2024/01/06

The SNOLAB Science Program

Jodi Cooley
Executive Director | SNOLAB
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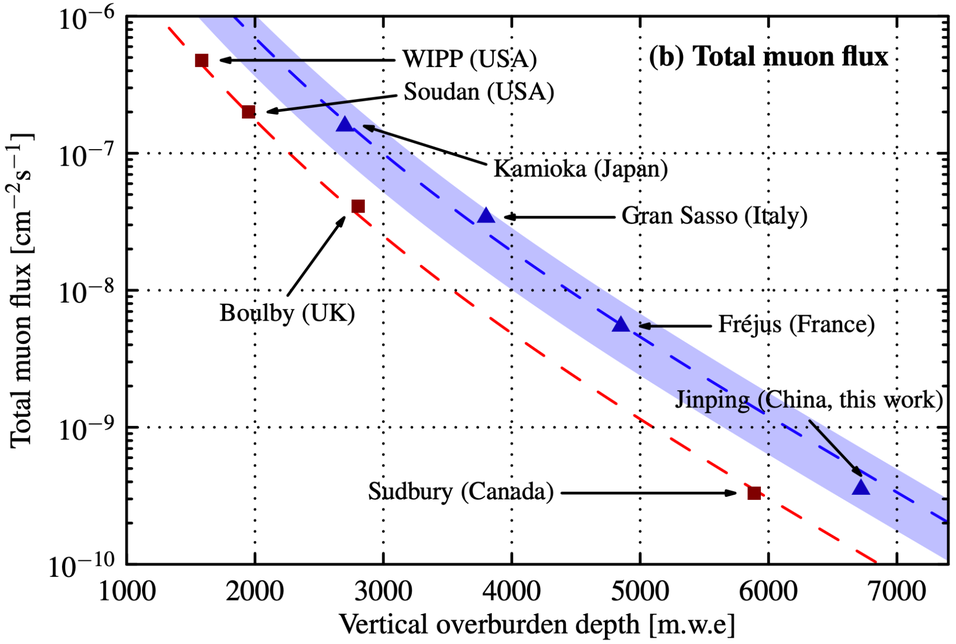
Adjunct Research Professor | SMU

Land Acknowledgement

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.

Introducing 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.



"A visit to SNOLAB" on YouTube

Introducing 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

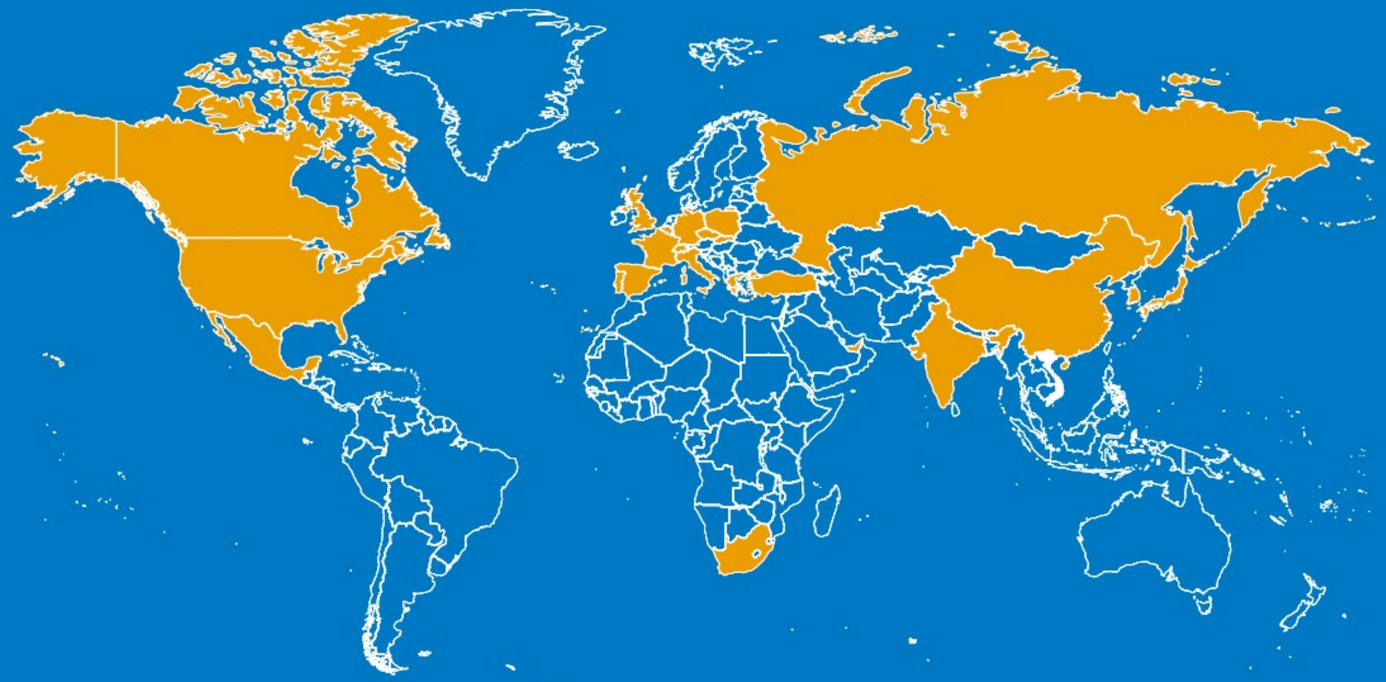
1000+
annual academic users/collaborators

25%
of those users/ collaborators are Canadian researchers

24
Our international collaborators come from 24 countries

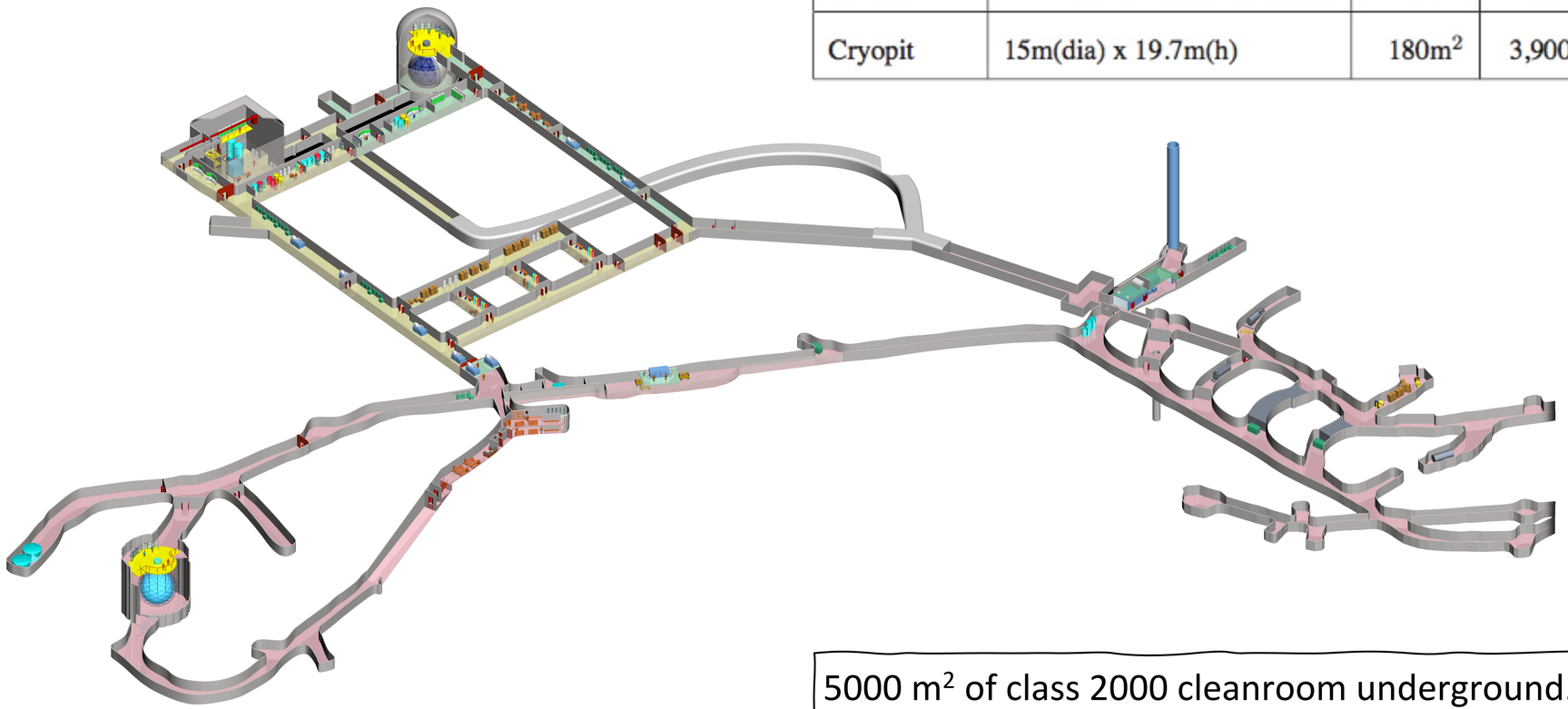
164
Our international collaborators come from 164 institutions

- Participating Countries



SNOLAB Layout

Area	Dimensions	Area	Volume
SNO Cavern	24m (dia) x 30m(h)	250m^2	9,400 m^3
Ladder Labs	32m(l)x6m(w)x5.5m(h)	190m^2	960 m^3
	23m(l)x7.5m(w)x7.6m(h)	170m^2	1,100 m^3
Cube Hall	18.3m(l)x15m(w) x 19.7m(h)	280m^2	5,600 m^3
Cryopit	15m(dia) x 19.7m(h)	180m^2	3,900 m^3

