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Physics prospects with the second oscillation maximum at Deep Underground Neutrino Experiment

Current long-baseline neutrino-oscillation experiments such as NOνA and T2K are mainly sensitive to physics in the neighbourhood of the first oscillation maximum of the $\nu_\mu \rightarrow \nu_e$ oscillation probability. The future Deep Underground Neutrino Experiment (DUNE) utilizes a wide-band beam tune optimized for CP violation sensitivity that fully covers the region of the first maxima and part of the second. In the present study, we elucidate the role of second oscillation maximum in addressing issues pertaining to unknowns in the standard three flavour paradigm. We consider a new DUNE beam tune optimized for coverage of the region of the second oscillation maxima which could be realized using proposed accelerator upgrades that provide multi-MW of power at proton energies of 8 GeV. We find that addition of the multi-MW 8 GeV beam to DUNE wide-band running leads to modest improvement in sensitivity to CP violation, mass hierarchy, the octant of θ_{23} as well as the resolution of δ and the Jarlskog invariant. Significant improvements to the DUNE neutrino energy resolution yield a much larger improvement in performance. We conclude that the standard DUNE wide-band beam when coupled with excellent detector resolution capabilities is sufficient to resolve δ to better than $\sim 12^\circ$ for all values of δ in a decade of running. For second maxima (8 GeV 3MW) beam running concurrently with the standard wide-band (80 GeV 2.2 MW) beam for 5 of the 10 years, it is found that δ can be further resolved better than $\sim 10^\circ$ for all values of δ.

Primary authors: ROUT, Jogesh (JAWAHARLAL NEHRU UNIVERSITY); Ms SHAFAQ, Sheeba (JNU); BISHAI, Mary (Brookhaven National Laboratory); MEHTA, Poonam (Jawaharlal Nehru University)

Presenter: Ms SHAFAQ, Sheeba (JNU)

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