

# The SuperCDMS Experiment at SNOLAB

Sukeerthi Dharani

*On behalf of the SuperCDMS collaboration*

2026 CAP Congress

*23 Jun, 2026*



THE UNIVERSITY  
OF BRITISH COLUMBIA

# SuperCDMS collaboration



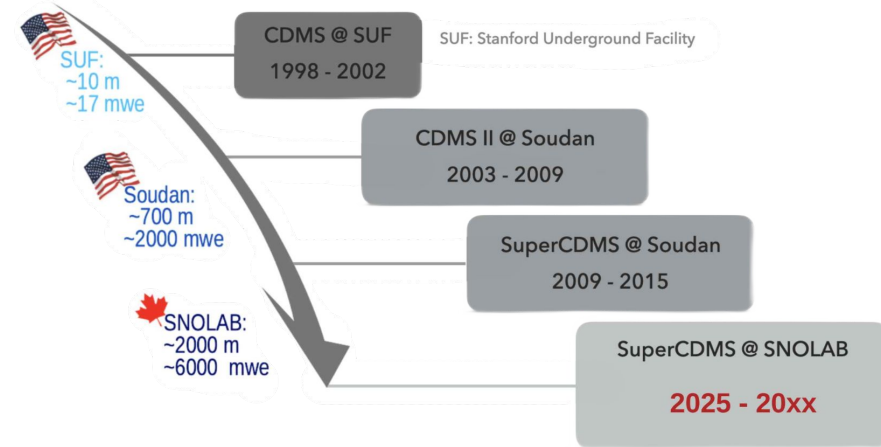
# SuperCDMS experiment



- **Super Cryogenic Dark Matter Search** experiment
- Use semiconductor crystal detectors Si and Ge
- Operate at cryogenic temperature  $O(10\text{mK})$
- Measure energy deposition in the form of phonons and ionization
- Search for sub-GeV DM
- Recent publications:

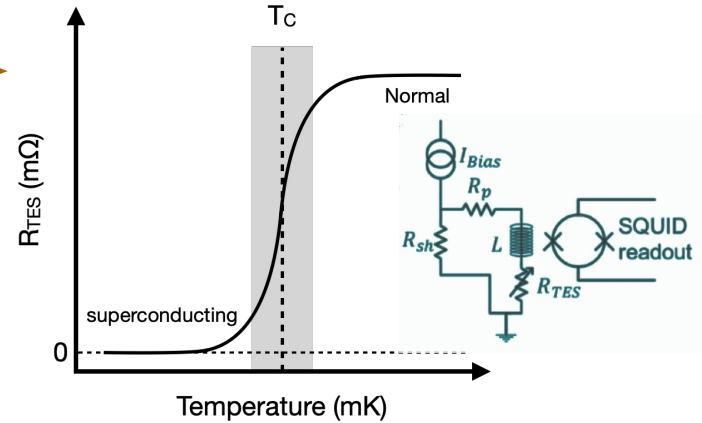
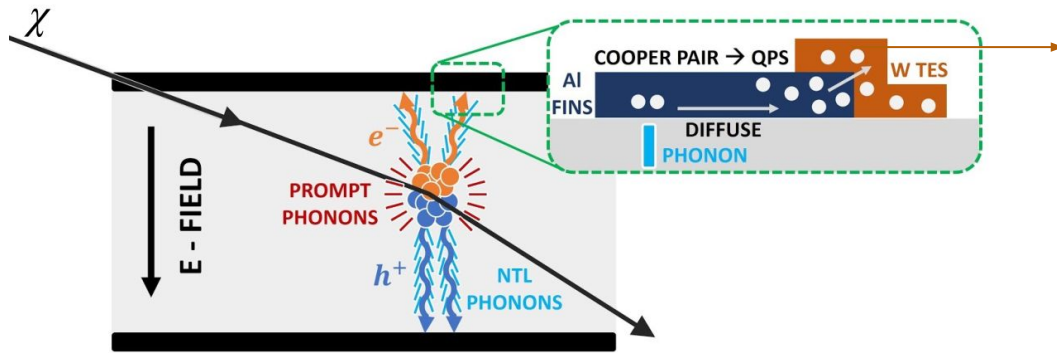
- [Search for low-mass \*\*electron-recoil dark matter\*\* using a single-charge sensitive SuperCDMS-HVeV detector](#)
- [Low-energy calibration of SuperCDMS HVeV \*\*cryogenic silicon\*\* calorimeters using Compton steps](#)
- [Multi-channel, multi-template \*\*event reconstruction\*\* for SuperCDMS data using machine learning](#)
- [G4CMP: Condensed matter physics simulation using the GEANT4 toolkit](#)
- [Investigating the \*\*sources of low-energy events\*\* in a SuperCDMS-HVeV detector](#)
- [Constraints on \*\*dark photons and axion like particles\*\* from the SuperCDMS Soudan experiment](#)

Full publication list at: <https://supercdms.slac.stanford.edu/science-results/publications>



Poster: Multi-Channel Multi-Template Event Reconstruction in SuperCDMS | Antoine Rehberg

# Detection principle



- Particle interactions produce electron-hole (eh) pairs and phonons

Drifting eh pairs  
→ charge sensor (HEMTs)

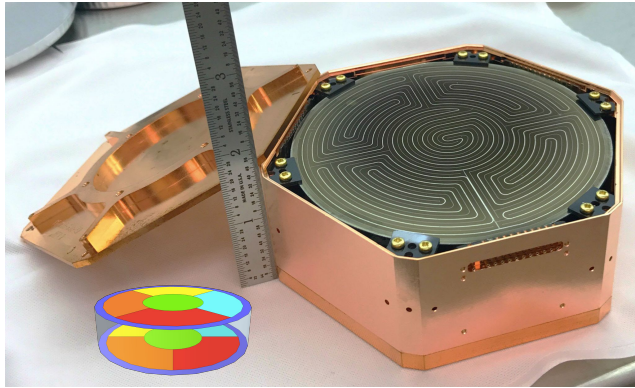
phonons  
→ phonon sensor (QETs)

QET: Quasiparticle Trap Assisted Electrothermal Feedback Transition Edge Sensor  
HEMT: High Electron Mobility Transistor

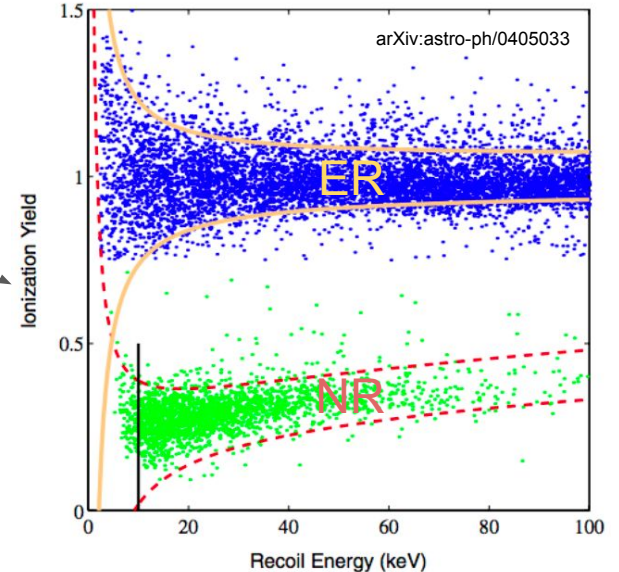
# SuperCDMS detectors

## 1) Interleaved Z-sensitive ionization phonon (iZIP)

- 12 phonon channels + 4 charge channels
- Small bias voltage ( $< 10$  V)
- Measuring ionization + phonon
  - ER/NR discrimination
  - better background rejection



Yield is charge to phonon ratio



ER: Electron recoil  
NR: Nuclear recoil

# SuperCDMS detectors

## 2) High Voltage (HV)

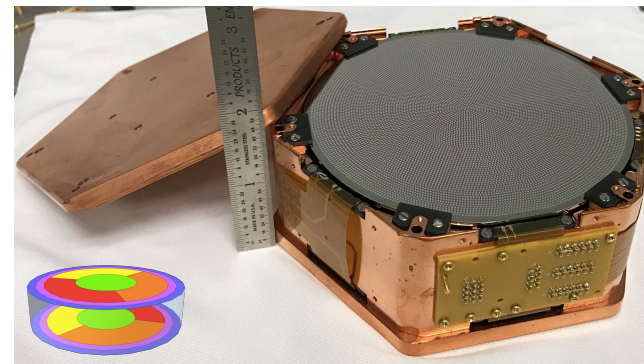
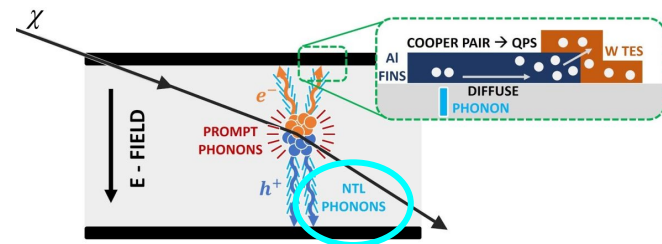
- 12 phonon channels
- Large bias voltage (~100 V)
- **NTL amplification**

$$E_{total} = \underbrace{E_{recoil}} + \underbrace{(N_{eh} \cdot e \cdot V_{bias})}$$

Primary recoil energy

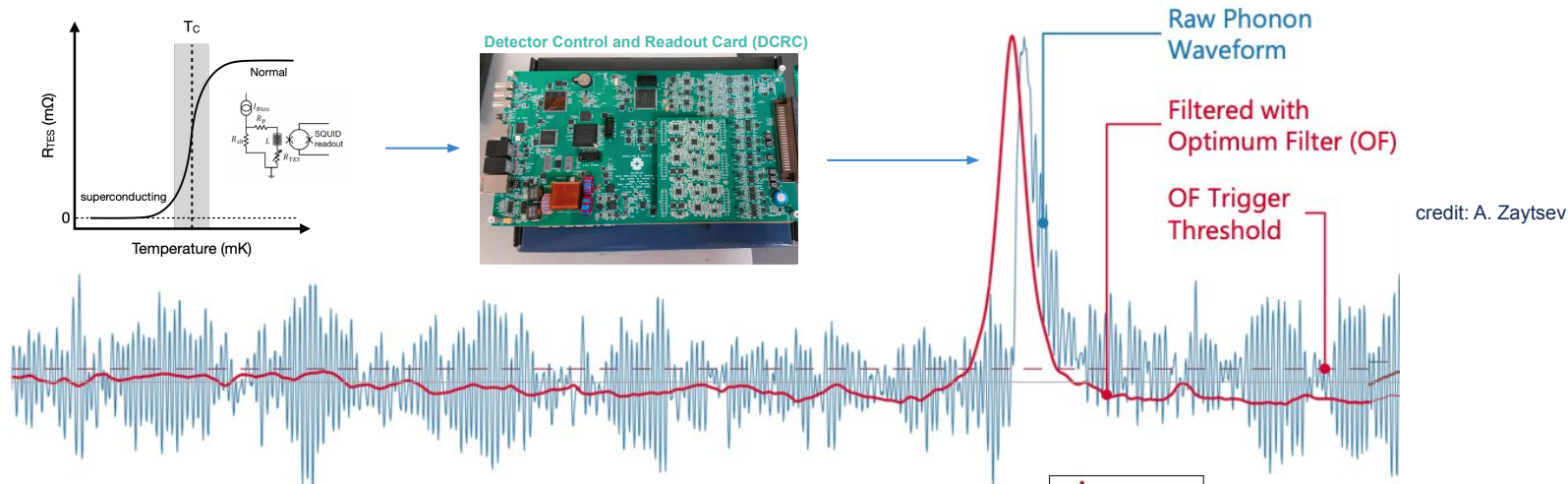
NTL phonon energy

- Amplification of signal → low threshold → **low mass DM search**
- no ER/NR discrimination
- Energy resolution  $O(10 \text{ eV})$



