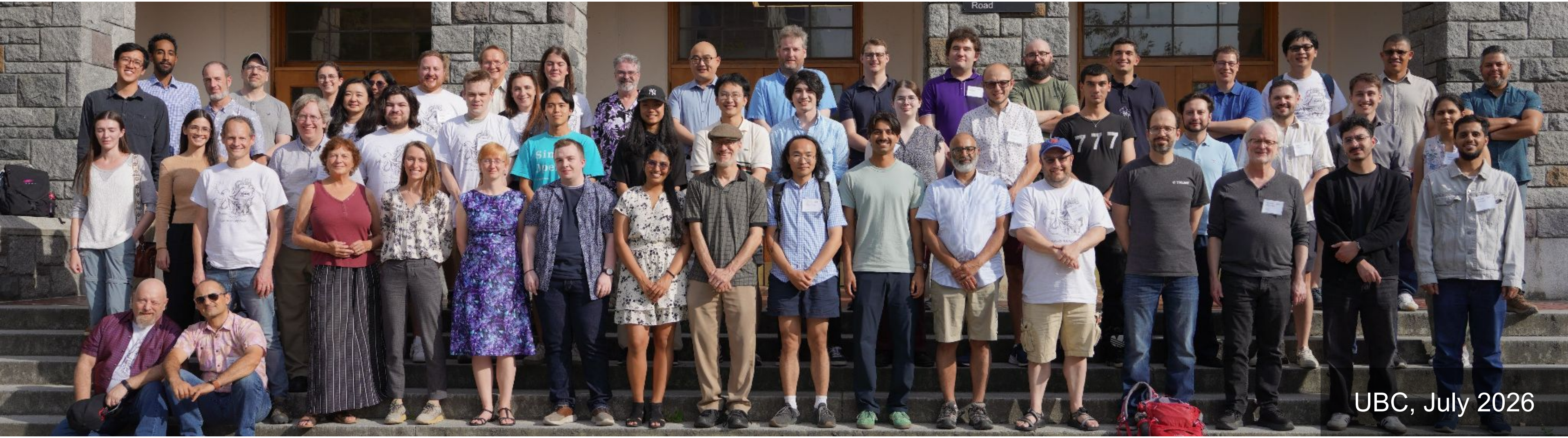
The SuperCDMS SNOLAB experiment

Overview and status of commissioning and the first science run

Matthew Wilson
On behalf of the SuperCDMS Collaboration

Light Dark World 2026
July 29, 2026



UBC, July 2026

@SuperCDMS

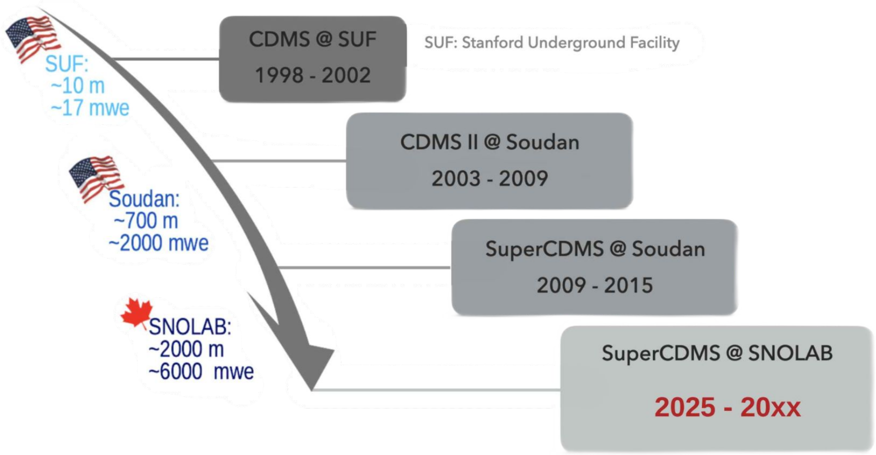
supercdms.slac.stanford.edu

The SuperCDMS Experiment

- **Super C**ryogenic **D**ark **M**atter **S**earch
- Using semiconductor Si and Ge detectors
- Operated at cryogenic temperatures O(10 mK)
- Measures energy depositions from phonon and ionization signals

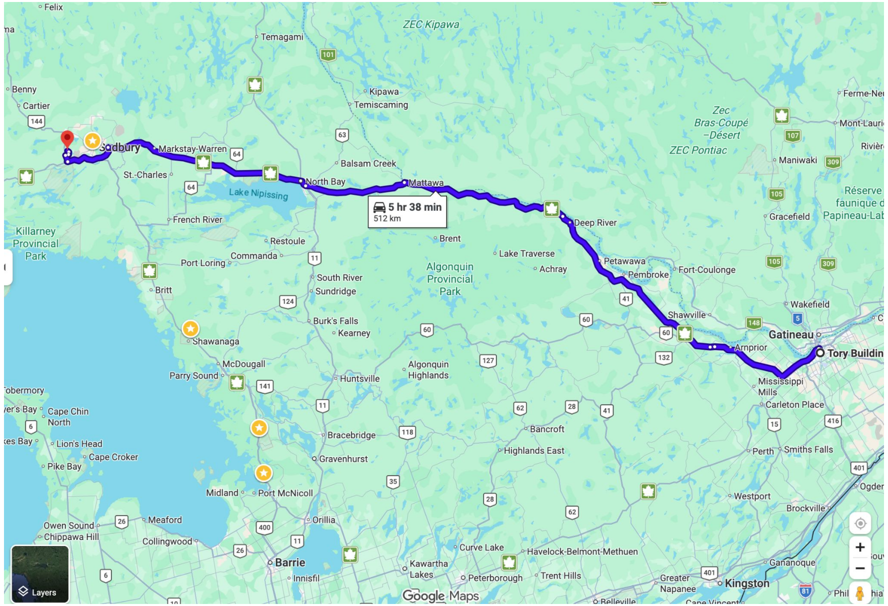
SNOLAB vs Soudan:

- 10^3 reduction in cosmic rays
- 250 reduction in μ-induced neutrons



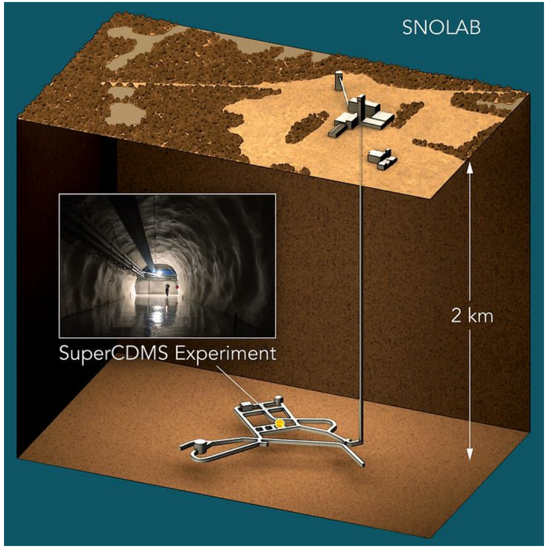
SuperCDMS SNOLAB

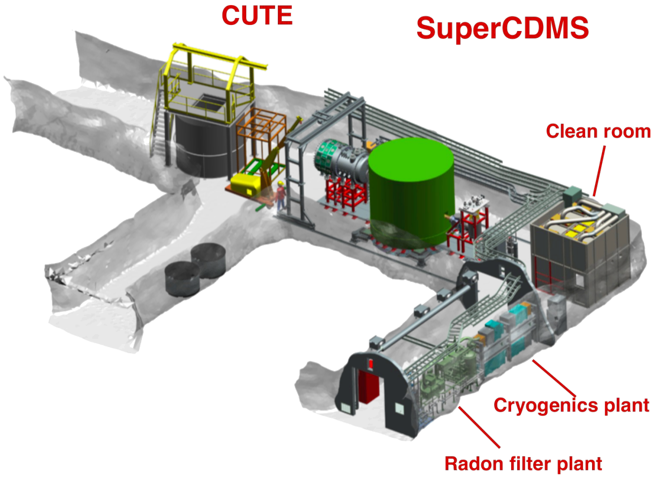
- Located in Sudbury, Canada

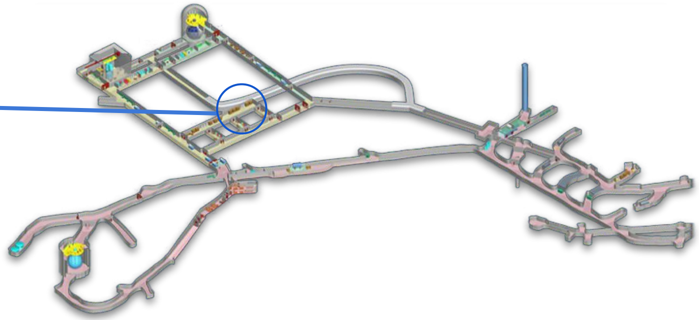


SuperCDMS SNOLAB

- Located in Sudbury, Canada
- 2 km rock overburden (~6000 m.w.e)
    - ~0.286 μ/m^2/day
- Class 2000 cleanroom
- Host to many low-background experiments

