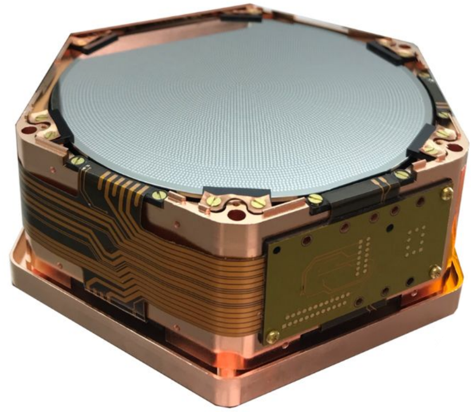


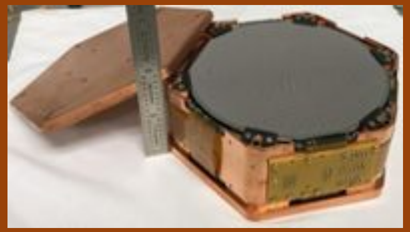
SuperCDMS SNOLAB

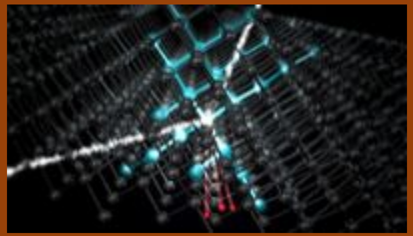
February 2024 EAC Review

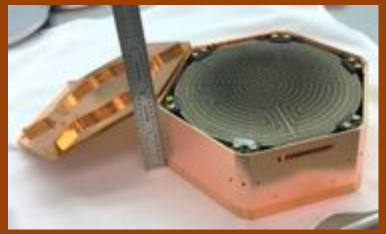
Tarek Saab

Spokesperson

February 08, 2024







SuperCDMS Representatives

- *Tarek Saab* Spokesperson & Deputy Operations Manager
- *Miriam Diamond* Collaboration Council & Board Chair
- *Rob Cameron* Operations Manager
- *Richard Partridge* I&I Manager
- *Joel Sander* Operations Scientist
- *Wolfgang Rau* Deputy Operations Manager
- *Pekka Sinervo* Operations Shift Planner & Shipping Coordinator
- *Andy Kubik* PI of SNOLAB group

The SuperCDMS Collaboration

2022 Collab Mtg at U. Toronto

>130 scientists at 28 institutions & 6 Countries, including 3 US national labs and 2 Canadian labs

SuperCDMS Detector Technology

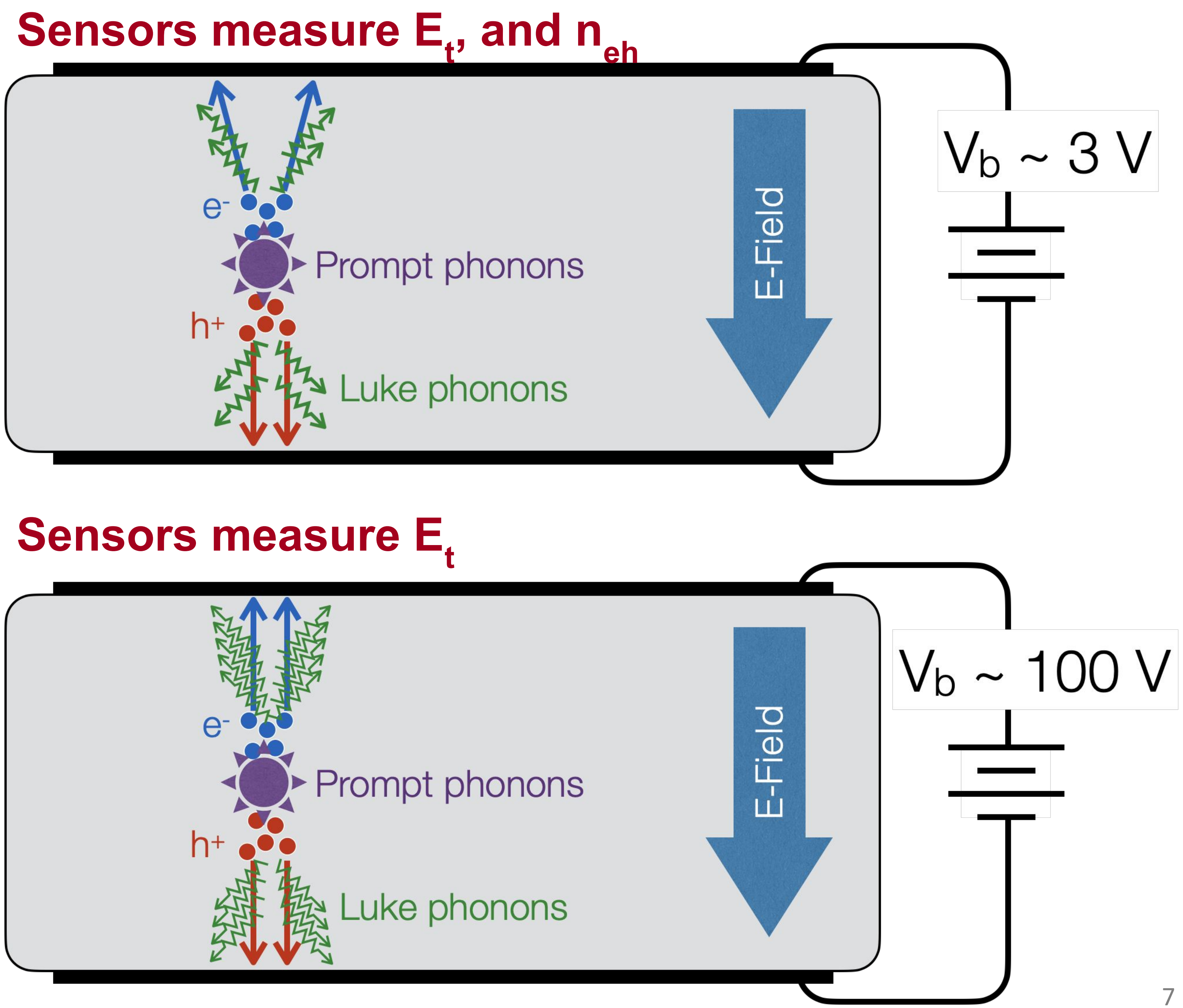
iZIP Detector

- Low background
- Prompt phonon and ionization signals allow for discrimination between nuclear and electron recoil events

HV Detector

- Low threshold
- Drifting electrons/holes across a potential (V_b) generates a large number of phonons (Luke phonons).
- Enables very low thresholds
- Trade-off: No event-by-event NR/ER discrimination

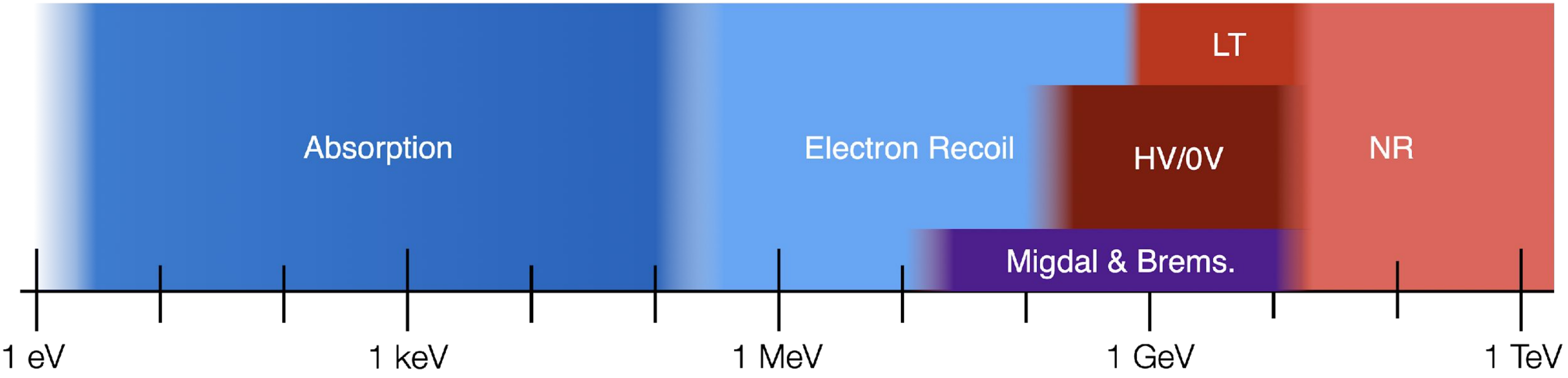
HV and iZIP provide complementary functionality



