Testing and Characterization of SuperCDMS HV Detectors at CUTE

Tyler Reynolds

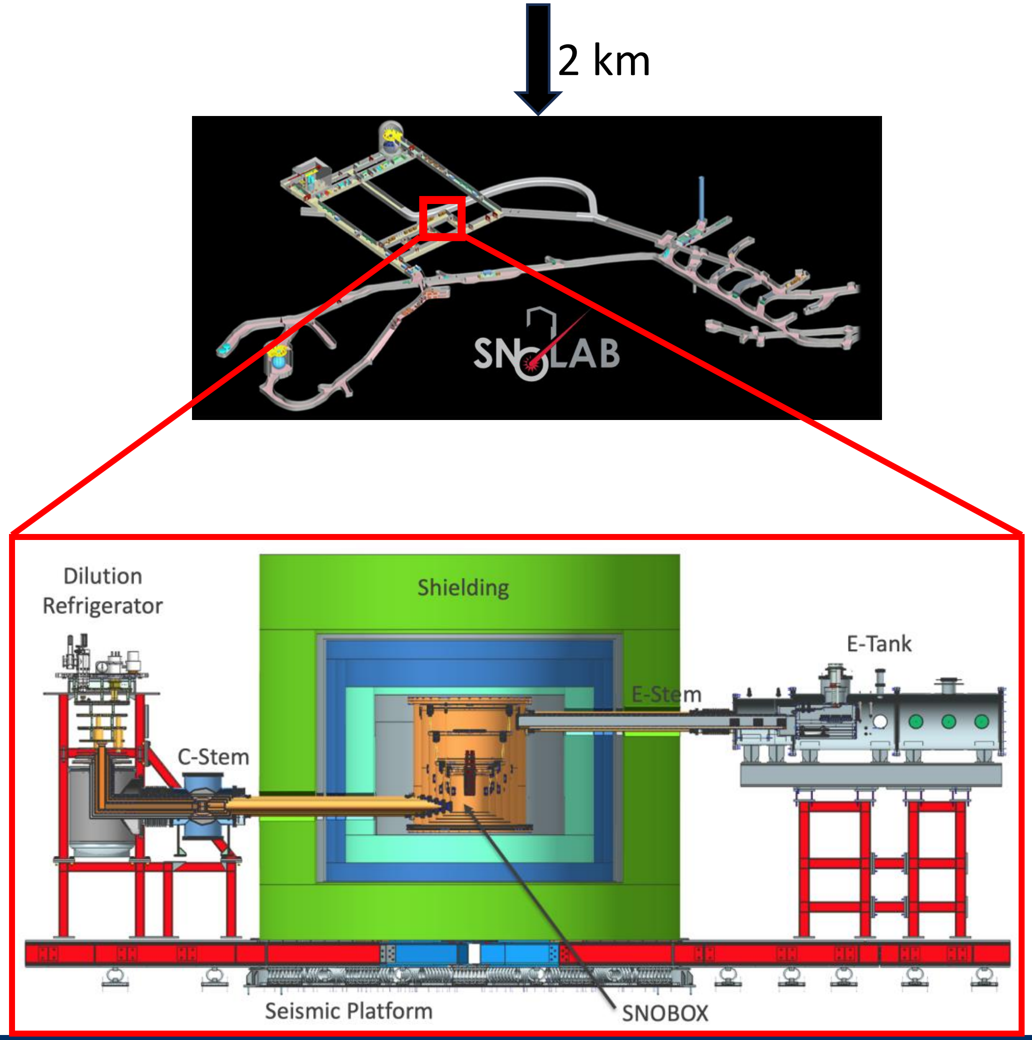
On behalf of the SuperCDMS Collaboration

