The Cryogenic Underground Test facility at SNOLAB

By: Matthew Stukel

For CAP Congress 2024
2024/05/28

Cryogenic Calorimeters

SNOLAB

CRESST

Cryogenic **Rare Event Search**
with Superconducting Thermometers

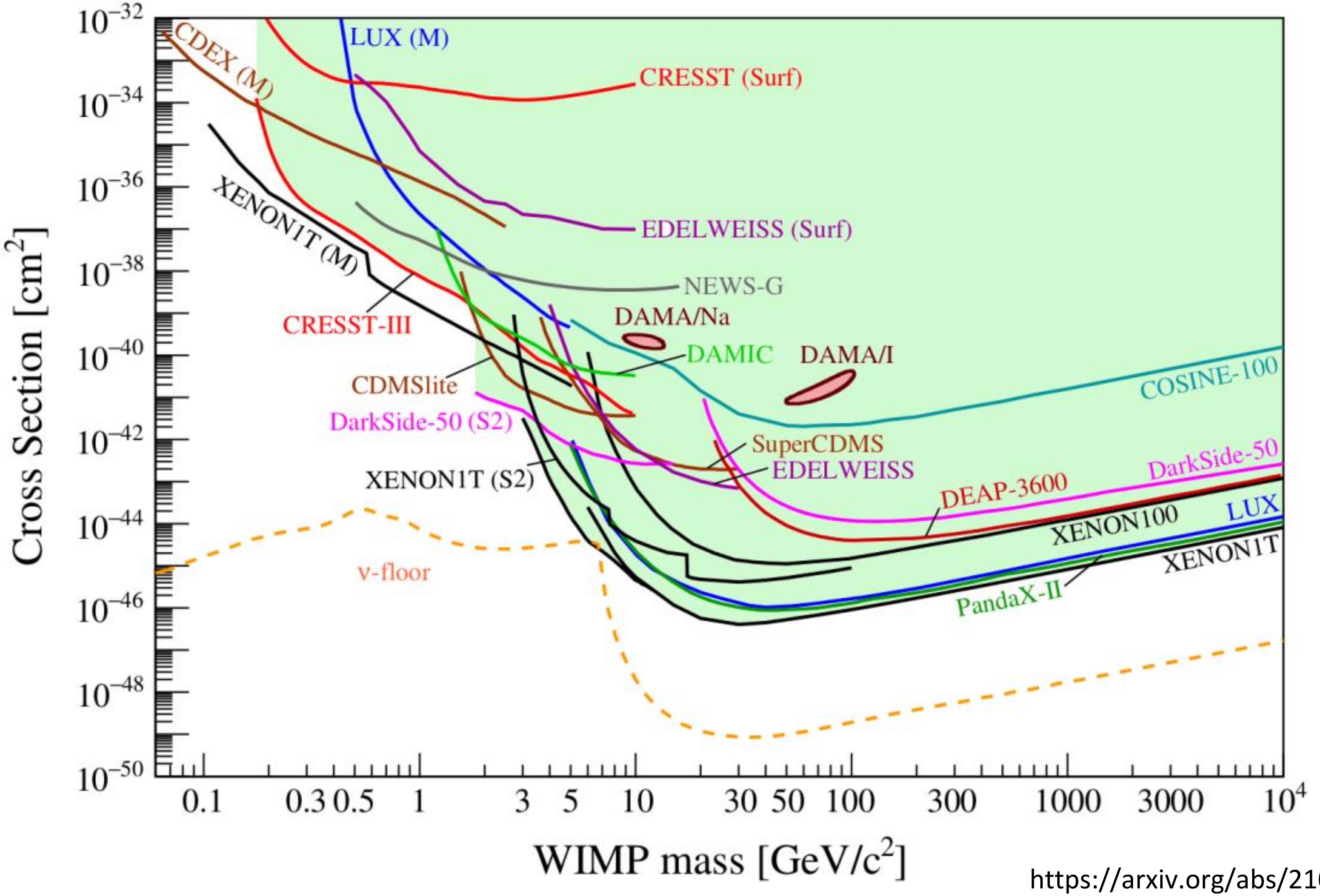
SUPER CDMS

Cryogenic Dark Matter Search

Best one

SPICE/HERALD

Others

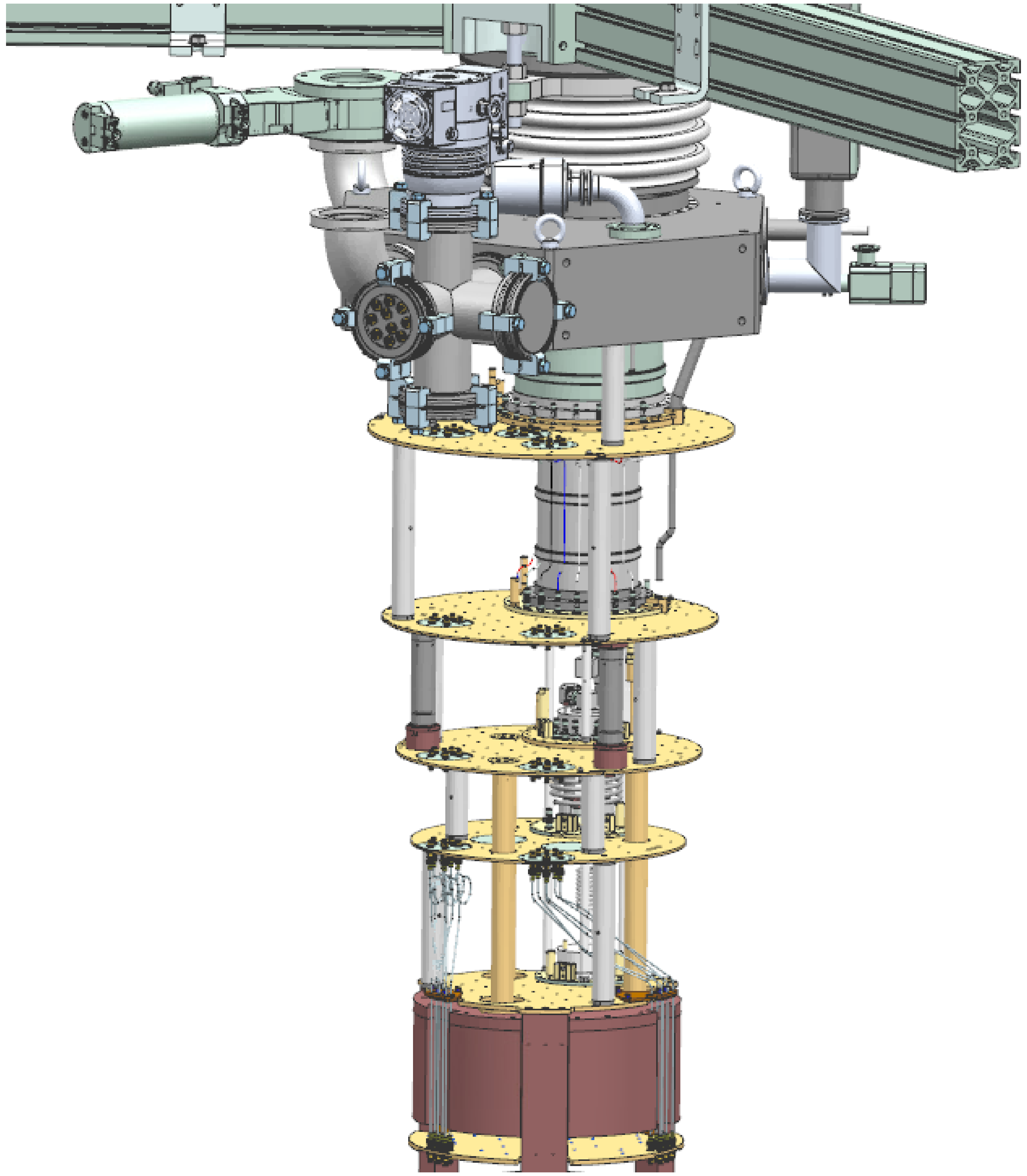


https://arxiv.org/abs/2104.07634

CUTE: Cryogenic Underground TEst facility

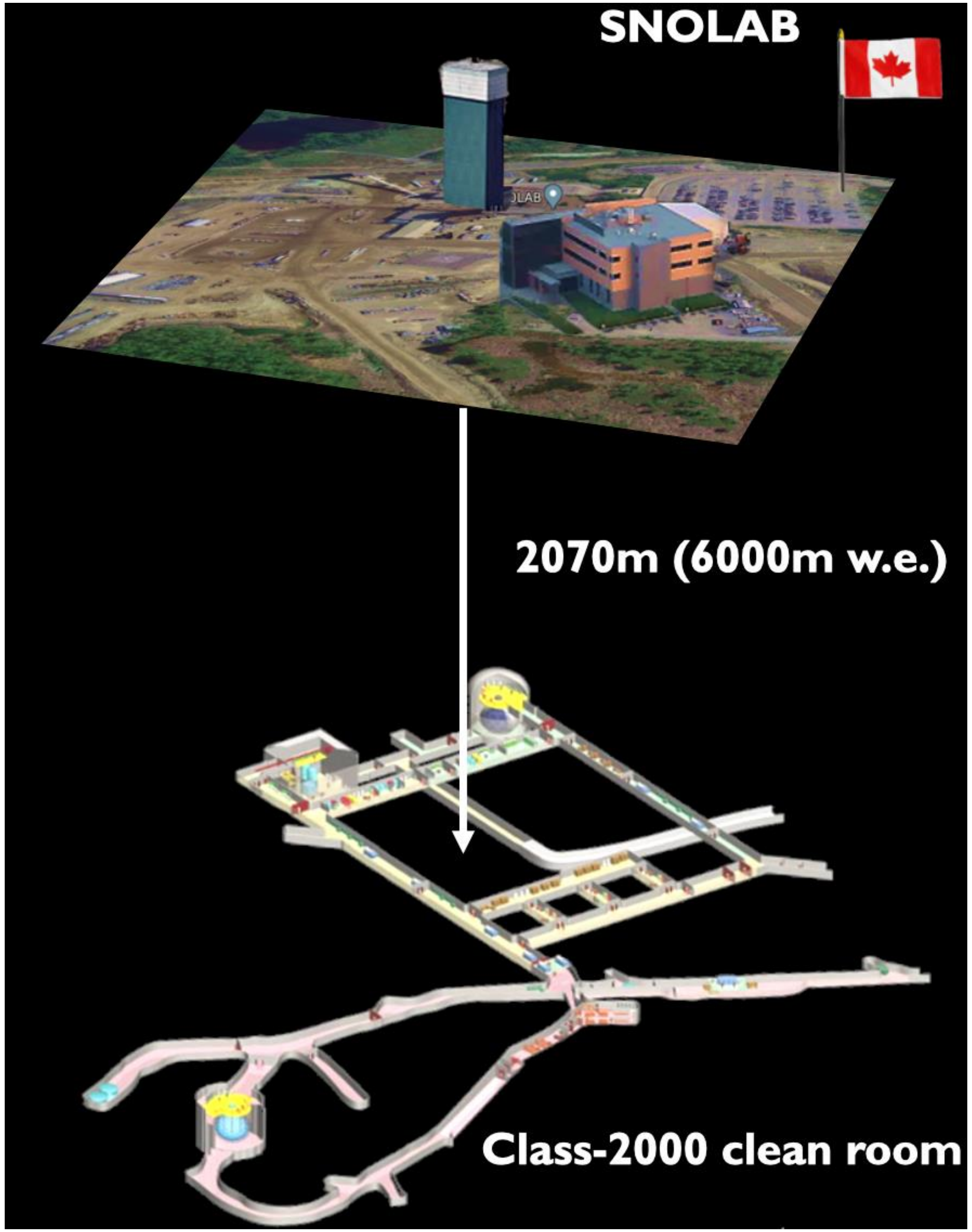
Cryogenic

- Pulsed-Tube Dry-Dilution fridge purchased from Cryoconcept
- Base temperature: 12 mK with payload
- Can support up to a 20 kg payload
- Cooldown Cycle: 1 week
  - 3 day warm-up, 3.5 days cooldown
- Fridge can run unattended for extended periods (many months)
- Facility Paper: https://www.frontiersin.org/articles/10.3389/fphy.2023.1319879/full

