First operation and assessment of SuperCDMS SNOLAB detectors at the CUTE facility

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on behalf of the SuperCDMS collaboration

The journey of SuperCDMS detectors

- Detectors assembled at SLAC and shipped to SNOLAB in 2023.

- **At SLAC (0-5 m.w.e*)**:
  - High trigger rate ~ 35 Hz/detector (pile-up, saturation) and very short testing time to avoid cosmogenic exposure.

- **At SNOLAB (~ 6000 m.w.e)**:
  - Reduced cosmic-ray backgrounds (~2 μ/m^2/week)
  - Opportunity to test SCDMS systems (e.g. detectors) in CUTE before the main experiment is operational.
  - CUTE testing experience can inform on useful analyses, operational logistics, train personnel, etc.

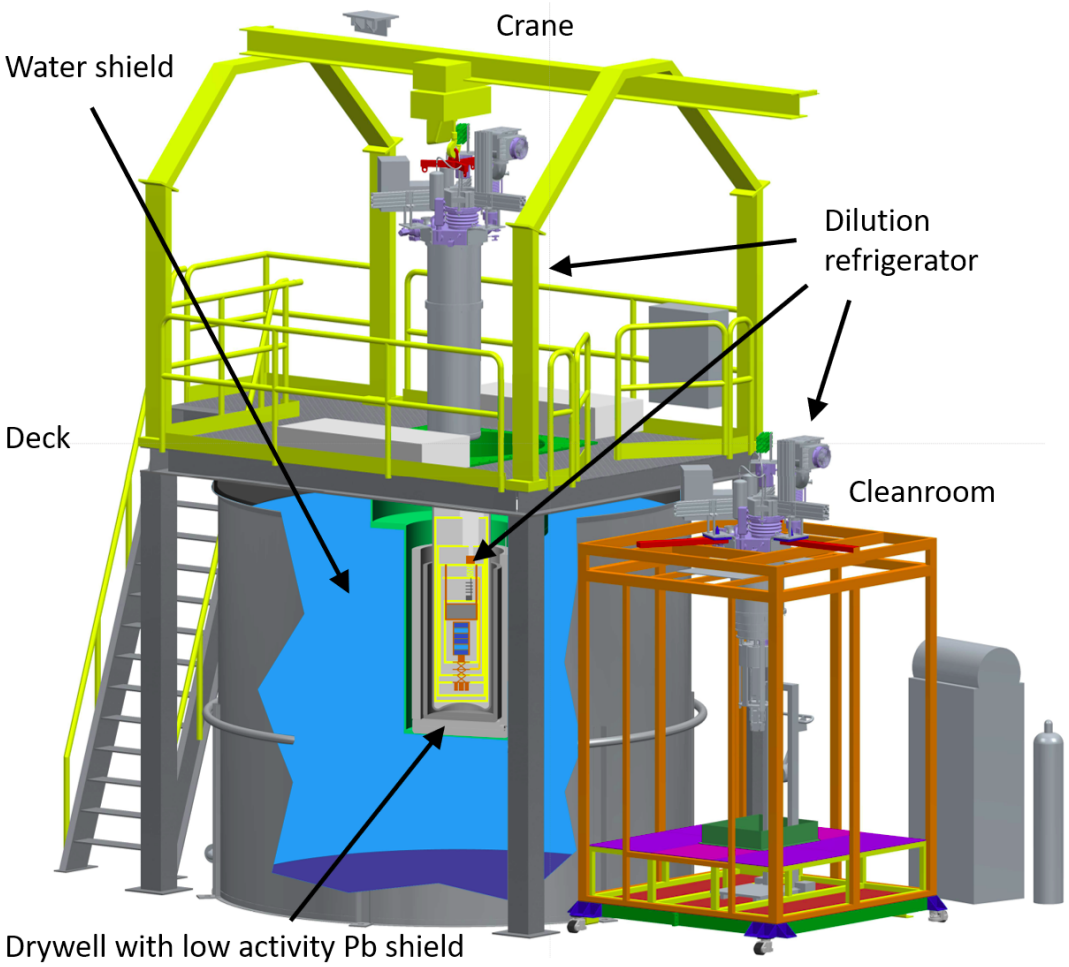
**m.w.e = meter water equivalent*

SuperCDMS: dark matter experiment using ultra-pure Si and Ge detectors to search for low-mass dark matter candidates. (Review Tyler's talk on the status of SuperCDMS SNOLAB)

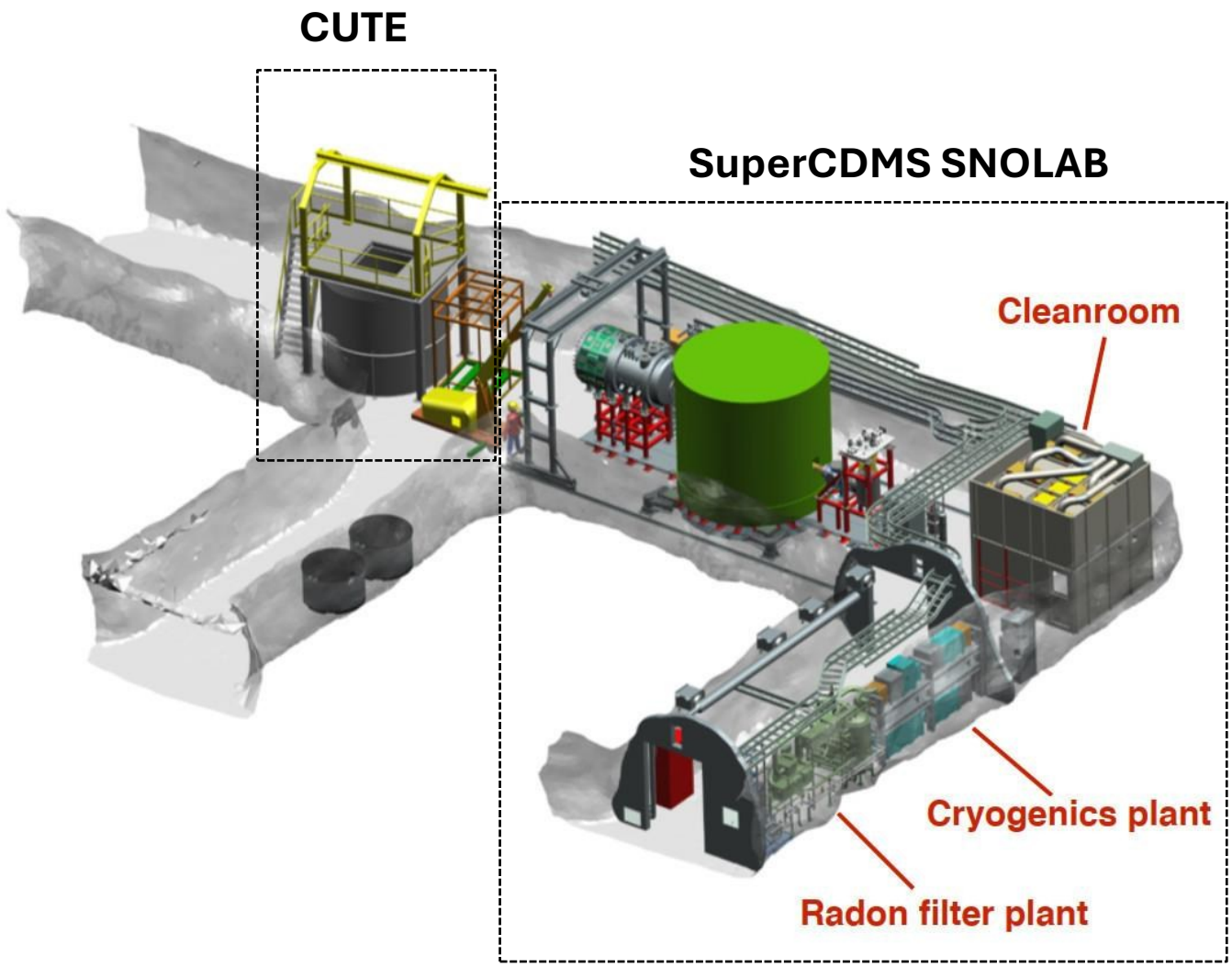
SLAC > Tucson > El Paso > Dallas > Memphis > Sault Ste. Marie > SNOLAB

Indirect +5 000 km truck route to SNOLAB with low altitude to prevent exposing the detectors against too much cosmogenic activation.

