

Low energy excess in diamond-MMC (MAGNETO) and STJ (BeEST) detectors

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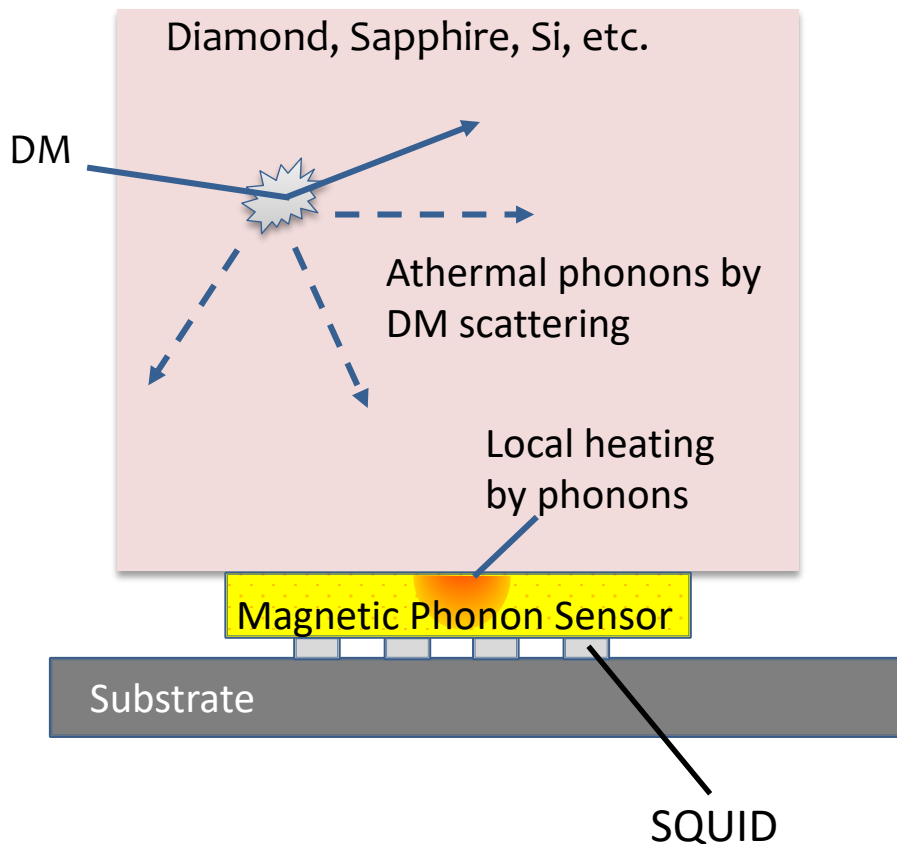
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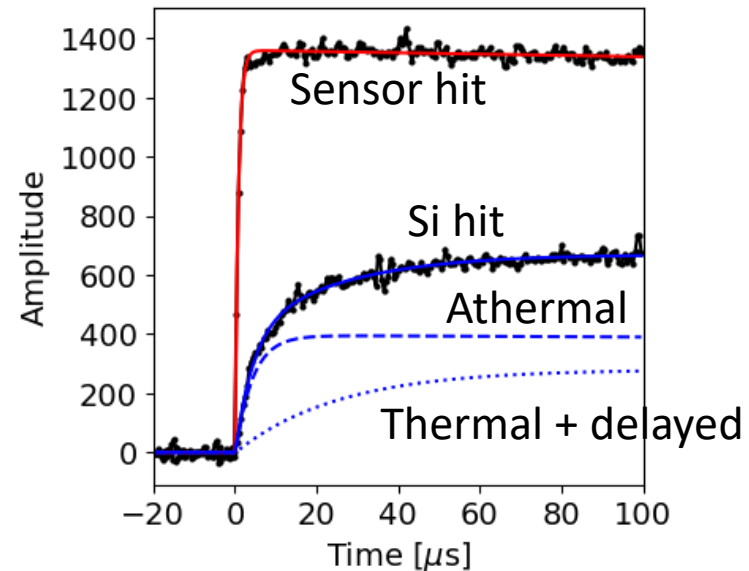
LLNL-PRES-853556



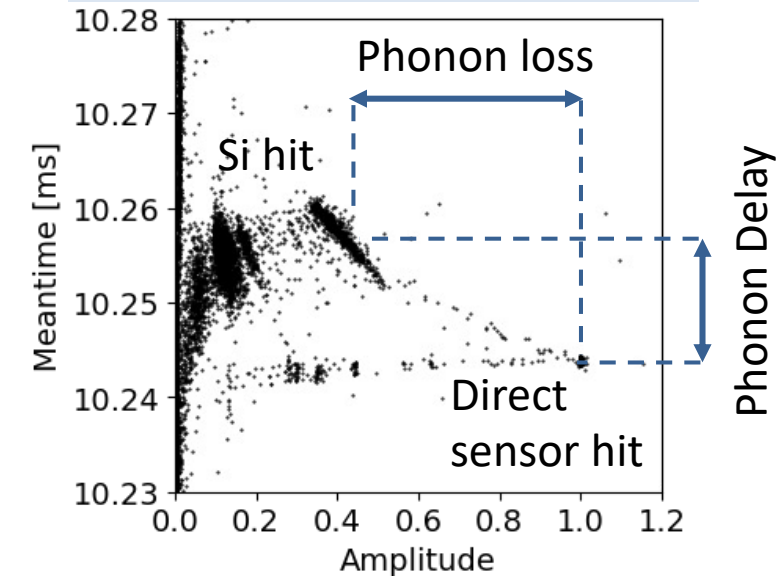
MAGNETO-DM: Fast Phonon Sensing for Sub-GeV DM Detection



