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Role of high energy beam tunes in optimizing the sensitivity to current unknowns at DUNE

NF Topical Groups:

■ (NF1) Neutrino oscillations; ■ (NF3) Beyond the Standard Model ; ■ (NF5) Neutrino properties

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Abstract:
Even though neutrino oscillations have been conclusively established, there are a few unanswered questions pertaining to leptonic Charge Parity violation (CPV), mass hierarchy (MH) and θ_{23} octant degeneracy. Addressing these questions is of paramount importance at the current and future neutrino experiments including the Deep Underground Neutrino Experiment (DUNE) which has a baseline of 1300 km. In the standard mode, DUNE is expected to run with a *low energy* (LE) tuned beam which peaks around the first oscillation maximum ($2-3$ GeV) (and then sharply falls off as we go to higher energies). However, the wide band nature of the beam available at long baseline neutrino facility (LBNF) allows for the flexibility in utilizing beam tunes that are well-suited at higher energies as well. In this work, we utilize a beam that provides high statistics at higher energies which is referred to as the *medium energy* (ME) beam. This opens up the possibility of exploring not only the usual oscillation channels but also the $\nu_\mu \to \nu_\tau$ oscillation channel which was otherwise not accessible. Our goal is to find an optimal combination of beam tune and runtime (with the total runtime held fixed) distributed in neutrino and antineutrino mode that leads to an improvement in the sensitivities of these parameters at DUNE. In our analysis, we incorporate all the three channels ($\nu_\mu \to \nu_e, \nu_\mu \to \nu_\mu, \nu_\mu \to \nu_\tau$) and develop an understanding of their relative contributions in sensitivities

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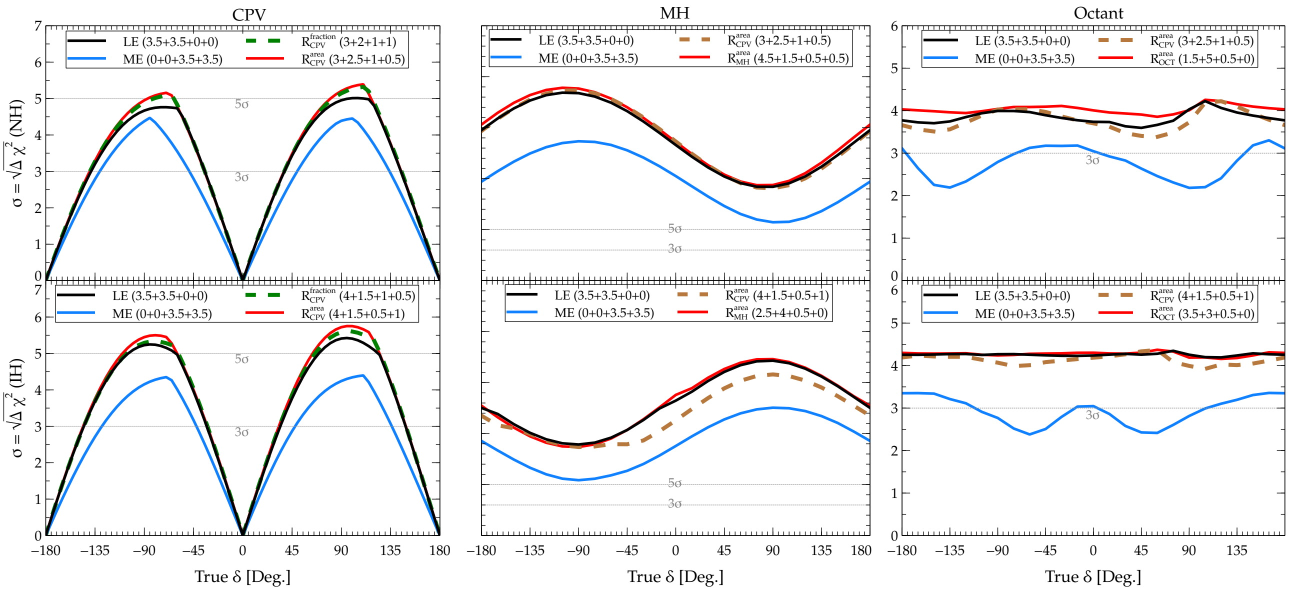

Figure 1: The senstivity to CPV, MH and θ_{23} octant for the different combinations of runtime and beam tunes is shown in the figure.

at the level of $\Delta\chi^2$. Finally, we obtain the preferred combination of runtime using both the beam tunes as well as neutrino and antineutrino mode that lead to enhanced sensitivity to the current unknowns in neutrino oscillation physics *i.e.*, CPV, MH and θ_{23} octant.

We keep the total runtime at DUNE fixed at 7 years and numerically calculate $\Delta\chi^2$ as a function of true $\delta \in [-\pi, \pi]$ after varying the distribution of runtime among the following four variables :

- Runtime using LE beam and in neutrino mode ($\mathcal{R}_{\rm LE}$)
- Runtime using LE beam and in anti-neutrino mode ($\overline{\mathcal{R}}_{\rm LE}$)
- Runtime using ME beam and in neutrino mode ($\mathcal{R}_{\rm ME}$)
- Runtime using ME beam and in anti-neutrino mode ($\overline{\mathcal{R}}_{\rm ME}$).

We present our main results by estimating the optimized runtime combinations of $(\mathcal{R}_{\rm LE}, \overline{\mathcal{R}}_{\rm LE}, \mathcal{R}_{\rm ME}, \overline{\mathcal{R}}_{\rm ME})$ that give the best sensitivities to resolve CPV, MH and octant of θ_{23}. Fig. 1 summarizes our results for the optimal combinations of runtimes and which are reported as $(\mathcal{R}_{\rm LE} + \overline{\mathcal{R}}_{\rm LE} + \mathcal{R}_{\rm ME} + \overline{\mathcal{R}}_{\rm ME})$ for the three different questions addressed in the present work. For more details, please see [1].

References

[1] J. Rout, S. Roy, M. Masud, M. Bishai and P. Mehta, "Impact of high energy beam tunes on the sensitivities to the standard unknowns at DUNE," [arXiv:2009.05061 [hep-ph]].