2024/05/31

# SNOLAB Facility Overview

Andy Kubik
Research Scientist @ SNOLAB
Adjunct Prof. @ U. of Toronto

# Introducing SNOLAB

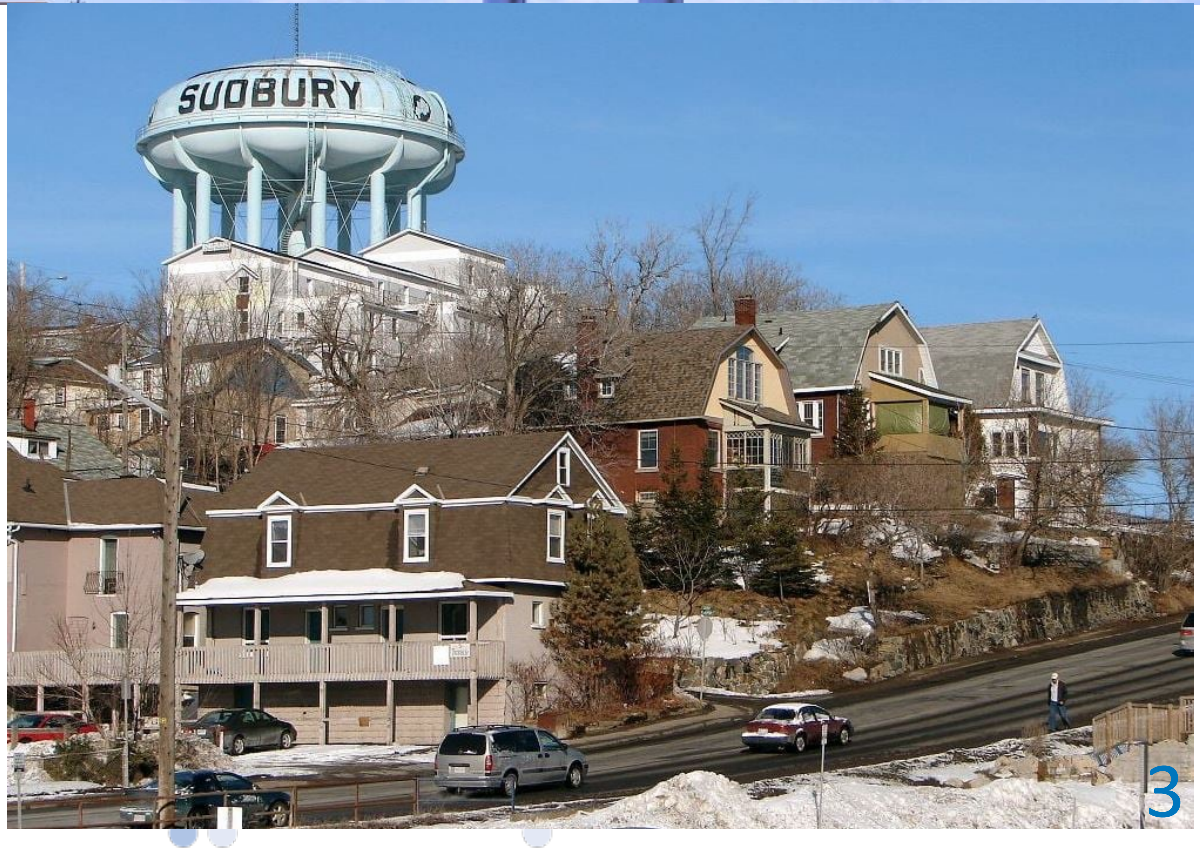
SNOLAB hosts rare event searches and measurements. It's located 2 km underground in the active Vale Creighton nickel mine near Sudbury, Ontario, Canada.

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.

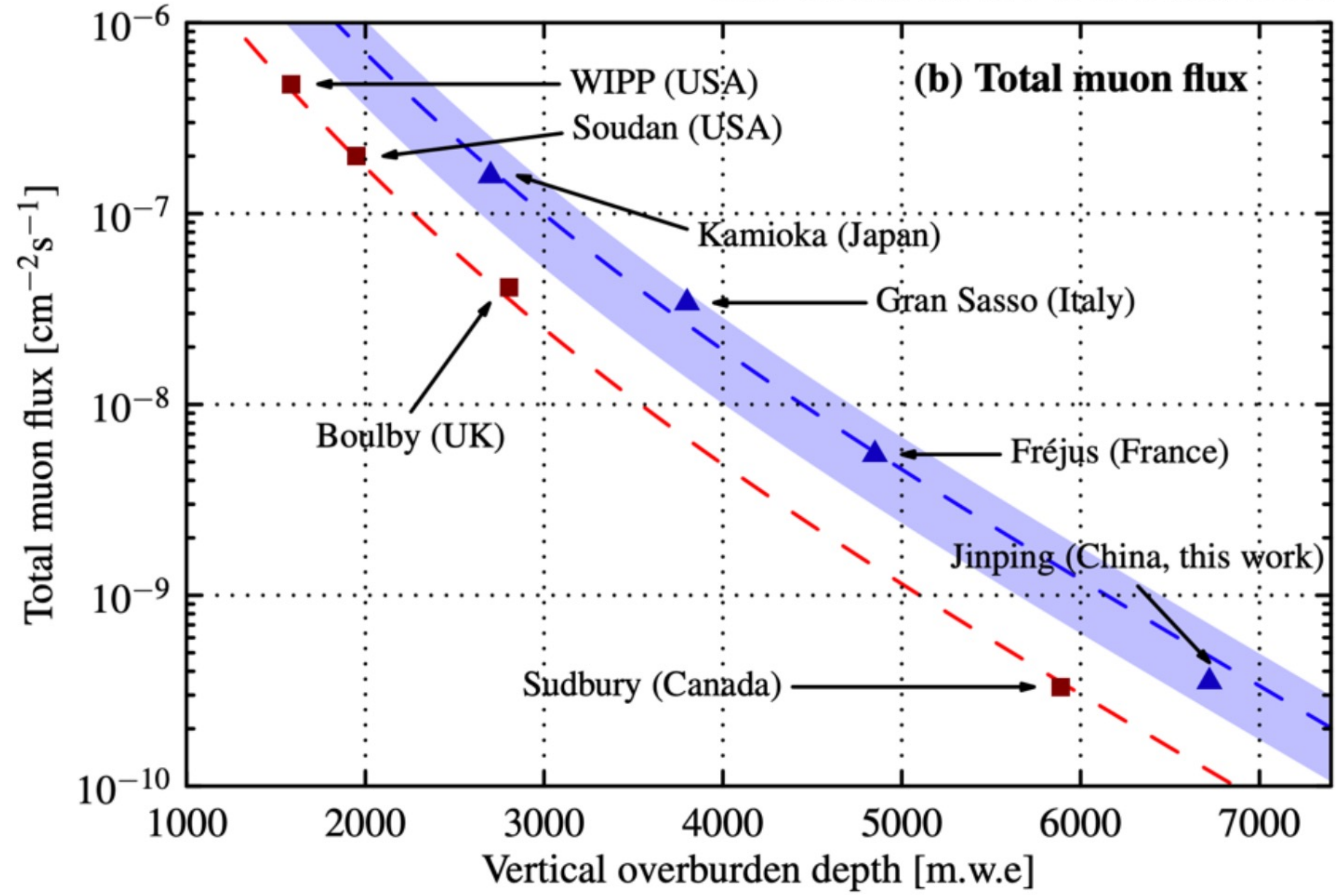

MICHIGAN
Toronto
Detroit


CANADA
NICKEL
1751-1951
5
CENTS


SUDBURY

# SNOLAB


Guo et al.. arXiv:2007.15925v2



# Infrastructure: Surface Spaces & Support

**Offices, Clean Labs, Shipping/Receiving on Surface**

- Dedicated office space for users.
- Clean room laboratories for surface work and final checks before shipping underground.
- Chemistry, fume hoods, ICP-MS, lots of material etching to remove surface contamination, etc.
- Multiple meeting rooms (10-20 people) and auditorium seating 150.
- Full machine shop (CNC, water jet cutting, 3D printing, etc.)

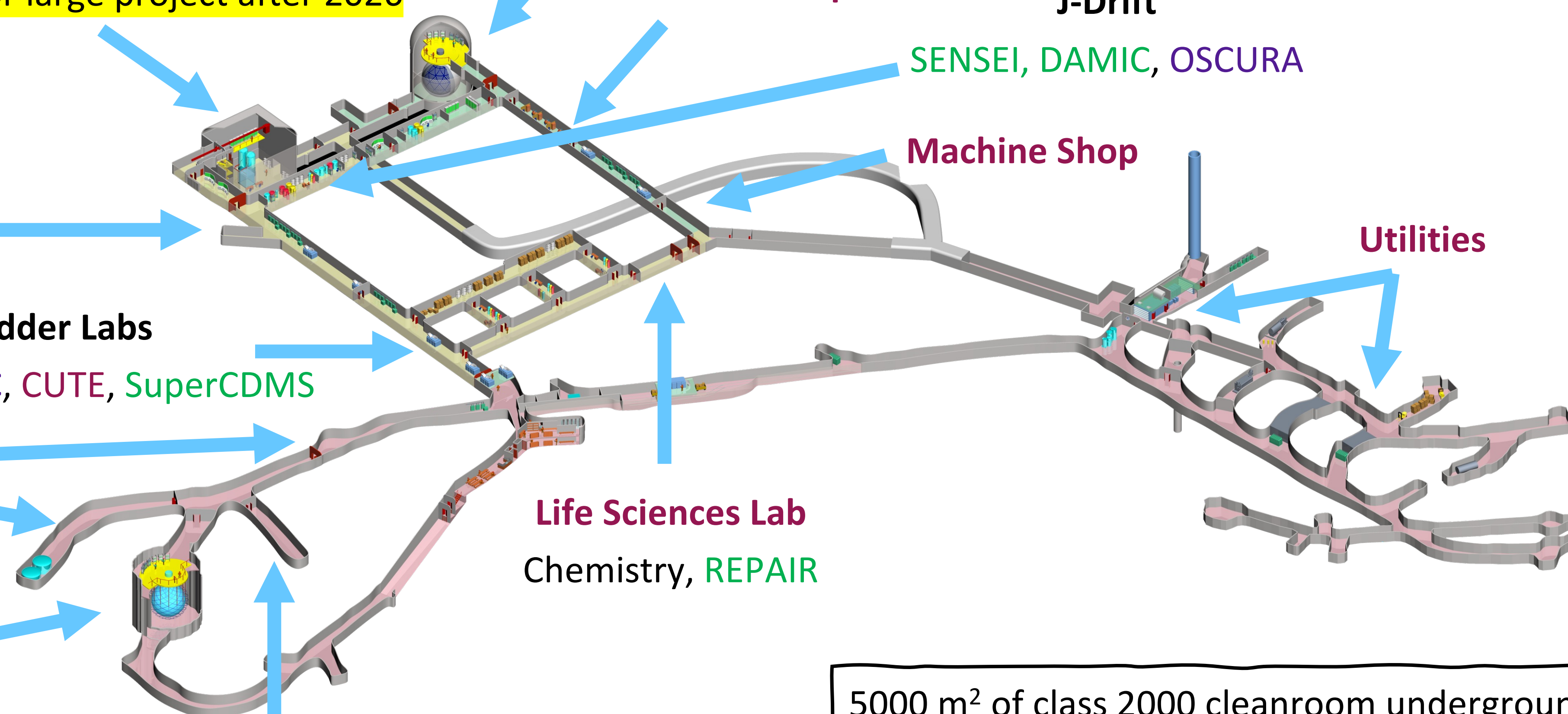
# SNOLAB Underground – at a Glance

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, OSCURA

**Machine Shop**

**Utilities**

**Halo Stub**

HALO

potential breakthrough for future expansion

**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$^3$


CAUTION

# Infrastructure:  Underground Facilities

**Besides experiments, SNOLAB has multiple facilities to support projects underground.**

**Liquid Nitrogen Plant**

- Low radon liquid nitrogen plant underground.
- Capacity to supply all necessary LN to users

**Ultra-pure Water (UPW) plant**

- Originally built to support SNO facility, now supplies entire lab with UPW for various uses

**Chemistry Lab with fume hood**

**Machine shop**

**Gaseous (Low Radon) Nitrogen Plant**

**Several Low Radon clean rooms**

# Low Background Counting Facility

**Provides material screening for SNOLAB projects and the wider community (including industry)**

**Gamma Counting**

- Ultra-pure Ge detectors (5 different detectors with different sensitive ranges, etc)
- PGT Coaxial Detector (PGT), Canberra Coaxial Detector (Lively), Canberra Well Detector, Eurisys Mesures Coaxial Detector (Vue Des Aples), Canberra Coaxial Detector (Gopher)

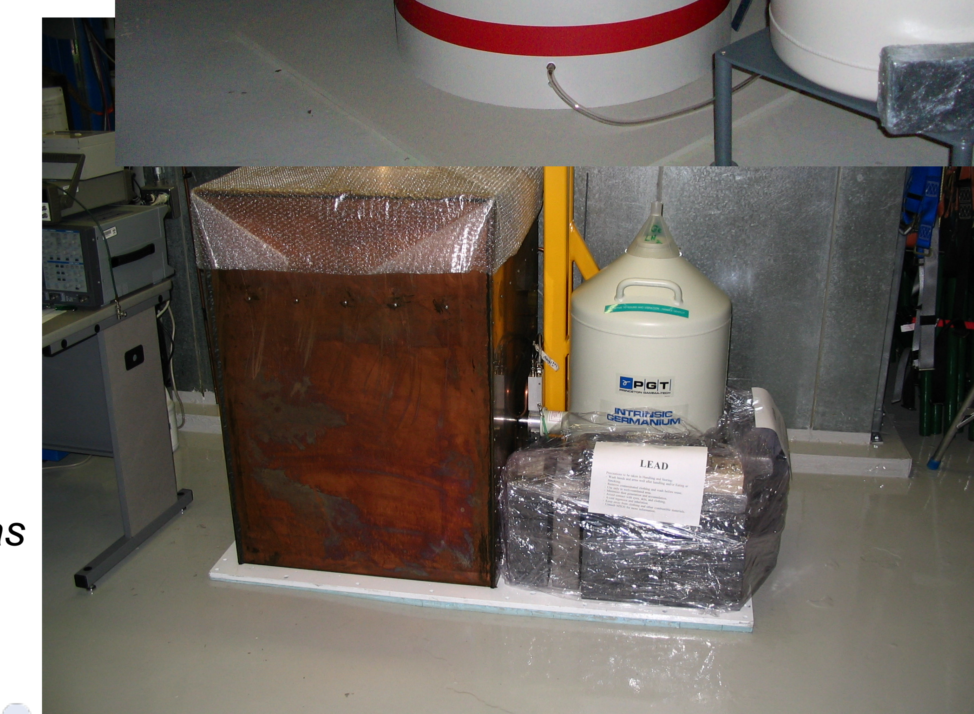
**Alpha Counting**

- XIA UltraLo-1800 alpha counter
- Maximum sample weight: 9kg
  Maximum sample thickness: 6.3mm

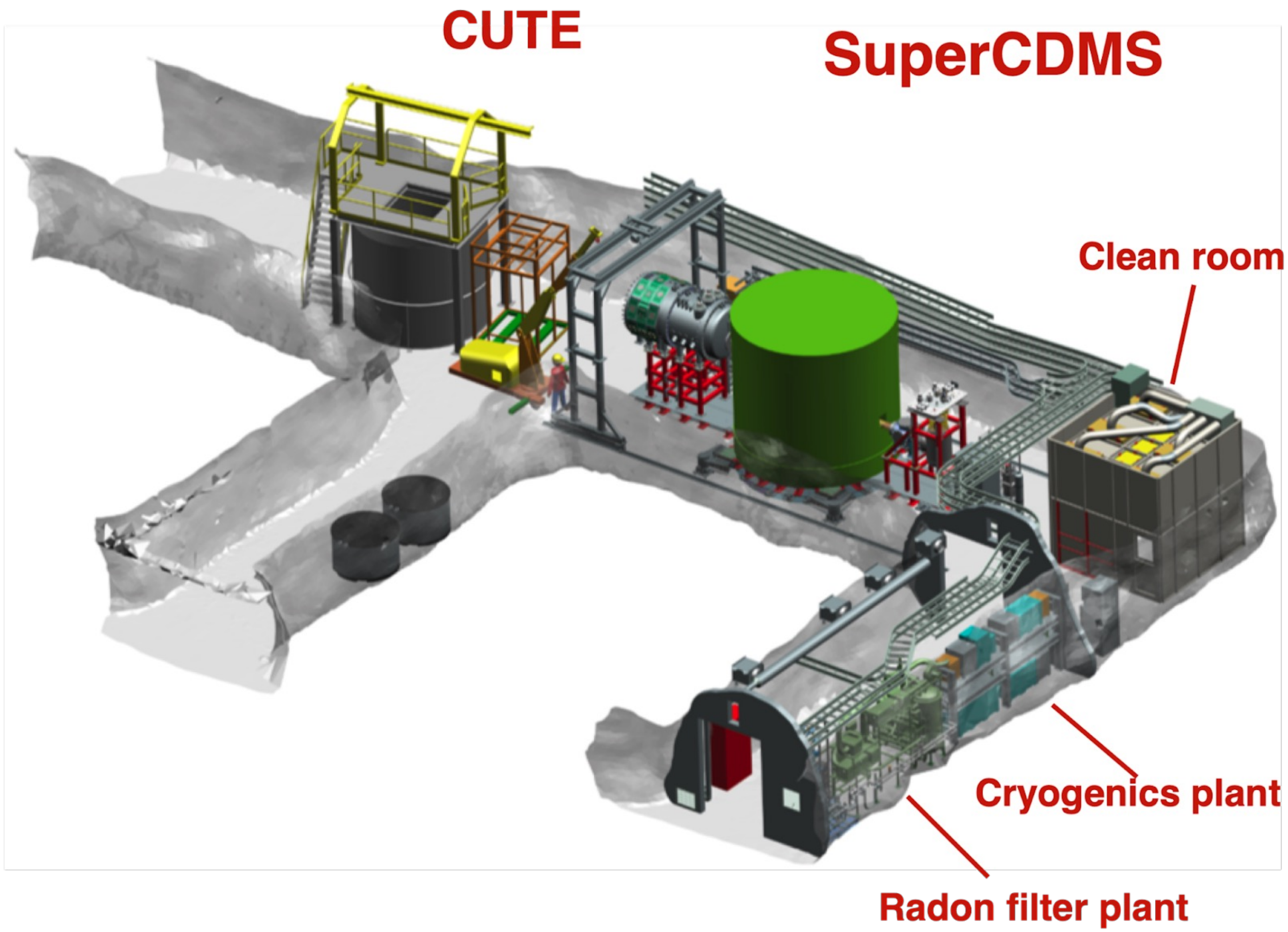
**Radon Emanation**

- Provide Radon emanation study of all construction materials
- *Electrostatic Counter(ESC) and Liquid Nitrogen Cooled Traps + Lucas Cell*