@SuperCDMS

supercdms.slac.stanford.edu

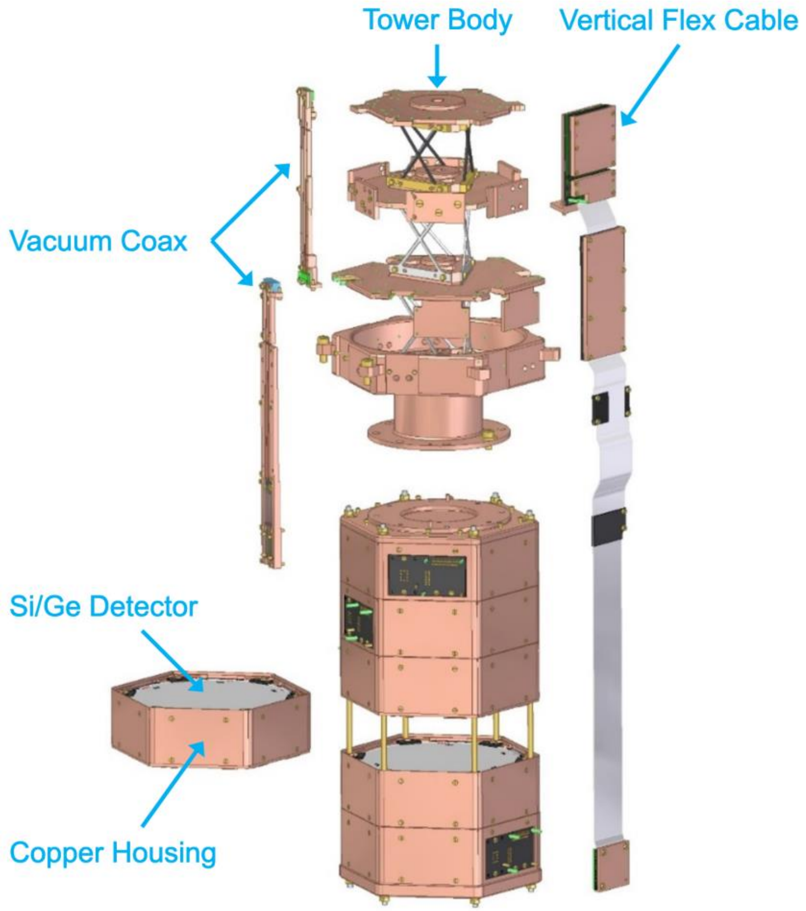
An introduction to SuperCDMS

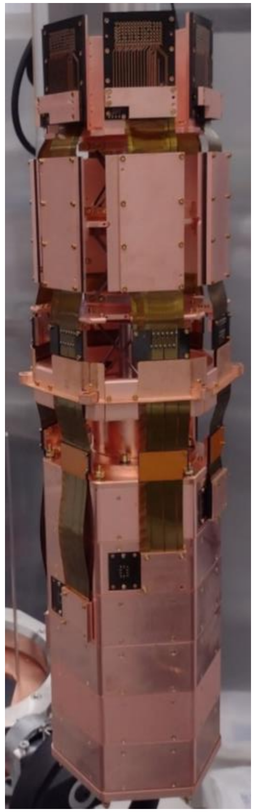
- Direct detection of dark matter
  - Focusing on WIMPs with mass 1-10 GeV/c^2
  - Also sensitive to dark photons, ALPs, etc.
- 2 km underground at SNOLAB – shielding from cosmic rays



