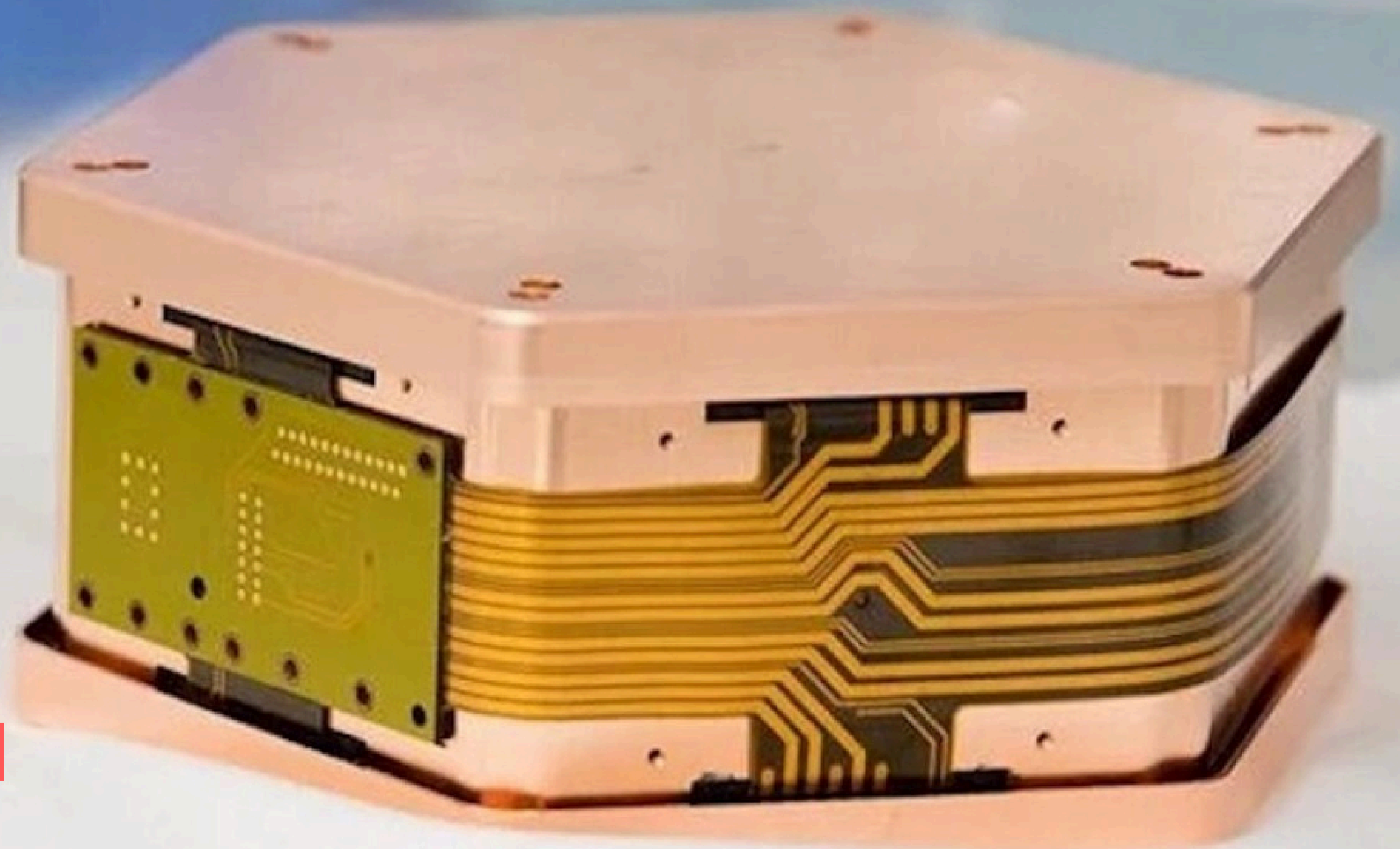
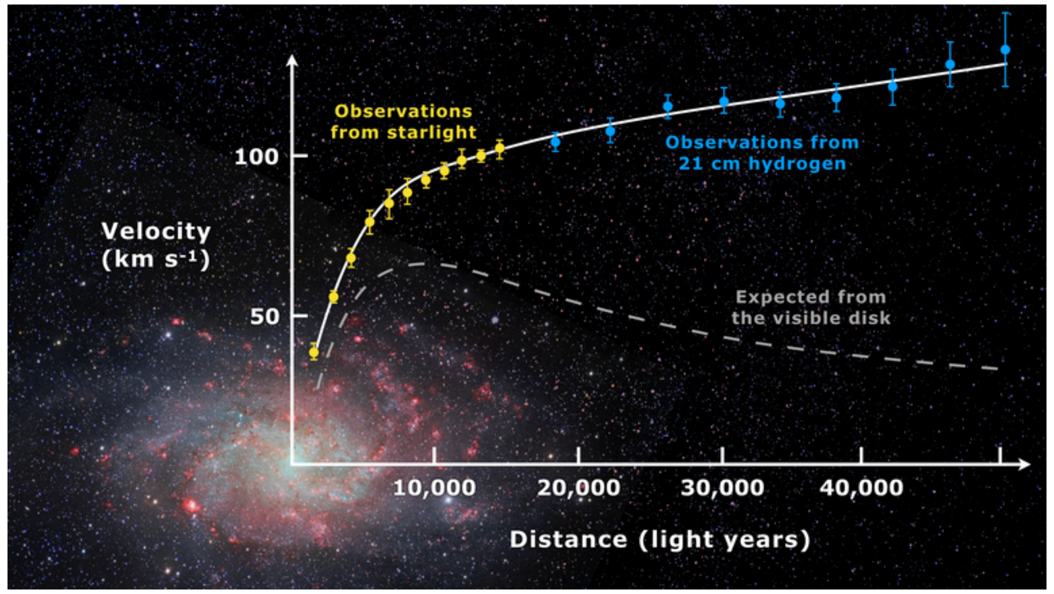
First Glimpses of the SuperCDMS High Voltage Detectors



