SUPPORTING ACTIVITIES

I. THEORETICAL PHYSICS

Expert community at JINR has accumulated comprehensive knowledge and extensive experience of theoretical research in quantum field theory and elementary particle physics, theory of atomic nuclei, condensed matter physics and methods of mathematical physics. Enhanced coordination of research in theoretical physics and experimental programs is one of the main priorities of the JINR scientific policy.

Quantum field theory and particle physics

In the forthcoming years, the milestones in theoretical research in the field of particle physics at JINR will be determined by the physics programmes of major international projects (LHC, RHIC, FAIR, K2K, etc) as well as by "home" experimental programmes, the NICA/MPD project at JINR first of all. In this context, the central topics of theoretical investigations will be precision tests of the Standard Model, new physics beyond the Standard Model, heavy-quark physics, flavour and CP-violation, hadron structure and polarization phenomena, strongly interacting matter under extreme conditions and new states of hadron matter, neutrino physics, astroparticle physics and the dark matter problem. Development of a variety of theoretical methods and models is indispensable to the research programme in particle physics. Further elaboration of the renormalization group approach and related methods such as functional RG, multiloop calculations in perturbation theory (QCD, Electroweak theory, Minimal Supersymmetric Standard Model), lattice simulations in gauge theories, QCD sum rules, parton distribution functions, chiral perturbation theory, models of confinement and QCD vacuum, hadronization models, thermodynamics of hot and dense strongly interacting matter, high-dimension theories and string theory methods will be particularly significant for theoretical studies in elementary particle physics.

Superstring theory and quantum gravity

Superstring Theory is the most serious and worldwide pursued candidate for the unification of all fundamental interactions including Quantum Gravity. The investigation of Superstring Theory requires the use of the most advanced methods of modern mathematical physics and development of new mathematical techniques. Moreover, the knowledge of these methods becomes a peculiar know-how in theoretical investigations in astroparticle physics, Quantum Gravity, cosmological models and black hole physics. An exhaustive study of Superstring Theory in different regimes requires search for classical and quantum superstring solutions, detailed investigation of the landscape of superstring vacua, application of modern mathematical methods to the fundamental problems of supersymmetric gauge theories, development of microscopic description of black hole physics, elaboration of cosmological models of the early Universe. Further development of the theory of classical and quantum integrable systems, quantum groups and supergroups, non-commutative geometry will play a crucial role in these integrated investigations.

Nuclear theory

The mainstream of nuclear studies over the world during the last decade has been the properties of nuclei far from the valley of stability. Experiments with rare-isotope beams are especially critical. However, the investigations are still in their infancy and are limited by no access to the rarest isotopes and the beam intensities available today. No doubt these studies will prevail in the long-time perspective as well.

That is the reason why microscopic models with a growing predictive power should be developed in the framework of nuclear theory. A variety of models based on realistic effective interactions or realistic nuclear density functional will be explored. Special attention will be paid to the analysis of excitation spectra of very heavy nuclei since they provide unique information on higher-lying nuclear shells, the very shells governing the stability of superheavy nuclei. The description of nuclear reaction rates provides new insight into astrophysics. Properties of unstable nuclei as well as their behavior under stellar media conditions will be extensively investigated. They are needed as nuclear physics input to simulation of the dynamics of the core collapse supernovae and calculation of elemental abundance.

Nuclear reaction models exploring modern microscopic approaches in the nuclear structure theory will be developed. In particular, the novel four-body approach to the analysis of reactions with the halo nuclei should be mentioned. These theoretical advances will enable a study of new forms of collectivity, such as modes involving oscillations of weakly bound neutrons against the core and coupling to the continuum of scattering states. The rigorous mathematical methods in few-body theory will be developed and applied to study fundamental properties of exotic nuclear, atomic and molecular few-body quantum systems.

In the context of the NICA/MPD project, the mixed quark-hadron phase formation will be studied within the relativistic mean field approach accounting for finite size effects and change of hadron properties in hot and dense medium. The non-nucleonic degrees of freedom in nuclei will be explored by systematic consideration of interactions between leptons and very light nuclei at relativistic energies. Analysis of these interactions will be based on the Bethe-Salpeter approach to the relativistic bound state problem.

Condensed matter and statistical physics

Successful development of technology and applied solid-state physics related to nanosize electronic devices is impossible without detailed investigation of the fundamental aspects of nanoscale phenomena. One of the stream lines in condensed matter research at JINR will include theoretical studies of electronic, thermal, and transport characteristics of various nanomaterials and nanostructures, elaboration of a variety of models for description of the spin-polarized electrons and magnetic nanostructures, influence of the shape, topology, chirality, size, structure, arrangement on the properties of nanoscale systems, carbon nanostructures in particular. Another important line of theoretical research will be focused on thermodynamic, transport, and spectroscopic properties of new complex materials exhibiting strong electronic and magnetic correlations.

