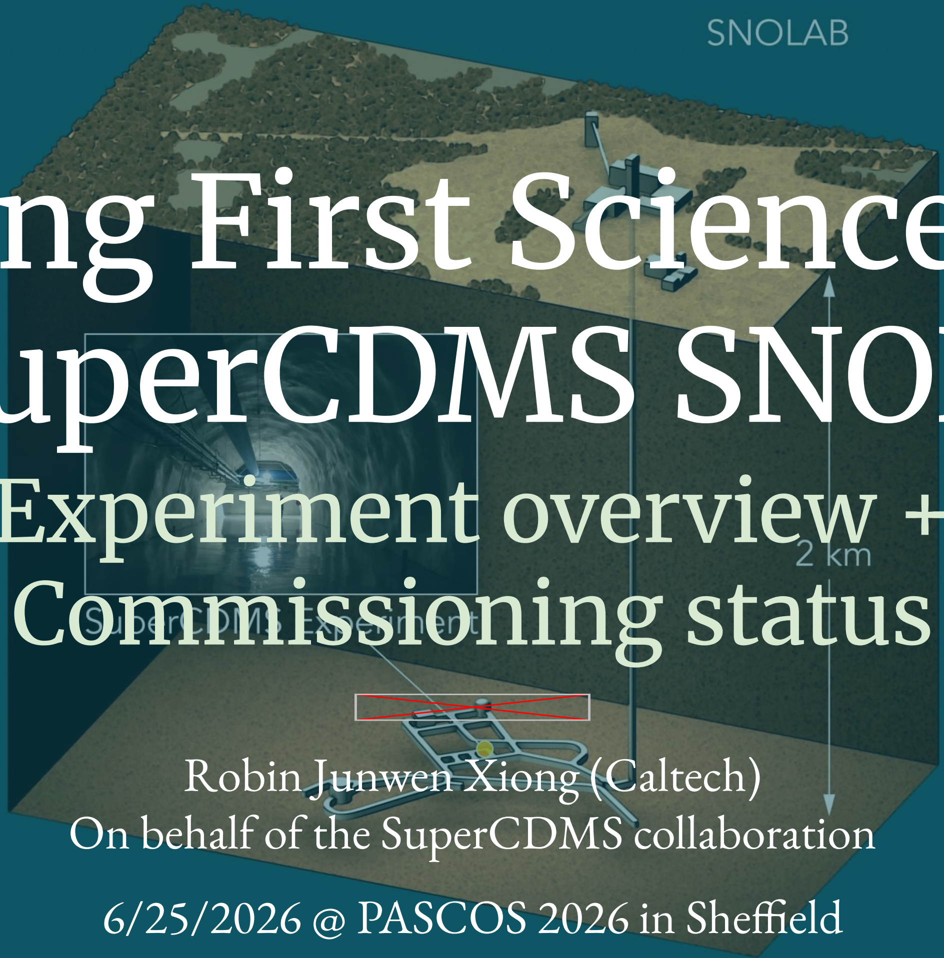
Nearing First Science Data at SuperCDMS SNOLAB

Experiment overview + Commissioning status



SUPER CDMS
Cryogenic Dark Matter Search

Robin Junwen Xiong (Caltech)
On behalf of the SuperCDMS collaboration

6/25/2026 @ PASCOS 2026 in Sheffield

Photo credit: Greg Stewart

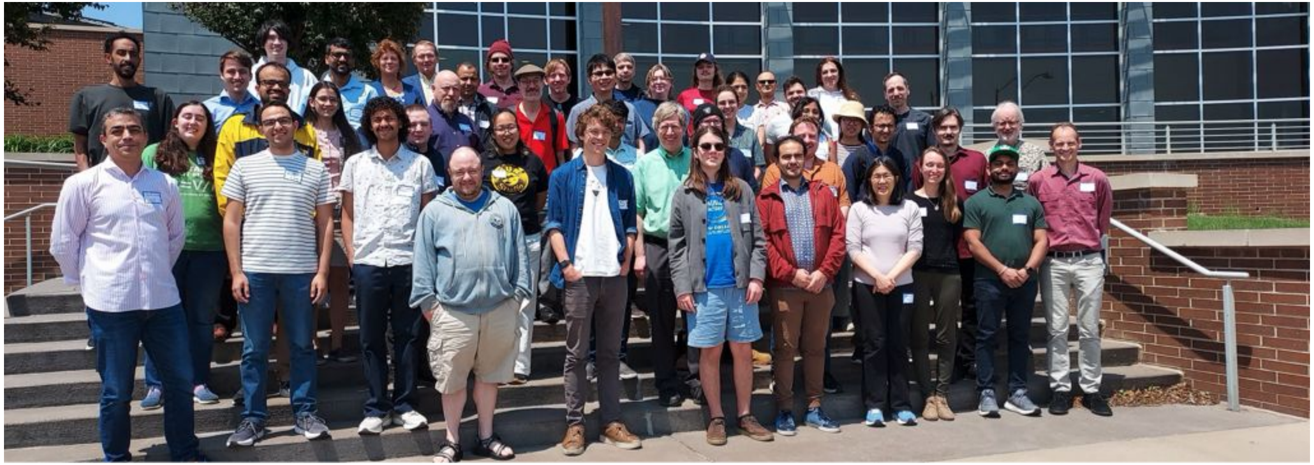
Caltech

Outline

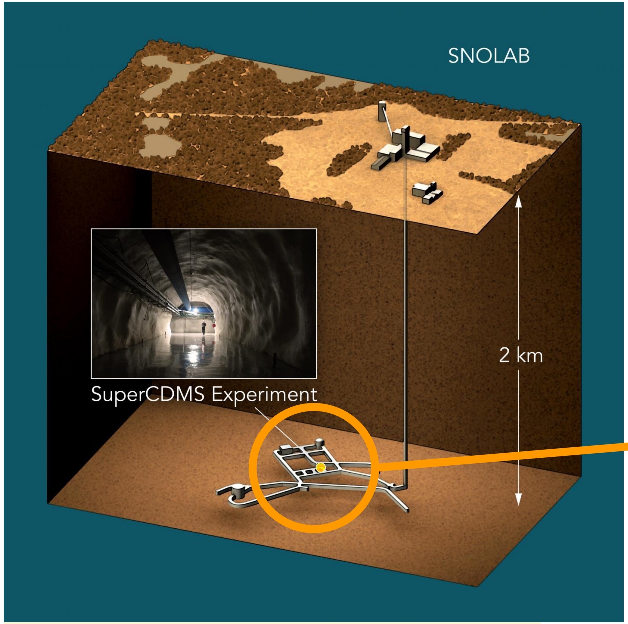
- Overview of the experiment
  - The SuperCDMS SNOLAB detector
  - Latest sensitivity projection
- Commissioning status
- Preparing for science analysis
- Conclusion

Super Cryogenic Dark Matter Search experiment

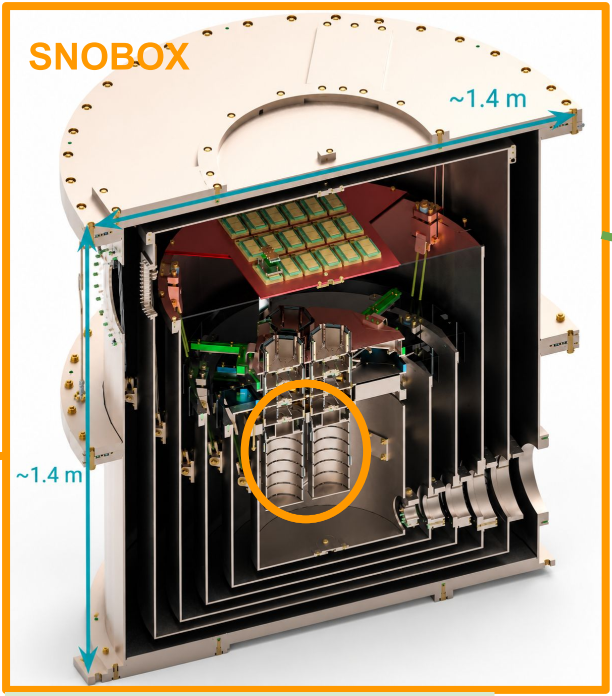
- 128 authors
- 25 institutes in 6 countries: US, Canada, Germany, France, India, Spain, and United Arab Emirates



