GSTU  
GSU

Minsk

IAP NASB  
INP BSU  
IP NASB  
JIPNR-Sosny NASB

Bulgaria

Sofia

SU

Canada

Montreal

UdeM

Vancouver

TRIUMF

CERN

Geneva

CERN

Czech Republic

Prague

CU

France

Clermont-Ferrand

LPC

Orsay

LAL

Georgia

Tbilisi

HEPI-TSU

Germany

Munich

MPI-P

Zeuthen

DESY

Israel

Rehovot

WIS

Italy

Pisa

INFN

Netherlands

Amsterdam

NIKHEF

Russia

Moscow

ITEP

LPI RAS

MSU

Protvino

IHEP

Vladikavkaz

NOSU

Bratislava

CU

Slovakia

IP SAS

Spain

Barcelona

IFAE

USA

Lemont, IL

ANL

Uzbekistan

Samarkand

SSU

## Search for New Physics in the Lepton Sector

**Leaders:** V.V. Glagolev  
Z. Tsamalaidze

### Participating countries and international organizations:

Belarus, Bulgaria, Czech Republic, France, Georgia, Germany, Italy, Japan, Kazakhstan, Russia, Slovakia, Switzerland, Ukraine, United Kingdom, USA.

### Issues addressed and main goals of research:

The COMET experiment at J-PARC, the Mu2e experiment at Fermilab and the MEG II experiment at PSI are a dedicated search for the CLFV processes  $\mu^- N \rightarrow e^- N$ ,  $\mu^+ \rightarrow e^+ \gamma$ . Once neutrino masses are included, the process is allowed but still unobservable since the rate is proportional to  $(\Delta m_{ij}^2 / M_W^2)^2$ , where  $\Delta m_{ij}^2$  is the mass difference squared between *i*th and *j*th neutrino mass eigenstates, and  $M_W$  is the mass of the W boson. The predicted rates for the  $\mu^- N \rightarrow e^- N$  and  $\mu^+ \rightarrow e^+ \gamma$  CLFV processes are less than  $10^{-50}$  each. This makes this process a very theoretically clean place to search for NP effects. In many NP models that include a description of neutrino mass, the rates for these processes are enormously enhanced so that they occur at a level to which the COMET and Mu2e experiment will have sensitivity. Conversion measurement at the level of  $10^{-17}$ , which is COMET goal, is a factor of 10000 better than the current experimental limit  $B(\mu^- + Au \rightarrow e^- + Au) < 7 \cdot 10^{-13}$  from SINDRUM-II at PSI.

The T2K experiment is the first to study the mechanism of CP-symmetry breaking in the lepton sector, which is experimentally manifested in the difference between oscillation probabilities of neutrinos and antineutrinos. The observation of CP-symmetry breaking in neutrino oscillations together with nonconservation of the lepton number can serve as an argument in favor of explaining the baryon asymmetry of the Universe through the mechanism of leptogenesis (leptogenesis is the process of the appearance of lepton-antilepton asymmetry (nonzero lepton number) in the early stages of the formation of Universe). On the data of the T2K experiment, observation of CP violation with a significance of  $3\sigma$  or higher is expected in case of large CP violation and the measurement of neutrino mixing parameters,  $\theta_{23}$  and  $\Delta m_{32}^2$ , with an accuracy of  $1.7^\circ$  or better and 1%, respectively.

### Expected results in the current year:

- Participation in preparation, engineering and physics run, data acquisition and analysis of Phase-a.
- Finalization of assembling, testing, calibration, installation, cosmic test and maintenance of the straw detector for Phase-I.
- R&D program for production of straw tubes of a 12-mm wall thickness and 5 mm diameter. Creating a straw prototype (64 channels) with new tubes (12 mm, 5 mm) and measurements on the beam.
- Test (certification) of the LYSO crystals to be used in the calorimeter. Development and optimization of the crystal calibration method for the COMET calorimeter. Participation in calorimeter designing, assembling, installation, cosmic test and maintenance.
- Participation in assembly and maintenance of the CRV for Phase-I.
- Participation in assembling, testing, installation and maintenance of the whole detector system for Phase-I.
- Complex detector system (tracker, calorimeter etc.) simulation.
- Participation in the engineering and physics run, the data acquisition and analysis.
- Tests of the *CsI* and *BaF<sub>2</sub>* electromagnetic calorimeter elements with the gamma sources and electron beam.
- Design of the platform and equipment for assembling the unique SuperFGD target with a volume of about 2 cubic meters.
- Creation of the unique box support system to ensure target assembly.

- Creation of electronics of the Super FGD photodetector calibration system.
- Assembly of the Super FGD as part of the near detector of the T2K experiment.
- Investigation of systematic uncertainties for measuring  $\delta_{cp}$ .
- Search for manifestations of new physics in the T2K data.
- Filling the batch of Mu2e scintillation counters with CKTN and testing them for leakage.
- Maintenance of the visualization and control software.
- Development and tests of the Mu2e electromagnetic calorimeter preamplifiers at JINR.
- Participation in radiation hardness tests of detector elements.
- Participation in development of the positron tracker for the MEG-II experiment, DAQ, data analysis.
- Participation in data taking and analysis of experimental data obtained with CERN hadron beams.

### List of projects:

Project	Leader	Priority (period of realisation)
1. COMET	Z. Tsamalaidze	1 (2021-2023)
2. T2K-II	V.V. Glagolev Yu.I. Davydov	1 (2022-2022)

### List of Activities:

Activity or Experiment Laboratory or another Division of JINR Responsible person	Leaders Main researchers	Status
<b>1. COMET Project</b>	<b>Z. Tsamalaidze</b>	R&D Realization
DLNP	G. Adamov, A.M. Artikov, A.V. Boykov, D.Sh. Chokheli, P.G. Evtukhovich, I.L. Evtukhovich, V.A. Kalinnikov, Kh. Khubashvili, E.S. Kaneva, A.V. Pavlov, B.M. Sabirov, A.G. Samartsev, A.V. Simonenko, V.V. Tereschenko, S.V. Tereschenko, N. Tsverava, I.I. Vasilyev, E.P. Velicheva, A.D. Volkov, I.Yu. Zimin	
BLTP	D.Aznabaev, A. Issadykov, G.A. Kozlov	
MLIT	D. Goderidze, A. Khvedelidze	
VBLHEP	D. Baigarashev, T.L. Enik	
<b>2. T2K-II Project</b>	<b>V.V. Glagolev Yu.I. Davydov</b>	R&D Realization
DLNP	A.M. Artikov, V.Yu. Baranov, A.V. Boykov, A.O. Brazhnikov, D.L. Demin, N.V. Khomutov, N.V. Kirichkov, V.I. Kiseeva, A.O. Kolesnikov, A.V. Krasnoperov, K.K. Limarev, V.L. Malyshev, B.A. Popov, A.V. Shaikovskiy, A.A. Sinita, I.A. Suslov, V.V. Tereschenko, S.V. Tereschenko, I.I. Vasilyev	
BLTP	G.A. Kozlov, V.A. Matveev	

### 3. Mu2e Experiment

V.V. Glagolev

R&D  
Realization

DLNP

A.M. Artikov, N.V. Atanov, O.S. Atanova, V.Yu. Baranov,  
Yu.I. Davydov, D.L. Demin, V.I. Kolomoets, S.M. Kolomoets,  
A.V. Sazonova, A.N. Shalyugin, I.A. Suslov, V.V. Tereschenko,  
S.V. Tereschenko

BLTP

D.I. Kazakov, G.A. Kozlov

MLIT

V.V. Korenkov, O.V. Tarasov, V.V. Uzhinsky

VBLHEP

A.S. Galoyan

### 4. MEG Experiment

N.V.Khomutov

Data taking  
Data processing

DLNP

V.A. Baranov, Yu.I. Davydov, V.V. Glagolev, A.O. Kolesnikov,  
N.P. Kravchuk, V.A. Krylov, N.A. Kuchinsky, V.L. Malyshev,  
A.M. Rozhdestvensky

### 5. CERN Neutrino platform

B.A. Popov

Data taking  
Data processing

DLNP

N.V. Atanov, A.O. Kolesnikov, A. V. Krasnoperov, V.V. Lyubushkin,  
V.L. Malyshev, S.V. Tereschenko, V.V. Tereschenko

## Collaboration

### Country or International Organization

### City

### Institute or laboratory

Belarus

Minsk

BSU  
INP BSU  
IP NASB

Bulgaria

Sofia

SU

Czech Republic

Prague

CTU  
CU

France

Paris

IN2P3

Georgia

Tbilisi

GTU  
HEPI-TSU  
UG

Italy

Frascati

INFN LNF

Pisa

UniPi

Japan

Fukuoka

Kyushu Univ.

Osaka

Osaka Univ.

Tsukuba

KEK

Kazakhstan

Almaty

INP

Romania

Bucharest

IFIN-HH

Russia

Gatchina

NRC KI PNPI

Irkutsk

ISU

Moscow

ITEP

Moscow, Troitsk

NNRU "MEPhI"

Novosibirsk

INR RAS

BINP SB RAS

NSU

Slovakia	Bratislava	CU
		IP SAS
Switzerland	Villigen	PSI
Ukraine	Kharkov	ISMA NASU
United Kingdom	Didcot	RAL
	London	Imperial College
USA	Batavia, IL	Fermilab
	Charlottesville, VA	UVa
	Lexington, KY	UK

## Study of Neutrino Oscillations

### Leaders:

D.V. Naumov  
A.G. Olshevskiy

### Participating countries and international organizations:

China, Czech Republic, France, Germany, Japan, Italy, Romania, Russia, Slovakia, Switzerland, Turkey, USA.

### Issues addressed and main goals of research:

- Measurement of the neutrino mixing angle  $\theta_{13}$  and the squared mass difference  $\Delta m^2_{ee}$  in the Daya Bay experiment.
- Neutrino mass hierarchy determination and measurement of the CP violation phase of the neutrino mixing matrix in the JUNO and NOvA experiments.
- Measurement of solar neutrino fluxes, search for the sterile neutrino state and new particles.
- Study of tau neutrino production in proton-nuclear interactions at CERN SPS.
- Development of the LiAr Light Collection System of the DUNE ND.

### Expected results in the current year:

- Physics analysis of the Daya Bay experiment data on determination of  $\theta_{13}$  and other oscillation parameters.
- Estimation of the mass hierarchy measurements precision in the JUNO experiment with the TAO near detector.
- Use of the NOvA experiment Remote Operation Centre at JINR for shift working.
- Data analysis in the NOvA experiment, new results considering the hierarchy and CP.
- Mass test of JUNO PMTs with scanning stations.
- Monitoring of the JUNO veto system planes with cosmic muons.
- Installation and commissioning of the JUNO detector (PMT, HV, TT-veto).
- Development of the GNA project: GPU support and automatic differentiation.
- Preparation of the full physics run and data analysis of the pilot run data, development of algorithms of charm particles decay search in high track density conditions.
- Analysis of solar neutrino parameters and search for rare processes in the Borexino detector, the DS-50 data analysis.

### List of projects:

Project	Leader	Priority (period of realisation)
1. JUNO	D.V. Naumov	1 (2009-2023)
2. NOvA/DUNE	A.G. Olshevskiy	1 (2015-2023)

## List of Activities:

Activity or Experiment	Leaders	Status
Laboratory or another Division of JINR Responsible person	Main researchers	
<b>1. JUNO Project</b>	<b>D.V. Naumov</b> <b>M.O. Gonchar</b>	Construction Data taking
DLNP	N.V. Anfimov, T.A. Antoshkina, S.V. Biktemerova, A.E. Bolshakova, A.V. Chetverikov, A.V. Chukanov, S.G. Dmitrievsky, D.A. Dolzhikov, D.V. Fedoseev, Yu.A. Gornushkin, V.O. Gromov, M.V. Gromov, A.V. Krasnoperov, K. Kuznetsova, Yu. Malyskin, E.A. Naumova, I.B. Nemchenok, A.G. Olshevskiy, A.V. Rybnikov, A.B. Sadovsky, A.S. Selunin, V.I. Sharov, A.V. Shaydurova, V.B. Shutov, O.Yu. Smirnov, S.A. Sokolov, A.P. Sotnikov, V.D. Tchalyshev, K.A. Treskov, V. Zavadskiy	
MLIT	N.A. Balashov, N.A. Kutovskiy	
<b>2. NOvA/DUNE Project</b>	<b>A.G. Olshevskiy</b> <b>N.A. Anfimov</b> <b>O.B. Samoylov</b>	Data taking R&D
DLNP	A.I. Antoshkin, A.V. Chetverikov, D.V. Fedoseev, V.O. Gromov, A.I. Kalitkina, O.A. Klimov, Ch. Kullenberg, L.D. Kolupaeva, D.V. Korablev, K.I. Kuznetsova, A.D. Morozova, O.N. Petrova, A.Yu. Rybnikov, V.I. Sharov, A.S. Selyunin, A.S. Sheshukov, S.A. Sokolov, A.P. Sotnikov, V.V. Tchalyshev, S.G. Vasina	
BLTP	I.D. Kakorin, K.S. Kuzmin, V.A. Matveev, V.A. Naumov	
MLIT	N.A. Balashov, A.V. Baranov, A.G. Dolbilov, E.A. Kuznetsov, N.A. Kutovskiy	
<b>3. Experiment Ds Tau</b>	<b>Yu.A. Gornushkin</b>	R&D
DLNP	A.V. Chukanov, S.G. Dmitrievsky, A.B. Sadovsky, A.P. Sotnikov, S.G. Vasina	
<b>4. Experiment Borexino/DarkSide</b>	<b>O.Yu. Smirnov</b>	Data processing
DLNP	M.V. Gromov, D.V. Korablev, O.B. Samoylov, A.P. Sotnikov, A.S. Sheshukov, A.V. Vishneva	



## **Collaboration**

### **Country or International Organization**

China

Czech Republic

France

Germany

Italy

Japan

Romania

Russia

Slovakia

Switzerland

Turkey

USA

### **City**

Beijing

Prague

Strasbourg

Aachen

Hamburg

Milan

Salerno

Fukuoka

Nagoya

Tokyo

Magurele

Irkutsk

Moscow

Bratislava

Bern

Ankara

Batavia, IL

Cambridge, MA

Indianapolis, IN

### **Institute or laboratory**

IHEP CAS

CU

CRN

RWTH

Univ.

UNIMI

INFN

Kyushu Univ.

Nagoya Univ.

Toho Univ.

ISS

ISU

SINP MSU

CU

Uni Bern

METU

Fermilab

Harvard Univ.

IUPUI

## PANDA Experiment at the FAIR Accelerator Complex

**Leader:** G.D. Alexeev  
**Deputies:** A.S. Vodopyanov  
 A.N. Skachkova

### Participating countries and international organizations:

Belarus, CERN, Germany, Italy, Russia.

### Issues addressed and main goals of research:

The study of the exotic nuclear-matter states and the nucleon structure in the PANDA experiment at the FAIR. Start of construction of the PANDA muon detector.

### Expected results in the current year:

- Signing of the FAIR-JINR contract on the Muon System construction.
- Preparation of a mass production workshop for MDT detectors.
- Finalizing of electronics design.
- Calibration of the prototype at CERN to all types of particles in the energy range of 0.5-1 GeV.
- Particle identification algorithms (PID) tuned on beam test results.

### List of projects:

Project	Leader	Priority (period of realisation)
1. Experiment PANDA at FAIR	G.D. Alexeev Deputy: A.N. Skachkova	1 (2022-2023)

### List of Activities:

Activity or Experiment Laboratory or another Division of JINR Responsible person	Leaders Main researchers	Status
1. <b>Experiment PANDA</b>  DLNP A.N. Skachkova	<b>G.D. Alexeev</b>  V.M. Abazov, G.A. Golovanov, S.A. Kutuzov, A.A. Piskun, I.K. Prokhorov, A.M. Rozhdestvensky, A.G. Samartsev, N.B. Skachkov, V.V. Tokmenin, L.S. Vertogradov, Yu.L. Vertogradova, V.P. Volnykh, A.Yu. Verkheev, N.I. Zhuravlev	Technical proposal
VBLHEP A.S. Vodopyanov	V.I. Astakhov, M.Yu. Barabanov, B.V. Batyunya, V.A. Budilov, V.K. Dodokhov, A.A. Efremov, A.A. Feshchenko, A.S. Galoyan, E.K. Koshurnikov, V.I. Lobanov, Yu.Yu. Lobanov, P.V. Nomokonov, I.A. Oleks, E.A. Strokovsky, S.S. Shimansky, A.O. Sidorin	
MLIT	T.I. Mikhaylova, V.V. Uzhinsky	

BLTP

A.S. Sorin, O.V. Teryaev

## **Collaboration**

### **Country or International Organization**

Belarus

CERN

Germany

Italy

Russia

### **City**

Minsk

Geneva

Darmstadt

Frankfurt/Main

Munich

Genoa

Trento

Novosibirsk

Omsk

Protvino

### **Institute or laboratory**

IP NASB

CERN

GSI

Univ.

TUM

INFN

UniGe

ECT\*

BINP SB RAS

OB IM SB RAS

IHEP

## Astrophysical Researches with the TAIGA Experiment

**Leader:** A.N. Borodin  
**Deputy:** L.G. Tkachev

### Participating countries and international organizations:

Germany, Italy, Japan, Mexico, Poland, Republic of Korea, Romania, Russia.

### Issues addressed and main goals of research:

- Search for local galactic sources of gamma rays with energies above 20-30 TeV.
- Study of gamma rays fluxes from known sources in the same energy region.
- Search for diffuse gamma rays from the galactic disk.
- Study of the energy spectrum and the mass composition of cosmic rays in the energy range of  $10^{15}$  to  $10^{17}$  eV in order to detect spots of Lorentz invariance violation.
- Search for galactic PeVatrons.
- The TAIGA observatory also plans to introduce a "hybrid method" of observation - the combined use of IACT and HiScore wide angle Cherenkov detectors. This method will not only significantly improve the quality of high-energy gamma-rays emission signals selection from background hadron events, but will also help to match currently available parts of the cosmic ray spectrum obtained by ground-based and orbital detectors.
- In the NUCLEON space experiment, the spectra and elemental composition of cosmic rays were measured in the energy range of  $10^{11}$ - $10^{15}$  eV. Further progress in applying this technique is the planned OLVE-HERO experiment. The unique parameters of the detector within 5 years of direct extra-atmospheric measurements will provide data, large statistics which allow identifying changes to the cosmic ray composition at the energy up to  $10^{16}$  eV and measuring the angular anisotropy of the cosmic rays.

### Expected results in the current year:

- Completion of manufacturing and testing the fourth IACT telescope and design of the fifth IACT telescope at JINR.
- Development of event simulation programs in the TAIGA experiment. Upgrade of software for data collection and processing for the IACT telescope, as well as for their hybrid mode of operation in conjunction with HiScore detectors.
- MC simulation of the joint operation of the IACT telescope and the TAIGA observatory's wide-angle Cherenkov detectors and optimization of the selection of gamma rays events from the background.
- Monitoring of the brightest gamma-ray sources in a hybrid mode at the TAIGA observatory. Upgrade of software for the IACT data analysis.
- Completion of the data analysis of the TUS space experiments.
- Design and beam tests of OLVE-HERO prototypes.
- Study of the Crab Nebula gamma radiation in the energy range of 2-10 TeV. Observation of the brightest extragalactic sources of gamma radiation Mrk-421, Mrk-501.

### List of projects:

Project	Leader	Priority (period of realisation)
1. TAIGA	A.N. Borodin	1 (2015-2023)

## List of Activities:

Activity or Experiment	Leaders	Status
Laboratory or another Division of JINR Responsible person	Main researchers	
<b>1. Experiment TAIGA</b>	<b>A.N. Borodin</b>	Realization
DLNP	A.V. Blinov, V.M. Grebenyuk, F.F. Grinyuk, M.V. Lavrova, A. Pan, S.Yu. Porokhovoy, L.G. Tkachev	
VBLHEP	N.V. Gorbunov, A.V. Skrypnik	
MLIT	I. Satyshev	
<b>2. Experiment TUS</b>	<b>L.G. Tkachev</b>	Completion
DLNP	A.V. Blinov, V.M. Grebenyuk, F.F. Grinyuk, M.V. Lavrova, A.V. Tkachenko	
<b>3. Experiment OLVE-HERO</b>	<b>L.G. Tkachev</b>	Preparation
DLNP	A.V. Blinov, V.M. Grebenyuk, N.I. Kalinin, M.V. Lavrova, A. Pan, S.Yu. Porokhovoy, A.B. Sadovsky, A.V. Tkachenko	
VBLHEP	N.V. Gorbunov	
MLIT	I. Satyshev	
FLNP	A.D. Rogov	

## Collaboration

### Country or International Organization

Germany

Italy

Japan

Mexico

Poland

Republic of Korea

Romania

Russia

### City

Hamburg

Munich

Tubingen

Zeuthen

Turin

Wako

Puebla

Warsaw

Seoul

Magurele

Irkutsk

Moscow

Moscow, Troitsk

### Institute or laboratory

Univ.

MPI-P

Univ.

DESY

UniTo

RIKEN

BUAP

UW

EWU

ISS

RIAP ISU

NNRU "MEPhI"

SINP MSU

INR RAS

## Investigations of Compressed Baryonic Matter at the GSI Accelerator Complex

**Leaders:** V.P. Ladygin  
V.V. Ivanov

**Deputy:** O.Yu. Derenovskaya

### Participating countries and international organizations:

Czech Republic, France, Germany, Poland, Romania, Russia.

### Issues addressed and main goals of research:

Expertize of the design of the superconducting dipole magnet, design and development of straw detector prototype for the CBM experiment at the FAIR/GSI accelerator complex. Study of the multiparticle dynamics in heavy ion collisions at SIS100. Development of algorithms and software for the trigger, simulation and data analysis. Participation in HADES experimental at SIS18 and SIS100.

### Expected results in the current year:

- Expertize of the preparation and magnetic calculations for the superconducting dipole magnet for the CBM experiment. Optimization of the RICH detector.
- Design and testing of the straw detector prototype.
- Development of the algorithms and software for the trigger and data analysis.
- Simulation of the multiparticle dynamics in heavy ion collisions.
- Development of the mathematical methods and fast computing algorithms for the data analysis and selection of the signal events.
- Participation in experimental data taking using pion, proton and heavy ion beams with HADES at SIS18. Development of the algorithms for data analysis. Participation in experimental data analysis. Theoretical interpretation of the obtained data.

### List of projects:

Project	Leader	Priority (period of realisation)
1. CBM	V.P. Ladygin V.V. Ivanov	1 (2011-2023)
2. HADES	V.P. Ladygin O.V. Fateev	1 (2010-2023)

### List of Activities:

Activity or Experiment	Leaders	Status
Laboratory or other Division of JINR Responsible person	Main researchers	
1. <b>CBM Project Expertize of the design and manufacture of the superconducting dipole magnet</b>	<b>V.P. Ladygin V.V. Ivanov</b>	Realization

**and straw detector prototype.  
Development of the algorithms  
and software for trigger,  
simulation and data analysis**  
VBLHEP

S.P. Avdeev, I.V. Boguslavsky, A.V. Bychkov, D.V. Dementiev,  
V.V. Elsha, O.V. Fateev, Yu.V. Gusakov, A.P. Ierusalimov,  
G.D. Kekelidze, N.B. Ladygina, V.M. Lysan, A.I. Malakhov,  
Yu.A. Murin, A.D. Sheremetiev, A.L. Voronin, A.P. Zinchenko,  
N.I. Zamyatin

MLIT

P.G. Akishin, E.P. Akishina, E.I. Alexandrov, I.N. Alexandrov,  
D.V. Belyakov, O.Yu. Derenovskaya, I.A. Filozova, V.V. Ivanov,  
V.V. Ivanov (jr), A.V. Kryanov, S.A. Lebedev, A.M. Raportirenko,  
T.P. Sapozhnikova, P.V. Zrelov

BLTP

D. Blaschke, S.G. Bondarenko, V.V. Burov

**2. Experiment HADES**

**V.P. Ladygin  
O.V. Fateev**

Data taking Data processing
--------------------------------

VBLHEP

A.V. Belyaev, A.P. Ierusalimov, S.G. Reznikov, A.Yu. Troyan,  
A.I. Zinchenko

MLIT

V.V. Ivanov, S.A. Lebedev

DLNP

G.I. Lykasov

**Collaboration**

**Country or International Organization**

Czech Republic  
France  
Germany

**City**

Rez  
Orsay  
Darmstadt  
  
Dresden  
Frankfurt/Main  
Giessen  
Heidelberg  
Munich  
Krakow  
Bucharest  
Moscow  
  
Moscow, Troitsk

**Institute or laboratory**

NPI CAS  
IPN Orsay  
FAIR  
GSI  
TU Darmstadt  
HZDR  
Univ.  
JLU  
Univ.  
TUM  
SIP  
IFIN-HH  
ITEP  
NNRU "MEPhI"  
SINP MSU  
INR RAS

Poland  
Romania  
Russia

## Study of Rare Charged Kaon Decays and Search for Dark Sector in Experiments at the CERN SPS

**Leader:** V.D. Kekelidze  
**Deputies:** D.V. Peshekhonov  
 D.T. Madigozhin

### Participating countries and international organizations:

Belarus, Belgium, Bulgaria, Canada, CERN, Chile, Czech Republic, Germany, Italy, Mexico, Romania, Russia, Slovakia, Switzerland, United Kingdom, USA.

### Issues addressed and main goals of research:

Realization of the NA62 Project allows to clarify the CP-violation problem, to measure precisely very rare charged kaon decay to charged pions and two neutrinos, to carry out a search for supersymmetric particles and their partners to observe physics beyond the Standard Model. In addition, the characteristics of rare kaon and hyperon decays will be improved. Straw-detectors of the NA62 high resolution magnetic spectrometer working in vacuum will be supported during experimental runs. Development of a new detector prototype based on straws with a smaller diameter will be started to use it at higher intensity of the beams. Software for simulation, data analysis and processing will be developed.

The main objective of the NA64 experiment is to search for new physics beyond the SM, namely the search for the dark photon ( $A'$ ), hypothetical boson with 16.7 MeV mass and other manifestations of the dark sector in the experiments on the CERN SPS electron and muon secondary beams. Tracking detectors based on the straw tube technology support. Software for data MC simulation and analysis will be developed. Data analysis will be provided.

### Expected results in the current year:

#### In frame of NA62

- NA62 and NA48/2 data analysis will be carried out.
- Software for the simulation of the magnetic spectrometer and full set-up will be developed; system for detector calibration and event reconstruction will be upgraded; general software of the experiment will be developed.
- Calibration and testing of the NA62 straw detectors will be carried out.
- Participation in the NA62 experimental run at the CERN SPS.

#### In frame of NA64

- NA64, analysis of the experimental data.
- Development and putting into operation of new track stations based on 6~mm straw tubes. Operation and support of the detectors.
- Equipment preparation for the 2022 runs in the new experimental zone on the H4 and muon SPS channels, CERN.
- On-line and off-line software development, for the straw chambers analysis and for the DAQ experiment in particular.
- Participation in the data taking at the CERN SPS.



## List of projects:

Project	Leader	Priority (period of realisation)
1. NA62	V.D. Kekelidze Deputy: D.T. Madigozhin	1 (2010-2023)
2. NA64	V.A. Matveev D.V. Peshekhonov	1 (2017-2023)

## List of Activities:

Activity or Experiment Laboratory or other Division of JINR Responsible person	Leaders Main researchers	Status
1. <b>Experiment NA62</b>  VBLHEP	<b>V.D. Kekelidze</b>  A.Z. Baeva, A.A. Belkova, D. Baygarashev, T.L. Enik, D.D. Emelyanov, V.P. Falaleev, S.R. Gevorgyan, L.N. Glonti, V.N. Gorbunova, E.A. Gudzovsky, D. Kereibay, A.M. Korotkova, D.T. Madigozhin, N.A. Molokanova, S.A. Movchan, I.A. Polenkevich, S.N. Shkarovsky	Data taking Data analysis
2. <b>Experiment NA64</b>  VBLHEP	<b>V.A. Matveev</b> <b>D.V. Peshekhonov</b>  V.E. Burtsev, T.L. Enik, A.A. Festchenko, G.D. Kekelidze, E.A. Kasianova, V.A. Kramarenko, V.M. Lysan, S.S. Parzhitsky, V.V. Pavlov, L.N. Tarasova, E.V. Vasilieva, P.V. Volkov, I.A. Zhukov, A.V. Zinin	Preparation Data taking Data analysis
DLNP	V.N. Frolov	

## Collaboration

Country or International Organization	City	Institute or laboratory
Belarus	Minsk	INP BSU
Belgium	Louvain-la-Neuve	UCL
Bulgaria	Blagoevgrad	SWU
	Plovdiv	PU
	Sofia	SU
Canada	Vancouver	TRIUMF
		UBC
CERN	Geneva	CERN
Chile	Valparaiso	UTFSM
Czech Republic	Prague	CU
Germany	Bonn	UniBonn
	Mainz	JGU
Italy	Ferrara	INFN
	Florence	INFN
	Frascati	INFN LNF
	Naples	INFN
	Perugia	INFN
	Pisa	INFN

	Rome	INFN
		Univ. "Tor Vergata"
	Turin	INFN
Mexico	San Luis Potosi	UASLP
Romania	Bucharest	IFIN-HH
Russia	Moscow	LPI RAS
	Moscow, Troitsk	HPPI RAS
		INR RAS
	Protvino	IHEP
	Tomsk	TPU
Slovakia	Bratislava	CU
Switzerland	Zurich	ETH
United Kingdom	Birmingham	Univ.
	Bristol	Univ.
	Glasgow	U of G
	Lancaster	LU
USA	Boston, MA	BU
	Fairfax, VA	GMU
	Menlo Park, CA	SLAC
	Merced, CA	UCMerced
	Upton, NY	BNL

## CMS. Compact Muon Solenoid at the LHC

**Leader:** V.Yu. Karjavin

**Scientific leader:** I.A. Golutvin

### Participating countries and international organizations:

Armenia, Austria, Belarus, Belgium, Brazil, Bulgaria, CERN, China, Croatia, Cyprus, Czech Republic, Estonia, Finland, France, Georgia, Germany, Greece, Hungary, India, Iran, Ireland, Italy, Lithuania, Mexico, Montenegro, Netherlands, New Zealand, Pakistan, Poland, Republic of Korea, Russia, Serbia, Spain, Switzerland, Taiwan, Turkey, Ukraine, United Kingdom, USA, Uzbekistan.

### Issues addressed and main goals of research:

The CMS Collaboration has constructed a general-purpose detector to be operational at the start-up of the Large Hadron Collider (LHC/CERN) to exploit its full discovery potential. Study of fundamental properties of the matter in Super High Energy proton-proton and nucleus-nucleus interactions.

The major activities of JINR are focused on the following directions:

- hadron calorimetry, including endcap hadron;
- forward muon stations with cathode strip chambers;
- development and realization of Physics program to test SM and BSM.

### Expected results in the current year:

- Processing and analysis of experimental data, development and improvement of muon and jet reconstruction algorithms.
- Upgrade and technical support of the CMS detectors.
- CMS shifts, data taking, and data quality monitoring.
- Development of software for GRID-based distributed system for data processing and analysis. Data transmission between CMS Tier-1/Tier-2 and JINR.

### List of projects:

Project	Leader	Priority (period of realisation)
1. CMS	V.Yu. Karjavin I.A. Golutvin	1 (2010-2023)
2. Upgrade of the CMS Detector	V.Yu. Karjavin I.A. Golutvin	1 (2022-2023)

### List of Activities:

Activity or Experiment	Leaders	Status
Laboratory or other Division of JINR Responsible person	Main researchers	
1. Research physics programme with the CMS detector	S.V. Shmatov I.A. Golutvin	Realization

VBLHEP	V.Yu. Alexakhin, S.V. Afanasiev, P.D. Bunin, D.V. Budkovsky, I.I. Belotelov, M.G. Gavrilenko, I.N. Gorbunov, A.Yu. Kamenev, L.G. Kobylets, A.V. Lanev, A.I. Malakhov, M.V. Savina, V.V. Shalaev, S.G. Shulga, K.V. Slizhevsky, I.A. Zhizhin, V.A. Zykunov, A.V. Zarubin	
BLTP	M. Deka, A.V. Kotikov, G.A. Kozlov, A.V. Sidorov, O.V. Teryaev	
MLIT	V.V. Korenkov, G.A. Ososkov, V.V. Palchik, N.N. Voytishin	
GA&C	B.S. Yuldashev	
<b>2. Hadron calorimetry</b>	<b>A.V. Zarubin</b> <b>P.D. Bunin</b>	Commissioning Maintenance Data taking
VBLHEP	Yu.V. Ershov, N.S. Golova, L.G. Kobylets, A.M. Kurenkov	
BLTP	G. Adamov, M. Finger, M. Finger (Jn.), Z. Tsamalaidze	
<b>3. Forward muon station ME1/1</b>	<b>Yu. Karjavin</b>	Upgrade Commissioning Maintenance Data taking
VBLHEP	Yu.V. Ershov, N.N. Evdokimov, A.O. Golunov, N.V. Gorbunov, A.Yu. Kamenev, A.M. Kurenkov, A.M. Makan'kin, V.V. Perehygin, A.V. Zarubin	
MLIT	V.V. Palchik, N.N. Voytishin	
BLTP	G.Adamov, Z. Tsamalaidze	
<b>4. Construction of the high granularity calorimeter</b>	<b>S.V. Afanasyev</b>	Realization
4.1 Experimental facility for complex tests of HGCal Cassettes	<b>S.V. Afanasyev</b> <b>A.I. Malakhov</b>	
4.2 Cooling plates and sensors for the High Granularity Calorimeter	<b>A.V. Zarubin</b> <b>P.D. Bunin</b>	
VBLHEP	V.Yu. Alexakhin, Yu.V. Ershov, A.O. Golunov, N.V. Gorbunov, S.V. Kilchakovskaya, A.M. Kurenkov, V.A. Smirnov, E.V. Sukhov, T.V. Trofimov, V.V. Ustinov, N.I. Zamyatin, A.V. Zarubin	
MLIT	A. Khvedelidze, V.V. Korenkov, V.V. Palchik, N.N. Voytishin	
GA&C	B.S. Yuldashev	
<b>5. Development of software for distributed computation, data processing and analysis based on GRID-technology</b>	<b>V.V. Korenkov</b>	Realization
MLIT	I.A. Filozova, A.O. Golunov, V.V. Korenkov, V.V. Mitsyn, D.A. Oleynik, G.A. Ososkov, V.V. Palichik, A.Sh. Petrosyan, R.N. Semenov, T.A. Strizh, V.V. Trofimov, N.N. Voytishin	

**Collaboration**

<b>Country or International Organization</b>	<b>City</b>	<b>Institute or laboratory</b>
Armenia	Yerevan	Foundation ANSL
Austria	Vienna	HEPHY
Belarus	Gomel	GSU
	Minsk	INP BSU
Belgium	Antwerp	UAntwerp
	Brussels	ULB
		VUB
	Ghent	Ugent
	Leuven	KU Leuven
	Louvain-la-Neuve	UCL
	Mons	UMONS
Brazil	Rio de Janeiro, RJ	CBPF
		UERJ
	Sao Paulo, SP	Unesp
Bulgaria	Sofia	INRNE BAS
		SU
CERN	Geneva	CERN
China	Beijing	"Tsinghua"
		IHEP CAS
		PKU
	Hangzhou	ZJU
Croatia	Split	Univ.
	Zagreb	RBI
Cyprus	Nicosia	UCY
Czech Republic	Prague	CU
Estonia	Tallinn	NICPB
Finland	Helsinki	HIP
		UH
	Lappeenranta	LUT
France	Lyon	UL
	Paris	IN2P3
	Saclay	IRFU
	Strasbourg	IPHC
Georgia	Tbilisi	GTU
		HEPI-TSU
Germany	Aachen	RWTH
	Hamburg	DESY
		Univ.
	Karlsruhe	KIT
Greece	Athens	INP NCSR "Demokritos"
		NTU
		UoA
	Ioannina	UI
Hungary	Budapest	Wigner RCP
	Debrecen	Atomki
		UD

India	Chandigarh	PU
	Jatani	NISER
	Kolkata	SINP
	Mumbai	BARC
		TIFR
Iran	Tehran	IPM
Ireland	Dublin	UCD
Italy	Bari	INFN
	Bologna	INFN
	Catania	INFN LNS
	Florence	INFN
	Frascati	INFN LNF
	Genoa	INFN
	Milan	INFN
	Naples	INFN
	Padua	INFN
	Pavia	INFN
	Perugia	INFN
	Pisa	INFN
	Rome	INFN
	Trieste	INFN
	Turin	INFN
Lithuania	Vilnius	VU
Mexico	Mexico City	Cinvestav
	Puebla	BUAP
Montenegro	Podgorica	Univ.
Netherlands	Eindhoven	TU/e
New Zealand	Auckland	Univ.
	Christchurch	UC
Pakistan	Islamabad	QAU
Poland	Krakow	AGH
		AGH-UST
	Otwock (Swierk)	NCBJ
	Warsaw	UW
Republic of Korea	Daejeon	KIST
	Gwangju	CNU
	Seoul	KU
		SJU
		SKKU
		SNU
		Yonsei Univ.
Russia	Dolgoprudny	MIPT
	Gatchina	NRC KI PNPI
	Moscow	ITEP
		LPI RAS
		NIKIET
		NNRU "MEPhI"
		SINP MSU
	Moscow, Troitsk	INR RAS
	Novosibirsk	NSU
	Protvino	IHEP
	Snezhinsk	VNIITF
	St. Petersburg	Electron

	Tomsk	TPU
		TSU
	Zhukovsky	MDB
Serbia	Belgrade	INS "VINCA"
Spain	Madrid	CIEMAT
		UAM
	Oviedo	UO
	Santander	IFCA
Switzerland	Villigen	PSI
	Zurich	ETH
		UZH
Taiwan	Taipei	NTU
	Taoyuan City	NCU
Turkey	Adana	CU
	Ankara	METU
	Istanbul	BU
		YTU
Ukraine	Kharkov	KhNU
		NSC KIPT
		STC "IMK" NASU
United Kingdom	Bristol	Univ.
	Didcot	RAL
	London	Imperial College
USA	Baltimore, MD	JHU
	Batavia, IL	Fermilab
	Boston, MA	BU
		NU
	Boulder, CO	CU
	Buffalo, NY	UB
	Cambridge, MA	MIT
	Charlottesville, VA	UVa
	Chicago, IL	UIC
	College Park, MD	UMD
	College Station, TX	Texas A&M
	Columbus, OH	OSU
	Davis, CA	UCDavis
	Detroit, MI	WSU
	Evanston, IL	NU
	Gainesville, FL	UF
	Houston, TX	Rice Univ.
	Iowa City, IA	UIowa
	Ithaca, NY	Cornell Univ.
	Knoxville, TN	UTK
	Lawrence, KS	KU
	Lincoln, NE	UNL
	Livermore, CA	LLNL
	Los Angeles, CA	UCLA
	Lubbock, TX	TTU
	Madison, WI	UW-Madison
	Manhattan, KS	KSU
	Minneapolis, MN	U of M
	Nashville, TN	VU
	New Brunswick, NJ	RU NB
	New York, NY	RU

	Notre Dame, IN	ND
	Oxford, MS	UM
	Pasadena, CA	Caltech
	Pittsburgh, PA	CMU
	Princeton, NJ	PU
	Providence, RI	Brown
	Riverside, CA	UCR
	Rochester, NY	UR
	San Diego, CA	SDSU
	Santa Barbara, CA	UCSB
	Tallahassee, FL	FSU
	Tuscaloosa, AL	UA
	Wako, TX	BU
	West Lafayette, IN	Purdue Univ.
Uzbekistan	Tashkent	INP AS RUz



## Studies of the Nucleon and Hadron Structure at CERN

**Leader:** A.P. Nagaytsev  
**Deputy:** A.V. Guskov

### Participating countries and international organizations:

CERN, Czech Republic, France, Germany, India, Israel, Italy, Japan, Poland, Portugal, Russia, Taiwan, USA.

### Issues addressed and main goals of research:

Studies of the generalized parton distributions in various exclusive processes. Study of the mechanisms of exclusive production of photons, pions and vector mesons in the processes of deep inelastic scattering of muons on nuclei (DIS) and in processes of deep inelastic virtual Compton scattering (DVCS). Measurements of the polarizability of a pion. Study of the structure of nucleons in Drell-Yan processes. Study of inclusive and semi-inclusive processes in DIS reactions of muons and hadrons on polarized targets.

- Measurements of the structure functions of a nucleon, polarized parton distributions of nucleons.
- Measurements of the structure of nucleons in muon pair production (Drell-Yan, J/Psi).
- Spin effects in hadron interactions at 0.3-3.0-GeV.
- Study of the mechanisms of exclusive production of photons, pions and  $\rho$ -mesons in DIS and DVCS processes.
- Measurement of the Primakoff reactions cross sections.
- Creation and development of a set of programs for modeling and data processing. System support for CERN software.
- Preparation of detectors for the COMPASS-II spectrometer.

### Expected results in the current year:

- Measurement of  $\pi^0$  production in the processes of exclusive deep inelastic scattering of muons on a hydrogen target.
- Measurements of Collins and Sivers asymmetry on hydrogen and deuterium targets.
- Measurement of semi-inclusive scattering on hydrogen and deuterium targets with 2 hadrons production.
- Measurement of transverse spin asymmetries in semi-exclusive scattering processes.
- Software development and modeling of various reactions studied on the COMPASS-II spectrometer. Analysis of data in JINR and preparation of publications.
- Theoretical studies on the program COMPASS-I and COMPASS-II.

### List of projects:

Project	Leader	Priority (period of realisation)
1. COMPASS-II	A.P. Nagajtsev	1 (2011-2022)

### List of Activities:

Activity or Experiment	Leaders	Status
Laboratory or other Division of JINR Responsible person	Main researchers	
<b>I. Experiment COMPASS-II</b>	<b>A.P. Nagaytsev</b>	Data taking Data processing

<b>1. Hadron calorimeter</b>	<b>O.P. Gavrishchuk</b>	Maintenance
VBLHEP	V.A. Anosov	
DLNP	A.S. Selyunin, A.V. Rybnikov	
<b>2. Electromagnetic calorimeter</b>	<b>A.P. Nagaytsev</b> <b>N.V. Anfimov</b>	Maintenance
VBLHEP	V.A. Anosov, O.P. Gavrishchuk	
DLNP	A.I. Antoshkin, A.V. Guskov, V.M. Kudryavtsev, A.G. Olshevskiy, A.V. Rybnikov, A.S. Selyunin, I.E. Tchirikov-Zorin, V.N. Frolov	
<b>3. Muon system</b>	<b>G.D. Alekseev</b>	Maintenance
DLNP	V.M. Abazov, G.A. Golovanov, A.A. Piskun, A.G. Samartsev, V.V. Tokmenin, L.S. Vertogradov, N.I. Zhuravlev	
<b>4. System of the data taking</b>	<b>V.N. Frolov</b>	Maintenance
<b>5. Software development. Data analysis</b>	<b>E.V. Zemlyanichkina</b> <b>A.V. Guskov</b>	Realization
VBLHEP	R.R. Akhunzyanov, R. Gushcherski, A.V. Ivanov, Yu.I. Ivanshin, O.M. Kuznetsov, A.P. Nagaytsev, N.S. Rogacheva, D.V. Peshekhonov, I.A. Savin, E.A. Salmina	
DLNP	N.V. Anfimov, A.I. Antoshkin, I.I. Denisenko, A.O. Gridin, A. Maltsev, A.G. Olshevskiy, A.V. Rybnikov, A. Rymbekova, A.S. Selyunin	
MLIT	A.Sh. Petrosyan, P.V. Zrelov	
<b>6. Measurements of generalized parton distributions</b>	<b>A.P. Nagaytsev</b> <b>A.V. Guskov</b> <b>I.A. Savin</b>	Realization
VBLHEP	R.R. Akhunzyanov, R. Gushcherski, O.M. Kuznetsov, V.D. Peshekhonov, N.S. Rogacheva, E.A. Salmina, O.V. Teryaev, E.V. Zemlyanichkina	
DLNP	I.I. Denisenko, A. Maltsev, A.G. Olshevskiy, A. Rymbekova	
BLTP	O.V. Teryaev	
<b>7. Studies of Drell-Yan processes</b>	<b>A.V. Guskov</b>	Realization
DLNP	I.I. Denisenko, A.O. Gridin, A. Maltsev, E.O. Mitrofanov, A. Rymbekova	
<b>8. Spin effects in hadron interactions at 0.3-3.0 GeV</b>	<b>A.V. Kulikov</b> <b>D.A. Tsirkov</b>	Data processing
DLNP	T.I. Azaryan, S.N. Dymov, V.I. Komarov, V.S. Kurbatov, Zh. Kurmanaliev, A. Kunsafina, V.V. Shmakov, Yu.N. Uzikov, B.Zh. Zalikhanov	
<b>9. Studies of semi-inclusive reactions</b>	<b>I.A. Savin</b> <b>E.V. Zemlyanichkina</b>	Realization
VBLHEP	S.R. Gevorgyan, A.V. Ivanov, Yu.I. Ivanshin, N.S. Rogacheva, E.A. Salmina	

## II. Theoretical studies

BLTP

## O.V. Teryaev

Realization
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S.B. Gerasimov, A.V. Kotikov, A.M. Sidorov

### Collaboration

#### Country or International Organization

CERN

Czech Republic

France

Germany

India

Israel

Italy

Japan

Poland

Portugal

Russia

Taiwan

USA

#### City

Geneva

Brno

Liberec

Prague

Saclay

Bochum

Bonn

Freiberg

Mainz

Munich

Kolkata

Tel Aviv

Trieste

Turin

Yamagata

Otwock (Swierk)

Warsaw

Aveiro

Lisbon

Moscow

Protvino

Tomsk

Taipei

Urbana, IL

#### Institute or laboratory

CERN

BUT

TUL

CU

SPhN CEA DAPNIA

RUB

UniBonn

TUBAF

JGU

TUM

MIERE

TAU

INFN

INFN

Yamagata Univ.

NCBJ

WUT

UA

LIP

LPI RAS

IHEP

TPU

AS

I

## Strangeness in Hadronic Matter and Study of Inelastic Reactions Near Kinematical Borders

**Leaders:** E.A. Stokovsky  
E.S. Kokoulina  
D.O. Krivenkov

### Participating countries and international organizations:

Belarus, Czech Republic, Japan, Russia, Slovakia, Ukraine.

### Issues addressed and main goals of research:

Strangeness in hadronic matter and study of boundary effects:

- study of stabilizing effects of strangeness in nuclear matter and properties of the lightest hypernuclei;
- study of multi-particle dynamics in the inelastic proton-proton and proton-nucleus interactions with extremally high multiplicity;
- study of spectra and yields of soft photons in the deuteron-nucleus and nucleus-nucleus interactions.

### Expected results:

- Experimental conclusion about the existence of the hypernucleus  ${}^6_{\Lambda}\text{H}$ .
- New experimental data on the properties of the lightest hypernuclei and experimental verification of corresponding theoretical models for these hypernuclei.
- New experimental data on the drip-line location for loosely bound light hypernuclei with high neutron excess, necessary for the development of the theory of neutron-rich hypernuclei and models of their production in non-central nucleus-nucleus interactions.
- New experimental data on the production of strangeness and vector mesons (including those, containing strange quarks) by polarized photons (close to the relevant thresholds).
- Measurement of the measured energy spectra of gamma-quanta (in the energy range up to several MeV), produced in the interactions of different nuclear beams (from deuterium to heavy nuclei) of Nuclotron with various nuclear targets, with theoretical predictions depending on the multiplicity of charged and neutral particles, as well as on the photon emission angle; verification of various physical hypotheses about the mechanisms of production of "direct" photons in the nuclear interactions.
- Confirmation (or establishing of the upper boundaries) of cross sections for the production of new resonances, decaying into two  $\gamma$ -quanta.

### Expected results in the current year:

- Data taking for  ${}^6_{\Lambda}\text{H}$  search using beam of  ${}^7\text{Li}$  nuclei. Analysis of the first experimental data for the  ${}^6_{\Lambda}\text{H}$  search and for the measurements of hyperhydrogen isotopes  ${}^6_{\Lambda}\text{H}$  and  ${}^4_{\Lambda}\text{H}$  lifetimes.
- Upgrade of the HyperNIS magnetic spectrometer (tracking system) by adding the planes of GEM detectors. These detectors, which have already been (partially) purchased and are being tested at the HyperNIS setup by SFSKYA staff, will be integrated into this setup to improve accuracy of the hypernucleus decay vertex determination.
- Within the collaboration with Japan: data taking at LEPS/LEPS2 setups on the production of strangeness and vector mesons (including those, containing strange quarks) by polarized photons (close to the relevant thresholds); analysis of data on such reactions, taken before.
- Assembling the "shashlyk"-type electromagnetic calorimeter based on 16 planes of gallium-gadolinium garnet crystals and the absorber from a mixture of tungsten and copper between them. Equipping the calorimeter by electronics.

- Participation in the simulation of the calorimeter use in the SPD setup for the task of direct photon registration, within the development of the SPD physical program with polarized beams of light nuclei and protons. Participation in works on simulation of the polarimeters (to be created) for experiments with polarized beams at the VBLHEP accelerator complex.
- Preparing a new project to replace the one being completed.
- Comparison of the average of the transverse and longitudinal momentum components of charged particles as a function of multiplicity. Determination of the critical multiplicity at which the components become indistinguishable and establishing its connection with the pion condensate region.

### List of Activities:

Activity or Experiment Laboratory or other Division of JINR Responsible person	Leaders	Status
<b>1. Experiment NIS-GIBS</b>	<b>E.A. Strokovsky</b> <b>J. Lukstins</b> <b>D.O. Krivenkov</b>	Realization Data taking
VBLHEP	V.D. Aksinenko, M.H. Anikina, T. Atovullaev, A.V. Averyanov, A.N. Bayeva, S.N. Bazylev, A.E. Baskakov, D.V. Dementiev, A.A. Feschenko, A.A. Fedyunin, S.V. Gertsenberger, A.M. Korotkova, V.T. Matyushin, A.I. Maksimchuk, Yu.A. Murin, S. Nepochatych, O.V. Okhrimenko, S.N. Plyashkevich, N.G. Parfenova, M. Patsyuk, P.A. Rukoyatkin, A.V. Shipunov, M.O. Shitenkov, A.D. Sheremetiev, A.V. Shutov, N.A. Shutova, I.V. Slepnev, V.M. Slepnev, A.L. Voronin	
DLNP	B.A. Popov, V.V. Tereschenko, S.V. Tereschenko	
OCE	A.N. Parfenov	
<b>2. Experiment NEMAN</b>	<b>E.S. Kokoulina</b> <b>V.A. Nikitin</b>	Project preparation Data taking
VBLHEP	V.P. Balandin, N. Barlykov, Yu.T. Borzunov, V.B. Dunin, V. Dudin, O.P. Gavrischuk, A.S. Gribovsky, V.Yu. Ivanenko, A.V. Konstantinov, D.A. Kirillov, R.I. Kukushkina, Yu.P. Petukhov, V.V. Popov, I.A. Rufanov, S.Yu. Sinelchikova, M.V. Tokarev, V.A. Zykunov	
BLTP	Yu.A. Bystritsky	

### Collaboration

Country or International Organization	City	Institute or laboratory	
Belarus	Gomel	GSTU GSU	
	Minsk	"Radateh" BSUIR IAP NASB INP BSU IP NASB	
	Czech Republic	Prague	CTU CU
	Japan	Osaka	RCNP

Russia	Chernogolovka Moscow	ISSP RAS "Azimuth-Photonics" "FOMOS-MATERIALS" NNRU "MEPhI" SINP MSU
	Moscow, Zelenograd Protvino St. Petersburg Syktyvkar Banska Bistrica	RIMST IHEP SPbSPU DM Komi SC UrB RAS
Slovakia		UMB
Ukraine	Kiev	BITP NASU

**NICA Complex: Design and Construction of the Complex  
of Accelerators, Collider and Physics Experimental Facilities  
at Extracted and Colliding Ion Beams Aimed at Studying Dense  
Baryonic Matter and the Spin Structure of Nucleons and Light Ions,  
and at Carrying out Applied and Innovation Projects**

**Leaders:** V.D. Kekelidze  
A.S. Sorin  
G.V. Trubnikov

**Deputies:** A.V. Butenko  
V.M. Golovatyuk  
M.N. Kapishin

**Participating countries and international organizations:**

Armenia, Australia, Azerbaijan, Belarus, Bulgaria, CERN, Chile, China, Cuba, Czech Republic, Egypt, France, Georgia, Germany, Israel, Italy, Japan, Mexico, Moldova, Mongolia, Poland, Romania, Russia, Serbia, Slovakia, South Africa, Sweden, Ukraine, USA.

**Issues addressed and main goals of research:**

Search and investigation of phase transitions in strongly interacting nuclear matter at extremely high baryon densities, study of the nucleon spin structure, of light nuclei and polarization phenomena in few nucleon systems. Development of theoretical models of the studied processes and theoretical support of the experiments. Development of the Nuclotron accelerator complex as a basic facility for studying relativistic nuclear collisions in the range of atomic masses  $A = 1 \div 197$ . Investigation of reaction dynamics and studying modifications of hadron properties in nuclear matter, near-threshold strange hyperons production and search for hyper nuclei in interactions of the Nuclotron extracted ion beams with fixed targets at the BM@N detector. Investigation of the nuclear structure at short internucleon distances at the BM@N detector. Development and stage-by-stage creation of the NICA heavy ion collider accelerator complex, the multi-purpose detector (MPD/NICA) and spin physics detector (SPD/NICA) for experiments with colliding heavy ions beams. Modernization of extraction beam lines. Carrying out of experiments with ion beams and polarized proton and deuteron beams at the Nuclotron. Development of the infrastructure for applied research at NICA heavy ion beams.

**Expected results in the current year:**

- Development and expansion of the physical programme of the project - "White Paper" of the NICA project. Obtaining new theoretical results for processes of strong interactions in the non-perturbative QCD region, development and tests of models for nuclear matter properties descriptions at extremely high temperatures and densities, investigation of possible nuclear matter states and nuclear collision dynamics at extreme baryonic densities as well as observation of these phenomena in P-odd effects and spin asymmetries.
- Completion of the planned tasks within the Nuclotron-NICA project: assembly and testing of the main subsystems. Development of beam diagnostics systems. Increasing the intensity of the beam from the SPI polarized particle source. Preparation of the Nuclotron for solving first-priority tasks of the NICA program within available running time. Technical design on the SC resonator prototype for the proton linacs. Design of new proton and light ion linear accelerator LILAC.
- Commissioning of the HILAC linear accelerator ( $z/A \geq 0.14$ ), achieving its design parameters. Development and upgrade of the engineering infrastructure. The Booster tests and physics beam runs.
- Tests of the elements of the beam extraction and transportation system from the Booster to Nuclotron. Manufacturing the elements of beam transfer system from Nuclotron to Collider.

