Exploring the effect of Lorentz invariance violation with the currently running long-baseline experiments [Poster ID-309]

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Abstract

- Neutrinos can propagate very long distances without any deviation which enables us to investigate Planck suppressed physics such as CPT violation via neutrino oscillation.
- CPT violation can be studied through Lorentz invariance violation (LIV) in the long-baseline neutrino oscillation experiments.
- ⋆ In this work, for the first time we obtained the sensitivity limits on the LIV parameters from the NOνA and T2K experiments.
  - ⋆ Shows there effects on the Mass Hierarchy and CP violation sensitivities of NOνA experiment.

Lorentz Invariance Violation (LIV)

- CPT violation can arise from Lorentz violation, non-locality, non-commutative geometry and etc.
- Effective Lagrangian for Lorentz violating neutrinos and anti-neutrinos :

$$\mathcal{L} = \frac{1}{2}\bar{\Psi}_A(i\gamma^\mu\partial_\mu\delta_{AB} - M_{AB} + \hat{\mathcal{Q}}_{AB})\Psi_B + \text{h.c.},$$

Where $\hat{\mathcal{Q}}_{AB}$ is the Lorentz violating parameter.

- Effective Hamiltonian for neutrinos including Lorentz Violating contribution.

$$H = H_{\text{vac}} + H_{\text{mat}} + H_{\text{LIV}} ,$$

$$H_{\text{LIV}} = \begin{pmatrix} a_{ee} & a_{e\mu} & a_{e\tau} \\ a^*_{e\mu} & a_{\mu\mu} & a_{\mu\tau} \\ a^*_{e\tau} & a^*_{\mu\tau} & a_{\tau\tau} \end{pmatrix} - \frac{4}{3}E \begin{pmatrix} c_{ee} & c_{e\mu} & c_{e\tau} \\ c^*_{e\mu} & c_{\mu\mu} & c_{\mu\tau} \\ c^*_{e\tau} & c^*_{\mu\tau} & c_{\tau\tau} \end{pmatrix},$$

- We considered only $a_{\alpha\beta}$ in our analysis which, is analogous to Hamiltonian due to propagation NSI in matter.

$$H_{\text{LIV}} = \begin{pmatrix} a_{ee} & a_{e\mu} & a_{e\tau} \\ a^*_{e\mu} & a_{\mu\mu} & a_{\mu\tau} \\ a^*_{e\tau} & a^*_{\mu\tau} & a_{\tau\tau} \end{pmatrix}, H_{\text{NSI}} = V_{CC} \begin{pmatrix} \epsilon^m_{ee} & \epsilon^m_{e\mu} & \epsilon^m_{e\tau} \\ \epsilon^m_{\mu e} & \epsilon^m_{\mu\mu} & \epsilon^m_{\mu\tau} \\ \epsilon^m_{\tau e} & \epsilon^m_{\tau\mu} & \epsilon^m_{\tau\tau} \end{pmatrix},$$

$$a_{\alpha\beta} = \sqrt{2}G_F N_e \epsilon^m_{\alpha\beta} \equiv V_{CC}\epsilon^m_{\alpha\beta} .$$

- Oscillation probability for $\nu_\alpha \to \nu_\beta$ transition, after travelling L distance is,

$$\mathbf{P_{\alpha\beta}} = |\langle\nu_\beta|\nu_\alpha(\boldsymbol{L})\rangle|^2 = \left|\left\langle\nu_\beta|e^{-iHL}|\nu_\alpha\right\rangle\right|^2$$

Results

a) Effect of LIV parameters at probability level.