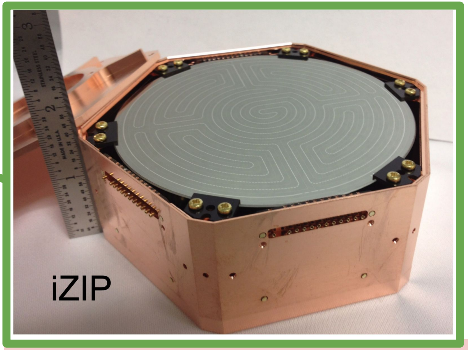
SuperCDMS SNOLAB experiment



SNOLAB in Ontario, Canada



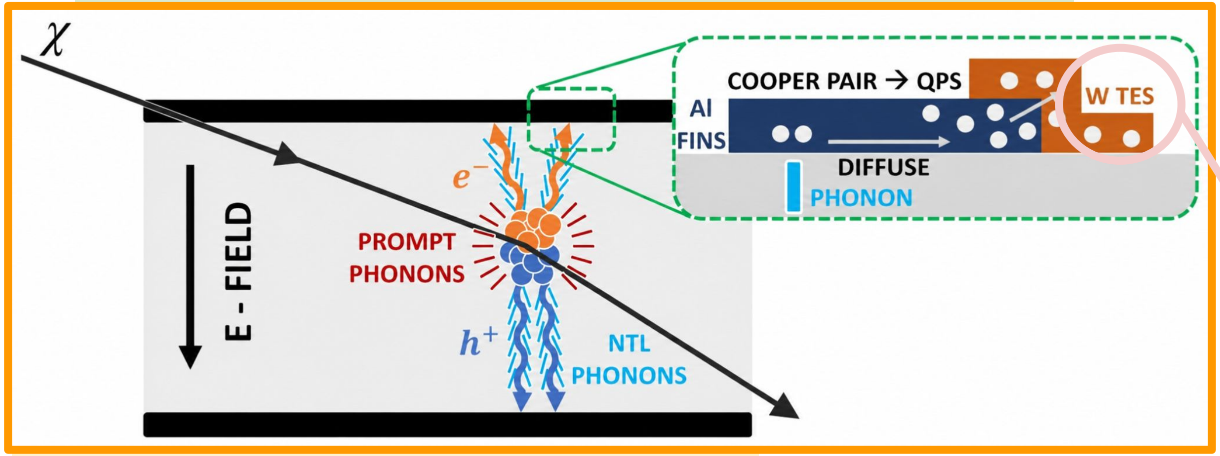
SNOBOX: 24 detectors cooled to ~25 mK



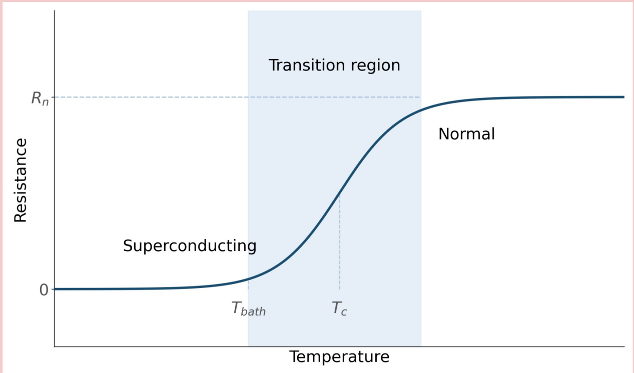
24 crystal detectors in 4 towers (each detector: 10 cm diameter and 3.3 cm thick)

Dark matter detection mechanism

QET (Quasiparticle-trapping-assisted Electrothermal-feedback Transition-Edge Sensors)



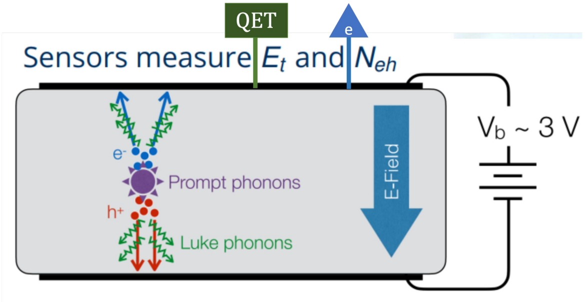
Dark matter (DM) particles ➤ nuclear recoil (NR) or electron recoil (ER) ➤ phonons

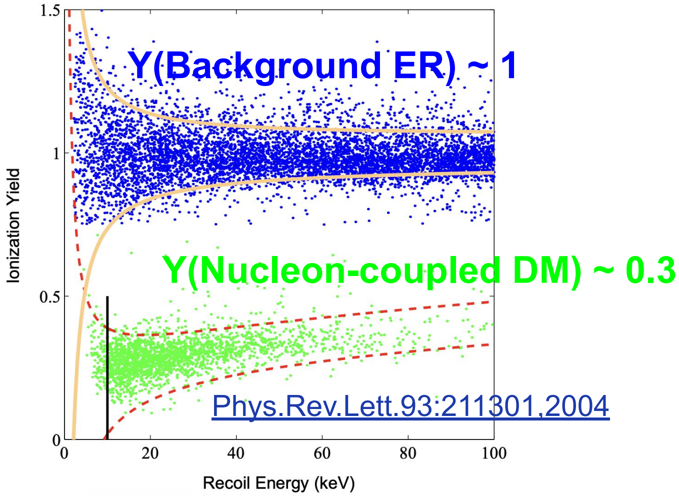


TES temperature increase ➤ resistance increase ➤ negative current pulse

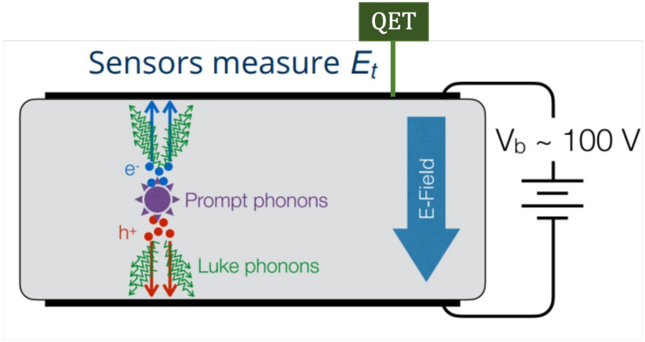
Detector architectures

iZIP (interleaved Z-sensitive Ionization and Phonon detector)





HV (high voltage): NTL (Neganov–Trofimov–Luke) phonon amplification from external E-field



Total phonon energy

Number of e-h pairs

$$E_{\text{ph}} = E_R + N_{eh} e V_b$$

Primary recoil energy

Bias voltage applied

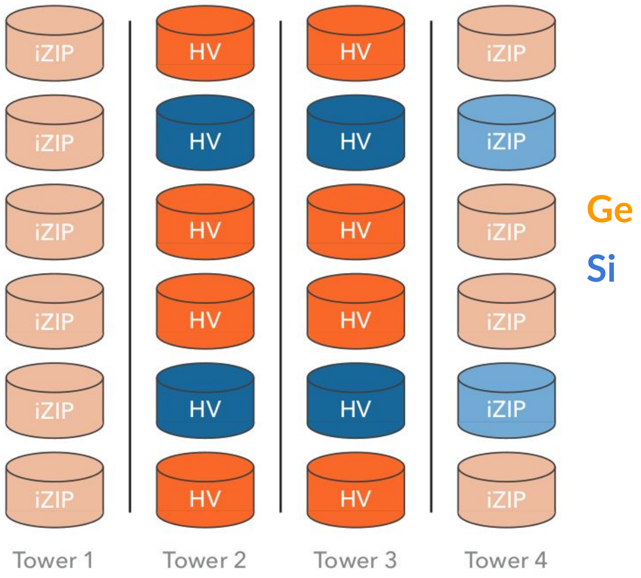
$$N_{eh} = \frac{E_R Y(E_R)}{\epsilon_{eh}}$$

