Referee report on the project

Study of neutrino properties in accelerator experiments

Neutrinos of three types are the upper weak isospin components of the Standard Model lepton doublets. Neutrinos have zero electric charges and are also characterized by small nonzero differences in the masses of neutrinos of different generations. The latter as well as ability to mix allow neutrinos to oscillate. This quantum mechanical effect implies that the flavor content of a neutrino flux evolves as it propagates at a rate that depends on neutrino mass-squared splittings and the mixing matrix elements, as well as energy and the propagated distance. Neutrino oscillations cannot be explained within the Standard Model, which, like a number of other phenomena such as the existence of dark matter, makes their study extremely interesting. It is worth to state that neutrino physics is far beyond the neutrino oscillations. It includes studying other neutrino properties as a particle (the absolute neutrino mass measurement, interaction and production cross-section studies etc) and search for new beyond Standard Model properties (electric charge, sterile neutrinos, neutrinoless double beta decay, etc).

The project under review is aimed to study the neutrino properties with accelerator beams. Accelerator experiments have a lot of advantages in studying the fundamental properties of the Standard Model. This is a good instrument for different areas of neutrino physics as well. The project comprises accelerator neutrino experiments: NOvA, T2K, DsTau and FASER, which the JINR physicists have already contributed to at different levels.

In particular, the JINR group has been participating in the NOvA experiment since 2014, with a wide range of contributions that include experimental methods, computing, Data Driven Trigger (DDT) and Data Acquisition (DAQ) software, three-flavor oscillation analysis, and other physics analyses and searches. Additionally, a NOvA Remote Operation Center (ROC) for data-taking control was built in Dubna as well as data storage and CPU cluster for data analysis. JINR scientists are involved in the management of NOvA occupying various positions such as exotic physics group convener, three-flavor oscillation analysis group convener, ROC-liaison, and DAQ, DDT, production, ROC experts. Group members were also involved in the full-fledged joint oscillation analysis of the NOvA and T2K experiments.

The JINR physicists has been participating in the T2K experiment since 2020 with a primary contribution to the near detector upgrade, the axion-like particles’ searches and systematic uncertainty evaluation based on data-quality checks for each data-taking period.

In the DsTau and FASER experiments, which are running at CERN SPS and LHC, respectively, the JINR group contributes with an expertise of using nuclear emulsion techniques and developing new software for effective very high track density data analysis. The JINR representatives are also involved in the management of the DsTau collaboration (CB Chair) as well as having the data simulation and mass processing responsibilities.

The general idea of the project, which is presented for the review, is to preserve present involvement of the JINR groups in these experiments but enhance JINR intellectual contribution using the complementary experience of the participating groups in NOvA, T2K, DsTau and FASER.

NOvA and T2K, solving the problem of measuring unknown oscillation parameters, have a similar setup. The presence at JINR of experts in the elements of analysis can play a synergetic role. An example of the already demonstrated synergy between those experiments is the joint NOvA/T2K analysis presented in 2024. The JINR employees have already participated in this analysis on the NOvA side, and it would be very productive for the next implementations to have (without violating the rules of experiments) colleagues from JINR on the T2K side as well.

One of the important systematics in this type of experiment is neutrino-nucleon cross-sections, for which NOvA and T2K implement a different approach and use different Monte Carlo generators and their settings. In this situation, it seems reasonable to conduct mutual checks in each of the experiments and use these cross checks for better understanding of systematic uncertainties. The JINR project participants have the necessary experience to perform such work, both at the level of theoretical calculations and their implementation in Monte Carlo generators.

The synergy between the DsTau and FASER experiments is quite obvious, since both experiments are aimed at studying various aspects of the production and interaction of tau neutrinos using the nuclear photo emulsion technique.

It should also be noted that all four experiments analyze data in order to search for exotic objects and non-standard interactions. Discussion of theoretical and methodological approaches (e.g., application of machine learning algorithms) can synergistically serve to better understand the details of this work.

I would like to point out that the list of authors of the project includes many young researchers without academic degrees, although the contribution of JINR to the experiments is quite noticeable. My recommendation for the future is to focus on defending dissertations by these people.

In general, the project is well balanced in human resources with a good fraction of young scientists and experienced colleagues. Financial request looks reasonable.

I recommend approving this project for the requested period of 3 years with the first priority.

Eduard Boos,
Member of PAC,
Professor