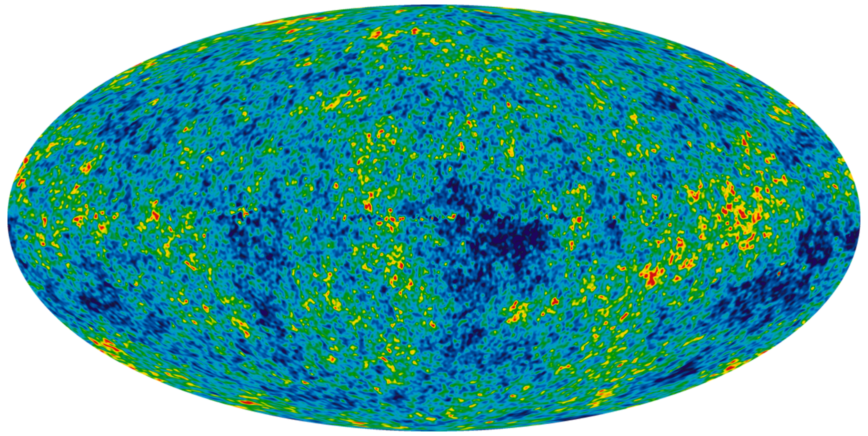
Yan Liu | TRIUMF
For the SuperCDMS Collaboration
05/28/2024

