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Discoveries in the Deep: Opportunities at SNOLAB

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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

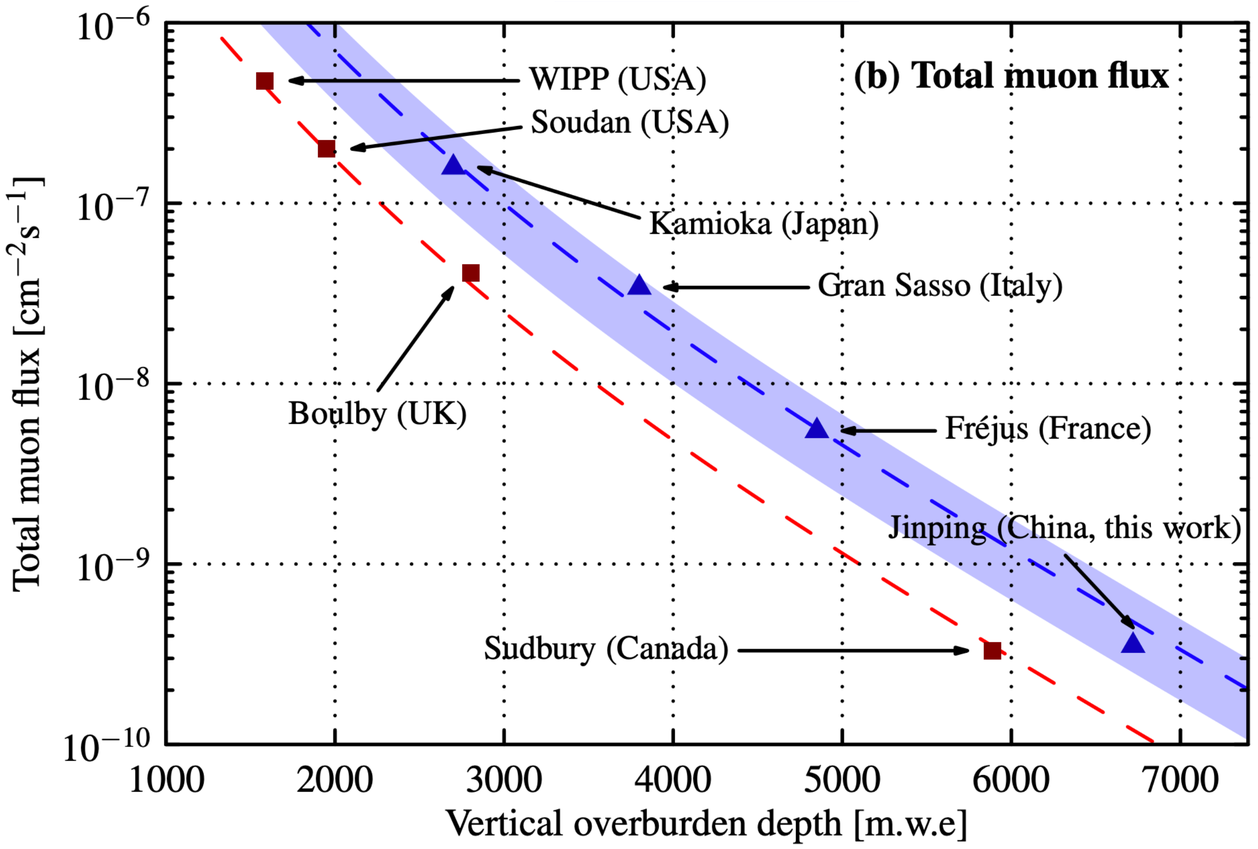
SNOLAB operations are funded by the Province of Ontario, and the Canada Foundation for Innovation

"A visit to SNOLAB" on YouTube

SNOLAB is *underground* to shield high energy radiation from space, *and clean* to remove backgrounds from dirt

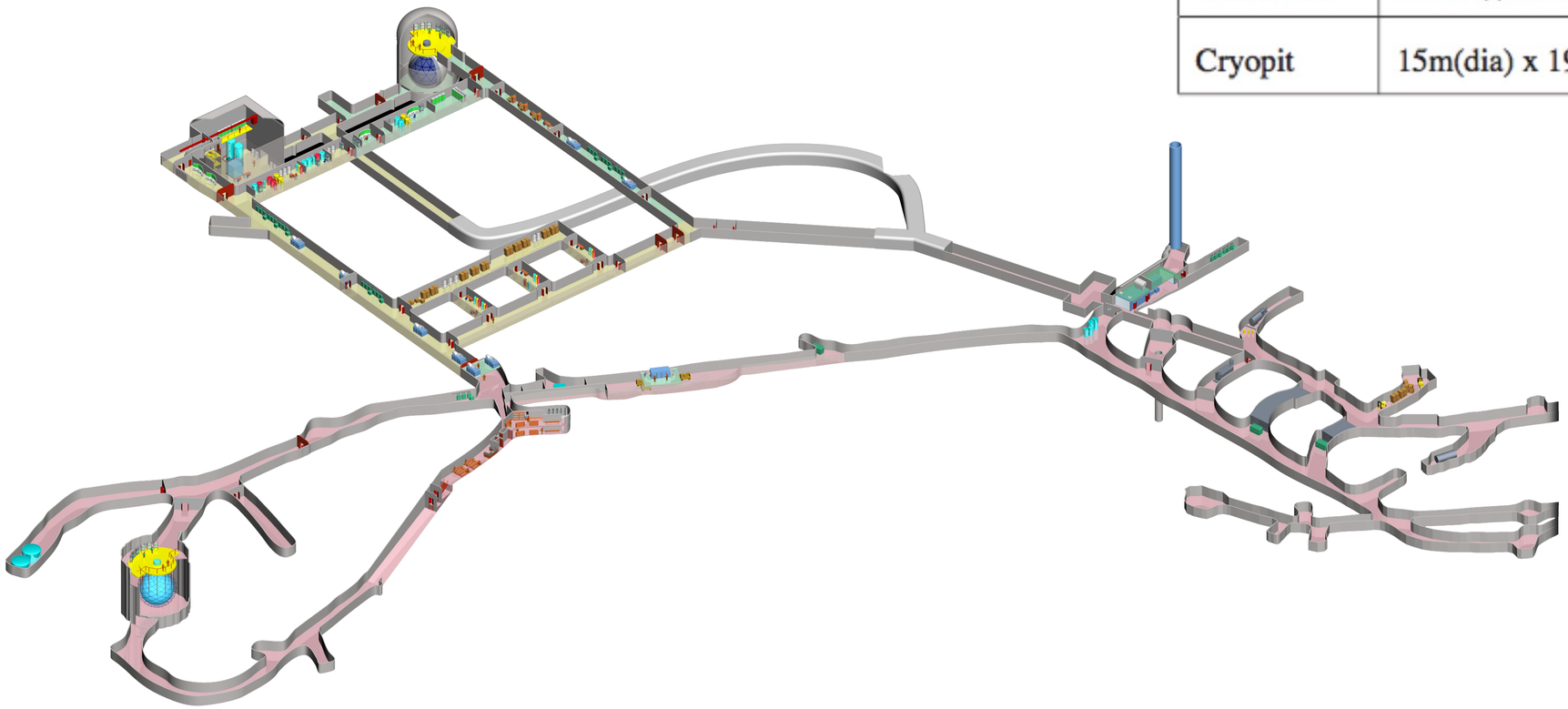
- Astrophysical systems emit high energy radiation which create muons in Earth's atmosphere
- 2 km granite shield
- SNOLAB has the lowest muon fluxes available
- Clean room throughout the underground facility
  - Dirt is high in radioactivity to us
- Growing community of users
- Rare event searches require low backgrounds