SuperCDMS Detectors & Dark Matter Mass Scales

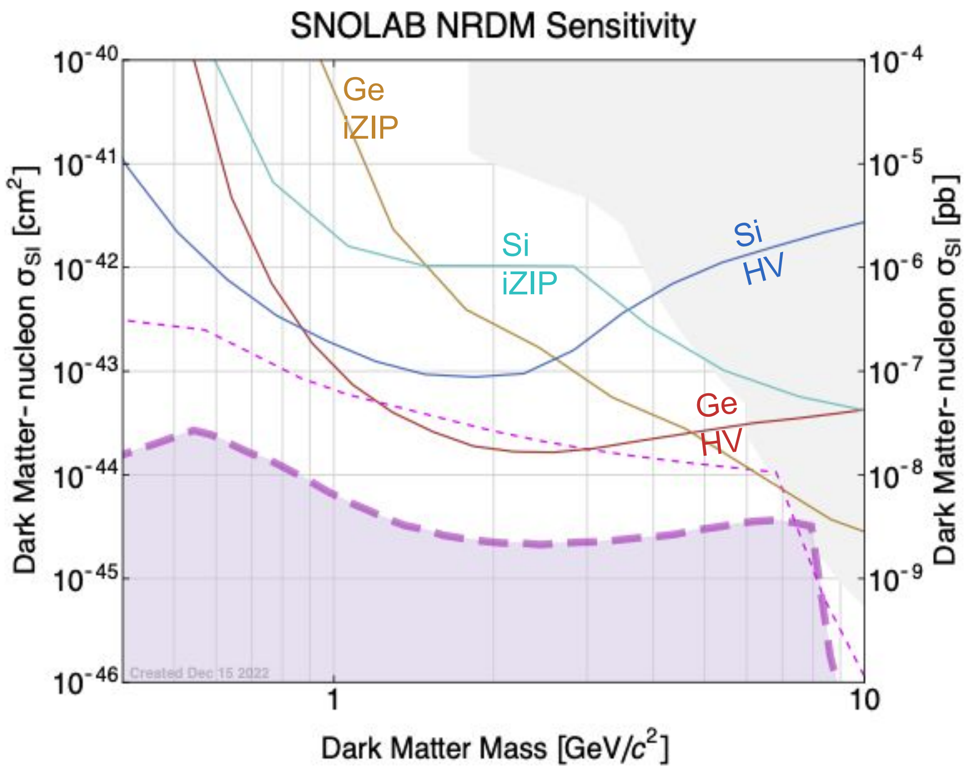
Dark Matter Mass Ranges

- High Mass Nuclear Recoil: Full discrimination, ≳ 5 GeV
- Low Threshold NR: Limited discrimination, ≳ 1 GeV
- HV & 0V Operation: No discrimination, ~0.3 – 10 GeV
- Migdal & Brems. Search: no discrimination, ~0.01 – 10 GeV
- Electron recoil: HV, no discrimination, ~0.5 MeV – 10 GeV
- Absorption (Dark Photons, ALPs): HV, no discrimination, ~1 eV – 500 keV (“peak search”)

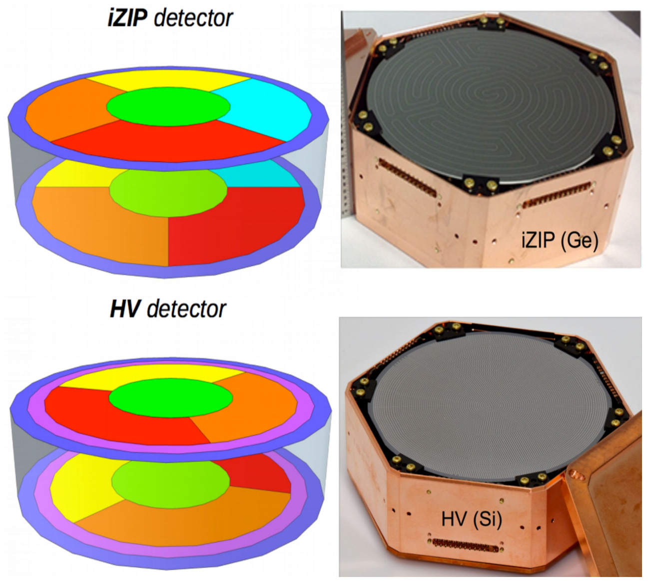


Science Strategy: Complementary Targets and Functionality

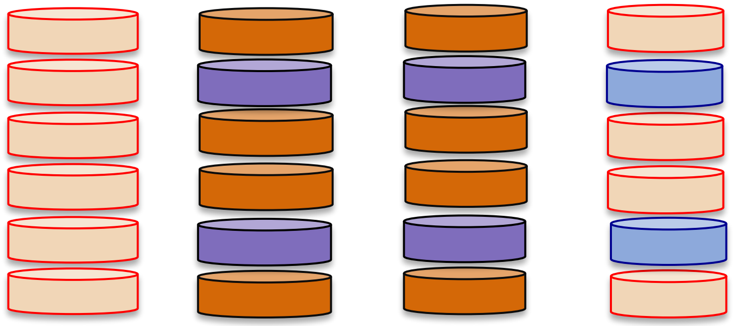
	Germanium	Silicon
HV	Lowest threshold for low mass DM Larger exposure, no ^{32}Si background	Lowest threshold for low mass DM Sensitive to lowest DM masses
iZIP	Nuclear Recoil Discrimination Understand Ge Backgrounds Sensitive to ^{8}B ν-scatter	Nuclear Recoil Discrimination Understand Si Backgrounds Sensitive to ^{8}B ν-scatter
Mass, Dimensions	1.5 kg 10 cm ∅, 3.3 cm thick	0.6 kg 10 cm ∅, 3.3 cm thick