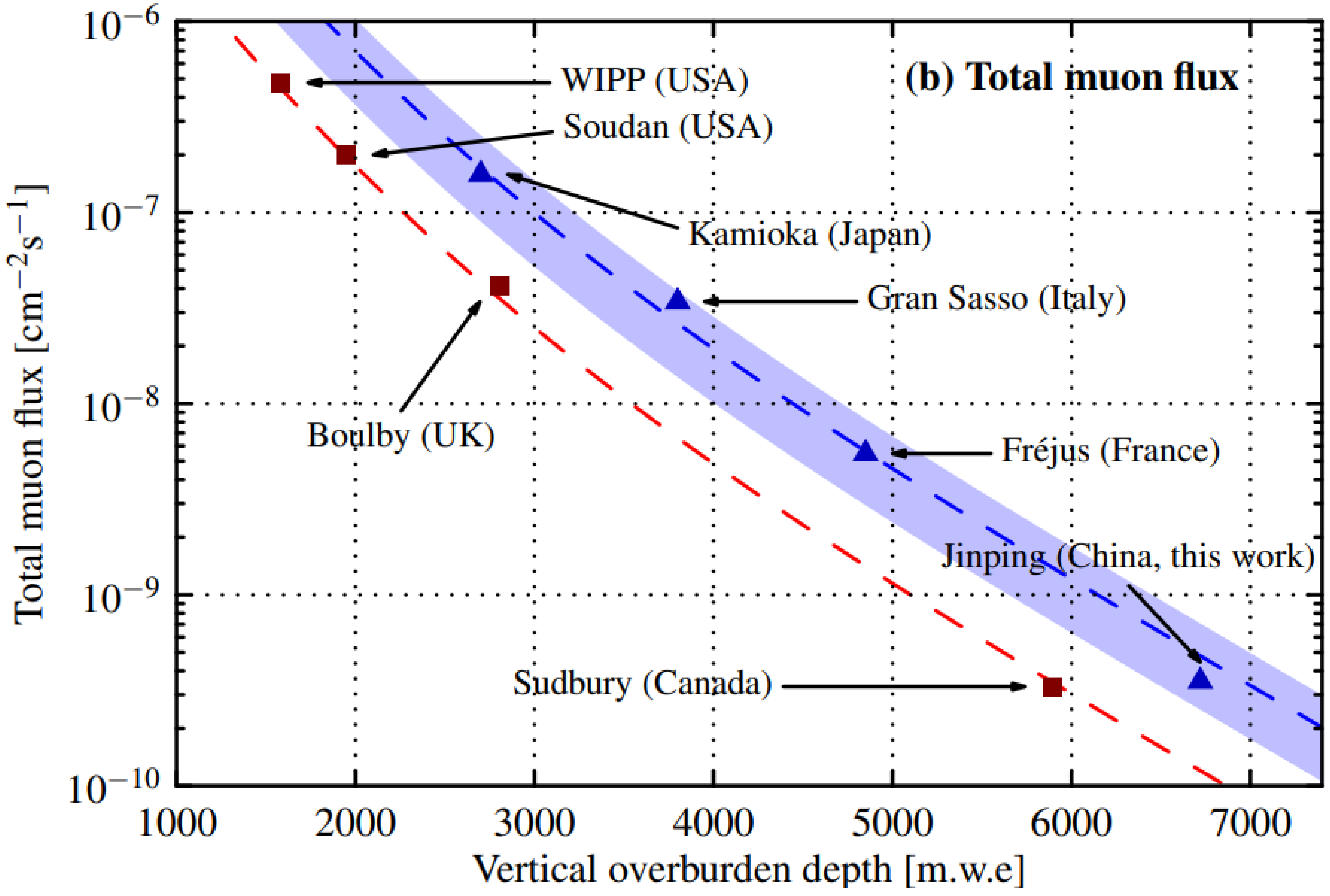


Underground

- SNOLAB is located at the Vale-Creighton mine just outside Sudbury
- See Christine talk: https://indico.cern.ch/event/1316311/contributions/5861273/
- It is 2 km deep and operates as a class-2000 clean room
- Hosts rare-event searches and measurements
- Jointly operated by the University of Alberta, Carleton University, Laurentian University, University of Montreal and Queen's University
- SNOLAB is located on the traditional territory of the Robinson-Huron Treaty of 1850