Guo et al., arXiv:2007.15925v2



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

Large Cavity Status

Cube Hall

DEAP-3600, PICO500, NEWS-G

potential for large project

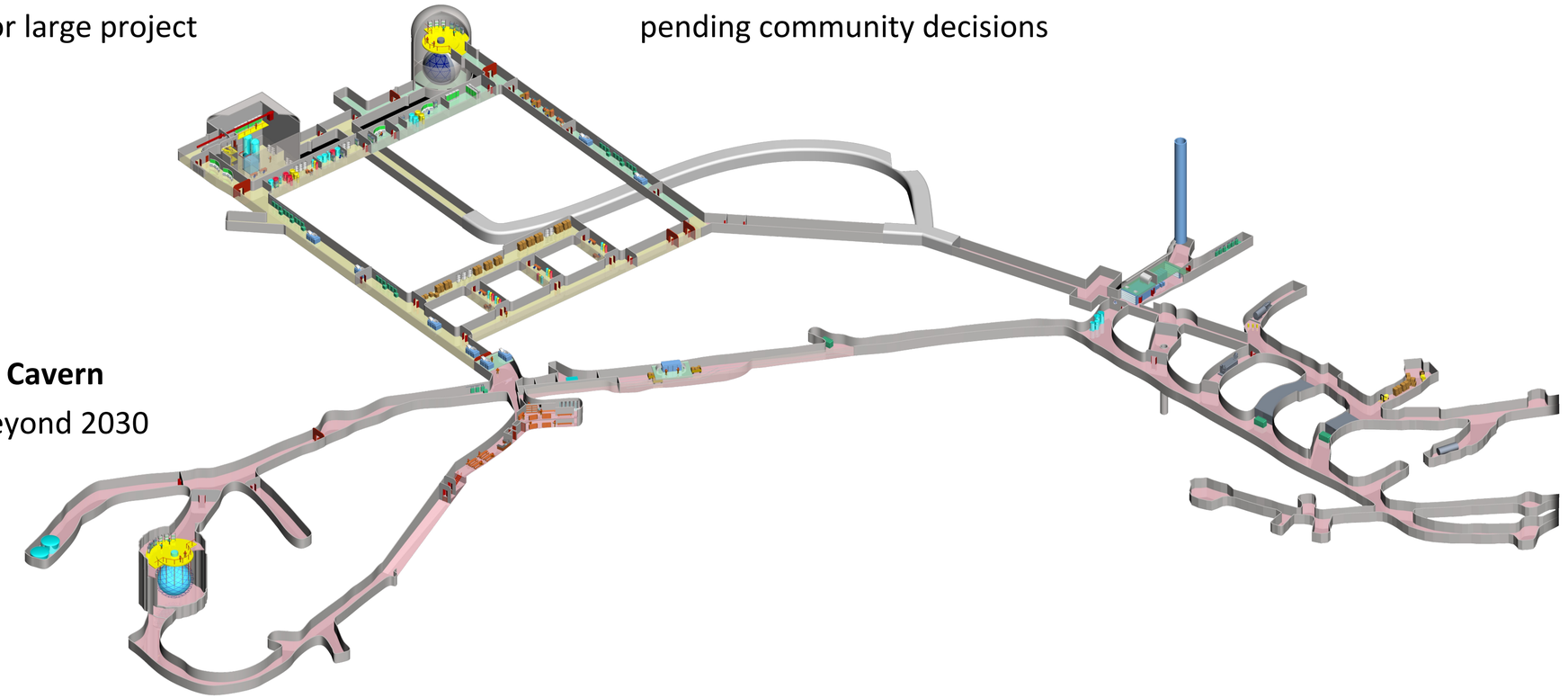
Cryopit

Ton-scale 0vbb beyond 2030

pending community decisions

SNO Cavern

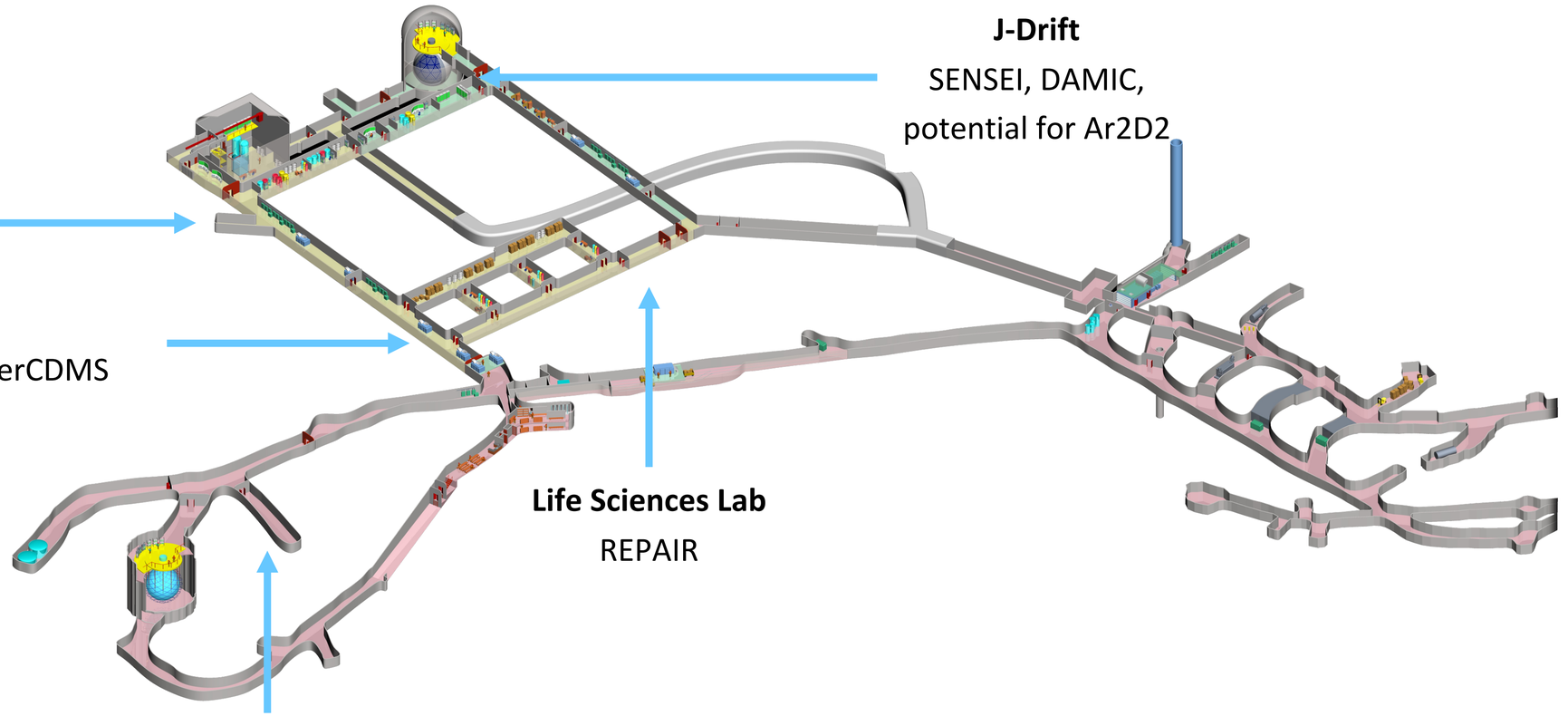
SNO+ beyond 2030



Small Cavity Status

Halo Stub
HALO
potential breakthrough
for future expansion

Ladder Labs
PICO40, SBC, CUTE, SuperCDMS



J-Drift
SENSEI, DAMIC,
potential for Ar2D2

Life Sciences Lab
REPAIR

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

SNOLAB people enable science

SNOLAB has a focus on User Support

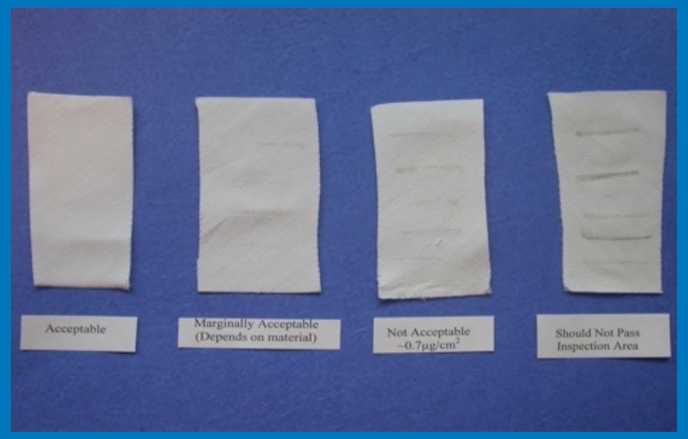
- Scientific
- Engineering
- Construction
- Operations

Sudbury hosts a strong mining/industrial base that projects can draw from

- Excavation
- Fabrication
- Integration

Laurentian University is the research anchor for the user base

Cleanliness is critical to SNOLAB operations and science



New Underground LN2 Plant

The LN2 Plant is operational since May 2022, creating high purity LN2 (99.999%)* at 3,000 L/week.

It is currently used for cooling down the HPGe detectors and will soon provide it GN2 through the LBL gas distribution system.
It is currently supplying the CUTE facility, and soon all users at SNOLAB will use this LN2 system.

* <0.001% oxygen

Additional SNOLAB Infrastructure

Power and Cooling (~2 MW capacity)
Backup Generator (2019)
Purified water (140 L/min capacity)
Purified liquid scintillator (LAB+PPO)
Network (10 Gb/s, more fibers available)
Wet chemistry lab (fume hood just operational)
Machine shop at surface and underground

Surface laboratories for additional chemistry and assembly (4700 ft^2, class 1000)
Offices, Meeting rooms, Auditorium

Open source code: https://github.com/pnnl/Radiopurity-database-assistant

Updated Radiopurity.org Framework

Pacific Northwest National Laboratory, SNOLAB

Material Assay Data Format (MADF)

Standardized, but flexible, json format

Database Assistant New!

Open source format for storing, displaying and manipulating MADFs

Public instance maintained by SNOLAB

https://www.radiopurity.org/ Upgraded!

Can share results easily with community when ready

MongoDB Database and python-based toolkit

Up-to-date standardized codebase

Improved structure, ability to modify

'old versions' collection in database to track changes to entries (linked by document ID)

This replaces a deprecated CouchDB database (Persephone)

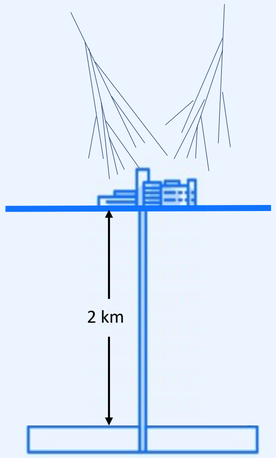
Science Strategy

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:

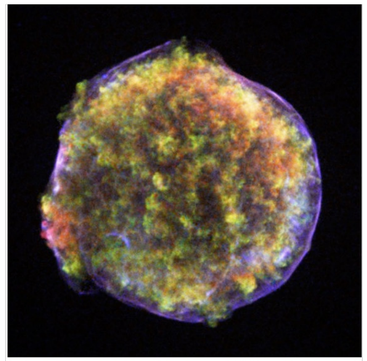
- Neutrino observatories (solar, supernovae, geo, reactor, etc.)
- Effects of radiation on biological systems
- Environmental monitoring (nuclear non-proliferation, aquifers, etc.)
- Effects of radiation on quantum technologies