CAP 2024 @ London, ON

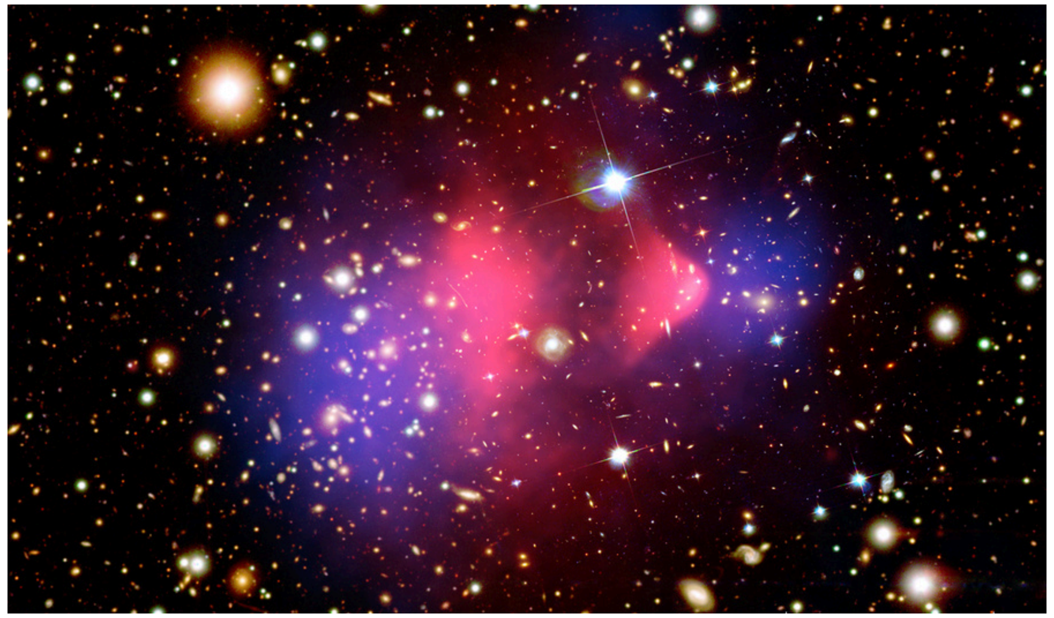
Dark Matter Properties



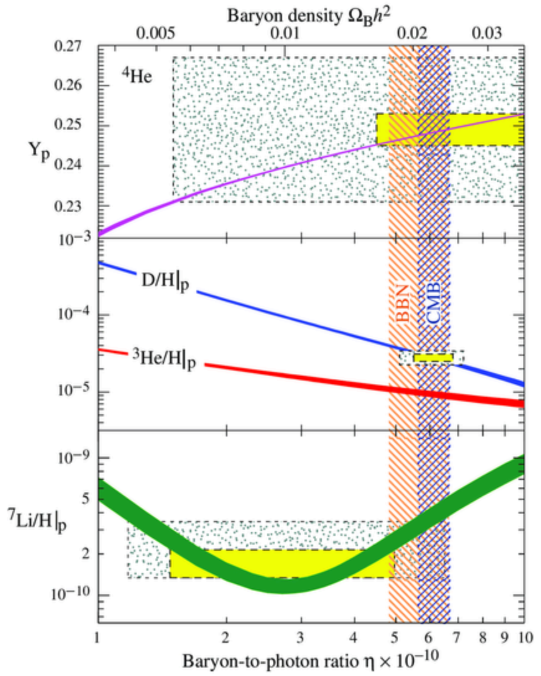
Discrepancy in galatic rotational curve



Cosmic Microwave Background



The Bullet cluster

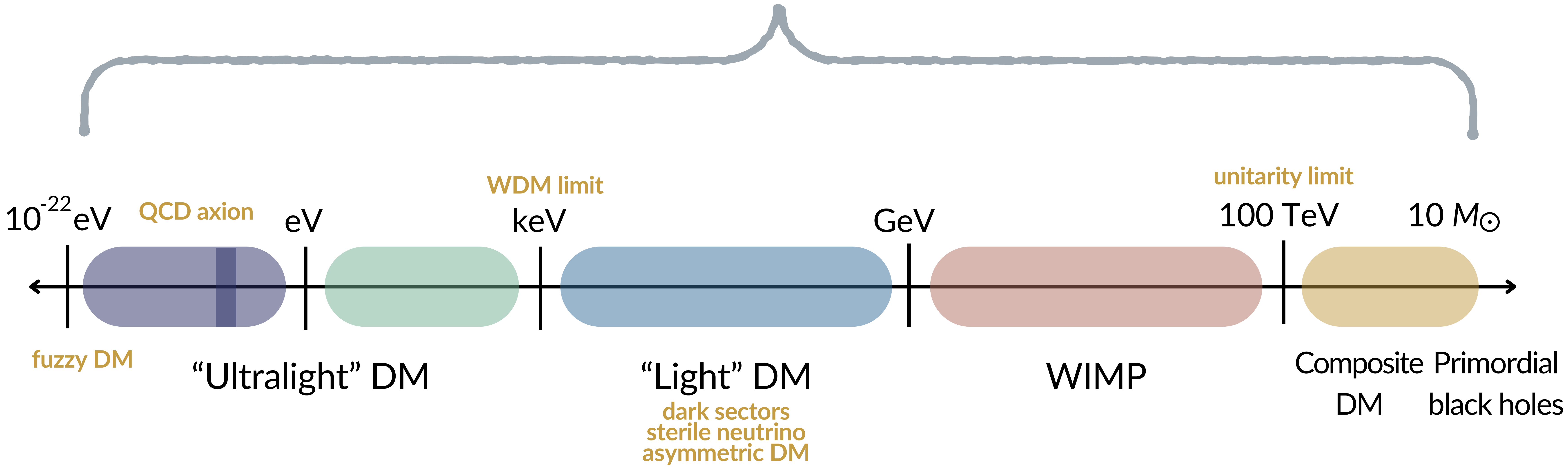


Big Bang Nucleosynthesis

- Dark
- Stable
- Non-baryonic
- Not “hot”
- ~25% of the total universe mass

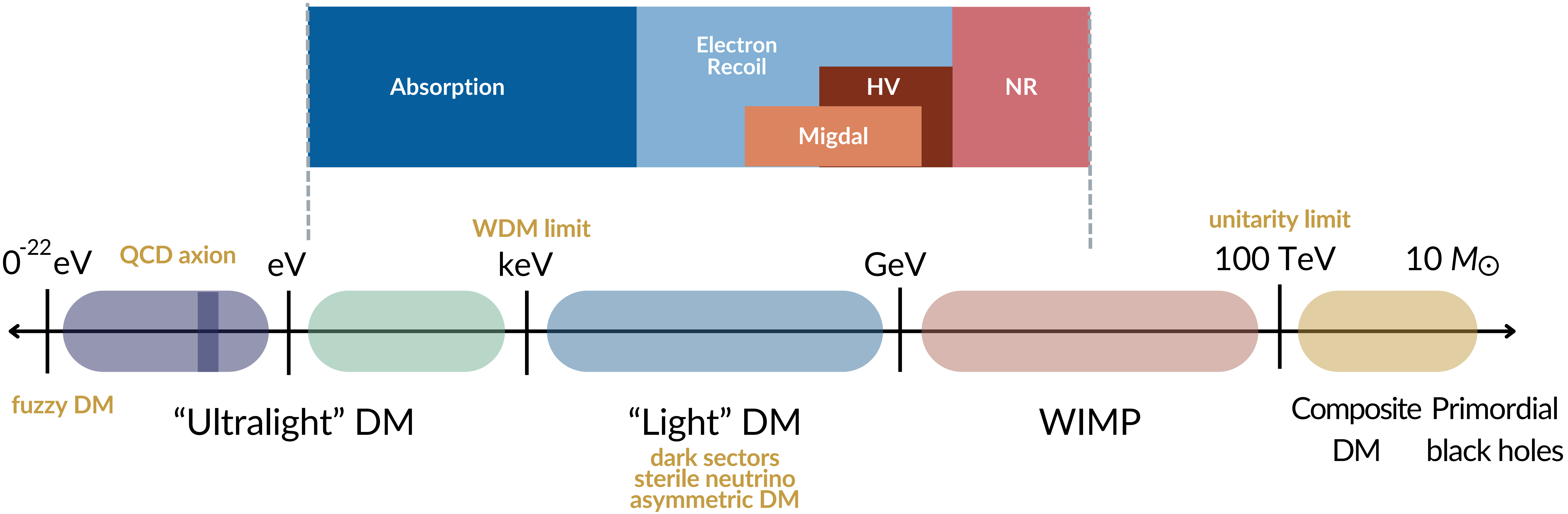
Dark Matter Mass

spanning across ~88 orders of magnitude



