First results from testing SuperCDMS SNOLAB detectors at CUTE

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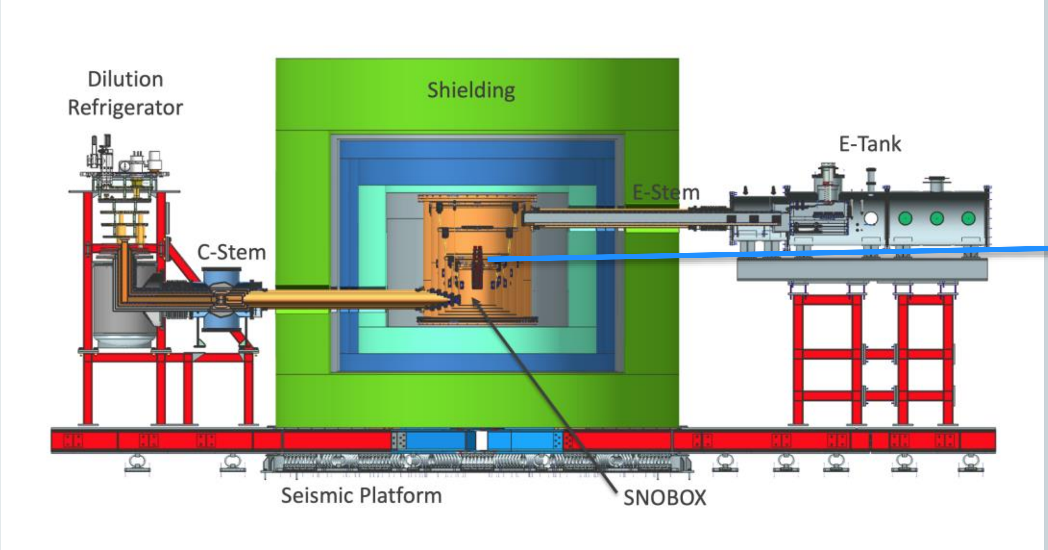
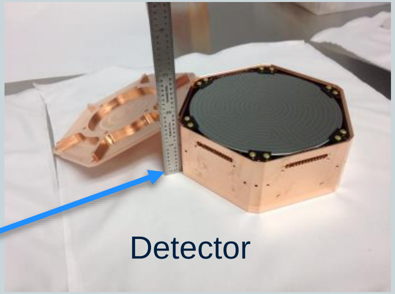
On behalf of the SuperCDMS collaboration

The SuperCDMS SNOLAB experiment

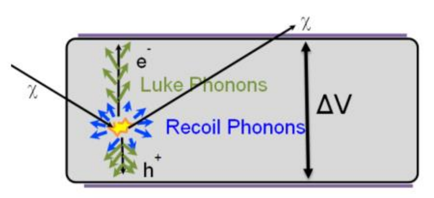
- 2^{nd} generation dark matter experiment at SNOLAB
- Cryogenic detectors which measure **phonons and ionization signals**
- Operated close to absolute zero (~ 10 mK)
- Payload in the form of towers with 6 detectors each (4 towers = 24 detectors)



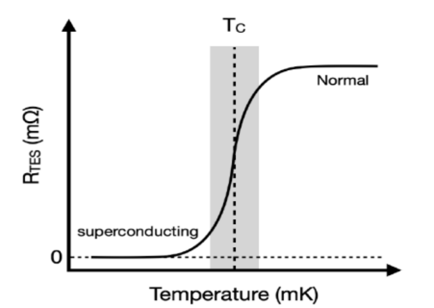


The SuperCDMS SNOLAB experiment

- Two kinds of detection technology:
    - Bolometric detection of **phonons** with **Transition Edge Sensors**
    - **Ionization** readout with **High Electron Mobility Transistors**
- Detector substrates: **Ge** and **Si** crystal
- Two detector types:
    - **iZIPs**: Phonon + charge readout (**NR/ER discrimination**)
    - **HV**: Amplified phonon only readout (**Lower threshold**)



$$E_T = E_R \left(1 + Y(E_R)\frac{eV_b}{\epsilon_{eh}}\right)$$



More info in next talk by Emanuele Michielin…

Why should we test and characterize detectors?

