06-6-1119-2014

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

Theme leaders: S.V. Shmatov
O. Chuluunbaatar

Deputies: N.N. Voytishin
P.V. Zrelov

Participating countries and international organizations:
Armenia, Belarus, Bulgaria, CERN, China, Egypt, France, Georgia, Italy, Kazakhstan, Mexico, Mongolia, Russia, Serbia, Slovakia, South Africa, United Kingdom, USA, Uzbekistan.

The problem under study and the main purpose of the research:
The theme is aimed at organizing and providing computational, algorithmic and software support for the preparation and implementation of experimental and theoretical research conducted with JINR's participation, at elaborating, developing and using computational methods for modelling complex physical systems studied within the projects of the JINR Topical Plan. Within the theme, mathematical methods and software, including those based on machine and deep learning algorithms using recurrent and convolutional neural networks, will be developed for modelling physical processes and experimental facilities, processing and analysing experimental data in the field of elementary particle physics, nuclear physics, neutrino physics, radiobiology, etc. Particular attention will be paid to the creation of systems for the distributed processing and analysis of experimental data, as well as information and computing platforms to support research conducted at JINR and other research centres.

The main directions of work are mathematical and computational physics to support JINR's large research infrastructure projects, primarily, the NICA flagship project in the fixed target mode (BM@N) and in the collider mode for relativistic heavy ion collisions (MPD) and polarized beams (SPD), the Baikal-GVD neutrino telescope. Cooperation with experiments at the world's accelerator centres (CERN, BNL, etc.), experiments in the field of neutrino physics and astrophysics, radiobiological research programmes will also be continued. The possibility of using the developed methods and algorithms within other projects is being considered. The major direction in modelling complex physical systems, including the states of dense nuclear matter and quantum systems, will be the development of methods, software packages and numerical research based on the solution of the corresponding systems of nonlinear, spatially multidimensional integral, integro-differential or differential equations in partial derivatives with a large number of parameters characterized by the presence of critical modes, bifurcations and phase transitions with the complex application of methods of computational physics, quantum information theory and hybrid quantum-classical programming methods.

Within the theme, it is also planned to develop work on the quantum intelligent control of technological processes and physical facilities at JINR, as well as quantum computing in quantum chemistry and physics.

In addition, the training of specialists in the field of computational physics and information technology within the IT School will be continued.

Projects in the theme:

	Name of the project	Project Leaders	Project code
1.	Mathematical methods, algorithms and software for modeling physical processes and experimental facilities, processing and analyzing experimental data	S.V. Shmatov *Deputies:* A.S. Ayriyan N.N. Voytishin	06-6-1119-1-2024/2026
2.	Methods of computational physics for the study of complex systems	E.V. Zemlyanaya O. Chuluunbaatar *Deputies:* Yu.L. Kalinovsky A. Khvedelidze	06-6-1119-2-2024/2026

Projects:

Name of the project Laboratory (Subdivision)	Project Leaders Responsible from laboratories	Status
1. Mathematical methods, algorithms and software for modeling physical processes and experimental facilities, processing and analyzing experimental data	**S.V. Shmatov** *Deputies:* **A.S. Ayriyan** **N.N. Voytishin**	Realization
MLIT	P.G. Akishin, E.P. Akishina, A.I. Anikina, E.I. Alexandrov, I.N. Alexandrov, D.A. Baranov, T.Zh. Bezhanyan, Yu.A. Butenko, J. Busa, S. Hnatich, P.V. Goncharov, N.V. Greben, H. Grigorian, O.Yu. Derenovskaya, A.V. Didorenko, N.D. Dikusar, V.V. Ivanov, A.A. Kazakov, A.I. Kazimov, Z.K. Khabaev, A.C. Konak, Yu. V. Korsakov, O.L. Kodolova, B.F. Kostenko, M.A. Mineev, Zh.Zh. Musulmanbekov, A.V. Nechaevsky, A.N. Nikitenko, E.G. Nikonov, D.A. Oleynik, G.A. Ososkov, V.V. Palichik, V.V. Papoyan, I.S. Pelevanyuk, A.Sh. Petrosyan, D.V. Podgainy, D.I. Pryahina, I. Satyshev, K.V. Slizhevsky, A.G. Soloviev, T.M. Solovjeva, O.I. Streltsova, Z.K. Tuhliev, Z.A.Sharipov, S.K. Slepnev, A.V. Uzhinsky, V.V. Uzhinsky, A.V. Yakovlev, V.B. Zlokazov, M.I. Zuev	
VBLHEP	V. Yu. Aleksakhin, A.A. Aparin, Yu.V. Bespalov, D.V. Budkovski, A.V. Bychkov, I.R. Gabdrakhmanov, A.S. Galoyan, K.V. Gertsenberger, V.M. Golovatyuk, D.K. Dryablov, M.N. Kapishin, V.Yu. Karzhavin, A.A. Korobitsyn, A.V. Krylov, A.V. Lanev, V.V. Lenivenko, S.P. Lobastov, S.P. Merts, A.A. Moshkin, A.A. Mudrokh, D.N. Nikiforov, M. Patsyuk, O.V. Rogachevsky, V.G. Ryabov, V.V. Shalaev, S.G. Shulga, I.A. Zhizhin, V. Zhezher, A.I. Zinchenko	
BLTP	D.I. Kazakov, M.V. Savina, O.V. Teryaev, V.D. Toneev	
FLNP	M. Balasoiu, M.-O. Dima, M.-T. Dima, A.I. Ivankov, A.H. Islamov, Yu.S. Kovalev, A.I Kuklin, Yu.N. Pepelishev, Yu.L. Ryzhikov, A.V. Rogachev, V.V. Skoy, M.V. Frontasyeva	
DLNP	V.A. Bednyakov, I.A. Belolaptikov, I.V. Borina, A.N. Borodin, V. Dik, I.I. Denisenko, T.V. Elzhov, A.A. Grinyuk, A.V. Guskov, E.V. Khramov, V.A. Krylov, V.S. Kurbatov, D.V. Naumov, A.E. Pan, D. Seitova, A.E. Sirenko, M.N. Sorokovikov, L.G. Tkachev, B.A. Shaibonov, E. Sholtan, A.C. Zhemchugov, D.Yu. Zvezdov	
LRB	I.A. Kolesnikova, Yu.S. Severyukhin, D.M. Utina	
UC	D.V. Kamanin, A.Yu. Verkheev, B.S. Yuldashev	

Brief annotation and scientific rationale:

The project is aimed at organizing and providing computational support for physics research programmes implemented with JINR's participation, at developing mathematical methods and software for modelling physical processes and experimental facilities, processing and analysing experimental data in the field of elementary particle physics, nuclear physics, neutrino physics, condensed matter, radiobiology, etc. The particular attention will be paid to the creation of systems for the distributed processing and analysis of experimental data, as well as information and computing platforms to support research at JINR and other world centers.

The main areas of work are mathematical and computational physics to support JINR's large research infrastructure projects, first of all, the experiments at the NICA accelerator complex and the Baikal-GVD neutrino telescope. Further cooperation with experiments at the largest world accelerator centers (CERN, BNL, etc.), experiments in the field of neutrino physics and astrophysics, radiobiological research programmers will also be continued. The possibility of using the developed methods and algorithms within other megascience projects is being considered.

Expected results upon completion of the project:

1. Revision of interaction generators and their development for modelling the processes of interactions of light and heavy nuclei, including those at NICA energies (FTF, QGSM, DCM-QGSM-SMM, etc.), and processes beyond the Standard Model, such as the production of candidate particles for the role of dark matter, additional Higgs bosons and processes that violate the

lepton number, etc. (QBH, Pythia, MadGraph, etc.) for LHC conditions at a nominal energy and a total integrated luminosity up to 450 fb^{-1}.

2. Development of algorithms for the reconstruction of charged particle tracks for experimental facilities, including those at NICA and the LHC, creation of appropriate software and its application for data processing and analysis, the study of the physical and technical characteristics of detector systems.
3. Development of scalable algorithms and software for processing multi-parameter, multi-dimensional, hierarchical data sets of exabyte volume, including those based on recurrent and convolutional neural networks, for machine and deep learning tasks, designed primarily for solving various problems in particle physics experiments, including for the NICA megaproject and neutrino experiments.
4. Creation and development of data processing and analysis systems and modern research tools for international collaborations (NICA, JINR neutrino programme, experiments at the LHC).
5. Development of algorithms and software for JINR's research projects in the field of neutron physics.
6. Development of algorithms, software and computing platforms for radiobiological research, applied research in the field of proton therapy and ecology.