Two Types of Detectors



Initial 4-tower payload



Tower 1
6 Ge iZIPs

Tower 2
4 Ge HV
2 Si HV

Tower 3
4 Ge HV
2 Si HV

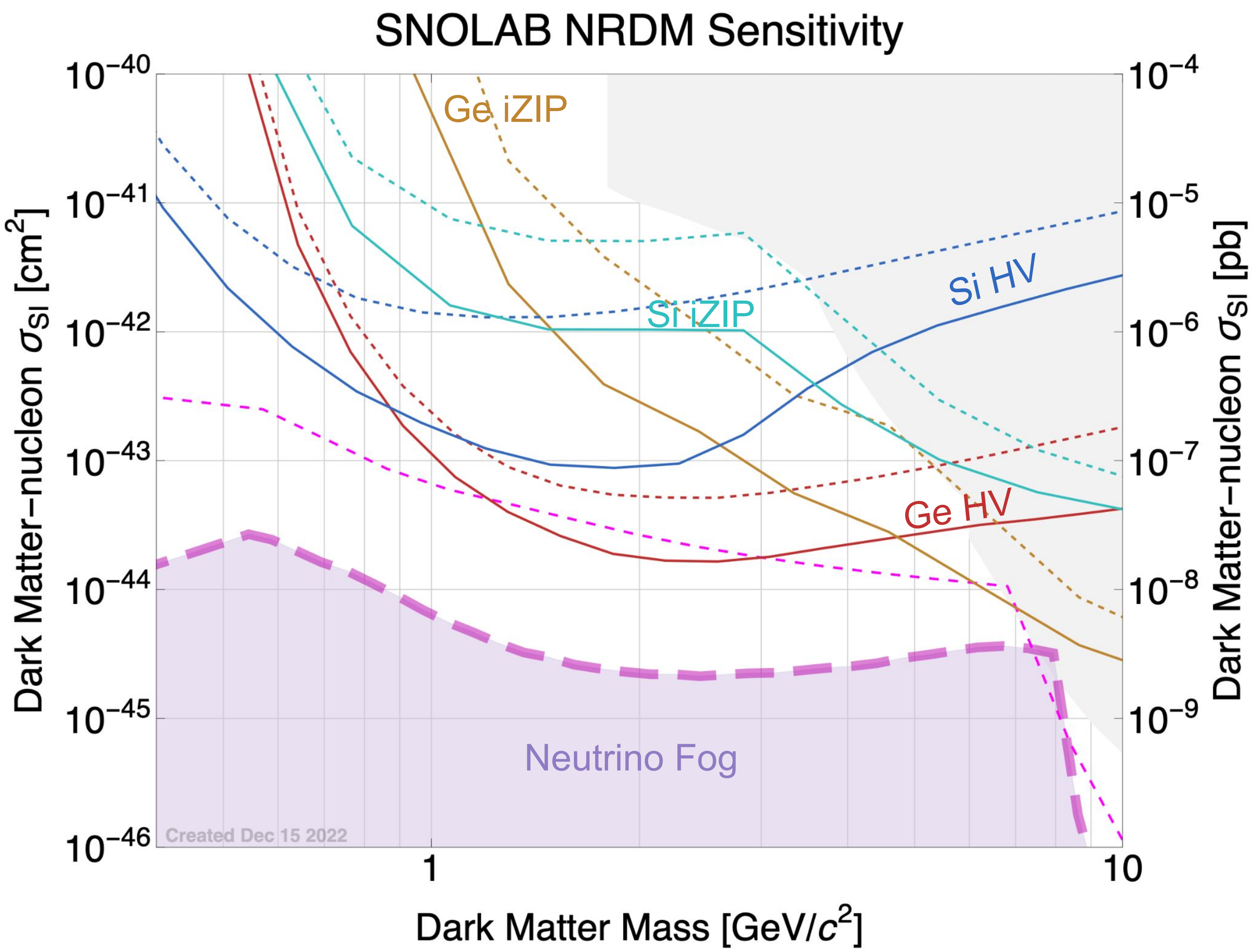
Tower 4
4 Ge iZIPs
2 Si iZIPs

2 technologies and 2 target materials cover the low-mass NRDM region, and provide sensitivity to electron-recoiling DM

Dark Matter Analysis: Sensitivity to Operating Conditions

- Dashed lines: Optimum Interval
  - Rapid improvement with time
  - Less sensitive to performance of all detectors

- Solid lines: Profile Likelihood
  - Ultimate scientific reach
  - Requires full exposure
  - Uses/benefits from information from all detectors to determine backgrounds



SuperCDMS Primary Science Goals

SuperCDMS SNOLAB infrastructure

- Provides a facility for world-leading, low-mass dark matter sensitivity down to the neutrino floor
- First science results will use the CUTE test facility, located in the same lab as SuperCDMS
- Small R&D detectors and prototype SuperCDMS detectors provide new science results 2021-2023

SuperCDMS SNOLAB 4-tower payload will provide

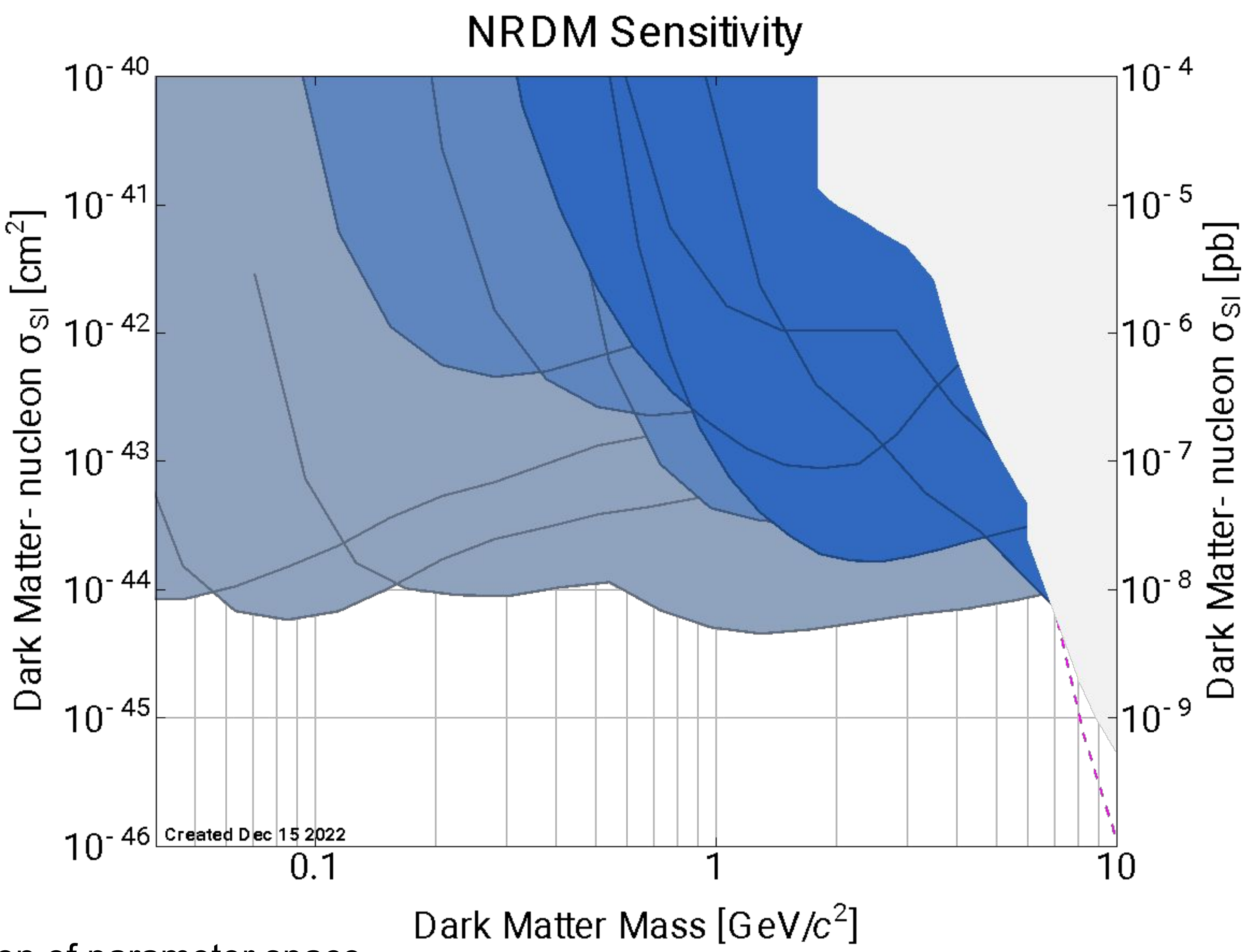
- An order of magnitude improvement WIMP limits for $0.5 < M_{DM} < 5$ GeV with a sequence of two year-long runs **[Dark Blue projections]**

The low background shielded cryostat

- Can hold SuperCDMS upgrades or partner collaborations to reach the neutrino floor for low mass WIMPs **[Light Blue/Gray projections]**

Snowmass paper: arXiv:2203.08463

SuperCDMS SNOLAB Primary Science goal



- Currently excluded region of parameter space
- Expected reach of the SuperCDMS@SNOLAB experiment
- Expected reach of SNOLAB facility with in-hand detector performance and improved backgrounds
- Expected reach of SNOLAB facility with detector performance & background and improvements

