Review report on the Project

"Methods of computational physics for the study of complex systems"

within the JINR theme “Methods, algorithms and software for modeling physical systems, mathematical processing and analysis of experimental data”

The project under consideration is devoted to the creation and exploration of mathematical models of complex systems in the field of nuclear physics, quantum mechanics, and biology. The main goal is the development of new numerical methods for solving nonlinear, spatially multidimentional, and multiparameter systems of integro-differential, differential, and algebraic equations. These methods, as it is planned, should be adapted to the possible existence of bifurcations and the critical behavior of solutions. Together with traditional finite difference and iterative methods, the authors of the project also plan to develop neural network algorithms, grid methods and parallel computations, Bayesian methods for estimating the free parameters of simulated processes, and methods of computer algebra.

In the project, numerical methods are the basis for practical work on mathematical modeling of concrete physical and biological systems, and dynamical evolution of these systems. The main directions of mathematical modeling are describe in five sections. They include, first, mathematical models of nuclear physics concerning mainly boundary eigenvalue problems for multidimentional systems of Schrodinger-type equations. Second, there presented mathematical models of the physics of condensed matter being under external influences and having phase transitions, bifurcations, and/or critical regime; they are relate to the interaction of high-energy charge particles with matter. superconducting processes and Josephson junctions in spin nanosructures, and the polaron physics. The third section is dealing with modeling and optimizing the work of experimental facilities for particle accelerations. In the forth section the mathematical models of the equation of state for dense nuclear matter are described. These models combine the traditional iterative and finite difference grid methods for solving nonlinear differential and integral equations with neural network algorithms. The fifth section is devoted to mathematical models of quantum information science. This is a very topical part of modern researches in the field of computational quantum systems, the theory of computational complexity, and quantum technologies.

Thus, it can be seen that the project covers a significant variety of topics, united by the same set of numerical methods and similar approaches to the construction of mathematical models. I think that announced goals of the project are quite adequate, correspond to the present level of investigations, and can be implemented.

There is a remark on the large number of tasks planned for three years. Are the authors of the project sure that the announced (relatively large) research group will be able to complete these tasks in these terms, even if there are no possible problems pointed out in Section "Risks"? Note that this remark relates only to the amount of work on the project, but not to its high scientific quality.

Note also that the project is made up in accordance with the Seven-Year Plan for the Development of JINR 2024 – 2030 and the Topical Plan of Laboratory of Information Technologies. The scientific experience and qualification of the participants of the project are quite sufficient to solve (in the full volume or in the main part) the stated tasks and thus to achieve the announced goals. I believe that the implementation of this project will be an important step in the development of applied mathematical models of complex systems in physics and biology.

So, I recommend supporting the project.

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