Implications of NSI Effects in Long-Baseline Neutrino Experiments

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Introduction

- Accelerator-based neutrino experiments offer exciting avenues to study neutrino physics.
- Neutrino gets influenced by a matter potential known as the Wolfenstein matter effect.
- Wolfenstein in addition to the neutrino mass matrix, introduced non-standard interaction (NSI) to investigate new physics.
- In this work, we will assume that new physics arises only from the NSI and is responsible for any deviation from SM physics.
- Here, we explore the outcome of the dual NSI effect in the future LBL experiments, DUNE and T2HK through parameter degeneracies, oscillation probability, and sensitivity to the CP violating parameter δ_{CP} plots.

Formalism

- The NSI can be characterised by six-dimensional four-fermion (ff) operators of the form:

$$\mathcal{L}_{NSI} = 2\sqrt{2}G_F \epsilon_{\alpha\beta}^{fC}[\overline{\nu_\alpha}\gamma^\rho P_L \nu_\beta][\overline{f}\gamma_\rho P_C f] + h.c. \quad (1)$$

. • Here, we scanned dual NSI parameter $\epsilon_{e\mu}$ and $\epsilon_{e\tau}$ simultaneously, to examine the conversion probability of $\nu_\mu \to \nu_e$ for the LBL studies which can be stated as the sum of three (plus higher order; cubic and beyond) terms in the presence of NSI:

$$P_{\mu e} = P_{SM} + P_{\epsilon_{e\mu}} + P_{\epsilon_{e\tau}} + P_{Int} + h.o., \quad (2)$$

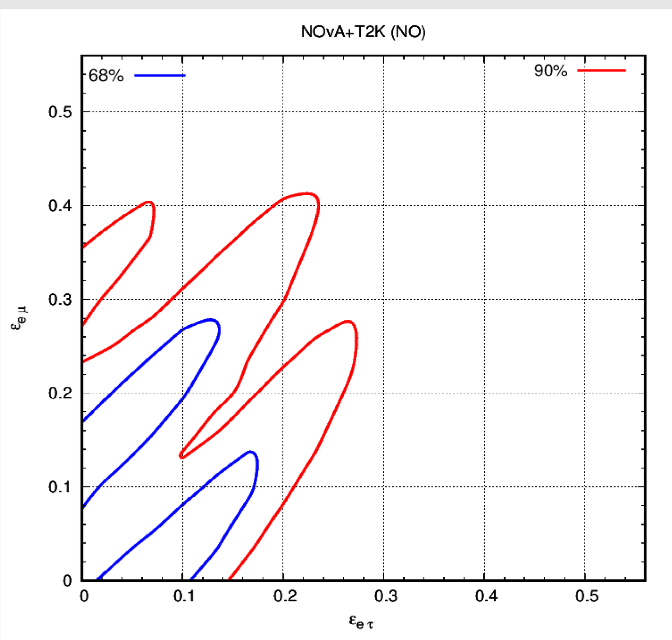
Analysis Details

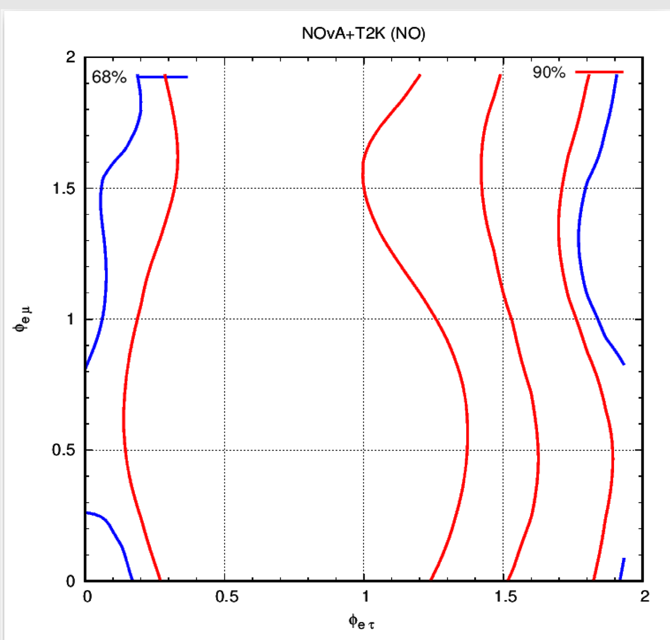
In our analysis, we used the software GLoBES and its additional public tool to implement NSI.

