Review report on the proposal of 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 "Methods of computational physics for the study of complex systems" initially opened in 2024 for three years, aims to develop methods for mathematical modeling of complex physical systems requiring numerical solution of multi-parameter systems of dynamic nonlinear, multidimensional equations characterized by a complexity of solutions, bifurcations, and phase transitions.

The project started in 2024 and the results achieved in 2024-2025 look quite decimal and serve a solid base for the further research and successful implementation of all objectives of the project which is proposed to be extended for next five years.

The research tasks of the project are closely related to the JINR research program and they are grouped into five subject areas, each of which has its own characteristics in terms of mathematical formulations of problems and applied methods of numerical research:

1. Investigation of complex systems in nuclear physics, atomic and molecular physics, and quantum mechanics that are described by Schrödinger-type equations and require high accuracy of numerical solutions.
2. The study of complex processes under external influences in materials and condensed media based on the combined application of molecular dynamics, dynamics of continuous media and nonlinear wave equations.
3. The problems of calculating physical fields and optimizing the operating modes of experimental setups under the condition of complex multidimensional geometry.
4. Studies of dense nuclear matter based on various versions of the equation of state that require correct consideration of such factors as the gravity, the live time of the phenomena, the influence of temperature effects, etc.
5. Investigation of quantum systems of various types based on hybrid methods of quantum informatics, computer algebra, and computational mathematics.

All the tasks in the project are extremely relevant, the research is aimed at obtaining results that are of scientific significance not only in the academic sense, but also in terms of possible practical applications in high technologies.

The mathematical modeling is an integral part of modern scientific research and requires high level qualification for:

- adequate mathematical formulation of problems within the framework of the studied models;
- development of new approaches based on the combined use of various methods to effectively take into account the features of the studied physical processes;

- development of algorithms and software packages based on modern programming technologies, including for high-performance massive calculations in a wide range of parameters of simulated systems.

The results of 2004-2005 confirmed that the project participants have the necessary knowledges and high scientific level. The leaders and many of participants of the project are known for their work in the field of developing modeling methods and conducting research on complex physical systems and processes. This gives grounds to count on the success of the project.

I believe that the project is important from the viewpoint of IT support for theoretical and experimental research at JINR in context of the development and the use of mathematical modeling methods. The project looks necessary for the successful implementation of the JINR scientific program and the extension of the project for period 2027-2031 deserves unconditional support with a high priority.

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