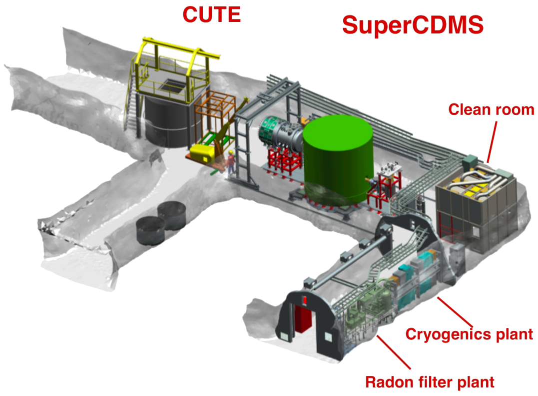


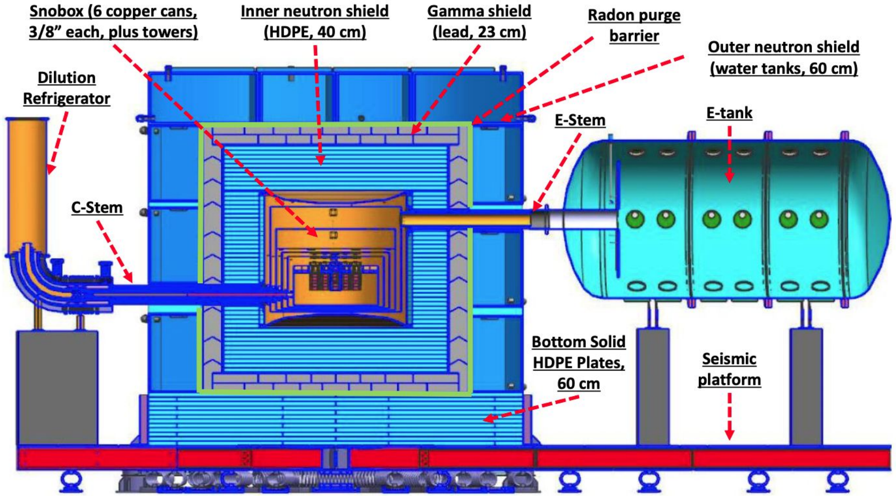




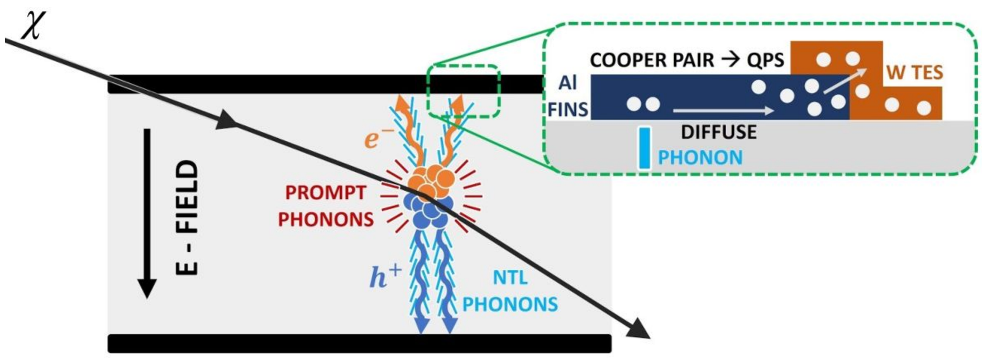
SuperCDMS SNOLAB

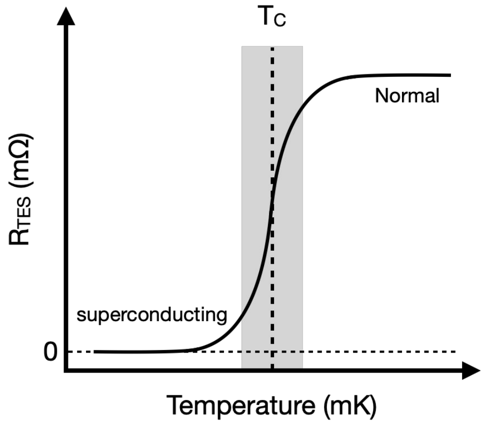
- **C-stem:** connection for heat conduction to the dilution fridge
- **E-stem**: carries the signals from the detectors
- **E-tank:** vacuum bulkhead where the detector boards are connected





Detection method



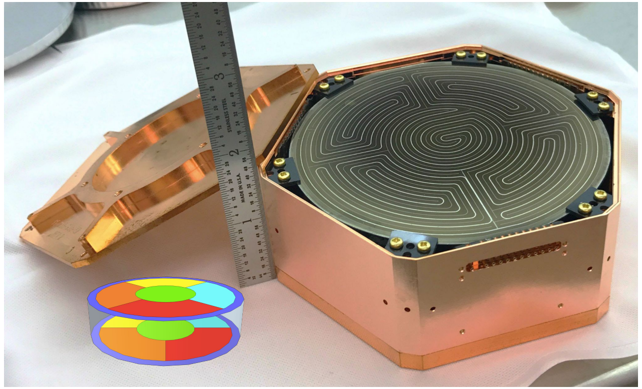


Particle interactions in the detector:

- Electron Recoils (ER) or Nuclear Recoils (NR)
- **Phonons:** QET phonon sensors
- **Drifting e/h pairs:** HEMT charge sensors

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

SuperCDMS Detectors



Interleaved **Z**-sensitive **I**onization and **P**honon (iZIP)

- 12 phonon channels & 4 charge channels
- Small bias voltage (< 10 V)
- **ER/NR discrimination**
- Improved background rejection

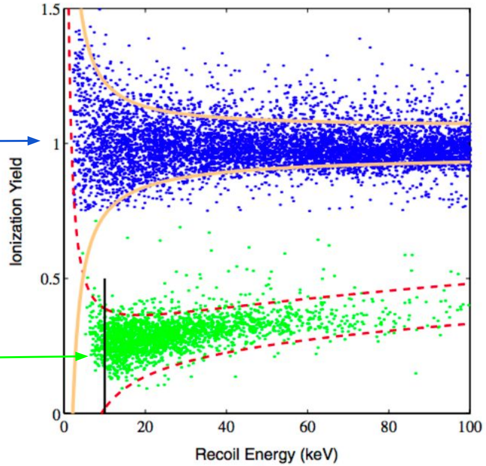
$$E_{ph} = E_R + \frac{Y(E_R)E_R}{\epsilon} e\Delta V$$

$Y(E_R) = 1$ –> ER

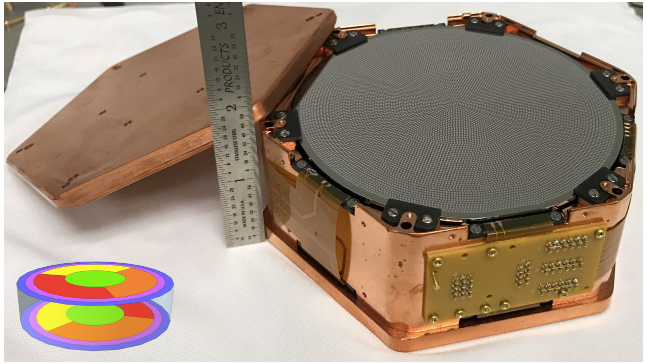
$Y(E_R) < 1$ –> NR

ER band

NR band

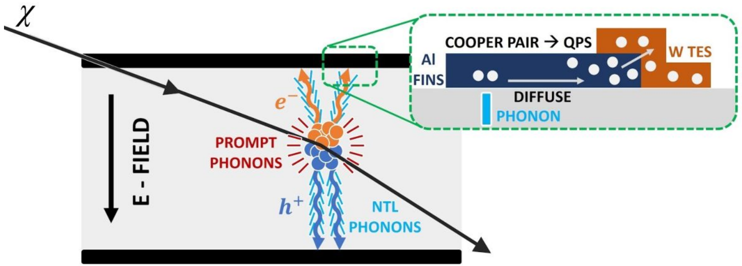


SuperCDMS Detectors



High **V**oltage (HV)

- 12 phonon channels
- Large bias voltage (up to ~100 V)
- **NTL amplification**
  - Amplified signal → low threshold → low mass DM search

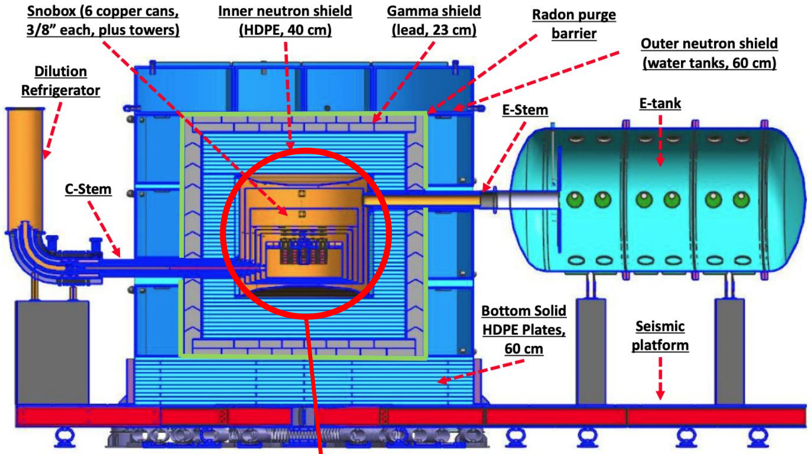


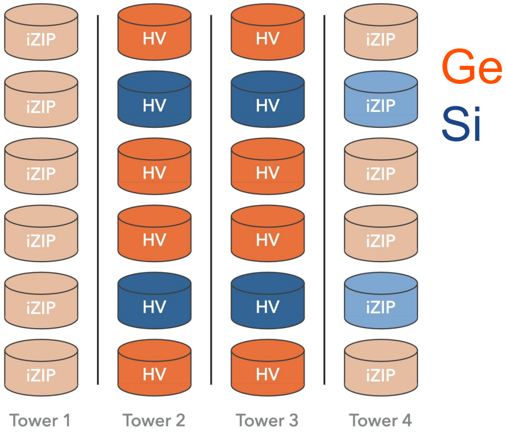
$$E_{ph} = E_R + \frac{Y(E_R)E_R}{\epsilon}\boxed{e\Delta V}$$