ER: Electron recoil  
NR: Nuclear recoil  
NTL: Neganov-Trofimov-Luke

# Data Acquisition and Trigger

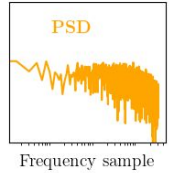
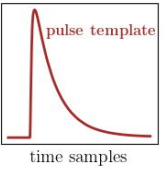


credit: A. Zaytsev

Optimum Filter (OF)  
algorithm used to find  
best amplitude

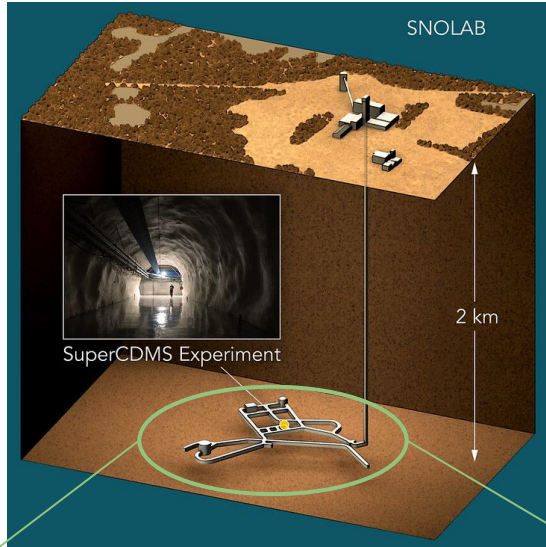
$$\chi^2(a) = \sum_n \frac{|\tilde{S}_n - a\tilde{A}_n|^2}{J_n}$$

- Signal
- Pulse amplitude
- Pulse template
- Noise PSD

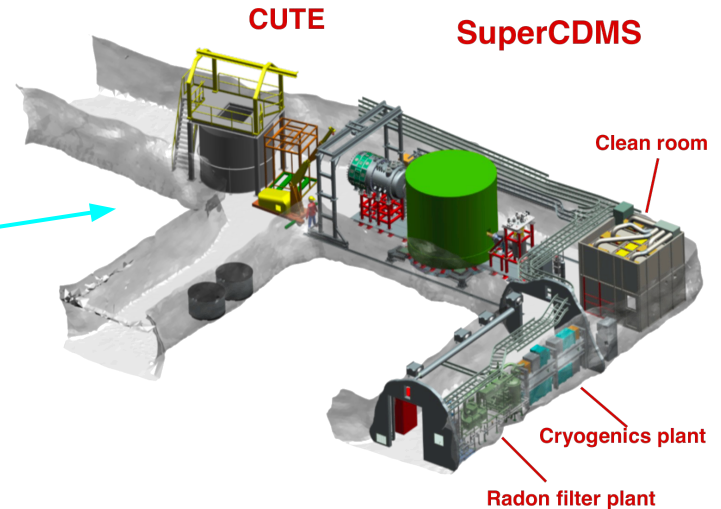
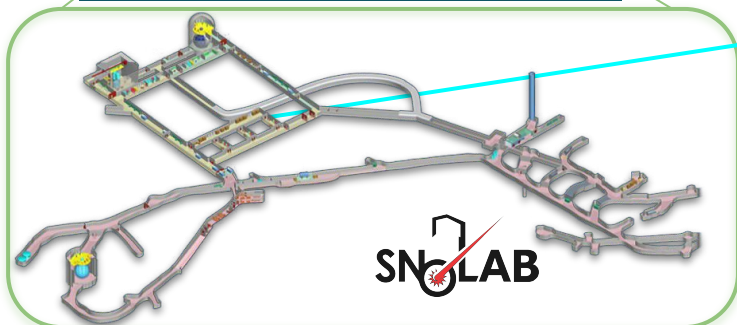


PSD: Power Spectral Density

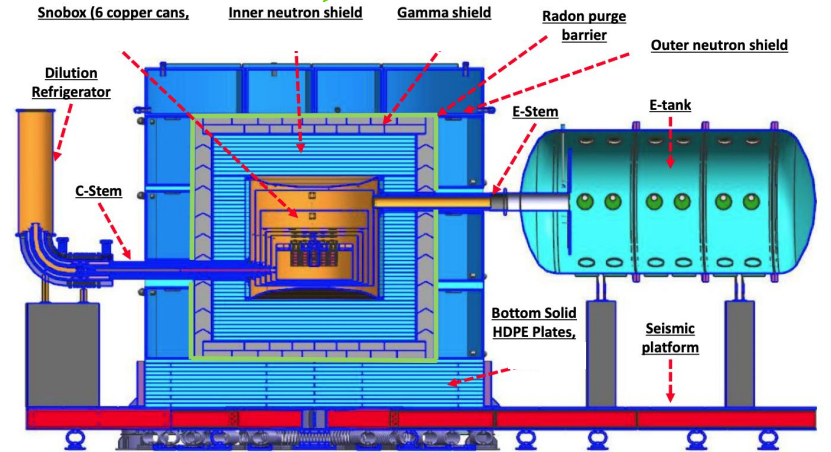
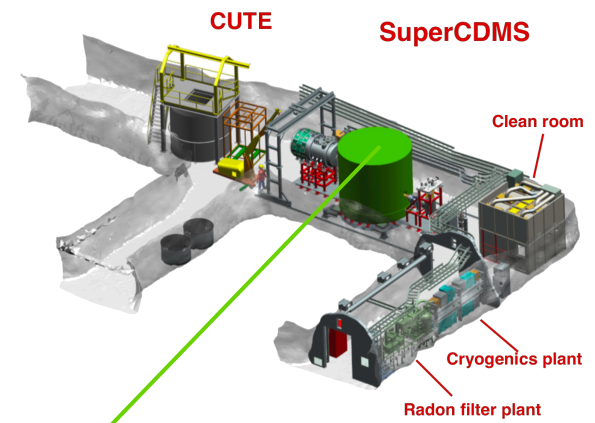
# SNOLAB underground laboratory



- Located in Sudbury, Canada
- 2 km rock overburden, 6010 m.w.e. ( $0.286 \mu\text{m}^2/\text{day}$ )
- Class 2000 clean room
- Hosts low background experiments



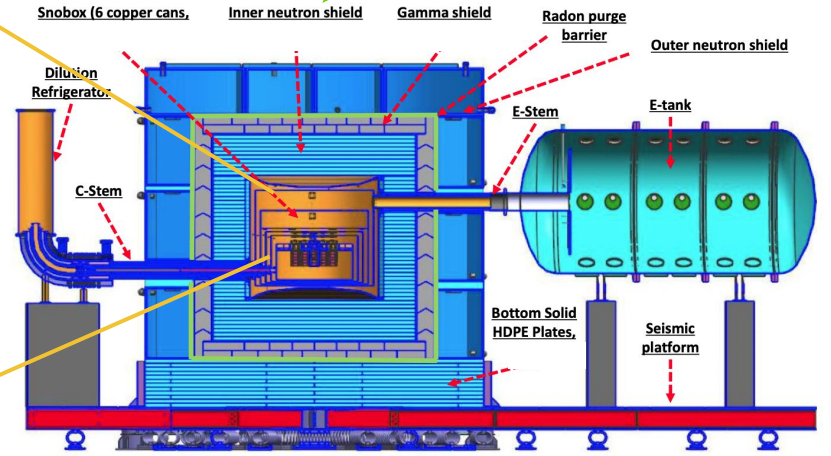
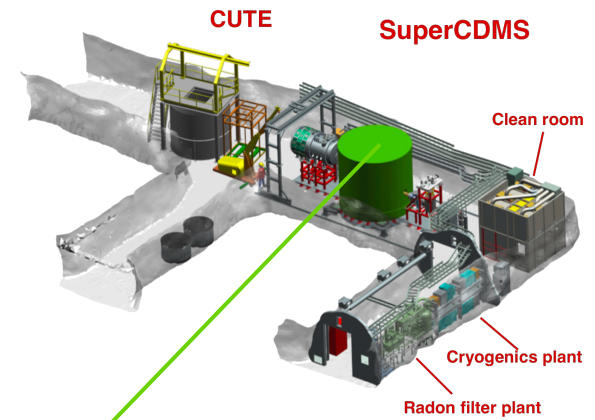
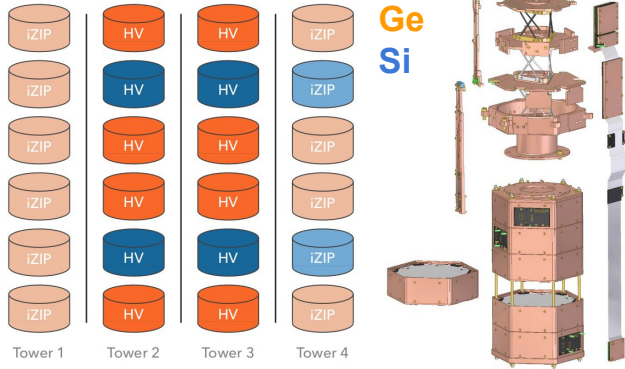
# SuperCDMS SNOLAB



Source: arXiv:1610.00006

# SuperCDMS SNOLAB

- Payload:
  - 4 towers with 6 detectors each
  - 2 iZIP and 2 HV towers
  - ~30kg in total



