A Brief Look at Current and Future Science Activities at SNOLAB

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SNOLAB
September 2, 2025

Queen's University

Laurentian University
Université Laurentienne

SNOLAB

Science Strategy

- **The science at SNOLAB** is currently focused on fundamental particle physics. Primarily looking at further **investigating the nature of matter**. Specifically:
  - What is the nature of dark matter?
  - What is the nature of the neutrino?
- **SNOLAB is interested in collaborating** on any scientific research that requires deep underground facilities. For example:
  - Neutrino observatories (solar, supernovae, geo, reactor, etc.)
  - Effects of radiation on biological systems
  - Environmental monitoring (nuclear non-proliferation, aquifers, etc.)
  - Effects of radiation on quantum technologies

SNOLAB –
At a Glance

Current Experiments
Future Experiments
Laboratory Facilities
Experiment Areas

Cryopit
Large neutrinoless double beta decay project

Cube Hall
DEAP-3600, PICO500, NEWS-G
potential for large project after 2026

Electrical Shop

J-Drift
SENSEI, DAMIC, OSCURA

Halo Stub
HALO
potential breakthrough for future expansion

Machine Shop

Utilities

Ladder Labs
PICO40, SBC, CUTE, SuperCDMS

Plants
UPW, LN2, Scintillator, Te Diol, TeA

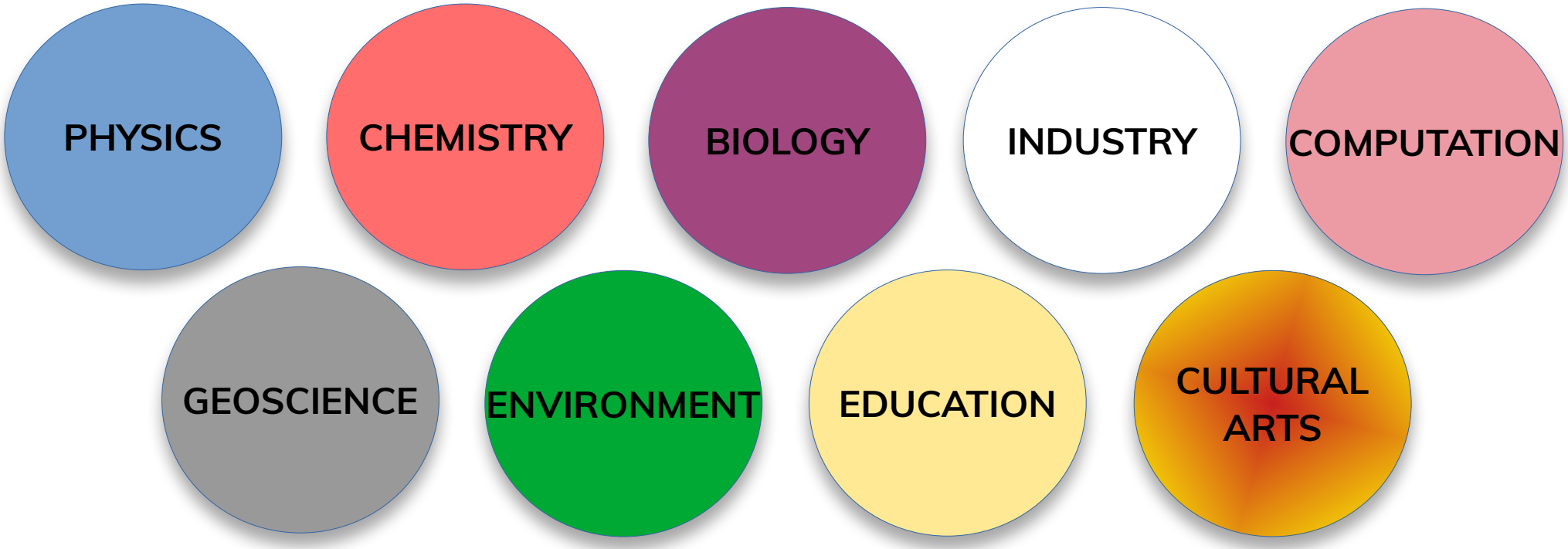
Life Sciences Lab
Chemistry, REPAIR

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

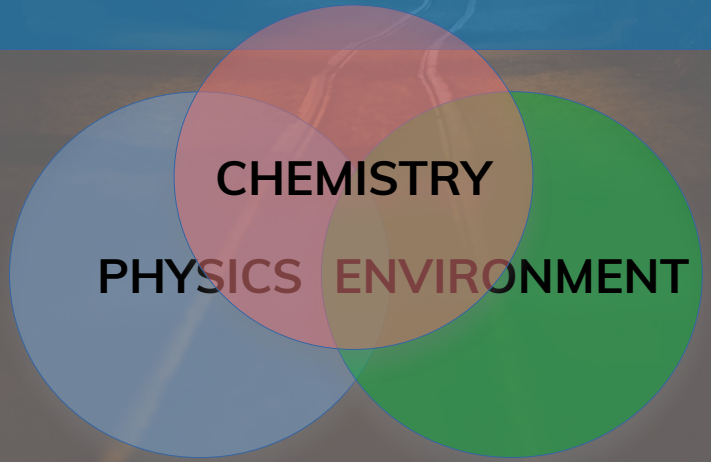
Low Background Lab
HPGe assay/screening, XRF, Radon Boards, FLAME
XIA, CTBT Dual HPGe

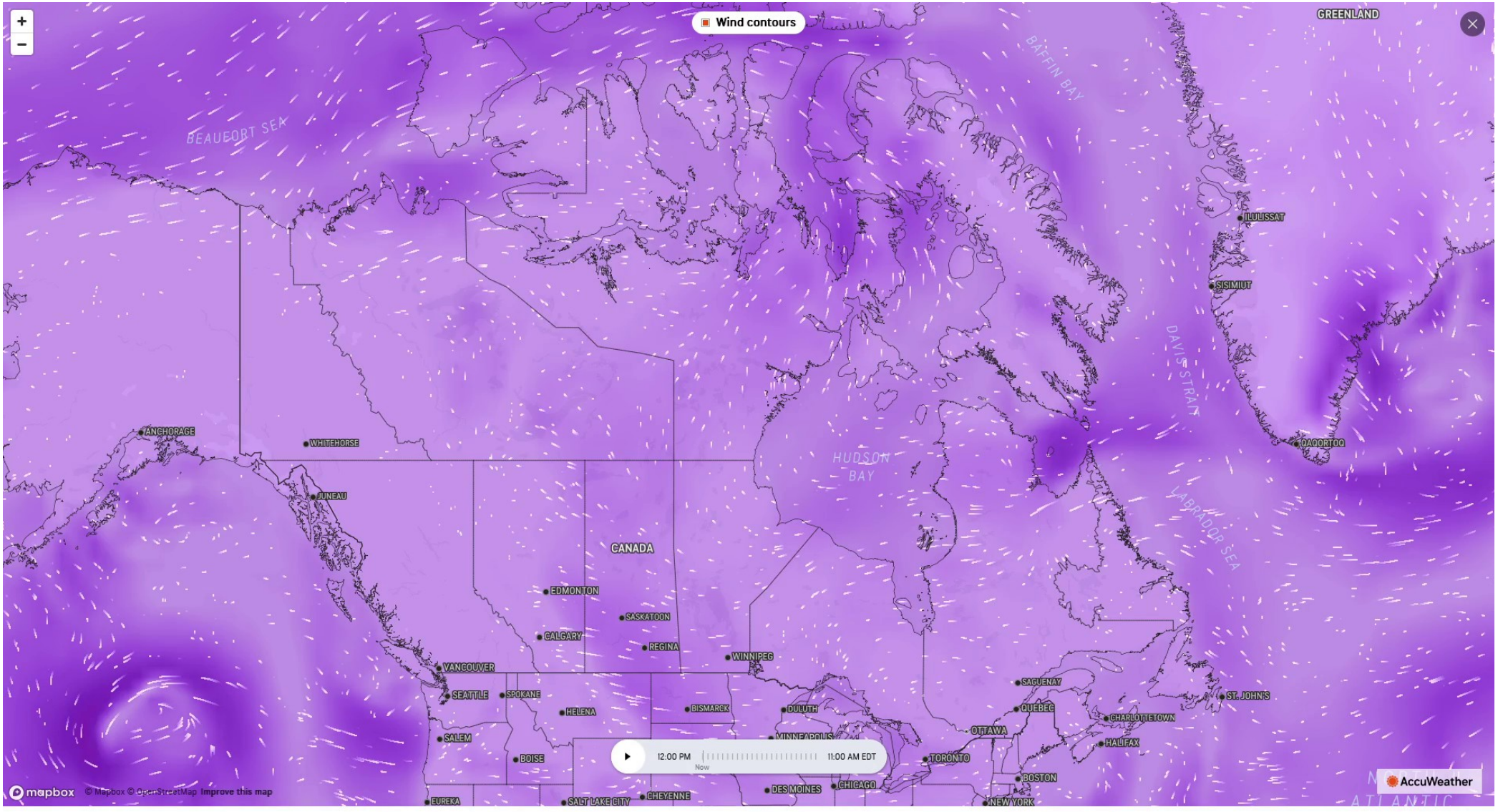
5000 m^2 of class 2000 cleanroom underground.
<2000 particles >0.5 μm in diameter per ft^3

