Referee report on the project: T2K-II

Based in Japan international experiments related to neutrino physics are well known and make the basis for modern particle physics. Huge results were achieved by Kamioka based experiments in different fields. Starting from proton decay search, the really breakthrough achievements were made in the neutrino sector. Together with study of ambient neutrinos, huge progress was recently achieved in the Kamioka neutrino detectors with neutrino beams send from KEK (K2K) and J-PARC synchrotron accelerator in Tokai (T2K). One of most intriguing recent results of T2K is a hint of a significant matter-antimatter asymmetry in neutrino oscillations published in Nature. These data throws more support behind the theory that namely neutrinos are the reason the Universe is dominated by matter. Now the T2K collaboration is working to reduce existing uncertainties and gather more data by upgrading the detectors and beamlines. The experiment roadmap includes the new Hyper-Kamiokande detector to replace the Super-Kamiokande. At once started in the middle of the coming decade it will address the biggest unsolved questions in physics through a multi-decade physics program. Together with DUNE, the Hyper-K is related to so-called "next generation of neutrino experiments", construction both of themes has just started. T2K, T2K-II, Hyper-Kamiokande are widely considered by scientific community between those worldwide efforts that will fundament progress of the particle physics in next 20 years. Investigations will be focused on making new discoveries in particle physics by examining some of the basic particles that we have known about for a long time – namely neutrinos and muons and by searching for previously-unseen fundamental particles (indirect search for Dark matter, dark photons, monopoles, etc) and additional astrophysical program (supernova detection, etc).

For the team of the project from the Laboratory of Nuclear Problem the first goal of the Project in JINR is to build a very unique active target Super Fine Granularity Detector (SuperFGD) consisting of about 2 million scintillation cubes pierced by scintillation fibers in three mutually perpendicular directions. This target is needed for the upgrade of the magnetized ND280 near detector of T2K. Due to its fine-grained geometry surrounded by TOF detectors and two High Angle Time Projection Chambers (HA-TPCs), the SuperFGD has a unique capability to reconstruct short tracks and to detect fast-neutrons, which is required for the reconstruction of (anti)neutrino energy as well as for improved reconstruction efficiency for outgoing charged particles produced at large angles (almost perpendicular and backward) with respect to the incoming (ani)neutrino direction. This would also allow lowering the momentum threshold for pions and knocked-out nucleons produced in (anti)neutrino interactions. It has to be noted with pleasure that the presented written project demonstrated successful start of the works in JINR. Further goals include the JINR group participation in the new generation Hyper-Kamiokande project which will continue the T2K-II experiment and will use the same set of near detectors. It is expected that the JINR group will be involved in the scientific program at all levels, from hardware to analysis.

From the previous review of the project in 2020 the JINR group successfully demonstrated its ability to work in frame of the large project in both directions: accomplishing building of the hardware for which the group is responsible for and what is probably even more important: search for own scientific tasks and new ideas. As an excellent example of such a task is the search for light dark matter dark photon that JINR group is started.

In my opinion it’s crucially and strategically highly important for JINR to participate in the leading experiments in the neutrino sector. In JINR this physics was traditionally addressed in different researchers conducted in or with significant contribution from Laboratory of Nuclear Problems. Therefore it is important to continue our involvements in these traditional activities of the laboratory on the highest possible level. Members of the presented project have high scientific and methodological groundwork in the field. Qualification of involved scientist, their previous results, successful first years of the project at JINR assure that the proposed JINR project will be successfully accomplished with highest visibility level inside of the collaboration and for external world.

Considering that the proposed project T2K-II is part for investigation of the most interesting modern physics, I strongly support the project and its approval at JINR with highest priority.

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