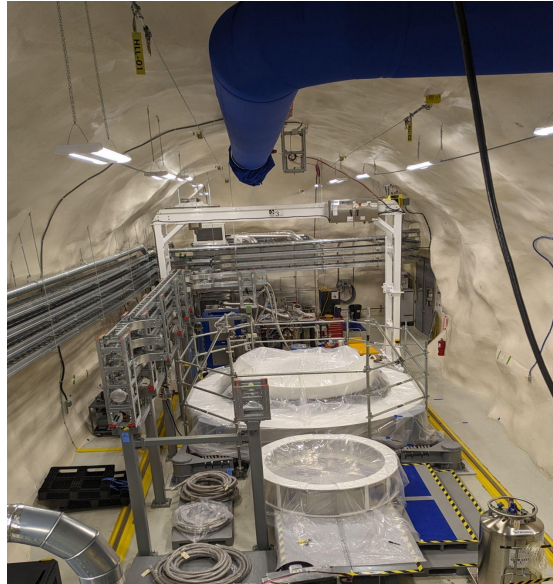
Source: arXiv:1610.00006

# SuperCDMS SNOLAB installation

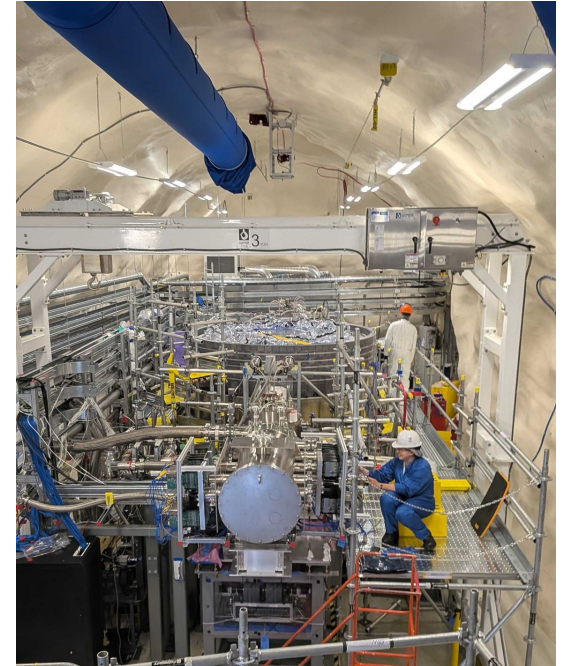
March 2024



Nov 2024

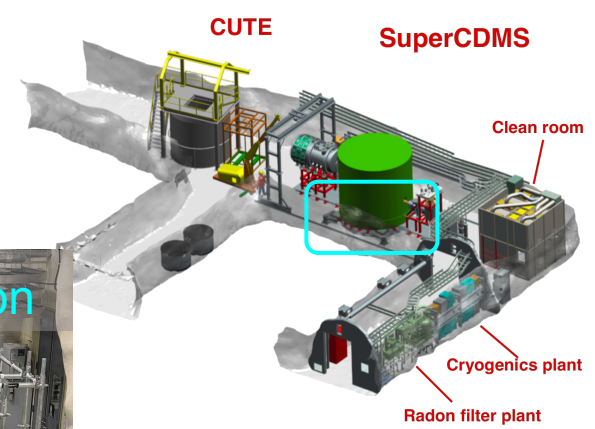
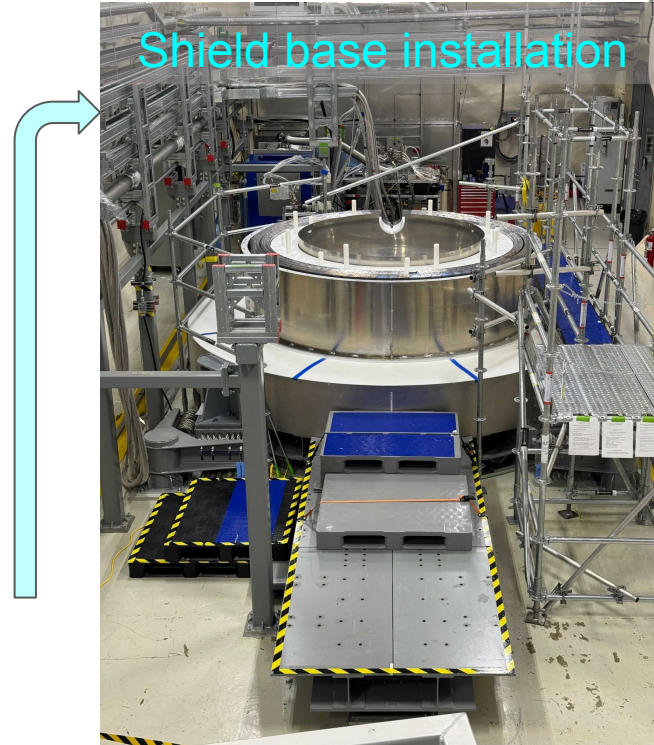
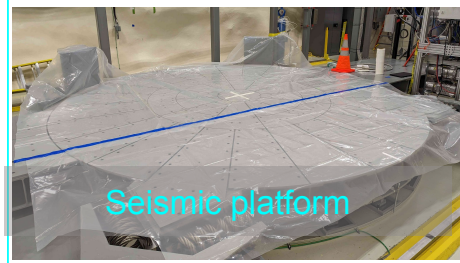
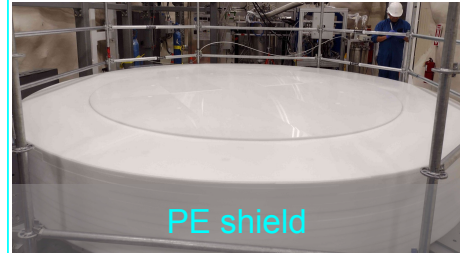


March 2026



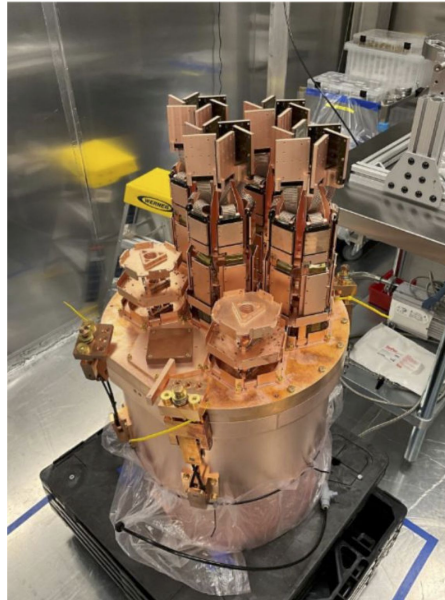
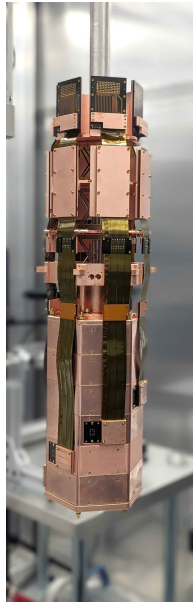
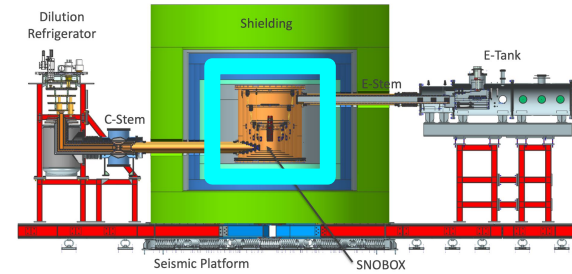
# SuperCDMS SNOLAB installation

- Shield installation in 2024



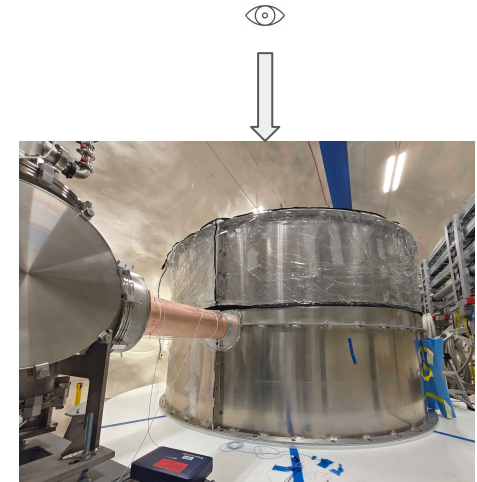
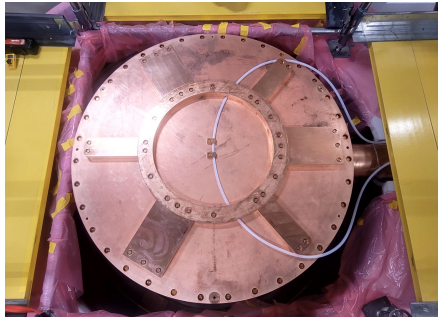
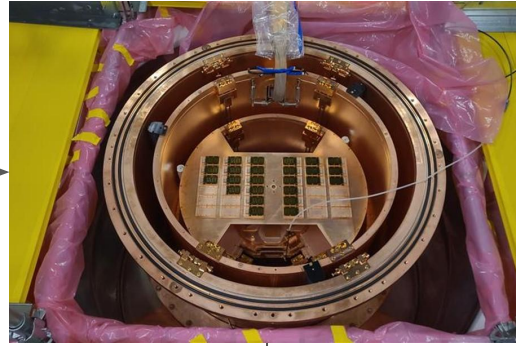
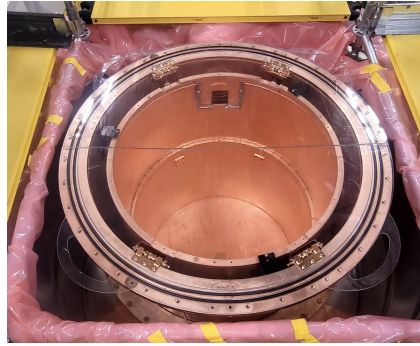
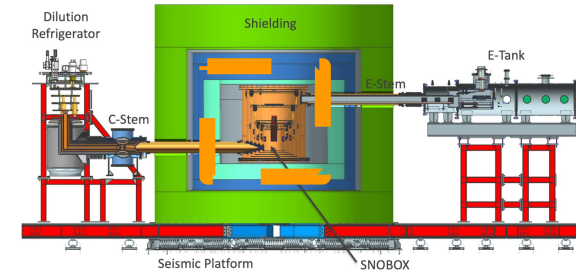
# SuperCDMS SNOLAB installation (2025)