**https://www.snolab.ca/users/services/gamma-assay/services.html**

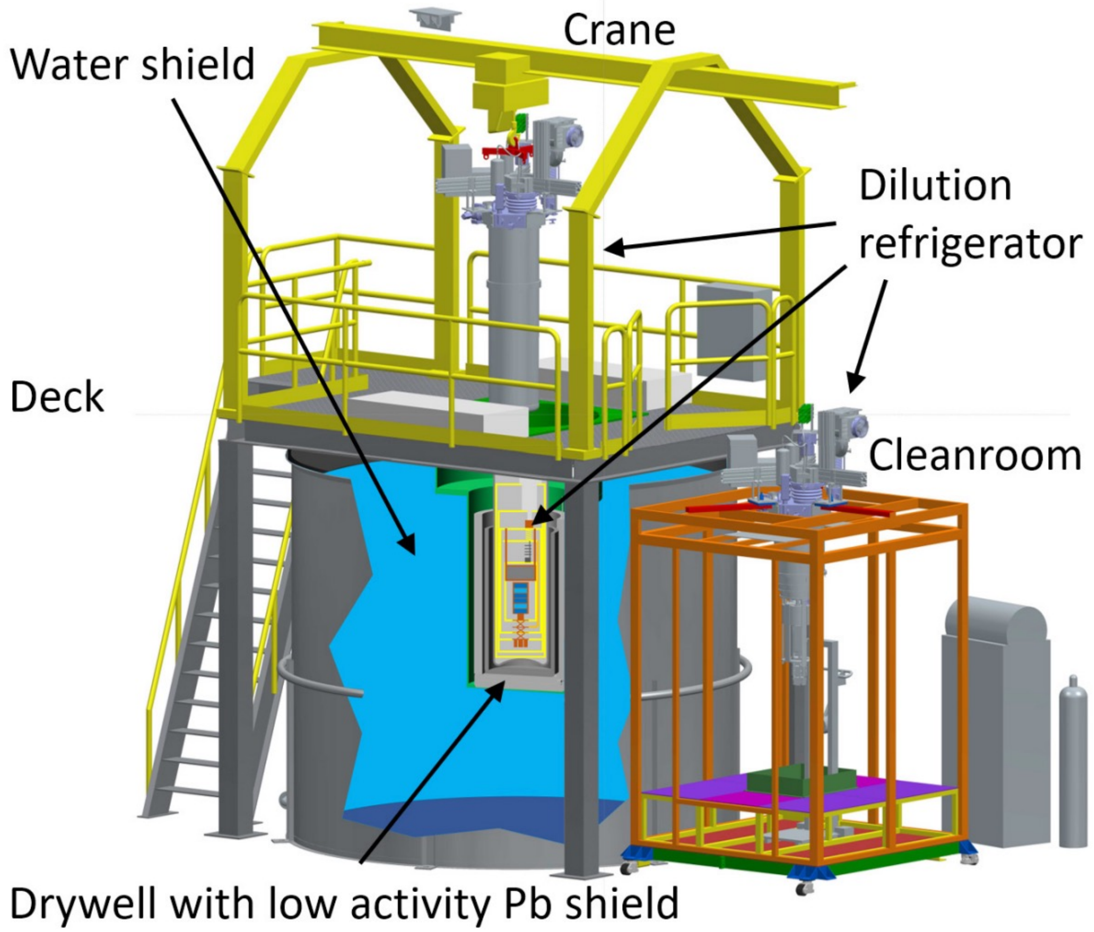
# **C**ryogenic **U**nderground **TE**st Facility (CUTE)



# Facility Overview

**What the CUTE Facility can offer:**

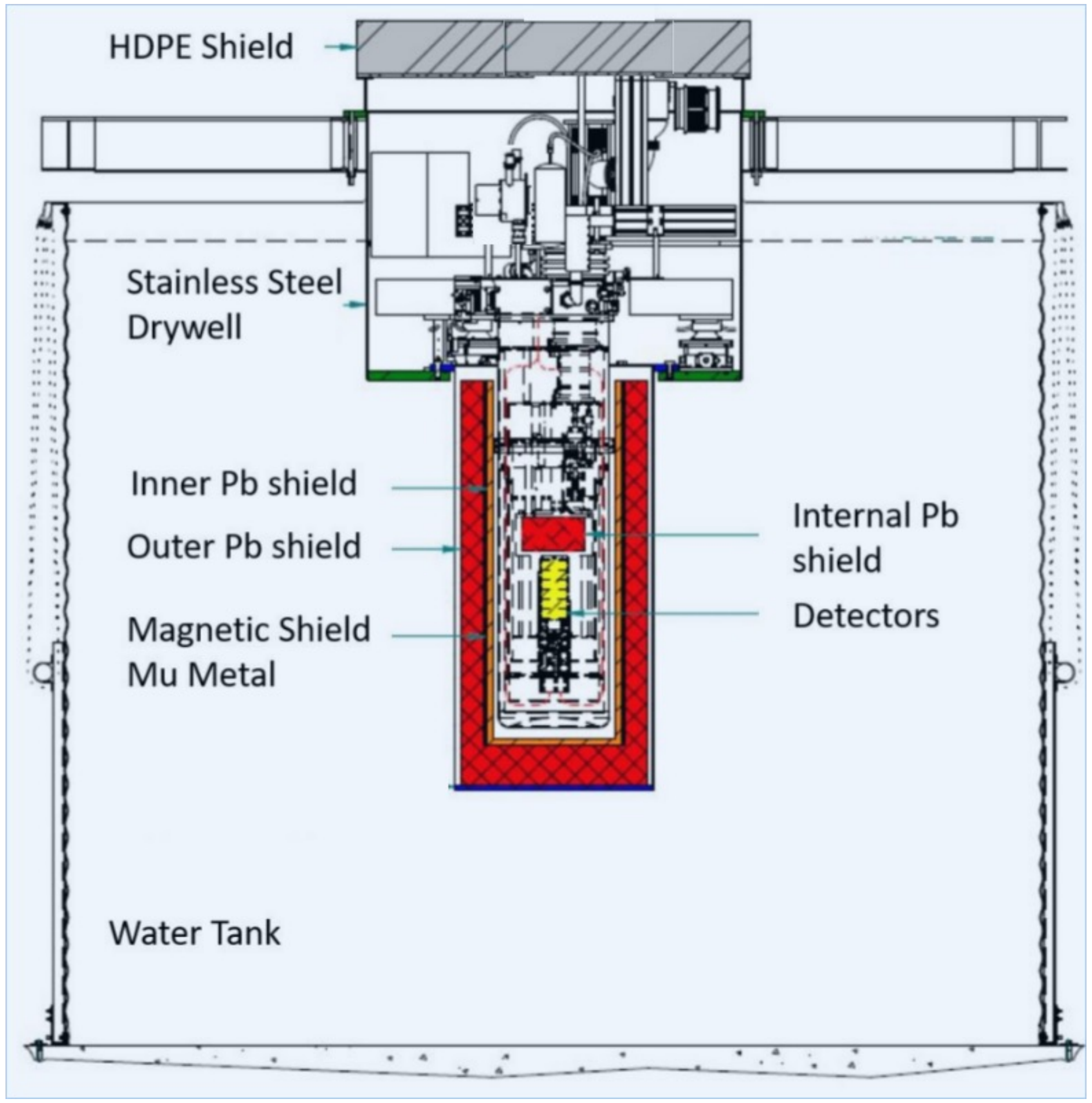
- SNOLAB operated facility (accepting proposals)
- Operational temperature as low as 12 mK
- Low overall radioactive background
- Minimal mechanical vibrations thanks to cryostat suspension system
- Low level of electromagnetic interference
- Availability of calibration sources (gamma, neutron)
- Full remote operations
- Low-radon, class 300 cleanroom to change payload
  - Typical Rn level < 15 mBq/$m^3$



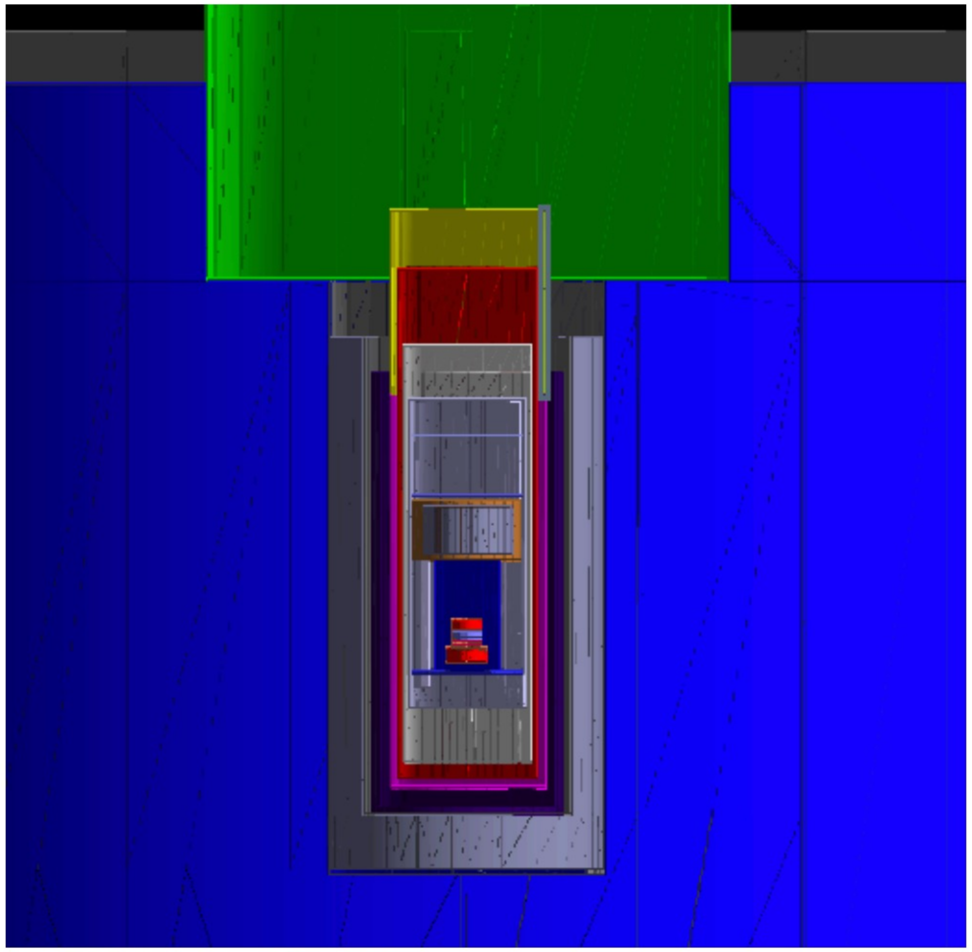
# Shielding

**Shielding:**

- ~ 10 cm low activity Lead in drywell
- Mu-metal reduces external B-field  by ~x50
- ~1.5 meter of water and 20 cm Polyethylene lid
- 15 cm Lead "plug" inside of cryostat
- Active low radon air purge in drywell



# Backgrounds



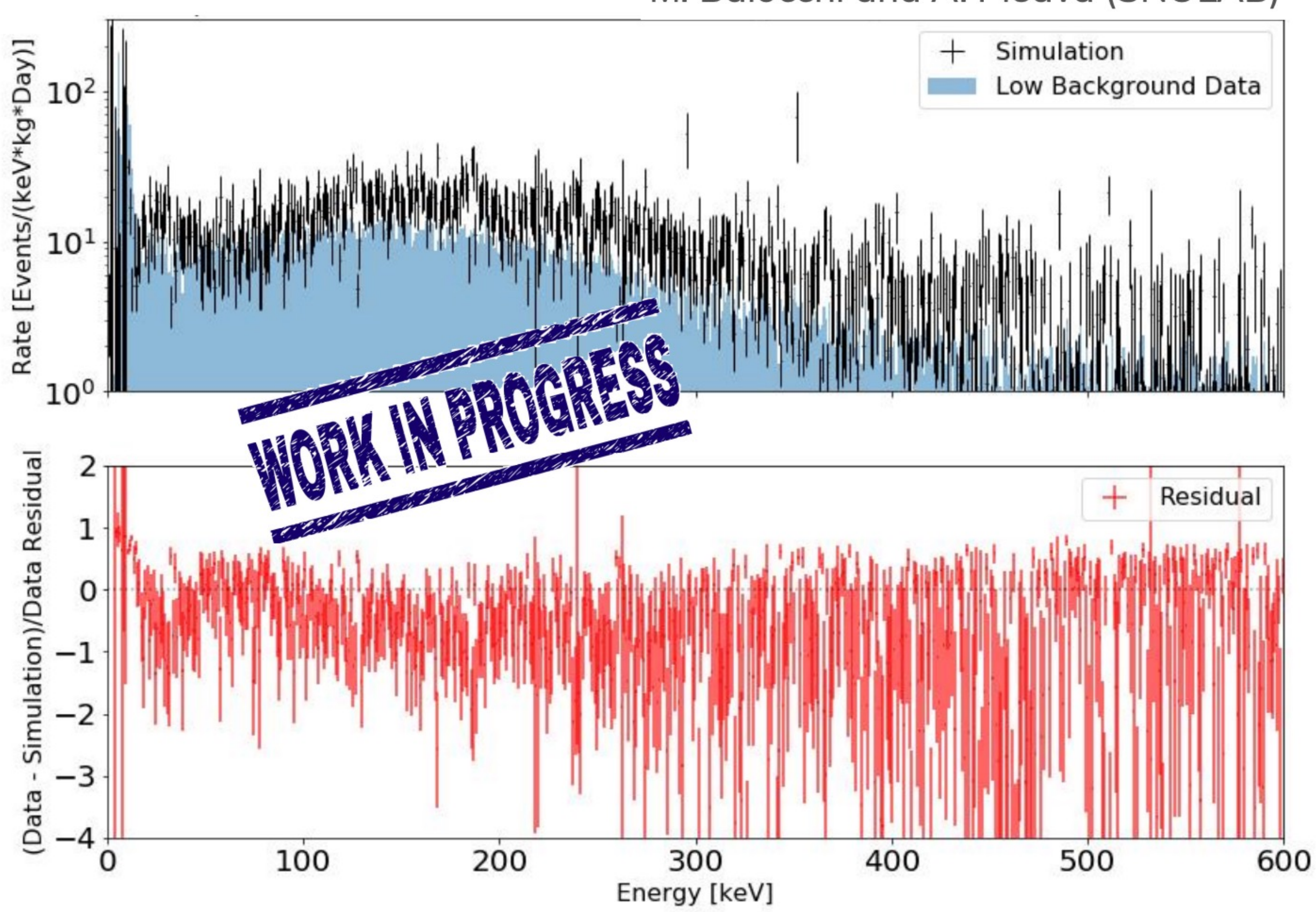
Geant4 visualization of the CUTE geometry

**Backgrounds:**

- Shielding and clean underground environment lead to low backgrounds
- All materials screened for activity using HPGe background counting facility at SNOLAB
- Create a full bill of materials in the facility
- Along with a detailed GEANT4 simulation, propagate background for each contaminate to <insert your favourite detector>
- Use Background Explore tool developed by B. Loer at PNNL to normalized contribution and generate expected event rate

# Backgrounds

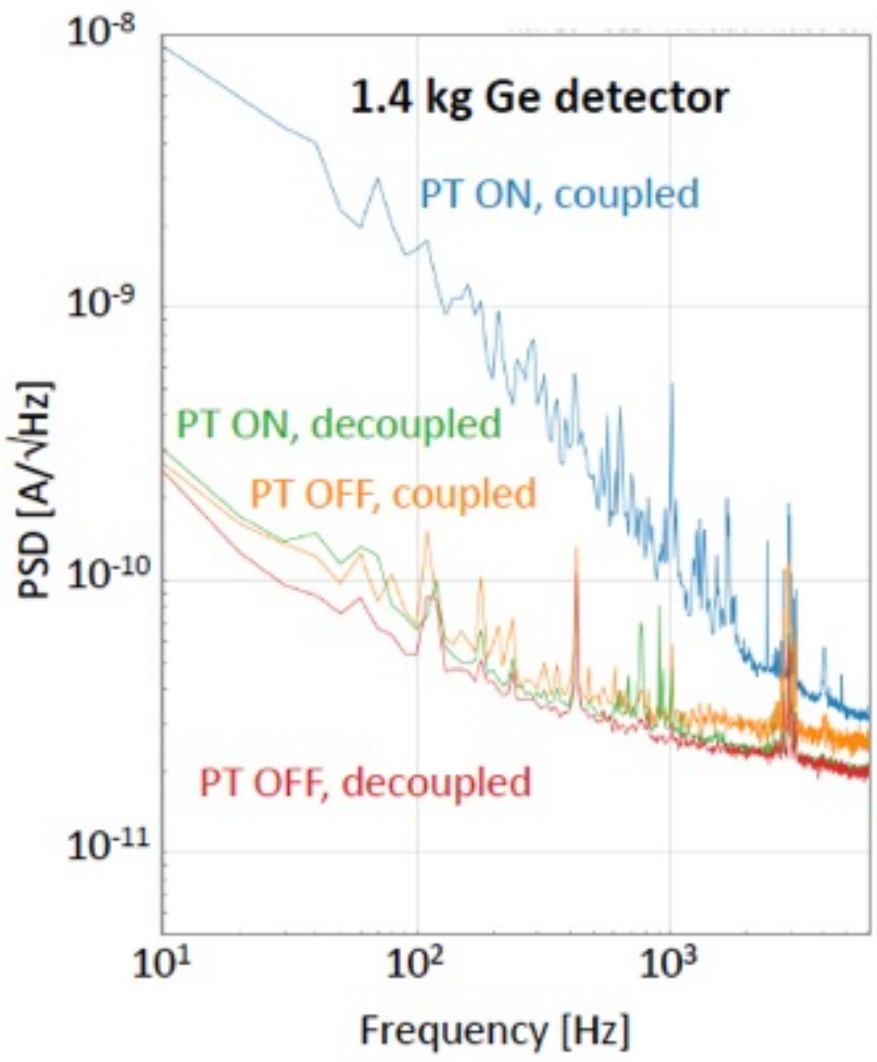
M. Baiocchi and A. Pleava (SNOLAB)