Disciplines at SNOLAB



ENVIRONMENTAL MONITORING




Wind contours
GREENLAND
BAFFIN BAY
BEAUFORT SEA
ILULISSAT
SISIMIUT
DAVIS STRAIT
ANCHORAGE
WHITEHORSE
QAQORTOQ
HUDSON BAY
JUNEAU
LABRADOR SEA
CANADA
EDMONTON
SASKATOON
CALGARY
REGINA
WINNIPEG
VANCOUVER
SAGUENAY
SEATTLE
SPOKANE
ST. JOHN'S
HELENA
BISMARCK
DULUTH
QUEBEC
CHARLOTTETOWN
OTTAWA
SALEM
MINNEAPOLIS
HALIFAX
BOISE
12:00 PM
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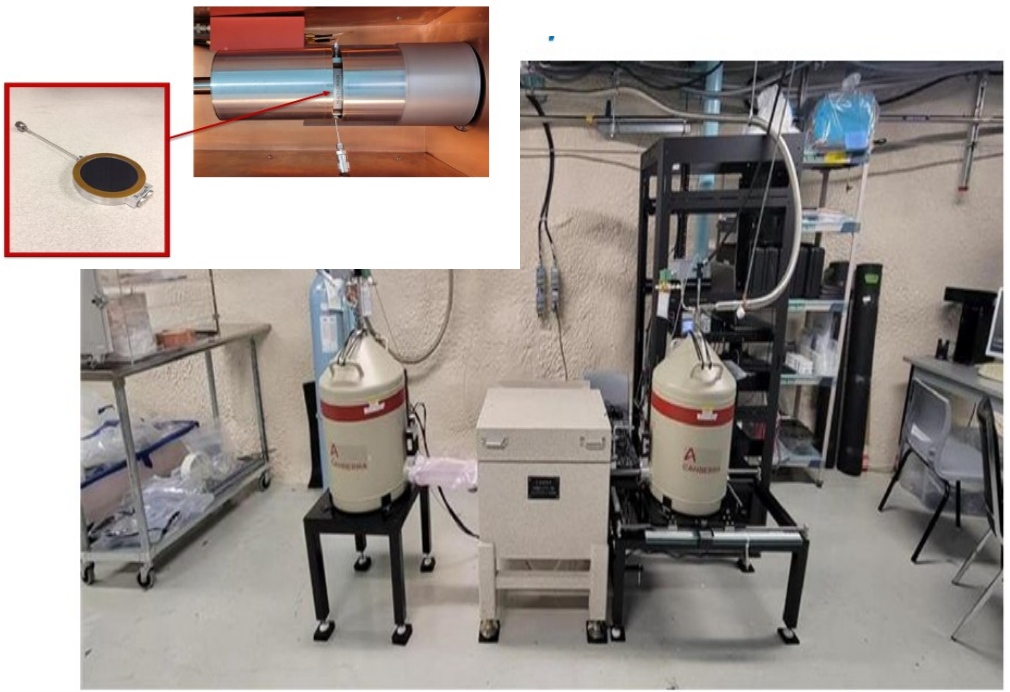
Now
TORONTO
BOSTON
DES MOINES
CHICAGO
EUREKA
SALT LAKE CITY
CHEYENNE
NEW YORK
ATLANTIC
mapbox
© Mapbox © OpenStreetMap Improve this map
AccuWeather
<32
32
48
64
80
96
112
>112

NUCLEAR FORENSICS

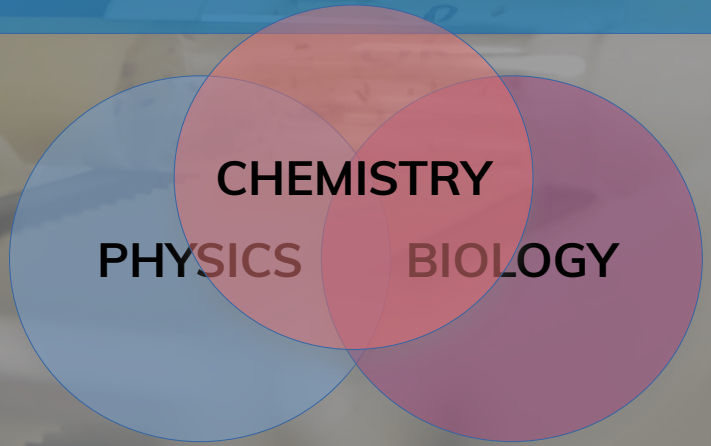
- Dual HPGe detector deployed by Health Canada for nuclear forensics
- SNOLAB is working to improve sensitivity to isotopes with γ-γ coincidences (and γ-β)



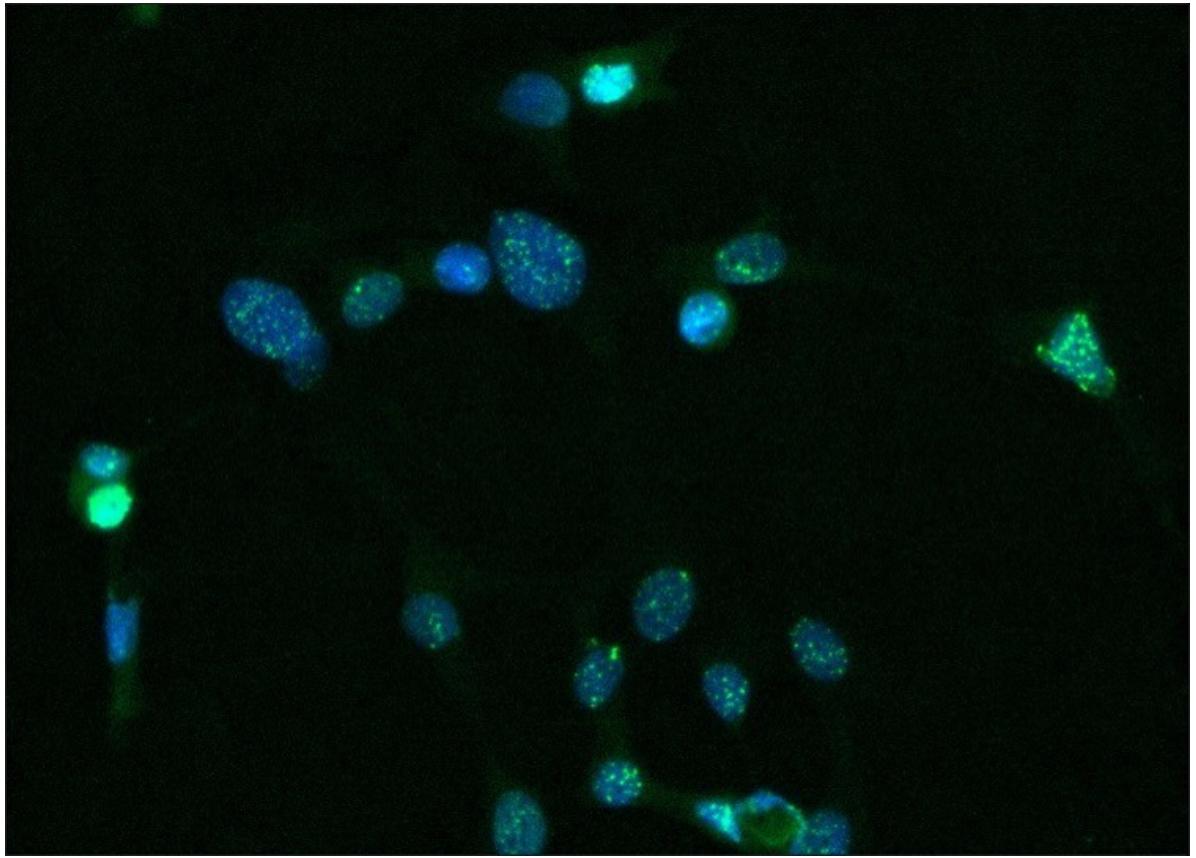
- Health Canada has installed a radiation monitoring station at SNOLAB (overflow parking lot) that is part of the Canada Radiation Monitoring Network
  - Air and water sampling
  - Live radiation monitoring (e.g., dosimetry)
  - c.f. Jean-Francois Mercier's SNOLAB seminar "Environment Radiation Health Monitoring at Health Canada" (Jan. 22, 2024)

- General take-away: we're excited at the expansion in directions and capability that complements the "traditional" astroparticle portfolio!

UNDERGROUND BIOLOGY



REPAIR

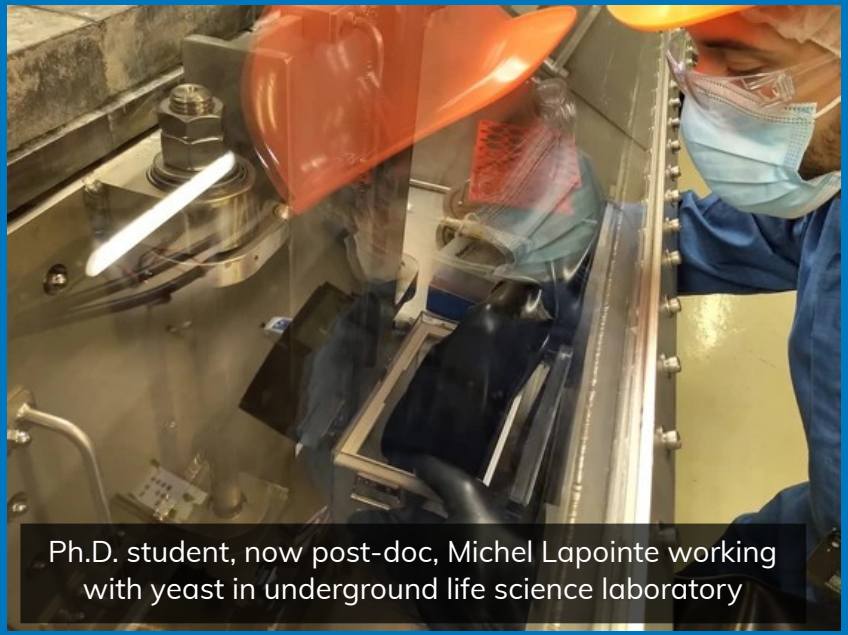


Study the effects of very low background radiation levels on living organisms.

Assess the markers for carcinogenesis and alterations to DNA in human cells as well as whole organism development and growth using lake whitefish embryos.

Partnership with Laurentian University and NOSM, led by university faculty.

Lapointe MR, Laframboise T, Pirkkanen J, Tai TC, Lees SJ, Santa Maria SR, Tharmalingam S, Boreham DR, Thome C. Protracted Exposure to a Sub-background Radiation Environment Negatively Impacts the Anhydrobiotic Recovery of Desiccated Yeast Sentinels. Health Phys. 2024 Jun 1;126(6):397-404. doi: 10.1097/HP.0000000000001804. Epub 2024 Apr 3. PMID: 38568172.

