2026/07/31

Advancing Science Underground: Capabilities and Research at SNOLAB

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Professor of Physics | Queen’s University

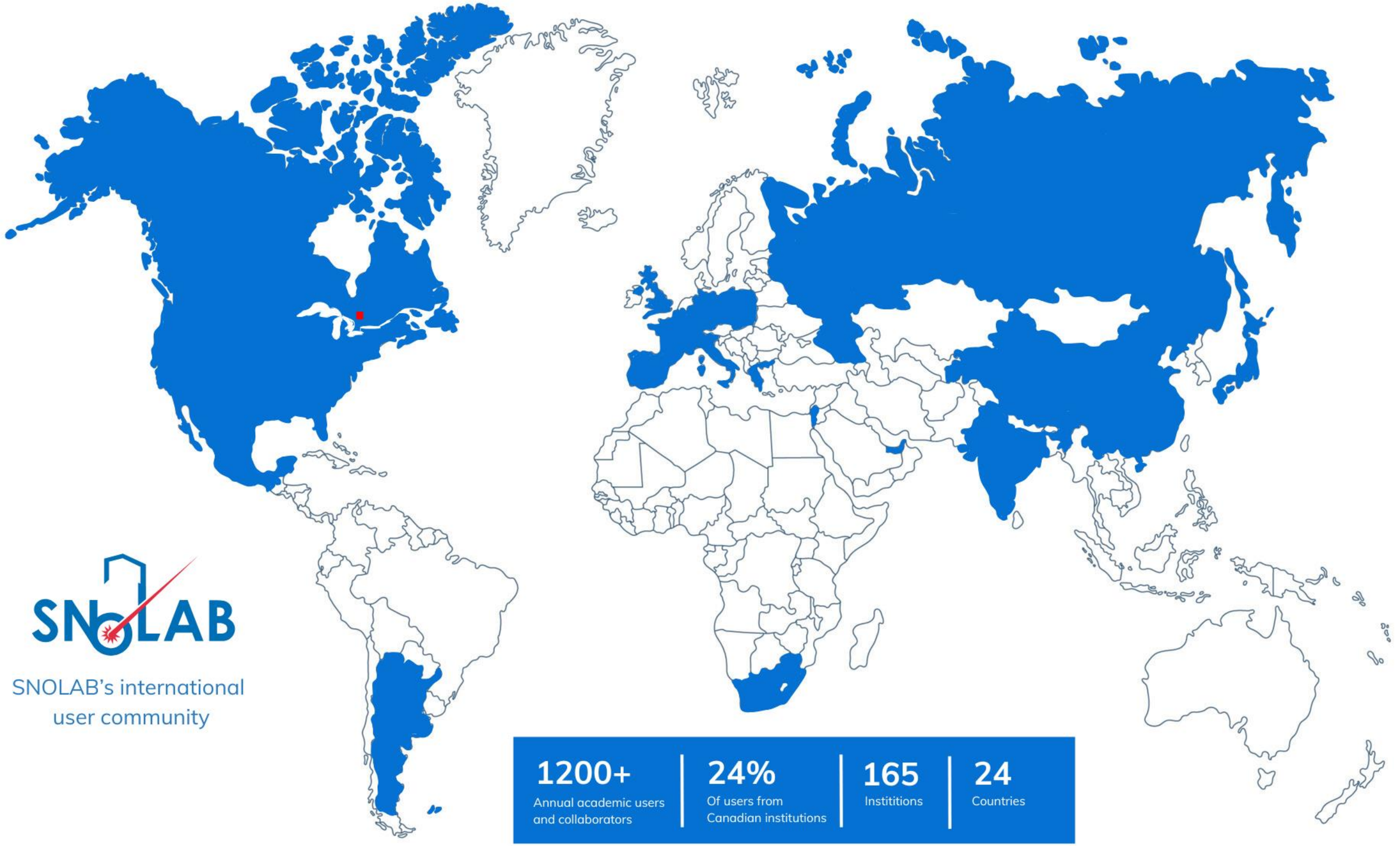
Introduction to SNOLAB

- SNOLAB hosts rare event searches and measurements.
- 2 km underground (Vale Creighton Mine near Sudbury, Ontario, Canada)
  - 5,000 m^2 class 2000 cleanroom
- Experiments supported by CFI-IF, NSERC, and international partners.

Visionary Partners

Carleton University
VALE
Université de Montréal
University of Alberta
Laurentian University / Université Laurentienne
Queen's University

INNOVATION
Canada Foundation for Innovation / Fondation canadienne pour l'innovation
Ontario



SNOLAB

SNOLAB's international user community

1200+	24%	165	24
Annual academic users and collaborators	Of users from Canadian institutions	Instititions	Countries

Reaching New Heights, Deep Underground

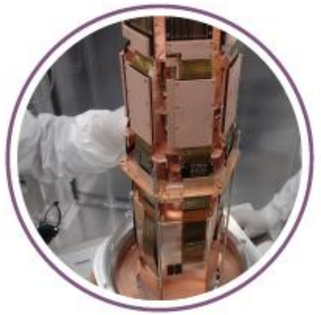
2023–2029 Strategic Plan

SNOLAB

Three core pillars drive our Strategic Plan.

Excellent Science

GOAL: Drive breakthrough discoveries at the frontiers of underground science



Cutting-Edge Infrastructure

GOAL: Continuously improve our research infrastructure to remain state of the art

Skilled People

GOAL: To foster and develop diverse talent in an inclusive environment

Our core values underpin our vision and goals.

Safety | Excellence | Teamwork | Accountability | Diversity

SNOLAB

1

Excellent science

Drive breakthrough discoveries at the frontiers of underground science.

Expected outcomes:

- Cementing of Canada's leadership in deep underground science
- A stronger, more competitive Canada in scientific discovery
- More Canadian researchers positioned as global leaders

Science Strategy

Increase our understanding of the particles and forces that have shaped the universe.

- What is the nature of dark matter?
- What is the nature of the neutrino?

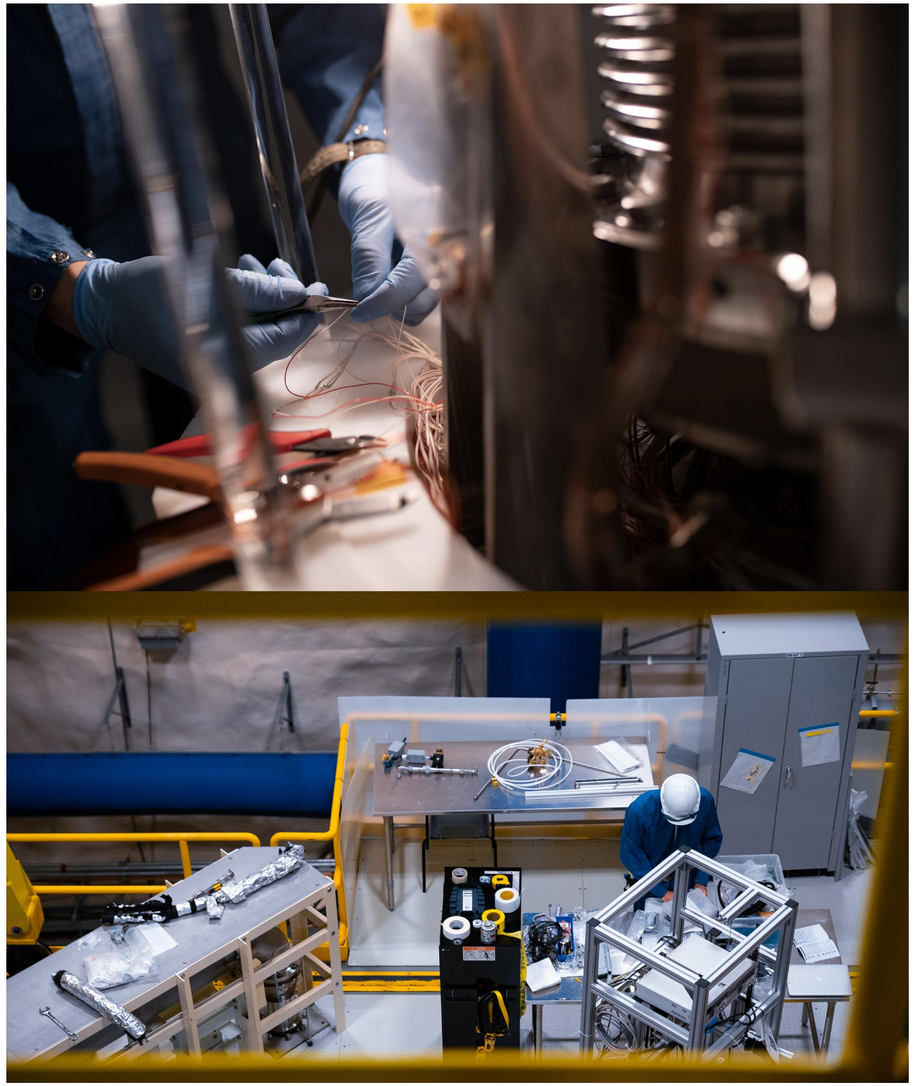
Continue to collaborate in scientific research requiring deep underground facilities.