Cryogenic Underground TEst facility (CUTE)



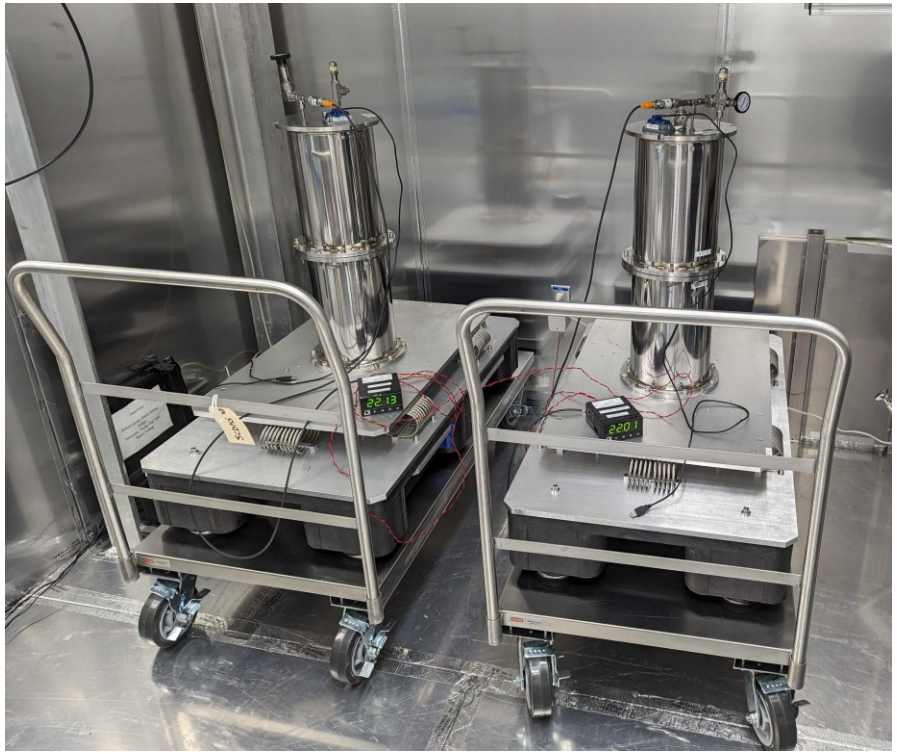
Super Cryogenic Dark Matter Search experiment @ SNOLAB



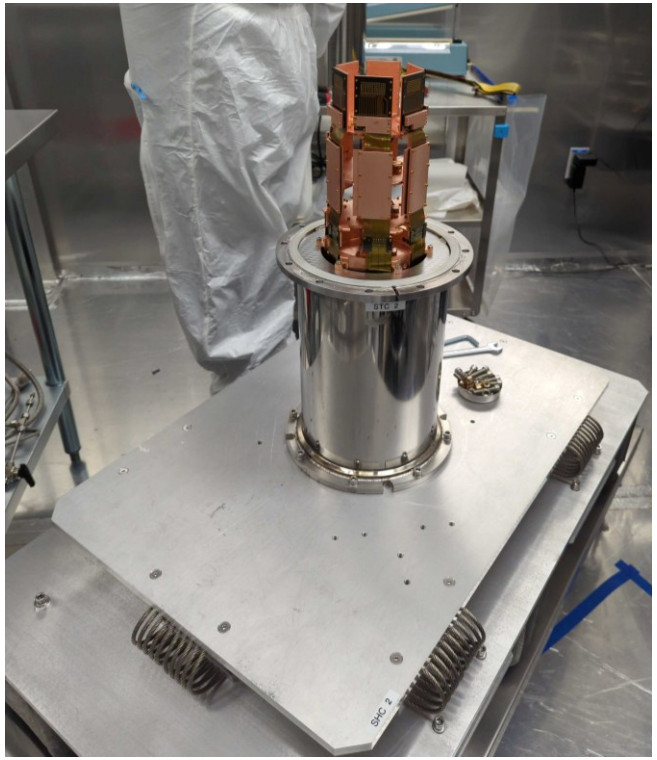
Detector towers in SuperCDMS low-radon cleanroom

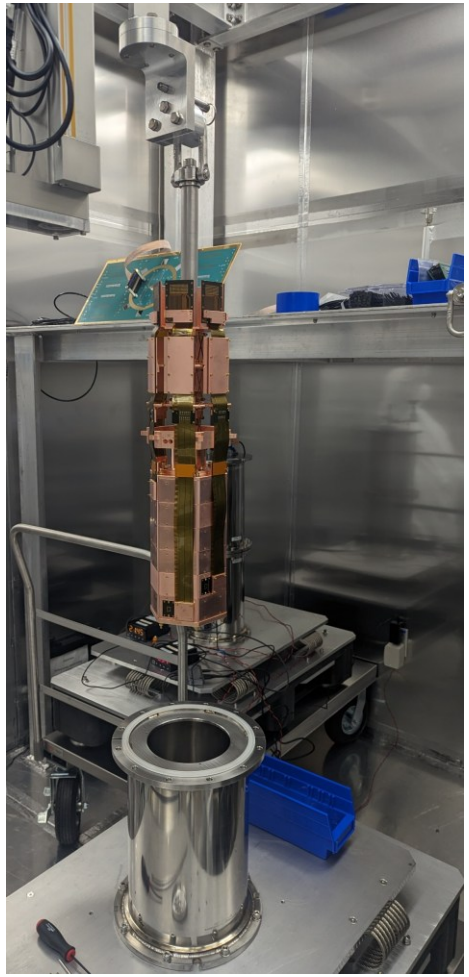
Radon (lab air): ~ 130 Bq/m^3
Radon (cleanroom air): < 1 Bq/m^3

Transport cart & storage container



Tower extraction





Assembly stand

Transferring the detector tower to CUTE

Goal:

Install and operate one SuperCDMS high-voltage (HV) tower in CUTE

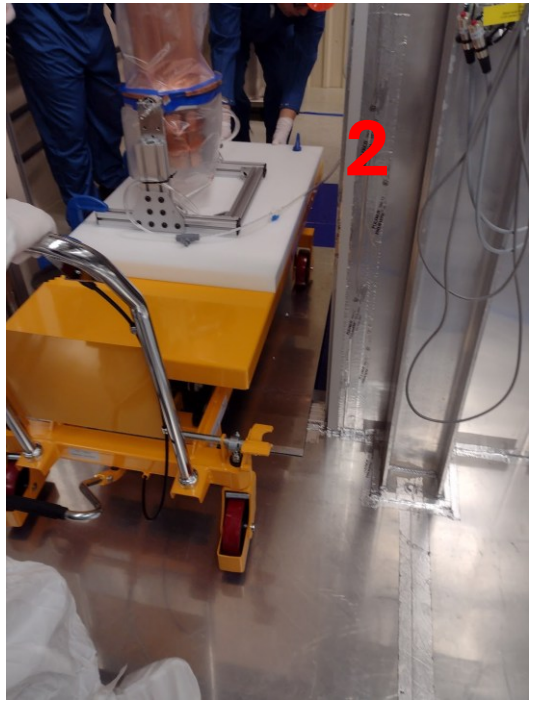
Challenges:

- The tower is fragile. Jolts/vibrations could damage wire-bonds and tensioned coax wires in the tower.
- Not expose the tower to a non-cleanroom environment (avoid dust or radon contamination).
- Insert tower into the CUTE cleanroom (1.84 m x 1.84 m x 2.3 m).
- Emergency plan in case of a “call to refuge”.

Distance between cleanrooms

CUTE cleanroom

1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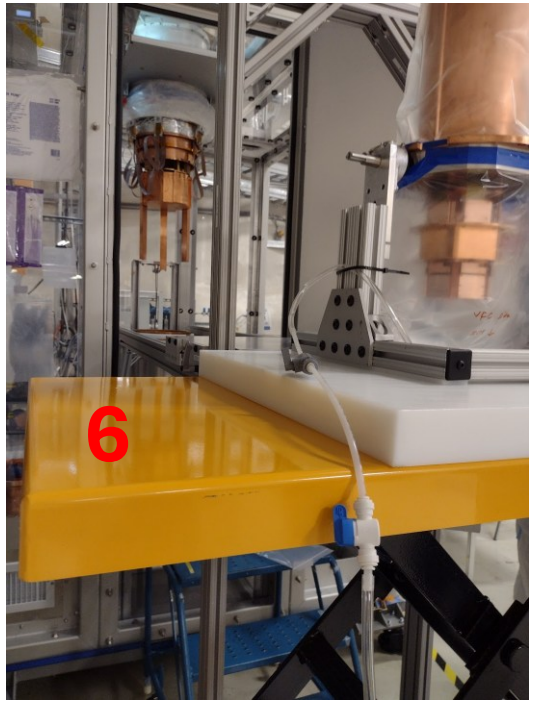
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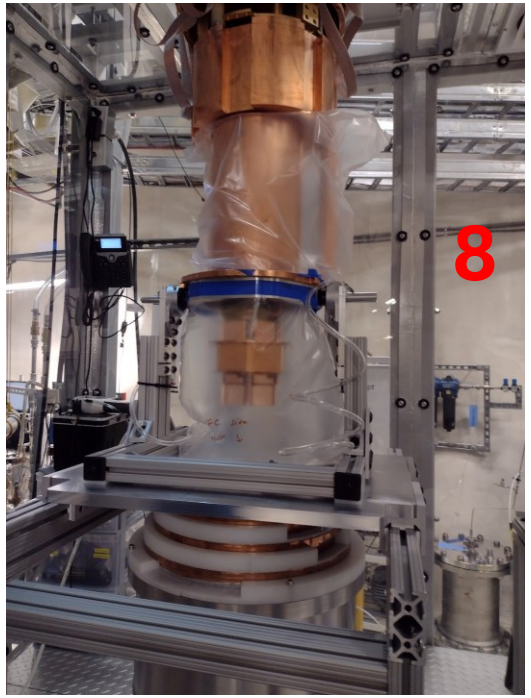
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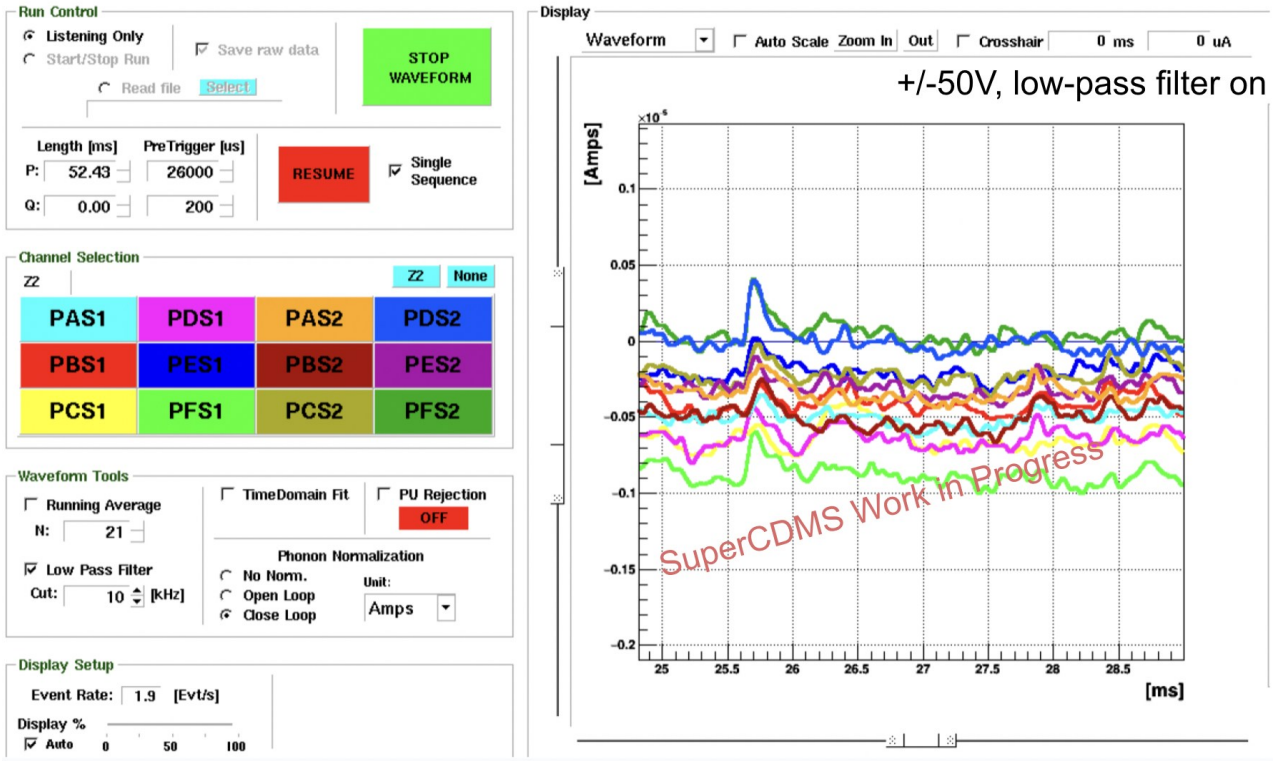
Detector operation