**Backgrounds:**

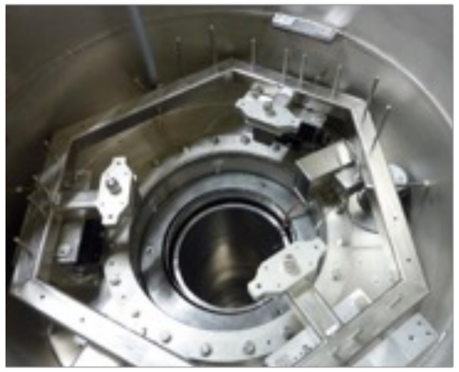
- Simulation validated with real data
- 600 g Ge detector
- Agreement is pretty good
- Rate from facility
  - 5.6 +/- 0.6 evts/kg/keV/day [1-1000 keV]

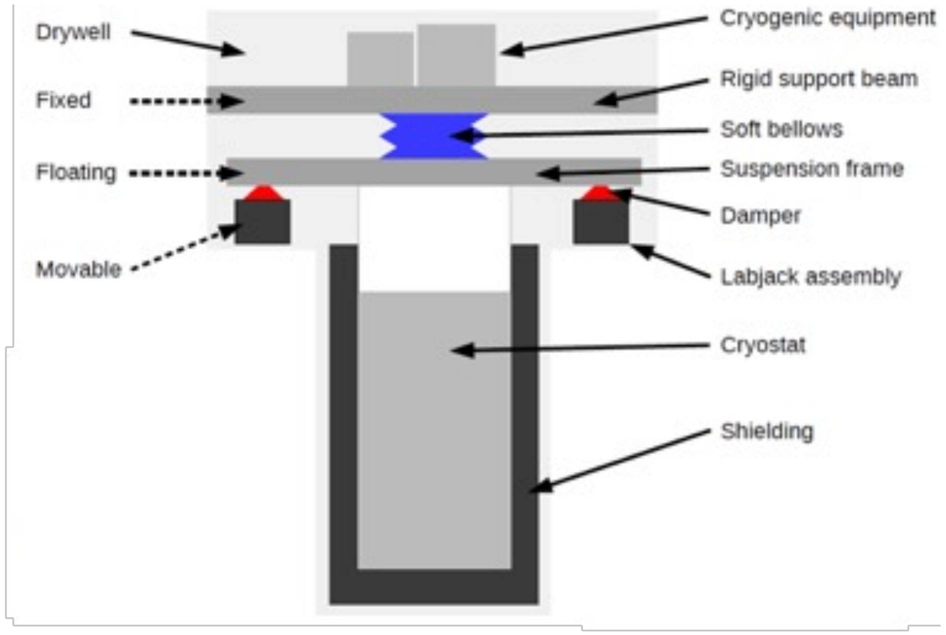
# Vibrational Isolation



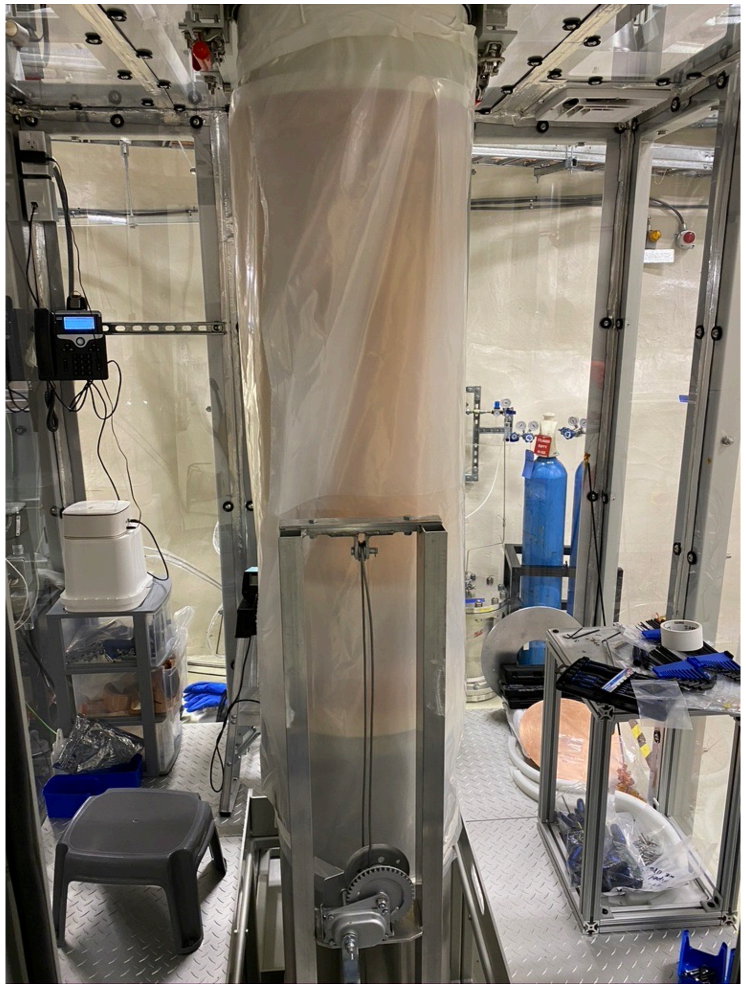

**Vibrations:**

- Suspension system decouples cryostat from pulse tube and environmental vibrations coupling in through the deck.
- We quantify the impact of vibrations with SuperCDMS detector
- Only marginal differences are seen in noise with suspension system active when we turn on and off the pulse tube cooler (one of our biggest sources of vibration)





# Dedicated Low Radon Clean Room



**We keep it clean:**

- All payload and fridge work done in our class 300 clean room
- Low radon air supplied from surface and passed through HEPA filters
- Typical radon levels < 15 Bq/m$^3$, but more often ~ 5 Bq/m$^3$ (depends on weather at surface)
- Now able to use SuperCDMS Radon Reduction system to further reduce radon to < 1 Bq/m$^3$

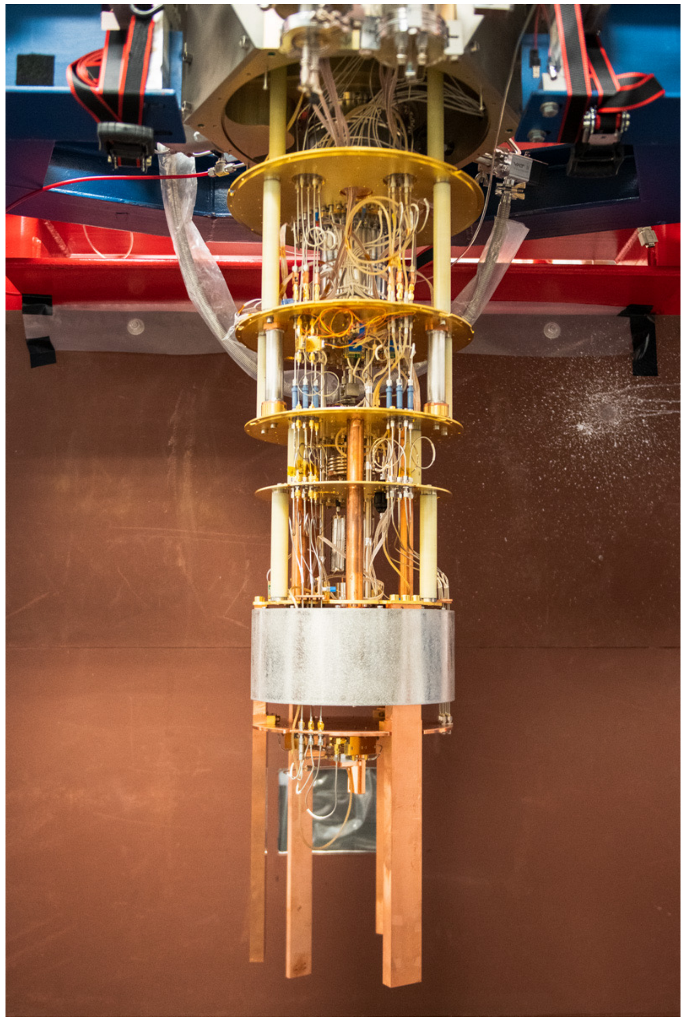
# Qubits in CUTE

**Funded proposal to study Qubits in a low radiation underground environment**

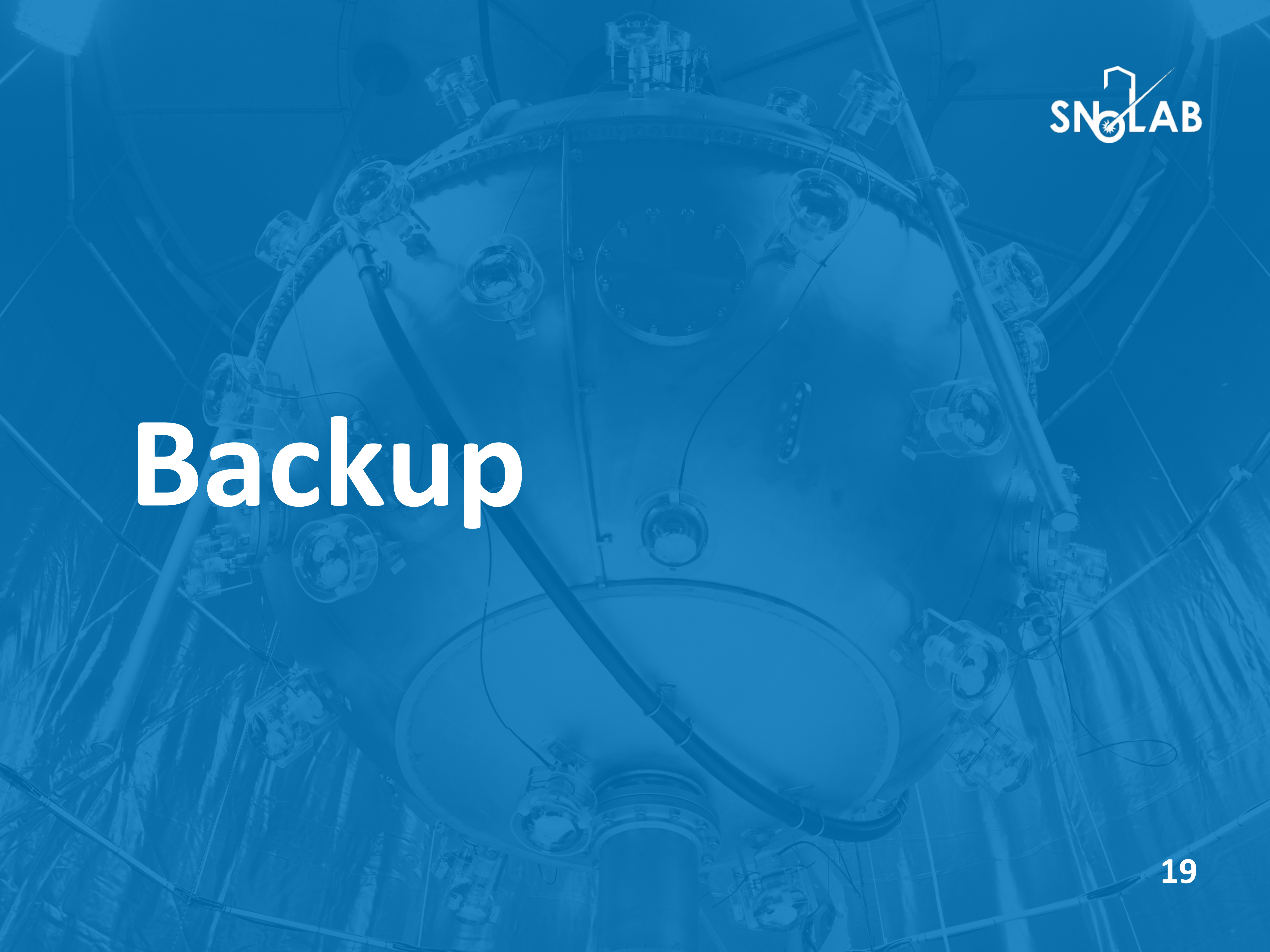
- Funded by US Army Research Office
- Collaboration between SNOLAB, University of Waterloo, and Chalmers University of Technology
- Prof. Chris Wilson at the IQC is the project leader
- Chalmer’s University will produce superconducting qubit arrays
- Upgrades to CUTE fridge to accommodate are funded and underway
- Similar upgrades for similar work on same fridge model at NEXUS (see photo)

**This is NEXUS (same fridge model)**

**For Illustrative purposes only**



# Thank You!



# Backup

# 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 requiring deep underground facilities.**

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

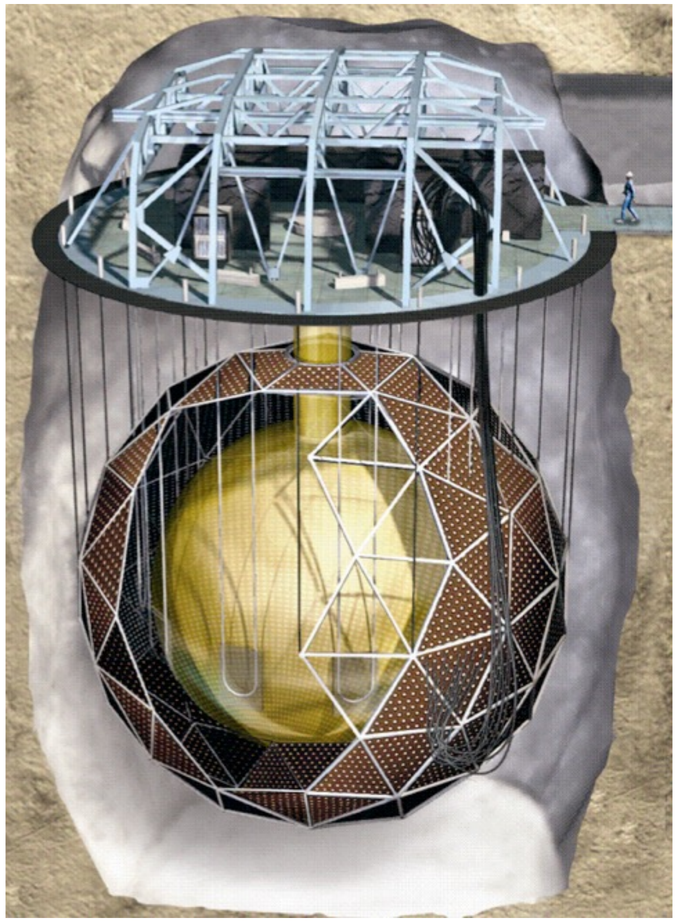
**SNOLAB is interested in pursuing new collaborations and opportunities in emerging areas of underground science**

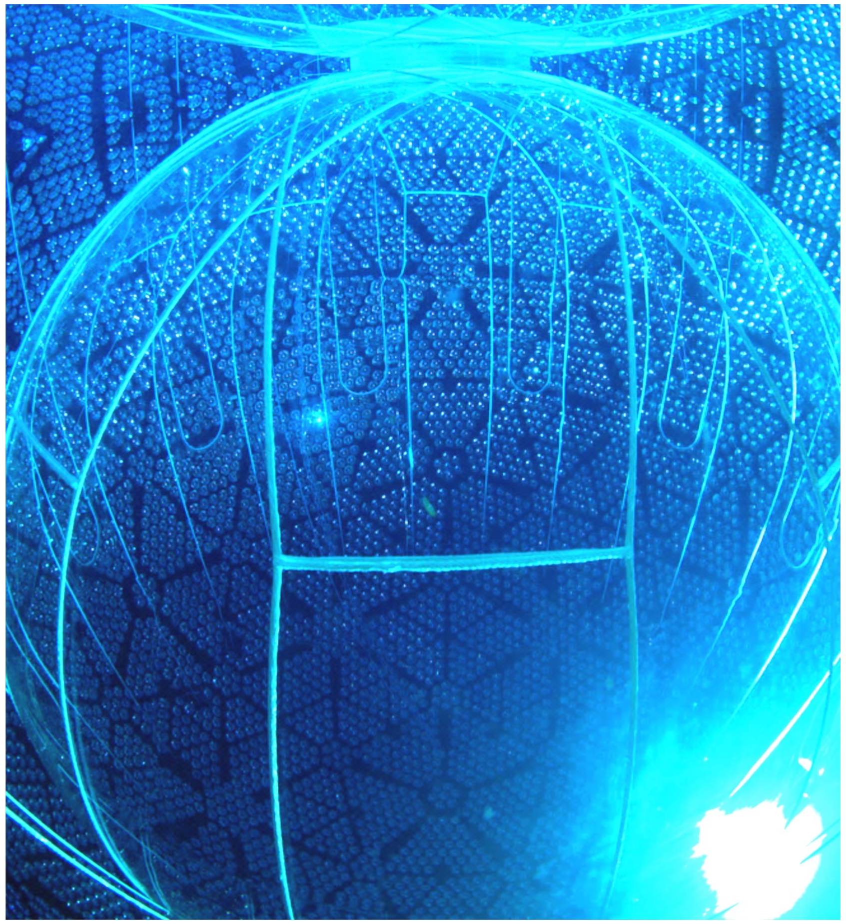
- Effects of radiation on quantum technologies