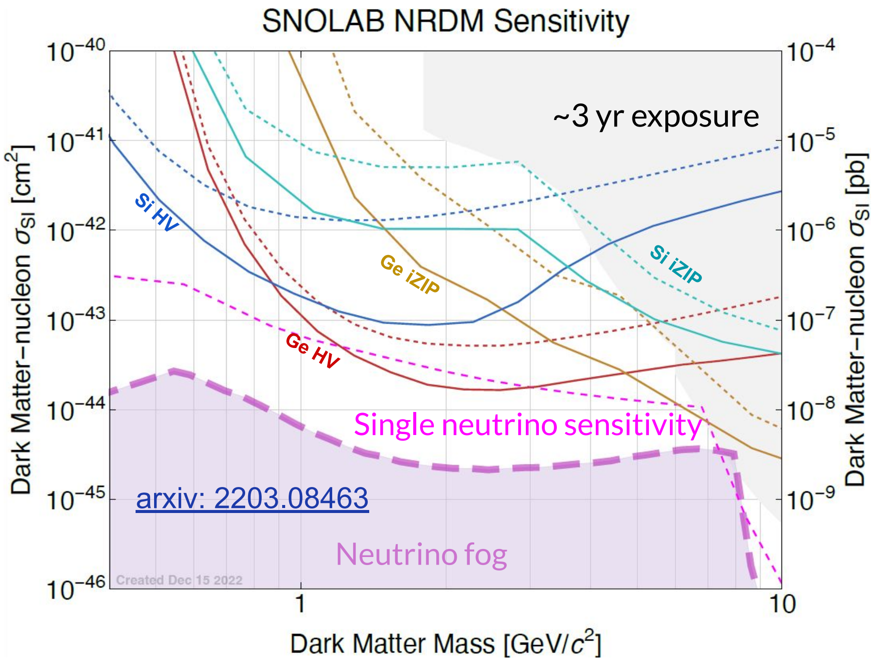
Ionization yield

Average energy to ionize 1 e-h pair

Expected sensitivity

Profile likelihood ratio (PLR- solid) - full signal/ background model
Optimal interval (OI- dashed) - no background model required





HV: 4 Si (2.4 kg) + 8 Ge (11.2 kg)
iZIP: 2 Si (1.2 kg) + 10 Ge (14 kg)
Total ~ 30 kg

Ge **HV**/ **iZIP**: more exposure at high mass
Si **HV**/ **iZIP**: reach to lower mass

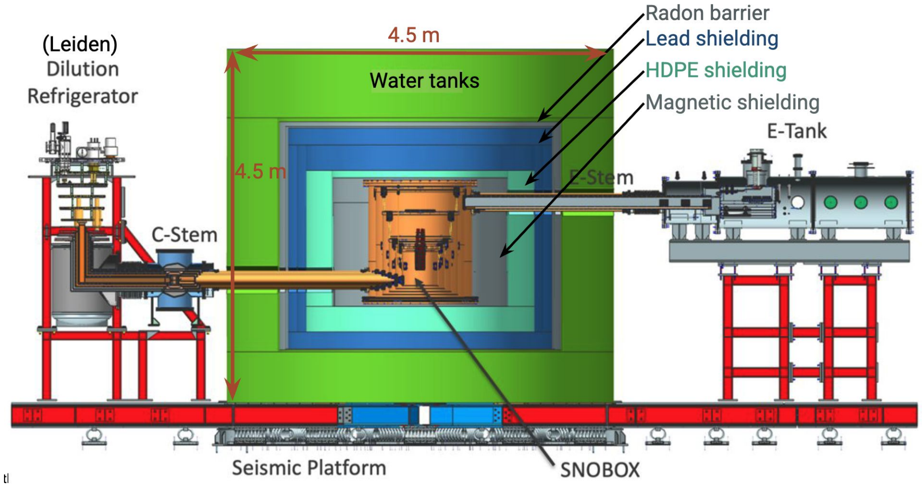
- **HV** vs **iZIP**: reach to lower mass

Commissioning status – construction done

Installation
Dec 2024

June 2025
Detector tower
Installed

First experiment
cool-down
Nov 2025



C-stem: connect dilution fridge to SNOBOX
E-stem: connect readout cables from cryostat to E-tank

Commissioning status – construction done

Installation
Dec 2024

June 2025
Detector tower
Installed

First experiment
cool-down
Nov 2025

Commissioning status – operation

- Phonon channel operation (Good knowledge)
- Superconducting transition temperature (Good knowledge)
- LED pulses (Good knowledge)
- Data challenge (Good knowledge)
- High voltage (More studies)
- Noise mitigation (More studies)
- iZIP charge readout (More studies)

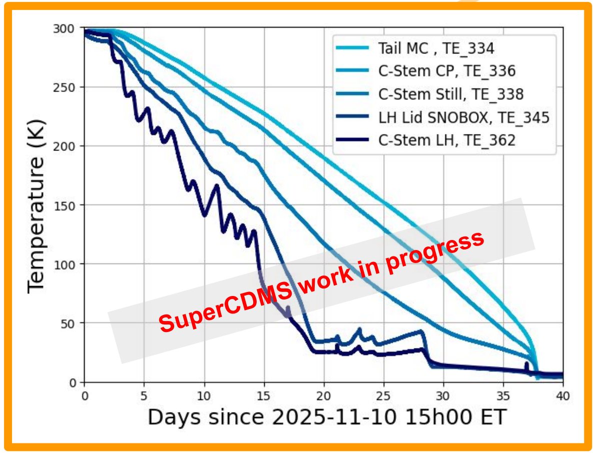
Good knowledge *More studies*

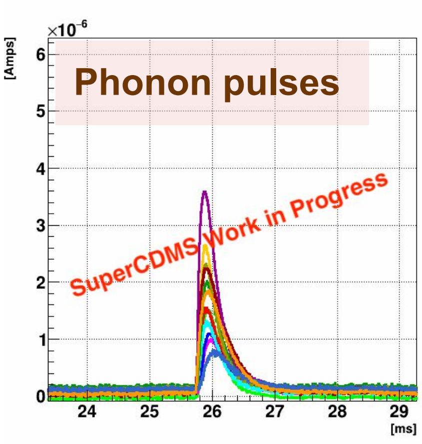
Installation
Dec 2024

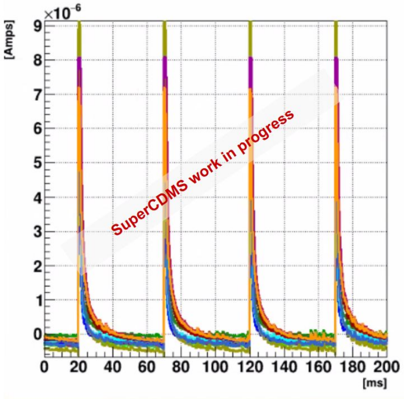
June 2025
Detector tower Installed

First experiment cool-down
Nov 2025

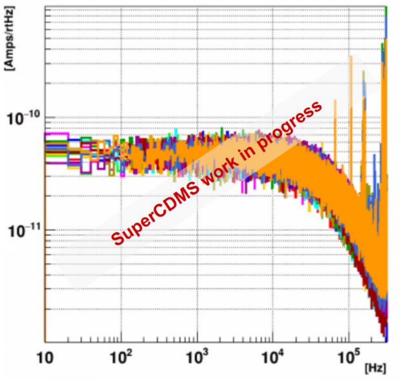
Jan 2026
Detector operation and calibration