- HV Tower #3 (2 Si / 4 Ge crystals) tested from Oct. 2023 - Mar. 2024.
- Operated at multiple bias voltages (up to 100 V).
- ~2 months of calibration data.
- ~2 weeks of low background data.



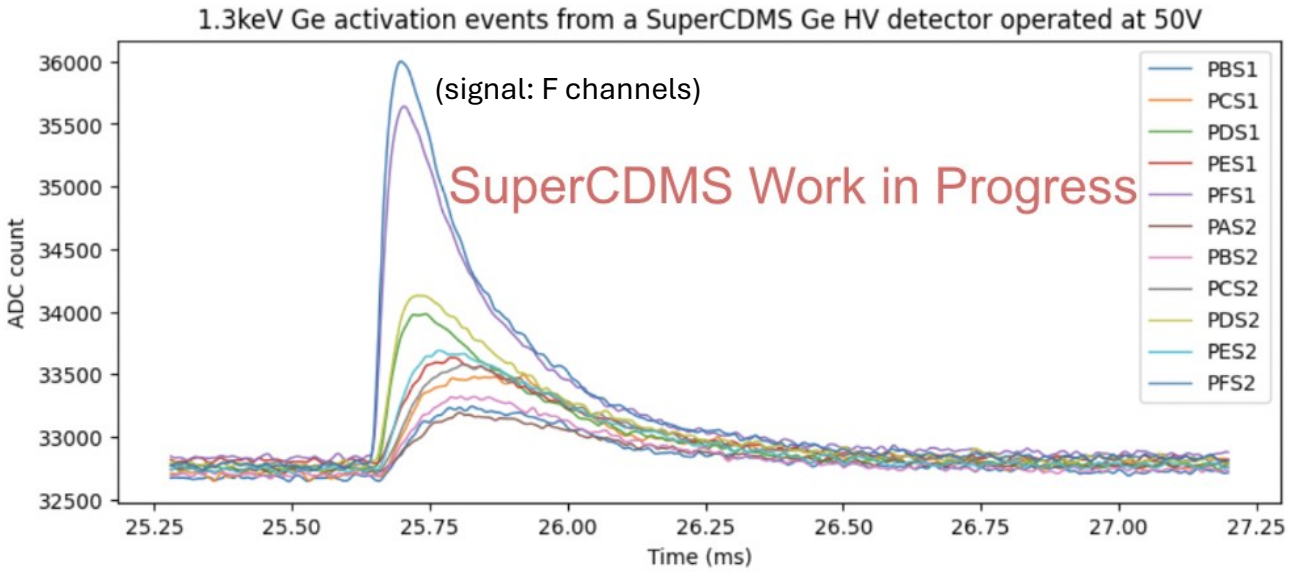
Some analysis tasks

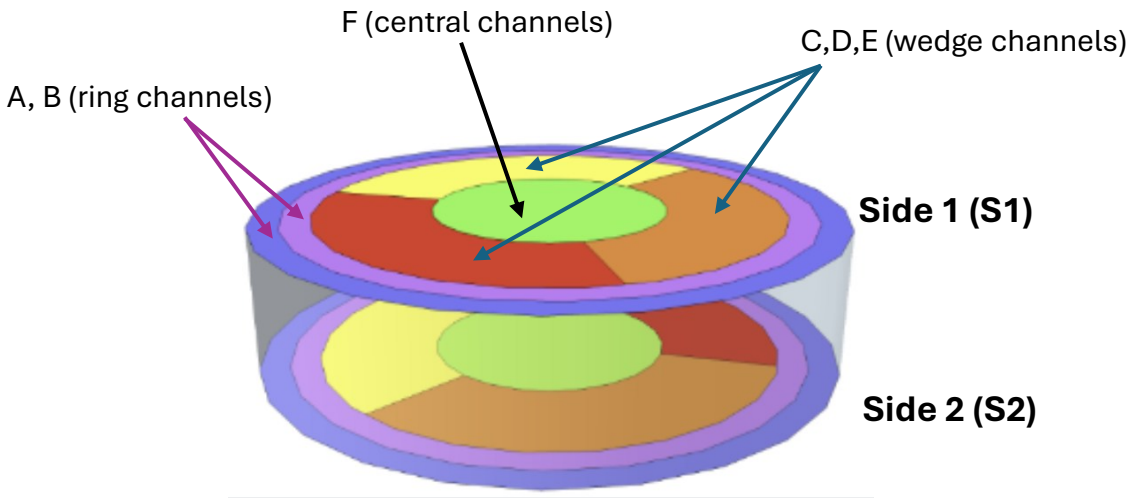
- Identifying features in the energy spectrum for calibration (i.e. Ge activation peaks, Si Compton steps)
- High Voltage amplification study
- Detector efficiency calculation
- Noise characterization (e.g. CUTE vs SLAC, readout electronics, effect of lab WiFi)

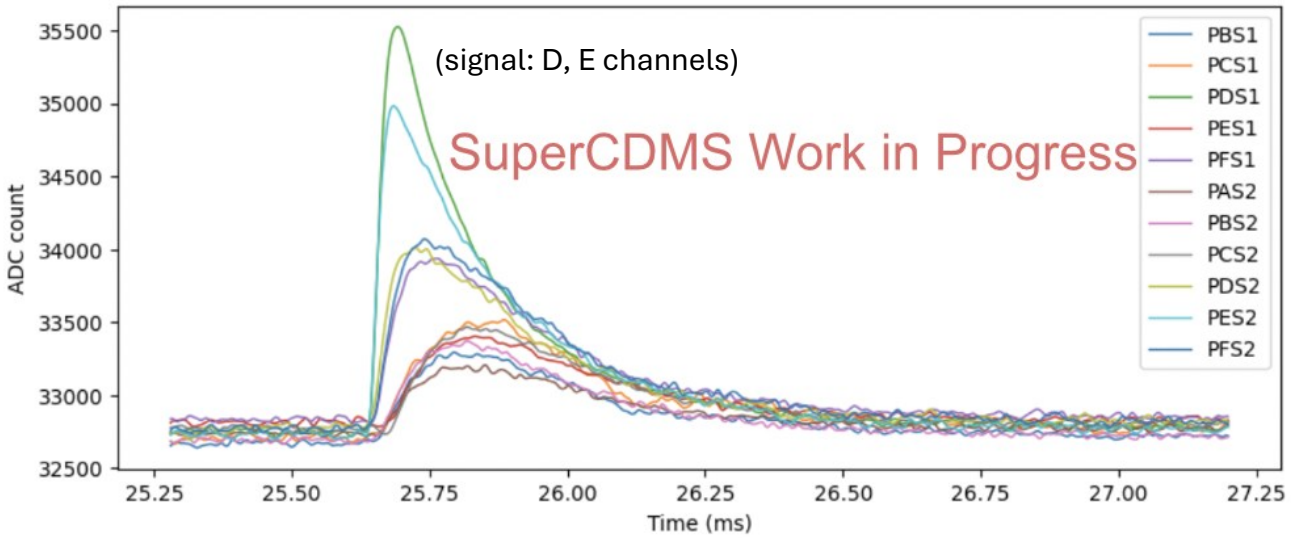
HV detector signals

Two events detected by a Ge detector operated at +/-25 V during CUTE tower testing.

