Contribution ID: **178** Type: **Invited Abstract**

Sub-keV Decay-Recoil Spectroscopy with Superconducting Quantum Sensors

Friday 17 June 2022 09:00 (30 minutes)

The recoiling daughter nucleus in weak nuclear decay processes (β or EC decay) is a unique probe for a wide range of nuclear structure properties and BSM physics scenarios. In particular, precision measurements of the recoil can be used to access model-independent information on the neutrino mass, the β-ν angular correlation, precise excited- and ground-state energies, and decay branching fractions. Despite the unique information contained in these recoiling nuclei, few cases have been studied due to the technical challenges associated with measuring heavy ions with eV-scale kinetic energies with high resolution. To address this, we have developed a program to perform these low-energy measurements using implanted rare isotopes in thin-film superconducting tunnel junctions (STJs). STJs are a cryogenic-charge sensitive quantum sensor technology that allow for count rate of up to 10 kHz/pixel, provide energy resolutions of 1-5 eV, and have low-energy thresholds of a few eV [1]. In this talk I will discuss this novel experimental concept and present data on the eV-scale measurements we have performed with STJs using ^{7}Be ($T_{1/2}$ = 53 days) EC decay relevant to structure and astrophysics [2] and BSM neutrino physics [3,4]. I will also present plans on extending this concept to perform measurements on short-lived species on-line at RIB facilities, and how our community can better leverage these technologies for high-impact structure measurements.
[1] S. Friedrich et al., J. of Low Temp. Phys. 200, 200 (2020)
[2] S. Fretwell et al., Phys. Rev. Lett. 125, 032701 (2020)
[3] K.G. Leach and S. Friedrich, arXiv: 2112.02029 (2021)
[4] S. Friedrich et al., Phys Rev. Lett. 126, 021803 (2021)

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Session Classification: NS2022 Plenary

Track Classification: Oral Presentations