LED pulses

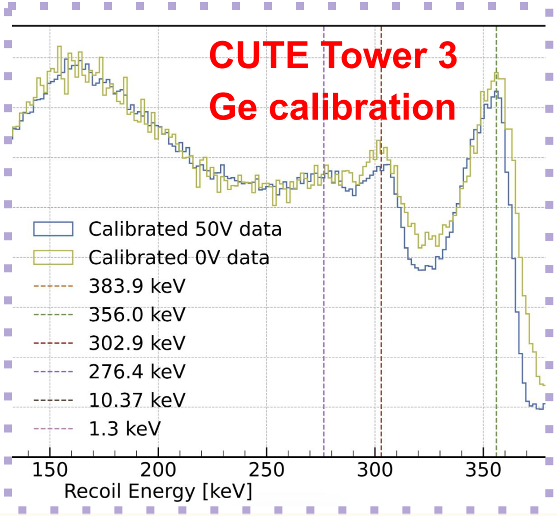


Superconducting noise

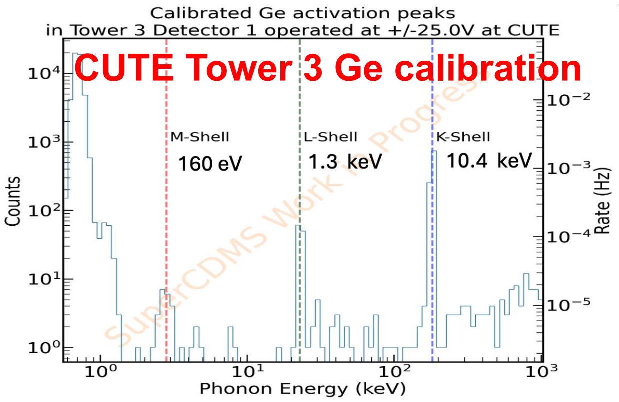
Commissioning status – calibration plan

- ^{252}Cf neutron calibration
- ^{133}Ba γ-calibration

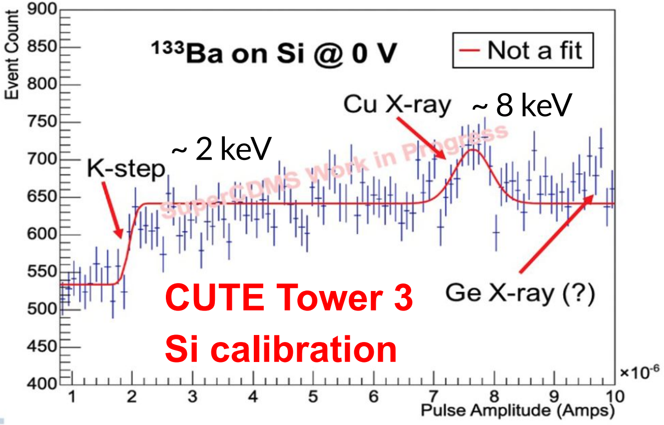
Good knowledge *More studies*



High energy calibration from Ba with T3 Ge @ CUTE (cryogenic underground testing facility)

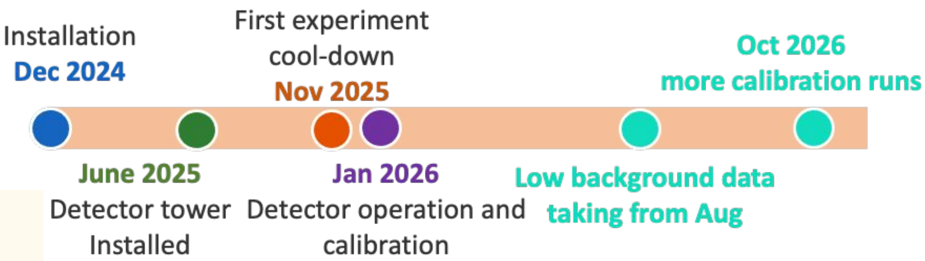


Low energy Cf calibration in ^{71}Ge activation

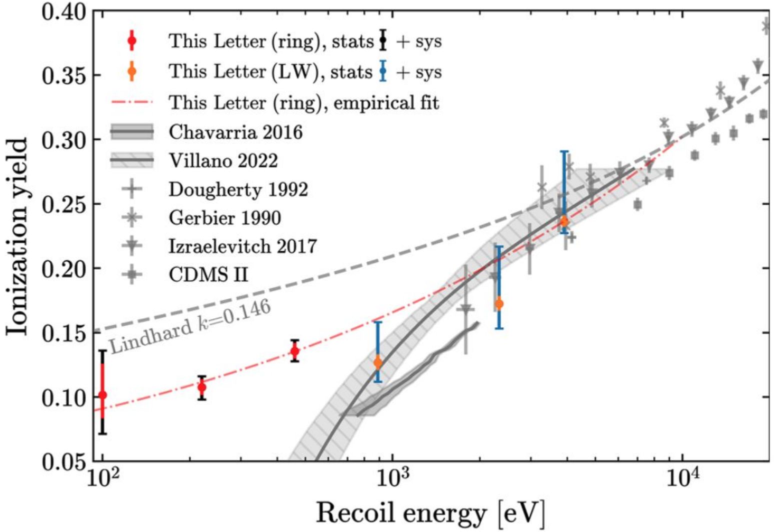


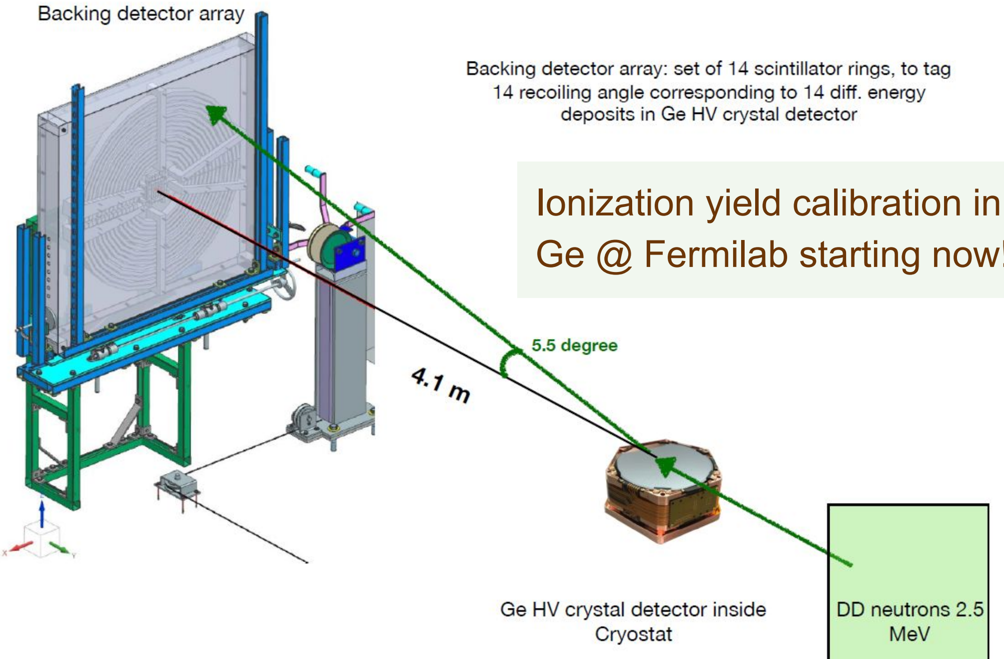
Low energy Ba calibration in Si

Commission timeline – SNOLAB and more



Ionization yield calibration in Si down to 100 eV ([Physical Review Letters 131.9 (2023): 091801]())



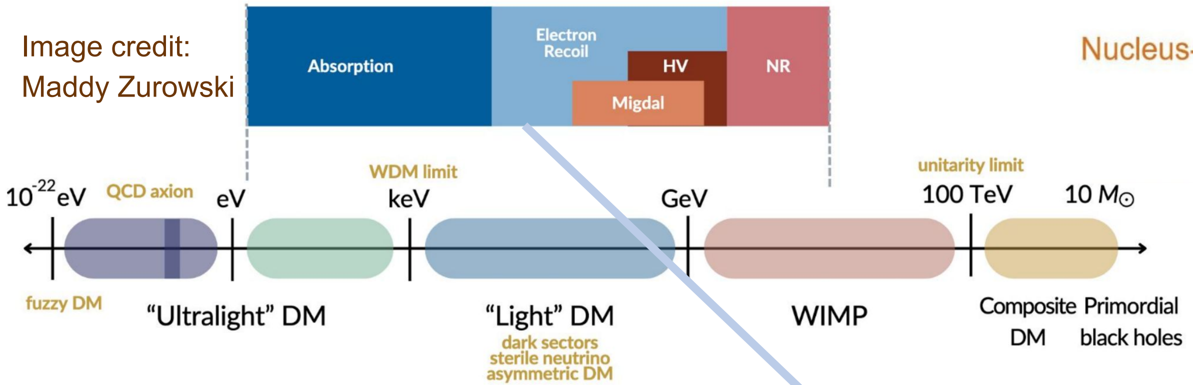


Ionization yield calibration in Ge @ Fermilab starting now!