SuperCDMS as a Dark Matter Experiment

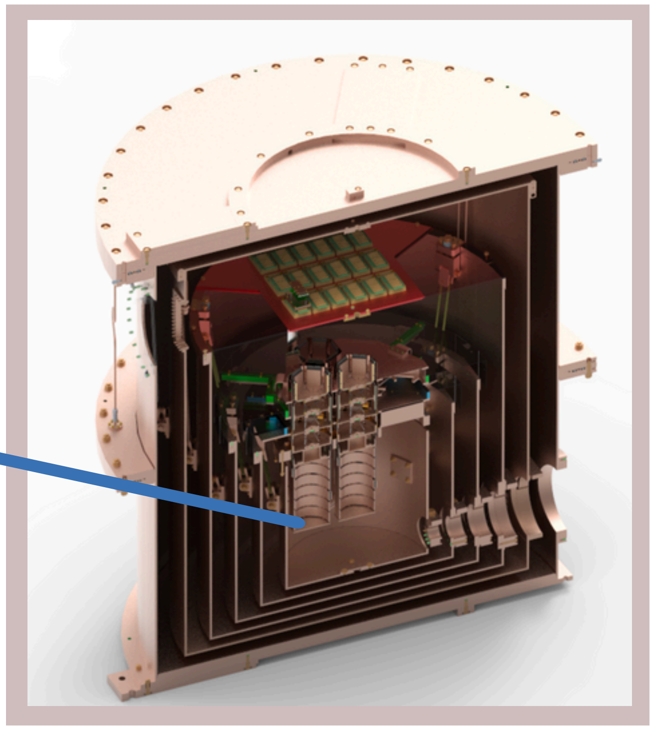
SuperCDMS SNOLAB is sensitive to various dark matter models across **10 orders of magnitude**!



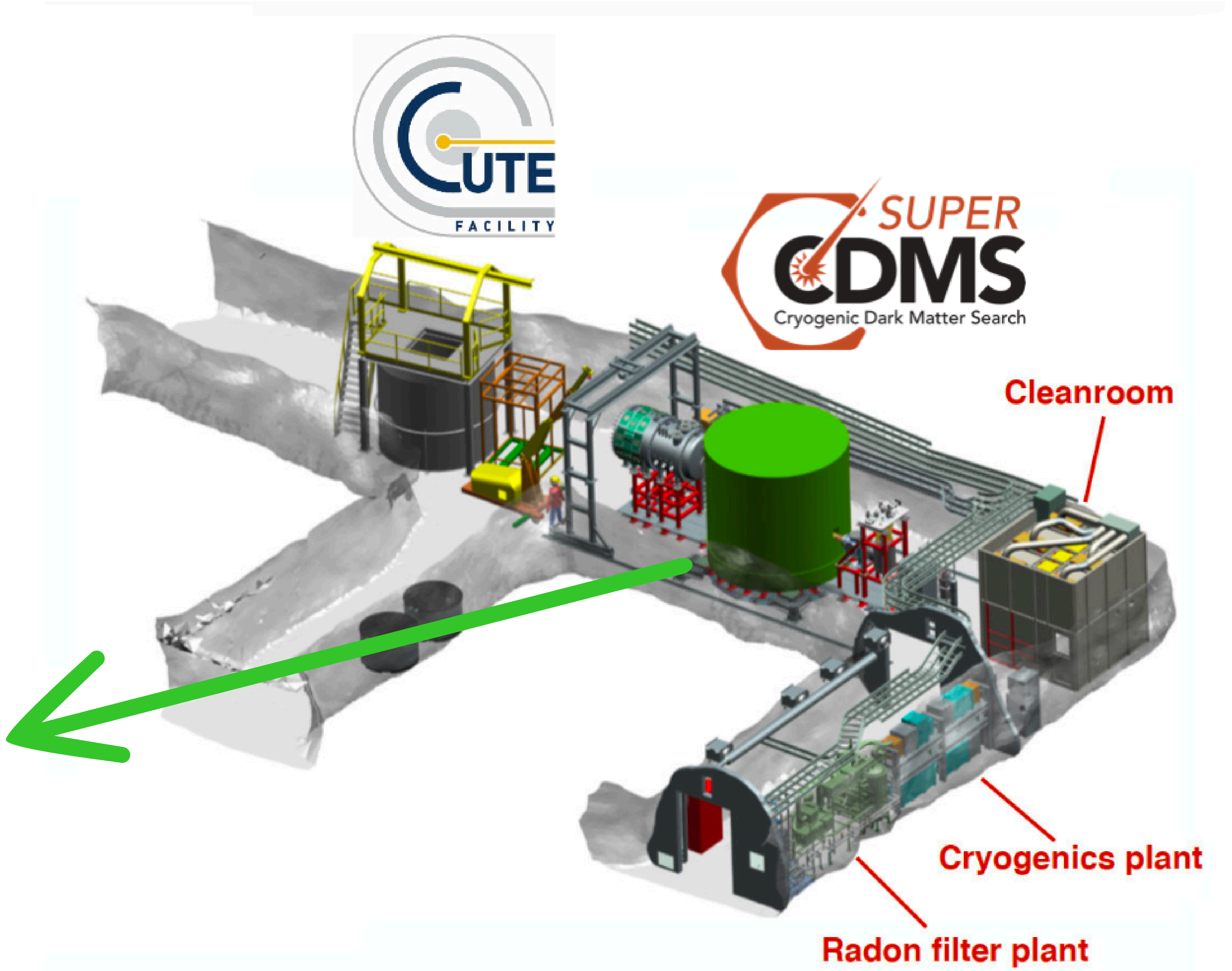
SuperCDMS SNOLAB Experiment

- 2 km underground in Sudbury, Canada
- Tower (stacks of 6 detectors) mounted inside a cryostat, which is surrounded by shielding to minimize background
- Germanium and Silicon crystals cooled down to ~10 mK to be sensitive to minute dark matter signals

