Referee report on the theme: "Study of Neutrino Oscillations"
02-2-1099-2010/2023

The phenomenon of neutrino oscillations, predicted by Bruno Pontecorvo 65 years ago, is now undoubtly confirmed by experiments. It has proven that at least two neutrino masses are non-zero and that the Standard model has to be extended. The search for new physics, which is exploited by modern experiments using different techniques, is, therefore, very promising, making the study of the neutrino oscillation phenomenon very competitive.

Some of the base neutrino oscillation parameters have already been measured with a good precision. At the same time, others that are quite intriguing such as the neutrino Mass Ordering (MO), CP-violating phase (δCP), and mixing angle θ_{23}, are not very well known. Two large-scale projects, JUNO and NOvA/DUNE, have set goals to measure these parameters using complementary approaches.

The JUNO experiment, now finishing construction, will use the neutrino flux from a nuclear reactor complex in China at a distance of 53 km, while NOvA and DUNE are using the neutrino beam produced by the NuMI complex at Fermilab and detecting it at 810 (1300) km. The reactor approach is relatively clean, providing the neutrino mass ordering measurement from the interference of atmospheric and solar oscillation regimes, while the accelerator one uses the oscillation matter effect, which depends on δCP and mixing angle θ_{23}.

A strategy for obtaining results on the mass ordering prior of δCP and mixing angle θ_{23} determination looks very clear and most promising. The JINR group has contributed significantly to the detector construction and physics analysis preparation of the JUNO experiment. JUNO is planning to start data taking in 2024 and achieve the nominal goal of MO determination at the level of ~3-4σ in six years. As is well known, the JUNO scientific program includes a wide range of other "first priority goals" for the modern physics, such as searches for physics beyond the Standard Model, proton decay, detection and study Super nova neutrinos, detection of geo-, atmospheric, and solar neutrinos.

The NOvA experiment is already taking data for several years and is approved to run through 2026, which will approximately double the present statistics. An expectation is that the final NOvA result on MO will stand between 2 and 4σ, depending on the values of other parameters. The physics of NOvA will be continued by the new international mega-science project DUNE, and the JINR group's experience in NOvA can be fully exploited there.

As a detector construction contribution, the JINR DLNP group was already deeply involved in the DUNE near detector liquid argon calorimeter being fully responsible for its light collection system. In addition, the presently discussed extension of the theme and the NOvA/DUNE project also include new contribution proposed by the JINR group from VBLHEP, consisting of a straw-tube tracker for the on-axis spectrometer of the DUNE near detector. Given the JINR's excellent experience in this detector technology, this proposal looks very reasonable. At the

same time, since this technology is also planned for some other projects at JINR an overall effect can be very synergetic but requires good coordination of efforts.

The physics potential of the DUNE experiment is very large, that is why continuing our study of neutrinos in DLNP without participating in this project would be definitely incomplete. For example, due to much larger baseline and excellent resolution of liquid argon far detectors, the 5σ MO measurement can be achieved just in the first two years of running. The leptonic CP-measurement will be more difficult, and its actual sensitivity significantly depends on the values of the other parameters. Therefore, most probably, a combined result of DUNE and HyperK will become a breakthrough.

Apart from the JUNO and NOvA/DUNE projects, the theme "Study of Neutrino Oscillation" also contains smaller activities, such as the analysis of Borexino, Dark Side, and NA65/FASER(ν) experiments. These activities use existing methodical and physics expertise of the group and promise to obtain new results.

In summary, the theme "Study of Neutrino Oscillations" 02-2-1099-2010/2023 is in an excellent shape, utilizing modern and complementary approaches to measure fundamental parameters in the leptonic sector. JINR's contributions to this theme include detector construction and physics analysis, which are well-justified and make JINR's participation in experiments important and visible. The size and qualifications of the participating individuals, as well as the requested resources, are suitable for the theme's objectives. It is particularly remarkable that this research attracts many young people, as evident from the composition of the research group. Therefore, I strongly recommend approving the extension of this theme with highest priority for the requested period.

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