2023/08/28
Topics in Astroparticle and Underground Physics

SNOLAB Research and Development Program

Jeter Hall
Director of Research

Vienna from across the Danube at night. Sehr schön!

Land Acknowledgment

SNOLAB is located on the traditional territory of the Robinson-Huron Treaty of 1850, shared by the Indigenous people of the surrounding Atikameksheng Anishnawbek First Nation as part of the larger Anishinabek Nation.

We acknowledge those who came before us and honour those who are the caretakers of the land and the waters.

SNOLAB

- SNOLAB hosts rare event searches and measurements. It’s located 2 km underground in the active Vale Creighton nickel mine near Sudbury, Ontario, Canada.

- SNOLAB is operated jointly by University of Alberta, Carleton University, Laurentian University, University of Montreal, and Queen’s University

- SNOLAB operations are funded by the Province of Ontario, and the Canada Foundation for Innovation

SNOLAB by Numbers

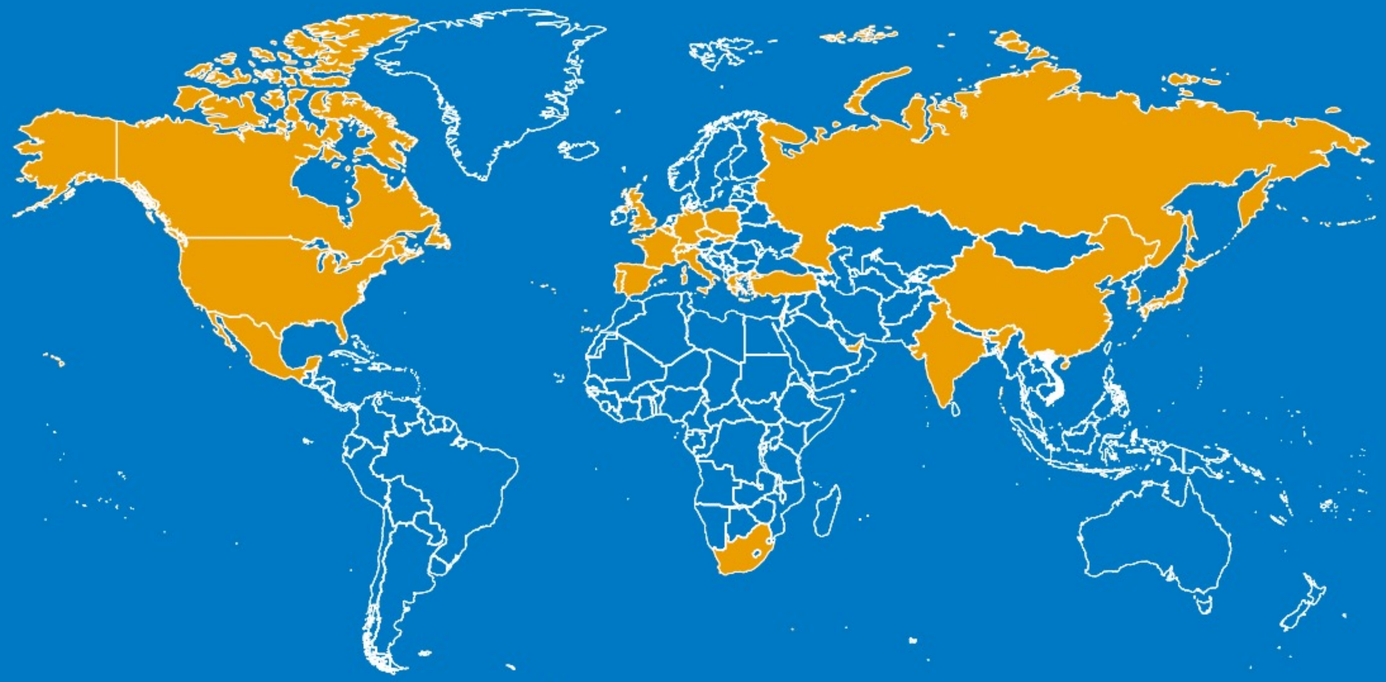
1000+
annual academic users/collaborators

