HVeV detectors down at CUTE

The LEGENDRE project

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EXCESS workshop 2024

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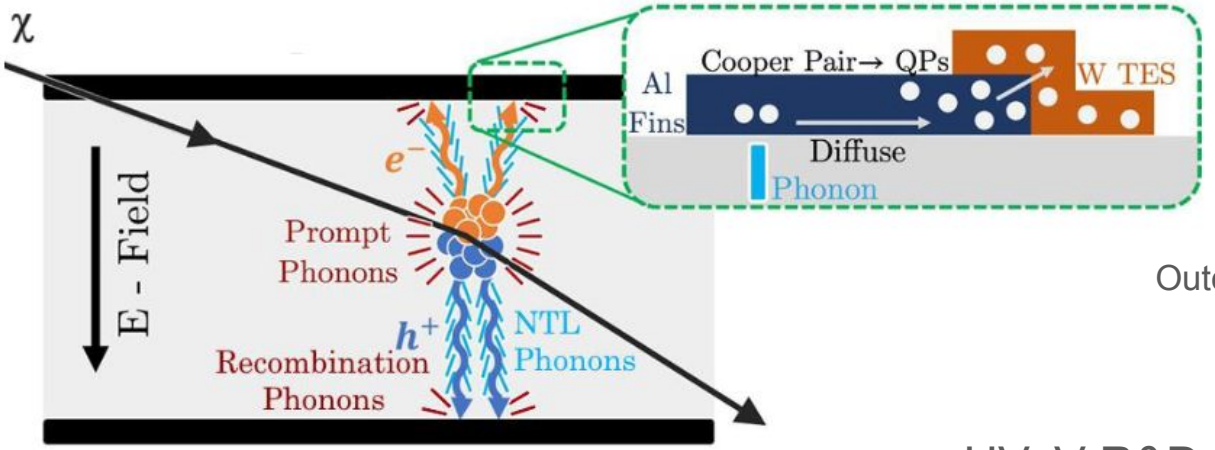
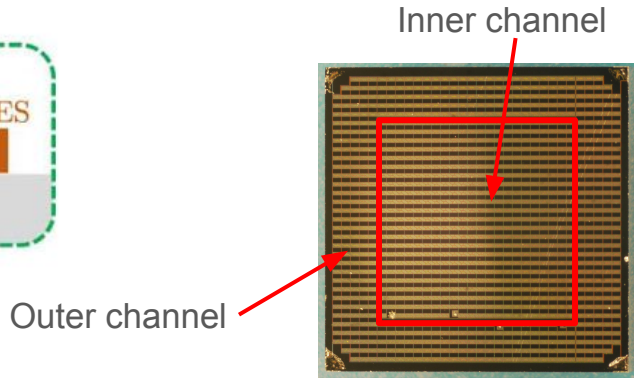
The HVeV SuperCDMS detectors

Main SNOLAB SuperCDMS experiment will have 12 kg-scale High Voltage detectors to push sensitivity to lower masses.





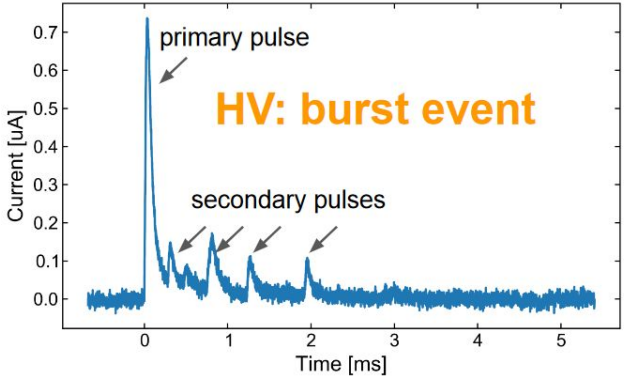
$$E_{\text{phonon}} = E_{\text{recoil}} + n_{\text{eh}} e V_{\text{bias}}$$