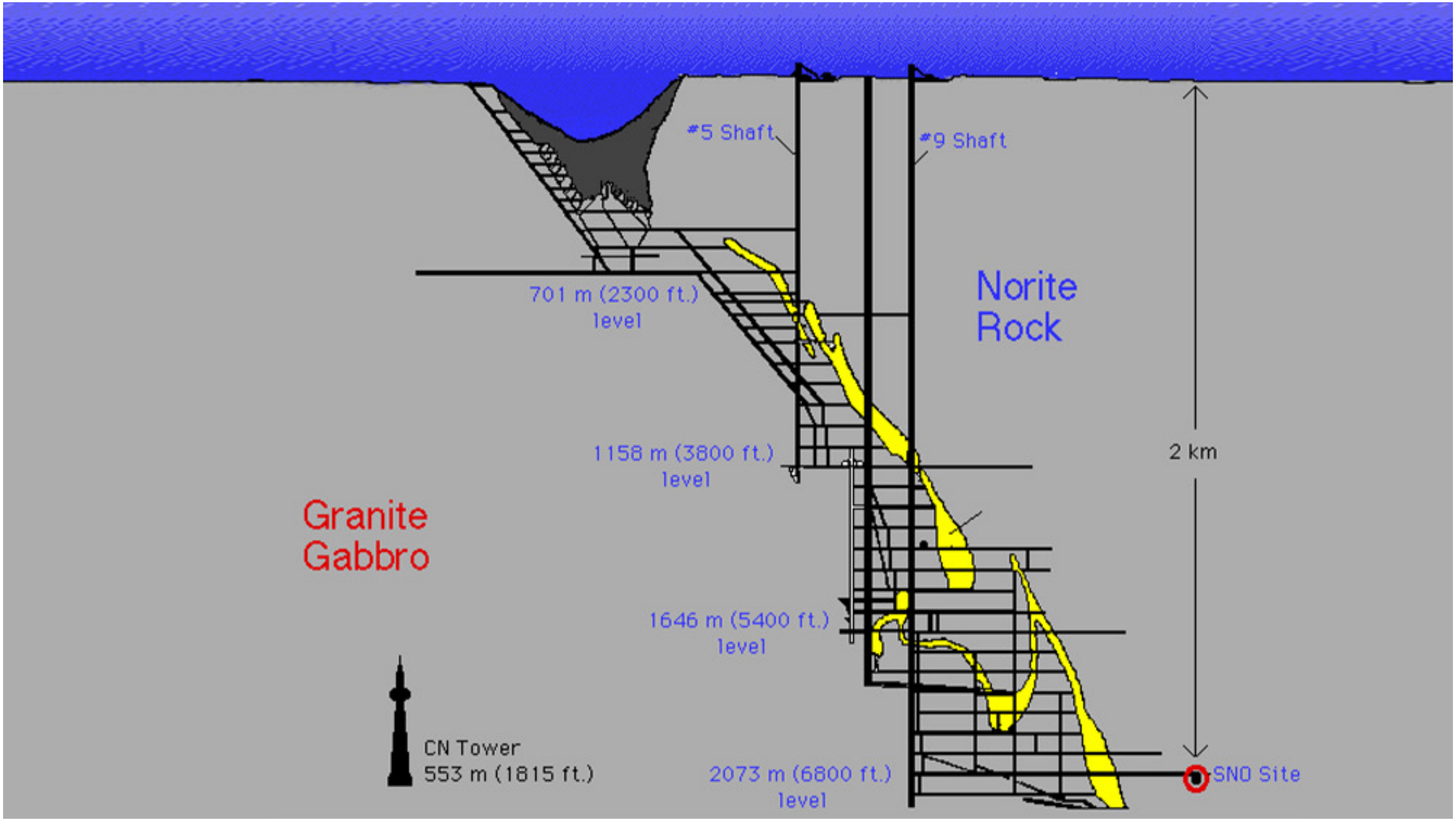
# The Sudbury Neutrino Observatory

**Nobel Prize in Physics 2015:** Takaaki Kajita & Arthur B. McDonald

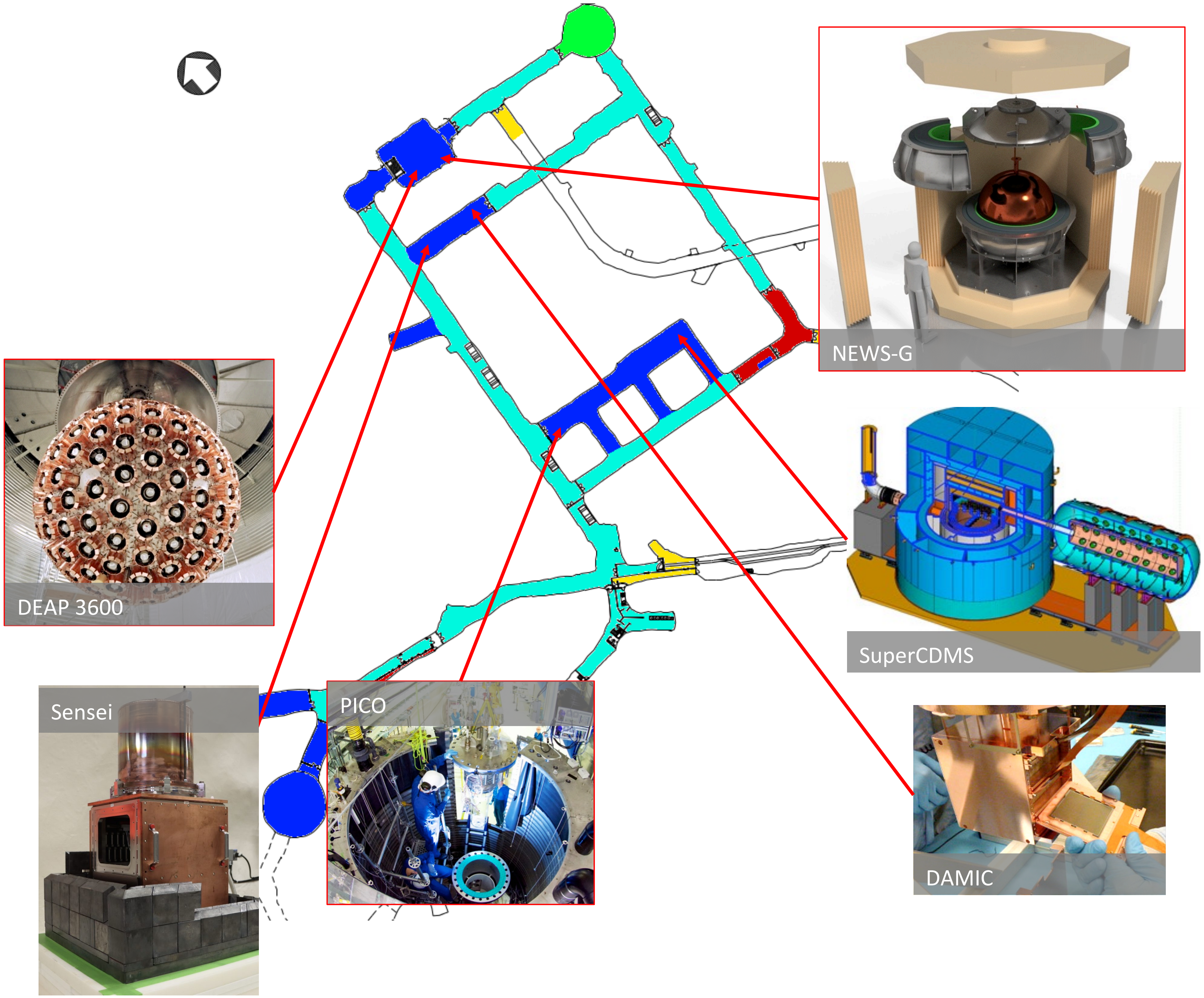
**2016 Breakthrough Prize in Fundamental Physics**:
Arthur B. McDonald and the SNO collaboration






#5 Shaft
#9 Shaft
Norite Rock
701 m (2300 ft.) level
1158 m (3800 ft.) level
2 km
Granite Gabbro
1646 m (5400 ft.) level
CN Tower
553 m (1815 ft.)
2073 m (6800 ft.) level
SNO Site

# Dark Matter detectors at SNOLAB

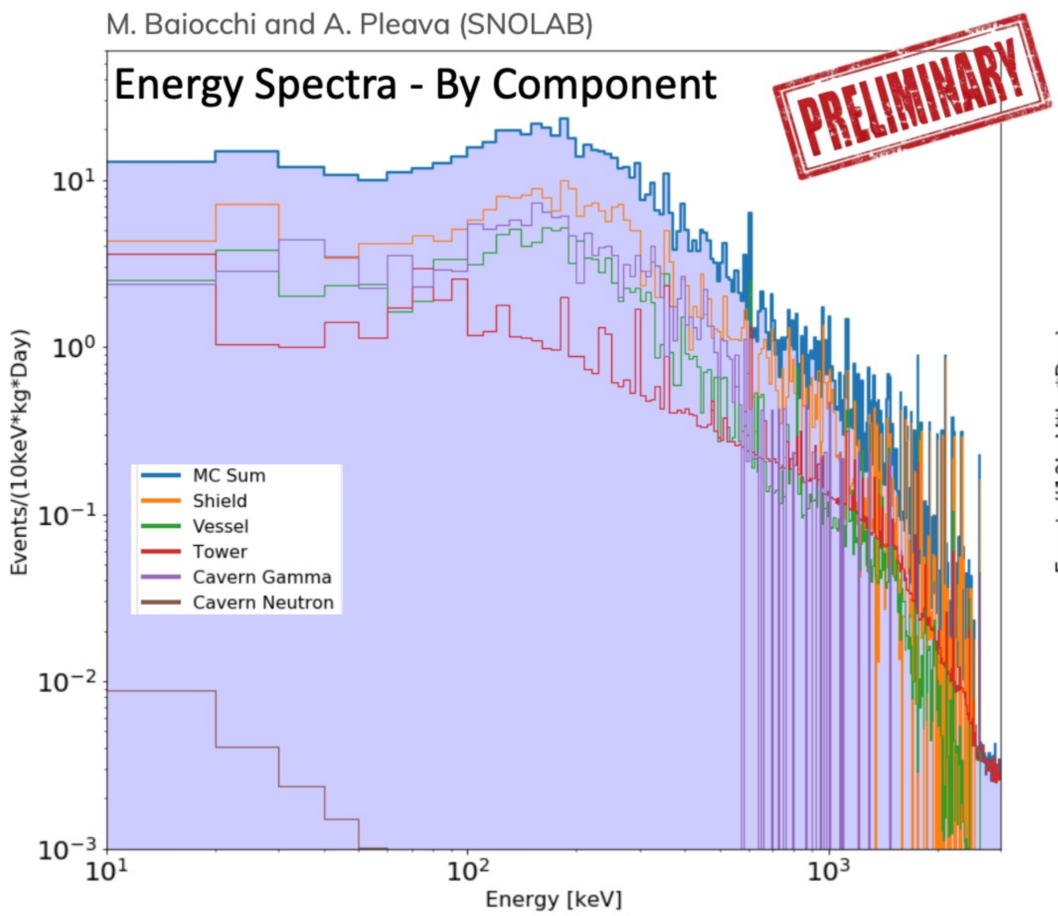


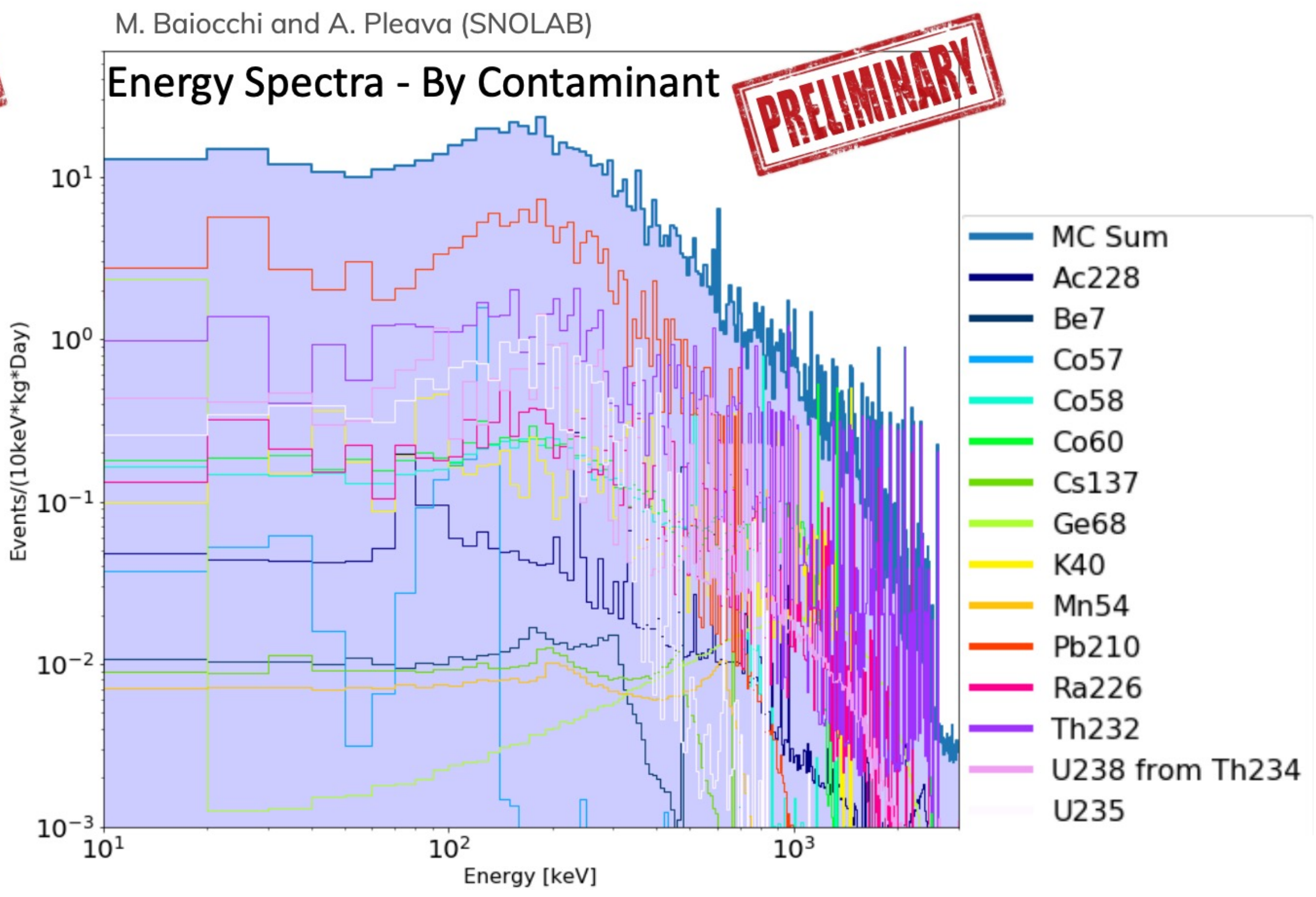
# Cryogenics

**Dilution Fridge:**

- Base temperature ~ 12 mK with payload
- Cooldown time ~ 3 ½ days, largely driven by ~100 kg internal Pb shielding
- Fridge can run unattended for extended periods, critical in the underground environment
  - New Liquid Nitrogen refill system allows for continuous running for ~ 2 months

# Backgrounds Budget



# Near Term Plans

**SNOLAB User Facility:**

- **CUTE is a SNOLAB user facility!**
- SNOLAB-maintained and continuously improved
  - Collect proposals
  - Expert committee will make recommendations, CUTE management will negotiate details
  - Work with users to implement their experiment

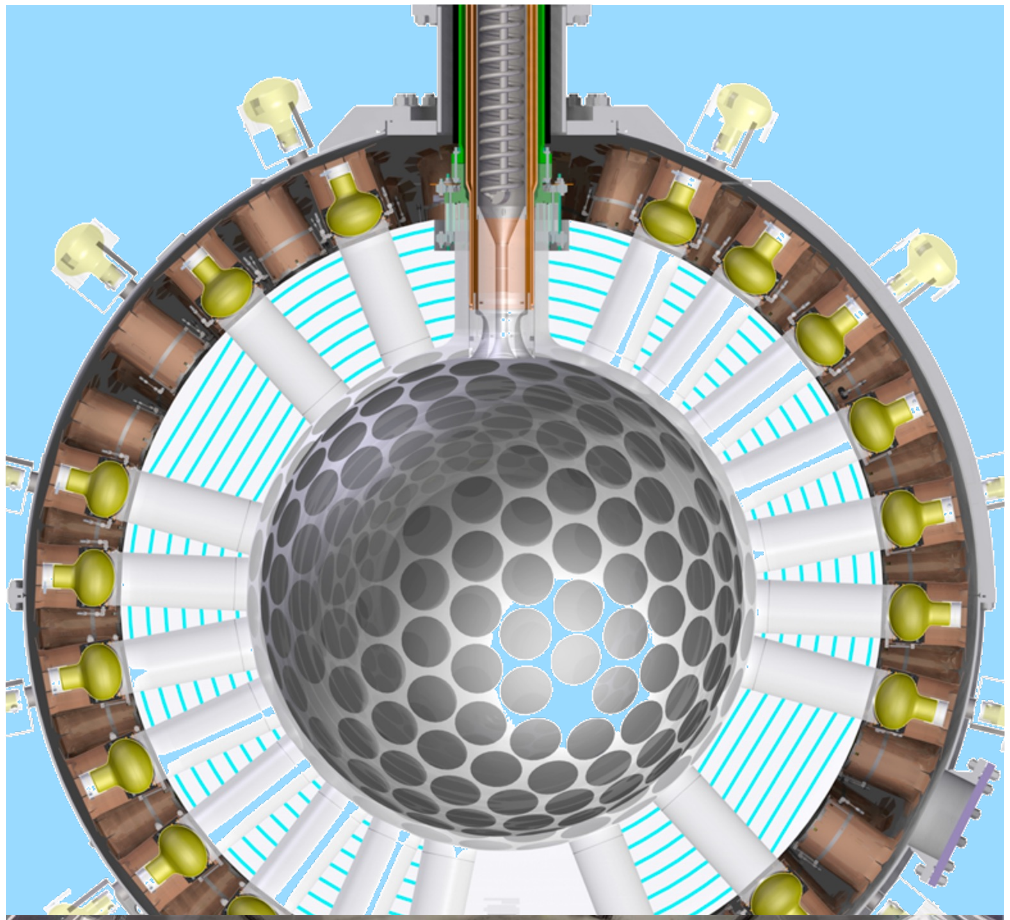
**Future Uses**

- **Detector testing**
  - Future DM detectors (total mass of ~ 20 kg are possible)
  - Rare event searches (such as $^{50}V$ rare nuclear decay search)
  - HVeV devices
  - Single photon IR sensors (Nanowire)
  - **Testing effect of backgrounds on superconducting qubits**
  - <insert your idea here>