25%
of those users/ collaborators are Canadian researchers

24
Our international collaborators come from 24 countries

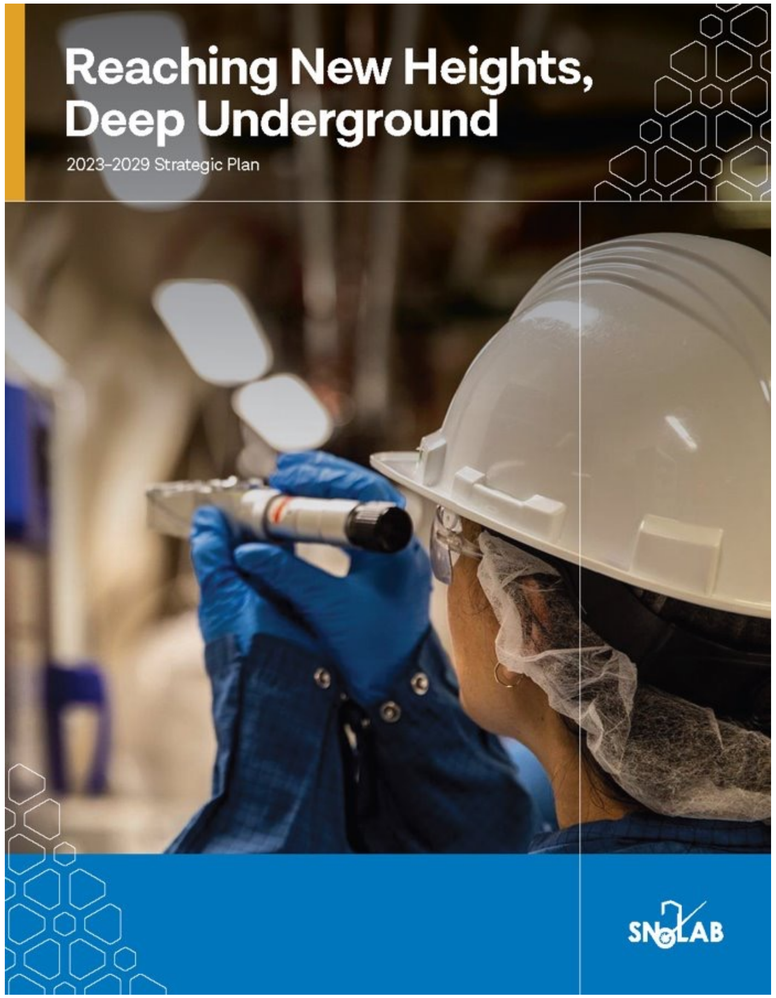
164
Our international collaborators come from 164 institutions

- Participating Countries



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



Dark matter

The only evidence for dark matter is through its gravitational influence. Our underground experiments aim to catch rare interactions between dark matter and the detectors by controlling and removing all known sources of radiation.

Current experiments

DAMIC, DEAP-3600, NEWS-G, Oscura, PICO-40, PICO-500, SENSEI, and SuperCDMS

Neutrinos

Studying the properties of the neutrino provides insights into the dominance of matter over antimatter and the nature of radioactive decay. Our very large neutrino detectors are needed because interactions are very rare.

Current experiments

HALO, LEGEND-1000, nEXO, and SNO+

Nuclear monitoring

We measure low levels of industrial radioactivity using our existing capabilities for measuring natural radioactivity in the materials that make up our detectors.

Current experiments

Collaboration with Health Canada, led by Canadian Nuclear Safety Commission

Quantum computing

Our low-radiation environment is ideal for studying the performance of qubits, which are fundamental to quantum computing but easily disturbed. Ionizing radiation is a key component of the noise in today's best qubits.

Current experiments

Collaboration with Institute for Quantum Computing, University of Waterloo

Life sciences

We collaborate with researchers to study the impact of low-background environments on biological systems. Radiation can damage cells in large doses, but we need to better understand the effects of sub-background radiation.

Current experiments

REPAIR, FLAME

SNOLAB Layout

Current Experiments
Future Experiments
Laboratory Facilities
Experiment Areas

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

Cryopit
nEXO/LEGEND

J-Drift
SENSEI, DAMIC, SENSEI

Electrical Shop

Machine Shop

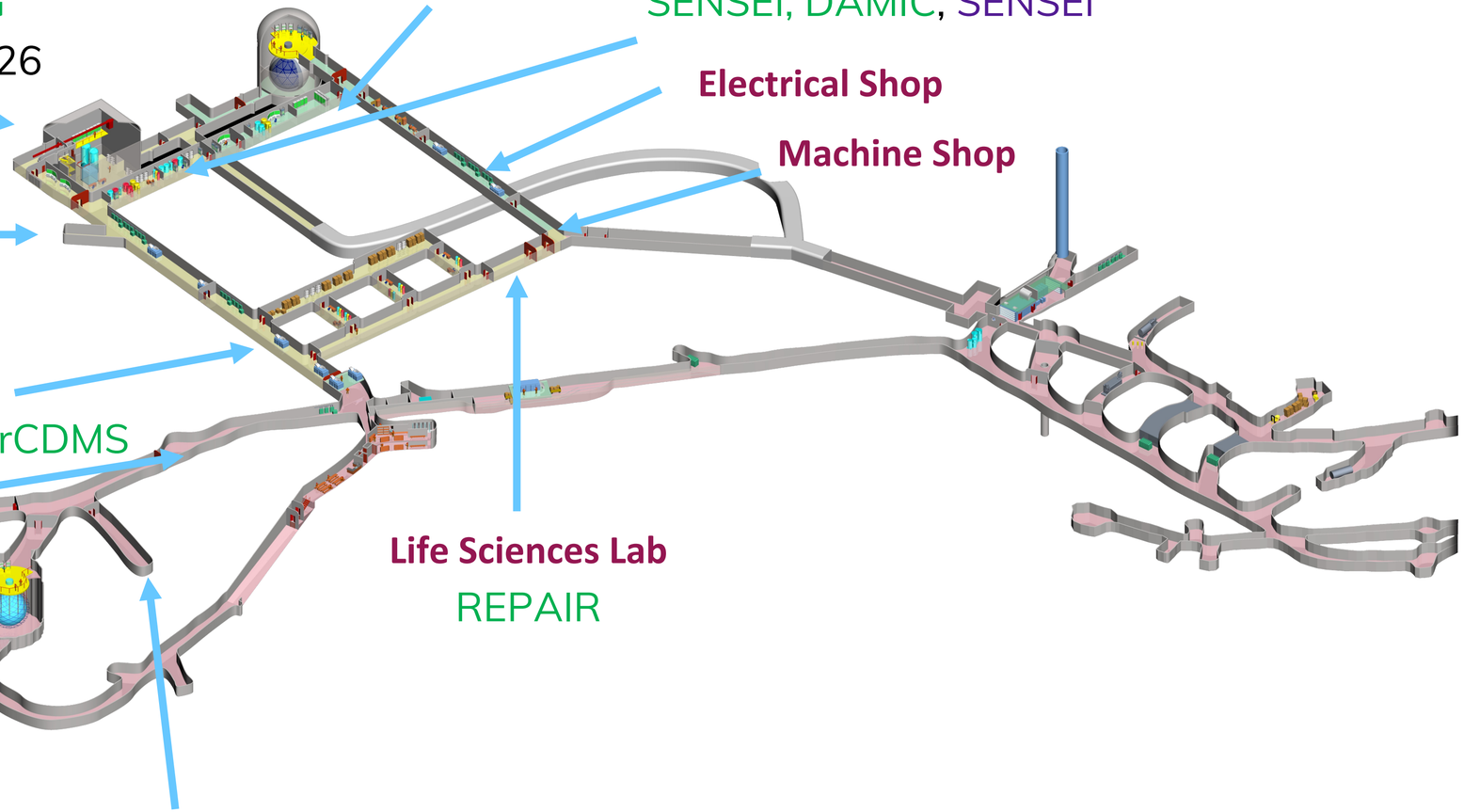
Halo Stub
HALO
potential breakthrough for future expansion