Early physics

- Detector calibration
- Noise characterization
- Background estimation
- Potential early dark matter searches

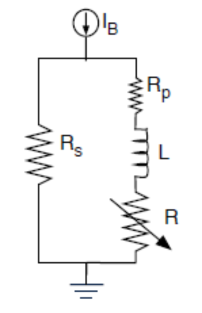
Logistics

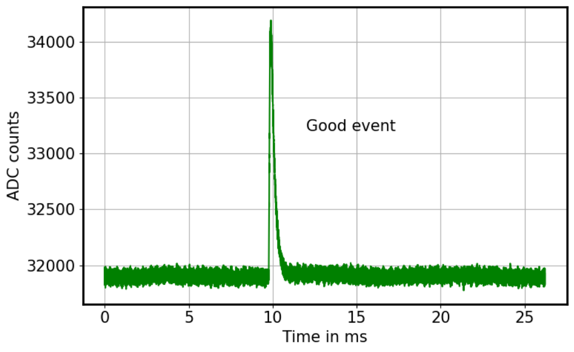
- Establishing functionality
- Optimizing operational logistics
- Assessing detector performance
- Identifying aspects that require improvement
- Personnel training

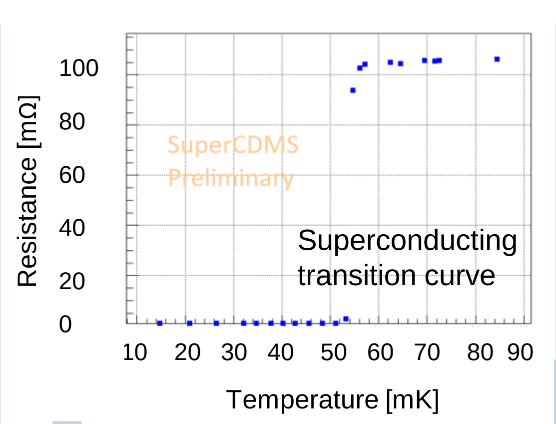
Preliminary tests at SLAC

- Ground level testing with minimal shielding
- Four runs roughly spanning a week each
- One run per tower
- Established basic operability of all devices
- Measured preliminary detector properties (R_p, R_n, optimal I_b etc.)
- Tested high voltage operability up to 100 V

Detector circuit diagram

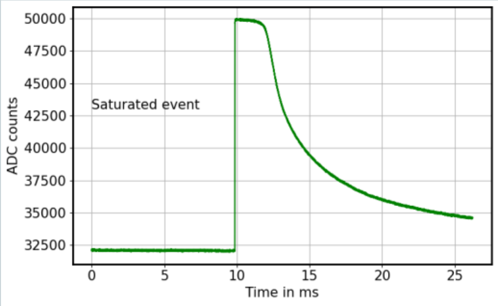


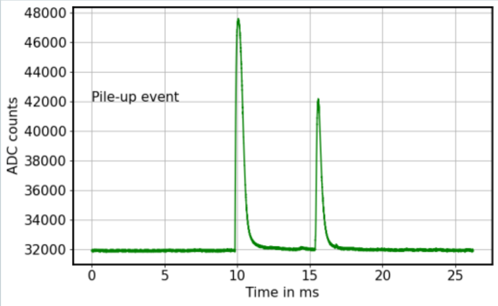




Limitation of on-surface testing

- High trigger rates of 35 Hz/ detector
- Increased cosmogenic exposure
- Very short testing times
- Well-defined set of tasks, but very limited scope





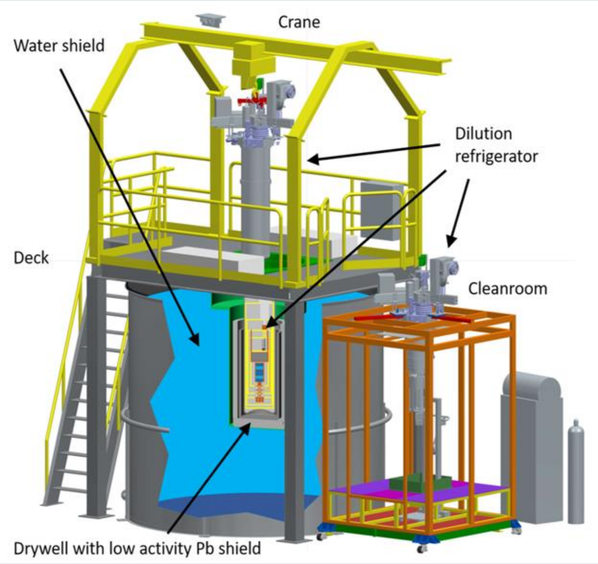
What do we need?

A well-shielded, low background site that supports SuperCDMS-style tower geometry, preferably close to the SuperCDMS site...