An introduction to SuperCDMS

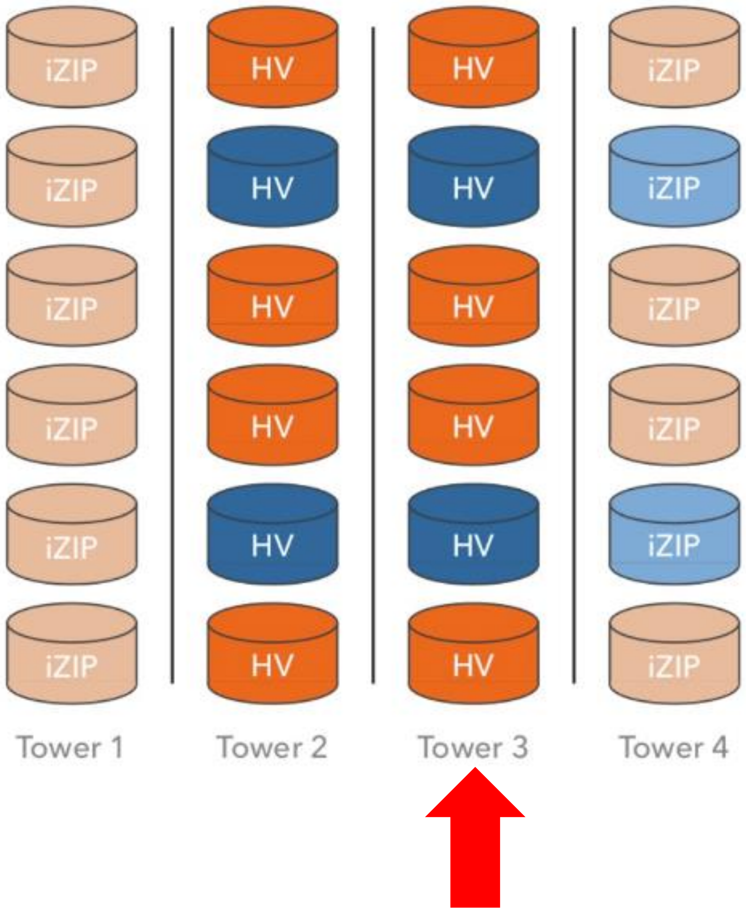
- Four arrays of detectors ("towers")
  - Six detectors per tower
- Two materials for rate complementarity
  - 18 germanium (Ge)
  - 6 silicon (Si)
- Two detector designs
  - 12 low background detectors ("iZIP")
  - 12 low threshold detectors ("HV")