- Neutrino observatories (solar, supernovae, geo, reactor, etc.)
- Effects of radiation on biological systems
- Environmental monitoring (nuclear non-proliferation, etc.)

Pursue new collaborations and opportunities in emerging areas of underground science

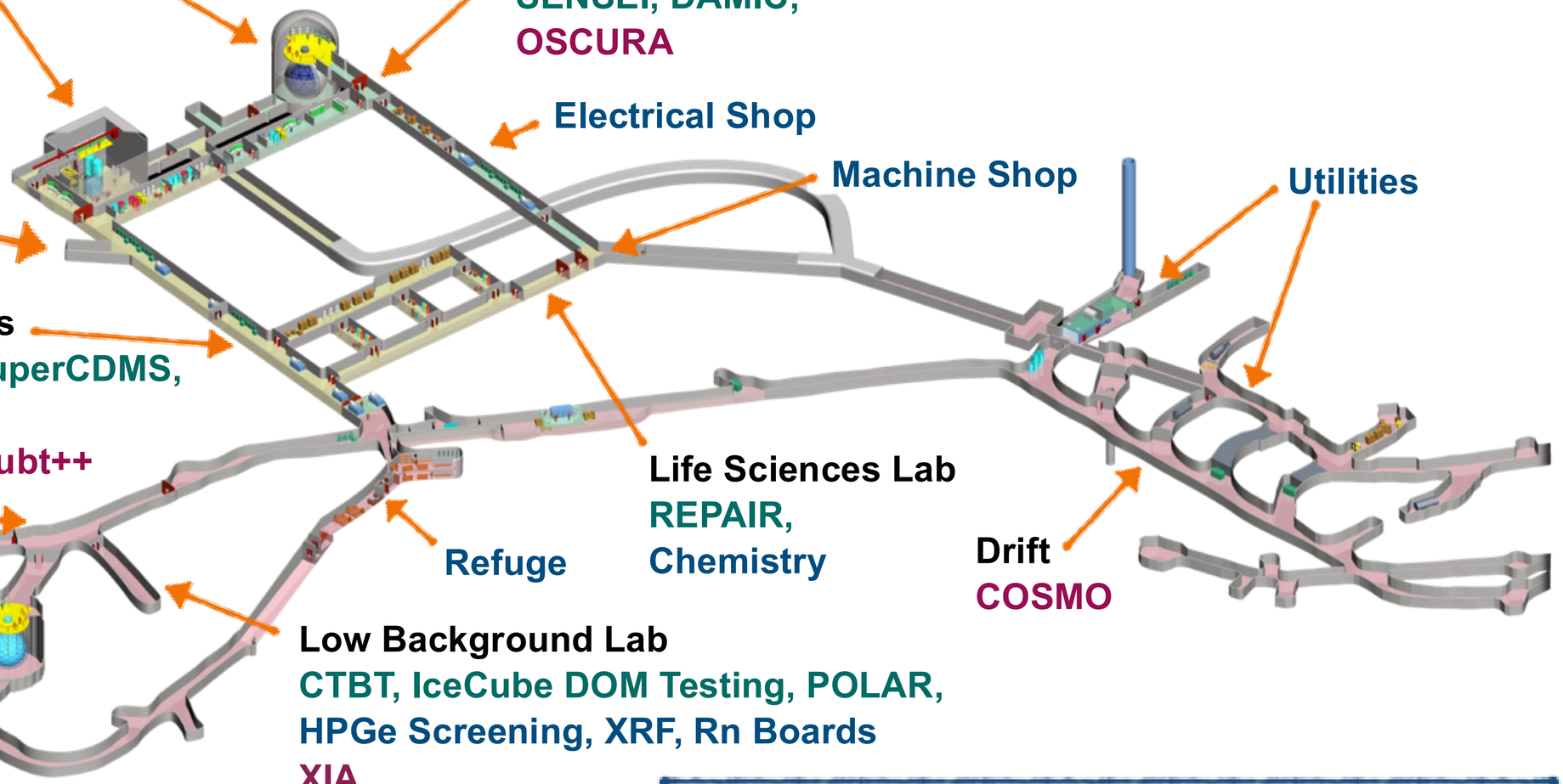
- Quantum technologies (quantum computers, sensors, and materials)

Become an intellectual hub that fosters collaboration and connection.



Spaces @ SNOLAB

Experiment Areas
Current Experiments
Laboratory Facilities
Future Experiments



Cryopit
XeStill
(XLZD Concept)

Cube Hall
DEAP-3600, NEWS-G,
PICO-500,
(Argo Concept)

J-Drift
SENSEI, DAMIC,
OSCURA

Electrical Shop

Halo Stub
HALO,
Potential breakthrough
for expansion
(Theia Concept)

Machine Shop

Utilities

Ladder Labs
PICO-40, SuperCDMS,
CUTE,
SBC, NuDoubt++

Plants
UPW, LN2,
Scintillator,
TeDiol, TeA

Life Sciences Lab
REPAIR,
Chemistry

Refuge

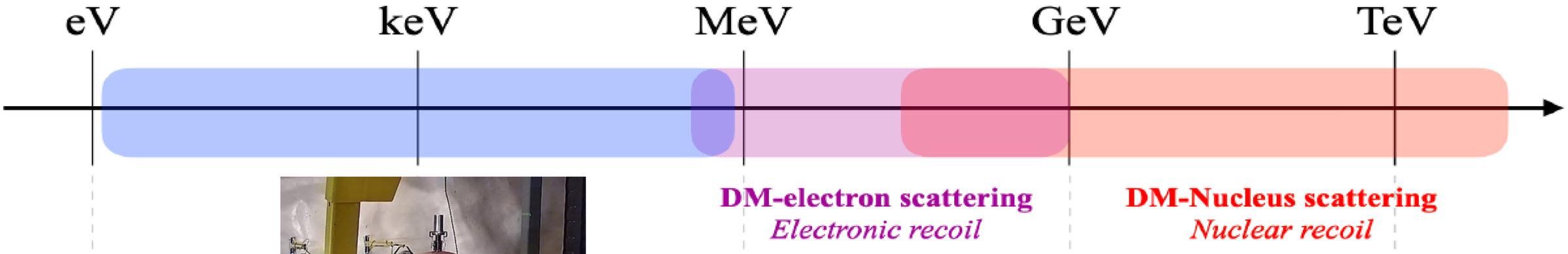
Drift
COSMO

Low Background Lab
CTBT, IceCube DOM Testing, POLAR,
HPGe Screening, XRF, Rn Boards
XIA

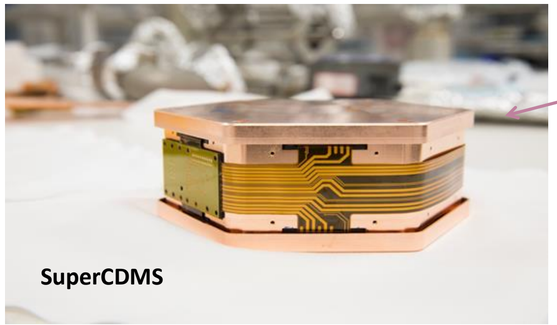
SNO Cavern
SNO+, SNO+Te
Potential for large
project after 2035

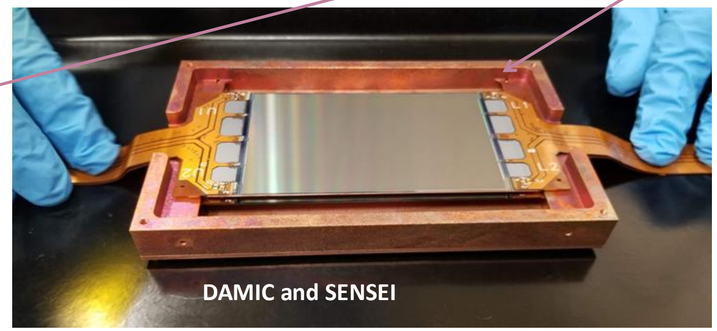
- 5,000 m^2 of class 2000 cleanroom
- <2000 particles >0.5 μm in diameter per ft^3