- Completion of the tunnel building works for installation the NICA collider elements and systems.
- Preparing the BM@N set-up for the physics run with a heavy ion beam extracted from the Nuclotron. New data collection with a heavy ion beam at BM@N. Analysis of new experimental data collected at BM@N.
- Construction and tests of the MPD setup systems in accordance with the work schedule. Serial production of the start option detectors.
- Preparation and presentation of the SPD project. Development of the physics motivation, modeling, optimization of the set-up configuration, including continuation of theoretical studies of Matveev-Muradyan-Tavkxelidze-Drell-Yang, J/psi production processes in polarized proton and deuteron collisions.
- Completion of the 1st-stage NICA computer cluster and its infrastructure.
- Completion of manufacturing and tests the NICA lattice collider magnetic system elements.
- Put the new cryogenic-compressor station and cryogenic facilities in building 1b.
- Reconstruction of the Measuring hall for the applied channels system.
- Completion of equipment installation at applied research channels, at the station for irradiation of electronic components and biological objects with long-range ions and at the station for irradiation of electronic components with low-energy ions.
- Expert assessment of the technology solutions used during development of the beamlines for applied research, of stations for irradiating electronic components and biological objects with long-range ions and of stations for irradiating electronic components with low-energy ions. Formulation of proposals for the development of beamlines and irradiation stations for applied research.
- Preparation of the program of the first experiments on beamlines for irradiation of electronic components and biological objects.

### List of projects:

Project	Leader	Priority (period of realisation)
1. Nuclotron-NICA	A.V. Butenko G.G. Khodzhibagiyan Scientific leader: I.N. Meshkov	1 (2011-2023)
2. BM@N	M.N. Kapishin	1 (2012-2026)
3. MPD	V.M. Golovatyuk V.D. Kekelidze	1 (2011-2025)
4. SPD	A.V. Guskov Deputy: V.P. Ladygin	1 (2020-2022)



## List of Activities:

Activity or Experiment	Leaders	Status
Laboratory or other Division of JINR Responsible person	Main researchers	
1.1. NICA injection complex: technical design preparation and construction of the NICA injection complex: (sources of heavy ions and polarized light nuclei, HILAC linear accelerators of heavy ions and light nuclei of beam transporting to the Nuclotron)	A.V. Butenko A.I. Govorov V.A. Monchinsky E.M. Syresin A.V. Tuzikov	Realization
1.1.a. Commissioning of the heavy ion source (KRION)	E.E. Donets	Realization
1.1.b. Upgrade the polarized proton and deuteron source (SPI)	V.V. Fimushkin R.A. Kuzyakin	Realization
1.1.c. Development and construction of the beam injection systems and beam transportation channels. Development of the beam control and diagnostics systems	D.E. Donets E.V. Gorbachev A.V. Tuzikov V.I. Volkov	Realization
1.1.d. Design and start of construction The new proton and light ion injector LILAC	A.V. Butenko A.I. Govorov K.A. Levterov B.V. Golovensky E.M. Syresin	Realization
VBLHEP	M.Yu. Averyanov, V.S. Alexandrov, A.V. Alfeev, V.P. Akimov, V.A. Andreev, A.M. Bazanov, A.Yu. Boytsov, A.A. Fateev, A.R. Galimov, N.I. Garanzha, A.G. Kobets, V.V. Kobets, V.N. Karpinsky, O.S. Kozlov, S.Yu. Kolesnikov, A.E. Kirichenko, M.V. Kulikov, L.V. Kutuzov, R.A. Kuzyakin, D.A. Lyuosev, A.A. Martynov, S.V. Mikhaylov, V.V. Myalkovsky, A.V. Nesterov, K.G. Osipov, R.V. Pivin, D.O. Ponkin, Yu.V. Prokofichev, A.Yu. Ramzdorf, D.N. Rassadov, S.V. Romanov, G.S. Sedykh, V.V. Seleznev, A.O. Sidorin, I.V. Shirikov, V.B. Shutov, V.V. Tarasov, A.V. Tuzikov, A.A. Voronin, A.V. Zakharov	
1.2. Assembling and start-up of the NICA Booster and its technological systems	A.V. Butenko G.G. Khodzhbagiyan I.N. Meshkov E.M. Syresin A.O. Sidorin	Realization
1.2.a. Magnet cryostat system, vacuum system, system of electron cooling	A.R. Galimov A.G. Kobets	Realization
1.2.b. Power supply and energy evacuation system	E.V. Ivanov V.N. Karpinsky	Projecting Realization

<b>1.2.c. RF accelerating system of the Booster</b>	<b>O. Brovko</b>	Realization
<b>1.2.d. Diagnostics, injection, beam extraction and transport systems</b>	<b>A.V. Tuzikov V.I. Volkov</b>	Projecting Realization
VBLHEP	N.N. Agapov, A.S. Averichev, M.Yu. Averiyarov, V.A. Andreev, R.V. Andryukhin, A.V. Alfeev, A.M. Bazanov, A.A. Baldin, V.I. Batin, A.N. Beloborodov, D.N. Bogoslovsky, V.P. Chernyaev, D.E. Donets, V.M. Drobin, A.A. Fateev, A.V. Filippov, S.A. Goncharov, E.V. Gorbachev, A.Yu. Grebentsov, G.E. Ivanov, P.R. Kharyuzov, A.E. Kirichenko, H.G. Khodzhbagiyani, S.A. Korovkin, O.S. Kozlov, S.Yu. Kolesnikov, A.V. Konstantinov, S.A. Kostromin, A.I. Korobkov, V.V. Kosachev, E.V. Kostyukhov, A.V. Kudashkin, G.L. Kuznetsov, E.A. Kulikov, O.A. Kunchenko, N.I. Lebedev, A.V. Lushin, S.V. Mikhaylov, V.A. Mikhaylov, V.V. Myalkovsky, A.V. Nesterov, D.N. Nikiforov, A.L. Osipenko, K.G. Osipov, A.V. Peltikhin, M.V. Petrov, G.A. Petrovsky, R.V. Pivin, N.V. Pilyar, O.V. Prozorov, S.V. Romanov, P.A. Rukoyatkin, T.V. Rukoyatkina, A.B. Safronov, N.V. Semin, G.S. Sedykh, V.V. Seleznev, A.S. Sergeev, A.V. Shabunov, V.S. Shvetsov, A.A. Shurygin, A.I. Sidorov, Z.I. Smirnova, A.N. Svidetelev, V.V. Tarasov, A.M. Tikhomirov, N.D. Topilin, Yu.A. Tumanova, V.I. Tyulkin, B.V. Vasilishin, A.I. Zagrai, A.Yu. Zakharov	
DLNP	E.V. Akhmanova, V.I. Hilinov, O.S. Orlov, A.Yu. Rudakov, N.A. Rybakov, L.V. Soboleva, A.A. Sidorin, S.L. Yakovenko	
<b>1.3. Development of the Nuclotron</b>	<b>A.V. Butenko A.O. Sidorin E.M. Syresin</b>	Projecting Realization
<b>1.3.a. Magnet cryostat system, vacuum system</b>	<b>A.R. Galimov</b>	Projecting Realization
<b>1.3.b. Power supply and energy evacuation system</b>	<b>E.V. Ivanov V.N. Karpinsky</b>	Projecting Realization
<b>1.3.c. RF accelerating system of the Nuclotron</b>	<b>O.I. Brovko</b>	Projecting Realization
<b>1.3.d. Diagnostics, injection, beam extraction and transportation systems</b>	<b>E.V. Gorbachev P.A. Rukoyatkin V.I. Volkov</b>	Projecting Realization
VBLHEP	S.Yu. Anisimov, A.S. Averichev, M.Yu. Averiyarov, V.A. Andreev, R.V. Andryukhin, A.V. Alfeev, A.M. Bazanov, V.V. Batin, V.V. Borisov, V.P. Chernyaev, D.E. Donets, A.A. Fateev, A.V. Filippov, A.Yu. Grebentsov, S.A. Goncharov, I.V. Gorelyshev, S. Gusev, G.E. Ivanov, A.E. Kirichenko, G.G. Khodzhbagiyani, A.I. Korobkov, O.S. Kozlov, S.Yu. Kolesnikov, N.G. Kondratiev, A.V. Konstantinov, A.V. Kopchenov, V.V. Kosachev, S.A. Kostromin,	

A.V. Kudashkin, G.L. Kuznetsov, O.A. Kunchenko, N.I. Lebedev, S.V. Mikhaylov, V.A. Mikhaylov, A.V. Merkuriev, D.V. Monakhov, V.V. Myalkovsky, A.V. Nesterov, A.L. Osipenkov, K.G. Osipov, G.A. Petrovsky, R.V. Pivin, O.V. Prozorov, S.V. Romanov, N.V. Semin, G.S. Sedykh, V.V. Seleznev, A.S. Sergeev, V.S. Shvetsov, A.I. Sidorov, A.A. Shurygin, V.V. Tarasov, A.V. Tuzikov, V.B. Vasilishin, A.Yu. Zakharov

**1.4. Technical design, R&D of technological systems and construction of the NICA heavy ion collider with an energy of  $E_{CM}=4-11$  GeV and an average luminosity of  $1 \cdot 10^{27} \text{ cm}^{-2} \text{ c}^{-1}$  and light polarised nuclei with a luminosity of  $1 \cdot 10^{32} \text{ cm}^{-2} \text{ c}^{-1}$  (by protons, at  $E_{CM}=27$  GeV)**

**S.A. Kostromin  
I.N. Meshkov  
E.M. Syresin**

Projecting Realization
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**1.4.a. Magnet cryostat and vacuum systems**

**A.R. Galimov  
G.G. Khodzhbagiyani**

Projecting Realization
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**1.4.b. Power supply and energy evacuation system**

**E.V. Ivanov  
V.N. Karpinsky**

Projecting Realization
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**1.4.c. RF system of the Collider**

**O.I. Brovko  
A.Yu. Grebentsov**

Projecting Realization
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**1.4.d. Beam diagnostics, injection and transportation systems**

**A.V. Tuzikov  
V.I. Volkov**

Projecting Realization
---------------------------

**1.4.e. Beam cooling systems**

**A.G. Kobets  
A.O. Sidorin**

Projecting Realization
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**1.4.f. Systems of proton and deuteron polarization monitoring and control**

**S.A. Kostromin**

Projecting Realization
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VBLHEP

S.A. Arefiev, N.N. Agapov, V.S. Alexandrov, A.V. Alfeev, V.A. Andreev, R.V. Andryukhin, A.S. Averichev, A.M. Bazanov, V.I. Batin, N.A. Blinov, O.I. Brovko, V.V. Borisov, S.A. Dolgy, A.M. Donyagin, V.M. Drobin, A.V. Eliseev, A.A. Fateev, A.V. Filippov, M.N. Filippov, N.A. Filippov, V.V. Fimushkin, O.M. Golubitsky, S.A. Goncharov, E.V. Gorbachev, I.V. Gorelyshev, Yu.V. Gusakov, G.E. Ivanov, I.E. Karpunina, M.A. Kashunin, H.G. Khodzhbagiyani, A.E. Kirichenko, S.V. Kirov, O.S. Kozlov, N.G. Kondratiev, A.V. Konstantinov, A.V. Kopchenov, A.I. Korobkov, S.A. Korovkin, V.V. Kosachev, A.V. Kudashkin, P.I. Kudryashov, E.A. Kulikov, M.V. Kulikov, O.A. Kunchenko, L.V. Kutuzov, G.L. Kuznetsov, R.A. Kuzyakin, N.I. Lebedev, A.A. Makarov, D.V. Monakhov, D.N. Nikiforov, A.M. Nikitin, E.A. Negey, A.V. Nesterov, A.L. Osipenkov, K.G. Osipov, M.V. Petrov, G.A. Petrovsky, R.V. Pivin, O.V. Prozorov, S.V. Romanov, P.A. Rukoyatkin, T.V. Rukoyatkina, N.V. Semin, M.M. Shandov, A.V. Shemchuk, E.V. Shevtchenko, V.M. Shumkov, A.A. Shurygin, A.O. Sidorin, A.I. Sidorov, S.A. Smirnov, Z.I. Smirnova, E.M. Syresin, A.N. Scherbakov, A.L. Svetov, V.S. Shvetsov, V.V. Tarasov, A.M. Tikhomirov, N.D. Topilin, G.V. Trubnikov, Yu.A. Tsvetkova, Yu.A. Tumanova, B.V. Vasilishin, A.I. Zagray, A.Yu. Zakharov, V.M. Zhabitsky, A.G. Zorin

DLNP	E.V. Akhmanova, V.I. Khilinov, O.S. Orlov, A.Yu. Rydakov, N.A. Rybakov, L.V. Soboleva, T.A. Stepanova, A.A. Sidorin, S.L. Yakovenko	
LRB	G.N. Timoshenko	
DRB	V.N. Buchnev, V.Yu. Schegolev	
<b>1.5. R&amp;D, construction and development of cryogenic systems</b>	<b>N.N. Agapov</b> <b>G.G. Khodzhbagiyon</b>	Projecting Realization
VBLHEP	A.B. Arefiev, V.I. Batin, N.A. Baldin, M.A. Basheva, D.M. Belov, Yu.T. Borzunov, V.M. Drobin, N.L. Egorova, N.E. Emelyanov, E.Yu. Filippova, I.N. Goncharov, S.P. Gorelikov, E.V. Gromova, S.V. Gudkov, E.Yu. Ivanenko, E.V. Ivanov, M.V. Kondratiev, K.K. Kozlovski, A.V. Konstantinov, V.A. Kosinov, E.A. Kulikov, D.V. Lobanov, Yu.A. Mitrofanova, V.V. Orlov, I.M. Petrov, R.V. Peshkov, S.A. Sidorov, S.A. Smirnov, E.I. Vorobiev, O.B. Yarovikova	
<b>2. BM@N project</b>	<b>M.N. Kapishin</b>	Realization
<b>2.1. Development of the operational area of the setup: increasing the radiation protection, improving detector subsystems and engineering infrastructure</b>	<b>S.Yu. Anisimov</b> <b>M.N. Kapishin</b> <b>S.M. Piyadin</b>	Realization
<b>2.2. Construction of the basic detector complex of the BM@N setup</b>	<b>M.N. Kapishin</b> <b>A.I. Maksymchuk</b>	Realization
<b>2.3. Development of the technological and engineering systems, control systems and test areas of the setup</b>	<b>S.Yu. Anisimov</b> <b>S.M. Piyadin</b> <b>N.D. Topilin</b>	Realization
VBLHEP	Kh.U. Abraamyan, G.N. Agakishiev, S.V. Afanasiev, K.A. Alishina, T.A. Atovullaev, V.A. Babkin, D.A. Baranov, P.N. Batyuk, S.N. Bazylev, D.N. Bogoslovsky, M.G. Buryakov, S.G. Buzin, A.I. Chebotov, B. Dabrovska, D.V. Dementiev, A.V. Dmitriev, P.O. Dulov, D.K. Dryablov, D.S. Egorov, V.V. Elsha, A.A. Fedyunin, I.A. Filippov, I.R. Gabdrakhmanov, A.V. Galavanov, O.P. Gavrischuk, K.V. Gertsenberger, V.M. Golovatyuk, M.N. Kapishin, V.Yu. Karzhavin, R.R. Kattabekov, V.D. Kekelidze, Yu.T. Kiryushin, S.V. Khabarov, Yu.S. Kovalev, V.I. Kolesnikov, A.A. Kolozhvari, L.D. Kovachev, Yu.A. Kopylov, A.S. Kuznetsov, S.N. Kuklin, E.M. Kulish, E.A. Ladygin, N.A. Lashmanov, V.V. Lenivenko, A.M. Makan'kin, A.I. Maksimchuk, A.I. Malakhov, S.P. Merts, A.N. Morozov, Yu.A. Murin, R.V. Nagdasev, D.N. Nikitin, S.V. Novozhilov, M.A. Patsyuk, Yu.P. Petukhov, S.M. Piyadin, V.A. Plotnikov, V.Yu. Rogov, P.A. Rukoyatkin, M.M. Rumyantsev, I.A. Rufanov, D.G. Sakulin, S.A. Sedykh, S.V. Sergeev, A.D. Sheremetiev, A.I. Sheremetieva, M.O. Shitenkov, A.S. Sorin, V.N. Spaskov, Yu.Yu. Stepanenko, E.A. Streletskaya, D.A. Suvarieva, I.V. Slepnev, V.M. Slepnev, I.P. Slepov, B.V. Sukhov, M.O. Shitenkov, A.V. Shutov, V.B. Shutov, A.V. Schipunov, N.D. Topilin, B.L. Topko, Yu.A. Topko, N.A. Tarasov, O.G. Tarasov, A.V. Terletsky, V.V. Teryaev, V.V. Tikhomirov, A.A. Timoshenko, N.D. Topilin, I.A. Tyapkin, V.A. Vasendina, A.V. Vishnevsky, A.A. Voronin, V.I. Yurevich, N.I. Zamyatin, V.N. Zhezher, A.I. Zinchenko, E.V. Zubarev	

MLIT

E.I. Alexandrov, I.N. Alexandrov, N.A. Balashov, I.A. Filozova, Zh.Zh. Musulmanbekov, V.V. Palichik, I.S. Pelevaniuk, D.V. Podgainy, O.I. Streltsova, N.N. Voytishin, M.I. Zuev

FLNP

E.I. Litvinenko

BLTP

M. Baznat, A.S. Khvorostukhin

**2.4. Analysis of BM@N experimental data and feasibility studies for BM@N program in heavy ion beams**

**M.N. Kapishin**  
**A.I. Zinchenko**

Realization

**3. MPD project**

**V.M. Golovatyuk**  
**V.D. Kekelidze**  
**A. Kisiel**

Realization

VBLHEP

S.V. Afanasev, G.N. Agakishiev, N.V. Anfimov, A.A. Aparin, V.I. Astakhov, S.V. Andreeva, T.V. Andreeva, G.S. Averichev, A.V. Averiyarov, V.A. Babkin, I.A. Balashov, M.Yu. Barabanov, D.A. Baranov, A.E. Baskakov, P.N. Batyuk, A.G. Bazhazhin, S.N. Bazylev, A.V. Belyaev, E.V. Belyaev, S.E. Beleaev, V. Benda, D.N. Bogoslovsky, I.V. Boguslavsky, M.G. Buryakov, A.V. Butorin, A.V. Bychkov, S.G. Buzin, V.V. Chalyshev, V.A. Cheplakova, V.V. Chepurinov, V.F. Chepurinov, G.A. Cheremukhina, P.V. Chumakov, B. Dabrovska, D. Dabrovsky, D.V. Dementiev, A.V. Dmitriev, V.Kh. Dodokhov, E.V. Dolbilina, A.G. Dolbilov, D.E. Donets, A.Yu. Dubrovin, P.O. Dulov, N.V. Dunin, V.B. Dunin, V. Dyatlov, A.A. Efremov, D.S. Egorov, V.V. Elsha, A.E. Emelianov, N.E. Emelianov, O.V. Fateev, Yu.I. Fedotov, A.A. Fedyunin, I.A. Filippov, M.A. Gaganova, T.T. Gandzhelashvili, I.V. Gapienko, O.P. Gavrischuk, K.V. Gertsenberger, N.V. Gorbunov, A.V. Ivanov, A.Yu. Isupov, S.I. Kakurin, M.N. Kapishin, L.A. Kartashova, G.D. Kekelidze, A.O. Kechechan, V.A. Kireev, Yu.T. Kiryushin, I.S. Kiryutin, H.G. Khodzhbagiyani, V.I. Kolesnikov, A. Kolozhvari, V.G. Komarov, E.V. Kozhin, V.A. Kramarenko, L.M. Krasnova, Yu.F. Krechetov, I.V. Kruglova, A.V. Krylov, S.I. Kukarnikov, S.N. Kuklin, E.A. Kulikov, N.A. Kozlenko, V.S. Kuz'min, N.A. Lashmanov, R. Lednicky, A.G. Litvinenko, G.N. Litvinova, A.N. Livanov, V.I. Lobanov, Yu.Yu. Lobanov, S.N. Lobastov, Yu. Lukstin'sh, D.T. Madigozhin, V.I. Maksimenkova, A.I. Malakhov, I.V. Malikov, L.V. Malinina, D.G. Melnikov, S.P. Merts, I.N. Meshkov, I.I. Migulina, Yu.I. Minaev, S.A. Movchan, N.A. Molokanova, A.E. Moskovsky, A.A. Moshkin, I.V. Moshkovsky, A.A. Mudrokh, Yu.A. Murin, K.A. Mukhin, D. Myktybekov, E.N. Nazarova, A.V. Nechaevsky, V.A. Nikitin, I.A. Oleks, O.E. Orlov, S.S. Parzhitsky, V.A. Pavlyukevich, V.A. Penkin, V.A. Petrov, D.V. Peshekhonov, N.V. Pilyar, S.M. Piyadin, A.E. Potanina, S.V. Razin, N.O. Ridinger, O.V. Rogachevsky, V.Yu. Rogov, K. Roslon, M.M. Rummyantsev, I.A. Rufanov, A.A. Rybakov, A.A. Rymshina, Z.Ya-O. Sadygov, V.M. Samsonov, A.A. Savenkov, S. Sebalos Sanches, S.A. Sedykh, T.V. Semchukova, A.Yu. Semenov, I.A. Semenova, S.V. Sergeev, N.A. Sergeeva, E.V. Serochkin, A.O. Sidorin, I.P. Slepov, V.M. Slepnev, I.V. Slepnev, Yu.A. Solnyshkin, A.S. Sorin, E.A. Streletskaya, N.V. Sukhov, S.I. Sukhovarov, N.N. Surkov, V.L. Svalov, A.V. Shabunov, A.D. Sheremetiev, A.I. Sheremeteva, R.A. Shindin, M.O. Shitenkov, K. Shtejer Dias, A.A. Shunko, A.B. Shutov, V.B. Shutov, A.N. Scherbakov, B.G. Schinov, A.V. Schipunov, N.A. Tarasov, A.V. Terletsky, O.V. Teryaev, A.A. Timoshenko, V.V. Tikhomirov, G.P. Tkachev, N.D. Topilin, A.V. Trubnikov, I.A. Tyapkin,

	S.Yu. Udovenko, V.A. Vasendina, I.N. Vasilev, S.V. Vereschagin, N.V. Vlasov, A.S. Vodopyanov, O.A. Volodina, A.A. Voronin, G.A. Yarygin, M.V. Zaitseva, N.I. Zamyatin, S.A. Zaporozhets, A.I. Zinchenko, D.A. Zinchenko, V.N. Zryuev	
DLNP	A.V.Guskov, A.G. Olshevsky	
MLIT	V.V. Ivanov, Zh.Zh. Musulmanbekov, T.A.Strizh	
FLNP	E.I. Litvinenko	
<b>3.1. Design and construction of the superconducting solenoid and magnet yoke</b>	<b>N.E. Emelyanov</b> <b>K.A. Mukhin</b> <b>N.D. Topilin</b>	Realization
VBLHEP	V.H. Dodokhov, A.A. Efremov, S.G. Gordeev, G.D. Kekelidze, V.I. Lobanov, Yu.Yu. Lobanov	
<b>3.2. Construction of the detector complex of the start configuration of the MPD setup</b>	<b>V.M. Golovatyuk</b> <b>V.D. Kekelidze</b>	Realization
VBLHEP	V.A. Babkin, C.N. Bazylev, A. Ivashkin, S.A. Movchan, Yu.A. Myrin, I.A. Tyapkin, N.D. Topilin, V.I. Yurevich	
<b>3.3. Design and creation of the data acquisition and control systems</b>	<b>S.N. Bazylev</b> <b>I.V. Slepnev</b>	Realization
VBLHEP	A.E. Baskakov, A.A. Fedyunin, I.A. Filippov, S.N. Kuklin, V.M. Slepnev, A.B. Shutov, A.V. Schipunov, N.A. Tarasov, A.V. Terletsky	
<b>3.4 Development of MPD physical program</b>	<b>V.I. Kolesnikov</b> <b>A.I. Zinchenko</b>	Realization
<b>4. Theoretical investigations, calculations and development of models describing nuclear matter properties at high temperatures and compressions, dynamics of high energy nuclear interactions at extremely high baryonic densities, spin and P-odd effects</b>	<b>D. Blaschke</b> <b>A.S. Sorin</b> <b>O.V. Teryaev</b>	Realization
BLTP	V.V. Braguta, A. Frizen, Yu.B. Ivanov, A.S. Khvorostukhin, Ya.N. Klopot, A.G. Oganessian, A. Parvan, A.A. Roenko	
MLIT	Yu.L. Kalinovsky, Zh.Zh. Musulmanbekov, E.G Nikonov	
DLNP	G.I. Lykasov	
VBLHEP	Kh.U. Abraamyan, D.A. Artemenkov, P.N. Batyuk, D.K. Dryablov, V.D. Kekelidze, M.A. Kozhin, R. Lednicky, A.G. Litvinenko, A.I. Malakhov, S.G. Reznikov, O.V. Rogachevsky, V. Voronyuk, V.N. Zhezher	
<b>5. Computer infrastructure: online and offline clusters of the distributed computer complex, system of simulation, data transfer and analysis, information and technological computer systems</b>	<b>A.G. Dolbilov</b> <b>O.V. Rogachevsky</b>	Realization

VBLHEP	V.F. Dydyshko, O.S. Fedoseev, D.G. Mel'nikov, Yu.I. Minaev, S.A. Mityukhin, D.V. Peshekhonov, I.P. Slepov, B.G. Schinov, I.V. Slepnev, S.N. Shkarovsky, V.L. Svalov	
MLIT	I.A. Kashunin, D.V. Kekelidze, V.V. Korenkov, V.V. Mitsyn, D.A. Oleynik, I.S. Pelevanyuk, A.Sh. Petrosyan, M.S. Plyashkevich, D.V. Podgainy, T.A. Strizh, V.V. Trofimov, P.V. Zrelov	
<b>6. SPD project: conceptual and technical design of the Spin Physics Detector (SPD) at the NICA collider</b>	<b>A.V. Gus'kov</b> <b>V.P. Ladygin</b>	Project preparation
VBLHEP	R.R. Akhunzyanov, V.A. Anosov, N.I. Azorsky, A.A. Baldin, E.G. Baldina, M.Yu. Barabanov, A.N. Beloborodov, A.V. Belyaev, V.V. Bleko, D.N. Bogoslovsky, I.V. Boguslavsky, V.B. Chmil, V.B. Dunin, A.A. Feshchenko, T.L. Enik, Yu.N. Filatov, O.P. Gavrischuk, A.S. Galoyan, L. Glonti, S.M. Golubykh, N.O. Grafov, A.S. Gribovsky, V.A. Gromov, S.A. Gromov, Yu.V. Gurchin, Yu.V. Gusakov, N.Ya. Ivanov, A.Yu. Isupov, E.A. Kas'yanova, G.D. Kekelidze, M.A. Kozhin, E.S. Kokoulina, E.V. Kostyukhov, Yu.A. Kopylov, P.S. Korovkin, A.Yu. Korzenev, V.A. Kramarenko, V.N. Kruglov, S.V. Khabarov, P.R. Kharyuzov, A.N. Khrenov, V.M. Lysan, R. Lednicky, A.M. Martovitsky, O. Minko, I.V. Moshkovsky, D.N. Nikiforov, S.N. Nagorny, V.A. Nikitin, V.V. Pavlov, S.S. Parzhitsky, E.E. Perepelkin, D.V. Peshekhonov, V.V. Popov, S.G. Reznikov, N.S. Rogacheva, A.B. Safonov, K.M. Salamatin, I.A. Savin, A.A. Savenkov, S.Yu. Starikova, Ya.T. Skhomenko, E.A. Streletskaya, A.I. Sheremetieva, S.S. Shimansky, O.G. Tarasov, A.A. Terekhin, O.V. Teryaev, A.V. Tishevsky, N.D. Topilin, B.L. Topko, Yu. A. Topko, Yu.A. Troyan, E.A. Usenko, E.V. Vasilieva, I.S. Volkov, P.V. Volkov, I.P. Yudin, N.I. Zamyatin, I.A. Zhukov, A.V. Zinin, E.V. Zubarev	
DLNP	V.M. Abazov, G.D. Alexeev, L.G. Afanasiev, A.P. Belova, A.V. Bobkov, T.V. Boltushkin, E.V. Brazhnikov, I.I. Denisenko, A.N. Fedorov, M. Finger, M. Finger (Jr.), V.N. Frolov, G.A. Golovanov, A.O. Gridin, K.I. Gritsay, A.V. Guskov, A.V. Karpishkov, N.V. Kirichkov, V.I. Komarov, A.V. Kulikov, V.S. Kurbatov, Zh. Kurmanaliev, S.A. Kutuzov, A. Maltsev, E.O. Mitrofanov, A.A. Pavlova, B. Parsamyan, A.A. Piskun, I.K. Prokhorov, E.P. Rezvaya, V.M. Romanov, A.I. Rudenko, A. Rymbekova, M.A. Rummyantsev, N.A. Rybakov, A.G. Samartsev, A.V. Semenov, A.A. Sinitsa, V.N. Shaikovsky, A.V. Shipilova, K. Shtejer, A.N. Skachkova, M. Slunecka, V. Sluneckova, V.V. Tereschenko, V.V. Tokmenin, N.O. Trunov, Yu.N. Uzikov, L.S. Vertogradov, Yu.L. Vertogradova, A.Yu. Verkheev, V.A. Vesenkov, N.I. Zhuravlev	
MLIT	P.V. Goncharov, D.A. Oleynik, G.A. Ososkov, A.Sh. Petrosyan, D.V. Podgainy, I.S. Pelevanyuk, V.V. Trofimov, V.V. Uzhinsky, M.I. Zuev	
BLTP	I.V. Anikin, S.V. Goloskokov, Yu. Klopot, D. Strizhik, N.I. Volchansky	

<p><b>7. Construction and development of the test zone for detector R&amp;D at the linear electron accelerator at DLNP</b> VBLHEP</p>	<p><b>A.S. Zhemchugov</b></p> <p>A.A. Baldin, T. L. Enik, O. Gavrishchuk, V.V. Kobets, Yu.A. Murin, V.G. Shabratov</p>	<p>Projecting Realization</p>
<p>DLNP</p>	<p>A.E. Brukva, M.I. Gostkin, D.L. Demin, V.G. Kruchonok, S.Yu. Porokhovoy, Ya.A. Samofalova, A.N. Trifonov, K.E. Yunenko</p>	
<p><b>8. Construction and development of infrastructure for applied and innovation research at the NICA complex</b></p>	<p><b>A.V. Butenko</b> <b>A.S. Sorin</b></p>	<p>Projecting Realization</p>
<p><b>8.1 Construction of beamlines for applied research, of stations for irradiation of electronic components and biological objects with long-range ions and stations for irradiation of electronic components with low-energy ions</b></p>	<p><b>A.V. Butenko</b> <b>E.M. Syresin</b></p>	<p>Realization</p>
<p><b>8.2 R&amp;D for the development and exploitation of irradiation stations for applied research at the NICA complex; organization of international collaboration</b></p>	<p><b>O.V. Belov</b> <b>S.I. Tyutyunnikov</b></p>	<p>Projecting Realization</p>
<p>VBLHEP</p>	<p>A.A. Baldin, E.A. Levterova, A.V. Rogachev, V.N. Shalyapin, 3 pers.</p>	
<p>DLNP</p>	<p>K.V. Belokopytova</p>	
<p>FLNP</p>	<p>M.V. Bulavin</p>	
<p><b>9. Construction of the complex of buildings with engineering infrastructure for object placement, engineering systems and carrying out R&amp;D for the NICA complex</b></p>	<p><b>N.N. Agapov</b> <b>V.D. Kekelidze</b> <b>N.D. Topilin</b></p>	<p>Projecting Realization</p>
<p><b>9.1. Technical designing, coordination of the construction of the building complex and engineering infrastructure development</b></p>	<p><b>A.V. Dudarev</b> <b>I.N. Meshkov</b></p>	<p>Projecting Realization</p>
<p><b>9.2. R&amp;D, production of prototypes and full-scale superconducting magnets for the NICA booster and collider</b></p>	<p><b>G.G. Khodzhibagiyan</b></p>	<p>Projecting Realization</p>
<p>VBLHEP</p>	<p>N.N. Agapov, V.V. Agapova, A.S. Averichev, A.M. Bazanov, N.P. Bazylev, V.I. Batin, N.A. Blinov, Yu.T. Borzunov, V.V. Borisov, A.A. Bortsova, A.V. Butenko, A.V. Bychkov, S.A. Dolgy, A.M. Donyagin, V.M. Drobin, N.A. Filippov, E.Yu. Filippova, E. Fischer, A.R. Galimov, O.M. Golubitsky, Yu.V. Gusakov, E.Yu. Ivanenko, V.N. Karpinsky, R.A. Karpunin, I.E. Karpunina, H.G. Khodzhibagiyan, S.Yu. Kolesnikov, A.V. Konstantinov, V.S. Korolev, S.A. Kostromin,</p>	



A.V. Kudashkin, G.L. Kuznetsov, E.A. Kulikov, O.A. Kunchenko, V.I. Lipchenko, D.V. Lobanov, A.A. Makarov, Yu.A. Mitrofanova, A.Yu. Merkur'ev, A.V. Nesterov, D.N. Nikiforov, M.S. Novikov, A.L. Osipenkov, R.V. Pivin, D.O. Ponkin, T.F. Prakhova, A.S. Sergeev, S.A. Smirnov, A.V. Shabunov, M.M. Shandov, A.V. Shemchuk, E.V. Shevtchenko, N.D. Topilin, Yu.A. Tumanova, A.S. Vinogradov, N.A. Zhil'tsova

MLIT

P.G. Akishin

**9.3. Upgrade and development of electric power and technological nets aimed at the increasing of economics and technical efficiency**

**N.N. Agapov  
N.V. Semin**

Projecting Realization
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VBLHEP

A.V. Alfeev, E. Fischer, A.M. Karetnik, H.G. Khodzhbagiyani, A.A. Makarov, M.I. Migulin, M.S. Novikov, E.V. Serochkin, V.M. Stepanov, A.N. Sotnikov, A.V. Shabunov, V.Yu. Shilov, O.M. Timoshenko, N.D. Topilin, V.P. Tchernyaev

AS&CC Office

Yu.N. Balandin, I.S. Frolov, L.I. Tikhomirov

OCE

V.N. Buchnev, 2 pers.

LRB

G.N. Timoshenko, 3 pers.

**Collaboration**

**Country or International Organization**

**City**

**Institute or laboratory**

Armenia

Yerevan

Foundation ANSL  
YSU

Australia

Sydney, NSW

Univ.

Azerbaijan

Baku

NNRC

Belarus

Minsk

BSUIR  
INP BSU  
IP NASB  
JIPNR-Sosny NASB  
PTI NASB  
SPMRC NASB

Bulgaria

Blagoevgrad

SWU

Plovdiv

PU

Sofia

INRNE BAS  
ISSP BAS  
LTD BAS  
SU

CERN

Geneva

CERN

Chile

Valparaiso

UTFSM

China

Beijing

"Tsinghua"

Hefei

CIAE  
IHEP CAS  
IPP CAS  
USTC

Hengyang

USC

Huzhou

HU

Jinan

SDU

	Lanzhou	IMP CAS
	Shanghai	Fudan
		SINAP CAS
	Wuhan	CCNU
	Yichang	CTGU
Cuba	Havana	InSTEC
Czech Republic	Liberec	TUL
	Olomouc	UP
	Prague	CTU
		CU
		VP
	Rez	NPI CAS
	Vitkovice	VHM
Egypt	Cairo	ECTP
	Giza	CU
France	Nantes	SUBATECH
	Saclay	CEA
Georgia	Tbilisi	AIP TSU
		GTU
Germany	Darmstadt	GSI
		TU Darmstadt
	Dresden	ILK
	Erlangen	FAU
	Frankfurt/Main	FIAS
		Univ.
	Giessen	JLU
	Julich	FZJ
	Mainz	JGU
	Regensburg	UR
	Tubingen	Univ.
Israel	Jerusalem	HUJI
	Tel Aviv	TAU
Italy	Brescia	Forgiatura Morandini
	Genoa	ASG
	Turin	INFN
Japan	Nagoya	Nagoya Univ.
	Tokyo	Nihon Univ.
Mexico	Mexico City	UNAM
	Puebla	BUAP
Moldova	Chisinau	IAP
		MSU
Mongolia	Ulaanbaatar	IPT MAS
Poland	Chorzow	Frako-Term
	Otwock (Swierk)	NCBJ
	Warsaw	WUT
	Wroclaw	ILT&SR PAS
		UW
Romania	Bucharest	IFIN-HH
		INCDIE ICPE-CA
	Magurele	INOE2000

Russia	Belgorod	BelSU
	Chernogolovka	LITP RAS
	Dolgoprudny	MIPT
	Dubna	PELCOM
	Fryazino	ISTOK
	Gatchina	NRC KI PNPI
	Kazan	Compressormash
		Spetshmash
		Cryogenmash
		Geliymash
		IBMP RAS
		ITEP
		LPI RAS
		MIREA
		MSU
		NNRU "MEPhI"
	Moscow	NRC KI
		SINP MSU
		VEI
		INR RAS
BINP SB RAS		
STL "Zaryad"		
SRSPU NPI		
IHEP		
SU		
KRI		
Moscow, Troitsk	Neva-Magnet	
	SPbSPU	
	SPbSU	
	DM Komi SC UrB RAS	
	NPI TPU	
	NOSU	
	FEFU	
	TECHNOLOGY	
	Univ.	
	IMS SAS	
Novosibirsk	UPJS	
	UZ	
Novocherkassk	UZ	
	UJ	
Protvino	WITS	
Samara	iThemba LABS	
St. Petersburg	SU	
Syktyvkar	Univ.	
	ISMA NASU	
Tomsk	KhNU	
Vladikavkaz	LTU	
Vladivostok	NSC KIPT	
Zhukovsky	BITP NASU	
Belgrade	Fermilab	
	MIT	
Bratislava	SUNY	
Kosice	BNL	
Zilina		
Johannesburg		
Somerset West		
Stellenbosch		
Stockholm		
Bolu		
Kharkov		
USA	Kiev	
	Batavia, IL	
	Cambridge, MA	
	Stony Brook, NY	
	Upton, NY	
Serbia		
Slovakia		
South Africa		
Sweden		
Turkey		
Ukraine		

## **Advanced Studies of Systems of New-Generation Accelerators and Colliders for Fundamental and Applied Research**

**Leader:** G.D. Shirkov  
V.V. Glagolev

### **Participating countries and international organizations:**

Armenia, Belarus, CERN, Georgia, Germany, Italy, Russia, Slovakia, Uzbekistan.

### **Issues addressed and main goals of research:**

Creating a network of five Precision Laser Inclinometers (PLI); creating a prototype of an amplitude interferometric length meter for a length of 16 m; creating a prototype of a laser reference line for a length of 128 m; creating a prototype of a seismic-stabilized research platform based on the PLI. Investigation of various carbon-based transmission photocathodes, installation of the second beamline with a 213-nm laser at the photogun bench, development of the photoinjector bench: 150-KeV electron energy achievement, development of radiation safety, interlock and control systems. Development, determination of design parameters and commissioning of the LINAC-200 linear electron accelerator with the aim of its experimental and educational applications. Optimization of accelerator parameters for users. Maintenance of the FLASH infrared undulator and participation in its experimental program, as well as in the new undulator development; development of photon diagnostics for FLASH, FLASH2 and XFEL and experiment participation. Experimental investigations of 3D ellipsoidal shape electron bunches with small emittances at PITZ with the new laser system. Preparation of proposals and start of JINR participation in international collaborations on future high-energy colliders.

### **Expected results in the current year:**

- Fabrication of the nanostructured carbon photocathodes and investigation of their electrophysical properties ( $\lambda = 213 / 266$  nm). Assembling of the pepper-pot emittance measurement system main components for the photoinjector bench. Vacuum system assembling and pumping. Design, fabrication and assembling of a cryopump for the bench vacuum system. Assembling, tuning and calibration of the nanosecond range high-sensitivity electron bunch charge sensor prototype. Bench startup with the energy of 120 keV.
- Optimization of the LINAC-200 beam parameters at 200 MeV. Extraction of the beam with wide-range parameters from single electrons to 30 mA with the repetition rate up to 25 Hz into the atmosphere, optimization of beam parameters for users. Manufacturing of the beam parallel transfer system (DLNP program) after the 2nd and 3rd accelerating stations. Modernization of the cooling, control and interlock systems.
- Development and creation of an absolute length meter with micron resolution for lengths of 1-10 m. Determining the sensitivity of the meter on a length of 0.1 m. R&D of the creation of a 128-meter laser reference line with the ability to measure the spatial position of the Measured Point on a controlled object (non-destructive testing). Measurement of microseismic activity at CERN and assessment of the effect of microseisms on the luminosity of the LHC collider, development of technical specifications for design and software of a small-sized PLI.
- Investigation of the electron beam and FEL physics: generation of infrared radiation from the JINR undulator at FLASH and measurements of a longitudinal bunch profile on the basis of this radiation; diagnostics of electron bunches at FLASH2 by using microchannel plate detectors; test experiments with XFEL microchannel plate detectors on the PETRA III synchrotron sources, experimental investigations of the 3D ellipsoidal shape electron bunches at PITZ with the new laser system.
- Preparation of proposals for JINR participation in international collaborations on future high-energy colliders. Analysis of 6-T high-efficient dipole magnets aimed at the FCC "low energy" pp-collider option at CERN.

## List of projects:

Project	Leader	Priority (period of realisation)
1. Precision laser metrology for accelerators and detector complexes	V.V. Glagolev M.V. Lyablin	1 (2016-2023)

## List of Activities:

Activity or Experiment Laboratory or another Division of JINR Responsible person	Leaders Main researchers	Status
<b>1. R&amp;D of Photoinjecting systems</b>  VBLHEP	<b>N.I. Balalykin</b> <b>M.A. Nozdrin</b>  V.F. Minashkin, V.G. Shabratov, A.V. Shevelkin	Technical proposal Realization
<b>2. LINAC-200 electron accelerator</b>  VBLHEP	<b>G.D. Shirkov</b> <b>V.V. Kobets</b>  N.I. Garanzha, V.F. Minashkin, M.A. Nozdrin, A.V. Skrypnik, A.G. Sorokin, V.G. Shabratov, A.S. Slepnev	Technical proposal Realization
DLNP	E.M. Acosta, A.E. Brukva, D.S. Shokin, A.S. Zhemchugov	
UC	D.S. Belozerov, K.B. Gikal, S.Z. Pakulyak, K.A. Verlamov, D.A. Zlydenny	
<b>3. Precision laser metrology for accelerators and detector complexes</b> DLNP	<b>V.V. Glagolev</b> <b>M.V. Lyablin</b>  I.V. Bednyakov, Yu.I. Davidov, V.I. Kolomoets, S.M. Kolomoets, A.A. Pluzhnikov, A.V. Sazonova, S.N. Studenov, G.T. Torosyan	Technical proposal Realization
BLTP	A.N. Baushev	
GA&C	G.V. Trubnikov	
<b>4. R&amp;D of free electron lasers</b>  UC	<b>E.M. Syresin</b> <b>O.I. Brovko</b> <b>M.V. Yurkov</b>  A.F. Chesnov, N.A. Morozov, D.C. Petrov	Technical proposal Realization
<b>5. Preparation of proposals and start of JINR participation in international collaborations on future high-energy colliders</b>	<b>G.D. Shirkov</b>	Program preparation

## **Colaboration**

### **Country or International Organization**

Armenia

Belarus

CERN

Georgia

Germany

Italy

Russia

Slovakia

Uzbekistan

### **City**

Garni

Gyumri

Yerevan

Minsk

Geneva

Tbilisi

Hamburg

Pisa

Nizhny Novgorod

Petropavlovsk-Kamchatsky

Bratislava

Tashkent

### **Institute or laboratory**

GGO

IGES NAS RA

Shirak Technologies

INP BSU

CERN

HEPI-TSU

DESY

INFN

IAP RAS

FRC GC RAS

KSU

IEE SAS

AS RUz

IS AS RUz

## Study of Polarization Phenomena and Spin Effects at the JINR Nuclotron-M Facility

**Leader:** E.A. Strokovsky  
**Deputies:** N.M. Piskunov  
 V.P. Ladygin  
 R.A. Shindin

### Participating countries and international organizations:

Bulgaria, CERN, Czech Republic, France, Germany, Japan, Poland, Romania, Russia, Slovakia, Switzerland, Sweden, United Kingdom, USA, Uzbekistan.

### Issues addressed and main goals of research:

Polarization studies are undoubtedly relevant now. They combine the efforts of the JINR Laboratories and many foreign laboratories, both participating and non-participating countries, in the design and conduct of experiments using unique beams of polarized deuterons with energies ranging from 5 MeV per nucleon to 5.6 GeV/n, secondary beams of polarized protons and neutrons, as well as beams of polarized protons directly accelerated in the Nuclotron. The possibility of obtaining beams of accelerated polarized protons in the Nuclotron without significant investment, demonstrated in 2017, became the basis for intensifying work on the spin program of the NICA project and, in particular, for the development of polarimetry techniques, the creation of new methods for precise control of the direction of the spin of protons, deuterons and other particles. This part of the work on the topic is directly related to the creation of the NICA complex and the testing of a new approach to controlling the polarization in the spin transparency mode. Of undoubted interest is also the study of the possibility of setting up experiments at the collider to measure EDM and parity violation. The most important scientific and methodological direction of work within the framework of the topic is the development of infrastructure for conducting research with polarized beams, namely: the creation and development of systems for polarimetry and spin direction control. At the forthcoming stage of work, due to the concentration of efforts on the implementation of the NICA project, this component also has the first priority. Within the framework of the theme, two projects are being carried out: ALPOM-2 and DSS. Preparation of the project on spin effects measurements in nucleon-nuclear scattering with using Movable Polarized Target Saclay-ANL-JINR (MPT) and Delta-Sigma and Delta-2 spectrometers. Extension proposals for these projects for 2019-2023. were reported at the STC VBLHEP in April 2021 and approved with a recommendation to assign the first priority to these works. Taking into account the presence of polarized beams, new experimental data will be obtained on the study of charge-exchange processes, on the study of the structure of 2- and 3-nucleon correlations in the reactions of deuteron-proton elastic scattering and deuteron breakup (experiments on the internal target of the Nuclotron), by measuring tensor analyzing power and spin correlation in the dp scattering reaction in the deuteron core region, as well as other processes that are important for the development of theoretical models describing the interactions of the simplest nuclear systems with allowance for relativism and the contribution of the meson and quark-gluon components of the internal motion of constituents in nucleons.

### Expected results in the current year:

- Works:
  - a) testing a low-energy polarimeter for protons and deuterons on the injection channel into the Nuclotron;
  - b) designing a polarizing helium-3 target.
- Carrying out work on approved projects and agreements, taking into account their resource availability, including ALPOM-2 and DSS projects. Completion of the data analysis on the analyzing powers  $A_y$ ,  $A_{yy}$  and  $A_{xx}$  in deuteron-proton elastic scattering at the energies 400-1300 MeV. Publication and reports of the results.
- Creation of a project for the placement of polarimetry elements for beam diagnostics and polarization control at the SPD section of the NICA collider ring.

- Modernization of the MPT. Preparation of the Delta-Sigma and Delta-2 spectrometers. Carrying out calculation and design work on detector around target (DTS).
- Continuation of the development of new calculation methods of the amplitudes and polarization characteristics of deuteron fragmentation and deuteron elastic scattering on protons and nuclei taking into account FSI and relativistic effects.
- Analysis of the possibility of staging new experiments with polarized beams of protons and deuterons at the NICA complex, in particular, on the search for EDM.

### List of projects:

Project	Leader	Priority (period of realisation)
1. ALPOM-2	N.M. Piskunov V.P. Ladygin	1 (2010-2023)
2. DSS	M. Janek K. Sekiguchi	1 (2010-2023)

### List of Activities:

Activity or Experiment Laboratory or other Division of JINR Responsible person	Leaders Main researchers	Status
<b>1. Development of spin physics research infrastructure at the Nuclotron and other facilities. Design, construction and development of spin control and polarimetry systems. The EDM searching analysis at NICA</b> VBLHEP	<b>A.V. Butenko</b>	Realization
DLNP	A.V. Averyanov, Yu.N. Filatov, V.V. Fimushkin, V.V. Glagolev, M.Yu. Korobitsyna, D.O. Krivenkov, R.A. Kuzyakin, M.V. Kulikov, V.P. Ladygin, K.S. Legostaeva, A.N. Livanov, N.M. Piskunov, S.G. Reznikov, R.A. Shindin, E.A. Stokovsky, A.M. Taratin	
MLIT	M. Finger, M. Finger (Jr.), Yu.N. Uzikov	
<b>2. ALPOM-2 Project</b> VBLHEP	<b>N.M. Piskunov</b> <b>E. Tomasi-Gustafsson</b> <b>C.F. Perdrisat</b> <b>V. Punjabi</b>	Data taking Data analysis Installation development
	S.N. Bazylev, Yu.P. Bushuev, A.A. Druzhinin, O.P. Gavrishchuk, V.V. Glagolev, D.A. Kirillov, A.N. Livanov, A.A. Povtoreyko, P.A. Rukoyatkin, R.A. Shindin, I.M. Sitnik	
<b>3. DSS Project</b> VBLHEP	<b>V.P. Ladygin</b> <b>M. Janek</b> <b>K. Sekiguchi</b>	Data taking Data analysis Installation development
DLNP	E.V. Chernykh, Yu.V. Gurchin, A.Yu. Isupov, A.N. Khrenov, N.B. Ladygina, A.N. Livanov, S.G. Reznikov, A.A. Terekhin, A.V. Tishevsky, I.S. Volkov	
	G.I. Lykasov	



**4. Delta-Sigma setup.  
Tests and inspections of the  
basic MPT systems, carrying  
out design and design work  
on new cryostat for MPT to have  
the polarizing and holding  
magnetic fields**

VBLHEP

DLNP

FLNP

**5. Experiments on the program  
STRELA at polarized beam**

VBLHEP

**6. Theoretical calculations  
Of polarized processes**

BLTP

VBLHEP

**R.A. Shindin**  
**Yu.A. Usov (DLNP)**  
**M. Finger (Jr.) (DLNP)**

Project preparation

C.P. Avdeev, A.A. Druzhinin, O.P. Gavrishchuk, N.O. Grafov,  
D.A. Kirillov, A.N. Livanov, A.P. Nagaytsev

N.S. Borisov, N.A. Bazhanov, M. Finger

A.N. Chernikov

**N.M. Piskunov**

Data taking

S.N. Bazylev, Yu.P. Bushuev, V.V. Glagolev, D.A. Kirillov,  
A.A. Povtoreyko, I.M. Sitnik

**V.V. Burov**  
**V.K. Lukyanov**

Data analysis

V.V. Burov

A.P. Ierusalimov, N.B. Ladygina

**Collaboration**

**Country or International Organization**

Bulgaria

CERN

Czech Republic

France

Germany

Japan

Poland

Romania

Russia

Slovakia

Sweden

Switzerland

**City**

Sofia

Geneva

Brno

Prague

Rez

Orsay

Saclay

Bochum

Dresden

Freiburg

Julich

Tubingen

Hiroshima

Wako

Otwock (Swierk)

Bucharest

Belgorod

Moscow

Moscow, Troitsk

Bratislava

Kosice

Zilina

Uppsala

Villigen

**Institute or laboratory**

UCTM

CERN

ISI CAS

CTU

CU

UJV

IPN Orsay

IRFU

RUB

TU Dresden

FMF

FZJ

Univ.

Hiroshima Univ.

RIKEN

NCBJ

INCDIE ICPE-CA

BeISU

LPI RAS

NRC KI

INR RAS

LPP LPI RAS

IP SAS

IEP SAS

UPJS

UZ

TSL

PSI

United Kingdom  
USA

Glasgow  
Newport News, VA  
Norfolk, VA  
Upton, NY  
Williamsburg, VA  
Tashkent

U of G  
JLab  
NSU  
BNL  
W&M  
Assoc. P.-S. PTI  
INP AS RUz

Uzbekistan

## **Research on Relativistic Heavy and Light Ion Physics. Experiments at the Accelerator Complex Nuclotron/NICA at JINR and CERN SPS**

**Leader:** A.I. Malakhov  
**Deputy:** S.V. Afanasiev

### **Participating countries and international organizations:**

Armenia, Bulgaria, CERN, China, Czech Republic, Germany, Japan, India, Mongolia, Poland, Romania, Russia, Slovakia, Switzerland, USA, Uzbekistan.

### **Issues addressed and main goals of research:**

Study of new phenomena in multiple particle productions associated with the manifestation of the quark and gluon degrees of freedom in the interaction of relativistic nuclei. Study of nucleon and nuclear interactions at the VBLHEP accelerator complex, CERN SPS. Energy scan of interactions of nuclei at 20-158 GeV/nucleon energies and the study of their dependence on the atomic number of nuclei. To search for the critical point on the phase diagram of nuclear matter at the NA61(SPS, CERN). Study of hadron production in hadron-nucleus interactions. Use of the obtained data for the precision calculations of neutrino spectra and fluxes in the accelerator experiments to study the neutrino oscillations. Investigation of nucleon clustering and the contribution of unstable nuclear-molecular States to the dissociation of light stable and radioactive isotopes, as well as the properties of rarefied baryonic matter in the dissociation of heavy nuclei. Experimental and theoretical study of deep subthreshold, cumulative processes, the formation of hadrons and antimatter in the transition energy region. Investigation of processes in the region of large  $P_T$  ( $P_T \geq 1$  GeV/c) in non-cumulative and cumulative kinematic regions at SPIN and FODS setups. Study of the behavior of elementary particles, nucleon resonances and nucleon fluctuations in nuclear matter on the SCAN spectrometer. Preparation of proposals of the experiments at the VBLHEP accelerator complex on the Nuclotron extracted beams and NICA Collider. Study of the short range nucleon-nucleon correlations and the cluster structure of the nuclei using the beams of ions, polarized protons and deuterons at the internal target of the Nuclotron in the framework of the SCAN-3 project.