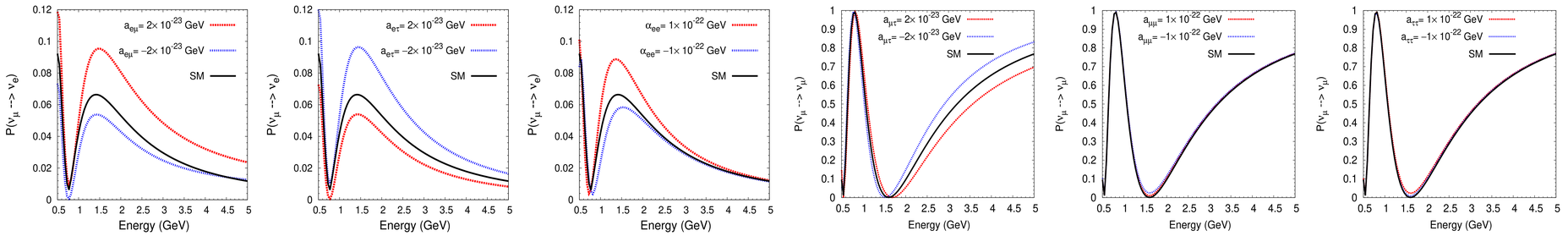
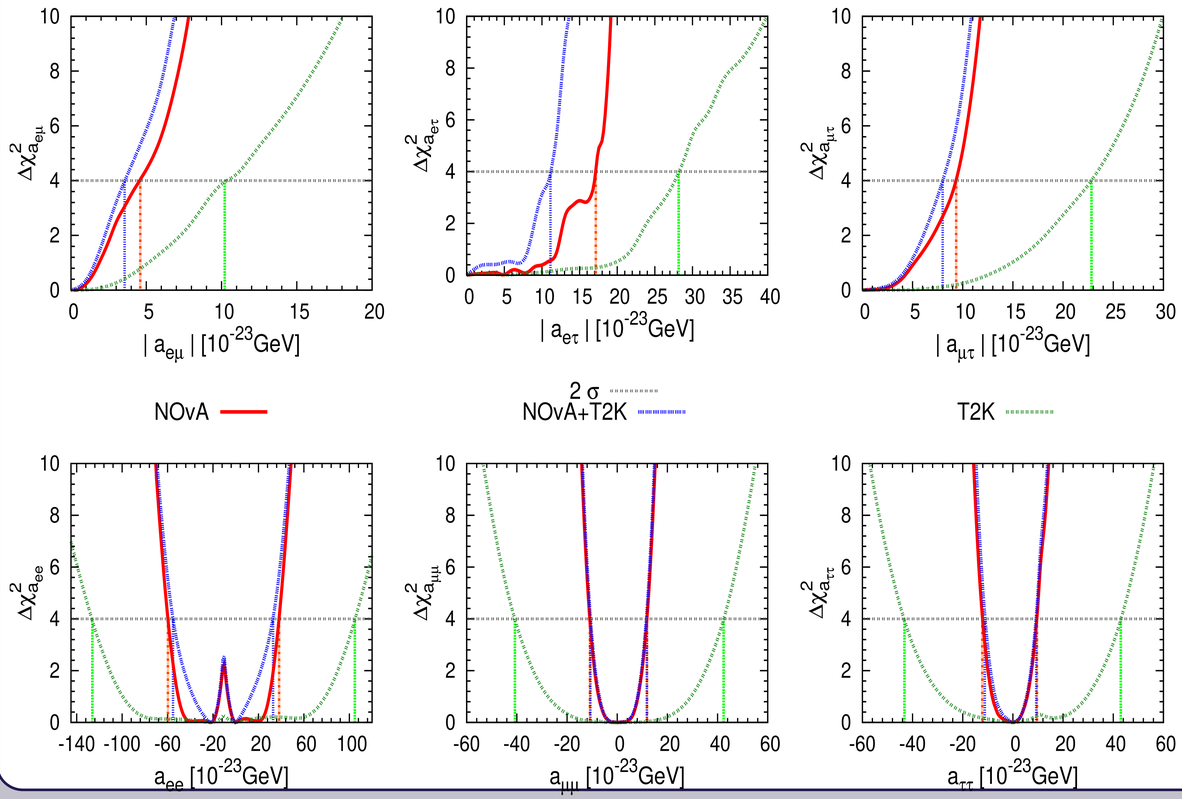


Fig.1: Appearance & disappearance probability in presence of LIV parameters for NOνA experiment.

b) Sensitivity limits on the LIV parameters form NOνA and T2K experiment.



Params.	Sensitivity limits on LIV parameter (in 10^{-22} GeV)		
	T2K	NOνA	T2K+NOνA
$\lvert a_{e\mu}\rvert$	< 1.02	< 0.46	< 0.36
$\lvert a_{e\tau}\rvert$	< 2.82	< 1.71	< 1.08
$\lvert a_{\mu\tau}\rvert$	< 2.28	< 0.93	< 0.8
a_{ee}	$[-12.62 : 10.47]$	$[-5.97 : 3.82]$	$[-5.52 : 3.29]$
$a_{\mu\mu}$	$[-4.09 : 4.24]$	$[-1.09 : 1.19]$	$[-1.07 : 1.18]$
$a_{\tau\tau}$	$[-4.33 : 4.3]$	$[-1.22 : 0.96]$	$[-1.12 : 0.93]$

Fig.2: Sensitivity limits on LIV parameters from NOνA and T2K experiment, and synergy of NOνA and T2K. The table shows the limits on the LIV parameters at 2σ C.L.

- Limits on LIV parameters obtained from T2K are much weaker than NOνA and the synergy of T2K and NOνA can improve the sensitivities on these parameters.
- The sensitivity limits obtained are slightly weaker than the bounds from Super-Kamiokande Collaboration.
- Other sensitivity studies like Mass Hierarchy and CPV sensitivities have done in details, in presence of Lorentz violating parameters [1].

Conclusions

- LIV parameters have significant effects on neutrino oscillation probabilities.
- Obtained the sensitivity limits on these parameters for the currently running long baseline experiments T2K and NOνA. We found that the limits obtained from T2K are much weaker than that of NOνA and the synergy of both the experiments can improve these sensitivities.
- The presence of LIV parameters affect the determination of discovery potential of MH and CP violation.

References

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[2] G. Barenboim, M. Masud, C. A. Ternes and M. Tortola, Phys. Lett. B 788, 308 (2019) arXiv:1805.11094.