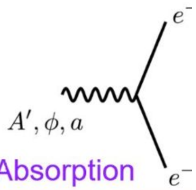
All possible analyses

[arxiv: 2203.08463](https://arxiv.org/abs/2203.08463)

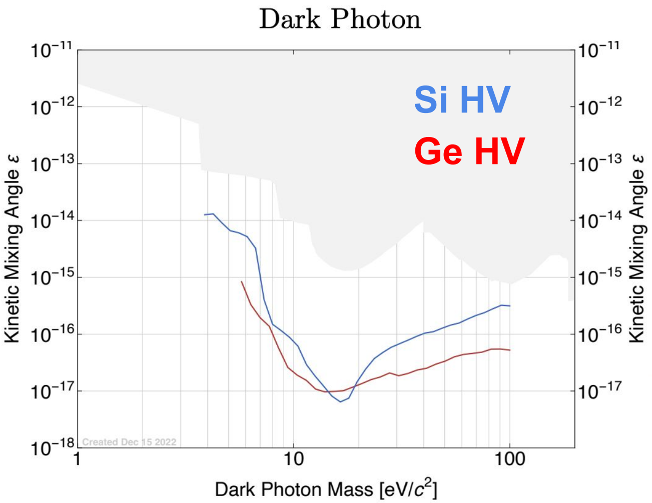
Image credit:
Maddy Zurowski



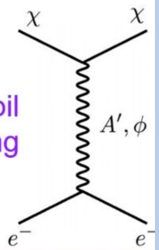
Nucleus-recoil scattering

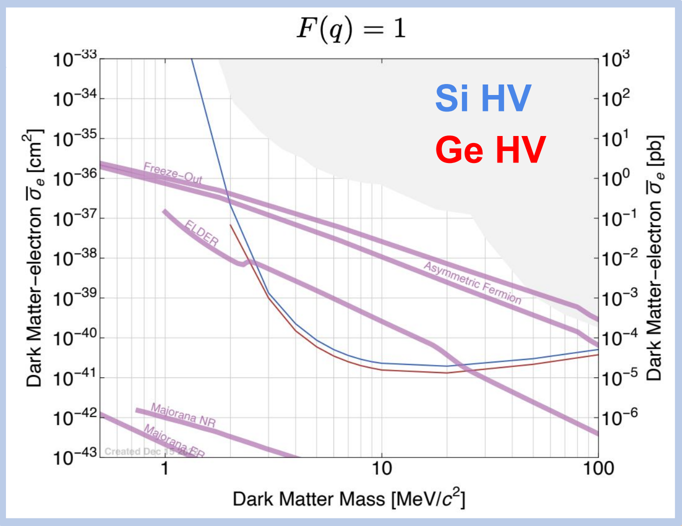


Absorption



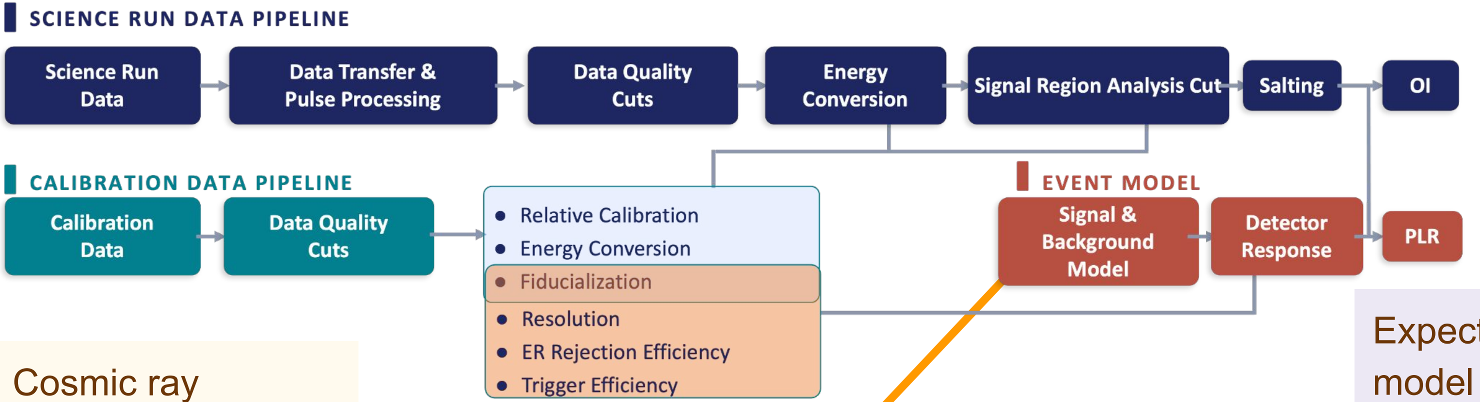
Electron-recoil scattering



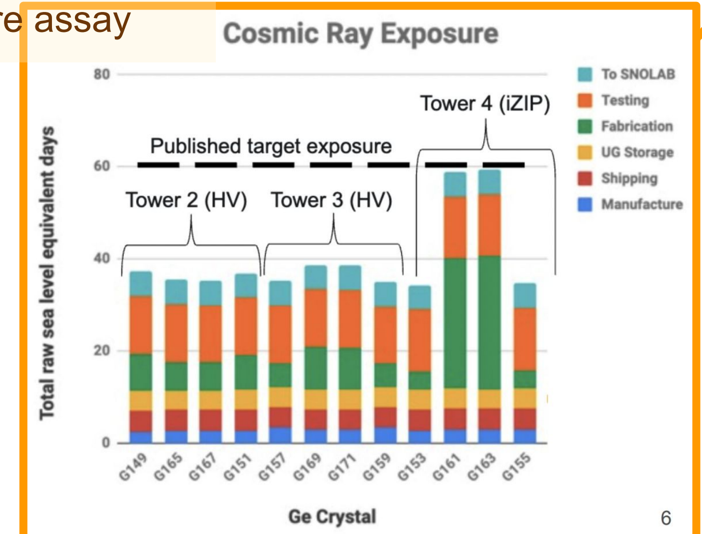


Analysis pipeline

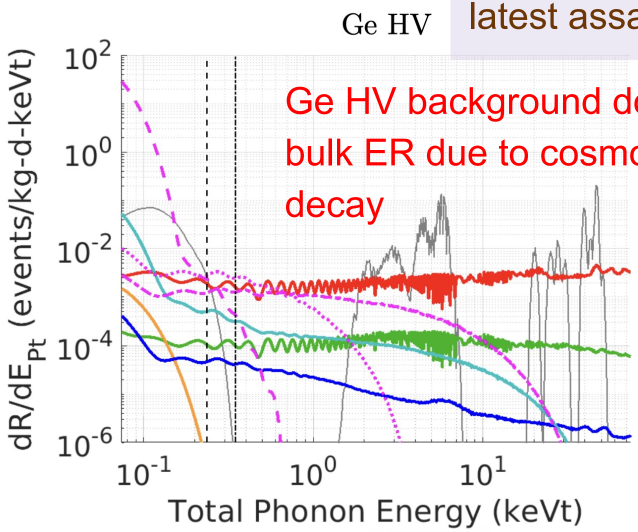
Science and calibration analysis pipeline under construction for both OI and PLR analyses!



Cosmic ray exposure assay



Expected background model to be updated with latest assay results



Ge HV background dominated by bulk ER due to cosmogenic tritium decay

Conclusion

- SuperCDMS SNOLAB is a cryogenic TES-based solid-state dark matter experiment
  - The combination of iZIP/ HV and Si/ Ge detectors gives nucleon-coupled DM sensitivities from 0.5 GeV to 10 GeV
- The experiment is currently being commissioned at SNOLAB, Canada
  - Lots of interesting calibration data to come!
- World-leading sensitivities are expected for nucleon-coupled DM below 3 GeV
  - Other signal models such as electron-coupled DM and dark photon absorption can be probed as well
- The full analysis pipeline is currently being constructed to enable both PLR and OI analysis!

Thank you!