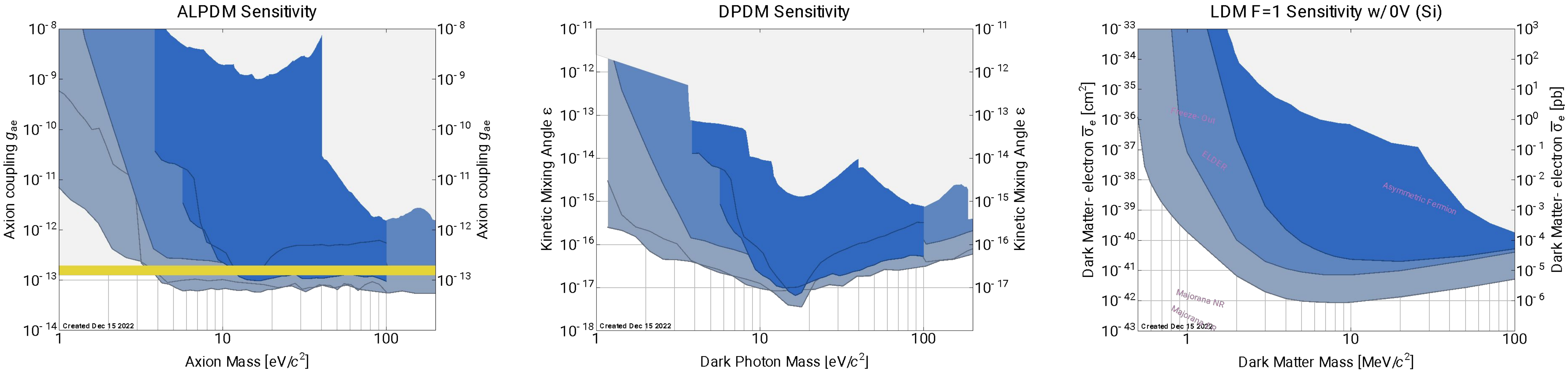
SuperCDMS Secondary Science Goals

Significant new parameter space can be explored with SuperCDMS SNOLAB

- Through 2024 with R&D detectors at NEXUS, CUTE, and surface test facilities

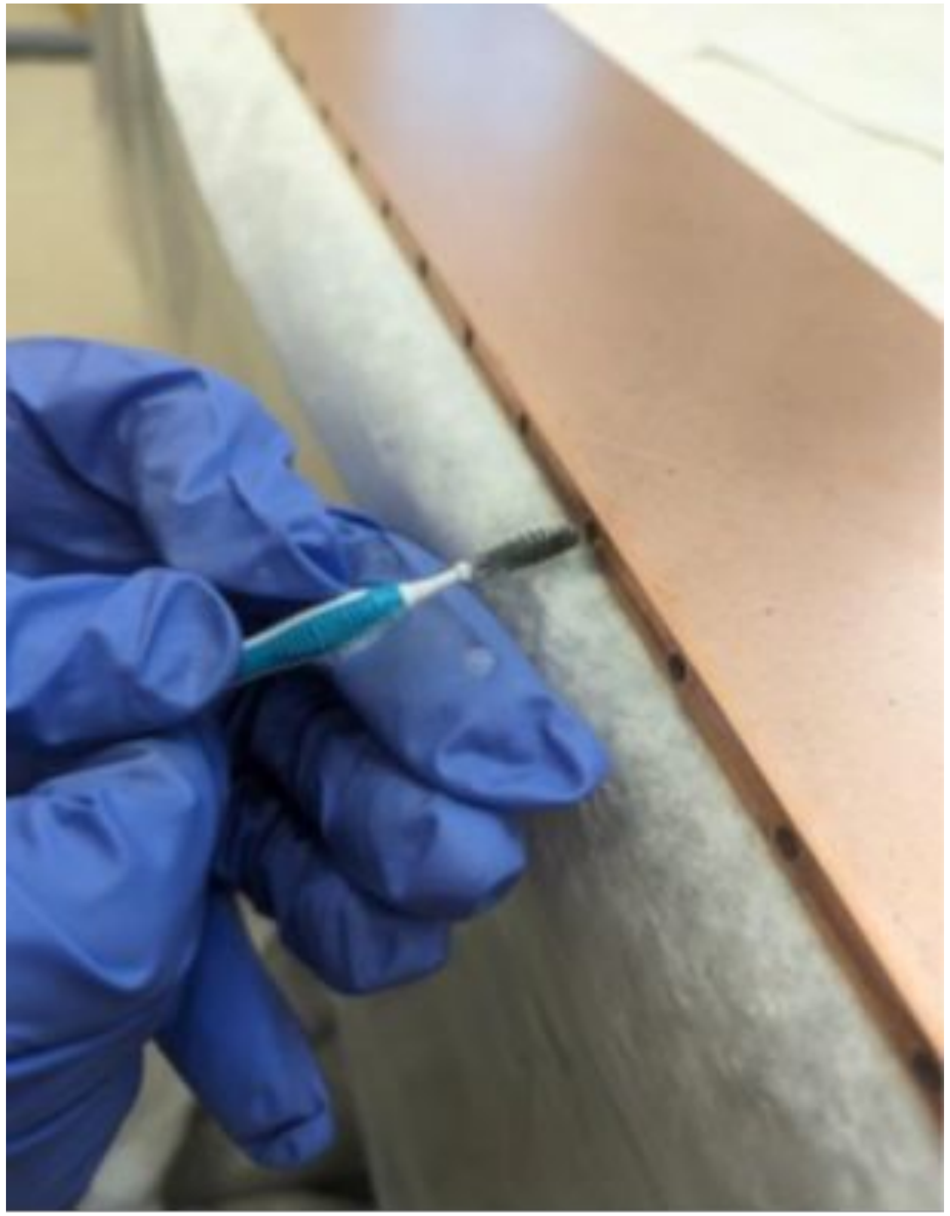
- After 2025 with:
  - SuperCDMS SNOLAB 4-tower runs **[Dark Blue projections]**
  - SuperCDMS SNOLAB upgrades **[Light Blue/Gray projections]**

SuperCDMS SNOLAB Secondary Science goals



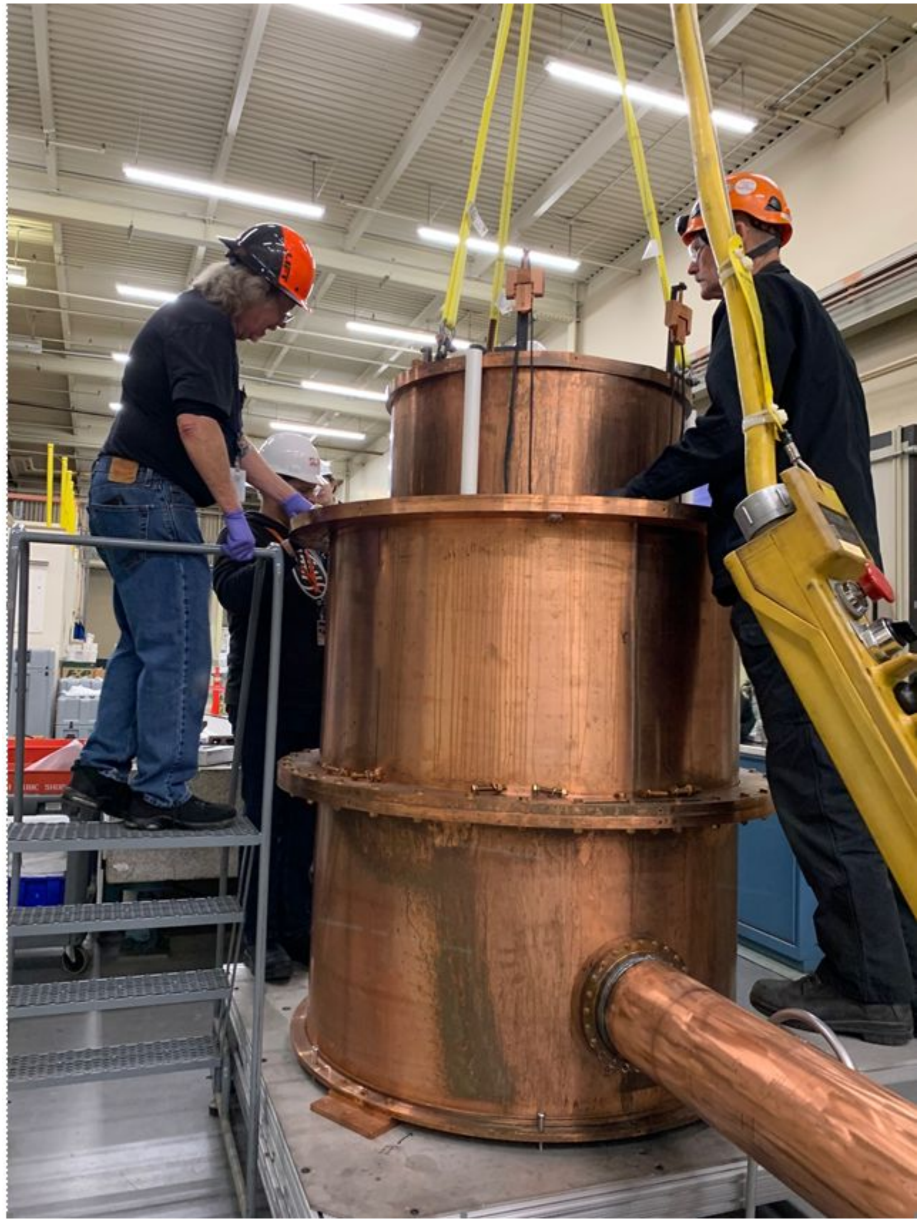
Major developments in on-site installation

- Cleaning and Passivation program
  - Collaboration members and personnel from SNOLAB began effort to etch and passivate Dilution Refrigeration "Tails" in November 2023 (the copper elements providing thermal connection to the cryostat)
    - Planned work program was reassessed due to the discovery of residue from the manufacturing process in most blind tapped holes in copper parts. SNOLAB provided essential support personnel in developing and implementing a cleaning program, that was completed in December, to remove the residue.
  - Collaboration members will return to SNOLAB in February 2024 to complete the etching and passivation of the DR tails.
  - We are developing an etching and passivation program for the remaining cryostat parts, once they are delivered to SNOLAB, that can be carried out by SNOLAB personnel with support as required by collaboration members.