- All detector towers in cryostat



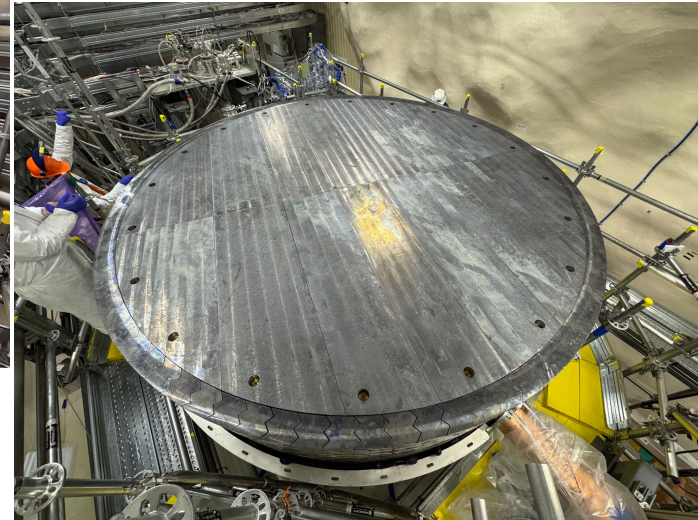
# SuperCDMS SNOLAB installation

- All towers in cryostat placed in outer shielding

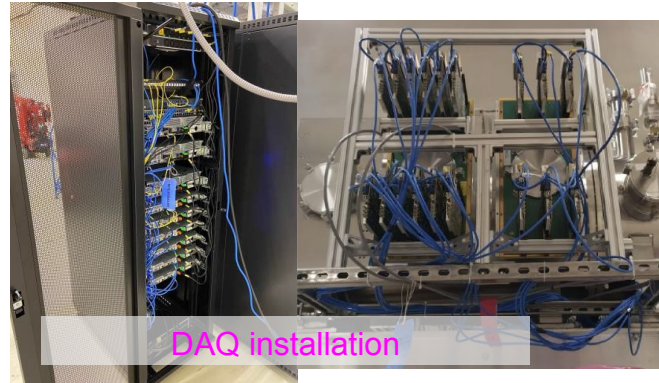
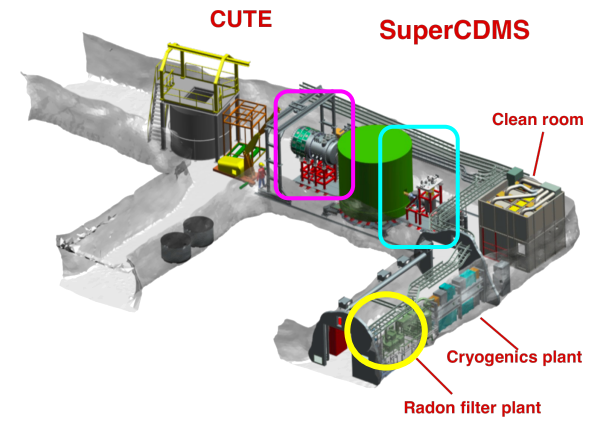
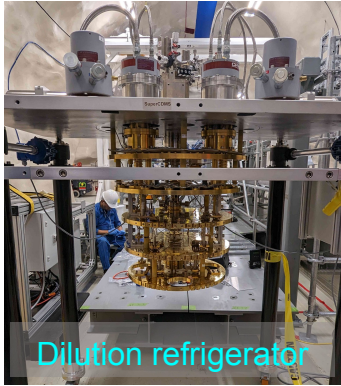


# SuperCDMS SNOLAB installation

- Shield installation (again!) – completing



# SuperCDMS SNOLAB installation

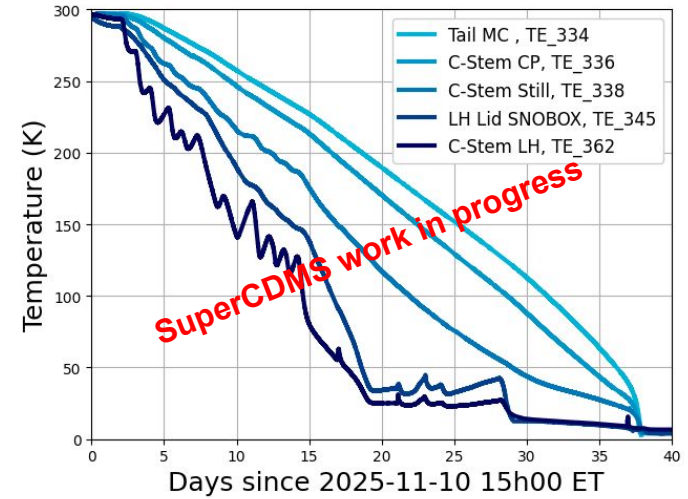


- Dilution refrigerator installed via C-stem
- E-stem connects the detector readout electronics to DAQ
- Radon filter plant provides for the radon barrier

All systems ready to go!

# Cooldown

- Started Nov 2025
- Break for winter holidays
- Reached base temperature in Jan 2026



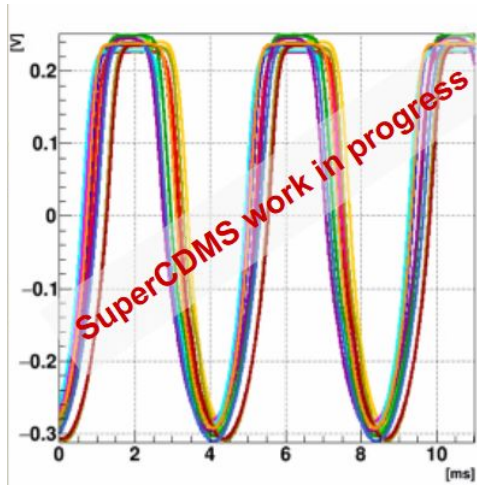
Poster: SuperCDMS Programmable Logic Controller System | Cassandra Harms

# Cooldown

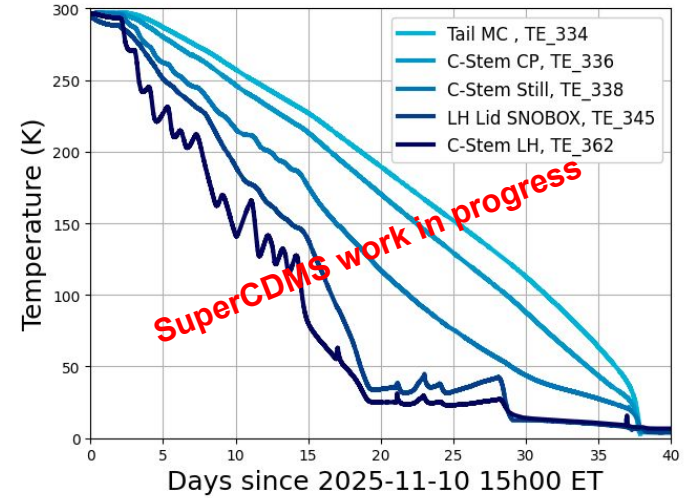
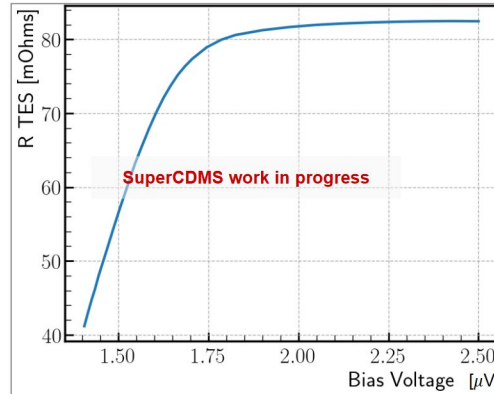
- Started Nov 2025
- Break for winter holidays
- Reached base temperature in Jan 2026

# Detector configuration

SQUIDS are functional! ✓

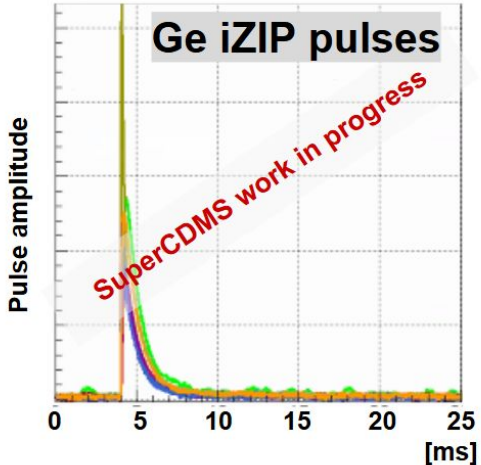
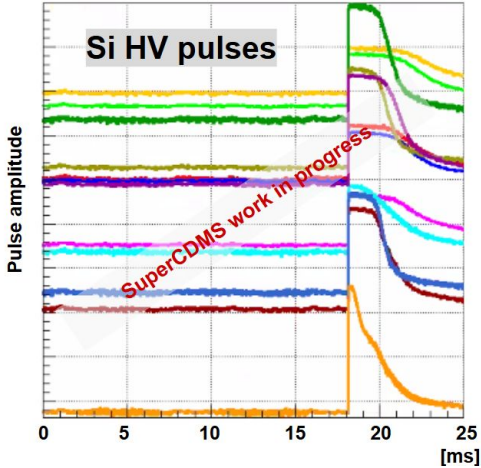
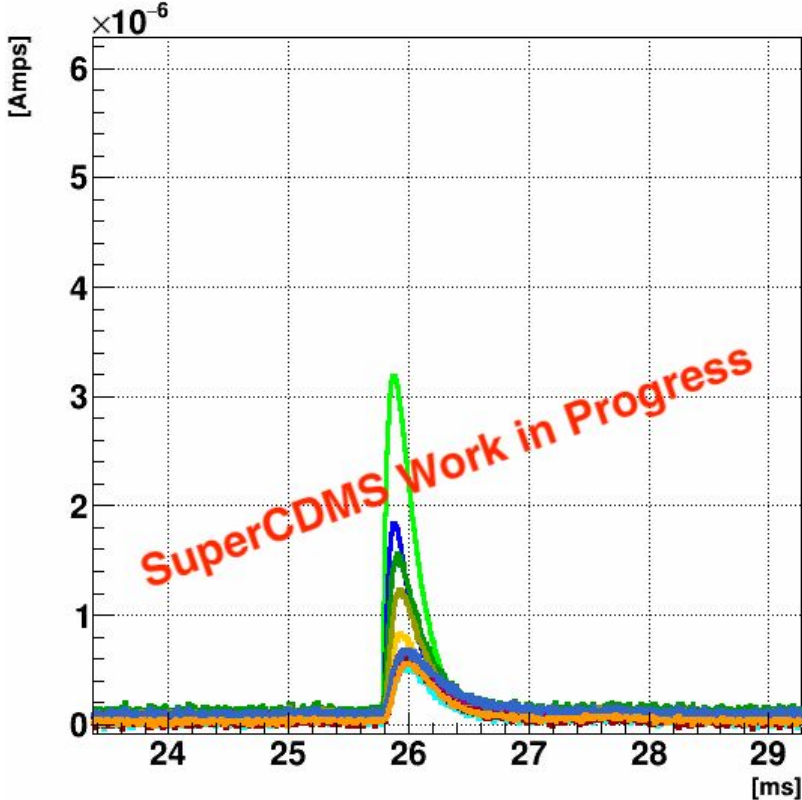


TES transition curves measured ✓



Poster: SuperCDMS Programmable Logic Controller System | Cassandra Harms

# First pulses



# Science run 1a

Scheduled “quiet” time: Mid July through Sep

→ Tasks before Science run 1a

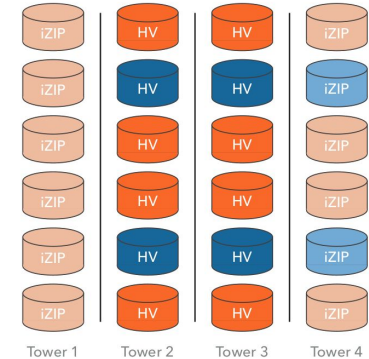
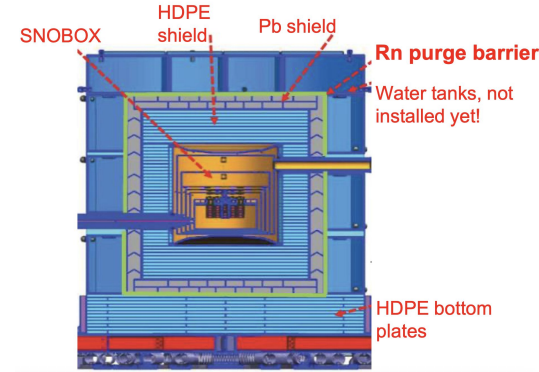
- Radon barrier purge system
- Troubleshoot issues with HV application, noise hunting, black-body radiation, etc.