Underground Advantage

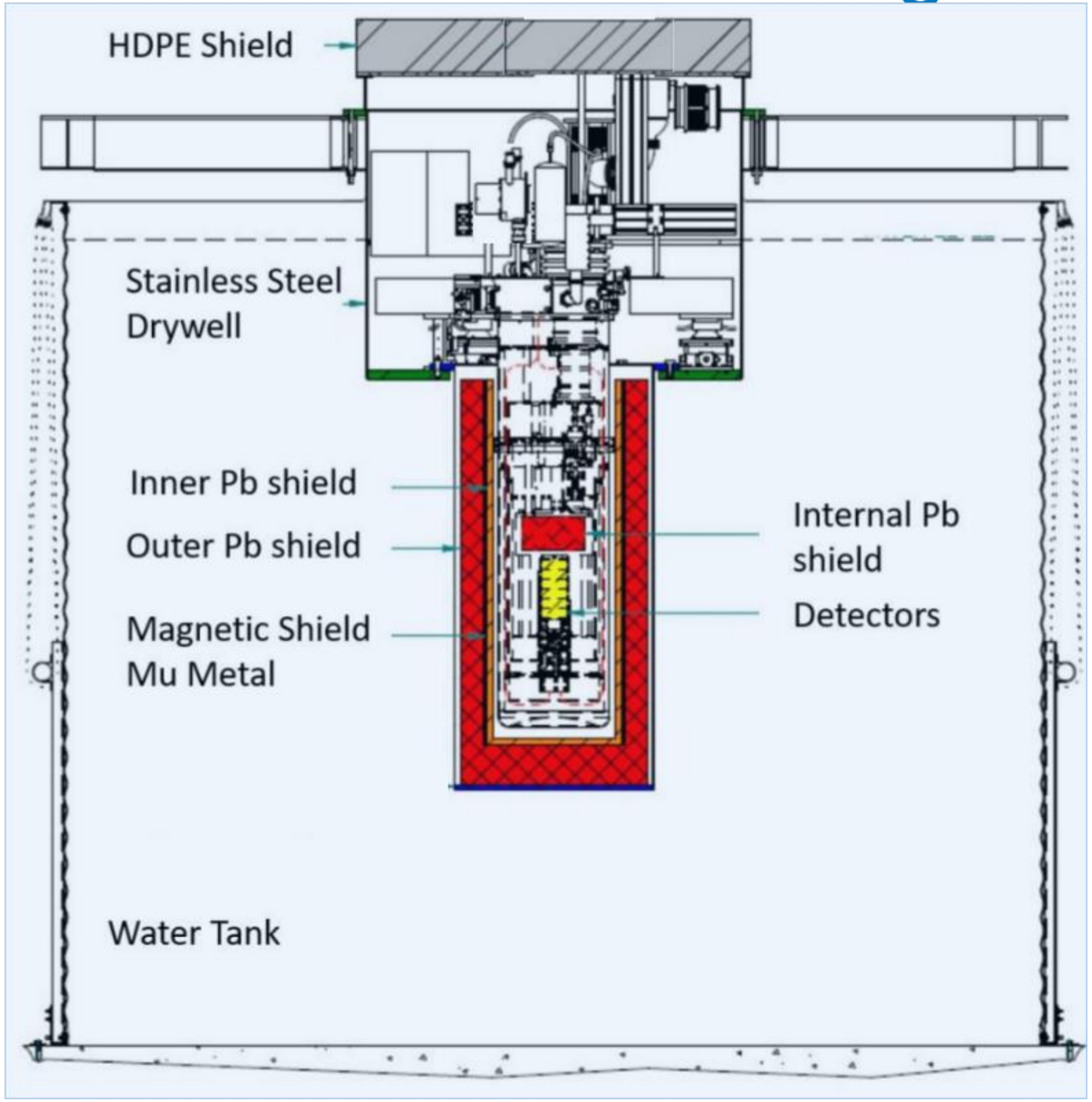


https://arxiv.org/pdf/2007.15925.pdf

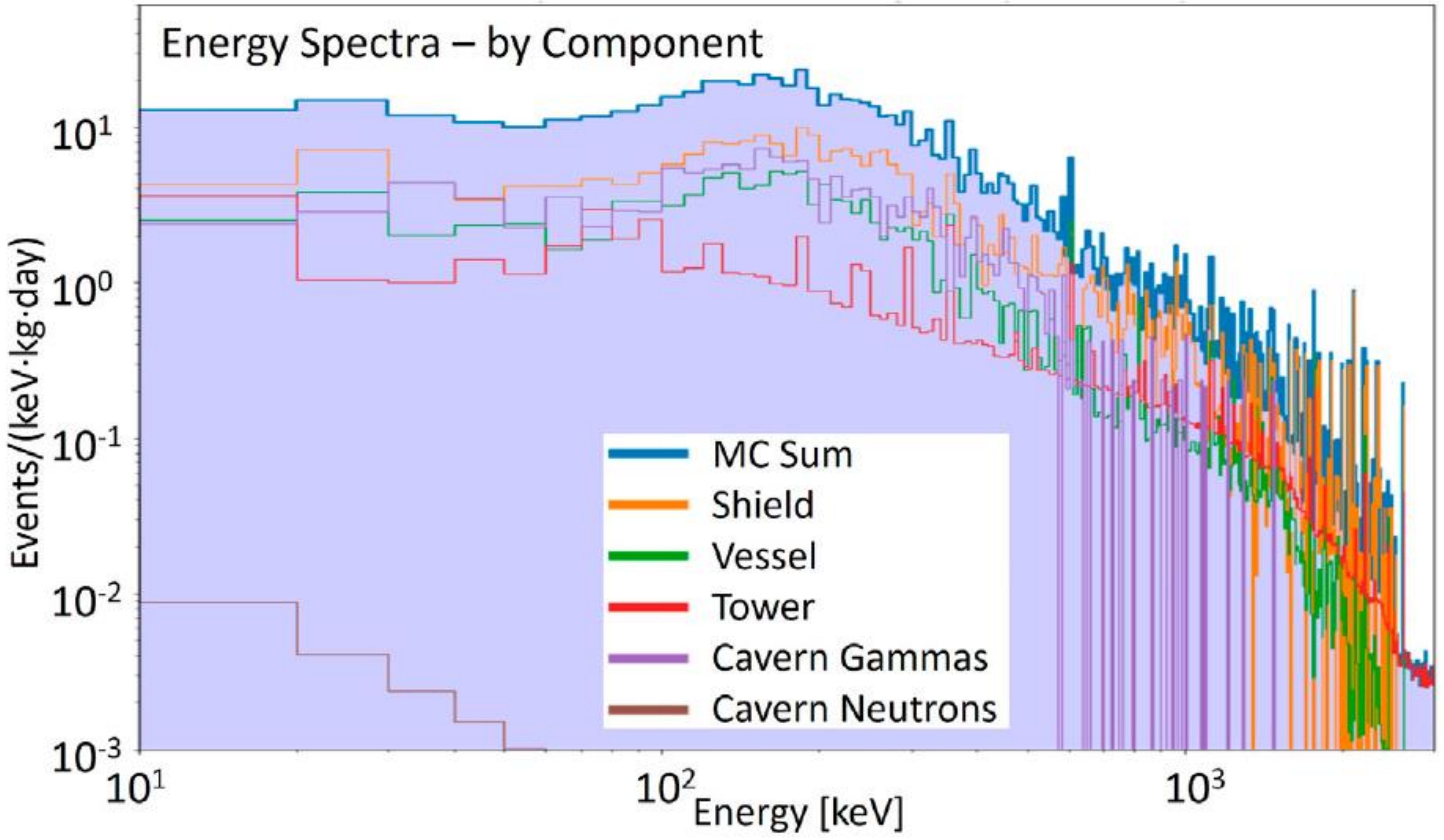
- One of the lowest muon flux in the world
- Class-2000 clean-room
- <2000 particle >0.5µm in diameter per cubic feet

Underground Backgrounds

- Ambient backgrounds (gammas, neutrons and alphas) are still present in SNOLAB
- 10 cm of low-activity lead in the drywell (gammas)
- Fridge is centrally located in a 1.5 m water tank (neutrons) with a 20 cm polyethylene lid
- 15 cm lead “cake” (cryostat component radiogenics)
- Low-radon air into the drywell