Major developments in on-site installation

- Cryostat Assembly and Testing
  - Trial assembly of the cryostat components (cans and stems) is ongoing at SLAC.
  - Work on the surface allows for direct / unconstrained access to equipment
  - Assembly team developing operating procedures necessary for ensuring that the underground assembly proceeds smoothly
    - SNOLAB and SuperCDMS personnel visited SLAC (in December) to acquire experience with cryostat assembly.

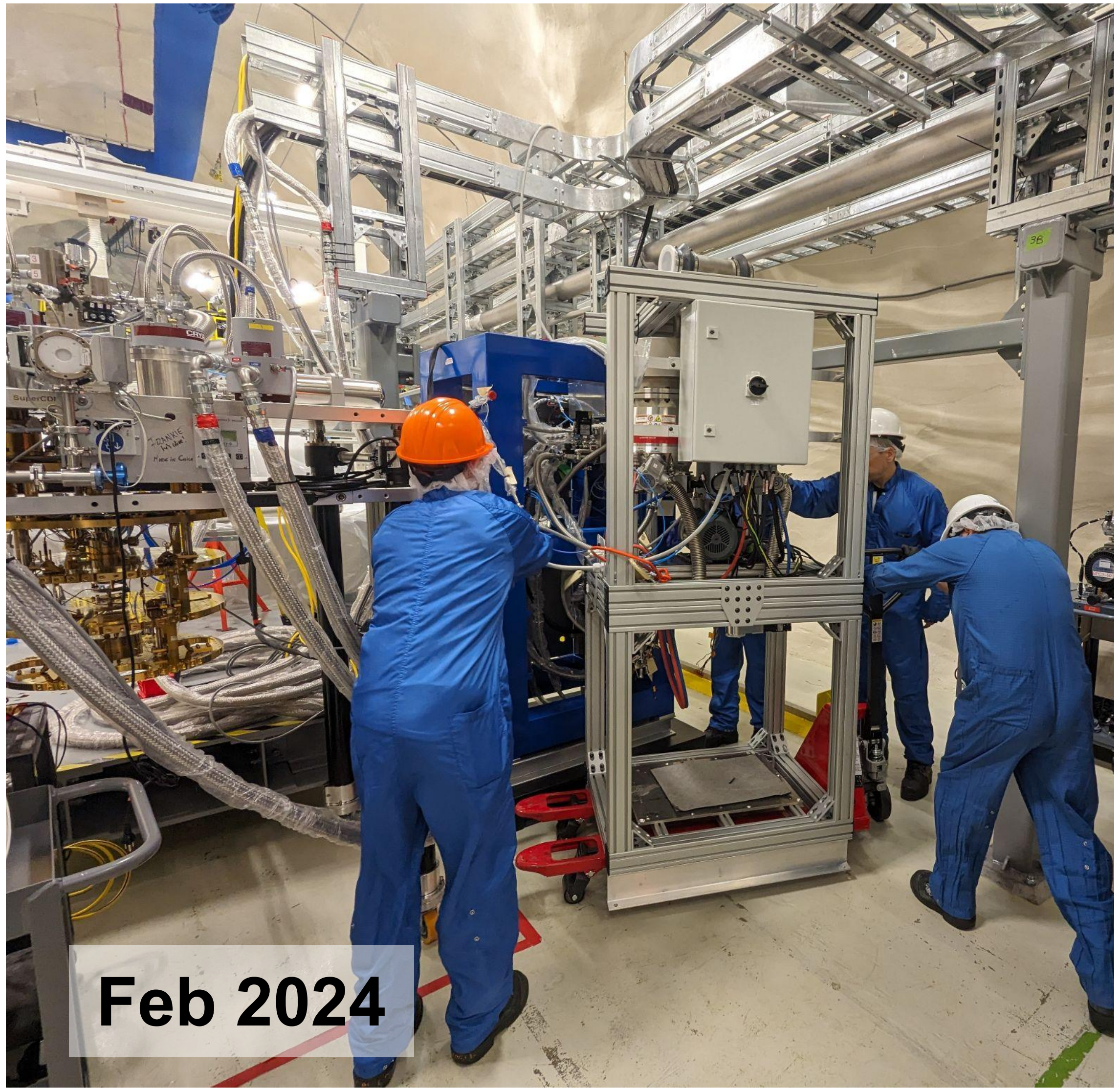


Major developments in on-site installation

- Underground Activity
  - As of Nov 2023, all 4 detector towers are underground at SNOLAB (a significant milestone for the experiment)
  - Most remaining elements (aside from cryostat) of experiment shipped to SNOLAB in October
    - Staged in the Access Lab, in the drift, in a surface shipping container, or in Laurentian University storage.
    - The collaboration has been successful importing the equipment with only GST being assessed (~1.25%)
    - SNOLAB has prioritized transport UG so that there is no backlog!
    - The schedule risks arising from shipment to Sudbury and then underground to have been largely retired.
  - The remaining large shipments are delivery of the cryostat components from SLAC, which will occur during the first half of 2024.
  - Underground shifts have routinely consisted of 3-5 collaboration members preparing for the next phase of the installation.
  - A significant increase in on-site effort is expected when the cryostat OVC is delivered, cleaned, passivated and shipped underground
  - Anticipate OVC and mu-metal shield installation followed by further lead shield installation in second quarter 2024.

Major developments in on-site installation

- Substantial progress installing cryogenic infrastructure underground



- All compressors now underground.

Major developments in on-site installation

- EH&S benchmarking exercise
  - Included SuperCDMS, SNOLAB, PNNL, SLAC, and Fermilab safety personnel
  - Charge:
    i. Assess whether the SuperCDMS hazards are adequately described in the Hazard List and whether mitigation efforts are sufficient.
    ii. Assess whether the HAR-MP adequately describes the SuperCDMS safety plan.
    iii. Recommend changes to the HAR-MP document in light of comparison with home institution safety guidelines.
  - Pre-meetings and a two-day exercise in late October including underground SNOLAB visit.
- Benchmarking response positive.
  - Relatively minor recommendations received from FNAL and PNNL safety specialists and have been addressed.