Detector

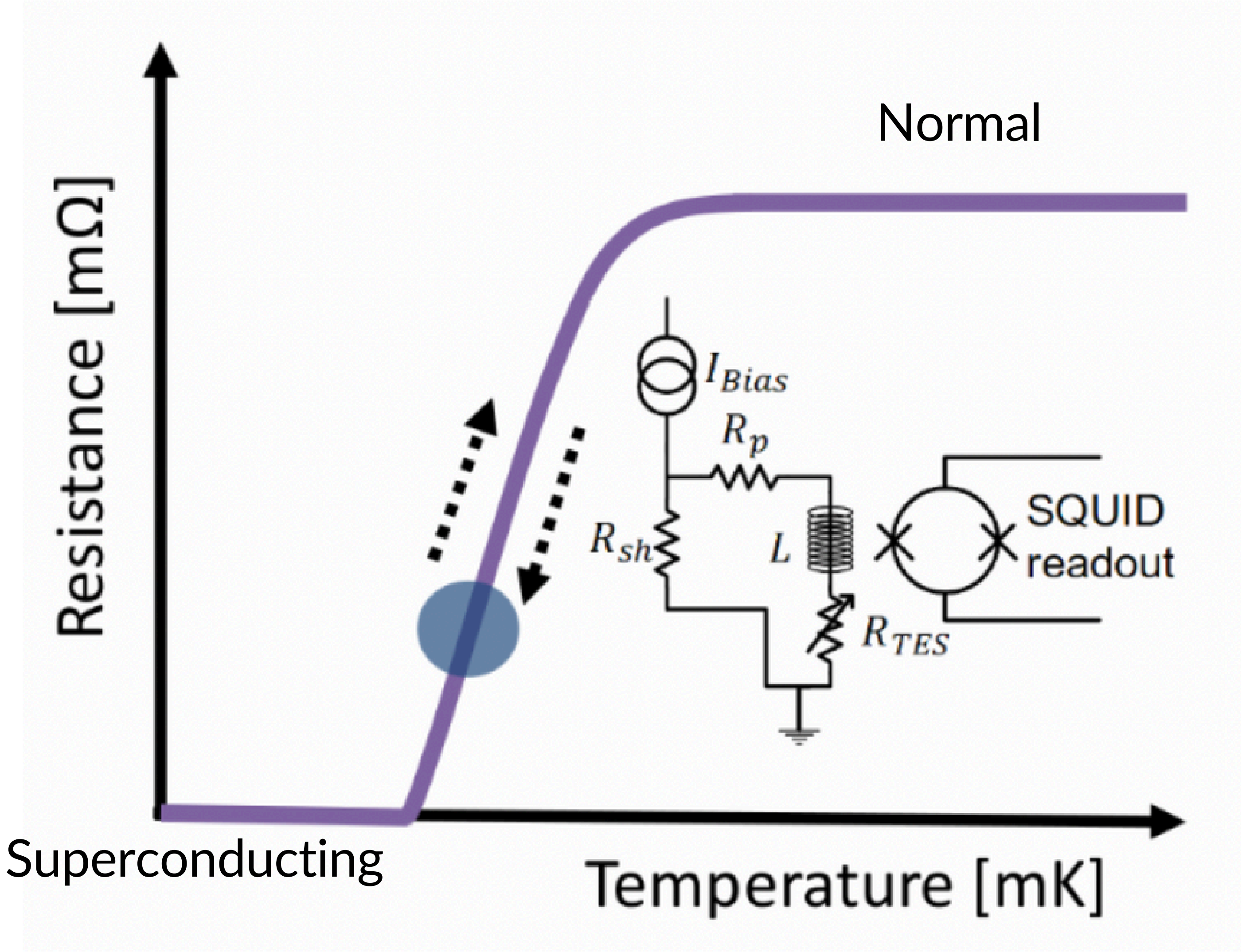


Cryostat



SuperCDMS SNOLAB layout

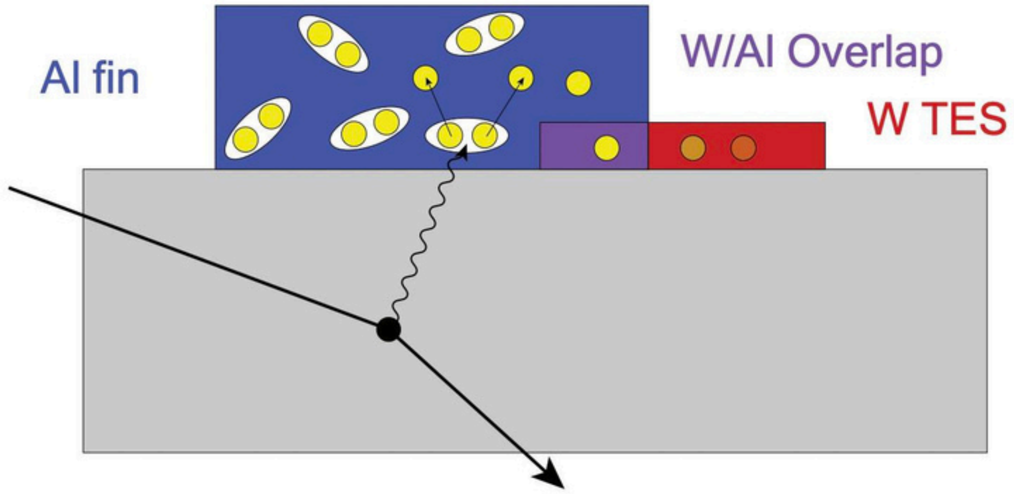
SuperCDMS SNOLAB Detector Technology



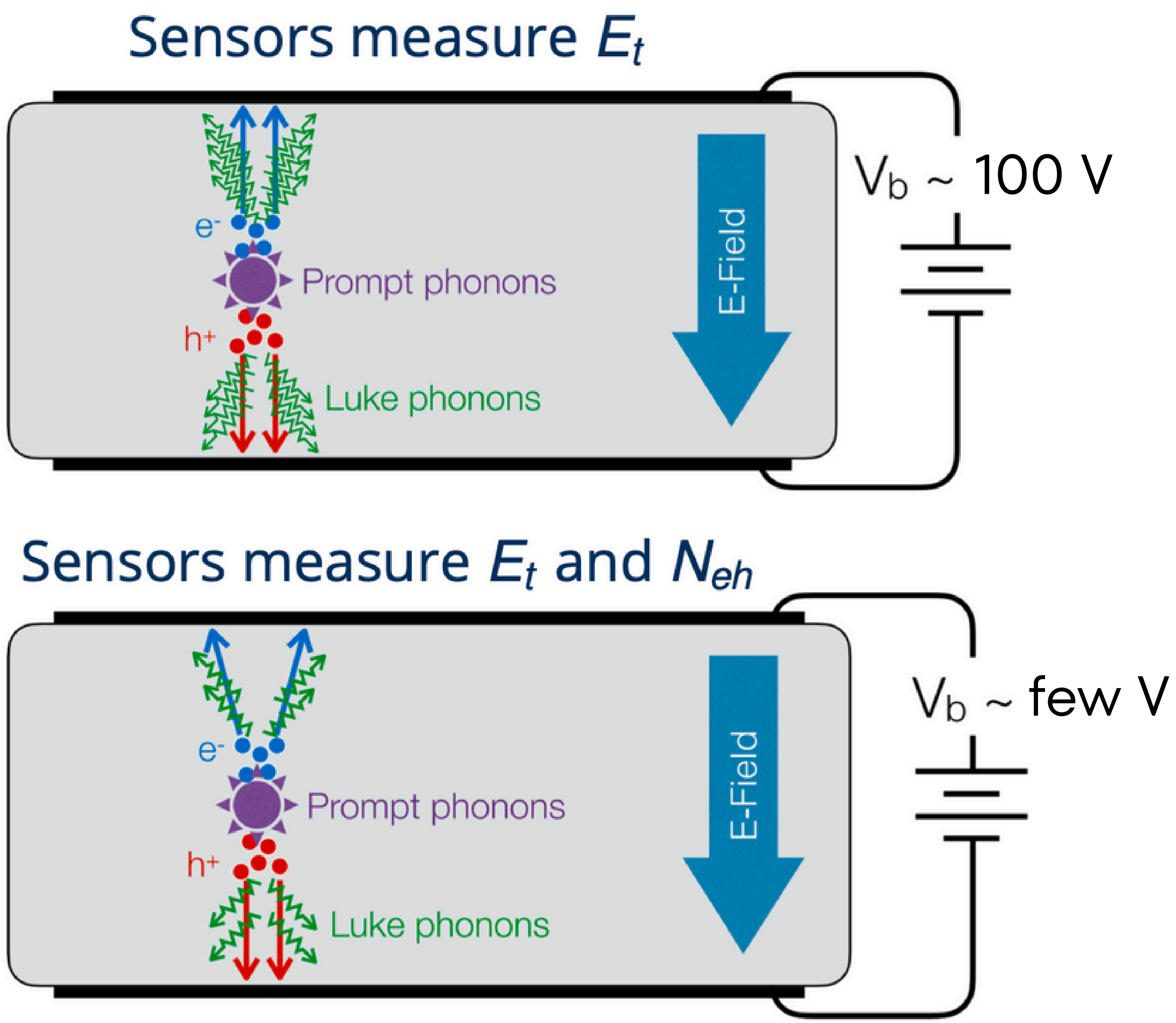
TES: Transition Edge Sensor

Athermal phonon detectors

- Only partial energy is measured
- To first order decoupled from crystal heat capacity
- Fast pulses compared to thermal measurement
- Signal is position dependent
- Al fins as phonon collectors which enable large coverage area



SuperCDMS SNOLAB Detector Technology



Two different detector configurations

- **HV detectors -> low threshold**
  - — Luke effect can amplify phonon signals under E field to lower detection threshold
  - — highest science reach