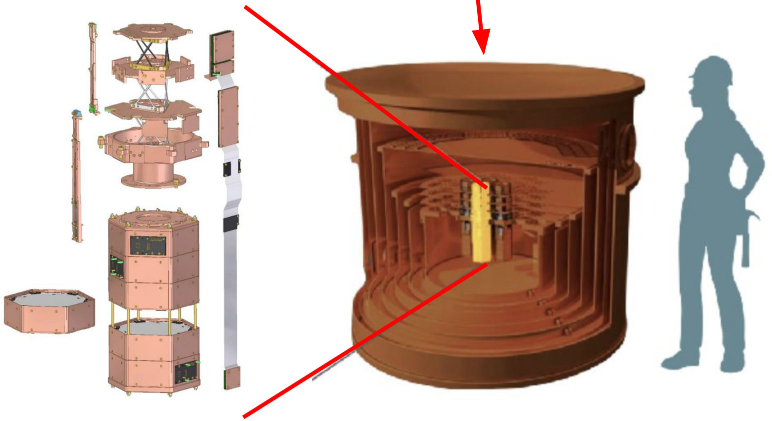
NTL: Neganov-Trofimov-Luke

Detector payload

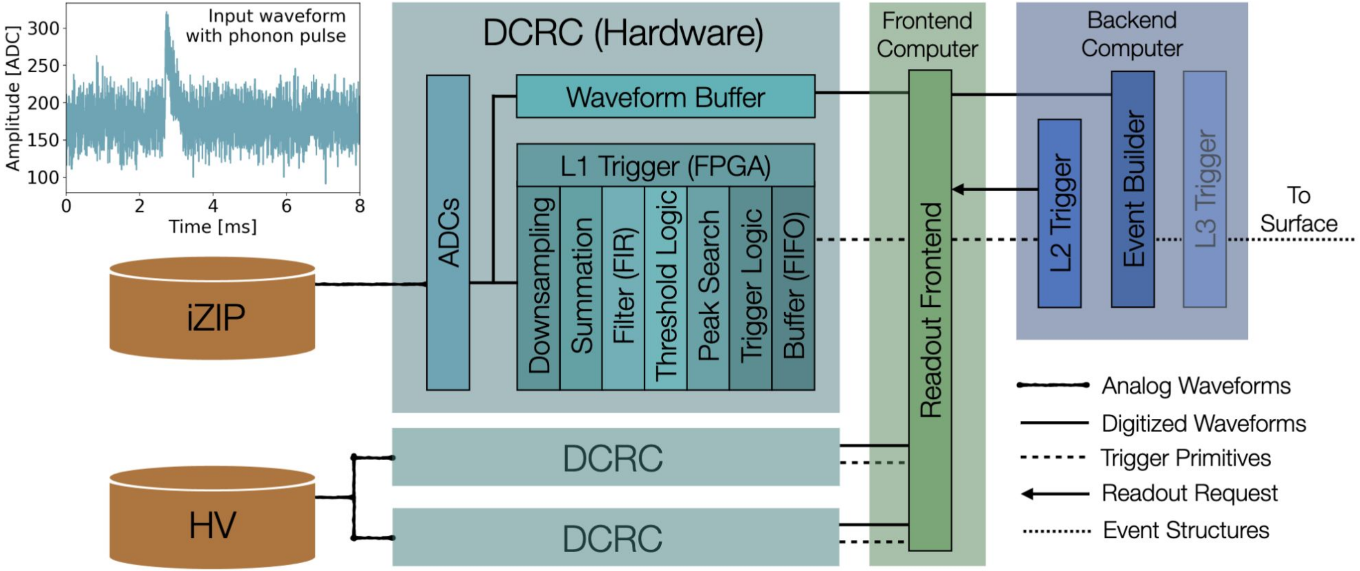
- 4 towers, 6 detectors each
- 2 iZIP, 2 HV towers
- ~30 kg total payload







Data Acquisition and Triggering



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DCRC: Detector Control and Readout Card

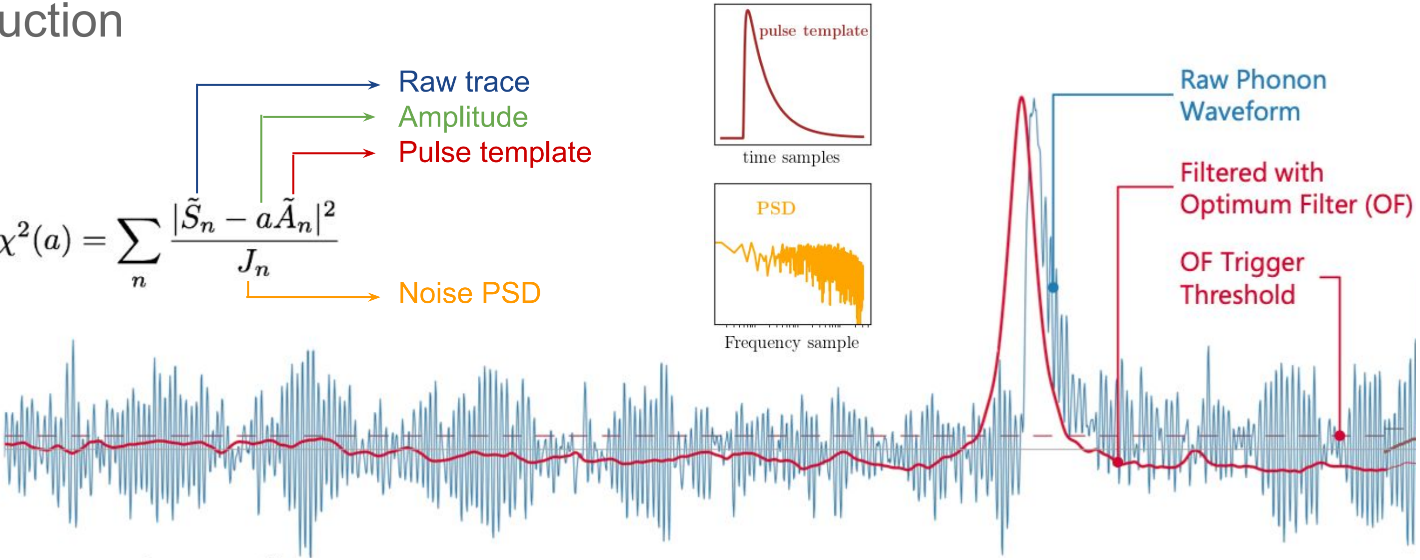
Data Acquisition and Triggering

The **O**ptimal **F**ilter (OF) is used for triggering and pulse reconstruction

Raw trace
Amplitude
Pulse template

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

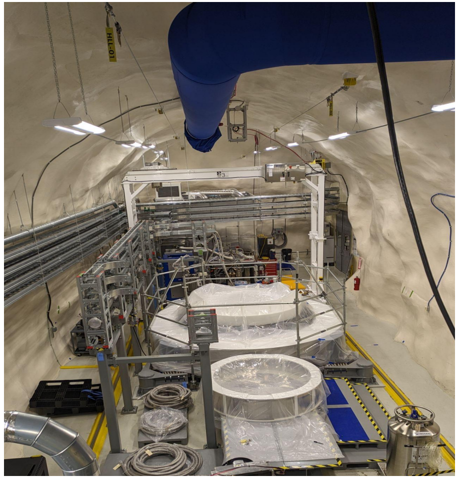
Noise PSD



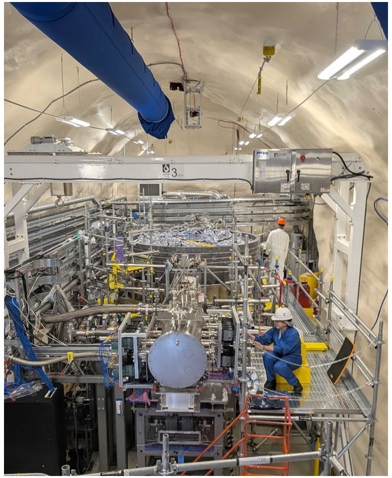
SuperCDMS SNOLAB Installation

March 2024

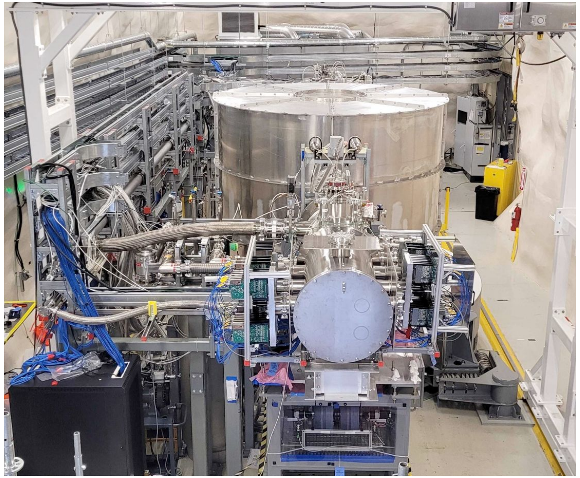
Nov 2024



March 2026

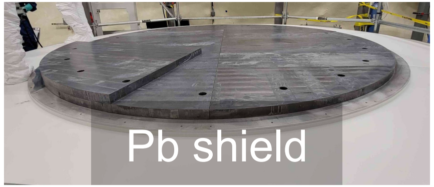


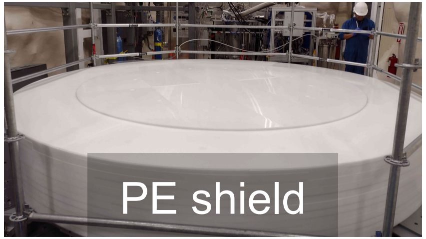
July 2026

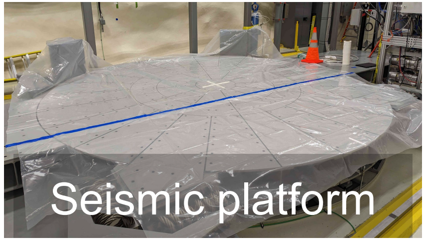


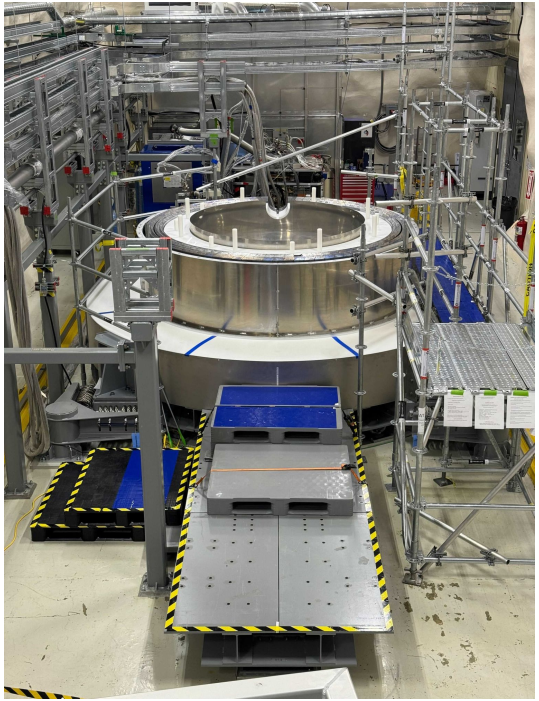
SuperCDMS SNOLAB Installation

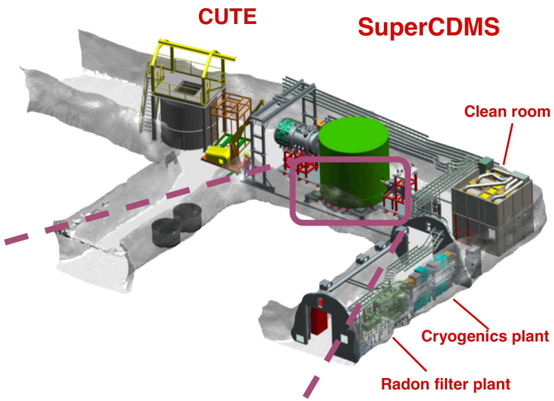
Shield base installation (2024)