Achieved Major Milestones / Deliverables

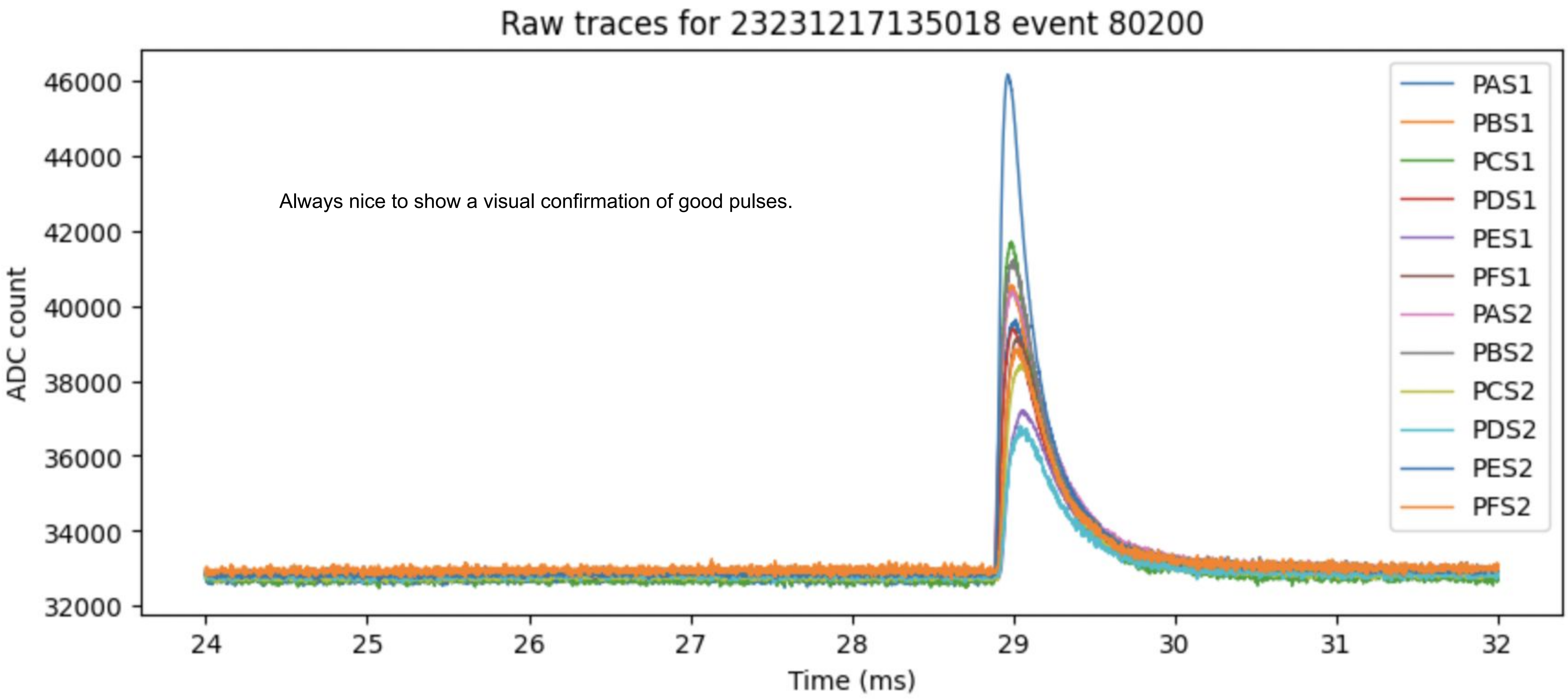
- *Detectors*
  - Completion of Tower 1 testing in the SLAC DR
  - All detector towers shipped to SNOLAB with successful acceptance testing: 11/27/2023 – 1/08/2024
    - *Towers 1, 3, and 4 have passed acceptance testing. Tower 2 is scheduled to undergo acceptance testing during the week of February 12, 2024.*
  - Completion of Tower 3 testing in CUTE: Extended to March 2024

- *Cryogenic System and Shielding*
  - Delivery of OVC chamber, E-Stem, and C-Stem to SNOLAB: The decision to perform a trial assembly of the complete cryostat at SLAC has uncovered a number of engineering and assembly challenges that delayed the delivery of the cryostat. We are currently evaluating options to mitigate the impact on schedule.
  - Installation of Mu-metal shield base: The mu-metal shield sections have been delivered underground, in preparation for installation of the bottom section on the shield base.

Experiment Status and First Science from Tower 3

- Tower 3 (HV detectors) Operating in CUTE since October 2023
  - Short warm-up needed on initial cooldown to fix small thermal touch. Facility performance since has been very good.
  - **Operation of the HV detectors has met or exceeded all reasonable expectations.**
  - Substantial progress made in understanding noise sources, particularly those impacting operation of multiple detectors.
    - Developing plans for a week of more intensive noise assessment, Feb. 20-23.
  - Substantial progress made towards understanding the operation of the detectors
    - *Performed energy calibration in Ge with observed 10 keV, 1.3 keV and 160 eV activation lines.*
    - *Establishing energy calibration in Si with evidence of Compton steps seen in Ba calibration*
  - Effective exercising of data taking including data quality monitoring, handling, and processing tools.
    - *Identified issues to address before commissioning of the full payload.*
  - End of Tower 3 run in CUTE has been pushed from early January to mid-March
    - Final four weeks will be used to further inform commissioning of the full payload in the SNOBOX cryostat and potentially acquire low-background data.

Experiment Status and First Science from Tower 3



Always nice to show a visual confirmation of good pulses.

Experiment Status and First Science from Tower 3

- Tower 3 (HV detectors) Operating in CUTE since October 2023
  - Short warm-up needed on initial cooldown to fix small thermal touch. Facility performance since has been very good.
  - Operation of the HV detectors has met or exceeded all reasonable expectations.
  - Substantial progress made in understanding noise sources, particularly those impacting operation of

- Due to the gradual obstruction of flow through the cold trap and into the dilution refrigerator (DF), the DF is being warmed up to room temp (yesterday) to clean the trap and the circulation lines.

- No change to payload; Tower 3 will be cooled back down over the weekend to resume the planned testing program."

    - *Identified issues to address before commissioning of the full payload.*
  - End of Tower 3 run in CUTE has been pushed from early January to mid-March
    - Final four weeks will be used to further inform commissioning of the full payload in the SNOBOX cryostat and potentially acquire low-background data.

Experiment Status and First Science from Tower 3

- Established methods to perform a relative calibration between the 12 channels in each detector even in the absence of specific spectral features and with inhomogeneous illumination.
- Developed parameters for event-position reconstruction, tested a new energy-reconstruction algorithm, and developed some basic data selection criteria (cuts) for the primary analyses.
- Measured baseline resolution under optimal conditions to be close to the resolution we expected: 55 eV Ge / 30 eV Si
- Data collected as of January:

Exposure [detector-days]	0V		HV	
	Background	**Ba Calib**	**Background**	**Ba Calib**
Silicon	12.9/10.4	16.5/14.8	5.5/5.1	15.1/7.7
Germanium	15.2/11.9	30.9/27.7	12.3/11.6	3.7/3.6

Background data include the data acquired with the activated Ge detectors.
The first / second exposure value corresponds to the total amount of data acquired / the data that we believe is of sufficient quality to be used for analysis.

Experiment Status and First Science from Tower 3

- Both an on-site and off-site labor pool essential for supporting the run.

- The off-site effort consists of a core expert team operating the detectors and working directly with the on-site team for any tests that require configuration changes.

- Data quality and fridge monitoring shifts (3 per day for 24/7 coverage) provided a consistent quick-turnaround analysis effort to ensure that the data taken are of sufficient quality.
  - Expert team focused on data management issues
  - Off-line analysis team followed up with more in-depth and detailed analyses
  - Effort was particularly intense at the beginning of the operation but has settled to a steady-state around the beginning of 2024.
  - Effort during initial portion of run averaged to about 9–10 FTE
  - 5-6 FTE expected for the remainder of the run

- Run was an essential learning ground for new members of the collaboration, many of whom have not had experience with previous generations of SuperCDMS, and help prepare them for data taking with the full experimental payload.
  - Special thanks to effort by Yan Liu, Aditi Pradeep, Tyler Reynolds, Andy Kubik, Vijay Iyer in ensuring success of the Tower 3 Run.

Collaboration Health and EDI

- Collaboration maintains an external and internal facing effort aimed at EDI effort
  - The **external effort** consists of a public statements posted at the collaboration's public website (https://supercdms.slac.stanford.edu/diversity-openness) describing the collaboration's formal position on
    - Scientific Code of Conduct
    - Diversity, Equality and Inclusion (EDI)
    - Openness in Research
    - Ombudsperson and Safe People resource, including confidential support
- The Code of Conduct includes a written process through the Executive Committee to address any allegation of a Code of Conduct violation.

Collaboration Health and EDI

- Collaboration maintains an external and internal facing effort aimed at EDI effort
  - The **internal effort** consists of providing (to all collaboration members)
    - Ombudsperson and Safe People serve as a non-threatening option to help members of the collaboration navigate a difficult situation while retaining privacy, protection from retaliation, and preventing a situation from worsening. They offer an informal path to resolve a situation.
    - Conducting an annual (anonymous) “Climate” survey aimed at assessing (see next 2 slides)
    - Opportunity for open-ended, confidential input with two specific issues raised.
      - Neither related to SNOLAB’s personnel or systems.
      - One fully addressed. The other was systemic; we are implementing a solution.
    - Review correlations in member responses (junior vs senior members), whether members facing challenging situations had opportunity for support, categories of where issues arose.