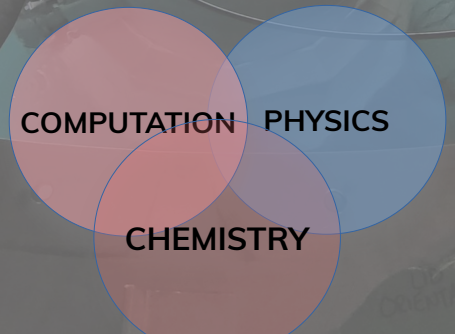


Ph.D. student, now post-doc, Michel Lapointe working with yeast in underground life science laboratory

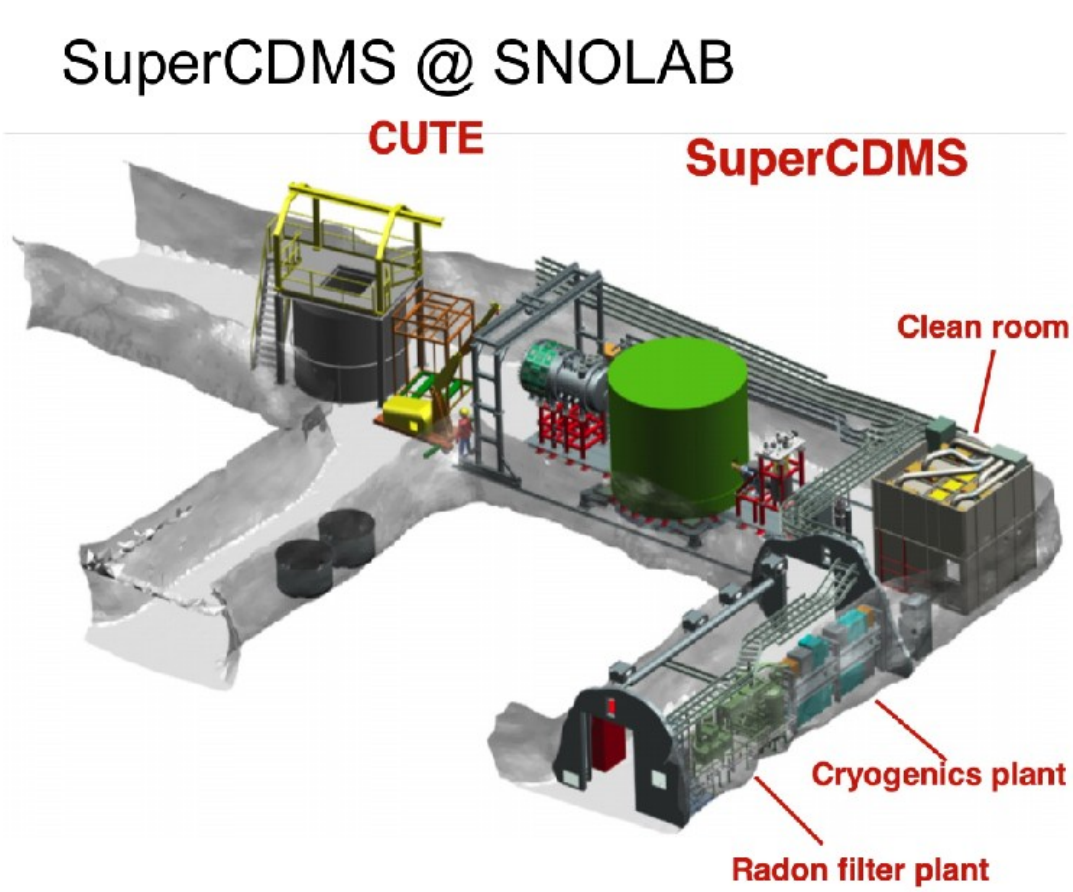
Yeast is produced underground in SNOLAB in the low-radiation environment and dried (it is still alive in this state). This yeast is then used in NASA programs (BioSentinel) aimed at assessing biological impact of deep-space radiation.

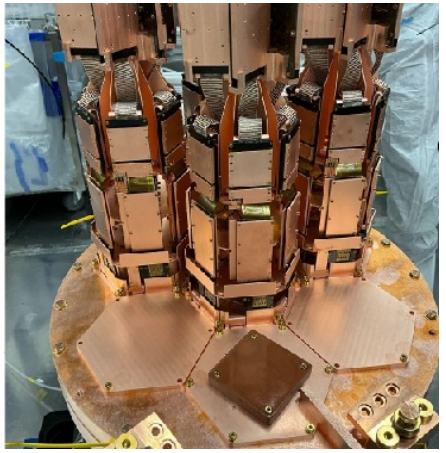
A new initiative to link deep underground laboratory biology programs is launching, and the NOSM group may take the lead on producing, sharing, and analyzing yeast samples distributed to any group that requests them,

HUNTING FOR DARK MATTER



Solid-State-Based: SuperCDMS

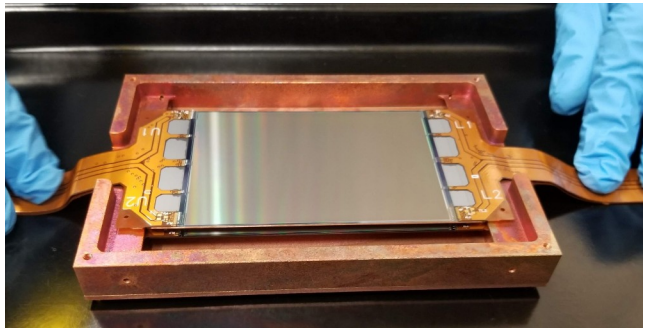




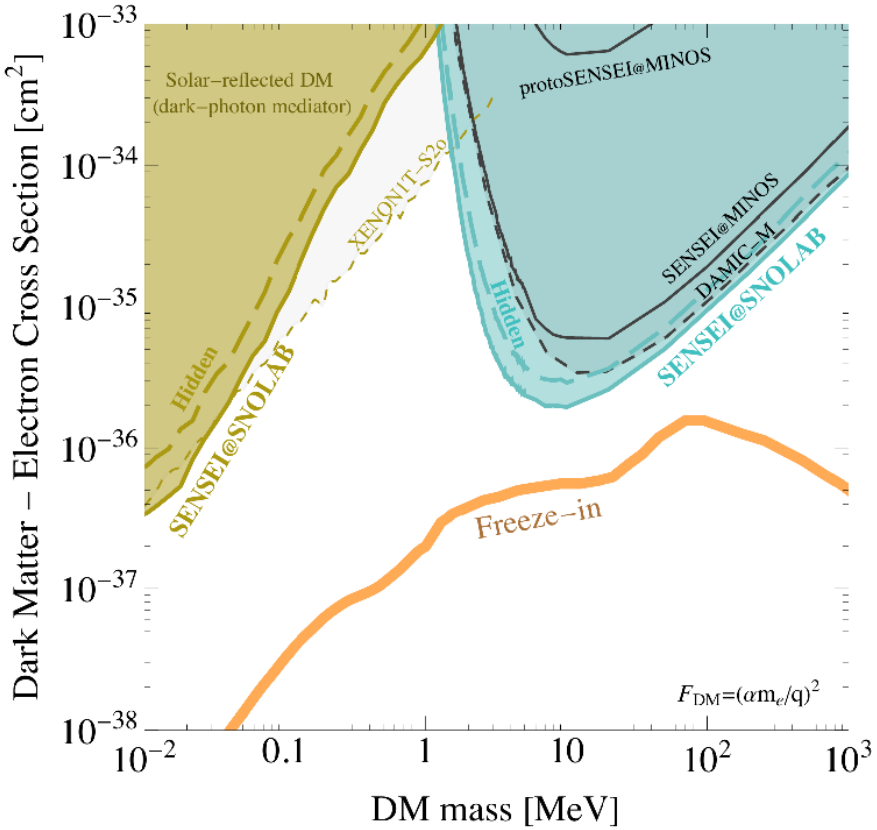
Construction aimed to be complete by the end of this year (summer is the target) with operations to begin in 2025-2026.

Use ultra-cold semiconducting crystals as tuning forks for dark matter: an interaction causes vibrations, read out as heat.

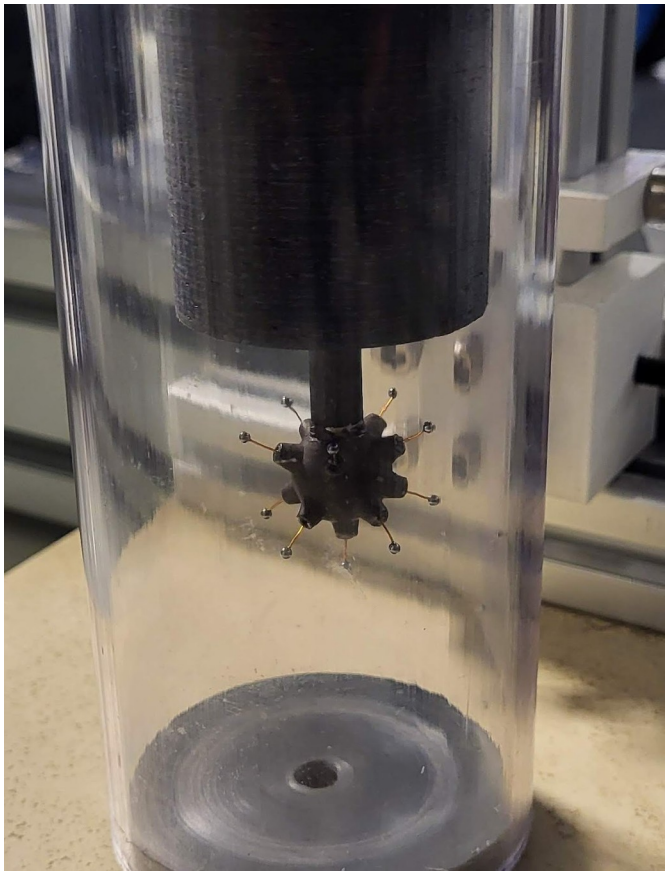
CCD-Based Detectors: DAMIC and SENSEI



SENSEI is pushing sensitivity boundaries in low-mass dark matter space, and SENSEI and DAMIC together are exploring low-energy noise common to many experiments.



Gas-Based Detector: NEWS-G

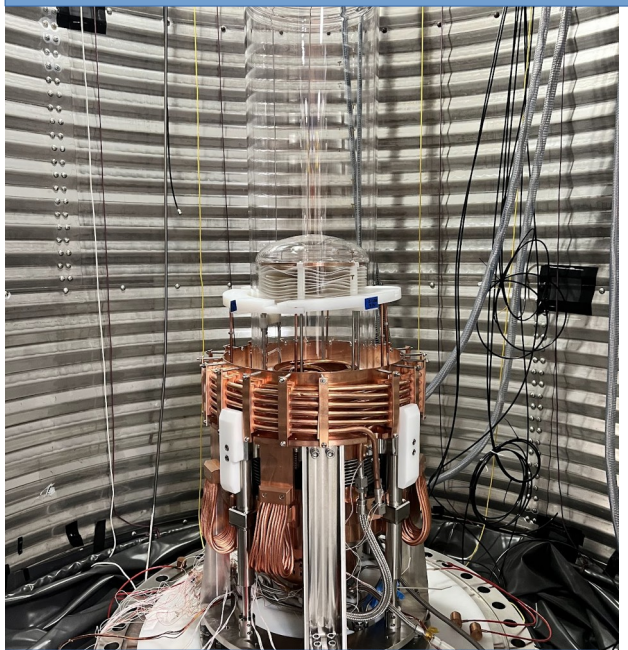


NEWS-G has been taking high-quality data in SNOLAB since 2022. The copper sphere houses methane, providing a low-mass target (hydrogen) sensitive to light dark matter collisions.

We look forward to increasing science results from this effort!

