Non-minimal Lorentz invariance violation as a solution to the θ_{23} discrepancy in T2K and NOvA

HaiXing Lin[1], Pedro Pasquini[2], Jian Tang[1] and Sampsa Vihonen[1*]

[1]School of Physics, Sun Yat-Sen University, Guangzhou 510275, China

[2] Tsung-Dao Lee Institute (TDLI), Shaghai JiaoTong University (SJTU), Shanghai 200240, China

*Contact email: sampsa@mail.sysu.edu.cn

Tsung-Dao Lee Institute

What are CTP and Lorentz symmetries and can they be broken?

Lorentz invariance and CPT are fundamental symmetries of the Universe. They ensure the laws of physics stay the same regardless of frame of reference. It is appropriate to ask whether either of these two symmetries can be broken [1].

Motivation to consider Lorentz Invariance Violation:

- **Curiosity:** Discovery of LIV or CPT violation would shake up our understanding of fundamental symmetries of the Universe.
- **Quantum gravity:** In some theories, LIV could help resolve the problems relating to quantum gravity and high energy physics.
- **Model testing:** If discovered, LIV or CPT breaking could help identify the underlying theory that describes the physics beyond the Standard Model.

Theoretical formulation of Lorentz invariance and CPT violations

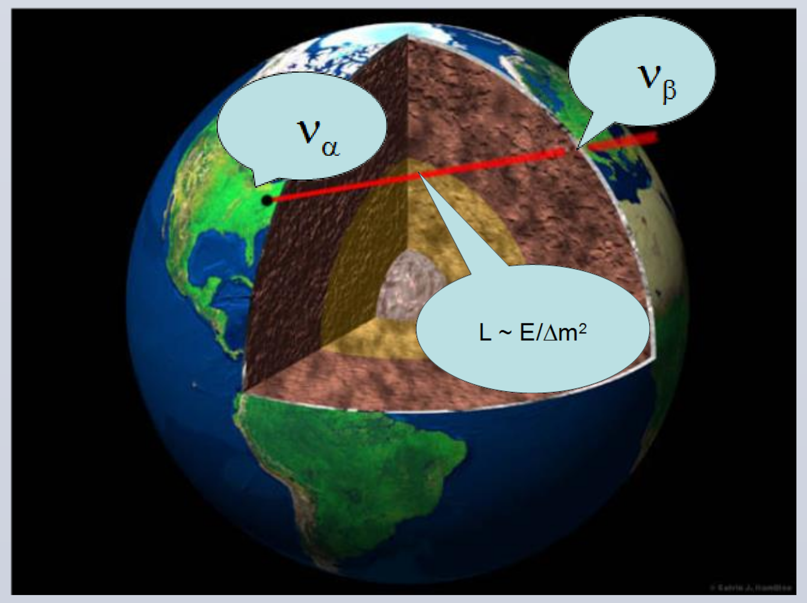
General free Lagrangian with LIV in *d* dimensions:

$$\mathcal{L}_{d-\text{dim}} = i\nu_{iL}^{\dagger}\bar{\sigma}^{\mu}\partial_{\mu}\nu_{iL} - i^{d-3}\gamma_i^{j_1\cdots j_{d-4}}\nu_{iL}^{\dagger}\sigma^k\partial_k\partial_1\cdots\partial_{j_{d-4}}\nu_{iL}$$

Energy-dispersion relations:

$$E^2 = (1+\bar{\gamma})^2\boldsymbol{p}^2 + m^2 \quad \text{where} \quad \bar{\gamma} = \gamma_i^{j_1\cdots j_{d-4}}p_k p_{j1}\cdots p_{j(d-4)}$$