- The best-fit values of the standard model parameters are taken from nuFIT v5.1 and PDG.
- We used the AEDL files available for simulating experiments like NOνA, T2K, T2HK, and DUNE.
- Next, we utilized GLoBES to combine the datasets of T2K and NOvA.

Obtained NSI Contraints

Allowed regions in the plane spanned by NSI coupling for $\epsilon_{e\mu}$ and $\epsilon_{e\tau}$ (left); $\phi_{e\mu}$ and phase $\phi_{e\tau}$(right) determined by the combination of T2K and NOvA for NO. The contours are drawn at the 68% and 90% C.L. for 2 d.o.f





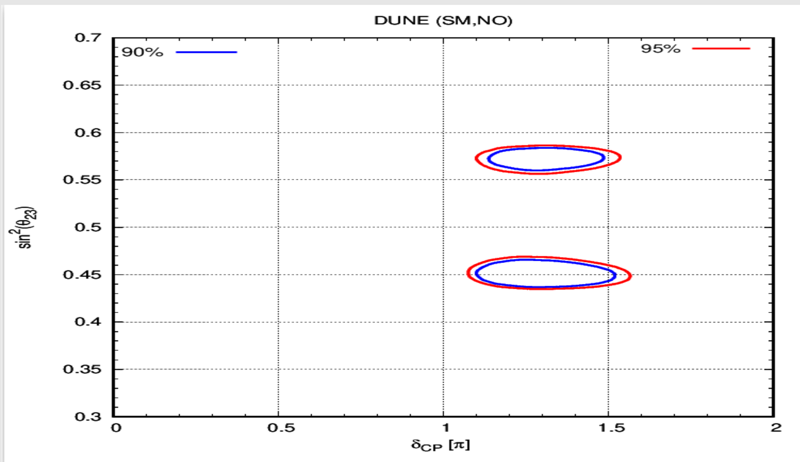
Mass ordering	$\lvert\epsilon_{e\mu}\rvert$	$\lvert\epsilon_{e\tau}\rvert$	χ^2
NO	0.1	0.033	0.659
IO	0.1	0.02	1.14

Mass ordering	$\phi_{e\mu}/\pi$	$\phi_{e\tau}/\pi$	χ^2
NO	1.06	1.87	0.549
IO	1.0	1.73	0.952

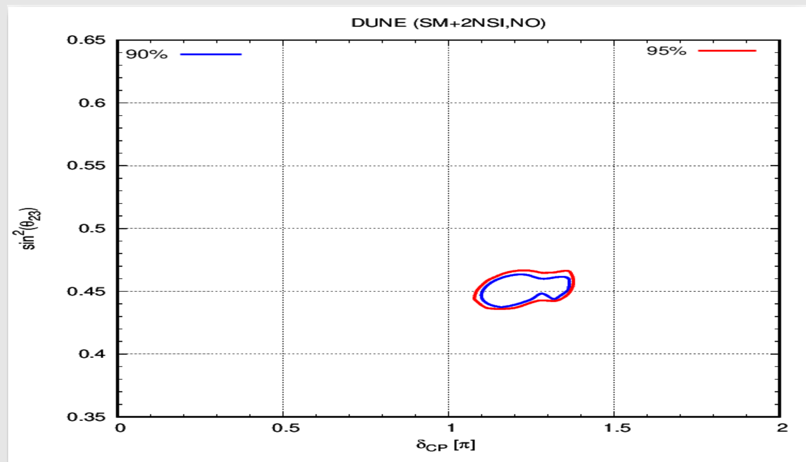
Parameter Degeneracies

1. We have explored the degeneracy issue for the standard model parameter θ_{23} in the presence of NSI arising simultaneously from both $e-\mu$ and $e-\tau$ sectors for DUNE and T2HK.
2. Allowed regions for DUNE and T2HK for NO in the SM case and with dual NSI arising from $e-\mu$ and $e-\tau$ sector are plotted. The contours are drawn at the 90% and 95% C.L. for 2 d.o.f.