Superheated Fluid Targets for Dark Matter: PICO

PICO-40L (70kg freon target)



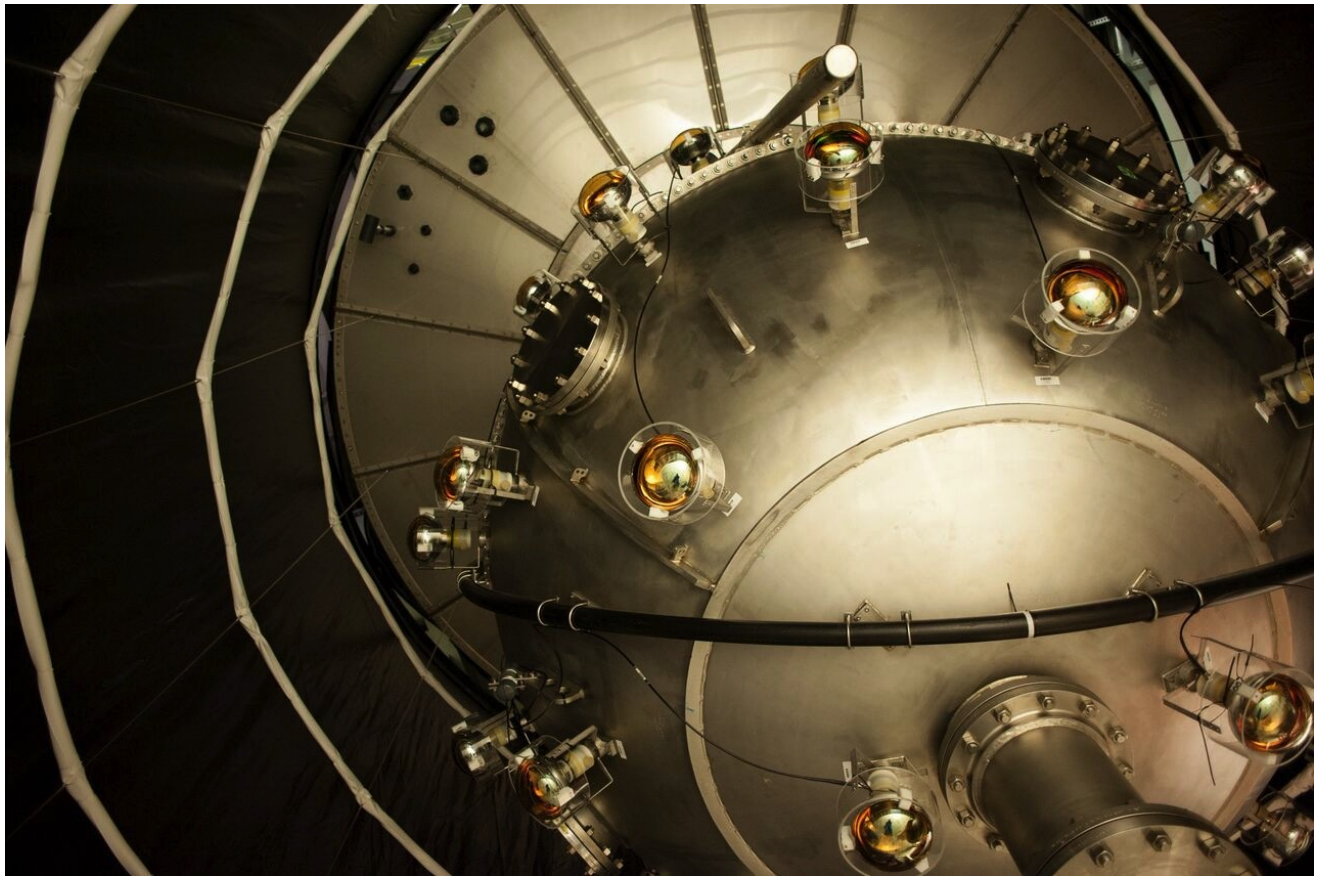
Operations

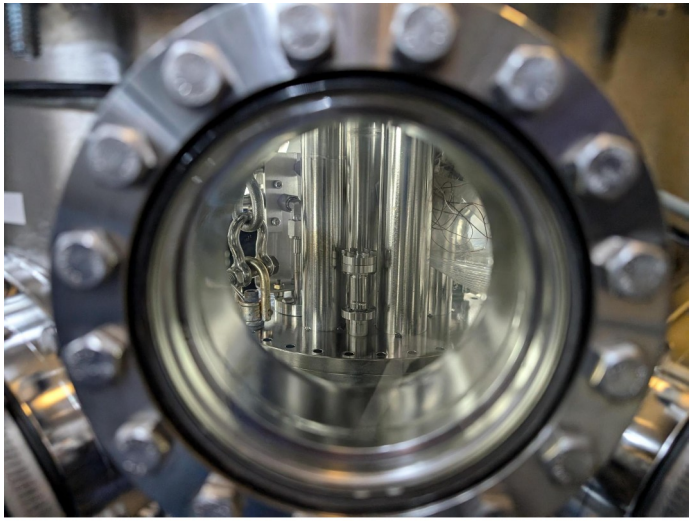
PICO-500 (250kg freon target)

In Construction


Lots of underground activity as construction proceeds through 2025, with the goal of starting operations in 2026.

Liquid Noble Targets: DEAP-3600





DEAP-3600 has just concluded a period of important upgrades and is headed for operations! DEAP has strong sensitivity for higher-mass dark matter.

Applying lessons

"We apologize to experimentalists for having no idea what is the mass of the Higgs boson, ..., and for not being sure of its couplings to other particles, except that they are probably all very small. For these reasons we do not want to encourage big experimental searches for the Higgs boson..."

John Ellis, Mary Gaillard, Dmitri Nanopolous. "A phenomenological profile of the Higgs boson". Nuclear Physics B, Volume 106, 1976, Pages 292-340.

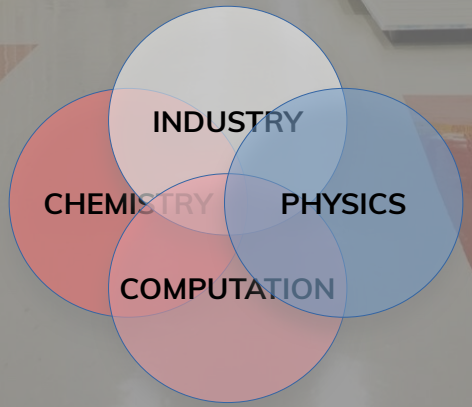
"I've been looking for you for over 20 years."
"Now, you have found me."

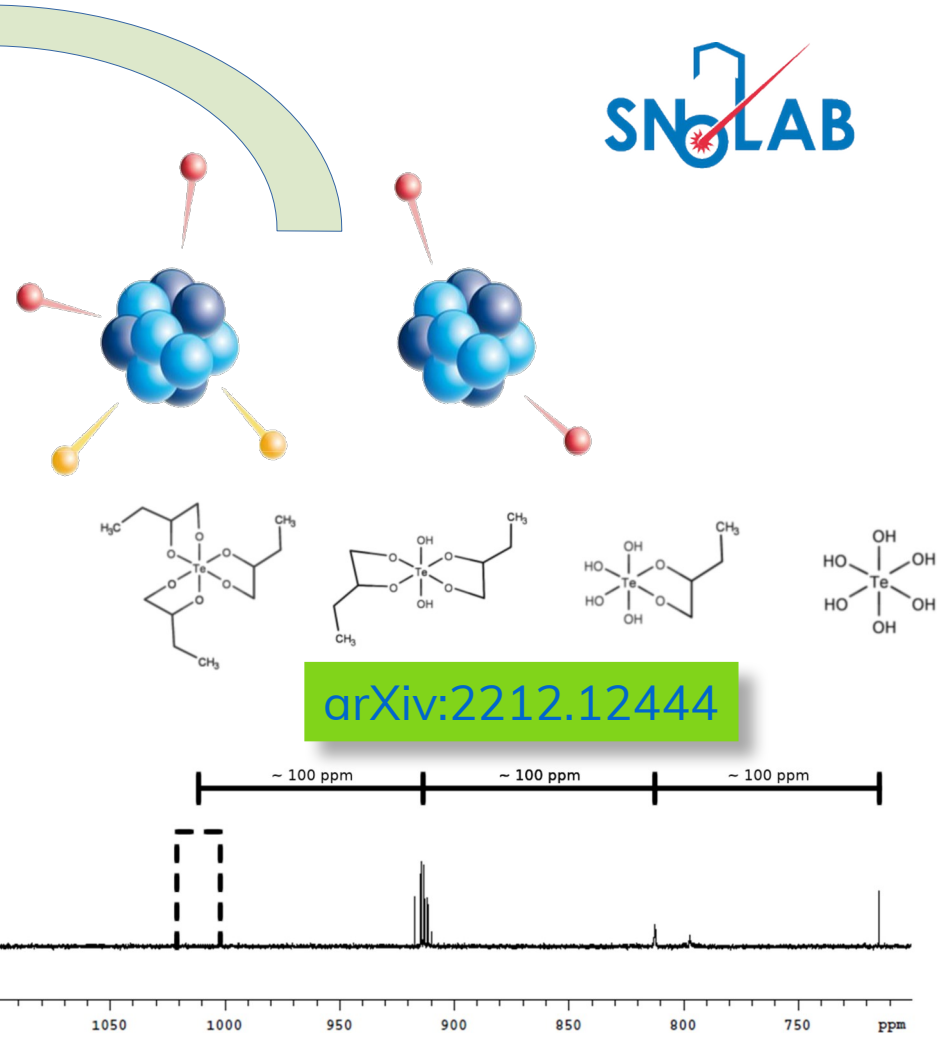
Sau Lan Wu's words to Peter Higgs, and his response, on July 4, 2012, upon the moment of their first meeting in real life.