Ladder Labs
PICO40, SBC, CUTE, SuperCDMS

Plants
UPW, Scintillator, Te Diol, TeA

Life Sciences Lab
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

SNOLAB Science is making an impact at TAUP 2023

“Status and prospects of the SuperCDMS Dark Matter experiment” – Stefan Zatschler in Dark Matter 1A

“Background simulations for the SuperCDMS experiment – Efficient GEANT4 simulations using Importance Biasing” – Birgit Zatschler in Dark Matter 1A

“Investigating Compton steps in SuperCDMS Si HVeV detectors” – Sudipta Das in Dark Matter 1A

“Searching for solar neutrino absorption with the DEAP-3600 experiment” – Veronika Shalamova in Neutrinos 2A

“Latest results from the NEWS-G dark matter experiment” – Jean-Marie Coquillat in Dark Matter 6B

“Latest results from the DEAP-3600 experiment at SNOLAB” – Simon Viel in Dark Matter 6B

“PICO-40L Bubble Chamber Status and First Results” – Colin Moore in Dark Matter 6B

“Latest results from the SENSEI experiment on sub-GeV dark matter searches” – Ana Martina Botti in Dark Matter 7B

“Confirmation of the excess of ionization events in DAMIC at SNOLAB with skipper CCDs” – Michelangelo Traina in Dark Matter 7B

“Neutrinoless double-beta decay search with SNO+” – Valentina Lozza in Neutrinos 3A

“0νββ Target Out Analysis for the SNO+ Experiment” – Ben Tam in Poster B

SNOLAB Science is making an impact at TAUP 2023

“Event Reconstruction in the SNO+ Experiment” – Tereza Kroupova in Poster B

“Neutrino physics with SNO+” – Tanner Kaptanoglu in Neutrinos 7B

“Oscura : Dark Matter search with 10 kg of skipper-CCD” – Nathan Saffold in Dark Matter 1A

“Novel multi-channel skipper-CCD packages for the OSCURA experiment” – Ana Martina Botti in Poster A

“Readout electronics development for the OSCURA experiment” – Ana Martina Botti in Poster A

“Measurements from HALO” – Stephen Sekula in Poster B

“Discovering the origin of matter with liquid xenon neutrinoless double-beta decay detectors: nEXO and beyond” – Sammule Sangiorgio

“Optimizing Energy Reconstruction for nEXO” – Clarke Hardy

“LEGEND-1000: A Ton-Scale Search for Neutrinoless Double-Beta Decay in Ge-76” – Vincente Guiseppe

“Neutron Veto Instrumentation for LEGEND-1000” – Michele Morella in Poster B

“Searching for Beyond-Standard-Model Physics with LEGEND-1000” – Samuel Watkins in Poster B

“SNO+ Tellurium Purification and Loading for Neutrinoless Double Beta Decay Search” – Steve Biller and Szymon Manecki in Poster B

SNOLAB Science is making an impact at TAUP 2023

“Low Background Measurement Program at SNOLAB” – Ian Lawson in UG Labs 2

“An ICP-MS based dust monitoring methodology to evaluate dust background mitigation procedures” – Maria Laura di Vacri in UG Labs 2

“Upgrading Radiopurity.org: a Community Material Assay Database” – Stephen Sekula in UG Labs 2

“The research and development program at SNOLAB” – Jeter Hall in UG Labs 1 (this talk!)