Pulse shapes by different origins



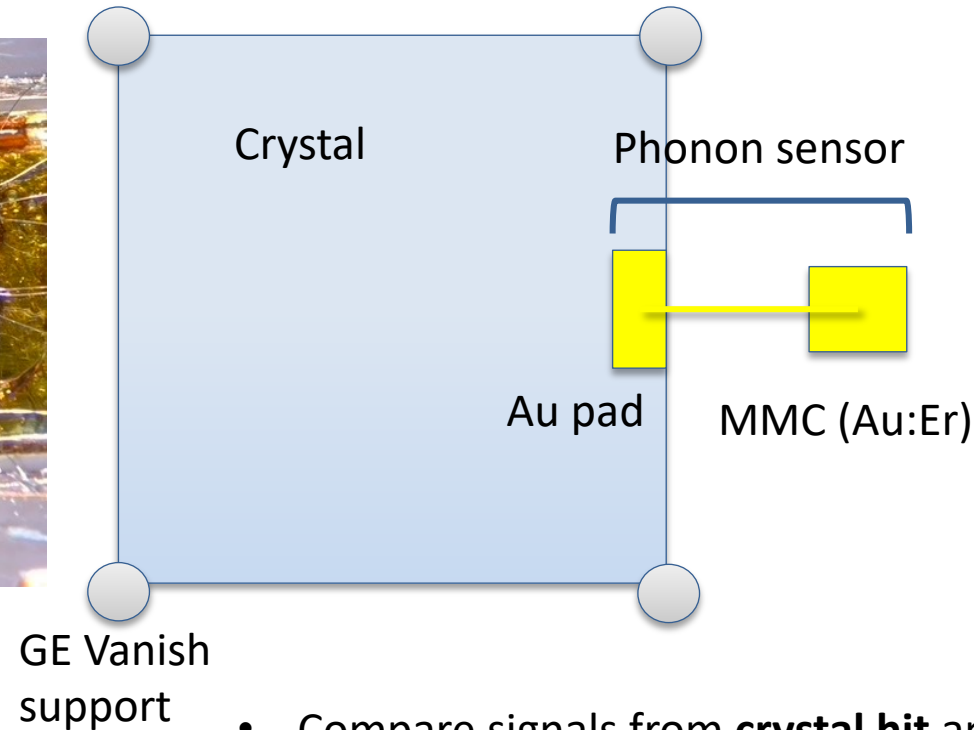
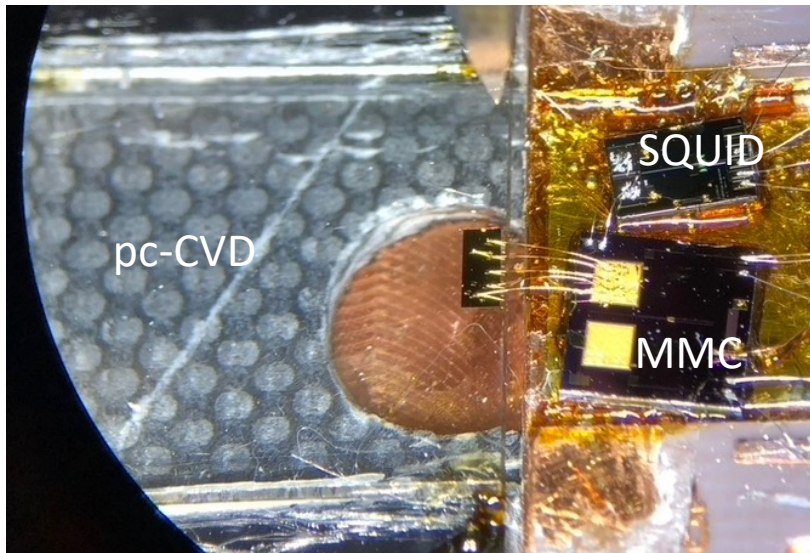
Pulse Shape Distribution



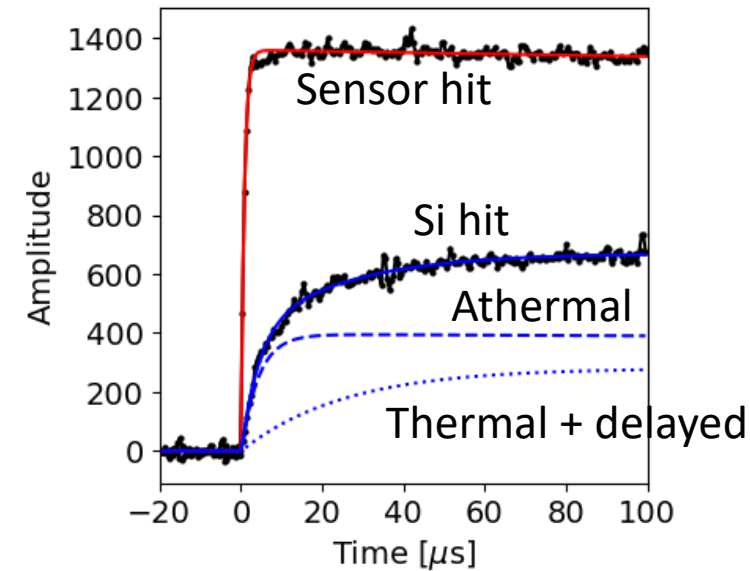
- Phonon Pulse Shape Discrimination with 100ns timing resolution
- Background reduction (NR/ER, thermal/athermal)
- Flexible crystal choice (no direct sensor fab)