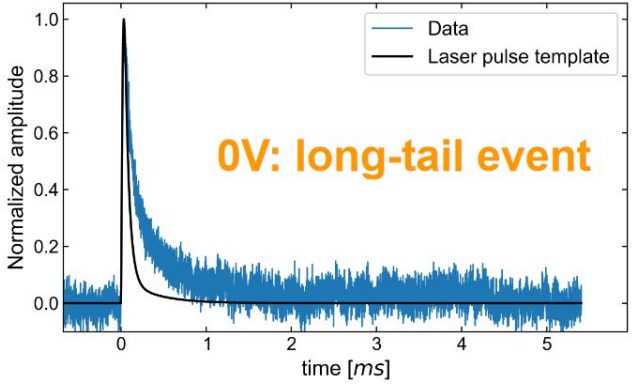
Neganov-Trofimov-Luke (NTL) gain

HVeV-R&D: 1 cm^2, 2-channel gram-size detectors with ~eV baseline resolution. With voltage bias applied, capability to resolve single charge!

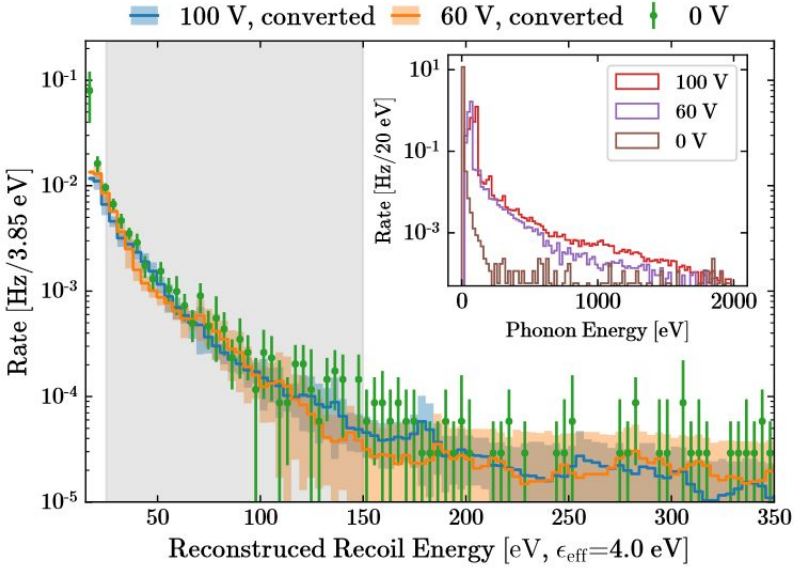
Since last time..

10.1103/PhysRevD.105.112006





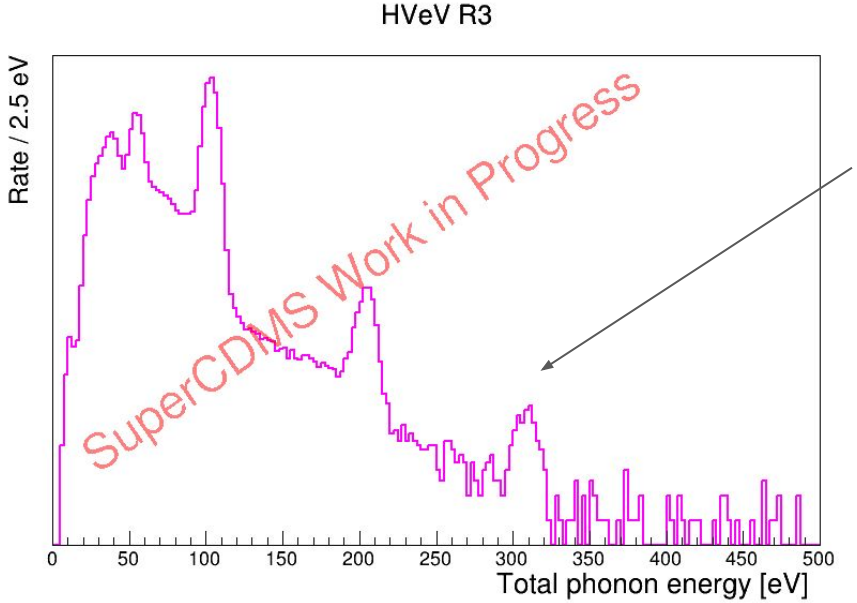
By comparing HV to 0V data, found secondary photons events originated from luminescence of the PCB holding the detector. HV low energy spectrum dominated by those.



..HVeV R3, moving UG and more detectors..

