

Exploring Phonon-mediated Sensors in Precision Electron Capture Experiments for Neutrino Physics

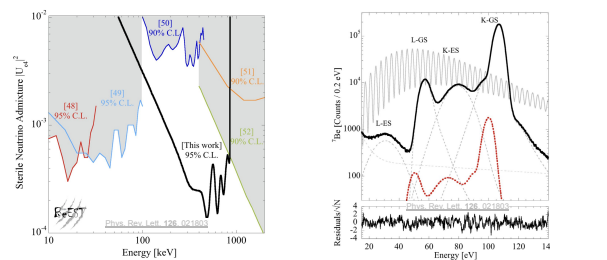
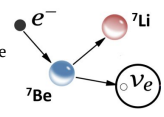


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Background

Precise measurements of electron capture (EC) decays provide a sensitive probe of physics beyond the Standard Model

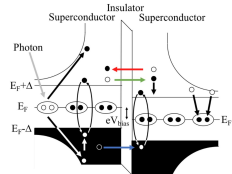
- Final state contains neutrino and recoiling atom
- Any new massive particle coupled to the neutrino can be detected through momentum conservation via the nuclear recoil



BeEST collaboration set world leading exclusion limits on sterile neutrino mass range & spatial width of neutrino

Nuclear recoil peaks non-gaussian, lower than expected E, & much broader than photon calibration signals. Why?

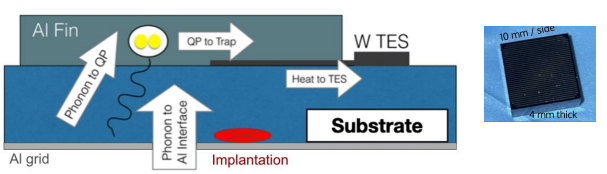
STJ Detectors



Goal of this work to understand mechanism driving broadening of BeEST EC decay spectra by investigating HVEV detectors

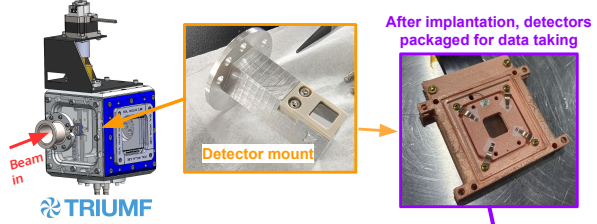
HVEV Detectors

- HVEV detectors used for SuperCDMS
- Silicon substrate instrumented with arrays of transition-edge sensors (TESs) with sub-eV energy resolution
- Phonon-mediated sensors provide complementary study to STJs, to see how different materials influence atomic & lattice effects in EC
- Heat in TES changes its R, which modulates the I in the circuit and the SQUID amplifies this change into a measurable signal



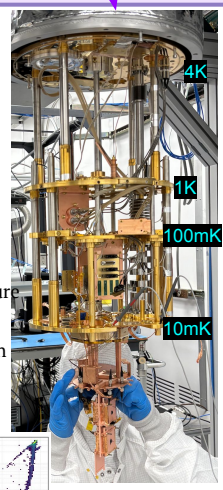
⁷Be Implantation

- HVEV detectors implanted with ⁷Be at 10s of keV at TRIUMF-ISAC beamline
- Received sub 1 Becquerel decay rate in 2 different runs



Data Collection

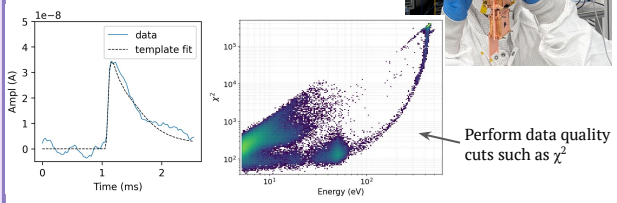
- Implanted detectors measured at SLAC in dilution fridge
- Optical fiber calibration line running from outside fridge to cold detectors



Data Analysis

- arqpy package (J.Ryan) used for data processing, optimal filter trigger, and feature extraction for data quality cuts
- Convert amplitude to energy via calibration (see right column)

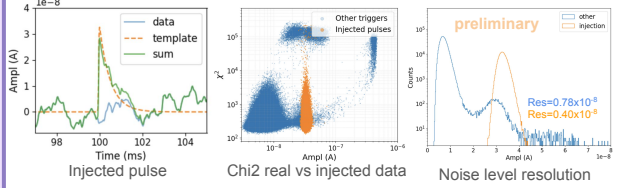
Real Data



Perform data quality cuts such as χ^2

Study lowest attainable resolution by injecting artificial pulses into real data

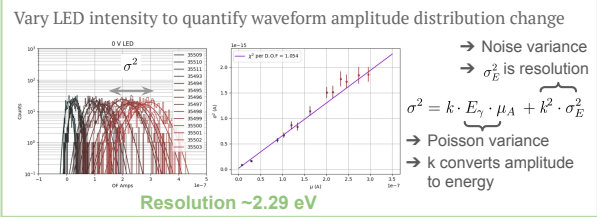
Artificial Pulses



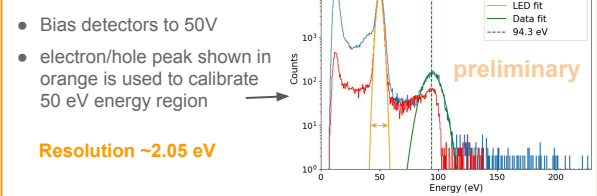
Energy Spectra

Science questions: 1. Do we get high resolution spectra using HVEV? 2. Do we see ⁷Be?

Shot Noise Calibration at 0V:



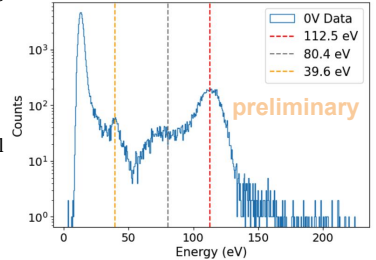
e/h Calibration at 50V:



Expected peak locations

- K-GS: 111 eV
- K-ES: 80 eV
- L-GS: 57 eV
- L-ES: 30 eV

Calibrated E-spectrum



No strong difference in E scale with applied HV, but resolution broader than desired & potential ⁷Be peaks not at expected energies

Future Plans

- Further analysis of the 1000+ hours of data collected
- Study how implantation affects detector performance
- Fabricate and implant more detectors with a higher dose of radioisotope with the goal of seeing stronger presence of ⁷Be

Acknowledgments: We would like to thank BeEST, SuperCDMS, DMQIS for their contribution to this work, & DOE-NP for their support.