Theoretical studies of chaos, integrability, and self-organization will be focused on investigation of strongly non-equilibrium phenomena and non-linear problems. The goal is to develop mathematical approaches for adequate description of avalanche dynamics, signal propagation in unstable and non-linear media, and non-equilibrium processes which are described by continuous and discrete models.

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

Systematic training of young scientists, PhD students and graduates is of vital importance for the future development of JINR. The Bogoliubov Laboratory of Theoretical Physics has successfully incorporated into its structure the continuously running educational project “Dubna International Advanced School of Theoretical Physics”. In the forthcoming years DIAS-TH will proceed to play a particularly important role in the educational system of JINR in close cooperation with the JINR University Centre.

The main goal of DIAS-TH is to organize and coordinate educational programmes for students, postgraduates and young scientists mainly in theoretical physics. Looking for and supporting gifted young theorists in the JINR Member States is one of the basic objectives of the project. Activities of DIAS-TH will include regular (3-4 per year) organization of schools in Dubna devoted to the most important directions of research in theoretical physics, running a variety of lecture courses and seminars for PhD students and young scientists from the JINR Member States and other countries, support of the JINR experimental programmes by organizing lecture courses and review lectures on new trends in modern physics and publication of lectures courses. The unique feature of DIAS-TH is its coherent integration into the current scientific life of BLTP which ensures regular and natural participation of the leading scientists in the education and training activities.

II. NETWORKS, COMPUTING, COMPUTATIONAL PHYSICS

Development of the networking, information and computing infrastructure

- Upgrade of the Dubna – Moscow link up to 40 Gbps in 2010 and 100 Gbps in 2015;
- Participation of JINR in the programme for the development of a new-generation research network;
- Participation in the effort to create the international segment within the projects GEANT2 and GLORIAD and to increase the bandwidth of the international channels;
- Transition to 10 GB Ethernet technology in the JINR local network to provide high-quality service for various data types including multimedia and real-time systems;
- Provision of wireless and mobile access to all services and resources;
- Implementation of modern approaches for control, management and protection of the network;
- Increase of the performance of the JINR Central Information and Computing Complex (JINR CICC) and of the data storage systems to meet the demands of data processing for LHC experiments and other experiments with JINR's participation; development and maintenance of middleware;
- Development of the program environment for information, algorithmic and software support of the research underway at JINR and Member State institutes on the basis of the JINR CICC;
- Development of distributed and parallel computing technologies;
- Development of the JINR Grid segment as part of the global Grid infrastructure with a full functioning set of services. Development of the technologies of "gridification" of software for application within the Grid environment.

Mathematical methods, algorithms and programs

- Development of mathematical methods for simulation and data processing;
- Increase of the efficiency of application software for solving problems of computational physics with the use of paralleling by MPI package and development of new tools allowing an effective use of multi-core PCs;
- Numerical algorithms and software for simulation of complex physical systems;
- Further development of methods, algorithms and software of computer algebra;
- Elaboration of methods and interfaces for processing enormous amount of distributed data;

- Elaboration of the middleware providing effective high-performance computations for addressing scientific problems in particle physics, relativistic nuclear physics, nuclear physics, and condensed matter physics.

III. EDUCATION

The development of JINR is based on the continuous influx of talented young scientists from the JINR Member States. The maintenance and development of the JINR Educational Programme as a whole is a responsibility of the JINR University Centre (UC). The key function of the UC is to coordinate training of graduate and undergraduate students coming from many institutes and universities of the Russian Federation and other Member States. Starting from 1998 JINR obtained a license and opened a post-graduate programme in 10 specialities.

As a result of the last two decades, a solid basis has been laid to bring the Educational Programme to a high level. The following objectives of its development for the next years appear to be justified:

1. A drastic increase of graduate and postgraduate students from JINR Member States who prepare Master and PhD thesis at JINR. Although at the present moment these students are coming from Russia, there is a strong interest in education opportunities at JINR from East European Member States (Poland, Czech Republic) and Associate Members (South Africa). The necessary conditions to achieve this goal require to:

a) create (in collaboration with JINR-based university departments) several educational modules (nuclear physics module, theoretical physics module, etc.). These modules have to be taught in English;

b) provide a special stipend for students coming to JINR; the stipend has to be larger than that offered at universities in the Member States;

c) obtain in the Member States the accreditations of the UC educational modules.

2. The UC educational infrastructure should be permanently upgraded, and creation of the modern student laboratories has to be completed in the next 2-3 years.

3. It is very important that the University Centre also offers programmes for scholars from Member States. These activities will be efficient if they involve school teachers. Taking into account a similar experience at CERN, a lecture programme for Member State school teachers has to be created at the UC.