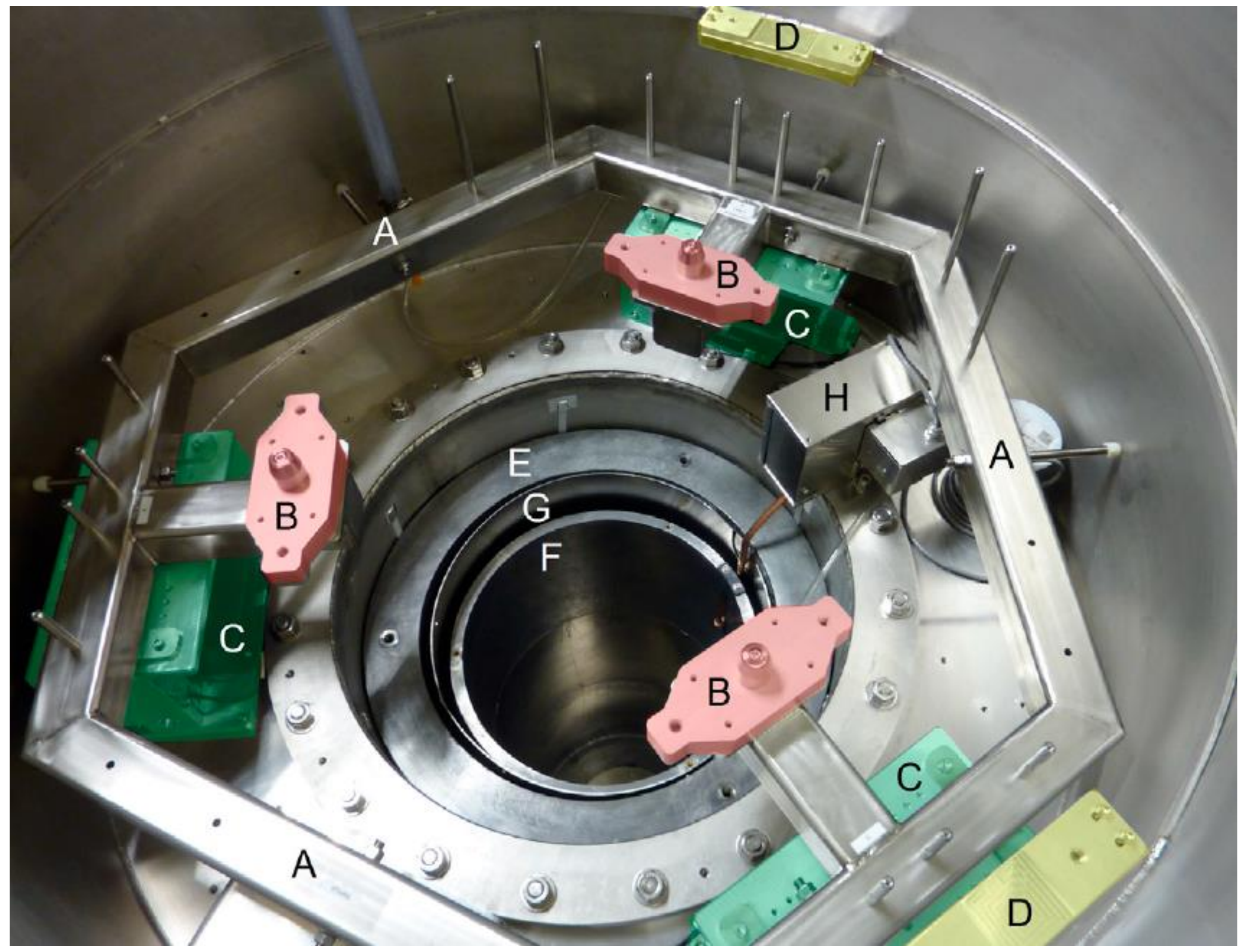


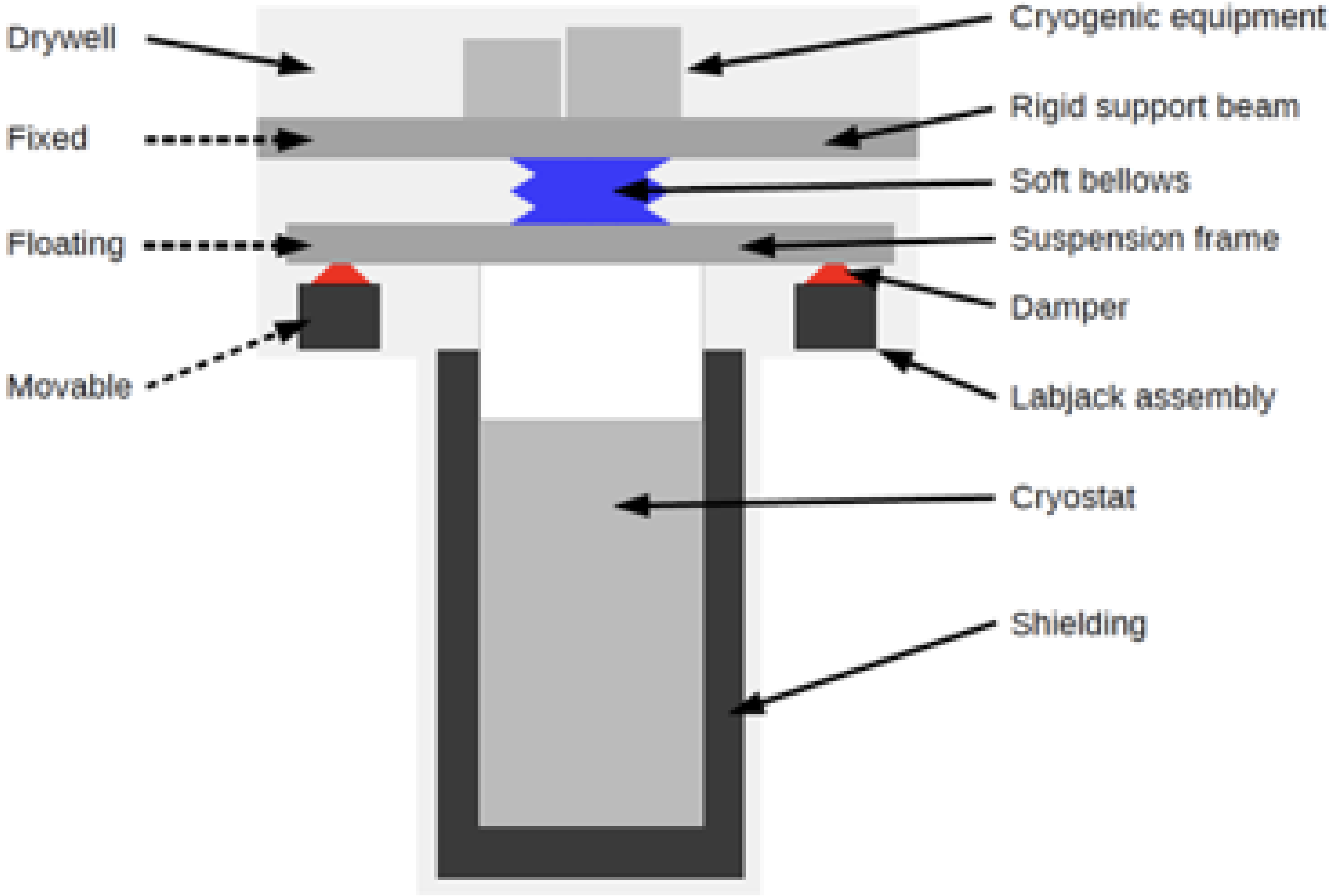
Underground Backgrounds

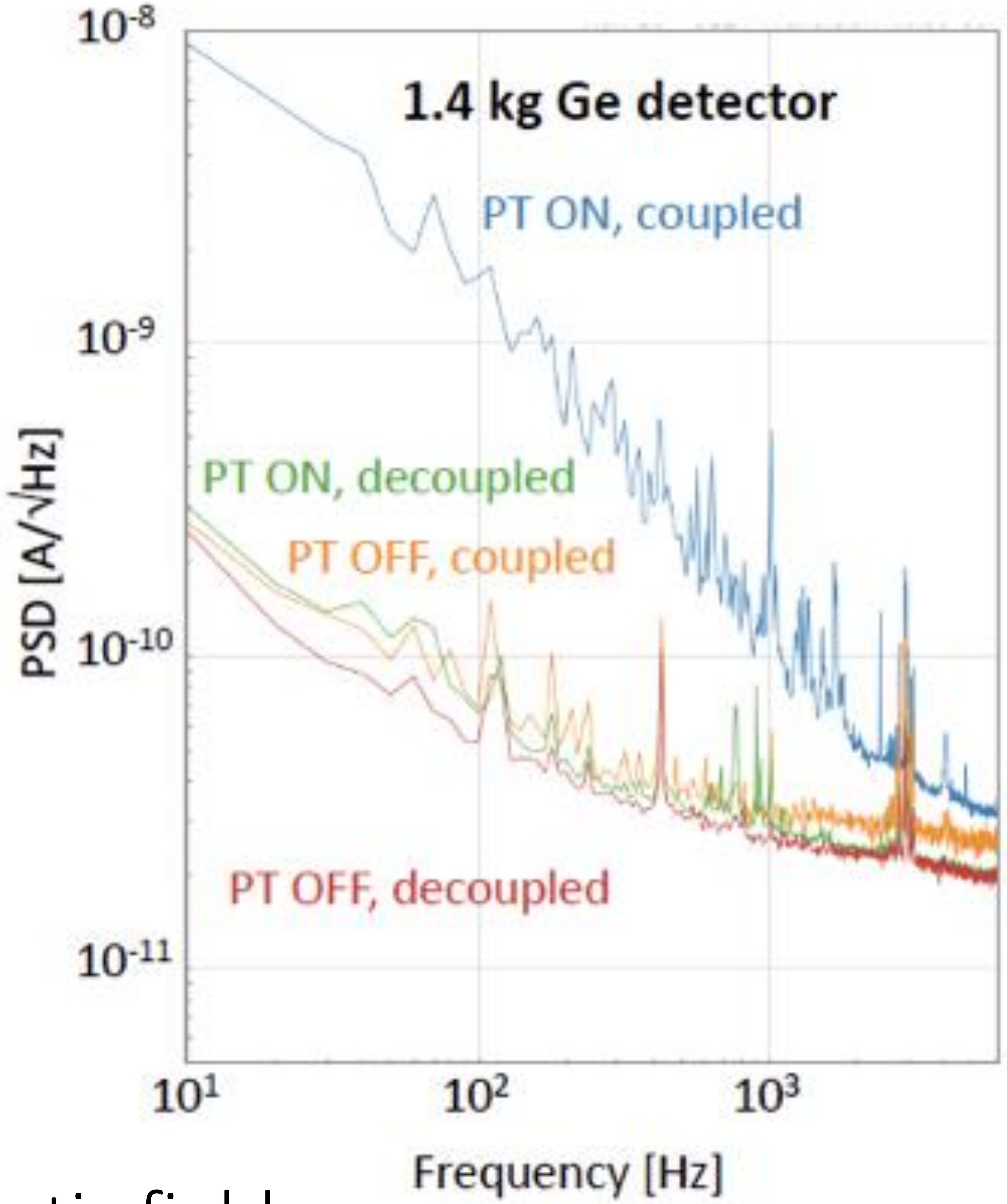


- All materials were screened prior to use in CUTE
- 6.7 +/- 0.8 events/keV/kg/day (for a 600 g SuperCDMS style Ge HV detector)
- < 0.5 event/keV/kg/day for nuclear recoils
- SNOLAB cavern gammas (30%), the inner layer lead shielding (20%), OVC (13%)