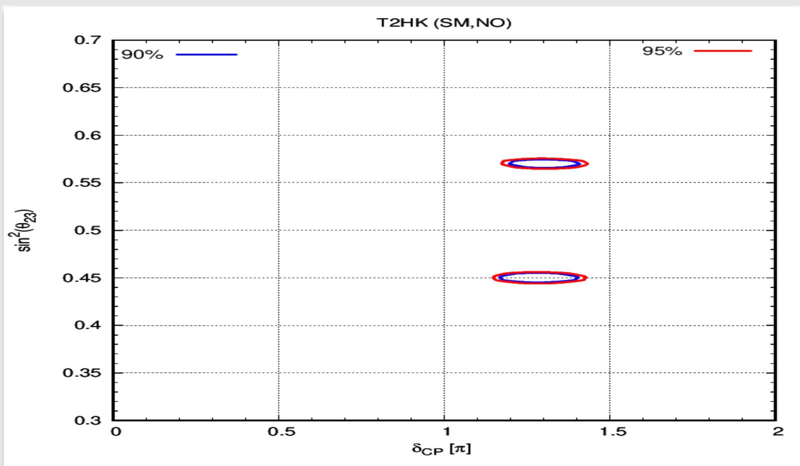
Parameter Degeneracy Plots



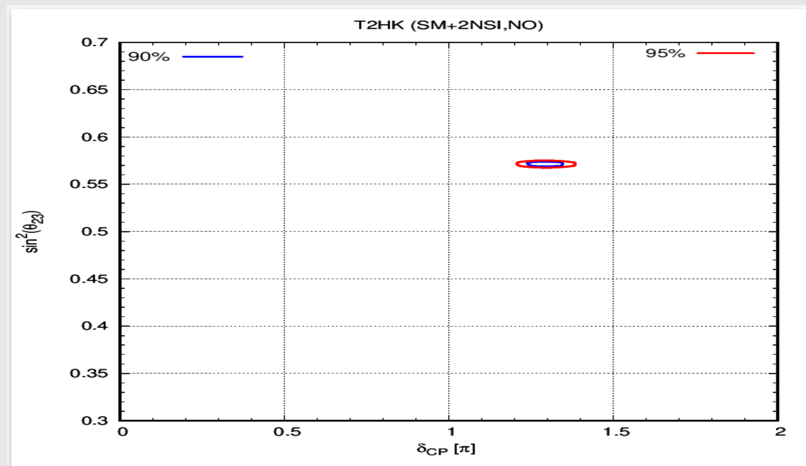
θ_{23} vs. δ_{CP} plot for DUNE in SM.