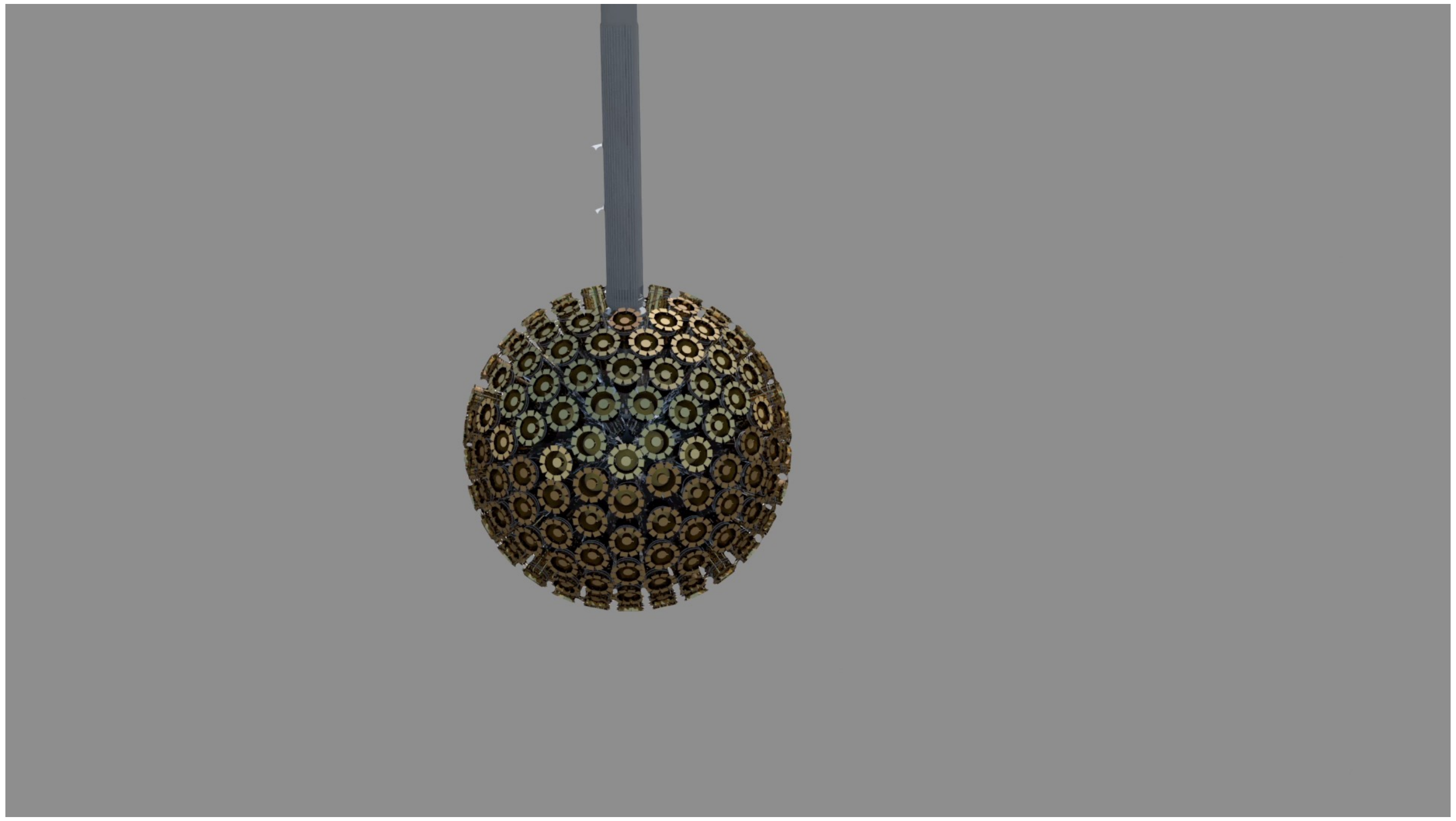
**Interested?**

***Have a project that would benefit from running at CUTE?***

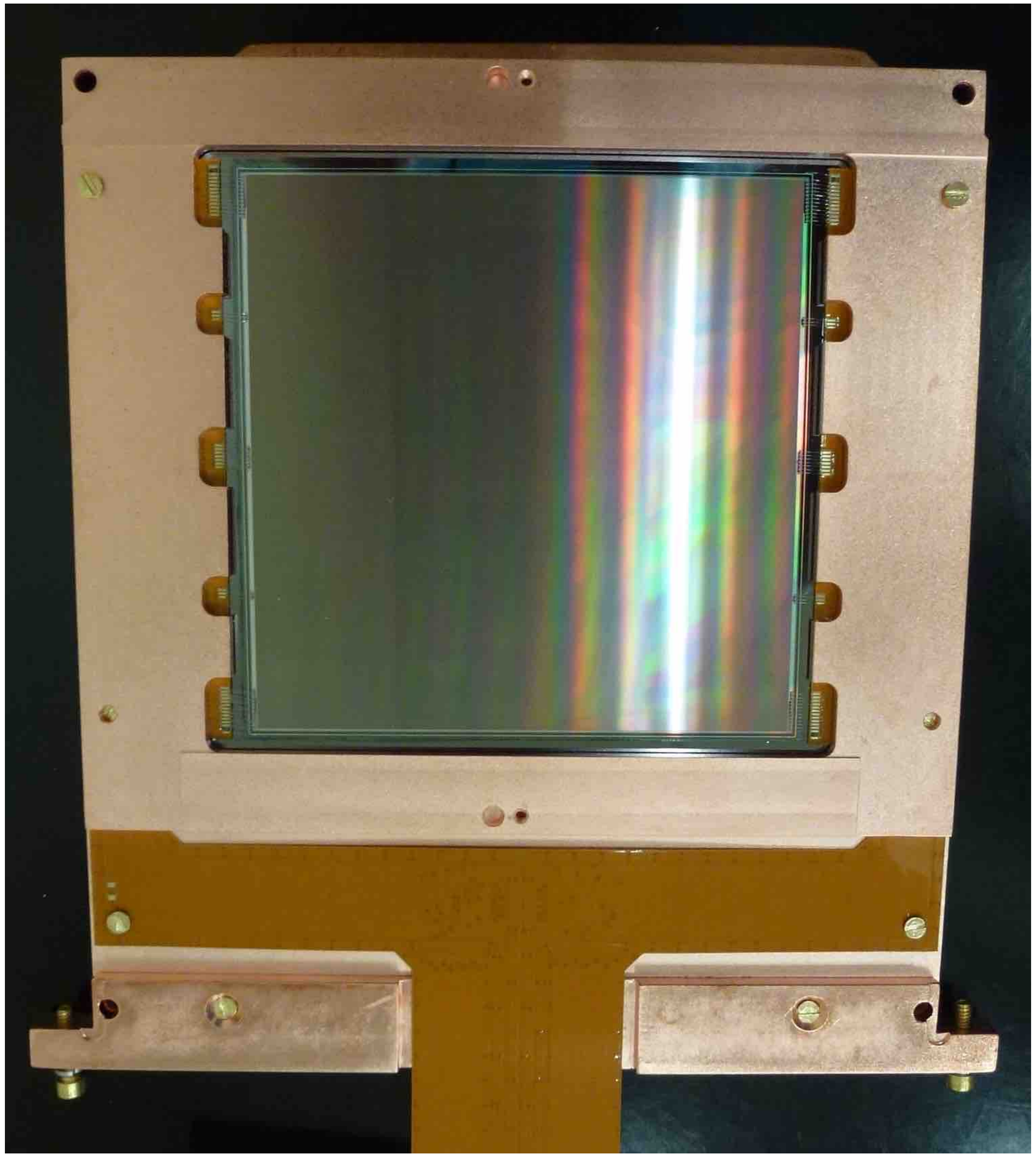
**Please let us know!**



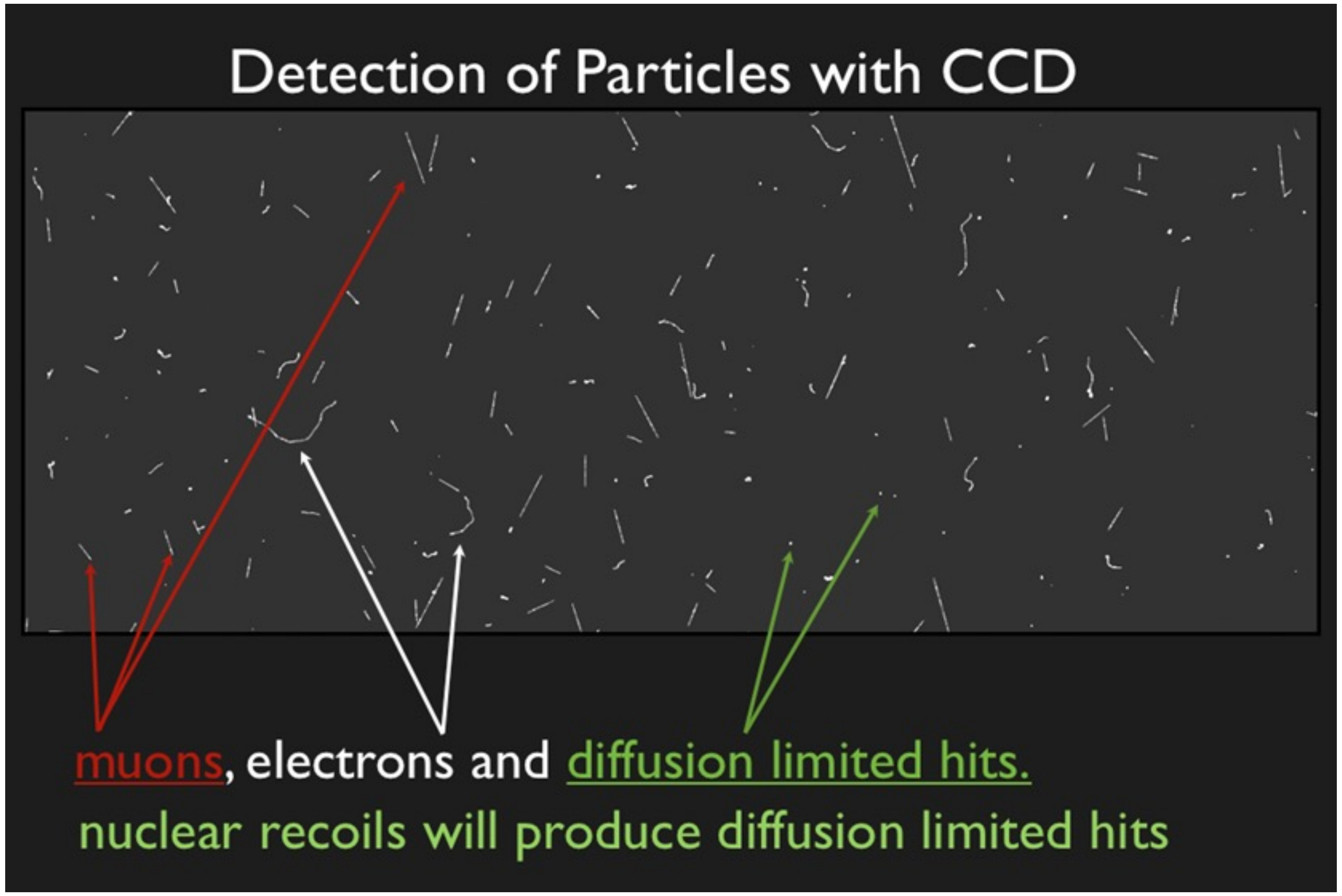
# Deap-3600



- **3600kg Liquid Argon**
- **Lots of mass, so DEAP-3600 is great a looking for higher mass DM particles.**
- **Signal is Scintillation at interaction, measured by Photomultiplier tubes**



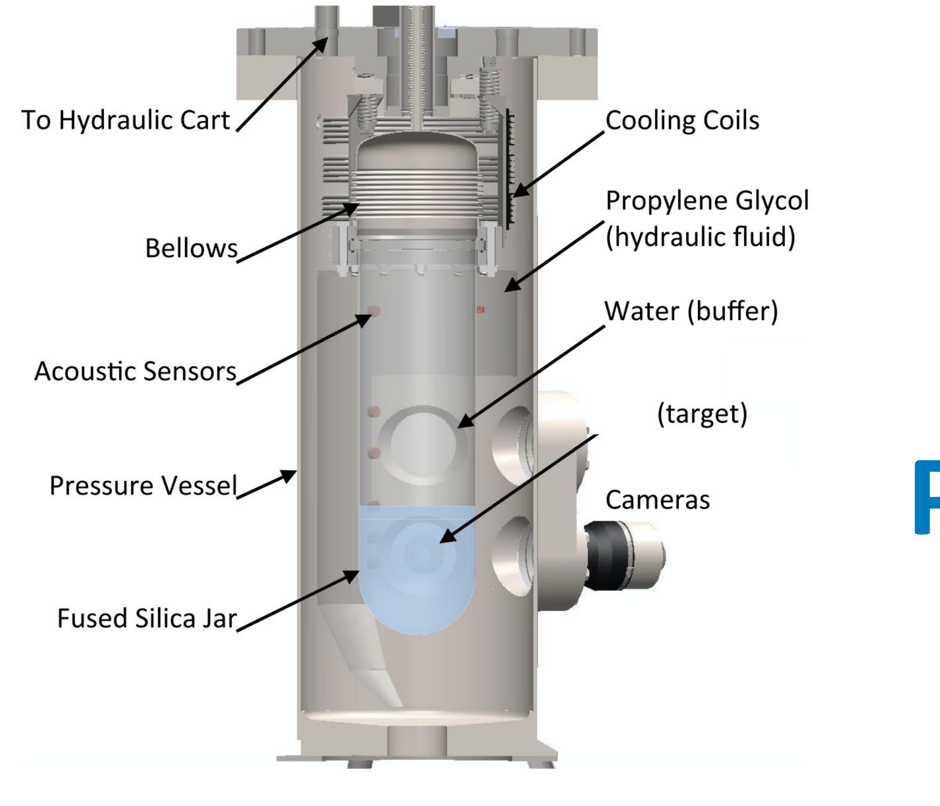
# Damic



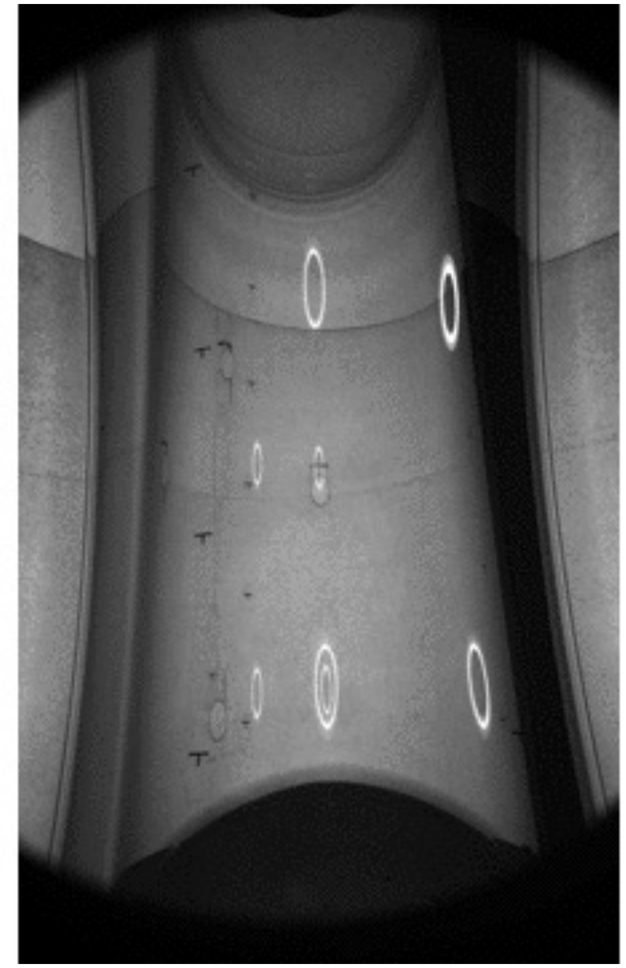

- **Damic uses Silicon CCDs (very much like the CCDs in your phone's camera). They essentially take a long exposure photo in a very shielded environment.**

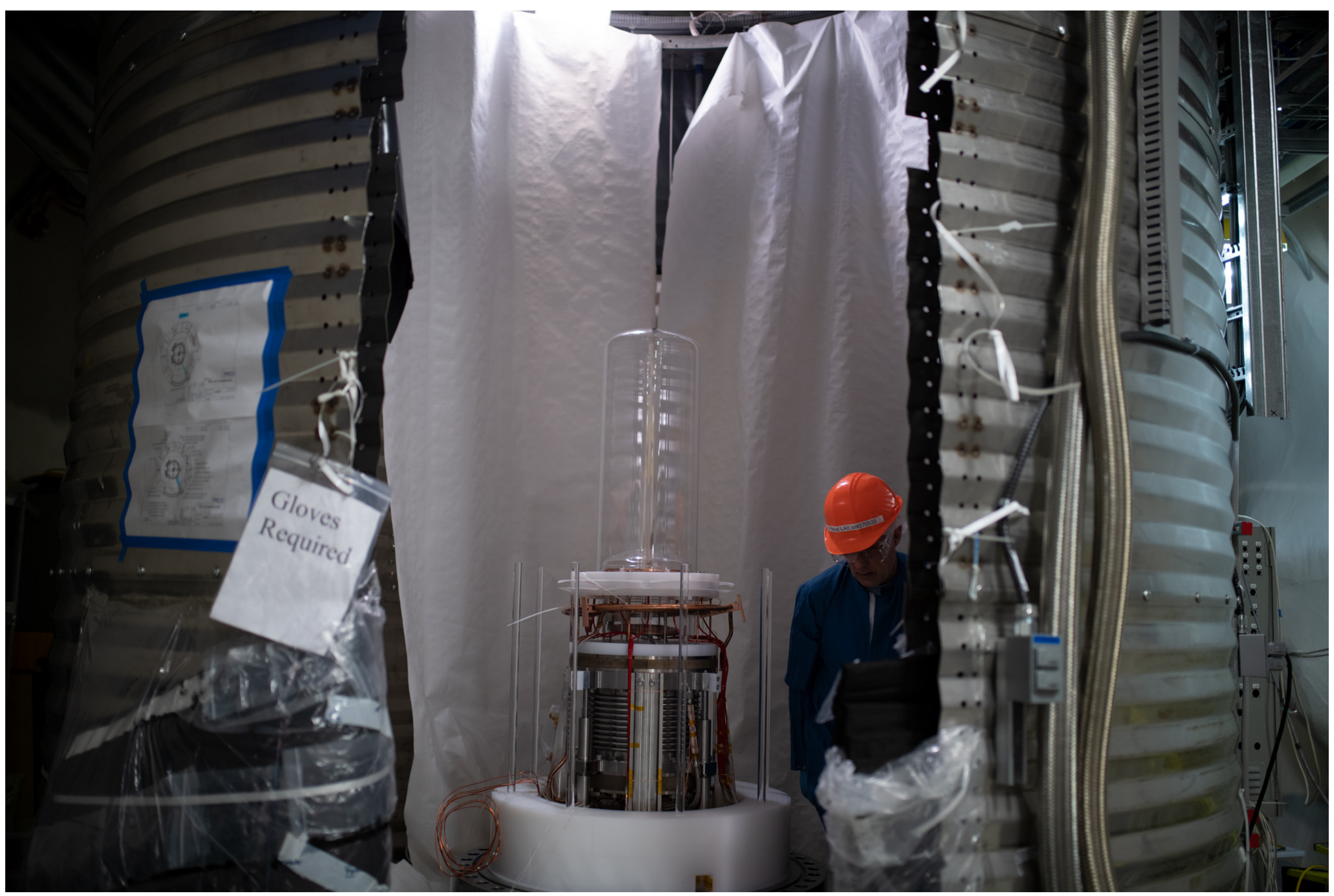
- **Each interaction creates an identifiable signature on the photo**