Underground Vibration

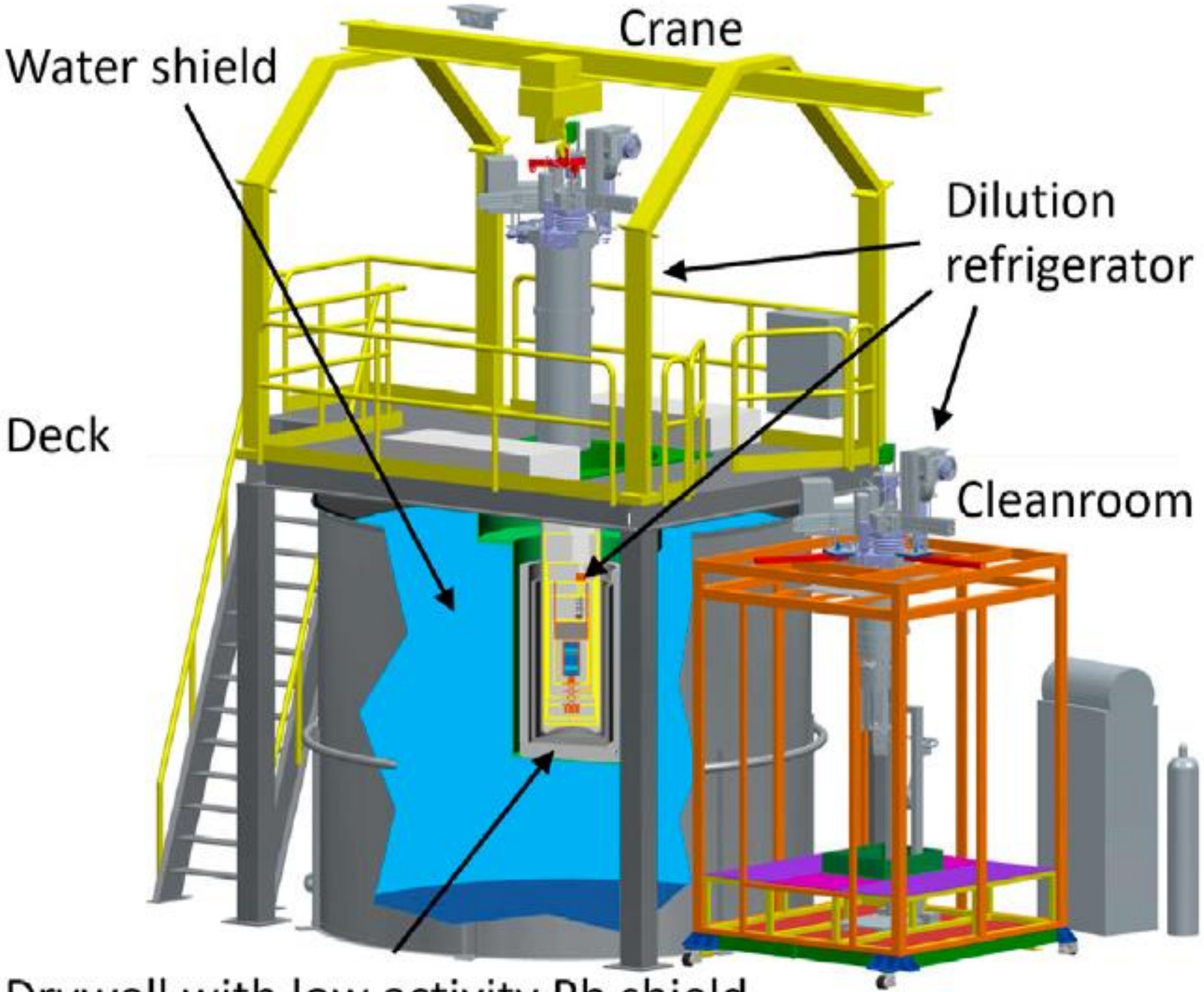


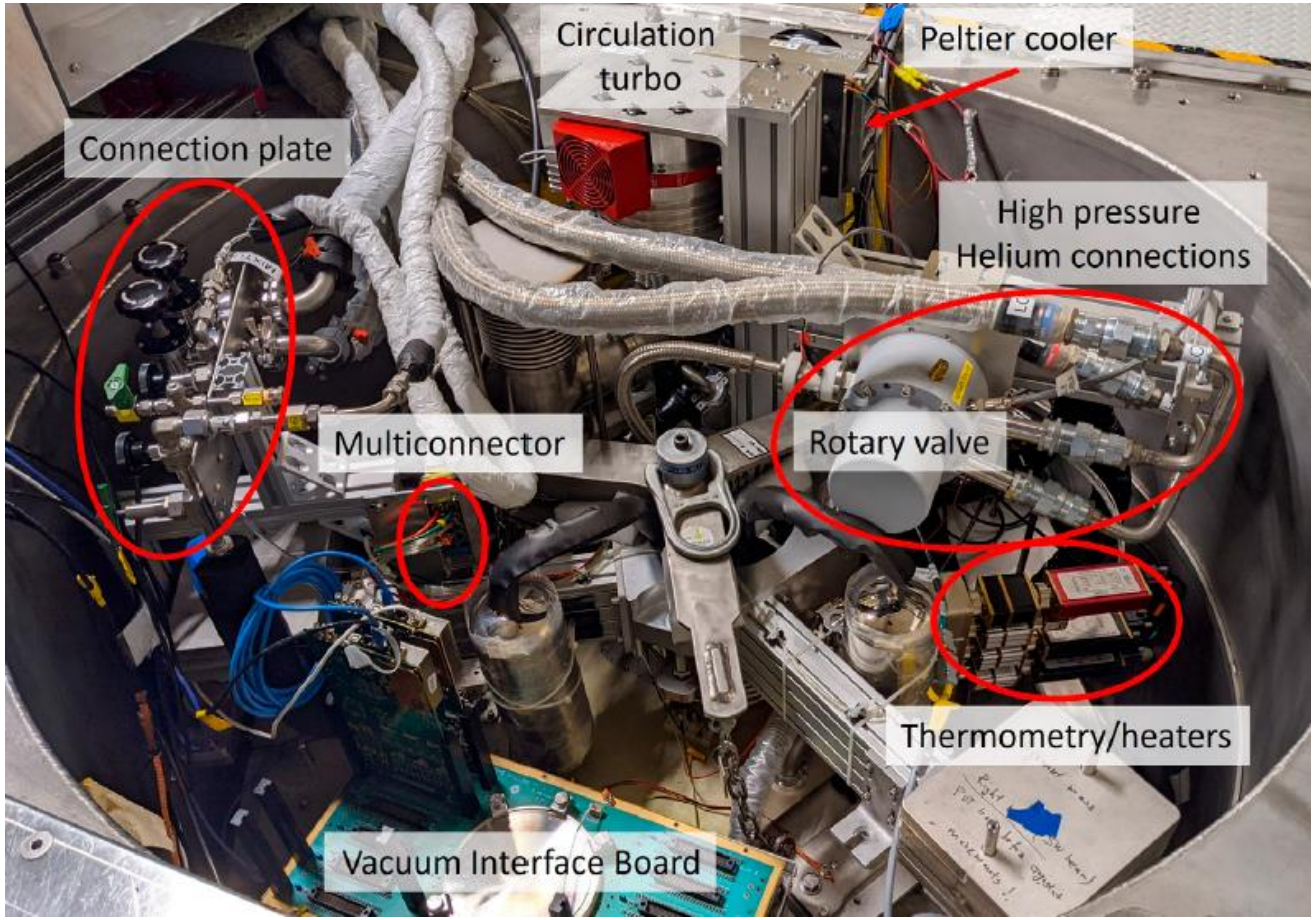




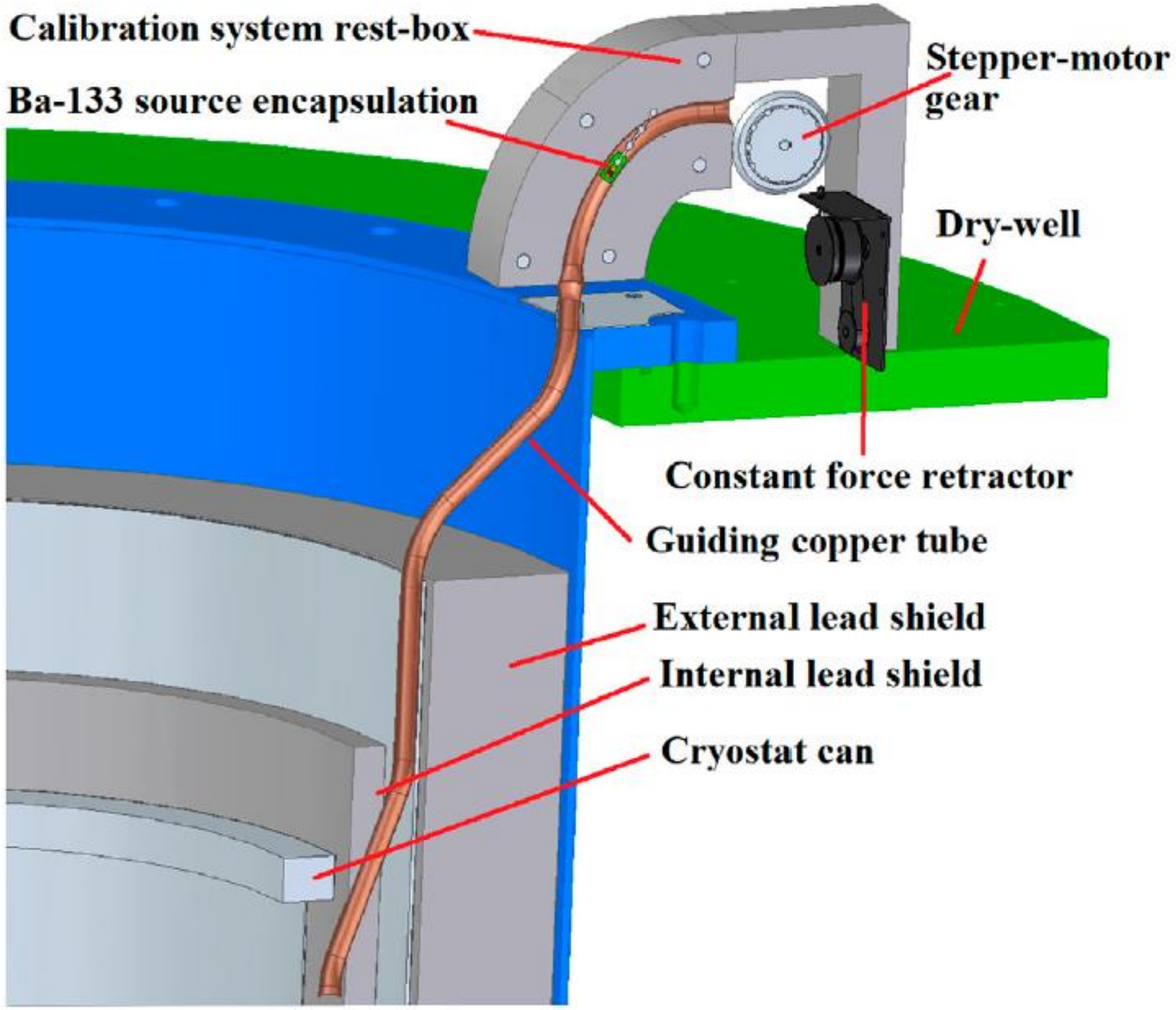
- Cryogenic devices are highly sensitive to vibrations and changing magnetic fields
- Mu-metal shielding reduces the magnetic field by a factor of 50
- Cryostat and pulse tube are decoupled through a suspension system