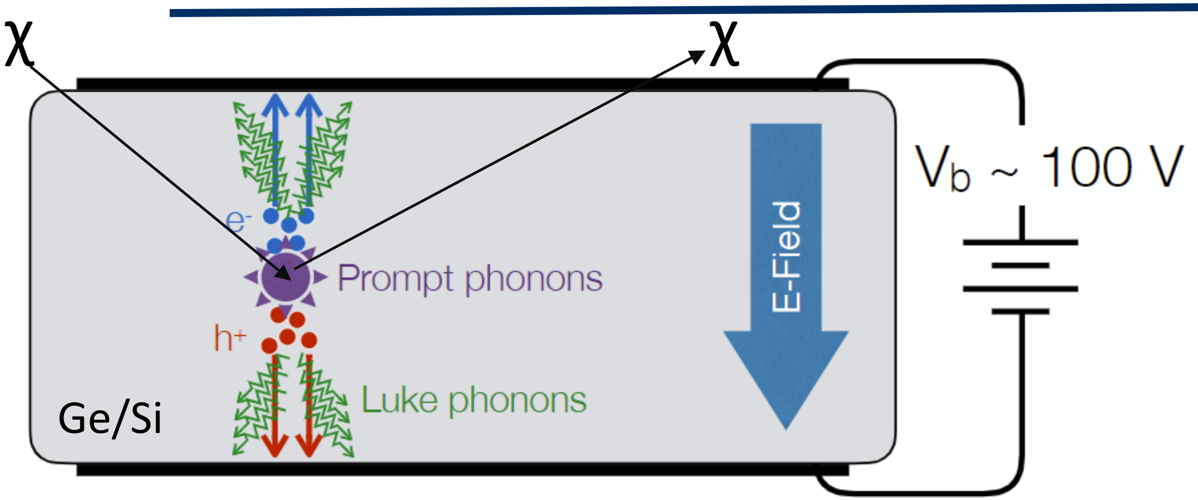
An introduction to SuperCDMS

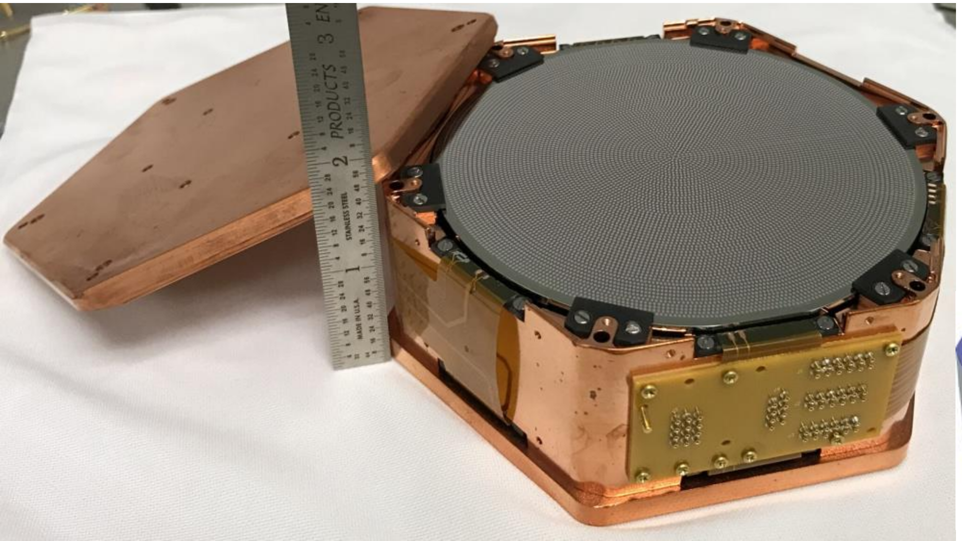
- Four arrays of detectors ("towers")
  - Six detectors per tower
- Two materials for rate complementarity
  - 18 germanium (Ge)
  - 6 silicon (Si)
- Two detector designs
  - 12 low background detectors ("iZIP")
  - 12 low threshold detectors ("HV")

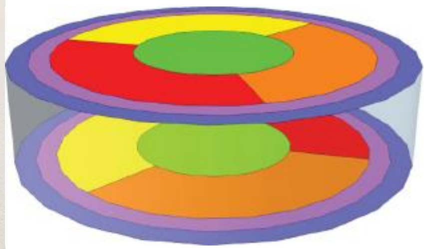


The star of this show!

HV Detectors







- Transition edge sensors measure phonon energy from energy depositions in detector crystals
- Neganov-Trofimov-Luke effect: crystal bias voltage accelerates electron-hole pairs, which shed phonons and cause gain in phonon signal