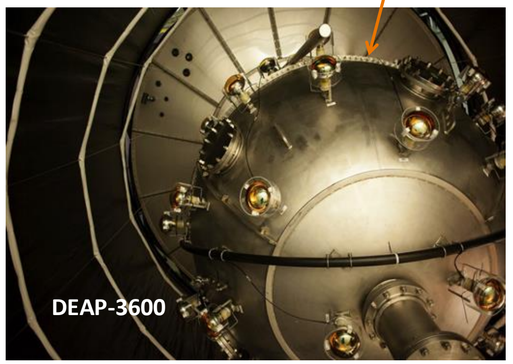
Searching For Dark Matter



GAS AND SOLID TARGETS | LIQUID TARGETS

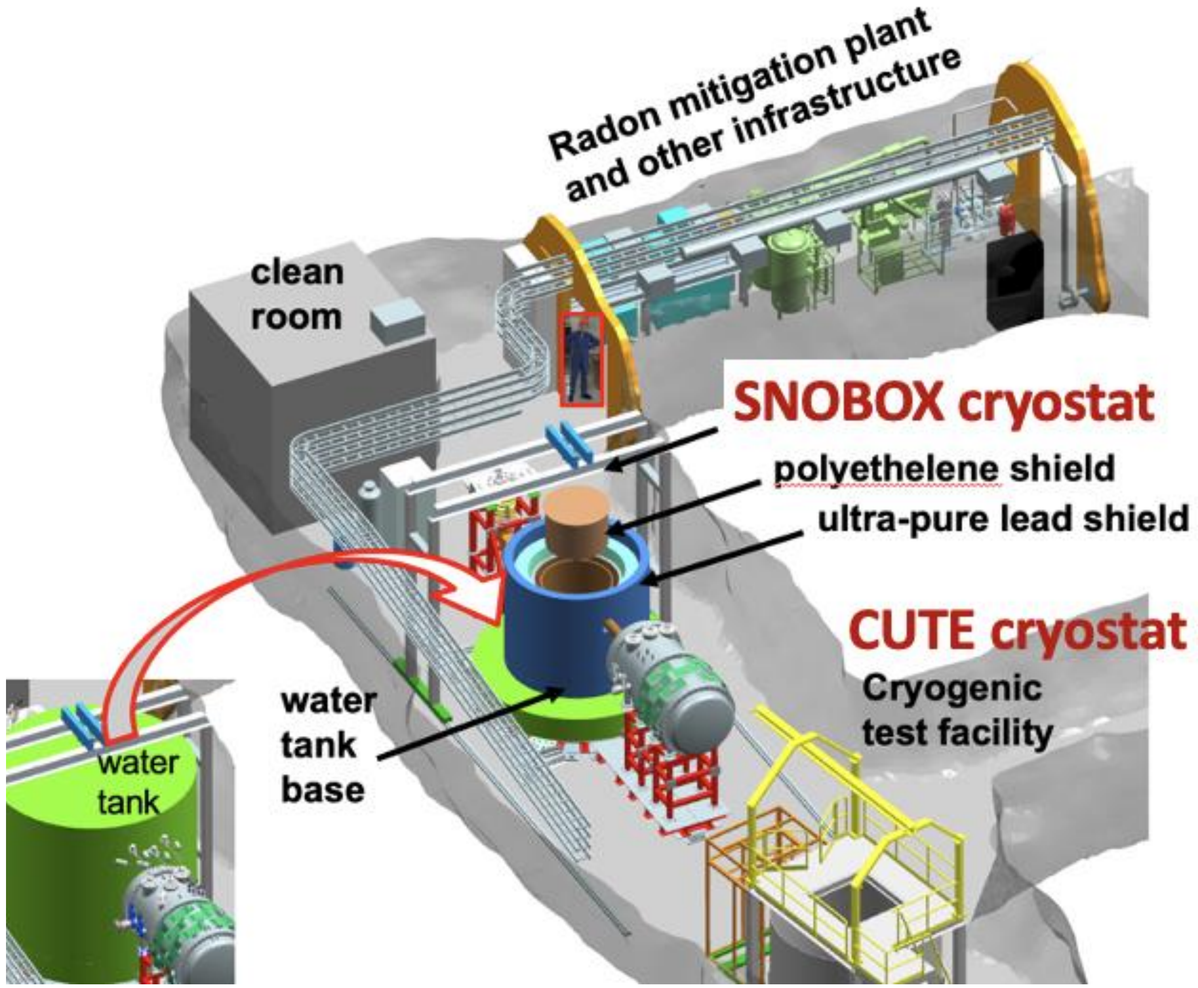






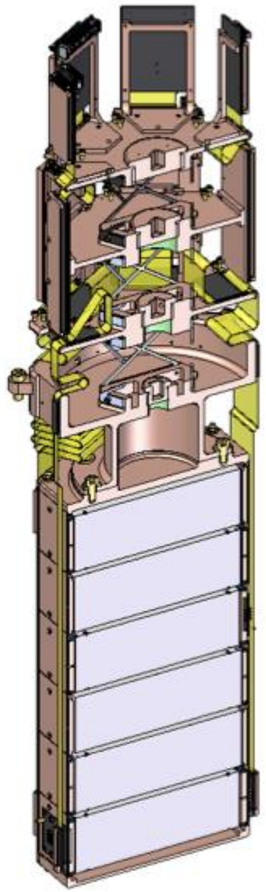
SuperCDMS SNOLAB

- SuperCDMS SNOLAB construction is underway in the Ladder Lab.
- Potential for world leading results from commissioning runs of some of the detectors in the CUTE test facility



SuperCDMS SNOLAB

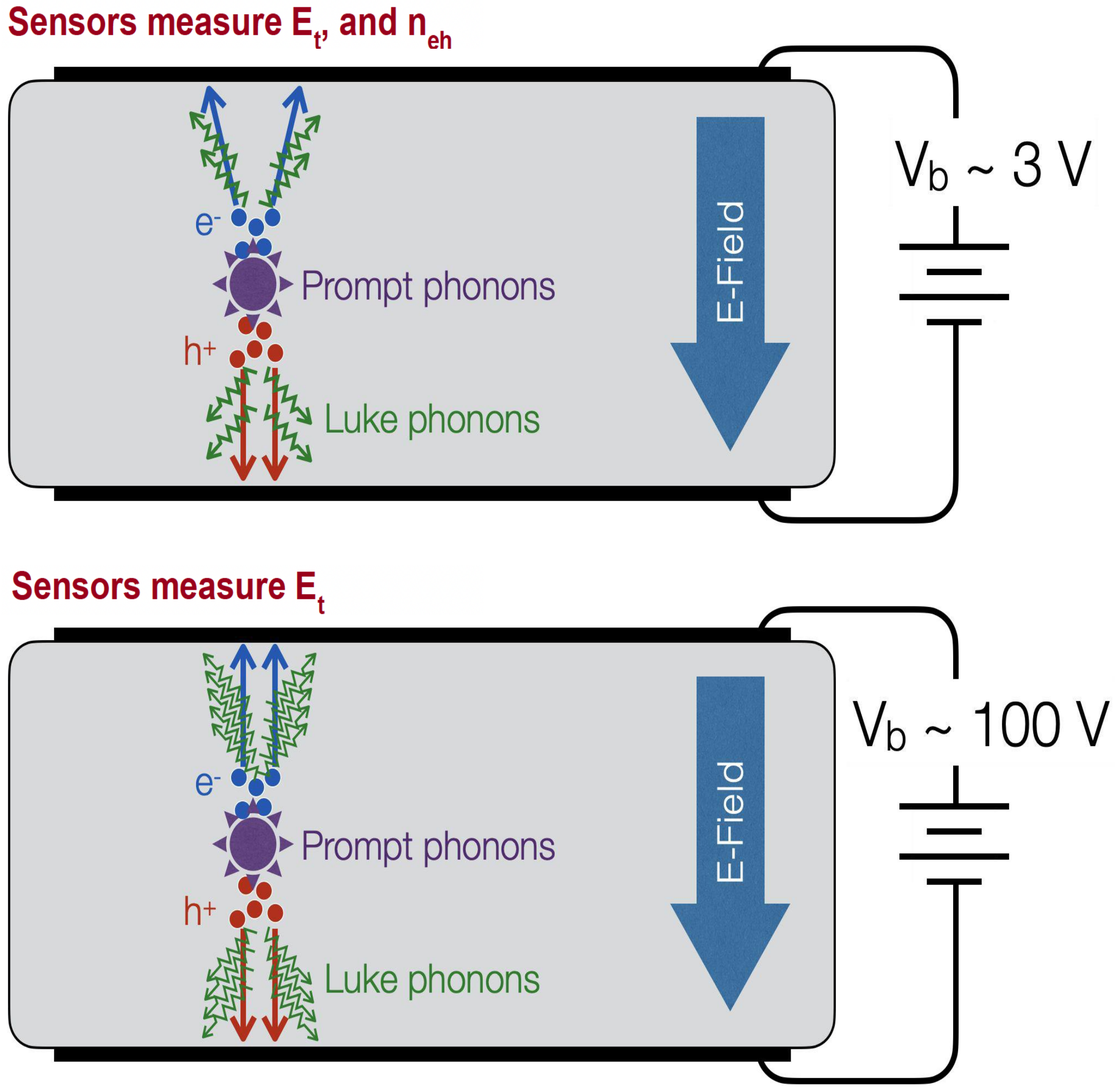
- SuperCDMS SNOLAB construction is underway in the Ladder Lab.
- Potential world leading results from commissioning runs of some of the detectors in the CUTE test facility
- Initial payload 4 towers, each with 6 detectors (1.39 kg Ge, 0.61 Si) each with diameter 100 mm, thickness 33.3 mm.
  - 2 HV towers (4 Ge + 2 Si)
  - 2 iZIP towers (6 Ge & 4 Ge + 2 Si)



SuperCDMS Detector Technology

HV and iZIP detectors provide complementary functionality

- iZIP Detector
  - Low background
  - Prompt phonon and ionization signals allow for discrimination between NR and ER
- HV Detector
  - Low threshold
  - Drifting electrons/holes across a potential generates a large number of phonons (Luke)
  - Enables very low thresholds
  - Trade-off: No event-by-event discrimination