### **Expected major results in the current year:**

- Investigation of new phenomena in multiple particle productions associated with the manifestation of the quark and gluon degrees of freedom.
- Preparation and performance of the experiments on the internal and extracted Nuclotron beams.
- NA61/SHINE data analysis (SPS, CERN). Study of hadron production in hadron-nucleus interactions. Use of the obtained data for the precision calculation of neutrino spectra and fluxes in the accelerator experiments to study the neutrino oscillations. Modernization of the TOF system. Configuration and testing of the three-arms SCAN magnetic spectrometer. Modernization of electronics for data taken. Analysis of experimental data.
- Analysis of the experimental data on the processes of the multiple emission of intermediate mass fragments on the beams of relativistic light ions using a  $4\pi$  PHASE-3 setup for the registration of nuclear fragments. Performing data analysis to determine the mechanism of multifragmentation and to obtain new information about the nuclear phase transitions "liquid-fog" and "liquid-gas". Investigation of properties of hot nuclei formed in the collisions of light relativistic ions with heavy targets. Production of the detector system for the registration of the decay of hypernuclei.
- Verification of the consequences of the principles of self-similarity and weakening of correlations in the formation of multiple particles.
- Upgrade of the SCAN setup. Analysis of the experimental data on the behavior of nucleon resonances and nucleon fluctuations in nuclei, on the search and study of properties of the bound state-meson in nuclear matter, study of np and pp correlations. Modernization of the Internal target of the Nuclotron.

- Search and study of the Hoyle state and more complex nuclear-molecular States in the dissociation of light nuclei. Analysis of the isotopic composition of the fragmentation of heavy nuclei. Use of automated microscopes, as well as improvement of the NE technology.
- Updating the Marusya installation for conducting the experimental studies with the extracted Nuclotron beams. Investigation of A-dependences of rare subthreshold and cumulative processes of the formation of pions, kaons and antiprotons depending on the type and energy of the incoming nuclei, the momentum and angle of the detected particles. Carrying out correlation experiments with registration of groups of particles in the final state, one of which is cumulative.
- Collection, processing and digitization of the film information obtained using bubble chambers and in electronic experiments with fixed targets under the conditions of registration of multiple birth of particles in the energy range of 1-300 GeV.
- Use of heavy and light ions for applied research.
- Analysis of the experimental data obtained in the PHENIX experiment.
- Processing of the experimental data from 5-9 Runs at the PHENIX setup. Participation in the formation of the program for e-RHIC.
- Preparation of a project to study spin asymmetries at the LHEP accelerator complex.
- Collection of new experimental data in pA-and AA-interactions in the region of large  $p_T$  ( $p_T \geq 1$  GeV/c) at SPIN and FODS facilities, data processing and publication of results.

### List of projects:

Project	Leader	Priority (period of realisation)
1. NA61	A.I. Malakhov	1 (2012 - 2023)
2. SCAN-3	S.V. Afanasiev	1 (2017 - 2022)
2. BECQUEREL	P.I. Zarubin	1 (2022 - 2022)

### List of Activities:

Activity or Experiment	Leaders	Status
Laboratory or other Division of JINR Responsible person	Main researchers	
1. Experiment NA61/SHINE	A.I. Malakhov G.L. Melkumov	Upgrade Preparation Data analysis
VBLHEP	V.A. Babkin, M.G. Buryakov, A.V. Dmitriev, V.M. Golovatyuk, V.I. Kolesnikov, R.Yu. Kolesnikov, V.A. Kireev, V.A. Lenivenko, V.A. Matveev, M.M. Romyantsev, A.A. Zajtsev	
DLNP	V.V. Lyubushkin, G.I. Lykasov, B.A. Popov, V.V. Tereschenko	
2. Experiment BECQUEREL	P.I. Zarubin	Data taking Data analysis
VBLHEP	D.A. Artemenkov, V. Bradnova, N.K. Kornegrutsa, V.V. Rusakova, P.A. Rukoyatkin, A.A. Zaytsev	
3. Experiment FASA-3 for registration of nuclear fragments	S.P. Avdeev	Upgrade Preparation Data analysis

DLNP	V.I. Stegaylov	
FLNR	V.V. Kirakosyan, E.M. Kozulin, G.V. Mushinsky, O.V. Strekalovsky	
VBLHEP	H.U. Abraamian, Z.A. Igamkulov, V. Karach, L.V. Korniyushina, A.G. Litvinenko, P.A. Rukoyatkin, Z.A. Sadygov	
<b>4. Project SCAN-3</b>	<b>S.V. Afanasiev</b> <b>A.I. L'vov</b>	Upgrade Preparation Data analysis
VBLHEP	Yu.S. Anisimov, A.A. Baldin, V. Bekirov, D.K. Dryablov, B.V. Dubinchik, P.R. Kharyuzov, S.V. Kilchakovskaia, Yu.F. Krechetov, A.S. Kuznetsov, M. Paraypan, D.G. Sakulin, V.A. Smirnov, E.V. Sukhov, V.V. Ustinov, V. Vartik	
<b>5. Search and investigation of new phenomena using information obtained with bubble chambers and their theoretical interpretation. Creation of data base of experimental data and educational programs in the field of relativistic nuclear physics</b>	<b>A.A. Baldin</b> <b>V.V. Glagolev</b>	Data analysis
VBLHEP	S.G. Arakelyan, E.G. Baldina, A.V. Belyaev, A.V. Beloborodov, Ver.V. Bleko, Vit.V. Bleko, D.N. Bogoslovsky, A.P. Ierusalimov, V.V. Ilyushchenko, P.R. Kharyuzov, D.S. Korovkin, O.V. Rogachevsky, A.B. Safonov, A.Yu. Troyan, Yu.A. Troyan	
DLNP	N.E. Pukhaeva	
<b>6. Investigation of deep subthreshold processes, applied and educational programs at MARUSYA set up</b>	<b>A.A. Baldin</b>	Preparation Data taking
VBLHEP	V.A. Arefiev, S.V. Afanasiev, E.G. Baldina, A.V. Belyaev, S.N. Bazylev, A.I. Berlev, A.V. Beloborodov, Ver.V. Bleko, Vit.V. Bleko, D.N. Bogoslavsky, D.K. Dryablov, E.A. Efimova, P.R. Kharyuzov, D.S. Korovkin, S.Yu. Starikova, I.V. Slepnev, S.S. Shimansky, A.B. Safonov, A.Yu. Troyan, Yu.A. Troyan	
BLTP	V.V. Burov, S.G. Bondarenko	
DLNP	A.N. Fedorov	
<b>7. Investigation with light and heavy ions for applied research</b>	<b>A.I. Malakhov</b>	Realization Preparation Data taking
VBLHEP	N.N. Agapov, Yu.S. Anisimov, A.A. Baldin, E.G. Baldina, D.K. Dryablov, M. Paraypan	
<b>8. Upgrade of equipment the station of internal target of the Nuclotron</b>	<b>S.V. Afanasiev</b> <b>R.Yu. Kolesnikov</b>	Upgrade Data taking
VBLHEP	Yu.S. Anisimov, V.N. Bekirov, D.K. Dryablov, B.V. Dubinchik, S.V. Kilchakovskaia, A.S. Kuznetsov, S.N. Kuznetsov, D.G. Sakulin, T.V. Trofimov	

<p><b>9. Test of the detectors for measurements and control the luminosity at the collider NICA</b> VBLHEP</p> <p>FLNP</p>	<p><b>A.G. Litvinenko</b></p> <p>R.A. Akbarov, K.U. Abraamyan, T.Y. Bokova, Z.A. Igamkulov, L.V. Korniyushina, I.I. Migulina, G.D. Milnov, A.Z. Sadygov, Z.Y. Sadygov, V.I. Shokin</p> <p>E.I. Litvinenko</p>	<table border="1" style="margin: auto;"> <tr> <td style="padding: 5px;"> R&amp;D Technical proposal </td> </tr> </table>	R&D Technical proposal
R&D Technical proposal			
<p><b>10. Study of the short range nucleon-nucleon correlations at modernized internal target station at Nuclotron</b> VBLHEP</p>	<p><b>V.P. Ladygin</b></p> <p>Yu.V. Gurchin, A.Yu. Isupov, A.N. Khrenov, N.B. Ladygina, A.I. Malakhov, S.G. Reznikov, A.A. Terekhin, A.V. Tishevsky</p>	<table border="1" style="margin: auto;"> <tr> <td style="padding: 5px;"> Preparation Data taking </td> </tr> </table>	Preparation Data taking
Preparation Data taking			
<p><b>11. The data processing of the Phoenix experiment. Preparing a program for measurements on the RHIC</b> VBLHEP</p>	<p><b>A.G. Litvinenko</b></p> <p>K.U. Abraamyan, S.V. Afanasiev, S.P. Avdeev, A.I. Malakhov, P.A. Rukoyatkin</p>	<table border="1" style="margin: auto;"> <tr> <td style="padding: 5px;"> Upgrade Data analysis </td> </tr> </table>	Upgrade Data analysis
Upgrade Data analysis			

## Collaboration

Country or International Organization	City	Institute or laboratory
Armenia	Yerevan	Foundation ANSL YSU
Bulgaria	Blagoevgrad Sofia	AUBG INRNE BAS Inst. Microbiology BAS SU
CERN	Geneva	CERN
China	Beijing	CIAE IHEP CAS
Czech Republic	Wuhan Prague	CCNU CTU CU IMC CAS
Germany	Rez Darmstadt Frankfurt/Main	NPI CAS TU Darmstadt FIAS Univ.
India	Jaipur	Univ.
Japan	Mumbai	BARC
Mongolia	Tsukuba	Univ.
Poland	Ulaanbaatar	IPT MAS
	Krakow	INP PAS
	Lodz	UL
	Otwock (Swierk)	NCBJ
	Warsaw	UW WUT
Romania	Bucharest	IFIN-HH INCDIE ICPE-CA UB
	Constanta	UOC
	Magurele	ISS

Russia	Belgorod	BeISU
	Chernogolovka	ISMAN RAS
	Moscow	ITEP
		LPI RAS
		MSU
		SINP MSU
	Moscow, Troitsk	INR RAS
	Protvino	IHEP
	Sarov	VNIIEF
	Smolensk	SSU
	St. Petersburg	FIP
	Tomsk	TPU
	Vladikavkaz	NOSU
	VTC "Baspik"	
Slovakia	Bratislava	IP SAS
	Kosice	UPJS
Switzerland	Geneva	UniGe
USA	Berkeley, CA	Berkeley Lab
	Iowa City, IA	UIowa
	Upton, NY	BNL
Uzbekistan	Jizzakh	JSPI
	Samarkand	SSU
	Tashkent	Assoc. P.-S. PTI

## Investigation of the Properties of Nuclear Matter and Particle Structure at the Collider of Relativistic Nuclei and Polarized Protons

**Leaders:** R. Lednicky  
Yu.A. Panebratsev

### Participating countries and international organizations:

Azerbaijan, Bulgaria, Czech Republic, France, Germany, Poland, Russia, Slovakia, USA.

### Issues addressed and main goals of research:

Investigation of the properties of nuclear matter with extremely high density and temperature, search for the signatures of the quark deconfinement and possible phase transitions at the collisions of heavy nuclei at the energies of the Relativistic Heavy Ion Collider (RHIC). Measurement of spin dependent structure functions of nucleons and nuclei using polarized proton beams at RHIC.

### Expected results in the current year:

- Beam Energy Scan-II data analysis for collider mode and fixed target measurements.
- Study of spin effects in collisions of transversely polarized protons at 510 GeV and forward rapidities.
- Study of event structure, collective variables, correlation characteristics, femtosopic correlation functions and high- $p_T$  processes.
- Study of future possibility of investigation of the nuclear structure and the proton spin in  $e-p$  and  $e-A$  collisions at colliders.
- Participation in joint educational programs in relativistic nuclear physics with BNL and universities of the JINR Member States. Development of JINR educational portal.

### List of projects:

Project	Leader	Priority (period of realisation)
1. STAR	Yu.A. Panebratsev R. Lednicky	1 (2010-2023)

### List of Activities:

Activity or Experiment	Leaders	Status
Laboratory or other Division of JINR Responsible person	Main researchers	
1. <b>Beam Energy Scan-II data analysis for collider mode and fixed target measurements</b> VBLHEP	<b>Yu.A. Panebratsev</b>	Data taking Data analysis
	A. Aitbayev, A.A. Aparin, G.S. Averichev, T.G. Dedovich, V.B. Dunin, A.O. Kechechyan, O. Kenzhegulov, A.A. Korobitsyn, S.S. Panyushkina, V.V. Tikhomirov, M.V. Tokarev, G.A. Yarygin	



<p><b>2. Study of spin effects in collisions of transversely polarized protons at 510 GeV at forward rapidities</b> VBLHEP</p>	<p><b>M.V. Tokarev</b></p>	<p>Data taking Data processing</p>
<p>MLIT</p>	<p>A.A. Aparin, T.G. Dedovich, V.V. Lyuboshits, E.I. Schakhaliev, O.V. Teryaev</p>	
<p>BLTP</p>	<p>Zh.Zh. Musulmanbekov</p>	
<p><b>3. The study of event structure, collective effects, femtoscopic correlations and high-<math>p_T</math> processes</b> VBLHEP</p>	<p><b>R. Lednický</b> <b>Yu.A. Panebratsev</b></p>	<p>Realization</p>
<p>MLIT</p>	<p>G.N. Agakishiev, A.A. Aparin, T.G. Dedovich, A.O. Kechechyan, A.A. Korobitsyn, S.S. Panyushkina, E.A. Pervyshina, E.I. Schakhaliev, S.I. Snigirev, M.V. Tokarev, A. Tutebayeva</p>	
<p>MLIT</p>	<p>G.A. Ososkov</p>	
<p><b>4. Participation in the heavy ion program Hot QCD in the STAR experiment at forward rapidities</b> VBLHEP</p>	<p><b>Yu.A. Panebratsev</b></p>	<p>Data taking Data processing Data analysis</p>
<p>MLIT</p>	<p>A.A. Aitbaev, G.N. Agakishiev, A.A. Aparin, G.S. Averichev, T.G. Dedovich, A. Kenzhegulov, E.V. Potrebenikova, M.V. Tokarev, A. Tutebaeva</p>	
<p>MLIT</p>	<p>V.V. Korenkov, V.V. Mitsyn, G.A. Ososkov</p>	
<p><b>5. Development of the software and formation of the infrastructure for the STAR data processing at JINR</b> VBLHEP</p>	<p><b>Yu.A. Panebratsev</b> <b>V.V. Korenkov</b></p>	<p>Realization</p>
<p>MLIT</p>	<p>A.A. Aparin, G.N. Agakishiev, A.A. Korobitsyn, P.D. Semchukiv</p>	
<p>MLIT</p>	<p>N. Balashov, V.V. Mitsyn, G.A. Ososkov, T.A. Strizh</p>	
<p><b>6. Participation in joint educational programs in relativistic nuclear physics with BNL and universities of the JINR Member States. Development of JINR educational portal</b> VBLHEP</p>	<p><b>N.E. Sidorov</b> <b>E.V. Potrebenikova</b></p>	<p>Realization</p>
<p>UC</p>	<p>E.I. Golubeva, K.V. Klygina, M.P. Osmachko, P.D. Semchukov, N.I. Vorontsova</p>	
<p>UC</p>	<p>S.N. Balalykin, A.O. Komarova, L.V. Platonova, O.A. Smirnov, T.G. Stroganova</p>	
<p><b>7. Elaboration of proposals for the development of detectors for the study of polarization phenomena at colliders</b> VBLHEP</p>	<p><b>V.B. Dunin</b></p>	<p>Project preparation</p>
<p>VBLHEP</p>	<p>V.V. Fimushkin</p>	

**8. Study of future possibility of investigation of the nuclear structure and the proton spin in  $e-p$  and  $e-A$  collisions at colliders**  
VBLHEP

DLNP

**A.A. Aparin**

Project preparation
---------------------

V.B. Dunin, A.A. Korobitsyn, N.A. Lashmanov, S.I. Manukhov, S.S. Panyushkina, V.Yu. Rogov

A.S. Zhemchugov

**Collaboration**

**Country or International Organization**

Azerbaijan

Bulgaria

Czech Republic

France

Germany

Poland

Russia

Slovakia

USA

**City**

Baku

Sofia

Prague

Rez

Nantes

Heidelberg

Warsaw

Moscow

Protvino

St. Petersburg

Kosice

Berkeley, CA

Bloomington, IN

Chicago, IL

Lemont, IL

New Haven, CT

Stony Brook, NY

University Park, PA

Upton, NY

**Institute or laboratory**

IRP ANAS

INRNE BAS

SU

CU

IP CAS

NPI CAS

SUBATECH

Univ.

WUT

ITEP

NNRU "MEPhI"

IHEP

SPbSU

UPJS

Berkeley Lab

IU

UIC

ANL

Yale Univ.

SUNY

Penn State

BNL

## ALICE.

### Study of Interactions of Heavy Ion and Proton Beams at the LHC

**Leader:** A.S. Vodopyanov

#### Participating countries and international organizations:

Armenia, Austria, Azerbaijan, Bangladesh, Brazil, Bulgaria, CERN, China, Croatia, Cuba, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, India, Indonesia, Italy, Japan, Malta, Mexico, Netherlands, Norway, Pakistan, Peru, Poland, Republic of Korea, Romania, Russia, Slovakia, South Africa, Sri Lanka, Sweden, Thailand, Turkey, Ukraine, United Kingdom, USA.

#### Issues addressed and main goals of research:

- Participation in the preparation of ALICE upgrade (Photon spectrometer PHOS, assembly of the setup).
- Participation in the upgrade of ALICE Inner Tracking System (ITS).
- Realization of experiments at the LHC, data analysis, preparation of publications.
- Physics research program at the ALICE detector.
- Development and upgrade of data analysis computing GRID-ALICE in Russia.
- Participation in the maintenance and operation tasks on the ALICE detector.

#### Expected results in the current year:

- Participation in the preparation of the proposal for the upgrade of photon spectrometer PHOS.
- Participation in the development of the ALICE ITS data control system.
- Participation in the physics project preparation.
- Physics simulation of heavy ions and protons interactions at LHC energies.
- Data analysis. Preparation of publications.
- Upgrade, testing and supporting of GRID.
- Participation in the maintenance and operation tasks on the ALICE detector.

#### List of projects:

Project	Leader	Priority (period of realisation)
1. ALICE	A.S. Vodopyanov	1 (2010-2023)

#### List of Activities

Activity or Experiment	Leaders	Status
Laboratory or other Division of JINR Responsible person	Main researchers	
1. Particle detectors	A.S. Vodopyanov	Realization
VBLHEP	V.I. Astakhov, V.A. Arefiev, V.H. Dodokhov, E.M. Klass, V.I. Lobanov, P.V. Nomokonov, I.A. Rufanov	

<p><b>2. Physical process simulation and data analysis</b> VBLHEP</p> <p>DLNP</p> <p>BLTP</p>	<p><b>B.V. Batyunya</b></p> <p>M.Yu. Barabanov, S.S. Grigoryan, A.V. Kuznetsov, L.V. Malinina, K.P. Mikhaylov, V.N. Pozdnyakov, E.P. Rogochaya, G.E. Romanenko, K. Roslon, B.D. Rumyantsev, Yu.L. Vertogradova</p> <p>G.I. Lykasov</p> <p>D. Blaschke, A.V. Sidorov</p>	<table border="1" style="margin-left: auto; margin-right: auto;"> <tr> <td>Realization</td> </tr> </table>	Realization
Realization			
<p><b>3. ALICE. Computing in the distributed environment-GRID</b> VBLHEP</p> <p>MLIT</p>	<p><b>A.S. Vodopyanov</b></p> <p>B.V. Batyunya, G.G. Stiforov</p> <p>A.O. Kondratiev, V.V. Mitsyn</p>	<table border="1" style="margin-left: auto; margin-right: auto;"> <tr> <td>Realization</td> </tr> </table>	Realization
Realization			
<p><b>4. Photon Spectrometer PHOS</b> VBLHEP</p>	<p><b>A.S. Vodopyanov</b> <b>P.V. Nomokonov</b></p> <p>N.V. Gorbunov, A.V. Kuznetsov, Yu.P. Petukhov, S.A. Rufanov</p>	<table border="1" style="margin-left: auto; margin-right: auto;"> <tr> <td>Realization</td> </tr> </table>	Realization
Realization			
<p><b>5. Inner Tracking System ITS</b> VBLHEP</p>	<p><b>A.S. Vodopyanov</b></p> <p>N.A. Baldin, R.A. Diaz, V.Kh. Dodokhov, S.C. Ceballos, M.A. Torshin</p>	<table border="1" style="margin-left: auto; margin-right: auto;"> <tr> <td>Realization</td> </tr> </table>	Realization
Realization			

## Collaboration

Country or International Organization	City	Institute or laboratory
Armenia	Yerevan	Foundation ANSL
Austria	Vienna	SMI
Azerbaijan	Baku	NNRC
Bangladesh	Dhaka	DU
Brazil	Campinas, SP	UNICAMP
	Porto Alegre, RS	UFRGS
	Santo Andre, SP	UFABC
	Sao Paulo, SP	USP
Bulgaria	Sofia	IAPS
		SU
CERN	Geneva	CERN
China	Beijing	CIAE
	Hefei	USTC
	Shanghai	SINAP CAS
	Wuhan	CCNU
		HBUT
Croatia	Split	Univ.
	Zagreb	RBI
		UZ
Cuba	Havana	CEADEN
Czech Republic	Prague	CTU
		IP CAS
	Rez	UJV
Denmark	Copenhagen	NBI
Finland	Helsinki	HIP
	Jyvaskyla	UJ

France	Clermont-Ferrand	LPC	
	Grenoble	LPSC	
	Lyon	UL	
	Nantes	SUBATECH	
	Orsay	IJCLab	
	Saclay	IRFU	
	Strasbourg	IPHC	
	Villeurbanne	CC IN2P3	
	Germany	Bonn	UniBonn
		Darmstadt	GSI
		TU Darmstadt	
Frankfurt/Main		FIAS	
		Univ.	
Heidelberg		Univ.	
Munich		TUM	
Munster		WWU	
Tubingen		Univ.	
Worms		ZTT	
Greece	Athens	UoA	
Hungary	Budapest	Wigner RCP	
India	Aligarh	AMU	
	Bhubaneswar	IOP	
	Chandigarh	PU	
	Guwahati	GU	
	Indore	IIT Indore	
	Jaipur	Univ.	
	Jammu	Univ.	
	Jatani	NISER	
	Kolkata	BNC	
		SINP	
		UC	
		VECC	
	Mumbai	BARC	
		IIT Bombay	
	Indonesia	Jakarta	LIPI
	Italy	Alessandria	DiSIT UPO
Bari		DIF	
		INFN	
		Poliba	
Bologna		INFN	
		UniBo	
Brescia		UNIBS	
Cagliari		INFN	
		UniCa	
Catania		INFN	
		UniCT	
Erice		EMFCSC	
Foggia		Unifg	
Frascati		INFN LNF	
Legnaro		INFN LNL	
Messina		UniMe	
Padua	INFN		
	UniPd		
Pavia	UniPv		

	Rome	CREF INFN Univ. "La Sapienza"
	Salerno	INFN
	Trieste	INFN UNITR
	Turin	INFN Polito UniTo
Japan	Vercelli	UPO
	Hiroshima	Hiroshima Univ.
	Nagasaki	NiAS
	Nara	NWU
	Osaka	RCNP
	Saga	Saga Univ.
	Tokai	JAEA
	Tokyo	UT
	Tsukuba	Univ.
	Wako	RIKEN
Malta	Msida	UM
Mexico	Culiacan	UAS
	Mexico City	Cinvestav UNAM
	Puebla	BUAP
Netherlands	Amsterdam	AUAS NIKHEF
	Utrecht	UU
Norway	Bergen	HVL UiB
	Oslo	UiO
	Tonsberg	USN
Pakistan	Islamabad	COMSATS PINSTECH
Peru	Lima	PUCP
Poland	Krakow	AGH INP PAS
	Otwock (Swierk)	NCBJ
	Warsaw	WUT
Republic of Korea	Cheongju	CBNU
	Daejeon	KIST
	Gangneung	GWNU
	Incheon	Inha
	Jeonju	JBNU
	Pusan	PNU
	Seoul	Konkuk Univ. SJU Yonsei Univ.
Romania	Bucharest	IFIN-HH UPB
	Magurele	ISS

Russia	Gatchina Moscow	NRC KI PNPI ITEP NNRU "MEPhI" NRC KI SINP MSU
	Moscow, Troitsk Novosibirsk Protvino Sarov St. Petersburg	INR RAS BINP SB RAS IHEP VNIIEF FIP
Slovakia	Bratislava Kosice	CU IEP SAS TUKE UPJS
South Africa	Cape Town Johannesburg Somerset West	UCT WITS iThemba LABS
Sri Lanka	Moratuwa	Univ.
Sweden	Lund	LU
Thailand	Bangkok Chachoengsao Nakhon Ratchasima	KMUTT TMEC SLRI SUT
Turkey	Istanbul	Univ. YTU
	Konya	Karatay Univ.
Ukraine	Kharkov Kiev	NSC KIPT BITP NASU
United Kingdom	Birmingham Daresbury Derby Liverpool	Univ. DL Univ. Univ.
USA	Austin, TX Berkeley, CA	UT Berkeley Lab UC
	Chicago, IL Columbus, OH Detroit, MI Houston, TX Knoxville, TN Los Alamos, NM New Haven, CT Oak Ridge, TN Omaha, NE San Luis Obispo, CA West Lafayette, IN	CSU OSU WSU UH UTK LANL Yale Univ. ORNL Creighton Univ. Cal Poly Purdue Univ.

## Development and Construction of the Prototype of a Complex for Radiotherapy and Applied Research with Heavy-Ion Beams at the Nuclotron-M

**Leader:** S.I. Tyutyunnikov

**Deputy leader:** A.A. Baldin

### Participating countries and international organizations:

Armenia, Australia, Belarus, Bulgaria, Czech Republic, Moldova, Mongolia, Romania, Russia, Slovakia, Ukraine.

### Issues addressed and main goals of research:

Investigation of various subcritical setups and using them for energy 104alibration and radioactive waste transmutation, research of radiation hardness of materials. The quasi-infinite target (Project E&T&RM).

### Expected main results:

Receiving data about the multiplicities and special distribution of energy-time neutron spectra. Research on massive targets of natural (depleted) uranium and thorium energy production capabilities and processing of radioactive waste, the study of radiation hardness of superconductors by the beams of neutrons and protons.

### Expected results in the current year:

- Installation of a big uranium target at the Phazotron in DLNP, beam adjustment on the target.
- Thermocouple device installation and 104alibration at the massive uranium target "BURAN".
- Pilot operation of the neutron spectrometer on recoil protons on the "BURAN" under irradiation with protons at Phazotron.
- Investigation of neutron leakage from the surface of the massive uranium target by activation method.
- Investigation of impact of high-power laser radiation on the radioactive decay of minor actinides.
- Investigation of radiation defects in high-temperature superconductors under the irradiation with protons with energy  $E = 660 \text{ MeV}$ .

### List of projects:

Project	Leader	Priority (period of realisation)
1. E&T&RM	S.I. Tyutyunnikov	2 (2018-2023)

### List of Activities:

Activity or Experiment	Leaders	Status
Laboratory or other Division of JINR Responsible person	Main researchers	
1. Development of the technical specifications for the detector system of setup "big uranium target" on the basis of the temperature sensor and silicon photomultipliers VBLHEP	S.I. Tyutyunnikov A.A. Solnyshkin A.A. Baldin Z. Y. Sadygov R.A. Akbarov  A.I. Berlev, I.P. Yudin	Realization



<p><b>2. Design, manufacture of detectors for the measurement of ion energy in the range of <math>E_e=0.1</math> GeV/nucleon on the Nuclotron-M beams</b></p> <p>VBLHEP</p>	<p><b>N.I. Zamyatin</b> <b>Y.S. Kopylov</b></p> <p>S.V. Khabarov, Yu.S. Kovalev, O.G. Tarasov</p>	<div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;">Realization</div>
<p><b>3. Upgrade of spectrum-analytical complex for activation measurements</b></p> <p>VBLHEP</p> <p>DLNP</p>	<p><b>V.N. Shalyapin</b> <b>V.I. Stegaylov</b></p> <p>I.A. Kryachko, M. Paraipan, E.V. Strekalovskaya, Toan Tran Ngor</p> <p>V.I. Stegaylov</p>	<div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;">Realization</div>
<p><b>4. Study of neutron fields of big uranium target at the Phazotron under the irradiation of proton <math>E_p=0.66</math> GeV</b></p> <p>VBLHEP</p> <p>DLNP</p>	<p><b>S.I. Tyutyunnikov</b> <b>A.A. Solnyshkin</b> <b>G.I. Smirnov</b> <b>M. Paraipan</b> <b>V.V. Pronskih</b> <b>E.A. Levterova</b> <b>V.M. Dzhavadova</b></p> <p>A.A. Baldin, Yu.S. Kovalyev, V.N.Shalyapin, A.V. Vishnesky, I.P. Yudin</p> <p>V.I. Stegaylov</p>	<div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;">Data taking</div>
<p><b>5. Production of the monitoring elements for the superconducting Systems</b></p>	<p><b>Yu.P. Filippov</b></p>	<div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;">R&amp;D</div>
<p><b>6. Development of HTS magnetic and cryogenic systems for experimental facilities (MPT). Carrying out construction works for the development of transverse polarization coils based on systems with HTSC</b></p> <p>FLNP</p> <p>VBLHEP</p>	<p><b>S.I. Tyutyunnikov</b></p> <p>A.N. Chernikov</p> <p>M.S. Novikov</p>	<div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;">R&amp;D</div>

## Collaboration

### Country or International Organization

Armenia  
Australia  
Belarus

Bulgaria  
Czech Republic

Moldova  
Mongolia  
Romania

### City

Yerevan  
Sydney, NSW  
Minsk

Sofia  
Brno  
Prague  
Rez

Chisinau  
Ulaanbaatar  
Baia Mare  
Bucharest

Iasi

### Institute or laboratory

YSU  
Univ.  
INP BSU  
ISEI BSU  
JIPNR-Sosny NASB  
RI PCP BSU  
INRNE BAS  
BUT  
CTU  
NPI CAS  
IAP  
IPT MAS  
TUCN-NUCBM  
IFIN-HH  
UMF  
UAIC

Russia	Magurele Timisoara Dubna	ISS UVT BSINP MSU IAS "Omega"
Slovakia	St. Petersburg Tomsk Bratislava	KRI TPU CU IP SAS SOSMT
Turkey	Bolu	Univ.
Ukraine	Kharkov	NSC KIPT

**Nuclear  
Physics  
(03)**

## Development of the FLNR Accelerator Complex and Experimental Setups (DRIBs-III)

**Leaders:** I.V. Kalagin  
S.N. Dmitriev  
S.I. Sidorchuk

**Scientific leader:** Yu.Ts. Oganessian

### Participating countries and international organizations:

Belgium, Bulgaria, Canada, CERN, China, Czech Republic, Egypt, France, Germany, Italy, Kazakhstan, Mongolia, Poland, Republic of Korea, Romania, Russia, Serbia, Slovakia, South Africa, USA.

### Issues addressed and main goals of research:

The implementation of the DRIBs-III project that includes the upgrade and development of the FLNR cyclotron complex, expansion of the experimental infrastructure of the Laboratory (construction of new physics set-ups), and development of accelerator systems. The project aims at improving the operation stability of accelerators, increasing the intensity and improving the quality of ion beams of stable and radioactive nuclides in the energy range from 5 to 100 MeV/nucleon, while at the same time reducing power consumption. The project objective is to significantly improve the efficiency of experiments on the synthesis of superheavy elements and light nuclei at nucleon drip lines and study of their properties. Moreover, the programme of experiments with beams of radioactive nuclides is anticipated to be expanded.

### Expected results in the current year:

- Experiments aimed at the synthesis and study of the properties of superheavy elements Fl–Lv at the new gas-filled recoil separator GFS-2 of the Factory of Superheavy Elements (SHE).
- Preparation for experiments on the synthesis of elements 119 and 120 in complete fusion reactions with  $^{50}\text{Ti}$  and  $^{54}\text{Cr}$  ions.
- Development of the pre-separator for radiochemical studies of SHE.
- Experiments at the gas-filled recoil separator GFS-3 aimed at the study of the chemical properties of elements 112 and 114.
- Completion of the upgrade of the U-400M cyclotron and its commissioning.
- Development of the infrastructure of the ACCULINNA-2 fragment separator (RF kicker, tritium target complex).
- Implementation of the physics experiments programme at U-400.
- Construction of the experimental hall of the U-400R cyclotron.
- Preparation for the reconstruction of the U-400 cyclotron (U-400R).
- Development of the detector system in the focal plane of the MAVR analyzer and MULTI spectrometer including the  $4\pi$ -neutron detector and the gamma-detector.
- Development of methods for the diagnostics of beams of stable and radioactive nuclides.
- Further development of the gas-cell-based laser ionization and separation set-up GALS.
- Completion of the assembly of the cryogenic gas ion catcher and the beginning of the adjustment of vacuum and cryogenic systems.
- Construction of the DC-140 cyclotron
- Preparation of basic engineering design data for a radiochemical laboratory of the first class.

Activity or Experiment	Leaders	Status
Laboratory or other Division of JINR Responsible person	Main researchers	
<b>1. Development of the Superheavy Element Factory</b>	<b>G.G. Gulbekian</b>	Preparation
FLNR	G. Bondarenko, S.L. Bogomolov, O.A. Chernyshev, B.N. Gikal, M.V. Habarov, G.N. Ivanov, I.A. Ivanenko, I.V. Kalagin, N.Yu. Kazarinov, V.A. Kostyrev, N.F. Osipov, S.V. Pashchenko, N.N. Pchelkin, A.V. Reshetov, V.A. Semin, V.A. Veryovochkin	
VBLHEP	A.A. Fateev, 2 pers.	
<b>2. Development of the U-400M and U-400R complexes</b>	<b>I.V. Kalagin</b>	Preparation Data taking
FLNR	S.L. Bogomolov, P.G. Bondarenko, Chernyshev O.A., G.G. Gulbekian, M.V. Habarov, G.N. Ivanov, I.A. Ivanenko, N.Yu. Kazarinov, N.F. Osipov, S.V. Pashchenko, N.N. Pchelkin, A.V. Reshetov, V.A. Semin, V.A. Sokolov, R.E. Vaganov	
MLIT	P.G. Akishin, E.A. Airian, A.M. Chervyakov, V.V. Korenkov	
DLNP	G.A. Karamysheva, E.V. Samsonov, S.B. Vorozhtsov	
VBLHEP	A.A. Fateev, 2 pers.	
<b>3. Construction of the DC-140 cyclotron complex</b>	<b>I.V. Kalagin</b>	Preparation
FLNR	S.L. Bogomolov, O.A. Chernyshev, G.G. Gulbekian, M.V. Habarov, G.N. Ivanov, I.A. Ivanenko, I.V. Kalagin, N.Yu. Kazarinov, V.A. Kostyrev, S.V. Mitrofanov, N.F. Osipov, S.V. Pashchenko, N.N. Pchelkin, V.A. Semin, V.A. Veryovochkin	
DLNP	G.A. Karamysheva, 5 pers.	
VBLHEP	A.A. Fateev, 2 pers.	
<b>4. Development of the ECR ion sources</b>	<b>S.L. Bogomolov</b>	Preparation
FLNR	V.V. Behterev, A.E. Bondarchenko, A.A. Efremov, G.N. Ivanov, K. I. Kuzmenkov, A.N. Lebedev, V.N. Loginov, V.E. Mironov, N.Yu. Yazvitskiy	
VBLHEP	E.D. Donets, V.M. Drobin, E.E. Donets, S.A. Kostomin	
<b>5. Development of the MT-25 microtron</b>	<b>S.V. Mitrofanov</b>	Preparation Data taking
FLNR	N.V. Aksenov, O.A. Chenyshov, N.F. Osipov, V.A. Semin, Yu.G. Teterev	

**6. Development of the fragment separator ACCULINNA-2**

FLNR

MLIT

**A.S. Fomichev**

Preparation  
Data taking

C.G. Belogurov, A.A. Bezbakh, V. Chudoba, E. M. Gazeeva, A.V. Gorshkov, V.A. Gorshkov, M.S. Golovkov, G. Kaminsky, S.A. Krupko, K. A. May, B. Mauey, I.A. Muzalevsky, E.Yu. Nikolskii, W. Piatek, P.G. Sharov, P. Shimkevich, S.I. Sidorchuk, R.S. Slepnev, S.V. Stepantsov, A. Swiercz, G.M. Ter-Akopian, M.N. Tran, R. Wolski

E.V. Ovcharenko, V.N. Schetinin

**7. Development of a GFS-3 pre-separator for radiochemical studies of SHE**

FLNR

**A.G. Popoko  
A.V. Eremin**

Preparation

O.N. Malyshev, Yu.A. Popov, A.I. Svirikhin

**8. Construction of the gas catcher and design of the MR-TOF spectrometerr**

FLNR

**A.M. Rodin**

Preparation

E.V. Chernysheva, A.V. Guljaev, A.V. Guljaeva, P. Kohout, A. Kohoutova, A.B. Komarov, L. Krupa, A.S. Novoselov, A. Opihal, A.V. Podshibyakin, V.S. Salamatin, S.V. Stepantsov, V.Yu. Vedeneev, S.A. Yukhimchuk

**9. Development of a separator based on resonance laser ionization**

FLNR

**S.G. Zemlyanov**

Preparation

K.A. Avvakumov, E.M. Kozulin, G.V. Myshinskiy, T. Tserensambuu, V.I. Zhemelik, B. Zuzaan

**10. Project preparation for the construction of a radiochemical laboratory of class 1**

FLNR

**N.V. Aksenov**

Preparation

G.A. Bozhikov, S.V. Mitrofanov, A.V. Sabelnikov

**Collaboration**

**Country or International Organization**

Belgium

Bulgaria

Canada

CERN

China

Czech Republic

Egypt

France

Germany

Italy

Kazakhstan

Mongolia

Poland

**City**

Leuven

Sofia

Vancouver

Geneva

Lanzhou

Olomouc

Prague

Rez

Giza

Shibin El Kom

Caen

Orsay

Vannes

Darmstadt

Heidelberg

Padua

Almaty

Nur-Sultan

Ulaanbaatar

Krakow

**Institute or laboratory**

KU Leuven

INRNE BAS

TRIUMF

CERN

IMP CAS

UP

VP

NPI CAS

CU

MU

GANIL

IPN Orsay

SigmaPhi

GSI

MPIK

INFN

INP

BA INP

ENU

NRC NUM

INP PAS

	Warsaw	HIL UW
		IEP WU
Republic of Korea	Daejeon	IBS
Romania	Bucharest	IFIN-HH
Russia	Moscow	HTDC
		ITEP
		ITT-Group
		NNRU "MEPhI"
	Moscow, Troitsk	INR RAS
	Nizhny Novgorod	IAP RAS
	Novosibirsk	BINP SB RAS
	Sarov	VNIIEF
	Snezhinsk	VNIITF
	St. Petersburg	IAI RAS
		NIIEFA
Serbia	Belgrade	INS "VINCA"
Slovakia	Bratislava	IP SAS
	Nova Dubnica	EVPU
South Africa	Somerset West	iThemba LABS
USA	College Station, TX	Texas A&M
	East Lansing, MI	MSU
	Livermore, CA	LLNL
	Nashville, TN	VU
	Oak Ridge, TN	ORNL

## Synthesis and Properties of Superheavy Elements, the Structure of Nuclei at the Limits of Nucleon Stability

**Leaders:** M.G. Itkis  
S.I. Sidorchuk

**Scientific leader:** Yu.Ts. Oganessian

### Participating countries and international organizations:

Belgium, Bulgaria, CERN, China, Czech Republic, Egypt, Finland, France, Germany, India, Italy, Japan, Kazakhstan, Mongolia, Poland, Republic of Korea, Romania, Russia, Slovakia, South Africa, Spain, Sweden, Switzerland, Ukraine, United Kingdom, USA, Vietnam.

### Issues addressed and main goals of research:

Synthesis of nuclei at stability limits and the investigation of their properties. Investigation of the mechanisms of heavy-ion-induced reactions. Study of the physical and chemical properties of heavy and superheavy elements.

### Expected results in the current year:

- Experiments aimed at the study of complete fusion reactions of actinide target nuclei with  $^{48}\text{Ca}$ ,  $^{50}\text{Ti}$ , and  $^{54}\text{Cr}$  ions performed at GFS-2 of the Factory of Superheavy Elements (SHE).
- Preparation for the synthesis of elements 119 and 120.
- Experiments aimed at studying the properties of the radioactive decay ( $\alpha$ -,  $\beta$ -decay, spontaneous fission properties) of No, Rf, and Sg heavy isotopes formed in reactions with Ne, Ca, Ti, and Cr ions at the SHELS separator using the GABRIELA and SFiNX detecting systems.
- Experiments for studying the chemical properties of Cn and Fl at the Factory of Superheavy Elements.
- Development of a technology for manufacturing accelerator targets from stable and radioactive isotopes, which are stable under long irradiation with high-intensity heavy-ion beams.
- Investigation of mass-energy and angular distributions of fragments produced in multi-nucleon transfer reactions. Study of the multi-body decay of low-excited heavy and superheavy nuclei. Development of physics facilities.
- Investigation of nuclei close the limits of nucleon stability: analysis of experimental data on studying the structure of the exotic nuclei  $^6\text{H}$ ,  $^7\text{He}$ ,  $^{8,9,10}\text{Li}$ ,  $^{27}\text{S}$  produced earlier using radioactive beams at the ACCULINNA-2 fragment separator.
- Experiments at MAVR aimed at studying reactions with the emission of fast charged particles near the kinematic limit in coincidence with fission fragments. Measurement of total cross sections for reactions with beams of weakly bound cluster nuclei.
- Preparation for experiments aimed at measuring cross sections of complete fusion reactions using the movable catcher of the U-400 accelerator.
- Theoretical studies of the mechanisms of nuclear reactions with heavy ions.
- Development and update of the web knowledge base on nuclear physics.



## List of Activities:

Activity or Experiment	Leaders	Status
Laboratory or other Division of JINR Responsible person	Main researchers	
1. <b>Synthesis of new isotopes of superheavy elements at DGFRS</b> FLNR	<b>V.K. Utyonkov</b>	Data taking
	F.Sh. Abdullin, D. A. Ibadullayev, N.D. Kovrijnykh, D.A. Kuznetsov, A.N. Polyakov, O.V. Petrushkin, R.N. Sagaidak, V.D. Shubin, V.G. Subbotin, I.V. Shirokovsky, M.V. Shumeiko, D.I. Solov'ev, L. Schlattauer, Yu.S. Tsyganov, A.A. Voinov, A.M. Zubareva	
2. <b><math>\alpha</math>-, <math>\beta</math>- and <math>\gamma</math>-spectroscopy of heavy nuclei at the SHELS separator</b> FLNR	<b>A.V. Yeremin</b>	Data taking
	V.I. Chepigina, M.L. Chelnokov, A.V. Isaev, I.N. Izosimov, D.E. Katrsev, A.A. Kuznetsova, O.N. Malyshev, R.S. Mukhin, Yu.A. Popov, V.M. Popov, A.G. Popeko, E.A. Sokol, A.I. Svirikhin, V.A. Sbitnev, M.S. Tezekbaeva	
3. <b>Chemical properties of superheavy elements</b> FLNR	<b>S.N. Dmitriev</b>	Data taking
	N.V. Aksenov, Yu.V. Albin, A.A. Astakhov, A.Yu. Bodrov, G.A. Bozhikov, I. Chuprakov, N.S. Gustova, K.V. Lebedev, A.Sh. Madumarov, E.V. Melnik, A.V. Sabelnikov, G.Ya. Starodub, G.K. Vostokin, M.G. Voronyuk	
4. <b>Experiments at the magnetic analyzer of superheavy atoms MASHA</b> FLNR	<b>A.M. Rodin</b>	Data processing
	E.V. Chernysheva, A.V. Guljaev, A.V. Guljaeva, A. Kohoutova, P. Kohout, A.B. Komarov, L. Krupa, A.S. Novoselov, A. Opihal, A.V. Podshibyakin, V.S. Salamatina, S.V. Stepanov, V.Yu. Vedenev, S.A. Yukhimchuk	
5. <b>Study of the processes of fusion-fission, quasi-fission and multi-nucleon transfer reactions. CORSET-DEMON, CORSAR, and MiniFOBOS set-ups</b> FLNR	<b>M.G. Itkis</b> <b>E.M. Kozulin</b>	Data taking
	T. Banerjee, I.N. Dyatlov, O.V. Falomkina, E. I. Galkina, Z.I. Gorya'nova, Yu.M. Itkis, D.V. Kamanin, V.V. Kirokasian, N.I. Kozulina, G.N. Knyazheva, K.A. Kulkov, E.A. Kuznetsova, C.H. Meghashree, E. Mukhamedzhanov, E.I. Nikolenko, K.V. Novikov, A.A. Ostroukhov, A. Pan, I.V. Pchelintsev, Yu.V. Pyatkov, E.O. Savelieva, Yu.B. Semenov, A.N. Solodov, A.O. Strekalovskiy, O.V. Strekalovskiy, R.S. Tikhomirov, I.V. Vorob'ev, A.O. Zhukova, V.E. Zhuchko	
	P.V. Goncharov, G.A. Ososkov, A.V. Uzhinsky, V.B. Zlokazov	
6. <b>Study of the structure of exotic nuclei near and beyond the drip-lines at the ACCULINNA-2 and COMBAS fragment separators</b> FLNR	<b>A.S. Fomichev</b>	Data processing
	A.G. Artukh, E. Batchuluun, S.G. Belogurov, A.A. Bezbakh, V. Chudoba, M.S. Golovkov, L.V. Grigorenko, A.V. Gorshkov, V. A. Gorshkov, E.M. Gazeeva, V.A. Gorshkov, A. Ismailova,	

G. Kaminski, S.A. Krupko, S.A. Klygin, G.A. Kononenko, K.A. May, B. Mauey, I.A. Muzalevskiy, E.Yu. Nikolskii, Yu.L. Parfenova, W. Piatek, S.A. Rimzhanova, Yu.M. Sereda, S.I. Sidorchuk, R.S. Slepnev, P.G. Sharov, S.V. Stepantsov, A. Swiercz, P. Szymkiewicz, G.M. Ter-Akopian, M. N. Tran, A.N. Vorontsov, R. Wolski, B. Zalewski

BLTP

S.N. Ershov, N.B. Shulgina

- 7. Investigation of reactions induced by stable and radioactive ion beams leading to the formation of exotic nuclei. Development of MAVR and MULTI set-ups**  
FLNR

**Yu.E. Penionzhkevich**

Data taking Preparation
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D.T. Aznabaev, A. Azhibekov, I. V. Butusov, T. Isataev, S.M. Lukyanov, V.A. Maslov, K.O. Mendibaev, R.V. Revenko, A. V. Shakhov, I. Sivacek, N.K. Skobelev, Yu.G. Sobolev, V.I. Smirnov, S.S. Stukalov, D.A. Testov

- 8. Theoretical studies of nuclear reaction mechanisms**

FLNR

**A.V. Karpov**

Data taking Data processing
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E.A. Cherepanov, A.S. Denikin, I. A. Egorova, M.A. Naumenko, V.A. Rachkov, V.V. Samarin, V.V. Saiko

- 9. Development and update of the network knowledge base on nuclear physics**

FLNR

**A.V. Karpov  
A.S. Denikin**

Data taking
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M.A. Naumenko, V.A. Rachkov, V.V. Samarin, V.V. Saiko

- 10. Laser spectroscopy of isotopes**

FLNR

**S.G. Zemlyanoy**

Data taking
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K.A. Avvakumov, G.N. Myshinskiy, T. Tserensambuu, V.I. Zhemelik, B. Zuzaan

## Collaboration

### Country or International Organization

Belgium

### City

Brussels

### Institute or laboratory

ULB

Leuven

KU Leuven

Bulgaria

Sofia

INRNE BAS

CERN

Geneva

CERN

China

Beijing

PKU

Lanzhou

IMP CAS

Czech Republic

Olomouc

UP

Prague

CTU

VP

Rez

NPI CAS

Egypt

Giza

CU

Shibin El Kom

MU

Finland

Jyvaskyla

UJ

France

Caen

GANIL

Orsay

CSNSM

IPN Orsay

Saclay

SPhN CEA DAPNIA

Strasbourg

CRN

IPHC

Germany	Darmstadt	GSI
	Heidelberg	MPIK
	Mainz	JGU
	Tubingen	Univ.
India	Kolkata	VECC
	New Delhi	IUAC
	Roorkee	IIT Roorkee
	Rupnagar	IIT Ropar
Italy	Catania	INFN LNS
	Legnaro	INFN LNL
	Messina	UniMe
	Naples	Unina
Japan	Tokai	JAEA
Kazakhstan	Almaty	IETP KazNU
		INP
	Nur-Sultan	ENU
Mongolia	Ulaanbaatar	NRC NUM
Poland	Krakow	INP PAS
	Poznan	AMU
	Warsaw	HIL UW
		UW
Republic of Korea	Daejeon	IBS
Romania	Bucharest	IFIN-HH
Russia	Dimitrovgrad	SSC RIAR
	Gatchina	NRC KI PNPI
	Moscow	MSU
		NNRU "MEPhI"
		NRC KI
		SINP MSU
	Sarov	VNIIEF
	St. Petersburg	Ioffe Institute
		KRI
		SPbSU
	Voronezh	VSU
Slovakia	Bratislava	CU
		IP SAS
South Africa	Somerset West	iThemba LABS
	Stellenbosch	SU
Spain	Huelva	UHU
Sweden	Goteborg	Chalmers
	Lund	LU
Switzerland	Villigen	PSI
Ukraine	Kiev	KINR NASU
United Kingdom	Manchester	UoM
USA	College Station, TX	Texas A&M
	East Lansing, MI	MSU
	Livermore, CA	LLNL
	Nashville, TN	VU
	Oak Ridge, TN	ORNL
Vietnam	Hanoi	IOP VAST
	Ho Chi Minh City	VNUHCM

## Non-Accelerator Neutrino Physics and Astrophysics

**Leaders:** E.A. Yakushev  
A. Kovalik

### Participating countries and international organizations:

Azerbaijan, Bulgaria, Czech Republic, Finland, France, Germany, Kazakhstan, Mongolia, Poland, Russia, Slovakia, Switzerland, United Kingdom, Uzbekistan.

### Issues addressed and main goals of research:

Search for and investigation of double-neutrino and neutrinoless modes of double beta decay, clarification of the neutrino nature, Majorana or Dirac, and absolute neutrino mass scale and hierarchies. Search for the neutrino magnetic moment and dark matter. Investigation of galactic and extragalactic neutrino sources, diffusive neutrino cosmic background, and search for exotic particles (monopoles). Use of the neutrino detector for a distant investigation of processes inside of the reactor core of the Kalinin Nuclear Power Plant (KNPP). Search for sterile neutrinos. Spectroscopy of nuclei far from stability. Development of new methods for charged and neutral particle detection.

### Expected results in the current year:

- Data taking in the  $2\beta 0\nu$  decay measurements of  $^{106}\text{Cd}$ ,  $^{82}\text{Se}$ , with the SuperNEMO spectrometer. Processing of the data collected in the GERDA experiment, set  $T_{1/2}$  limits for different  $2\beta$ -decay modes.
- Processing of experimental data and determination of  $T_{1/2}(2\beta 0\nu)$  for  $^{48}\text{Ca}$ ,  $^{96}\text{Zr}$ ,  $^{130}\text{Te}$ ,  $^{116}\text{Cd}$ ,  $^{82}\text{Se}$  and  $^{76}\text{Ge}$ .
- Data taking with the HPGe-based low-background vGeN spectrometer at the Kalinin Nuclear Power Plant. Search for a signal of coherent neutrino scattering on the germanium nuclei. Data taking start searching for the neutrino magnetic moment at the sensitivity level of  $\sim (5-9) \cdot 10^{-12} \mu_B$  after several years of data taking.
- Continuation of data taking in the EDELWEISS experiment with new detectors operating with an energy threshold of 0.1 keV suitable for the extra-low mass WIMP region. Analysis of previously accumulated data, determination of parameters for light dark matter for the mass region below  $1 \text{ GeV}/c^2$ . Start of the Ricochet phase of the experiment for precision CEnNS studying at ILL with the detectors developed by EDELWEISS.
- Start of data taking in the tone-scale LEGEND experiment, searching for  $2\beta 2\nu$  decay of  $^{76}\text{Ge}$ .
- Data taking with eight clusters of the BAIKAL-GVD neutrino telescope. Search for and study of high-energy neutrinos of the astrophysical nature. Constructing and commissioning of new detector clusters. Development and testing of new data acquisition and data transmission systems aiming at a lower energy threshold (Baikal project).
- Investigation of KLL and KMM Auger electrons in  $^{67}\text{Ga}$  and  $^{152,154,155}\text{Eu}$  decays.
- Development and testing of new low-threshold ( $\sim 200 \text{ eV}$ ) HPGe detectors for searching for the coherent neutrino scattering, as well as of plastic scintillator detectors for their active shielding.
- Results of search for sterile neutrinos on the 2016-2021 data accumulated by the DANSS spectrometer. Precision estimates of the gamma and neutron background at the location of the DANSS spectrometer (room A336 under the reactor of the 4th power unit of the KNPP). R&D results of the spectrometer modernization.
- The radiochemical laboratory of the 2nd class will be commissioned in the DLNP; equipment for the manufacture of radioactive sources for brachytherapy of cancer diseases will be installed; important work for obtaining of a sanitary and epidemiological certificates for the radiochemical laboratory will be concluded.
- Continuation of the MONUMENT project. Preparation for 2022 PSI accelerator run (purchasing of detectors and targets, update of the cryostats). Data taking. Analysis of previously accumulated data.