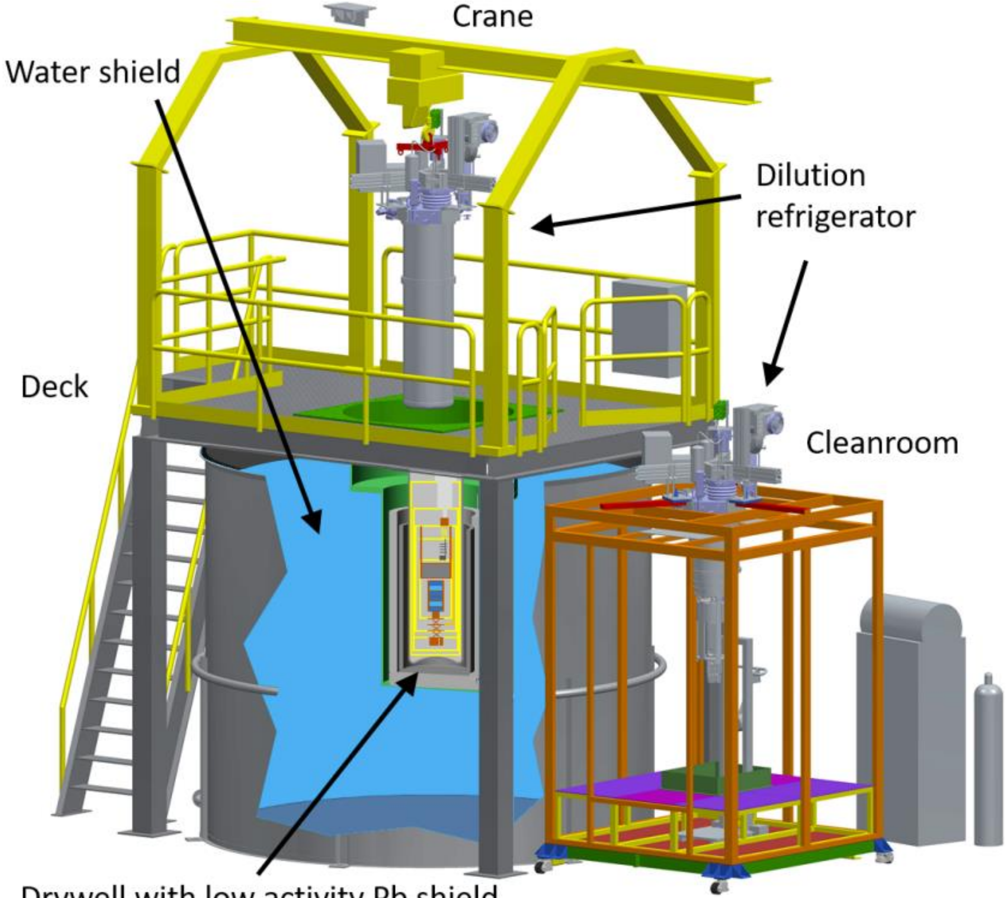
$$E_t = E_R + n_{eh} e V_b$$

- 12 channels, 6 per side
  - 2 outer ring channels for fiducialization
  - Side 2 rotated 120° with respect to side 1 for position reconstruction

Why Tower Testing?

- Towers all delivered underground recently
- First chance to operate these detectors in deep underground environment
  - Noise performance in low background environment
  - Operation of detectors with high voltage for extended periods
  - First campaign for calibrating detectors
  - Develop operating procedures