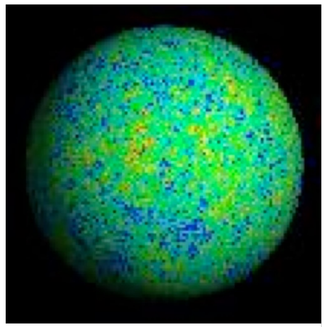
Dark Matter @ SNOLAB

Gravitational lensing

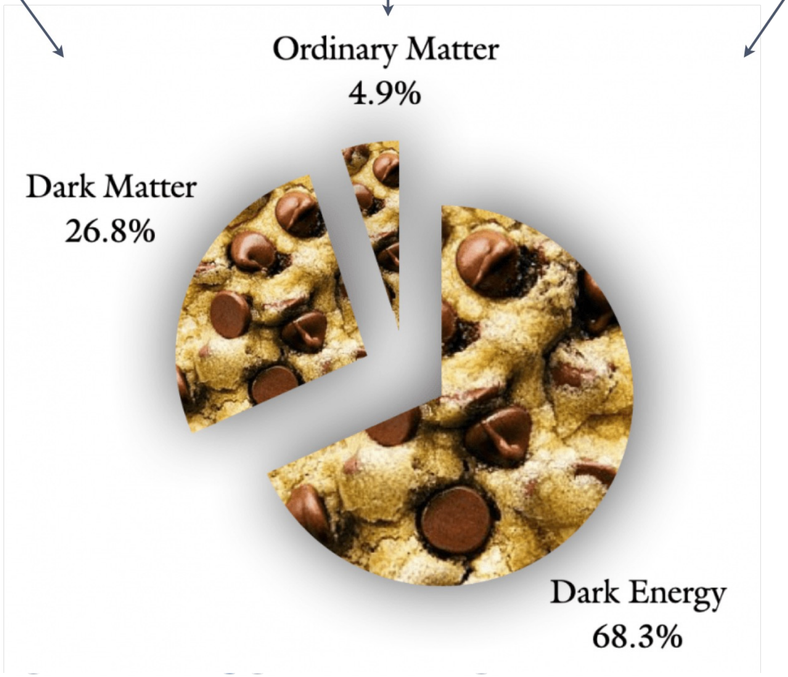
Galaxy clusters

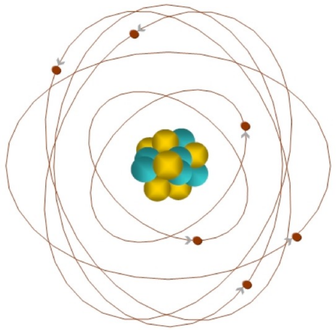


Supernovae Ia



Microwave background

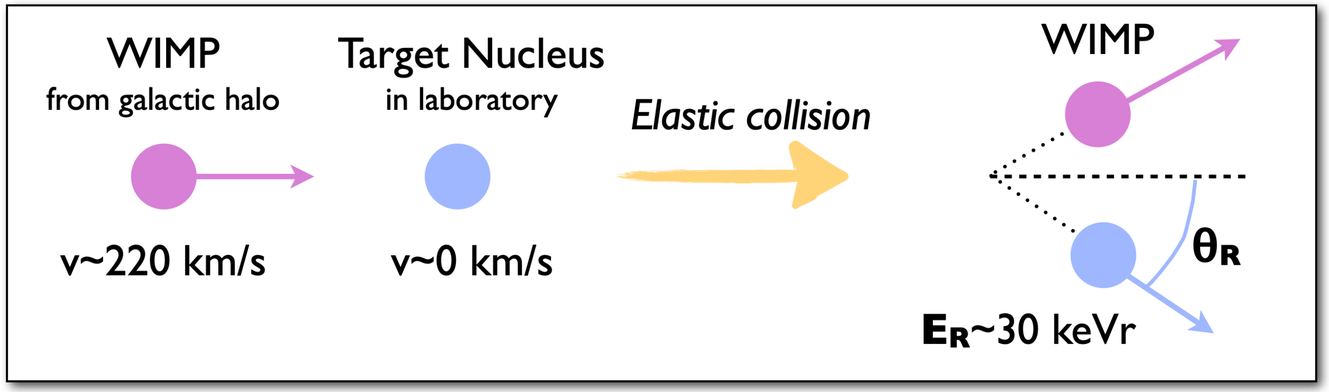




Big Bang nucleosynthesis

Direct Detection Principles

Assume that the dark matter is not only gravitationally interacting (WIMP).



- Elastic scatter of a WIMP off a nucleus
- Imparts a small amount of energy in a recoiling nucleus
- Can occur via spin-dependent or spin-independent channels
- Need to distinguish this event from the overwhelming number of background events

Direct Detection Detector Response

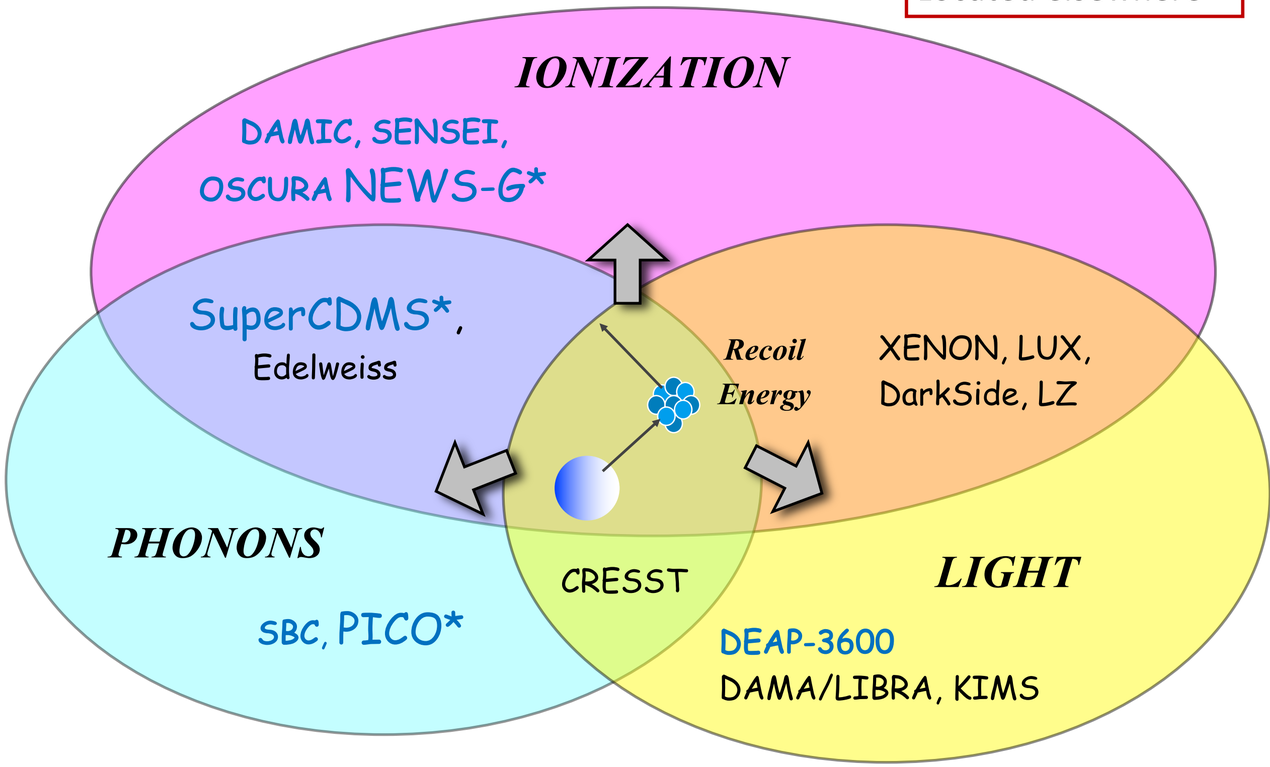
Located at SNOLAB
*At this conference
Located elsewhere

Count individual energy quanta

- Energy is detected via heat, ionization, and/or scintillation

The experiments at SNOLAB utilize all these techniques

- Bubble chambers and cryogenic detectors measure heat
  - PICO, SBC, SuperCDMS
- Semiconductors and gas detectors detect ionization
  - DAMIC, SENSEI, Oscura, NEWS-G, SuperCDMS
- Liquid argon scintillates well
  - DEAP-3600, SBC