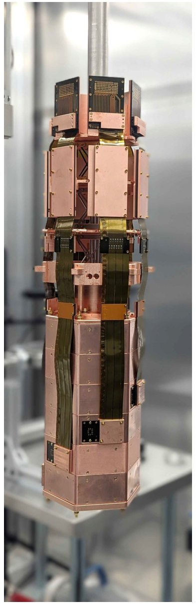


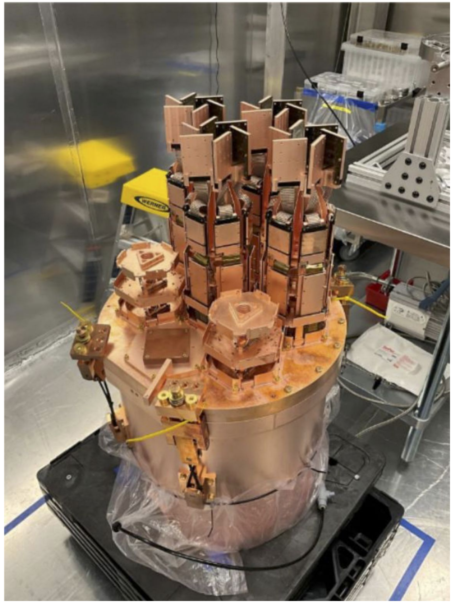


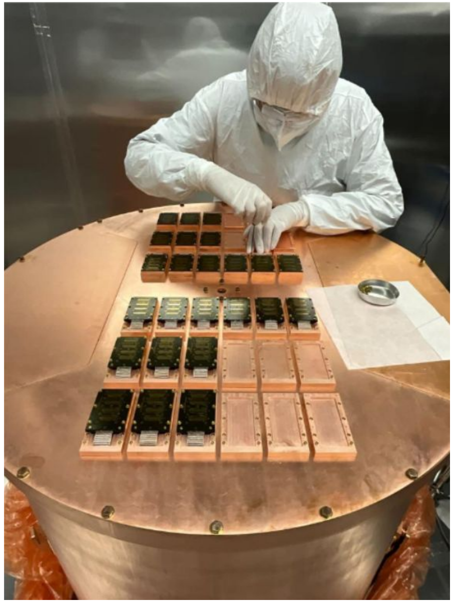


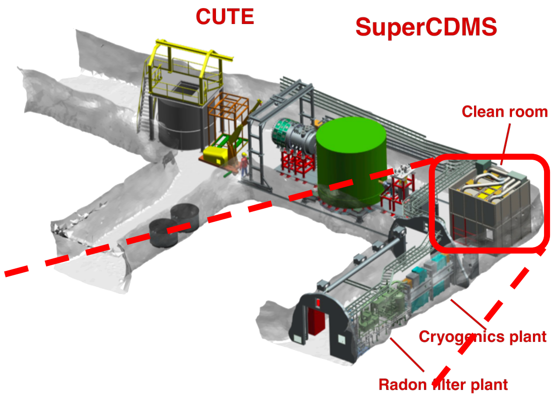
SuperCDMS SNOLAB Installation

Tower assembly (2025)



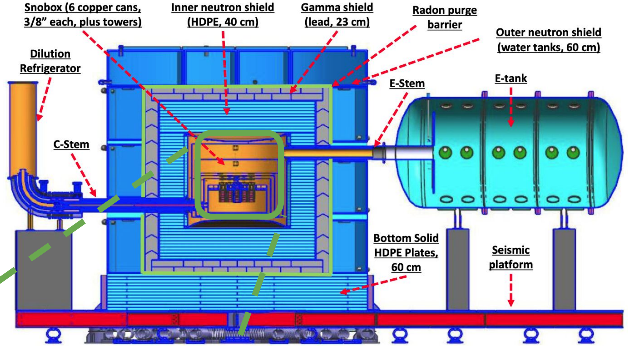


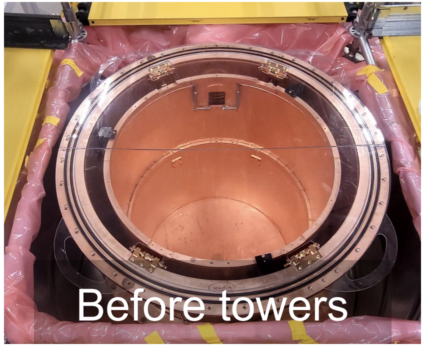


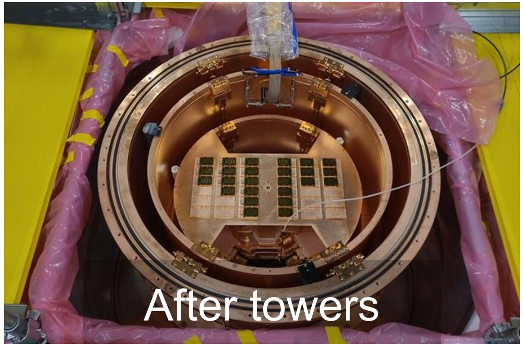


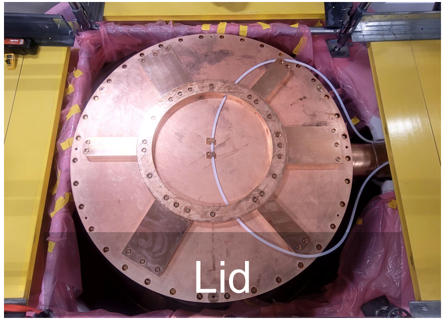
SuperCDMS SNOLAB Installation

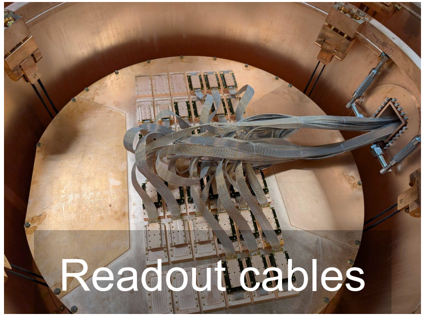
Cryostat installation (2025)





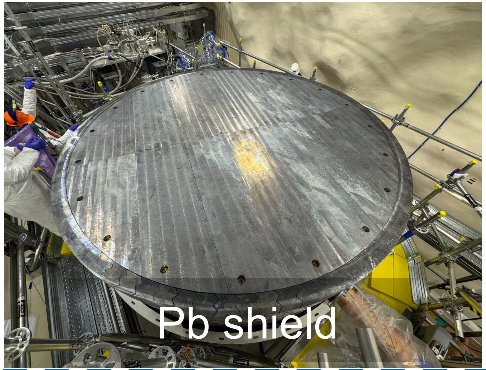


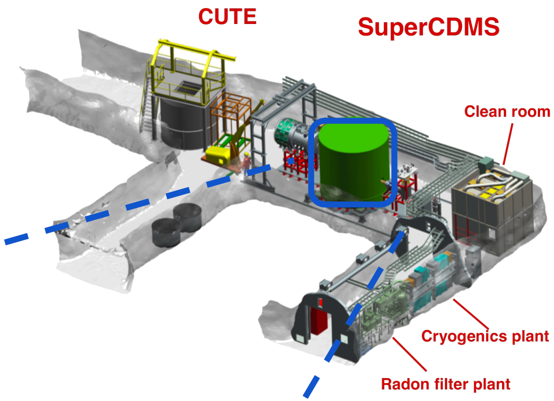




SuperCDMS SNOLAB Installation

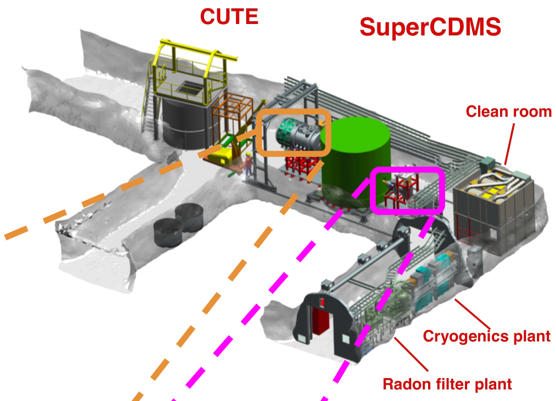
Shield top installation (2026)

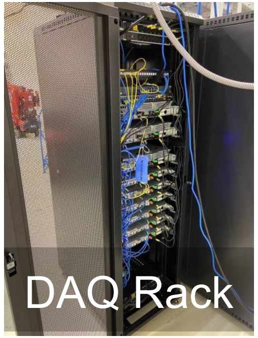


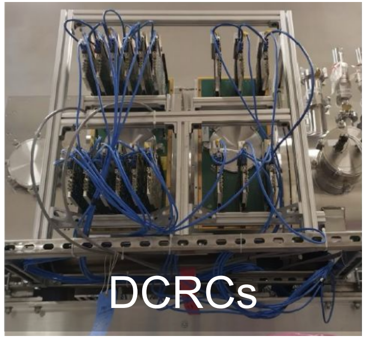


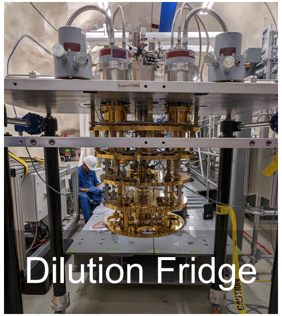
SuperCDMS SNOLAB Installation

E-tank, DAQ installation(2025)



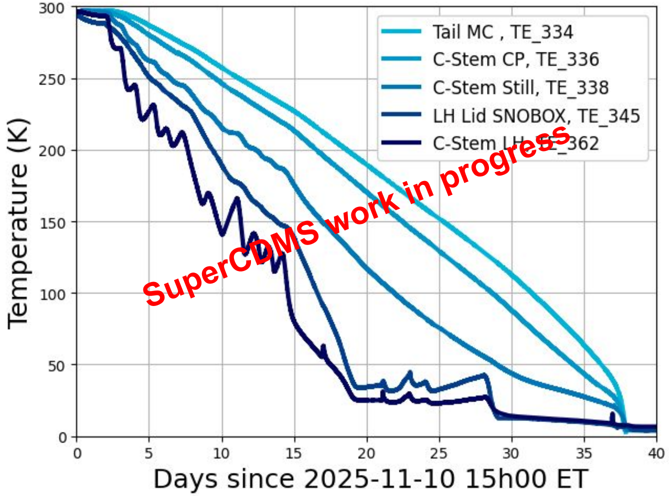


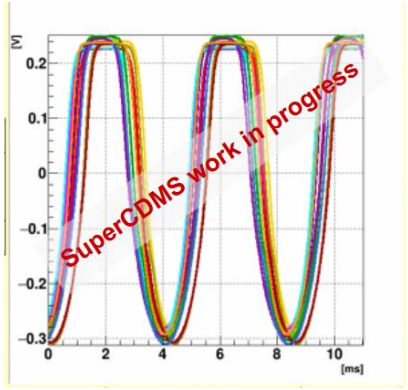




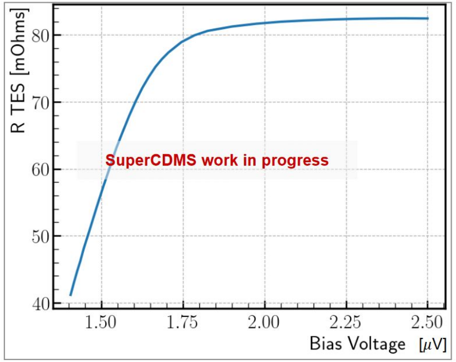
SuperCDMS SNOLAB Cooldown

- Began Nov 2025
- Reached base temperature in Jan 2026
    - Detector characterization began