→ Decisions to make

- which detectors, neutralization process, trigger set up.

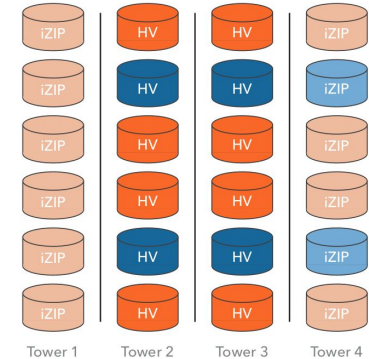
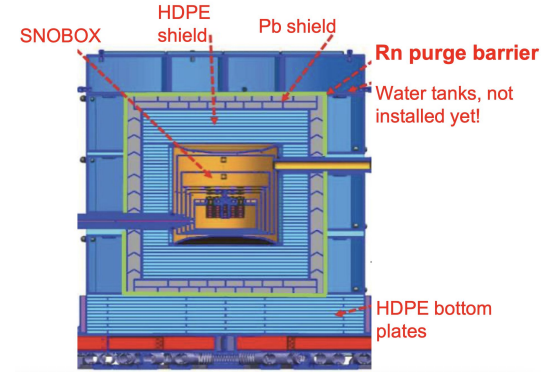
→ Low-background data-taking

→ Post completion maintenance period and prepare for Science run 1b



# Science run 1a → 1b

- Post completion of Science run 1a: Full warm-up
  - maintenance period for repairs
  - more troubleshooting and improvements
  - Ice-tank chilled-water backup
- Cooldown and data-taking: Early 2027
- Post completion of Science run 1b
  - Installation of water tank
  - Science run 2

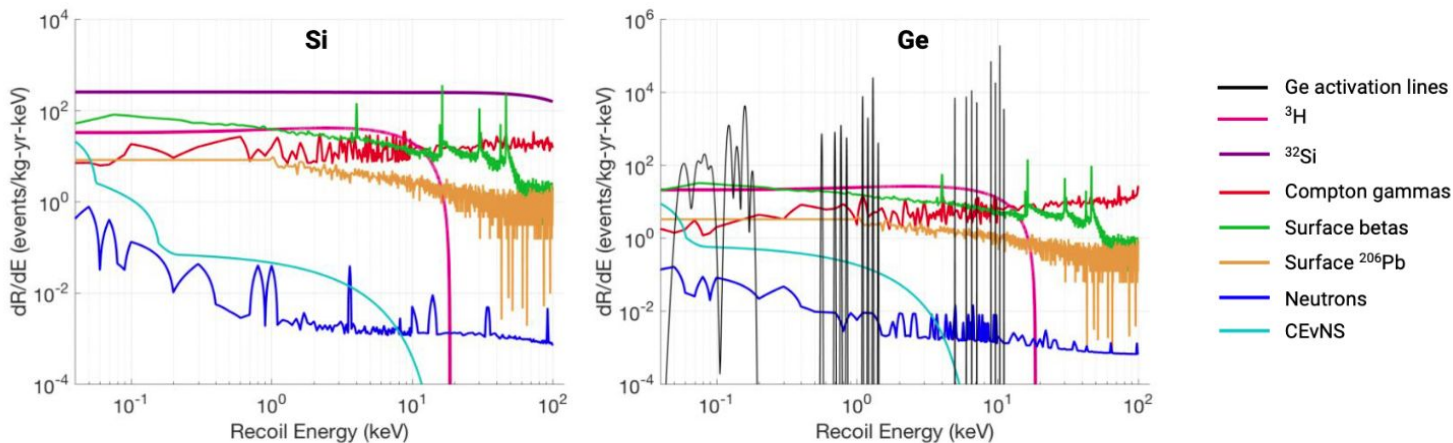


# SuperCDMS backgrounds

Detailed bookkeeping done using eTraveller and BGExplorer:

- 329 components catalogued
- 32 sources considered
- Tracking of location for cosmogenic and radon exposure

Challenge now is to turn this information into a background model suitable for analysis

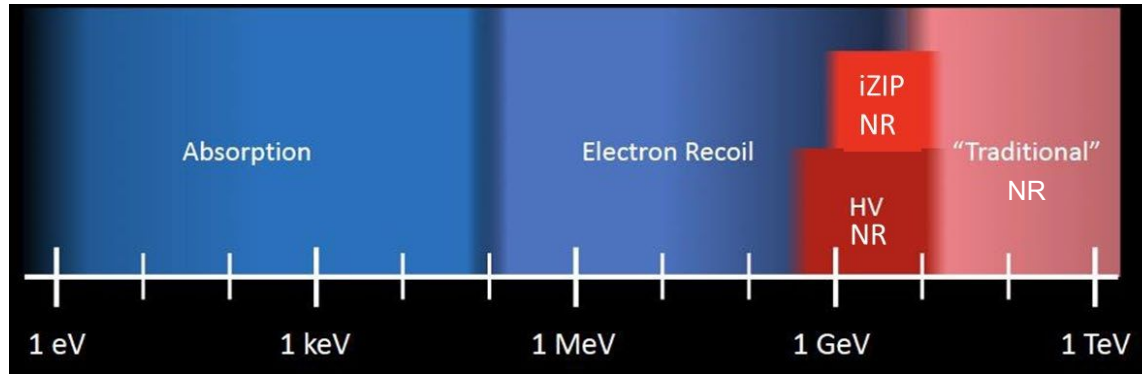


Slide credit: M..Zurowski

[Talk](#): Background modelling at SuperCDMS | Madeleine Zurowski | Jun 25, 2026, 3:00 p.m. | (PPD) R1-1 DM  
[Talk](#): Background simulation studies for the SuperCDMS experiment | Birgit Zatschler | Jun 25, 2026, 3:30 p.m. | (PPD) R1-1 DM

# SuperCDMS science search

Nuclear recoil	iZIP, ER background free	$>5 \text{ GeV}/c^2$
	iZIP, limited ER/NR discrimination	$>1 \text{ GeV}/c^2$
	HV, no discrimination	$\sim 0.3 - 10 \text{ GeV}/c^2$
Electron recoil	HV, no discrimination	$\sim 0.5 \text{ MeV}/c^2 - 10 \text{ GeV}/c^2$
Absorption (dark photons, ALPs)	HV, no discrimination	$\sim 1 \text{ eV}/c^2 - 500 \text{ keV}/c^2$ (peak search)

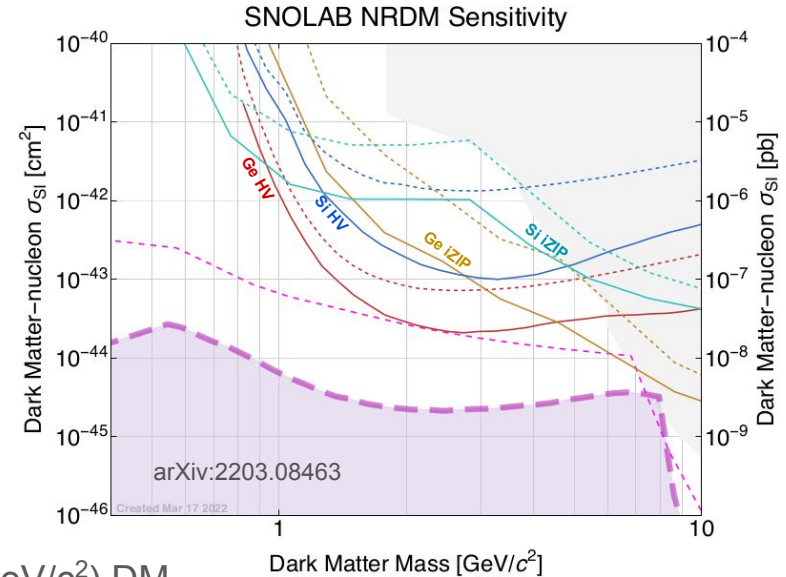


Refer to doi:10.1139/cjp-2024-0127 (Snowmass) for sensitivity forecast

# SuperCDMS SNOLAB projected sensitivity for NRDM

- The projected sensitivities for Nuclear Recoil
  - Optimum interval - dashed
  - Profile likelihood - solid

	Germanium	Silicon
HV	Low threshold for low mass DM, larger exposure Limited by tritium betas	Lowest threshold for low mass DM, sensitive for lowest DM masses Limited by $^{32}\text{Si}$ (and tritium) betas
iZIP	ER/NR discrimination, understand Ge background Limited by exposure	ER/NR discrimination, understand Si background Limited by exposure

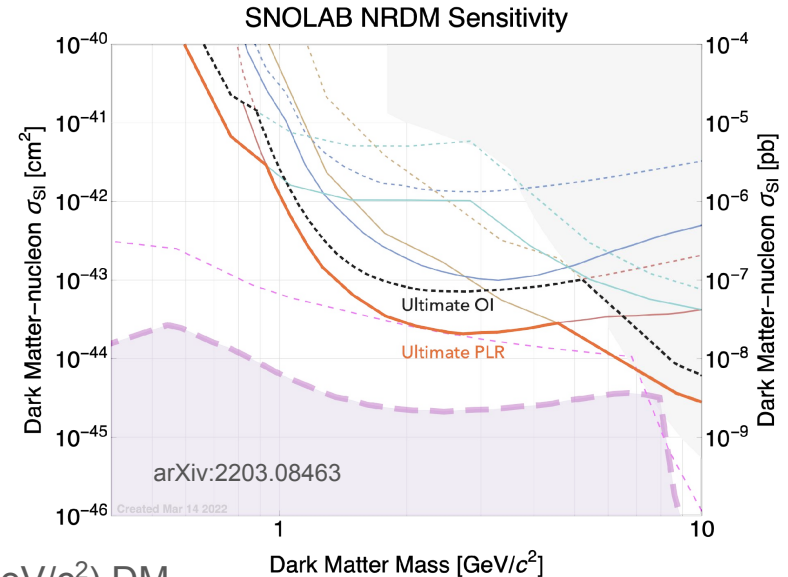


- Aiming for world leading sensitivity to low mass ( $\lesssim 10 \text{ GeV}/c^2$ ) DM
- Challenges: Understanding and modeling detector response, low-energy calibration

# SuperCDMS SNOLAB projected sensitivity for NRDM

- The projected sensitivities for Nuclear Recoil
  - Optimum interval - dashed
  - Profile likelihood - solid

