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Quantum field-theoretic framework for neutrino decoherence

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Neutrino oscillations probe quantum coherence over macroscopic distances and are therefore sensitive to possible environmental and beyond-Standard-Model effects. While neutrino decoherence is often introduced phenomenologically through Lindblad-type equations, its microscopic origin requires a consistent quantum field-theoretic treatment.

We present an open-system framework for neutrino propagation in which generalized master equations for the neutrino density matrix are derived from neutrino interactions with external degrees of freedom. The formalism incorporates momentum-changing transitions and reproduces the standard Lindblad equation in suitable limits. We consider three mechanisms of neutrino quantum decoherence: neutrino decay, elastic scattering in a medium, and propagation in a fluctuating classical axion-like-particle field. For neutrino decay, the dissipative terms are related to decay and inverse-decay widths, allowing phenomenological decoherence bounds to be translated into constraints on neutrino lifetimes. For elastic scattering, the framework describes decoherence, quantum-Zeno-like suppression of oscillations, and possible effects of non-standard interactions or dark-sector particles.

The talk is based on our recent results

[1] K.Stankevich, A.Studenikin, M.Vyalkov, Quantum field-theoretic framework for neutrino decoherence from scattering in a medium, Phys.Rev.D 114 (2026) 4. [2] A.Lichkunov, K.Stankevich, A.Studenikin, Neutrino quantum decoherence in a fluctuating ALPs field, Phys.Rev.D 112 (2025) 12. [3] K.Stankevich, A.Studenikin, M.Vyalkov, Generalized Lindblad master equation for neutrino evolution, Phys.Rev.D 111 (2025) 3.

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