THE NATURE OF DARK MATTER

THE MASS OF THE NEUTRINO

NEUTRINO SCIENCE

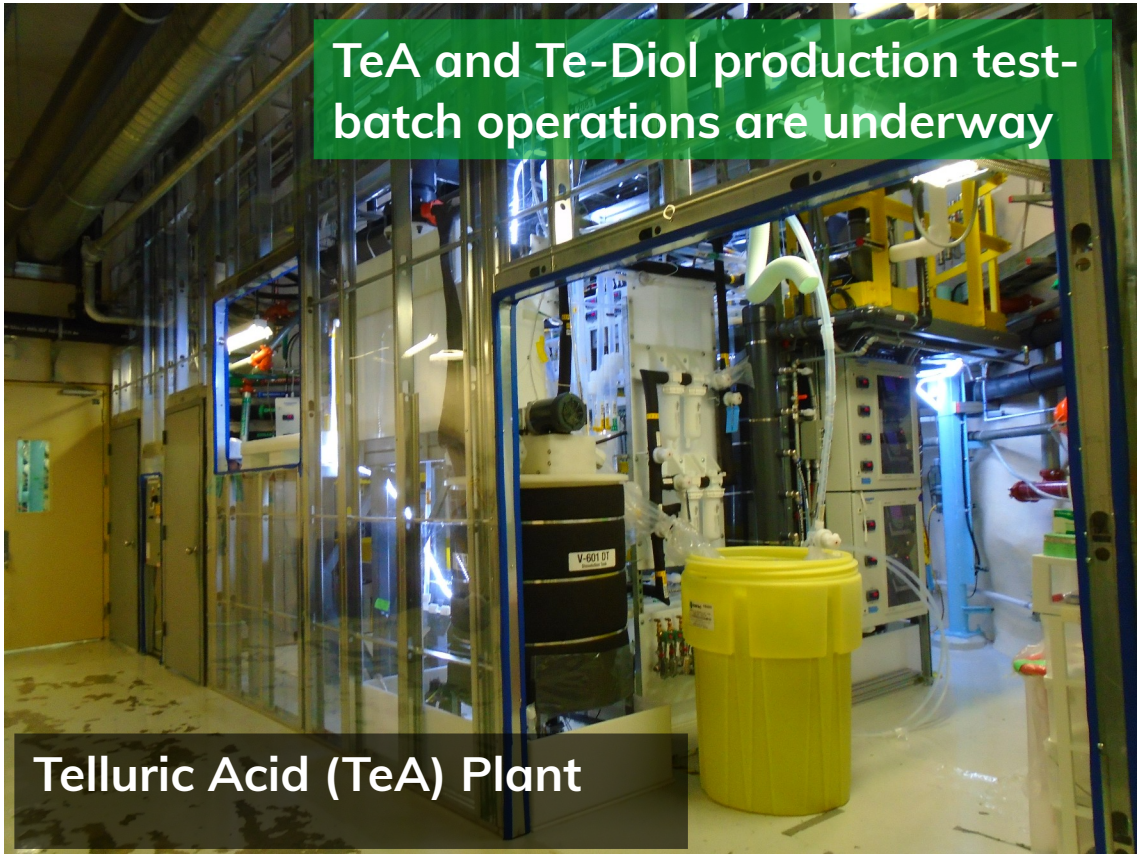


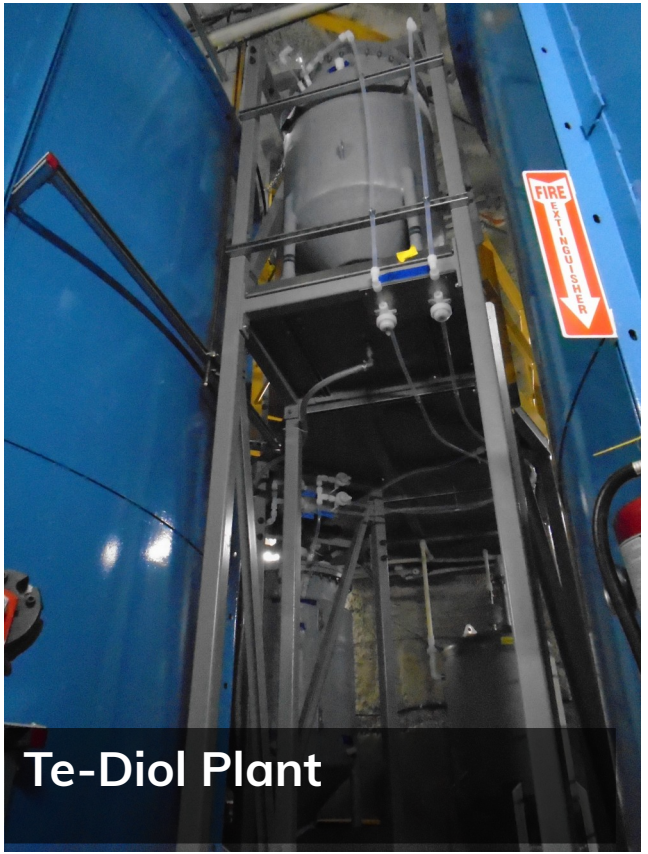


Tellurium-130 has a high natural abundance (34%) and provides a valuable avenue toward neutrinoless double beta decay → needs to be synthesized into a scintillator-soluble molecule at industrial scale (1.3 tonnes of Te-130, corresponding to 3.9 tonnes of Te).

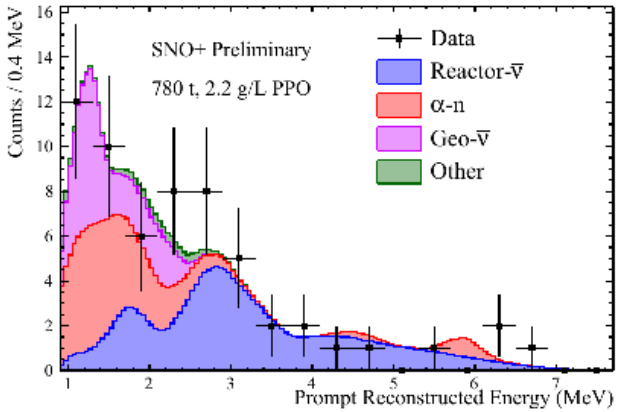
arXiv:2212.12444

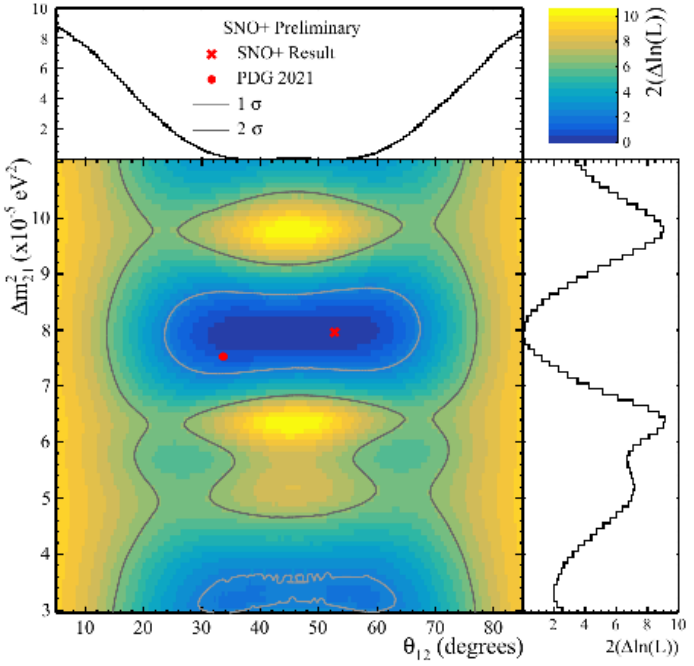
SNO+ TELLURIUM PLANTS





Oscillation Measurements





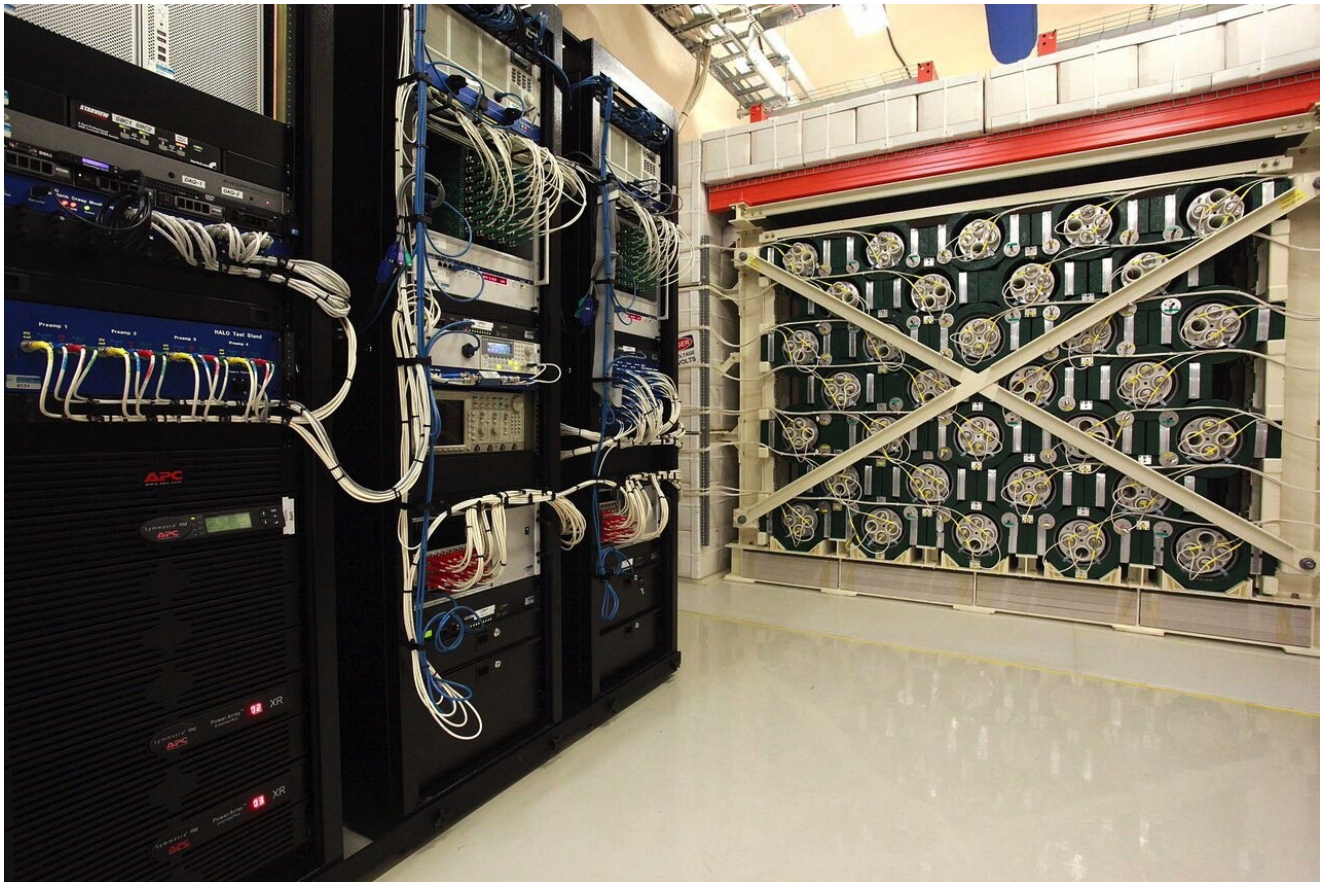
- Improvements in background rejection and statistics clear in stacked plot
  - Allows $\Delta m^2_{12}, \sin^2 2\theta_{12}$ fit
  - Best fit at $\Delta m^2_{12} = (7.95^{+0.48}_{-0.41}) \times 10^{-5}$ eV^2
  - Can approach global average uncertainty in 3 years exposure