MAGNETO-DM R&D Data: Crystal Screening

Tested various crystals for phonon propagation study



Pulse shapes by different origins

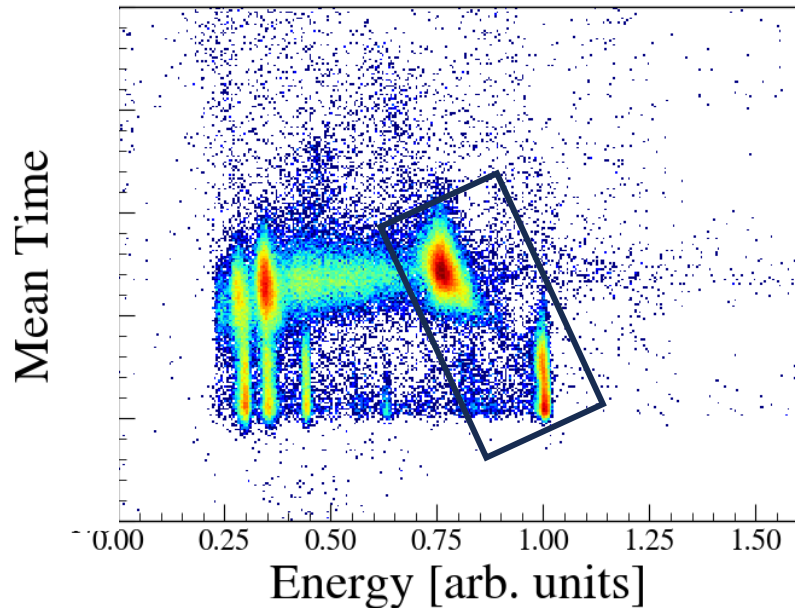


- Compare signals from **crystal hit** and **phonon sensor hit**
- Extract phonon collection efficiency and timescale