## List of projects:

Project	Leader	Priority (period of realisation)
1. SuperNEMO	O.I. Kochetov	1 (2013-2023)
2. $\nu$ GEN (GEMMA)	A.V. Lubashevskiy E.A. Yakushev	1 (2010-2023)
3. EDELWEISS/RICOCHET	E.A. Yakushev	1 (2010-2023)
4. GERDA (LEGEND)	K.N. Gusev	1 (2010-2023)
5. DANSS	Yu.A. Shitov	1 (2011-2023)
6. BAIKAL	I.A. Belolaptikov	1 (2009-2023)
7. MONUMENT	D.R. Zinatulina	1 (2021-2023)

## List of Activities:

Activity or Experiment Laboratory or another Division of JINR Responsible person	Leaders Main researchers	Status
<b>1. SuperNEMO Project</b>	<b>O.I. Kochetov</b>	R&D Data taking
DLNP	D.V. Filosofov, I.I. Kamnev, D.V. Karaivanov, F.F. Klimenko, M.A. Mirzaev, I.B. Nemchenok, A.V. Rahimov, A.V. Salamatin, A.A. Smolnikov, Yu.A. Shitov V.V. Timkin, V.I. Tretyak, O.V. Vagina	
BLTP	F. Simkovic	
<b>2. Investigation of <math>2K2\nu</math> and <math>2K0\nu</math> decays of <math>^{106}\text{Cd}</math> with the TGV spectrometer</b>	<b>N.I. Rukhadze</b> <b>I. Shtekl</b>	Data taking
DLNP	S.L. Katulina, A.V. Salamatin, V.G. Sandukovskiy, V.V. Timkin	
BLTP	F. Simkovic	
<b>3. GERDA (LEGEND) Project</b>	<b>K.N. Gusev</b>	Preparation Data taking
DLNP	M.V. Fomina, A.A. Klimenko, O.I. Kochetov, A.V. Lubashevsky, I.B. Nemchenok, N.S. Romyantseva, V.G. Sandukovsky, E.A. Shevchik, M.V. Shirchenko, A.A. Smolnikov, I.V. Zhitnikov, D.R. Zinatulina	
BLTP	F. Simkovic	
<b>4. <math>\nu</math>GEN (GEMMA) Project</b>	<b>A.V. Lybashevsky</b> <b>E.A. Yakushev</b>	Upgrade Data taking
DLNP	V.V. Belov, S.A. Evseev, D.V. Filosofov, M.V. Fomina, L. Grubchin, U.B. Gurov, A.Kh. Inoyatov, S.L. Katulina, S.V. Kazartsev, Z.Kh. Khukhvatov, S.P. Kiyarov, A.S. Kuznetsov, D.V. Medvedev, D.V. Ponomarev, D.S. Pushkov, S.V. Rozov, I.E. Rozova, A.V. Salamatin, V.G. Sandukovsky, K.V. Shakhov, T.A. Shevchik, M.V. Shirchenko, V.P. Volnykh, I.V. Zhitnikov	

**5. EDELWEISS/RICOCHET Project**

**E.A. Yakushev**  
**S.V. Rozov**

Upgrade  
Data taking

DLNP

V. Belov, S. Evseev, D. Filosofov, Yu. Gurov, A. Inoyatov, D. Karavainov, S. Kazartsev, J. Khushvaktov, A.V. Lubashevsky, N.A. Mirzaev, L.L. Perevoshchikov, D.V. Ponomarev, F.V. Rakhimov, I.E. Rozova, A. Salamatin, K.V. Shakhov, N. Temerbulatov, V. Trofimov, Yu. Vaganov

**6. BAIKAL Project**

**I.A. Belolaptikov**

Preparation  
Data taking

DLNP

V.F. Allakhverdyan, P.I. Antonov, I.V. Borodina, I.S. Dotsenko, M.S. Dovbnenko, R. Dvornicky, A.A. Doroshenko, T.V. Elzhov, A.N. Emelianov, S.A. Evseev, K.V. Golubkov, N.A. Gorshkov, M.S. Katulin, S.A. Katulin, S.L. Katyulina, E.V. Khramov, M.M. Kolbin, K.V. Konishev, A.V. Korobchenko, M.V. Kruglov, Y.M. Malyshkin, M.B. Milenin, M.L. Minaev, V. Nazari, D.V. Naumov, T. Orazgali, D.A. Orlov, L.L. Perevoshchikov, D.P. Petukhov, E.N. Pliskovski, I.E. Rozova, V.D. Rushay, A.V. Salamatin, G.B. Safronov, S.I. Sinegovsky, A.E. Sirenko, M.N. Sorokovikov, N.I. Sosunov, I.A. Stepkin, B.A. Shaybonov, K.I. Shevchenko, Yu.V. Yablokova

**7. Investigation of spectra of low-energy electrons after radioactive decays to obtain data for atomic and nuclear physics and for nuclear medicine. Development of ultrastable energy calibration for the KATRIN neutrino project. Investigation of decays of rare-earth radionuclides and structure of their excited states**

**A.Kh. Inoyatov**  
**A. Kovalik**

Data taking

DLNP

M.A. Abd Al'ngar, M.S. Dovbnenko, S.V. Fateev, D.V. Filosofov, N.V. Morozova, V.A. Morozov, L.L. Perevoshchikov, A.E. Sirenko, V.I. Stegailov, A.A. Solnyshkin, Yu.V. Yablokova

FLNR

I.N. Izosimov

**8. Radiochemical support of irradiation of targets, separation of radionuclides from them by radiochemistry and mass separation methods, preparation of ionizing radiation sources for physical research at DLNP; chemical, radiochemical and mass separator support of low-background measurements for neutrino physics**

**D.V. Filosofov**  
**A.Kh. Inoyatov**

Preparation

DLNP

A.E. Baimukhanova, J.A. Dadakhanov, D.V. Karaivanov, E.S. Kurakina, N.A. Mirzayev, N.V. Morozova, A.V. Rakhimov, J.K. Samatov, A.A. Solnyshkin, Yu.A. Vaganov, A.I. Velichkov

<p><b>9. Development of methods for the separation of elements (radiochemistry and mass separation); development of methods for obtaining radioisotopes for nuclear medicine and the synthesis of radiopharmaceuticals based on them; development and manufacture of micro sources for cancer brachytherapy; study of the physicochemical properties of condensed matter using the method of perturbed angular correlations of nuclear radiation</b></p> <p>DLNP</p> <p>FLNR</p>	<p><b>D.V. Filosofov</b></p> <p>A. Baymukhanova, E. Denisova, D.V. Karaivanov, E.S. Kurakina, A.A. Solnyshkin, A.V. Salamatin, D.A. Salamatin, N.T. Temerbulatova, Yu.A. Vaganov, A.I. Velichkov,</p> <p>G.A. Bozhikov</p>	<table border="1" style="width: 100%; text-align: center;"> <tr> <td>Preparation</td> </tr> </table>	Preparation
Preparation			
<p><b>10. Development and production of low-energy-threshold HPGe detectors. Development and production of special types of Si and Ge detectors for low background measurements. Development and production of plastic scintillators for low-background spectrometers, neutron detectors, and cosmic muon detection. Development and production of a muon detection network for continuous atmosphere control in the Moscow region</b></p> <p>DLNP</p> <p>FLNR</p> <p>VBLHEP</p>	<p><b>E.A. Yakushev</b></p> <p>Yu.B. Gurov, L. Grubchin, K.N. Gusev, S.L. Katulina, I.B. Nemchenok, D.V. Ponomarev, S.V. Rozov, V.G. Sandukovskiy</p> <p>A.M. Rodin</p> <p>N.I. Zamyatin</p>	<table border="1" style="width: 100%; text-align: center;"> <tr> <td>Preparation</td> </tr> </table>	Preparation
Preparation			
<p><b>11. DANSS Project</b></p> <p>DLNP</p>	<p><b>Yu.A. Shitov</b></p> <p>V.V. Belov, D.V. Filosofov, M.V. Fomina, S.V. Kazartsev, S.P. Kiyarov, A.S. Kuznetsov, F. Mamedov, D.V. Medvedev, D.S. Pushkov, I.E. Rozova, A.V. Salamatin, E.A. Shevchik, V.P. Volnykh, I.V. Zhitnikov</p>	<table border="1" style="width: 100%; text-align: center;"> <tr> <td>Data taking Upgrade</td> </tr> </table>	Data taking Upgrade
Data taking Upgrade			
<p><b>12. MONUMENT Project</b></p> <p>DLNP</p>	<p><b>D.R. Zinatulina</b> <b>M.V. Shirchenko</b></p> <p>V.V. Belov, M.V. Fomina, K.N. Gusev, S.V. Kazartsev, N.S. Rumyantseva, E.A. Shevchik, Yu.A. Shitov, I.V. Zhitnikov</p>	<table border="1" style="width: 100%; text-align: center;"> <tr> <td>Data taking Upgrade</td> </tr> </table>	Data taking Upgrade
Data taking Upgrade			

## Collaboration

Country or International Organization	City	Institute or laboratory
Azerbaijan	Baku	IRP ANAS
Bulgaria	Plovdiv	PU
	Sofia	INRNE BAS
Czech Republic	Prague	CTU
	Rez	NPI CAS
Finland	Jyvaskyla	UJ
France	Grenoble	UGA
	Lyon	IPNL
	Modane	LSM
	Orsay	CSNSM
	Saclay	CEA
Germany	Heidelberg	MPIK
	Karlsruhe	KIT
	Mainz	JGU
	Munich	TUM
Kazakhstan	Almaty	INP
Mongolia	Ulaanbaatar	IPT MAS
Poland	Krakow	INP PAS
	Lublin	UMCS
Russia	Dubna	Dubna State Univ.
	Gatchina	NRC KI PNPI
	Moscow	ITEP
		NNRU "MEPhI"
		SC "VNIINM"
		SINP MSU
	Moscow, Troitsk	HPPI RAS
		INR RAS
	Neutrino	BNO INR RAS
	St. Petersburg	FIP
		KRI
	Tomsk	NPI TPU
	Voronezh	VSU
Slovakia	Bratislava	CU
		IEE SAS
Switzerland	Villigen	PSI
United Kingdom	London	UCL
	Manchester	UoM
Uzbekistan	Tashkent	INP AS RUz
		NUU



## Investigations of Neutron Nuclear Interactions and Properties of the Neutron

**Leader:** E.V. Lychagin  
**Deputies:** Yu.N. Kopatch  
P.V. Sedyshev

### Participating countries and international organizations:

Albania, Armenia, Australia, Austria, Azerbaijan, Belarus, Botswana, Bulgaria, CERN, China, Croatia, Czech Republic, Egypt, Finland, France, Georgia, Germany, Hungary, IAEA, India, Italy, Japan, Kazakhstan, Moldova, Mongolia, North Macedonia, Norway, Poland, Republic of Korea, Romania, Russia, Serbia, Slovakia, Slovenia, South Africa, Switzerland, Thailand, Turkey, Ukraine, USA, Uzbekistan, Vietnam.

### Issues addressed and main goals of research:

Experimental and theoretical investigations of symmetry breaking effects in reactions with neutrons and fundamental properties of the neutron to test the parameters of the Standard Model and search for "new physics". Investigation of the properties of excited nuclei, reactions with emission of charged particles, fission physics. Obtaining of relevant data for astrophysics, nuclear power engineering and nuclear waste transmutation problem using neutron- and gamma-induced reactions. Application of neutron physics methods in other fields of science and technology. Development and construction of detectors of neutrons and other ionizing radiation, as well as applied methods in nuclear physics with neutrons. Development of the Intense REsonance Neutron Source (IREN) and the experimental base at the IREN and IBR-2 facilities.

### Expected results in the current year:

#### Investigations of violations of fundamental symmetries in neutron-nucleus interactions and related data

- Measurement of spectra and angular correlations of gamma-rays in low-lying resonances to search for P- and T-odd effects.
- Measurement of the yields of hydrogen isotopes in ternary and quaternary fission of  $^{252}\text{Cf}$ .
- Measurement of angular and energy distributions of elastically and inelastically scattered neutrons in reactions with neutrons with an energy of 14 MeV.
- Measurements of angular and energy distributions of prompt fission neutrons (PFN) in the  $^{235}\text{U}(n, f)$  and  $^{239}\text{Pu}(n, f)$  reactions in the resonance region using a position-sensitive twin ionization chamber and 32 scintillation counters.
- Measurement of angular correlations of gamma-rays in the  $^{232}\text{Th}(n, \gamma)$  reaction in neutron resonances.
- Determination of model concepts of modern values of the level density and radiation widths of nuclei of various shapes and types in the capture of slow neutrons.
- Carrying out an experiment to search for a singlet deuteron.
- Measurement of the fast neutron cross section for the  $^{148}\text{Sm}(n, \alpha)^{145}\text{Nd}$  reaction, measurement of fast and resonance neutron cross sections for the  $^6\text{Li}(n, \alpha)^3\text{H}$ ,  $^{14}\text{N}(n, p)^{14}\text{C}$ ,  $^{35}\text{Cl}(n, p)^{35}\text{S}$  reactions.

#### Investigation of fundamental properties of the neutron, UCN physics

- Development, installation and testing of the necessary experimental equipment for realization of an experiment to measure the efficiency of extracting very cold neutrons from a source by a specially designed reflector.

- Simulation of the propagation of very cold neutrons (VCN) in various diamond nanopowders to optimize their parameters and increase the efficiency of VCN extraction from the source.
- Investigation of the effect of the density of diamond nanopowders on the properties of slow neutron reflectors developed on their basis.
- Design of an experimental setup to demonstrate the time focusing of UCN at a pulsed reactor.
- Investigation of the possibility of increasing the intensity of a UCN source, based on the idea of time focusing using strong magnetic fields and neutron resonance spin-flippers.
- Theoretical study of nonstationary phenomena in the reflection of UCN from an oscillating resonance potential.

#### **Applied and methodological research**

- Measurement of neutron fluxes and spectra by the counting and current method at beamline 1 of the IBR-2 reactor to simulate the possibility of measuring the neutron lifetime. Development and construction of a data acquisition system for the detector's current mode.
- Development of a prototype setup for neutron polarization by transmission through a  $^3\text{He}$  target.
- Carrying out vacuum and cryogenic tests of a cryostat with a superconducting magnet to create an all-wave neutron polarizer.
- Development and testing of an elemental analysis technique using the tagged neutron method and high-resolution gamma-ray detectors.
- Investigation with the use of the EG-5 accelerator of the optical and electronic properties of semiconductor materials under X-ray irradiation.
- Development of a modernization project for the EG-5 accelerator and its infrastructure.
- Neutron activation and resonance neutron analysis of archaeological, biological and environmental samples at the IREN facility and at beamlines 3 and 11b of the IBR-2 reactor.
- Creation of a network database of neutron activation analysis to automate studies of the elemental composition of samples of various nature at INP (Alma-Ata, Kazakhstan) and organization of routine neutron activation analysis at the automated site created in 2017-2019 at INP.
- Completion of modernization of REGATA facility at the IBR-2 reactor.
- Determination of the elemental content of plant, biological, geological samples, as well as new materials, including nanomaterials, by means of the neutron activation analysis method at the IBR-2 reactor using the REGATA facility.
- Determination of radiation hardness of clean materials.
- The use of low-background gamma spectrometry and alpha spectrometry to analyze the content of radionuclides in environmental objects.

#### **Development of the IREN facility**

- Providing the neutron beam time from IREN for physical experiments.

#### **List of projects:**

<b>Project</b>	<b>Leader</b>	<b>Priority (period of realisation)</b>
1. TANGRA	Yu.N. Kopatch	1 (2014-2022)
2. Modernization of the EG-5 accelerator	A.S. Doroshkevich	1 (2022-2022)
3. Investigation of prompt fission neutron emission in fission (ENGRIN)	Sh.S. Zeynalov Deputy: L.V. Mitsyna	1 (2022-2022)

## List of Activities:

Activity or Experiment	Leaders	Status
Laboratory or other Division of JINR Responsible person	Main researchers	
<b>1. Investigations of violations of fundamental symmetries in neutron-nucleus interactions and related data</b>	<b>Yu.N. Kopatch</b>	Upgrade Data taking Data analysis
FLNP	G.S. Ahmedov, D. Berikov, S.B. Borzakov, N-S. Carjan, I.I. Chuprakov, G.V. Daniljan, A.S. Doroshkevich, S. Enkhbold, N.A. Fedorov, Yu.M. Gledenov, D.N. Grozdanov, N.A. Gundorin, C. Hramco, V.L. Kuznetsov, E.V. Kuznetsova, S. Mazhen, Zh.V. Mezentseva, V.V. Novitsky, I.A. Oprea, K.D. Oprea, A.B. Popov, P.V. Sedyshev, M.V. Sedysheva, O.V. Sidorova, N.V. Simbirtseva, V.R. Skoj, A.M. Suhovoj, S.A. Telezhnikov, T.Yu. Tretyakova, Vu Dyk Kong, A. Yergashov, Sh.S. Zeynalov, 19 engineers, 15 workers	
<b>2. Investigation of fundamental properties of the neutron, UCN physics</b>	<b>E.V. Lychagin</b>	Upgrade Data taking Data analysis
FLNP	G.G. Bunatyan, T.L. Enik, A.I. Frank, W.I. Furman, S.V. Gorunov, G.V. Kulin, A.G. Malinin, L.V. Mitsyna, A.Yu. Muzychka, A.Yu. Nezvanov, Yu.N. Pokotilovskij, A.B. Popov, N.Yu. Rebrova, A.V. Strelkov, E.I. Sharapov, K.N. Zhernenkov, 4 engineers, 1 worker	
<b>3. Applied research</b>	<b>P.V. Sedyshev</b>	Upgrade Data taking Data analysis
FLNP	G.S. Ahmedov, S.B. Borzakov, O. Chaligava, A.Yu. Dmitriev, N.A. Fedorov, M.V. Frontasyeva, W.I. Furman, D.S. Grozdoz, D.N. Grozdanov, N.A. Gundorin, G.Y. Hristozova, Yu.N. Kopatch, M. Kulik, Zh.V. Mezentseva, A.Yu. Muzychka, P.S. Nekhoroshkov, I.A. Oprea, K.D. Oprea, V.N. Shvetsov, V.R. Skoj, N.V. Simbirtseva, K.N. Vergel, N.S. Yushin, I. Zinicovscaia, 22 engineers, 4 workers	
<b>4. Development of the IREN facility</b>	<b>V.N. Shvetsov</b>	Upgrade
FLNP	E.A. Golubkov, V.G. Pjataev, 17 engineers, 1 worker	
VBLHEP	V.F. Minashkin, A.P. Sumbaev, V.N. Zamrij, 3 engineers	
DLNP	I.N. Meshkov	
<b>5. Development of experimental infrastructure of the IREN facility</b>	<b>V.N. Shvetsov</b>	Upgrade

**6. Modernization of EG-5 accelerator**

FLNP

**A.S. Doroshkevich**

Upgrade
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A.P. Kobzev, A.N. Likhachev, 4 engineers

**7. Project ENGRIN**

FLNP

**Sh.S. Zeynalov**

Data taking Data analysis
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A.M. Lebedev, L.V. Mitsyna, O.V. Sidorova, A.M. Sukhovoy

**8. Project TANGRA**

FLNP

**Yu.N. Kopatch**

Upgrade Data taking Data analysis
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F. Aliev, N.A. Fedorov, N.A. Gundorin, D.N. Grozdanov, C. Hramco, I.A. Oprea, K.D. Oprea, P.V. Sedyshev, V.R. Skoj, V.N. Shvetsov, T.Yu. Tretyakova

VBLHEP

U.Yu. Aleksakhin, S.V. Khabarov, Yu.N. Rogov, R.A. Salmin, M.G. Sapozhnikov, V.M. Slepnev, N.I. Zamjatin, E.V. Zubarev

DLNP

A.V. Krasnoperov, A.B. Sadovskii, A.V. Salamatin

LRB

G.N. Timoshenko

**Collaboration**

**Country or International Organization**

Albania

**City**

Tirana

**Institute or laboratory**

UT

Armenia

Yerevan

SRCHCH

Australia

Melbourne, VIC

Univ.

Austria

Innsbruck

Univ.

Azerbaijan

Baku

BSU

IGG ANAS

IRP ANAS

Belarus

Minsk

BSU

INP BSU

SPMRC NASB

Botswana

Palapye

BIUST

Bulgaria

Plovdiv

PU

UFT

Sofia

IE BAS

INRNE BAS

CERN

Geneva

CERN

China

Beijing

IHEP CAS

Xi'an

NINT

Croatia

Zagreb

Oikon IAE

RBI

Czech Republic

Ostrava

VSB-TUO

Prague

CEI

CTU

Rez

CVR

Egypt

Alexandria

Univ.

Cairo

NRC

Giza

CU

	Mansoura	MU
	Shibin El Kom	MU
Finland	Jyvaskyla	UJ
	Oulu	UO
France	Cadarache	CC CEA
	Grenoble	ILL
		LPSC
	Saclay	LLB
	Strasbourg	IPHC
Georgia	Tbilisi	AIP TSU
		TSU
Germany	Darmstadt	GSI
	Dresden	HZDR
	Kleve	HSRW
	Mainz	JGU
	Munich	TUM
	Tubingen	Univ.
Hungary	Budapest	RKK OU
IAEA	Vienna	IAEA
India	Varanasi	BHU
Italy	Rome	ENEA
Japan	Kyoto	KSU
	Tsukuba	KEK
Kazakhstan	Almaty	INP
	Kyzylorda	KazSRIRG
	Nur-Sultan	ENU
Moldova	Chisinau	IChem
		IMB ASM
Mongolia	Ulaanbaatar	CGL
		NRC NUM
North Macedonia	Skopje	UKiM
Poland	Gdansk	GUT
	Krakow	INP PAS
	Lodz	UL
	Lublin	UMCS
	Opole	UO
	Otwock (Swierk)	NCBJ
	Poznan	AMU
	Wroclaw	UW
Republic of Korea	Daejeon	KAERI
	Pohang	PAL
	Seoul	Dawonsys
Romania	Baia Mare	TUCN-NUCBM
	Bucharest	IFIN-HH
		INCDIE ICPE-CA
		IGR
		UB
		UPB
	Cluj-Napoca	INCDTIM
	Constanta	UOC
	Galati	UG
	Iasi	NIRDTP
		UAIC

	Magurele	ISS NIMP
	Oradea	UO
	Pitesti	ICN
	Ramnicu Valcea	I.C.S.I.
	Sibiu	ULBS
	Targoviste	UVT
	Timisoara	UVT
Russia	Borok	IBIW RAS
	Dolgoprudny	MIPT
	Dubna	Diamant Dubna State Univ.
	Gatchina	NRC KI PNPI
	Grozny	CSPU
	Irkutsk	LI SB RAS
	Ivanovo	ISUCT
	Izhevsk	UdSU
	Moscow	GIN RAS GPI RAS IA RAS IKI RAS IPCE RAS ITEP MSU NRC KI Sechenov Univ. SIAS SINP MSU SC "IASRWA" VNIIA
	Moscow, Troitsk	INR RAS
	Nizhny Novgorod	IPM RAS
	Obninsk	IPPE
	Sevastopol	IBSS
	St. Petersburg	Botanic garden BIN RAS FIP Ioffe Institute KRI SPMU SPSFTU
	Tula	TSU
	Vladikavkaz	NOSU
	Voronezh	VSU
	Yekaterinburg	UrFU
Serbia	Belgrade	IPB Univ.
	Novi Sad	UNS
Slovakia	Bratislava	CU IEE SAS
	Ljubljana	IP SAS GeoSS
Slovenia	Bellville	UWC
South Africa	Pretoria	UNISA
	Stellenbosch	SU

Switzerland	Villigen	PSI
Thailand	Hat Yai	PSU
Turkey	Canakkale	COMU
Ukraine	Berdyansk	BSPU
	Donetsk	DonIPE
	Kharkov	ISMA NASU
		NSC KIPT
	Kiev	KINR NASU
		NUK
	Uzhhorod	IEP NASU
USA	Durham, NC	Duke
	Los Alamos, NM	LANL
	Oak Ridge, TN	ORNL
Uzbekistan	Tashkent	INP AS RUz
Vietnam	Hanoi	IOP VAST
		VNU





**Condensed  
Matter Physics,  
Radiation  
and Radiobiological  
Research  
(04)**

## **Investigations of Functional Materials and Nanosystems Using Neutron Scattering**

### **Leaders:**

D.P. Kozlenko  
V.L. Aksenov  
A.M. Balagurov

### **Participating countries and international organizations:**

Armenia, Azerbaijan, Belarus, Bulgaria, China, Czech Republic, Egypt, France, Germany, Hungary, India, Italy, Japan, Kazakhstan, Latvia, Mongolia, Poland, Romania, Russia, Serbia, Slovakia, South Africa, Spain, Switzerland, Tajikistan, Ukraine, United Kingdom, USA, Uzbekistan, Vietnam.

### **Issues addressed and main goals of research:**

Investigations of structural features and dynamics of novel functional materials and nanosystems focused on determination of microscopic mechanisms of the formation of physical properties and phenomena that are important for the development of modern concepts in the areas of condensed matter physics, materials science, chemistry, geophysics, engineering sciences, biology, pharmacology, and for the development of modern technologies.

### **Expected results in the current year:**

#### **Realization of scientific program**

- Determination of characteristics of the atomic and magnetic structure of giant magnetostrictive alloys depending on thermodynamic conditions, synthesis conditions, alloying additives and thermomechanical processing.
- Determination of parameters of the atomic and magnetic structure of simple and complex oxides with a spinel-type structure under high pressure.
- Determination of parameters of crystal, magnetic and electronic subsystems of multifunctional oxides based on cobalt, manganese, iron in the region of spin transition and antiferromagnetic-ferromagnetic-paramagnetic and metal-insulator phase transitions in a wide range of temperatures and pressures.
- Analysis of structural and magnetic properties of low-dimensional van der Waals magnets.
- Study of the effect of microstructure of electrodes with varying composition on charge-discharge processes in compact electric power sources. Clarification of structural mechanisms responsible for the capacity and lifetime of batteries. Selection of optimal discharge/charge modes during cycling.
- Analysis of processes of deposition and intercalation of electrically active ions and their derivatives from liquid and solid electrolytes at electrochemical interfaces in compact electric power sources. A comparative study of characteristics of adsorption layers (density, thickness, homogeneity) at electrochemical interfaces for electrolytes and electrodes.
- Study of phenomena and effects induced by the interaction of ferromagnetic and superconducting order parameters in complex structures with helicoidal magnetic ordering.
- Investigation of structural stability of colloidal systems, including biomedical solutions, in bulk and at interfaces under various conditions. Determination of characteristics of adsorption layers at interfaces in case of loss of stability as a result of external influence of gradient electric and magnetic fields, as well as temperature effects. Study of the effect of aggregate formation in bulk on adsorption.
- Investigation of the structure of a number of advanced nanosystems based on composite carbon- and silicon-containing materials, including those based on fullerenes, nanodiamonds and their bioactive derivatives. Study of complex multicomponent systems. Determination of conditions for synthesis of homogeneous systems. Investigation of effects of phase separation in advanced practical systems.
- Determination of structural characteristics of magnetic elastomers and carbosilane dendrimers, holding promise for technological applications.
- Study of structure and vibrational spectra of molecular complexes: ionic-molecular inclusive materials and complexes with electric charge transfer, structural and dynamic parameters of hydrogen bonds in bioactive materials.

- Investigation of molecular mechanisms of protein interaction, dimerization and functional characteristics of supramolecular structures and molecular complexes. Study of regularities and relationships between structural characteristics and functions of proteins, protein complexes and membrane-protein aggregates. Analysis of the effect of composition and external parameters on the phase state of membranes.
- Determination of structural characteristics and diffusion properties of lipid nanosystems for transport of drugs and nano-drugs.
- Analysis of metamorphic, geodynamic and evolutionary processes in the lithosphere using data on textures of deep-seated and near-surface rocks. Study of regularities in the development of instability of rocks under high temperatures and pressures. Investigation of relationships between seismic anisotropy of lithosphere rocks and textures of minerals, preferentially-oriented cracks and pores.
- Investigation of crystallographic texture and phase composition of biological objects (mollusk shells, corals, animal bones, teeth, biomineralized structures).
- Nondestructive testing of residual internal stresses and microstrains in real industrial products and advanced structural materials induced by various technological processes (metal and heat treatment, welding, rolling, stamping, 3D printing, etc.).
- Investigation of relationships between microstructure and thermomechanical properties of advanced functional and structural materials (high-strength steels, aluminum and magnesium alloys, composites, cermets, etc.), analysis of mechanical behavior of structural materials under external stimuli (load, temperature).
- Analysis of internal structure and construction of 3D models of objects of cultural and natural heritage, industrial materials and products using neutron tomography and radiography data.
- Clarification of mechanisms of radiation damage to solids, obtaining long-life operating data on radiation damage resistance of materials.

#### **Realization of instrument development program for the IBR-2 spectrometers**

- Development and construction of the main units for a new inverse geometry inelastic scattering spectrometer at the beamline 2.
- Development and construction of elements of basic configuration of a small-angle scattering and imaging spectrometer at beamline 10.
- Development of neutron guide and detector system for the new DN-6 diffractometer for studies of microsamples, aimed at improving its technical parameters and expanding the available range of high pressures.
- Improvement of technical parameters and expansion of experimental capabilities of the GRAINS multifunctional reflectometer (startup of a new neutron beam chopper, development of electrochemical and liquid cells for conducting experiments).
- Modernization of the available IBR-2 spectrometers (HRFD, RTD, DN-12, YuMO, FSD, REFLEX, REMUR, SKAT, EPSILON) aimed at improving their technical characteristics (enhancement of luminosity, suppression of neutron background, improvement of data acquisition systems and expansion of experimental capabilities).
- Development and construction of a prototype of a small-angle spin-echo scattering spectrometer at beamline 9.
- Improvement of technical characteristics of the radiography and tomography spectrometer at beamline 14 (spatial resolution, radiation resistance of the detector system).
- Upgrade of the FSS correlation spectrometer at beamline 13 and improvement of its technical parameters. Further development of the RTOF correlation method.
- Development of neutron methods for condensed matter research, including spin-echo, neutron standing waves, neutron wave splitting, neutron magnetic resonance, radiography, tomography, and other techniques.
- Development of neutron scattering methods for in-operando monitoring and study of electrochemical materials and interfaces.

#### **List of projects:**

<b>Project</b>	<b>Leader</b>	<b>Priority (period of realisation)</b>
1. DINSS	D.M. Chudoba	1 (2021-2023)

## List of Activities:

Activity or Experiment	Leaders	Status
Laboratory or other Division of JINR	Main researchers	
<b>1. Study of structure and properties of new inorganic and organic functional materials</b>	<b>A.M. Balagurov</b> <b>D.P. Kozlenko</b> <b>S.I. Tiutiunnikov</b> (VBLHEP)	Data taking
FLNP	E.B. Askerov, A.I. Beskrovnyi, I.A. Bobrikov, N.O. Golosova, S.E. Kichanov, M.L. Kraus, E.V. Lukin, G.M. Mironova, D.S. Neov, A. Pavlyukoych, B.N. Savenko, N.Yu. SamoiloVA, V.A. Turchenko	
MLIT	V.B. Zlokazov	
VBLHEP	V.A. Artyukh, V.V. Efimov, Yu.S. Kovalev, I.A. Kryachko, A.V. Rogachev, V.N. Shalyapin, N.I. Zamyatin	
<b>2. Investigation of structural and magnetic properties of materials under extreme conditions</b>	<b>D.P. Kozlenko</b>	Data taking
FLNP	A. Asadov, N.M. BelozeroVA, N.O. Golosova, S.E. Kichanov, E.V. Lukin, A.V. Rutkauskas, B.N. Savenko	
<b>3. Real-time investigations of physical and chemical processes in functional materials</b>	<b>A.M. Balagurov</b>	Data taking
FLNP	I.A. Bobrikov, A.I. Beskrovnyi, O.Yu. Ivanshina, E.P. Popov, N.Yu. SamoiloVA, V.G. Simkin, S.V. Sumnikov, G.M. Mironova, T.N. Vershinina	
<b>4. Computer simulation of structure and properties of new functional materials and nanosystems</b>	<b>A. Pawlukoje</b>	Data taking
FLNP	Kh.T. Kholmurodov	
<b>5. Investigation of structural and magnetic properties of layered nanostructures</b>	<b>Yu.V. Nikitenko</b>	Data taking
FLNP	S.V. Kozhevnikov, A.V. Petrenko, V.D. Zhaketov	
<b>6. Investigation of structure of carbon-and silicon-containing nanomaterials</b>	<b>V.L. Aksenov</b>	Data taking
FLNP	D.M. Chudoba, M. Jazdzewska, T.V. Nagornaya, A.Zh. Nazarova, A.A. Tomchuk, T.V. Tropin	
<b>7. Investigation of molecular dynamics of functional materials</b>	<b>D.M. Chudoba</b>	Data taking
FLNP	P. Bilski, E.A. Goremychkin, M. Jazdzewska, M. Klepacka, J. Krawczyk, K.B. Ludzik-Dychto, T.V. Nagornaya, Z. Surowiec, J. Waliszewski, I. Zuba	
<b>8. Investigation of dispersed systems and complex fluids in bulk and at interfaces</b>	<b>M.V. Avdeev</b>	Data taking
FLNP	E.N. Kosiachkin, A.V. Nagorny, A.V. Tomchuk, T.V. Tropin	

<b>9. Investigation of structural organization of biogenic and non-biogenic nanoparticles, composites based on magnetic fluids, polymers and other nanomaterials</b> FLNP	<b>M. Balasoiu</b>	Data taking
DLNP	O.I. Ivankov, A.Kh. Islamov, A.I. Kuklin, A. Nabiev, A.V. Rogachev, D.V. Soloviev, V.A. Turchenko	
FLNR	K.I. Gritsay	
MLIT	N.E. Lizunov, O.L. Orelovich	
	A.G. Soloviev, T.M. Solovieva	
<b>10. Investigation of supramolecular structure and functional characteristics of biological nanosystems</b> FLNP	<b>A.I. Kuklin</b>	Data taking
MLIT	Yu.E. Gorshkova, O.I. Ivankov, A.Kh. Islamov, Yu.S. Kovalev, T.N. Murugova, A.V. Rogachev, V.V. Skoy, D.V. Soloviev	
	A.G. Soloviev, T.M. Solovieva	
<b>11. Investigations of structure and properties of lipid membranes and complexes</b> FLNP	<b>M.A. Kiselev</b>	Data taking
MLIT	O.I. Ivankov, V.A. Maslova	
	E.V. Zemlyanaya	
<b>12. Investigations of structure and properties of biohybrid complexes</b> FLNP	<b>Yu.E. Gorshkova</b>	Data taking
	O.Yu. Ivanshina, T.V. Tropin	
<b>13. Investigation of internal stresses and microstrains in structural materials and industrial products</b> FLNP	<b>G.D. Bokuchava</b>	Data taking
	A.A. Kruglov, B. Mukhametuly, I.V. Papushkin, A.V. Tamonov, Yu.V. Taran, T.N. Vershinina	
<b>14. Investigation of features of internal structure of cultural and natural heritage objects, structural materials and industrial products</b> FLNP	<b>D.P. Kozlenko</b>	Data taking
	S.E. Kichanov, E.V. Lukin, K.M. Nazarov, A.V. Rutkauskas, B.N. Savenko, I.Yu. Zel	
<b>15. Investigation of texture and properties of rocks and minerals, structural materials, biological objects</b> FLNP	<b>D.I. Nikolaev</b>	Data taking
	B. Altangerel, T.I. Ivankina, T.A. Lychagina, V.V. Sikolenko, R.N. Vasin	
<b>16. Study of radiation damage effects in solid-state materials</b>  VBLHEP	<b>S.I. Tiutiunnikov (VBLHEP)</b>	Data taking
	V.A. Artyukh, V.V. Efimov, Yu.S. Kovalev, I.A. Kryachko, E.A. Levterova, A.V. Rogachev, V.N. Shalyapin, N.I. Zamyatin	

<b>17. Development of IBR-2 spectrometers</b>	<b>M.V. Avdeev</b> <b>D.P. Kozlenko</b> <b>D.M. Chudoba</b>	Realization
FLNP	A.I. Beskrovnyi, I.A. Bobrikov, V.I. Bodnarchuk, G.D. Bokuchava, E.A. Goremychkin, S.V. Kichanov, A.I. Kuklin, E.V. Lukin, Yu.V. Nikitenko, Yu.V. Petrenko, B.N. Savenko, V.G. Simkin, V.I. Sukhanov, V.A. Turchenko	

<b>18. Development of neutron methods to study functional materials and nanosystems</b>	<b>G.D. Bokuchava</b> <b>D.P. Kozlenko</b> <b>M.V. Avdeev</b>	Data taking
FLNP	S.E. Kichanov, E.N. Kosiachkin, S.V. Kozhevnikov, E.V. Lukin, Yu.V. Nikitenko, A.V. Rutkauskas, V.D. Zhaketov	

## Collaboration

Country or International Organization	City	Institute or laboratory
Armenia	Yerevan	Foundation ANSL SRCHCH
Azerbaijan	Baku	AzTU IP ANAS
Belarus	Minsk	BSTU IAP NASB INP BSU RI PCP BSU SPMRC NASB
Bulgaria	Sofia	ASCI Ltd IE BAS IEES BAS INRNE BAS ISSP BAS UCTM
China	Harbin	HEU
Czech Republic	Prague	BC CAS CTU CU IG CAS IMC CAS IP CAS
Egypt	Rez Cairo	NPI CAS ASU EAEA
France	Giza Grenoble	CU IBS ILL
Germany	Saclay Berlin	LLB BAM HZB
	Bochum Bonn Darmstadt Freiberg Geesthacht Gottingen Halle	RUB UniBonn TU Darmstadt TUBAF GKSS Univ. MLU

	Hamburg	DESY
	Julich	FZJ
	Karlsruhe	KIT
	Kiel	IFM-GEOMAR
	Konstanz	Univ.
	Rostock	Univ.
	Stuttgart	MPI-FKF
Hungary	Budapest	Wigner RCP
India	Patna	NIT Patna
Italy	Messina	UniMe
Japan	Minato	Keio Univ.
	Tokyo	Waseda Univ.
Kazakhstan	Almaty	INP
Latvia	Riga	ISSP UL
Mongolia	Ulaanbaatar	IPT MAS
Poland	Bialystok	BUT
		UwB
	Krakow	AGH-UST
		INP PAS
		JU
	Lublin	UMCS
	Poznan	AMU
	Siedlce	UPH
	Szczecin	WPUT
	Warsaw	INCT
	Wroclaw	UW
Romania	Baia Mare	TUCN-NUCBM
	Bucharest	IFIN-HH
		INCDIE ICPE-CA
		UB
		UPB
	Cluj-Napoca	INCDTIM
		RA BC-N
		UBB
	Constanta	MINAC
		UOC
	Craiova	UC
	Iasi	NIRDTP
		TUIASI
		UAI
		UAIC
		USAMV
	Magurele	NIMP
	Pitesti	ICN
		UPIT
	Targoviste	UVT
	Timisoara	ICT
		ISIM
		LMF CCTFA
		UVT
	Tulcea	DDNI
Russia	Chelyabinsk	SUSU
	Chernogolovka	ISSP RAS
	Dolgoprudny	MIPT

	Dubna	Dubna State Univ.
	Gatchina	NRC KI PNPI
	Kaliningrad	IKBFU
	Kazan	KFU
		KNRTU
	Moscow	IA RAS
		IC RAS
		ICP RAS
		IEPT RAS
		IGEM RAS
		IGIC RAS
		IMET RAS
		INMI RAS
		Inst. Immunology
		IPE RAS
		MIET
		MISiS
		MSU
		NNRU "MEPhI"
		NRC KI
		PIN RAS
		SINP MSU
	Moscow, Troitsk	HPPI RAS
		INR RAS
	Nizhny Novgorod	IPM RAS
		UNN
	Perm	ICMM UrB RAS
		ITCh UrB RAS
	Rostov-on-Don	RIP SFU
	St. Petersburg	CRISM "Prometey"
		IMC RAS
		Ioffe Institute
		SPbSU
	Sterlitamak	SB BSU
	Tula	TSU
	Tyumen	UTMN
	Yekaterinburg	IMP UB RAS
		UrFU
Serbia	Belgrade	INS "VINCA"
Slovakia	Bratislava	CU
	Kosice	IEP SAS
South Africa	Pretoria	Necsa
		UP
Spain	Barcelona	ICMAB-CSIC
	Leioa	BCMaterials
	Madrid	CENIM-CSIC
Switzerland	Villigen	PSI
Tajikistan	Dushanbe	NAST
		PHTI NAST
		TTU
Ukraine	Donetsk	DonIPE
		DonNU
	Kiev	DonIPE NASU
		NUK



United Kingdom  
USA  
Uzbekistan  
Vietnam

Didcot  
Berkeley, CA  
Tashkent  
Da Nang  
Hanoi

RAL  
UC  
INP AS RUz  
DTU  
IOP VAST

## Development of the IBR-2 Facility with a Complex of Cryogenic Neutron Moderators

**Leaders:** A.V. Vinogradov  
A.V. Belushkin  
A.V. Dolgikh

### Participating countries and international organizations:

Azerbaijan, Belarus, Mongolia, Poland, Romania, Russia, Spain.

### Issues addressed and main goals of research:

The main task of the theme is to increase the efficiency of the use of the IBR-2 facility for realization of the program of experimental studies, maintenance of operational reliability and safety of the reactor, creation of the complex of cryogenic neutron moderators.

### Expected results in the current year:

- Provision of the IBR-2 reactor operation for physics investigations.
- Check assembling, adjustment and testing of the backup movable reflector MR-3R at the FLNP test bench. Experimental investigations on determination of dynamic characteristics and parameters of vibrations of the units and structure modules at the stage of assembly and bench testing of MR-3R.
- Operation of cryogenic moderators CM-201 and CM-202 in the trial operation mode.
- Phased replacement and upgrade of the basic technological and electrical safety-related equipment of the IBR-2 facility.

### List of projects:

Project	Leader	Priority (period of realisation)
1. Construction of the complex of cryogenic moderators at the IBR-2 facility	K.A. Mukhin	1 (2014-2022)

### List of Activities:

Activity or Experiment Laboratory or other Division of JINR	Leaders	Status
1. <b>Operation of the IBR-2 facility in the regular mode</b> FLNP	<b>A.V. Dolgikh</b> <b>A.V. Vinogradov</b> M.V. Andrianov, A.A. Belyakov, Yu.N. Pepelyshev, S.V. Rudenko, S.A. Tsarenkov, V.A. Trepalin, 30 engineers, 50 workers	Realization
2. <b>Provision of physics research program</b> FLNP	<b>A.V. Vinogradov</b> <b>A.V. Dolgikh</b> A.A. Belyakov, Yu.N. Pepelyshev, S.V. Rudenko, V.A. Trepalin, 57 engineers, 68 workers	Realization
3. <b>Test operation of equipment of cryogenic moderators CM-201 and CM-202. Operation of cryogenic moderators using new cryogenic refrigerator by Linde in the regular place</b> FLNP	<b>A.A. Belyakov</b> <b>K.A. Mukhin</b> E.P. Shabalin, 15 engineers, 15 workers	Realization

4. **Assembling of backup movable reflector MR-3R**  
FLNP

**A.V. Vinogradov**  
**A.V. Dolgikh**

Realization
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A.A. Belyakov, 5 engineers, 5 workers

5. **Step-by-step replacement and upgrade of basic technological and electrical equipment**  
FLNP

**A.V. Vinogradov**  
**A.V. Dolgikh**

Realization
-------------

A.A. Belyakov, A.V. Trepalin, 30 engineers, 50 workers

## Collaboration

### Country or International Organization

Azerbaijan

Belarus

Mongolia

Poland

Romania

Russia

Spain

### City

Baku

Minsk

Ulaanbaatar

Krakow

Bucharest

Moscow

Valencia

### Institute or laboratory

IRP ANAS

NNRC

JIPNR-Sosny NASB

IPT MAS

AGH-UST

IFIN-HH

ENES

Geliymash

INEUM

OKSAT NIKIET

SSDI

SYSTEMATOM

UPV

## **Scientific and Methodological Research and Developments for Condensed Matter Investigations with IBR-2 Neutron Beams**

**Leaders:** V.I. Bodnarchuk  
V.I. Prikhodko

### **Participating countries and international organizations:**

Argentina, Armenia, Belarus, Czech Republic, Germany, Hungary, Republic of Korea, Romania, Russia, Sweden, Switzerland, Ukraine, United Kingdom, Uzbekistan.

### **Issues addressed and main goals of research:**

Regular operation, modernization and development of control systems for CM-201 and CM-202 cryogenic moderators. Development and equipping of new spectrometers, as well as modernization and reconstruction of equipment for the existing IBR-2 spectrometers in order to improve their parameters, expand experimental capabilities and ensure their faultless operation. Scientific and technical support for the development of beam-forming systems, neutron detectors, sample environment systems, cryostats and cryomagnetic systems, as well as electronics and software of data acquisition systems. Development of FLNP information and computing infrastructure.

### **Expected results in the current year:**

- Maintenance of regular operation of the complex of CM-201 and CM-202 cryogenic pelletized moderators for physics experiments. Automation of the vacuum system and the system for supplying helium to the pneumatic transport pipeline of the CM-202 cryogenic moderator; upgrade and development of software for control systems of the CM-202 moderator. Manufacturing of a prototype dropper for the formation of methane pellets for a complex of cryogenic moderators and carrying out of pre-commissioning works.
- Investigation of radiation resistance of materials using the radiation research facility. Neutron activation analysis of irradiated samples using a high-purity germanium spectrometer.
- Development of a new system for data acquisition from PSD-based multi-detector systems for the DN-12 diffractometer.
- Introduction of new MPD32-USB 3 electronic modules into data acquisition systems at IBR-2 spectrometers.
- Introduction of industrial digitizers in PSD-based measuring systems. Optimization of digitizer parameters to obtain the best counting and coordinate characteristics of PSD. Application of a new 32-channel digitizer for data acquisition from a prototype of the scintillation PSD developed and manufactured at the CM Department.
- Installation and adjustment of the Astra-M scintillation detector for the FSD diffractometer.
- Manufacturing and assembly of sectors of the BSD detector, assembly and adjustment of eight MPD32-USB 3 modules for data acquisition on the HRFD diffractometer in accordance with the project schedule.
- Completion of the second stage of assembling the detector system for the REMUR spectrometer.
- Manufacturing, installation and commissioning of a beam monitor on the YuMO spectrometer.
- Development of technology for creating thermal neutron detectors based on the B<sub>4</sub>C converter, manufacturing and testing of detector prototypes.
- Commissioning of a horizontal-vertical cryostat with a superconducting magnet on the DN-12 diffractometer in cooperation with the specialists from the NICM Department.
- Research and development of devices based on closed-cycle cryocoolers for obtaining temperatures in the range of 4.2-0.5 K by liquefying <sup>3</sup>He and pumping out its saturated vapor.
- Application of VITESS, McStas and other software packages for simulating neutron scattering in samples and in individual components of spectrometers. Complex calculations and optimization of spectrometers.
- Development of a system to control the frequency and rotation phase of mechanical neutron beam choppers based on programmable logic controllers (PLC). Modernization of PLC devices at the request of users, development of technical specifications for the application of PLC for automation of spectrometer components (positioning devices, control systems of special sample environment equipment, etc.).

- Development and manufacturing of units for neutron beam choppers with two drums for REMUR and GRAINS reflectometers.
- Development of a mechanical neutron beam filter with time focusing.
- Development of specialized sample cells for the GRAINS reflectometer (cell with humidity control, liquid-solid flow cell).
- Maintenance and development of the Sonix+ software package at the request of users, as well as on the basis of the latest versions of the software packages and systems used. Upgrade of Sonix+ on the DN-6, DN-12, RTD spectrometers. Development of modules (within the framework of Sonix+) for controlling MPD32 controllers and CAEN N673 digitizer, as well as software for new detectors on HRFD and FSD diffractometers.
- Software support for further automation of control systems for the complex of cryogenic pelletized moderators CM-201 and CM-202.
- Modernization of the FLNP central data repository for experimental data. Development of Wi-Fi network in buildings 42 (first and second floors), 42a and 44.

### List of projects:

Project	Leader	Priority (period of realisation)
1. Construction of a wide-aperture backscattering detector (BSD) for the HRFD diffractometer	V.M. Milkov	(2021-2023)

### List of Activities:

Activity or Experiment Laboratory or other Division of JINR	Leaders Main researchers	Status
1. <b>Maintenance of regular operation and development of the complex of CM-201 and CM-202 cryogenic pelletized moderators. Further automation of moderators' control systems</b>	<b>M.V. Bulavin</b>	Realization
2. <b>Investigation of radiation resistance of materials, electronics and detectors for large-scale physics facilities: ANLAS, CMS, NICA, ITER, ESS, etc.; applied research</b> FLNP	<b>M.V. Bulavin</b>  A.V. Altynov, M.O. Belova, A.V. Galushko, A.S. Kirilov, K.A. Mukhin, T.B. Petukhova, 10 engineers	Realization
3. <b>Development of VITESS software package and simulation of individual components of spectrometers. Investigation of neutron background conditions at IBR-2 spectrometers, development of recommendations to reduce the background level</b> FLNP	<b>V.I. Bodnarchuk</b>  R. Erhan, V.V. Sadilov	Realization
4. <b>Development of the horizontal/vertical cryostat with a superconducting magnet. Development and modernization of cryostats at IBR-2 spectrometers. Modernization of the cryogenic test bench for working with liquid helium</b> FLNP	<b>A.N. Chernikov</b> <b>S.E. Kichanov</b>  A.P. Buzdavin, 1 engineer, 1 laboratory assistant	Realization

- |   |  |   |
|---|--|---|
| <p><b>5. Completion of development and construction of the BSD detector. Putting the detector into operation at the HRFD diffractometer. Commissioning of the upgraded ASTRA-M detector at FSD</b><br/>FLNP</p>   | <p><b>V.M. Milkov</b><br/><b>A.A. Bogdzel</b><br/><b>A.S. Kirilov</b></p>  | <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;">Realization</div> |
| <p>G.D. Bokuchava, V.A. Drozdov, V.V. Shvetsov, V.G. Simkin, 3 engineers, 4 laboratory assistants</p>   |  |   |
| <p><b>6. Development and investigation of prototypes of PSD systems based on counters with a resistive anode wire up to 1 m long and large-area (~1 m<sup>2</sup>) scintillation position-sensitive detectors. Development of a 2D PSD with a central opening for a direct beam for the REMUR spectrometer. Investigation of boron-based neutron converters. Development and equipping of IBR-2 spectrometers with beam monitors</b><br/>FLNP</p> | <p><b>A.V. Churakov</b><br/><b>V.M. Milkov</b><br/><b>A.A. Bogdzel</b></p> | <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;">Realization</div> |
| <p>V.A. Drozdov, A.K. Kurilkin, V.M. Milkov, S.M. Murashkevich, V.V. Zhuravlev, 3 engineers</p>   |  |   |
| <p><b>7. Modernization of detector and data acquisition electronics for IBR-2 spectrometers</b><br/><br/>FLNP</p>   | <p><b>A.A. Bogdzel</b><br/><b>A.S. Kirilov</b></p>                         | <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;">Realization</div> |
| <p>V.A. Drozdov, E.I. Litvinenko, V.M. Milkov, S.M. Murashkevich, V.M. Shvetsov, V.V. Zhuravlev, 2 engineers</p>  |  |   |
| <p><b>8. Introduction of programmable logic controllers in control systems for actuators, sample environment equipment and spectrometers' choppers. Installation of additional equipment at IBR-2 spectrometers at the request of instrument responsables</b><br/>FLNP</p>  | <p><b>V.I. Bodnarchuk</b><br/><b>I.V. Gapon</b></p>                        | <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;">Realization</div> |
| <p>A.V. Altynov, A.S. Kirilov, T.B. Petukhova, N.D. Zernin, V.V. Zhuravlev, 2 engineers</p>   |  |   |
| <p><b>9. Maintenance and development of the Sonix+ software package and installation of its new versions at IBR-2 spectrometers. Development of FLNP central servers and network infrastructure in accordance with the development strategy of the JINR computer network. Modernization of Laboratory's mail system and Wi-Fi network</b><br/>FLNP<br/><br/>MLIT</p>  | <p><b>A.S. Kirilov</b><br/><b>V.I. Prikhodko</b></p>                       | <div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;">Realization</div> |
| <p>A.S. Kirilov, G.A. Sukhomlinov, 4 engineers</p> <p>A.G. Dolbilov, 1 engineer</p>   |  |   |

## Collaboration

### Country or International Organization

Argentina

Armenia

Belarus

Czech Republic

Germany

Hungary

Republic of Korea

Romania

Russia

Sweden

Switzerland

Ukraine

United Kingdom

Uzbekistan

### City

Bariloche

Yerevan

Minsk

Rez

Berlin

Darmstadt

Julich

Budapest

Daejeon

Bucharest

Cluj-Napoca

Iasi

Targoviste

Dubna

Gatchina

Moscow

Moscow, Troitsk

Yekaterinburg

Lund

Villigen

Lviv

Didcot

Tashkent

### Institute or laboratory

CAB CNEA

Foundation ANSL

BSTU

INP BSU

NPI CAS

HZB

GSI

FZJ

Wigner RCP

KFE

INCDIE ICPE-CA

INCDTIM

UAIC

UVT

Dubna State Univ.

NRC KI PNPI

NRC KI

PC ITER RF

INR RAS

IMP UB RAS

ESS ERIC

PSI

LPNU

RAL

INP AS RUz

## Modern Trends and Developments in Raman Microspectroscopy and Photoluminescence for Condensed Matter Studies

**Leaders:** G.M. Arzumanyan  
N. Kučerka

### Participating countries and international organizations:

Armenia, Belarus, Bulgaria, Poland, Romania, Russia, Serbia, Slovakia, Uzbekistan.

### Issues addressed and main goals of research:

Fundamental and applied research in the field of spontaneous and nonlinear Raman microspectroscopy aimed at highly sensitive biosensing. Study of mechanisms and nature of surface-enhanced Raman scattering (SERS) taking into account the anomalous ratio of line intensities in the anti-Stokes and Stokes spectral regions. Applied research is aimed at the use of Raman spectroscopy and fluorescence microscopy in biomedical research, in particular, in the search for spectral markers of NETosis, as well as some features of lipid-protein interactions.

### Expected results in the current year:

- Detection of Raman spectra of organic molecules in the low-frequency region using Bragg filters simultaneously in the Stokes and anti-Stokes regions.
- Investigation of a possible anomaly in the ratio of the peaks  $aSt / St$  in the SERS spectra depending on the continuous and pulsed pumping modes.
- Synthesis of liposomes / liposomes with embedded proteins and the study of their chemical structure and morphology by Raman spectroscopy and fluorescence microscopy.
- UV-induced NETOSIS: identification of dependence on wavelength and intensity of irradiation.
- Application of fluorescence microscopy to identify programmed death of neutrophil cells under the influence of various activators, including UV radiation.