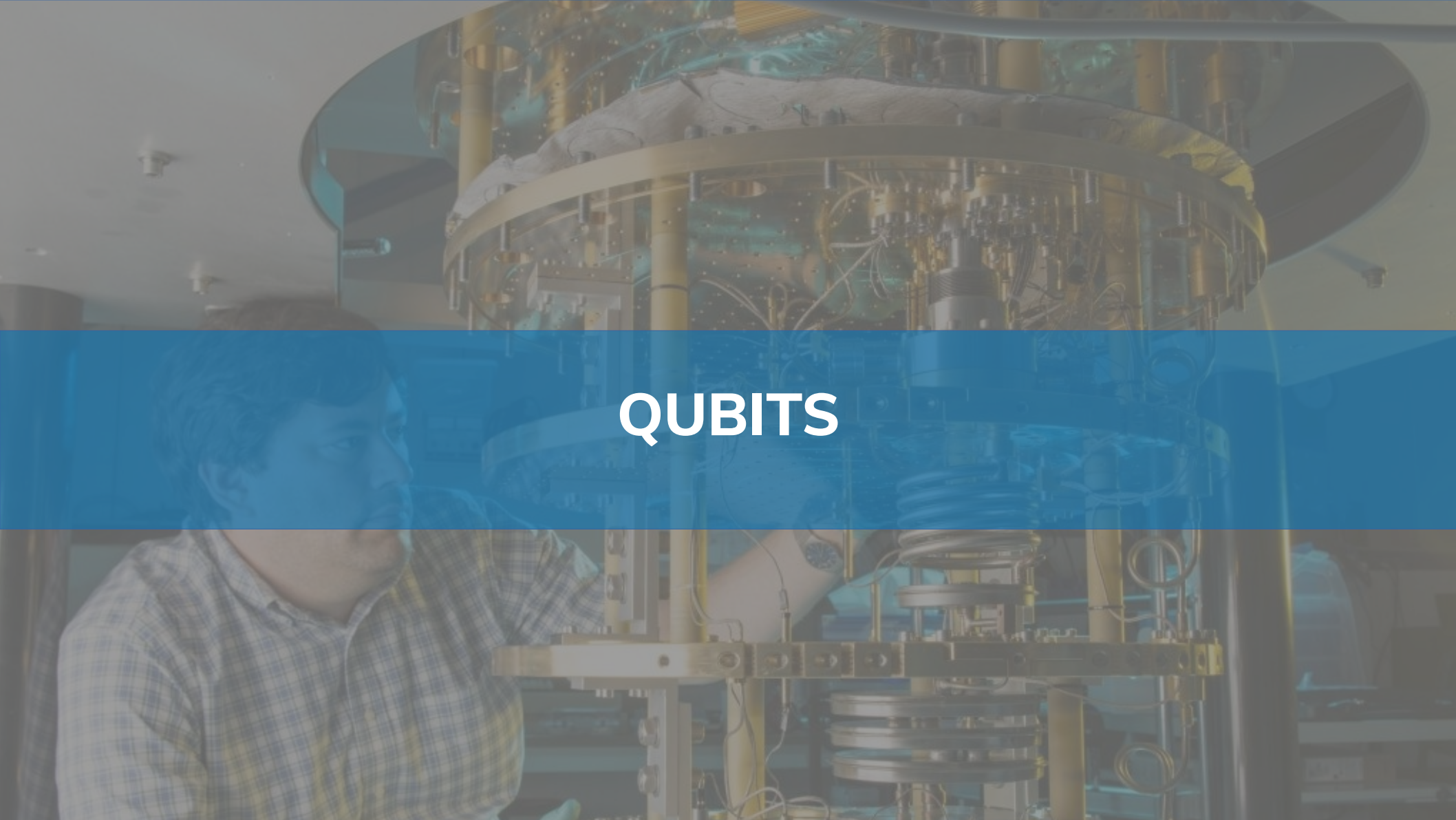
SNO+ has been a science machine, with publications stemming from its “water phase” running (2017-2019) and more recently from its “partial fill” scintillator phase (2019-2020).

Headline grabbers have been their water-only reactor neutrino detection and their recent neutrino mixing parameter results.

HALO

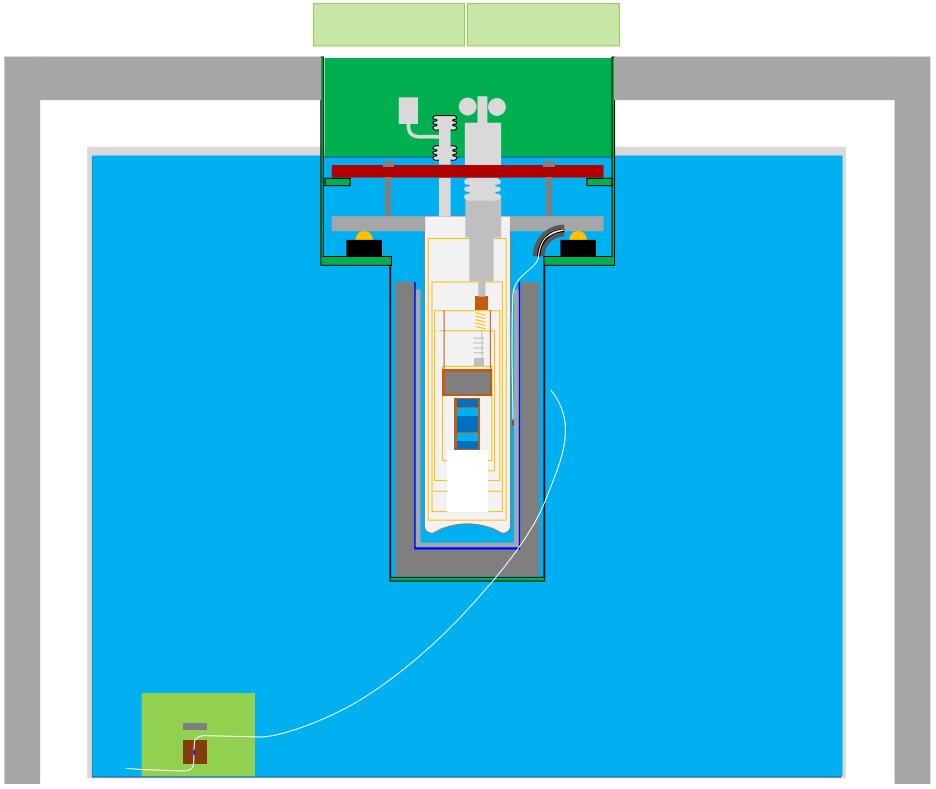
- Supernova Early Warning Detector (neutrino burst detection)
- 79 tonnes of recycled lead and 128 recycled SNO neutral current detectors.
- > 99% uptime
- Longest continuously running experiment at SNOLAB (13 years)





QUBITS

CRYOGENIC UNDERGROUND TEST ENVIRONMENT (CUTE) FACILITY



Main system components:
Payload
Cryostat
Magnetic shielding
Water tank
Drywell
Deck
Low activity lead
Very low activity lead
Internal lead
Polyethylene
Suspension system
Extra frame for Pulse Tube (PT)/turbo
Gamma source
Neutron source

Qubits in CUTE

- ***'Characterization of qubits in a deep underground environment'*** chosen for funding by the US Army Research Office.
- Prof. Chris Wilson at the Institute for Quantum Computing is the project leader.
- Chalmer's University will produce cutting-edge superconducting qubit arrays.
- Arrays tested in Sweden, Waterloo, then SNOLAB (housed in CUTE).
- First data from SNOLAB qubits obtained this year, with interpretation forthcoming and additional qubit designs deployable in CUTE.

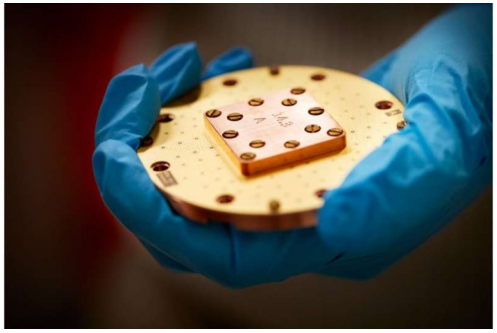
Quantum challenge to be solved one mile underground

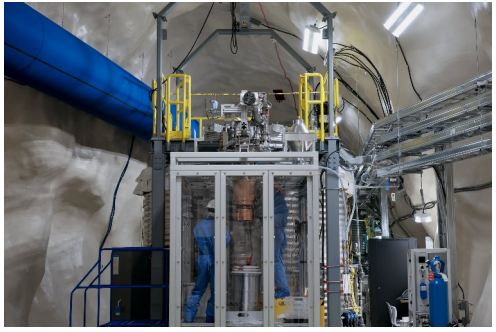
by Chalmers University of Technology

This is where the Swedish qubits are going | The Canadian underground labor…

Radiation from space is a challenge for quantum computers as their computation time becomes limited by cosmic rays. Researchers from Chalmers University of Technology, Sweden, and University of Waterloo in Canada are now going deep underground in the search for a solution to this problem—in a two-kilometer-deep mine.

A recently discovered cause of errors in quantum computers is cosmic radiation. Highly charged particles from space disturb the





FUTURE DIRECTIONS

Community-Oriented Programs

- SNOLAB Underground Science Institute
  - An intellectual support program at SNOLAB
  - **Just concluded: Summer 2025 Lecture Series!**
    - **Visit https://indico.snolab.ca/e/susi2025 for lecture videos**