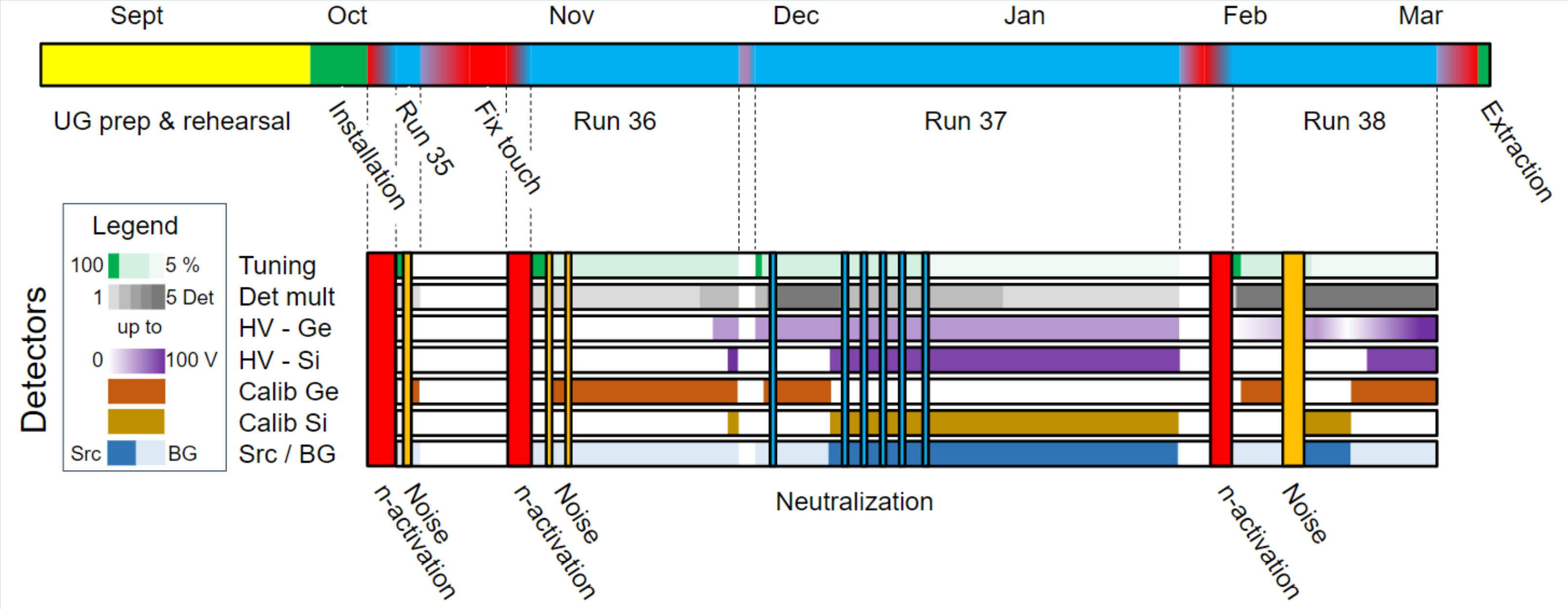
Where do we go? SNOLAB...

CUTE facility overview

- Cryogenic Underground Test facility at SNOLAB
- Checks all the boxes:
  - ☑ Several layers of shielding (ambient background of few events/ keV/ kg-day)
    - ☑ Natural rock overburden (~ 2 km)
    - ☑ Facility shielding (water, lead and HDPE)
  - ☑ Adjacent to SuperCDMS
  - ☑ Made to accommodate SuperCDMS tower geometry

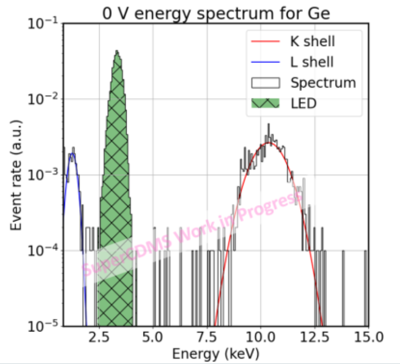


SuperCDMS tower testing at CUTE



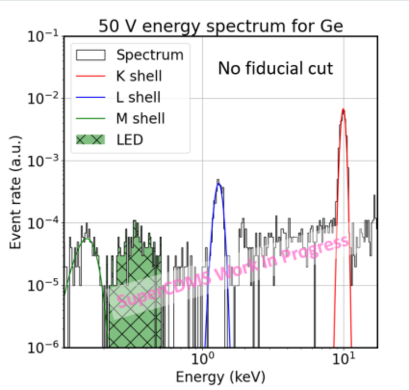
Key outcomes: Ge calibration

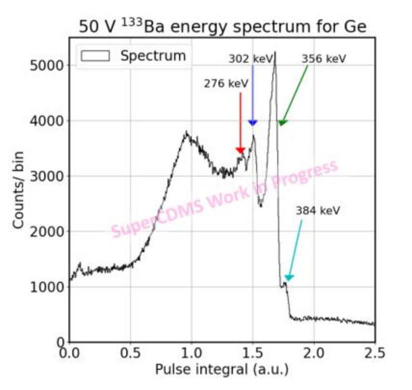
Neutron activation produces peaks at known energies in the spectrum



$$^{70}\mathrm{Ge} + n \rightarrow {}^{71}\mathrm{Ge}$$

Peak / Shell	Peak position	Probability
K	10.37 keV	87.6%
L	1.3 keV	10.5%
M	0.16 keV	1.78%





