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Impact of LIV Effects Induced by Quantum-Gravity–Motivated Modified Dispersion Relations on Neutrino Coherence Length

Lorentz Invariance Violation may arise in several approaches to Quantum Gravity theories, where microscopic space-time fluctuations can induce modified dispersion relations, causing energetic particles to propagate at different effective velocities. Neutrinos are particularly well-suited particles to probe such effects due to their tiny masses, weak interactions, and ability to propagate coherently over macroscopic and astrophysical distances.

In this work, we investigate how QG-induced fluctuations and LIV effects can impact neutrino coherence, modifying the standard oscillation framework. We propose an effective neutrino coherence length that incorporates QG-induced decoherence effects, beyond the conventional wave-packet separation mechanism. Analytical expressions for the modified coherence length are derived, and their dependence on neutrino energy and on the parameters characterizing the quantum-gravity–motivated modified dispersion relation is analyzed. We apply this framework to simulations of neutrinos emitted from core-collapse supernovae, where galactic-scale propagation distances enhance sensitivity to coherence-loss effects.

We discuss the phenomenological implications of these results for supernova neutrino observations and for long-baseline neutrino oscillation experiments employing large-mass liquid argon detectors, highlighting their potential to constrain LIV and QG-inspired scenarios via deviations from the standard oscillation pattern.

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