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Probing Lorentz Invariance Violation with Atmospheric Neutrinos at INO-ICAL

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Unified theories such as string theory suggests spontaneous Lorentz Invariance Violation(LIV) by introducing a new spacetime structure at the Planck Scale ($m_p \sim 10^{19}$ GeV). This effect can be observed at low energies with strength of $\sim 1/m_p$ using perturbative approach. In the Minimal Standard Model Extension (SME) framework, the neutrino mass-induced flavor oscillation gets modified in the presences of LIV. The Iron Calorimeter (ICAL) detector at the proposed India-based Neutrino Observatory (INO) offers an unique window to probe these LIV parameters by observing atmospheric neutrinos and anti neutrinos separately over a wide range of baselines in the multi-GeV energy range. In this paper, for the first time, we study in detail how the CPT-violating LIV parameters $(a_{e\mu}, a_{e\tau}, a_{\mu\tau})$ can alter muon survival probabilities and expected μ^- and μ^+ event rates at ICAL. Using 500 kt·yr exposure of ICAL, we place stringent bounds on these CPT-violating LIV parameters at 95% C.L which are slightly better than the present Super-Kamiokande limits. We discuss the effect of the marginalization over the oscillation parameters and the advantage of having the hadron energy information and charge identification capability at ICAL in constraining these LIV parameters. We also study the impact of these LIV parameters on mass ordering determination and precision measurement of atmospheric oscillation parameters.

Primary author: Mr SAHOO, SADASHIV (Institute of Physics, Bhubaneswar, Homi Bhabha National Institute, Mumbai, INDIA)

Co-authors: KUMAR, Anil (Institute of Physics, Bhubaneswar, India); Dr AGARWALLA, Sanjib Kumar (Institute of Physics, Bhubaneswar, INDIA)

Presenter: Mr SAHOO, SADASHIV (Institute of Physics, Bhubaneswar, Homi Bhabha National Institute, Mumbai, INDIA)

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