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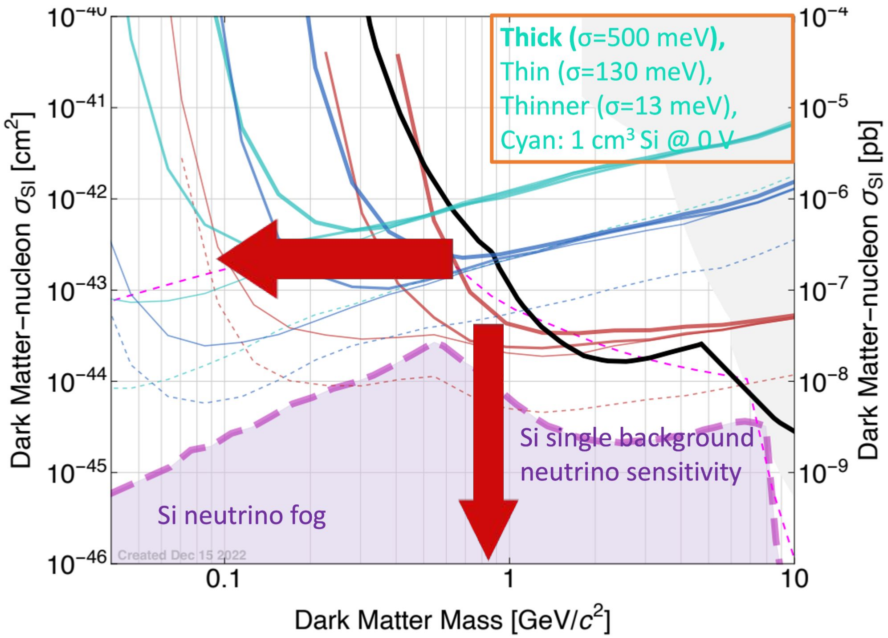
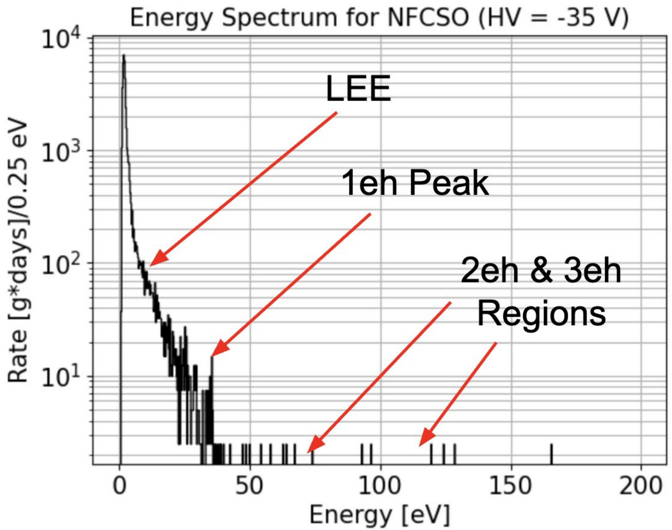
Questions?

Backup

Potential SNOLAB upgrades

arxiv: 2203.08463





Possible low energy resolution sensors:

- KIPM (arxiv: 2402.04473) and qubit-based detectors (arxiv: 2405.17192, arxiv: 2601.16261)

Emergent background mitigation

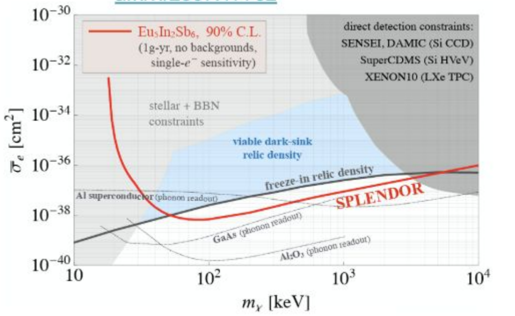
- Low energy excess seen at HVeV (plot credit: Kyle Kennard)

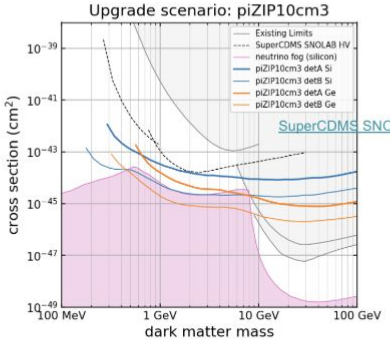
Potential SNOLAB upgrades

Charge-based potential future payloads (piZIPs, SPLENDOR)

- **SPLENDOR** (✅ low threshold, 🔼 position resolution)
  - Charge pulses are faster than phonon → better position resolution
  - Novel low bandgap semiconductors for charge-only detection
  - sub-eV detection thresholds, measured 7 electron resolution
  - Plans to further enhance resolution with quantum sensing readout
- phonon-**iZIPs** (✅ low threshold, 🔼 position resolution, 🔼 exposure)
  - iZIPs with power to discriminate between NTL and prompt phonons
  - Lower threshold from NTL gain, but retains good position sensitivity

[arxiv:/2507.17782](https://arxiv.org/abs/2507.17782)





[SuperCDMS SNOMASS projections]()

A. Pradeep | SLAC National Accelerator Lab | IDM 2026

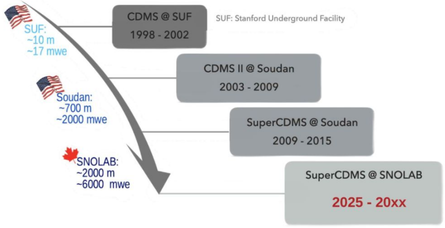
17

Slide credit: [Aditi Pradeep]()

History of the experiment

SuperCDMS experiment

- **Super C**ryogenic **D**ark **M**atter **S**earch experiment
- Use semiconductor crystal detectors Si and Ge
- Operate at cryogenic temperature O(10mK)
- 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

3

Sukeerthi Dharani | SuperCDMS SNOLAB experiment | 2026 CAP Congress | 23 Jun 2026

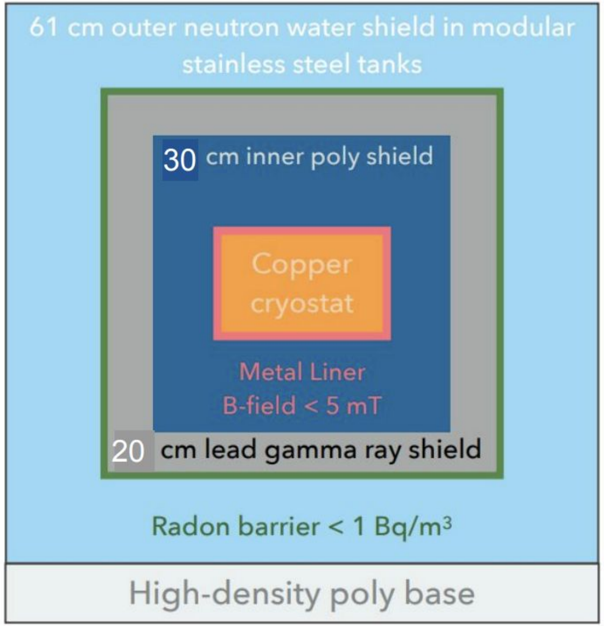
The Cryogenic Dark Matter Search Strategy

- The CDMS approach to direct detection:
  - *Modular detectors of 2 target materials cooled to cryogenic temperatures*
  - *Detect phonons and ionization liberated by scattering*
- The collaboration has a 25-year history of such experiments
  - **CDMS I** at the Stanford Underground Facility:
    First experiment to probe for supersymmetric WIMPs
  - **CDMS II** at the Soudan Underground Laboratory:
    World leading limits on WIMPs for nearly a decade
  - **SuperCDMS Soudan**:
    New detector technologies (iZIP and CDMSlite), target low-mass dark matter
  - **SuperCDMS SNOLAB***:*
    Multiple targets and technologies explore new candidates and interactions