Moving NEXUS: 225 mwe of rock overburden.

3 detectors running in the same optical cavity to study and exclude coincident events. Baseline energy resolution of best detector ~3 eV.



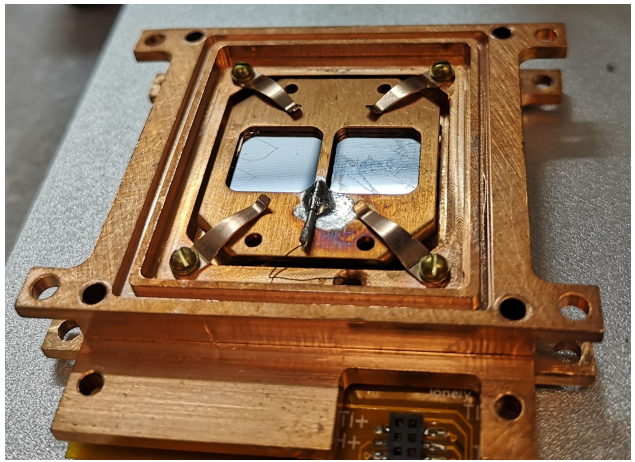
Spectrum with coincidence cut applied.

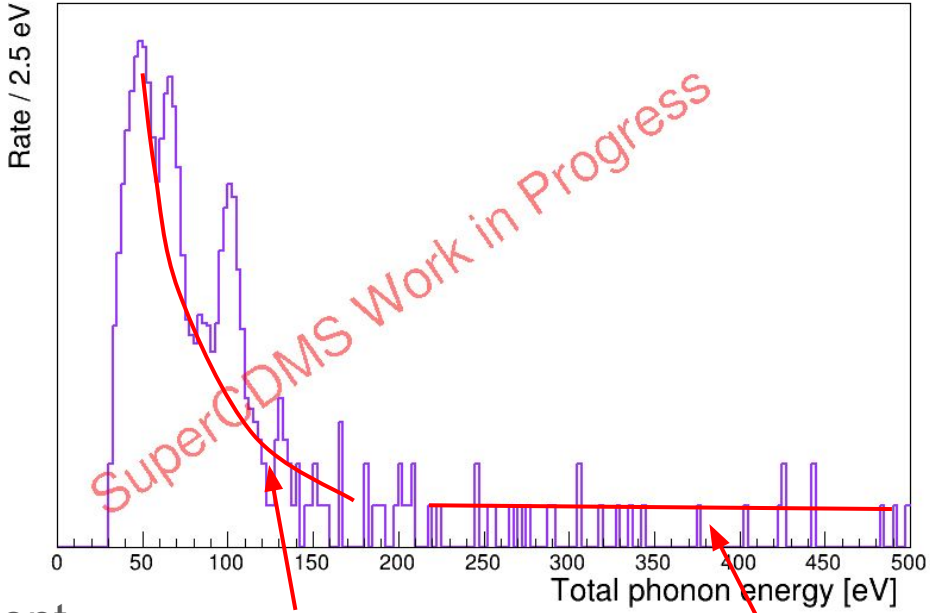
Confirmation of non-detector origin of the low energy background.

Results out in a few days!

..HVeV R4, design of new detector holders..

New design with no rigid PCB to get rid of luminescens events.





Four detectors in same cavity to veto coincident events: elimination of e/h peaks after first one.

Analysis of this run almost finished, exciting results coming soon!

The low energy excess and HVeV

What HVeV provides us for the study of the LEE:

- eV energy resolution.
- Study possible ionization components by varying voltage bias.
- Two channels, possibility to study position distribution.
- Detectors with different sensor geometry masks.
- Data taken previously with same detectors both on surface and shallow UG facility for rate comparison.

