SuperCDMS HVeV: Single Charge Resolving Silicon Detectors with eV-scale Resolution

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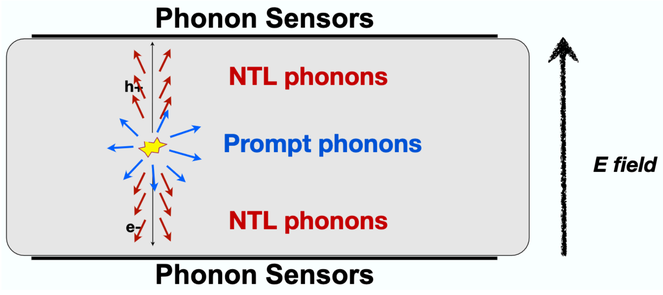
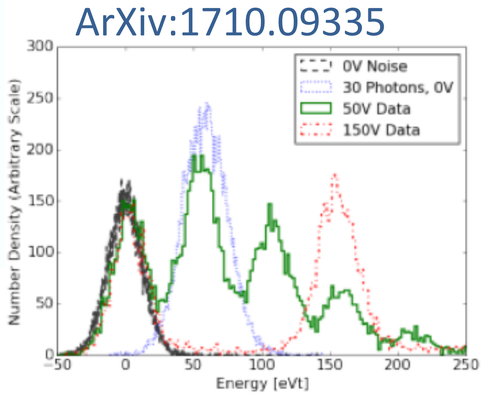
On Behalf of the SuperCDMS Collaboration

Single Charge Detection with HV Gain

SuperCDMS employs phonon calorimeters with eV-scale resolution to detect athermal phonons generated in Si crystals. With a high crystal bias, the total phonon energy is proportional to the charge produced by an event. We can achieve exquisite charge resolution by operating around 100V bias.



ArXiv:1710.09335

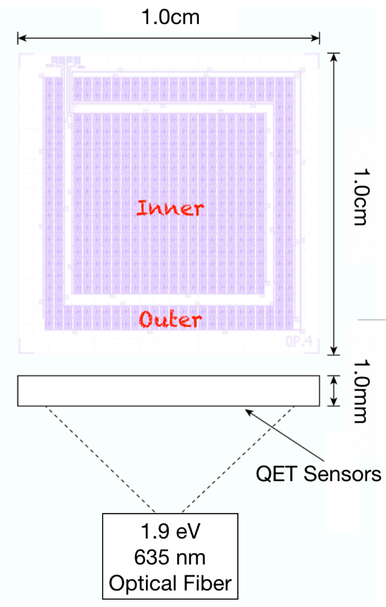


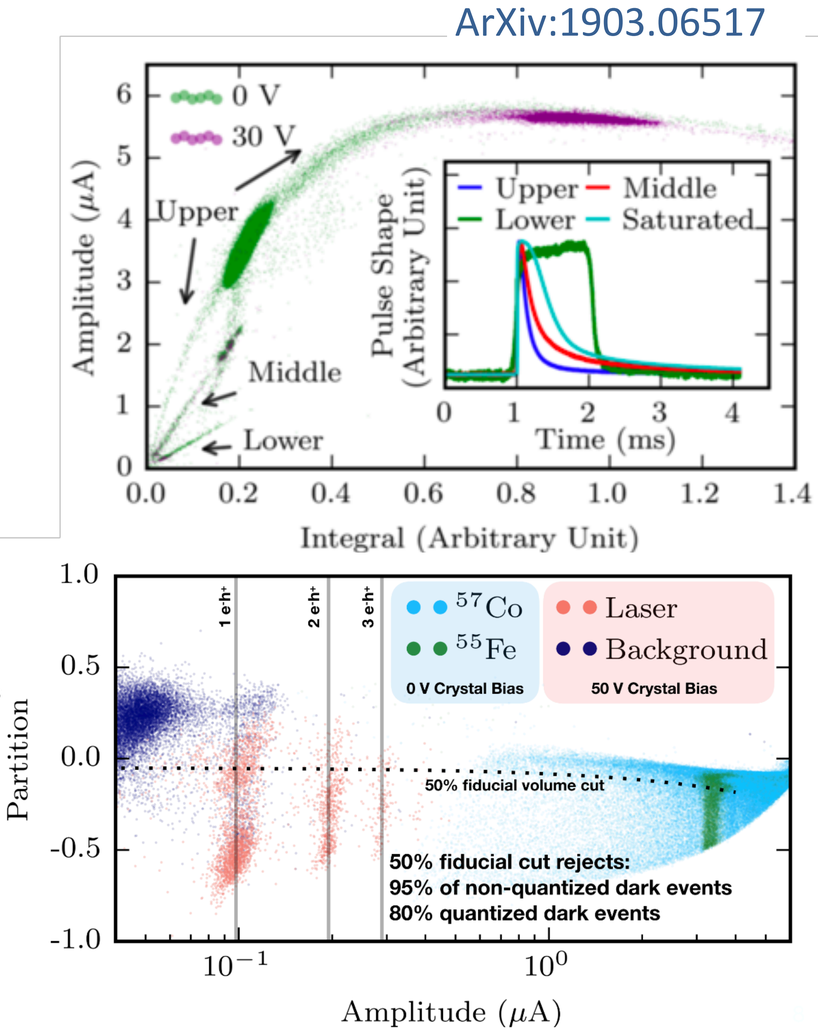
$$E_{phonon} = E_{recoil} + V * n_{eh}$$
$$= E_{recoil}\left[1 + V * \left(\frac{y(E_{recoil})}{\varepsilon_{eh}}\right)\right]$$