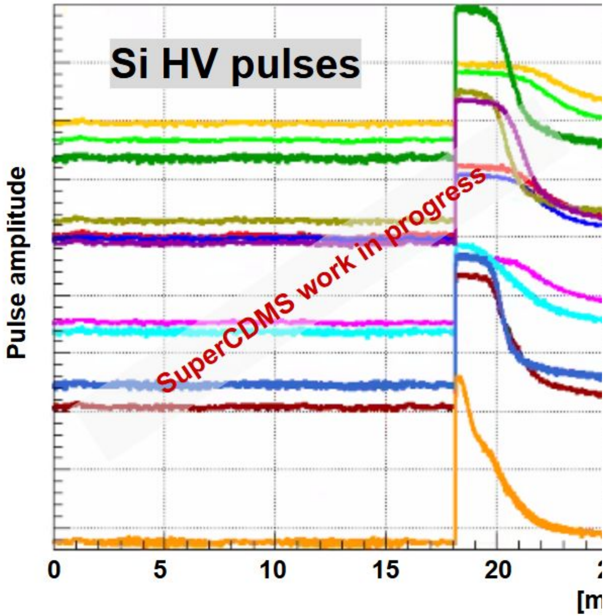


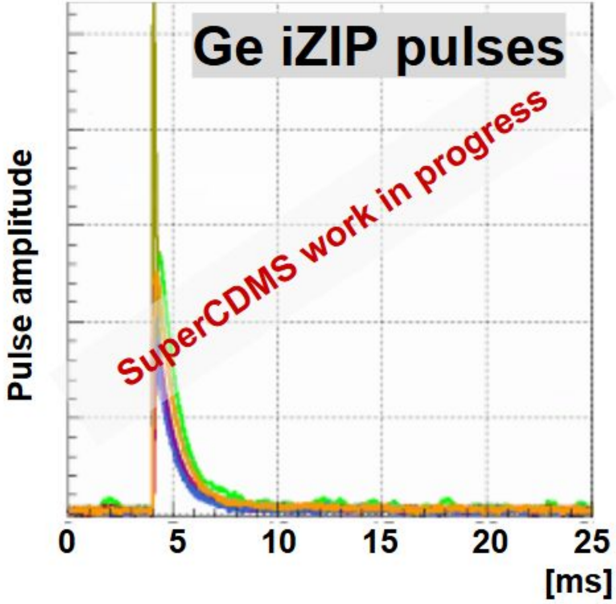
SQUID modulation curves

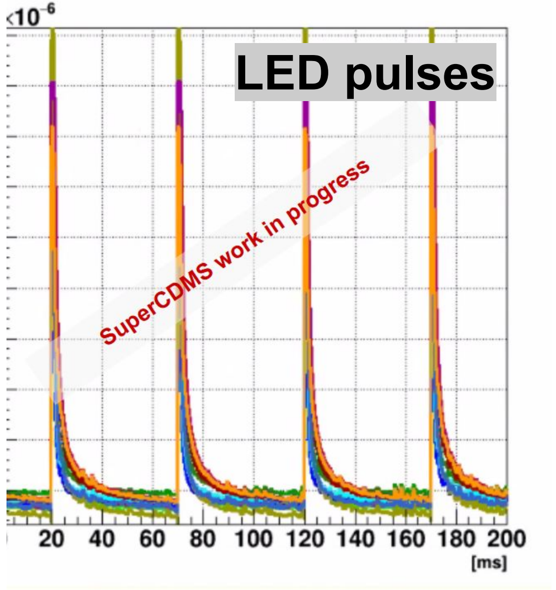


TES resistance profile

SuperCDMS SNOLAB Commissioning





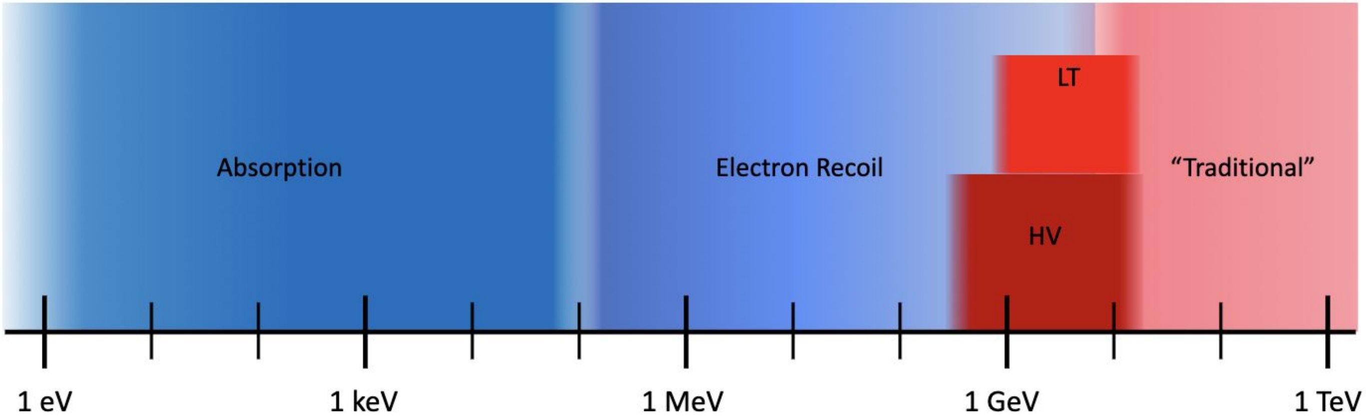


SuperCDMS SNOLAB Science Run 1a/b

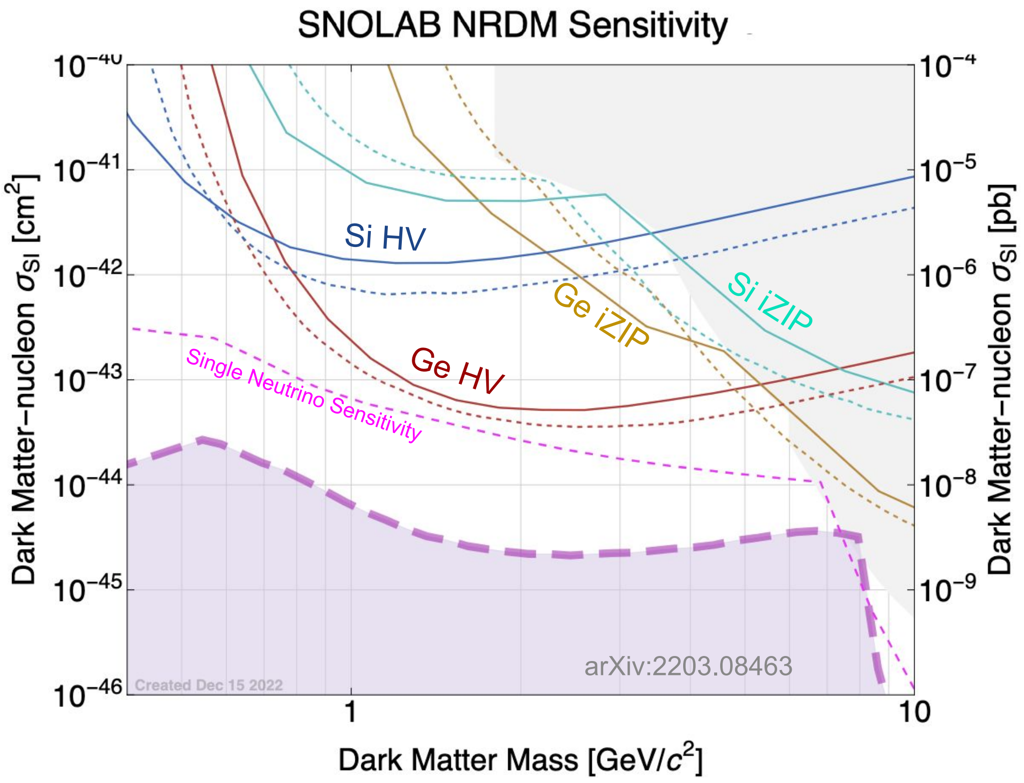
- SR1a:
  - Starting July-Aug 2026 during SNOLAB “quiet” time and anticipated to continue until Sept 2026
  - Science data taking + refinement of processes (detector optimization, flash sequences, trigger setup)
- Between SR1a and SR1b:
  - Full warm-up
  - Maintenance and repairs
  - Ice-tank chilled water backup
- SR1b:
  - Cooldown and data taking: early 2027
- After SR1b:
  - Installation of water tanks
  - Science Run 2

Science Reach

“Traditional” NR	iZIP, “background free”	$\gtrsim$ 5 GeV
Low Threshold NR	iZIP, limited discrimination	$\gtrsim$ 1 GeV
HV Mode	HV, no discrimination	~0.3 – 10 GeV
Electron recoil	HV, no discrimination	~0.5MeV – 10 GeV
Absorption (Dark Photons, ALPs)	HV, no discrimination	~1 eV – 500 keV



