Theoretical Physics

The studies conducted at BLTP are interdisciplinary; they are directly integrated into international projects with the participation of scientists from major research centres in the world and are closely coordinated with the JINR experimental programmes. Intensive development of the research is planned in nuclear and particle astrophysics, Higgs boson phenomenology, hadron physics under extreme conditions (in connection with the experimental programme of the NICA/MPD project, and experiments at RHIC, LHC and FAIR), lattice QCD calculations. Studies in condensed matter physics will be more tightly correlated with practical problems in the field of nanotechnology for creation of new materials and electronic devices.

Quantum field theory and particle physics

Theoretical research in the field of particle physics will be emphasized on the support of physics programmes of major international collaborations with JINR's participation (LHC, RHIC, FAIR, etc.) and of those at the JINR basic facilities, primarily, of the NICA/MPD project. Major attention will be paid to the phenomenology of the Standard Model including studies of the Higgs boson, searches for new physics beyond the Standard Model, neutrino physics, hadron structure and spin physics, phase transitions in hot and dense hadronic matter, heavy flavor physics and hadron spectroscopy, the dark matter problem, and astrophysical aspects of elementary particle physics.

Nuclear theory

The first-priority direction in the area of low-energy nuclear physics will be studies of exotic and superheavy nuclei which is the goal of the experimental projects DRIBs III and the Factory of superheavy elements at JINR and all others megaprojects in Europe, the United States, China, and Japan. This demands that the corresponding theoretical studies be developed. Microscopic selfconsistent nuclear models owing to include, in the theoretical schemes, the anharmonic and fragmentation effects beyond the mean field approximation will be elaborated there. The models will be applied to analyse quantitatively the processes of nuclear fusion and fission and to predict the rates of various nuclear reactions for astrophysical purposes. Nuclear reactions in stellar environment will be studied with the rigorous methods of the few-body theory as well. More attention will be given to cluster effects in the properties of exotic heavy nuclei and the mechanisms of transfer of nucleons, clusters and disintegration of a nucleus in the field of the other one. The mathematically rigorous and effective methods of the few-body theory will be developed and applied in studies of various quantum few-body systems, e.g. collisions of ultracold atoms and molecules in confined geometry of laser traps. Investigations of high-energy collisions of heavy ions will be performed in close connections with the NICA/MPD project aimed at revealing the most informative observables for experimentalists. In the framework of the advanced models the color degrees of freedom will be considered directly and the effect of the medium-modified quark-hadron interaction on the dilepton production will be investigated.

Theory of condensed matter

Theoretical research will be focused on the analysis of systems with strong electronic correlations such as transition metal compounds, high-temperature superconductors, colossal magneto-resistance compounds (manganites), heavy-fermion systems, low-dimensional quantum magnets with strong spin-orbit interaction, topological insulators, etc. The electronic band structure, spectral properties of charge carrier quasiparticles, magnetic and charge collective excitations, metalinsulator and magnetic phase transitions, Cu- and Fe-based high-T_c superconductivity, charge and spin-orbital ordering will be studied. Research in this field will be aimed at supporting the experimental studies of these materials conducted at the Frank Laboratory of Neutron Physics. Investigations in the field of nanostructures and nanoscaled phenomena will be addressed to a study of physical characteristics of nanomaterials promising for various applications in modern nanotechnologies. The problem of quantum transport in carbon-based and molecular devices as well as the resonance tunneling phenomena in various heterostructures and the layered superconductors will be investigated. Models in condensed matter physics will be studied by using methods of equilibrium and non-equilibrium statistical mechanics with the aim of revealing general properties of many-particle systems based on the ideas of self-similarity and universality.

Modern mathematical physics

Superstring theory, the most serious and worldwide pursued candidate for the unification of all fundamental interactions including quantum gravity, will be the central topic in mathematical physics studies at BLTP. A wide range of precise classical and quantum superstring solutions, 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, the models of particles and superparticles, as well as new versions of the supersymmetric quantum mechanics, including models based on semi-simple super groups will be studied. To apply and develop new ideas generated with the string theory, it is crucial to use mathematical methods of the theory of integrated systems, quantum groups and non-commutative geometry, superfield methods, including the method of harmonic superspaces.

Research and education project DIAS-TH

The general objective of the continuously running BLTP project “Dubna International School of Theoretical Physics (DIAS-TH)” will be the promotion of scientific and educational programmes at JINR. The unique feature of DIAS-TH is its coherent integration into the scientific life of BLTP, which will ensure regular and natural participation of the leading scientists in education and training activities. Cooperation of DIAS-TH with international and Russian foundations (UNESCO, DAAD, DFG, RFBR, etc.) and state organizations (BMBF, INFN, CNRS) is very important for the successful implementation of this project.