Apologies if the list is incomplete.

Community Development

https://indico.cern.ch/event/1299890/

Students attending the third Canadian Astroparticle Summer Student Talk competition
(a collaboration of SNOLAB, Laurentian University, and the McDonald Institute)

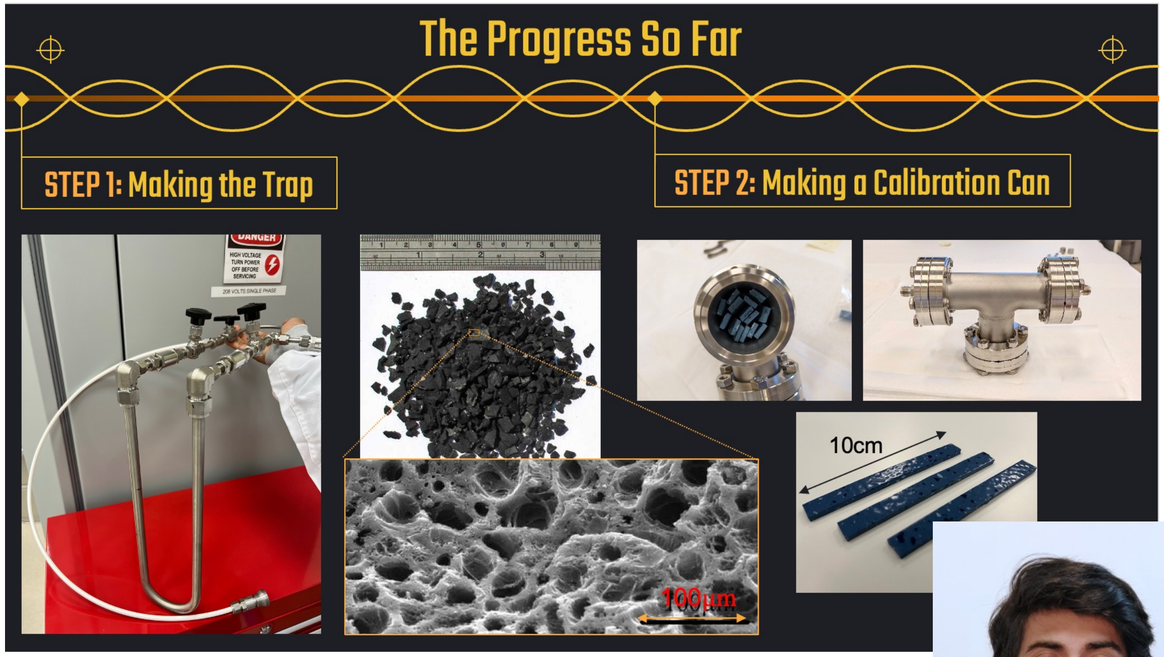
- **Rotating cohort of 15 co-op students are critical to the capability development**
- **Developing Summer lectureship and scientific affiliates program**

Capability Development

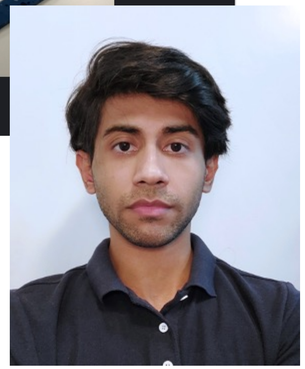
Not complete list!

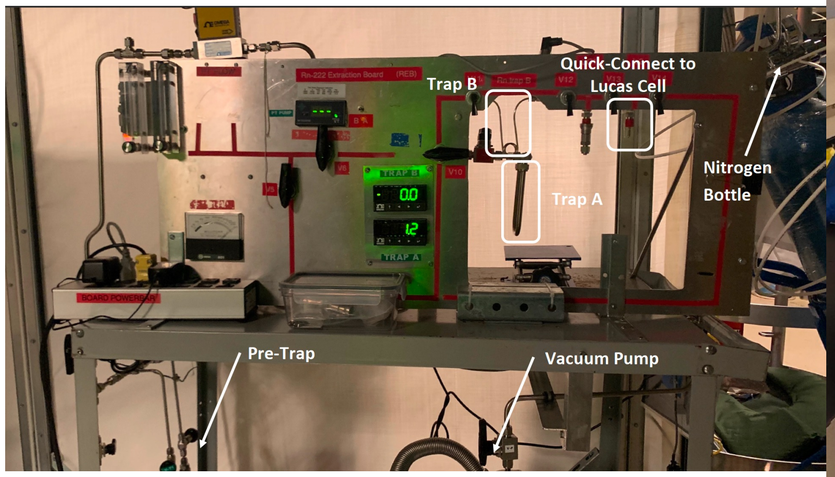
- **Cryogenics** are in many experiments. The lab plans to target this area for development of expertise.
- **Radon** is a fact of life underground, and a critical background concern for most current experiments. The lab plans to target this area for development of capability and expertise.
- The **project management** office is fully staffed, accelerating scientific excellence.
- Community levels of HPGe screening capacity appear sufficient for current and future use. No plans for development.
- The community has asked for an increased focus on **lab environment monitoring**, so we are developing capability in monitoring seismic activity, radon levels, dust levels, temperature, pressure, etc.
- Engineering support continues to develop expertise in requested disciplines including **seismic modeling**.