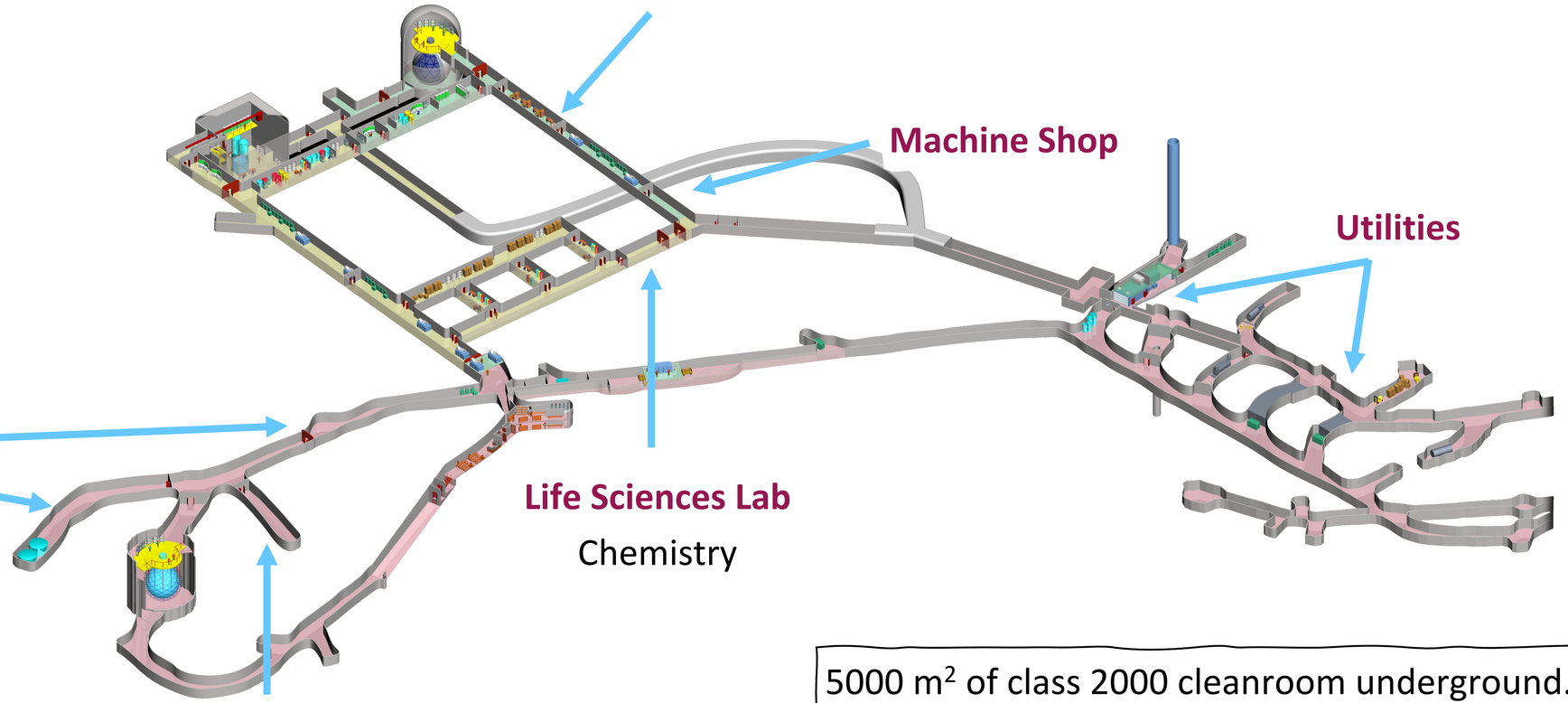


5000 m^2 of class 2000 cleanroom underground.
<2000 particles >0.5 µm in diameter per ft^3

arXiv:2006.12746

SNOLAB –
Facilities

Current Experiments
Future Experiments
Laboratory Facilities
Experiment Areas



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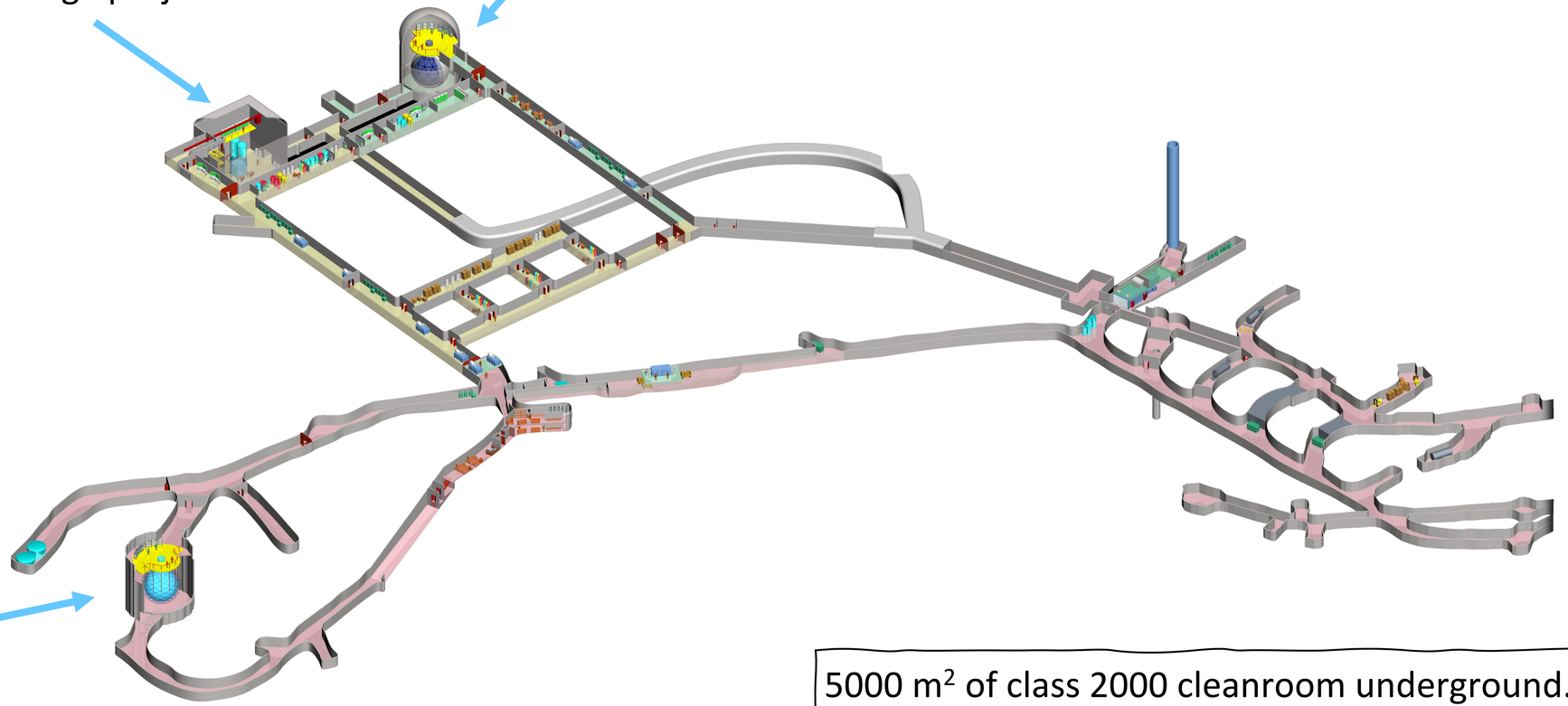
SNOLAB –
Large Cavity Status

Current Experiments
Future Experiments
Laboratory Facilities
Experiment Areas

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

Cryopit
nEXO/LEGEND



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

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

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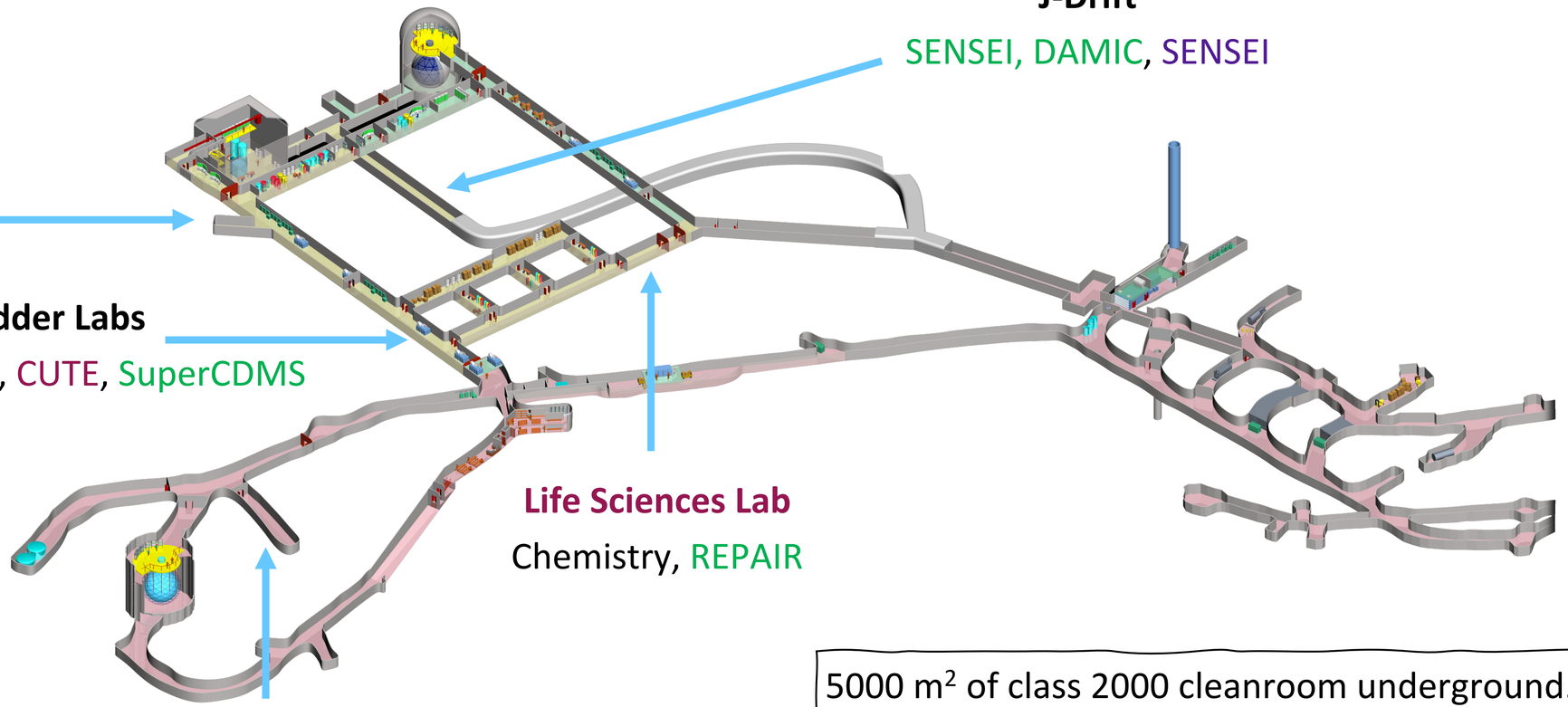
SNOLAB -
Small Cavity Status