Surface Event Rejection

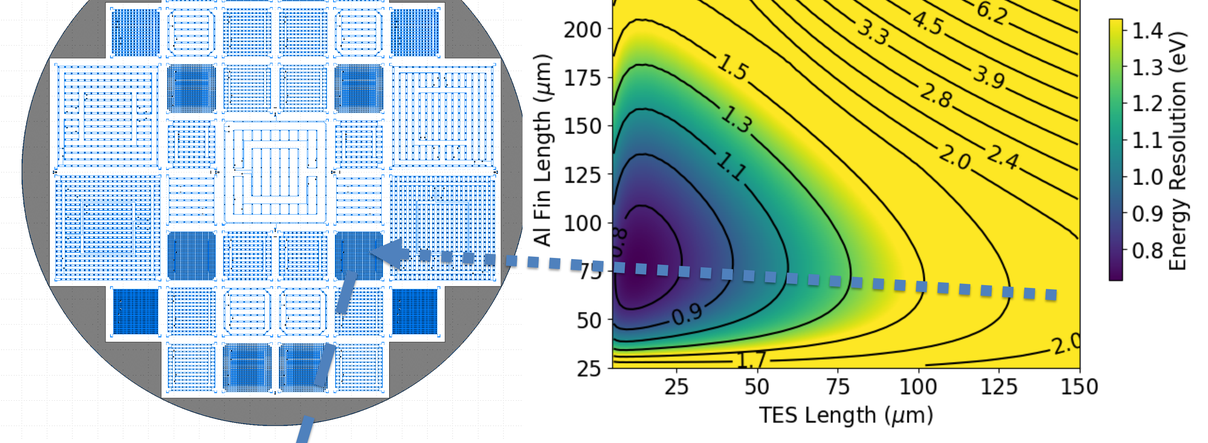
- 1.9 eV laser photons are injected into the cryostat by an optical fiber. Photon pulses, with an average of ~2 photons/pulse are generated uniformly across the instrumented detector surface.
- Rapid absorption of near-surface phonons produces pulse shape differences that allow us to discriminate between bulk and surface events (shown in upper plot)
- The two-channel sensor design (an inner and outer channel) also allows for radial event reconstruction, and rejection of events near the outer walls of the detector (shown in lower plot)

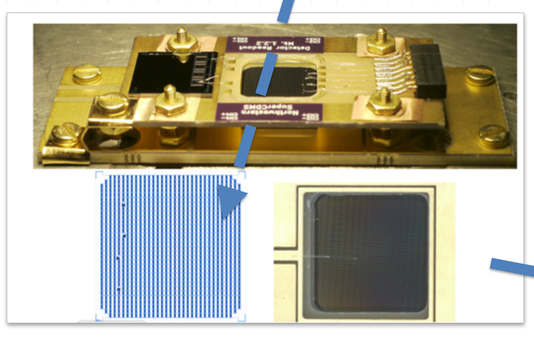
ArXiv:1903.06517

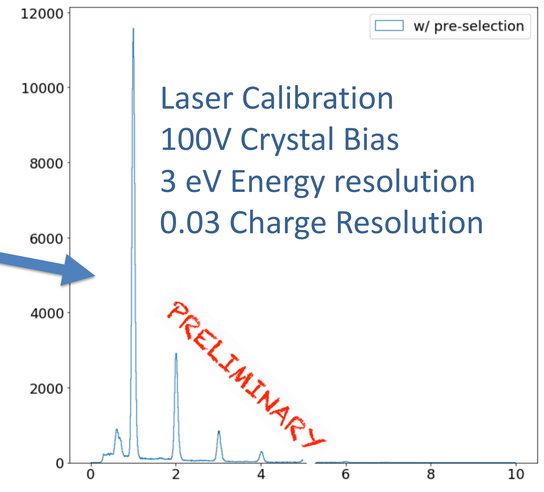




Top: Pulse shape rejection (integral versus amplitude) demonstrating rejection of direct surface hits. Bottom: Radial rejection of non-quantized charge events along the side wall