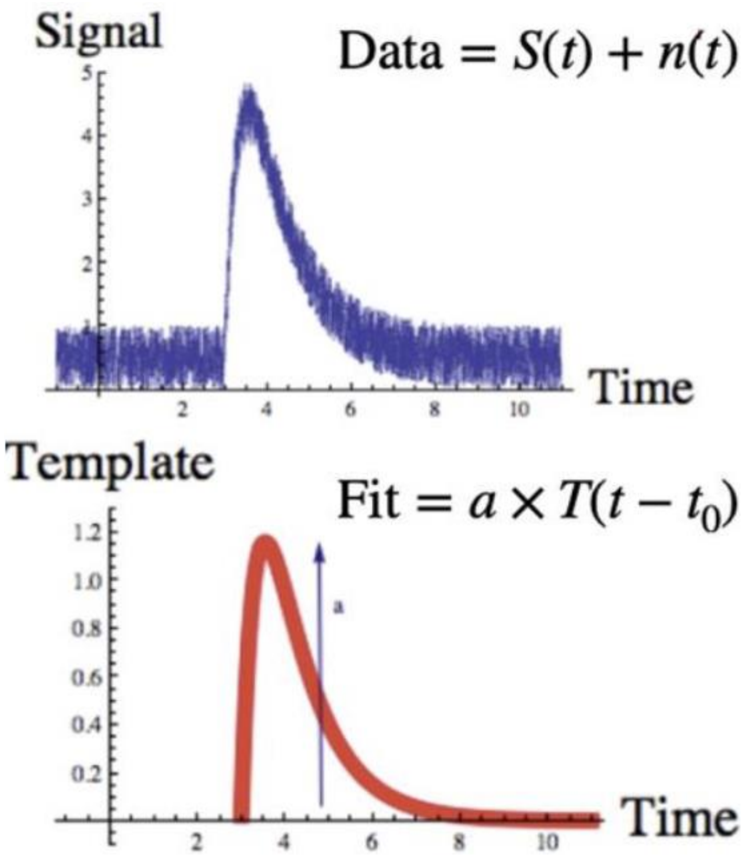
CUTE @ SNOLAB



- Class-300 clean room for detector installation
- Background < 10 dru
  - Water tank and lead as shielding
  - Drywell purged with low-radon air
- Dilution refrigerator
  - Base temperature: 13 mK
- Payload: tower 3

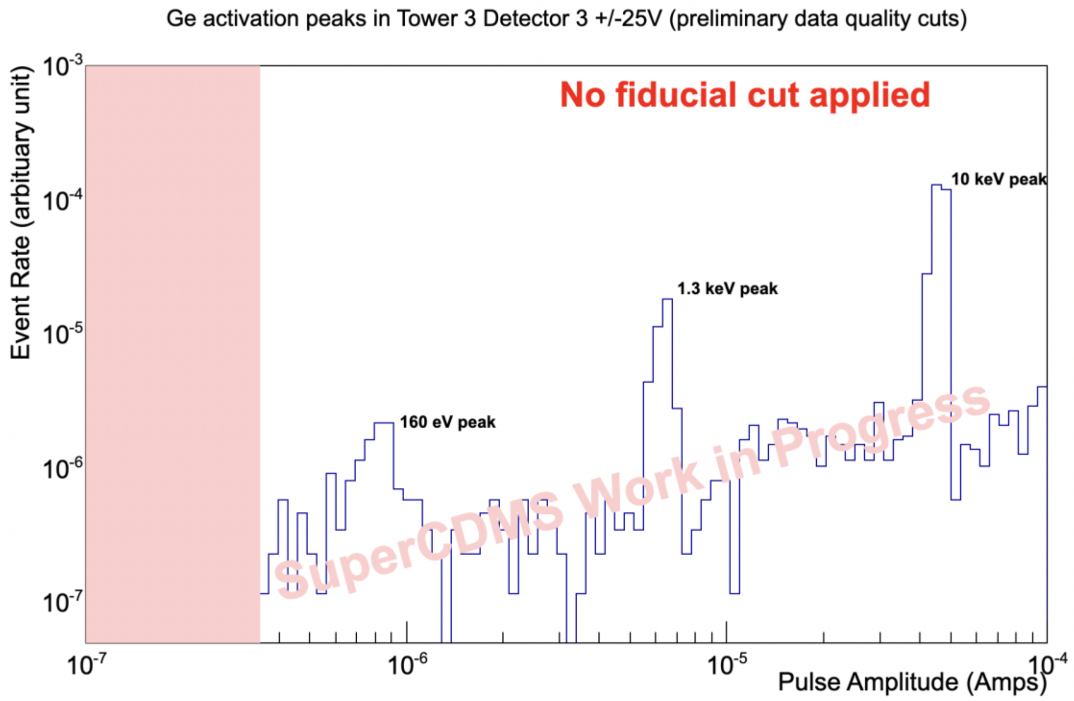
Analysis of data

- Data taken Nov. 10, 2023 to present day
- Optimum filter as energy estimator
  - Fit to raw pulses in Fourier domain
  - Fitted pulse amplitude ∝ enegy
- Reject pulses with unexpected shapes (non-particle sources, event pileups, etc.)
- No fiducial volume cut – coming soon



Ge Calibration

- ^{252}Cf neutron source
  - ^{70}Ge + n → ^{71}Ge
- Electron-capture decay: ^{71}Ge + e → ^{71}Ga + ν_e
  - K-shell: 10.3 keV
  - L-shell: 1.3 keV
  - M-shell: 160 eV
- 3 days live-time shown here



Si Calibration

- Compton scattering with ^{133}Ba
  - Scattering cross section decreases below atomic binding energies (Compton steps)