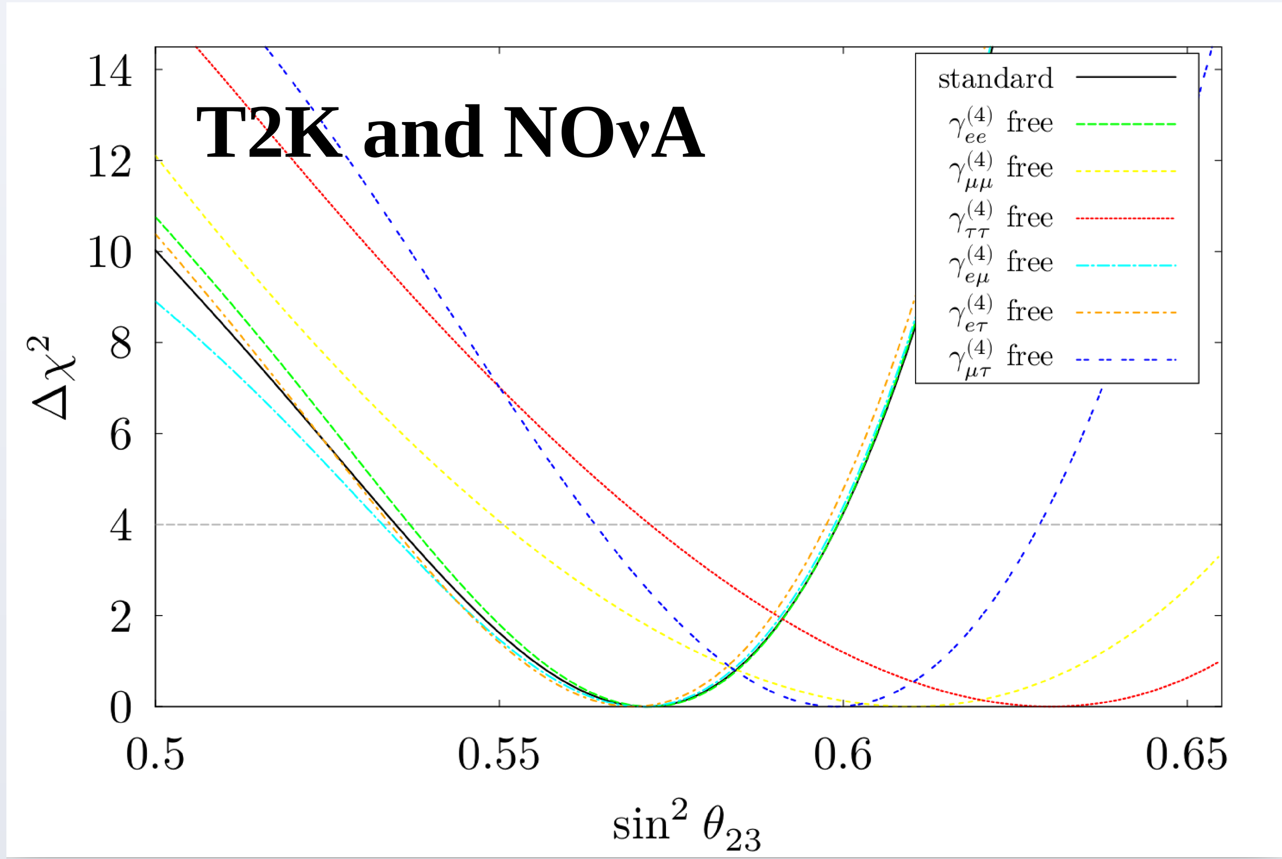
Discrepancy in θ_{23} measurements in T2K and NOvA



T2K and NOvA have measured different values for the atmospheric mixing angle [2, 3]:

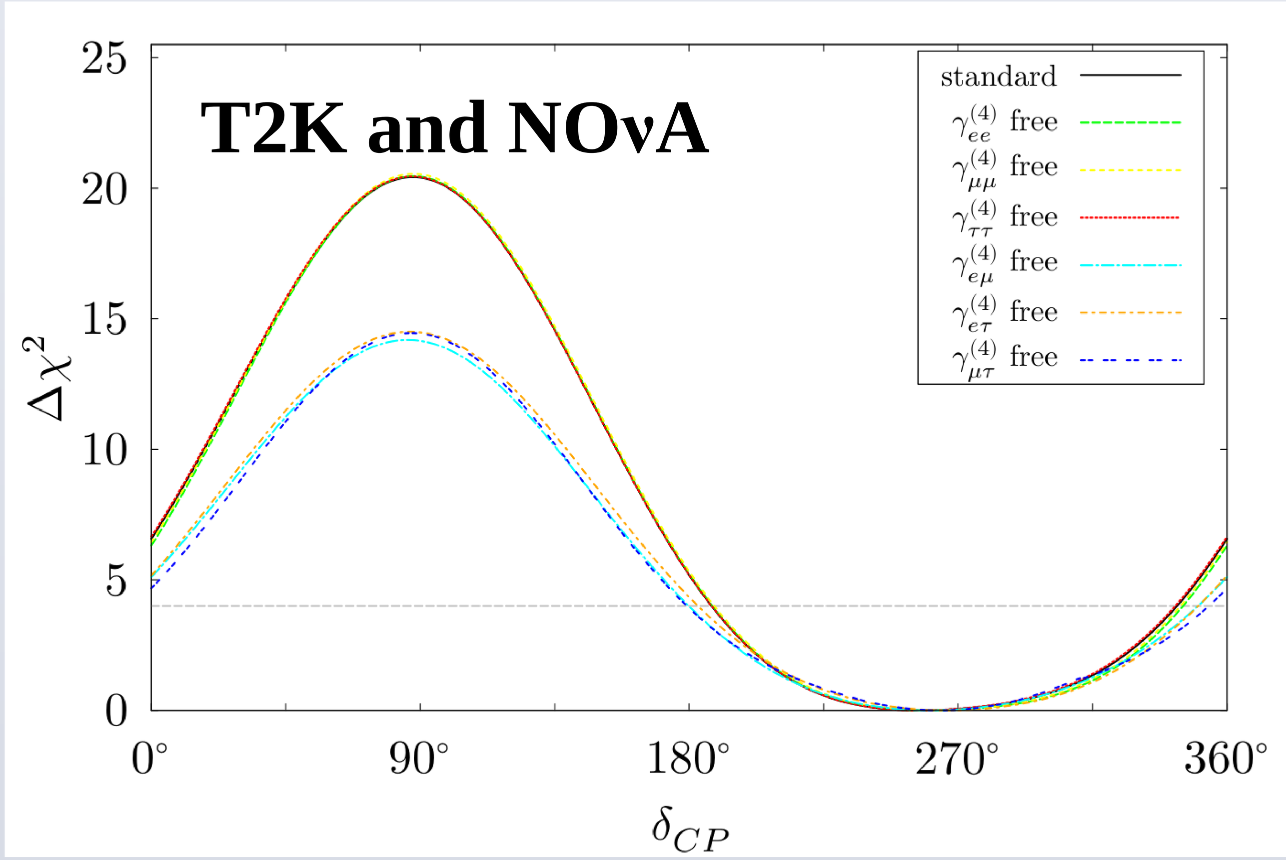
	Best fit:	Goodness of fit:
T2K:	$\theta_{23} = 46.5°$	$\chi^2_{\min} = 163$
NOvA:	$\theta_{23} = 48.4°$	$\chi^2_{\min} = 40$

Non-minimal LIV as solution to T2K and NOvA tension



Fit results (1 d.o.f.):

$\gamma_{ee}^{(4)} = -1.8\times10^{-24}$	$\Delta\chi^2 = 0.8$
$\gamma_{\mu\mu}^{(4)} = -8.0\times10^{-24}$	$\Delta\chi^2 = 2.5$
$\gamma_{\tau\tau}^{(4)} = +8.7\times10^{-24}$	$\Delta\chi^2 = 5.5$
$\gamma_{e\mu}^{(4)} = +1.0\times10^{-24}$	$\Delta\chi^2 = 3.8$
$\gamma_{e\tau}^{(4)} = -0.7\times10^{-24}$	$\Delta\chi^2 = 1.8$
$\gamma_{\mu\tau}^{(4)} = +3.1\times10^{-24}$	$\Delta\chi^2 = 14.8$



Present bounds [4]:

$\gamma_{e\mu}^{(4)} < 10^{-19}$ and $\gamma_{\mu\tau}^{(4)} < 10^{-28}$

Conclusion: $\gamma_{\tau\tau}^{(4)}$ and $\gamma_{\mu\mu}^{(4)}$ could alleviate the tension between T2K and NOvA.

REFERENCES

1) V. A. Kostelecky and S. Samuel, Spontaneous Breaking of Lorentz Symmetry in String Theory, Phys. Rev. D39, 683 (1989).

2) T2K Collaboration (K. Abe *et al.*), Search for CP violation in Neutrino and Antineutrino Oscillations by the T2K experiment with 2.2×10^{21} protons on target, Phys. Rev. Lett.121, 171802 (2018) [arXiv:1807.07891].

3) NOvA Collaboration (M. Acero *et al.*), First measurement of neutrino oscillation parameters using neutrinos and antineutrinos by NOvA, Phys. Rev. Lett. 123, 151803 (2019) [arXiv:1906.04907].

4) V. A. Kostelecky and N. Russell, Data Tables for Lorentz and CPT Violation, Rev. Mod. Phys. 83, 11 (2011) [arXiv:0801.0287v14].

ACKNOWLEDGMENTS

This project was supported in part by National Natural Science Foundation of China under Grant Nos. 12075326, 11505301 and 11881240247. PP is supported by the Shanghai Pujian Program (20PJ1407800) and the National Natural Science Foundation of China (No. 12090064). SV was additionally supported by China Postdoctoral Science Foundation under grant No. 2020M672930. JT further acknowledges the support from CAS Center for Excellence in Particle Physics (CCEPP).