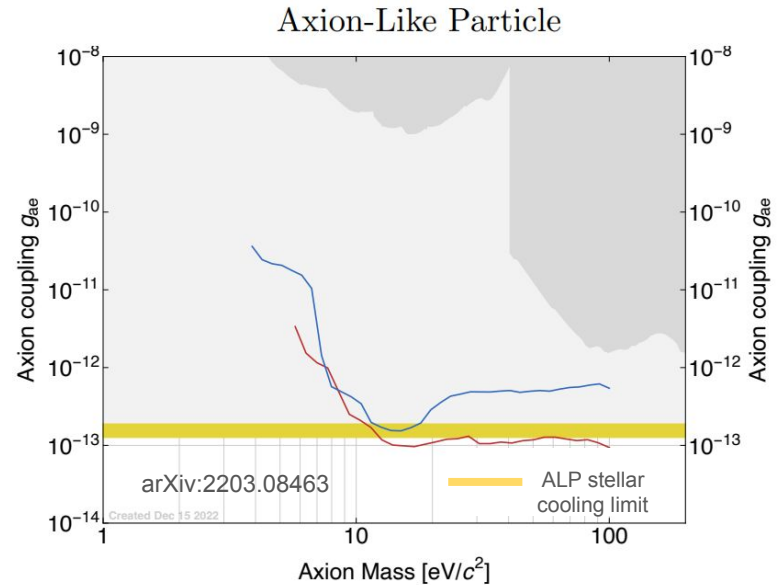
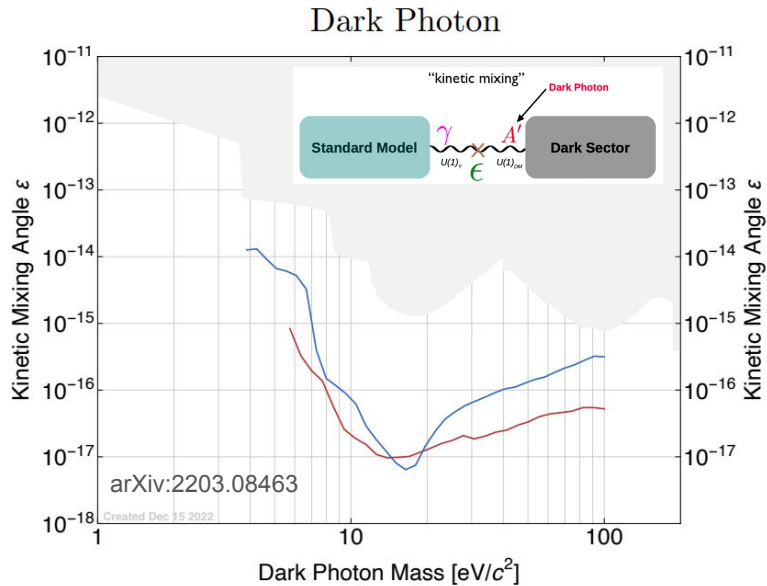
	Germanium	Silicon
HV	Low threshold for low mass DM, larger exposure Limited by tritium betas	Lowest threshold for low mass DM, sensitive for lowest DM masses Limited by $^{32}\text{Si}$ (and tritium) betas
iZIP	ER/NR discrimination, understand Ge background Limited by exposure	ER/NR discrimination, understand Si background Limited by exposure



- Aiming for world leading sensitivity to low mass ( $\lesssim 10 \text{ GeV}/c^2$ ) DM
- Challenges: Understanding and modeling detector response, low-energy calibration

# SuperCDMS SNOLAB projected sensitivity for ERDM

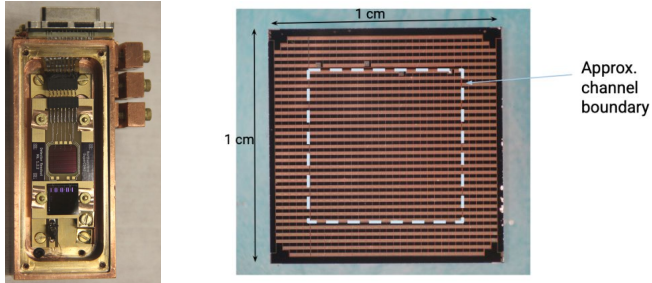
- PLR-based 90% CL projected sensitivities for Electron Recoil
- HV detectors: **Si** / **Ge**



# SuperCDMS R&D programs

## SuperCDMS HVeV

Gram scale versions of SuperCDMS HV with eV resolution



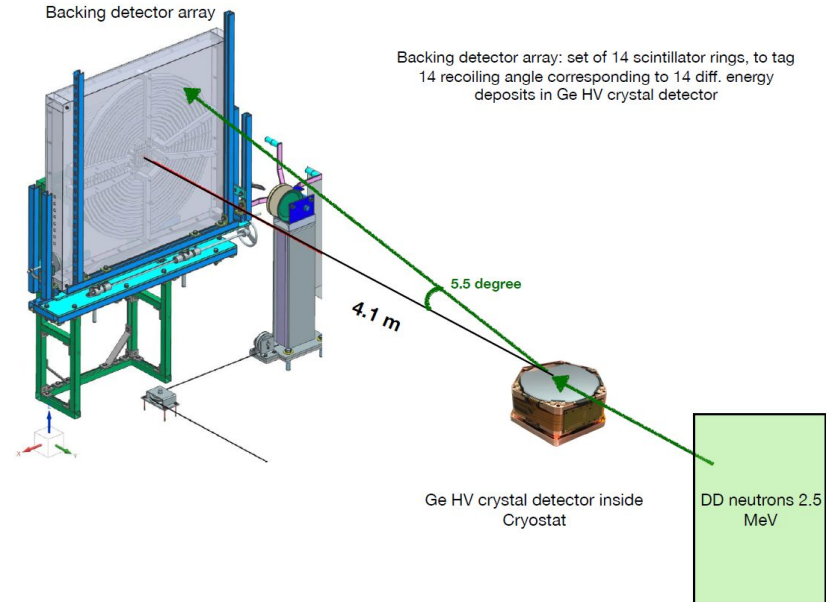
1 cm<sup>2</sup>, gram-size detectors with eV baseline resolution

- 5 runs since 2017
  - PhysRevLett. 121, 051301
  - Phys. Rev. D 102, 091101(R)
  - Phys. Rev. D 111, 012006
  - Phys. Rev. D 113, 032001
  - Run 5 publication in progress (*p31 in this talk*)
- DM limits, NR yield, detector response modeling, background hunting, Low Energy Excess (LEEs)

## SuperCDMS IMPACT



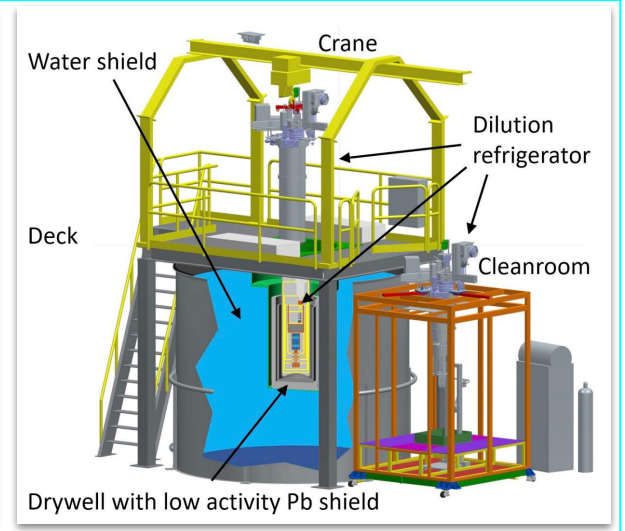
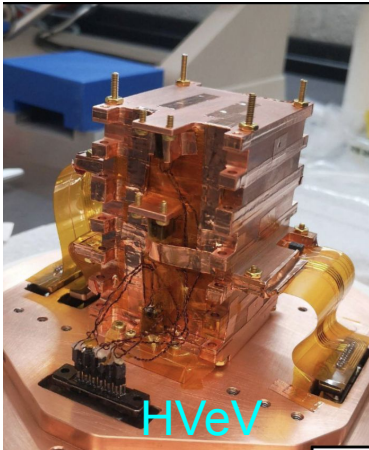
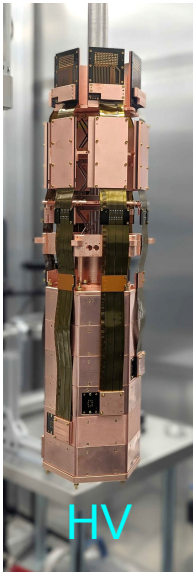
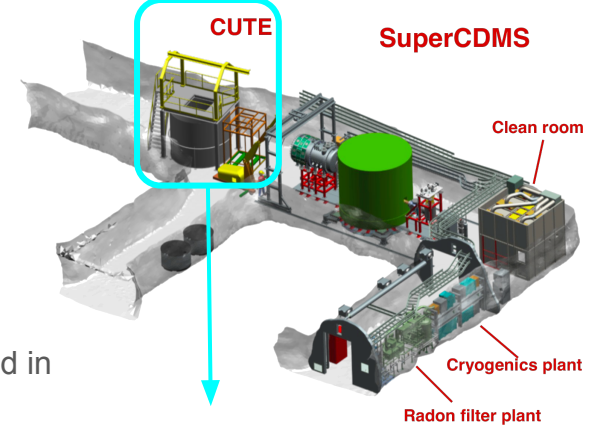
Deployment of HV detector in low-energy neutron beam for NR yield studies