$$E_t = E_r + N_{eh} e V_b$$

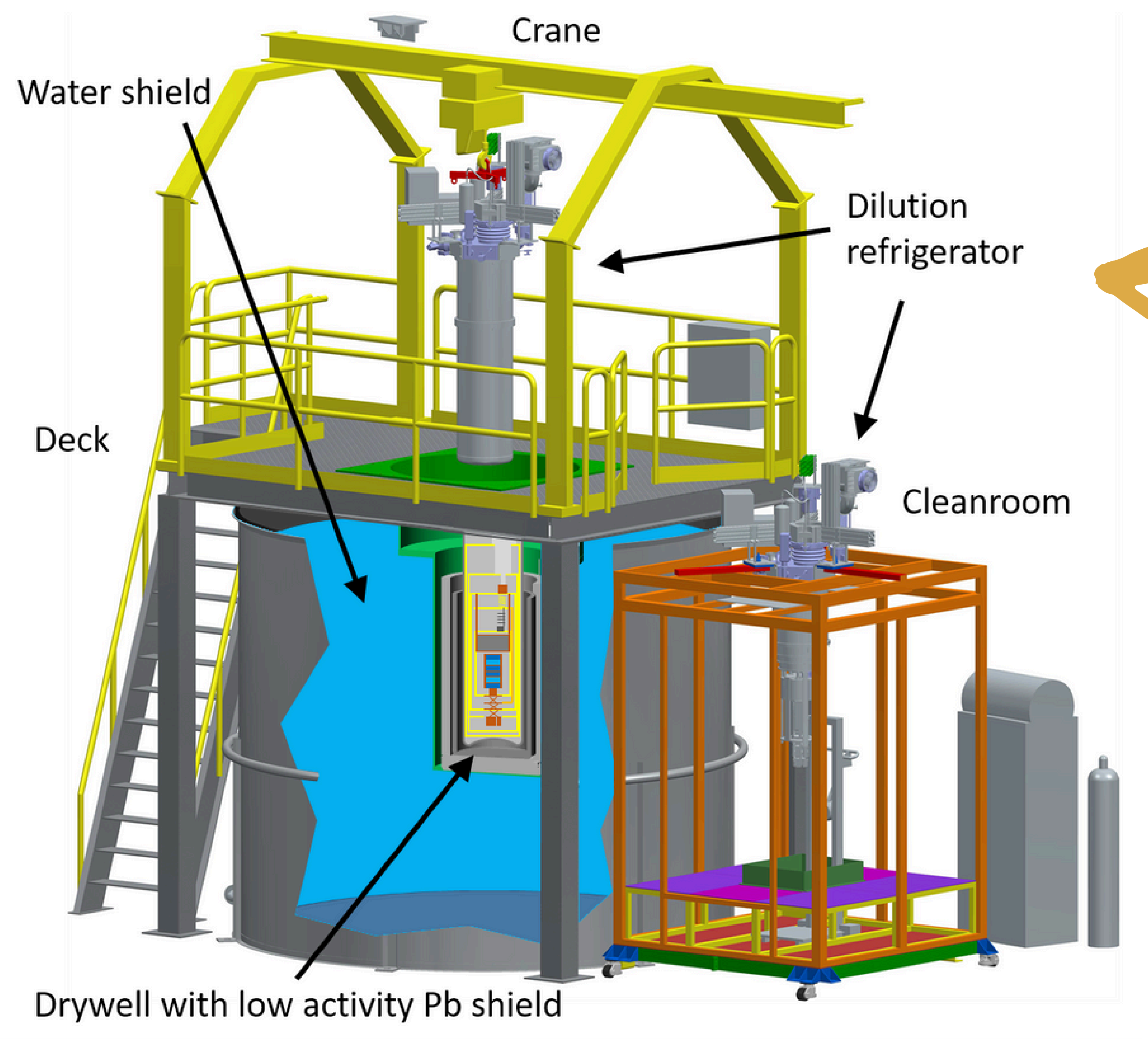
total phonon energy

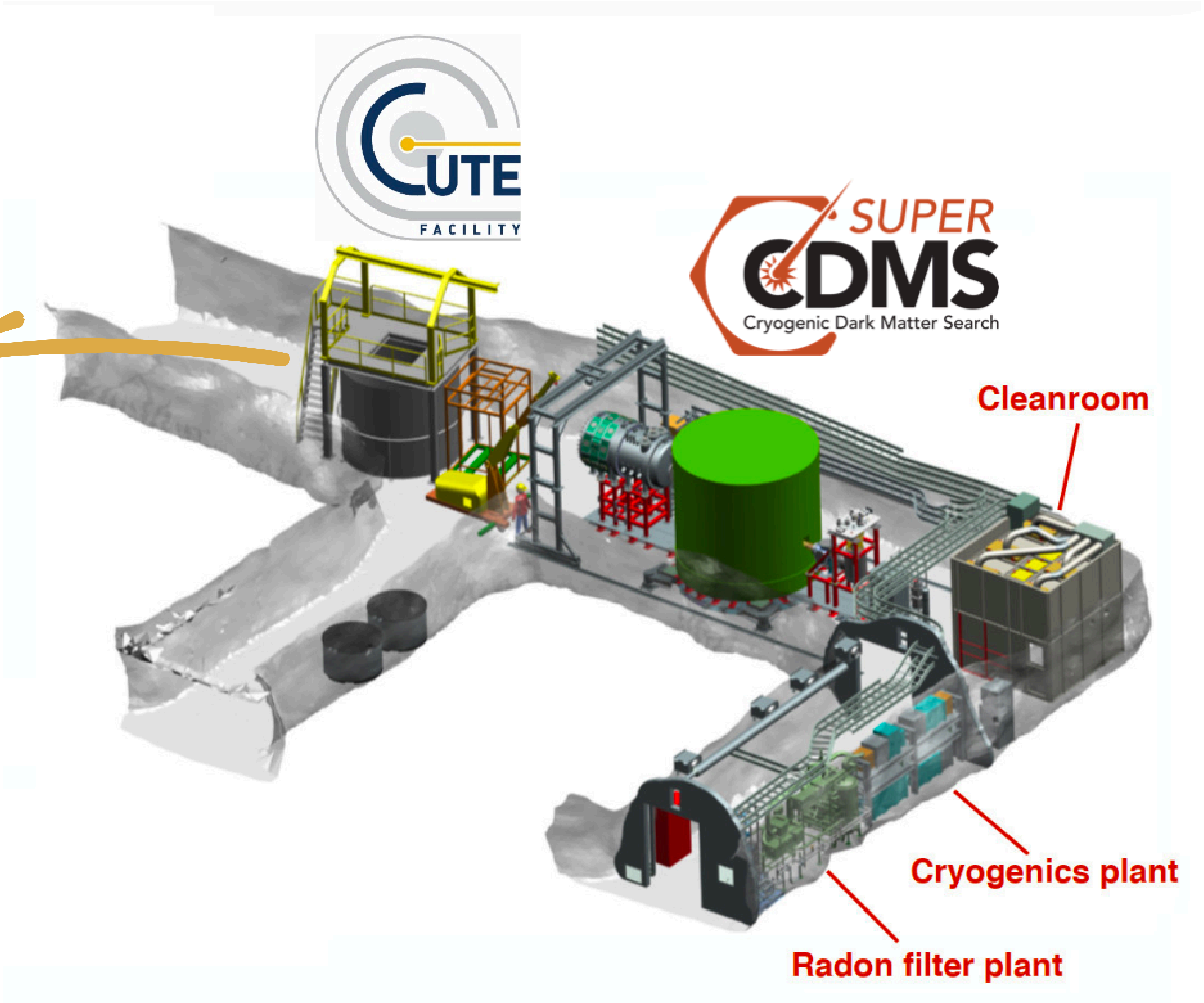
primary recoil energy

Luke phonon energy

- **iZIP detectors -> low background**
  - — ionization-based NR/ER background discrimination
  - — higher dynamic range