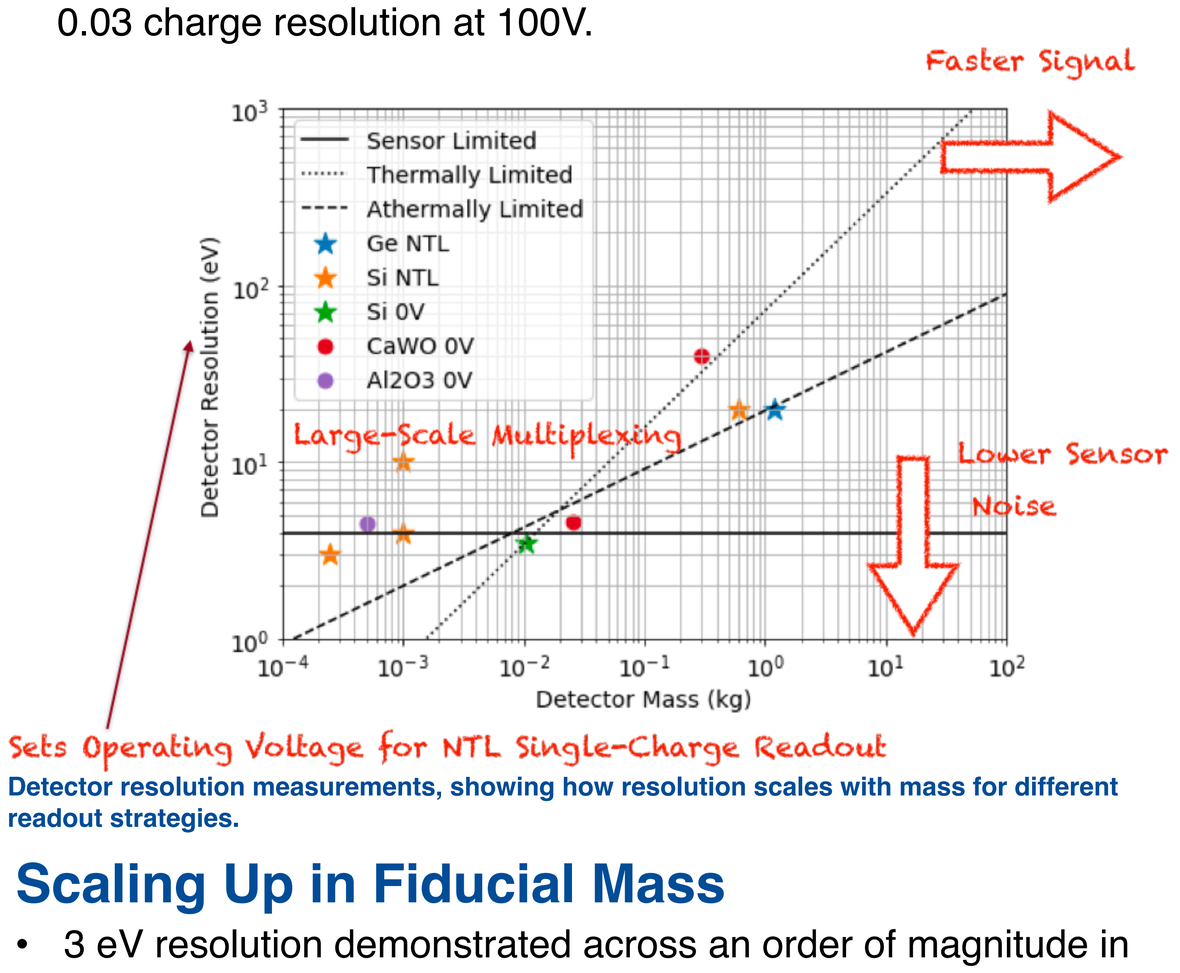




Top Right: Optimization space. Left: sensor layout and realized device. Bottom Right: Initial detector performance for laser calibration data.

Phonon Sensor Optimization

- Detector resolution depends on the energy transport efficiency from the crystal to the TES, and minimizing thermal noise in the TES by minimizing heat capacity.
- This produces an optimization space (above) that we have begun to probe with a dedicated fabrication run of 1cm detectors. The first tested detector achieved 3 eV resolution and 0.03 charge resolution at 100V.



Detector resolution measurements, showing how resolution scales with mass for different readout strategies.

Scaling Up in Fiducial Mass

- 3 eV resolution demonstrated across an order of magnitude in mass.
- Scaling above 10g in mass at the same phonon resolution requires lowering intrinsic sensor noise and faster signal bandwidth.
- Larger mass single electron detectors can also be achieved by increasing maximum bias voltage

Scan for references and more information