The raw pulses of different channels suggest strong position dependence. This will be exploited to develop a fiducial volume cut.







Ge calibration

^{252}Cf neutron source

- $^{70}Ge + n \rightarrow {}^{71}Ge$ ($T_{1/2}$ = 11.43 d)

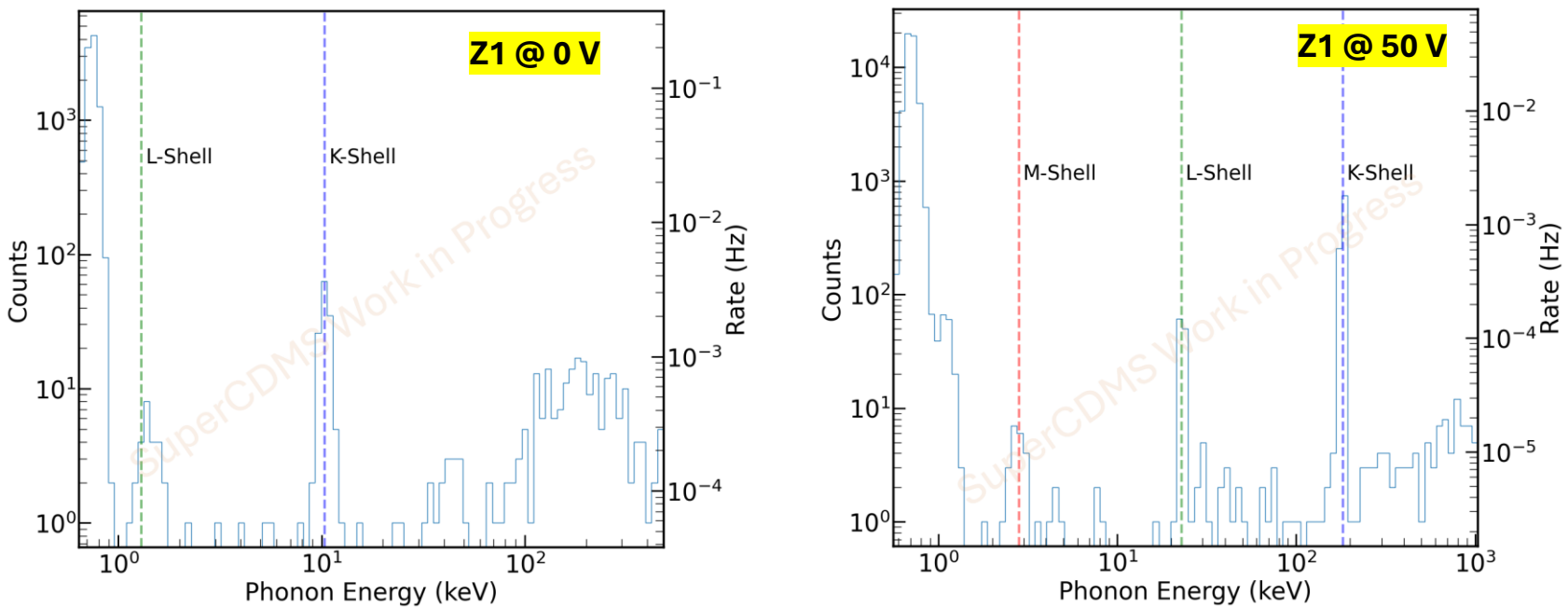
Electron-capture decay:

$^{71}Ge + e \rightarrow {}^{71}Ga + \nu_e$

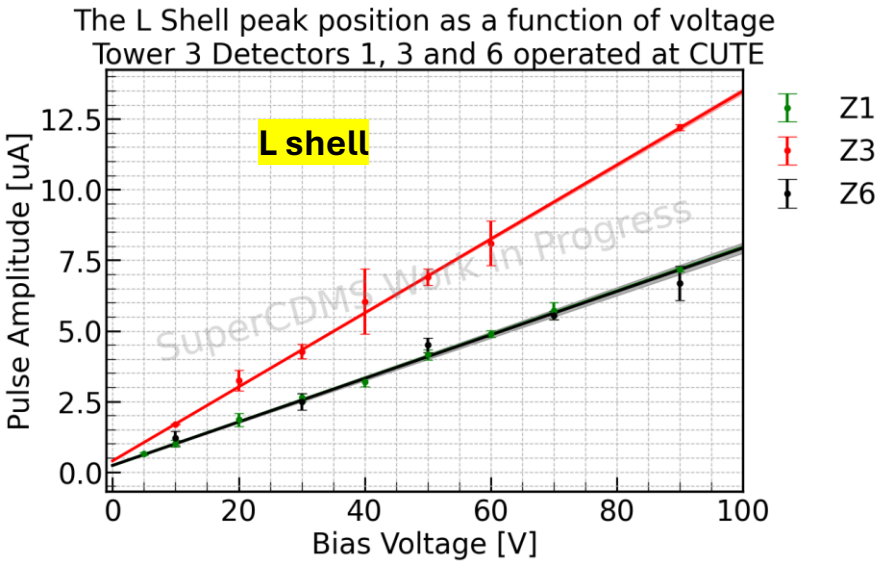
Binding energies:

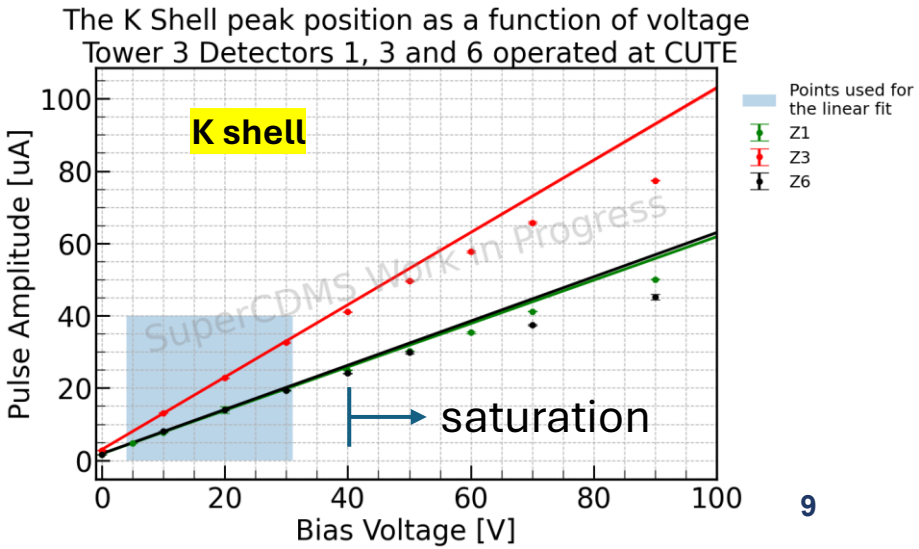
- K-shell: ~10.37 keV
- L-shell: ~1.3 keV
- M-shell: ~0.16 keV

Calibrated detector response to low-energy electron recoils



High Voltage amplification





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Baseline resolution of Ge detectors

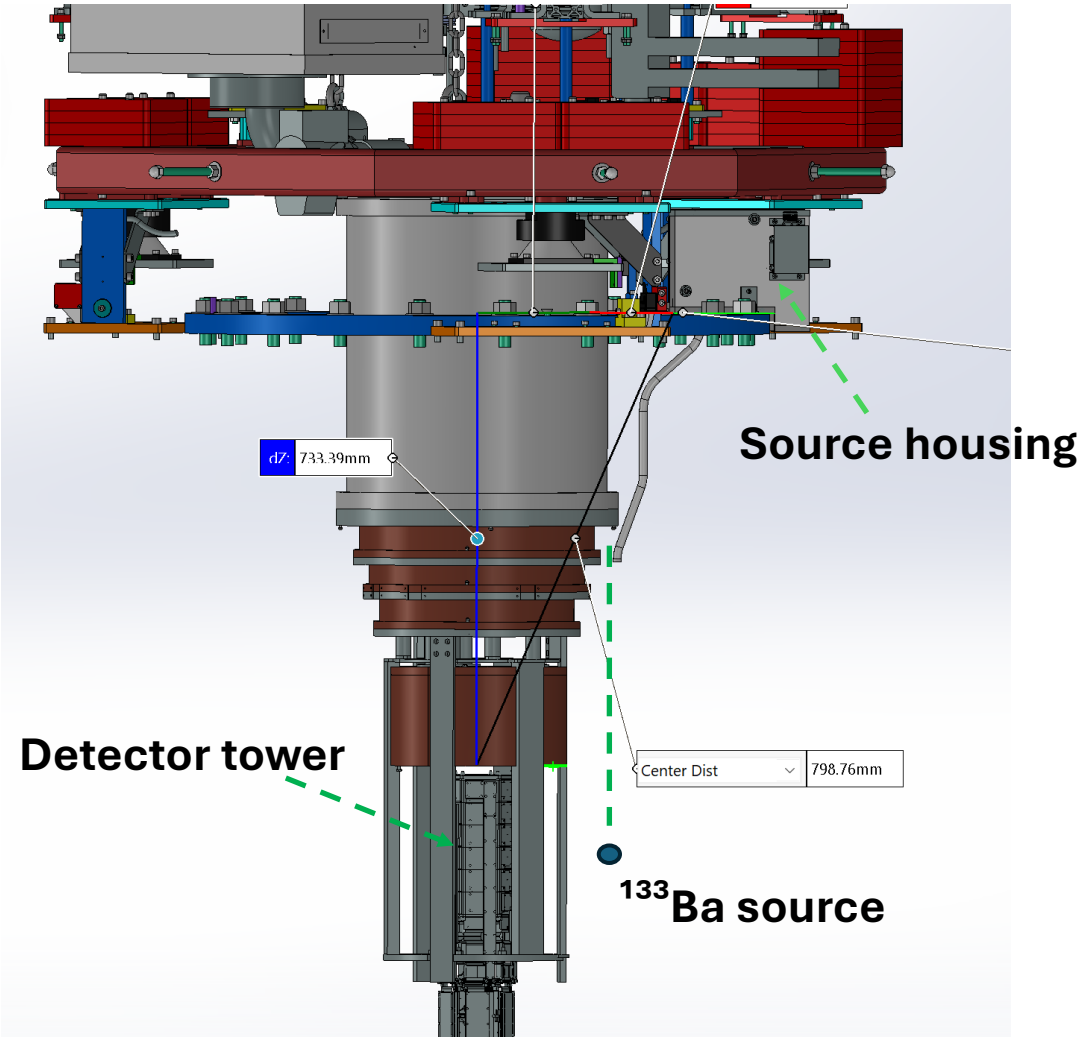
Summary of measured baseline resolutions in total phonon energy units; SuperCDMS Work in Progress Results	
Detector/Voltage	**Best baseline resolution (eV)**
Z1 @ 0V	84.6 ± 0.7
Z3 @ 0V	73.2 ± 1.0
Z6 @ 0V	307.7 ± 13.0