# SuperCDMS R&D programs at CUTE

## Testing programs at Cryogenic Underground Test facility

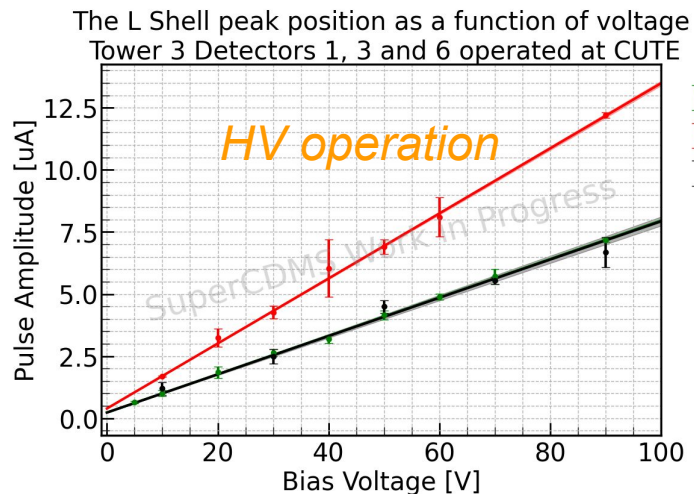
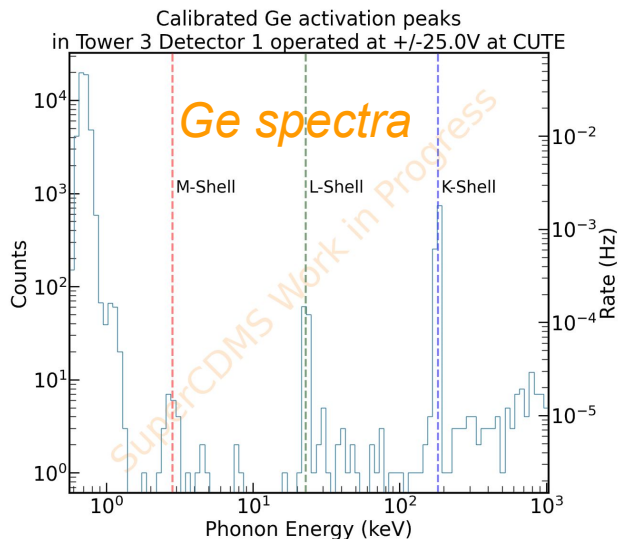
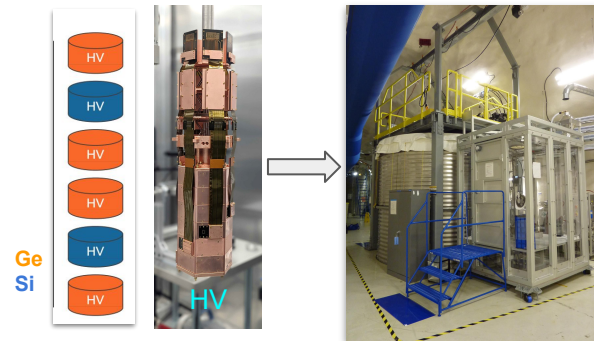
- SuperCDMS HV tower testing to understand detector characteristics - Oct'23 to Mar'24
- HVeV: data-taking with 6 detectors to study Low Energy Excess (LEE) - completed in Sep'24



# SuperCDMS R&D programs at CUTE

## HV tower testing at Cryogenic UndergrounD TEst facility (CUTE)

- SuperCDMS HV tower testing to understand detector characteristics - Oct 2023 to March 2024



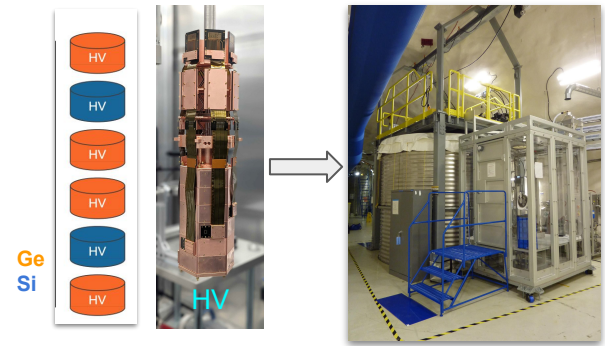
⇒ Upcoming publication

Talk: Performance results of germanium high-voltage detectors tested in the Cryogenic UndergrounD TEst facility  
Ruchi Soni | Jun 22, 2026, 3:30 p.m. | (PPD) M2-9 Neutrinos

# SuperCDMS R&D programs at CUTE

## HV tower testing at Cryogenic Underground Test facility (CUTE)

- SuperCDMS HV tower testing to understand detector characteristics - Oct 2023 to March 2024

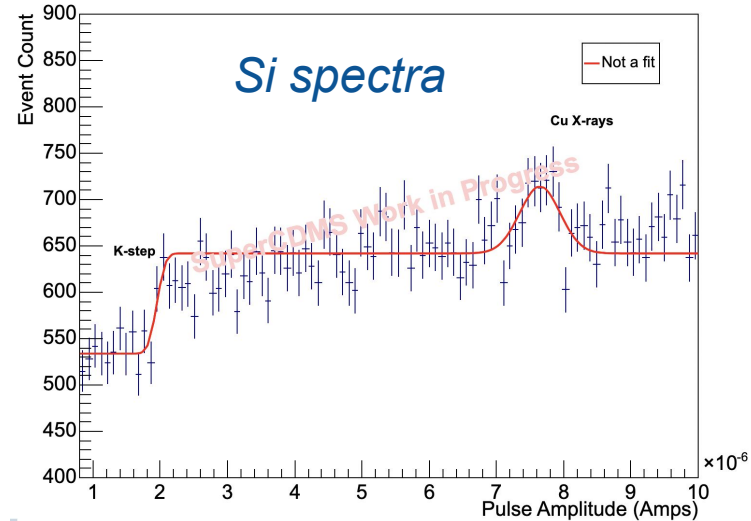


## Si calibration

- Compton steps: Reduction in interaction rate due to scattering below binding energy
  - 1.84 keV (K step)
  - 150 and 100 eV ( $L_1$  and  $L_2$  step)

⇒ Analysis ongoing

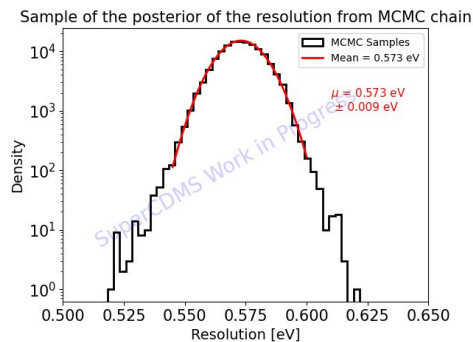
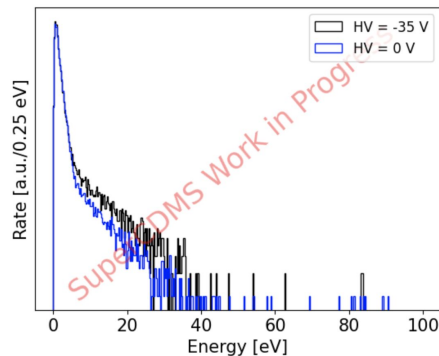
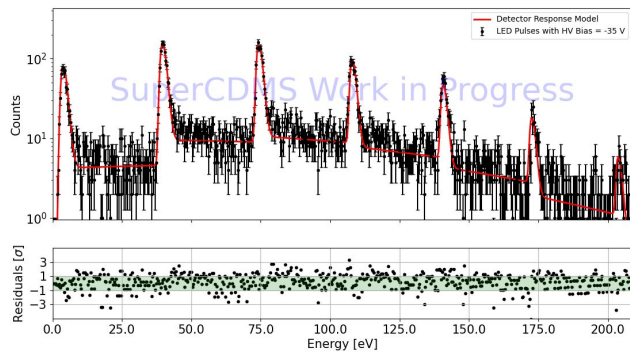
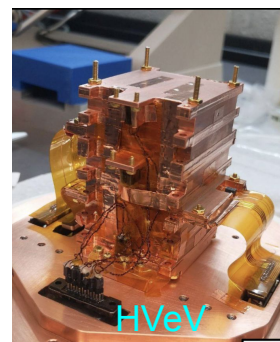
Ba calibration for Tower 3 Detector 2 at 0V (preliminary data quality cuts)



# SuperCDMS R&D programs at CUTE

## HVeV program at Cryogenic UndergrounD TEst facility (CUTE)

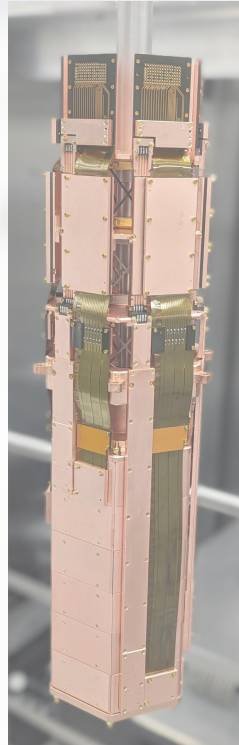
- HVeV: data-taking with 6 detectors to study Low Energy Excess (LEE)
- ~4 months of data-taking in 2024



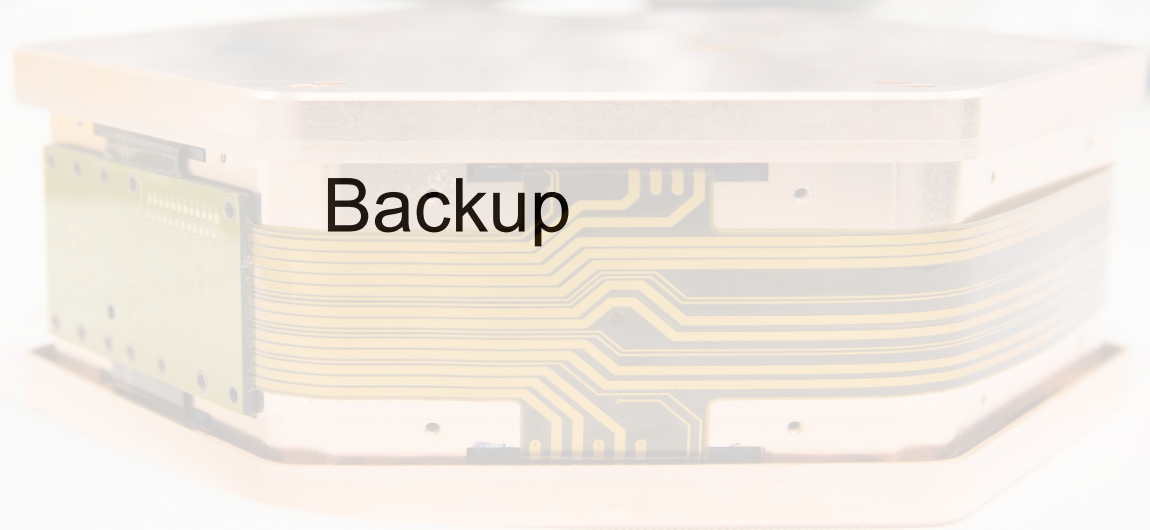
Talk: HVeV Run 5: The Latest Generation of High-Voltage, Electronvolt-Scale Cryogenic Silicon Calorimeters in the Search for Dark Matter  
Mason Buchanan | Jun 25, 2026, 2:45 p.m | (PPD) R1-1 DM

# Summary

- SuperCDMS experiment: direct DM detection, targeting sub-GeV DM masses
- Cryogenic Si/Ge detectors:
  - iZIP: background rejection
  - HV: low threshold
- R&D programs at CUTE facility at SNOLAB
- Primary installation complete at SNOLAB
- Experiment status:
  - ◆ commissioning completing soon
  - ◆ Science run 1a starting mid-July through September
  - ◆ Post maintenance → run 1b.



