Report on the "Theory of complex systems and advanced materials"
Proposal

The Bogoliubov Laboratory of Theoretical Physics in Dubna has a rich history of important research in Condensed matter theory and Statistical physics. The Proposal"Theory of complex systems and advanced materials" is well-founded in this background. This is a large-scale research project covering a variety of hot topics in modern physics. The Proposal consists of four sub-projects: "Complex materials", "Mathematical models of statistical physics of complex systems", "Nanostructures and Nanomaterials", and "Methods of quantum field theory in complex systems".

Two of them "Complex materials" and "Nanostructures and nanomaterials" deal with many problems of condensed matter theory scattered mainly around the investigations of new advanced materials with special emphasis on their structural and physical properties including their potential technological applications. The first of the two includes studies of different complex materials and systems such as atomically thin semiconductors, colossal magneto-resistance compounds, heavy-fermion systems, low-dimensional quantum magnets with strong spin-orbit interaction, and topological insulators as well as smart composite materials, fractal and layered structures, and biological macromolecules. The second one concentrates on the nanostructures and nanomaterials such as graphene, transition metal dichalcogenides, including their possible modifications and chemical functionalizations. Another important part of this work includes the studies of topological superconductivity in strongly correlated electronic systems and of stacks of Josephson junctions as well as other various Josephson nanostructures.

The other two subprojects "Mathematical Models of statistical physics of complex systems" and "Methods of quantum field theory in complex systems" are aimed at studies of a more fundamental nature and at mathematical issues of statistical physics, and adjacent areas of mathematical physics, quantum mechanics and quantum field theories. The subproject "Mathematical models of statistical physics of complex systems" deals with the exact non-perturbative solutions of systems with many degrees of freedom making use of methods available for the theory of integrable systems and with the development of promising mathematical tools for this theory such as the theory of special functions and representation theory. The other sub-project "Methods of quantum field theory in complex systems" studies the statistical characteristics of fluctuating fields in the

models of both equilibrium and non-equilibrium statistical physics and stochastic dynamics with renormalization group methods. Its goal is the identification of phase transitions and the calculation of associated universal critical exponents and non-universal amplitudes in systems at criticality.

I should note that the studies planned in the first two subprojects also have a great potential for applications in the development of new microelectronic devices, systems of information storage and transmission, and on nanoelectronics, spintronics, etc. At the same time, in the other two projects, cutting-edge studies are supposed to advance the fundamental understanding of mathematical mechanisms governing the large stochastic systems in statistical physics and quantum field theory.

This balance between applied and fundamental research makes this Proposal exceptional and unique. It is very important that the large part of the research is planned to be conducted in close cooperation with experimentalists from other JINR laboratories: the Frank Laboratory of Neutron Physics, the Flerov Laboratory of Nuclear Reactions, and the Dzhelepov Laboratory of Nuclear Problems. The computational facilities of the Meshcheryakov Laboratory of Information Technology as well as its human resources will also be involved in the project. In addition, wide cooperation with laboratories from other parts of Russia as well as from member states is also planned. The worldwide geography of scientific groups, which are outlined and directly involved in this project, reflects the international reputation of the Bogoliubov laboratory as a famous research center in condensed matter theory and statistical physics. The high qualification of its staff which consists of world-known experts in the fields under investigation within this project makes me confident that the aims of this Proposal will be achieved without a doubt.

It is important to mention that a high fraction of young researchers is directly involved in the making of the scientific research and this makes the project important for future further BLTP perspectives.

To conclude, in view of this, I strongly recommend the opening of the new Theme “Theory of complex systems and advanced materials” within the topical plan of JINR.

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