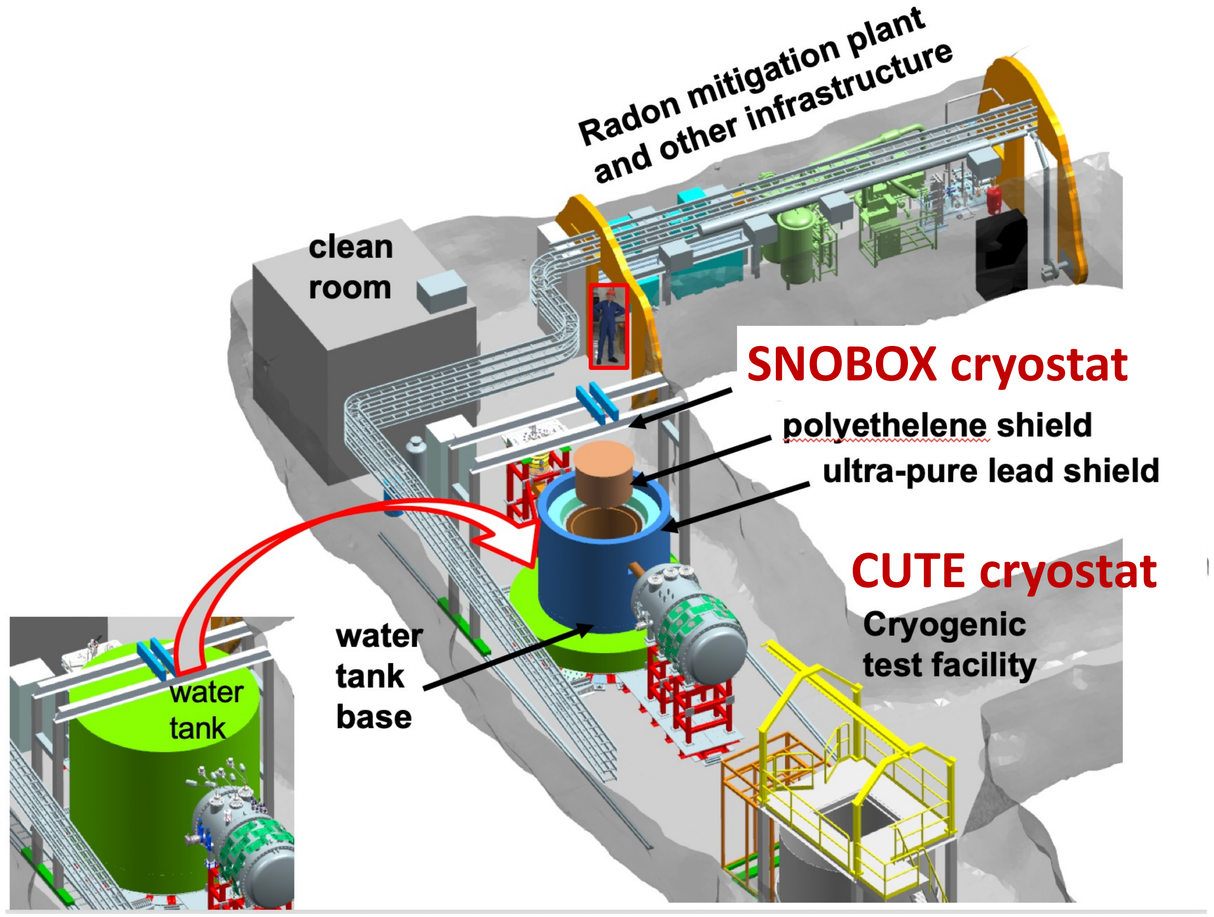


The direct detection of dark matter experiments are currently the most common experiment type at SNOLAB! I apologize that I will not be able to cover all of them!

SuperCDMS SNOLAB

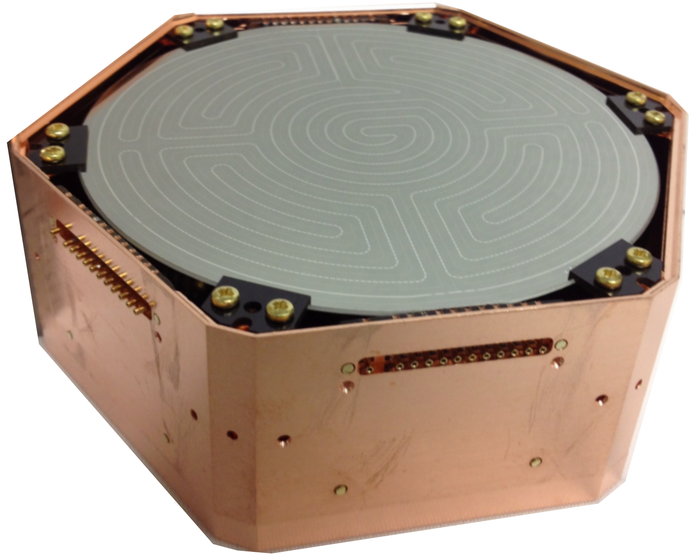
- SuperCDMS SNOLAB construction is underway in the Ladder Lab.

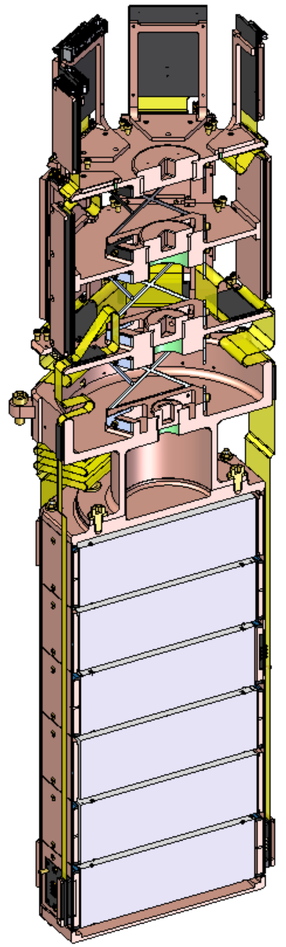
- We expect world leading science results from commissioning runs of some of the detectors in the CUTE test facility.