TEsting Facility



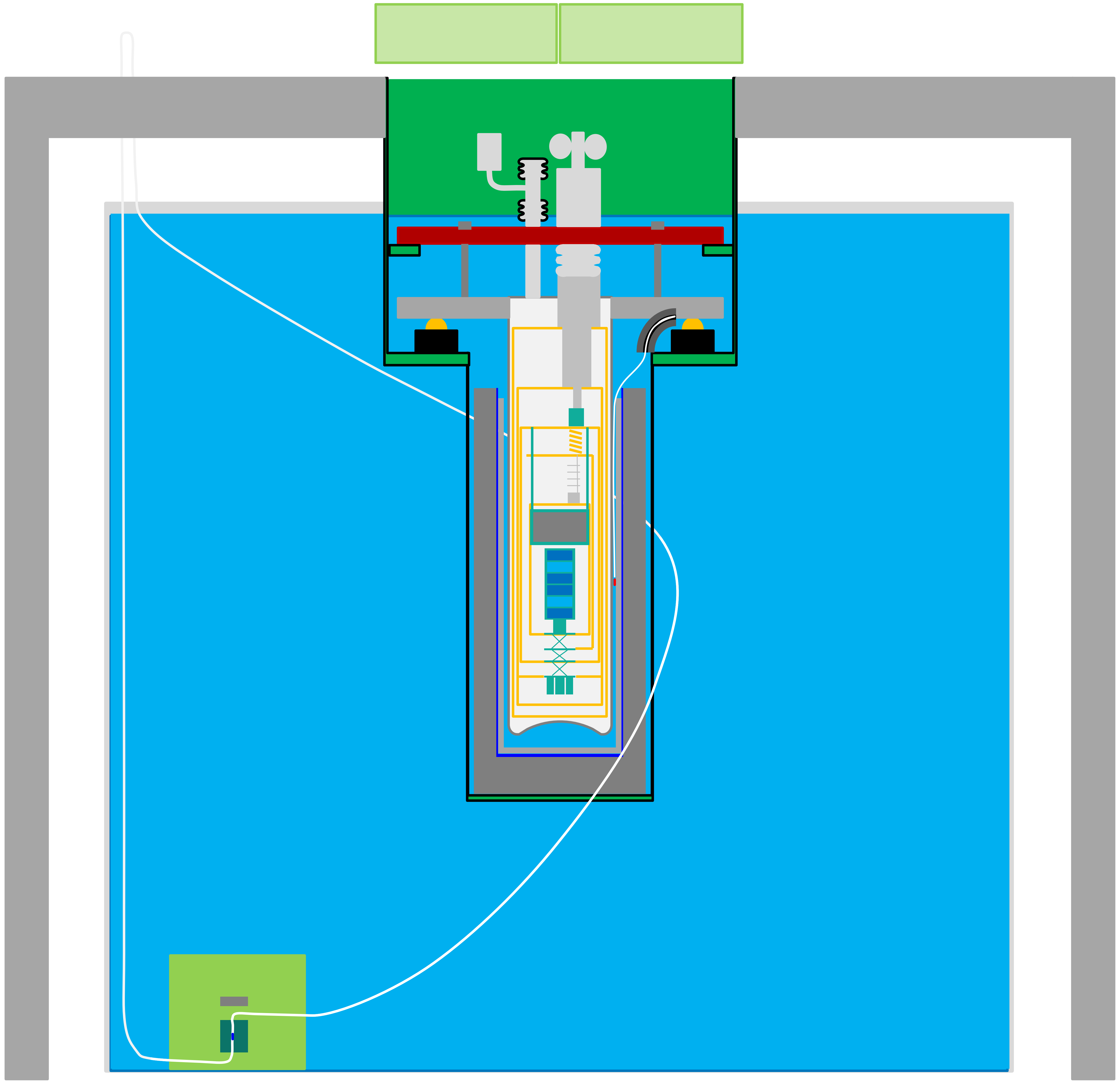


TEsting Facility: Calibration

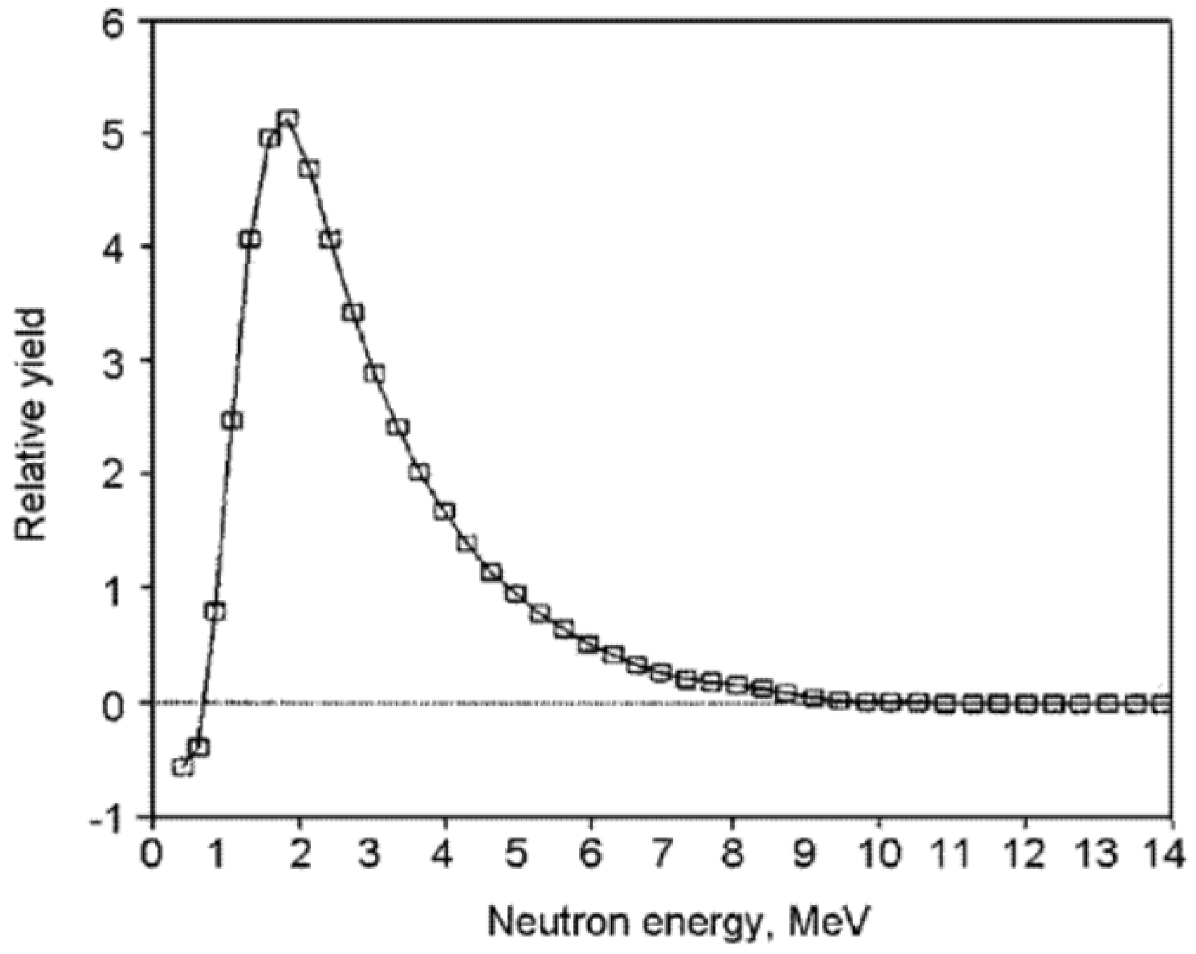


- Ba-133 calibration source (350 keV gamma, 37 kBq), can be deployed along the length of the cryostat
- Internal Fe-55 source (6 keV) is also possible for low energy calibration

TEsting Facility: Calibration



- Cf-252, 37.5 kBq source
- Branching ratio of 3% to undergo spontaneous fission
- Stepper motor allows motion through the water tank
- Will be implemented at the end of the current experimental campaign



CUTE Experimental Program

Completed: SuperCDMS Tower Testing

Speaker: Dr. Yan Liu

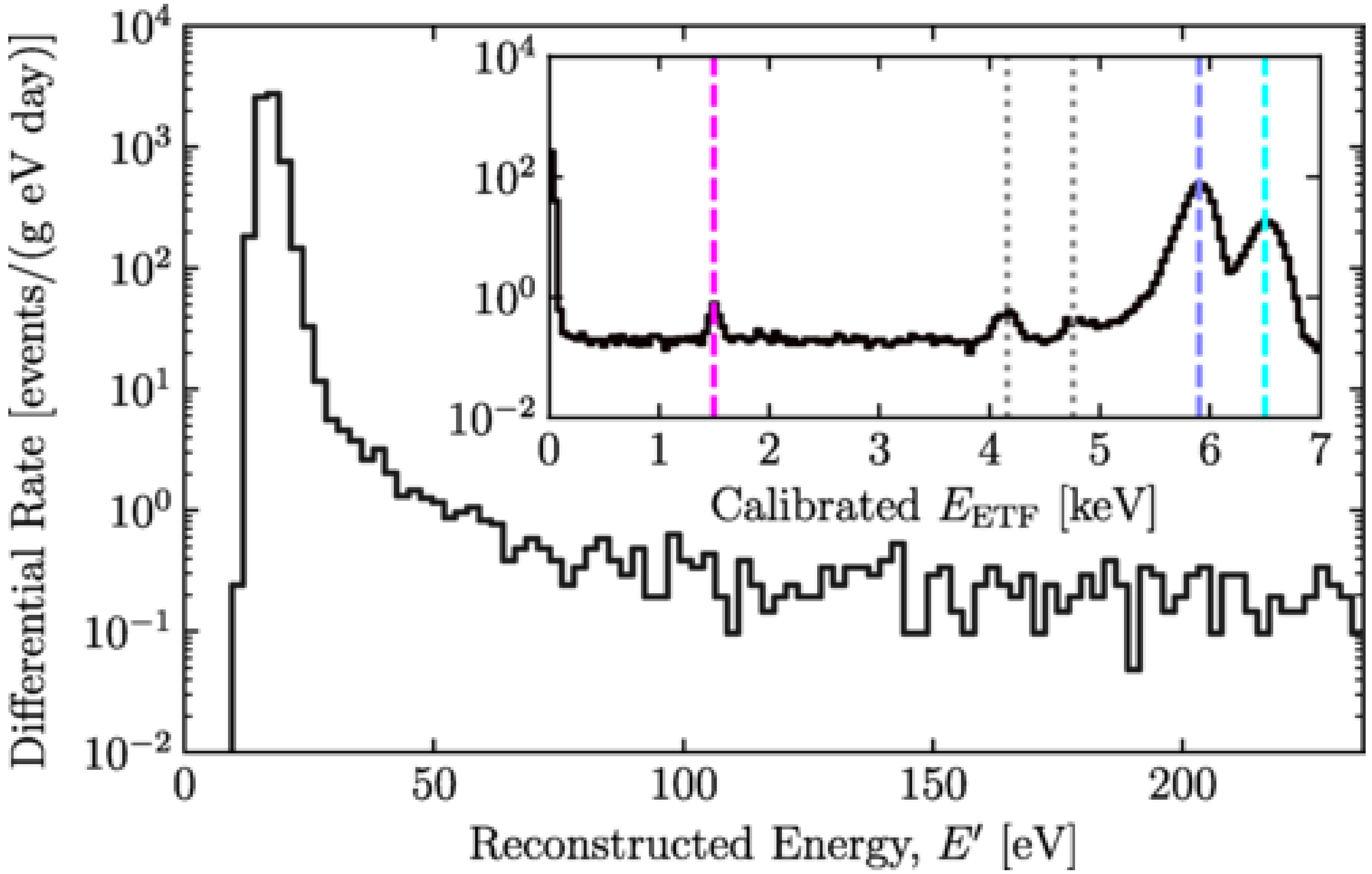
Title: First Glimpses of the SuperCDMS High Voltage Detectors (PPD T2-1)