Expected results of the project in the current year:

1. Revision of FTF and QGSM models and development of software modules for modelling nuclear interactions of charmed hadrons, light hyper-nuclei.
2. Development of the DCM-QGSM-SMM generator: considering the dependence of the lifetime of resonances on the density of the nuclear medium, the suppression of the production cross section of pseudoscalar mesons, and the enhancement of the production of hyperons in a dense nuclear medium, including the deformation of nuclei.
3. Development of software for simulating the events indicated in the previous paragraph, taking into account the performance of the NICA SPD facility.
4. Evaluation of cross sections and modelling of the processes of production of dark matter particles within extended two-doublet Higgs models (MadGraph generator).
5. Debugging the procedure for testing sensitive elements of the high-granularity calorimeter of the CMS experiment, including track reconstruction and the evaluation of the efficiency of each detector cell.
6. Development and adjustment of algorithms and methods for reconstructing muon trajectories in the Cathode-Strip Chambers (CSCs) of the muon system of the CMS experiment for the comparison of the continuous and discrete approaches of wavelet analysis for separating overlapping signals; estimation of the CSC spatial resolution and the aging effect on data obtained in 2024 at the GIF++ facility at CERN and in proton-proton beam collisions at the LHC.
7. Optimization of algorithms for local track reconstruction in the DCH and CSC detectors of the BM@N experiment, their fitting with scintillation detectors for global reconstruction and particle identification, detector alignment and estimation of their operation parameters with experimental data of 2022–2023.
8. Finding and checking correction parameters for the CSC and GEM detectors of the BM@N experiment, development and implementation of software for modelling and data processing methods, as well as their development and adaptation for the current configurations of a number of GEM and Silicon Profilometer tracking detectors in 2023–2024.
9. Study of the effectiveness of the application of machine learning methods based on decision trees for the particle identification task in the MPD experiment.
10. Optimization of the software platform of the MPD experiment: development and implementation in MPDRoot on the basic rules of OOP, unified tests of algorithms and interaction of classes, etc..
11. Development and training of a neural network for searching and restoring tracks in the vertex detector and tracker of the SPD facility, for restoring clusters in the electromagnetic calorimeter and in the SPD muon system.
12. Development of a data processing and storage model: specification of data types and formats, estimation of computational costs for processing at each stage of data transformation, formulation of technical requirements for a real-time data selection system, a distributed data processing and storage system, and offline processing software.

13. Creation of a prototype of a system that provides multi-stage data processing on a real-time event filtering cluster, SPD OnLine Filter.

14. Creation of prototypes of the SPD task management system based on the PanDA package and the data management system based on the RUCIO DDM package.

15. Development of a prototype system for data processing for the Baikal telescope.

16. Development of a test package for the primary processing of small-angle experimental data from the YuMO spectrometer for a multi-detector system with a position-sensitive detector.

17. Development of a C++ library for converting online condition data into JSON, implementation of DCS data conversion to CREST. Modification of Athena package algorithms using COOL for CREST. Development and maintenance of the operation of information systems for the BM@N and MPD experiments to describe the geometry of facilities, configuration of detectors, management process.

18. Study of the background from cosmic protons for the TAIGA observatory, estimation of the number of evaporation neutrons and investigation of their interaction in the OLVE-HERO detector.

19. Analysis of test data from the prototype of a digital calorimeter for proton therapy, development of an algorithm based on a cellular automaton for track recognition and reconstruction.

20. Application of piecewise polynomial approximation based on the high-order basis element method for processing and analysing neutron noise from the IBR-2M reactor.

21. Development of a behavioral analysis module that will automate the analysis of video data obtained during the testing of laboratory animals in various test systems.

22. Application of algorithms for the automatic selection of optimal data augmentation policies, testing of various loss minimization functions, determination of the most effective methods for classifying images with plant diseases.

23. Improving the existing functionality and providing new opportunities for monitoring and predicting the state of the environment. Automation of the monitoring process using simulation.