### List of projects:

Project	Leaders	Priority (period of realisation)
1. BIOPHOTONICS	G.M. Arzumanyan N. Kučerka Deputy: K.Z. Mamatkulov	1 (2021-2023)

### List of Activities

Activity or Experiment	Leaders	Status
Laboratory or other Division of JINR	Main researchers	
1. Study of the features of Stokes and anti-Stokes components of SERS spectra from analyte molecules in order to understand the processes of enhancement in SERS spectroscopy FLNP	G.M. Arzumanyan  Ye. Arynbek, K.Z. Mamatkulov, I.A. Morkovnikov, 2 engineers	Data taking



<b>2. Determination of the range of pump intensities for recording reproducible aSt / St spectra</b> FLNP	<b>G.M. Arzumanyan</b> <b>K.Z. Mamatkulov</b>	Data taking
	Ye. Arynbeq, M.Yu. Vorobyeva, 1 engineer	
<b>3. Stabilization of membrane proteins and studies of their structure using lipodiscs/liposomes by Raman spectroscopy, electron microscopy and SANS</b> FLNP	<b>G.M. Arzumanyan</b> <b>N. Kučerka</b>	Realization Data taking
	A. Damir, K.Z. Mamatkulov, M.Yu. Vorobyeva	
<b>4. Testing the technique for obtaining Raman spectra of lipodiscs/liposomes with membrane proteins and “empty” lipodiscs/liposomes</b> FLNP	<b>K.Z. Mamatkulov</b> <b>N. Kučerka</b>	Realization
	Ye. Arynbeq, A. Damir, M.Yu. Vorobyeva, 1 engineer	
<b>5. Study of the influence of lipid environment on the structure of membrane protein</b> FLNP	<b>G.M. Arzumanyan</b> <b>N. Kučerka</b>	Data taking
	K.Z. Mamatkulov, M.Yu. Vorobyeva, 1 engineer, 2 laboratory assistants	
<b>6. Search for spectral / Raman markers of NETosis</b> FLNP	<b>G.M. Arzumanyan</b> <b>N. Kučerka</b>	Realization
	K.Z. Mamatkulov, M.Yu. Vorobyeva, 1 engineer, 2 laboratory assistants	
<b>7. Study of mechanisms of sterile activation of NETosis under UV radiation</b> FLNP	<b>G.M. Arzumanyan</b> <b>K.Z. Mamatkulov</b>	Data taking Realization
	A. Damir, M.Yu. Vorobyeva, D.S. Zakritnaya	
<b>8. Mastering the technique of ultra-low frequency Raman spectroscopy ~ (5-10) cm<sup>-1</sup></b> FLNP	<b>G.M. Arzumanyan</b> <b>K.Z. Mamatkulov</b>	Realization
	Ye. Arynbeq, M.Yu. Vorobyeva, 2 engineers	

## Collaboration

### Country or International Organization

Armenia

Belarus

Bulgaria

Poland

Romania

Russia

Serbia

Slovakia

Uzbekistan

### City

Yerevan

Minsk

Sofia

Krakow

Brasov

Bucharest

Cluj-Napoca

Magurele

Moscow

Belgrade

Kosice

Jizzakh

### Institute or laboratory

Foundation ANSL

BSUIR

SOL instruments

ISSP BAS

JU

UNITBV

CSSNT-UPB

INCNTIM

NIMP

GPI RAS

LMPR MONIKI

Univ.

UPJS

JSPI

## Development of the Conceptual Design of a New Advanced Neutron Source at JINR

**Leaders:** V.N. Shvetsov  
M.V. Bulavin

### Participating Countries and International organizations:

Argentina, Belarus, Czech Republic, France, Germany, Hungary, Romania, Russia, South Africa, Sweden, Uzbekistan.

### Issues addressed and main goals of research:

Development of the conceptual design of a new advanced neutron source at JINR.

### Expected main results in the current year:

- Selection of a concept for the new source. Technical specification for the design of the new source with a suite of instruments for neutron beam based research.
- Publication of a "White book". CDR of the new neutron source project.
- Simulation of the first three instruments for the new source.
- Start of R&D on fuel for the new source.

### List of Activities:

Activity or experiment	Leaders
Laboratory or other Division of JINR	Main researchers
<b>1. Scientific rationale for the creation of the new source, "White book"</b>	<b>V.N. Shvetsov</b> <b>M.V. Bulavin</b>
<b>2. Development and justification of the choice of a conceptual design of a high-flux pulsed neutron source of periodic operation</b> OKSAT NIKIET	<b>V.N. Shvetsov</b> <b>M.V. Bulavin</b>  I.T. Tretiakov
<b>3. Preparatory work on the manufacturing of fuel loading/target for the new source</b> FLNP  SC "VNIINM"	<b>V.N. Shvetsov</b> <b>M.V. Bulavin</b>  A.V. Vinogradov, A.V. Dolgikh  Yu.A.Ivanov
<b>4. Development of the concept of layout of neutron moderators, neutron beamlines and instruments</b>	<b>V.N. Shvetsov</b> <b>M.V. Bulavin</b>

**5. Development of technical specifications for the design of the new source with a suite of research instruments at beamlines**

FLNP

**V.N. Shvetsov**  
**M.V. Bulavin**

A.V. Vinogradov

**Collaboration**

**Country or International Organization**

Argentina

Belarus

Czech Republic

France

Germany

Hungary

Romania

Russia

South Africa

Sweden

Uzbekistan

**City**

Bariloche

Minsk

Rez

Grenoble

Berlin

Julich

Budapest

Bucharest

Gatchina

Moscow

Moscow, Troitsk

Pretoria

Lund

Tashkent

**Institute or laboratory**

CAB CNEA

BSTU

NPI CAS

ILL

HZB

FZJ

Wigner RCP

INCDIE ICPE-CA

NRC KI PNPI

NRC KI

OKSAT NIKIET

SC "VNINM"

INR RAS

UP

ESS ERIC

INP AS RUz

## Development of the SOLCRY S Structural Research Laboratory at the SOLARIS National Synchrotron Radiation Centre

**Leader:** N. Kučerka

### Participating Countries and International organizations:

Belarus, Poland, Russia, Slovakia, Ukraine.

### Issues addressed and main goals of research:

The development of a new laboratory for structural research of new materials (catalysts, polymers, etc.), nanomaterials (nanoparticles, nanocomposites, etc.), materials under extreme conditions (superconductors, perovskites, etc.) and biomaterials (proteins, DNA, etc.) utilizing synchrotron X-rays.

### Expected main results in the current year:

- Construction of extended experimental hall for the SOLCRY S laboratory.
- Installation and commissioning of the superconducting wiggler as a synchrotron radiation source for the end stations of the SOLCRY S beamlines.
- Design of beamlines equipment and additional facilities.

### List of Activities:

Activity or experiment	Leaders
Laboratory or other Division of JINR	Main researchers
<b>1. Elaboration and development of technical infrastructure within a scope necessary to install and properly operate the research equipment of the SOLCRY S laboratory</b>	<b>N. Kučerka</b>
<b>2. Design, purchase and installation of a superconducting wiggler as a radiation source in the X-ray range with an upper photon energy at least 20 keV.</b>	<b>N. Kučerka</b>
<b>3. Design, purchase and installation of research lines of synchrotron radiation</b>	<b>A.I. Kuklin E.V. Lukin</b>
<b>4. Design, purchase and installation of measuring stations for diffraction studies and studies of scattering at small angles</b>	<b>A.I. Kuklin E.V. Lukin</b>

**5. Design and assembly of control systems as well as of data acquisition and storage systems**

**N. Kučerka  
A.I. Kuklin  
E.V. Lukin**

### **Collaboration**

#### **Country or International Organization**

Belarus

Poland

Russia

Slovakia

Ukraine

#### **City**

Minsk

Krakow

Poznan

Novosibirsk

Bratislava

Kiev

#### **Institute or laboratory**

BSU

SOLARIS

AMU

BINP SB RAS

CU

NUK

## Radiation Physics, Radiochemistry, and Nanotechnology Investigations Using Beams of Accelerated Heavy Ions

**Leaders:** S.N. Dmitriev  
P.Yu. Apel

### Participating countries and international organizations:

Belarus, Bulgaria, China, Cuba, Czech Republic, Germany, Hungary, Kazakhstan, Moldova, Mongolia, Poland, Romania, Russia, Serbia, Slovak Republic, South Africa, Spain, USA, Vietnam.

### Issues addressed and main goals of research:

Transition to a new level of research and development in the fields of radiation solid-state physics, applied radiochemistry, and materials science opening the way to nanotechnology applications. The main emphasis will be on the modification of materials in the nanometer range and on the study of the effects produced by heavy ions in matter with the aim of revealing the fundamental mechanisms and developing nanotechnology applications of ion beams. Upgrade of the FLNR equipment for the production of medical isotopes and the development of materials modification methods.

### Expected results in the current year:

- Determination of threshold values of specific ionization energy losses of heavy ions for the formation of latent tracks in  $Y_4Al_2O_9$ ,  $Al_2O_3$ ,  $TiO_2$ ,  $Si_3N_4$
- Creation of experimental set-up for homogeneous doping of materials with helium and hydrogen ions with energies of 1-4 MeV.
- Determination of the conditions for the formation of nanoholes and nanochannels in graphene oxide under high-energy heavy ion impact.
- Experimental study and theoretical description of electrokinetic and osmotic properties of track-etched membranes with pore radii of 10-20 nm.
- Determination of ion-selective properties of membranes obtained from ion-irradiated polymer foils using soft photolysis and liquid extraction of photolysis and radiolysis products from tracks.
- Development of hybrid membranes composed of a Ti-coated track etched membrane and a layer of nanofibers produced by electrospinning from chitosan, collagen and hyaluronic acid.
- Development of the fabrication method for track-etched membranes on the basis of the biodegradable polymer polylactide.
- Study of the membrane distillation process for the desalination of seawater using composite track-etched membranes with a thin hydrophobic layer.
- Study of the elemental composition of modified track-etched membranes and their Cs cation sorption ability using nondestructive XRFA method.

### List of Activities:

Activity or Experiment Laboratory or other Division of JINR	Leaders Main researchers	Status
1. Investigations of radiation damages in solids and formation of nanostructures	V.A. Skuratov P.Yu. Apel	Data taking

FLNR V.A. Altynov, I.V. Blonskaja, O.M. Ivanov, L.I. Kravets, O.V. Kristavchuk, N.S. Kirilkin, E.A. Korneeva, N.E. Lizunov, A.N. Nechaev, A. Olejniczak, K. Olejniczak, O.L. Orelovich, R. Rymchanov, A. Rossouw, D.V. Shchegolev, V.K. Semina, V.V. Shirkova, A.S. Sohatsky, G.V. Serpionov, I.I. Vinogradov, Y. Yamauchi

MLIT V.V. Trofimov

FLNP I.A. Bobrikov, M.V. Frontasyeva, A.I. Kuklin

LRB I.V. Koshlan

**2. Production of ultra-pure isotopes**

**N.V. Aksenov**

Preparation

FLNR

A.Yu. Bodrov, G.A. Bozhikov, I. Chuprakov, N.S. Gustova, A.Sh. Madumarov, S.V. Mitrofanov, A.V. Sabelnikov

**3. Radioanalytical studies**

**M.V. Gustova**

Data taking

FLNR

D. Abdusamadzoda, N.S. Gustova, S.P. Kaplina, T.N. Sabelnikova, M.G. Voroniuk

**4. Project of specialized beam lines at DC-140**

**S.V. Mitrofanov**

Preparation

FLNR

S.L. Bogomolov, O.A. Chernyshev, B.N. Gikal, G.N. Ivanov, I.A. Ivanenko, I.V. Kalagin, N.Yu. Kazarinov, V.A. Kostyrev, N.F. Osipov, S.V. Pashchenko, N.N. Pchelkin, V.A. Semin, V.A. Veryovochkin

VBLHEP

A.A. Fateev, 2 pers.

**Collaboration**

**Country or International Organization**

**City**

**Institute or laboratory**

Belarus

Gomel

GSU

Minsk

BSU

Bulgaria

Plovdiv

PU

Sofia

TU-Sofia

China

Beijing

PKU

Cuba

Havana

CEADEN

Czech Republic

Brno

BUT

Olomouc

UP

Prague

CU

Rez

NPI CAS

Germany

Darmstadt

GSI

Hungary

Budapest

GetGiro Kft

Kazakhstan

Almaty

PhysTI

Nur-Sultan

BA INP

ENU

NU

Moldova

Chisinau

MSU

Mongolia

Ulaanbaatar

CGL

NRC NUM

Poland

Lublin

UMCS

Torun

UMK

Warsaw

INCT

WUT

Romania	Baia Mare Bucharest	TUCN-NUCBM CSSNT-UPB IFIN-HH UPB
Russia	Magurele Chernogolovka	INFLPR BInEPCP RAS ISSP RAS
	Dubna Kaliningrad Krasnodar Moscow	Trackpore Technology IKBFU KSU GPI RAS IC RAS ISPM RAS LPI RAS MAI MIEM NMRC RB RIVS SINP MSU
	Novosibirsk Obninsk Saratov St. Petersburg Vladimir	ISP SB RAS REATRACK-Filter SSMU Ioffe Institute Vladisart
Serbia	Belgrade	INS "VINCA"
Slovakia	Bratislava	IEE SAS
		PF SK
South Africa	Bellville Port Elizabeth Pretoria Stellenbosch	UWC NMU UP SU
Spain	Barcelona Valencia	UPC UV
USA	Knoxville, TN Stanford, CA	UTK SU
Vietnam	Hanoi	IOP VAST



## **Research on the Biological Effects of Heavy Charged Particles of Different Energies**

**Leaders:** E.A. Krasavin  
A.N. Bugay

### **Participating countries and international organizations:**

Armenia, Belarus, Bulgaria, Cuba, Czech Republic, Germany, Italy, Mongolia, Poland, Romania, Russia, Serbia, Slovakia, Vietnam.

### **Issues addressed and main goals of research:**

Theoretical and experimental research on the biological effects of heavy charged particles of different energies at JINR's basic facilities.

The research and development will include:

- Research on the mechanisms of the development of DNA molecular damage and its repair in cultures of human and mammalian normal and tumor cells and in histological sections of tissues of different parts of animals' central nervous system after exposure to radiations of different LET.
- Research on the induction and molecular nature of different types of gene and structural mutations in mammalian and lower eukaryote cells depending on the radiation dose and LET, repair status, oxidative stress development, and genetic stability mechanisms.
- Research on the formation of complex chromosomal aberrations in normal and tumor cells of humans and laboratory animals. Evaluation of long-term consequences of exposure to radiations of different LET.
- Research on behavioral reaction disorders and pathomorphological changes in different structures of the brain, spinal cord, and critical organs and systems of irradiated laboratory animals. Conducting a search for new radioprotective drugs.
- Research on radiation-induced effects in microglia, oligodendrocytes and their precursors, and in the myelin sheath after exposure to densely ionizing radiation.
- Research on the mechanisms of the action of Ara-C and other radiosensitizers for the irradiation of different normal and tumor cell cultures and mice with transplanted tumors.
- Development of an hierarchy of mathematical models of radiation-induced biological effects that would describe the development of radiation-induced pathologies at different organization levels (from molecules to cell populations) and at different times (acute and long-term consequences).
- Improvement of accelerator-based radiobiological experiment procedures. Calculation of shieldings for new nuclear physics facilities; evaluation of the radiation conditions and development of radiation safety systems for them. Participation in the creation and tests of nuclear planetary science instruments.

### **Expected results in the current year:**

- To continue the analysis of clustered DNA double-strand break (DSB) formation and repair in human skin fibroblast nuclei and radioresistant U87 tumor cells after accelerated heavy charged particle exposure.
- To continue the analysis of the formation and structure of complex clustered DNA damage by immunocytochemical staining of the repair proteins  $\gamma$ H2AX, 53BP1, OGG1, and XRCC1 in human fibroblast nuclei after accelerated heavy ion exposure.
- To continue comparative analysis of the proportion of different DNA DSB repair pathways in human fibroblasts by immunocytochemical staining of the repair proteins RAD51 (HR) and DNA PKcs (NHEJ) after exposure to radiations of different quality.

- To continue studying the formation and repair kinetics of clustered DNA DSBs in neuron precursor cell nuclei and mature neurons and in glial cells of the mammalian central nervous system (CNS) after accelerated heavy charged particle exposure — using the cell subpopulation markers NeuN, doublecortin, GFAP, BrdU, and calbindin.
- To continue experiments to study the expression of the genes encoding the repair proteins (RAD51, DNAPKcs, NBS1, MRE11, etc.) in human skin fibroblasts after accelerated heavy charged particle exposure.
- To continue studying apoptosis induction in human skin fibroblasts and mammalian CNS neurons after accelerated heavy charged particle exposure.
- To continue studying DNA DSB formation and repair in mammalian CNS neurons after  $\gamma$ -ray and accelerated heavy ion exposure.
- To continue research on the induction of structural rearrangements in cells of laboratory yeast strains by radiations of different LET.
- To study the radiosensitivity of probiotic yeast strains.
- To continue research on the influence of respiratory impairment caused by mitochondrial DNA damage on yeast cells' sensitivity to radiation's lethal and mutagenic effects.
- To map the mutations that decrease yeast cells' radiosensitivity and study the radioprotection mechanism.
- To study the influence of yeast phosphatase HAP1 inactivation on the radiosensitivity and genetic stability of the nuclear and mitochondrial genomes.
- To analyze structural and chromosomal damage in radiation-induced mutants at different times after irradiation of a mammalian cell culture.
- To perform metaphase analysis of long-term chromosomal damage after irradiation of *Macaca mulatta* monkeys' head with accelerated krypton ions.
- To continue an mFISH analysis of complex aberration induction in human normal (lymphocytes) and tumor (Cal51 breast carcinoma) cells by photons, accelerated protons, and accelerated nitrogen ions.
- To continue mFISH analysis of chromosomal aberrations induced in human peripheral blood lymphocytes by different types of radiation used in cancer therapy.
- To continue mFISH karyotyping and analysis of structural and numerical chromosomal aberrations in different lines of human stem cells cultivated *in vitro*.
- To continue premature chromatin condensation analysis of the induction of chromatin breaks in human normal (lymphocytes) and tumor (Cal51 breast carcinoma) cells by  $\gamma$ -rays and accelerated protons and ions at different times after exposure.
- To study the secretion of the inflammatory cytokines TNF alpha, IL-1, IL-6, and MCP-1 in mouse brain homogenates at different times after mouse head irradiation with Bragg peak protons.
- To evaluate the level of the myelin basic protein (MBP) in mouse brain homogenates at different times after mouse head irradiation with Bragg peak protons.
- To continue studying the effect of cytosine arabinoside (Ara-C) on the survival of different mammalian and human normal and tumor cell lines by the criteria of clone formation and apoptosis after exposure to accelerated protons and  $\gamma$ -rays.
- To continue studying the formation and elimination of  $\gamma$ H2AX/53BP1 foci in cultures of U87 glioblastoma and B16 melanoma cells after exposure to Bragg peak protons and  $\gamma$ -rays — under normal conditions and in the presence of Ara-C ( $\pm$ HU).
- To continue studying DNA DSB formation in different parts of rodent CNS after *in vivo* irradiation with accelerated protons and  $\gamma$ -rays without radiomodifiers and in the presence of Ara-C ( $\pm$ HU).
- To continue studying modifications of small laboratory animals' behavioral reactions after heavy charged particle (HCP) exposure in the presence of AraC.
- To evaluate the pathological changes in different cell populations of the brain and the possibility of arresting such damage by the neuroprotective drug Cerebrolysin.
- To continue studying morphological and functional changes in the CNS of SD rats and CD-1 mice after accelerated proton exposure.
- To continue research on pathogenesis in different mammalian tissues and organs after HCP exposure.
- To study the long-term effects of the morphological changes in the rat CNS after accelerated proton exposure.
- To study changes in the lipid composition of the mouse and rat brain after accelerated proton exposure.
- To continue mathematical modeling of DNA damage formation and repair after irradiation of normal and tumor cells with HCP of different energies.

- To continue mathematical modeling of the dynamics of a tumor cell population after ionizing radiation exposure in the presence of DNA synthesis inhibitors.
- To perform mathematical modeling of the growth of a tumor cell population after ionizing radiation exposure in the presence of metal nanoparticles.
- To continue molecular dynamics modeling of impairments in the structure and functioning of mutant and oxidized forms of neuron proteins.
- To continue mathematical modeling of radiation-induced neurogenesis and gliogenesis impairments and neuroinflammatory processes in CNS structures.
- To continue the design, testing, and calibration of nuclear planetary science instruments using fast neutron generators at the LRB's stand.
- To ensure the conduction of radiobiological experiments at JINR's accelerators.
- To participate in the design and fabrication of the SODIB biological long-range ion irradiation station at the Nuclotron's radiobiological channel.
- To develop a project of a galactic cosmic ray simulator at the SODIB biological long-range ion irradiation station at the Nuclotron's radiobiological channel.
- To measure the radiation environment (neutron fields) around the NICA booster during commissioning.

### List of projects:

Project	Leader	Priority (period of realisation)
1. Research on the biological effects of heavy charged particles with different energies	E.A. Krasavin A.N. Bugay	1 (2015-2023)

### List of Activities:

Activity or Experiment	Leaders	Status
Laboratory or other Division of JINR	Main researchers	
1. Radiobiological research at charged particle beams	E.A. Krasavin	Data taking Realization Modeling
LRB	T.N. Bazlova, T.Zh. Bezhanyan, Yu.V. Bogdanova, A.V. Boreyko, N.N. Budennaya, V.N. Chausov, O.O. Chernyak, S.-D. Er Khan, K. Erzhan, T.A. Fadeeva, A.S. Filatova, E.M. Ignat, E.V. Ilyina, M.D. Isakova, A.A. Ivanov, T.S. Khramko, A.N. Kokoreva, I.A. Kolesnikova, N.A. Koltivaya, D.A. Komarov, O.V. Komova, V.L. Korogodina, I.V. Koshlan, N.A. Koshlan, M.A. Kovalenko, R.A. Kozhina, E.A. Kulikova, M.E. Krupnova, P.V. Kutsalo, E.A. Kuzmina, M. Lalkovičova, P.-O. Lkhasuren, K.N. Lyakhova, O.N. Matchuk, L.A. Melnikova, E.A. Nasonova, S.S. Negovellov, A. Nurkasova, M.A. Ostrovsky, A.S. Pavlova, D.V. Petrova, E.V. Pronskikh, Yu.S. Severyukhin, D.D. Shamina, N.V. Shvaneva, E.V. Smirnova, S.I. Tiunchik, D.M. Utina, V.S. Vinogradova, Yu.V. Vinogradova, M.G. Zadneprianetc, N.I. Zhuchkina	
2. Radiation research	G.N. Timoshenko	Preparation Data taking Modeling
LRB	L.G. Beskrovnaya, D.V. Davydov, I.S. Gordeev, V.A. Krylov, E.N. Lesovaya, E.N. Pavlik	
3. Mathematical modeling of radiation-induced effects	A.N. Bugay	Data taking Modeling

LRB

S.V. Aksenova, A.S. Batova, A.V. Chizhov, E.B. Dushanov, I.M. Enyagina, A.A. Glebov, E.A. Kolesnikova, B. Lkhagva, B. Munkhbaatar, M.S. Panina, A.Yu. Parkhomenko, M. Piotrowski, M.A. Vasilyeva

#### 4. Training activity

LRB

**E.A. Krasavin**

**A.N. Bugay**

**S.Z. Pakuliak (UC)**

L.G. Beskrovnaya, A.V. Boreyko, N.N. Budennaya, V.N. Chausov, A.V. Chizhov, E.B.Dushanov, I.V. Koshlan, E.N. Lesovaya, G.N. Timoshenko, M.G. Zadneprianetc

### Collaboration

#### Country or International Organization

#### City

#### Institute or laboratory

Armenia

Yerevan

YSU

Belarus

Minsk

IBCE NASB

Inst. Physiology NASB

SPMRC NASB

Bulgaria

Sofia

IE BAS

Inst. Microbiology BAS

NCRRP

Cuba

San Jose de las Lajas

CENTIS

Czech Republic

Brno

IBP CAS

Prague

CTU

Germany

Darmstadt

GSI

Italy

Naples

Unina

Udine

UniuD

Mongolia

Ulaanbaatar

IPT MAS

Poland

Krakow

INP PAS

Szczecin

US

Romania

Bucharest

IFIN-HH

UMF

Cluj-Napoca

UBB

Iasi

IBR

Russia

Moscow

FMBC

IBMC

IBMP RAS

IHNA Ph RAS

IKI RAS

MSU

NMRC Oncology

NRC KI

SF IPh

SINP MSU

Skoltech

NMRRC

ITEB RAS

SRI MP

Serbia

Belgrade

INS "VINCA"

Univ.

Slovakia

Bratislava

CU

Kosice

IEP SAS

Vietnam

Hanoi

INPC VAST

VINATOM

## **Research on Cosmic Matter on Earth and in Nearby Space; Research on the Biological and Geochemical Specifics of the Early Earth**

**Leaders:** E.A. Krasavin  
A.Yu. Rozanov  
V.N. Shvetsov

### **Participating countries and international organizations:**

Italy, Russia, United Kingdom, USA.

### **Issues addressed and main goals of research:**

Research and development will include:

- Biogeochemical studies of cosmic dust.
- Studies of microfossils and organic compounds in meteorites and ancient terrestrial rocks.
- Studies of cosmic matter with nuclear physics methods.
- As a result of studying and generalizing the research materials on modern and fossil cosmic dust as well as ancient terrestrial objects and modern extremophile organisms, data will be obtained on the forms of ancient terrestrial and extraterrestrial life.

As the results:

- Obtaining new data on the amount of cosmic matter falling on the whole Earth's surface. Obtaining data on the dynamics of cosmic dust fallout on large territories.
- Evaluation of the following parameters of particles of extraterrestrial origin: morphology, structure, size distribution, and elemental, isotopic, and mineralogical composition. Assessment of changes in these characteristics in different plates in different time intervals.
- Creation of a cosmic dust collection, where dust microparticles will be characterized by quantity (concentration) and the size distribution.
- Obtaining new information on the role of microorganisms in the formation and evolution of life on Earth and processes of weathering, precipitation growth, etc.
- Research on the synthesis of complex prebiotic compounds from formamide under exposure to ionizing radiations of different qualities with meteorite samples as catalysts.
- Generalization of the obtained data on the forms of ancient terrestrial and, possibly, extraterrestrial life.

### **Expected results in the current year:**

- To continue the search for and study of microfossils in meteorites and terrestrial rocks using electron microscopy.
- To conduct neutron activation analysis of meteorites and cosmic dust.
- To continue research on the synthesis of complex prebiotic compounds from formamide under the action of accelerated ions using meteorites and minerals of terrestrial origin as catalysts.
- To continue data collection and processing (electronic microscopy and energy-dispersive X-ray spectroscopy images) to create an illustrated atlas of microfossils in carbonaceous chondrites.
- To study extremophiles of the underground biosphere, weathering crusts, and permafrost.

## List of projects:

Project	Leader	Priority (period of realisation)
1. Research on cosmic matter on Earth and in nearby space; research on the biological and geochemical specifics of the early Earth	E.A. Krasavin Scientific leader: A.Yu. Rozanov	1 (2013-2022)

## List of Activities:

Activity or Experiment Laboratory or other Division of JINR	Leaders Main researchers	Status
1. <b>Studies of biofossils in meteorites and ancient terrestrial rocks</b>  LRB	<b>A.Yu. Rozanov</b> <b>E.A. Krasavin</b>  A.N. Afanasyeva, A.K. Rymin	Data taking Realization Modeling
2. <b>Research on the synthesis of complex prebiotic compounds from formamide</b>  LRB	<b>R. Saladino</b>  M.I. Kapralov, E.A. Saprykin	Data taking Realization Modeling
3. <b>Biogeochemical and biological studies of cosmic dust</b>	<b>V.A. Tselmovich</b>	Data taking Realization Modeling
4. <b>Cosmic matter research with nuclear physics methods</b>  FLNP	<b>V.N. Shvetsov (FLNP)</b>  M.V. Frontasyeva, I. Zinicovscaia	Data taking Realization Modeling

## Collaboration

Country or International Organization	City	Institute or laboratory
Italy	Rome	Univ. "La Sapienza"
	Viterbo	UNITUS
Russia	Borok	IPE RAS
	Moscow	IGEM RAS
		IKI RAS
		INMI RAS
		MSU
		PIN RAS
	Novosibirsk	BIC SB RAS
United Kingdom	Buckingham	UB
USA	Athens, AL	ASU

## Biomedical and Radiation-Genetic Studies Using Different Types of Ionizing Radiation

**Leader:** G.V. Mitsyn  
S.L. Yakovenko

**Deputy:** S.V. Shvidky

### Participating countries and international organizations:

Belgium, China, Czech Republic, Moldova, Poland, Romania, Russia, South Africa, USA.

### Issues addressed and main goals of research:

Biomedical and clinical research of proton radiotherapy for cancer treatment. Formation of an experimental data base in the field of radiation mutagenesis in the animal germ cells.

### Expected results in the current year:

- Evaluation of effectiveness of conducted radiation treatment of different neoplasms.
- Increase of functional capability of the developed 3D treatment planning software.
- Design and construction of prototype equipment for dynamic conformal irradiation of deep-seated tumours with the proton beam.
- Development and improvement of detectors and tools for clinical dosimetry of medical hadron beams.
- Continuation of research to determine forms of fibroblast cell death depending on the dose of ionizing radiation.
- Study of mechanisms of functional and neurochemical disorders in the central nervous system during exposure to radiation with different linear energy transfer.
- Mastering of new methods for evaluation of effectiveness of cytotoxic activity of nanoparticles on tumour cells.
- Continuation of the molecular analysis of gamma- and neutron-induced intragenic structural changes in germline cells.
- Continuation of the sequence analysis of inherited DAN changes at the genome level of the offspring.
- Continuation of the work on the analysis of the transcriptome in somatic cells differing in radiosensitivity.
- Assessment of radioresistance of D.melanogaster strains and the human cell line HEK293 expressing DSUP protein (gamma rays, protons, heavy ions).
- Transcriptome analysis of D.melanogaster strains and the human cell line HEK293 expressing Dsup protein.
- Study of distribution of GEP-Dsup fusion protein on D.melanogaster polytene chromosomes.
- Development of a project of a specialized isochronous cyclotron for proton therapy.
- Measurements of the magnetic field of the MC1 bending magnet for the transport line of the AIC-144, Krakow, Poland.

### List of projects:

Project	Leader	Priority (period of realisation)
1. Further development of methods, technologies, schedule modes and provision of radiotherapy	G.V. Mitsyn	1 (2017-2022)
2. RADIOGENE: Molecular genetics of radiation-induced changes at the gene, genome and transcriptome level in Drosophila melanogaster	I.D. Alexandrov	1 (2017-2022)

- |    |   |                 |               |
|----|---|-----------------|---------------|
| 3. | Study of the radioprotective properties of the Damage suppressor (Dsup) protein on a model organism <i>D.melanogaster</i> and the human cell culture HEK293 | E.V. Kravchenko | 1 (2021-2022) |
|----|---|-----------------|---------------|

### List of Activities:

Activity or Experiment	Leaders	Status
Laboratory or other Division of JINR	Main researchers	
<b>1. Further development of methods, technologies, schedule modes and provision of radiotherapy</b> DLNP	<b>G.V. Mitsyn</b>	Realization
	A.V. Agapov, I.V. Alexandrova, O.V. Belov, K. Belokopytova, G.V. Donskaya, V.N. Gaevsky, I.I. Klochkov, I. Khosenova, Ye.I. Luchin, I.Ye. Miller, A.G. Molokanov, S.A. Pisareva, A.V. Rzyanina, K.N. Shipulin, S.V. Shvidky	
<b>2. RADIOGENE: Molecular genetics of radiation-induced changes at the gene, genome and transcriptome level in <i>Drosophila melanogaster</i></b> DLNP	<b>I.D. Alexandrov</b>	Realization
	M.V. Alexandrova, K.P. Afanasyeva, N.E. Kharchenko, S.V. Korablinova, L.N. Korovina, N.V. Orlova, A.N. Rusakovich, O.P. Solodilova	
<b>3. Study of the radioprotective properties of the Damage suppressor (Dsup) protein on a model organism <i>D.melanogaster</i> and the human cell culture HEK293</b> DLNP	<b>E.V. Kravchenko</b>	Realization
	A.E. Ivanova, O.A. Kuldoshina, A.V. Rzyanina, A.S. Yakunenko, M.P. Zarubin	
<b>4. Development of methods and programs for creating cyclotron-type accelerators. Development and upgrade of cyclotrons for medical application</b> DLNP	<b>G.A. Karamysheva</b>	Realization
	K.S. Bunyatov, A.F. Chesnov, S.N. Dolya, S.B. Fedorenko, R.V. Galkin, A.L. Gibinsky, S.V. Gursky, G.G. Kazakova, O.V. Karamyshev, I.N. Kiyan, O.E. Lepkina, O.V. Lomakina, I.V. Lyapin, V.A. Malinin, D.S. Petrov, D.V. Popov, G.D. Shirkov, S.G. Shirkov, V.L. Smirnov, A.S. Vorozhtsov, S.B. Vorozhtsov	
MLIT	I.V. Amirhanov, T.V. Karamysheva	



## **Collaboration**

### **Country or International Organization**

Belgium

China

Czech Republic

Moldova

Poland

Romania

Russia

South Africa

USA

### **City**

Louvain-la-Neuve

Hefei

Prague

Rez

Chisinau

Krakow

Otwock (Swierk)

Poznan

Bucharest

Dubna

Moscow

Rostov-on-Don

Somerset West

Lansing, MI

### **Institute or laboratory**

IBA

IPP CAS

ADVACAM

PTC

UJV

MSU

INP PAS

NCBJ

GPCC

IFIN-HH

RDH-9

DMS RAS

FMBC

IBMP RAS

VIGG RAS

SFedU

iThemba LABS

IONETIX

## Novel Semiconductor Detectors for Fundamental and Applied Research

**Leader:** G.A. Shelkov

**Deputy:** V.A. Rozhkov

### Participating countries and international organizations:

Belarus, Canada, CERN, Croatia, Cuba, Czech Republic, Egypt, Germany, Israel, Italy, Japan, New Zealand, Poland, Romania, Russia, South Africa, Switzerland, Ukraine, United Kingdom, USA, Vietnam.

### Issues addressed and main goals of research:

Conducting scientific and methodological studies of high-resolution hybrid matrix detectors for high-energy physics and the atomic nucleus as well as semiconductor detectors with increased radiation resistance.

Development of scientific cooperation with research institutes to study the possibility of using the developed detectors in other fields of science and technology (primarily in the field of healthcare and mining).

Development of infrastructure for studies of the properties of semiconductor detectors, including particle beam tests for use by JINR groups and institutes of the participating countries.

Study of formation of defects in materials as a result of various physical influences.

Extension of the existing "experimental" base of PAS.

Creation of facilities and experiments on accelerators to obtain new information to verify theoretical ideas in the processes of strong, weak and electromagnetic interactions of elementary particles and light nuclei at intermediate energies.

Creating a setup for carrying out measurements with test electron beams.

### Expected results in the current year:

- Development of a prototype and software for the "head" tomograph.
- Development of prototype detectors, electronics based on FPGA and software for Timepix4.
- Organization of collaboration with biophysicists of the Moscow Institute of Physics and Technology and Moscow State University using the MARS microtomograph.
- Creating a prototype module of a compact radiation-resistant electromagnetic calorimeter in conjunction with the FCAL collaboration.
- Completion of the ordering system of the monochromatic positron beam and commissioning of the PALS spectrometer on a monochromatic positron beam.
- Testing the method of ion etching on the created etching system and applying it to study thin-film multilayer materials.
- Conducting experiments with Active Target (GDH).
- Commissioning of the LINAC-200.

### List of projects:

Project	Leader	Priority (period of realisation)
1. Novel semiconductor detectors for fundamental and applied research	G.A. Shelkov V.A. Rozhkov	1 (2015-2023)
2. Development of experimental techniques and applied research with slow monochromatic positron beams (PAS)	A.G. Kobets K. Siemek Scientific leader: I.N. Meshkov	1 (2016-2023)
3. GDH&SPASCHARM	Yu.A. Usov A. Kovalik	1 (2011-2022)

## List of Activities:

Activity or Experiment Laboratory or other Division of JINR	Leaders Main researchers	Status
<b>1. Project "Novel semiconductor detectors for fundamental and applied research"</b> DLNP  FLNR  FLNP	<b>G.A. Shelkov</b> <b>V.A. Rozhkov</b>  S. Abdelshakur, E.A. Cherepanova, A. Gongadze, M.I. Gostkin, V.G. Kruchonok, D.A. Kozhevnikov, .K. Kuznetsov, A.V. Lapkin, A. Leyva, S.Yu. Porokhovoy, D.D. Rastorguev, T.O. Rudenko, A.S. Zhemchugov  A.T. Isatov, S. Mitrofanov, Yu.G. Teterev  A.A. Ahmedov, Yu.N. Kopach, D.A. Telezhniko	<div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;">Realization</div>
<b>2. Project "Development of experimental techniques and applied research with slow monochromatic positron beams (PAS)"</b> DLNP  FLNR  FLNP  VBLHEP	<b>A.G. Kobets</b> <b>K. Semek</b> <b>I.N. Meshkov</b>  E.V. Akhmanova, V.I. Hilinov, O.S. Orlov, A.Yu. Rudakov, A.A. Sidorin, L.V. Soboleva, V.I. Hilinov, S.L. Yakovenko F.V. Skuratov  M. Kulik  V.V. Kobets	<div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;">Realization</div>
<b>3. GDH&amp;SPASCHARM Project</b> DLNP  FLN	<b>Yu.A. Usov</b> <b>A. Kovalik</b> N.S. Borisov, N.A. Bazhanov, A.S. Dolzhenkov, A.N. Fedorov, I.V. Gapienko, I.S. Gorodnov, V.A. Kashevarov, A.B. Lazarev, A.B. Neganov, Yu.A. Plis, A.B. Sadovsky  S.B. Gerasimov, S.S. Kamalov	<div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;">Realization</div>
<b>4. Construction of the setup for measurements with electron test beams in DLNP (LINAC-200)</b> DLNP  UC  VBLHEP	<b>V.V. Kobets</b> <b>M.I. Gostkin</b> <b>G.D. Shirkov</b> E. Acosta, V.Yu. Baranov, A.E. Brukva, Yu.I. Davydov, D.L. Demin, I. N. Garanzha, K.I. Gritsay, V.V. Glagolev, A.V. Krasnoperov, V.G. Kruchonok, A.A. Nozdrin, E.V. Malinina, S.Yu. Porokhovoy, Ya.A. Samofalova, S.A. Smirnov, D.S. Shokin, R.V. Timonin, A.N. Trifonov, K.E. Yanenko, A.S. Zhemchugov, P.P. Zhuravlev D.S. Belozеров, K.B. Gikal, M.A. Nozdrin, K.A. Varlamov, D.A. Zlydenny  N.I. Garanzha, A.G. Sorokin, V.G. Shabrotov	<div style="border: 1px solid black; padding: 5px; width: fit-content; margin: 0 auto;">Realization</div>

## Collaboration

### Country or International Organization

Belarus  
Canada

CERN  
Croatia  
Cuba  
Czech Republic  
Egypt

Germany

Israel  
Italy  
Japan  
New Zealand  
Poland

Romania  
Russia

South Africa  
Switzerland  
Ukraine

United Kingdom

USA

Vietnam

### City

Minsk  
Halifax  
Regina  
Sackville  
Geneva  
Zagreb  
Havana  
Prague  
Cairo  
New Borg El-Arab  
Bochum  
Bonn  
Giessen  
Hamburg  
Mainz  
Jerusalem  
Pavia  
Tsukuba  
Christchurch  
Krakow

Magurele  
Arkhangelsk  
Belgorod  
Dubna  
Moscow

Moscow, Troitsk  
Protvino  
St. Petersburg

Tomsk  
Somerset West  
Basel  
Kharkov

Glasgo  
London  
York

Amherst, MA  
Kent, OH  
Los Angeles, CA  
Seattle, WA

Ho Chi Minh City

### Institute or laboratory

BSTU  
SMU  
U of R  
MAU  
CERN  
RBI  
CEADEN  
CTU  
NRRR  
E-JUST  
RUB  
UniBonn  
JLU  
DESY  
JGU  
HUJI  
INFN  
KEK  
UC  
AGH  
INP PAS  
ISS  
NArFU  
BelSU  
Dubna State Univ.  
ITEP  
MSU  
NNRU "MEPhI"  
INR RAS  
IHEP  
NWRSCC  
SPbSPU  
TPU  
iThemba LABS  
Uni Basel  
IERT NASU  
NSC KIPT  
U of G  
QMUL  
Univ.  
UMass  
KSU  
UCLA  
UW  
CNT VINATOM

**Networking,  
Computing,  
Computational  
Physics  
(05)**

## Information and Computing Infrastructure of JINR

**Leader:** V.V. Korenkov  
**Deputy:** T.A. Strizh

### Participating Countries and International organizations:

Armenia, Azerbaijan, Belarus, Bulgaria, CERN, China, Czech Republic, Egypt, France, Georgia, Germany, Italy, Kazakhstan, Moldova, Mongolia, Poland, Romania, Russia, Slovakia, South Africa, Sweden, Taiwan, Ukraine, USA.

### Issues addressed and main goals of research:

The purpose of the theme is to develop the network, information and computing infrastructure of JINR for the research and production activities of the Institute and its Member States on the basis of state-of-the-art information technologies in accordance with the Seven-Year Plan for the development of JINR. A particular direction within the theme is the development of the JINR MLIT Multifunctional Information and Computing Complex (MICC) presented as a Project.

### Expected main results in the current year:

- Provision of the stable, safe and integral functioning of the JINR information and telecommunication network (backbone network (2x100 Gbps); transport network of the NICA megaproject (8x100 Gbps); MLIT mesh network (100 Gbps); telecommunication channels (3x100 Gbps); Wi-Fi network at the Institute's sites) for reliable data exchange between the Institute's subdivisions, the JINR Member States and international organizations collaborating with JINR. Provision of the full-scale and optimal operation of the guaranteed power supply and climate control systems of the MICC computing infrastructure. Implementation of the project on a new fire safety system of the MICC infrastructure. Expansion of the performance and storage system of the MICC basic grid component, i.e. the Tier1 center at JINR: processor capacities up to 300 kHS06, dCache storage systems on disks up to 13.1 PB.

Enlargement of the computing resources and data storage systems as part of the Tier2/CICC integral component: processor capacities up to 150 kHS06, disk storages up to 6.5 PB.

Expansion of the capacity of the MICC general distributed data storage and access system based on the EOS file system up to 30 PB. Support and maintenance of user work with the EOS system.

Extension of a set of applied applications available to users in the cloud service for scientific and engineering computing (<http://saas.jinr.ru>). Optimization of the computing environment for neutrino experiments, i.e. the neutrino platform. Enlargement of the resources of the MICC cloud, including at the expense of the resources acquired by the Baikal-GVD, JUNO, NOvA/DUNE experiments, and their maintenance.

Equipping of the hierarchical data processing and storage system of the "Govorun" supercomputer with an 8 PB warm layer based on the Ruler SSD. Creation of a polygon for quantum computing based on large-memory nodes. Creation of a polygon simulating the operation of the MPD detector based on the DAOS data reception and processing technology. Integration of the cold layer of the hierarchical data processing and storage system of the "Govorun" supercomputer under the EOS FS management with a common storage for the NICA experiments.

Support and updates of grid middleware. Support and maintenance of the operation of the WLCG virtual organizations, the experiments NICA, COMPASS, NOvA, ILC, etc., local user groups on the MICC Tier1 and Tier2 resources. Maintenance of the unified system of access to the CVMFS software. Development of a prototype of the distributed data

processing system for the SPD experiment, which uses the MICC storage systems (tape and disk) and heterogeneous computing resources.

Further development of the distributed information and computing platform based on DIRAC integrating cloud resources of the organizations of the JINR Member States. Implementation of the system for monitoring the operability and performance of the resources integrated in DIRAC. Integration of new computing and storage resources.

Creation and testing of a set of services for the prototype of the MICC unified resource management system. Development of a concept and a work plan for the creation of a custom Big Data infrastructure to solve JINR's urgent tasks.

Expansion of the functions of the MICC monitoring system with additional accounting elements to track user actions over time. Update and support of the monitoring system, inclusion of monitoring the parameters of new MICC elements in the monitoring.

- Development and maintenance of the electronic document system EDS "Dubna", the project management system APT EVM for NICA, the systems ADB2, ISS, "Document Base", HR LHEP, CERNDDB, EDS "Advance reports" at the request of end users and in accordance with the developed concept of the cloud SaaS platform of the unified administrative and business information system. Maintenance of the JINR Information System for Scientific Certification (ISSC).

Trial operation of the server of scientific publications based on the Invenio-JOIN<sup>2</sup> software program, provision of interaction with the PIN IS at the level of bibliographic metadata. Development and commissioning of tools for integrating the PIN and JOIN<sup>2</sup> systems with the aim of transferring the publication data entry to the JOIN<sup>2</sup> system.

Maintenance of the JINRLIB and MATHLIB program libraries. Replenishment of JINRLIB with computational physics programs. Update of mathematical program libraries, their integration with modern programming languages.

Maintenance and modernization of central information servers, portals and databases for information support and software of the MLIT and JINR activity: development of the services of the "Visit Centre" portal; modernization and administration of the website of the PEPAN and "PEPAN Letters" journals; creation and support of websites of conferences, symposia at the request of the laboratories and other JINR subdivisions; organization of websites of the JINR subdivisions and conferences in a hosting mode.

Implementation and maintenance of the web-based information and analytical system to automate the process of managing network and other types of software licenses.

Development of the information and computing system for radiobiological studies, including the experimental data processing and storage system for analyzing behavioral and morphological changes in the central nervous system of laboratory animals.

Implementation of the air quality management system (AQMS) and air quality modeling system (ADMoss) into the MICC environment.

Development of the project on a "Personal Account" system, which takes into account the peculiarities of working with personal information and simplifies access to the JINR information and computing resources.

- Organization and holding of special courses and tutorials on novel supercomputer technologies, technologies and tools for solving applied tasks on the basis of machine and deep learning methods. Conducting of special courses and tutorials in the JINR Member States in accordance with international cooperation programs. Organization of specialized courses on training IT specialists to solve tasks related to data processing and analysis for megascience experiments, including the NICA project.

Creation of an intelligent robotics laboratory for the development of cognitive control systems on the basis of the NICA accelerator complex and in other JINR laboratories, development of a laboratory workshop on robotics. Holding of schools on artificial intelligence and quantum computing.

### List of projects:

Project	Leader	Priority (period of realisation)
1. MICC	V.V. Korenkov	1 (2017-2023)

### List of Activities:

Activity or Experiment Laboratory or other Division of JINR	Leaders Main researchers
1. MICC Project	<b>V.V. Korenkov</b> <b>A.G. Dolbilov</b> <b>V.V. Mitsyn</b> <b>T.A. Strizh</b>
MLIT	Eu.I. Aleksandrov, I.N. Aleksandrov, K.N. Angelov, A.S. Baginyan, A.I. Balandin, N.A. Balashov, A.V. Baranov, S.D. Belov, D.V. Belyakov, A.S. Bondyakov, Yu.A. Butenko, A.I. Churin, S.V. Chashchin, S.V. Gavrilov, A.P. Gavrish, T.M. Goloskokova, A.O. Golunov, E.N. Grafova, Eu.A. Grafov, Gromova, A.E. Gushchin, I.S. Kadochnikov, A.S. Kamensky, V.A. Kapitonov, I.A. Kashunin, A.O. Kondratiev, G.A. Korobova, E.Yu. Kulpin, N.A. Kutovskiy, A.A. Lavrentiev, S.B. Marchenko, M.A. Matveev, Ye. Mazhitova, S.V. Mitsyn, A.V. Nechaevsky, D.A. Oleynik, G.A. Ososkov, I.S. Pelevanyuk, A.Sh. Petrosyan, M.S. Plyashkevich, D.V. Podgainy, L.A. Popov, D.I. Pryakhina, Ya.I. Rozenberg, T.F. Sapozhnikova, R.N. Semenov, M.L. Shishmakov, I.A. Sokolov, O.I. Streltsova, V.V. Trofimov, N.N. Voitishin, A.S. Vorontsov, A.V. Uzhinskiy, A.Yu. Zakomoldin, P.V. Zrelov, M.I. Zuev
„ VBLHEP	K.V. Gertsenberger, Yu.P. Minaev, A.N. Moshkin, O.V. Rogachevsky, B.G. Shchinov, S.V. Shmatov
FLNP	G.A. Sukhomlinov
LRB	V.N. Chausov
FLNR	A.G. Polyakov, V.V. Sorokoumov
DLNP	Yu.P. Ivanov
BLTP	K.V. Kulikov, I.R. Rahmonov, A.A. Sazonov, Yu.M. Shukrinov
UC	I.N. Semeniushkin
2. Information and software support of the research-and-production activity at JINR	<b>P.V. Zrelov</b> <b>V.V. Korenkov</b> <b>I.A. Filozova</b>
MLIT	N.A. Balashov, D.V. Belyakov, N.A. Davyudova, T.M. Goloskokova, D.S. Golub, P. Jancik, L.A. Kalmykova, A.A. Karlov, D.V. Kekelidze, D.I. Koshlan, S.A. Kretova, S.V. Kunyaev, N.A. Kutovskiy, G.G. Musulmanbekov,



M.S. Plyashkevich, L.V. Popkova, A.V. Prikhodko, V.M. Pushkina, A.M. Raportirenko, T.F. Sapozhnikova, S.V. Semashko, R.N. Semenov, G.V. Shestakova, D.B. Stankus, V. Svozik, T.S. Syresina, N.N. Vorobieva, A.V. Uzhinskiy, V.M. Yagafarova, A.G. Zaikina, T.N. Zaikina

FLNP

I. Pavliková, M.V. Frontasyeva, W. Badawy, A. Yu. Dmitriev

DSOA

S.N. Nedelko

**3. Development of the system for training and retraining of IT specialists based on the JINRMICC and its educational components**

**V.V. Korenkov**  
**T.A. Strizh**  
**O.I. Streltsova**

MLIT

N.A. Balashov, S.D. Belov, V.V. Galaktionov, T.M. Goloskokova, N.I. Gromova, O.V. Ivantsova, I.S. Kadochnikov, M.H. Kirakosyan, N.A. Kutovskiy, V.V. Mitsyn, S.V. Mitsyn, I.K. Nekrasova, A.V. Nechaevsky, D.A. Oleynik, A.Sh. Petrosyan, D.V. Podgainy, A.G. Reshetnikov, T.F. Sapozhnikova, R.N. Semenov, Sh.G. Torosyan, V.V. Trofimov, S.V. Ulyanov, A.V. Uzhinskiy, M.I. Zuev

UC

S.Z. Pakuliak

**Collaboration**

**Country or International Organization**

**City**

**Institute or laboratory**

Armenia

Yerevan

IIAP NAS RA

Azerbaijan

Baku

ADA  
IP ANAS

Belarus

Minsk

BSTU  
INP BSU  
JIPNR-Sosny NASB

Bulgaria

Sofia

UIIP NASB  
INRNE BAS  
SU

CERN

Geneva

CERN

China

Beijing

IHEP CAS

Czech Republic

Ostrava

VSB-TUO

Prague

IP CAS

Egypt

Cairo

ASRT

Giza

CU

France

Marseille

CPPM

Georgia

Tbilisi

GRENA

GTU

TSU

Germany

Darmstadt

GSI

Frankfurt/Main

Univ.

Hamburg

DESY

Karlsruhe

KIT

Zeuthen

DESY

Italy

Bologna

INFN

Kazakhstan

Almaty

INP

Nur-Sultan

BA INP

Moldova

Chisinau

IMCS

MSU

Mongolia	Ulaanbaatar	RENAM
Poland	Warsaw	NUM
Romania	Bucharest	IMGW-PIB
	Cluj-Napoca	IFIN-HH
	Magurele	INCDTIM
Russia	Chernogolovka	IFA
		LITP RAS
		SCC IPCP RAS
	Dubna	Dubna State Univ.
		SCC "Dubna"
		SEZ "Dubna"
	Gatchina	NRC KI PNPI
	Moscow	FRC IM RAS
		IITP RAS
		ISP RAS
		ITEP
		KIAM RAS
		MPEI
		MSK-IX
		MSU
		NRC KI
		PRUE
		RCC MSU
		RSCC
		SINP MSU
	Moscow, Troitsk	INR RAS
	Novosibirsk	BINP SB RAS
		ICMMG SB RAS
	Pereslavl-Zalesskiy	PSI RAS
	Protvino	IHEP
	Puschino	IMPB RAS
	Samara	SU
	St. Petersburg	FIP
		ITMO Univ.
		SPbSPU
		SPbSU
	Vladikavkaz	NOSU
Slovakia	Kosice	IEP SAS
	Presov	PU
South Africa	Cape Town	UCT
Sweden	Lund	LU
Taiwan	Taipei	ASGCCA
Ukraine	Kharkov	NSC KIPT
	Kiev	BITP NASU
USA	Arlington, TX	UTA
	Batavia, IL	Fermilab
	Upton, NY	BNL

## **Methods, Algorithms and Software for Modeling Physical Systems, Mathematical Processing and Analysis of Experimental Data**

**Leaders:** Gh. Adam  
P.V. Zrelov

**Deputies:** J. Busa  
O. Chuluunbaatar

### **Participating Countries and International organizations:**

Armenia, Belarus, Brazil, Bulgaria, Canada, CERN, China, Czech Republic, France, Georgia, Germany, Hungary, Italy, Kazakhstan, Lithuania, Moldova, Mongolia, Poland, Romania, Russia, Slovakia, South Africa, Switzerland, Tajikistan, United Kingdom, USA, Vietnam.

### **Issues addressed and main goals of research:**

Carrying out paramount advanced research in computational mathematics and physics, directed to the creation of new mathematical methods, algorithms, and software for the numerical or symbolic-numerical solution of topics arising in experimental and theoretical physics studies. This subject area includes a wide spectrum of investigations approved for completion in JINR within the seven-year period 2017–2023 in high energy physics, nuclear physics, physics of condensed matter and of nanostructures, biophysics, information technologies, the solution of which is inseparable from the use of computing. Such subject matters of the utmost importance in JINR are the NICA project, the neutrino program, the superheavy and exotic nuclei physics, the neutron based investigations. The needed numerical or symbolic-numerical computing will be done on the Multifunctional Information and Computing Complex (MICC), primarily the HybriLIT heterogeneous computing platform which involves the training and test cluster HybriLIT and the "Govorun" supercomputer and the emerging Big Data distributed infrastructure. The research teams include both experienced scientists with outstanding scientific achievements and enthusiastic young scientists and engineers. The requested financing will cover salaries, participations in scientific conferences, scientific visits and the acquisition of a minimal number of personal computers and licenses, within the approved resources for MLIT-JINR. A distinctive feature of this research is the close cooperation of the Meshcheryakov Laboratory of Information Technologies (MLIT) with research groups from all JINR laboratories and Member State institutions.

### **Expected main results in the current year:**

- Three-dimensional computer simulation of magnets for the NICA (JINR), NUCLOTRON (JINR) and CBM (GSI) projects. The magnetic field map construction for analysis of the field distribution quality in the working areas of the magnets.  
Optimization of a portable magnetic device designed to study the ROT-effects in the fission of heavy nuclei.  
Implementation of a hybrid FEM-BEM method for modeling complex magnetic accelerator systems in the COMSOL Multiphysics® environment and its use to multi-physical modeling of the magnetic system for the SC230 isochronous cyclotron. Development of methods for correcting the average magnetic field of an isochronous cyclotron based on the solution of the equations of motion. Development and implementation of the CORD (Closed ORbit Dynamics) program into the JINRLIB library for the analysis of field maps of the SC230 isochronous cyclotron.  
Molecular dynamics modeling of structural changes in metals and metal composites under irradiation with heavy ions and alpha particles, description of experimental data.  
Numerical simulation of phase transitions (melting, evaporation and ablation) in materials exposed to femtosecond laser pulses.  
Numerical study of the statistical properties of structures with extended nanosize defects.  
Computer modeling of spin dynamics in spintronic materials and development of methods governing spin reversal effects.  
Investigation of the spin filtering effect by the corrugation graphene.