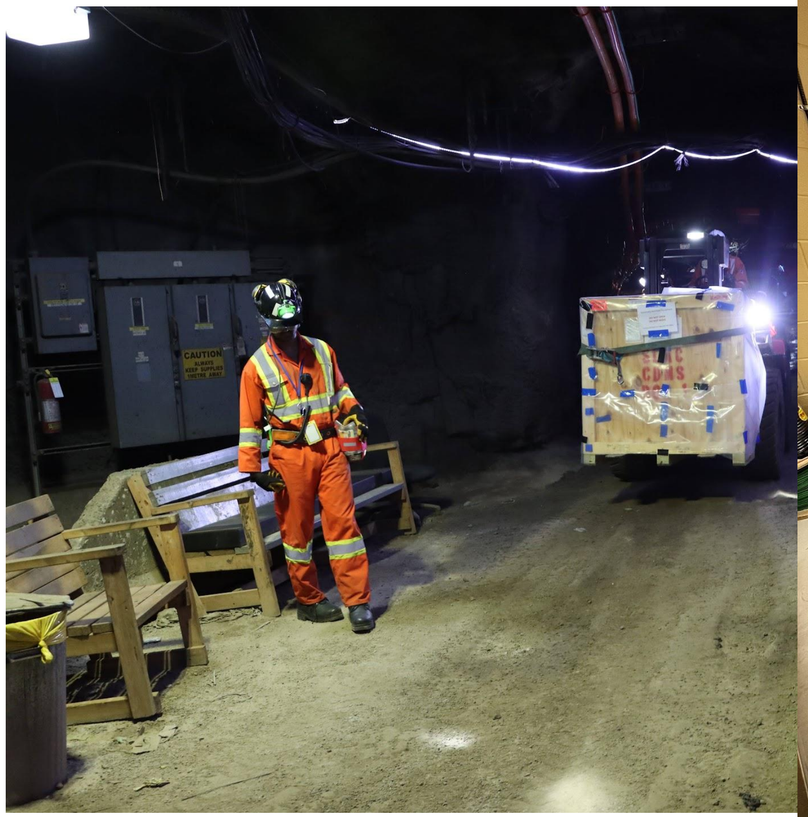


SuperCDMS Experiment: Fridge Arrives Underground

SuperCDMS Fridge arrived underground on Saturday, February 4th, 2023.

Courtesy of the SuperCDMS Collaboration & SNOLAB.

SuperCDMS Experiment: Towers Arrive Underground



Courtesy of the SuperCDMS Collaboration & SNOLAB.

First pair of SuperCDMS Towers arrived underground on Saturday, May 15th, 2023. All towers underground as of November 2023.

SuperCDMS Experiment: Cryostat Installation

Courtesy of the SuperCDMS Collaboration & SNOLAB.

Acid etching and repacking in the clean labs, transport underground, and final installation underground occurred in the first half of 2025.

SuperCDMS Experiment: Detector Installation

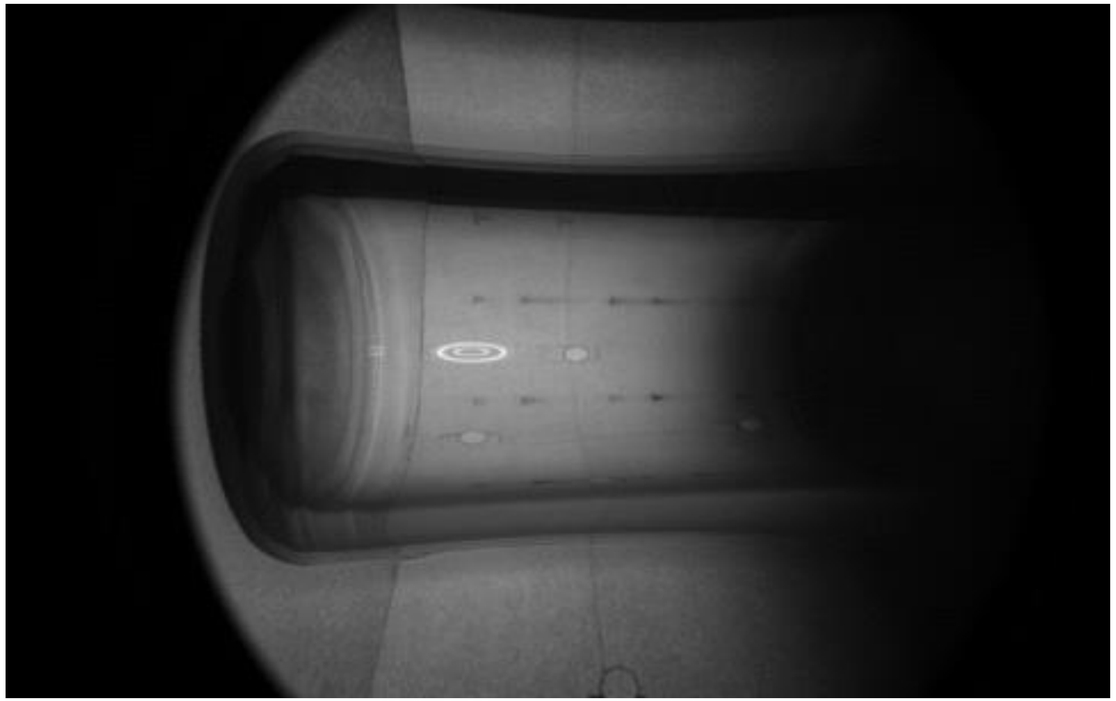
Tower installation into the SuperCDMS cryostat happened in parallel with the outer can installation in the first half of 2025.

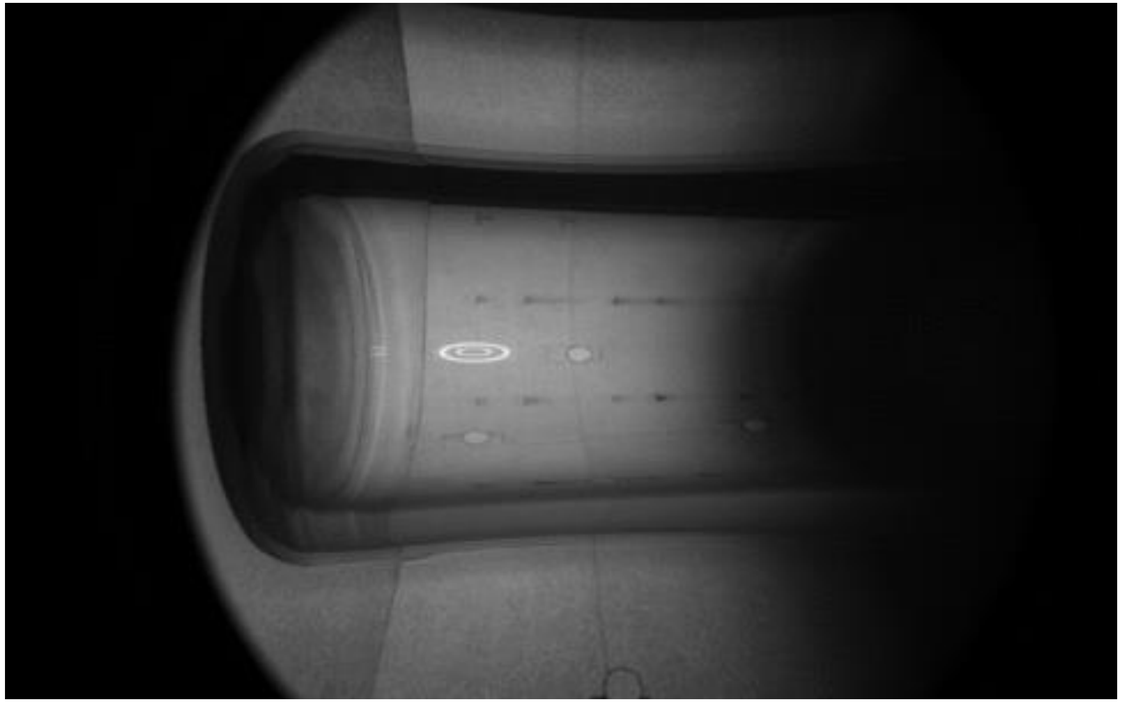
Courtesy of the SuperCDMS Collaboration & SNOLAB.

SuperCDMS Experiment: Shield and Commissioning

Completion of shield construction and commissioning of the detector is underway.