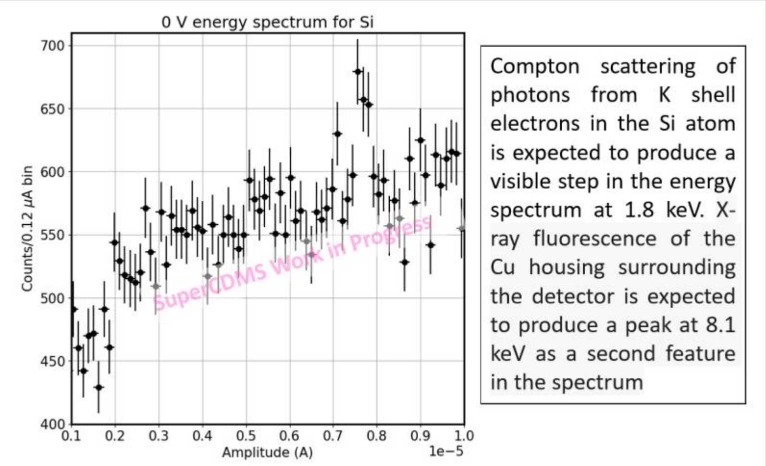
- *Both low and high energy calibration possible*
- *High energy calibration with external source*
- *Advanced reconstruction algorithms promise excellent energy resolution*

Key outcomes: Si calibration

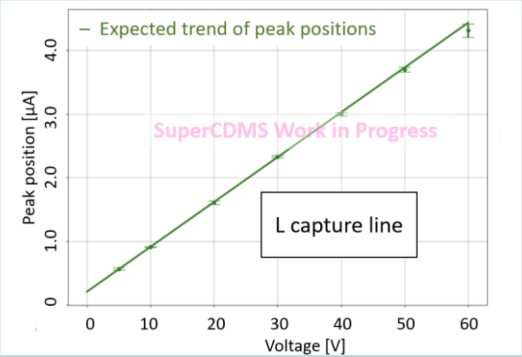
Compton steps at the lowest energies corresponding to atomic energy levels of the Si atom

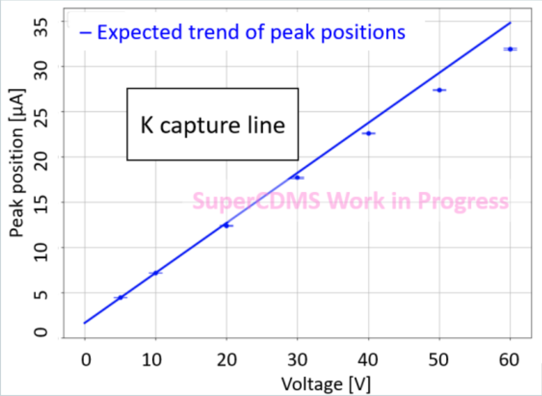
Material	K step	L1 step	L2 step
Si	1.839 keV	0.150 keV	0.099 keV

- *Observation of K step at 0 V with a few days of data*
- *Observation of Cu X-ray peak (8.1 keV) from the surrounding detector housing at 0 V*
- *Potential hints of features consistent with L1 and L2 steps with a few weeks of data at 90 V*



Key outcomes: Amplification studies





Amplification consistent with NTL gain. Position of L shell peak scales linearly with voltage. Position of K shell peak scales linearly up to 30 V when TES saturation kicks in.

Key outcomes: New tools and methods

- Reconstruction techniques
    - Saturation reconstruction
    - Position reconstruction
- Detector volume fiducialization
- Noise reduction systems
- Detector neutralization schemes
- Electric field distortion from adjacent detectors

Summary

- SuperCDMS has successfully tested all four towers at SLAC
- SLAC tower testing was limited by high trigger rates and desire to minimize cosmic exposure
- One HV tower was successfully tested in a low background environment at CUTE for the first time
- Established means of calibrating detectors at low and high energies
- Many interesting observations made; analysis underway

Thank you!