Slide credit: Sukeerthi Dharani
Slide credit: Priscilla Cushman

Shielding layer

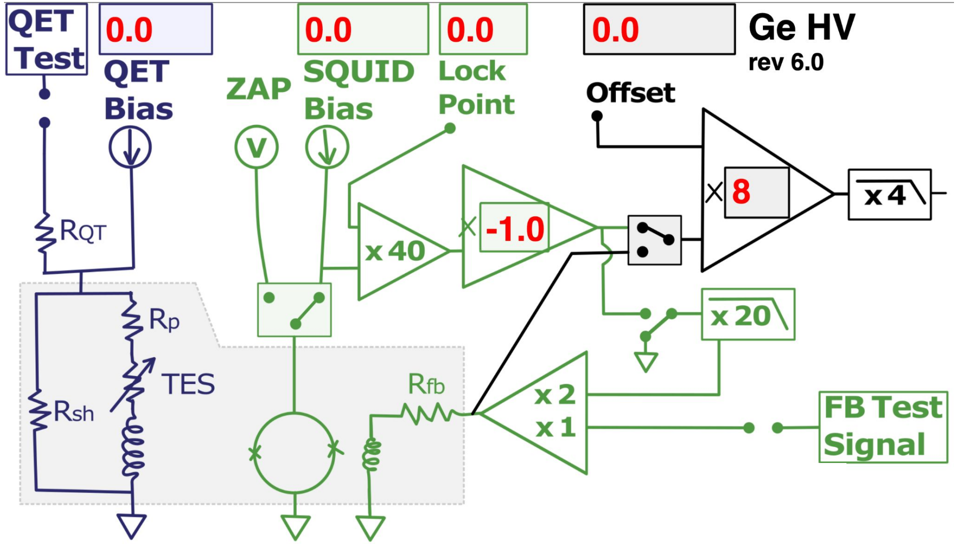
- Outer neutron shield:
  - Reduce MeV neutrons from cavern wall by ~10^6, ~20 for μ-induced neutrons (GeV)
- Gamma-ray shield:
  - Reduces MeV gammas from cavern wall by ~10^5
  - Inner layer is 1cm ancient lead, ^{210}Pb < 1 Bq/kg
  - Reduce Bremsstrahlung ^{210}Bi in shield by factor of ~20
- Radon 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

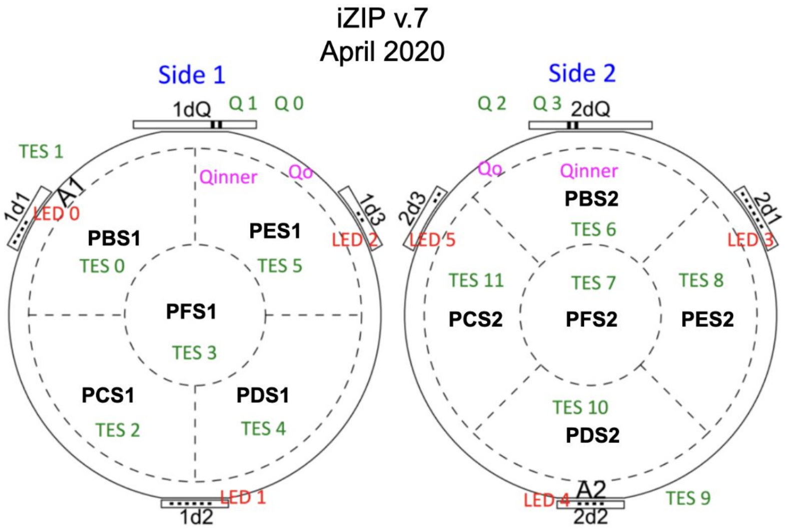


Slide credit: M. J. Wilson

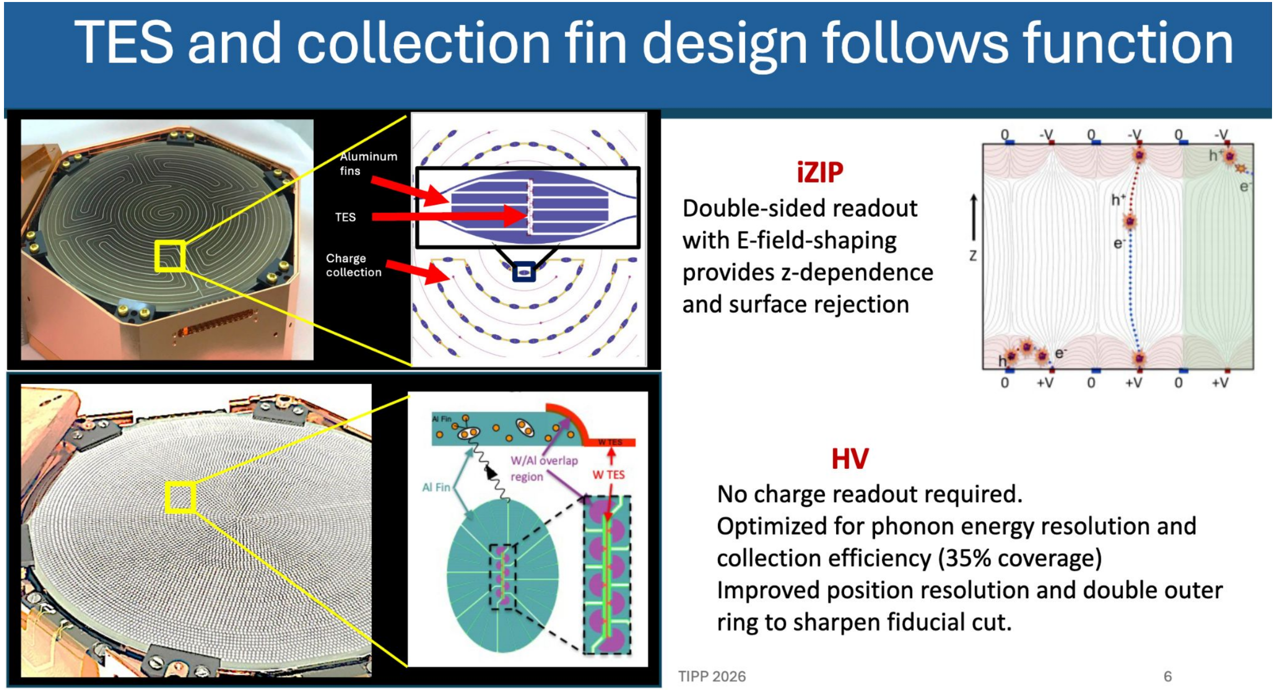
Slide credit: [Sukeerthi Dharani]

Detector control and readout card





QET coverage



Slide credit: [Priscilla Cushman]

iZIP coverage: 4%

Background models

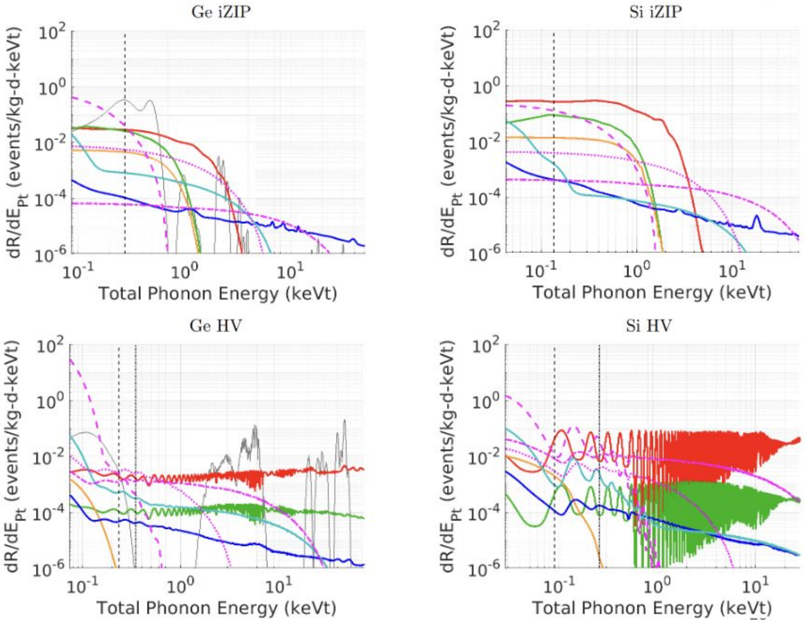
Full sensitivity: arXiv:2203.08463

Backgrounds for NRDM searches

Phonon energy spectra after analysis cuts

Black vertical dashed line: 7σ analysis threshold
Black vertical dot-dashed line: leakage threshold
Red: bulk ERs due to Compton, 3H, 32Si
Green: surface ERs
Mustard: surface NRs due to 206Pb
Blue: bulk NRs due to neutrons
Cyan: bulk NRs due to solar neutrino CEνNS
Grey: Germanium activation lines

Magenta: candidate DM signals for
- Mχ ≈ 1.6, 5, and 16 GeV/c² for iZIP
- Mχ ≈ 0.5, 1.6, and 5 GeV/c² for HV for cross sections at the exclusion sensitivity