PICO Bubble Chamber



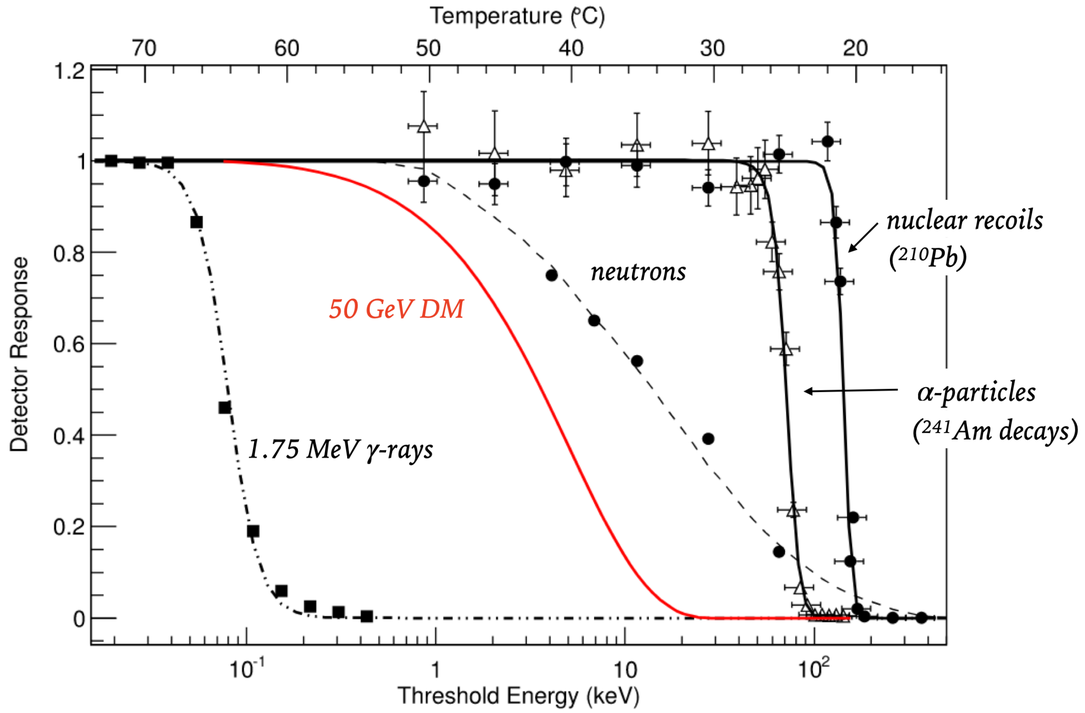


Courtesy of the PICO Collaboration

- Bubbles form in superheated liquid (C3F8) when a particle deposits enough energy to cause the liquid to boil
- Bubbles are detected by cameras and piezoelectric sensors.

PICO Detector Response

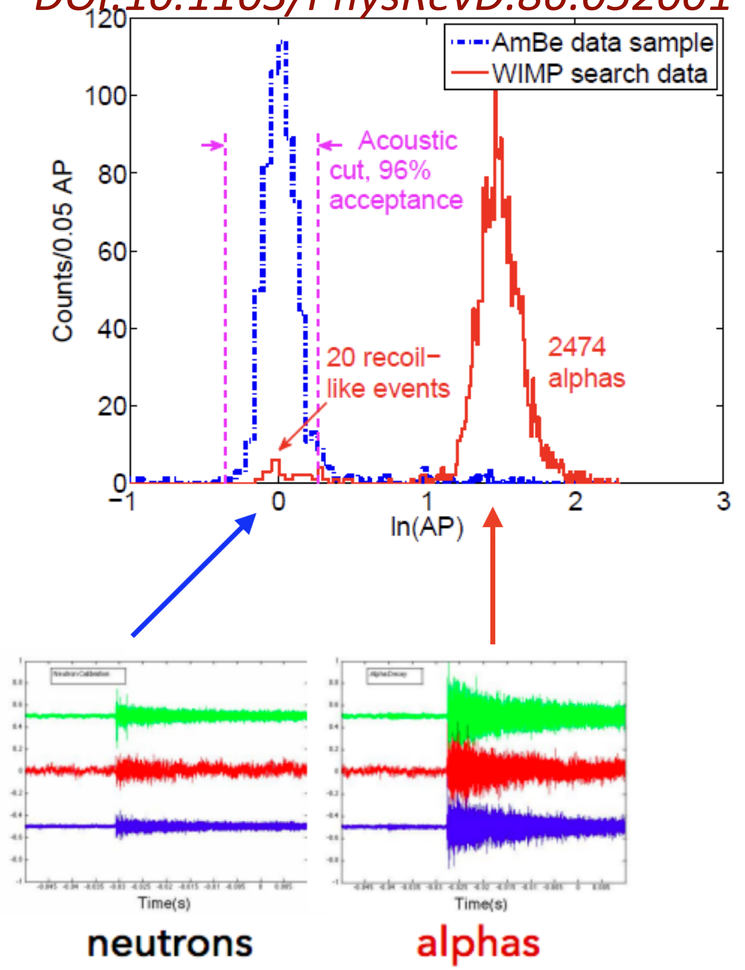
- Heavier particles have higher thresholds
- Tune the chamber to be unresponsive to most backgrounds(ER).
- Underground location and shielding to mitigate neutrons.



PICO Detector Response

- Heavier particles have higher thresholds
- Tune the chamber to be unresponsive to most backgrounds(ER).
- Underground location and shielding to mitigate neutrons.
- But what about alphas?
  - Acoustic discrimination with piezoelectric sensors

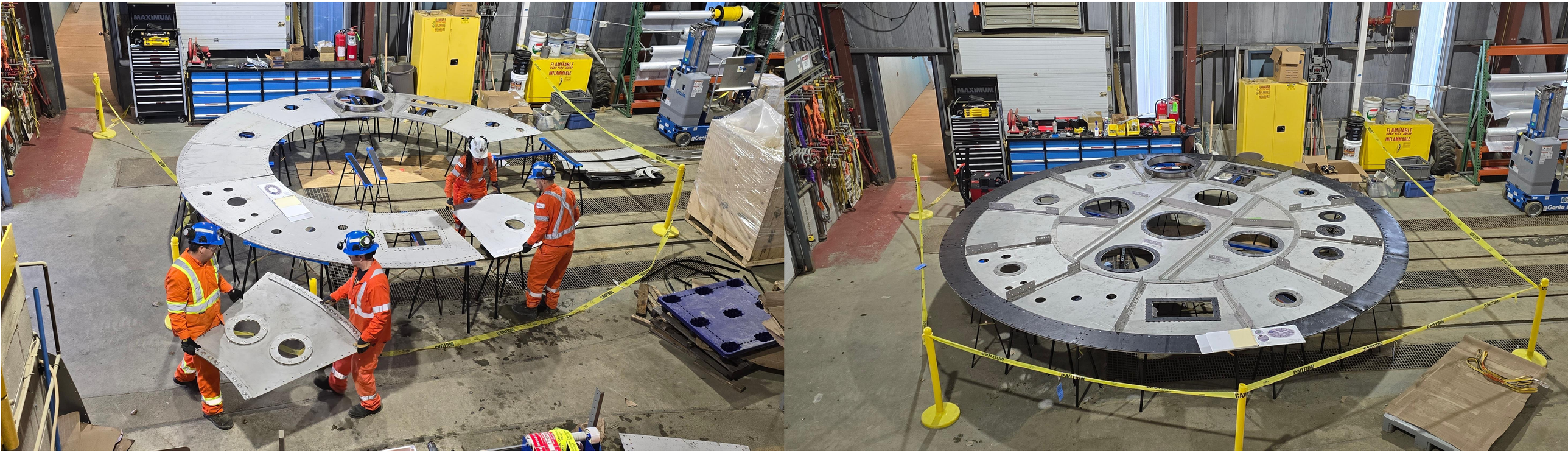
DOI:10.1103/PhysRevD.86.052001



PICO-500 Experiment: Construction Underway

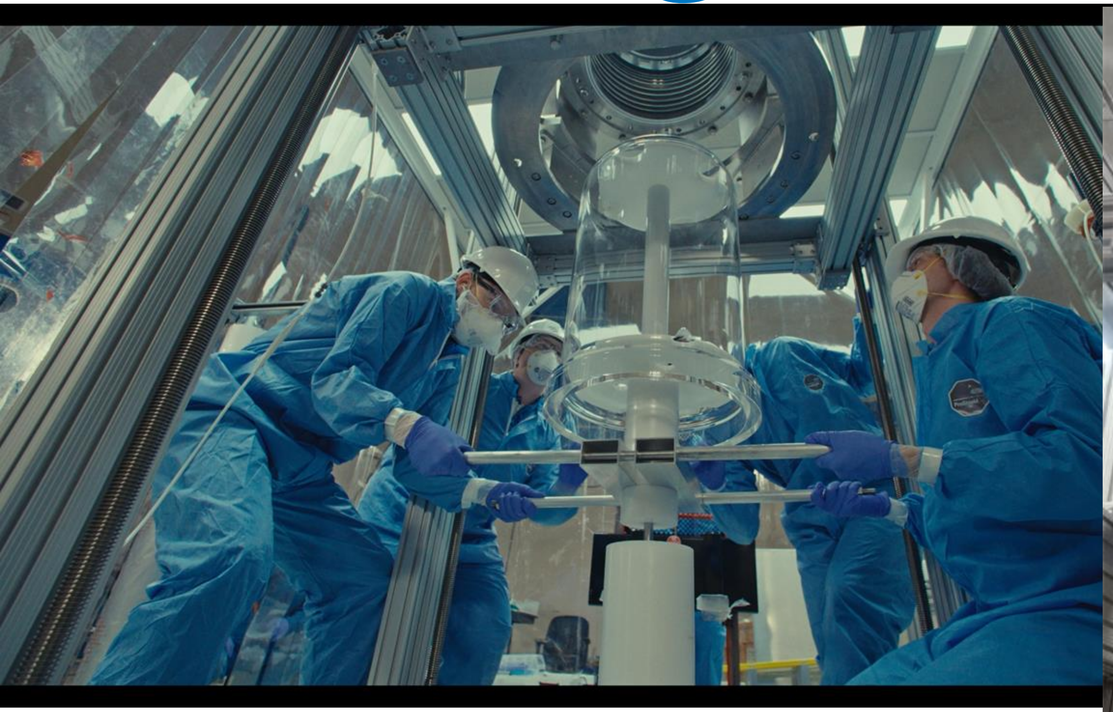
Pressure vessel brought underground in September and October 2024.