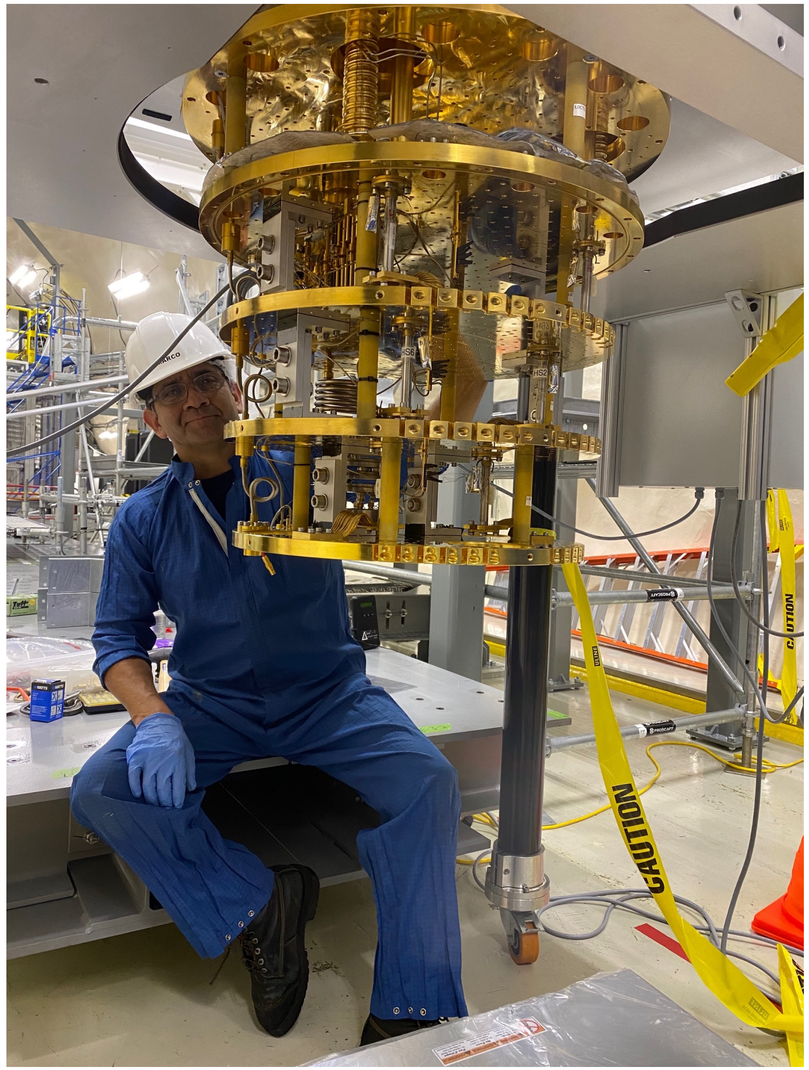
SuperCDMS SNOLAB

- SuperCDMS SNOLAB construction is underway in the Ladder Lab.
- We expect world leading science results from commissioning runs of some of the detectors in the CUTE test facility.
- Initial payload 4 towers, each w/6 detectors (1.39 kg Ge crystals, 0.61 kg Is crystals) each 100 mm diameter, 33.3 mm thick:
  - 2 HV (4 Ge + 2 Si)
  - 2 iZIP (6 Ge & 4 Ge + 2 Si)