2.	**Methods of computational physics for the study of complex systems**	**E.V. Zemlyanaya** **O. Chuluunbaatar** *Deputies:* **Yu.L. Kalinovsky** **A. Khvedelidze**	Realization
	MLIT	V. Abgaryan, P.G. Akishin, I.V. Amirkhanov, A.S. Ayriyan, E.A. Ayrjan, D.R. Badreeva, I.V. Barashenkov, M.V. Bashashin, A.A. Bogolubskaya, M. Bures, J. Buša, Jr. J. Buša, Yu.A. Butenko, A.M. Chervyakov, G. Chuluunbaatar, Kh. Chuluunbaatar, D. Goderidze, H. Grigorian, A.A. Gusev, T.V. Karamysheva, V.V. Kornyak, D.S. Kulyabov, K.V. Lukyanov, N.V. Makhaldiani, S.D. Mavlonberdieva, T.I. Mikhailova, A.V. Nechaevsky, E.G. Nikonov, Yu. Palii , G.V. Papoyan, V.V, Papoyan, D.V. Podgainy, R.V. Polyakova, T.P. Puzynina, A.R. Rakhmonova, V.S. Rikhvitsky, I.A. Rogojin , B. Saha, I. Sarkhadov, S.I. Serdyukova, Z.A. Sharipov, O.I. Streltsova, L.A. Syurakshina, O.V. Tarasov, A.G. Torosyan, Z.K. Tukhliev, A.V. Volokhova, O.O. Voskresenskaya, R.M. Yamaleev, D.A. Yanovich, E.P. Yukalova, O.I. Yuldashev, M.B. Yuldasheva, M.I. Zuev	
	BLTP	A.A. Donkov, A.V. Friesen, M. Hnatic, V.K. Lukyanov, R.G. Nazmitdinov, I.R., Rahmonov, Yu.M. Shukrinov, S.I. Vinitsky, V.I. Yukalov, V.Yu. Yushankhai	
	FLNR	E. Batchuluun, A.V. Karpov, M.N. Mirzaev, V.V. Samarin, Yu.M. Sereda	

FLNP	A.N. Bugay, A.V. Chizhov
DLNP	O.V. Karamyshev, G.A. Karamysheva, I.N. Kiyan
LRB	A.N. Bugay, A.V. Chizhov

Brief annotation and scientific rationale:
The project is aimed at the development and application of mathematical and computational methods for modelling complex physical systems studied within the JINR Topical Plan and described by systems of dynamic nonlinear, spatially multidimensional integral, integro-differential or differential equations that depend on the parameters of models. The evolution of solutions to such systems can be characterized by the occurrence of critical modes, bifurcations and phase transitions. Mathematical modelling is an inseparable part of modern scientific research. It entails an adequate mathematical formulation of problems within the models under study, the adaptation of known numerical approaches or elaboration of new ones to effectively take into account the features of the studied physical processes, the development of algorithms and software packages for high-performance simulation on modern computer systems, including the resources of the JINR Multifunctional Information and Computing Complex.

Expected results upon completion of the project:
1. Development of methods, algorithms and software packages for conducting the numerical research of interactions of various types in complex systems of nuclear physics and quantum mechanics.
2. Methods for modelling multifactorial processes in materials and condensed matter under external actions.
3. Methods for solving simulation tasks in the design of experimental facilities and the optimization of their operating modes.
4. Methods for modelling complex processes in dense nuclear matter based on the equation of state.

   Methods for modelling quantum systems using quantum information theory methods and hybrid quantum-classical programming methods.

Expected results of the project in the current year:
1. Development of a mathematical formulation of the problem within the strong coupling channels method with the Woods–Saxon optical potential and regular boundary conditions for modelling sub-barrier heavy ion fusion and fission reactions.
2. Development of methods and calculation of the energy of adsorption on the Au layer of heavy and superheavy atoms.
3. Development and optimization of the method of self-similar approximations for solving nonlinear equations that do not contain small parameters and describe quantum mechanical systems, including spin ensembles and cold atoms in traps.
4. Development of a method and a programme that initiates, within the transport-statistical approach, the initial state of colliding nuclei with nuclear potentials, which are used for further calculations in collision dynamics.
5. Modelling of proton-nucleus interactions, based on a microscopic model of the optical potential, over a wide range of energies and for a large variety of atomic numbers of target nuclei with the aim at assessing the influence of the nuclear medium on the processes of proton scattering by intranuclear nucleons.
6. Investigation of the dynamics of a shock wave in an irradiated material based on a model described by the combination of molecular dynamic equations, thermal conductivity equations and wave equations. Determination of the parameters of the wave equation based on the results of the numerical solution of molecular dynamics equations.
7. Simulation of the interaction of amyloid beta and antimicrobial peptides with phospholipid membranes in vesicular and bicellar structures in the coarse-grained model; study of the dynamic properties of this interaction based on the calculation of the phonon spectra of systems; construction of the free energy profile of the process of pulling the peptide out of the membrane depending on the distance between the centers of mass and the conformation of the peptide (replica exchange umbrella sampling).
8. Study of localized structures in systems described by nonlinear damped-driven equations. Investigation of the formation of a hydrated electron based on a modified polaron model that takes into account the Coulomb interaction, calculation of the observed characteristics of this process.
9. Adaptation of the COMSOL Multiphysics® package to the HybriLIT heterogeneous platform in order to enhance the efficiency of computations and reduce the computational time through the use of a mixed vector-scalar formulation of magnetostatics and a hybrid finite and boundary element method. Development and software implementation of difference

schemes for solving a boundary value problem for a 4th order equation describing the distribution of physical fields in 2D and 3D regions of various configurations.