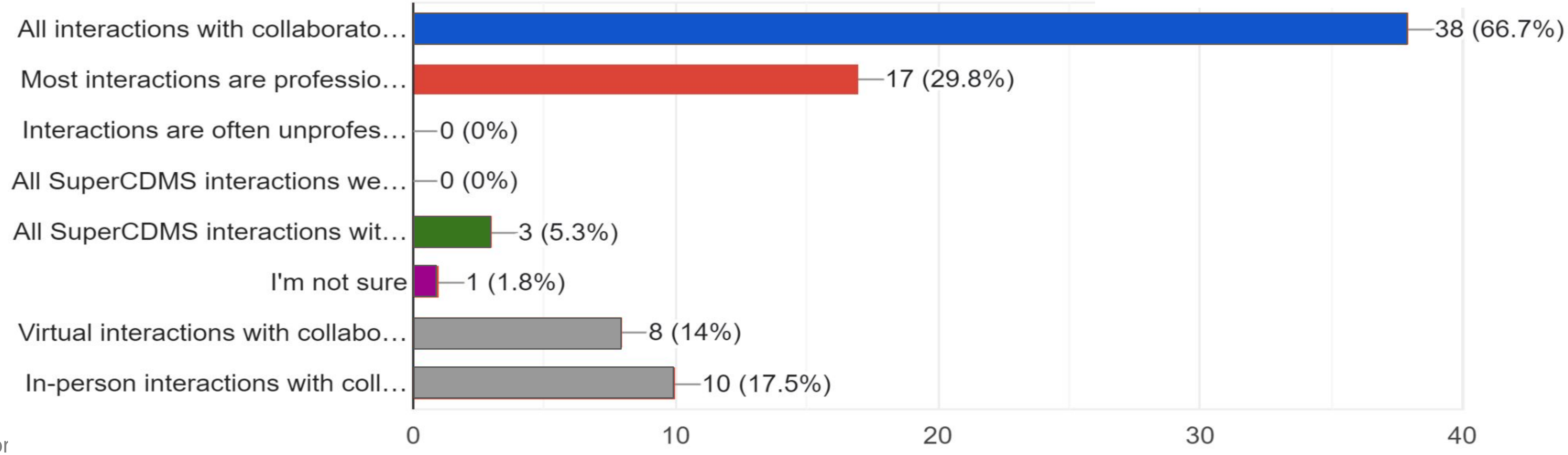
Collaboration Health and EDI: “Climate” Survey Example 1

2. The SuperCDMS Collaboration believes that an inclusive and professional environment is a requirement for any scientific community. Collegial interactions are expected at all times, and people must be treated with respect regardless of seniority, sex (including pregnancy), sexual orientation and/or gender identity, disability, physical appearance, body size, race, color, nationality, ethnicity, genetic information, institutional affiliation, and religion. Based on your experiences and observations in the past year, how would you characterize the SuperCDMS environment?

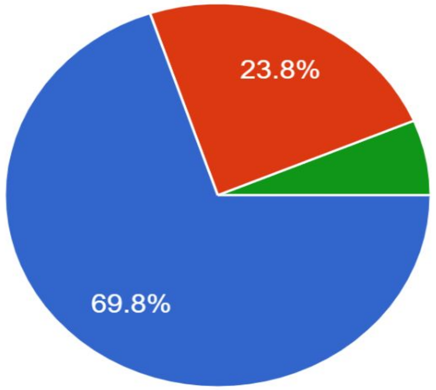
in the past year?

- All interactions with collaborators are professional and collegial
- Most interactions are professional and collegial
- Interactions are often unprofessional or non-collegial
- All SuperCDMS interactions with collaborators are professional and collegial, but this was not always true…
- I'm not sure