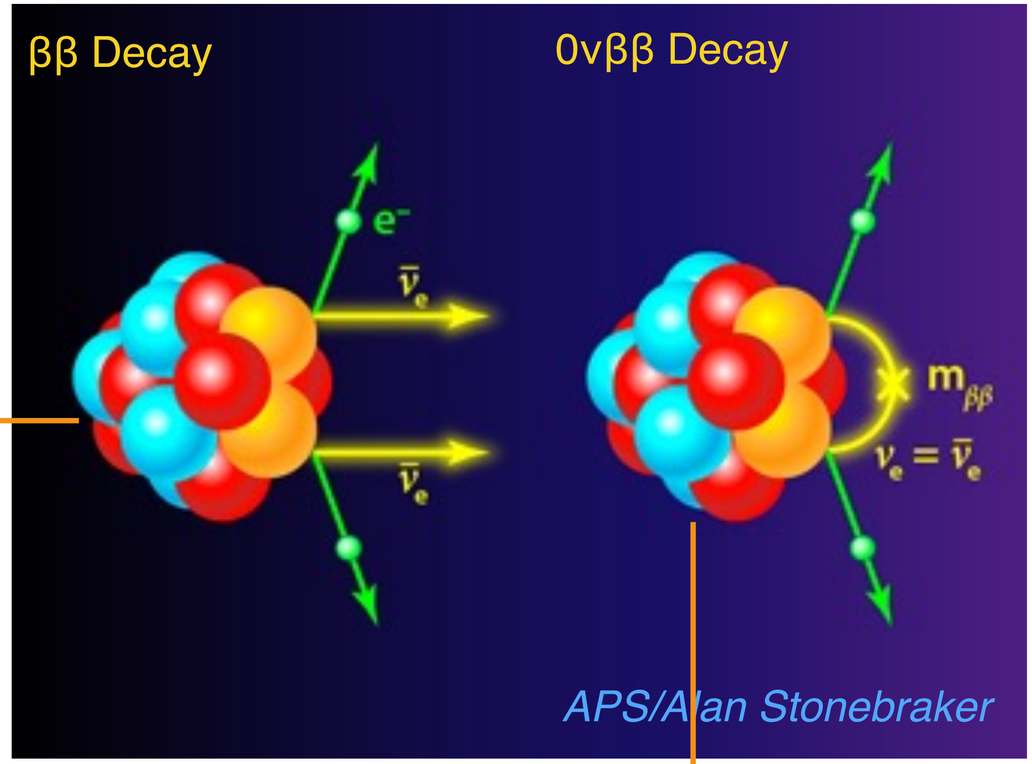
The latest photos…

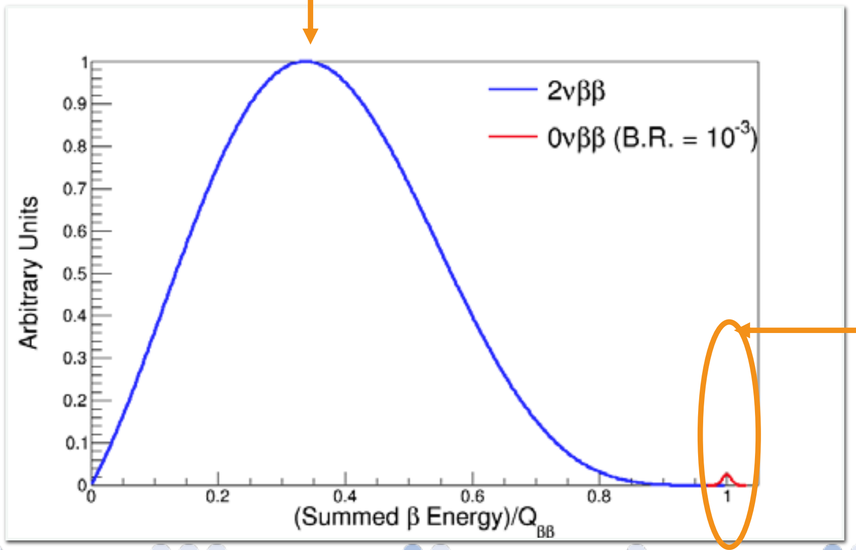


Neutrino Program @ SNOLAB

Double Beta Decay

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

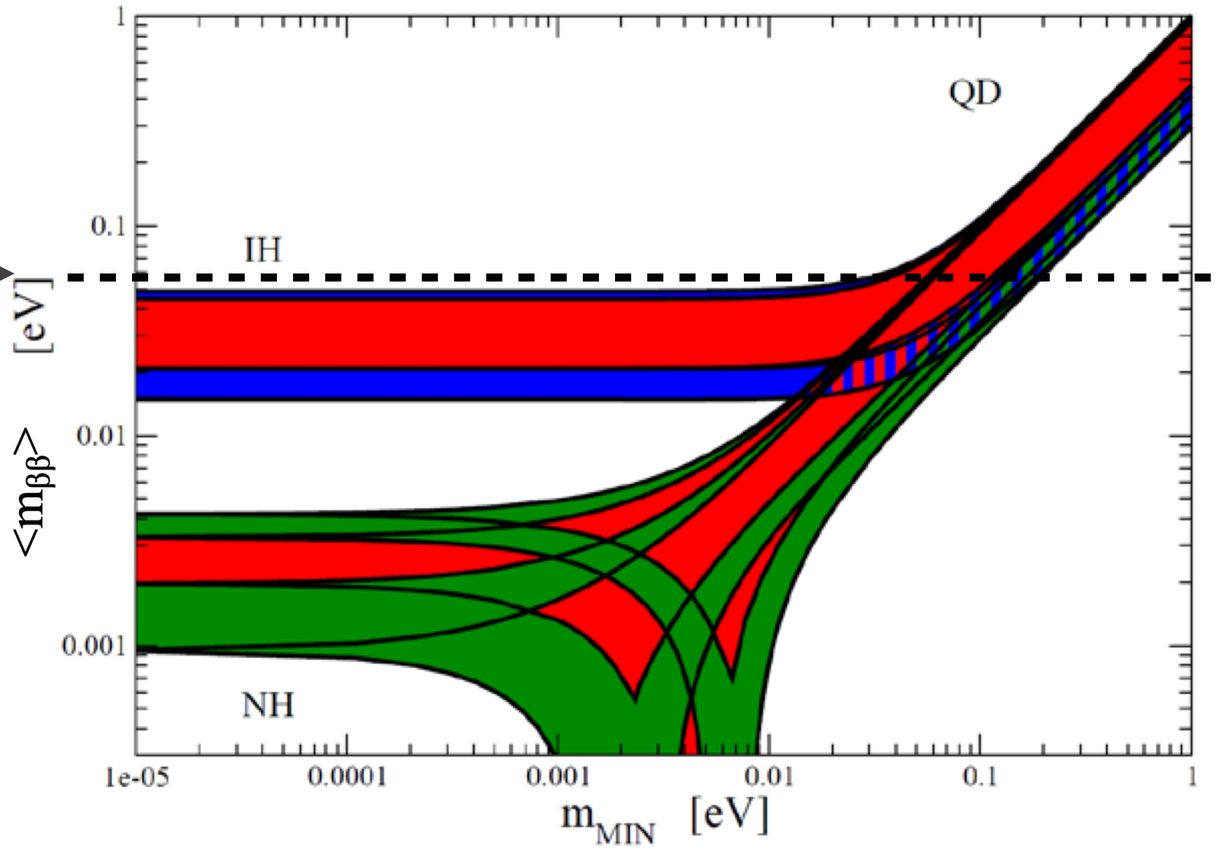




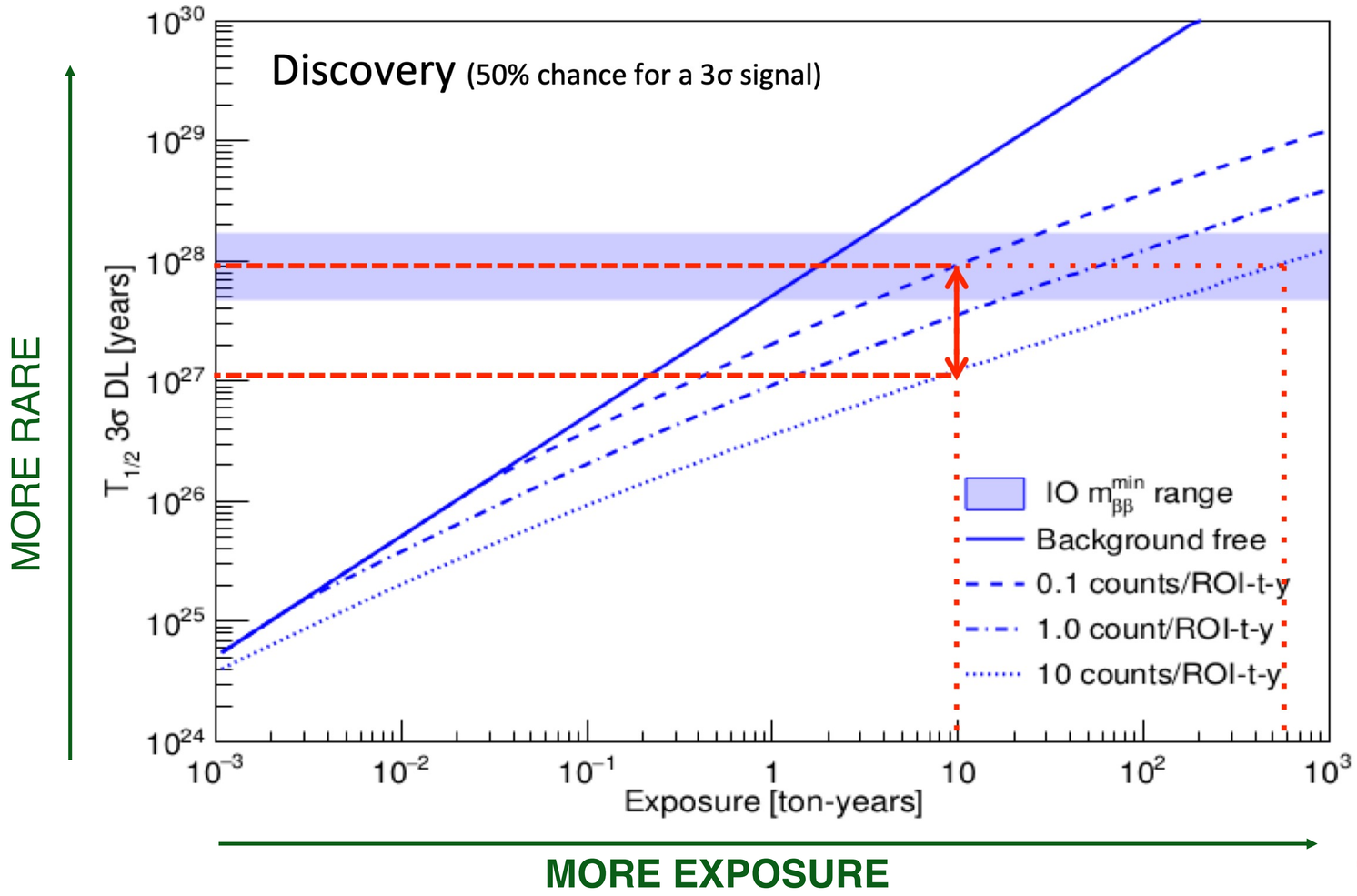
If neutrinos are Majorana particles, then neutrino-less double beta decay should be allowed.

Sensitivity of Next Generation $0\nu\beta\beta$ Decay Experiments

Goal of next generation $0\nu\beta\beta$ decay experiments 3σ sensitivity to effective Majorana neutrino mass parameter $m_{\beta\beta} = 15meV$