Slide credit: Kelly Stifter

ERDM spectrum

Full sensitivity: arXiv:2203.08463

Backgrounds for ERDM searches

Phonon energy spectra after analysis cuts

Black vertical dashed line: 7σ analysis threshold

Black vertical dot-dashed line: leakage threshold

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

Green: surface ERs

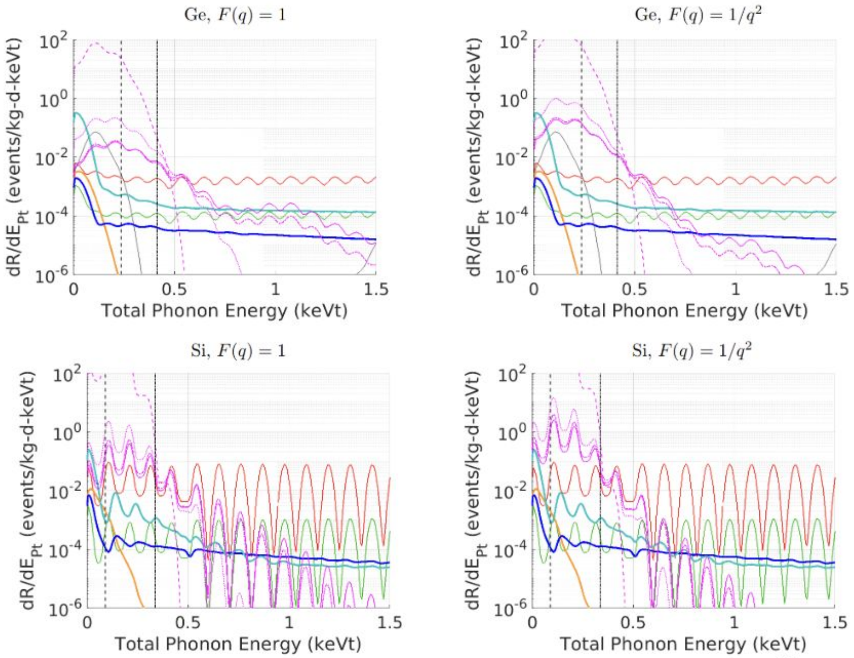
Mustard: surface NRs due to 206Pb

Blue: bulk NRs due to neutrons

Cyan: bulk NRs due to solar neutrino CEνNS

Grey: Germanium activation lines

Magenta: candidate DM signals for Mχ ≈ 1, 3, 10, and 30 MeV/c^2 and cross section at the exclusion sensitivity



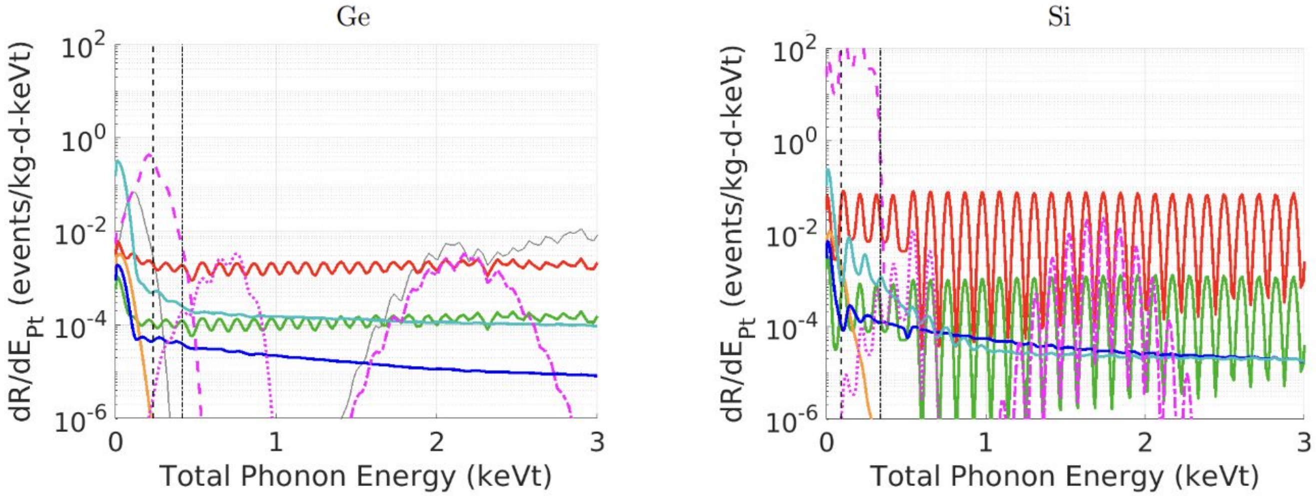
Slide credit: Kelly Stifter

Dark photon and ALP spectrum

Full sensitivity: arXiv:2203.08463

Backgrounds for absorption searches

Phonon energy spectra after analysis cuts. Black vertical dashed line: 7σ analysis threshold, black vertical dot-dashed line: leakage threshold, red: bulk ERs due to Compton, 3H, 32Si, green: surface ERs, mustard: surface NRs due to 206Pb , blue: bulk NRs due to neutrons, cyan: bulk NRs due to solar neutrino CEνNS, Grey: Germanium activation lines, magenta: candidate DM signals for Mχ ≈ 6, 20, and 60 eV/c^2 and coupling at the exclusion sensitivity.



Slide credit: Kelly Stifter

CUTE T3 Ge resolution @ 0V

Best measured baseline resolution (single-detector operation mode at 0 V)	
Detector	**Baseline Resolution (eV)**
1	89.2 ± 0.7
3	80.2 ± 1.0
6	167 ± 2

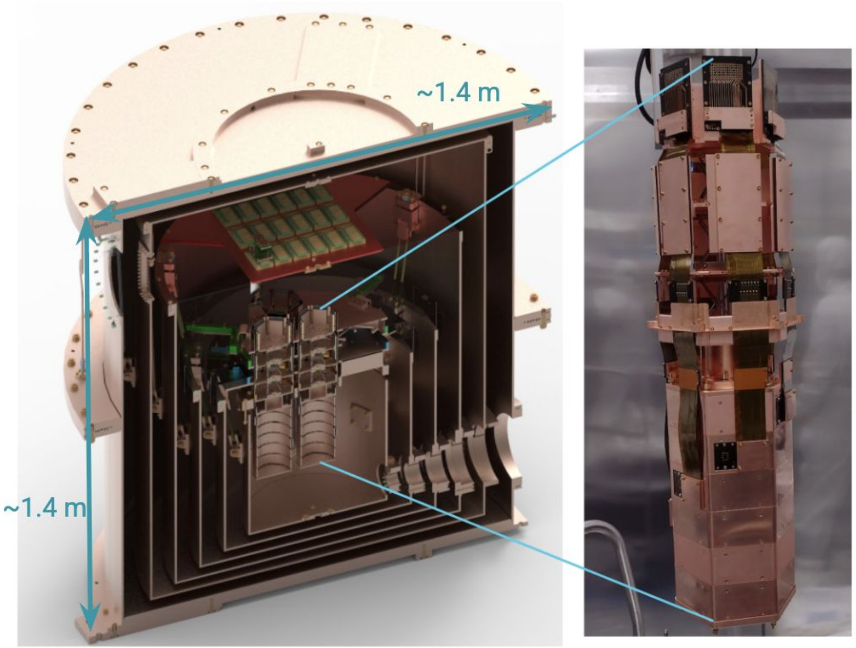
- The values for detectors 1 and 3 are slightly above the originally predicted resolution range; one key factor contributing to this deviation is the superconducting transition temperature which is higher than originally planned, but we have also identified other sources (mainly noise pickup) that contribute to a worsening of the resolution. Additional measures have been taken to reduce the noise pickup at the SuperCDMS SNOLAB setup which is expected to lead to an improved performance.
- Detector 6 under-performed considerably for currently not fully understood reasons.

SNOBOX 6 thermal stages

SuperCDMS

Towers placed in SNOBOX - 6 cans forming giant dilution fridge:

- OVC – Room temp
- SH – <50 K
- LH – <5 K
- ST – 1 K
- CP – <230 mK
- MC – <30 mK



Slide credit: Maddy Zurowski