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Rare Isotope Doped Superconducting Sensors as Powerful Probes of BSM Physics

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Nuclear beta and electron capture (EC) decay serve as sensitive probes of the structure and symmetries at the microscopic scale of our Universe. As such, precision measurements of the final-state products in these processes can be used as powerful laboratories to search for new physics from the meV to TeV scale, as well as addressing fundamental questions of quantum mechanics at the subatomic scale. Significant advances in "rare isotope"availability and quality, coupled with decades of sensing technique development from the AMO community have led us into a new era of fundamental tests of nature using unstable nuclei. For the past few years, we have taken the approach of embedding radioisotopes in thin-film superconducting tunnel junctions (STJs) to precisely measure the recoiling atom that gets an eV-scale "kick"following electroweak nuclear decay. These recoils are encoded with the fundamental quantum information the decay process and final-state products, and carry unique signatures of weakly coupled beyond standard model (BSM) physics, if they exist. These include information on the neutrino mass, BSM weak forces, and potential "dark"particles created within the energy-window of the decay. Our measurements have provided a complimentary and (crucially) model-independent portal to the dark sector with sensitivities that push towards synergy between laboratory and cosmological probes. In this talk, I will briefly discuss the broad program we have developed to provide world-leading searches in these areas as well as the technological advances across several sub-disciplines of science required to enable this work, including subatomic physics, quantum engineering, atomic theory, and materials science.

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