Probing Lorentz Invariance Violation with Atmospheric Neutrinos at INO-ICAL

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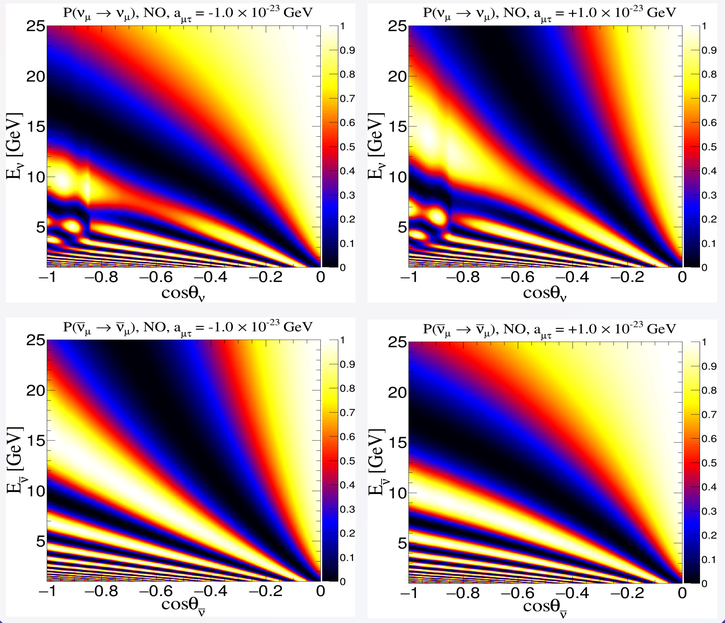
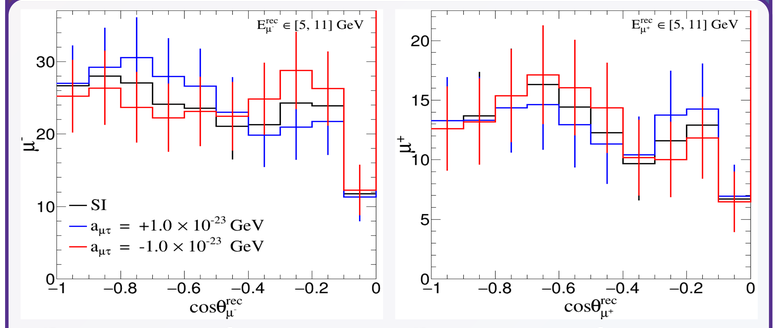
1. Introduction

- The Iron Calorimeter (ICAL) detector is an upcoming 50kt atmospheric neutrino detector at the India-based Neutrino Observatory (INO).
- Its prime goals are to determine mass ordering and precise measurements of atmospheric oscillation parameters.
- 1.5T magnetic field helps it to identify the charge of muons.
- ICAL has 10-15% resolution of muon momenta in the range of 1-25 GeV and < 1° zenith angle resolution over 15-12 800 km range of baselines.
- Using its excellent muon detection response, the isotropic component of the CPT-violating Lorentz Invariance Violation (LIV) has been studied.

2. Effects of $a_{\mu\tau} = \pm 10^{-23}$ GeV

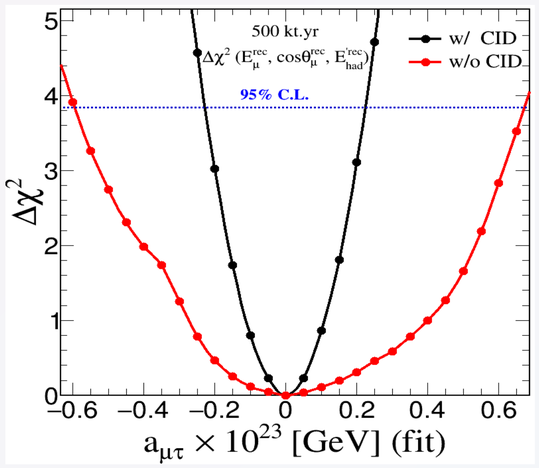


3. Reconstructed Event Distributions



Reconstructed μ^- events | Reconstructed μ^+ events

4. Placing Limit on $a_{\mu\tau}$ by ICAL



$$\mathcal{H}_{\rm L}^{\rm eff} = \frac{1}{2E} U \begin{pmatrix} 0 & 0 & 0 \\ 0 & \Delta m^2_{21} & 0 \\ 0 & 0 & \Delta m^2_{31} \end{pmatrix} U^\dagger + \begin{pmatrix} a_{ee} & a_{e\mu} & a_{e\tau} \\ a^*_{e\mu} & a_{\mu\mu} & a_{\mu\tau} \\ a^*_{e\tau} & a^*_{\mu\tau} & a_{\tau\tau} \end{pmatrix} + \sqrt{2} G_F N_e \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

For the transformation of $\nu_L \to \bar{\nu}_R,\ a(\overline{\nu}_R) = -a(\nu_L)$

5. Conclusion

95% C. L. constraints on CPT-violating LIV parameters using ICAL for 10 years

Observable		$a_{e\mu}$ (10^{-23} GeV)	$a_{e\tau}$ (10^{-23} GeV)	$a_{\mu\tau}$ (10^{-23} GeV)
(E_μ, $\cos\theta_\mu$, E'_{had}) CID	w/o	$-3.97 < a_{e\mu} < 3.37$	$-4.71 < a_{e\tau} < 3.96$	$-0.59 < a_{\mu\tau} < 0.67$
	w/	$-1.97 < a_{e\mu} < 1.34$	$-2.80 < a_{e\tau} < 1.58$	$-0.23 < a_{\mu\tau} < 0.22$

Comparison with Super-K (SK) and IceCube (IC) constraints

Experiments	$a_{e\mu}$ (10^{-23} GeV)	$a_{e\tau}$ (10^{-23} GeV)	$a_{\mu\tau}$ (10^{-23} GeV)
§SK (95% C.L.)	$\mathrm{Re}(a_{e\mu}) < 1.8$ $\mathrm{Im}(a_{e\mu}) < 1.8$	$\mathrm{Re}(a_{e\tau}) < 4.1$ $\mathrm{Im}(a_{e\tau}) < 2.8$	$\mathrm{Re}(a_{\mu\tau}) < 0.65$ $\mathrm{Im}(a_{\mu\tau}) < 0.51$
‡IC (90% C.L.)	–	–	$\lvert\mathrm{Re}(a_{\mu\tau})\rvert < 0.29$ $\lvert\mathrm{Im}(a_{\mu\tau})\rvert < 0.29$

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