Referee report on the project

JINR participation in the Japanese neutrino program: from T2K to Hyper-Kamiokande

«T2K experiment»

(JINR Participation)

Neutrino physics is an extremely rich area of research, closely related to particle and nuclear physics, astrophysics (including cosmic ray physics and gamma-ray astronomy), cosmology, and even geophysics. In all these fields, neutrinos can act either as a subject of study or as a research tool; in both cases, the neutrino physics provides a very rich source of motivation for researches in a very wide range of energies – from hundreds of keV (neutrinos from β-decay or electron capture) up to a few EeV (neutrino-induced showers detected by radio, acoustic or fluorescence techniques). Neutrino flavor transitions, being themselves very interesting as demonstration of fundamental quantum behavior unparalleled in classical physics, are also one of a few phenomena that clearly require a theory beyond the standard model of electroweak interactions. Neutrinos have the potential to help us in understanding the mysterious dark sector of the Universe (which includes dark matter, energy, and radiation). And for sure neutrinos in the near future will help us study the interior of the Earth.

The atomic nucleus is a primary laboratory, as it can signal the existence of extremely rare decays from which information about neutrino properties can be extracted. In addition, the search for leptonic dark matter is closely related to the rare nuclear processes, as it will be the case if the seasonal modulation of signals in underground detectors is confirmed to be related to cold dark matter. Thus, we deal here with a cornerstone in the neutrino studies, those will eventually open a window to a deeper understanding of the structure of the Universe, as it can be deduced from the consequences of a direct detection of the exotic processes. On the other hand, the Universe is an ultimate tool for expanding knowledge on neutrino properties – both by testing cosmological models and by detecting high-energy processes involving neutrinos (e.g., γ-ν flares from blazars).

Another potential line of research is the complementarity that exists between low- and high-energy phenomena involving neutrinos. One can thus investigate possible connections between the high-energy observables extracted from LHC data (like the ATLAS and CMS data on heavy neutrinos) and low-energy processes (like neutrinoless double beta decay) in order to eventually set-up limits on the standard-model extensions near the Fermi scale (like the left-right symmetric models).

Traditionally, neutrino physics is the main direction of the DLNP scientific program. The neutrino remains the most mysterious particle of the Standard Model, and the study of its properties is a top priority worldwide. Among the main topics in the neutrino physics at the moment are to clarify the issue of CP violation in the leptonic sector of the standard model (including determination of the value of the CP phase δ_{CP}), defining the hierarchy of the neutrino mass spectrum, and refining other parameters of the PMNS mixing matrix (θ_{ij}).

The major physics goals of T2K-II experiment are measurements of the neutrino oscillation parameters θ_{23} and Δm^2_{32} with a precision of 1.7° and 1%, respectively, as well as a confirmation at the level of 3σ (or better) of the matter-antimatter asymmetry in the neutrino sector in the currently wide allowed range of the phase δ_{CP} values – the parameter responsible for the CP (matter-antimatter) asymmetry. Achievement of these goals requires reduction of the statistical and systematic errors, and thus a significant upgrade of the beamline and of the T2K's ND280 detector, as well as improvements in the respective software and analysis methods.

The T2K near detector complex consisting of the INGRID on-axis detector that directly measures the neutrino beam profile and the ND280 off-axis detector that measures neutrino interactions, has already contributed a lot in understanding the neutrino interactions with nuclei. Undoubtedly, the new goals of the T2K collaboration are quite realistic.

Having great experience in detectors, electronics, data processing, and design engineering, JINR group was invited to participate in the first-class neutrino experiment T2K. The JINR group has been accepted by the T2K collaboration as a new member and has joined the international team, whose scope will be the realization of the novel scintillator detector, the SuperFGD, selected as the main neutrino target for an upgrade of the ND280 detector. The SuperFGD detector design will allow nearly 4π coverage for neutrino interactions at the near detector and will provide lower energy thresholds, significantly reducing systematic errors for the experiment.

Among the contributions of the JINR group, one can highlight refinement of the parameters in the neutrino beam modeling, developing and debagging new electronic hardware for the SuperFGD calibration system, participation in the analysis of the data collected by the detector ND280 and T2K-II, development of an assembly algorithm, platform, and equipment for assembling a unique SuperFGD target.

The JINR T2K team is well balanced, including senior and junior scientists, and has a reasonable FTE = 14.

Let me also note that participation in the Project under consideration will contribute to the establishment and strengthening of international scientific cooperation between JINR and Japan scientific society represented by the High Energy Accelerator Research Organization (KEK).

Summarizing, through this Project JINR has unique possibility to participate in the one of the most advanced neutrino experiments in World, providing significant contribution to the ND280 upgrade and T2K (HK). I strongly recommend supporting the Project for the period 2022-2024, as a matter of top priority.

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