Current Experiments
Future Experiments
Laboratory Facilities
Experiment Areas

J-Drift
SENSEI, DAMIC, SENSEI

HaloStub
HALO
potential breakthrough for future expansion

Ladder Labs
PICO40, SBC, CUTE, SuperCDMS



Life Sciences Lab
Chemistry, REPAIR

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

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SNOLAB –
At a Glance

Current Experiments
Future Experiments
Laboratory Facilities
Experiment Areas

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

Cryopit
nEXO/LEGEND

Electrical Shop

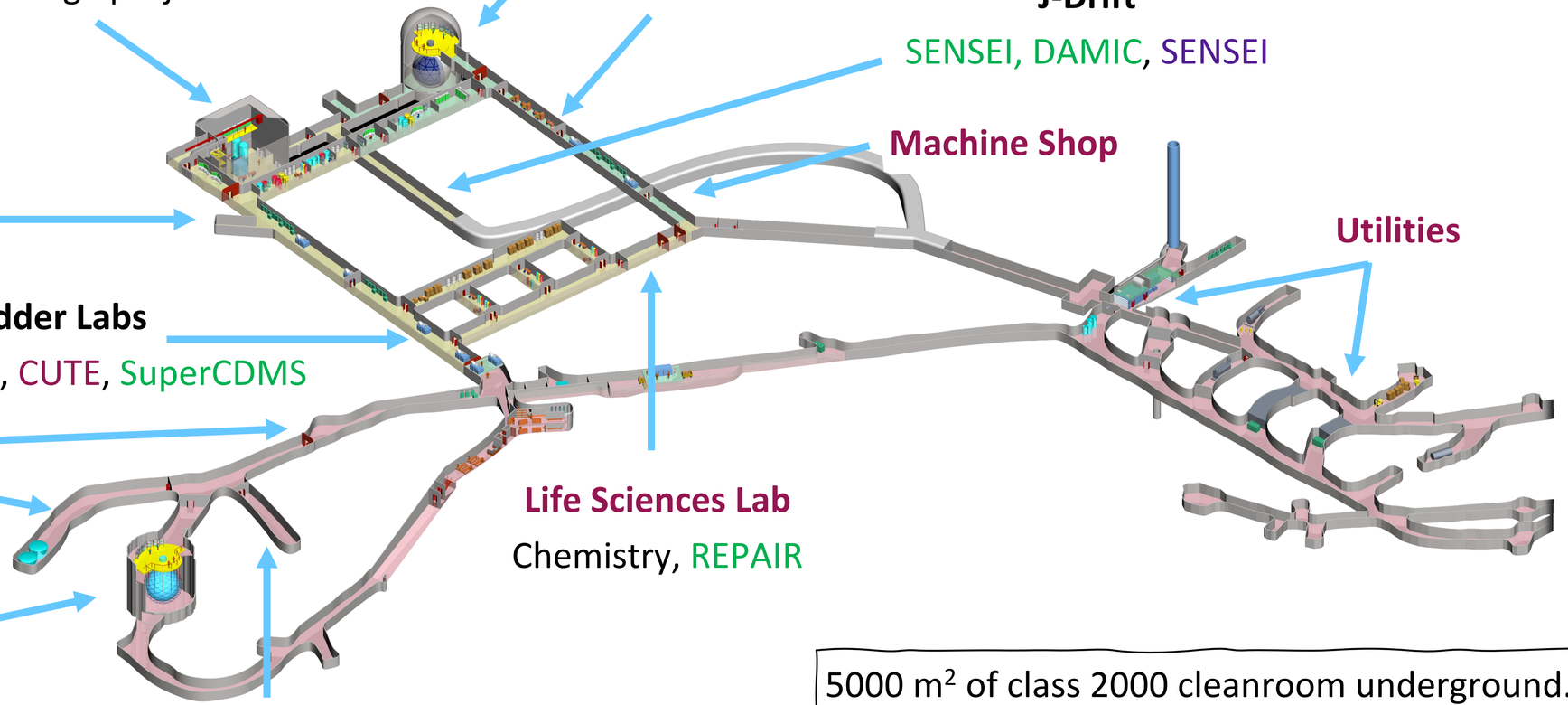
J-Drift
SENSEI, DAMIC, SENSEI

Halo Stub
HALO
potential breakthrough for future expansion

Machine Shop

Utilities

Ladder Labs
PICO40, SBC, CUTE, SuperCDMS



Plants
UPW, 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
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Science Strategy

The science at SNOLAB is focused on increasing 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?

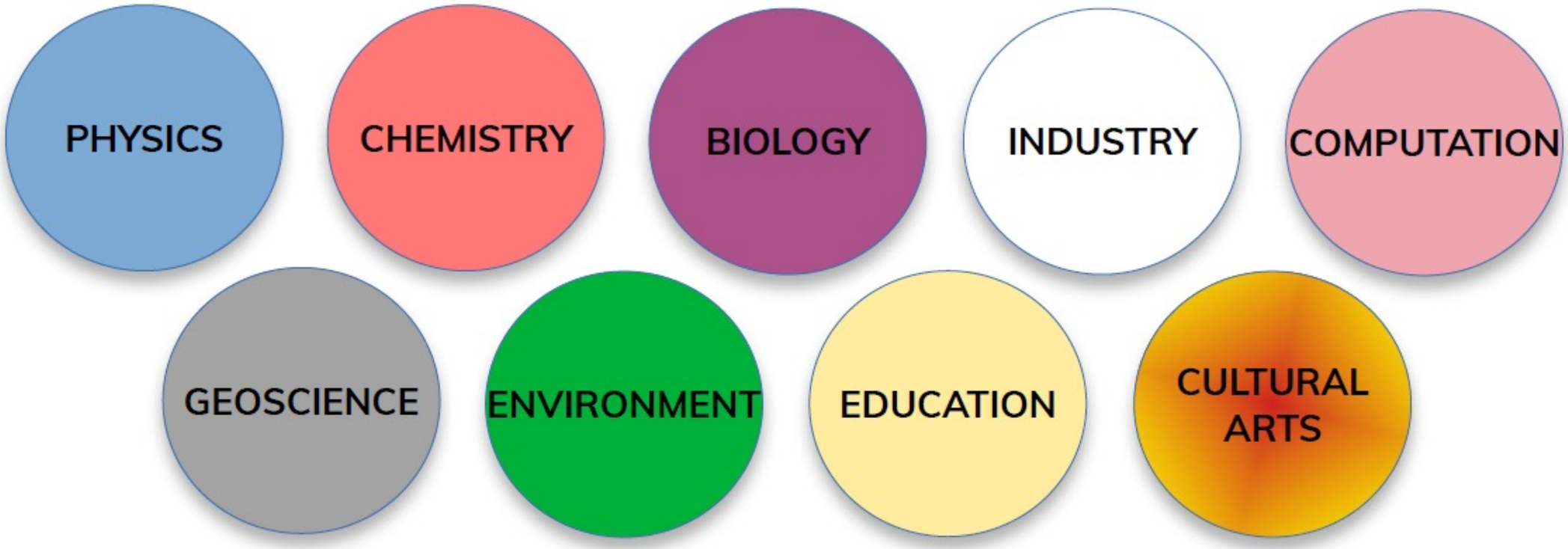
SNOLAB collaborates with scientific research required deep underground facilities.

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

SNOLAB is interested in pursuing new collaborations and opportunities in emerging areas of underground science

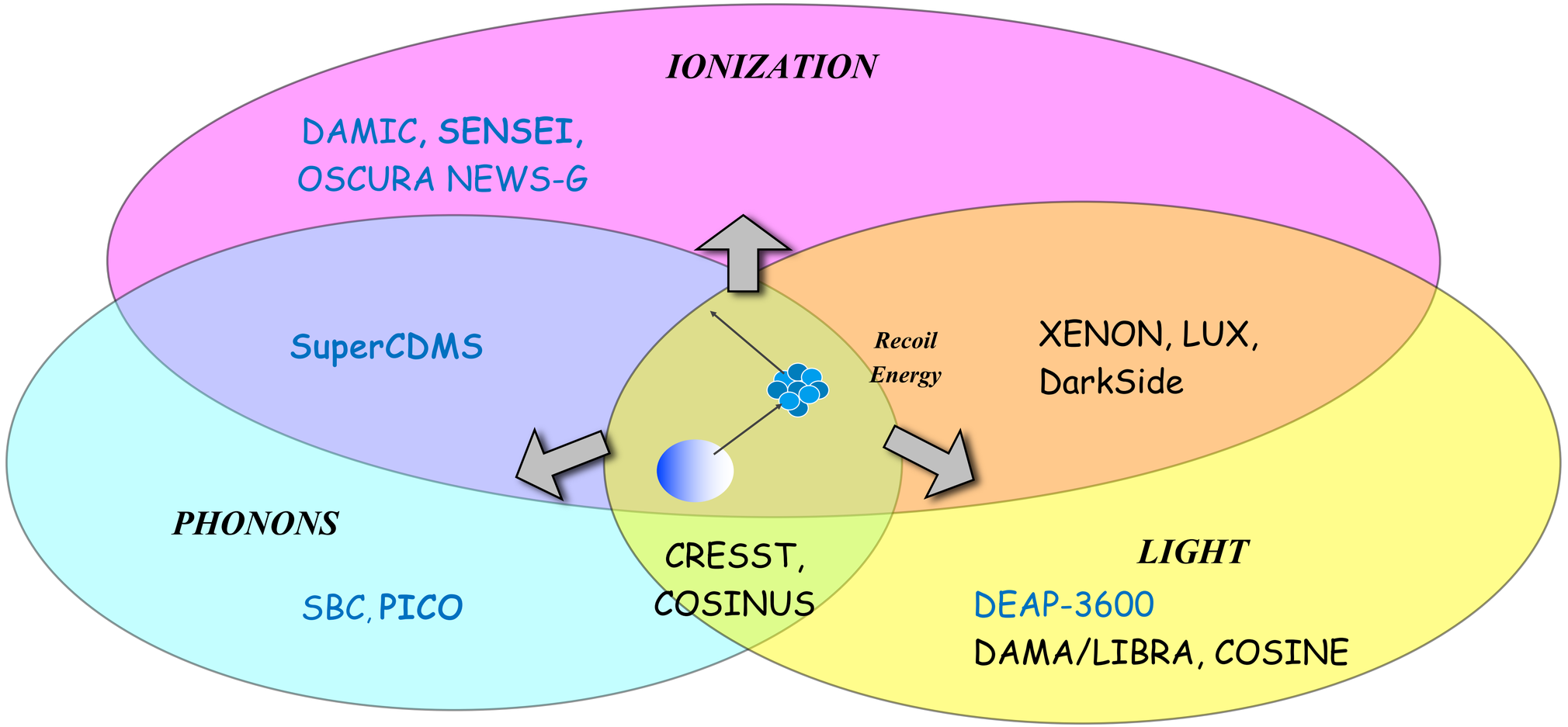
- Effects of radiation on quantum technologies