θ_{23} vs. δ_{CP} plot for DUNE in SM along with dual NSI

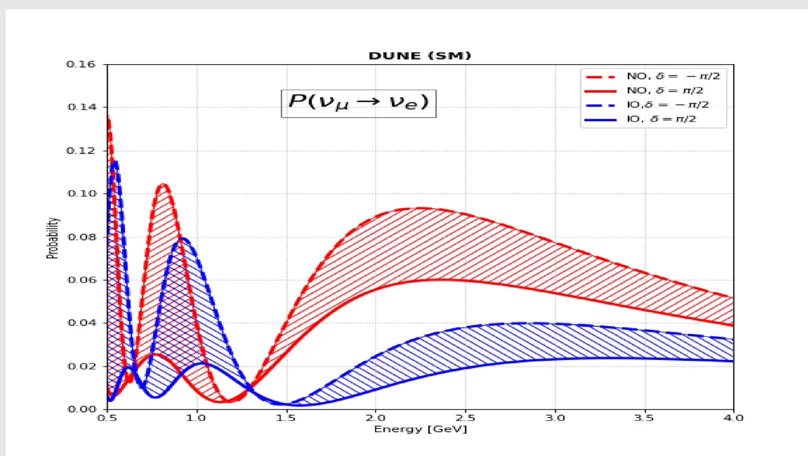


θ_{23} vs. δ_{CP} plot for T2HK in SM

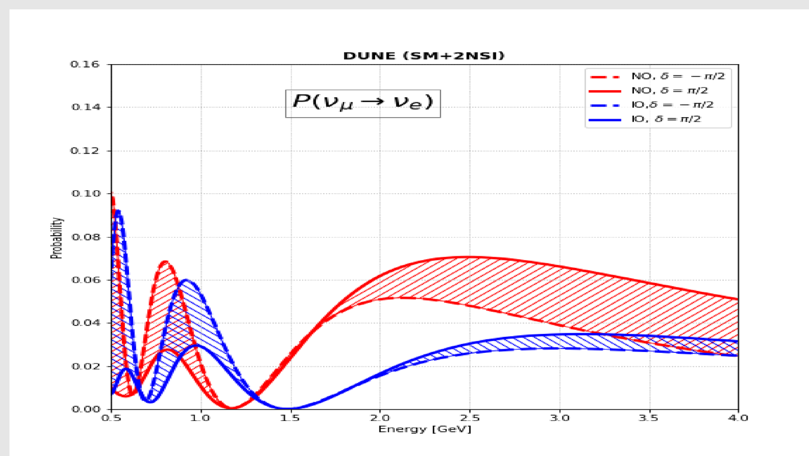


θ_{23} vs. δ_{CP} plot for T2HK in SM along with dual NSI.

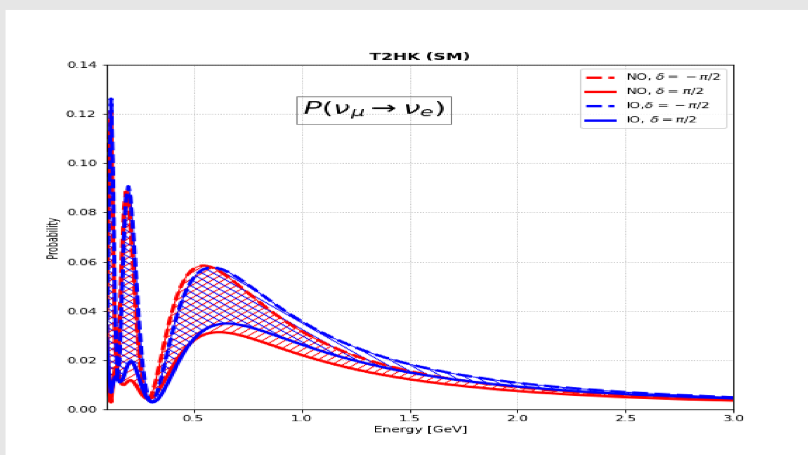
Probability Plots



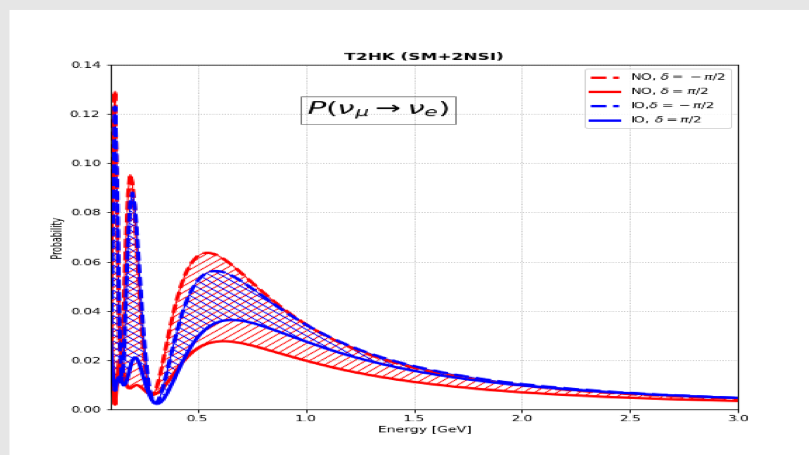
Probability Plots for DUNE in SM.



Probability Plots for DUNE in SM along with dual NSI scenario.



Probability Plots for T2HK in SM.



Probability Plots for T2HK in SM along with dual NSI scenario.

Results

1. In this work, we assumed that new physics occurs in the form of NSI contributing simultaneously from $e-\mu$ and $e-\tau$ sectors. In doing so, we obtained the dual constraints on NSI parameters by combining the NOνA and T2K datasets.
2. When we utilize the NSI arising from both sectors, simultaneously, DUNE prefers the lower octant, and T2HK prefer the higher octant.
3. Moreover, we observed striking effects of dual NSI constraints on neutrino probabilities in both DUNE and T2HK.
4. Further studies will help us to understand the nature of NSI and help extract the parameters in the neutrino sector.