Research and software implementation of methods for the numerical solution of stiff systems describing spintronic models.

Study of nucleus-nucleus and proton-nucleus interactions in a wide range of energies using microscopic models and various models of the density of colliding nuclei. Investigation of reactions involving the  $^{17}\text{F}$  isotope on stable targets at medium energies.

Application of the dibaryon resonance model to study and calculate the characteristics of light nuclei with  $A = 6$ , including the two-proton decay of  $^6\text{Be}$ .

Estimation of the drip-line for neutron-excess nuclei.

Study of spatially localized temporally periodic or quasiperiodic solutions of the  $\phi$ -4 equation on the basis of new finite-mode approximations for the bound state of the wobbling kink and breather in one dimension and for the three-dimensional oscillon.

Analytical and numerical study of the role of the spinor field in the formation of black holes and the evolution of the Universe.

Development of algorithms for computing the primary atomic displacement cross sections by fast electrons in solids.

Modernization of software developed for the study of properties of new materials and nanosystems by modern neutron scattering methods.

Extension of the basic element method (BEM) to the solution of stiff problems and its use for solving applied problems, including processing and analysis of neutron noise of the IBR-2M reactor and approximating the dependence of the energy losses of charged particles in the ionization chamber (STAR experiment).

Development of Bayesian automatic adaptive quadrature algorithms of high fidelity.

Application to open systems of the developed methodology for the stochastization of dynamic one-step systems.

Modification of the Bayesian selection method of the best model parameters of nuclear matter in the analysis of the latest existing and planned discoveries of astrophysical phenomena of compact stars by multichannel astronomy.

Numerical study of the quark-hadron phase transition in the energy range of the NICA collider.

Numerical analysis of heavy ion fragmentation reactions in the framework of transport-statistical models, comparison with the experiment.

- Development of phenomenological models of hadron-hadron interactions of the Geant4 package for the energy range in which the perturbative QCD does not work, and their application for calculating the experimental conditions of JINR, GSI, CERN experiments with hadronic and nuclear beams.  
Creation of a combined generator of nucleus-nucleus collisions DCM-QGSM-SMM, with further modification by including the production of heavy resonances, dileptons and hyperfragments. Mass generation of nucleus-nucleus collisions for the BM@N and MPD experiments.  
Optimization, development and refactoring of the MPD detector software.  
Development of alignment algorithms for the time-projection camera TPC of the MPD detector, taking into account the accumulating space charge.  
Development of the structure, software and operating model of a quantum intelligent regulator of nitrogen and helium consumption for a superconducting magnet, taking into account possible operating modes, various emergency situations included.  
Development of an intelligent system for controlling the modes of the high-frequency stations of the Nuclotron of the NICA accelerating complex using quantum soft computations.  
Completion of the development and upgrade of information systems of geometric and configuration databases, as well as a database of metadata of physical events for the NICA experiments.  
Development of event reconstruction algorithms, realistic simulation of responses and detailed ROOT geometry for the configuration of the central track detectors of the BM@N experiment in 2022.  
Development and implementation of algorithms for modeling and data reconstruction in the track detectors of the BM@N experiment for the preparation and conduct of the physical session in 2022.  
Development of the data acquisition software for the Baikal-GVD project.  
Monte Carlo modeling of the OLVE-HERO prototype within the FAIRRoot and Geant4 framework. Study of the systematic errors and the influence of the geometry of the experiment on the results.  
Testing the developed algorithms for building the distributions of cosmic rays arrival directions for their correctness while processing the NUCLEON experiment data obtained in different modes of the cosmic apparatus flight.

Development of non-standard statistics analysis methods of rare events in experiments with superheavy nuclei.

Agreed support for the ATLAS experiment software: further development of the ATLAS Event Picking Service, maintenance of the ATLAS EventIndex monitoring system; development and upgrade of the CREST information system, software for the conversion of ATLAS ConditionDB data from COOL API to CREST; upgrade of operational monitoring of the ATLAS TDAQ system based on new versions of GRAFANA.

Improvement of methods for reconstructing the trajectories of charged particles and calculations of the efficiency and resolution of cathode-strip chambers with updated electronics in the CMS experiment.

Testing, debugging in accordance with user requirements and commissioning of the geometry database for the CBM experiment. Development of a database concept for selecting useful events.

- Solving the problem of image segmentation based on deep learning algorithms for morphological research in radiation biology. Application of the neural network approach and computer vision methods for the tasks of analyzing radiobiological research data.

Creation of a computer package for calculating the QCD phase diagram on the HybriLIT platform.

Further development of efficient scalable deep learning algorithms of the local and global types for the reconstruction of multiple tracks and vertices of events in high-energy physics experiments related to MPD, BM@N, BES-III, SPD and CBM.

Application of machine learning methods for the recognition and analysis of the properties of fine structures in the mass distribution of nuclear reaction products in experiments with transuranium elements.

Enhancement of the efficiency of the applied deep learning algorithms for the tasks of predicting the state of the environment and detecting plant diseases; development of new, time series based, statistical analysis methods for air pollution monitoring; expansion of forecasting areas to new regions of Russia, Europe and Asia.

Utilization of the shared CPU-GPU memory of the HybriLIT computational platform for the COMSOL Multiphysics® environment to improve the speed of simulations.

Investigation of the structure and properties of polydispersed vesicular systems in the framework of the separated form factors model: parallel optimization of the model parameter fitting to the experimental small-angle scattering data.

Development of methods and software packages for high-performance numerical research of complex processes in multiparameter models of nuclear physics and condensed matter physics.

Development, optimization and implementation of new parallel versions of algorithms and programs for molecular dynamics modeling on the HybriLIT platform.

Simulation of the evolution of liquid crystals under the influence of orienting forces using molecular dynamics software packages on modern graphic systems.

Development of a parallel version of the FITTER program designed to study the supramolecular structure and functional characteristics of biological nanosystems and polymer nanomaterials.

Development of highly scalable parallel algorithms and programs for solving nonlinear magnetostatic problems by the finite element discontinuous hp-method.

Development of parallel algorithms and programs for studying the properties of nuclear matter in heavy ion collisions and the cores of compact stars.

Development and application of new computational methods for the treatment of basic problems of relativistic quantum chemistry and physics, in particular, in the study of the electronic structure and spectroscopic properties of heavy atoms and molecules.

Development and numerical implementation of the method of Compton pulse spectroscopy of light atoms and molecules.

Development of a software and hardware complex for collecting, storing and analyzing Big Data for solving service and applied problems (monitoring and security of computing systems, physical and engineering applications).

Development of a prototype system for intelligent monitoring of the functioning and security of distributed computing systems based on Big Data technologies and machine learning methods.

Application of Big Data methods, algorithms, and platforms to solving relevant applied tasks, including the analysis of JINR's performance indicators and automated intelligent text processing of scientific publications.

- Development of quantum algorithms for modeling the electron shells of atoms of superheavy elements. Development of algorithms based on quantum neural networks for solving equations of mathematical physics.

Quantum information processing in artificial intelligence networks with long- and short-term memories of active nodes.

Development of quantum circuits, of quantum and classical algorithms, based on the tensor network method, for modeling phase transitions in quantum chromodynamics at nonzero temperature and finite baryon density.

Study of the relationship between the negativity of the Wigner function and the nonclassicality of states of finite-dimensional quantum systems.

Formulation of constructive models for the study of decomposition of quantum systems into subsystems and analysis of quantum correlations within multi-component systems.

Development and implementation of a grid version of the algorithm for computing Gröbner and involutive bases of algebraic nonlinear polynomial systems.

Development of finite element schemes with interpolation Hermite polynomials for solving boundary value problems for systems of ordinary differential equations.

Creation of a package for high precision evaluation of 3- and 4-point one-loop Feynman integrals with the help of the method of functional reduction.

## List of Activities:

<b>Activity or experiment</b>	<b>Leaders</b>
Laboratory or other Division of JINR	Main researchers
<b>1. Mathematical and computation methods for simulation of complex physical systems</b>	<b>Gh. Adam</b>
MLIT	<b>J. Busa</b>
	<b>I.V. Puzynin</b>
	V. Abgaryan, S. Adam, P.G. Akishin, I.V. Amirkhanov, P.Kh. Atanasova, A.S. Ayriyan, E.A. Ayrjan, I.V. Barashenkov, M.V. Bashashin, A.A. Bogolubskaya, A.M. Chervyakov, N.D. Dikussar, H. Grigorian, M. Kakenov, Yu.L. Kalinovskiy, T.V. Karamysheva, D.S. Kulyabov, K.V. Lukyanov, N.V. Makhaldiani, T.I. Mikhailova, G.J. Musulmanbekov, E.G. Nikonov, R.V. Polyakova, T.P. Puzynina, V.S. Rikhhvitsky, B. Saha, I. Sarkhadov, S.I. Serdyukova, Z.A. Sharipov, N.Yu. Shirikova, A.G. Soloviev, T.M. Solovieva, Z.K. Tukhliev, O.O. Voskresenskaya, R.M. Yamaleev, E.P. Yukalova, O.I. Yuldashev, M.B. Yuldasheva, E.V. Zemlyanaya
VBLHEP	G.N. Agakishiev, H.G. Khodzhibagiyan, V.P. Ladygin, E.E. Perepelkin, M.M. Shandov
BLTP	D.E. Alvarez-Castillo, D. Blaschke, A.A. Donkov, A.V. Friesen, M. Hnatič, R.V. Jolos, A.S. Khvorostukhin, E.E. Kolomeitsev, S. Liebing, V.K. Lukyanov, L.A. Malov, K.A. Maslov, R.G. Nazmitdinov, I.R. Rakhmonov, L.A. Sevastyanov, Yu.M. Shukrinov, A.V. Sushkov, D.N. Voskresensky, V.I. Yukalov
FLNR	A.G. Artukh, E. Batchuluun, M.N. Mirzaev, A. Oleinichak, Yu.M. Sereda, V.A. Skuratov
FLNP	A.S. Doroshkevich, T.A. Lychagina, D.I. Nikolaev, V.V. Novitsky, E.P. Popov, Yu.N. Pepelyshev
DLNP	G.A. Karamysheva, O.V. Karamyshev, I.N. Kiyan, I.D. Lyapin, V.A. Malinin, D.V. Popov, K. Semek, G.D. Shirkov
<b>2. Software complexes and mathematical methods for processing and analysis of experimental data</b>	<b>P.V. Zrelov</b>
MLIT	<b>V.V. Ivanov</b>
	E.P. Akishina, E.I. Aleksandrov, I.N. Aleksandrov, D.A. Baranov, A.S. Bondyakov, J. Buša Jr., O.Yu. Derenovskaya, I.A. Filozova,

S. Hnatič, A.I. Kazymov, A.O. Kondratyev, B.F. Kostenko, E.A.Kuznetsov, M.A. Mineev, G.J. Musulmanbekov, V.V. Palichik, D.I. Pryakhina, A.G. Reshetnikov, V.S. Rikhvitsky, T.F. Sapozhnikova, I. Satyshev, S.V. Semashko, G.V. Shestakova, S.K. Slepnev, A.G. Soloviev, A.N. Sosnin, S.V. Ulyanov, V.V. Uzhinsky, N.N. Voitishin, A.V. Yakovlev, V.B. Zlokazov

VBLHEP

A.S. Andreev, P.N. Batyuk, B.V. Batyunya, O.I. Brovko, A.V. Butenko, A.V. Bychkov, I.R. Gabdrakhmanov, A.S. Galoyan, K.V. Gertsenberger, I.A. Golutvin, E.V. Gorbachev, N.V. Gorbunov, A.Yu. Kamenev, M.N. Kapishin, V.Yu. Karzhavin, S.A. Kostromin, V.V. Lenivenko, A.M. Makan'kin, S.P. Merts, D.V. Monakhov, A.N. Morozov, M. Patsyuk, V.V. Pereilygin, Yu.P. Petukhov, G.P. Reshetnikov, O.V. Rogachevsky, M.M. Rumyantsev, S.V. Shmatov, V.N. Spaskov, A.V. Zarubin, V. Zhezher

BLTP

V.D. Toneev

FLNR

Yu.S. Tsyganov, V.K. Utenkov

DLNP

V.A. Bednyakov, I.A. Belolaptikov, V.M. Grebenyuk, A.G. Olshevsky, A.E. Pan, D.B. Pontecorvo, F.V. Prokoshin, B.A. Shaibonov, L.G. Tkatchev

UC

S.Z. Pakulyak

### 3. Numerical methods, algorithms and software for multicore and hybrid architectures and Big Data analytics

MLIT

**Gh. Adam**

**O. Chuluunbaatar**

**P.V. Zrellov**

**O.I. Streltsova**

P.Kh. Atanasova, A.S. Ayriyan, D.R. Badreeva, D.A. Baranov, M.V. Bashashin, S.D. Belov, D.V. Belyakov, J. Buša Jr., Yu.A. Butenko, A.M. Chervyakov, G. Chuluunbaatar, I.A. Filozova, P.V. Goncharov, H. Grigorian, A.A. Gusev, A.V. Ilina, J.N. ogly Javazade, I.S. Kadochnikov, M. Kakenov, Yu.L. Kalinosky, M.A. Matveev, A.V. Nechaevsky, D.A. Oleinik, G.A. Ososkov, V.V. Papoyan, I.S. Pelevanyuk, A.Sh. Petrosyan, D.V. Podgainy, D.I. Pryakhina, I.V. Puzynin, T.P. Puzynina, R.N. Semenov, Z.A. Sharipov, A.G. Soloviev, T.M. Solovieva, A.V. Stadnik, V. Svozik, L.A. Syurakhshina, Z.K. Tukhliev, A.V. Uzhinsky, A.V. Volokhova, O.I. Yuldashev, M.B. Yuldasheva, E.V. Zemlyanaya, E.I. Zhabitskaya

MLIT-MICC

V.V. Mitsyn, T.A. Strizh

FLNR

R. Kabytayeva, S.V. Mitrofanov, Yu.Ts. Oganessian, Yu.V. Pyatkov

BLTP

D. Blaschke, A.A. Donkov, A.V. Friesen, A.S. Hvorostuhin, Yu.V. Popov, S.I. Vinitsky, D.N. Voskresensky, V.Yu. Yushankhai

VBLHEP

A.Yu. Boytsov, E.E. Donets, K.V. Gertsenberger

DLNP

G.A. Karamysheva, A.S. Zhemchugov

FLNP

M. Balasoju, W. Badavy, M.V. Frontaseva, M.F. Kiselev, N. Kucherka, A.I. Kukli, I. Pavlikova, I. Zinicovscaia

LRB

I.A. Kolesnikova, M.G. Lalkovicova, K.N. Lyakhova, Yu.S. Severiukhin, D.M. Utina

#### 4. Methods, algorithms and software of computer algebra and quantum computing

MLIT

BLTP

VBLHEP

LRB

#### D.V. Podgainy A.M. Khvedelidze

V. Abgaryan, M. Bures, O. Chuluunbaatar, A.A. Gusev, V.V. Korniyak, E.A. Kotkova, Yu. Palii, A.M. Raportirenko, I.A. Rogozhin, N. Saktaganov, A.V. Stadnik, O.I. Streltsova, O.V. Tarasov, A.G. Torosyan, D.A. Yanovich, E.P. Yukalova, M.I. Zuev

R.G. Nazmitdinov, V.V. Braguta, A. I. Titov, N.A. Tyurin, S.I. Vinitsky, V.I. Yukalov

O.V. Rogachevsky

A.V. Czhizhov

#### Collaboration

##### Country or International Organization

Armenia

##### City

Yerevan

##### Institute or laboratory

Foundation ANSL

RAU

YSU

Belarus

Brest

BrSU

Minsk

IM NASB

Brazil

Sao Carlos, SP

IFSC USP

Bulgaria

Plovdiv

PU

Sofia

IMI BAS

INRNE BAS

SU

Canada

Toronto

IBM Lab

CERN

Geneva

CERN

China

Beijing

CIAE

IHEP CAS

Czech Republic

Ostrava

VSB-TUO

Prague

CTU

France

Nancy

UL

Saclay

IRFU

Georgia

Tbilisi

GTU

TSU

UG

Germany

Darmstadt

GSI

Frankfurt/Main

Univ.

Hamburg

Univ.

Karlsruhe

KIT

Kassel

Uni Kassel

Munich

LMU

Rostock

Univ.

Hungary

Budapest

Wigner RCP

Italy

Genoa

INFN

Kazakhstan

Almaty

INP

KazNU

Lithuania

Kaunas

VMU

Moldova

Chisinau

IAP

MSU



Mongolia	Ulaanbaatar	IMDT MAS
Poland	Krakow	INP PAS JU UEK
	Lublin	UMCS
	Warsaw	IMGW-PIB
	Wroclaw	UW
Romania	Bucharest	IFIN-HH UB
	Cluj-Napoca	INCDTIM
	Magurele	IFA ISS
	Timisoara	UVT
Russia	Dolgoprudny	MIPT
	Dubna	Dubna State Univ.
	Gatchina	NRC KI PNPI
	Irkutsk	ISU
	Moscow	GPI RAS ITEP MRSU MSU NNRU "MEPhI" PFUR PRUE RCC MSU SINP MSU
	Moscow, Troitsk	INR RAS
	Perm	PSNRU
	Puschino	IMPB RAS
	Saratov	SSU
	St. Petersburg	NIIEFA SPbSU
	Vladikavkaz	NOSU
Slovakia	Banska Bistrica	UMB
	Kosice	IEP SAS TUKE UPJS
	Zilina	UZ
South Africa	Cape Town	UCT
	Port Elizabeth	NMU
	Stellenbosch	SU
Switzerland	Zurich	ETH
Tajikistan	Dushanbe	PHTI NAST
	Khujand	KSU
United Kingdom	London	Imperial College
	Plymouth	Univ.
USA	Cambridge, MA	MIT
	Davis, CA	UCDavis
	Los Angeles, CA	UCLA
	Louisville, KY	U of L
	San Diego, CA	SDSU
	Upton, NY	BNL
Vietnam	Hanoi	VNU
	Ho Chi Minh City	CNT VINATOM

**Analytical and Methodological Work to Assess the Prospects  
of Scientific Research and Cooperation  
in the Main Directions of JINR's Development.  
Organization of International Cooperation**

**Leaders:** V.A. Matveev  
S.N. Nedelko

**Deputies:** O.A. Culicov  
D.V. Kamanin

**Participating Countries and International organizations:**

Member States of JINR, states participating in JINR activities on the basis of bilateral agreements, international organizations.

**Issues addressed and main goals of research:**

Development of analytical materials concerning prospects of scientific research. Preparation of scientific research plans. Development of science-organization and methodological materials for the special-purpose financing of research areas, themes and projects. Development and application of information systems for the analysis of results of theoretical and experimental research. Organization of international cooperation with the Member States of JINR, with states participating in JINR activities on the basis of bilateral agreements, and with scientific research institutions with which JINR has collaboration agreements.

**Expected results in the current year:**

- Improvement of the organization and coordination of JINR scientific research work.
- Analysis of the results of JINR activities for 2021 in the main research areas.
- Update, administration and support of the electronic system for maintaining the Topical Plan for JINR Research and International Cooperation (Topical Plan). Preparation for the publication of the Topical Plan for the year 2023. Identification of JINR's priority research directions for 2023.
- Development of JINR's grantmaking activities and participation in special-purpose programmes for financing scientific research in 2022.
- Preparation of analytical materials for ministries and agencies.
- Development and promotion of JINR's information resources on the Internet. Support of the system of accounting of protocols on scientific and technological cooperation.
- Promotion of realization of JINR's right to independently confer academic degrees. Support of the operation of JINR's dissertational councils.
- Preparation for the publication of the JINR Annual Report for 2021. Preparation of materials for the INIS system.
- Scientific and organizational support and preparation of materials of JINR's governing and advisory bodies.
- Prompt interaction with representatives of Member States and states participating in the activities of JINR on the basis of bilateral agreements in the fields of scientific research. Organization and holding of meetings of cooperation committees. Interaction with international organizations.
- Organization and holding of contests for JINR Prizes, preparation of materials for nominating candidates for memberships in academies of sciences, for conferring honorary titles, for awarding medals and other decorations.

## List of Activities:

<b>Activity or experiment</b> Laboratory or other Division of JINR	<b>Leaders</b> Main researchers
<b>1. Preparation for the publication of the Topical Plan for 2023</b>  DSOA	<b>S.N. Nedelko</b> <b>O.A. Culicov</b> <b>A.S. Zhemchugov</b> N.A. Boklagova, D.S. Korobov
<b>2. Support and improvement of the operation of JINR's governing and advisory bodies</b>  DSOA  ICD	<b>S.N. Nedelko</b> <b>O.A. Culicov</b> <b>D.V. Kamanin</b> T.V. Bogdanova, N.A. Boklagova, T.B. Ivashkevich, D.S. Korobov, N.I. Sissakian  O.N. Belova, N.M. Dokalenko, O.M. Korotchik, A.A. Kotova, E.N. Rusakovich
<b>3. Preparation of analytical materials for ministries and agencies</b>  DSOA  ICD  STL	<b>S.N. Nedelko</b> <b>O.A. Culicov</b> <b>A.S. Zhemchugov</b> <b>D.V. Kamanin</b> N.A. Boklagova, S.V. Degtyarev, T.B. Ivashkevich, D.S. Korobov, O.V. Krupa, N.I. Sissakian  A.A. Kotova, A.E. Vasiliev  E.V. Ivanova, V.V. Litsitis
<b>4. Development of JINR's grantmaking activities and participation in special-purpose programmes for financing scientific research</b>  DSOA	<b>S.N. Nedelko</b> <b>O.A. Culicov</b> <b>D.V. Kamanin</b>  N.A. Boklagova, D.S. Korobov., N.I. Sissakian
<b>5. Support for the operation of JINR's dissertation councils</b>  DSOA  VBLHEP	<b>S.N. Nedelko</b> <b>A.S. Zhemchugov</b> T.B. Ivashkevich, N.I. Sissakian  O.V. Belov
<b>6. Organizational support for JINR's activities under Russian and international protocols and agreements</b>  DSOA  ICD	<b>S.N. Nedelko</b> <b>O.A. Culicov</b> <b>D.V. Kamanin</b>  S.V. Degtyarev, L.I. Kalinina, N.I. Sissakian  T.V. Keselis, A.A. Kotova
<b>7. Provision for the operation and development of JINR's Internet resources</b>  DSOA	<b>S.N. Nedelko</b> <b>D.V. Kamanin</b>  N.A. Boklagova, N.V. Borozna, N.A. Bykova, A.Yu. Chigireva, D.S. Korobov, K.P. Moisenz, A.G. Nanev, N.I. Sissakian,

IDA

N.V. Zaikina, I.T. Suleymanov

SCSS SID

B.M. Starchenko

Editorial office of the weekly newspaper "Dubna: science, community, progress"

E.M. Molchanov

UC

S.Z. Pakulyak, A.A. Suschevich

**8. Preparation for the publication of JINR Annual Reports. Preparation of materials for the INIS system**

SCSS SID

**S.N. Nedelko**  
**A.S. Zhemchugov**  
**O.A. Culicov**

S.N. Kruglova, Yu.G. Shimanskaya, B.M. Starchenko

DSOA

N.A. Boklagova, S.V. Degtyarev, D.S. Korobov, O.V. Krupa

**9. International cooperation**

ICD

**D.V. Kamanin**  
**S.N. Nedelko**  
**W. Chmielowski**

O.N. Belova, T.V. Keselis, A.A. Kotova, M.G. Loschilov,  
Yu.N. Polyakova, A.E. Vasiliev

DSOA

N.A. Boklagova, O.A. Culicov, D.S. Korobov, A.S. Zhemchugov

**Educational  
Programme  
(06)**

## **Organization, Support and Development of the JINR Human Resources Programme**

### **Leaders:**

V.A. Matveev  
S.Z. Pakuliak

### **Participating Countries and International organizations:**

Armenia, Azerbaijan, Belarus, Bulgaria, CERN, Cuba, Czech Republic, Kazakhstan, Moldova, Mongolia, Poland, Romania, Russia, Serbia, Slovakia, South Africa, Ukraine, Vietnam.

### **Issues addressed and main goals of research:**

Development of the human resources training programmes at JINR aimed at further employment of the trainees as scientific and engineering specialists of the Institute; creation of appropriate conditions for students and PhD students from universities of the Member States to enable them to work on their qualification theses based on the research conducted in the laboratories of the Institute; support of the educational process for students of the JINR-based departments at the universities of the Russian Federation, as well as participation in the development of network training programmes; organisation and running of international student practices and schools for young people from the JINR Member States; training of students, PhD students, and interns on the basis of cooperation agreements with the universities of the JINR Member States and international organisations; building and maintenance of the laboratory environment intended for hands-on training in scientific and engineering disciplines; support and further development of the system of training courses aimed at gaining or improving professional skills and qualifications of JINR technical and engineering personnel; development of the JINR educational portal (edu.jinr.ru) and interactive exposition "JINR main facilities"; further development of the set of e-learning courses on the main areas of research conducted at JINR in the official languages of the Institute and by its leading experts; development of virtual and real laboratories allowing students to be trained using modern experimental equipment; development of the JINR outreach programme and promotion of modern science achievements among school students and teachers, organisation of excursions and online tours of the JINR basic facilities; participation in science festivals, exhibitions, and forums promoting JINR; development of cooperation and communication with educational centres for school students; design and production of information materials for the JINR information centres, administration of the UC groups in the social media.

### **Expected major results in the current year:**

- Support and supervision of the educational process at the JINR-based departments of the Russian universities.
- Support of the system of assigning young researchers to JINR laboratories for preparation of their PhD theses.
- Organisation and running of the International Student Practices in JINR Fields of Research for students of the JINR Member States' universities.
- Expansion of the scientific scope and duration of research projects of the Summer Student Programme at JINR and increasing the number of its participants.
- Development of an information system on the preparation of qualification theses by students and PhD students from universities of the JINR Member States in the Institute laboratories.
- Organisation and running of the Engineering and Physics Training hands-on activities for students and PhD students from the JINR Member States, further development of the existing laboratory works, development of a laboratory work on dosimetry.
- Organisation of scientific schools for physics teachers from the Institute Member States at CERN and JINR.
- Further development of virtual tours of JINR and video-conferences with educational institutions of the Institute Member States.
- Development of a set of e-learning courses in nuclear physics, particle physics, condensed matter physics, and the basic facilities of JINR.
- Promotion of modern educational resources in the JINR Member States.
- Organisation of the participation of JINR in science festivals on the basis of Russian universities.

- Development of the language courses programme aimed at teaching Russian as a foreign language and English to JINR personnel.
- Participation of JINR in an interdisciplinary social educational project "Summer School-2022".
- Participation in the design and production of printed, video, and exhibition information materials intended for the JINR information centres.
- Running of popular science events in schools (lectures, demonstrations of chemical and physical experiments, quizzes, quests, excursions, meetings with scientists, vocational orientation events, and competitions for school and university students).
- Organisation of the participation of JINR in career forums at universities.

### List of projects:

Project	Leader	Priority (period of realisation)
1. Open information and educational environment for supporting fundamental and applied multidisciplinary research at JINR	Yu.A. Panebrattsev	1 (2021-2023)

### List of Activities:

Activity or experiment	Leaders
Laboratory or other Division of JINR	Main researchers
1. <b>Organization of the educational process at JINR</b>	<b>V.A. Matveev</b> <b>S.Z. Pakuliak</b>
DLNP V.A. Bednyakov D.V. Naumov A.S. Zhemchugov	A.G. Olshevskiy, A.Yu. Verkheev
BLTP D.I. Kazakov A.P. Isaev A.B. Arbuzov	Yu.M. Shukrinov, A.A. Vladimirov
FLNP V.N. Shvetsov E.V. Lychagin O.A. Culikov	M.V. Avdeev, A.V. Belushkin
VBLHEP N.A. Stokovsky A.S. Sorin O.V. Belov	D.K. Dryablov, S.V. Shmatov
FLNR S.I. Sidorchuk A.V. Karpov A.G. Popeko	S.G. Belogurov, K.B. Gikal
MLIT V.V. Korenkov T.A. Strizh O.Yu. Derenovskaya	I.S. Pelevanyuk

LRB  
A.N. Bugay  
E.A. Krasavin  
I.V. Koshlan

G.N. Timoshenko

Directorate  
V.D. Kekelidze  
L. Kostov  
B.N. Gikal

B.Yu. Sharkov, E.D. Uglov

ICD  
D.V. Kamanin  
A.A. Kotova

W. Chmielowski

## 2. Developing of modern educational projects

VBLHEP

## Y.A. Panebrattsev

G.N. Agakishiev, E.I. Golubeva, R.V. Klygina,  
Yu.D. Orlova, M.P. Osmachko, G.D. Semchukov, N.E. Sidorov,  
N.I. Vorontsova, G.A. Yarygin

## 3. Outreach and JINR promotion

DLNP

## A.A. Suschevich

N.V. Anfimov, M.V. Shirchenko, A.Yu. Verkheev

BLTP

A.V. Andreev, A.V. Frizen

FLNP

M.V. Bulavin, D.M. Chudoba, C. Khramko

VBLHEP

D.K. Dryablov, D.I. Klimansky

FLNR

K.B. Gikal, A.V. Karpov

MLIT

I.S. Pelevanyuk

LRB

T.S. Khramko, I.A. Kolesnikova, Yu.S. Severyukhin

Universal  
JINR library

M.S. Pilipenko

## 4. Engineering and Physics Training

VBLHEP

## M.A. Nozdrin

G.A. Filatov, S.A. Goncharov, V.V. Kobets, V.V. Kosachev,  
K.G. Osipov, R.V. Pivin, D.O. Ponkin, I.V. Shirikov

DLNP

A.V. Chetverikov, A.N. Trifonov, A.S. Zhemchugov

FLNR

D.S. Belozеров, A.Yu. Bodrov, V.A. Buzmakov, K.B. Gikal,  
A.M. Kapitonov, A.V. Khalkin, E.V. Melnik, K.V. Papenkov,  
A.V. Sabelnikov, K.A. Verlamov, V.Yu. Zhigolev,  
D.A. Zlydenny

## Collaboration

### Country or International Organization

Armenia

### City

Yerevan

### Institute or laboratory

YSU

Azerbaijan

Baku

IP ANAS

Belarus

Gomel

GSU

Minsk

INP BSU

Bulgaria

Sofia

INRNE BAS

SU

CERN

Geneva

CERN



Cuba	Havana	ASC
Czech Republic	Prague	CTU
		CU
Kazakhstan	Almaty	KazNU
	Nur-Sultan	ENU
	Ust-Kamenogorsk	EKSU
Moldova	Chisinau	ASM
		MSU
Mongolia	Ulaanbaatar	MNUE
		NUM
Poland	Krakow	INP PAS
	Poznan	AMU
Romania	Bucharest	UB
Russia	Arkhangelsk	NArFU
		NSMU
	Belgorod	BelSU
	Dolgoprudny	MIPT
	Dubna	Dubna State Univ.
	Ivanovo	ISU
	Kazan	KFU
		KNRTU
	Kostroma	KSU
	Krasnodar	KSU
	Moscow	BMSTU
		MPEI
		MSU
		NNRU "MEPhI"
		NRU HSE
	Smolensk	SSU
	St. Petersburg	SPbSU
	Tomsk	TPU
		TSU
	Tula	TSU
	Vladikavkaz	NOSU
	Vladivostok	FEFU
	Voronezh	VSU
	Yakutsk	NEFU
	Yaroslavl	YSU
	Yekaterinburg	UrFU
Serbia	Novi Sad	UNS
Slovakia	Bratislava	CU
	Kosice	STM
		UPJS
South Africa	Somerset West	iThemba LABS
	Stellenbosch	SU
Ukraine	Kiev	BITP NASU
		NUK
Vietnam	Hanoi	IOP VAST



## Alphabetical List of Collaborators

### Albania

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#### Tirana

UT | University of Tirana | <http://www.unitir.edu.al/>, 1128

### Argentina

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#### Bariloche

CAB CNEA | Bariloche Atomic Centre National Atomic Energy Commission | <http://www.cab.cnea.gov.ar/>, 1143, 1140

#### Buenos Aires

CNEA | National Atomic Energy Commission | <https://www.argentina.gob.ar/comision-nacional-de-energia-atmica/>, 1135

### Armenia

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#### Garni

GGO | Garni Geophysical Observatory, 1127

#### Gyumri

IGES NAS RA | Institute of Geophysics and Engineering Seismology named after A. Nazarov | <http://iges.am/>, 1127

#### Yerevan

Foundation ANSL | A.I. Alikhanian National Science Laboratory Yerevan Physics Institute Foundation | <http://www.yerphi.am/>, 1135, 1137, 1138, 1081, 1083, 1065, 1087, 1088, 1142, 1143, 1133, 1119

IIAP NAS RA | Institute for Informatics and Automation Problems of the National Academy of Sciences of the Republic of Armenia | <http://iiap.sci.am/>, 1118

RAU | Russian-Armenian University | <http://www.rau.am/>, 1135, 1136, 1119

Shirak Technologies | “Shirac” Technological Company | <http://www.shte.net/>, 1127

SRCHCH | Scientific Research Center of the Historical and Cultural Heritage of the Ministry of Education, Science, Culture and Sport of RA (SN-CO) | <https://armheritage.am/>, 1128, 1142

YSU | Yerevan State University | <http://www.y-su.am/>, 1136, 1137, 1138, 1117, 1065, 1087, 1107, 1077, 1119, 1139

### Australia

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#### Melbourne, VIC

Univ. | University of Melbourne | <http://unimelb.edu.au/>, 1137, 1128

#### Perth, WA

UWA | University of Western Australia | <http://www.uwa.edu.au/>, 1138

#### Sydney, NSW

Univ. | University of Sydney | <http://sydney.edu.au/>, 1137, 1138, 1065, 1107

### Austria

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#### Innsbruck

Univ. | University of Innsbruck | <http://www.uibk.ac.at/>, 1136, 1128

#### Linz

JKU | Johannes Kepler University Linz | <http://www.jku.at/>, 1137

#### Vienna

HEPHY | Institute of High Energy Physics | <http://www.hephy.at/>, 1083

ITP TU Wien | Institute for Theoretical Physics Vienna University of Technology | <http://www.itp.tuwien.ac.at/>, 1117

SMI | Stefan Meyer Institute for Subatomic Physics of the Austrian Academy of Sciences | <https://www.oeaw.ac.at/smi/home/>, 1088

### Azerbaijan

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#### Baku

ADA | Azerbaijan Diplomatic Academy | <https://www.ada.edu.az/>, 1118

AzTU | Azerbaijan Technical University | <http://aztu.edu.az/>, 1142

Branch MSU | Branch of the Lomonosov Moscow State University | <http://www.msu.az/>, 1137

BSU | Baku State University | <http://bsu.edu.az/>, 1135, 1128

IGG ANAS | Institute of Geology and Geophysics of the Azerbaijan National Academy of Sciences | <http://gia.az/>, 1128

IP ANAS | Institute of Physics of the Azerbaijan National Academy of Sciences | <http://physics.mehdiyev.me/>, 1135, 1081, 1142, 1118, 1139

IRP ANAS | Institute of Radiation Problems of the Azerbaijan National Academy of Sciences | <http://irp.science.az/>, 1066, 1100, 1128, 1105

NNRC | National Nuclear Research Center | <http://www.mntm.az/>, 1065, 1088, 1105

### Bangladesh

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#### Dhaka

DU | University of Dhaka | <http://www.univdhaka.edu/>, 1088

### Belarus

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#### Brest

BrSU | Brest State A.S. Pushkin University | <http://www.brsu.by/>, 1119

#### Gomel

GSTU | Pavel Sukhoi State Technical University of Gomel | <http://www.gstu.by/>, 1135, 1117, 1081, 1086

GSU | Francisk Skorina Gomel State University | <http://gsu.by/>, 1135, 1081, 1083, 1086, 1131, 1139

## **Minsk**

“Radateh” | “Radateh” Ltd. | <http://www.radateh.com/>, 1086

BSTU | Belarusian State Technological University | <http://www.belstu.by/>, 1137, 1142, 1143, 1140, 1126, 1118

BSU | Belarusian State University | <http://www.bsu.by/>, 1135, 1144, 1128, 1141, 1131

BSUIR | Belarusian State University of Informatics and Radioelectronics | <http://www.bsuir.by/>, 1086, 1065, 1133

IAP NASB | State Scientific Institution “Institute of Applied Physics of the National Academy of Sciences of Belarus” | <http://iaph.bas-net.by/>, 1081, 1086, 1142

IBCE NASB | Institute of Biophysics and Cell Engineering NAS of Belarus | <http://ibp.org.by/ru/>, 1077

IM NASB | Institute of Mathematics of the National Academy of Sciences of Belarus | <http://im.bas-net.by/>, 1119

INP BSU | Institute for Nuclear Problems of Belarusian State University | <http://www.new.inp.bsu.by/>, 1135, 1123, 1081, 1144, 1096, 1083, 1086, 1065, 1127, 1107, 1128, 1142, 1143, 1118, 1139

Inst. Physiology NASB | Institute of Physiology of the National Academy of Sciences of Belarus | <http://physiology.by/>, 1077

IP NASB | B.I.Stepanov Institute of Physics of the National Academy of Sciences of Belarus | <http://ifan.basnet.by/>, 1135, 1136, 1137, 1081, 1144, 1108, 1086, 1065

ISEI BSU | International Sakharov Environmental Institute of the Belarusian State University | <http://www.iseu.bsu.by/>, 1107

JIPNR-Sosny NASB | State Scientific Institution “Joint Institute for Power and Nuclear Research - Sosny” of the National Academy of Sciences of Belarus | <http://sosny.bas-net.by/>, 1135, 1081, 1065, 1107, 1105, 1118

PTI NASB | Physical Technical Institute of the National Academy of Sciences of Belarus | <http://www.phti.by/>, 1065

RI PCP BSU | Research Institute for Physical Chemical Problems of the Belarusian State University | <http://fhp.bsu.by/>, 1107, 1142

SOL instruments | SOL instruments LTd. | <http://solinstruments.com/>, 1133

SPMRC NASB | Scientific and Practical Materials Research Centre of the National Academy of Sciences of Belarus | <http://www.physics.by/>, 1137, 1065, 1128, 1142, 1077

UIIP NASB | United Institute of Informatics Problems of the National Academy of Sciences of Belarus | <http://www.uiip.bas-net.by/>, 1118

## **Belgium**

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### **Antwerp**

UAntwerp | University of Antwerp | <http://www.uantwerpen.be/>, 1083

## **Brussels**

ULB | Université Libre de Bruxelles | <http://www.ulb.ac.be/> VUB | Vrije Universiteit Brussel | <http://www.ulb.be/>, 1136, 1083, 1130

VUB | Vrije Universiteit Brussel | <http://www.vub.ac.be/>, 1136, 1083

## **Ghent**

Ugent | Ghent University | <http://www.ugent.be/>, 1083

## **Leuven**

KU Leuven | Catholic University of Leuven | <http://www.kuleuven.be/>, 1083, 1129, 1130

## **Louvain-la-Neuve**

IBA | Ion Beam Applications | <http://iba-worldwide.com/> UCL | Catholic University of Louvain | <http://uclouvain.be/>, 1132

UCL | Catholic University of Louvain | <http://uclouvain.be/>, 1136, 1096, 1083

## **Mons**

UMONS | University of Mons | <http://web.umons.ac.be/>, 1083

## **Botswana**

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### **Palapye**

BIUST | Botswana International University of Science and Technology | <http://www.biust.ac.bw/>, 1128

## **Brazil**

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### **Brasilia, DF**

UnB | University of Brasilia | <http://www.unb.br/>, 1137

### **Campinas, SP**

UNICAMP | State University at Campinas | <http://www.unicamp.br/>, 1088

### **Florianopolis, SC**

UFSC | Federal University of Santa Catarina | <http://ufsc.br/>, 1136

### **Juiz de Fora, MG**

UFJF | Federal University of Juiz de Fora | <http://www2.ufjf.br/>, 1138

### **Natal, RN**

IIP UFRN | International Institute of Physics of the Federal University of Rio Grande do Norte | <http://www.iip.ufrn.br/>, 1137

### **Niteroi, RJ**

UFF | Federal Fluminense University | <http://www.uff.br/>, 1136

### **Porto Alegre, RS**

UFRGS | Federal University of Rio Grande de Sul | <http://www.ufrgs.br/>, 1088

### **Rio de Janeiro, RJ**

CBPF | Brazilian Center for Physics Research | <http://portal.cbpf.br/>, 1083

UERJ | State University of Rio de Janeiro | <http://www.uerj.br/>, 1083

## **Santo Andre, SP**

UFABC | University Federal of ABC |  
<http://www.ufabc.edu.br/>, 1117, 1088

## **Sao Carlos, SP**

IFSC USP | Institute of Physics of São Carlos of the  
University of São Paulo | <http://www.ifsc.usp.br/>,  
1119

## **Sao Jose dos Campos, SP**

ITA | Aeronautics Institute of Technology |  
<http://www.ita.br>, 1136

## **Sao Paulo, SP**

UEP | Unit of Professional Education Santa Case de  
São Paulo | <http://www.santacasasp.org.br/>, 1136

Unesp | São Paulo State University |  
<http://www2.unesp.br/>, 1083

USP | University of São Paulo | <http://www5.usp.br/>,  
1137, 1138, 1117, 1088

## **Vitoria, ES**

UFES | Federal University of Espirito Santo |  
<http://www.ufes.br/>, 1138

## **Bulgaria**

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### **Blagoevgrad**

AUBG | American University in Bulgaria |  
<http://www.aubg.edu/>, 1087

SWU | South-West University “Neofit Rilski” |  
<http://www.swu.bg/>, 1096, 1065

### **Plovdiv**

PU | Plovdiv University “Paisii Hilendarski” |  
<https://uni-plovdiv.bg/>, 1137, 1096, 1065, 1100,  
1128, 1131, 1119

UFT | University of Food Technologies-Plovdiv |  
<http://uft-plovdiv.bg/>, 1128

### **Sofia**

ASCI Ltd | ASCI Ltd | <http://www.asci.bg/>, 1142

IAPS | Institute for Advanced Physics Studies |  
<http://iaps.institute/>, 1088

IE BAS | Academician Emil Djakov Institute of  
Electronics of the Bulgarian Academy of Sciences |  
<http://www.ie-bas.org.bg/>, 1128, 1142, 1077

IEES BAS | Institute of Electrochemistry and Energy  
Systems “Academic Evgeni Budevski” of the  
Bulgarian Academy of Sciences |  
<http://iees.bas.bg/>, 1142

IMech BAS | Institute of Mechanics of the Bulgarian  
Academy of Sciences | <http://www.imbm.bas.bg/>,  
1137

IMI BAS | Institute of Mathematics and Informatics of  
the Bulgarian Academy of Sciences |  
<http://math.bas.bg/>, 1119

INRNE BAS | Institute for Nuclear Research and  
Nuclear Energy of the Bulgarian Academy of  
Sciences | <http://www.inrne.bas.bg/>, 1135, 1136,  
1137, 1138, 1117, 1083, 1065, 1087, 1066, 1107,  
1129, 1130, 1100, 1128, 1142, 1118, 1119, 1139

Inst. Microbiology BAS | Stephan Angeloff Institute of  
Microbiology of the Bulgarian Academy of  
Sciences | <http://microbio.bas.bg/>, 1087, 1077

ISSP BAS | Georgi Nadjakov Institute of Solid State  
Physics of the Bulgarian Academy of Sciences |  
<http://www.issp.bas.bg/>, 1137, 1065, 1142, 1133

LTD BAS | Laboratory for Technical Development of  
the Bulgarian Academy of Sciences |  
<http://www.pronto.phys.bas.bg/>, 1065

NBU | New Bulgarian University | <http://www.nbu.bg/>,  
1136

NCRRP | National Centre of Radiobiology and  
Radiation Protection | <http://ncrrp.org/>, 1077

SU | Sofia University “St. Kliment Ohridski” |  
<http://www.uni-sofia.bg/>, 1135, 1137, 1138, 1117,  
1081, 1144, 1096, 1083, 1065, 1087, 1066, 1088,  
1118, 1119, 1139

TU-Sofia | Technical University of Sofia | <http://tu-sofia.bg/>, 1065

UCTM | University of Chemical Technology and  
Metallurgy | <http://dl.uctm.edu/>, 1097, 1142

## **Canada**

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### **Corner Brook**

MUN | Memorial University of Newfoundland -  
Grenfell Campus | <http://www.grenfell.mun.ca/>,  
1135

### **Edmonton**

U of A | University of Alberta; Theoretical Physics  
Institute; Avadh Bhatia Physics Laboratory |  
<http://www.ualberta.ca/>, 1138, 1117

### **Halifax**

SMU | Saint Mary's University | <http://smu.ca/>, 1126

### **Hamilton, ON**

McMaster | McMaster University |  
<http://www.mcmaster.ca/>, 1136

### **Kingston, ON**

Queen's | Queen's University |  
<http://www.queensu.ca/>, 1137

### **London, ON**

Western | Western University - Canada |  
<http://www.uwo.ca/>, 1137

### **Montreal**

Concordia | Concordia University Montreal |  
<http://www.concordia.ca/>, 1137, 1138

UdeM | University of Montreal |  
<http://www.umontreal.ca/>, 1135, 1117, 1081

### **Quebec**

UL | Laval University | <http://www.ulaval.ca/>, 1137

### **Regina**

U of R | University of Regina |  
<https://www.uregina.ca/>, 1126

### **Sackville**

MAU | Mount Allison University |  
<https://www.mta.ca/>, 1126

### **Saskatoon**

U of S | University of Saskatchewan |  
<http://www.usask.ca/>, 1136

## Toronto

IBM Lab | IBM Toronto Software Lab |  
<http://www.ibm.com/>, 1119

## Vancouver

TRIUMF | Canada's particle accelerator centre |  
<http://www.triumf.ca/>, 1081, 1096, 1129

UBC | University of British Columbia |  
<http://www.ubc.ca/>, 1096

## Waterloo

WLU | Wilfrid Laurier University |  
<https://www.wlu.ca/>, 1136

## CERN

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### Geneva

CERN | European Organization for Nuclear Research  
(Switzerland) | <http://home.cern/>, 1135, 1138,  
1117, 1123, 1081, 1108, 1096, 1083, 1085, 1065,  
1127, 1097, 1087, 1088, 1129, 1130, 1128, 1126,  
1118, 1119, 1139

## Chile

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### Valparaiso

UTFSM | Technical University Federico Santa Maria |  
<http://www.usm.cl/>, 1096, 1065

UV | University of Valparaiso | <http://www.valpo.edu/>,  
1135

## China

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### Beijing

“Tsinghua” | Tsinghua University |  
<http://www.tsinghua.edu.cn/>, 1083, 1065

CIAE | China Institute of Atomic Energy |  
<http://www.ciae.ac.cn/>, 1136, 1065, 1087, 1088,  
1119

IHEP CAS | Institute of High Energy Physics of the  
Chinese Academy of Sciences |  
<http://www.ihep.ac.cn/>, 1123, 1099, 1083, 1065,  
1087, 1128, 1118, 1119

ITP CAS | Institute of Theoretical Physics of the  
Chinese Academy of Sciences |  
<http://english.itp.cas.cn/>, 1136

PKU | Peking University | <http://www.pku.edu.cn/>,  
1135, 1136, 1083, 1130, 1131

### Hangzhou

ZJU | Zhejiang University |  
<http://www.zju.edu.cn/english/>, 1083

### Harbin

HEU | Harbin Engineering University |  
<http://www.hrbeu.edu.cn/>, 1142

### Hefei

IPP CAS | Institute of Plasma Physics of the Chinese  
Academy of Sciences | <http://english.ipp.cas.cn/>,  
1065, 1132

USTC | University of Science and Technology of  
China | <http://www.ustc.edu.cn/>, 1065, 1088

### Hengyang

USC | University of South China |  
<http://english.usc.edu.cn/>, 1065

## Huzhou

HU | Huzhou University | <http://www.zjhu.edu.cn/>,  
1065

## Jinan

SDU | Shandong University | <http://en.sdu.edu.cn/>,  
1065

## Lanzhou

IMP CAS | Institute of Modern Physics of the Chinese  
Academy of Sciences | <http://www.imp.cas.cn/>,  
1135, 1065, 1129, 1130

## Shanghai

Fudan | Fudan University | <http://www.fudan.edu.cn/>,  
1065

SINAP CAS | Shanghai Institute of Applied Physics of  
the Chinese Academy of Sciences |  
<http://english.sinap.cas.cn/>, 1065, 1088

## Wuhan

CCNU | Central China Normal University; Institute of  
Particle Physics | <http://ioppweb.ccnu.edu.cn/>,  
1065, 1087, 1088

HBUT | Hubei University of Technology |  
<http://www.hbut.edu.cn/>, 1088

WHU | Wuhan University | <http://en.whu.edu.cn/>, 1117

WIPM CAS | Wuhan Institute of Physics and  
Mathematics of the Chinese Academy of Sciences |  
<http://english.wipm.cas.cn/>, 1135

## Xi'an

NINT | Northwest Institute of Nuclear Technology,  
1128

## Yichang

CTGU | China Three Gorges University |  
<http://eng.ctgu.edu.cn/>, 1065

## Croatia

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### Split

Univ. | University of Split | <http://www.unist.hr/>, 1083,  
1088

### Zagreb

Oikon IAE Oikon OOO | Oikon Ltd. Institute for  
Applied Ecology | <http://www.oikon.hr/>, 1128

RBI | Rudjer Boskovic Institute | <http://www.irb.hr/>,  
1083, 1088, 1128, 1126

UZ | University of Zagreb | <http://www.unizg.hr/>, 1088

## Cuba

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### Havana

ASC | Academy of Sciences of Cuba |  
<http://www.academiaciencias.cu/>, 1139

CEADEN | Centre of Technological Applications and  
Nuclear Development | <http://www.ceaden.cu/>,  
1088, 1131, 1126

InSTEC | Higher Institute of Technologies and Applied  
Sciences | <http://www.instec.cu/>, 1065

### San Jose de las Lajas

CENTIS | Center of Isotopes "CENTIS" |  
<http://www.centis.cu/>, 1077

## Cyprus

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### Nicosia

UCY | University of Cyprus | <http://www.ucy.ac.cy/>, 1083

## Czech Republic

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### Brno

BUT | Brno University of Technology | <http://www.vutbr.cz/>, 1085, 1107, 1131

IBP CAS | Institute of Biophysics of the Czech Academy of Sciences | <http://www.ibp.cz/>, 1077

ISI CAS | Institute of Scientific Instruments of the Czech Academy of Sciences | <http://www.isibrno.cz/>, 1097

### Liberec

TUL | Technical University of Liberec | <http://www.tul.cz/>, 1085, 1065

### Olomouc

UP | Palacky University Olomouc | <http://www.upol.cz/>, 1137, 1065, 1129, 1130, 1131

### Opava

SIU | Silesian University of Opava | <http://www.slu.cz/>, 1138

### Ostrava

VSb-TUO | Technical University of Ostrava | <http://www.vsb.cz/>, 1128, 1118, 1119

### Prague

ADVACAM | ADVACAM s.r.o. | <http://advacam.com/>, 1132

BC CAS | Biology Centre of the Czech Academy of Sciences | <https://www.bc.cas.cz/>, 1142

CEI | Czech Environmental Institute | <http://www.ceu.cz/>, 1128

CTU | Czech Technical University in Prague | <http://www.cvut.cz/>, 1135, 1138, 1117, 1144, 1086, 1065, 1097, 1087, 1088, 1107, 1130, 1100, 1128, 1142, 1077, 1126, 1119, 1139

CU | Charles University in Prague | <http://www.cuni.cz/>, 1135, 1136, 1081, 1144, 1099, 1096, 1083, 1085, 1086, 1065, 1097, 1087, 1066, 1142, 1131, 1139

IG CAS | Institute of Geology of the Czech Academy of Sciences | <http://www.gli.cas.cz/>, 1142

IMC CAS | Institute of Macromolecular Chemistry of the Czech Academy of Sciences | <http://www.irsm.cas.cz/>, 1087, 1142

IP CAS | Institute of Physics of the Czech Academy of Sciences | <http://www.fzu.cz/>, 1135, 1066, 1088, 1142, 1118

PTC | Proton Therapy Center Czech s.r.o | <http://www.ptc.cz/>, 1132

VP | Vacuum PRAGUE | <http://www.vakuum.cz/>, 1065, 1129, 1130

### Řež

CVŘ | Centrum Výzkumu Řež - Research Centre Řež | <http://cvrez.cz/>, 1128

NPI CAS | Nuclear Physics Institute of the Czech Academy of Sciences | <http://www.ujf.cas.cz/>,

1135, 1137, 1138, 1117, 1106, 1065, 1087, 1066, 1107, 1129, 1130, 1100, 1142, 1143, 1140, 1131  
ÚJV | “ÚJV Řež, a.s.” | <http://www.ujv.cz/>, 1097, 1088, 1132

### Vitkovice

VHM | Vitkovice Heavy Machinery a.s. | <http://www.vitkovice.cz/>, 1065

## Denmark

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### Copenhagen

NBI | Niles Bohr Institute of the University of Copenhagen | <http://www.nbi.ku.dk/>, 1088

### Lyngby

DTU | Technical University of Denmark | <http://www.dtu.dk/>, 1137

## Ecuador

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### Quito

USFQ | University of San Francisco, Quito | <http://www.usfq.edu.ec/>, 1137

## Egypt

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### Alexandria

Univ. | Alexandria University | <http://www.alexu.edu.eg/>, 1128

### Cairo

ASRT | Academy of Scientific Research and Technology | <http://www.asrt.sci.eg/>, 1118

ASU | Ain Shams University | <http://www.asu.edu.eg/>, 1142

EAEA | Egyptian Atomic Energy Authority | <http://www.eaea.org.eg/>, 1142

ECTP | Egyptian Center for Theoretical Physics | <http://www.mti.edu.eg/>, 1065

NRC | National Research Centre | <http://www.nrc.sci.eg/>, 1128

NRRA | Nuclear and Radiological Regulatory Authority, 1126

### Giza

CU | Cairo University | <http://cu.edu.eg/>, 1136, 1137, 1065, 1129, 1130, 1128, 1142, 1118

### Mansoura

MU | Mansoura University | <http://www.mans.edu.eg/en/>, 1128

### New Borg El-Arab

E-JUST | Egypt-Japan University for Science and Technology | <https://ejust.edu.eg/>, 1126

### Shibin El Kom

MU | Menoufia University | <http://mu.menoufia.edu.eg/>, 1129, 1130, 1128

## Estonia

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### Tallinn

NICPB | National Institute of Chemical Physics and Biophysics | <http://www.kbfi.ee/>, 1083