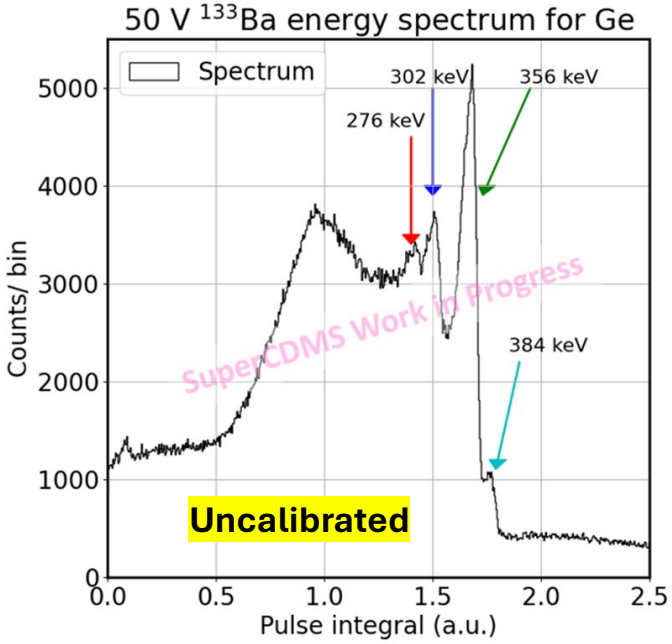
Detectors 1 and 3 have baseline resolutions consistent with expectations at SNOLAB (further improvements anticipated).

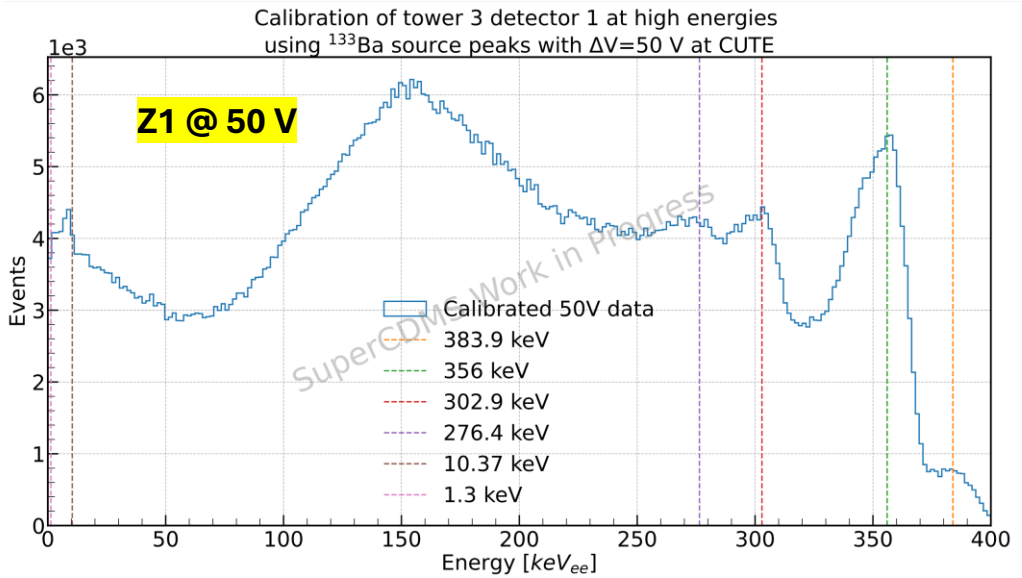
Detector 6 is underperforming (investigation ongoing). Not representative of the baseline resolutions of SNOLAB detectors.

Ge calibration

Calibrated high-energy spectrum by deploying a ^{133}Ba γ-ray source







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Final remarks

Significant progress in the construction of SuperCDMS SNOLAB.

- All detector towers already underground
- Data taking expected to commence later this year.

Major milestone for the collaboration: successful testing of a HV tower in the CUTE facility.

- Accomplished the tower installation despite many challenges.
- Satisfactory operation of the detectors over four months. Valuable data collected.
- Data analysis in progress.
- Demonstrated the possibility of performing low- and high- energy calibration of Ge detectors. (Paper in preparation)

SuperCDMS collaboration meeting @ SNOLAB (Summer 2024)