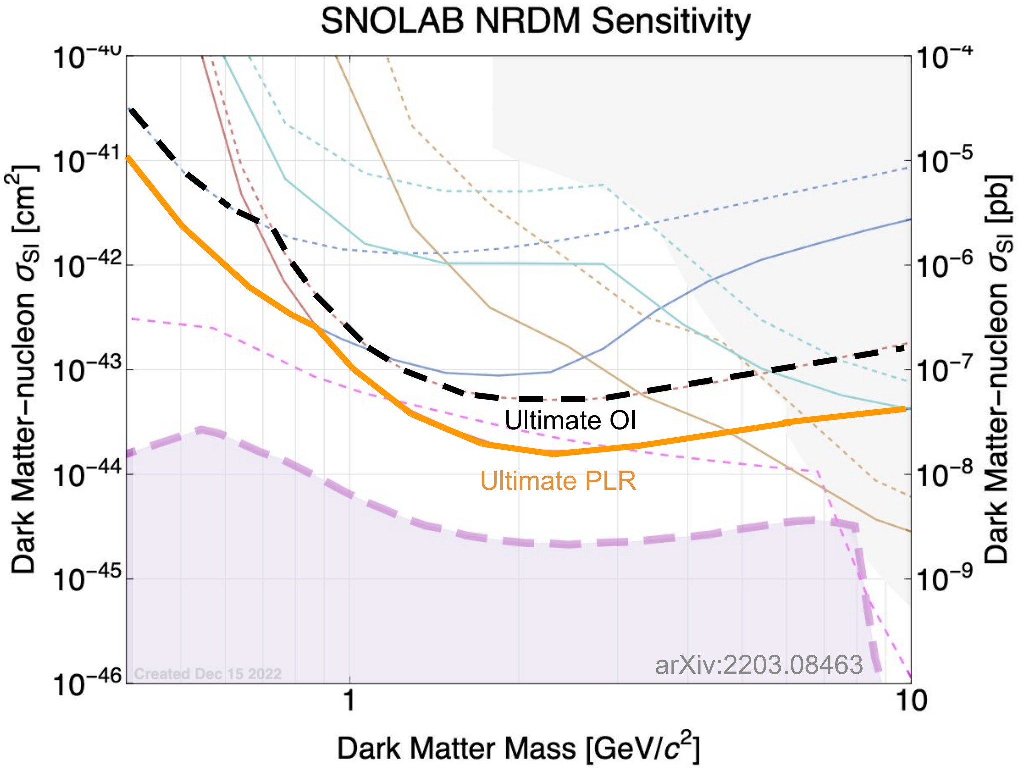
Science Reach



	Si	Ge
HV	Lowest threshold for low-mass DM, Sensitive to the lowest DM	Low threshold for low-mass DM, larger exposure, no ^{32}Si background
iZIP	ER/NR discrimination, understand Si background	ER/NR discrimination, understand Ge background

Projections assuming full science run of 4 years with 80% livetime

Science Reach



	Si	Ge
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Projections assuming full science run of 4 years with 80% livetime

Optimum **I**nterval (**OI**): no prior knowledge of the background

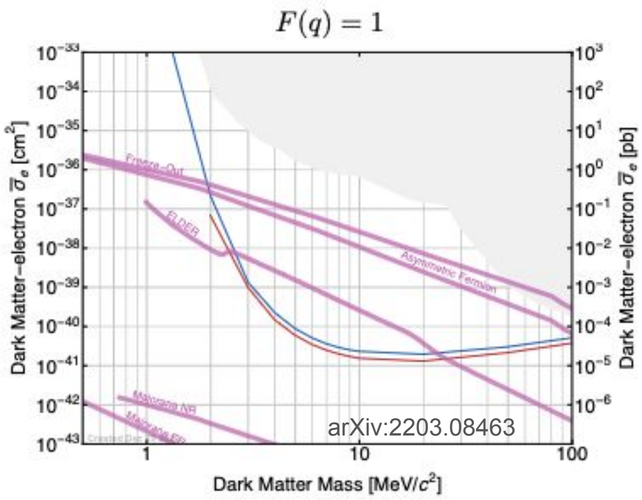
Profile likelihood analysis (PRL)

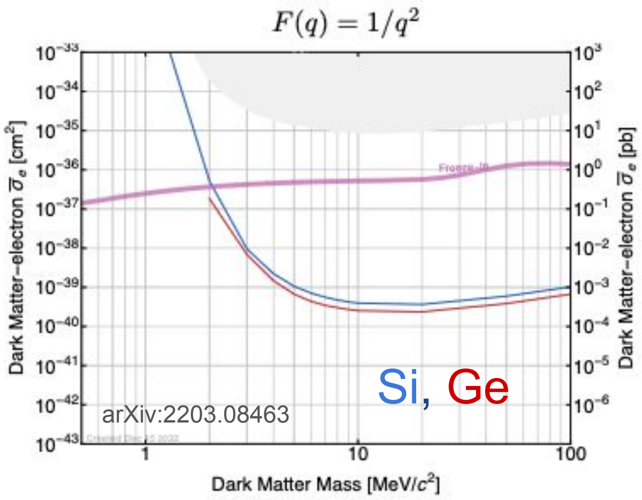
Science Reach: LDM

	Si	Ge
HV	Lowest threshold for low-mass DM, Sensitive to the lowest DM	Low threshold for low-mass DM, larger exposure, no ^{32}Si background
iZIP	ER/NR discrimination, understand Si background	ER/NR discrimination, understand Ge background

Projections assuming full science run of 4 years with 80% livetime

Electron-recoil dark matter



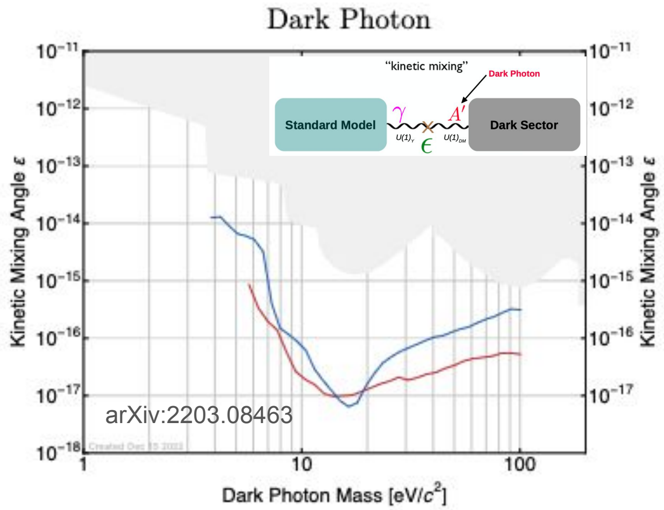


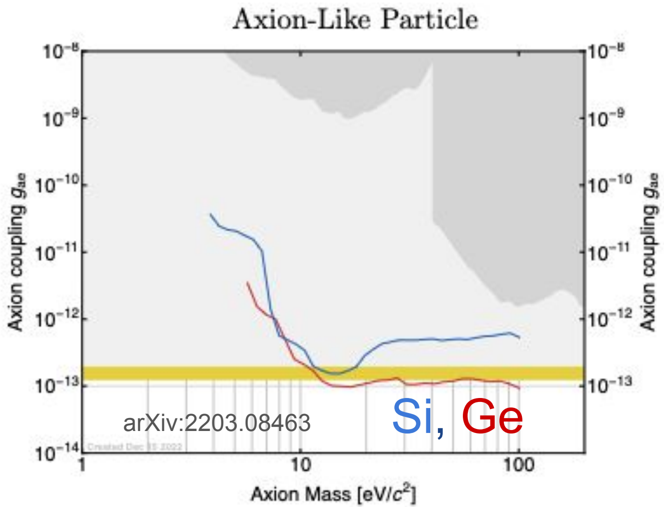
Science Reach: LDM

	Si	Ge
HV	Lowest threshold for low-mass DM, Sensitive to the lowest DM	Low threshold for low-mass DM, larger exposure, no ^{32}Si background
iZIP	ER/NR discrimination, understand Si background	ER/NR discrimination, understand Ge background

Absorption models

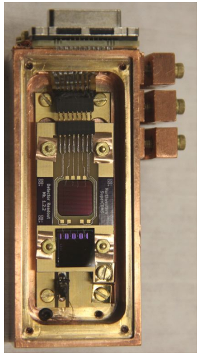
Projections assuming full science run of 4 years with 80% livetime

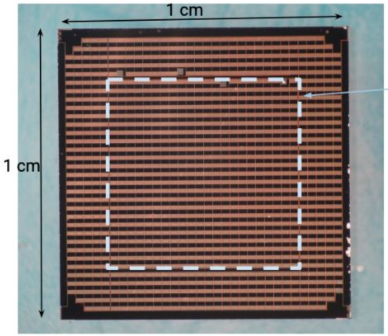




R&D: HVeV

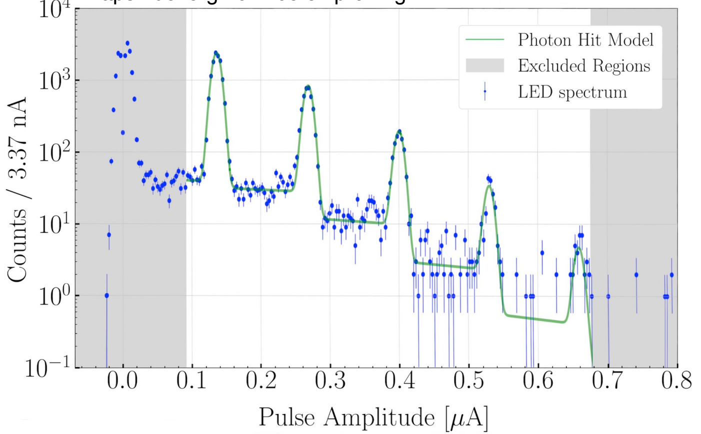
- Gram scale versions of SuperCDMS HV with eV resolution
  - **LDM limits**
  - NR yield
    - PhysRevLett.131.091801
  - detector response modeling, background hunting
    - PhysRevD.109.112018, PhysRevD.105.112006
  - Low Energy Excess (LEEs)