- **Smaller detector, but very sensitive. Great for lower mass DM candidates which interact with either nuclei or electrons.**



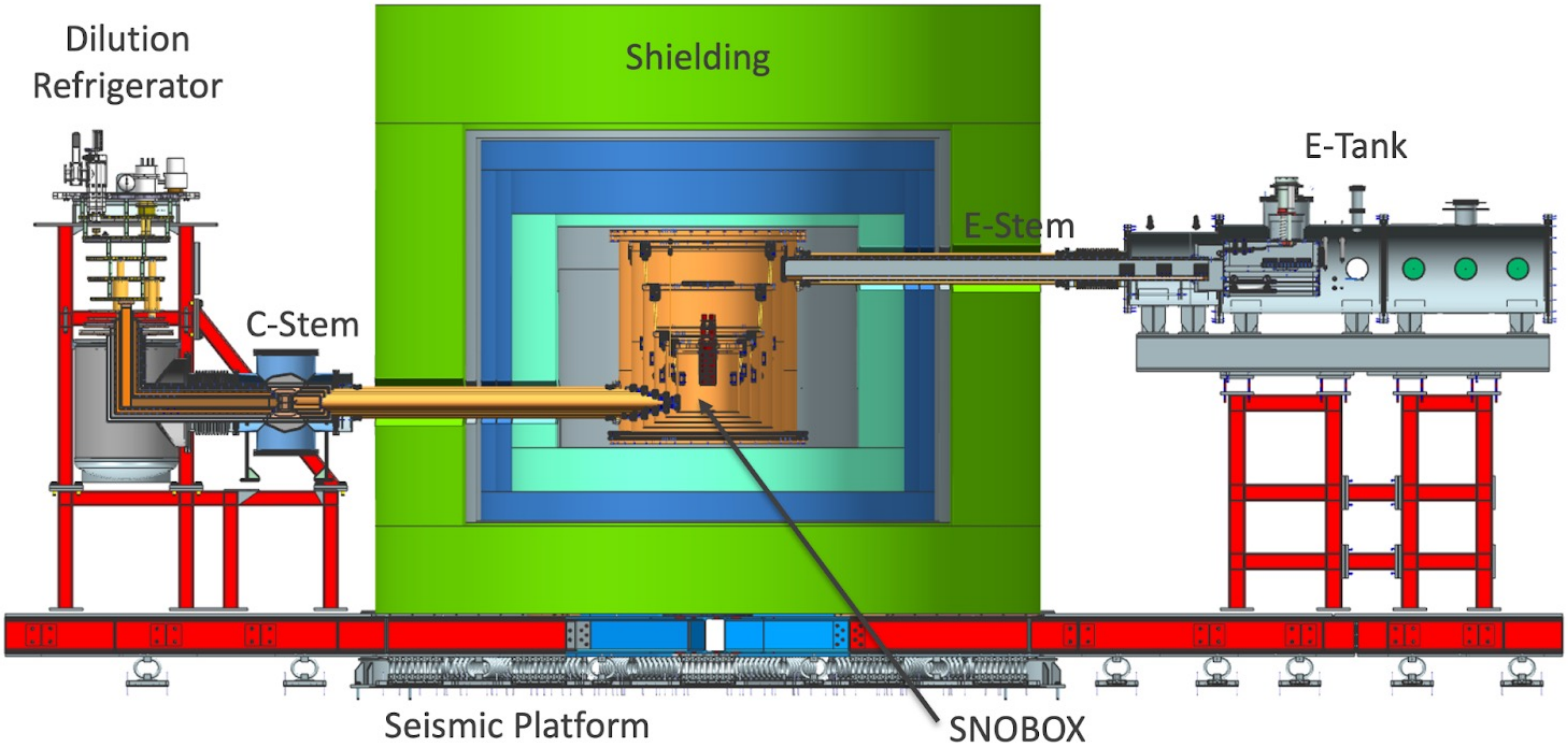

# Pico





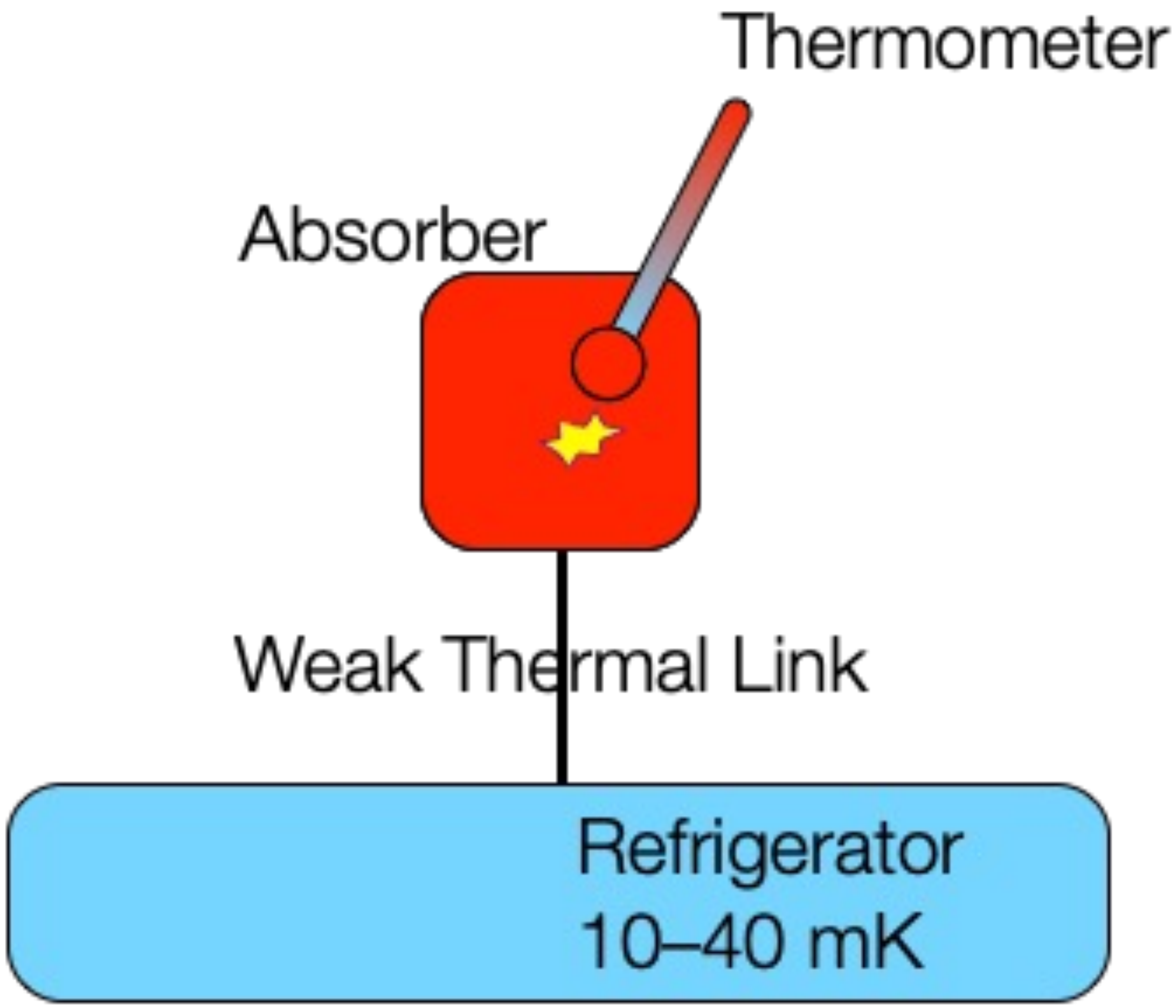

- **40L Superheated $C_3F_8$ Bubble chamber**
- **Interaction nucleates a bubble which is then caught on camera (and "heard" by sensitive microphones)**
- **$C_3F_8$ is particularly sensitive to DM candidates with spin. The detector is also not very sensitive to electron recoils and therefore naturally reduces a lot of backgrounds!**

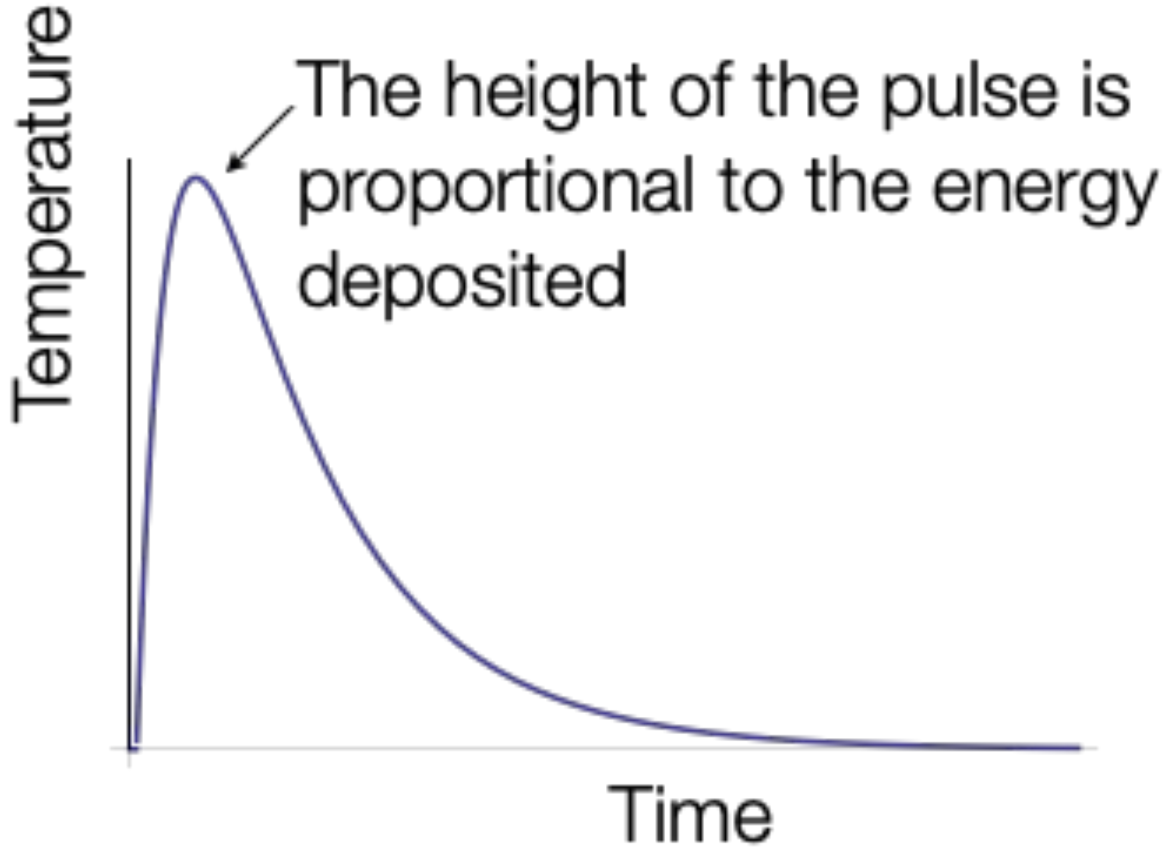
# SuperCDMS:
# Super Cryogenic Dark Matter Search



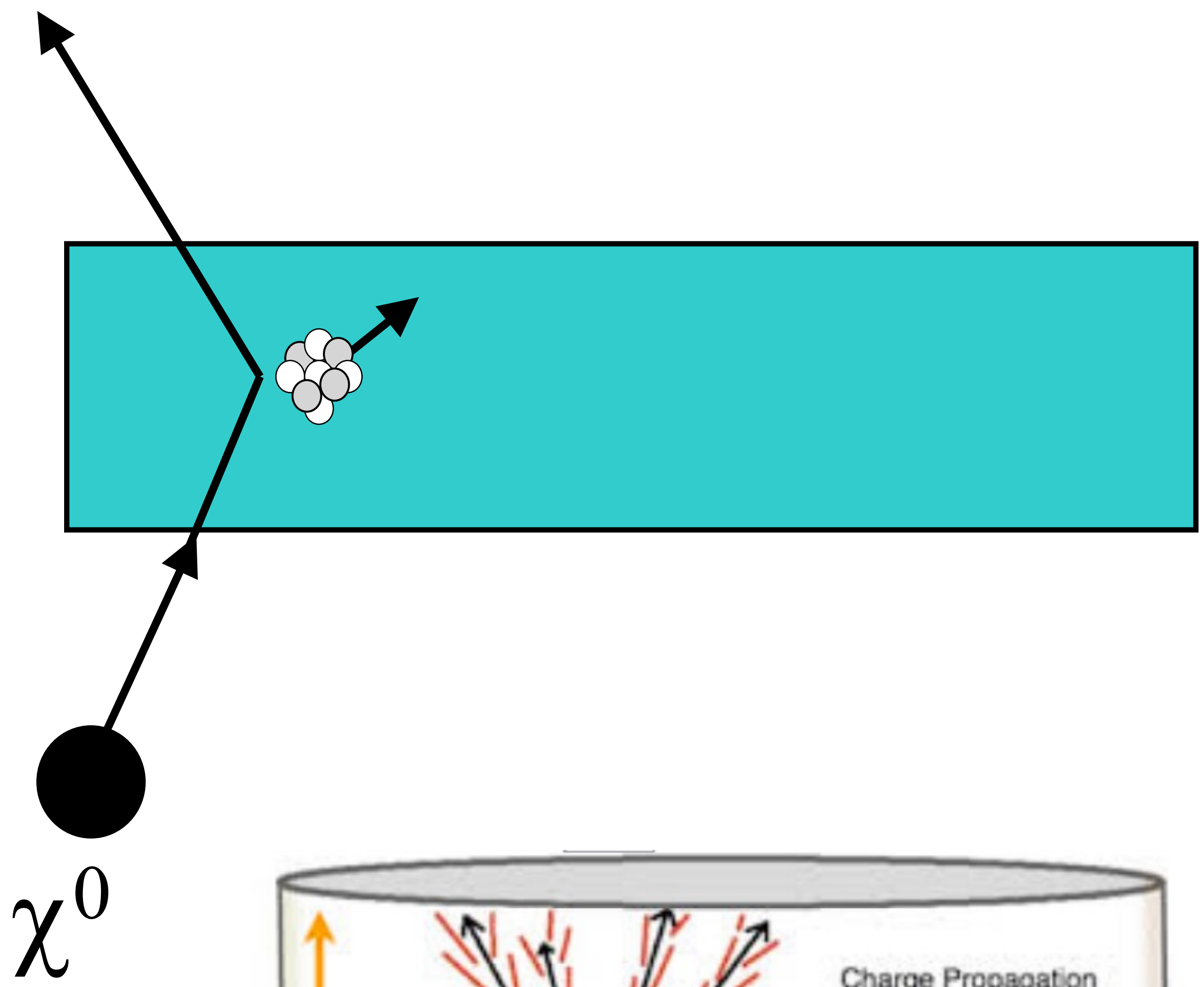

I'm going to spend a little more time on SuperCDMS than the others (because I'm working on it)…