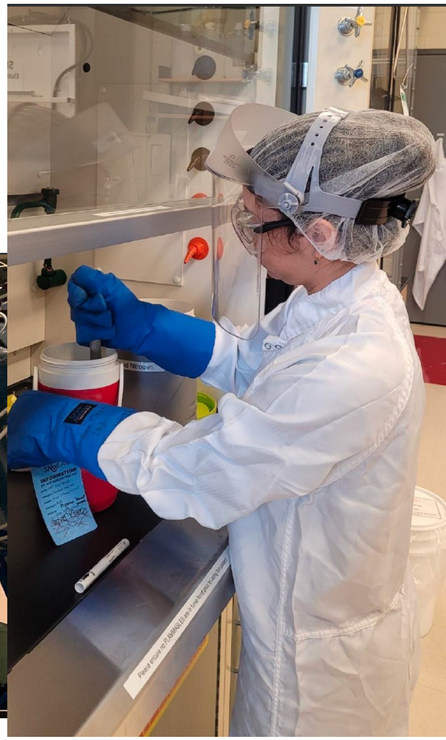
Radon assay and mitigation is a key component of our development program



Yusuf Ahmed is working on a better radon trap, and a source to calibrate that trap.







Student Ana Molina Colina preparing a salt bath to remove moisture from a radon assay of humid air.

These students worked with SNOLAB staff Lina Anselmo, Aleksandra Bialek, and Nasim Fatemighomi

New radon detectors are being built at SNOLAB

- **Implementing small spherical proportional counters (a la NEWS-G) as a potential way to get beta sensitivity and lower backgrounds (led by Pierre Gorel)**
- **New Lucas cell counters at the lowest background achieved in SNO (led by Nasim Fatemighomi)**

Mark Volin created a Bateman equation solver and simulator to help with radon counting

Background goal of <1 Rn-222/week.

Best detectors currently at ~4/day.

Lauren Fearn was able to observe first radon alpha decays in a stainless steel spherical proportional counter

SNOLAB is investing research time in improving operations

- **Project to apply machine learning to oxygen sensor data to predict failures**

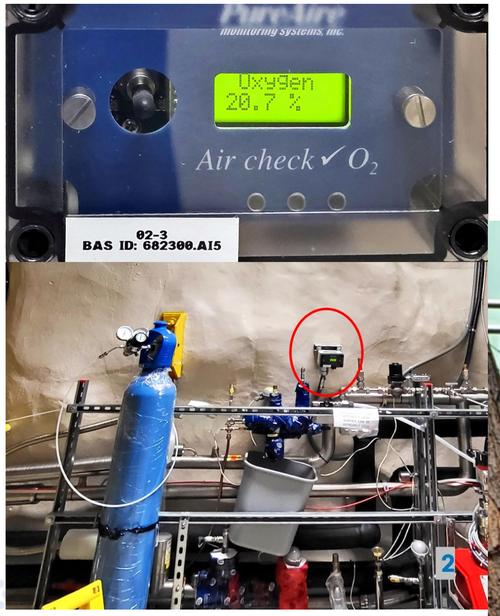
  (led by Stephen Sekula and Allan Barr)

Problem Background

There are 10 oxygen sensors located in the Cube Hall at SNOLAB.

These sensors occasionally fail, resulting in unnecessary evacuations of the Cube Hall

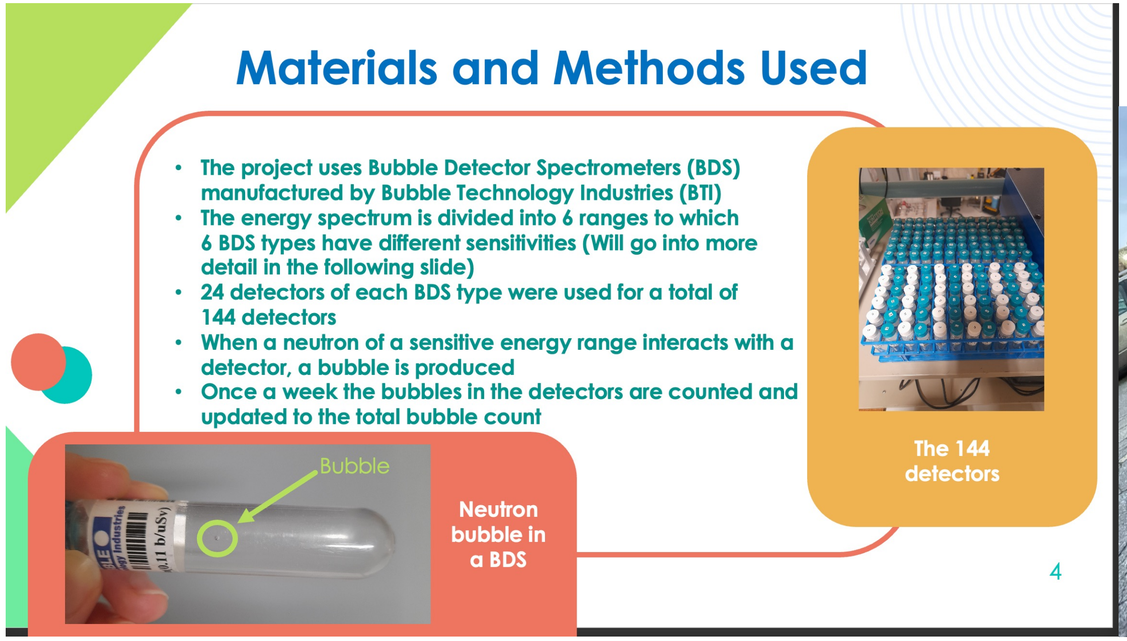
Question: Using historic sensor data, can we identify the causes of oxygen sensor failure, and/or predict when a sensor is going to fail?



