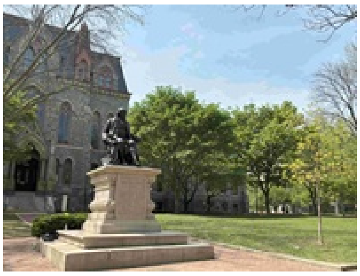

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High-Voltage Phonon-Focusing Detector with Spectral Filtering for Sub-eV Nuclear Recoil Discrimination

Wednesday 8 October 2025 20:00 (20 minutes)

We present a new cryogenic detector concept that exploits anisotropic phonon focusing in high-purity Ge or Si crystals, combined with high-voltage Luke amplification and phonon spectral filtering, to achieve nuclear recoil (NR) and electronic recoil (ER) discrimination down to ~1 eV recoil energies. The detector is oriented so that ballistic longitudinal phonons from an event are concentrated by crystal anisotropy into a well-defined caustic on the surface, where a single, ultra-low-capacitance quasiparticle-trap-assisted TES (QET) with high-gap superconducting fins is placed to preferentially capture the high-frequency prompt phonons. The opposite face, instrumented with a conventional CDMS-style QET array using lower-gap fins, also serves as the high-voltage electrode and is optimized to absorb softer, late-arriving Luke phonons.

Nuclear recoils produce a larger fraction of prompt ballistic phonons collected at the focusing hot spot, while electronic recoils generate more late Luke phonons predominantly absorbed by the base. By combining spatial selectivity from phonon focusing with frequency selectivity from superconducting gap engineering, and exploiting the strong bias dependence of the ER Luke component, timing differences and spectral partition between the two faces provide robust NR/ER separation without ionization readout.

This concept directly addresses the challenge of achieving background discrimination at the eV scale, a critical threshold for detecting low-mass dark matter and coherent elastic neutrino-nucleus scattering (CEνNS). Simulations indicate that with <111> orientation, accurate sensor placement, and 50–150 V bias across a 1 cm crystal, discrimination is achievable for individual events. The approach builds on phonon-based detector technologies developed for CDMS but adds the new capability of phonon "color"discrimination and optimized geometry for focusing, representing a significant step toward single-electron sensitivity with phonon-only readout.

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