Thanks for your attention

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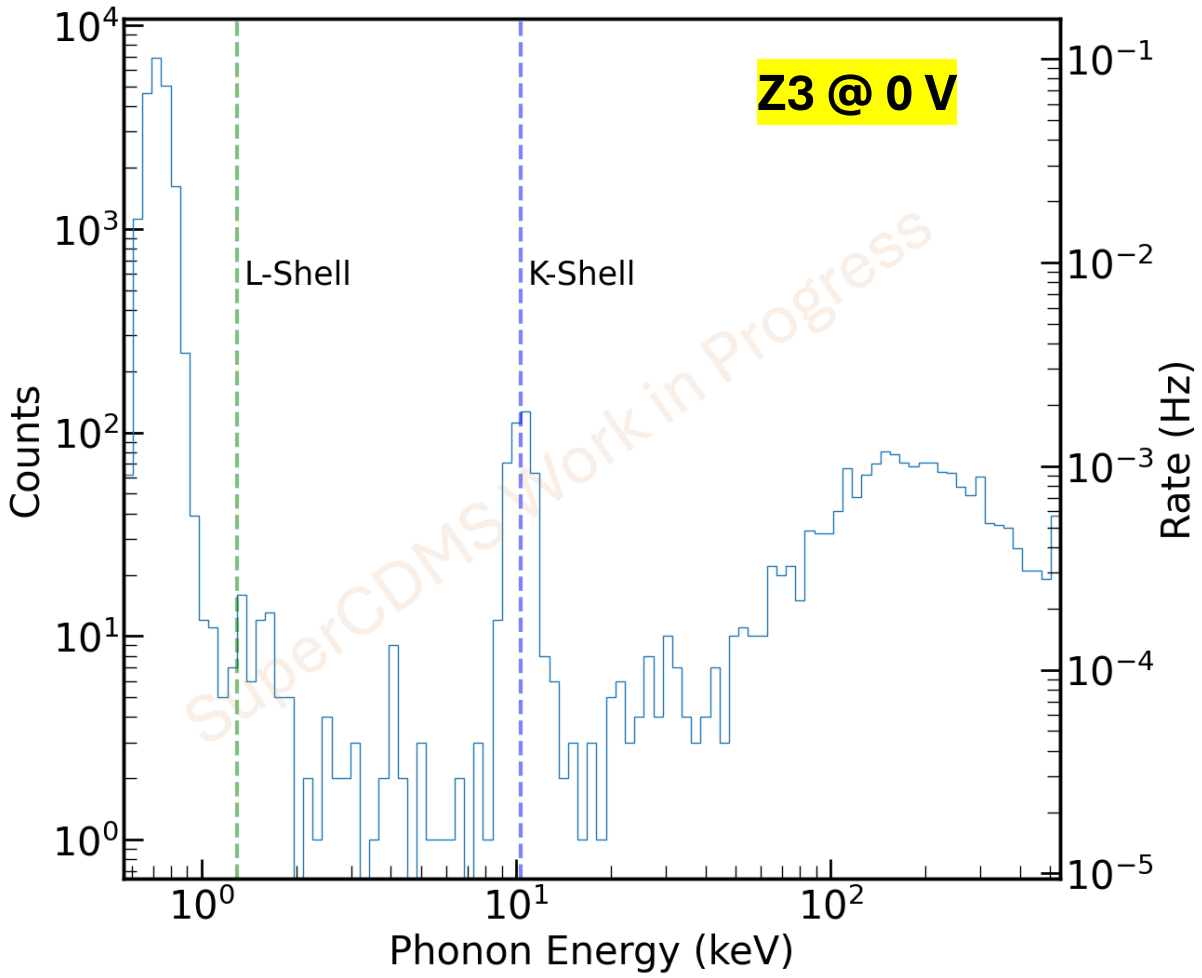
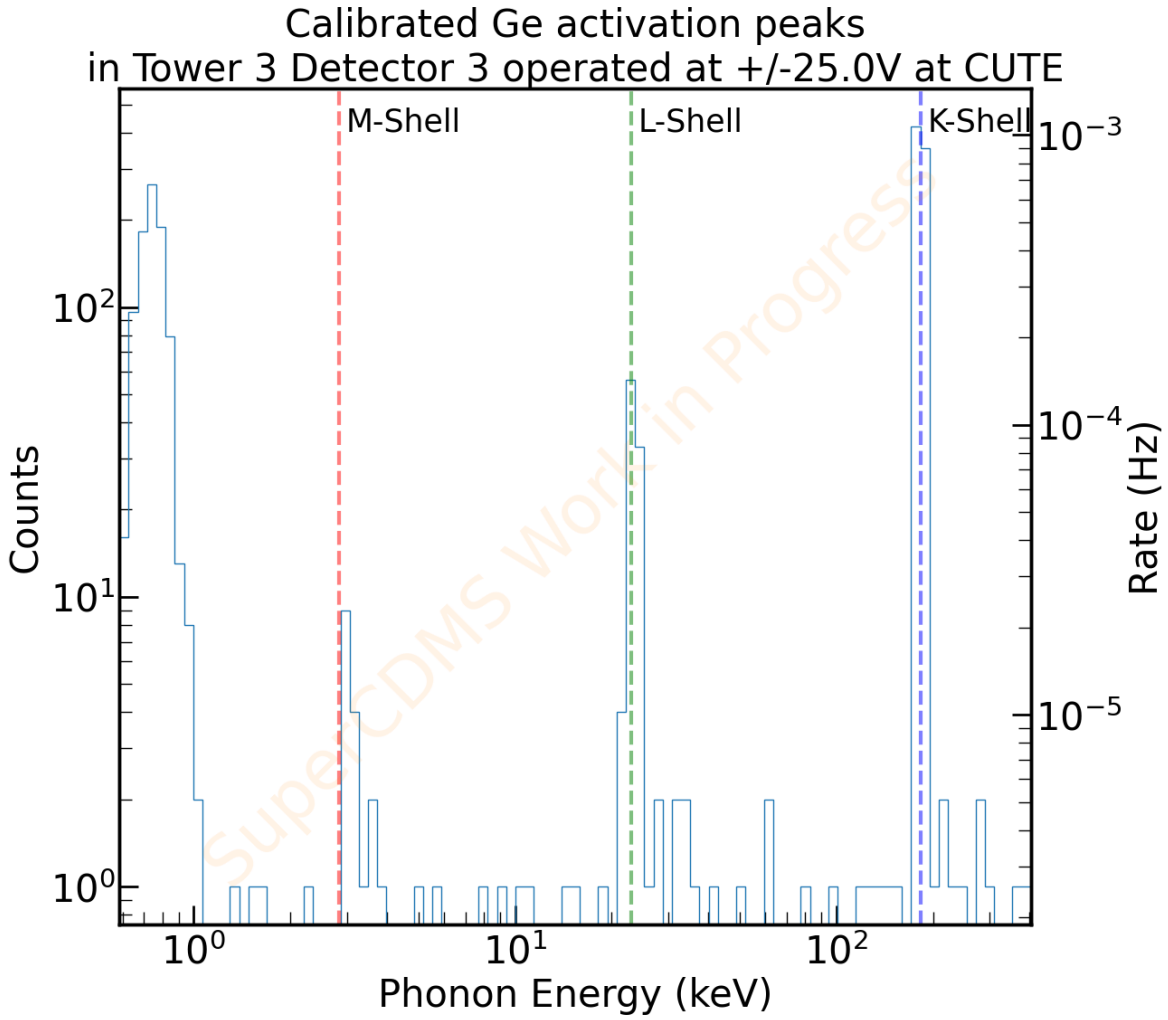
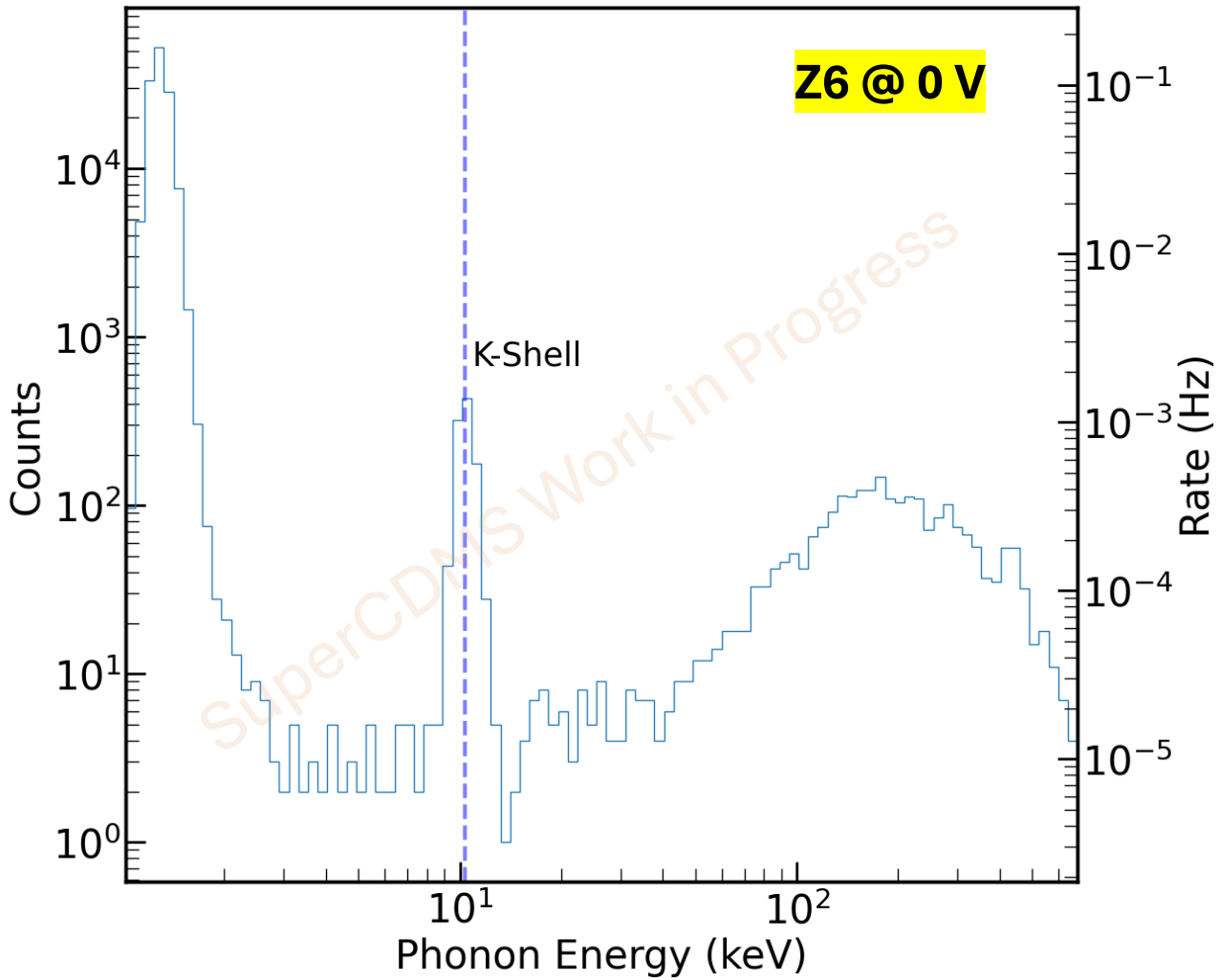
Extra slides