Disciplines at SNOLAB



Dark Matter @ SNOLAB

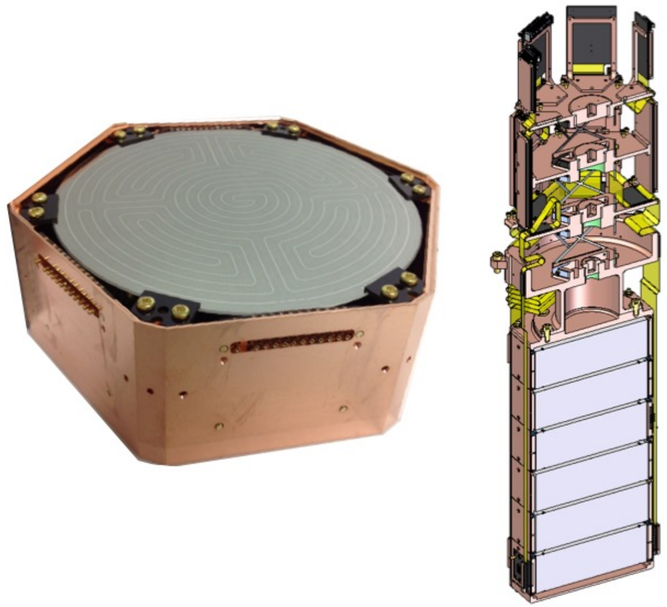
Direct Detection of Dark Matter

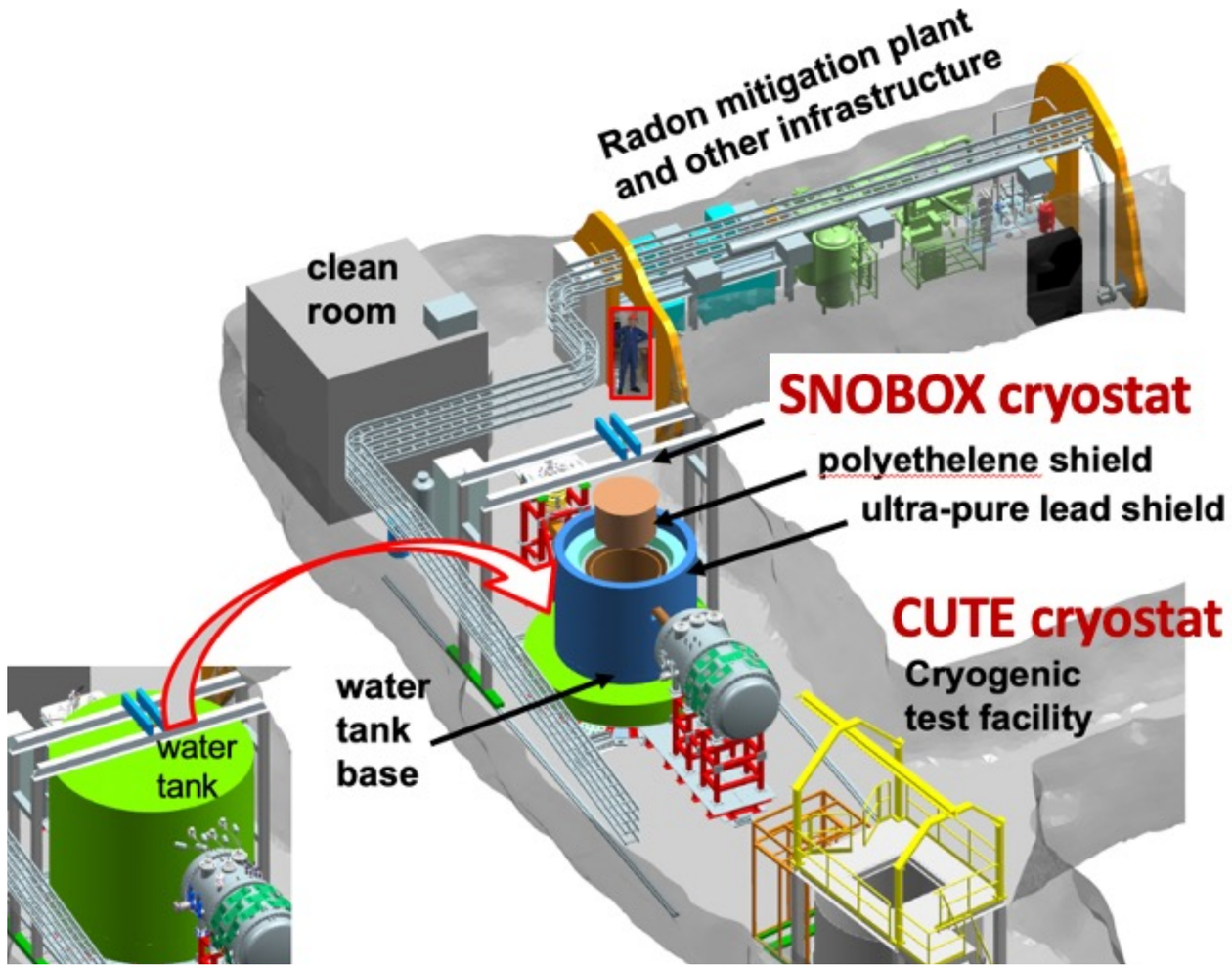


The direct detection of dark matter experiments are currently the most common experiment type at SNOLAB! I apologize that I will not be able to cover all of them!

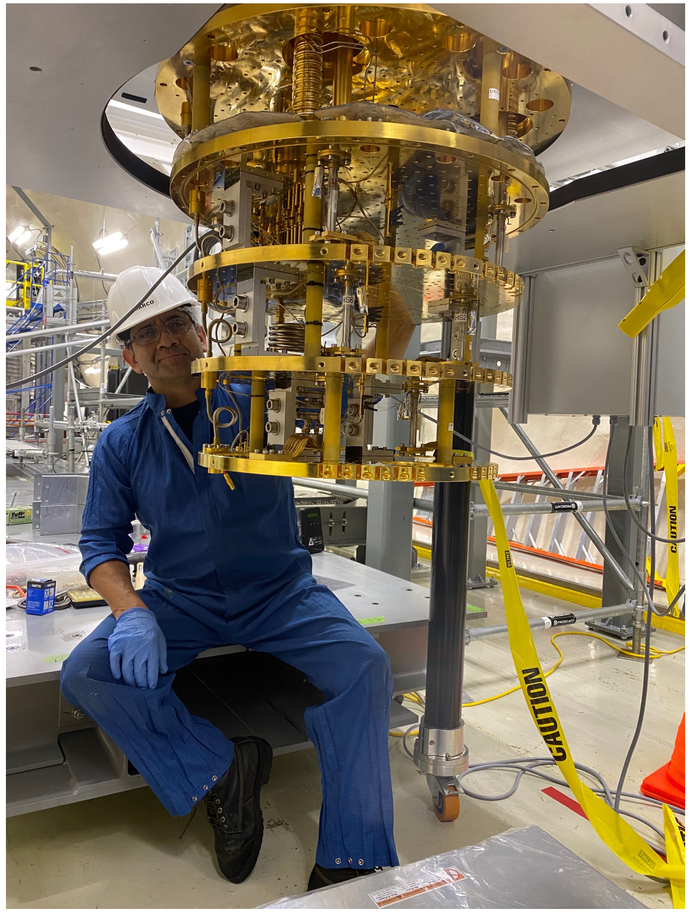
SuperCDMS SNOLAB

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





SuperCDMS Construction Underway!



SuperCDMS Fridge arrived underground on Saturday, February 4th 2022!

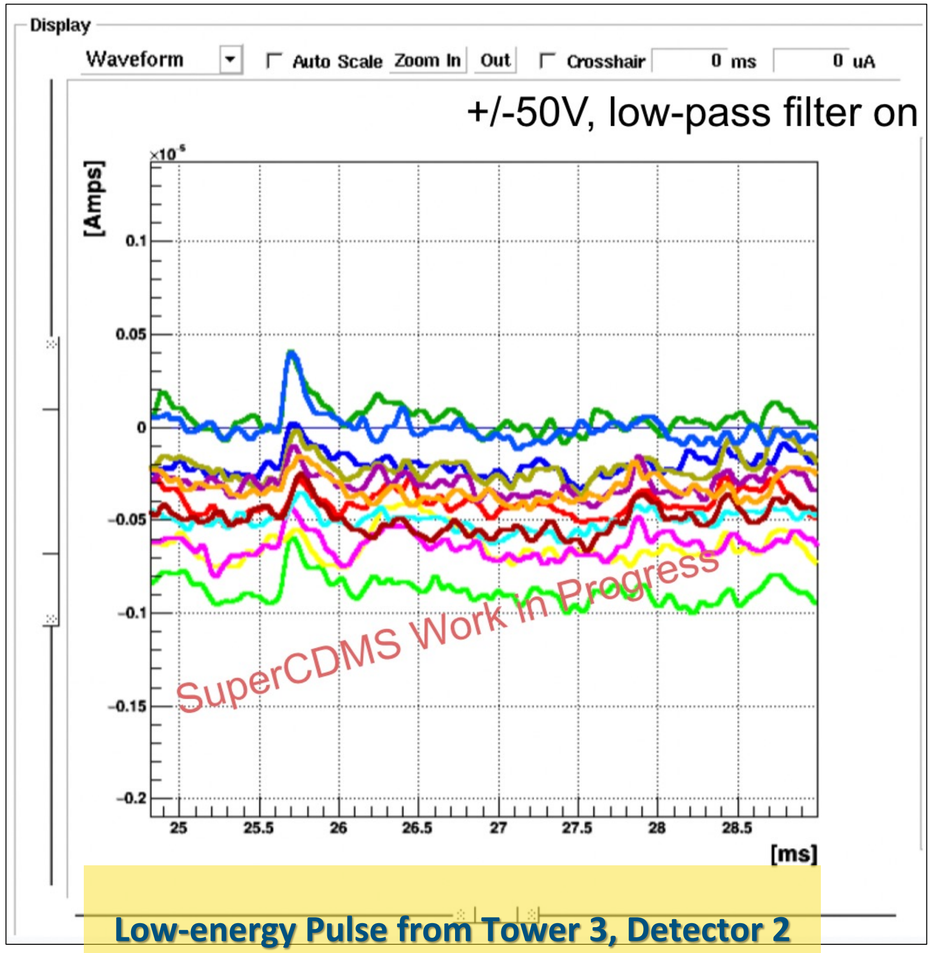
Courtesy of the SuperCDMS Collaboration.

SuperCDMS Construction Underway!

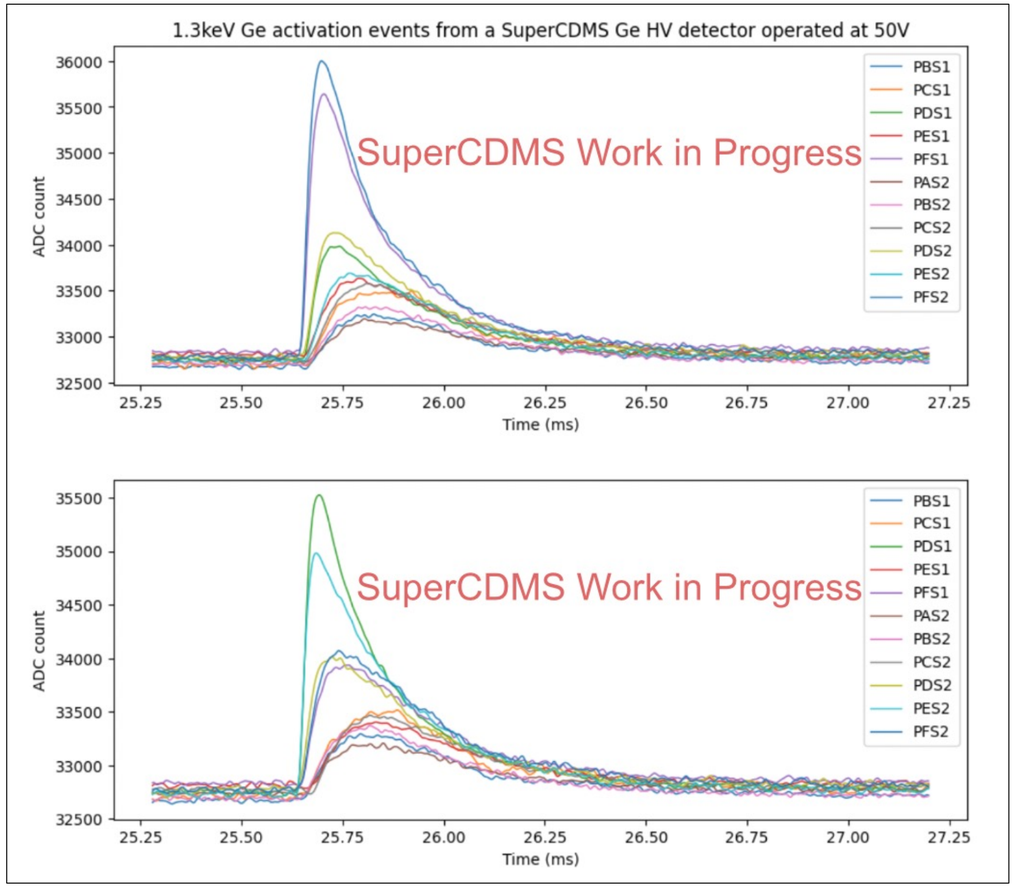
SuperCDMS Towers 3 & 4 arrived underground on Saturday, May 15th, 2022!