Katherine Latosinsky investigated new analysis techniques to predict oxygen sensor failures.

SNOLAB is measuring the laboratory backgrounds

- **Project to deploy neutron and gamma survey counters throughout the laboratory (led by Steffon Luomo)**

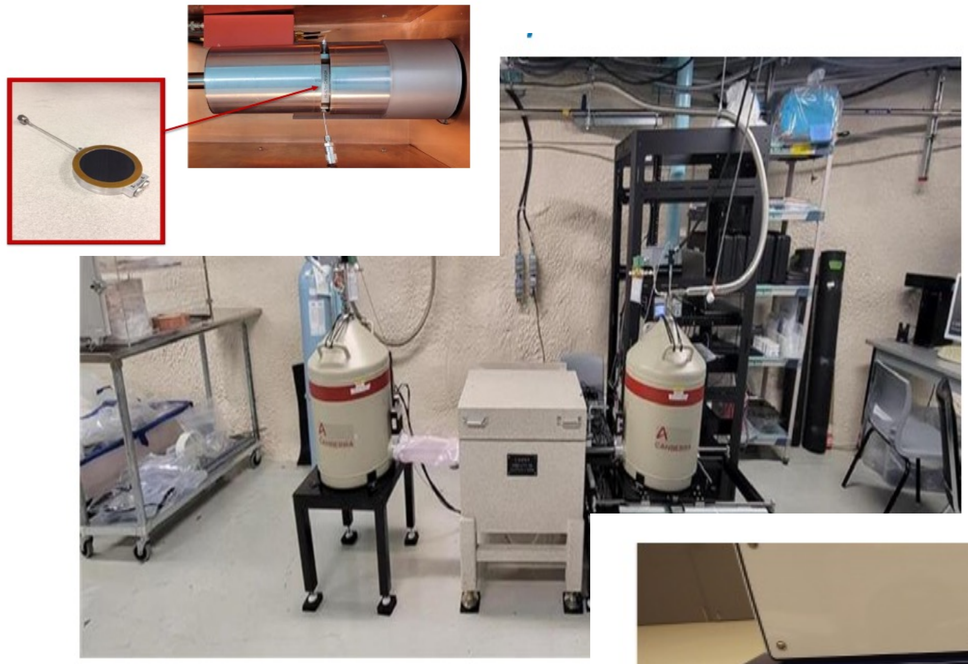


Tatum Channing deployed a set of over 100 bubble detectors to measure the fast neutron flux in SNOLAB

Background Characterization Capabilities

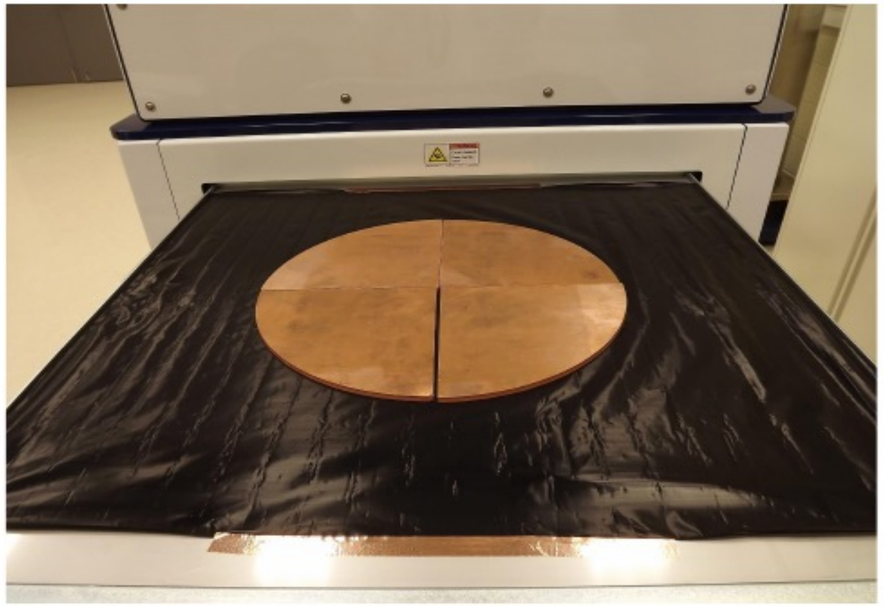
Assay Capabilities

- HPGe Counters
- XIA Alpha counter (surface)
- Radon emanation measurements
- New ICPMS
- Radon monitoring