Calibrated energy spectrum for Ge detector 3

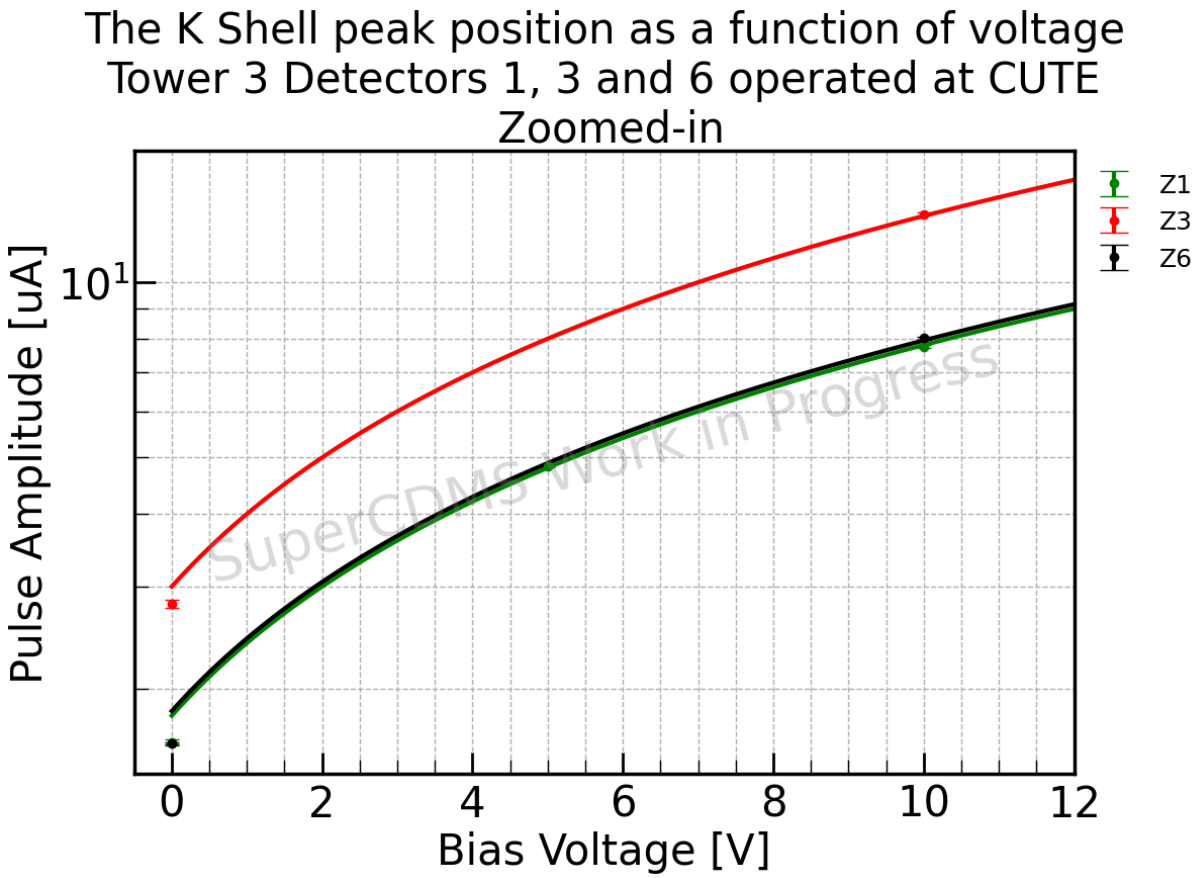




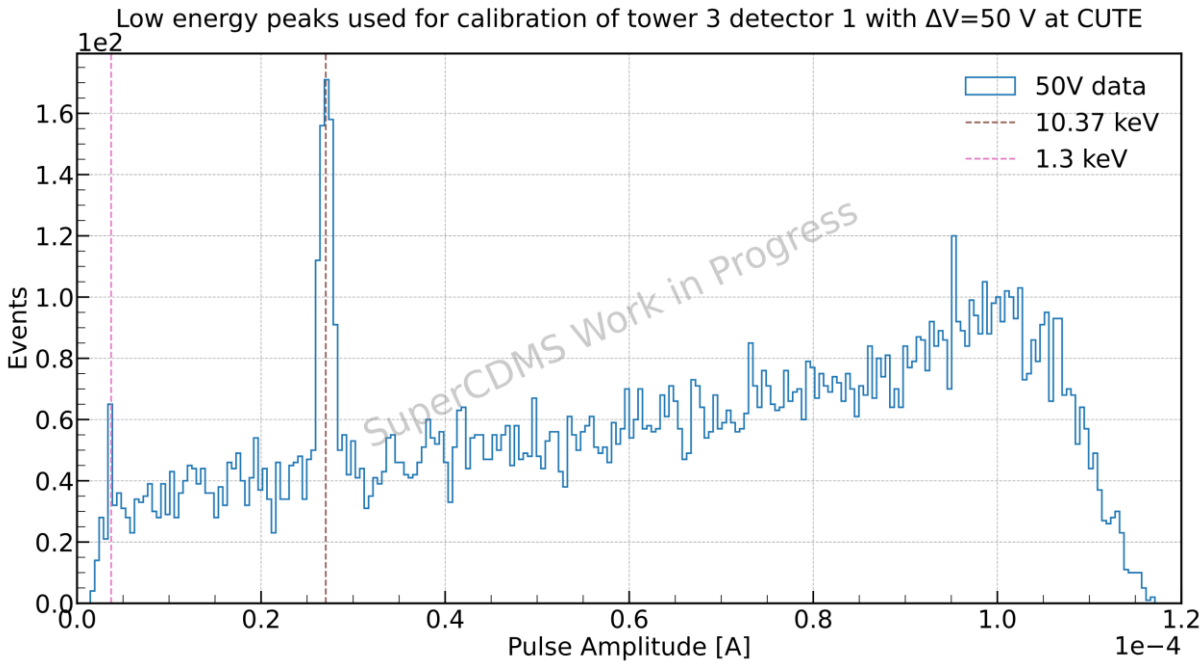
Calibrated energy spectrum for Ge detector 6

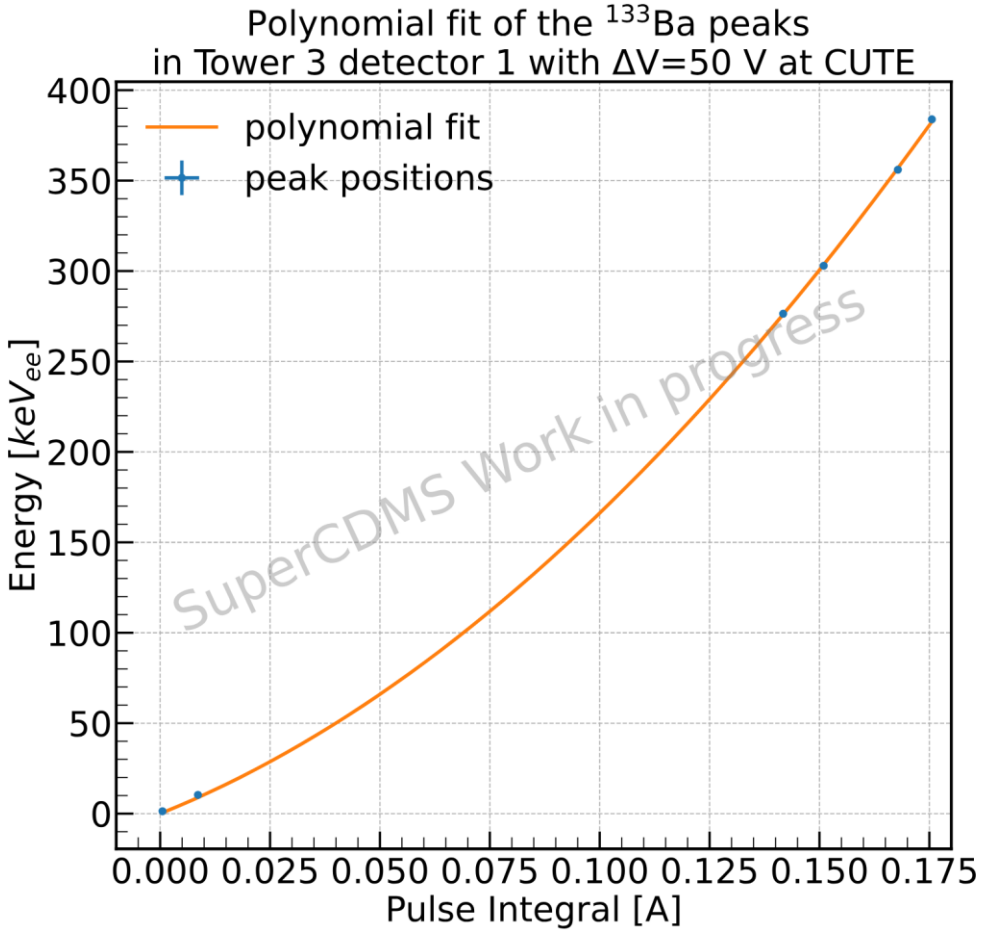


HV amplification (Zoom-in)