Courtesy of the SuperCDMS Collaboration & SNOLAB.

SuperCDMS Tower 3 in CUTE



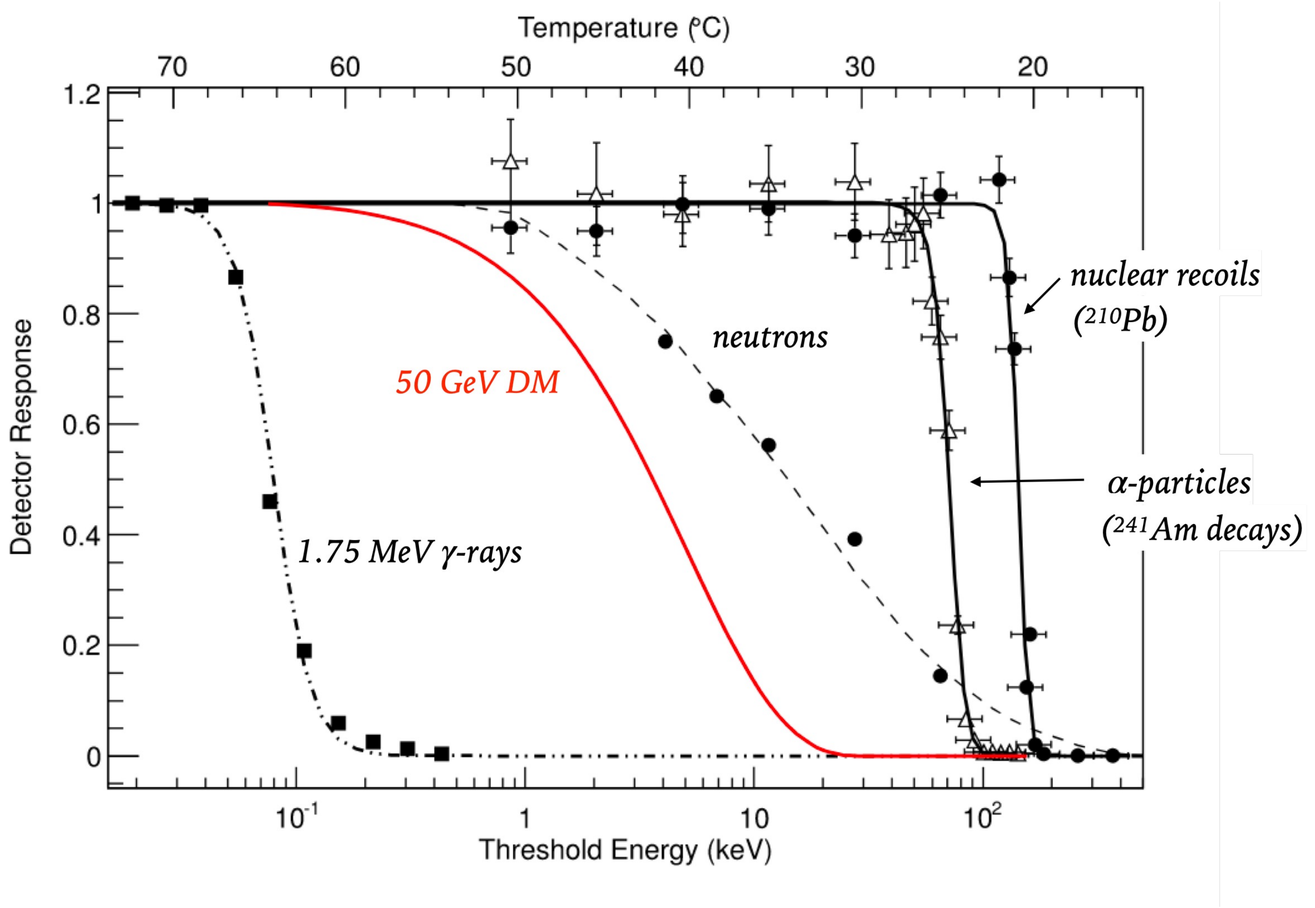
Low-energy Pulse from Tower 3, Detector 2 (Si), all 12 phonon channels shown.



Two 1.3 keV germanium activation peak events in Tower 3, Detector 3 (Ge) … strong position dependence of the signal visible in sensors.

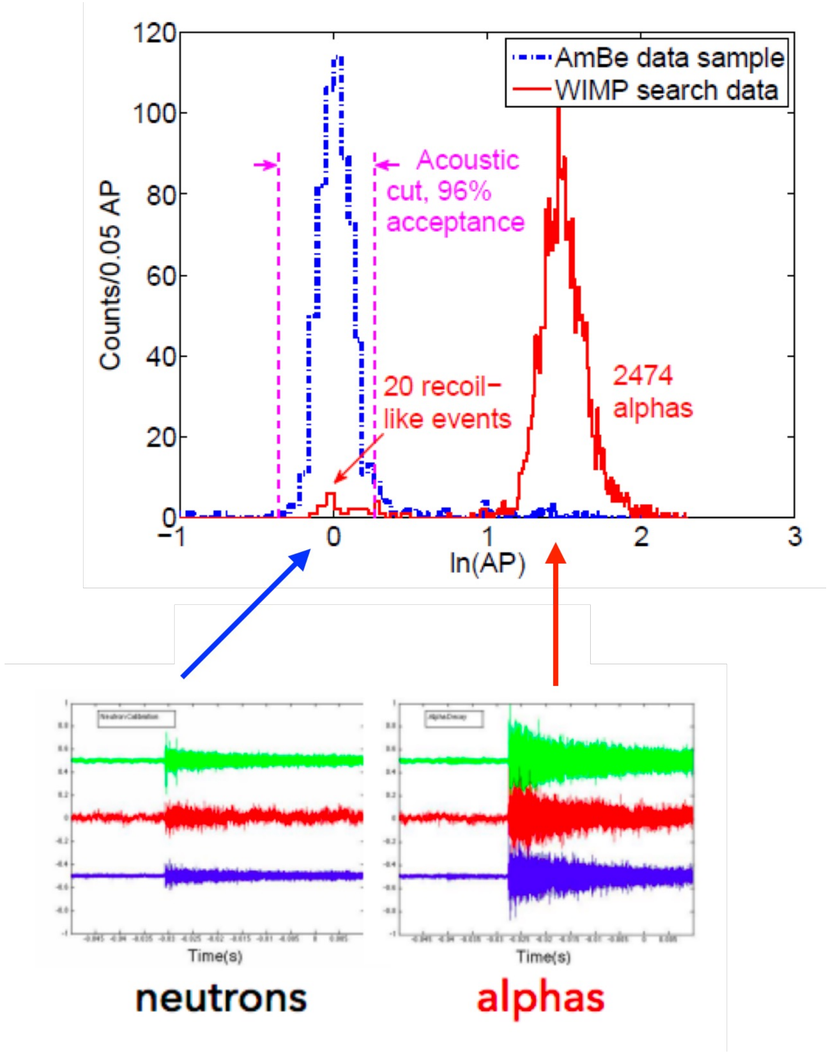
PICO Detector Response

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

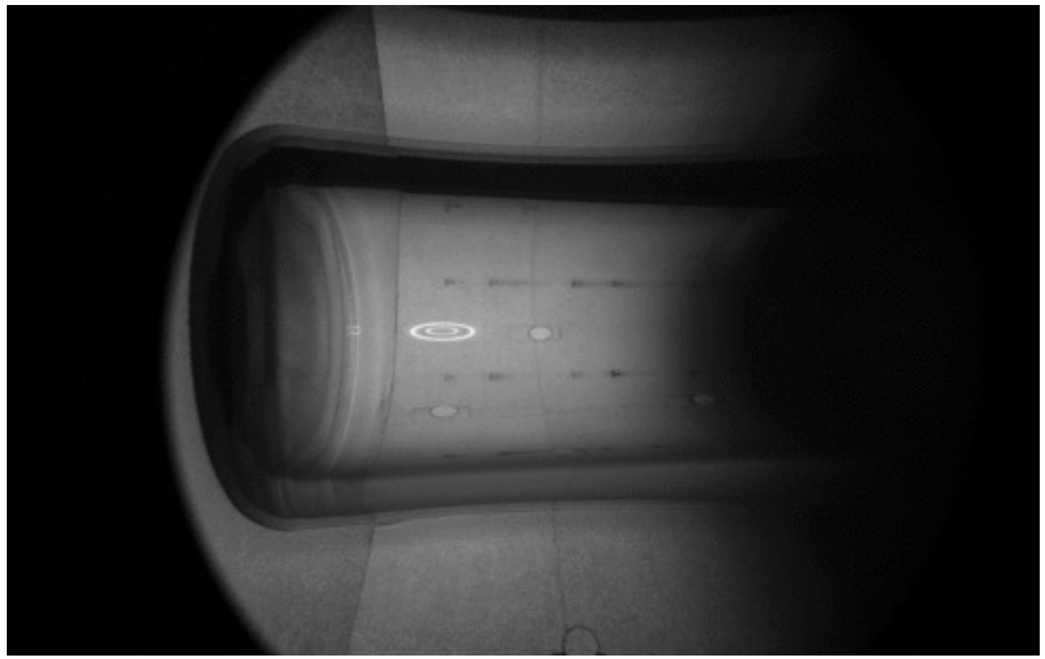


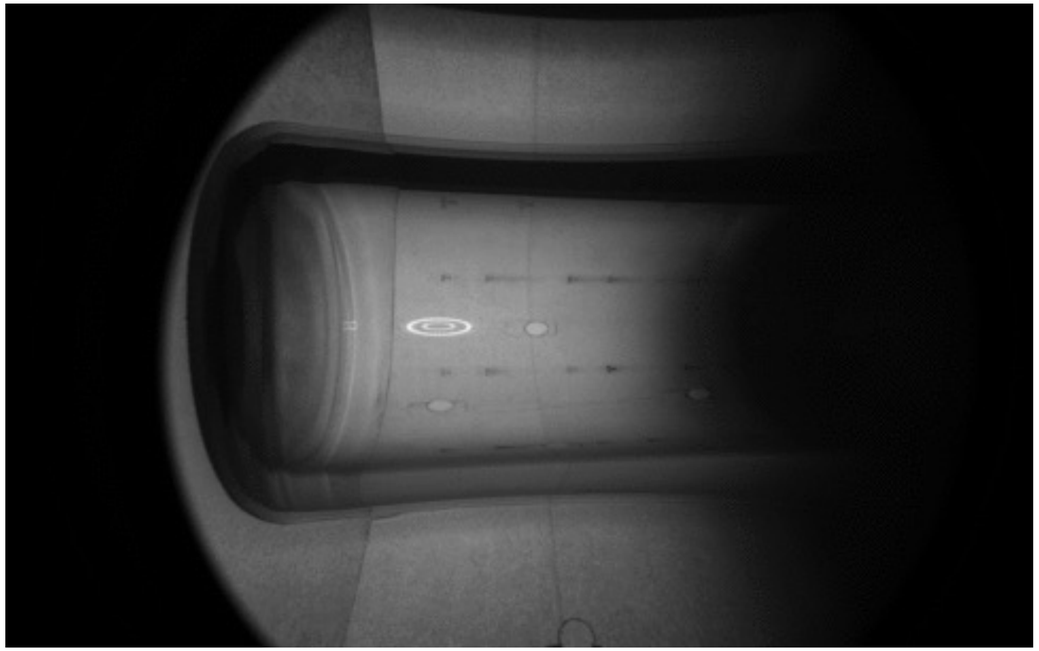
PICO Detector Response

- 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



PICO-40L Begins Operations





Courtesy of the PICO Collaboration.