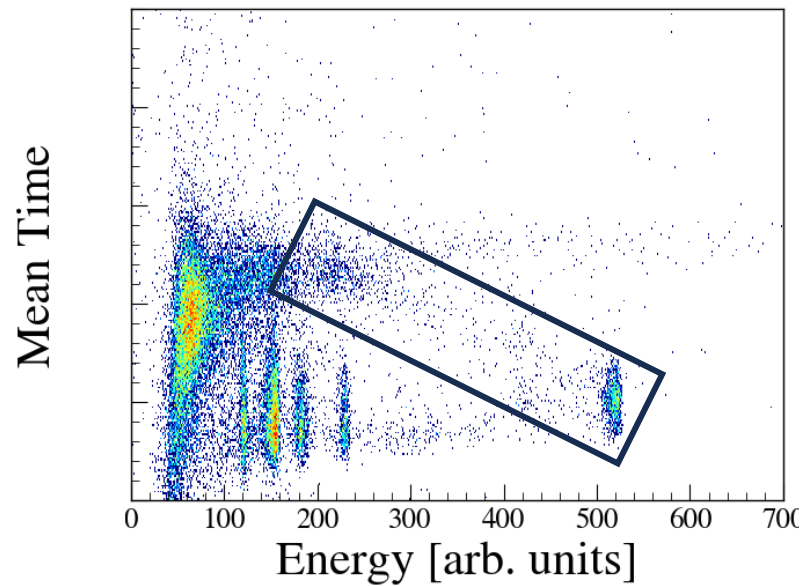
Phonon Collection Efficiency

Quantification of athermal phonon collection efficiencies

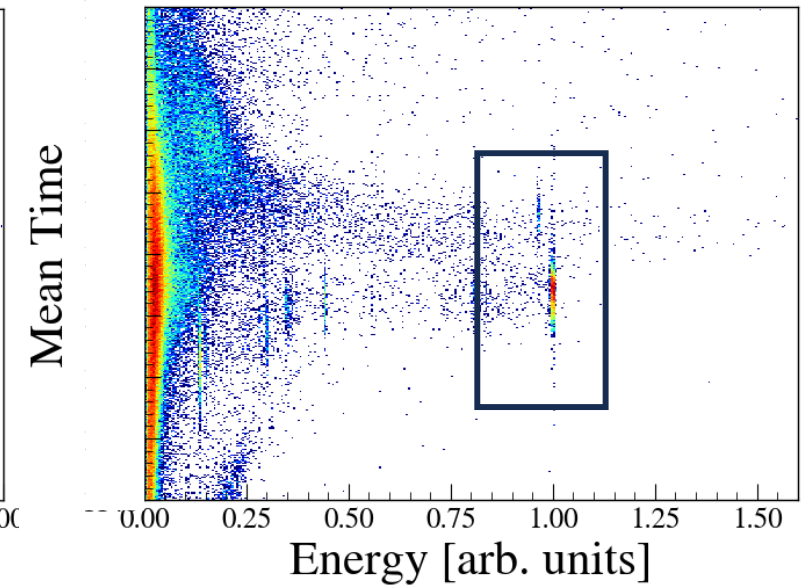
I. Kim et al, LTD-20



Sapphire 5mm x 5mm x 500um
Similar result with 1cm x 1cm x 1mm



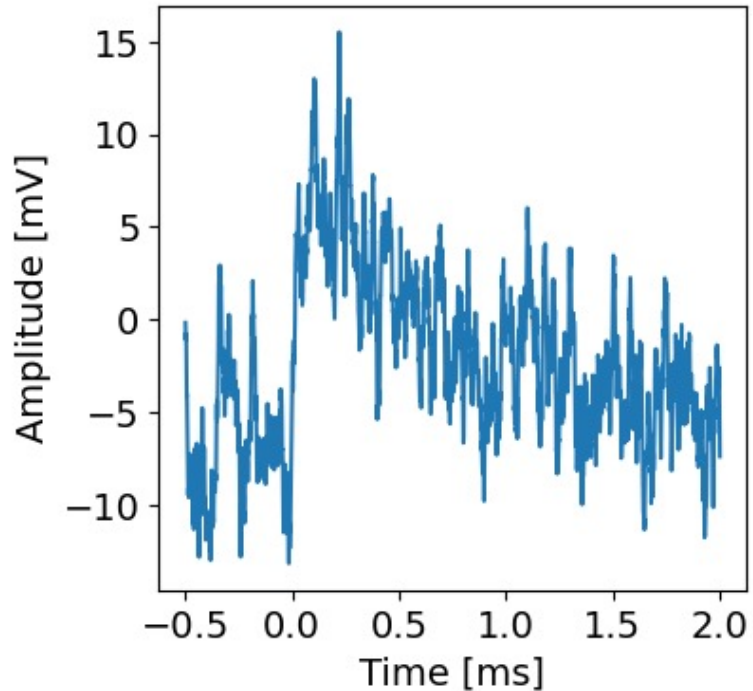
sc-CVD 5mm x 5mm x 250um



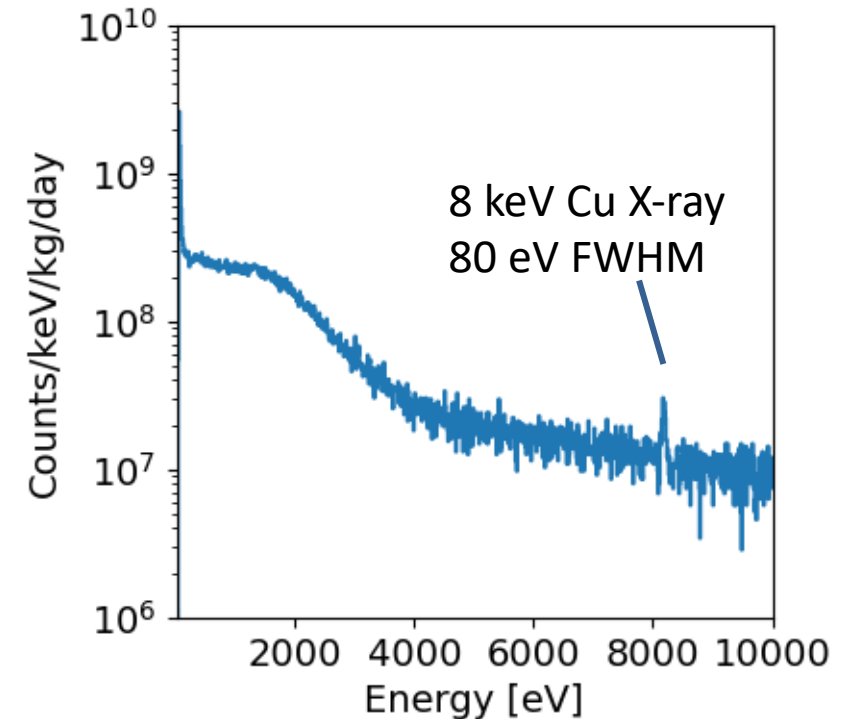
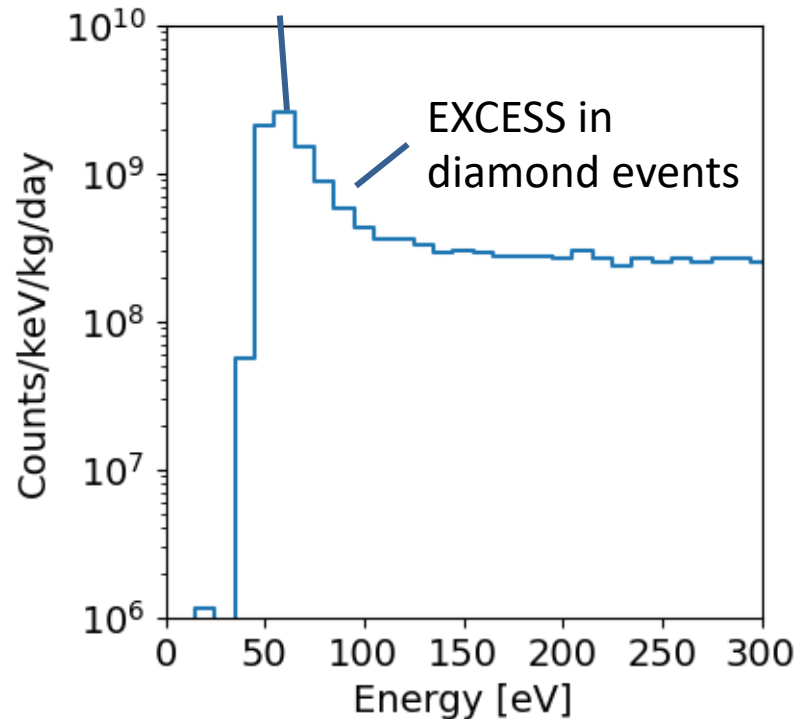
pc-CVD 1cm x 1cm x 500um