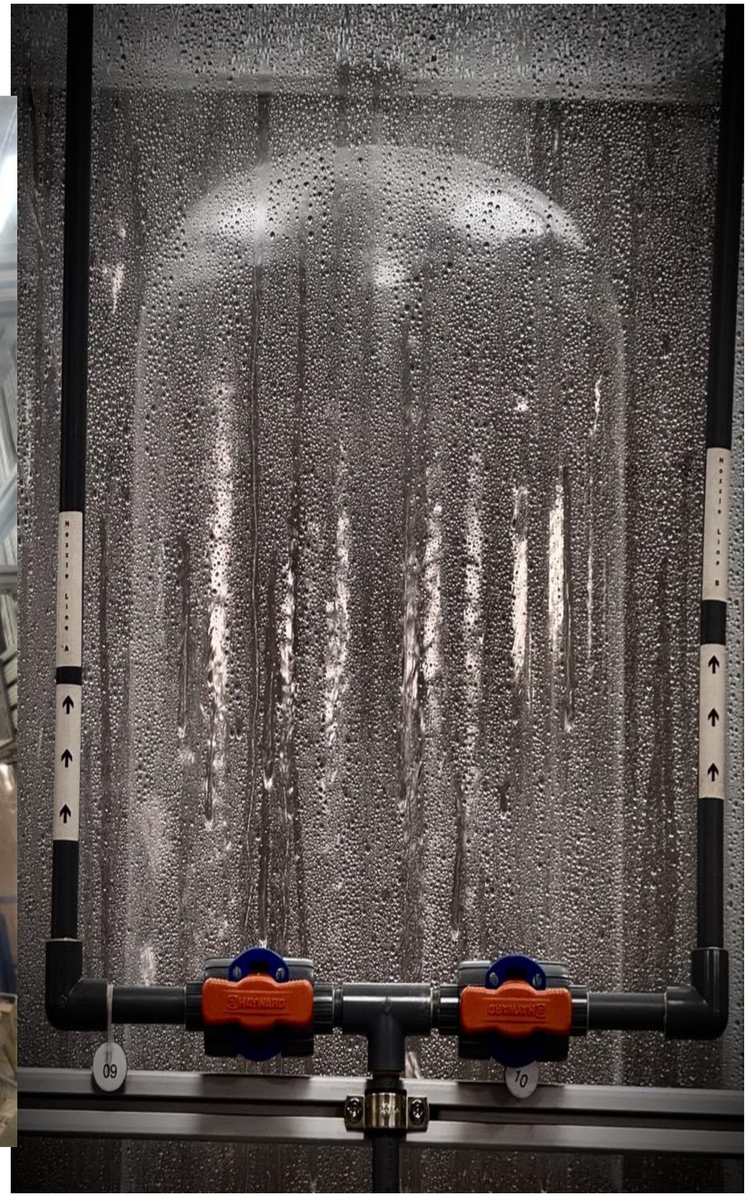
PICO-500 Experiment: Lid Test Assembly



Water tank lid was fabricated and a test assembly completed in the SNOLAB warehouse in November 2024.

PICO-500 Experiment: Cleaning Campaign





Inner quartz vessel cleaning campaign at SNOLAB happened in 2025

PICO-500 Experiment: Pressure Vessel Welding

Pressure vessel welding happened underground in 2025.

PICO-500 Experiment: Construction Underway

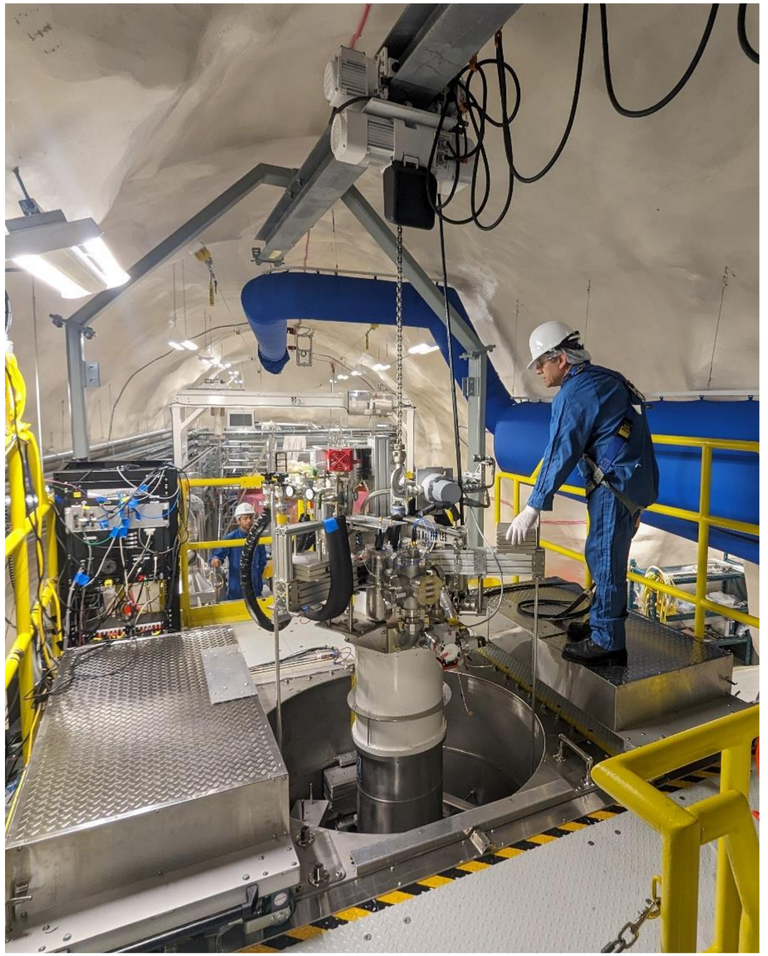
Outer and inner jar assembly in 2026.

Quantum Science at SNOLAB

CUTE water tank & cleanroom

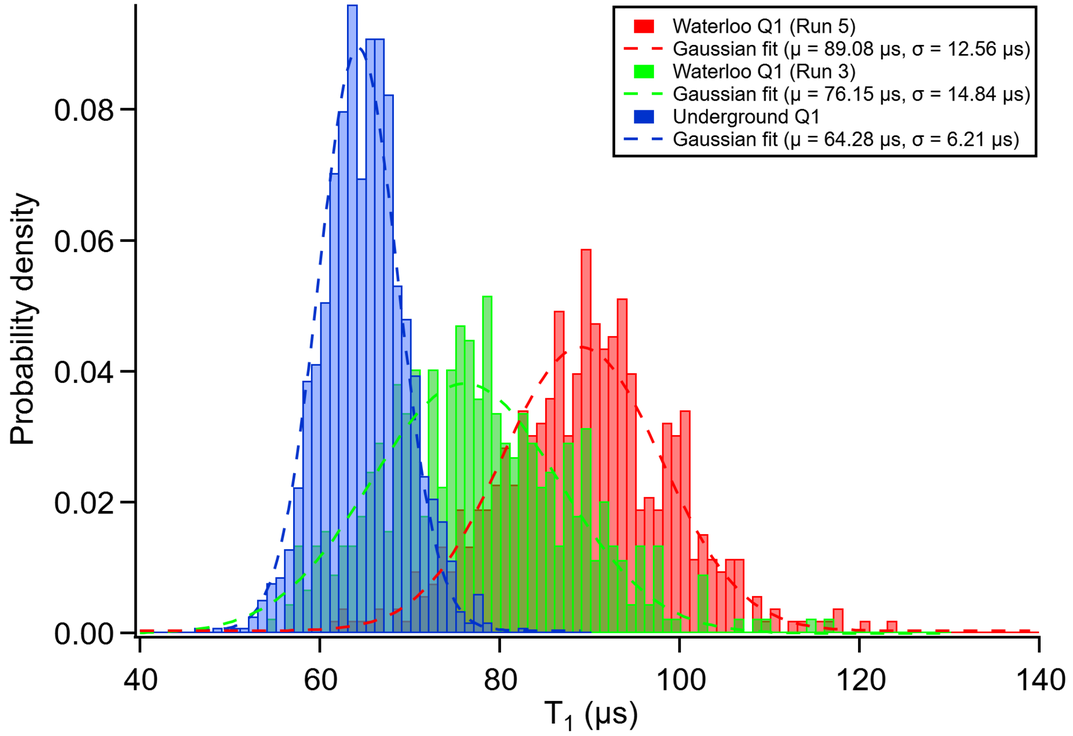
Qubit installation in cleanroom

Lowering of DR into drywell



Quantum Science at SNOLAB

- First qubit data comparison between surface and underground operations shows some interesting differences
- Smaller standard deviation of T_1 coherence time observed underground at CUTE (blue) versus at the surface at University of Waterloo (green & red)
- Broadening of distributions also observed when qubits exposed to gamma rays from ^{133}Ba source
- Analysis is ongoing… stay tuned!