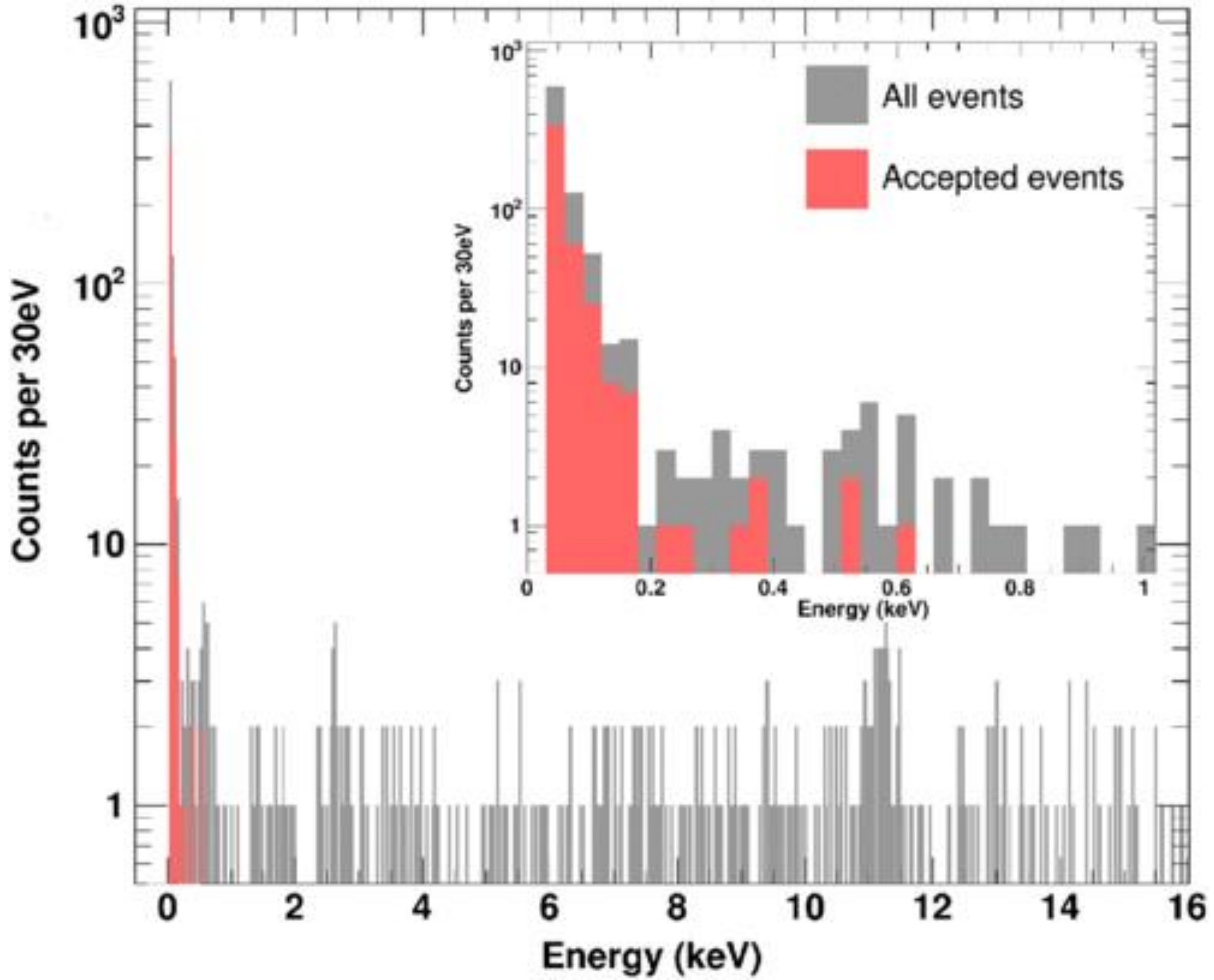
When: 15h30

Indico Link:
https://indico.cern.ch/event/1316311/contributions/5861281/

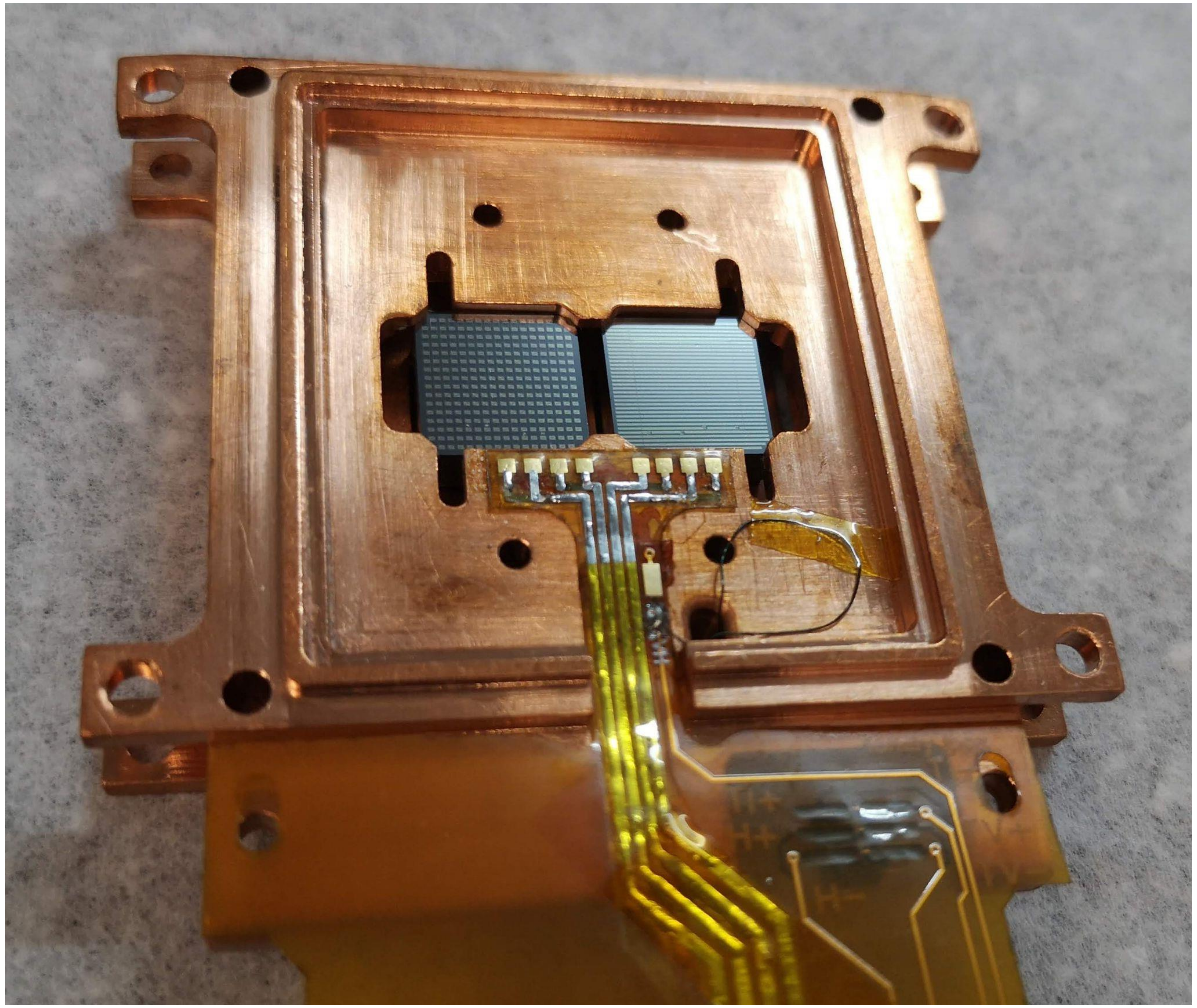
Current: HVeV

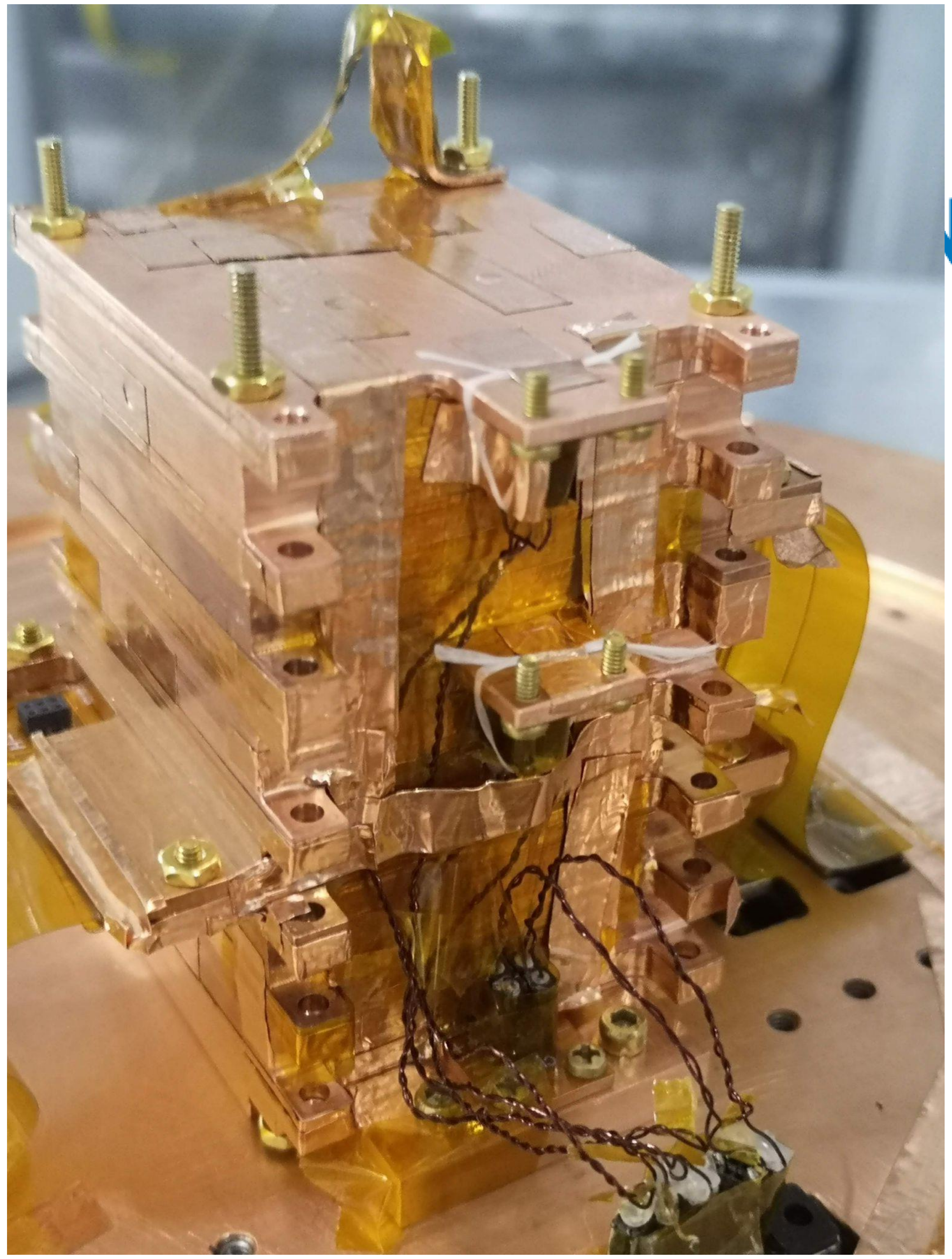
- Dark matter detectors have lowered the energy threshold down to the eV scale
- An exponential excess at low energies has been observed
- Across many different experiments (SuperCDMS CPD, CRESST-III, EDELWEIS, NUCLEUS)
- Cause = Unknown





Current: HVeV





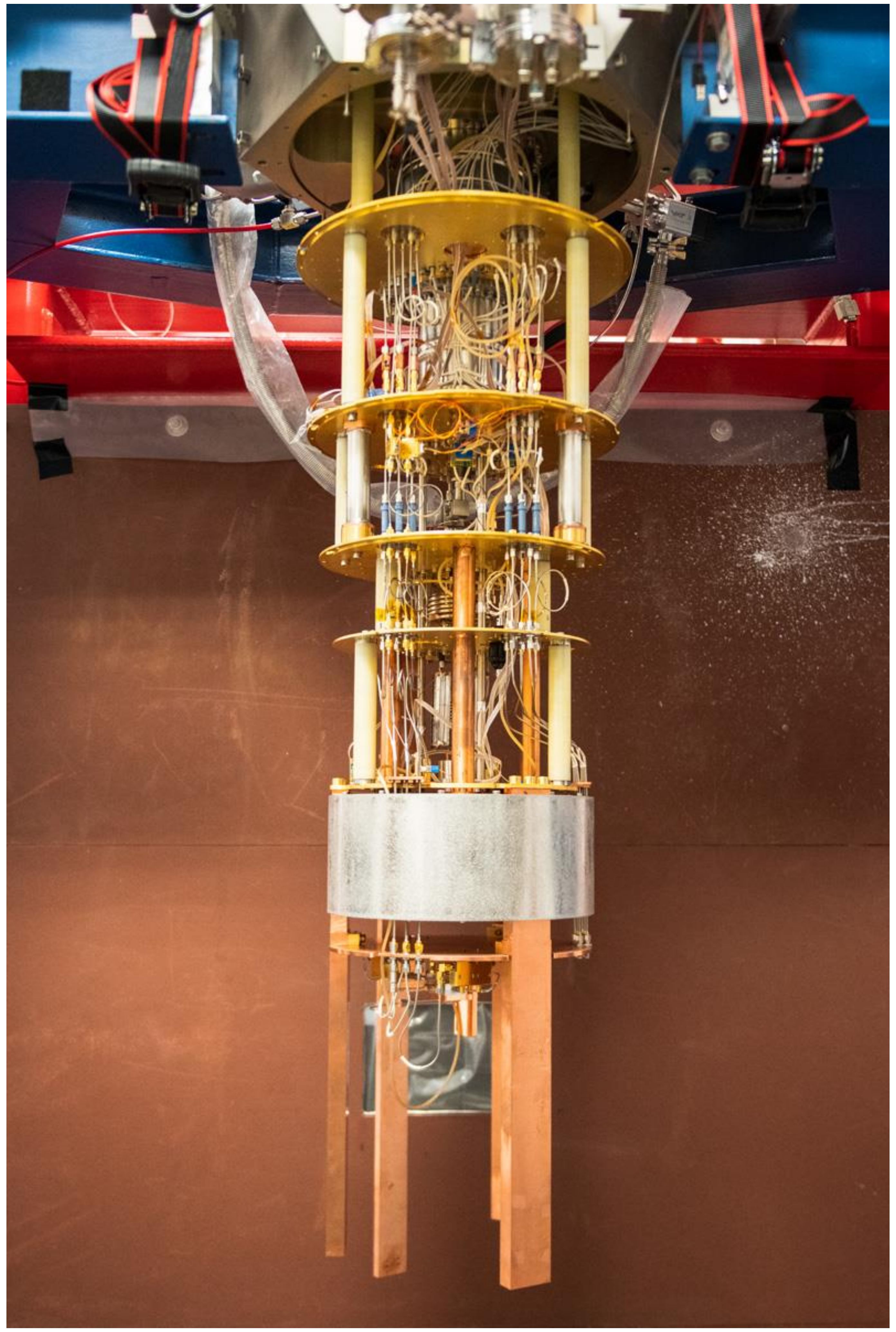
- Will run 6, 1g Si detectors capable of reaching 1 eV threshold at the CUTE facility
- Detector tower was put into CUTE at the end of March.
- Current run plan will go to the end of September