Implications on Background Requirements



J. Detwiler

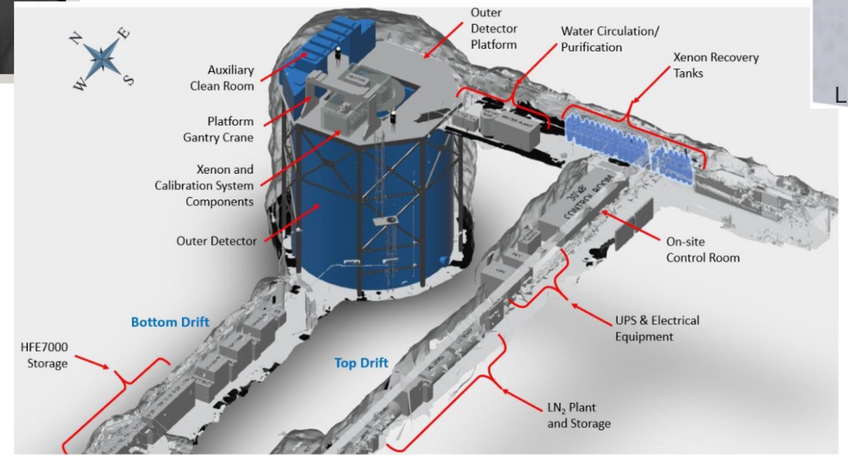
0νββ Decay at SNOLAB

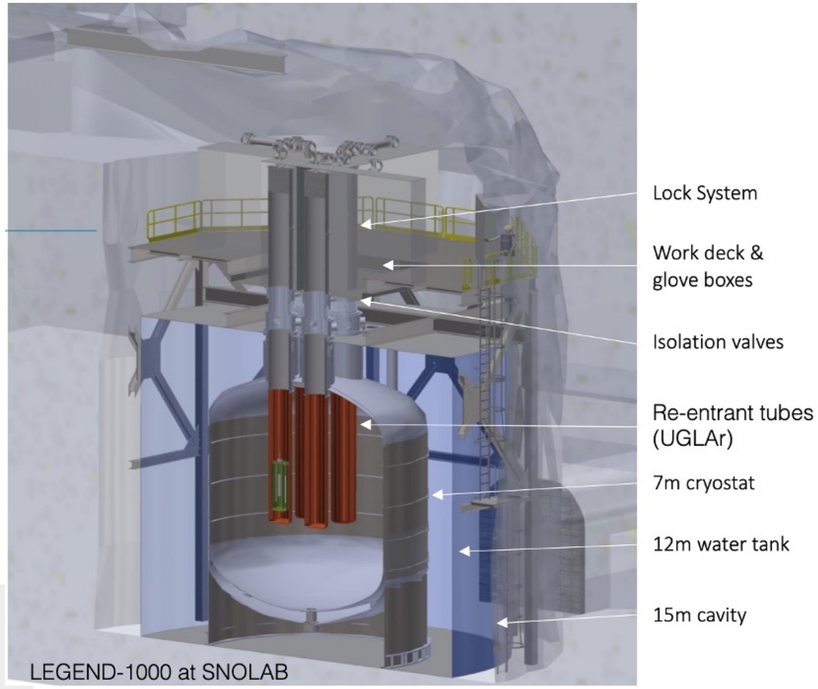
SNO+

- 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

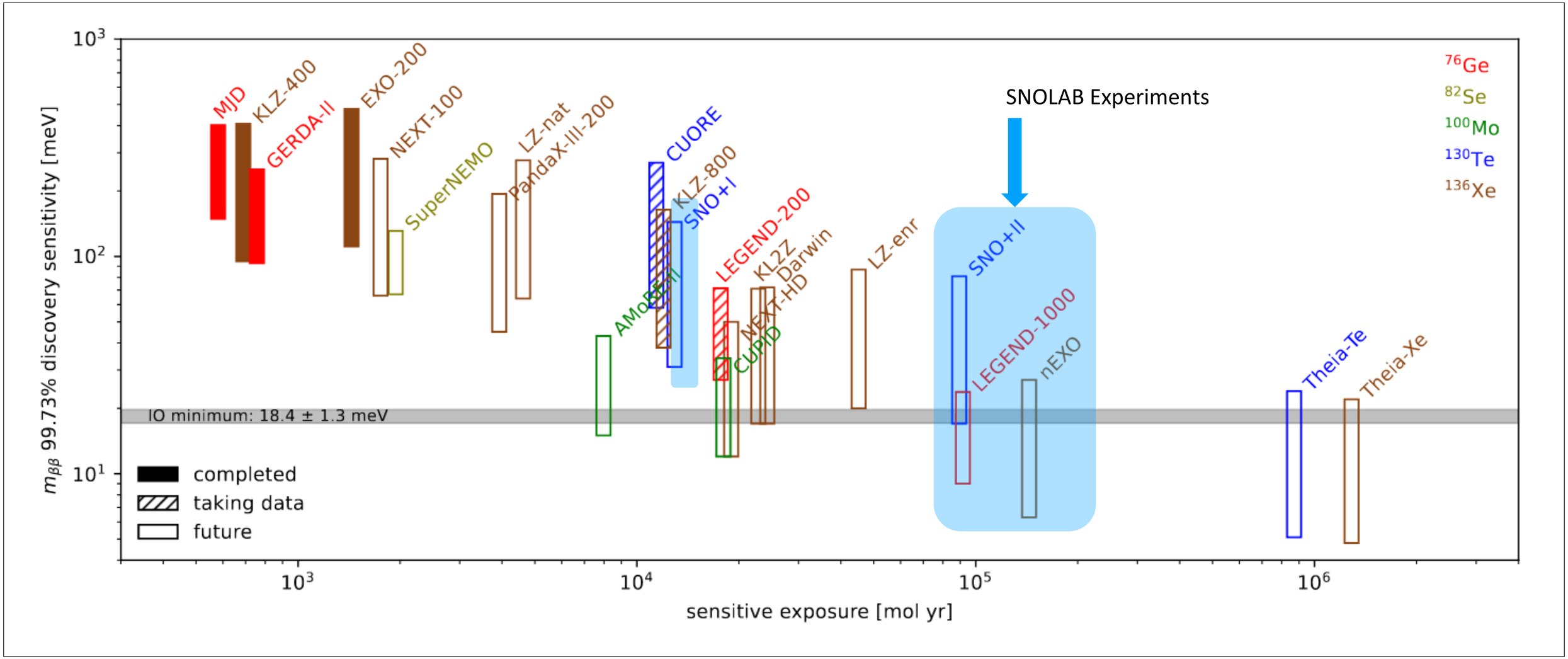
- 5000 kg xenon TPC detector
- Enriched with 90% ^{136}Xe enables sensitivity that reaches the Inverted Mass Ordering
- Builds on success of EXO-200
- Currently in design phase





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


10^3
10^2
10^1
$m_{\beta\beta}$ 99.73% discovery sensitivity [meV]
MJD
KLZ-400
GERDA-II
EXO-200
NEXT-100
SuperNEMO
LZ-nat
PandaX-III-200
CUORE
KLZ-800
SNO+I
AMoRE-II
LEGEND-200
KL2Z
Darwin
NEXT-HD
CUPID
LZ-enr
SNOLAB Experiments
SNO+II
LEGEND-1000
nEXO
Theia-Te
Theia-Xe
^{76}Ge
^{82}Se
^{100}Mo
^{130}Te
^{136}Xe
IO minimum: 18.4 ± 1.3 meV
completed
taking data
future
10^3
10^4
10^5
10^6
sensitive exposure [mol yr]

Concluding Points

- SNOLAB is a clean, underground laboratory hosting a variety of experiments.
- Experimental collaborations have produced many dark matter and neutrino results at SNOLAB, and many more are expected over the next decade
- I am very excited about the opportunities that SNOLAB provides the scientific community. I believe SNOLAB well positioned to attract world-class experiments and support major discoveries in the next decade.

Partners


LaurentianUniversity
UniversitéLaurentienne


Queen's
UNIVERSITY


Carleton
UNIVERSITY


Université
de Montréal


UNIVERSITY OF
ALBERTA


VALE

Questions?