PICO-40L bubbles! Regular operations began in February 2022.

Construction of PICO 500 ongoing.

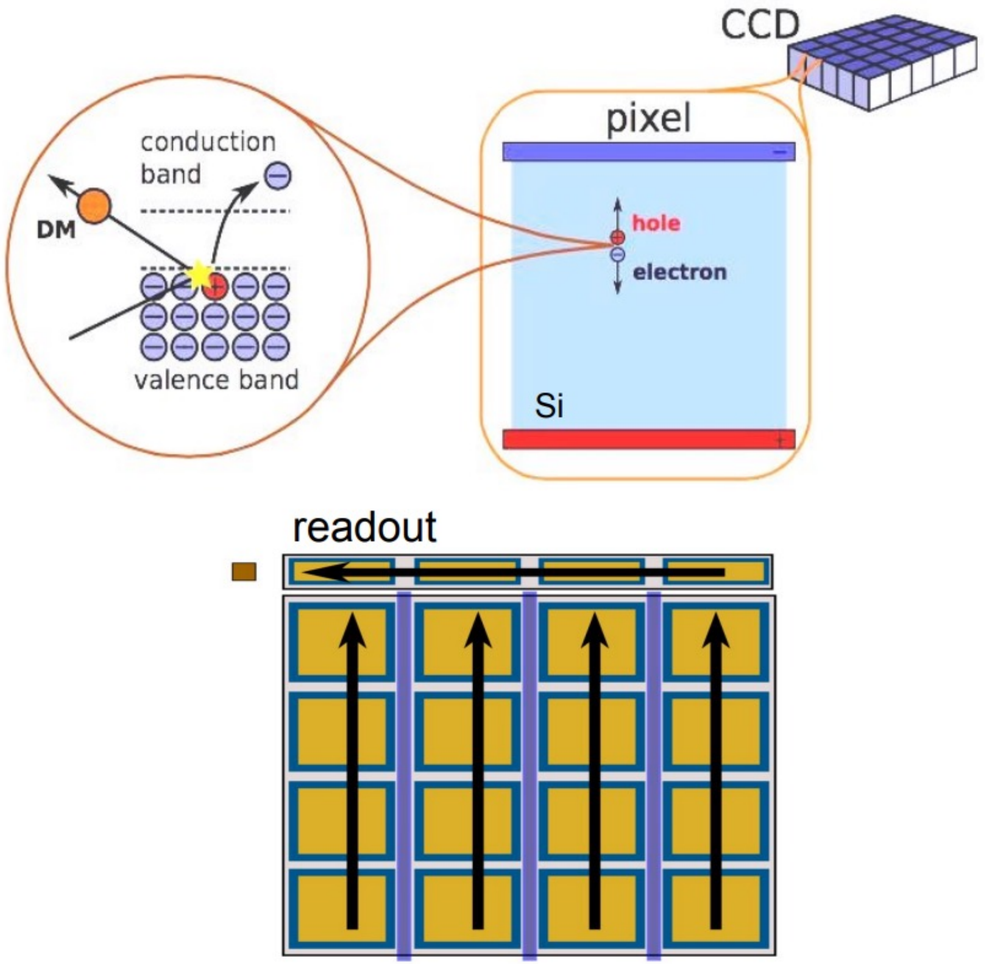
CCD Detectors

Silicon charge-coupled devices (CCDs) w/ Skipper amplification (designed by LBNL):

- Energy threshold of Si bandgap (~1.1 eV)
- Low dark current (~10-4 e-/pix/day)
- Sub-electron (~0.1e-) readout noise

Access to low-mass searches:

- Electron scattering of 1-1000 MeV DM
- Nuclear scattering of 1-1000 MeV DM via Migdal effect
- Absorption of 1-1000 eV DM
- Scattering of milli-charged particles
- Etc…



SENSEI @ SNOLAB: New Results

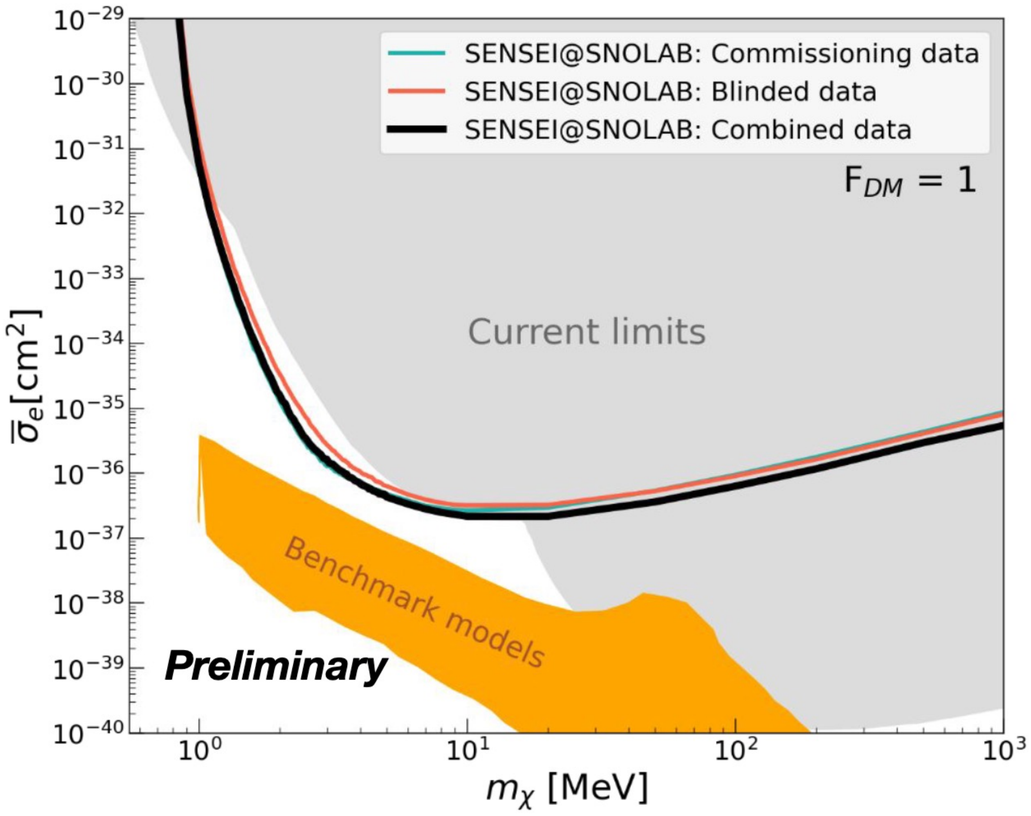
Dark matter-electron scattering limits

Data: 45 unblinded commissioning images, 37 hidden images, 2-10 e^- channels

Exposure: combined datasets amount to ~70 g-days per electron channel with current masks

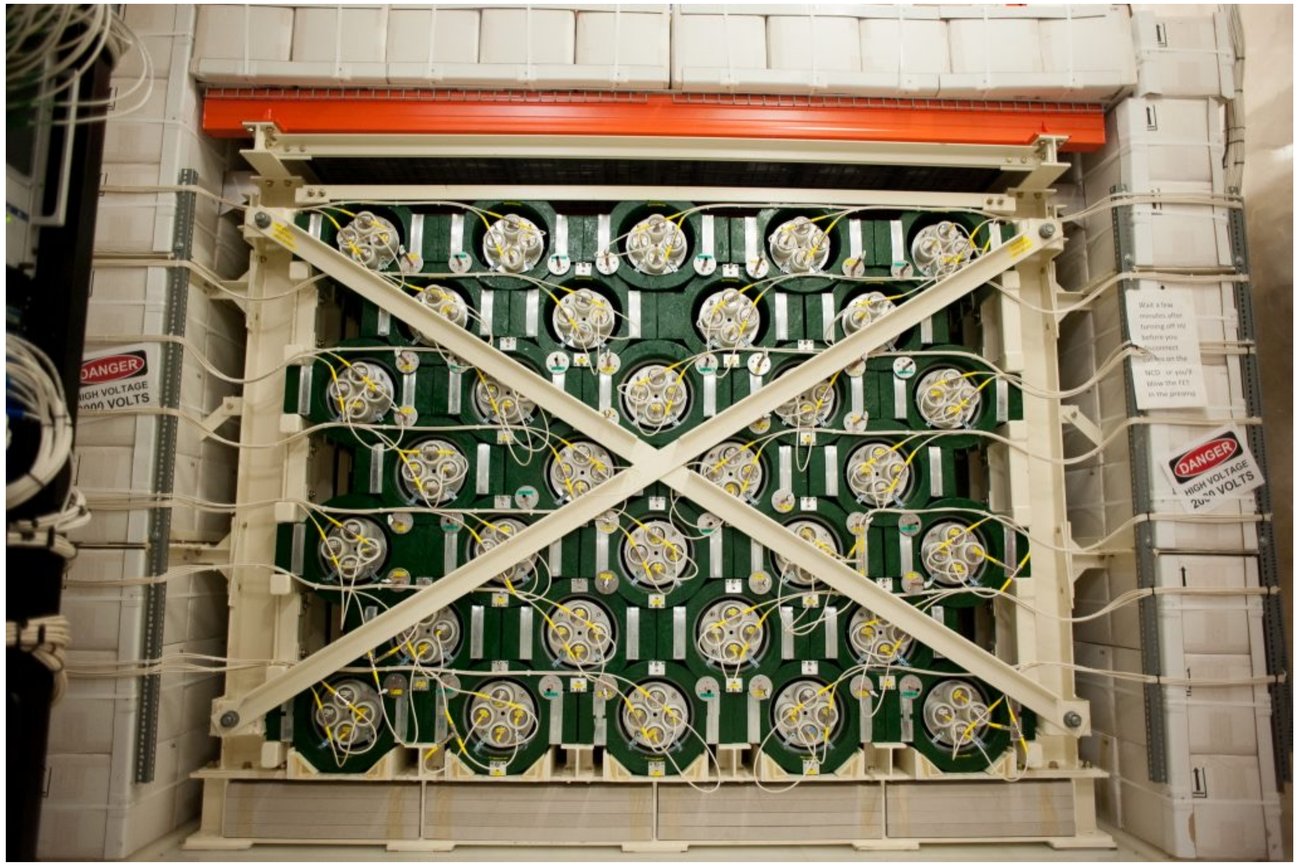
Three limits: blinded dataset, commissioning dataset, and combined commissioning + blinded exposure