Low Energy Analysis

Single pulse at 100 eV



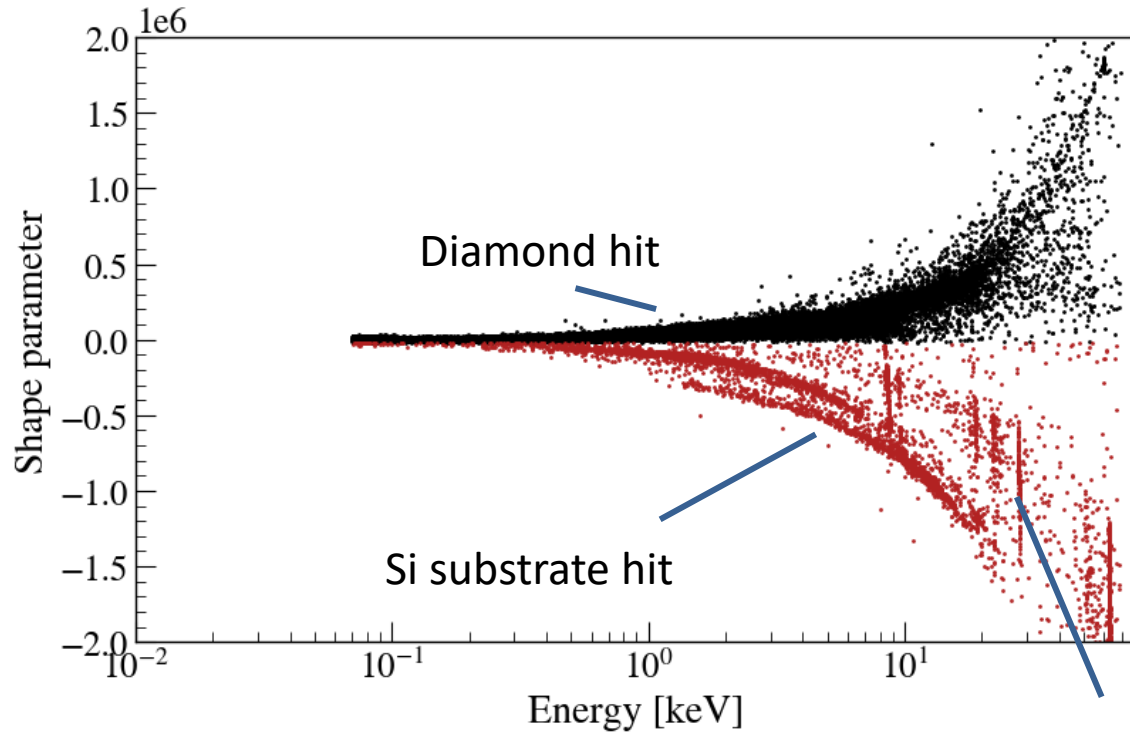
70 eV threshold



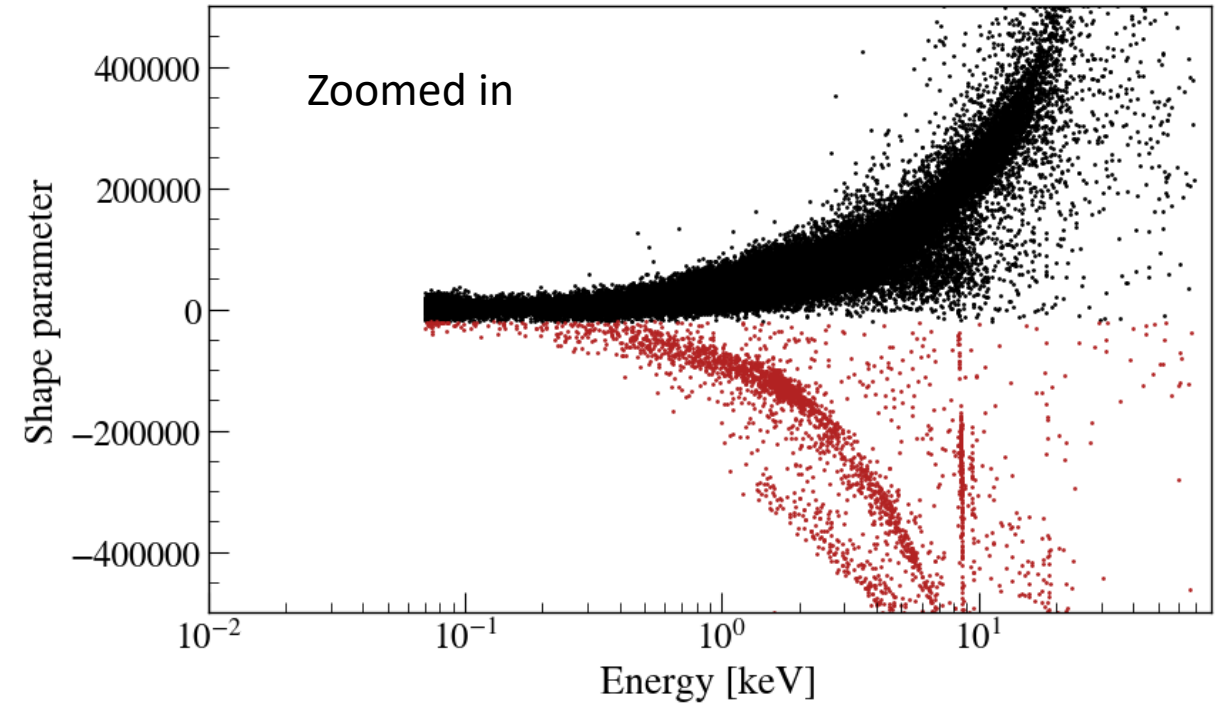
^{241}Am Calibration source
(160 eV FWHM @ 60 keV)

Sensor hit vs Crystal hit for EXCESS

Template fitting analysis for pulse shape discrimination

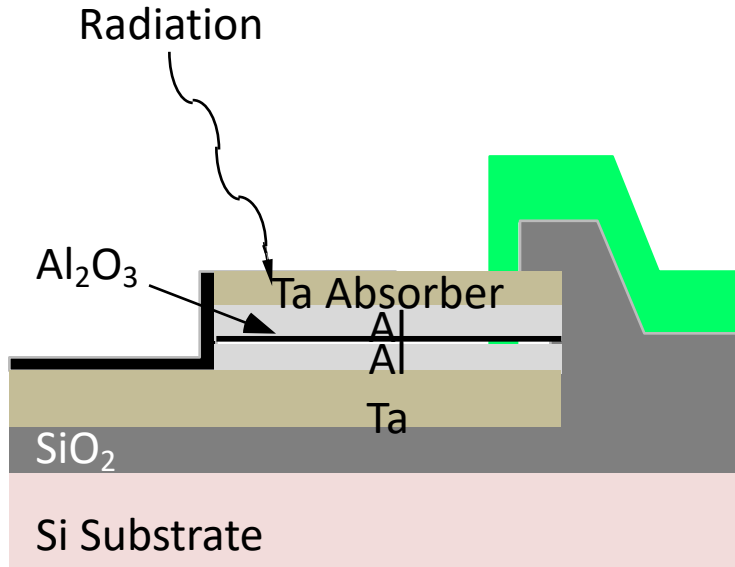