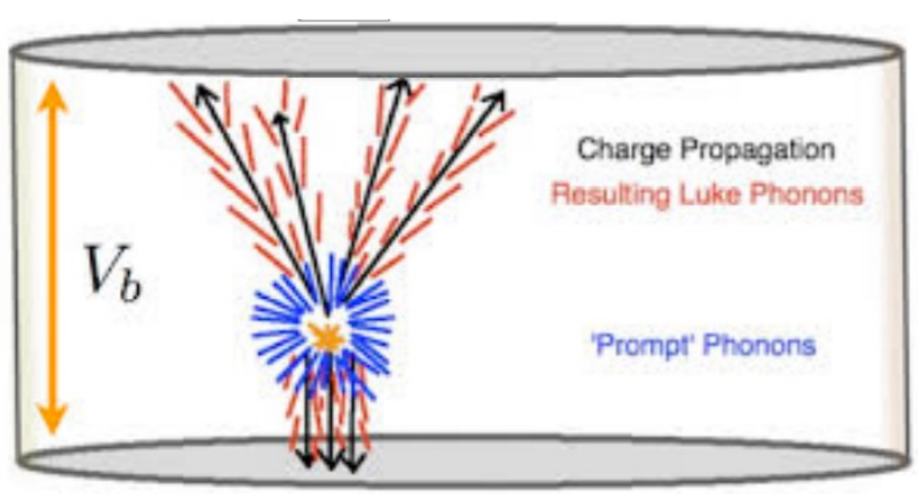
The Phonon Channel



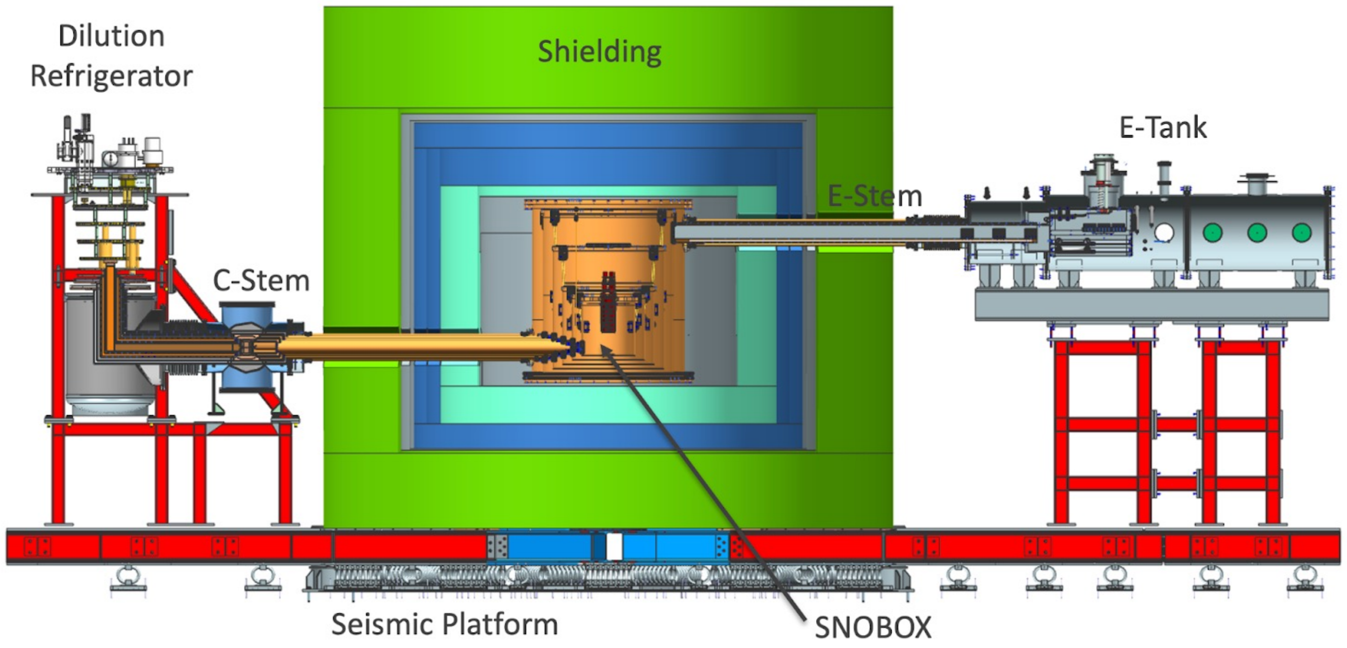




**Everybody has their choice of the favourite thermometer! Ours is a Transition Edge Sensor (TES).**



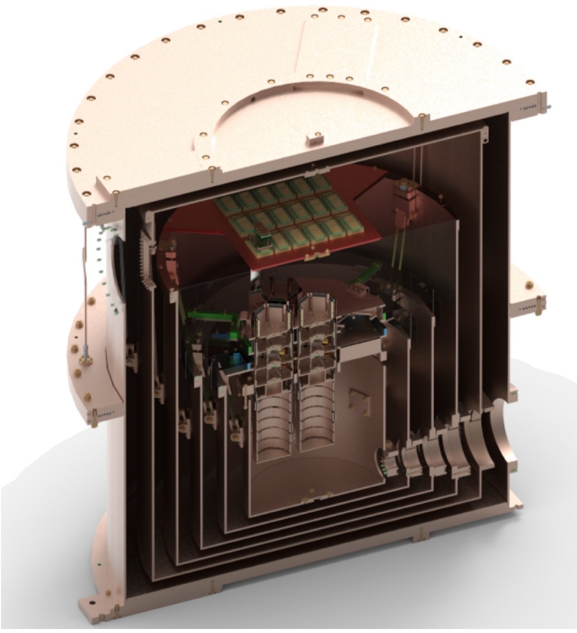

- General Idea:
  - Cryogenically cooled **Ge** or **Si** crystal
  - DM recoils off nucleus (or electron) in target, creating phonons (Heat) and liberating electron-hole pairs (**charge**)
  - Phonons read out using Transition Edge Sensor (TES) array. More about this in a second.
  - Electrons/holes drifted to surfaces by applying a Voltage bias to the top and bottom. This creates an electric field.

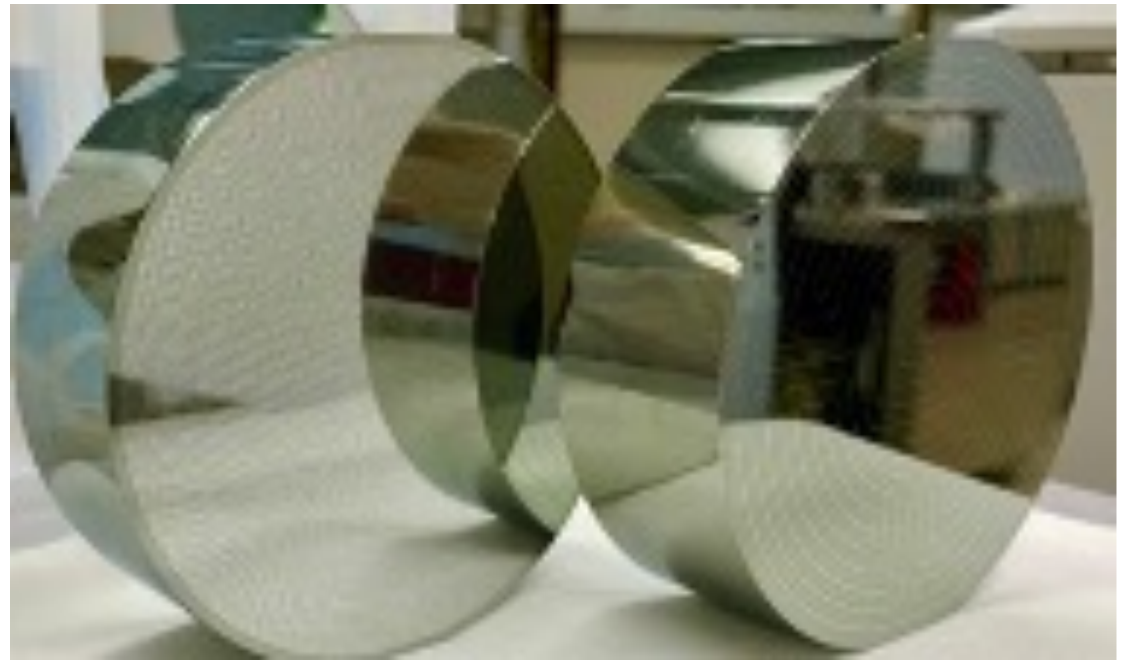




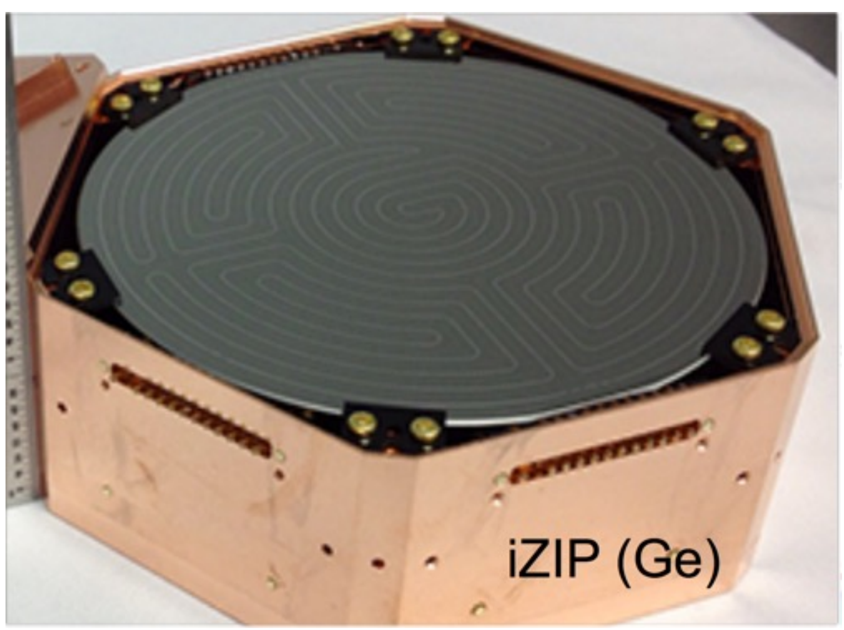
Exploiting the fundamental idea of lower temperature
→ Lower amount of random motions
→ Lower noise
→ Better energy sensitivity & low threshold

**The workhorse of SuperCDMS is our He3/He4 dilution refrigerator. This cools our detectors down to about 15 mK.**

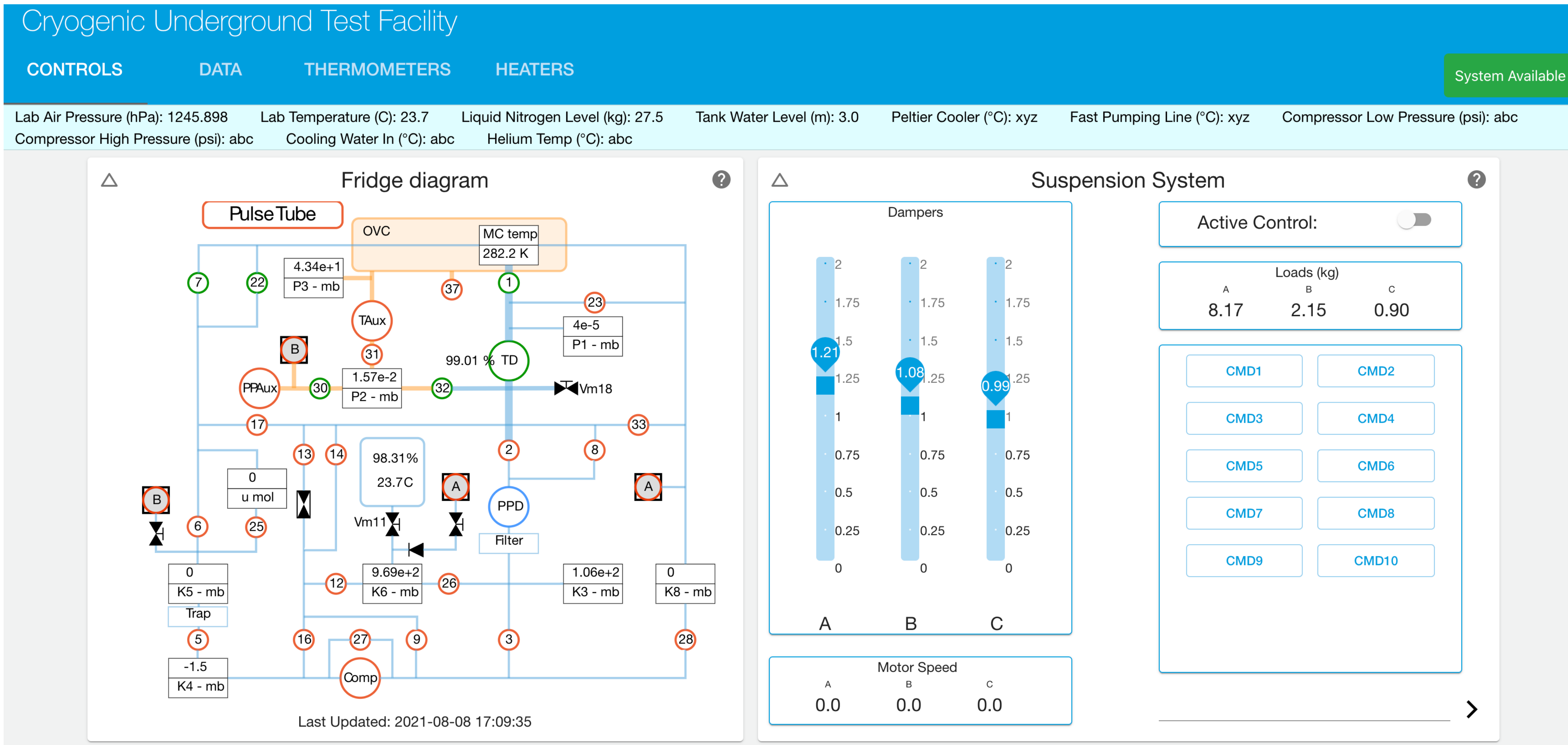




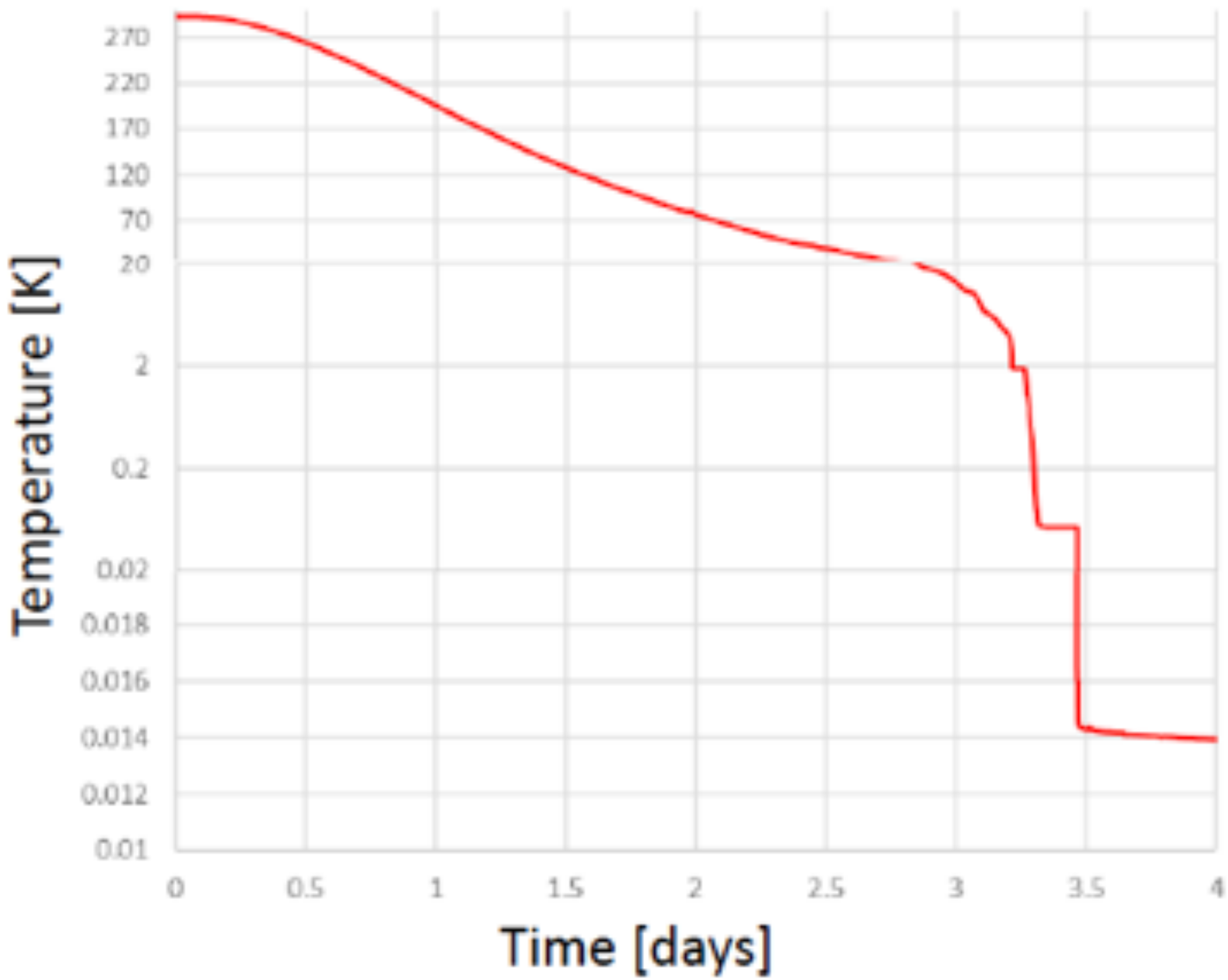
- **Cryogenic Silicon and Germanium**
  - 3”-4” diameter
  - 1”-1.33” thick