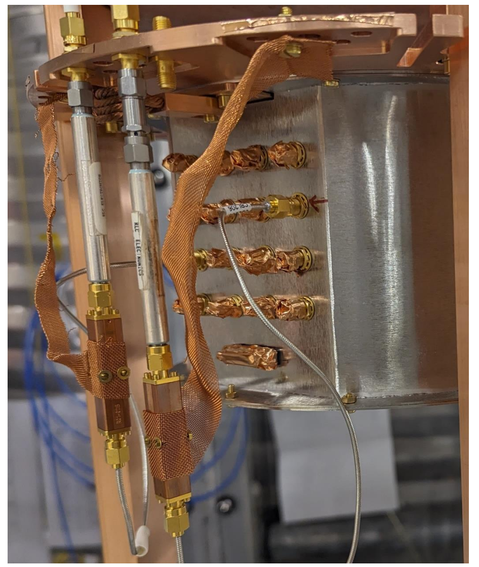


Quantum Science at SNOLAB

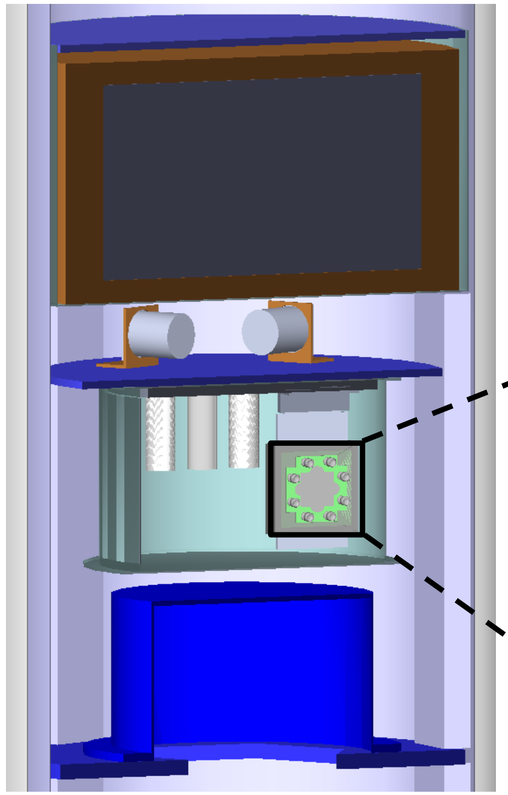
Future work includes:

- Upgrade of CUTE facility to include additional RF readout lines and device mounting schemes
- Operation of Qubit Tower to study correlated errors across physically separated devices
- Device simulations using Geant4 condensed matter physics (G4CMP) phonon/charge transport code, including G4CMP development to improve general QIS applicability

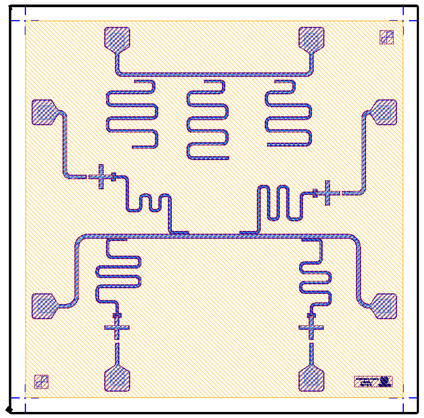
Qubit Tower



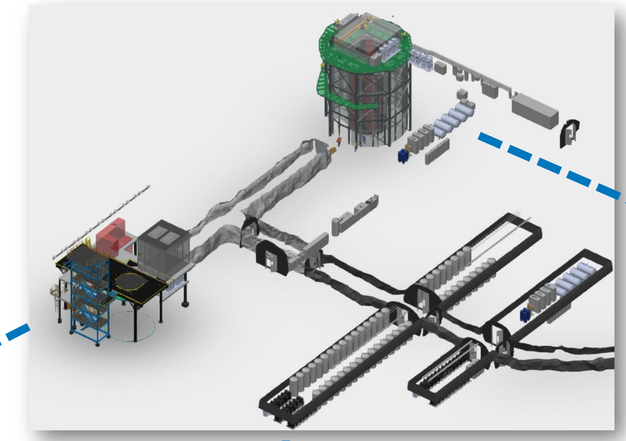
Simulation geometry

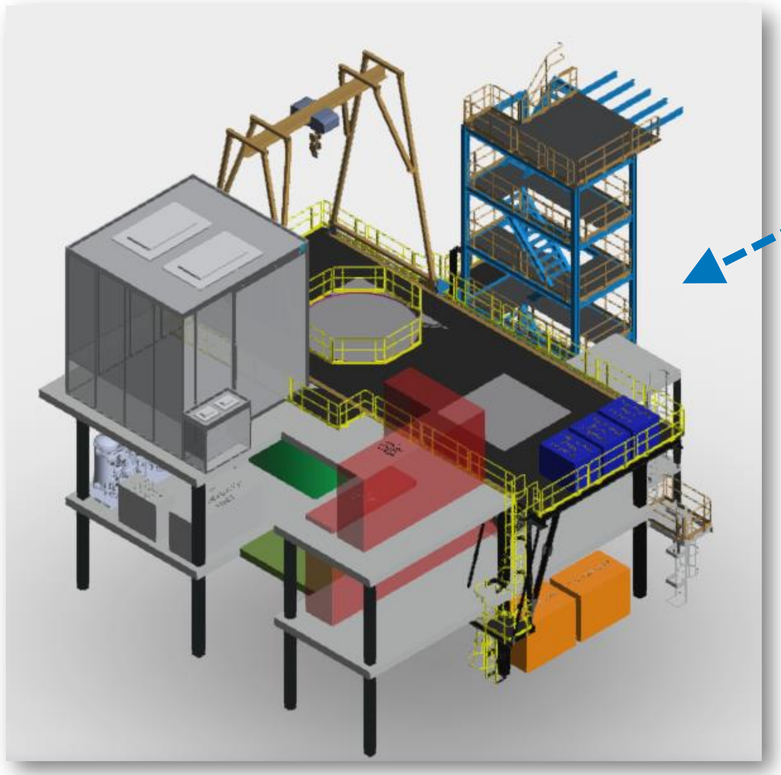


2-qubit device

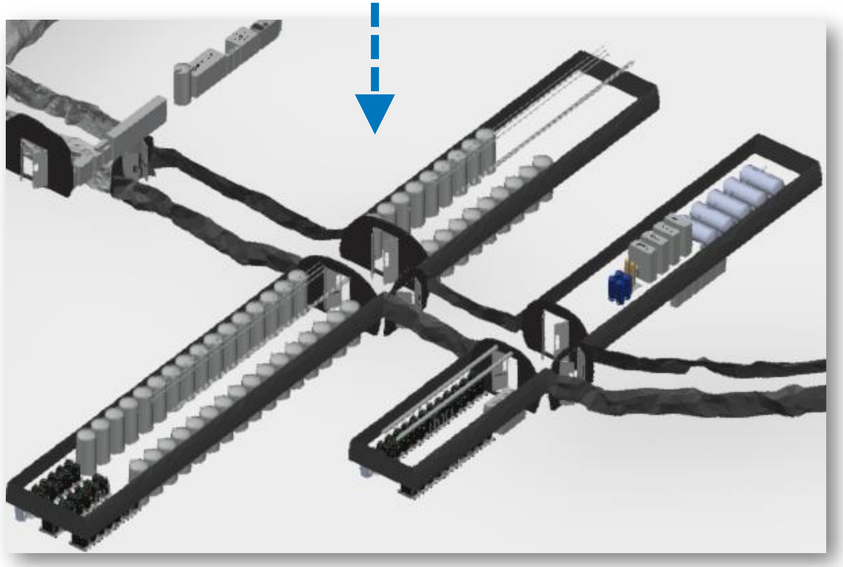


XLZD @ SNOLAB Concept

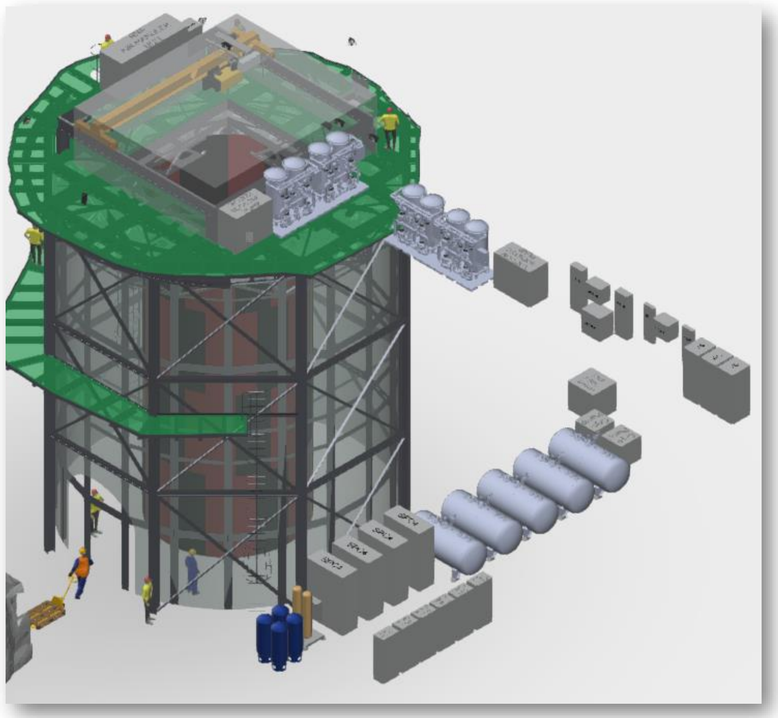




Xenon Process Systems
& Clean Assembly Areas



Xenon Storage &
Recovery



Detector, Shielding Tank
& Cooling Systems

New Funding to Advance XLZD Design

SNOLAB's proposal focused on 4 objectives:

- **Cryostat:** understand how to build the XLZD cryostat in the SNOLAB Cryopit.
- **Heat Rejection:** develop the chilled-water system needed to support XLZD cryogenic operations and assess associated oxygen-deficiency hazards.
- **Xenon Storage & Recovery:** develop solutions for underground storage and recovery of up to 100 tonnes of xenon.
- **Logistics:** increase capacity for movement of materials and equipment into SNOLAB.

SNOLAB in 15 years:

The world's leading underground science facility

Here's how we envision SNOLAB in 15 years:

A global powerhouse in discovery science

Leading transformative experiments that push the boundaries of knowledge

A vibrant intellectual and training hub

Attracting and nurturing the next generation of leaders

A unique state-of-the-art infrastructure

Continuously evolving to support high-impact underground science and top-tier talent

A national centre for scientific knowledge

Inspiring Canadians and improving science literacy

15 Year Plan: Why Now?

New decision-making framework was introduced in the 2024 Canadian federal budget to support Canadian Major Research Infrastructures.

– *Six research facilities introduced including SNOLAB*

Central Pillar Lifecycle funding for designated facilities

- *Requires CFI to assess long-term capital and operational needs of each MRF*

SNOLAB was asked to provide detailed and reliable budget estimates for the next 15 years under three budget scenarios.

1. *Maintaining current levels of operation*
2. *Fully supporting the needs of the Canadian research community*
3. *Increasing global competitiveness.*

Process for Developing the 15 Year Plan

- **Engagement with SNOLAB staff (Dec `24 and Jan `25).**
- **Roth consulting on asset management plan and JLR & EXP consulting on architectural estimates.**
- **Multiple engagements with SNOLAB community.**
  - SEF meeting
  - SNOLAB Future Projects
  - Town Hall at CAP
  - Annual MI meeting

Delivery of World-Class Science: Astroparticle and Neutrino Physics, Quantum Techologies, UG Biology

Future Project Workshop: many ideas for potential experiments

- Deep Underground Biology
- HeLIOS (superfluid He)
- Small-scale Experiments for light dark matter
- Cryogenic solid-state detectors for dark matter detection
- Skipper CCDS and related efforts
- Liquid Noble Bubble Chambers
- 0νββ decay w/ bolometers
- R&D for normal hierarchy

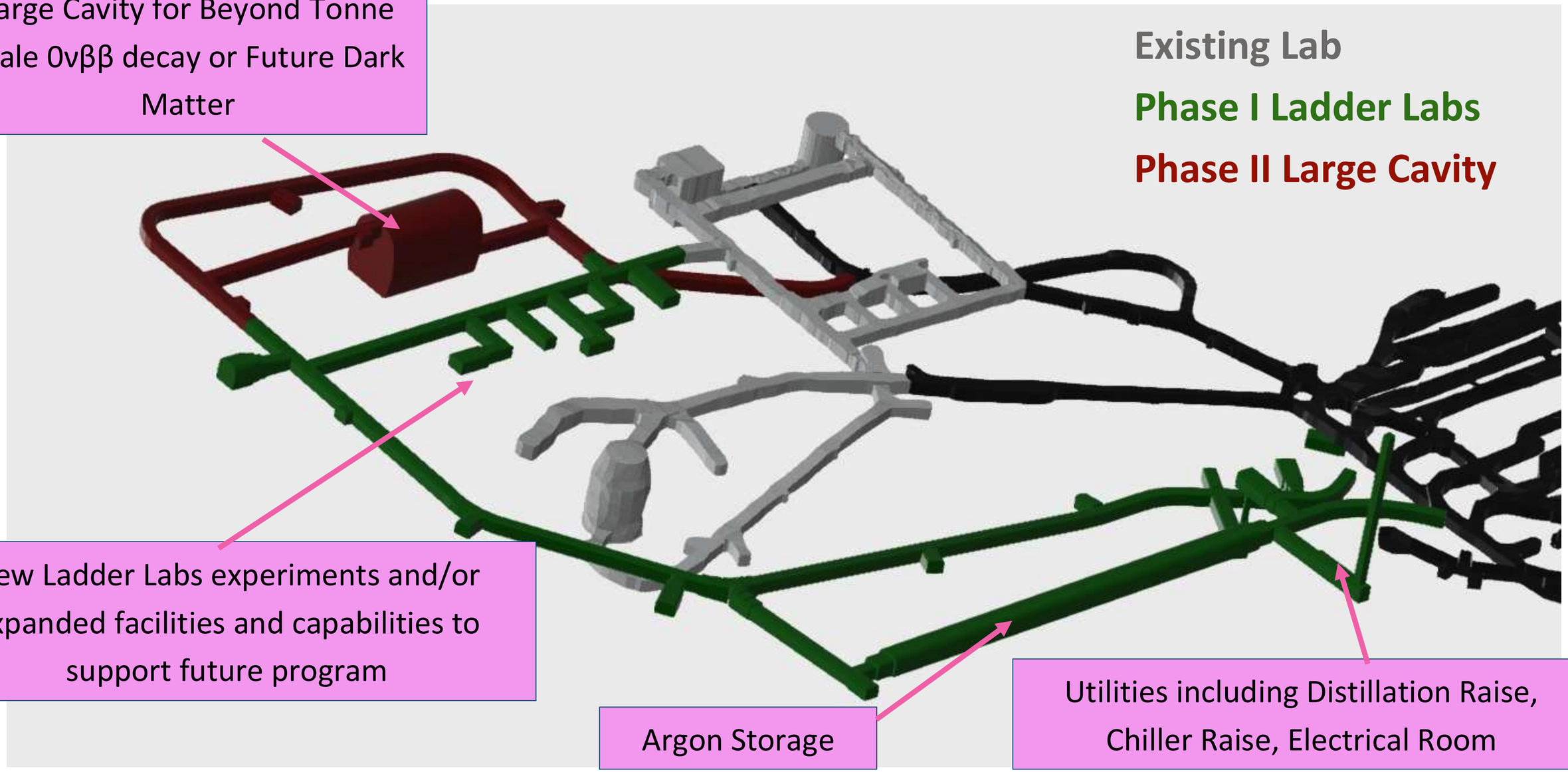
- Beyond SNO+ Te
- ARGO, ARGO-lite, Darkside-LM
- nEXO 2.0
- NEXT
- XLZD
- Theia at SNOLAB

**This list is illustrative. It is not exhaustive, nor does it indicate SNOLAB approval or space allocation.*

***Community Report from the 2025 SNOLAB Future Projects Workshop. [arXiv:2507.11368]*

New Underground Lab Space

Large Cavity for Beyond Tonne Scale 0νββ decay or Future Dark Matter



New Ladder Labs experiments and/or expanded facilities and capabilities to support future program

Argon Storage

Utilities including Distillation Raise, Chiller Raise, Electrical Room

15 Year Plan Summary

Maintaining current levels of operation

- Current laboratory at 100% occupancy
- New modest surface building offsite: “New Campus”.
- ~15% increase in staff

Fully supporting the needs of the Canadian research community

- Expand underground laboratory with New Ladder Labs to meet increased demands for space and capabilities.
- New larger surface building offsite: “New Campus”.
- ~55% increase in staff

Increasing global competitiveness

- Expanded underground laboratory with New Ladder Labs and Large Cavern to potentially host a Beyond Tonne-scale 0νββ Beta Decay, a Beyond 3rd Generation Dark Matter Experiment, or something else
- “New Campus” with expanded facilities (guesthouse, cafeteria, …?)
- ~70% increase in staff

Conclusions

- SNOLAB is the world's deepest and cleanest underground research laboratory, SNOLAB has established Canada as a global leader in underground science, infrastructure, and expertise.
- SNOLAB's uniquely low-radiation environment enables a broad, multidisciplinary program of world-class research.
- Experimental collaborations at SNOLAB have already delivered impactful scientific results, with many additional world-leading discoveries anticipated in the coming decade.
- In collaboration with the Canadian scientific community, SNOLAB is making a bid to host XLZD.
- Our recently completed 15-year plan positions SNOLAB to support and enable future generations of scientific programs.

Discussion and Questions

MRF and 15-Year Plan