Paper in preparation to present full results

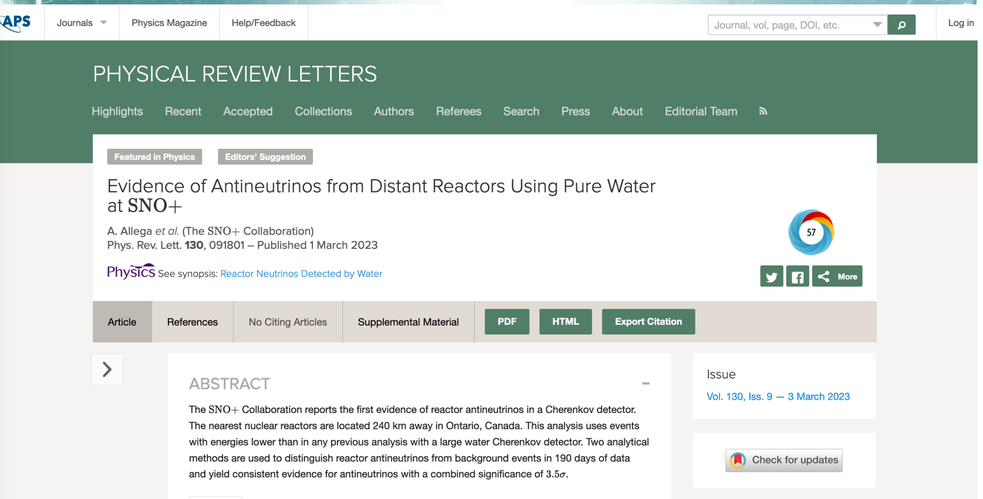


Neutrino Program @ SNOLAB

HALO



- 79 tonnes of annular lead blocks instrumented with 128 tubular Helium-3 neutron detectors to detect neutrinos from supernovae within our galaxy.
  - Detects neutrons that result from neutrinos interacting with lead
- Part of the worldwide Supernova Early Warning System (SNEWS)
  - Aims to detect supernovae by their neutrino burst, before their light reaches Earth, allowing time to notify astronomical observatories all over the world.
- ***It is the longest running experiment at SNOLAB***

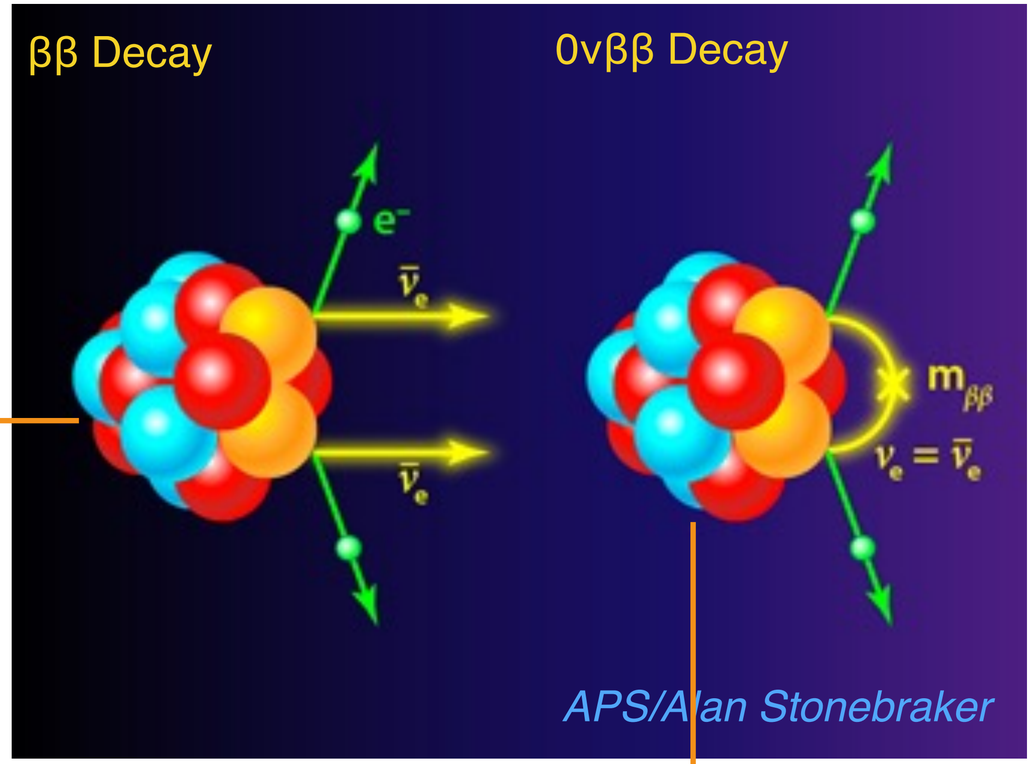


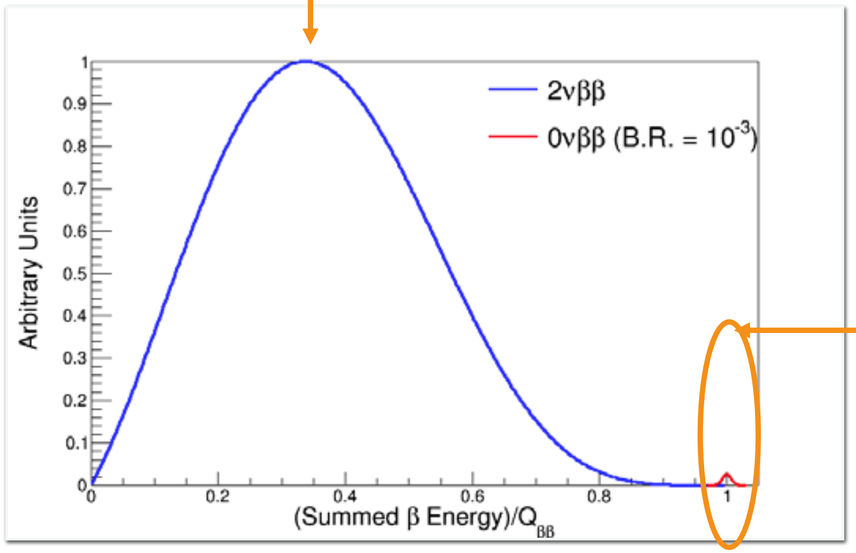
On Going SNO+ Neutrino Physics

- SNO+ is an operating neutrino detector with 780 tonnes of liquid scintillator
- Water Phase: completed
  - First observation of reactor neutrinos in water
  - set world-leading limits on invisible nucleon decay
  - measured the ^{8}B solar neutrino flux with very low backgrounds
- Pure Scintillator Phase: ongoing
  - detecting low energy ^{8}B solar neutrinos
  - detecting reactor (and geo) antineutrinos to independently measure $[\![\Delta m]\!]122$
  - supernova neutrino live
  - Results expected for ^{8}B neutrinos soon.

Double Beta Decay

2 neutrino double beta decay is allowed in some isotopes, involves transformation of 2 neutrons into two protons





If neutrinos are Majorana particles, then neutrino-less double beta decay should be allowed.

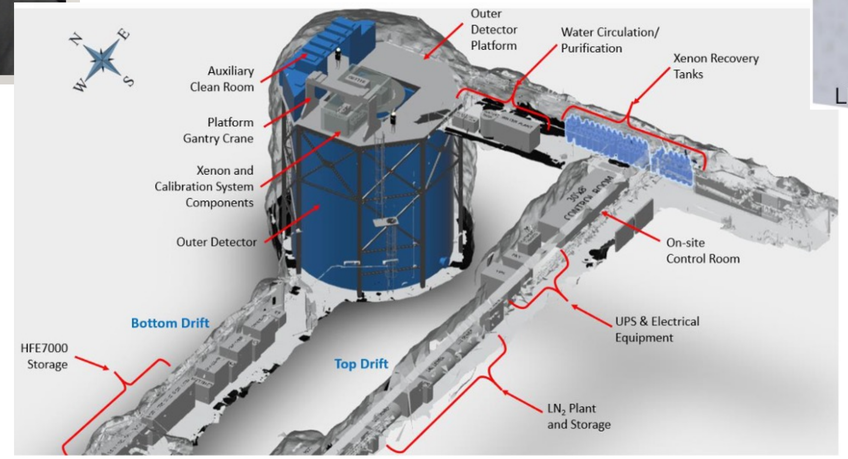
0νββ Decay at SNOLAB

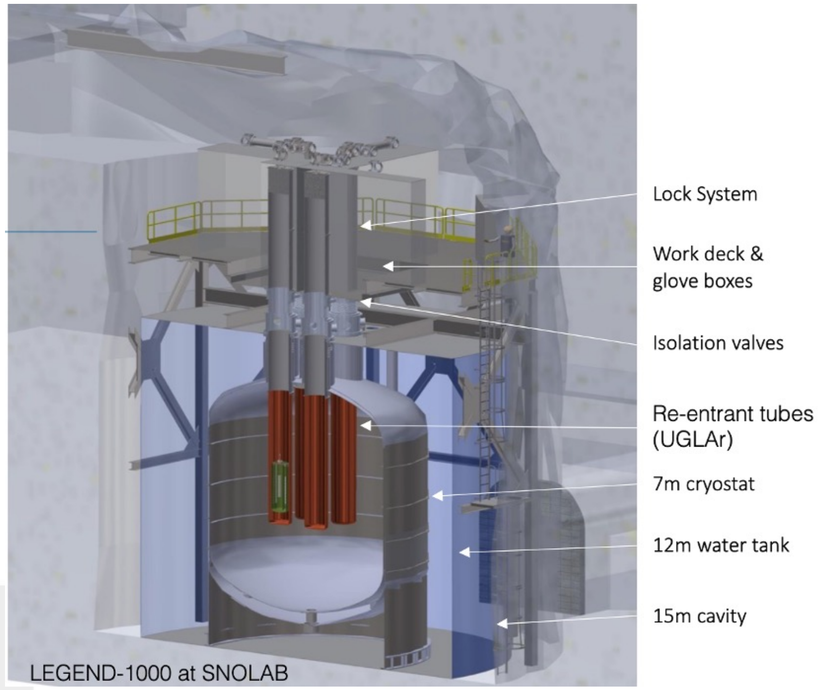
SNO+

- Plan to add more than 1,000 kg of ^{130}Te to the detector with sensitivity that reaches the Inverted Mass Ordering
- Tellurium plant has been installed and preparations are ongoing for systems tests.