E_γ / keV	E_{CE} / keV
356	207.3
...	
81	**19.5**
79	**18.7**
53	**9.1**

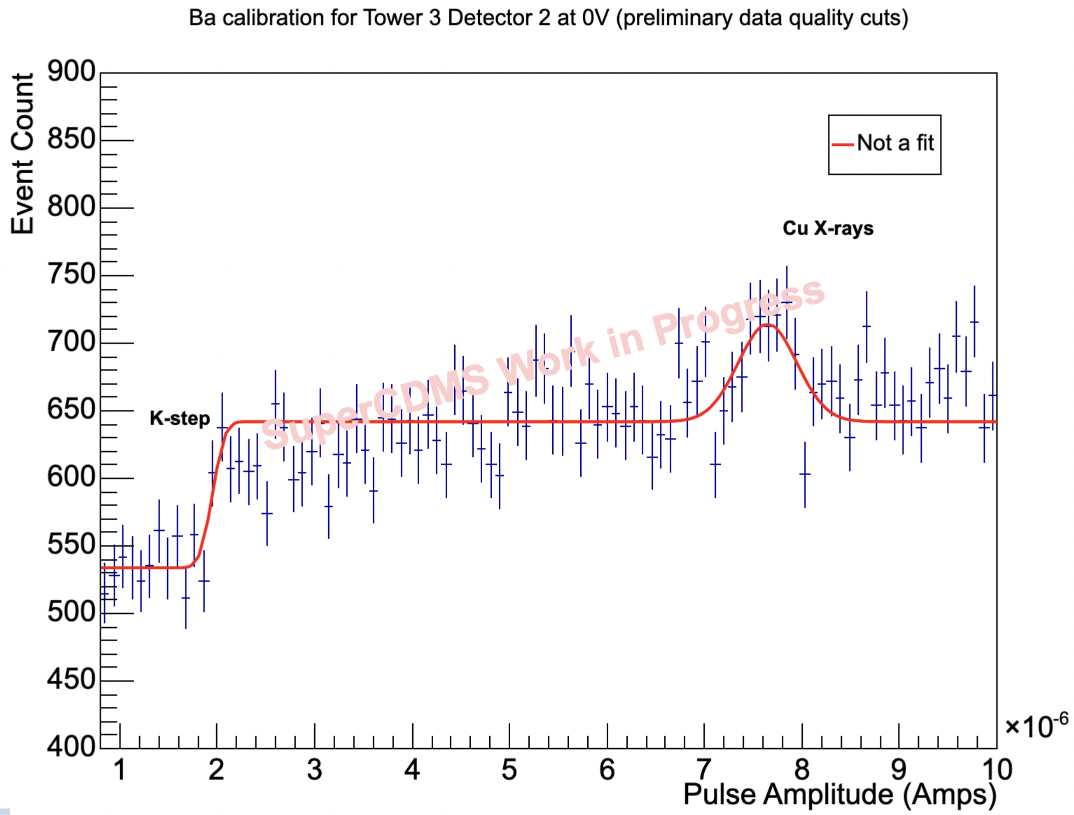
Ref.: https://nds.iaea.org

	label	E_{CS} / keV
Ge	K 1s	**11.10**
	L_1 2s	**1.42**
	L_2 $2p_{1/2}$	**1.25**
Si	K 1s	**1.84**
	L_1 2s	**0.15**
	L_2 $2p_{1/2}$	**0.10**

Ref.: https://xdb.lbl.gov

Stefan Zatschler

- 4 days live-time shown here
- (Red "fit" line only to guide the eye)



Conclusion

- Data taking and analysis still ongoing!
  - Expected end of testing in mid-March
- Successfully demonstrated stable operation of HV detectors
- Ge detectors have been calibrated with electron capture peaks
- Si detector calibration moving ahead – K step seen, looking for the L step
- Stay tuned for more results!

Backup Slides