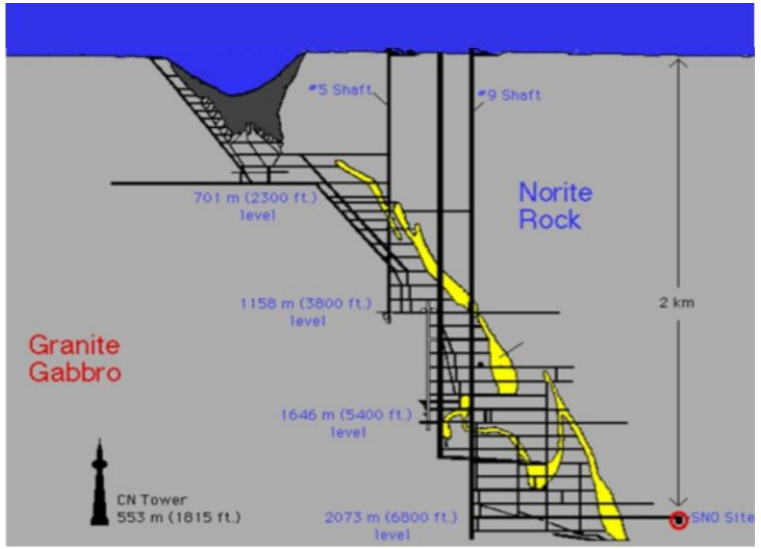
We need more, and possibly better, data!

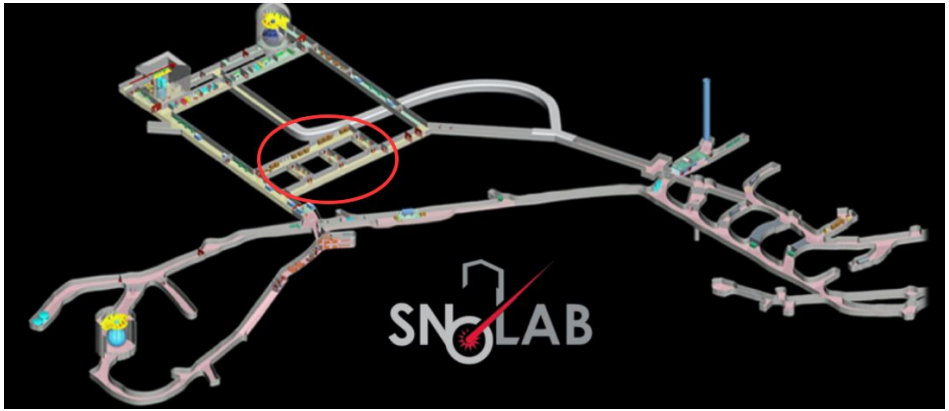
..Moving to SNOLAB..

2 km underground, 6800 mwe overburden.

Whole lab cleanroom of class 2000 or better.

Muon flux of 0.27 μ/m²/day.





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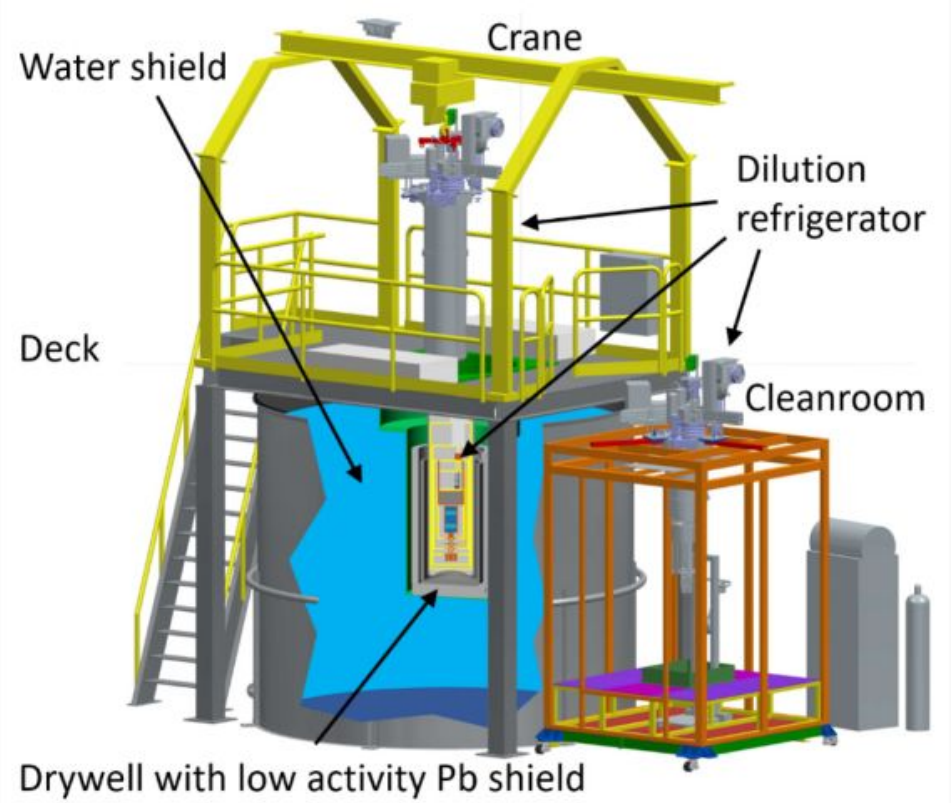
..To the CUTE test facility