Underground Background Measurements

- Radon (Durridge RAD7 continuous monitoring)
- Neutron Backgrounds (Bubble Technology BDS System - 144 detectors at 6 thresholds)
- Gamma Backgrounds: (2 NaI Detectors – Detailed spectra up to 3 MeV)
- EMI Backgrounds: (RIGOL Spectrum Analyzer – 9 kHz to 7.5 GHz)

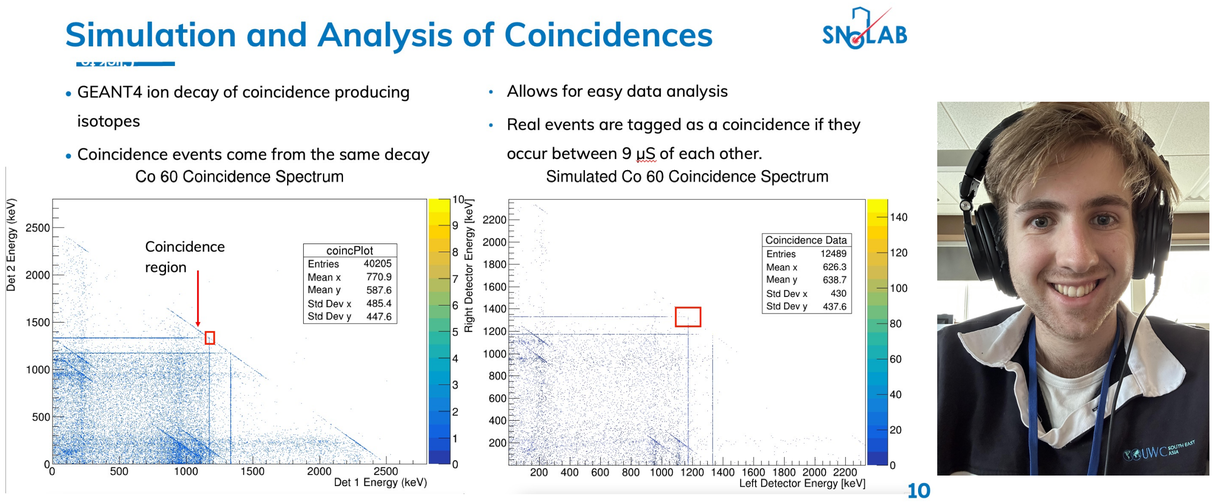


See talk by Ian Lawson’s in the Underground Lab session 2

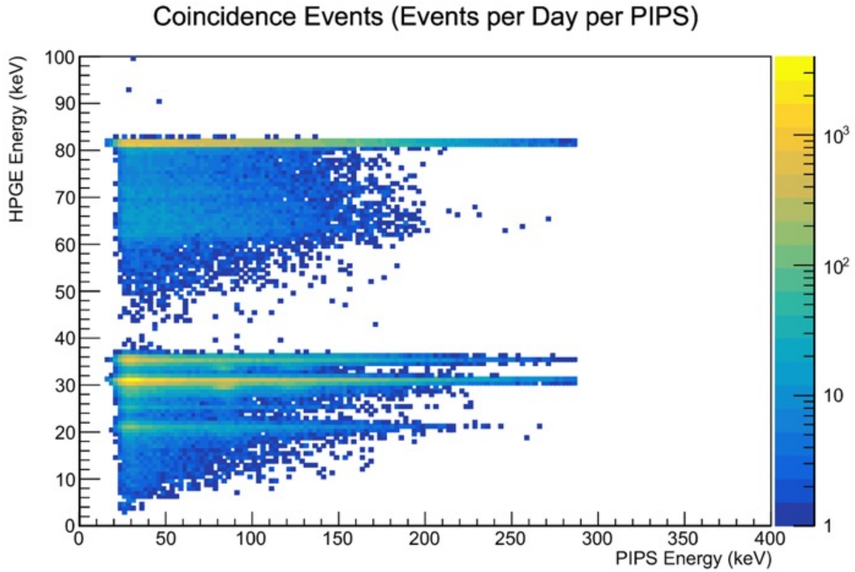
SNOLAB is enhancing the gamma counting with coincidence capability

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

(led by Ian Lawson, Steffon Luomo and the rest of the low backgrounds group)



Maxwell Bridgewater simulated and analyzed coincident events to understand potential MDA improvements



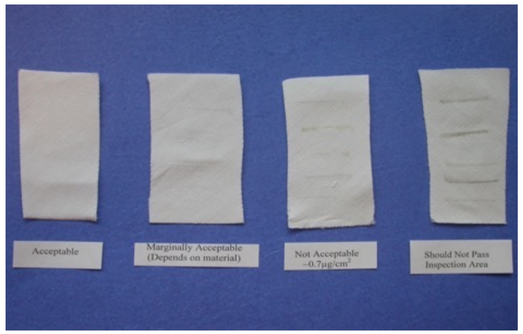
Beta-gamma coincidence calibration using a Xe-133 sample from Health Canada