nEXO

- 5000 kg xenon TPC detector
- Enriched with 90% ^{136}Xe enables sensitivity that reaches the Inverted Mass Ordering
- Builds on success of EXO-200
- Currently in design phase



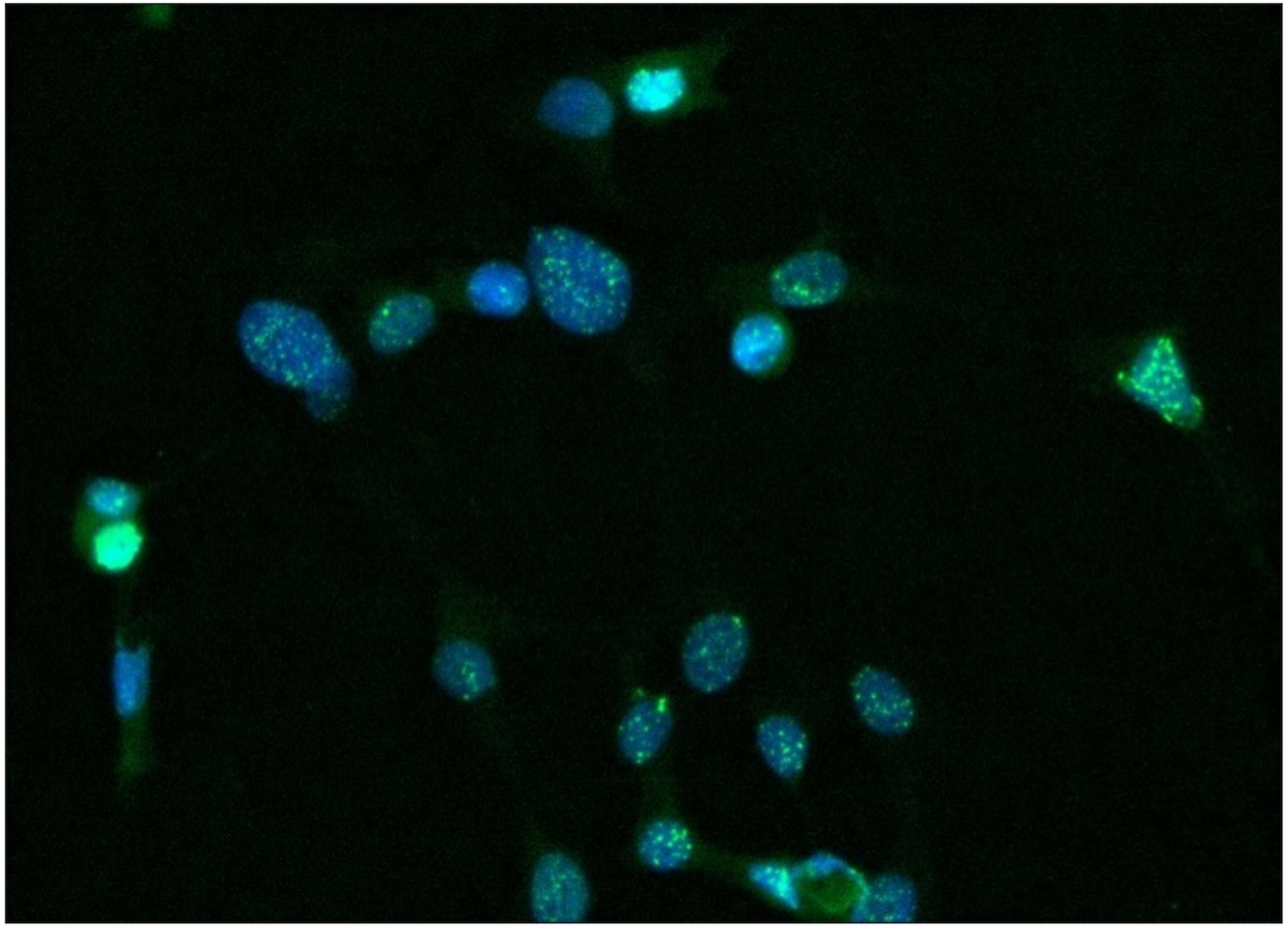


LEGEND-1000

- 1000 kg of Ge detectors enriched to more than 90% in ^{76}Ge enables sensitivity to the inverted mass ordering
- operated in a liquid argon active shield
- Builds on success of GERDA and Majoranna
- Currently in design phase

Biology @ SNOLAB

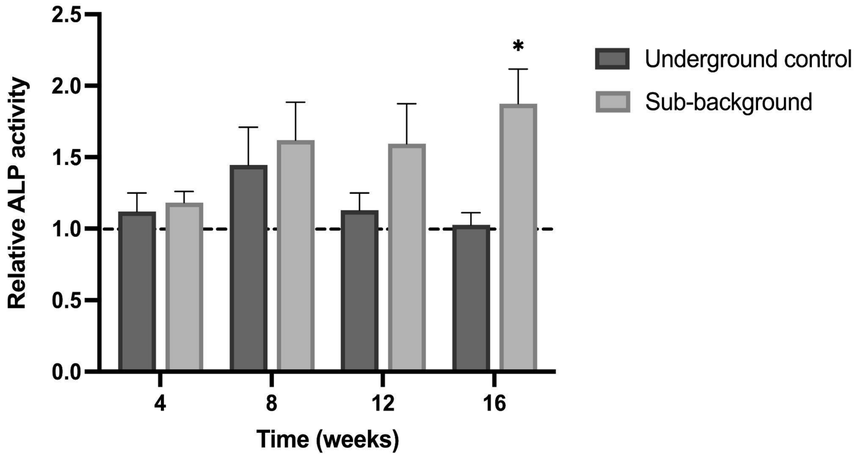
REPAIR



- 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.

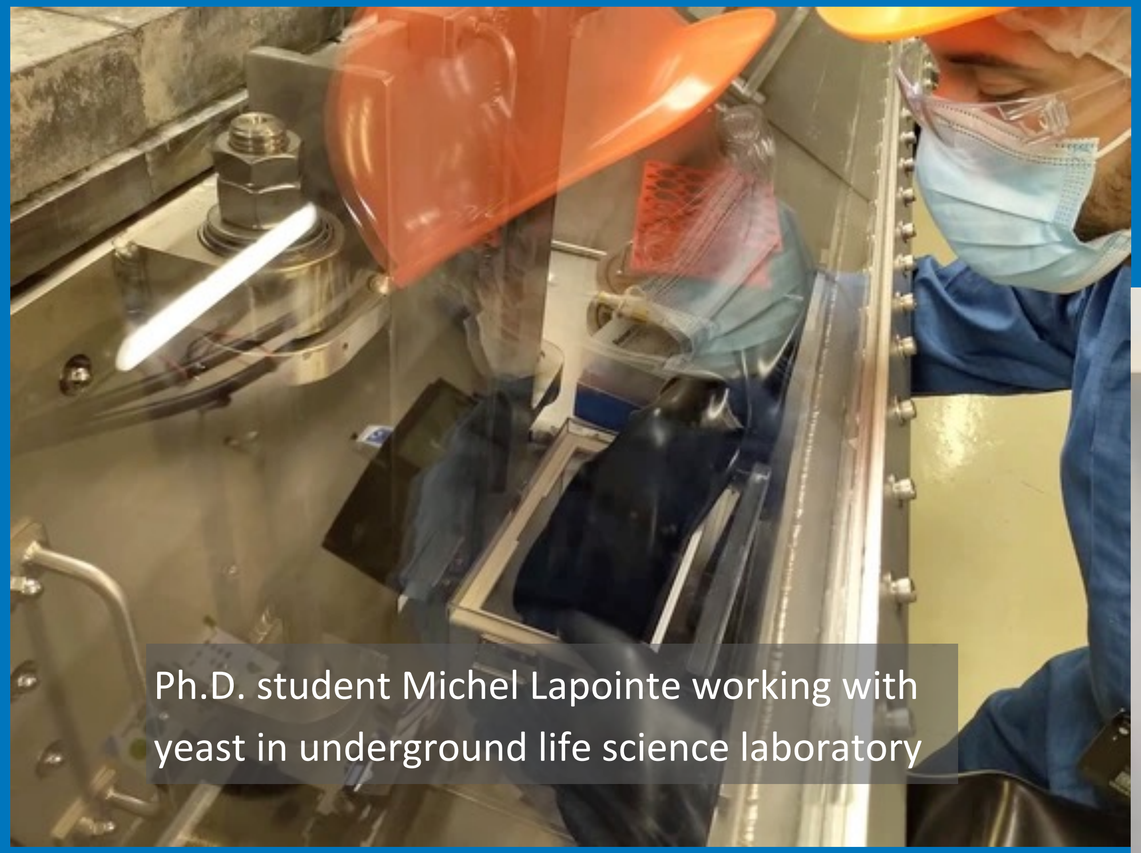
REPAIR: New Results

Human cells (CGL1) cultured in the **absence of natural background radiation** elicited a **greater expression of a marker** (ALP) for neoplastic transformation (**cancer**).



c.f. *Radiation Research, 199(3):290-293 (2023)*

Courtesy of REPAIR Collaboration



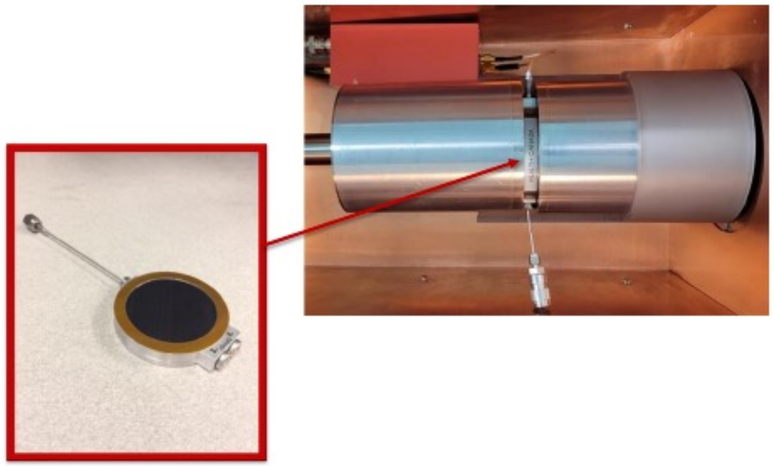
Ph.D. student Michel Lapointe working with yeast in underground life science laboratory

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 deepspace radiation. *(Results pending publication in Health Physics Journal)*

Nuclear Monitoring @ SNOLAB

Nuclear Forensics

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



Quantum Initiatives @ SNOLAB

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 will be tested in Sweden, Waterloo, then SNOLAB (housed in CUTE).
- Project is newly selected, contracting has just started.

Conclusions

- SNOLAB is a clean, underground laboratory hosting a variety of experiments and we welcome opportunities to collaborate and solve difficult problems.
- Experimental collaborations have produced many scientific results at SNOLAB and many more world-leading results are expected over the next decade
- SNOLAB has a broad, multidisciplinary science program. We hope to see your experiment in out lab some day soon!