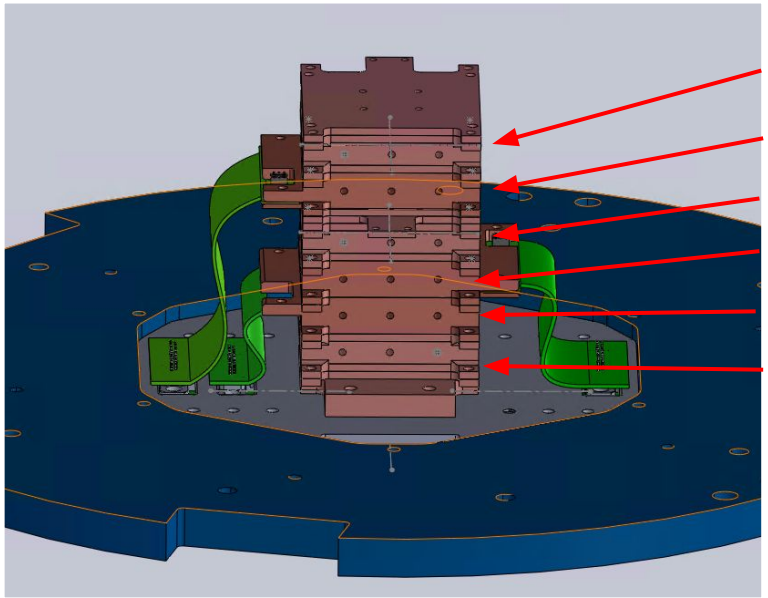
Dry dilution refrigerator, ~15 mK temperature.
Vibration decoupling system.
Water tank and lead for shielding.
~10 d.r.u. background level.
Class 500 cleanroom for detector installation.

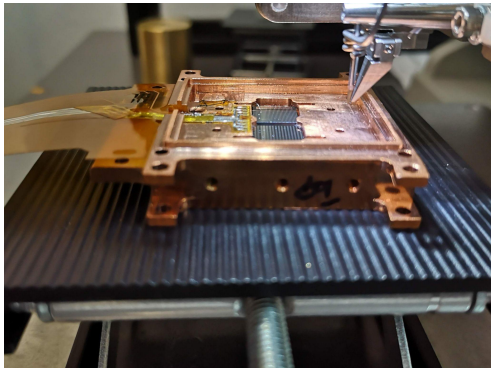
The experiment payload

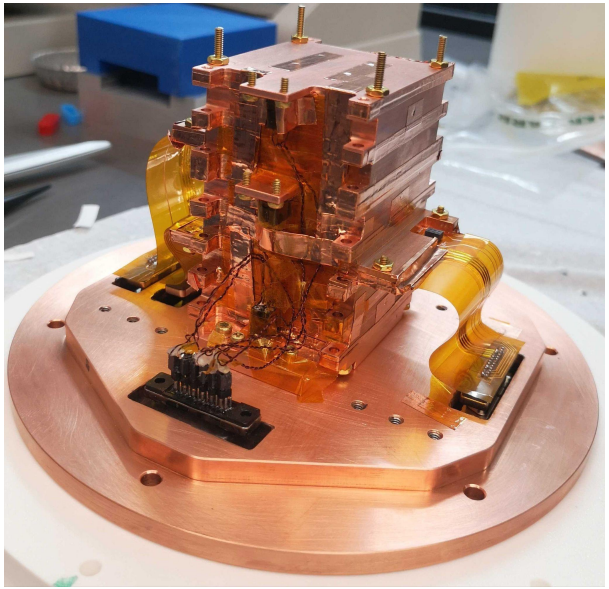
6 HVeV detectors stacked in a light-tight “tower”.