Phonon sensor hit



STJ Working Principle

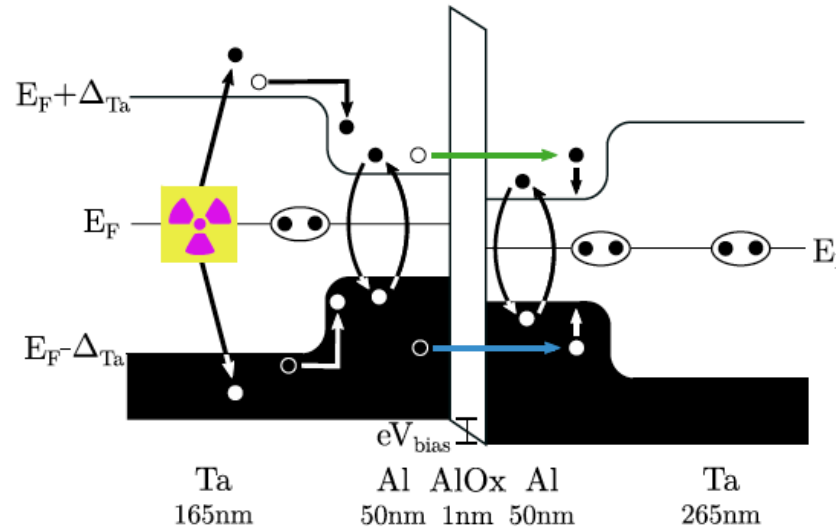
STJ Cross Section



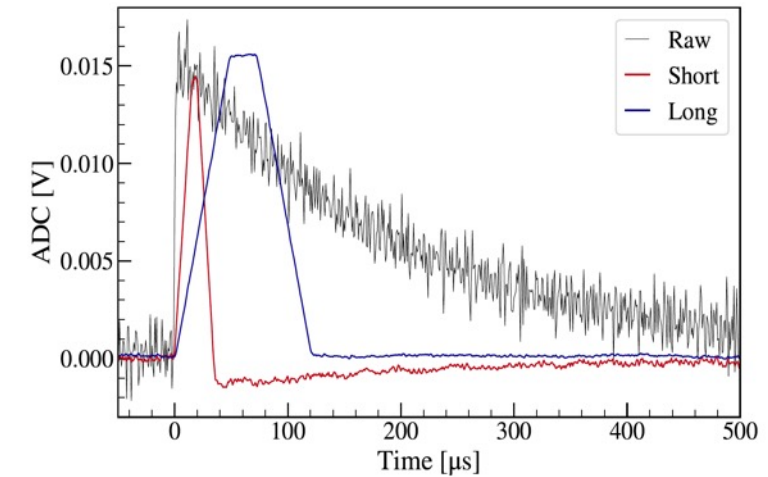
$200 \times 200 \mu\text{m}^2$

$$\text{Energy resolution } E_{\text{FWHM}} = 2.355 \sqrt{1.7 \Delta \cdot E_{\text{X-ray}} \left(F + 1 + \frac{1}{n} \right)}$$