### Tartu

UT | University of Tartu | <http://www.ut.ee/>, 1138

## Finland

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### Helsinki

HIP | Helsinki Institute of Physics | <http://www.hip.fi/>, 1083, 1088

UH | University of Helsinki | <http://www.helsinki.fi/>, 1135, 1137, 1083

### Jyväskylä

UJ | University of Jyväskylä | <http://www.jyu.fi/>, 1088, 1130, 1100, 1128

### Lappeenranta

LUT | Lappeenranta-Lahti University of Technology | <https://www.lut.fi/>, 1083

### Oulu

UO | University of Oulu; Microelectronics Instrumentation Laboratory | <http://www.oulu.fi/>, 1128

## France

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### Annecy-le-Vieux

LAPP | Laboratory of Annecy-la-Vieux for Particles Physics of the National Institute for Nuclear Physics and Particles Physics of the National Centre for Scientific Research | <http://lapp.in2p3.fr/>, 1138, 1117

### Bordeaux

UB | University of Bordeaux | <http://www.u-bordeaux.fr/>, 1136

### Cadarache

CC CEA | Centre de Recherche du Commissariat à l'Énergie Atomique et aux Énergies Alternatives Cadarache | <http://cadarache.cea.fr/cad>, 1128

### Caen

GANIL | Grand National Heavy Ion Accelerator | <http://www.ganil-spiral2.eu/>, 1136, 1129, 1130

### Clermont-Ferrand

LPC | Corpuscular Physics Laboratory Clermont-Ferrand of the Blaise Pascal University | <http://clrwww.in2p3.fr/>, 1081, 1088

### Dijon

UB | University of Burgundy | <http://www.u-bourgogne.fr/>, 1117

### Grenoble

IBS | Institute of Structural Biology | <http://www.ibs.fr/>, 1142

ILL | Institute Laue-Langevin | <http://www.ill.eu/>, 1128, 1142, 1140

LPSC | Laboratoire de Physique Subatomique et de Cosmologie | <http://lpsc.in2p3.fr/>, 1088, 1128

UGA | Université Grenoble Alpes | <https://www.univ-grenoble-alpes.fr/>, 1100

### Lyon

ENS Lyon | Ecole Normale Supérieure de Lyon; Physics Laboratory | <http://www.ens-lyon.fr/>, 1138, 1117

IPNL | Institute of Nuclear Physics of Lyon | <http://www.ipnl.in2p3.fr/>, 1100

UCBL | Claude Bernard University Lyon 1 | <http://www.univ-lyon1.fr/>, 1135

UL | Université de Lyon | <http://www.universite-lyon.fr/>, 1083, 1088

### Marseille

CPPM | Centre de Physique des Particules de Marseille | <http://cpmm.in2p3.fr/>, 1118

CPT | Centre of Theoretical Physics | <http://www.cpt.univ-mrs.fr/>, 1137, 1138, 1117

UPC - III | University Paul Cézanne - Aix-Marseille III | <https://www.univ-amu.fr/>, 1137

### Metz

UPV-M | Paul-Verlaine University of Metz | <http://www.univ-metz.fr/>, 1135

### Modane

LSM | Modane Underground Laboratory | <http://www-lsm.in2p3.fr/>, 1100

### Montpellier

UM2 | University of Montpellier 2 | <https://www.umontpellier.fr/>, 1135

### Nancy

UL | University of Lorraine | <http://www.univ-lorraine.fr/>, 1119

### Nantes

SUBATECH | Subatomic Physics Laboratory and Associated Technologies; UMR/EMN/IN2P3/CNRS/University of Nantes | <http://www-subatech.in2p3.fr/>, 1138, 1117, 1065, 1066, 1088

### Nice

UN | University Nice Sophia Antipolis | <http://unice.fr/>, 1137

### Orsay

CSNSM | Center for Nuclear and Mass Spectrometry-IN2P3/CNRS | <http://www.csnsm.in2p3.fr/>, 1136, 1130, 1100

IJCLab | Irene Joliot-Curie Lab | <https://www.ijclab.in2p3.fr/en/home/>, 1136, 1088

IPN Orsay - IN2P3/CNRS | Institute of Nuclear Physics Orsay - IN2P3/CNRS | <http://ipnwww.in2p3.fr/>, 1106, 1097, 1129, 1130

LAL - 11 - IN2P3/CNRS | Linear Accelerator Laboratory of the University of Paris-Sid 11 - IN2P3/CNRS | <http://www.lal.in2p3.fr/>, 1081

### Paris

ENS | École Normale Supérieure Paris | <http://www.ens.fr/>, 1138, 1117

IN2P3 | National Institute of Nuclear Physics and Physics Particles | <http://www.in2p3.cnrs.fr/>, 1144, 1083

LPTHE - IN2P3/CNRS | Laboratory of Theoretical Physics and High Energy of the Pierre et Marie Curie - IN2P3/CNRS | <http://lpthe.jussieu.fr/>, 1117

LUTH | Laboratory Universe and Theories, Observatory of Paris | <http://www.luth.obspm.fr/>, 1138



UPMC 6 | Pierre et Marie Curie University Henri Poincaré Institute Paris 6 | <https://www.sorbonne-universite.fr/>, 1135, 1137

### Saclay

CEA | Alternative Energies and Atomic Energy Commission | <http://www.cea.fr/>, 1065, 1100

IRFU | Institute of Research into the Fundamental Laws of the Universe | <http://irfu.cea.fr/>, 1135, 1083, 1097, 1088, 1119

LLB | Léon Brillouin Laboratory CEA-CNRS | <http://www-llb.cea.fr/>, 1128, 1142

SPhN CEA DAPNIA | Nuclear Physics Division of the Commissariat for Atomic Energy | <http://irtu.cea.fr/Sphn>, 1135, 1085, 1130

### Strasbourg

CRN - IN2P3/CNRS | Centre of Nuclear Research - IN2P3/CNRS | <http://ireswww.in2p3.fr/>, 1099, 1130

IPHC - IN2P3/CNRS | Hubert Curien Multidisciplinary Institute of the University of Strasbourg - IN2P3/CNRS | <http://www.iphc.cnrs.fr/>, 1083, 1088, 1130, 1128

### Tours

Univ. | University of Tours | <http://www.univ-tours.fr/>, 1138

### Valenciennes

UVHC | University of Valenciennes and Hainaut-Combrésis | <http://www.uphf.fr/>, 1137, 1117

### Vannes

SigmaPhi | Company SigmaPhi Accelerator Technologies | <http://www.sigmaphi.fr/>, 1129

### Villeurbanne

CC IN2P3 | IN2P3 Computing Center | <https://cc.in2p3.fr/>, 1088

## Georgia

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### Tbilisi

AIP TSU | Ekvter Andronikashvili Institute of Physics of the Ivane Javakhishvili Tbilisi State University | <http://www.aiphysics.tsu.ge/>, 1065, 1128

GRENA | Georgian Research and Educational Networking Association | <http://www.grena.ge/>, 1118

GTU | Georgia Technical University | <http://gtu.ge/>, 1144, 1083, 1065, 1118, 1119

HEPI-TSU | High Energy Physics Institute of Ivane Javakhishvili Tbilisi State University | <http://www.hepi.tsu.ge/>, 1081, 1144, 1083, 1127

RMI TSU | Andrea Razmadze Mathematical Institute of the Ivane Javakhishvili Tbilisi State University | <http://rmi.tsu.ge/>, 1135

TSU | Ivane Javakhishvili Tbilisi State University | <http://www.tsu.ge/>, 1135, 1128, 1118, 1119

UG | University of Georgia | <http://www.ug.edu.ge/>, 1144, 1119

## Germany

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### Aachen

RWTH | Rheinisch-Westfaelische Technische Aachen University | <http://www.rwth-aachen.de/>, 1135, 1099, 1083

### Berlin

FU Berlin | Free University of Berlin | <http://www.fu-berlin.de/>, 1135

BAM | Federal Institute for Materials Research and Testing | <http://www.bam.de/>, 1142

HU Berlin | Humboldt University of Berlin | <http://www.hu-berlin.de/>, 1135

HZB | Helmholtz Berlin Centre for Materials and Energy of the Helmholtz Association | <http://www.helmholtz-berlin.de/>, 1136, 1142, 1143, 1140

### Bielefeld

Univ. | Bielefeld University | <http://www.uni-bielefeld.de/>, 1135, 1136

### Bochum

RUB | Ruhr University of Bochum | <http://www.ruhr-uni-bochum.de/>, 1135, 1085, 1097, 1142, 1126

### Bonn

UniBonn | University of Bonn | <http://www.uni-bonn.de/>, 1135, 1136, 1138, 1117, 1096, 1085, 1088, 1142, 1126

### Braunschweig

TU | Braunschweig Technical University | <http://www.tu-braunschweig.de/>, 1137

### Bremen

Univ. | University of Bremen | <http://www.uni-bremen.de/>, 1137

### Cologne

Univ. | University of Cologne | <http://www.uni-koeln.de/>, 1136

### Darmstadt

FAIR | Facility for Antiproton and Ion Research | <https://fair-center.eu/>, 1106

GSI | Helmholtz-Centre for the Study of Heavy Ions of the Helmholtz Association | <http://www.gsi.de/>, 1135, 1136, 1137, 1108, 1106, 1065, 1088, 1129, 1130, 1128, 1143, 1131, 1077, 1118, 1119

TU Darmstadt | Technical University Darmstadt | <http://www.tu-darmstadt.de/>, 1135, 1136, 1137, 1106, 1065, 1087, 1088, 1142

### Dortmund

TU Dortmund | Technical University of Dortmund | <http://www.uni-dortmund.de/>, 1135, 1137

### Dresden

HZDR | Helmholtz-Zentrum Dresden-Rossendorf of the Helmholtz Association | <http://www.hzdr.de/>, 1136, 1106, 1128

IFW | Leibniz Institute for Solid State and Materials Research Dresden | <http://www.ifw-dresden.de/>, 1137

ILK | Institute of Air Handling and Refrigeration of the Helmholtz Association | <http://www.ilkdresden.de/>, 1065

MPI PkS | Max Planck Institute for the Physics of Complex Systems | <http://www.mpipks-dresden.mpg.de/>, 1137

TU Dresden | Technical University of Dresden | <http://tu-dresden.de/>, 1137, 1097

## **Erlangen**

FAU | Friedrich Alexander University of Erlangen-Nuremberg | <http://www.fau.eu/>, 1135, 1136, 1065

## **Frankfurt/Main**

FIAS | Frankfurt Institute for Advanced Studies | <http://fias.institute.de/>, 1135, 1065, 1087, 1088

Univ. | Goethe University of Frankfurt on Main | <http://www.uni-frankfurt.de/>, 1136, 1108, 1106, 1065, 1087, 1088, 1118, 1119

## **Freiberg**

TUBAF | Technical University Bergakademie of Freiberg | <http://tu-freiberg.de/>, 1085, 1142

## **Freiburg**

FMF | Albert-Ludwig's University of Freiburg | <http://www.uni-freiburg.de/>, 1097

## **Geesthacht**

GKSS | Research Center in Geesthacht of the Helmholtz Association | <http://www.hzgd.de/>, 1142

## **Giessen**

JLU | Justus Liebig University Giessen | <http://www.uni-giessen.de/>, 1136, 1106, 1065, 1126

## **Göttingen**

Univ. | University of Göttingen | <http://www.uni-goettingen.de/>, 1142

## **Halle**

MLU | Martin-Luther University of Halle-Wittenberg | <http://www.uni-halle.de/>, 1142

## **Hamburg**

DESY | Deutsches Elektronen-Synchrotron DESY of the Helmholtz Association | <http://www.desy.de/>, 1135, 1117, 1123, 1083, 1127, 1142, 1126, 1118

Univ. | University of Hamburg | <http://www.uni-hamburg.de/>, 1135, 1136, 1099, 1125, 1083, 1119

## **Hannover**

LUH | Leibniz University of Hannover | <http://www.uni-hannover.de/>, 1138, 1117, 1123

## **Heidelberg**

MPIK | Max Planck Institute for Nuclear Physics | <http://www.mpi-hd.mpg.de/>, 1129, 1100, 1130

Univ. | University of Heidelberg | <http://www.uni-heidelberg.de/>, 1135, 1106, 1066, 1088

## **Jena**

Univ. | Friedrich-Schiller University of Jena | <http://www.uni-jena.de/>, 1135, 1137, 1117

## **Julich**

FZJ | Research Centre Jülich of the Helmholtz Association | <http://www.fz-juelich.de/>, 1135, 1065, 1097, 1142, 1143, 1140

## **Kaiserslautern**

TUK | Technical University of Kaiserslautern | <http://www.uni-kl.de/>, 1135

## **Karlsruhe**

KIT | Karlsruhe Institute of Technology | <http://www.kit.edu/>, 1135, 1083, 1100, 1142, 1118, 1119

## **Kassel**

Uni Kassel | University of Kassel | <http://www.uni-kassel.de/>, 1119

## **Kiel**

IFM-GEOMAR | GEOMAR Helmholtz Centre for Ocean Research Kiel | <http://www.geomar.de/>, 1142

## **Kleve**

HSRW | Rhine-Waal University of Applied Sciences | <https://www.hochschule-rhein-waal.de/>, 1128

## **Konstanz**

Univ. | University of Konstanz | <https://www.uni-konstanz.de/>, 1142

## **Leipzig**

UoC | University of Leipzig | <http://www.uni-leipzig.de/>, 1136, 1137, 1138, 1117

## **Magdeburg**

OVGU | Otto-von-Guericke University Magdeburg | <http://www.uni-magdeburg.de/>, 1137

## **Mainz**

HIM | Helmholtz-Institute Mainz | <http://www.hi-mainz.de/>, 1135

JGU | Johannes Gutenberg University of Mainz | <http://www.uni-mainz.de/>, 1135, 1136, 1096, 1085, 1065, 1130, 1100, 1128, 1126

## **Munich**

LMU | Ludwig-Maximilians University of Munich | <http://www.uni-muenchen.de/>, 1135, 1119

MPI-P | Max Planck Institute for Physics of Munich | <http://www.mpp.mpg.de/>, 1117, 1081, 1125

TUM | Technical University of Munich | <http://portal.mytum.de/>, 1108, 1106, 1085, 1088, 1100, 1128

## **Munster**

WWU | Westfälische Wilhelms-Universität (University of Münster) | <http://www.uni-muenster.de/>, 1088

## **Oldenburg**

IPO | Institute of Physics of the Carl von Ossietzky University of Oldenburg | <http://www.uol.de/en/physics/>, 1138

## **Potsdam**

AEI | Max Planck Institute for Gravitational Physics Albert Einstein Institute | <http://www.aei.mpg.de/>, 1138, 1117

## Regensburg

UR | University of Regensburg | <http://www.uni-regensburg.de/>, 1135, 1136, 1065

## Rostock

Univ. | University of Rostock | <http://www.uni-rostock.de/>, 1135, 1136, 1137, 1117, 1142, 1119

## Siegen

Univ. | University of Siegen | <http://www.uni-siegen.de/>, 1136

## Stuttgart

MPI-FKF | Max Planck Institute for Solid State Research | <http://www.fkf.mpg.de/>, 1142

## Tubingen

Univ. | Eberhard Karls University of Tübingen | <http://uni-tuebingen.de/>, 1135, 1125, 1065, 1097, 1088, 1130, 1128

## Worms

ZTT | Center for Technology Transfer and Telecommunications of the University of Worms | <https://www.hs-worms.de/>, 1088

## Wuppertal

UW | University of Wuppertal | <http://www.uni-wuppertal.de/>, 1135, 1137

## Zeuthen

DESY | Deutsches Elektronen-Synchrotron DESY of the Helmholtz Association (Zeuthen) | <http://www.desy.de/>, 1135, 1117, 1081, 1125, 1118

## Greece

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### Athens

INP NCSR “Demokritos” | Institute of Nuclear and Particle Physics of the National Centre for Scientific Research “Demokritos” | <http://www.inp.demokritos.gr/>, 1136, 1083

NTU | National Technical University of Athens | <http://www.ntua.gr/>, 1083

UoA | National and Kapodistrian University of Athens | <http://www.uoa.gr/>, 1138, 1117, 1083, 1088

### Ioannina

UI | University of Ioannina | <http://www.uoi.gr/>, 1083

### Thessaloniki

AUTH | Aristotle University of Thessaloniki | <http://www.auth.gr/>, 1138

## Hungary

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### Budapest

ELTE | Eötvös Loránd University | <http://www.elte.hu/>, 1135

GetGiro Kft | GetGiro IT Limited Liability Company | <http://getgiro.com/>, 1131

RKK OU | Rejto Sándor Faculty of Light Industry and Environmental Engineering of the Obuda University | <http://rkk.uni-obuda.hu/>, 1128

Wigner RCP | Institute for Particle and Nuclear Physics, Wigner Research Centre for Physics |

<http://wigner.mta.hu/>, 1135, 1136, 1137, 1117, 1083, 1088, 1142, 1143, 1140, 1119

## Debrecen

Atomki | Institute of Nuclear Research of the Hungarian Academy of Science | <http://www.atomki.hu/>, 1136, 1083

UD | University of Debrecen | <http://www.unideb.hu/>, 1083

## IAEA

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### Vienna

IAEA | International Atomic Energy Agency | <http://www.iaea.org/>, 1128

## ICTP

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### Trieste

ICTP | Abdus Salam International Centre for Theoretical Physics Italy | <http://www.ictp.it/>, 1135, 1138

## India

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### Aligarh

AMU | Aligarh Muslim University | <http://www.amu.ac.in/>, 1088

### Bhubaneswar

IOP Institute of Physics, Bhubaneswar | <http://www.iopb.res.in/>, 1135, 1088

### Chandigarh

PU | Panjab University | <http://pu.ac.in/>, 1136, 1083, 1088

### Chennai

IMSc | Institute of Mathematical Science (National Institute for Research in the Theoretical Sciences) | <http://www.imsc.res.in/>, 1135, 1138

### Guwahati

GU | Gauhati University | <https://guportal.in/>, 1088

### Indore

IIT Indore | Indian Institute of Technology Indore | <https://www.iitsystem.ac.in/>, 1088

### Jaipur

Univ. | University of Rajasthan | <http://www.uniraj.ac.in/>, 1087, 1088

### Jammu

Univ. | University of Jammu | <http://www.jammuuniversity.in/>, 1088

### Jatani

NISER | National Institute of Science Education and Research of the Department of Atomic Energy | <http://www.niser.ac.in/>, 1083, 1088

### Kasaragod

CUK | Central University of Kerala | <http://cukerala.ac.in/>, 1136

### Kolkata

BNC | S.N. Bose National Centre for Basic Sciences | <http://www.bose.res.in/>, 1138, 1117, 1088

IACS | Indian Association for the Cultivation of Science | <http://www.iacs.res.in/>, 1137, 1138  
MIERE | Matrivani Institute of Experimental Research and Education, 1085  
SINP | Saha Institute of Nuclear Physics | <http://www.saha.ac.in/>, 1083, 1088  
UC | University of Calcutta | <http://www.caluniv.ac.in/>, 1088  
VECC | Variable Energy Cyclotron Centre of the Department of Atomic Energy | <http://www.vecc.gov.in/>, 1135, 1088, 1130

## **Mumbai**

BARC | Bhabha Atomic Research Centre of the Department of Atomic Energy | <http://www.barc.gov.in/>, 1083, 1087, 1088  
IIT Bombay | Indian Institute of Technology Bombay | <https://www.iitsystem.ac.in/>, 1088  
TIFR | Tata Institute of Fundamental Research | <http://www.tifr.res.in/>, 1083

## **New Delhi**

IUAC | Inter-University Accelerator Center | <http://www.iuac.res.in/>, 1136, 1130

## **Patna**

NIT Patna | National Institute of Technology Patna | <http://www.nitp.ac.in/>, 1142

## **Roorkee**

IIT Roorkee | Indian Institute of Technology Roorkee | <https://www.iitr.ac.in/>, 1130

## **Rupnagar**

IIT Ropar | Indian Institute of Technology Ropar | <http://www.iitrpr.ac.in/>, 1130

## **Varanasi**

BHU | Banaras Hindu University | <http://www.bhu.ac.in/>, 1128

## **Indonesia**

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### **Jakarta**

LIPI | Indonesian Institute of Sciences | <http://lipi.go.id/>, 1088

## **Iran**

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### **Tehran**

IPM | Institute for Studies in Theoretical Physics and Mathematics of the Institute for Research Fundamental Sciences | <http://www.ipm.ac.ir/>, 1138, 1083

### **Zanjan**

IASBS | Institute for Advanced Studies in Basic Sciences | <http://iasbs.ac.ir/>, 1136, 1137

## **Ireland**

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### **Dublin**

DIAS | Dublin Institute for Advanced Studies | <http://www.dias.ie/>, 1138  
UCD | University College Dublin | <https://www.ucd.ie/>, 1083

## **Israel**

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### **Jerusalem**

HUJI | Hebrew University of Jerusalem | <http://www.huji.ac.il/>, 1065, 1126

### **Rehovot**

WIS | Weizmann Institute of Science | <http://www.weizmann.ac.il/>, 1117, 1081

### **Tel Aviv**

TAU | Tel Aviv University | <http://www.tau.ac.il/>, 1138, 1085, 1065

## **Italy**

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### **Alessandria**

DiSIT UPO | Department of Science and Technological Innovation of the University of Eastern Piedmont Amedeo Avogadro | <https://www.disit.uniupo.it/>, 1088

### **Bari**

DIF | Interuniversity Department of Physics | <https://www.uniba.it/>, 1088  
INFN | National Institute for Nuclear Physics, Section of Bari | <http://www.ba.infn.it/>, 1083, 1088  
Poliba | Polytechnic University of Bari | <http://www.en.poliba.it/>, 1088

### **Bologna**

BRC ENEA | Bologna Research Centre of the Italian National Agency for New Technologies, Energy and the Sustainable Economic Development | <http://www.bologna.enea.it/>, 1136  
INFN | National Institute for Nuclear Physics, Section of Bologna | <http://www.bo.infn.it/>, 1083, 1088, 1118  
UniBo | University of Bologna | <http://www.unibo.it/>, 1088

### **Brescia**

Forgiatura Morandini | Forgiatura Morandini | <http://www.morandini.it/>, 1065  
UNIBS | University of Brescia | <https://en.unibs.it/>, 1088

### **Cagliari**

INFN | National Institute for Nuclear Physics, Section of Cagliari | <http://www.ca.infn.it/>, 1088  
UniCa | University of Cagliari | <http://www.unica.it/>, 1088

### **Catania**

INFN | National Institute for Nuclear Physics, Section of Catania | <https://www.ct.infn.it/>, 1088  
INFN LNS | National Institute for Nuclear Physics, National Laboratory of the South | <http://www.lns.infn.it/>, 1136, 1083, 1130  
UniCT | University of Catania | <http://www.unict.it/>, 1137, 1088

### **Erice**

EMFCS | Ettore Majorana Foundation and Centre for Scientific Culture | <http://www.ccsem.infn.it/>, 1088

## **Ferrara**

INFN | National Institute for Nuclear Physics, Section of Ferrara | <http://www.fe.infn.it/>, 1096

## **Fisciano**

UNISA | University of Salerno | <http://web.unisa.it/>, 1137, 1117

## **Florence**

INFN | National Institute for Nuclear Physics, Section of Florence | <http://www.fi.infn.it/>, 1096, 1083

## **Foggia**

Unifg | University of Foggia | <https://www.unifg.it/>, 1088

## **Frascati**

INFN LNF | National Institute for Nuclear Physics, National Laboratory of Frascati | <http://www.lnf.infn.it/>, 1138, 1117, 1144, 1096, 1083, 1088

## **Genoa**

ASG | ASG Superconductors D.p.a. | <http://www.asg.it/>, 1065

INFN | National Institute for Nuclear Physics, Section of Genoa | <http://www.ge.infn.it/>, 1108, 1083, 1119

UniGe | University of Genoa | <https://unige.it/en>, 1108

## **Legnaro**

INFN LNL | National Institute for Nuclear Physics, Legnaro National Laboratories | <http://www.lnl.infn.it/>, 1088, 1130

## **Messina**

UniMe | University of Messina | <http://www.unime.it/>, 1136, 1088, 1130, 1142

## **Milan**

INFN | National Institute for Nuclear Physics, Section of Milan | <http://www.mi.infn.it/>, 1083

UNIMI | University of Milan | <http://www.unimi.it/>, 1099

## **Naples**

INFN | National Institute for Nuclear Physics, Section of Naples | <http://www.na.infn.it/>, 1135, 1136, 1096, 1083

Unina II | University of Naples Federico II | <http://www.unina.it/>, 1130, 1077

## **Padua**

INFN | National Institute for Nuclear Physics, Section of Padua | <http://www.pd.infn.it/>, 1083, 1088, 1129

UniPd | University of Padua | <http://www.unipd.it/>, 1135, 1138, 1117, 1088

## **Pavia**

INFN | National Institute for Nuclear Physics, Section of Pavia | <http://www.pv.infn.it/>, 1135, 1117, 1083, 1126

UniPv | University of Pavia | <http://www.unipv.it/>, 1088

## **Perugia**

INFN | National Institute for Nuclear Physics, Section of Perugia | <http://www.pg.infn.it/>, 1136, 1096, 1083

## **Pisa**

INFN | National Institute for Nuclear Physics, Section of Pisa | <http://www.pi.infn.it/>, 1135, 1138, 1117, 1081, 1096, 1083, 1127

UniPi | University of Pisa | <http://www.unipi.it/>, 1144

## **Rome**

“Tor Vergata” | University of Rome “Tor Vergata” | <http://web.uniroma2.it/>, 1096

CREF | Enrico Fermi Center for Study and Research | <https://www.cref.it/>, 1088

ENEA | Italian National Agency for New Technologies, Energy and Sustainable Economic Development | <http://www.enea.it/>, 1128

INFN | National Institute for Nuclear Physics, Section of Rome | <http://www.roma1.infn.it/>, 1096, 1083, 1088

Univ. “La Sapienza” | University of Roma “La Sapienza” | <http://www.uniroma1.it/>, 1088, 1112

## **Salerno**

INFN | National Institute for Nuclear Physics, Section of Salerno | <http://www.sa.infn.it/>, 1099, 1088

## **Trento**

ECT\* | European Centre for Theoretical Studies in Nuclear Physics and Related Areas | <https://www.ectstar.eu/>, 1108

## **Trieste**

INFN | National Institute for Nuclear Physics, Section of Trieste | <http://www.ts.infn.it/>, 1083, 1085, 1088

SISSA/ISAS | International School for Advanced Studies | <http://www.sissa.it/>, 1135, 1138, 1117

UNITR | University of Trieste | <http://www.univ.trieste.it/>, 1088

## **Turin**

INFN | National Institute for Nuclear Physics, Section of Turin | <http://www.to.infn.it/>, 1096, 1083, 1085, 1065, 1088

Polito | Polytechnic University of Turin | <http://www.polito.it/>, 1088

UniTo | University of Turin | <http://www.unito.it/>, 1135, 1136, 1138, 1117, 1125, 1088

## **Udine**

Uniid | University of Udine | <http://www.uniud.it/>, 1077

## **Vercelli**

UPO | Amedeo Avogadro Piemonte Eastern University | <http://www.unipmn.it/>, 1088

## **Viterbo**

UNITUS | Tuscia University | <http://www3.unitus.it/>, 1112

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## **Japan**

### **Chiba**

Chiba U | Chiba University | <http://www.chiba-u.ac.jp/e/>, 1135

CIT | Chiba Institute of Technology | <http://www.it-chiba.ac.jp/>, 1117

## **Fukuoka**

Kyushu Univ. | Kyushu University |  
<http://www.kyushu-u.ac.jp/>, 1144, 1099

## **Hiroshima**

Hiroshima Univ. | Hiroshima University |  
<http://www.hiroshima-u.ac.jp/>, 1097, 1088

## **Kobe**

Kobe Univ. | Kobe University | <http://www.kobe-u.ac.jp/>, 1136

## **Kyoto**

KSU | Kyoto Sangyo University | <http://www.kyoto-su.ac.jp/>, 1117, 1128

Kyoto Univ. | Kyoto University | <http://www.kyoto-u.ac.jp/>, 1135

RIMS | Research Institute for Mathematical Sciences of Kyoto University | <http://www.kurims.kyoto-u.ac.jp/>, 1117

## **Minato**

Keio Univ. | Keio University - Minato |  
<http://www.keio.ac.jp/>, 1142

## **Morioka**

Iwate Univ. | Iwate University | <http://www.iwate-u.ac.jp/>, 1136

## **Nagasaki**

NiAS | Nagasaki Institute of Applied Sciences |  
<https://nias.ac.jp/index.html/>, 1088

## **Nagoya**

Nagoya Univ. | Nagoya University |  
<http://www.nagoya-u.ac.jp/>, 1135, 1099, 1065

## **Nara**

NWU | Nara Women's University | <http://www.nara-wu.ac.jp/nwu/en/index.html/>, 1088

## **Osaka**

Osaka Univ. | Osaka University | <http://www.osaka-u.ac.jp/>, 1135, 1136, 1144

RCNP | Research Center for Nuclear Physics of Osaka University | <http://www.rcnp.osaka-u.ac.jp/>, 1136, 1086, 1088

## **Saga**

Saga Univ. | Saga University | <http://www.saga-u.ac.jp/>, 1088

## **Tokai**

JAEA | Japan Atomic Energy Agency |  
<http://www.jaea.go.jp/>, 1088, 1130

## **Tokyo**

Keio Univ. | Keio University - Tokyo |  
<http://www.keio.ac.jp/>, 1138

Meiji Univ. | Meiji University |  
<http://www.meiji.ac.jp/cip/>, 1135

Nihon Univ. | Nihon University | <http://www.nihon-u.ac.jp/>, 1065

Toho Univ. | Toho University | <http://www.toho-u.ac.jp/>, 1099

Tokyo Tech | Tokyo Institute of Technology |  
<http://www.titech.ac.jp/>, 1135

UT | University of Tokyo; Centre for Nuclear Study  
CNS; Institute for Cosmic Ray Research; Institute  
Centre for Elementary Particle Physics ICEPP |  
<http://www.u-tokyo.ac.jp/>, 1135, 1138, 1088

Waseda Univ. | Waseda University |  
<http://www.waseda.jp/>, 1142

## **Tsukuba**

KEK | High Energy Accelerator Research Organization  
| <http://legacy.kek.jp/>, 1135, 1117, 1144, 1128,  
1126

Univ. | University of Tsukuba |  
<http://www.tsukuba.ac.jp/>, 1087, 1088

## **Utsunomiya**

UU | Utsunomiya University | <http://www.utsunomiya-u.ac.jp/>, 1137

## **Wako**

RIKEN | RIKEN Wako Institute; Institute of Physical  
and Chemical Research | <http://www.riken.jp/>,  
1125, 1097, 1088

## **Yamagata**

Yamagata Univ. | Yamagata University |  
<http://www.yamagata-u.ac.jp/>, 1085

## **Kazakhstan**

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### **Almaty**

FAPHI | Fesenkov Astrophysical Institute of the  
National Centre of Space Researches and  
Technologies | <http://aphi.kz/>, 1135

IETP KazNU | Institute of Experimental and  
Theoretical Physics of the Al-Farabi Kazakh  
National University | <http://www.ietp.kz/>, 1130

INP | Institute of Nuclear Physics of Ministry of  
Energy of the Republic of Kazakhstan |  
<http://www.inp.kz/>, 1135, 1136, 1144, 1129, 1130,  
1100, 1128, 1142, 1118, 1119

KazNU | Al-Farabi Kazakh National University |  
<http://www.kaznu.kz/>, 1136, 1119, 1139

PhysTI | Physics - Technical Institute |  
<http://www.sci.kz/>, 1131

### **Kyzylorda**

KazSRIRG | Kazakh Scientific Research Institute of  
Rice Growing named after I. Zhakhayev, 1128

### **Nur-Sultan**

BA INP | Branch of the Astana Institute of Nuclear  
Physics of Ministry of Energy of the Republic of  
Kazakhstan | <http://www.inp.kz/>, 1135, 1129, 1131,  
1118

ENU | L.N. Gumilyov Eurasian National University |  
<http://www.enu.kz/>, 1129, 1130, 1128, 1131, 1139

NU | Nazarbayev University | <http://nu.edu.kz/>, 1131

### **Ust-Kamenogorsk**

EKSU | Sarsen Amanzholov East Kazakhstan State  
University | <http://www.vkgu.kz/>, 1139

## **Latvia**

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### **Riga**

ISSP UL | Institute of Solid State Physics of the  
University of Latvia | <http://www.cfi.lu.lv/>, 1142

## Lithuania

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### Kaunas

VMU | Vytautas Magnus University |  
<http://www.vdu.lt/>, 1136, 1119

### Vilnius

VU | Vilnius University | <http://www.vu.lt/>, 1138, 1083

## Luxembourg

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### Luxembourg

Univ. | University of Luxembourg |  
<http://www.en.uni.lu/>, 1138

## Malta

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### Msida

UM | University of Malta | <https://www.um.edu.mt/>,  
1088

## Mexico

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### Cuernavaca

UNAM | National Autonomous University of Mexico  
Campus Morelos | <http://www.unam.mx/>, 1135

### Culiacan

UAS | Autonomous University of Sinaloa |  
<https://www.uas.edu.mx/>, 1088

### Mexico City

Cinvestav | Centre for Advanced Investigations and  
Studies of the National Polytechnical Institute |  
<http://www.cinvestav.mx/>, 1083, 1088

UNAM | National Autonomous University of Mexico  
(Mexico City) | <http://www.unam.mx/>, 1136, 1065,  
1088

### Puebla

BUAP | Autonomous University of Puebla |  
<http://www.buap.mx/>, 1125, 1083, 1065, 1088

### San Luis Potosi

UASLP | Autonomous University of San Luis Potosi |  
<http://www.uaslp.mx/>, 1096

## Moldova

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### Chisinau

ASM | Academy of Sciences of Moldova |  
<http://www.asm.md/>, 1139

IAP | Institute of Applied Physics of the Ministry of  
Education, Culture and Research of the Republic of  
Moldova | <http://www.phys.asm.md/>, 1136, 1065,  
1107, 1119

IChem | Institute of Chemistry | <http://chem.md/>, 1128

IMB ASM | Institute of Microbiology and  
Biotechnology of the Academy of Sciences of  
Moldova | <http://www.imb.asm.md/>, 1128

IMCS | Vladimir Andrunachievici Institute of  
Mathematics and Computer Science |  
<http://www.math.md/>, 1118

MSU | Moldova State University | <http://usm.md/>,  
1065, 1131, 1132, 1118, 1119, 1139

RENAM | Research and Educational Networking  
Association of Moldova | <http://www.renam.md/>,  
1118

## Mongolia

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### Ulaanbaatar

CGL | Central Geological Laboratory |  
<http://cengeolab.com/>, 1128, 1131

IMDT MAS | Institute of Mathematics and Digital  
Technology of the Mongolian Academy |  
<https://imdt.ac.mn/>, 1119

IPT MAS | Institute of Physics and Technology of the  
Mongolian Academy of Sciences | <https://ipt.ac.mn>,  
1135, 1137, 1065, 1087, 1107, 1100, 1142, 1105,  
1077

MNUE | Mongolian National University of Education |  
<http://mnue.mn/>, 1139

NRC NUM | Nuclear Research Center of the National  
University of Mongolia | <http://nrc.num.edu.mn/>,  
1129, 1130, 1128

NUM | National University of Mongolia |  
<http://www.num.edu.mn/>, 1137, 1118, 1139

## Montenegro

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### Podgorica

Univ. | University of Montenegro |  
<http://www.ucg.ac.me/>, 1083

## Netherlands

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### Amsterdam

AUAS | Amsterdam University of Applied Sciences |  
<https://www.amsterdamuas.com/>, 1088

NIKHEF | National Institute for Subatomic Physics |  
<http://www.nikhef.nl/>, 1081, 1088

### Eindhoven

TU/e | Eindhoven University of Technology |  
<https://www.tue.nl/en/>, 1083

### Utrecht

UU | Utrecht University | <http://www.uu.nl/>, 1088

## New Zealand

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### Auckland

Univ. | University of Auckland |  
<http://www.auckland.ac.nz/>, 1137, 1083

### Christchurch

UC | University of Canterbury |  
<http://www.canterbury.ac.nz/>, 1083, 1126

### Hamilton

Univ. | University of Waikato |  
<http://www.waikato.ac.nz/>, 1135

## North Macedonia

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### Skopje

UKiM | Ss. Cyril and Methodius University in Skopje |  
<http://www.ukim.edu.mk/>, 1128

## Norway

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### Bergen

HVL | Western Norway University of Applied Sciences | <https://www.hvl.no/en/>, 1088

UiB | University of Bergen | <http://www.uib.no/>, 1136, 1088

### Oslo

UiO | University of Oslo | <http://www.uio.no/>, 1136, 1117, 1088

### Tonsberg

USN | University College of Southeast Norway | <https://www.usn.no/english/>, 1088

### Trondheim

NTNU | Norwegian University of Science and Technology | <http://www.ntnu.edu/>, 1135, 1138

## Pakistan

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### Islamabad

COMSATS | COMSATS University Islamabad | <https://www.comsats.edu.pk/>, 1088

PINSTECH | Pakistan Institute of Nuclear Science and Technology, 1088

QAU | Quaid-i-Azam University | <http://www.qau.edu.pk/>, 1083

## Peru

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### Lima

PUCP | Pontifical Catholic University of Peru | <https://www.pucp.edu.pe/>, 1088

## Poland

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### Bialystok

BUT | Bialystok University of Technology | <https://pb.edu.pl/>, 1142

UwB | University of Bialystok | <http://www.uwb.edu.pl/>, 1138, 1142

### Chorzow

Frako-Term | Frako-Term LTD Company is a Research and Development | <http://frakoterm.pl/pl/>, 1065

### Gdansk

GUT | Gdańsk University of Technology | <http://pg.edu.pl/>, 1128

### Katowice

US | University of Silesia in Katowice | <http://www.us.edu.pl/>, 1137, 1123

### Kielce

JKU | Jan Kochanowski University of Kielce | <http://www.ujk.edu.pl/>, 1135

### Krakow

AGH | University of Science and Technology | <http://www.agh.edu.pl/>, 1083, 1088, 1126

AGH-UST | AGH University of Science and Technology | <http://www.agh.edu.pl/>, 1083, 1142, 1105

INP PAS | Henryk Niewodniczański Institute of Nuclear Physics of the Polish Academy of Sciences

| <http://www.ifj.edu.pl/>, 1135, 1136, 1123, 1087, 1088, 1129, 1130, 1100, 1128, 1142, 1077, 1132, 1126, 1119, 1139

JU | Jagiellonian University in Kraków | <http://www.uj.edu.pl/>, 1137, 1142, 1133, 1119

SIP | Marian Smoluchowski Institute of Physics of the Jagiellonian University | <https://if.uj.edu.pl/>, 1106

SOLARIS | SOLARIS National Synchrotron Radiation Centre | <https://synchrotron.uj.edu.pl/>, 1141

UEK | Cracow University of Economics | <https://uek.krakow.pl/en/>, 1119

### Lodz

UL | University of Łódź | <http://www.uni.lodz.pl/>, 1135, 1138, 1087, 1128

### Lublin

UMCS | Marie Curie-Skłodowska University in Lublin | <http://www.umcs.pl/>, 1136, 1100, 1128, 1142, 1131, 1119

### Opole

UO | University of Opole | <http://www.uni.opole.pl/>, 1128

### Otwock (Swierk)

NCBJ | National Centre for Nuclear Research | <http://www.ncbj.gov.pl/>, 1135, 1136, 1083, 1085, 1065, 1097, 1087, 1088, 1128, 1132

### Poznan

AMU | Adam Mickiewicz University in Poznań | <http://www.amu.edu.pl/>, 1137, 1130, 1128, 1142, 1141, 1139

GPCC | Maria Skłodowska–Curie Greater Poland Cancer Center | <http://www.wco.pl/>, 1132

IMP PAS | Institute of Molecular Physics of the Polish Academy of Sciences | <http://www.ifmpan.poznan.pl/>, 1137

### Siedlce

UPH | University of Natural Sciences and Humanities | <http://www.uph.edu.pl/>, 1142

### Szczecin

US | University of Szczecin | <http://www.usz.edu.pl/>, 1077

WPUT | West Pomeranian University of Technology in Szczecin | <http://www.zut.edu.pl/>, 1142

### Torun

UMK | Nicolaus Copernicus University | <http://www.umk.pl/>, 1131

### Warsaw

HIL UW | Heavy Ion Laboratory of Warsaw University | <http://www.slj.uw.edu.pl/>, 1129, 1130

IEP WU | Institute of Experimental Physics of Warsaw University | <http://en.ifd.fuw.edu.pl/>, 1129

IMGW-PIB | Institute of Meteorology and Water Management, National Research Institute | <https://www.imgw.pl/>, 1118, 1119

INCT | Institute of Nuclear Chemistry and Technology | <http://www.ichtj.waw.pl/>, 1142, 1131

IPC PAS | Institute of Physical Chemistry of the Polish Academy of Sciences | <http://ichf.edu.pl/>, 1137



UW | University of Warsaw | <http://www.uw.edu.pl/>,  
1136, 1117, 1125, 1083, 1087, 1130  
WUT | Warsaw University of Technology |  
<http://www.pw.edu.pl/>, 1085, 1065, 1087, 1066,  
1088, 1131

### **Wroclaw**

ILT&SR PAS | Institute of Low Temperature and  
Structure Research of the Polish Academy of  
Sciences | <http://www.intibs.pl/>, 1065  
ITP UW | Institute for Theoretical Physics of the  
University of Wroclaw |  
<http://www.ift.uni.wroc.pl/>, 1135  
UW | University of Wroclaw | <http://www.uni.wroc.pl/>,  
1138, 1117, 1065, 1128, 1142, 1119  
WUT | Wroclaw University of Science and  
Technology | <http://www.pwr.edu.pl/>, 1137

## **Portugal**

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### **Aveiro**

UA | University of Aveiro | <http://www.ua.pt/>, 1138,  
1085

### **Coimbra**

UC | University of Coimbra | <http://www.uc.pt/>, 1135

### **Lisbon**

LIP | Laboratory of Instrumentation and Experimental  
Particle Physics | <http://www.lip.pt/>, 1085

## **Republic of Korea**

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### **Cheongju**

CBNU | Chungbuk National University |  
<http://www.cbnu.ac.kr/>, 1135, 1088

### **Daegu**

KNU | Kyungpook National University |  
<http://en.knu.ac.kr/>, 1135, 1136

### **Daejeon**

CTPCS IBS | Center for Theoretical Physics of  
Complex Systems of the Institute for Basic Science  
| <https://pcs.ibs.re.kr/>, 1137  
IBS | Institute for Basic Science | <http://www.ibs.re.kr/>,  
1136, 1129, 1130  
KAERI | Korea Atomic Energy Research Institute |  
<http://www.kaeri.re.kr/>, 1128  
KFE | Korea Institute of Fusion Energy |  
<https://www.kfe.re.kr/eng/index/>, 1143  
KIST | Korea Institute of Science and Technology  
Information | [https://eng.kist.re.kr/kist\\_eng/main/](https://eng.kist.re.kr/kist_eng/main/),  
1083, 1088

### **Gangneung**

GWNU | Gangneung-Wonju National University |  
<http://www.gwnu.ac.kr/>, 1088

### **Gwangju**

CNU | Chonnam National University |  
<http://www.jnu.ac.kr/>, 1083

### **Incheon**

Inha | Inha University | <https://eng.inha.ac.kr/>, 1137,  
1088

### **Jeonju**

JBNU | Jeonbuk National University |  
<http://www.cbnu.edu/eng/>, 1136, 1088

### **Pohang**

PAL | Pohang Accelerator Laboratory |  
<http://pal.postech.ac.kr/>, 1128

### **Pusan**

PNU | Pusan National University |  
<http://www.pusan.ac.kr/>, 1088

### **Seoul**

Dawonsys "Dawonsys o., Ltd" | Company "Dawonsys  
o., Ltd" | <http://www.dawonsys.com/>, 1128  
EWU | Ewha Womans University |  
<http://www.ewha.ac.kr/>, 1125  
Konkuk Univ. | Konkuk University |  
<http://www.konkuk.ac.kr/>, 1088  
KU | Korea University | <http://www.korea.edu/>, 1083  
SJU | University of Sejong |  
<https://eng.sejong.ac.kr/index.do/>, 1083, 1088  
SKKU | Sungkyunkwan University |  
<http://www.skku.edu/>, 1138, 1083  
SNU | Seoul National University |  
<http://www.en.snu.ac.kr/>, 1135, 1136, 1083  
Yonsei Univ. | Yonsei University |  
<https://www.yonsei.ac.kr/>, 1083, 1088

## **Romania**

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### **Baia Mare**

TUCN-NUCBM | Technical University of Cluj-  
Napoca - North University Center of Baia Mare |  
<http://www.utcluj.ro/>, 1107, 1128, 1142, 1131

### **Brasov**

UNITBV | Transilvania University of Brasov |  
<https://www.unitbv.ro/en/>, 1133

### **Bucharest**

CSSNT-UPB | Center for Surface Science and  
Nanotechnology of the University Politehnica of  
Bucharest | <http://cssnt-upb.ro/>, 1133, 1131  
IFIN-HH | Horia Hulubei National Institute of Physics  
and Nuclear Engineering | <http://www.ifin.ro/>,  
1136, 1137, 1117, 1144, 1106, 1096, 1065, 1087,  
1088, 1107, 1129, 1130, 1128, 1142, 1105, 1131,  
1077, 1132, 1118, 1119  
IGR | Geological Institute of Romania | <https://igr.ro/>,  
1128  
INCDIE ICPE-CA | National Institute of Research and  
Development in Electrical Engineering ICPE-CA |  
<http://www.icpe-ca.ro/>, 1065, 1097, 1087, 1128,  
1142, 1143, 1140  
UB | University of Bucharest | <http://www.unibuc.ro/>,  
1136, 1087, 1128, 1142, 1119, 1139  
UMF | "Carol Davila" University of Medicine and  
Pharmacy Bucharest | <http://www.umf.ro/>, 1107,  
1077  
UPB | University Politehnica of Bucharest |  
<http://www.upb.ro/>, 1088, 1128, 1142, 1131

## Cluj-Napoca

- INCDTIM | National Institute for Research and Development of Isotopic and Molecular Technologies | <http://www.itim-cj.ro/>, 1128, 1142, 1143, 1133, 1118, 1119
- RA BC-N | Romanian Academy Cluj-Napoca Branch | <http://www.acad-cluj.ro/>, 1142
- UBB | Babeş-Bolyai University | <http://www.ubbcluj.ro/>, 1142, 1077
- UTC-N | Technical University of Cluj-Napoca | <http://utcluj.ro/>, 1137

## Constanta

- MINAC | Museum of National History and Archeology in Constanța | <https://www.minac.ro/>, 1142
- UOC | “Ovidius” University of Constanta | <http://www.univ-ovidius.ro/>, 1087, 1128, 1142

## Craiova

- UC | University of Craiova | <http://cis01.central.ucv.ro/>, 1142

## Galati

- UG | University of Galați | <http://www.ugal.ro/>, 1128

## Iasi

- IBR | Institute of Biological Research Iași of the National Institute of Research and Development for Biological Sciences | <http://www.dbioro.eu/>, 1077
- NIRDTP | National Institute of Research and Development for Technical Physics | <http://www.phys-iasi.ro/>, 1128, 1142
- TUIASI | “Gheorghe Asachi” Technical University of Iași | <http://www.tuiasi.ro/>, 1142
- UAI | University “Apollonia” of Iași | <http://univapollonia.ro/>, 1142
- UAIC | Alexandru Ioan Cuza University of Iași | <http://www.uaic.ro/>, 1107, 1128, 1142, 1143
- USAMV | University of Agricultural Sciences and Veterinary Medicine | <http://www.uaiasi.ro/>, 1142

## Magurele

- IFA | Institute of Atomic Physics | <http://www.ifa-mg.ro/>, 1118, 1119
- INFLPR | National Institute for Laser, Plasma and Radiation Physics | <http://www.inflpr.ro/>, 1131
- INOE2000 | National Institute for Research and Development in Optoelectronics | <http://www.inoe.ro/>, 1065
- ISS | Institute for Space Sciences | <http://www2.spacescience.ro/>, 1099, 1125, 1087, 1088, 1107, 1128, 1126, 1119
- NIMP | National Institute of Materials Physics | <http://www.infim.ro/>, 1128, 1142, 1133

## Oradea

- UO | University of Oradea | <http://www.uoradea.ro/>, 1128

## Pitești

- ICN | Institute for Nuclear Research - Pitești | <http://www.nuclear.ro/>, 1128, 1142
- UPIT | University of Pitești | <http://www.upit.ro/>, 1142

## Ramnicu Valcea

- I.C.S.I. | National Research and Development Institute for Cryogenics and Isotopic Technologies | <http://www.icsi.ro/>, 1128

## Sibiu

- ULBS | Lucian Blaga University of Sibiu | <https://www.ulbsibiu.ro/ro/>, 1128

## Targoviste

- UVT | Valahia University of Târgoviște | <http://www.valahia.ro/>, 1128, 1142, 1143

## Timisoara

- ICT | "Coriolan Drăgulescu" Institute of Chemistry | <http://acad-icht.tm.edu.ro/>, 1142
- ISIM | National R&D Institute for Welding and Materials Testing - ISIM Timisoara | <http://www.isim.ro/>, 1142
- LMF CCTFA | Laboratory of Magnetic Fluids of the Center for Fundamental and Advanced Technical Research of the Romanian Academy, Branch Timișoara | <http://acad-tim.tm.edu.ro/cctfa>, 1142
- UVT | West University of Timișoara | <http://www.uvt.ro/>, 1137, 1107, 1128, 1142, 1119

## Tulcea

- DDNI | “Danube Delta” National Institute for Research and Development | <http://www.ddni.ro/>, 1142

## Russia

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### Arkhangelsk

- NArFU | Northern (Arctic) Federal University named after M.B. Lomonosov | <http://narfu.ru/>, 1126, 1139
- NSMU | Northern State Medical University | <http://www.nsmu.ru/>, 1139

### Belgorod

- BeISU | Belgorod National Research State University | <http://www.bsu.edu.ru/>, 1135, 1137, 1065, 1097, 1087, 1126, 1139

### Borok

- IBIW RAS | Federal State Budgetary Institution of Science “I.D. Papanin Institute for the Biology of Inland Waters of the Russian Academy of Sciences” | <http://ibiw.ru/>, 1128
- IPE RAS | Federal State Budgetary Institution of Science “Schmidt Institute of the Physics of the Earth of the Russian Academy of Sciences” | <http://www.ifz.ru/>, 1112

### Chelyabinsk

- SUSU | South Ural State University | <https://www.susu.ru/ru/>, 1142

### Chernogolovka

- BInEPCP RAS | Federal State Budgetary Institution of Science “Branch of the Institute of Energy Problems for Chemical Physics of the Russian Academy of Sciences” | <http://binep.ac.ru/>, 1131
- ISMAN RAS | Federal State Budgetary Institution of Science “Institute of Structural Macrokinetics and Materials Science of the Russian Academy of Sciences” | <http://www.ism.ac.ru/>, 1087

ISSP RAS | Federal State Budgetary Institution of Science “Institute of Solid State Physics of the Russian Academy of Sciences” | <http://issp.ac.ru/>, 1086, 1142, 1131

LITP RAS | Federal State Budgetary Institution of Science “L.D. Landau Institute for Theoretical Physics of the Russian Academy of Sciences” | <http://www.itp.ac.ru/>, 1135, 1138, 1117, 1065, 1118

SCC IPCP RAS | Federal State Budgetary Institution of Science “Supercomputer Centre of the Institute of Problems of Chemical Physics of the Russian Academy of Sciences” | <http://www.icp.ac.ru/>, 1118

### **Dimitrovgrad**

SSC RIAR | Joint Stock Company “State Scientific Centre Research Institute of Atomic Reactors” Rosatom State Nuclear Energy Corporation | <http://www.niiar.ru/>, 1130

### **Dolgoprudny**

MIPT | Moscow Institute of Physics and Technology State University | <http://mipt.ru/>, 1136, 1083, 1065, 1128, 1142, 1119, 1139

### **Dubna**

BSINP MSU | Branch of the Skobeltsyn Institute of Nuclear Physics of the Lomonosov Moscow State University | <http://www.msu.dubna.ru/>, 1107

Diamant | Diamant LLC | <http://diamant-sk.ru/>, 1128

Dubna State Univ. | Dubna State University | <http://www.uni-dubna.ru/>, 1100, 1128, 1142, 1143, 1126, 1118, 1119, 1139

IAS “Omega” | Institute for Advanced Studies “Omega” | <http://dubna-oez.ru/>, 1107

PELCOM | “Pelcom Dubna Mashinostroitelny Zavod” | <http://pelcom.ru/>, 1065

RDH-9 | Radiological Department of Hospital № 9 | <http://msch9fmba.ru/radiologicheskoe-otdelenie-2/>, 1132

SCC “Dubna” | “Dubna” Satellite Communication Centre, Branch of the Federal State Unitary Enterprise “Russian Satellite Communication Company” | <http://www.rssc.ru/>, 1118

SEZ “Dubna” | Special Economic Zone of Technical-Innovative type “Dubna” | <http://oezdubna.ru/>, 1118

Trackpore Technology | Closed Joint Stock Company “Trackpore Technology” Membrane Technologies and the Future, Dubna Branch | <http://www.trackpore.ru/>, 1131

### **Fryazino**

ISTOK | Joint Stock Company “Research and Production Corporation “ISTOK” named after Shokin” | <http://www.istokmw.ru/>, 1065

### **Gatchina**

NRC KI PNPI | Federal State Budgetary Institution “B.P. Konstantinov Petersburg Nuclear Physics Institute” of the National Research Centre “Kurchatov Institute” | <http://www.pnpi.spb.ru/>, 1135, 1136, 1137, 1123, 1144, 1083, 1065, 1088, 1130, 1100, 1128, 1142, 1143, 1140, 1118, 1119

### **Grozny**

CSPU | Chechen State Pedagogical University | <https://chspu.ru/>, 1128

### **Irkutsk**

ISDCT SB RAS | Federal State Budgetary Institution of Science “Matrosov Institute for System Dynamics and Control Theory of the Siberian Branch of the Russian Academy of Sciences” | <http://www.idstu.irk.ru/>, 1135

ISU | Irkutsk State University | <http://isu.su/>, 1144, 1099, 1119

LI SB RAS | Federal State Budgetary Institution of Science “Limnological Institute of the Siberian Branch of the Russian Academy of Sciences” | <http://www.lin.irk.ru/>, 1128

RIAP ISU | Research Institute of Applied Physics of the Irkutsk State University | <http://api.isu.ru/>, 1125

### **Ivanovo**

ICS RAS | Federal State Budgetary Institution of Science “Institute of Solution Chemistry of the Russian Academy of Sciences” | <http://www.isc-ras.ru/>, 1135