10. Development of methods and study of the formation of magnetic fields of isochronous cyclotrons under various operating modes. Preparation of instructions and registration of the CORD (Closed ORbit Dynamics) programme in the JINRLIB library. CORD implements calculations to study the effect of betatron oscillations and the phase motion of beam particles on the magnetic field of the MSC230 cyclotron.

11. Adaptation of the neural network approach to the approximate calculation of multiple integrals arising in the study of pion survival in heavy ion collisions; elaboration of methods aimed at extending to finite temperatures the previously developed model of the quark-hadron phase transition in cold nuclear matter.

12. Modelling and calculation of cosmological redshift values based on the equation of state; investigation of the possibility of reconstructing the mass spectrum of an isolated neutron star from the data on the age and surface temperature of pulsars, based on simulations of their temperature evolution; simulation of the processes of scattering and production of particles in dense and hot nuclear matter.

13. Development of an evolution operator trotterization algorithm for von Neumann and Lindblad equations and implementation of the corresponding quantum circuit on a quantum simulator in the QISKit environment. Improving the performance of the quantum circuit simulator by increasing the simulation speed using multiprocessing.

14. Creation of a package of modules designed to decompose a quantum system into subsystems based on the use of the tensor products of representations of wreath products of finite cyclic groups.

15. Determination of the relationship between the characteristics of the entanglement of composite quantum systems and the negativity of Wigner quasiprobability distributions. Development of a functional reduction method for two-loop Feynman integrals and its application to the calculation of integrals corresponding to diagrams with four and five external lines.

Activities:

	Name of the activity:	Leaders	Implementation period
	Laboratory (Subdivision)	Responsible from laboratories	
1.	**Intelligent control of technological processes and physical equipment's in JINR and quantum computing in quantum chemistry and physics**	**P.V. Zrelov** **S.V. Ulyanov**	2024-2026
	MLIT	D.A. Baranov, O.V. Ivantsova, M.S. Katulin, E.A. Kuznetsov, A.G. Reshetnikov, A.R. Ryabov, N.V. Ryabov, L.A. Syurakshina, D.P. Zrelova	
	VBLHEP	Yu.G. Bespalov, O.I. Brovko, D.N. Nikiforov, G.P. Reshetnikov	
	BLTP	V.Yu. Yushankhai	

Brief annotation and scientific rationale:

The main addressed issues of the activity are the development and effective application of intelligent computing technologies and the quantum self-organization of inaccurate knowledge in robust control tasks in order to enhance the reliability of the functioning of physical facilities. The solution of the tasks is based on the possibility of increasing the robustness of existing control systems through embedded knowledge bases. Self-organized control systems are designed and supported by software tools developed in the project on the basis of a platform that combines soft computing and quantum knowledge base optimizers. Embedded self-organized controllers will be developed for systems of the intelligent control of JINR's technological processes, devices and facilities (including for cases of unforeseen and unpredictable situations) and intelligent cognitive robotics tasks.

The investigation of the effectiveness of quantum algorithms is aimed at solving the tasks of quantum chemistry and physics of new functional materials. The application of well-known quantum algorithms and their development will be carried out on simulators of classical computing architecture. It is planned to create a software product for calculating the electronic and magnetic structures of molecular complexes and crystal fragments of new functional materials using quantum simulators on classical computing architectures.

Expected results upon completion of the activity:
1. Creation of a prototype of a quantum fuzzy PID controller and of a demonstration robot with a built-in controller prototype.
2. Creation of a prototype of an intelligent control system for cryogenic systems of superconducting magnets of the NICA accelerator complex on the basis of the quantum fuzzy PID controller. Preparing a patent.
3. Methodology of building and structure of an intelligent control system for a high-frequency station.
4. Verification of the effectiveness of quantum algorithms of variational type implemented on quantum simulators of classical architecture by applying them to the quantitative description of the dissociation of simple molecules, as well as the electronic and spin structure of the ground state of typical lattice models of quantum theory.

Expected results of the activity in the current year:
– creation of a prototype of a quantum fuzzy PID controller;

– creation of the structure of and development of a quantum fuzzy inference algorithm for a prototype of an intelligent control system for cryogenic systems of superconducting magnets of the NICA accelerator complex on the basis of the quantum fuzzy PID controller.