4 detectors (same as R4) in same optical cavity.

Each detector facing a LED to be used for calibration.





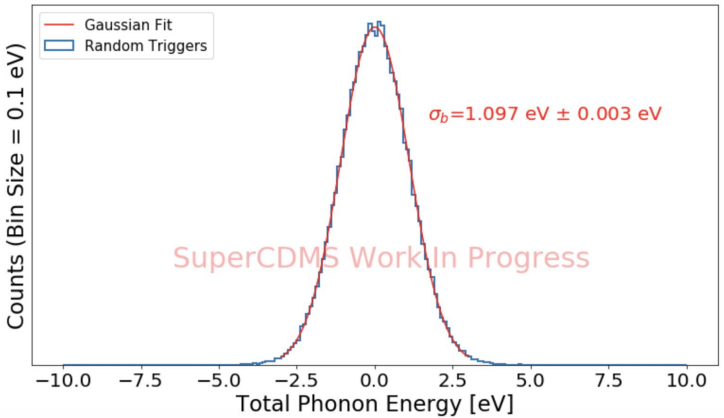


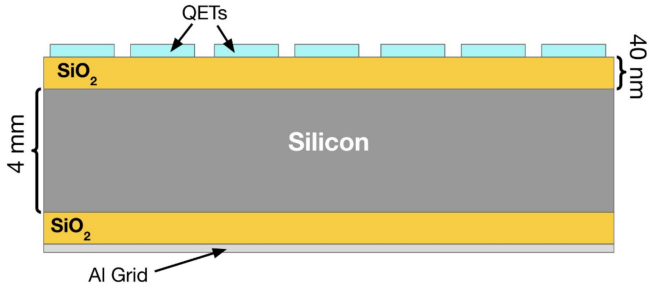
The HVeV detectors for the CUTE run

Four detectors in the bottom boxes are the same ran at NEXUS for R4:

- Does the rate/shape of LEE changes moving deeper UG, to a facility that has more than one order of magnitude better background level rate?

Two detectors on the top box are from the new HVeV generation: lower Tc for better resolution, test run at NEXUS showed 1 eV baseline resolution.





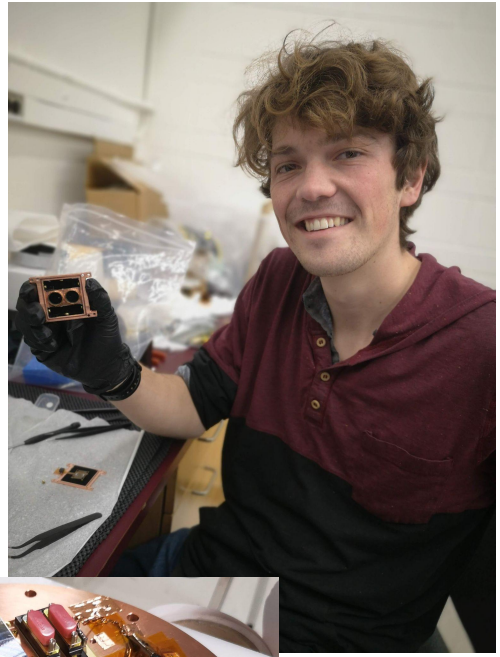
Furthermore, those 2 detectors have insulating SiO2 layers to inhibit charges tunneling through the interfaces between deposited metals and Si to reduce 1 e/h peak event rate.