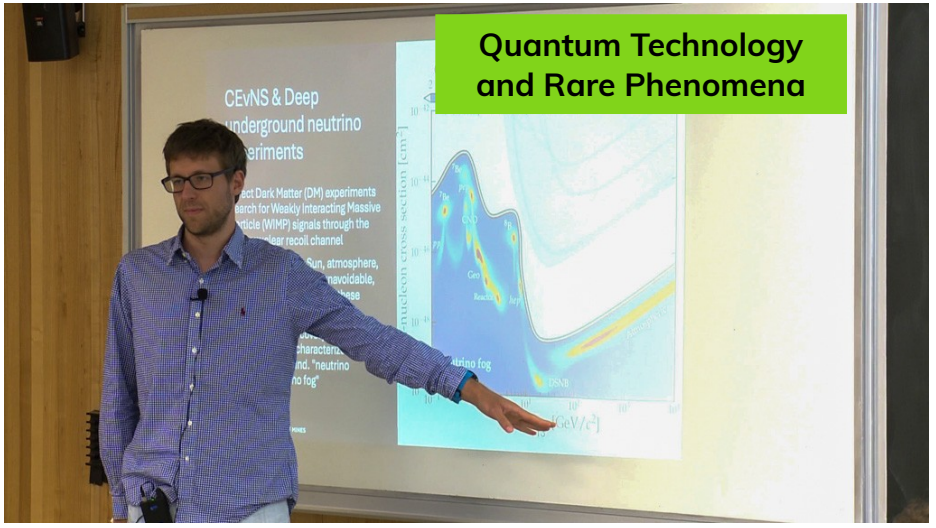
https://indico.snolab.ca/e/susi2025

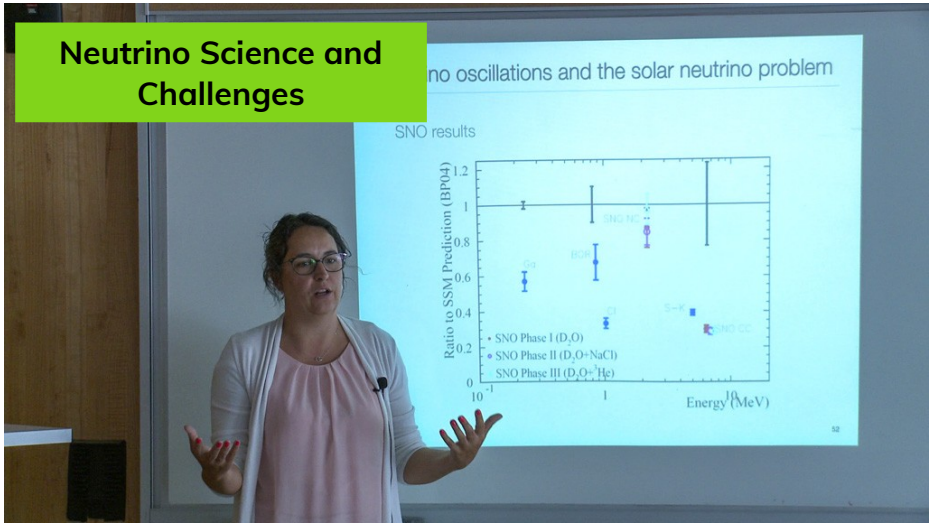
Lectures

Dan Hooper

Cosmology and Astrophysical Theory

Wouter Van De Pontseele

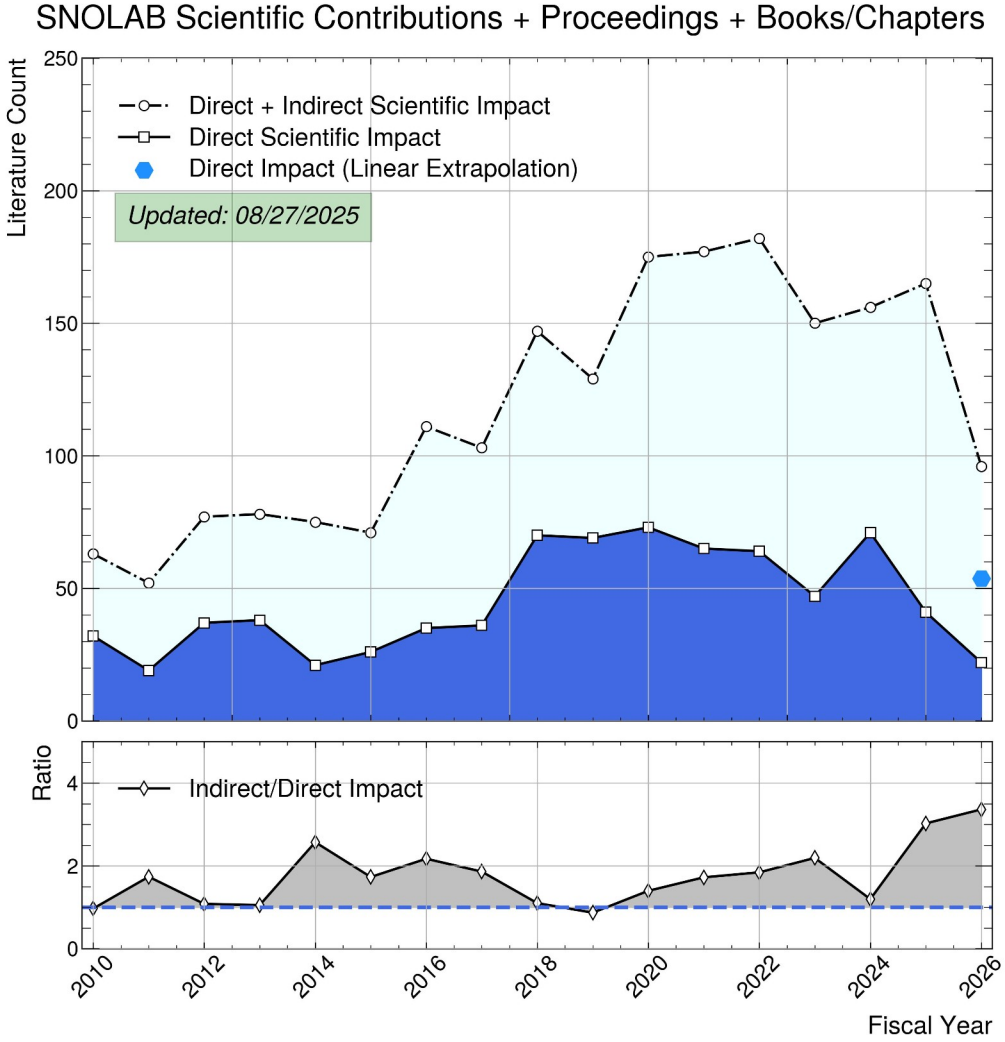


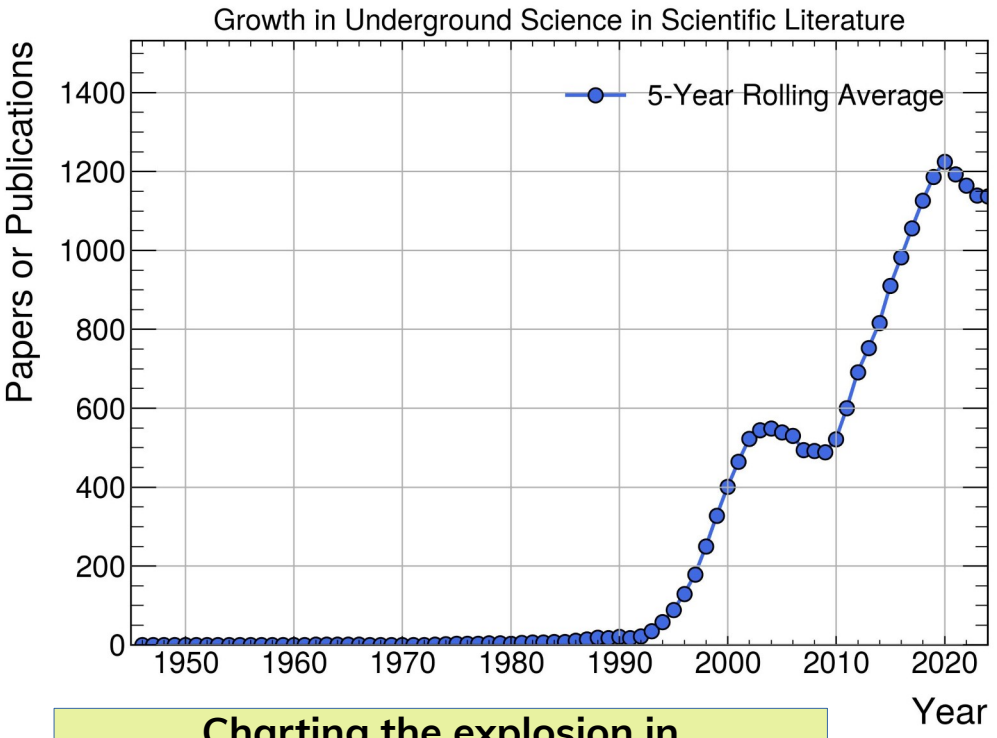


Roxanne Guenette

https://indico.snolab.ca/e/susi2025

CONCLUSIONS AND OUTLOOK





Charting the explosion in "Underground Science" using INSPIREHEP API

What Wasn't Covered?

- Geoscience: seismic monitoring
- Cleanliness: techniques and assays → assess the value of choices and actions
- Laboratory characterization: backgrounds throughout the lab (neutrons, gamma rays, radon, etc)
- Broader Environmental Monitoring: air and water quality, low-level environmental radiation monitoring, etc.
- … and a lot more!

Summary

- SNOLAB welcomes opportunities to cross disciplines in order to solve challenging problems
  - Strategic Plan
  - Community Engagement
- The problems of this century will benefit from a combination of many experts with varied perspectives → we aim to facilitate this.

