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Detection of Elastic Coherent Neutrino Scattering, Qubit Decoherence, and Energy Accumulation-Release Processes in Materials

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The detection of nuclear recoils caused by elastic coherent scattering of solar and reactor neutrinos is of significant scientific and practical importance, representing a key milestone in the direct search for dark matter particles. While modern detectors are sensitive to registering these small energy depositions, a challenge lies in discriminating particle interactions from energy accumulation and delayed avalanche-like release processes present in detector materials. These processes are material-specific but occur universally across all detector types, with quantitative models lacking even for common materials.

In noble-liquid dual-phase detectors, like a B$- scale experiment planned by the XLZD collaboration, long-lived chemical radicals, metastable molecules, and clusters formed around impurities in the bulk liquid and at surfaces and interfaces can store energy for extended periods. However, investigations into these impurity-related backgrounds are complicated by the accumulation of electrons and ions at the liquid-gas interface. These issues can be addressed using ideas and techniques developed in studies of charged liquid surfaces and impurities and ions interactions with liquid and solid helium.

In solid-state low-temperature detectors, excess background noise is inherently tied to long and unsteady relaxation processes in disordered solids and glasses. Stored energy releases can mimic low-energy interactions with particles and cause quantum errors and decoherence in qubits but are much more frequent than particle incidence. These effects have been largely overlooked in extensive past and present studies of decorative materials in quantum materials.

Excess backgrounds in particle detectors are deeply connected to unresolved quantum materials challenges and longstanding condensed matter problems. With substantial investments in next-generation dark matter & neutrino detectors and in quantum information technologies, insufficient inter-disciplinary collaboration represents an organizational challenge that could prove costly when paradigm changes are needed.

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