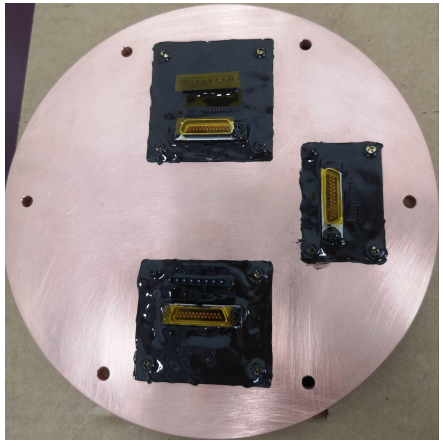
Run preparation

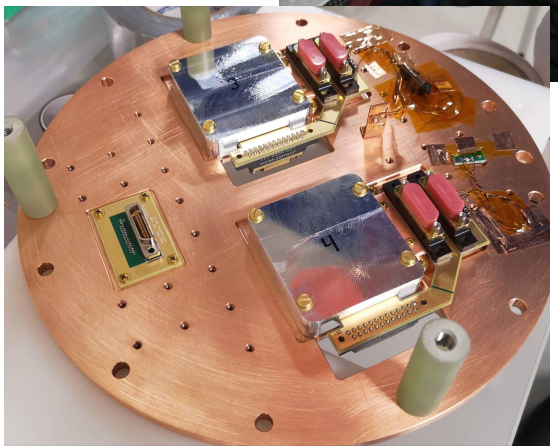
Readout electronic cables shielded all the way down to the mixing chamber plate where detectors installed.

Focus on IR leakage mitigation: optically isolating feedthrough at each fridge stage, epoxy mixed with copper dust at mixing chamber stage.

SQUIDs shielded with Al shield.



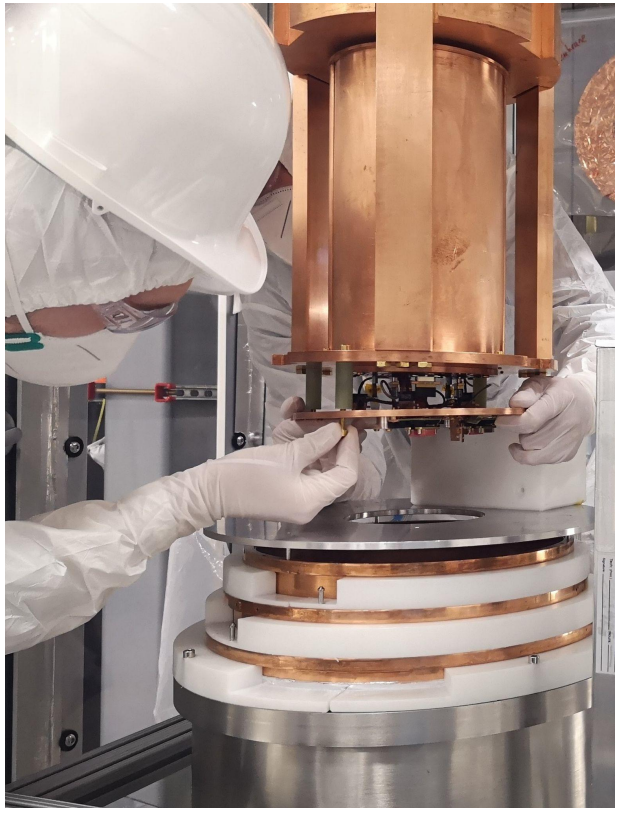




Run status

Detectors installed in the CUTE fridge in April.

Base temperature of ~12 mK reached early May, taking data since.



All detectors transitioned to superconductive.

10 working channels.

LEDs for calibration working.

Running through the summer, running also during the current no access period since everything is remotely controlled.

Run goals

Get more information on the LEE:

- Comparison to NEXUS data. Measure decay time rate after cooling down.
- Study of ionization components: is the HVeV LEE events only from “heat-only” events? If so, can we use 0V data to model the HV LEE?
- Extend the study to lower energies using new generation of HVeV detectors.
- Can we extract more useful information exploiting the 2 channels?
  - Position dependence
  - Correlated noise
- Study rate as function of the different Al coverage.

Study of HVeV specific characteristics:

- Does SiO2 help reducing the “leakage” rate on the first e/h peak?
- Can we separate ER/NR exploiting the different ionization yield?

Summary

The SuperCDMS HVeV program has shown incredible features, providing eV resolution devices able to resolve single charges!

Currently running at deep underground at SNOLAB, in the CUTE facility:

- First time for these so sensitive devices in a so clean environment
- Addition of the new generation of devices, with sub-eV resolution
- Goal to extract as much information possible on the LEE to share with the community to help understanding this background

Already learning a lot from the data that are coming now!

Bonus: all this information is going to be invaluable in helping understanding the main SuperCDMS SNOLAB experiment that is in the installation phase!