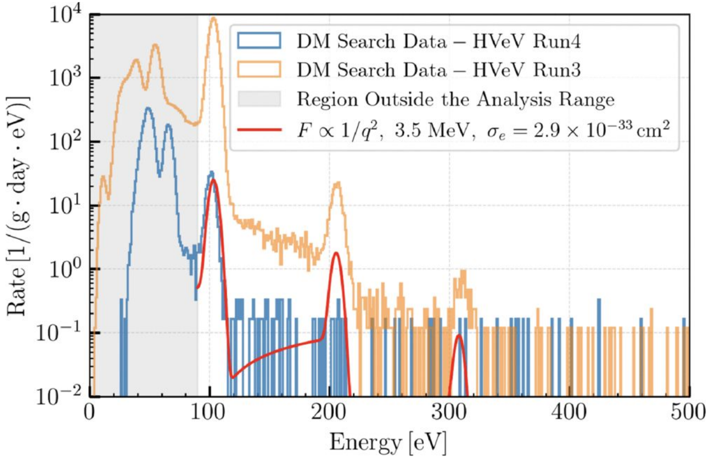




Approx. channel boundary

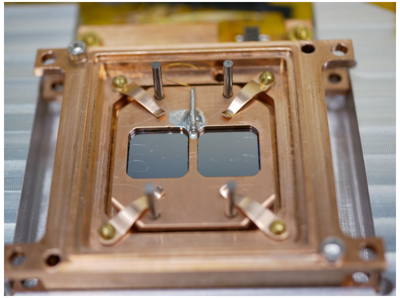
https://doi.org/10.1103/5lnp-6mng

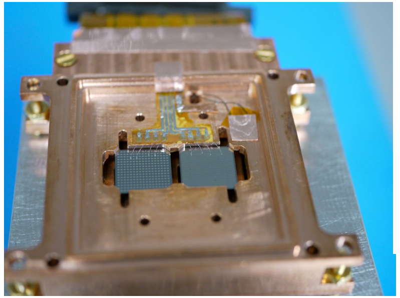


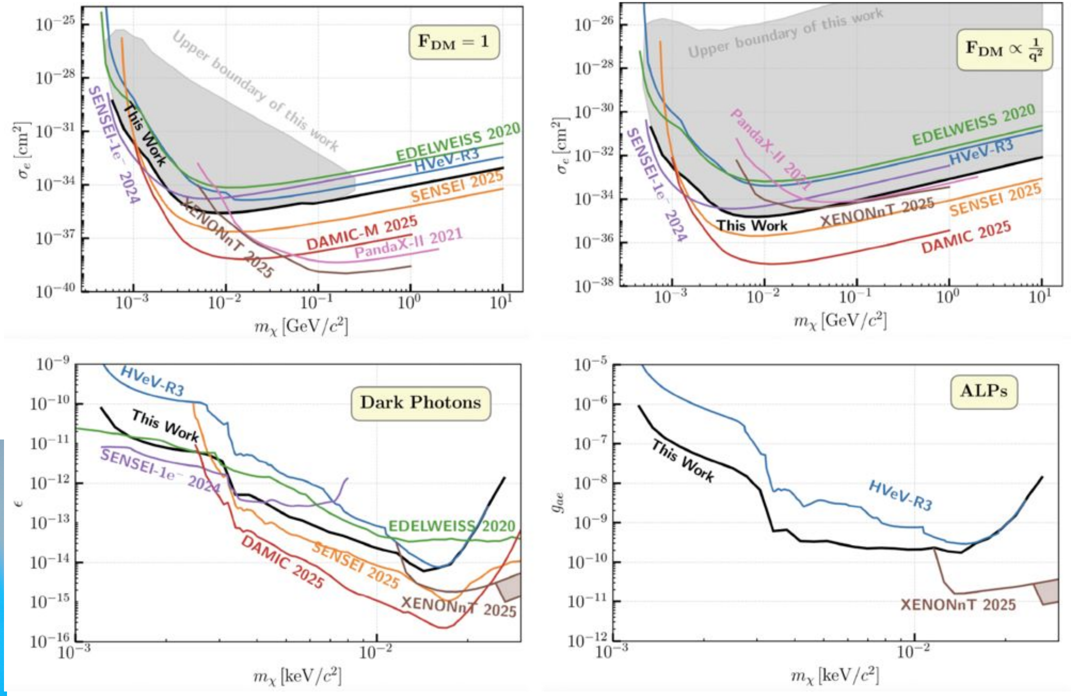


R&D: HVeV

- HVeV Run 4 (NEXUS facility)
  - 4 HVeV detectors
  - minimizing of luminescence from the printed circuit boards in the detector holder



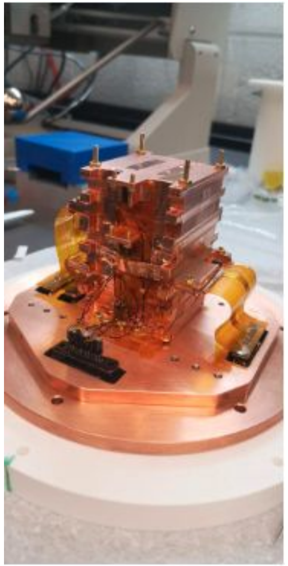


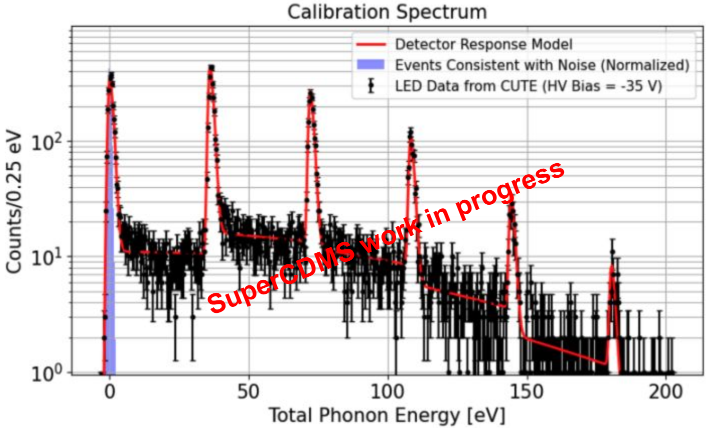


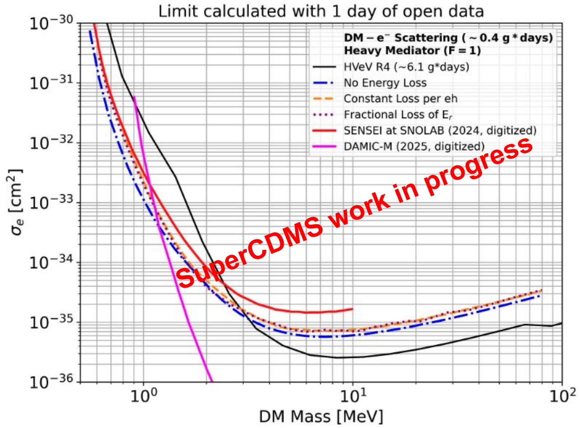
https://doi.org/10.1103/5lnp-6mng

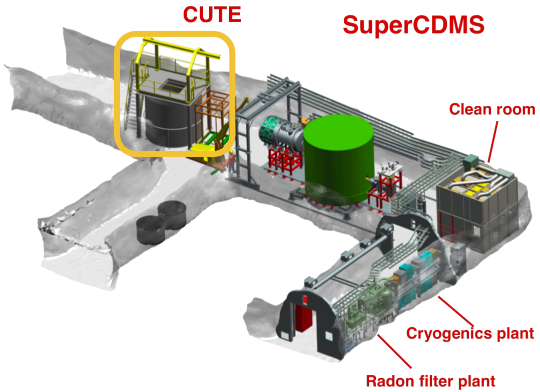
R&D: HVeV

- HVeV at CUTE
  - 6 HVeV detectors operated in 2024
  - **~0.59 eV resolution!**





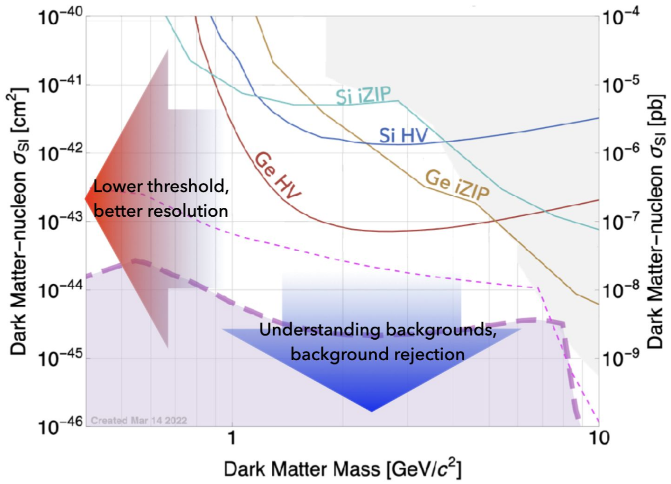




CUTE: Cryogenic **U**nderground **TE**st facility

Summary

- SuperCDMS SNOLAB is a direct DM detection experiment, targeting sub-GeV DM masses and LDM candidates
- Cryogenic Si/Ge detectors:
  - iZIP: background rejection
  - HV: low threshold
- Science Run 1a beginning July-Aug 2026
- R&D programs designed to probe more parameters space and lower DM masses
  - Improvements to detector design
  - Different target materials



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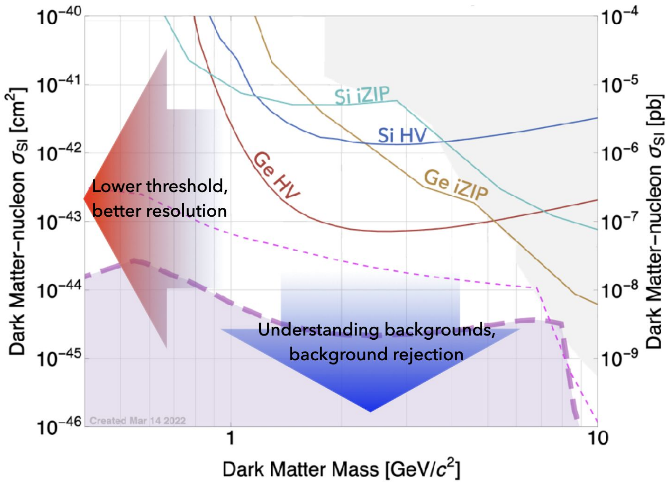
Stayed tuned!



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

HVeV Publications:

- PhysRevLett. 121, 051301
- Phys. Rev. D 102, 091101(R)
- Phys. Rev. D 111, 012006
- Phys. Rev. D 113, 032001
- Run 5 publication in progress

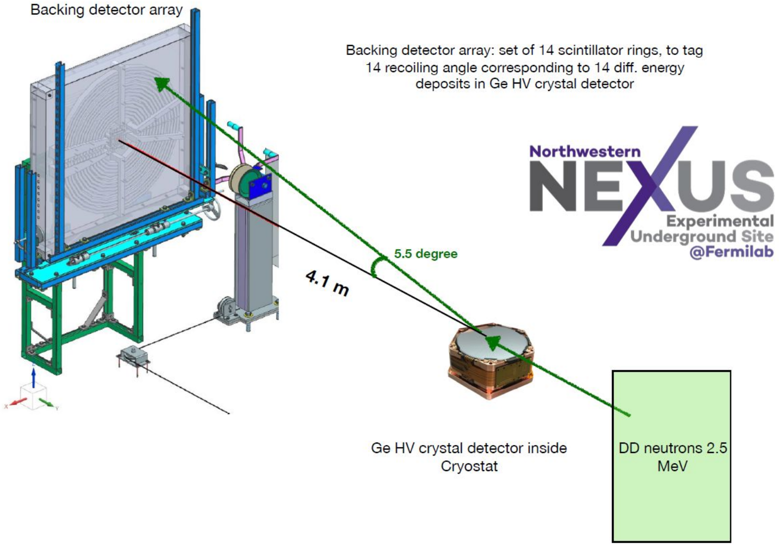
Full publication list at https://supercdms.slac.stanford.edu/science-results/publications