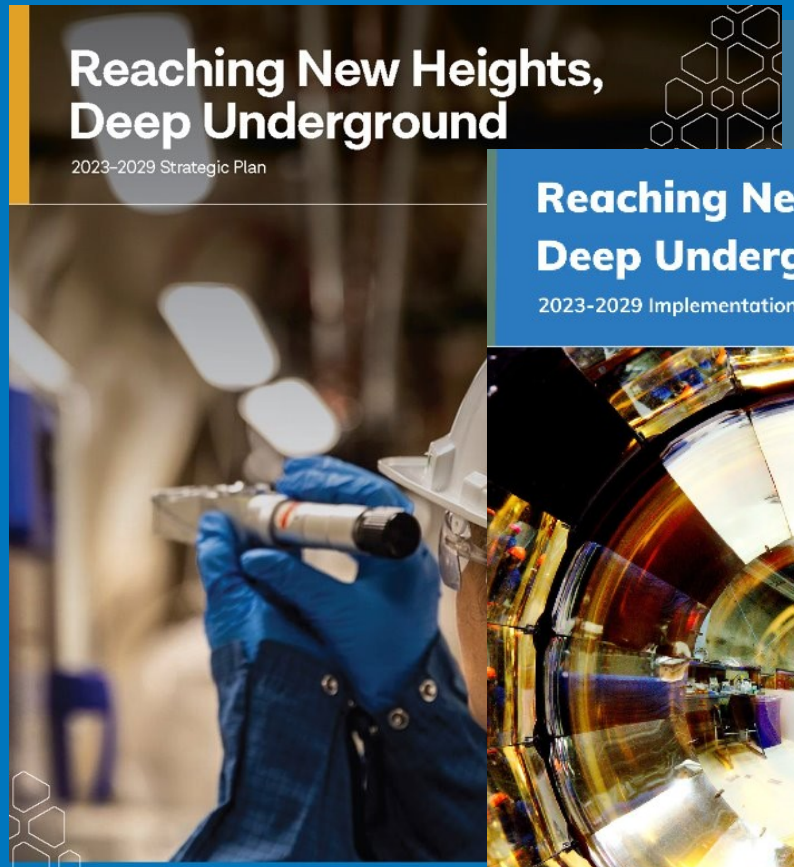
ACKNOWLEDGEMENTS

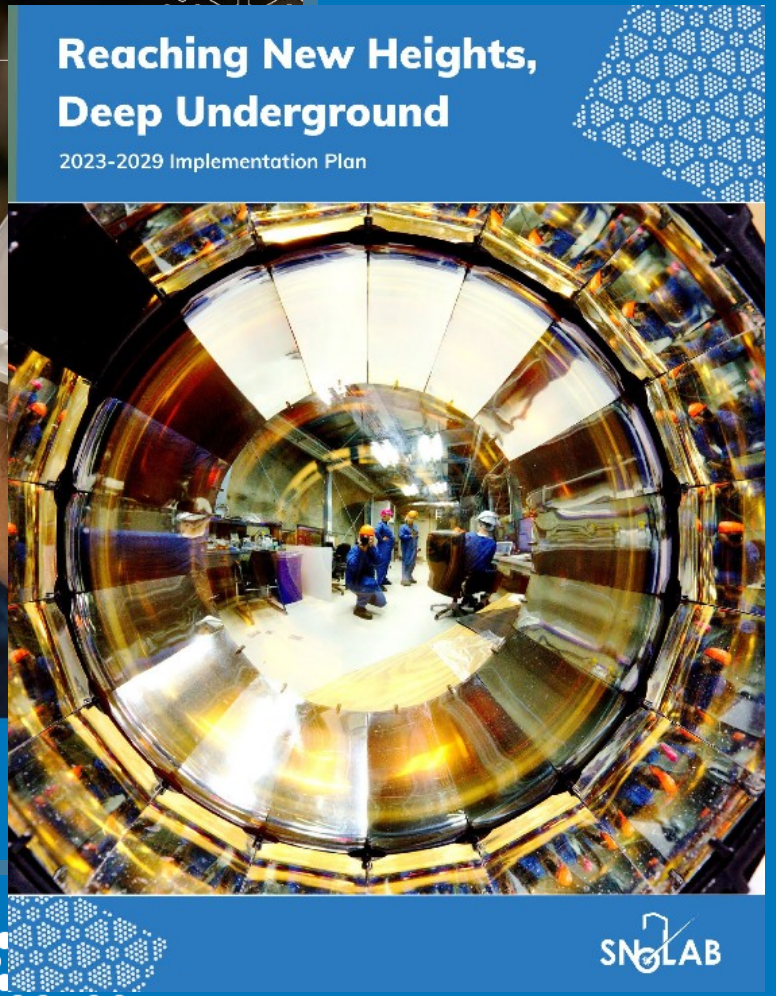
I would like to thank SNOLAB and its staff for support through underground space, logistical and technical services. SNOLAB operations are supported by the Canada Foundation for Innovation and the Province of Ontario, with underground access provided by Vale Canada Limited at the Creighton mine site.

Ask Questions.

Seek Answers.

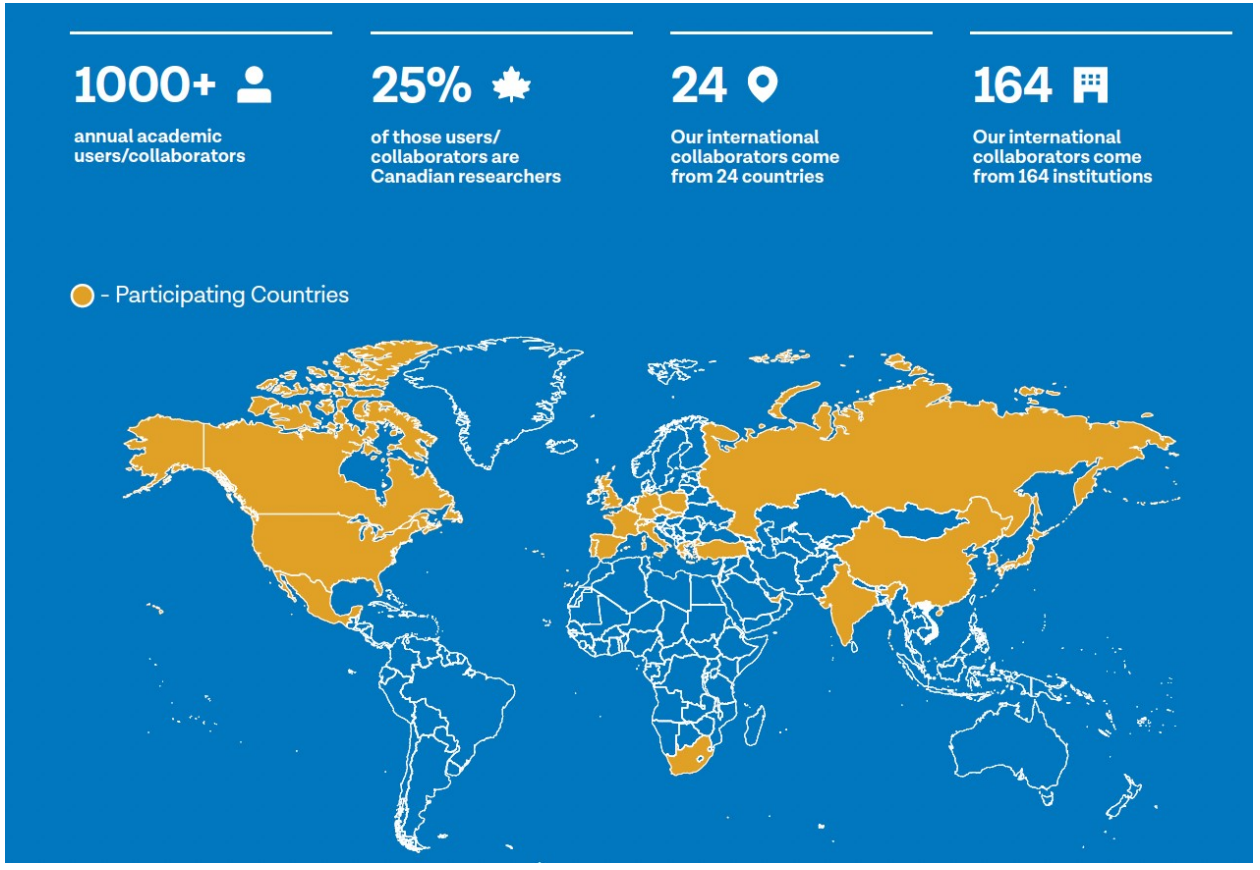
Go Deep.





APPENDIX

SNOLAB by the Numbers

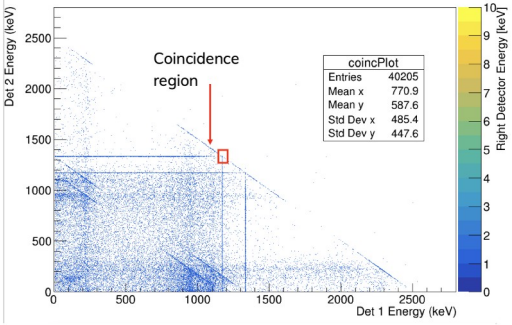


Maxwell Bridgewater Simulation/ analysis of coincident events

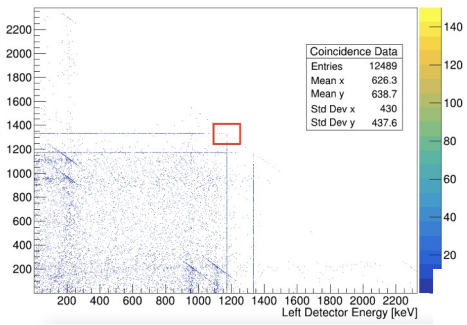
Simulation and Analysis of Coincidences

- GEANT4 ion decay of coincidence producing isotopes
- Coincidence events come from the same decay
- Allows for easy data analysis
- Real events are tagged as a coincidence if they occur between 9 μS of each other.

Co 60 Coincidence Spectrum

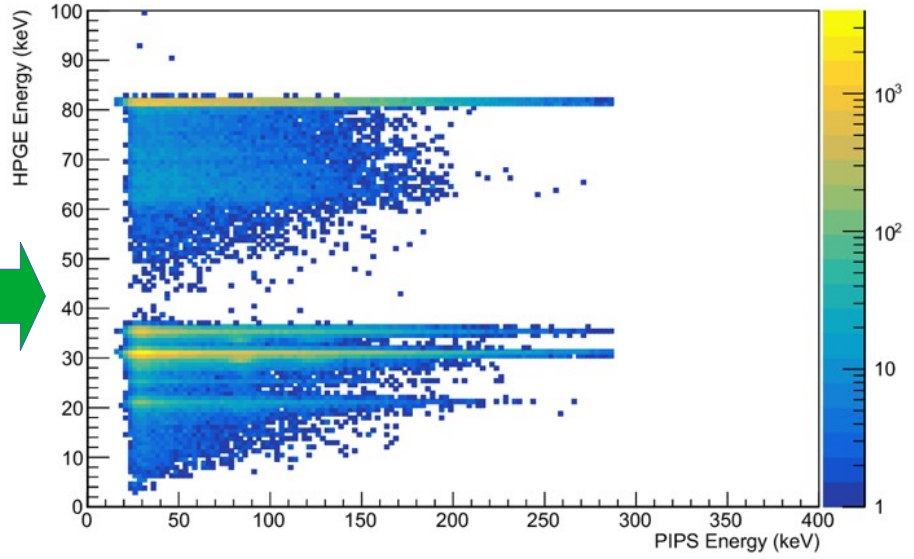


Simulated Co 60 Coincidence Spectrum



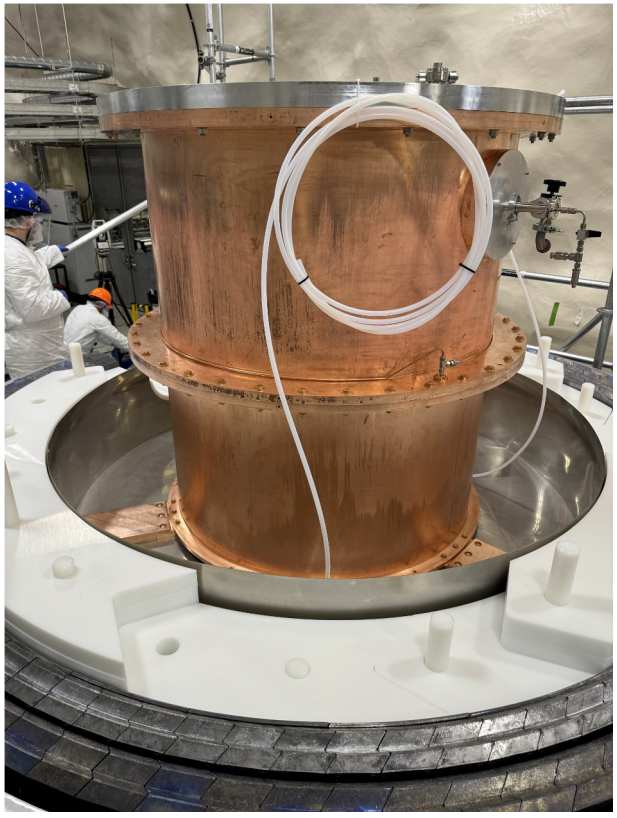
β-γ coincidence calibration using a Xe-133 sample from Health Canada

Coincidence Events (Events per Day per PIPS)



Semiconducting Crystals: SuperCDMS and HVeV

SuperCDMS Cleaning and Construction



HVeV Detectors in CUTE