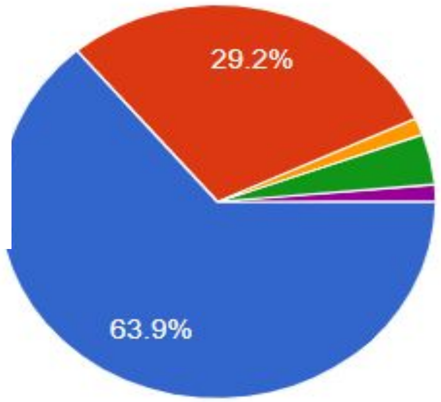
↓ 2023 Results



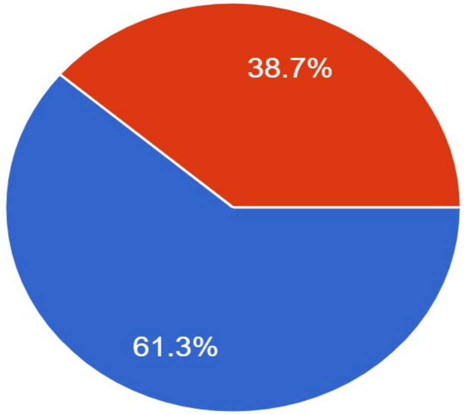
↓ 2022 Results



↓ 2021 Results



↓ 2020 Results

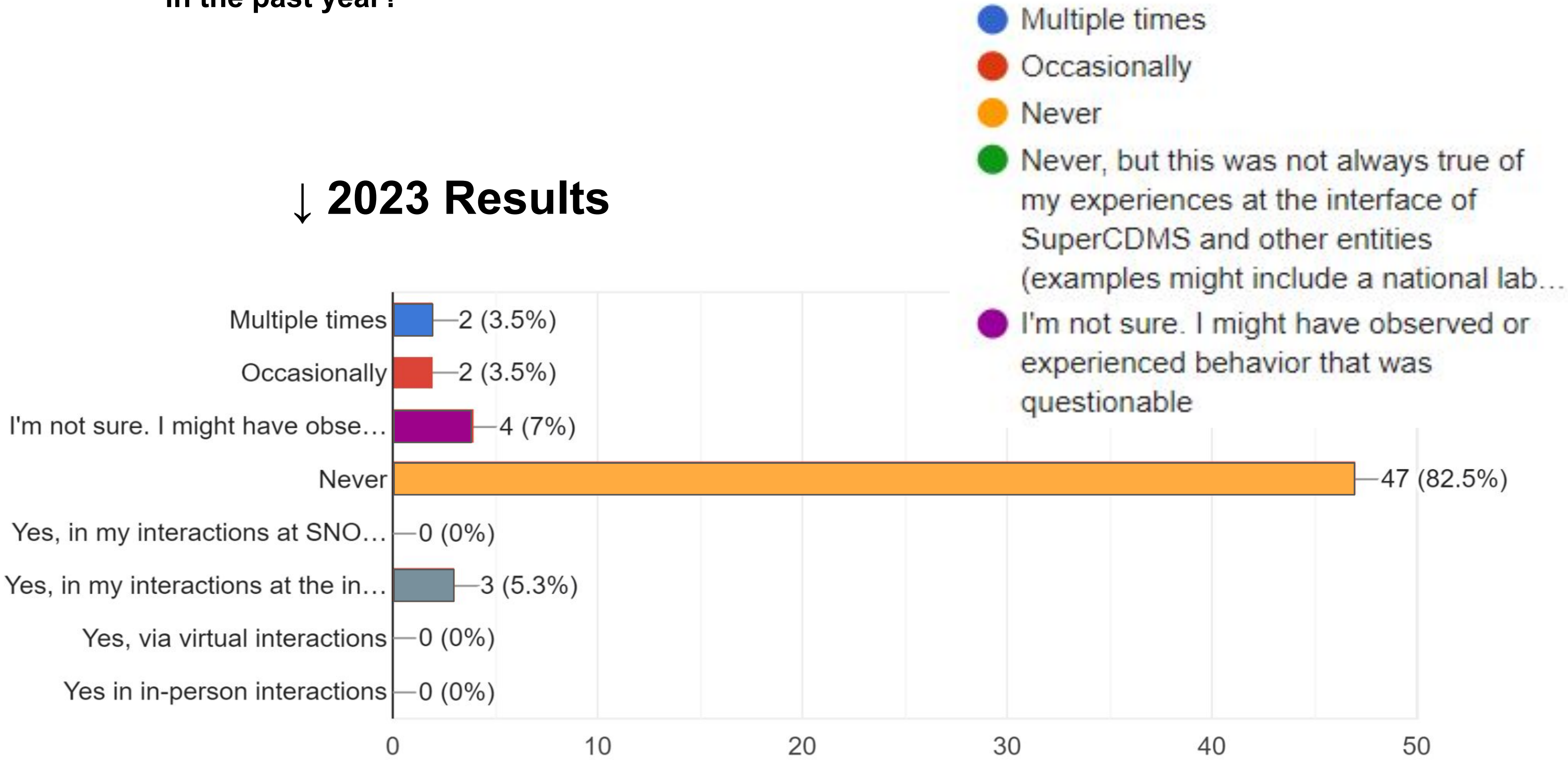


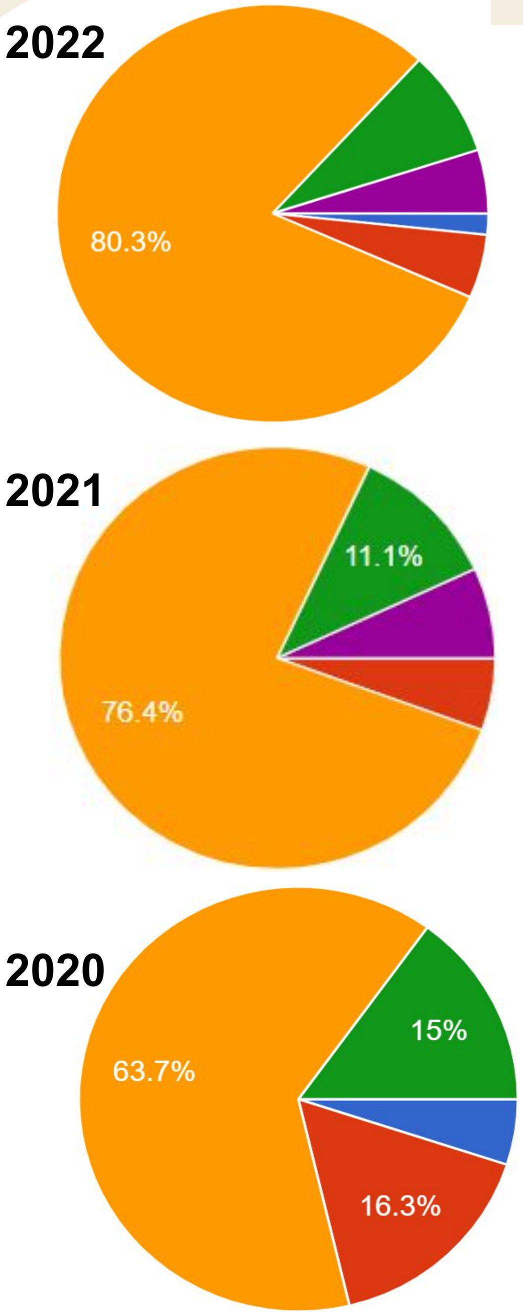
Collaboration Health and EDI: “Climate” Survey Example 2

4. To "discriminate" against someone means to treat that person differently, or less favorably, because of seniority, sex (including pregnancy), sexual orientation and/or gender identity, disability, physical appearance, body size, race, color, nationality, ethnicity, genetic information, institutional affiliation, and religion. In the past year, have you experienced or observed another person experiencing *discrimination* within SuperCDMS?

in the past year?

↓ 2023 Results

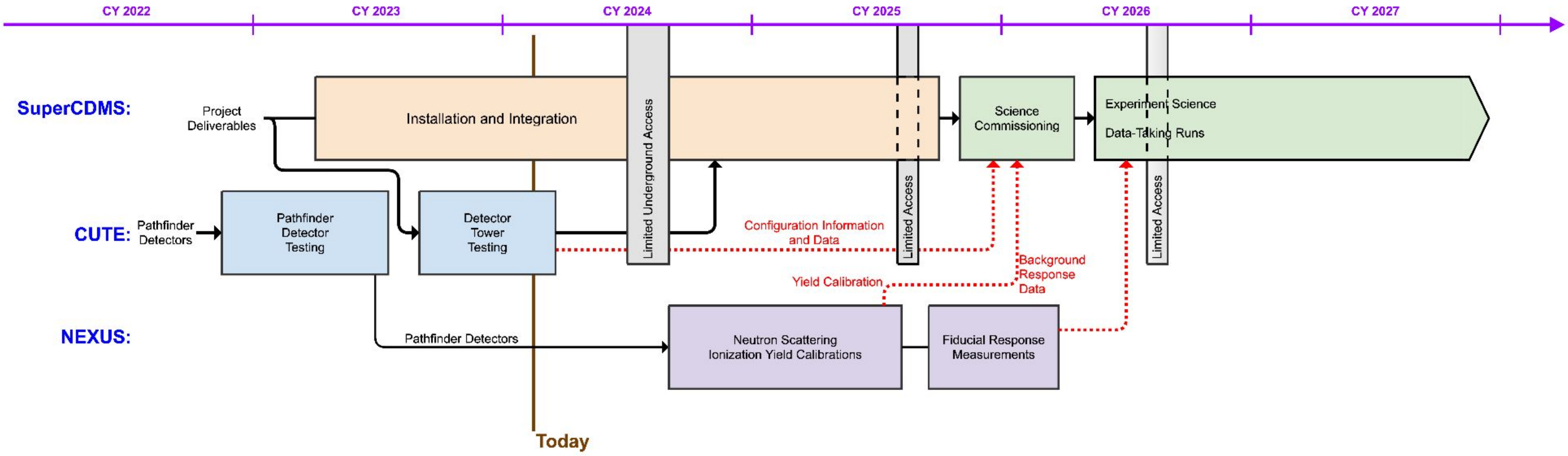




- A series of 7 similar questions to those shown on this and the and prior slide with follow-up questions for each. Also ask questions assessing barriers to obtaining support.

Bird's Eye View Forecasted Schedule

- Anticipating a transition from the I&I to Operations phases in fall 2025



Challenges

- Main challenge in the short term arises from maintaining (and growing) collaboration expertise in key areas. relevant areas.
  - Critical expertise in software and computing was lost in Winter 2023 due to SuperCDMS postdocs accepting (very well earned) research positions in Europe
  - Aim to to replace lost expertise via combination of in-collaboration personnel and new hires, but process takes time.
  - Many members (grad students/postdocs) people gained expertise operating the HV tower at CUTE, however, only a few became real experts. Ensuring the continuity and availability of expertise for SuperCDMS commissioning is a challenge and priority.

- Mid term challenge revolves around maintaining collaboration on-site shift effort needed to meet the current demands on Installation activities and Tower run, and the expected increase in demand as 2024 progresses
  - Collaboration Shift coordinator is the unsung hero in ensuring there are always sufficient hands on deck to turn all the screws that need tightening.
  - Collaboration revisiting on-site shift component of service policy.

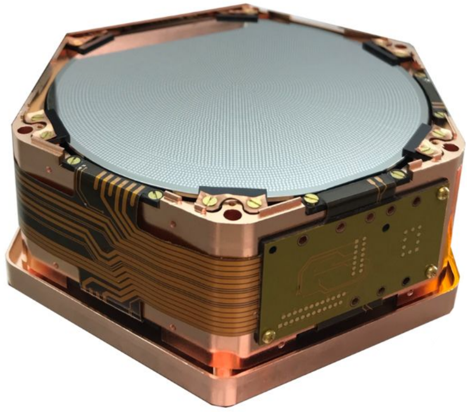
Conclusion

- *All 4 detector towers safely shipped to SNOLAB and underground*

- Installation & Integration is progressing well
  - pre-assembly at SLAC of cryostat components has proven to be invaluable
  - preparing for shipment of cryostat elements from SLAC to SNOLAB

- Testing of HV tower 3 in CUTE is proceeding well
  - Sneak peek at how operation of the full payload will happen
  - Detectors:
    - Noise issues being addressed and resolved
    - Neutralization strategies established
    - Calibrations strategies validated
  - Data:
    - Date transport, quality checking, handling and processing being exercised and improved
  - Shift process being exercised and improved

- Collaboration responding & adapting to the challenges of I&I and testing



Thank You