Backup Slides

Other SuperCDMS R&D

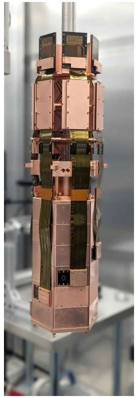
SuperCDMS Impact

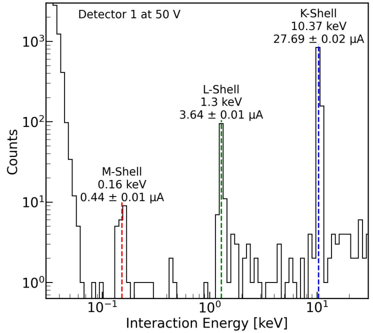
- Deployment of HV detector in low-energy neutron beam for NR yield studies

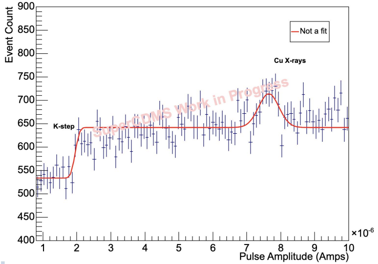


CUTE Tower Testing

- SuperCDMS HV tower testing to understand detector characteristics
- Ge and Si Calibration





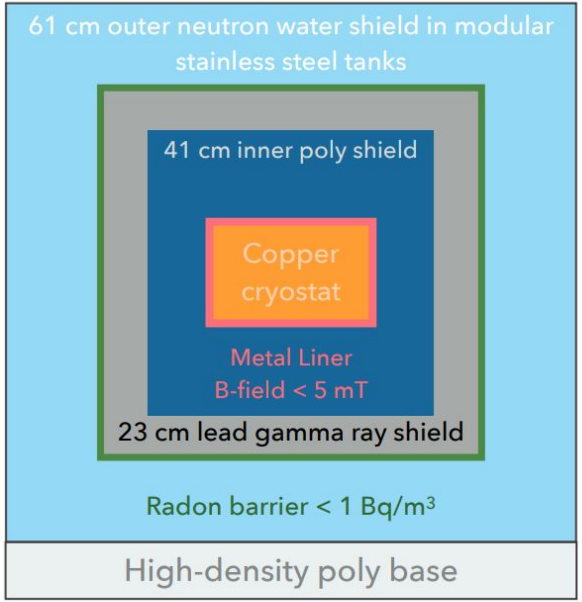


Pre-print: https://doi.org/10.48550/arXiv.2606.26391

Analysis in progress

SuperCDMS SNOLAB Shielding

- Outer neutron shield:
  - Reduce MeV neutrons from cavern wall by ~10^6, ~20 for μ-induced neutrons (GeV)
- Gamma-ray shield:
  - Reduces MeV gammas from cavern wall by ~10^5
  - Inner layer is 1cm ancient lead, ^{210}Pb < 1 Bq/kg
  - Reduce Bremsstrahlung ^{210}Bi in shield by factor of ~20
- Radon barrier:
  - Al sheet banded around the lead shield with taped joints
  - Reduce ~100 Bq/m^3 to <0.1 Bq/m^3 (mine air)
- Inner neutron shield:
  - Stacked 2" thick poly sheets
  - Reduces neutron rate by >10 μ-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 ~25
  - Reduces Bremsstrahlung from ^{210}Bi β-decay by ~20



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 SNOLAB Backgrounds

Phonon energy spectra after analysis cuts

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

Green: surface ERs

Mustard: surface NRs due to ^{206}Pb

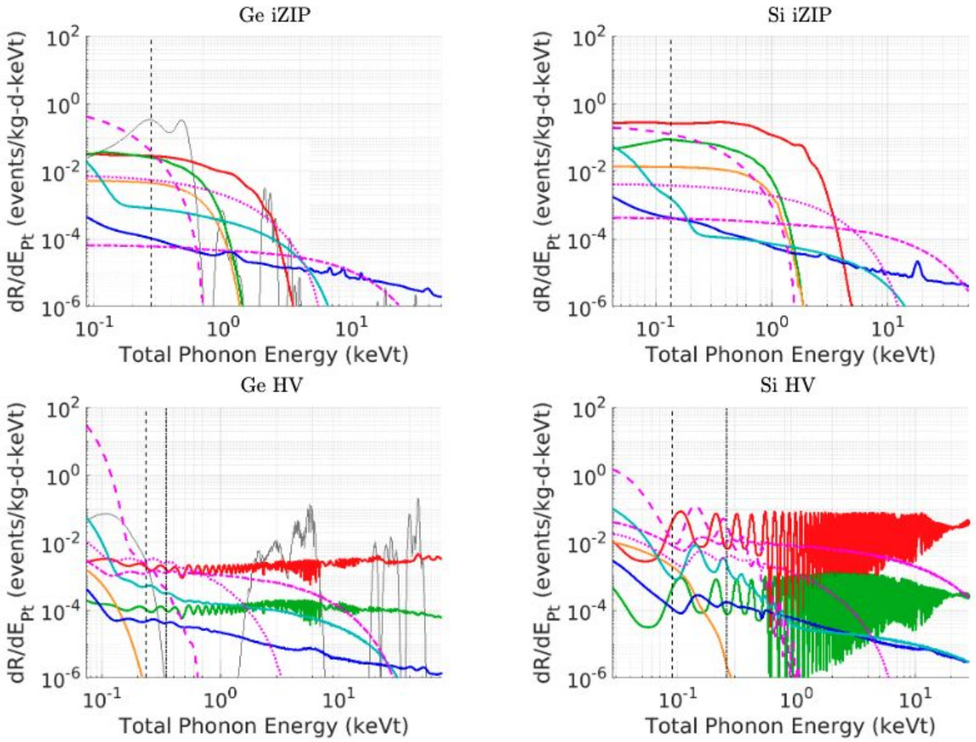
Blue: bulk NRs due to neutrons

Cyan: bulk NRs due to solar neutrino CEvNS

Grey: Germanium activation lines

Magenta: candidate DM signals for

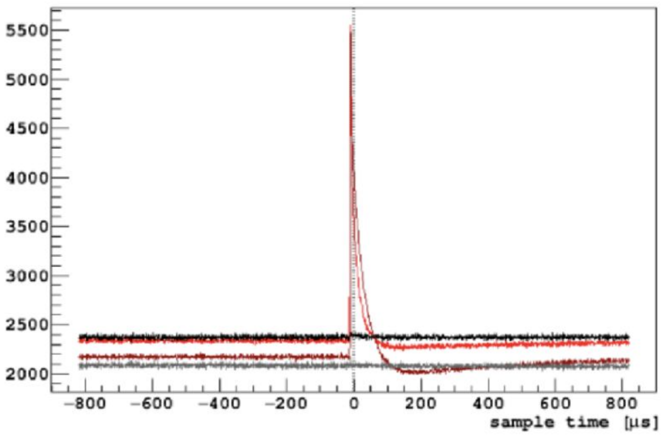
- $M_\chi \approx$ 1.6, 5, and 16 GeV/c^2 for iZIP
- $M_\chi \approx$ 0.5, 1.6, and 5 GeV/c^2 for HV for cross sections at the exclusion sensitivity



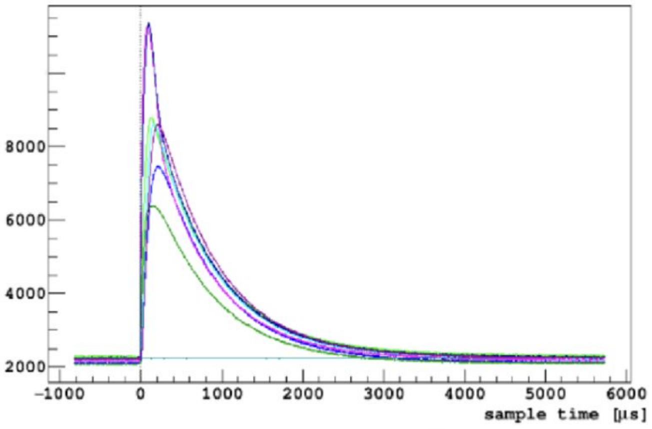
arXiv:2203.08463

SuperCDMS Waveforms

100 μs Ionization signal

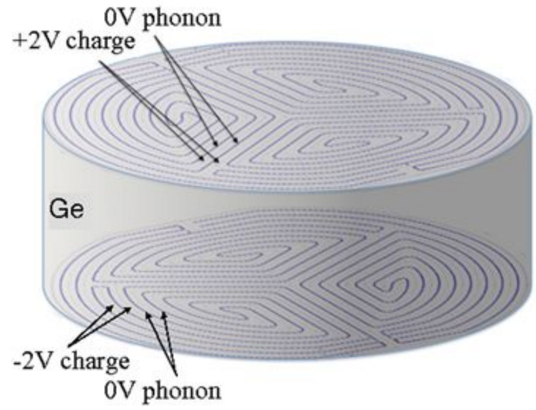


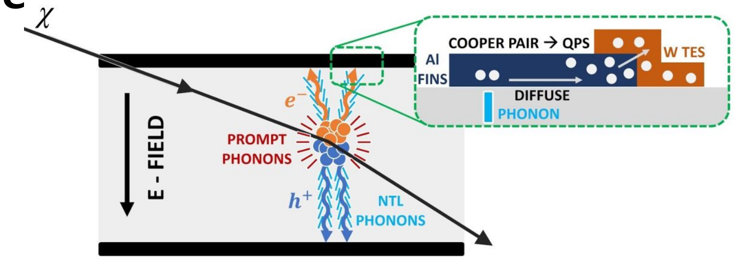
3000 μs phonon signal

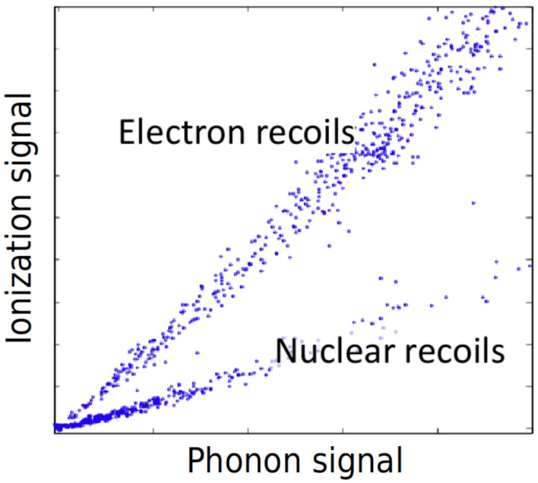


Sampling frequencies:
Ionization: 2.5 MHz
Phonon: 625 kHz

SuperCDMS iZIP ER/NR discrimination







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

$Y(E_R) = 1$ –> ER

$Y(E_R) < 1$ –> NR

https://indico.lip.pt/event/899/attachments/2293/3162/20210408_LIP_Seminar_BvKrosigk.pdf