Future: Qubit

- Study of qubits in a low-radiation environment
- How does ionizing radiation effect the coherence of qubits and how it causes correlated errors
- Collaboration between SNOLAB, University of Waterloo and Chalmers University
- Large upgrade required to the fridge setup for redout cabling

This is NEXUS (same fridge model)

For Illustrative purposes only



Conclusion

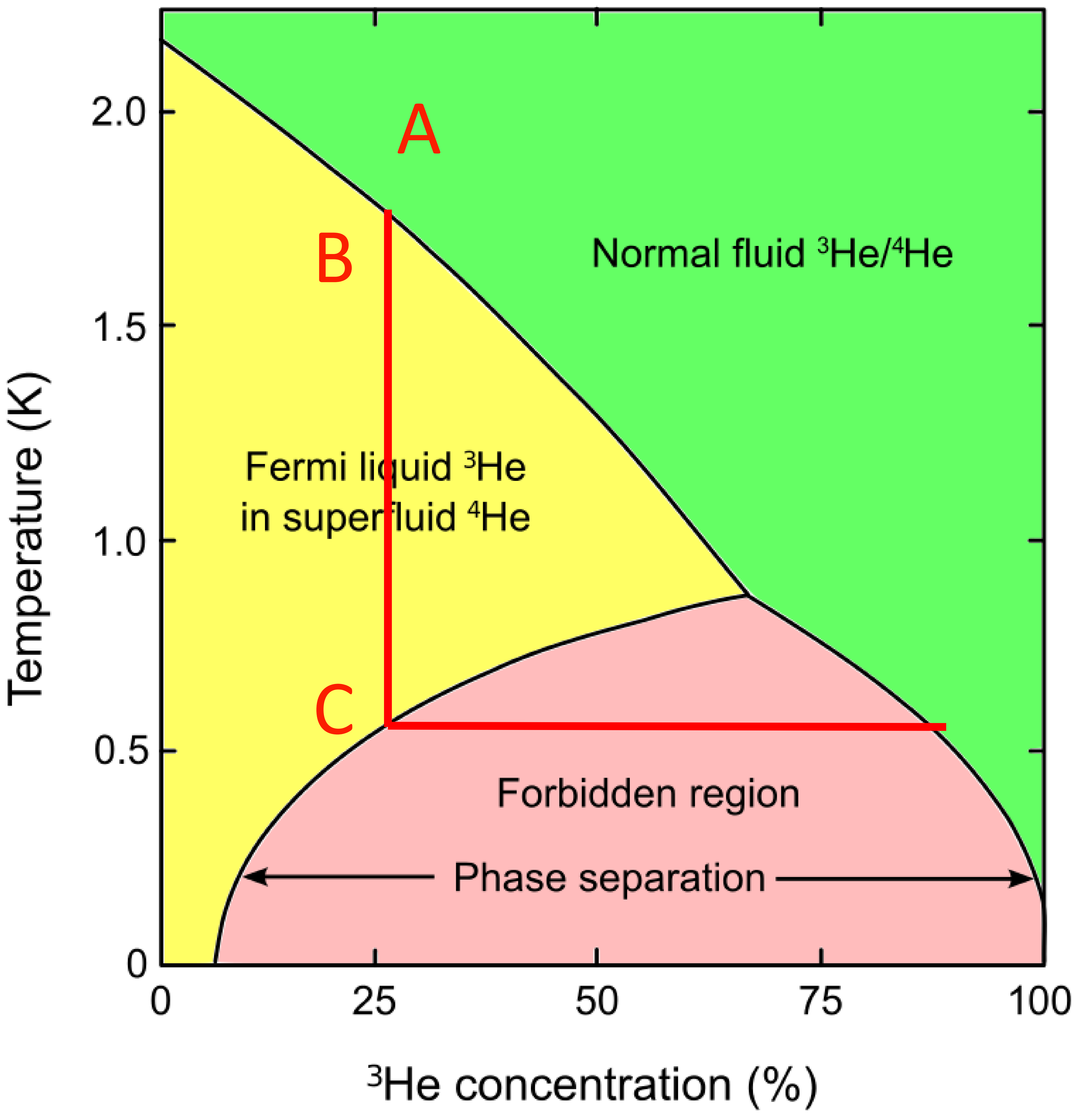
- CUTE is a SNOLAB user facility
- Successfully ran SuperCDMS tower for 6 months

- HVeV is currently investigating the LEE
- Quantum computing program in the fall/winter
- Provides a low-background vibrationally isolated environment
- Have a project you would like to run at CUTE?
- **<u>Email:</u>** matthew.stukel@snolab.ca

Thank you to Andy Kubik for photos and some slides

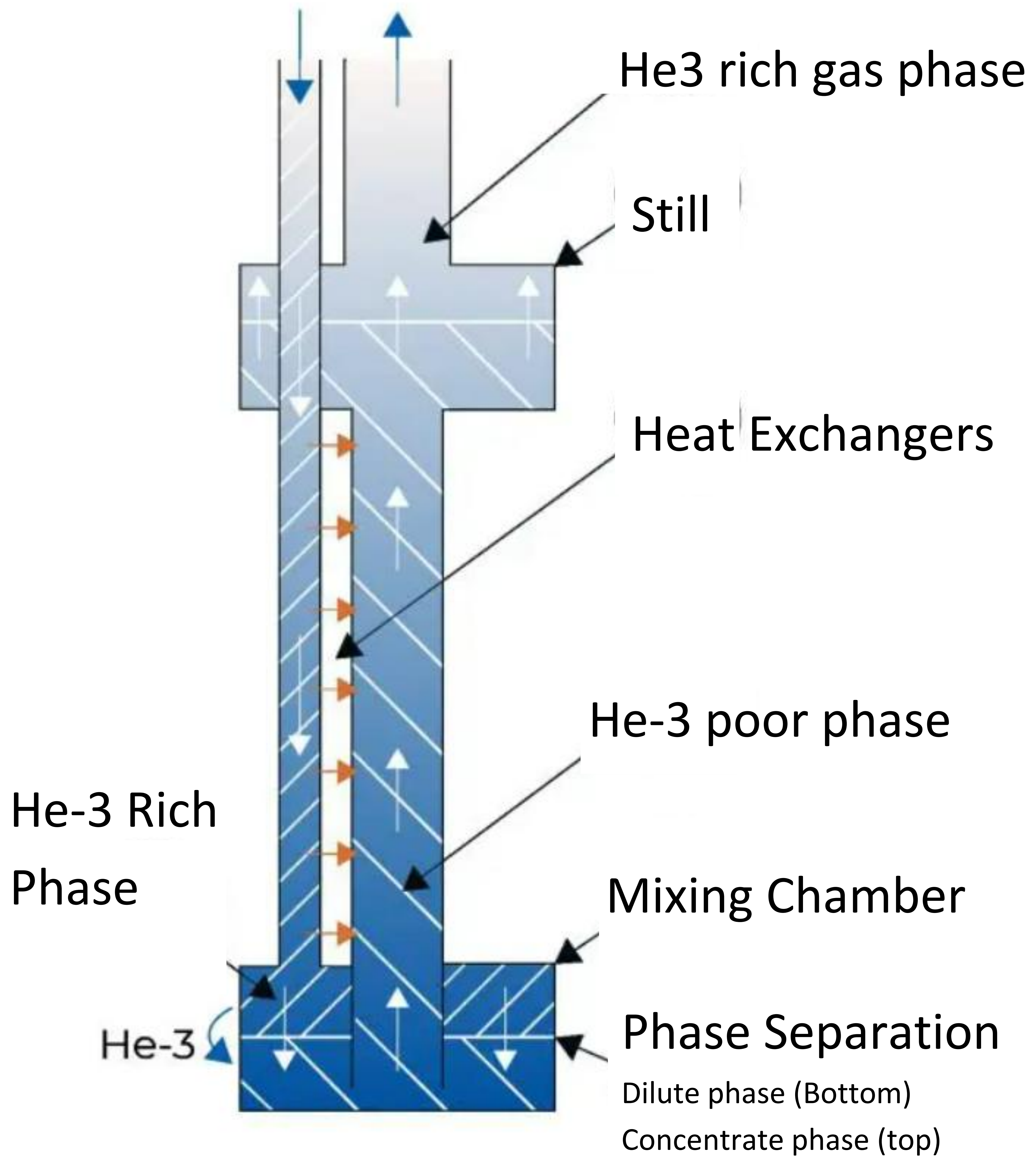
Extra Slides

How to reach mK: Dilution Technique?



- Dilution refrigeration utilizes the properties of <u>^3He-^4He</u> mixtures to achieve mK cooling
- ^4He obeys Bose statistics while ^3He obeys Fermi statistics.
- Mixing the two isotopes together is what allows mK temperature to be achieved
- A mix of He3/He4 starts at temperature <u>A</u>
- If the temperature is lowered below point <u>B</u> that mix is now a superfluid
- When lower then point C ^3He-^4He separate into dilute and concentrated phases.
- This happens in the mixing chamber
- Concentrated phase will “float” on-top of the dilute phase
- <u>It takes energy to move ^3He from the dilute to concentrated phase which is taken from well isolated environment providing the cooling</u>

How to reach mK?



1. He-3 enters the dilution unit pre-cooled by the pulse tube at around 3K
2. It proceeds to the mixing chamber and is cooled by the heat exchangers
3. In the mixing chamber the phase separation occurs
4. He3 is pumped out to the still causing He3 to move from the concentrated phase to the dilute phase. Which takes energy from the system, thus providing the cooling
5. The He3 that was pumped out provides the cooling for the incoming He3
6. In the still He3 is evaporated and the cycle begins again