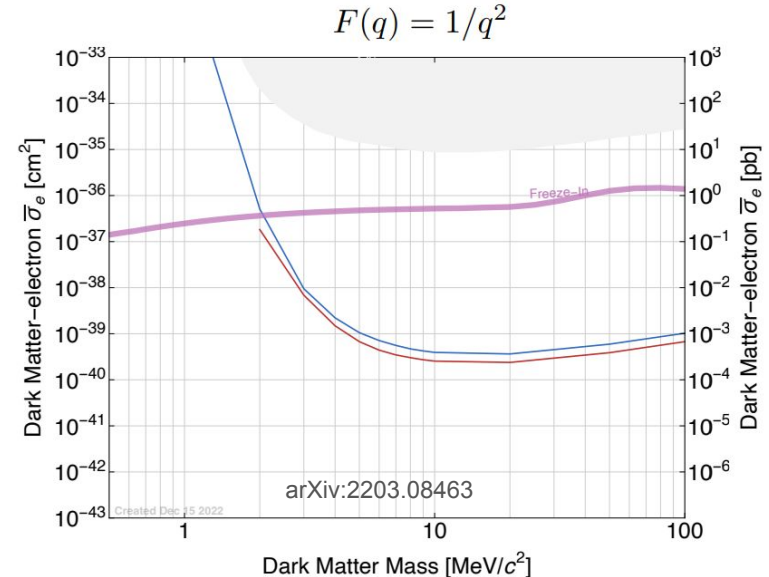
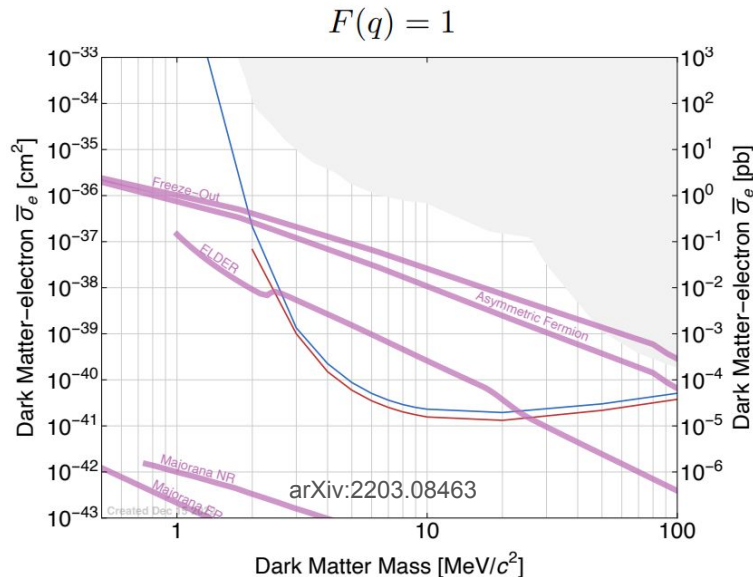
Stay Tuned!



Backup

# SuperCDMS SNOLAB projected sensitivity for ER-LDM

- PLR-based 90% CL projected sensitivities for Electron Recoil
  - for heavy mediator (form factor  $F(q) = 1$ , left)
  - a light mediator (form factor  $F(q) = 1/q^2$ , right)
- HV detectors: Si: blue; Ge: red



# SuperCDMS SNOLAB: Shielding

## ▶ Outer neutron shield:

- ▶ Reduce MeV neutrons from cavern wall by  $\sim 10^6$ ,  $\sim 20$  for  $\mu$ -induced neutrons (GeV)

## ▶ Gamma-ray shield:

- ▶ Reduces MeV gammas from cavern wall by  $\sim 10^5$
- ▶ Inner layer is 1cm ancient lead,  $^{210}\text{Pb} < 1$  Bq/kg
- ▶ Reduce Bremsstrahlung  $^{210}\text{Bi}$  in shield by factor of  $\sim 20$

## ▶ Radon barrier:

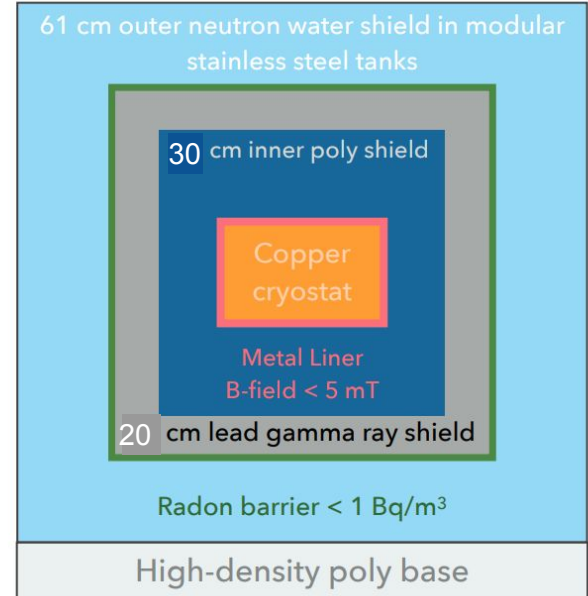
- ▶ Al sheet banded around the lead shield with taped joints
- ▶ Reduce  $\sim 100$  Bq/m<sup>3</sup> to  $< 0.1$  Bq/m<sup>3</sup> (mine air)

## ▶ Inner neutron shield:

- ▶ Stacked 2" thick poly sheets
- ▶ Reduces neutron rate by  $> 10$   $\mu$ -induced neutron from rock
- ▶ Neutrons from lead
- ▶ Absorbs backscatter from SNOBOX vacuum cans
- ▶ No neutron "reflection" from lead

## ▶ Copper cans of Cryostat System:

- ▶ 6.7 cm of copper in nested cans (SNOBOX)
- ▶ Copper is radiopure compared to lead
- ▶ Final gamma shield
- ▶ Reduce residual gammas by  $\sim 25$
- ▶ Reduces Bremsstrahlung from  $^{210}\text{Bi}$   $\beta$ -decay by  $\sim 20$



Slide credit: M. J. Wilson

# SuperCDMS SNOLAB: Backgrounds

## Cosmogenic

- Cosmic ray muons
- Spallation neutrons
- Activated materials

## Environmental

- Airborne radon & daughters
- Radio-impurities in materials

"Singles" Background Rates (counts/kg/keV/year)	Electron Recoil				Nuclear Recoil ( $\times 10^{-6}$ )	
	Ge HV	Si HV	Ge iZIP	Si iZIP	Ge iZIP	Si iZIP
Coherent Neutrinos					2300.	1600.
Detector-Bulk Contamination	21.	290.	8.5	260.		
Material Activation	1.0	2.5	1.9	15.		
Non-Line-of-Sight Surfaces	0.00	0.03	0.01	0.07	–	–
Bulk Material Contamination	5.4	14.	12.	88.	440.	660.
Cavern Environment	–	–	–	–	510.	530.
Cosmogenic Neutrons					73.	77.
Total	27.	300.	22.	370.	3300.	2900.

Phys. Rev. D **95**, 082002

# SuperCDMS backgrounds

Phonon energy spectra after analysis cuts

Black vertical dashed line:  $7\sigma$  analysis threshold

Black vertical dot-dashed line: leakage threshold

Red: bulk ERs due to Compton,  $^3\text{H}$ ,  $^{32}\text{Si}$

Green: surface ERs

Mustard: surface NRs due to  $^{206}\text{Pb}$

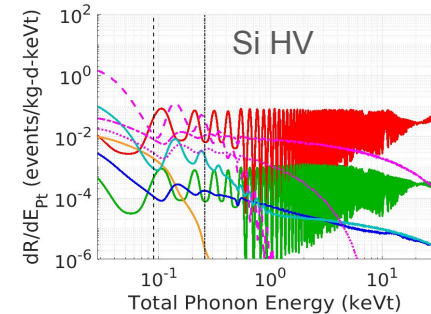
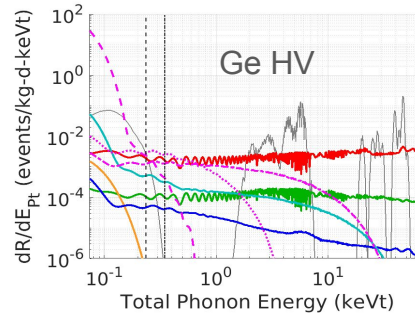
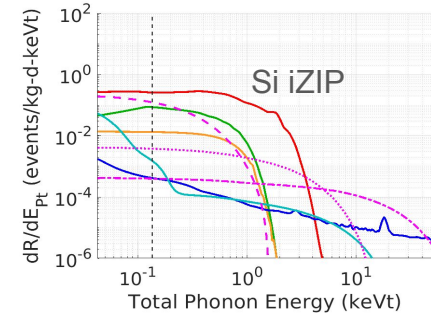
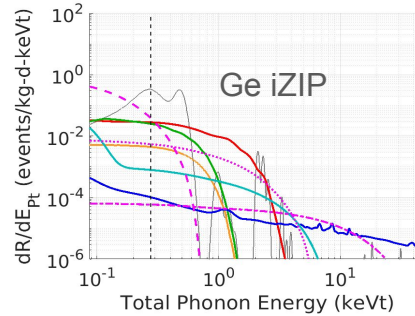
Blue: bulk NRs due to neutrons

Cyan: bulk NRs due to solar neutrino CEvNS

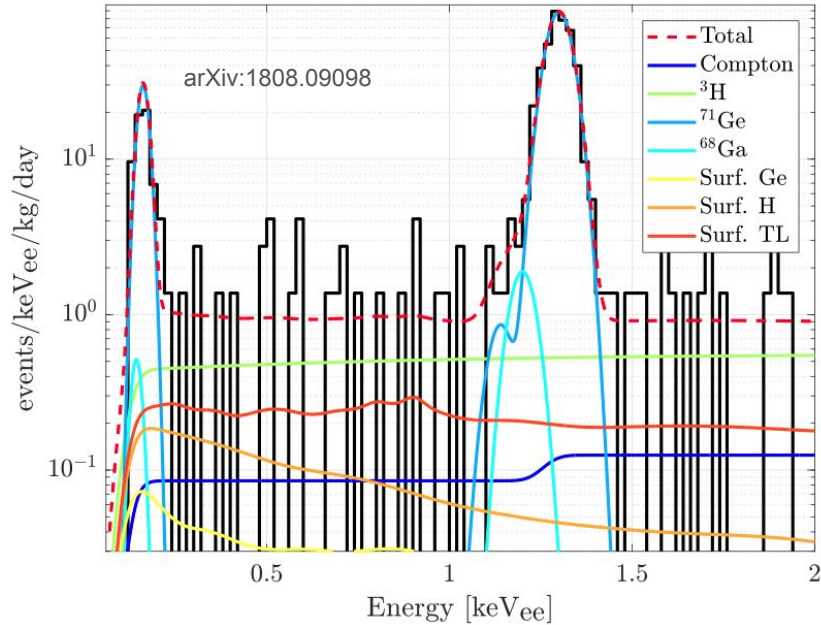
Grey: Germanium activation lines

Magenta: candidate DM signals for

- $M_\chi \approx 1.6, 5, \text{ and } 16 \text{ GeV}/c^2$  for iZIP
- $M_\chi \approx 0.5, 1.6, \text{ and } 5 \text{ GeV}/c^2$  for HV for cross sections at the exclusion sensitivity



# CDMSlite spectra and backgrounds



# SuperCDMS SNOLAB: ER/NR

$$E_{ph} = E_R + \frac{Y(E_R)E_R}{\epsilon} e\Delta V$$

$Y(E_R) = 1 \rightarrow$  ER

$Y(E_R) < 1 \rightarrow$  NR