2.	**Training of specialists in the field of computational physics and information technology**	**V.V. Korenkov** **A.V. Nechaevsky** **D.I. Pryahina** **O.I. Streltsova**	2024-2026
	MLIT	T.Zh. Bezhanyan, O.Yu. Derenovskaya, E.Mazhitova, I.S. Pelevanyuk, A.S. Vorontsov, E.N. Voytishina, M.I. Zuev	
	UC	D.V. Kamanin, A.Yu. Verkheev	

Brief annotation and scientific rationale:
The training and retraining of specialists in computational physics and information technology on the basis of the Multifunctional Information and Computing Complex (MICC) of the Joint Institute for Nuclear Research (JINR) and its educational components are performed for:
– upskilling JINR staff members in order to develop scientific projects, including megascience ones, which are implemented at JINR or with its participation, as well as to create and support the JINR Digital EcoSystem (DES);

– disseminating competencies in computational physics and information technology to the regions of Russia and the JINR Member States to enhance the personnel potential of JINR and organizations cooperating with the Institute.

The main prerequisite for the creation of the activity is the necessity to form a research environment in order to ensure the professional growth of IT specialists, the creation and development of scientific groups, and the engagement of new specialists in JINR projects. The additional training of the personnel, mainly on request of the JINR Laboratories, should be aimed at developing special competencies, in-depth knowledge and practical skills in computational physics and information technology.

Expected results upon completion of the activity:
1. Holding events for JINR staff members to study state-of-the-art information technologies and opportunities to work on the MICC components and in the DES.
2. Forming a set of JINR projects in which students can participate.
3. Forming a list of competencies and required courses for the implementation of projects.
4. Elaboration of training courses and educational programmes that will provide personnel training for solving a variety of tasks within projects.
5. Creation of an ecosystem for the implementation of educational programmes on the basis of the JINR MICC, including the cloud infrastructure, the HybriLIT heterogeneous computing platform, which comprises the education and testing polygon and the “Govorun” supercomputer.
6. Creation of a software and information environment and a platform for organizing and holding events, lectures, workshops, hackathons, etc.
7. Involvement of specialists from JINR and JINR Information Centres, researchers from the JINR Member States’ organizations, lecturers from leading educational organizations that cooperate with JINR in order to hold educational and scientific events.
8. Forming event programmes and organizing interaction with universities and JINR Information Centres.

Expected results of the activity in the current year:

1. Holding events for JINR staff members (seminars for users of the JINR MICC and the DES).
2. Creation of an ecosystem component for the implementation of educational programmes.
3. Conducting JINR Schools of Information Technologies.
4. Conducting training practices for students of the Russian Federation and the JINR Member States.
5. Elaboration of training courses on information technology.

Collaboration

Country or International Organization	**City**	**Institute or laboratory**
Armenia	Yerevan	Foundation ANSL
		YSU
Belarus	Gomel	GSU
	Minsk	IM NASB
		IP NASB
		INP BSU
Bulgaria	Sofia	SU
CERN	Geneva	CERN
China	Beijing	CIAE
Egypt	Cairo	ASRT
	Giza	CU
France	Saclay	IRFU
Georgia	Tbilisi	GTU
		TSU
		UG
Italy	Genoa	INFN
Kazakhstan	Almaty	IETP KazNU
		INP
	Astana	ENU
Mexico	Mexico City	UNAM
Mongolia	Ulaanbaatar	IMDT MAS
		MUST
Russia	Arkhangelsk	NArFU
	Dubna	Dubna State Univ.
	Gatchina	NRC KI PNPI
	Irkutsk	ISU
	Moscow	ITEP
		LPI RAS
		MSU
		NNRU “MEPhI”
		PFUR
		RCC MSU
		RSTSREC
		SINP MSU
	Moscow, Troitsk	INR RAS
	Petropavlovsk-Kamchatsky	KSU
	Protvino	IHEP
	Puschino	IMPB RAS
	Samara	SSU
	Saratov	SSU
	Saint Petersburg	SPbSU
	Tomsk	TPU
	Tula	TSU
	Tver	TvSU
	Vladikavkaz	NOSU
	Vladivostok	FEFU

	Voronezh	VSU
Serbia	Belgrade	Univ.
Slovakia	Kosice	UPJS
South Africa	Cape Town	UCT
United Kingdom	Oxford	Univ.
USA	Arlington, TX	UTA
Uzbekistan	Tashkent	AS RUz