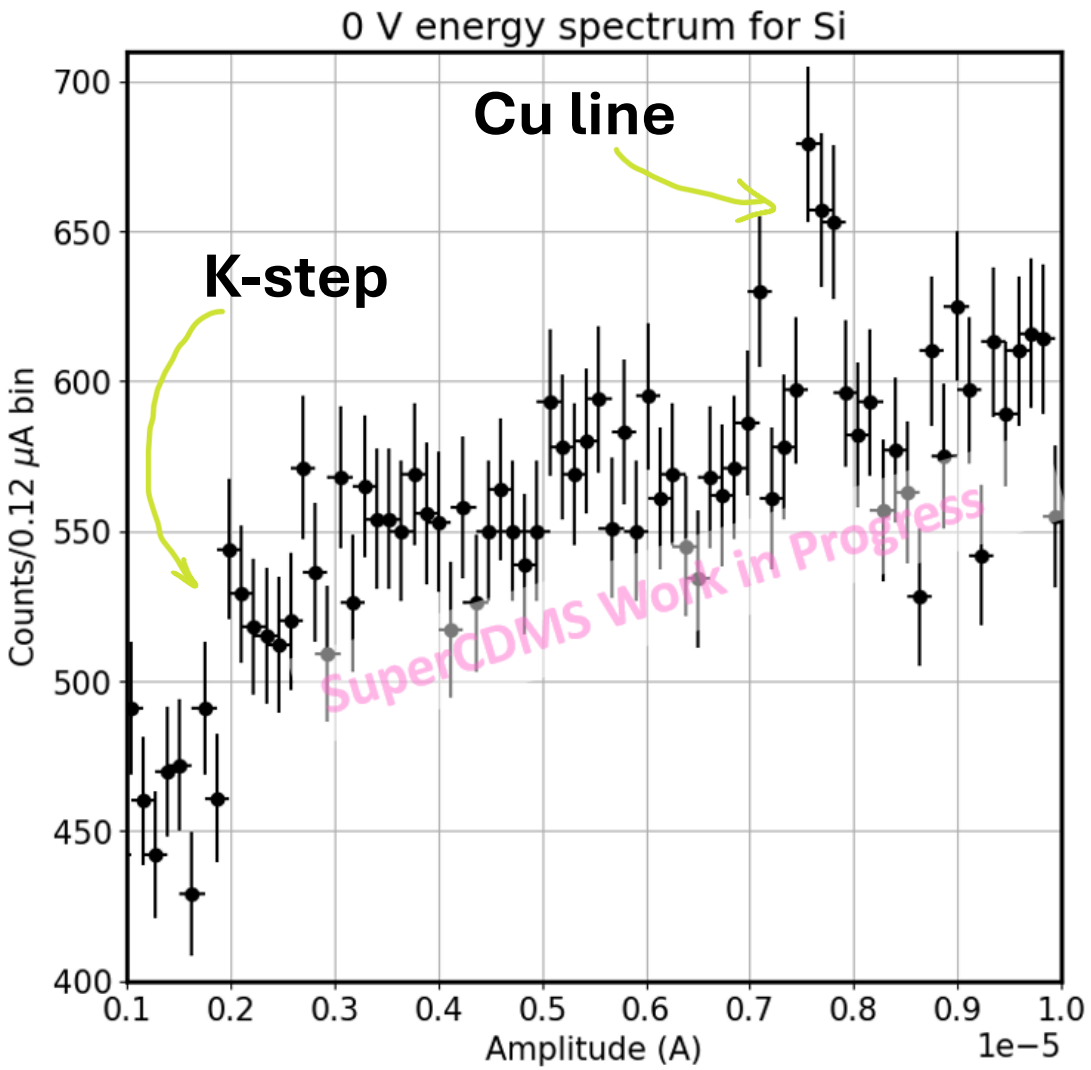


High-energy calibration





Si calibration



Si detectors lack suitable activation lines for the low-energy calibration.

Alternative approach: Si Compton steps produced by ^{133}Ba gammas for calibration down to 100 eV.

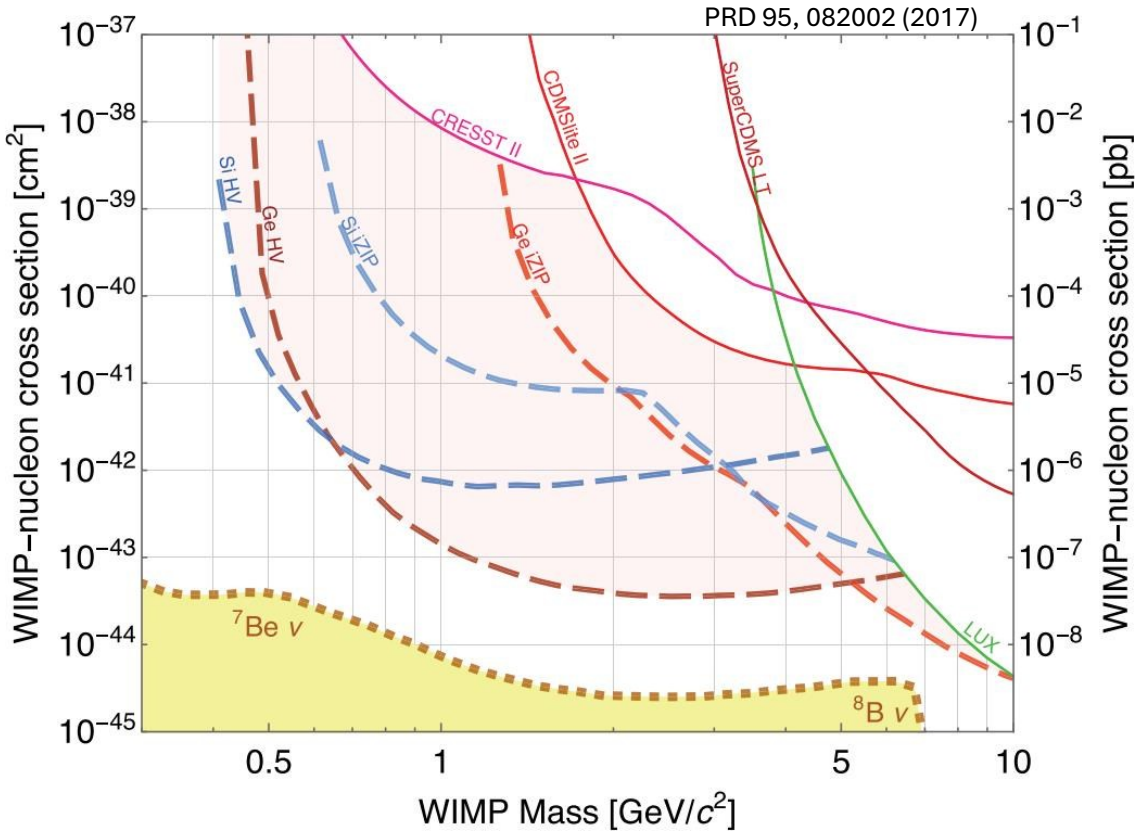
Features:

- 1.8 keV Compton step (photon interactions with K-shell e-).

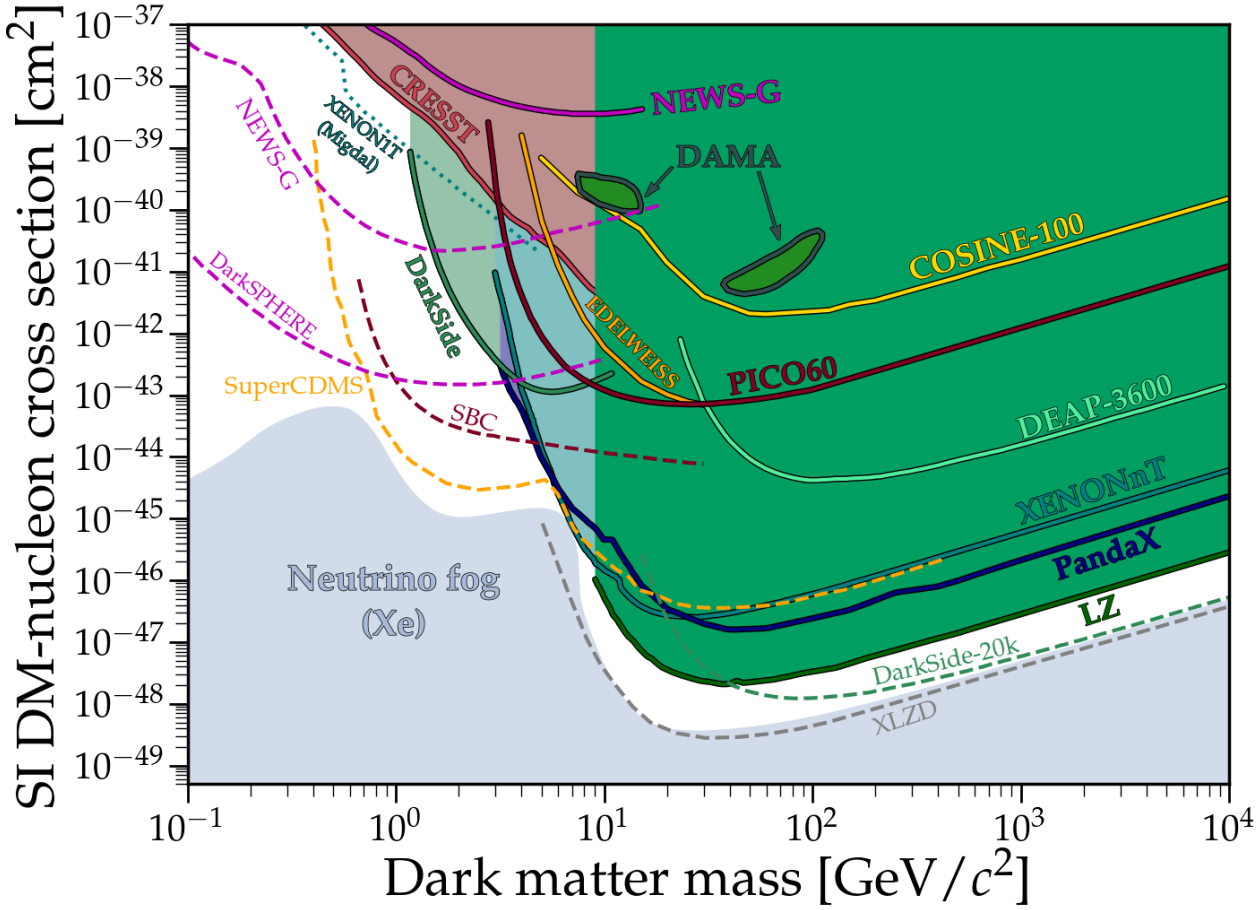
- 8.1 keV X-ray fluorescence line (photon interactions with copper, e.g. detector housing).

SuperCDMS science reach

Primary science goal: search for nucleon-coupled dark matter in the 0.5 - 5 GeV/c² mass range



Credit: cajohare/**DirectDetectionPlots**



Secondary science goals: Sub-GeV DM via electron scattering, Axion-Like Particles, ^{8}B solar neutrinos observation, etc.