STJ Operating Principle



STJ Signal

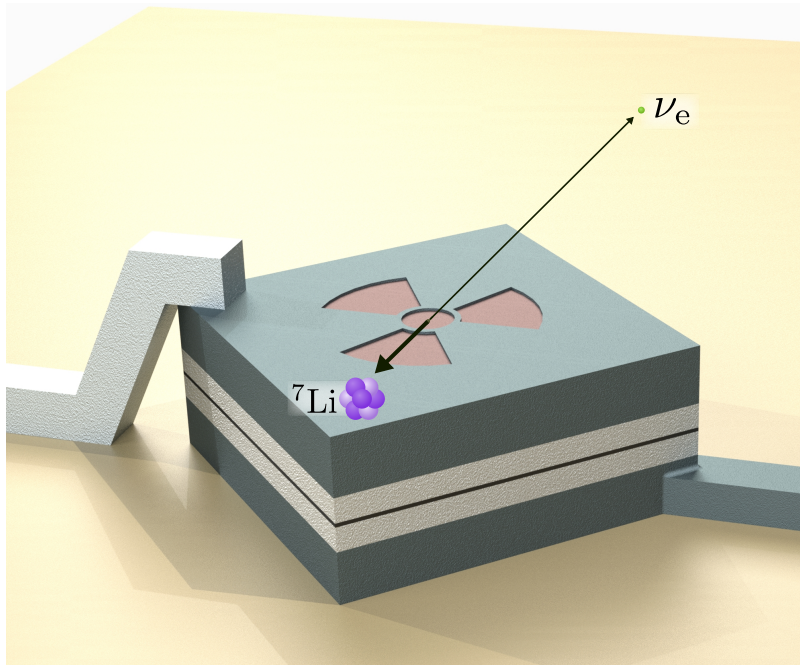


- 1 us rise-time
- 300 us decay-time
- Perfect exponential shape

- Completely insensitive to thermal phonons (~1 meV band gap)
- Short excess charge life-time (~μs)

BeEST Experiment for keV Sterile Neutrino Search

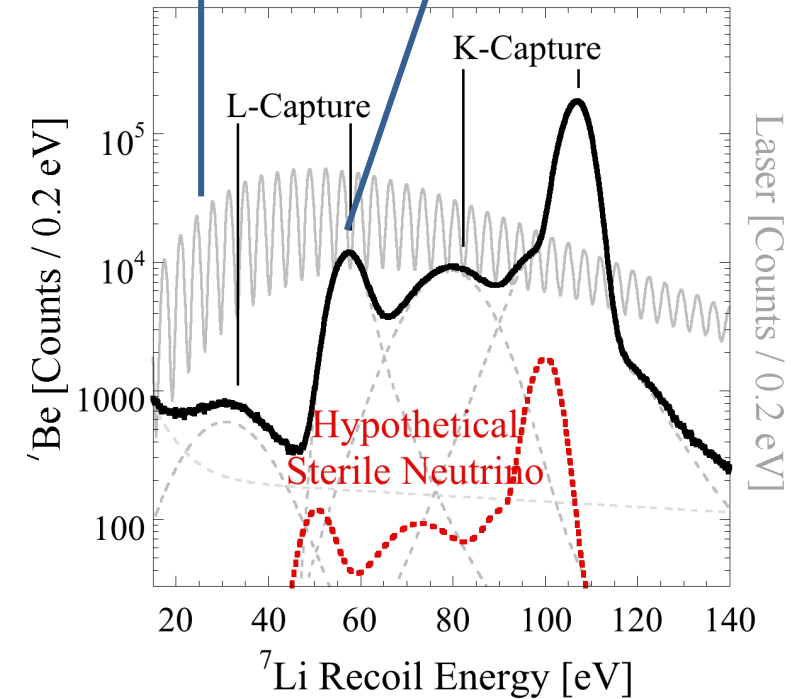
- Measure eV-scale nuclear recoil peaks to search for keV neutrinos



- Implant radioactive ${}^7\text{Be}$ into STJ detectors.
- Measure recoil energy of ${}^7\text{Li}$ daughter.