ISU | Ivanovo State University | <http://ivanovo.ac.ru/>, 1135, 1139

ISUCT | Ivanovo State University of Chemistry and Technology | <http://isuct.ru/>, 1128

### **Izhevsk**

UdSU | Udmurt State University | <http://udsu.ru/>, 1128

### **Kaliningrad**

IKBFU | Immanuel Kant Baltic Federal University | <http://www.kantiana.ru/>, 1142, 1131

### **Kazan**

Compressormash | Open Joint Stock Company “Kazancompressormash” | <http://compressormash.ru/>, 1065

KFU | Kazan Volga Region Federal University | <http://kpfu.ru/>, 1135, 1137, 1138, 1142, 1139

KNRTU | Kazan National Research Technological University | <http://www.kstu.ru/>, 1142, 1139

Spetshmash | Ltd. “Research and Productio Enterprise Spetshmash” | <http://spmsh.ru/>, 1065

### **Khabarovsk**

PNU | Pacific National University | <http://pnu.edu.ru/>, 1136

### **Kostroma**

KSU | Kostroma State University | <http://ksu.edu.ru/>, 1139

### **Krasnodar**

KSU | Kuban State University | <http://kubsu.ru/>, 1131, 1139

### **Moscow**

“FOMOS-MATERIALS” | Open Joint Stock Company “FOMOS-MATERIALS” | <http://newpiezo.com/>, 1086

“Azimuth-Photonics” | “Azimuth-Photonics” | <http://www.azimp.ru/>, 1086

BMSTU | Bauman Moscow State Technical University | <https://www.bmstu.ru/>, 1139

Cryogenmash | Public Joint Stock Company "Cryogenmash" | <http://cryogenmash.ru/>, 1065

DMS RAS | Department of Medical Sciences, RAS | <http://www.ras.ru/>, 1132

ENES | LLC "Engineering Center of Nuclear Equipment Strength", 1105

FMBC | Russian State Research Center – Burnasyan Federal Medical Biophysical Center of Federal Medical Biological Agency | <http://fmbafmbc.ru/>, 1077, 1132

FRC IM RAS | Federal State Institution "Federal Research Center "Informatics and Management of the Russian Academy of Sciences" | <http://www.frccsc.ru/>, 1118

Geliymash | Open Joint Stock Company "Researching and Production Association "Geliymash" | <http://geliymash.ru/>, 1065, 1105

GIN RAS | Federal State Budgetary Institution of Science "Geological Institute of the Russian Academy of Sciences" | <http://www.ginras.ru/>, 1128

GPI RAS | Federal State Budgetary Institution of Science "General Physics Institute of the Russian Academy of Sciences" | <http://www.gpi.ru/>, 1128, 1133, 1131, 1119

HTDC | High-Tech Diagnostic Centre, 1129

IA RAS | Federal State Budgetary Institution of Science "Institute of Archaeology of the Russian Academy of Sciences" | <http://archaeolog.ru/>, 1128, 1142

IBMC | Federal State Budgetary Institution of Science Institute of Biomedical Chemistry | <http://www.ibmc.msk.ru/>, 1077

IBMP RAS | Federal State Budgetary Institution of Science "State Scientific Centre of the Russian Federation - Institute for Biomedical Problems of the Russian Academy of Sciences" | <http://www.imbp.ru/>, 1065, 1077, 1132

IBRAE | Federal State Budgetary Institution of Science "Institute for the Problems of the Safe Development of Atomic Energy of the Russian Academy of Sciences" | <http://www.ibrae.ac.ru/>, 1135

IC RAS | Federal State Institution "Federal Research Center " Crystallography and Photonics "of the Russian Academy of Sciences | <https://kif.ras.ru/>, 1142, 1131

ICP RAS | Semenov Institute of Chemical Physics of the Russian Academy of Sciences | <http://chph.ras.ru/>, 1142

IEPT RAS | Federal State Budgetary Institution of Science "Institute of Earthquake Prediction Theory and Mathematical Geophysics of the Russian Academy of Sciences" | <http://www.mitp.ru/>, 1142

IGEM RAS | Federal State Budgetary Institution of Science "Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry of the Russian Academy of Sciences" | <http://www.igem.ru/>, 1142, 1112

IGIC RAS | Federal State Budgetary Institution of Science "Kurnakov Institute of General and Inorganic Chemistry of the Russian Academy of Sciences" | <http://www.igic.ras.ru/>, 1142

IHNA Ph RAS | Federal State Budgetary Institution of Science "Institute of Higher Nervous Activity and Neurophysiology of the Russian Academy of Sciences" | <http://www.ihna.ru/>, 1077

IITP RAS | Federal State Budgetary Institute of Science "Institute for Information Transmission Problems (Kharkevich Institute) of the Russian Academy of Sciences" | <http://iitp.ru/>, 1118

IKI RAS | Federal State Budgetary Institution of Science "Space Research Institute of the Russian Academy of Sciences" | <http://www.iki.rssi.ru/>, 1128, 1077, 1112

IMET RAS | Federal State Budgetary Institution of Science "A.A. Baikov Institute of Metallurgy and Materials Science of the Russian Academy of Sciences" | <http://www.imet.ac.ru/>, 1142

IMM RAS | Federal State Budgetary Institution of Science "Institute for Mathematical Modeling of the Russian Academy of Sciences" | <http://www.imamod.ru/>, 1135

INEUM | Institute of Electronic Control Computers named after I.S. Bruk | <http://www.ineum.ru/>, 1105

INMI RAS | Federal State Budgetary Institution of Science "Winogradsky Institute of Microbiology of the Russian Academy of Sciences" | <http://www.inmi.ru/>, 1142, 1112

Inst. Immunology | National Research Center – Institute of Immunology Federal Medical-Biological Agency of Russia | <http://nrcii.ru/>, 1142

IPCE RAS | Federal State Budgetary Institution of Science "A.N. Frumkin Institute of Physical Chemistry and Electrochemistry of the Russian Academy of Sciences" | <http://www.phyche.ac.ru/>, 1128

IPE RAS | Federal State Budgetary Institution of Science "Schmidt Institute of Physics of the Earth of the Russian Academy of Sciences" | <http://www.ifz.ru/>, 1142

ISP RAS | Federal State Budgetary Institution of Science "Ivannikov Institute for System Programming of the Russian Academy of Sciences" | <http://www.ispras.ru/>, 1118

ISPM RAS | Federal State Budgetary Institution of Science "Enikolopov Institute of Synthetic Polymeric Materials of the Russian Academy of Sciences" | <http://www.ispm.ru/>, 1131

ITEP | Federal State Budgetary Institution "Russian Federation State Scientific Centre - Alikhanov Institute for Theoretical and Experimental Physics" of the National Research Centre "Kurchatov Institute" | <http://www.itep.ru/>, 1135, 1137, 1138, 1117, 1081, 1144, 1106, 1083, 1065, 1087, 1066, 1088, 1129, 1100, 1128, 1126, 1118, 1119

ITT-Group | "ITT-Group", 1129

KIAM RAS | Federal State Budgetary Institution of Science "Federal Research Center "Keldysh Institute of Applied Mathematics of the Russian

Academy of Sciences" | <http://www.keldysh.ru/>, 1118

LMPR MONIKI | Laboratory of Medical and Physics Research of the M. Vladimirovsky Moscow Regional Research Clinical Institute | <http://www.medphyslab.ru/>, 1133

LPI RAS | Federal State Budgetary Institution of Science "P.N. Lebedev Physical Institute of the Russian Academy of Sciences" | <http://www.lebedev.ru/>, 1135, 1137, 1138, 1117, 1081, 1096, 1083, 1085, 1065, 1097, 1087, 1131

MAI | Moscow Aviation Institute | <https://mai.ru/>, 1131

MI RAS | Federal State Budgetary Institution of Science "Steklov Mathematical Institute of the Russian Academy of Sciences" | <http://www.mi.ras.ru/>, 1135, 1137, 1138, 1117

MIEM | A.N. Tikhonov Moscow Institute of Electronics and Mathematics | <http://miem.hse.ru/>, 1131

MIET | National Research University of Electronic Technology | <http://www.miet.ru/>, 1142

MIREA | Moscow State University Information Technology, Radioengineering and Electronics - Russian Technological University | <http://www.mirea.ru/>, 1137, 1065

MISiS | National University of Science and Technology "MISiS" | <http://www.misis.ru/>, 1135, 1142

MPEI | National Research University "Moscow Power Engineering Institute" | <http://mpei.ru/>, 1118, 1139

MRSU | Moscow Region State University | <https://mgou.ru/>, 1119

MSK-IX | Joint-stock company "Center of interaction of computer networks" MSK-IX " | <https://www.msk-ix.ru/>, 1118

MSU | Lomonosov Moscow State University | <http://www.msu.ru/>, 1135, 1136, 1138, 1117, 1081, 1065, 1087, 1130, 1128, 1142, 1077, 1112, 1126, 1118, 1119, 1139

NIKIET | Joint Stock Company "A.N. Dollezhal Research and Development Institute of Power Engineering" | <http://www.nikiet.ru/>, 1083

NMRC Oncology | N.N. Blokhin National Medical Research Center of Oncology | <https://www.ronc.ru/>, 1077

NMRC RB | National Medical Research Center for Rehabilitation and Balneology of the Ministry of Health of the Russian Federation | <https://www.nmicrk.ru/>, 1131

NNRU "MEPhI" | National Nuclear Research University "MEPhI" | <http://www.mephi.ru/>, 1136, 1137, 1144, 1125, 1106, 1083, 1086, 1065, 1066, 1088, 1129, 1130, 1100, 1142, 1126, 1119, 1139

NRC KI | National Research Centre "Kurchatov Institute" | <http://www.nrcki.ru/>, 1136, 1137, 1065, 1097, 1088, 1130, 1128, 1142, 1143, 1140, 1077, 1118

NRU HSE | National Research University Higher School of Economics | <http://www.hse.ru/>, 1137, 1117, 1139

OKSAT NIKIET | Department of Integrated Process Control Systems | <http://www.nikiet.ru/>, 1105, 1140

PC ITER RF | Institution "Project Center ITER" | <http://www.iterf.ru/>, 1143

PFUR | Peoples' Friendship University of Russia | <http://www.rudn.ru/>, 1135, 1136, 1137, 1119

PIN RAS | Paleontological Institute of the Russian Academy of Sciences | <http://www.paleo.ru/>, 1142, 1112

PRUE | Plekhanov Russian University of Economics | <https://www.rea.ru/>, 1118, 1119

RCC MSU | Research Computing Center Lomonosov Moscow State University | <http://www.sccc.msu.ru/>, 1118, 1119

RIVS | I.I. Mechnikov Research Institute of Vaccines and Sera | <http://www.instmech.ru/>, 1131

RSCC | Federal State Unitary Enterprise "Russian Satellite Communications Company" | <http://www.rsc.ru/>, 1118

SAI MSU | Sternberg Astronomical Institute of the M.V. Lomonosov Moscow State University | <http://www.sai.msu.ru/>, 1138, 1117

SC "IASRWA" | Stock Company "Interregional Agency for Scientific Restoration of Works of Art" | <http://mnrhu.ru/>, 1128

SC "VNIINM" | Stock Company "A.A. Bochvar High-Technology Research Institute of Inorganic Materials" | <http://www.bochvar.ru/>, 1100, 1140

SCC RAS | Scientific Council for Cybernetics of the Russian Academy of Sciences | <http://www.ras.ru/>, 1135, 1117

Sechenov Univ. | Sechenov University | <https://www.sechenov.ru/>, 1128

SF IPH | Federal State Budgetary Institution of Science "State Foundation Institute of Pharmacology" | <http://www.academpharm.ru/>, 1077

SIAS | State Institute for Art Studies | <http://sias.ru/>, 1128

SINP MSU | Skobeltsyn Institute of Nuclear Physics of the M.V. Lomonosov Moscow State University | <http://www.sinp.msu.ru/>, 1135, 1136, 1137, 1117, 1099, 1125, 1106, 1083, 1086, 1065, 1087, 1088, 1130, 1100, 1128, 1142, 1131, 1077, 1118, 1119

Skoltech | Skolkovo Institute of Science and Technology | <https://www.skoltech.ru/>, 1077

SSDI | Joint Stock Company "State Specialized Design Institute" | <http://aogspi.ru/>, 1105

SYSTEMATOM | Closed Joint Stock Company "Nuclear and Radiation Safety Systems" | <http://www.systematom.ru/>, 1105

VEI | Federal State Unitary Enterprise "All-Russian Electrotechnical Institute" | <http://www.vei.ru/>, 1065

VIGG RAS | Federal State Budgetary Institution of Science "Vavilov Institute of General Genetics of the Russian Academy of Sciences" | <http://www.vigg.ru/>, 1132

VNIIA | Federal State Unitary Enterprise "All-Russian Research Institute of Automatics" Russian Federal Atomic Energy Agency | <http://www.vniia.ru/>, 1128

VNIIMS | Federal Agency of Technical Regulating and Metrology National Metrology Institute All-Russian Research Institute of Metrological Service | <http://www.vniims.ru/>, 1117

### **Moscow, Troitsk**

HPPI RAS | Federal State Budgetary Institution of Science “Institute for High Pressure Physics of the Russian Academy of Sciences” | <http://www.hpptroitsk.ru/>, 1137, 1096, 1100, 1142

INR RAS | Federal State Budgetary Institution of Science “Institute for Nuclear Research of the Russian Academy of Sciences” | <http://www.inr.ru/>, 1135, 1136, 1138, 1117, 1144, 1125, 1106, 1096, 1083, 1065, 1097, 1087, 1088, 1129, 1100, 1128, 1142, 1143, 1140, 1126, 1118, 1119

LPP LPI RAS | “Laboratory of Photomeson Processes Department of High-Energy Physics” Federal State Budgetary Institution of Science “P.V. Lebedev Physical Institute of the Russian Academy of Sciences” | <http://www.lebedev.ru/>, 1097

### **Moscow, Zelenograd**

RIMST | Joint Stock Company “Research Institute of Material Science and Technology” | <http://www.niimv.ru/>, 1086

### **Neutrino**

BNO INR RAS | Baksan Neutrino Observatory Federal State Budgetary Institution of Science “Institute for Nuclear Research of the Russian Academy of Sciences” | <http://www.inr.ru/bno/>, 1100

### **Nizhny Novgorod**

IAP RAS | Federal Research Center Institute of Applied Physics of the Russian Academy of Sciences | <http://www.iapras.ru/>, 1127, 1129

IPM RAS | Federal State Budgetary Institution of Science “Institute for Physics of Microstructures of the Russian Academy of Sciences” | <http://ipmras.ru/>, 1128, 1142

UNN | N.I. Lobachevsky State University of Nizhny Novgorod National Research University | <http://www.unn.ru/>, 1142

### **Novocherkassk**

South Russian State Polytechnic University (NPI) named after M.I. Platov | <https://www.npi-tu.ru/>, 1065

### **Novosibirsk**

BIC SB RAS | Federal State Budgetary Institution of Science “Federal Research Center “Boreskov Institute of Catalysis of the Siberian Branch of the Russian Academy of Sciences” | <http://www.catalysis.ru/>, 1112

BINP SB RAS | Federal State Budgetary Institution of Science “Budker Institute of Nuclear Physics of the Siberian Branch of the Russian Academy of Sciences” | <http://www.inp.nsk.su/>, 1135, 1117, 1123, 1144, 1108, 1065, 1088, 1129, 1141, 1118

ICMMG SB RAS | Institute of Computational Mathematics and Mathematical Geophysics of Siberian Branch of the Russian Academy of Sciences | <https://icmmg.nsc.ru/>, 1118

IM SB RAS | Federal State Budgetary Institution of Science “Sobolev Institute of Mathematics of the Siberian Branch of the Russian Academy of Sciences” | <http://math.nsc.ru/>, 1135

ISP SB RAS | Federal State Budgetary Institution of Science “A.V. Rzhanov Institute of Semiconductor Physics of the Siberian Branch of the Russian Academy of Sciences” | <http://www.isp.nsc.ru/>, 1137, 1131

NIIC SB RAS | Nikolaev Institute of Inorganic Chemistry SB RAS | <http://www.niic.nsc.ru/>, 1137

NSU | Novosibirsk State University | <http://www.nsu.ru/>, 1138, 1144, 1083

STL “Zaryad” | STL “Zaryad”, 1065

### **Obninsk**

IPPE | Joint Stock Company “State Scientific Centre of the Russian Federation - Institute of Physics and Power Engineering” | <http://www.ippe.ru/>, 1128

NMRRC | A. Tsyb National Medical Research Radiological Center | <https://mrrc.nmicr.ru/>, 1077

REATRACK-Filter | REATRACK-Filter LLC | <http://www.reatrack.ru/>, 1131

### **Omsk**

OB IM SB RAS | Federal State Budgetary Institution of Science “Institute of Mathematics of the Siberian Branch of the Russian Academy of Sciences” | <http://ofim.oscsbras.ru/>, 1108

OmsU | F.V. Dostoevsky Omsk State University | <http://www.omsu.ru/>, 1135, 1136

### **Pereslavl-Zalesskiy**

PSI RAS | Federal State Budgetary Institution of Science “Aylamazyan Program Systems Institute of the Russian Academy of Sciences” | <http://skif.pereslavl.ru/psi-info/>, 1118

### **Perm**

ICMM UrB RAS | Federal State Budgetary Institution of Science “Institute of Continuous Media Mechanics of the Russian Academy of Sciences Ural Branch” | <http://www.icmm.ru/>, 1142

ITCh UrB RAS | Federal State Budgetary Institution of Science “Institute of Technical Chemistry of the Russian Academy of Sciences Ural Branch” | <http://www.itcras.ru/>, 1142

PSNRU | Perm State National Research University | <http://www.psu.ru/>, 1135, 1137, 1119

### **Petropavlovsk-Kamchatsky**

FRC GC RAS | Kamchatka branch of the Federal Research Center “Geophysical Service of Russian Academy of Sciences” | <https://www.emsd.ru/>, 1127

KSU / Kamchatsky State University named after Vitus Bering | <https://www.kamgu.ru/>, 1127

### **Protvino**

IHEP | Federal State Budgetary Institution “Russian Federation State Scientific Centre - Institute for High Energy Physics” of the National Research Centre “Kurchatov Institute” | <http://www.ihep.su/>,

1135, 1137, 1138, 1117, 1081, 1108, 1096, 1083, 1085, 1086, 1065, 1087, 1066, 1088, 1126, 1118

### **Puschino**

IMPB RAS | Federal State Budgetary Institution of Science "Institute of Mathematical Problems of Biology of the Russian Academy of Sciences" | <http://www.impb.ru/>, 1118, 1119

ITEB RAS | Federal State Budgetary Institution of Science "Institute of Theoretical and Experimental Biophysics of the Russian Academy of Sciences" | <http://web.iteb.ru/>, 1077

### **Rostov-on-Don**

RIP SFU | Research Institute of Physics of the Southern Federal University | <http://ip.sfedu.ru/>, 1142

SFedU | Southern Federal University | <http://www.sfedu.ru/>, 1135, 1132

### **Samara**

SSU | Samara State University | <http://samsu.ru/>, 1135

SU | Samara National Research University | <http://www.ssau.ru/>, 1135, 1137, 1065, 1118

### **Saratov**

SSMU | Saratov State Medical University named after V. I. Razumovsky | <http://www.sgm.ru/>, 1131

SSU | N.G. Chernyshevsky Saratov State University | <http://www.sgu.ru/>, 1135, 1136, 1137, 1117, 1119

### **Sarov**

VNIIEF | Russian Federal Nuclear Centre - All-Russian Scientific Research "Institute of Experimental Physics" | <http://www.vniief.ru/>, 1135, 1087, 1088, 1129, 1130

### **Sevastopol**

IBSS | Federal Research Center "A.O. Kovalevsky Institute of Biology of the Southern Seas of RAS" | <http://imbr-ras.ru/>, 1128

### **Smolensk**

SSU | Smolensk State University | <http://www.smolgu.ru/>, 1087, 1139

### **Snezhinsk**

VNIITF | Russian Federal Nuclear Centre - All-Russian Scientific Research Institute of Technical Physics | <http://www.vniitf.ru/>, 1083, 1129

### **Sochi**

SRI MP | Federal State Budgetary Scientific Institution "Scientific Research Institute of Medical Primatology" | <http://www.primatologia.ru/>, 1077

### **St. Petersburg**

Botanic garden BIN RAS | Federal State Budgetary Institution of Science "Botanic Garden of the V.L. Komarov Botanic Institute of the Russian Academy of Sciences" | <http://botsad-spb.com/>, 1128

CRISM "Prometey" | Central Research Institute of Structural Materials "Prometey" named after I.V. Gorynin of National Research Center "Kurchatov Institute" | <http://www.cris-m-prometey.ru/en/>, 1142

Electron | Joint Stock Company "National Research Institute "Electron" | <http://www.electron.spb.ru/>, 1083

ETU | Saint Petersburg State Electrotechnical University "LETI" | <http://www.eltech.ru/>, 1137

FIP | V.F. Fock Institute of Physics of the Saint Petersburg State University | <http://www.niif.spbu.ru/>, 1087, 1088, 1100, 1128, 1118

IAI RAS | Institute for Analytical Instrumentation of the Russian Academy of Sciences | <http://iairas.ru/>, 1129

IMC RAS | Federal State Budgetary Institution of Science "Institute of macromolecular Compounds of the Russian Academy of Sciences" | <http://macro.ru/>, 1142

Ioffe Institute | Federal State Budgetary Institution of Science "Ioffe Physic Technical Institute of the Russian Academy of Sciences" | <http://www.ioffe.ru/>, 1137, 1130, 1128, 1142, 1131

ITMO Univ. | National Research University of Information Technologies, Mechanics and Optics | <http://www.ifmo.ru/>, 1137, 1118

KRI | V.G. Khlopin Radium Institute | <http://www.khlopin.ru/>, 1065, 1107, 1130, 1100, 1128

Neva-Magnet | Neva-Magnet S&E, Ltd | <http://www.magnet.spb.su/>, 1065

NIIEFA | D.V. Efremov Scientific Research Institute of Electrophysical Apparatus | <http://www.niiefa.spb.su/>, 1129, 1119

NWRSCC | North-West Regional Scientific and Clinical Center named after L.G. Sokolov Federal Medical and Biological Agency | <https://med122.com/>, 1126

PDMI RAS | Federal State Budgetary Institution of Science "St. Petersburg Department of V.A. Steklov Institute of Mathematics of the Russian Academy of Sciences" | <http://www.pdmi.ras.ru/pdmi/>, 1137, 1138

SPbSPU | Saint Petersburg Polytechnic University Peter the Great | <http://www.spbstu.ru/>, 1135, 1137, 1086, 1065, 1126, 1118

SPbSU | Saint Petersburg State University | <http://spbu.ru/>, 1135, 1136, 1137, 1065, 1066, 1130, 1142, 1118, 1119, 1139

SPMU | Saint Petersburg Mining University | <https://www.spmi.ru/>, 1128

SPSFTU | Saint Petersburg State Forest Technical University | <http://spbftu.ru/>, 1128

### **Sterlitamak**

SB BSU | Sterlitamak branch of the Bashkir State University | <http://strbsu.ru/>, 1142

### **Syktyvkar**

DM Komi SC UrB RAS | Federal State Budgetary Institution of Science "Department of Mathematics Komi Sciences Centre of the Russian Academy of Sciences Ural Branch" | <http://www.komisc.ru/>, 1086, 1065

### **Tomsk**

IHCE SB RAS | Federal State Budgetary Institution of Science “Institute of High Current Electronics of the Siberian Branch of the Russian Academy of Sciences” | <http://www.hcei.tsc.ru/>, 1135

NPI TPU | Nuclear Physics Institute of the National Research Tomsk Polytechnic University | <http://www.npi.tpu.ru/>, 1065, 1100

TPU | National Research Tomsk Polytechnic University | <http://tpu.ru/>, 1138, 1117, 1096, 1083, 1085, 1087, 1107, 1126, 1139

TSPU | Tomsk State Pedagogical University | <http://www.tspu.edu.ru/>, 1138

TSU | National Research Tomsk State University | <http://www.tsu.ru/>, 1135, 1083, 1139

## **Tula**

TSU | Tula State University | <http://tsu.tula.ru/>, 1128, 1142, 1139

## **Tver**

TvSU | Tver State University | <http://tversu.ru/>, 1135

## **Tyumen**

UTMN | University of Tyumen | <https://www.utm.ru/>, 1142

## **Vladikavkaz**

NOSU | North-Ossetian State University named after K.L. Khetagurov | <http://www.nosu.ru/>, 1081, 1065, 1087, 1128, 1118, 1119, 1139

VTC “Baspik” | Vladikavkaz Technological Centre “Baspik” | <http://baspik.all.biz/>, 1087

## **Vladimir**

Vladisart | “Vladisart” | <http://www.vladisart.ru/>, 1131

## **Vladivostok**

FEFU | Far Eastern Federal University | <http://dvfu.ru/>, 1136, 1065, 1139

## **Voronezh**

VSU | Voronezh State University | <http://www.vsu.ru/>, 1137, 1130, 1100, 1128, 1139

## **Yakutsk**

NEFU | North-Eastern Federal University in Yakutsk | <http://www.s-vfu.ru/>, 1139

## **Yaroslavl**

YSU | P.G. Demidov Yaroslavl State University | <https://www.uniyar.ac.ru/>, 1139

## **Yekaterinburg**

IMP UB RAS | Federal State Budgetary Institution of Science “M.N. Mikheev Institute of Metal Physics of Ural Branch of the Russian Academy of Sciences” | <http://www.imp.uran.ru/>, 1137, 1142, 1143

UrFU | Urals Federal University named after the First President of Russia B.N. Yeltsin | <http://urfu.ru/>, 1128, 1142, 1139

## **Yoshkar-Ola**

VSUT | Volga State University of Technology | <http://www.volgatech.net/>, 1135

## **Zhukovsky**

MDB | Joint Stock Company “Myasishchev Design Bureau” | <http://www.emz-m.ru/>, 1083

TECHNOLOGY | LLC “TECHNOLOGY” | <https://geliy24.ru/>, 1065

## **Serbia**

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### **Belgrade**

INS “VINČA” | “Vinca” Institute of Nuclear Sciences | <http://www.vin.bg.ac.rs/>, 1137, 1083, 1129, 1142, 1131, 1077

IPB | Institute of Physics Belgrade of the University of Belgrade | <http://www.phy.bg.ac.rs/>, 1136, 1117, 1128

Univ. | University of Belgrade | <http://www.bg.ac.rs/>, 1135, 1117, 1065, 1128, 1133, 1077

### **Novi Sad**

UNS | University of Novi Sad | <http://www.uns.ac.rs/>, 1128, 1139

## **Slovakia**

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### **Banska Bistrica**

UMB | Matej Bel University | <http://www.umb.sk/>, 1117, 1086, 1119

### **Bratislava**

CU | Comenius University in Bratislava | <http://uniba.sk/>, 1135, 1136, 1137, 1081, 1144, 1099, 1096, 1088, 1107, 1130, 1100, 1128, 1142, 1141, 1077, 1139

IEE SAS | Institute of Electrical Engineering of the Slovak Academy of Sciences | <http://www.elu.sav.sk/>, 1127, 1100, 1128, 1131

IMS SAS | Institute of Measurement Science of the Slovak Academy of Sciences | <http://www.um.sav.sk/>, 1065

IP SAS | Institute of Physics of the Slovak Academy of Sciences | <http://www.fu.sav.sk/>, 1135, 1136, 1081, 1144, 1097, 1087, 1107, 1129, 1130, 1128

PF SK | PROGRESA FINAL SK, s.r.o. | <http://www.progresafinal.sk/>, 1131

SOSMT | Slovak Office of Standards, Metrology and Testing | <http://www.unms.sk/>, 1107

### **Košice**

IEP SAS | Institute of Experimental Physics of the Slovak Academy of Sciences in Košice | <http://www.new.saske.sk/uef/>, 1135, 1137, 1097, 1088, 1142, 1077, 1118, 1119

STM | Slovak Technical Museum | <http://www.stm-ke.sk/>, 1139

TUKE | Technical University of Košice | <http://www.tuke.sk/>, 1088, 1119

UPJŠ | Pavol Jozef Šafárik University in Košice | <http://www.upjs.sk/>, 1137, 1065, 1097, 1087, 1066, 1088, 1133, 1119, 1139

### **Nová Dubnica**

EVPU | Electrotechnical Research and Projecting Company Nová Dubnica, j.s.c. | <http://www.evpu.sk/>, 1129

### **Presov**



PU | University of Prešov | <http://www.unipo.sk/>, 1118

## **Žilina**

UŽ | University of Žilina | <http://www.uniza.sk/>, 1065, 1097, 1119

## **Slovenia**

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### **Ljubljana**

GeoSS | Geological Survey of Slovenia | <http://www.geo-zs.si/>, 1128

UL | University of Ljubljana | <http://www.uni-lj.si/>, 1137

## **South Africa**

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### **Bellville**

UWC | University of the Western Cape | <http://www.uwc.ac.za/>, 1128, 1131

### **Cape Town**

UCT | University of Cape Town | <http://www.uct.ac.za/>, 1117, 1088, 1118, 1119

### **Johannesburg**

UJ | University of Johannesburg | <http://www.uj.ac.za/>, 1065

WITS | University of the Witwatersrand | <http://www.wits.ac.za/>, 1136, 1065, 1088

### **Port Elizabeth**

NMU | Nelson Mandela University | <http://www.mandela.ac.za/>, 1131, 1119

### **Pretoria**

Necsa | South African Nuclear Energy Corporation | <http://www.necsa.co.za/>, 1142

UNISA | University of South Africa | <http://www.unisa.ac.za/>, 1137, 1128

UP | University of Pretoria | <http://up.ac.za/>, 1136, 1142, 1140, 1131

### **Somerset West**

iThemba LABS | iThemba Laboratory for Accelerator Based Sciences | <http://www.tlabs.ac.za/>, 1136, 1065, 1088, 1129, 1130, 1132, 1126, 1139

### **Stellenbosch**

SU | Stellenbosch University | <http://www.sun.ac.za/>, 1136, 1065, 1130, 1128, 1131, 1119, 1139

## **Spain**

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### **Barcelona**

ICMAB-CSIC | Institute of Materials Science of Barcelona-CSIC | <https://icmab.es/>, 1142

IEEC-CSIC | Institute of Space Science of the Higher Research Council | <http://www.ice.csic.es/>, 1138

IFAE | Institute for High Energy Physics | <http://www.ifae.es/>, 1081

UPC | Polytechnic University of Catalonia | <https://www.upc.edu/en/>, 1131

### **Bilbao**

UPV/EHU | University of the Basque Country | <http://www.ehu.eus/>, 1138

### **Huelva**

UHU | University of Huelva | <http://www.uhu.es/>, 1130

### **Leioa**

BCMaterials | Basque Center for Materials, Applications and Nanostructures | <https://www.bcmaterials.net/>, 1142

### **Madrid**

CENIM-CSIC | National Centre for Metallurgical Research of the Higher Research Council | <http://www.cenim.csic.es/>, 1142

CIEMAT | Centre for Energy, Environment and Technological Research | <http://www.ciemat.es/>, 1083

ICMM-CSIC | Materials Science Institute of Madrid of the Higher Research Council | <http://www.icmm.csic.es/>, 1137

UAM | Autonoma University of Madrid | <http://www.uam.es/>, 1117, 1083

### **Oviedo**

UO | University of Oviedo | <http://www.uniovi.es/>, 1083

### **Palma**

UIB | Illes Balears University | <http://www.uib.cat/>, 1136

### **Santander**

IFCA | Institute of Physics of Cantabria of the University of Cantabria | <http://ifca.unican.es/>, 1083

### **Santiago de Compostela**

USC | University of Santiago de Compostela | <http://www.usc.es/>, 1135, 1138

### **Valencia**

IFIC | Institute for Particle Physics of the University of Valencia | <http://ific.uv.es/>, 1138

UPV | Polytechnic University of Valencia | <http://webific.ific.uv.es/>, 1105

UV | University of Valencia | <http://www.uv.es/>, 1135, 1131

### **Valladolid**

UVa | University of Valladolid | <https://universityofvalladolid.uva.es/>, 1138

## **Sri Lanka**

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### **Moratuwa**

University of Moratuwa | <https://uom.lk/>, 1088

## **Sweden**

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### **Goteborg**

Chalmers | Chalmers University of Technology | <http://www.chalmers.se/>, 1136, 1130

### **Lund**

ESS ERIC | European Spallation Source ERIC Lund University | <https://europeanspallationsource.se/>, 1143, 1140

LU | Lund University | <http://www.lu.se/>, 1135, 1136, 1123, 1088, 1130, 1118

### **Stockholm**

SU | Stockholm University | <http://www.su.se/>, 1065

### **Uppsala**

TSL | Svedberg Laboratory of the Uppsala University |  
<http://www.tsl.uu.se/>, 1097

## Switzerland

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### Basel

Uni Basel | University of Basel |  
<http://www.unibas.ch/>, 1126

### Bern

Uni Bern | University of Bern | <http://www.unibe.ch/>,  
1135, 1099

### Geneva

UniGe | University of Geneva | <http://www.unige.ch/>,  
1087

### Villigen

PSI | Paul Scherrer Institute | <http://www.psi.ch/>, 1137,  
1144, 1083, 1097, 1130, 1100, 1128, 1142, 1143

### Zurich

ETH | Swiss Federal Institute of Technology Zurich |  
<http://www.ethz.ch/>, 1137, 1096, 1083, 1119

UZH | University of Zurich | <http://www.uzh.ch/>, 1083

## Taiwan

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### Taipei

AS | Academia Sinica | <http://www.sinica.edu.tw/>,  
1085

ASGCCA | Academia Sinica Grid Computing  
Certification Authority | <http://ca.grid.sinica.edu.tw/>,  
1118

IP AS | Institute of Physics of the Academia Sinica |  
<http://www.phys.sinica.edu.tw/>, 1137

NTU | National Taiwan University |  
<http://www.ntu.edu.tw/>, 1136, 1083

### Taoyuan City

NCU | National Central University |  
<http://www.ncu.edu.tw/>, 1138, 1083

## Tajikistan

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### Dushanbe

NAST | National Academy of Sciences of the Republic  
of Tajikistan | <https://anrt.tj/en/>, 1142

PHTI NAST | S.U. Umarov Physical-Technical  
Institute of the National Academy of Sciences of  
the Republic of Tajikistan | <http://www.phti.tj/>,  
1142, 1119

TTU | Tajik Technical University named after  
academician M.S. Osimi | <http://ttu.tj/en/main-en/>,  
1142

### Khujand

KSU | Khujand State University | <http://www.hgu.tj/>,  
1119

## Thailand

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### Bangkok

KMUTT | King Mongkut's University of Technology  
Thonburi | <https://global.kmutt.ac.th/>, 1088

### Chachoengsao

TMEC | Thai Microelectronics Center |  
<http://tmecl.nectec.or.th/>, 1088

### Hat Yai

PSU | Prince of Songkla University |  
<http://www.psu.ac.th/>, 1128

### Nakhon Ratchasima

SLRI | Synchrotron Light Research Institute |  
<https://www.slri.or.th/en/>, 1088

SUT | Suranaree University of Technology |  
<http://www.sut.ac.th/>, 1088

## Turkey

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### Adana

CU | Çukurova University | <http://www.cu.edu.tr/>,  
1083

### Ankara

METU | Middle East Technical University |  
<http://www.metu.edu.tr/>, 1099, 1083

### Canakkale

ÇOMU | Çanakkale Onsekiz Mart University |  
<http://www.comu.edu.tr/>, 1128

### Istanbul

BU | Boğaziçi University | <http://www.boun.edu.tr/>,  
1117, 1083

Univ. | Istanbul University |  
<http://www.istanbul.edu.tr/>, 1088

YTU | Yildiz Technical University |  
<http://www.yildiz.edu.tr/en/>, 1083, 1088

### Konya

Karatay Univ. | KTO Karatay University |  
<https://www.karatay.edu.tr/>, 1088

### Bolu

Univ. | Bolu Abant İzzet Baysal University |  
<https://www.ibu.edu.tr/>, 1065, 1107

## Ukraine

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### Berdyansk

BSPU | Berdyansk State Pedagogical University |  
<http://bdpu.org/>, 1128

### Dnipro

DNU | Oles Honchar Dnipro National University |  
<http://www.dnu.dp.ua/>, 1135

### Donetsk

DonIPE | Donetsk Institute for Physics and  
Engineering named after A.A. Galkin |  
<http://www.donfti.ru/>, 1128, 1142

DonNU | Donetsk National University |  
<http://donnu.ru/>, 1142

### Kharkov

IERT NASU | Institute of Electrophysics and Radiation  
Technologies of the National Academy of Sciences  
of Ukraine | <http://www.iert.kharkov.ua/>, 1126

ISMA NASU | Institute for Scintillation Materials of  
the National Academy of Sciences of Ukraine |  
<http://www.isma.kharkov.ua/>, 1144, 1065, 1128

KhNU | V.N. Karasin Kharkov National University | <http://www.univer.kharkov.ua/>, 1138, 1083, 1065

LTU | Company "LED, Technologies Ukraine" | <http://ltu.ua/>, 1065

NSC KIPT | National Science Centre - Kharkov Institute of Physics and Technology | <http://www.kipt.kharkov.ua/>, 1135, 1137, 1138, 1083, 1065, 1088, 1107, 1128, 1126, 1118

STC "IMK" NASU | State Scientific Organization "Institute for Single Crystals" of the National Academy of Sciences of Ukraine | <http://www.isc.kharkov.ua/>, 1083

## **Kiev**

BITP NASU | N.N. Bogolyubov Institute for Theoretical Physics of the National Academy of Sciences of Ukraine | <http://bitp.kiev.ua/>, 1135, 1136, 1138, 1117, 1086, 1065, 1088, 1118, 1139

DonIPE NASU | Donetsk Institute for Physics and Engineering named after A.A.Galkin of the National Academy of Sciences of Ukraine | <http://www.donphti.kiev.ua/>, 1142

IMP NASU | G.V. Kurdyumov Institute of Metal Physics of the National Academy of Sciences of Ukraine | <http://www.imp.kiev.ua/>, 1137

KINR NASU | Kiev Institute for Nuclear Research of the National Academy of Sciences of Ukraine | <http://www.kinr.kiev.ua/>, 1136, 1130, 1128

NUK | Taras Shevchenko National University of Kyiv | <http://www.univ.kiev.ua/>, 1136, 1137, 1128, 1142, 1141, 1139

## **Lutsk**

EENU | Lesya Ukrainka Eastern European National University | <http://eenu.edu.ua/>, 1135

## **Lviv**

IAPMM NASU | Pidstryhach Institute for Applied Problems of Mechanics and Mathematics of the National Academy of Sciences of Ukraine | <http://iapmm.lviv.ua/>, 1135

ICMP NASU | Institute for Condensed Matter Physics of the National Academy of Sciences of Ukraine | <http://www.icmp.lviv.ua/>, 1137

IFNU | Ivan Franko National University of Lviv | <http://www.lnu.edu.ua/>, 1135

LPNU | Lviv Polytechnic National University | <http://lp.edu.ua/>, 1143

## **Sumy**

SumSU | Sumy State University | <http://sumdu.edu.ua/>, 1135

## **Uzhhorod**

IEP NASU | Institute of Electron Physics of the National Academy of Sciences of Ukraine | <http://iep.org.ua/>, 1128

## **United Kingdom**

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### **Birmingham**

Univ. | University of Birmingham | <http://www.birmingham.ac.uk/>, 1096, 1088

### **Bristol**

Univ. | University of Bristol | <http://www.bris.ac.uk/>, 1096, 1083

### **Buckingham**

UB | University of Buckingham | <http://www.buckingham.ac.uk/>, 1112

### **Cambridge**

Univ. | University of Cambridge | <http://www.cam.ac.uk/>, 1138, 1117

### **Canterbury**

Univ. | University of Kent | <http://www.kent.ac.uk/>, 1135, 1138

### **Coventry**

Warwick | University of Warwick | <https://warwick.ac.uk/>, 1137

### **Daresbury**

DL | Daresbury Laboratory; Council for the Central Laboratory of the Research Councils | <http://www.cclrc.ac.uk/Activity/DL>, 1088

### **Derby**

Univ. | University of Derby | <https://www.derby.ac.uk/>, 1088

### **Didcot**

RAL | Rutherford Appleton Laboratory; Science and Technology Facilities Council | <http://www.stfc.ac.uk/>, 1144, 1083, 1142, 1143

### **Durham**

Univ. | Durham University | <http://www.dur.ac.uk/>, 1138, 1117

### **Glasgow**

U of G | University of Glasgow | <http://www.gla.ac.uk/>, 1138, 1096, 1097, 1126

### **Guildford**

Univ. | University of Surrey | <http://www.surrey.ac.uk/>, 1136

### **Lancaster**

LU | Lancaster University | <http://www.lancaster.ac.uk/>, 1096

### **Leeds**

UL | University of Leeds | <http://www.leeds.ac.uk/>, 1138

### **Liverpool**

Univ. | University of Liverpool | <http://www.liv.ac.uk/>, 1088

### **London**

Imperial College | Imperial College London | <http://www.imperial.ac.uk/>, 1135, 1138, 1117, 1144, 1083, 1119

QMUL | Queen Mary of the University of London | <http://www.qmul.ac.uk/>, 1135, 1126

UCL | University College London | <http://www.ucl.ac.uk/>, 1100

### **Manchester**

UoM | University of Manchester | <http://www.manchester.edu/>, 1130, 1100

### **Nottingham**

Univ. | University of Nottingham |  
<http://www.nottingham.ac.uk/>, 1138

### **Plymouth**

Univ. | University of Plymouth |  
<http://www.plymouth.ac.uk/>, 1119

### **Southampton**

Univ. | University of Southampton |  
<http://www.soton.ac.uk/>, 1117

### **York**

Univ. | University of York | <http://www.york.ac.uk/>,  
1117, 1126

## **USA**

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### **Amherst, MA**

UMass | University of Massachusetts Amherst |  
<https://www.umass.edu/>, 1138, 1126

### **Arlington, TX**

UTA | University of Texas Arlington |  
<http://www.uta.edu/>, 1118

### **Athens, AL**

ASU | Athens State University |  
<http://www.athens.edu/>, 1112

### **Austin, TX**

UT | University of Texas at Austin |  
<http://www.utexas.edu/>, 1088

### **Baltimore, MD**

JHU | Johns Hopkins University | <http://www.jhu.edu/>,  
1083

### **Batavia, IL**

Fermilab | Fermi National Accelerator Laboratory |  
<http://www.fnal.gov/>, 1144, 1099, 1083, 1065,  
1118

### **Berkeley, CA**

Berkeley Lab | Lawrence Berkeley National  
Laboratory of the University of California |  
<http://www.lbl.gov/>, 1087, 1066, 1088  
UC | University of California |  
<http://www.universityofcalifornia.edu/>, 1088, 1142

### **Bloomington, IN**

IU | Indiana University Bloomington |  
<http://www.iub.edu/>, 1066

### **Boston, MA**

BU | Boston University | <http://www.bu.edu/>, 1096,  
1083

NU | Northeastern University |  
<http://www.northeastern.edu/>, 1083

### **Boulder, CO**

CU | University of Colorado at Boulder |  
<http://www.colorado.edu/>, 1083

### **Buffalo, NY**

UB | University at Buffalo of the State University of  
New York | <http://www.buffalo.edu/>, 1083

### **Cambridge, MA**

Harvard Univ. | Harvard University |  
<http://www.harvard.edu/>, 1099

MIT | Massachusetts Institute of Technology |  
<http://www.mit.edu/>, 1083, 1065, 1119

### **Charlottesville, VA**

UVa | University of Virginia |  
<http://www.virginia.edu/>, 1144, 1083

### **Chicago, IL**

CSU | Chicago State University | <https://www.csu.edu/>,  
1088

UIC | University of Illinois at Chicago |  
<http://www.uic.edu/>, 1083, 1066

### **Cincinnati, OH**

UC | University of Cincinnati | <http://www.uc.edu/>,  
1117

### **College Park, MD**

UMD | University of Maryland | <http://www.umd.edu/>,  
1135, 1138, 1117, 1083

### **College Station, TX**

Texas A&M | Texas A&M University |  
<http://www.tamu.edu/>, 1083, 1129, 1130

### **Columbus, OH**

OSU | Ohio State University | <http://www.osu.edu/>,  
1083, 1088

### **Coral Gables, FL**

UM | University of Miami |  
<http://welcome.miami.edu/>, 1138, 1117

### **Davis, CA**

UCDavis | University of California, Davis |  
<http://ucdavis.edu/>, 1083, 1119

### **Detroit, MI**

WSU | Wayne State University | <http://wayne.edu/>,  
1083, 1088

### **Durham, NC**

Duke | Duke University | <http://www.duke.edu/>, 1128

### **East Lansing, MI**

MSU | Michigan State University |  
<http://www.msu.edu/>, 1135, 1129, 1130

### **Evanston, IL**

NU | Northwestern University |  
<http://www.northwestern.edu/>, 1083

### **Fairfax, VA**

GMU | George Mason University |  
<http://www.gmu.edu/>, 1096

### **Gainesville, FL**

UF | University of Florida | <http://www.ufl.edu/>, 1083

### **Houston, TX**

Rice Univ. | William Marsh Rice University |  
<http://www.rice.edu/>, 1083

UH | University of Houston | <http://www.uh.edu/>, 1088

### **Indianapolis, IN**

IUPUI | Indiana University - Purdue University  
Indianapolis | <http://www.iupui.edu/>, 1099

### **Iowa City, IA**

UIowa | University of Iowa | <http://www.uiowa.edu/>,  
1083, 1087

**Irvine, CA**

UCI | University of California, Irvine |  
<http://www.uci.edu/>, 1137

**Ithaca, NY**

Cornell Univ. | Cornell University |  
<http://www.cornell.edu/>, 1083

**Kent, OH**

KSU | Kent State University | <http://www.kent.edu/>,  
1126

**Knoxville, TN**

UTK | University of Tennessee of Knoxville |  
<http://www.utk.edu/>, 1083, 1088, 1131

**Lansing, MI**

IONETIX | Ionetix Corporation | <http://ionetix.com/>,  
1132

**Lawrence, KS**

KU | University of Kansas | <http://www.ku.edu/>, 1083

**Lemont, IL**

ANL | Argonne National Laboratory | Argonne, IL  
<http://www.anl.gov/>, 1135, 1136, 1081, 1066

**Lexington, KY**

UK | University of Kentucky | <http://www.uky.edu/>,  
1144

**Lincoln, NE**

UNL | University of Nebraska-Lincoln |  
<http://www.unl.edu/>, 1083

**Livermore, CA**

LLNL | Lawrence Livermore National Laboratory |  
<http://www.llnl.gov/>, 1083, 1129, 1130

**Long Beach, CA**

CSULB | California State University, Long Beach |  
<https://www.csulb.edu/>, 1135

**Los Alamos, NM**

LANL | Los Alamos National Laboratory; Meson  
Physics Facility LAMPF | <http://www.lanl.gov/>,  
1136, 1088, 1128

**Los Angeles, CA**

UCLA | University of California, Los Angeles |  
<http://www.ucla.edu/>, 1083, 1126, 1119

**Louisville, KY**

U of L | University of Louisville | <http://louisville.edu/>,  
1137, 1119

**Lubbock, TX**

TTU | Texas Tech University | <http://www.ttu.edu/>,  
1083

**Madison, WI**

UW-Madison | University of Wisconsin-Madison |  
<http://www.wisc.edu/>, 1083

**Manhattan, KS**

KSU | Kansas State University |  
<https://ksiteonline.com/>, 1083

**Menlo Park, CA**

SLAC | SLAC National Accelerator Laboratory is  
Operated by Stanford University |  
<http://www6.slac.stanford.edu/>, 1096

**Merced, CA**

UCMerced | University of California, Merced Madison |  
<http://www.ucmerced.edu/>, 1096

**Minneapolis, MN**

U of M | University of Minnesota | <http://twin-cities.umn.edu/>, 1135, 1117, 1083

**Nashville, TN**

VU | Vanderbilt University |  
<http://www.vanderbilt.edu/>, 1083, 1129, 1130

**New Brunswick, NJ**

RU NB | Rutgers University New Brunswick |  
<https://newbrunswick.rutgers.edu/>, 1083

**New Haven, CT**

Yale Univ. | Yale University | <http://www.yale.edu/>,  
1066, 1088

**New York, NY**

CUNY | City University of New York |  
<http://www2.cuny.edu/>, 1135, 1137, 1138, 1117

RU | Rockefeller University |  
<http://www.rockefeller.edu/>, 1135, 1083

SUNY | State University of New York |  
<http://www.suny.edu/>, 1138, 1117, 1065, 1066

**Newport News, VA**

JLab | Thomas Jefferson National Accelerator Facility;  
Southeastern Universities Research Association  
SURA | <http://www.jlab.org/>, 1135, 1117, 1097

**Norfolk, VA**

NSU | Norfolk State University | <http://www.nsu.edu/>,  
1097

**Norman, OK**

OU | University of Oklahoma | <http://www.ou.edu/>,  
1135, 1138

**Notre Dame, IN**

ND | University of Notre Dame | <http://www.nd.edu/>,  
1136, 1083

**Oak Ridge, TN**

ORNL | Oak Ridge National Laboratory |  
<http://www.ornl.gov/>, 1088, 1129, 1130, 1128

**Omaha, NE**

Creighton Univ. | Creighton University |  
<https://www.creighton.edu/>, 1088

**Oxford, MS**

UM | University of Mississippi |  
<http://www.olemiss.edu/>, 1083

**Pasadena, CA**

Caltech | California Institute of Technology |  
<http://www.caltech.edu/>, 1137, 1083

**Philadelphia, PA**

Penn | University of Pennsylvania |  
<http://www.upenn.edu/>, 1135, 1117

**Piscataway, NJ**

Rutgers | Rutgers University-State University of New Jersey | <http://www.rutgers.edu/>, 1137, 1138, 1117

### **Pittsburgh, PA**

CMU | Carnegie Mellon University  
<http://www.cmu.edu/>, 1083

### **Princeton, NJ**

PU | Princeton University; Joseph Henry Laboratories of Physics | <http://www.princeton.edu/>, 1083

### **Providence, RI**

Brown | Brown University | <https://www.brown.edu/>, 1083

### **Raleigh, NC**

NCCU | North Carolina Central University | <http://www.nccu.edu/>, 1136

### **Riverside, CA**

UCR | University of California, Riverside | <http://www.ucr.edu/>, 1083

### **Rochester, NY**

UR | University of Rochester | <http://www.rochester.edu/>, 1137, 1138, 1117, 1083

### **Salt Lake City, UT**

U of U | University of Utah | <http://www.utah.edu/>, 1117

### **San Diego, CA**

SDSU | San Diego State University | <http://www.sdsu.edu/>, 1135, 1083, 1119

### **San Luis Obispo, CA**

Cal Poly | California Polytechnic State University | California Polytechnic State University | <https://www.calpoly.edu/>, 1088

### **Santa Barbara, CA**

UCSB | University of California, Santa Barbara | <https://www.universityofcalifornia.edu/>, 1083

### **Seattle, WA**

UW | University of Washington | <http://www.washington.edu/>, 1126

### **Stanford, CA**

SU | Stanford University | <http://stanford.edu/>, 1131

### **Tallahassee, FL**

FSU | Florida State University | <http://www.fsu.edu/>, 1137, 1083

### **Tempe, AZ**

ASU | Arizona State University | <http://www.asu.edu/>, 1138

### **Tuscaloosa, AL**

UA | University of Alabama | <http://www.ua.edu/>, 1083

### **University Park, PA**

Penn State | Pennsylvania State University | <http://www.psu.edu/>, 1135, 1136, 1066

### **Upton, NY**

BNL | Brookhaven National Laboratory | <http://www.bnl.gov/>, 1096, 1065, 1097, 1087, 1066, 1118, 1119

### **Urbana, IL**

I | University of Illinois at Urbana-Champaign | <http://illinois.edu/>, 1085

### **Wako, TX**

BU | Baylor University | <http://www.baylor.edu/>, 1083

### **West Lafayette, IN**

Purdue Univ. | Purdue University | <http://www.purdue.edu/>, 1083, 1088

### **Williamsburg, VA**

W&M | College of William & Mary | <http://www.wm.edu/>, 1097

## **Uzbekistan**

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### **Jizzakh**

JSPI | Jizzakh State Pedagogical Institute named after A. Kadri | <http://jspi.uz/>, 1087, 1133

### **Namangan**

NamMTI | Namangan Institute of Engineering and Technology | <http://nammti.uz/>, 1136

### **Samarkand**

SSU | Samarkand State University named after Alisher Navoi | <http://www.samdu.uz/>, 1081, 1087

### **Tashkent**

AS RUz | Academy of Sciences of the Republic of Uzbekistan | <http://www.academy.uz/>, 1127

Assoc.“P.-S.” PTI | Physical Technical Institute Association “Physics-Sun” named after S.A.Azimov of the Academy of Sciences of the Republic of Uzbekistan | <http://www.fti.uz/>, 1136, 1137, 1097, 1087

IAP NUU | Institute of Applied Physics of the National University of Uzbekistan named after Mirzo Ulugbek | <http://nuu.uz/>, 1135, 1136

INP AS RUz | Institute of Nuclear Physics of the Academy of Sciences of the Republic of Uzbekistan | <http://www.inp.uz/>, 1136, 1083, 1097, 1100, 1128, 1142, 1143, 1140

IS AS RUz | Institute of Seismology named after G. A. Mavlyanov of the Academy of Sciences of the Republic of Uzbekistan | <https://www.seismos.uz/>, 1127

NUU | National University of Uzbekistan named after Mirzo Ulugbek | <http://nuu.uz/>, 1135, 1100

## **Vietnam**

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### **Da Nang**

DTU | Duy Tan University | <http://www.daytan.edu.vn/>, 1142

### **Hanoi**

IMS VAST | Institute of Material Science of the Vietnam Academy of Science and Technology | <http://ims.vast.ac.vn/>, 1137

INPC VAST | Institute of Natural Products Chemistry of the Vietnam Academy of Science and Technology | <http://vast.ac.vn/>, 1077

IOP VAST | Institute of Physics of the Vietnam Academy of Science and Technology | <http://www.iop.vast.ac.vn/>, 1135, 1117, 1130, 1128, 1142, 1131, 1139

VINATOM | Vietnam Atomic Energy Institute of the  
Ministry of Science and Technology |  
<https://vinatom.gov.vn/en/>, 1077

VNU | Vietnam National University Hanoi |  
<http://www.vnu.edu.vn/>, 1128, 1119

### **Ho Chi Minh City**

CNT VINATOM | Center for Nuclear Techniques,  
VINATOM | <https://vinatom.gov.vn/en/>, 1126,  
1119

VNUHCM | Vietnam National University, Ho Chi  
Minh City | <https://vnuhcm.edu.vn/>, 1130