SNOLAB has a focus on cryogenics operations

- Underground liquid nitrogen production since 2022 (supplies most of the lab needs)
  - Have learned some operational issues with the argon in pressure swing ‘nitrogen’ systems
  - Team is working on reliability and remote operations (led by Lee Herechuk and the systems operator team)
- CUTE (shielded dilution refrigerator) has been operational since 2020, can run for weeks unattended (led by Andy Kubik and Wolfgang Rau and the CUTE team)
  - Two new projects funded, Marie Curie fellowship and a Qubit project

SNOLAB has a focus on clean operations

- ICPMS will be first used to perform routine QA/QC on the ultra pure water we produce (led by Sharayah Read)
- Dust measurements of actual radioactive fallout successfully guiding operations (see talk by Maria Laura di Vacri in UG Labs 2)



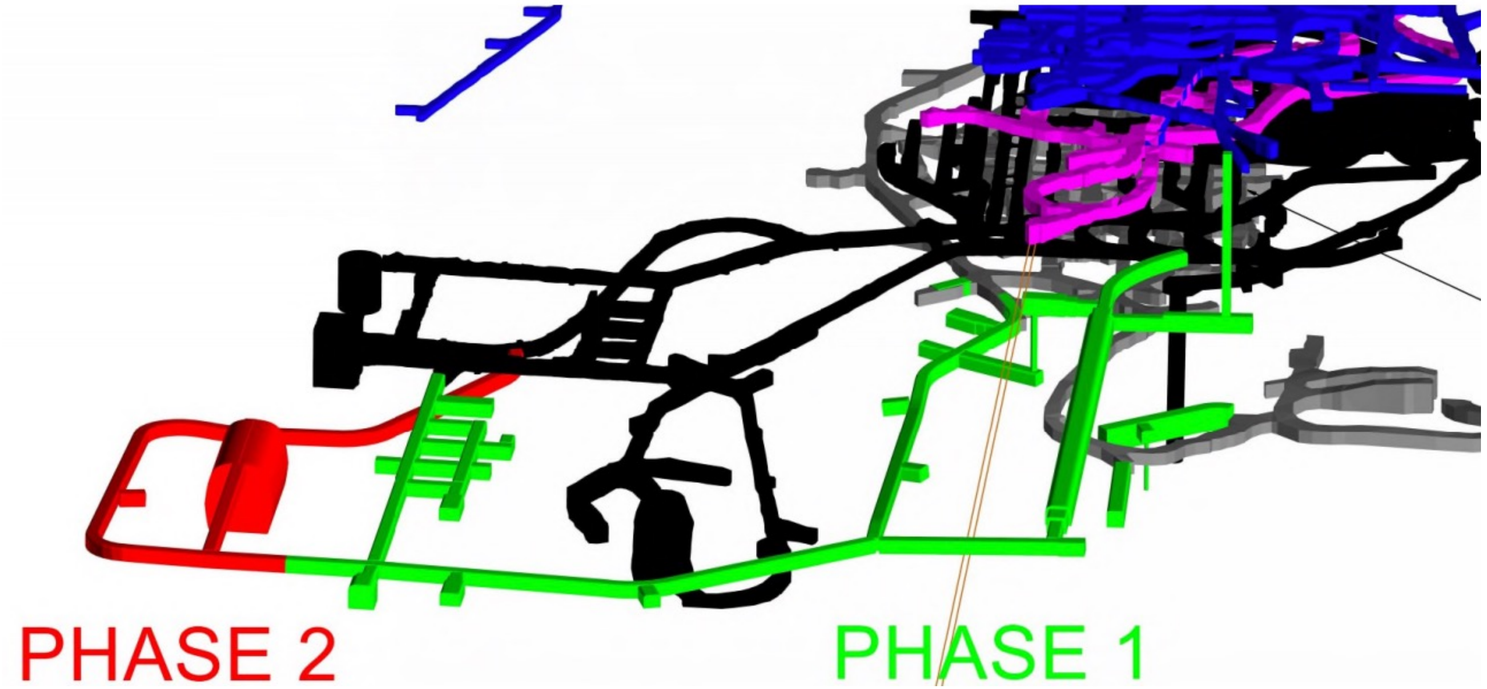
Final Thoughts

- SNOLAB is a world-class underground laboratory in Canada with the lowest muon fluxes available
- The experiments are the highest priority, but we have been able to accomplish some research and development projects to improve the infrastructure
- Have not covered the full scope of the program (not even the co-op students)
- There is a wealth of future research and development topics to improve our support of the science at SNOLAB
- We are always looking for new ways to collaborate on future experiments or infrastructure R&D

Questions?

Expansion Concept

- Expansion study conceptual, phased design complete
- Estimated CAD $200M, 5 years
- No current path for funding, and would require demand from the research community
- **Expect space to be constrained over the 2023-2029 period, rotating experiments through existing floor space**



SNOLAB is watching electroforming projects, but no large activities at SNOLAB currently

- **Participating in the NEWS-G calls around the ECuMe project to grow a copper sphere**
- **Some equipment at SNOLAB, but no systematic program yet**

Partners


LaurentianUniversity
UniversitéLaurentienne


Queen's
UNIVERSITY


Carleton
UNIVERSITY


Université
de Montréal


UNIVERSITY OF
ALBERTA


VALE