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Neutrino backgrounds in matter-wave interferometry: implications for dark matter searches and beyond-Standard Model physics

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We present a comprehensive theoretical analysis of neutrino-induced decoherence in macroscopic matter-wave interferometry experiments designed to search for dark matter and beyond-Standard Model physics. Our calculation includes contributions from the cosmic neutrino background (CνB), solar neutrinos, and reactor antineutrinos, accounting for coherent scattering processes across nuclear, atomic, and macroscopic length scales. Within the Standard Model, we find negligible decoherence rates for planned experiments such as MAQRO (s/σs ~ 10−27) and terrestrial interferometers like Pino (s/σs ~ 10−22). However, these experiments achieve competitive sensitivity to beyondStandard Model physics through light vector mediator interactions, with CνB constraining coupling products to gνgn ⊠ 10−17 for Z ′ masses below 1 eV. Our results provide a theoretical framework for interpreting matter-wave interferometry measurements in terms of neutrino interaction physics and for deriving constraints on BSM models from experimental data.

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