Consistent with the calculated full recoil energy of 56.828eV

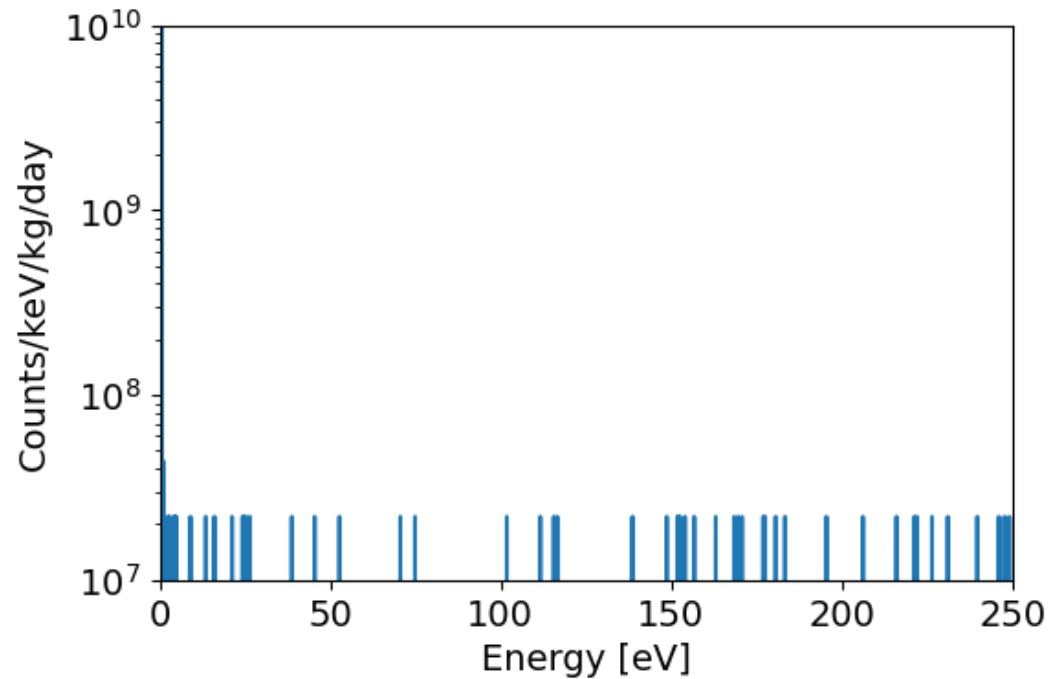
Laser Calibration



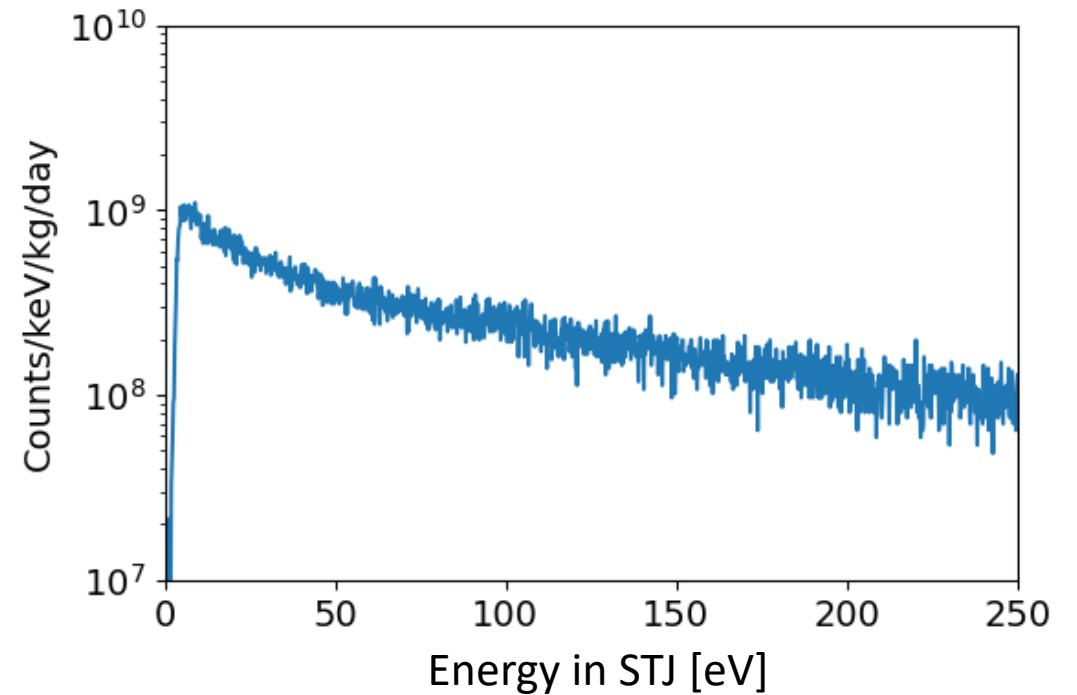
- Heavy sterile neutrinos would reduce ${}^7\text{Li}$ recoil.
- Other BSM particles would affect spectral details.

BeEST Low Energy Data – Coincidence Spectrum

1 day background spectrum (1g)



With ^7Be source (478 keV gamma)



Caveat: Phonon collection efficiency is unknown.
Energy scale might be very different

Summary

- EXCESS is observed in a diamond crystal signals.
- Near term goal is improving pulse shape resolving power at $E < 150$ eV, with improved energy threshold.
- Background run of diamond detector will give useful information, as well as improved shape analysis.
- BeEST STJ detectors have not seen EXCESS in $E < 150$ eV region, in both sensor and crystal hit events. However, phonon collection efficiency might be low and it needs energy calibration for Si substrate events.



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