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Exploring Matter Effect and Associated Degeneracies at DUNE

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Matter effect plays a pivotal role in the upcoming Deep Underground Neutrino Experiment (DUNE) to address pressing fundamental issues such as leptonic CP violation, neutrino mass hierarchy, and precision measurements of the oscillation parameters in the precision era. In this paper, for the first time, we explore in detail the capability of DUNE to establish the matter oscillation as a function of $\delta_{\rm CP}$ and θ_{23} by excluding the vacuum oscillation. With the optimized neutrino beam design and using an exposure of 300 kt·MW·years, DUNE can confirm the presence of Earth's matter effect at 2σ C.L. irrespective of the choices of hierarchy, $\delta_{\rm CP}$, and θ_{23}. Moreover, DUNE can rule out the vacuum oscillation at 3σ (5σ) significance with a $\delta_{\rm CP}$ coverage of 64% (46%) for normal hierarchy and maximal θ_{23}, whereas for inverted hierarchy, the $\delta_{\rm CP}$ coverage is 82% (43%). The relative 1σ precision in the measurement of line-averaged constant Earth matter density (ρavg) for maximal CP-violating choices of $\delta_{\rm CP}$ is around 10% to 15% depending on the choice of neutrino mass hierarchy. The same for CP-conserving values of $\delta_{\rm CP}$ is around 25% to 30%. We find that if $\delta_{\rm CP}$ turns out to be around -90° or 90°, the precision in measuring ρ_{avg} in DUNE is better than that one can achieve using the atmospheric data from Super-Kamiokande, combined data from Solar and KamLand, and from the full exposure of T2K and NOνA. We also identify new degeneracies in (ρ_{avg}-$\delta_{\rm CP}$) and (ρ_{avg}-$\sin^2\theta_{23}$) planes and notice that the uncertainty in $\delta_{\rm CP}$ affects the measurement of ρ_{avg} more than that of θ_{23}. A detailed understanding of these degeneracies are essential to correctly assess the outcome of DUNE.

Working group

WG1

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