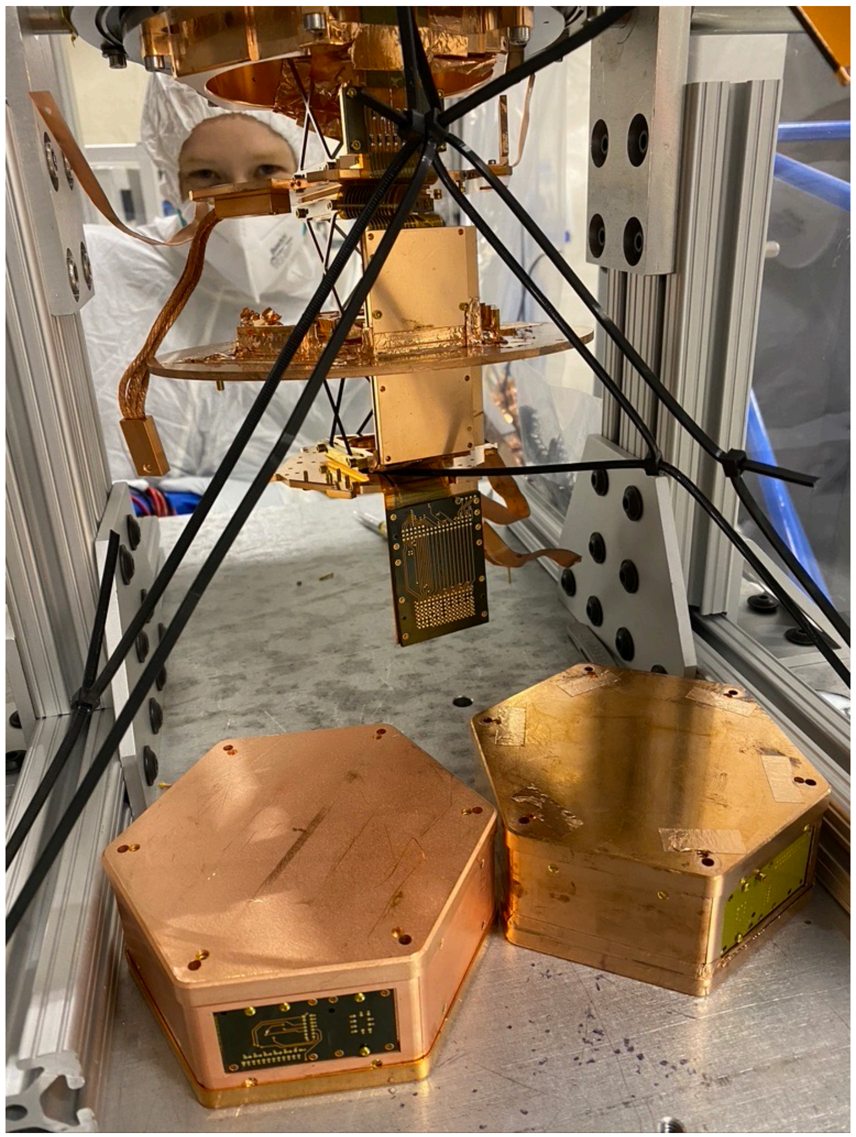

# Remote Operations

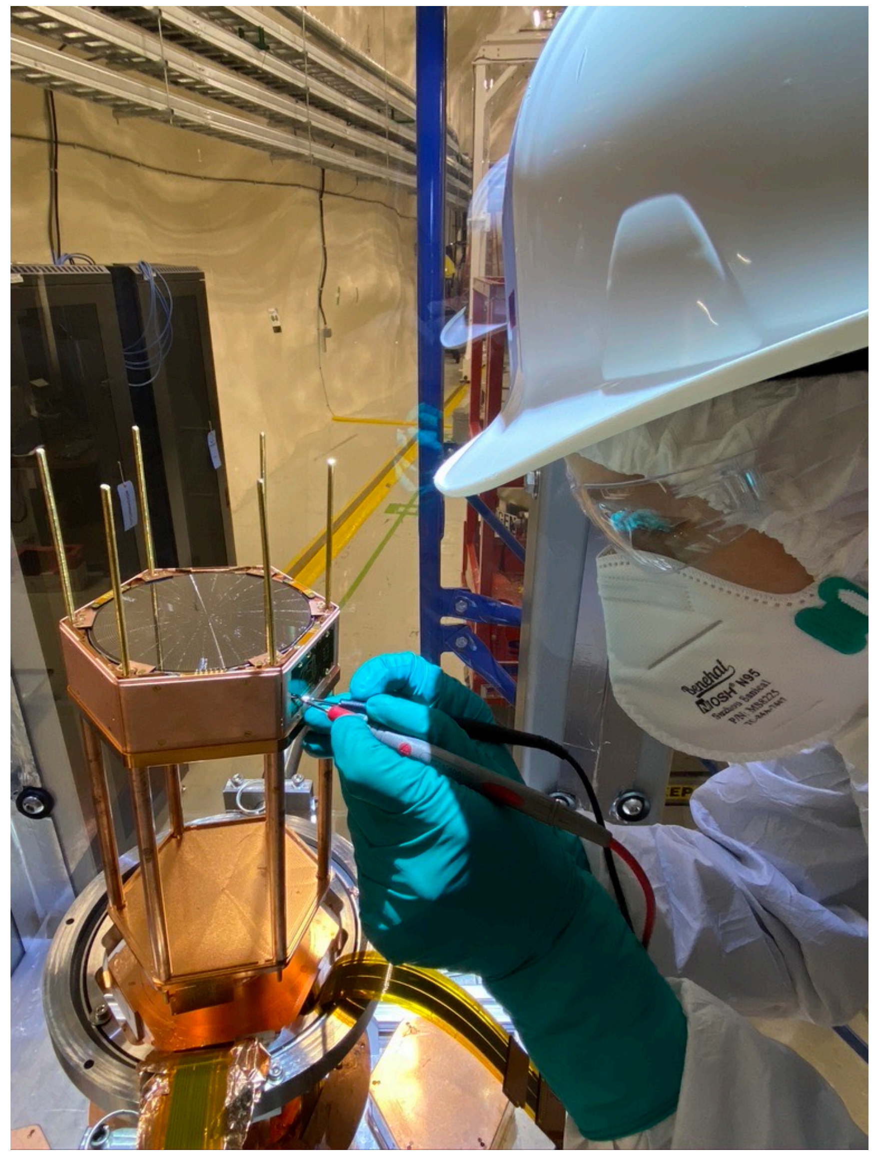


CUTE Fridge cooldown



# "Ops" Tower in CUTE





**SuperCDMS Detector Testing:**

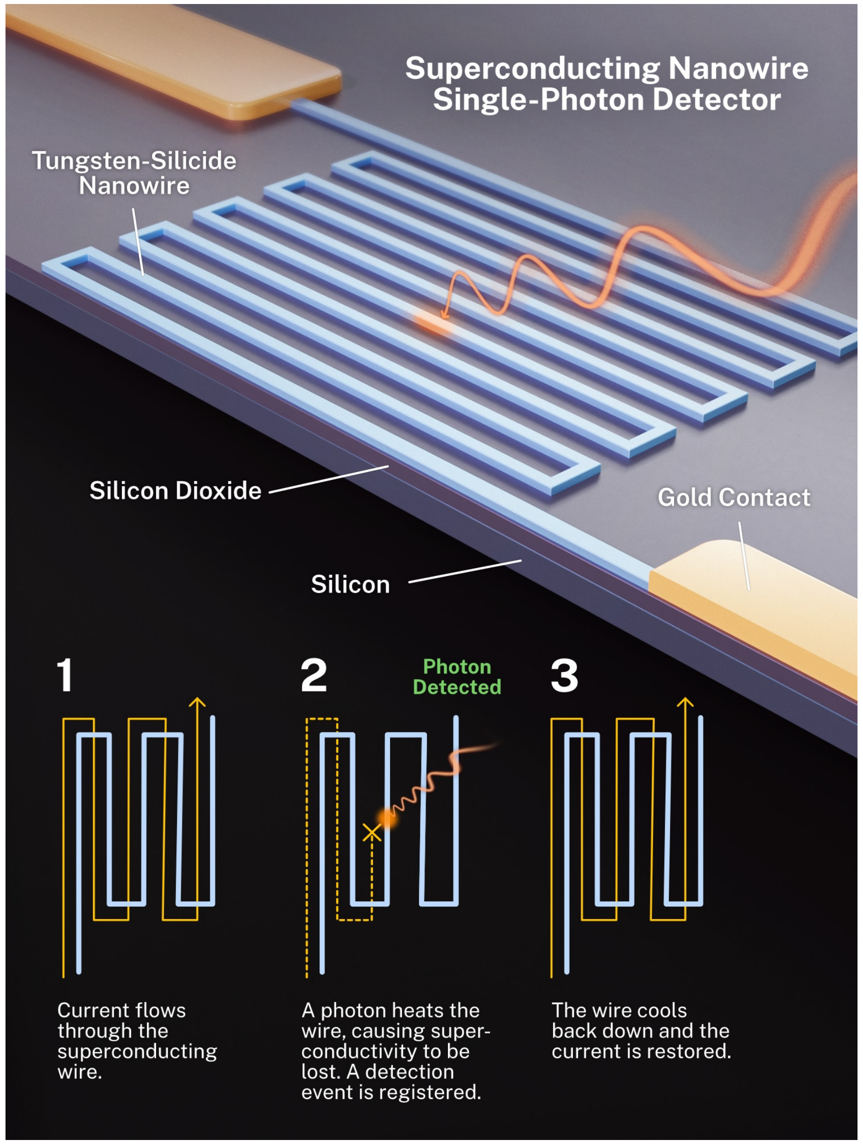
- Current work
- Single SuperCDMS HV detector (Ge or Si)
- Focus on:
  - Facility performance
  - Calibration
  - Noise hunting
  - Preparing for tower data

# Full Tower(s) in CUTE

**<u>SuperCDMS Full Tower Test:</u>**

- Towers 3 and 4 arrived at SNOLAB earlier this year
  - Tower 3: 4 Ge and 2 Si HV detectors
  - Tower 4: 4 Ge and 2 Si iZIP detectors
- Priority is testing towers for SuperCDMS, but we hope to run long enough to get physics data as well

# SuperConducting Nanowires

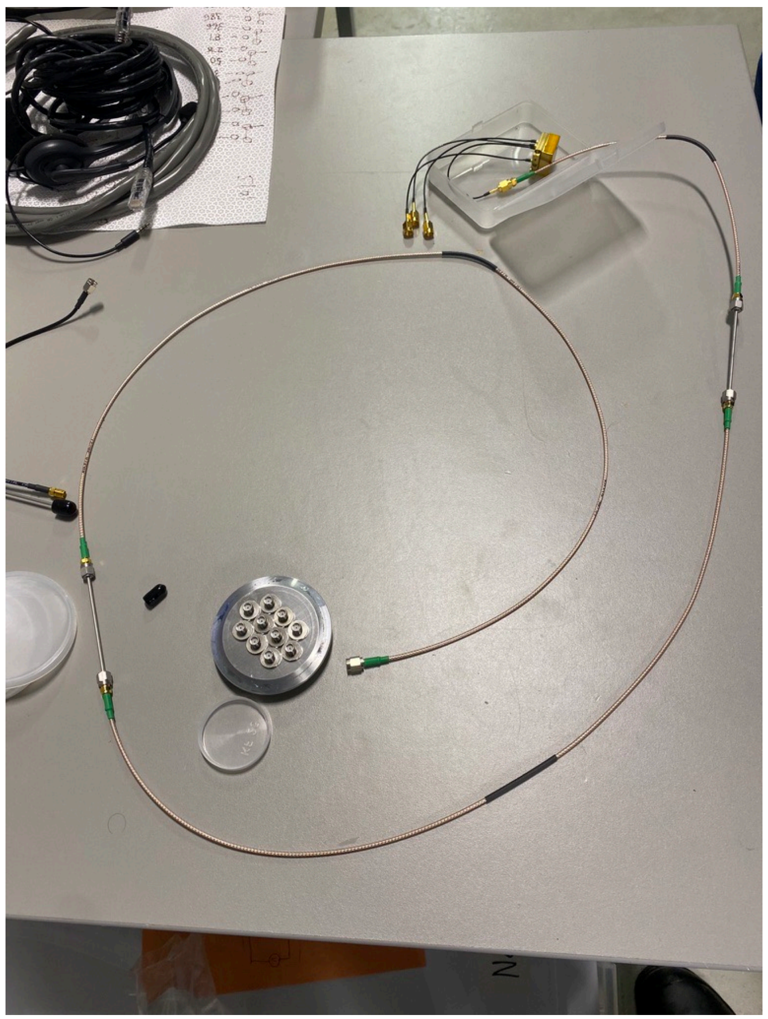


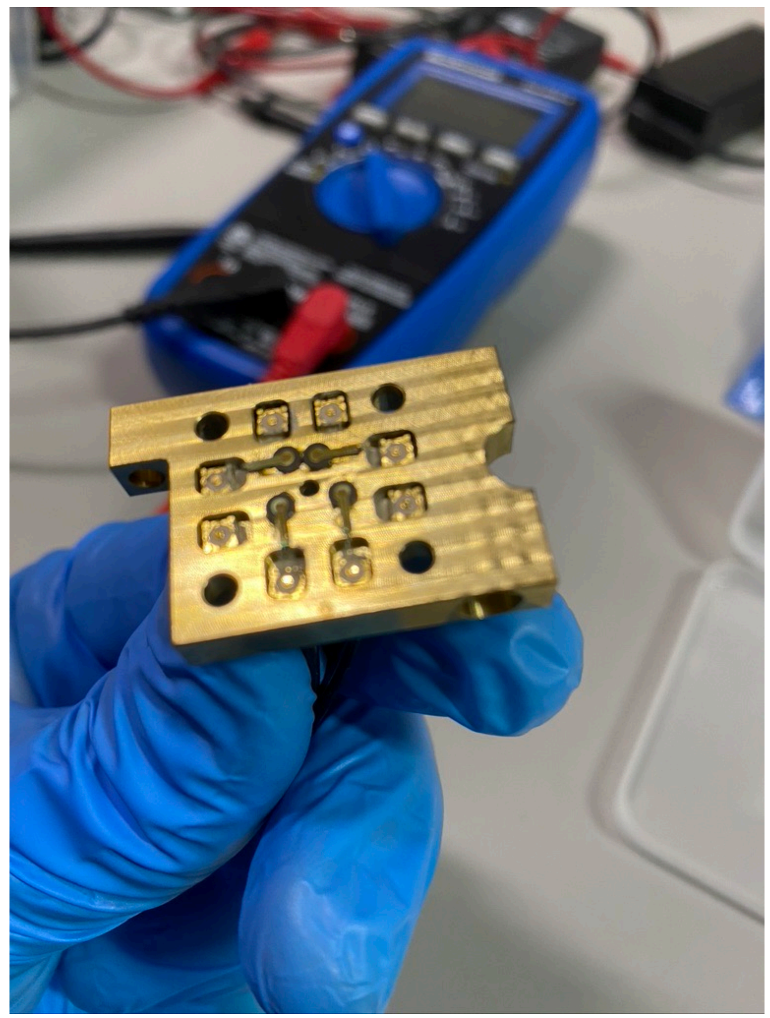

*Credit: S. Kelley/NIST*

**<u>How do we understand the non-ionizing radiation environment in CUTE?</u>**

- Increasingly important as we move to lower and lower energy threshold
- Can measure the infrared portion using SuperConducting Nanowire Single-Photon Detectors (SNSPDs)
- Sensitive to short-wave infrared photons
- Spectral information from tunable threshold
- Simple readout, low cost to set up
- Potential for DM hunting as well

# Superconducting Nanowires



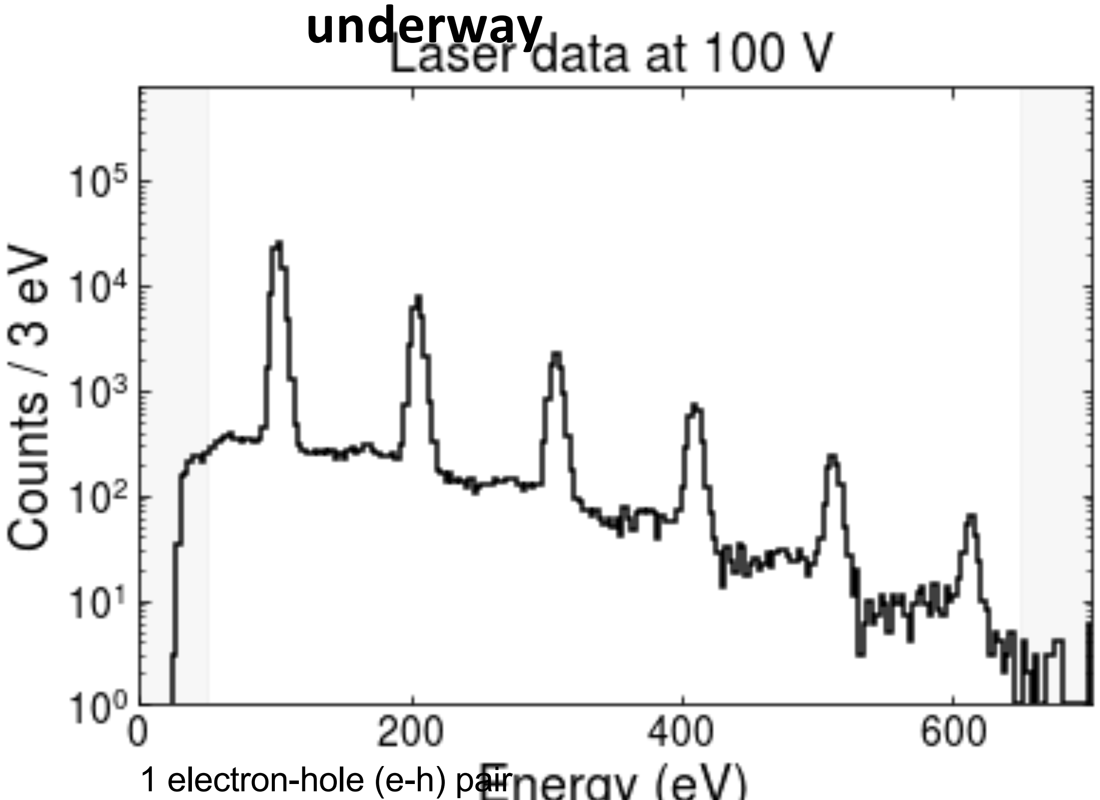


**<u>Collaboration between SNOLAB and NIST</u>**

- Proof of principle device in hand
- Can run at 1 Kelvin so testing can be in parallel with other projects
- Currently working on readout wiring, hope to test device soon

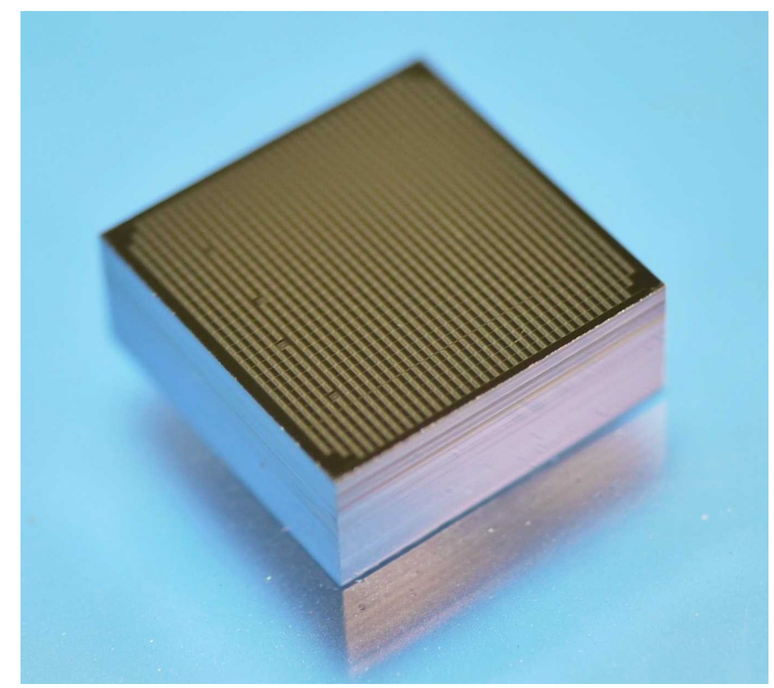
# Another Facility for HVeV Operations

- **HVeV Detectors Underground**
  - **Proposal for 5 detectors**
  - **Plan for readout and installation underway**




1 electron-hole (e-h) pair
Fill-in between peaks: charge trapping and impact ionization

**See Ziqing's talk from yesterday!**



D. W. Amaral *et al.,* Phys. Rev. D 102, 091101(R), 2020
F. Ponce, et al., Phys. Rev. D 101, 031101(R), 2020
R. Ren et al., Phys. Rev. D 104, 032010, 2021

# The CUTE Team

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|---|---|
| PI | until 2020: G. Gerbier (W. Rau: Co-PI) |
| | since 2020: W. Rau |
| Project Manager | until 2017: Ph. Camus |
| | 2018-2020: S. Nagorny |
| Operations Manager | until 2022: S. Scorza, A. Kubik interim |
| SNOLAB team | A. Kubik, J. Hall, S. Scorza (until 2022) (Research Scientists) |
| | J. Gauthier (until 2022) (Operations Engineer) |
| | R. Schleehahn (Operations Engineer) |
| | J.M. Olivares (Technical support) |
| | M. Baiocchi, A. Pleava, S. Jess, Y. Esenullah (students) |
| | Support from SNOLAB technical team |
| On-site work | J. Corbett, M. Ghaith, S. Nagorny (until 2020) |
| Off-site | R. Germond (slow control) |
| | Z. Hong (facility upgrades) |
| | T. Aramaki (payload) |
| | B. Serfass, E. Fascione, E. Michielin, |
| | R. Underwood, Y. Liu et al (DAQ) |
| | A. Mayer, S. Pandey, T. Reynolds, A. Reyes, V. Iyer, A. Pradeep, M. Al-Bakry, |
| | R. Bhattacharyya, S. Dharani |
| | P. Pakarha (2018/19, calibration) |
| | K. Dering, S. Crawford (design engineering, until 2019/20) |