  - — radioactive background measurements

Cryogenic Underground TEst Facility

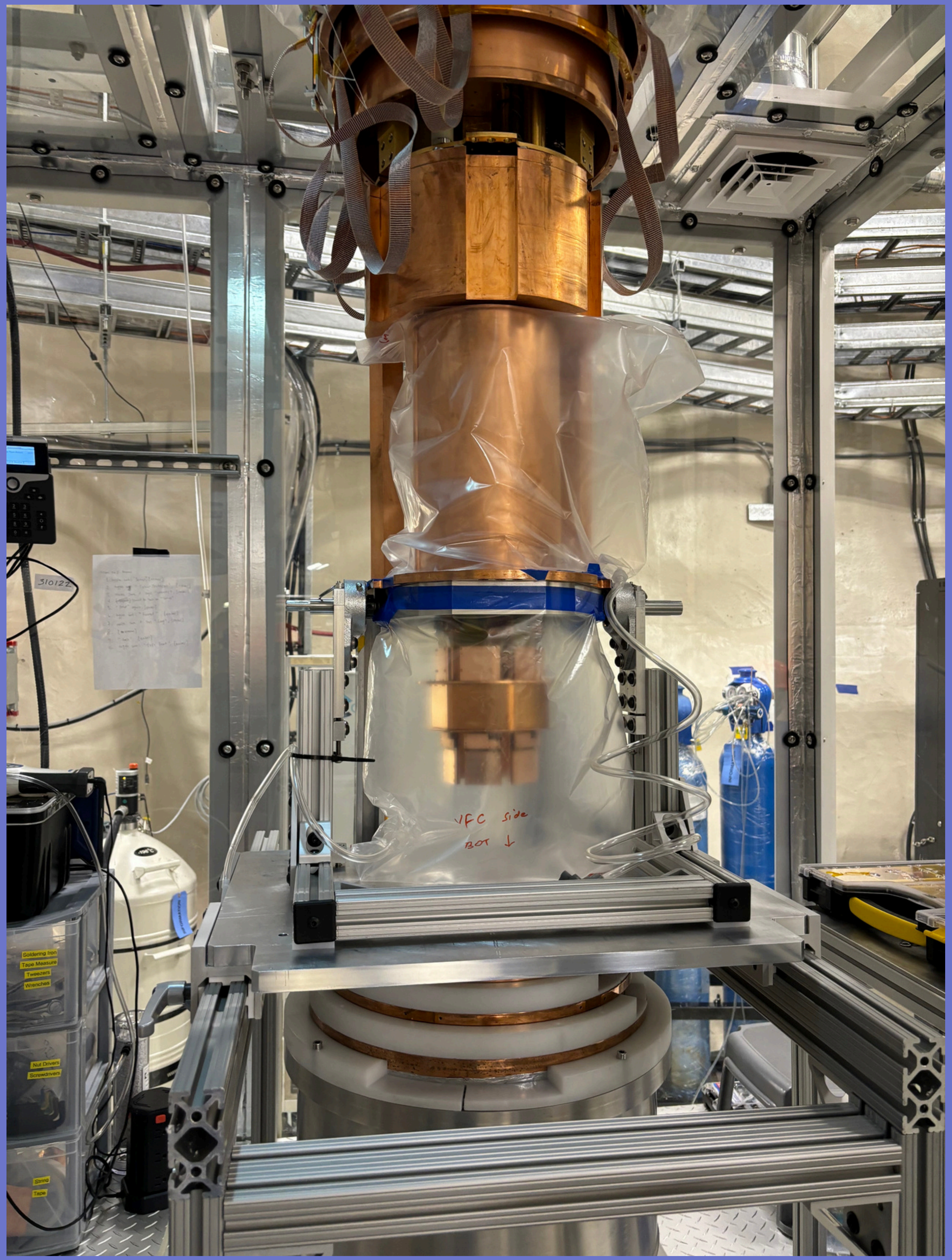




Installing Tower into CUTE Fridge

A major milestone of the experiment:

A SuperCDMS SNOLAB High Voltage tower operated in an underground, low background environment.



SuperCDMS Tower is being installed at CUTE

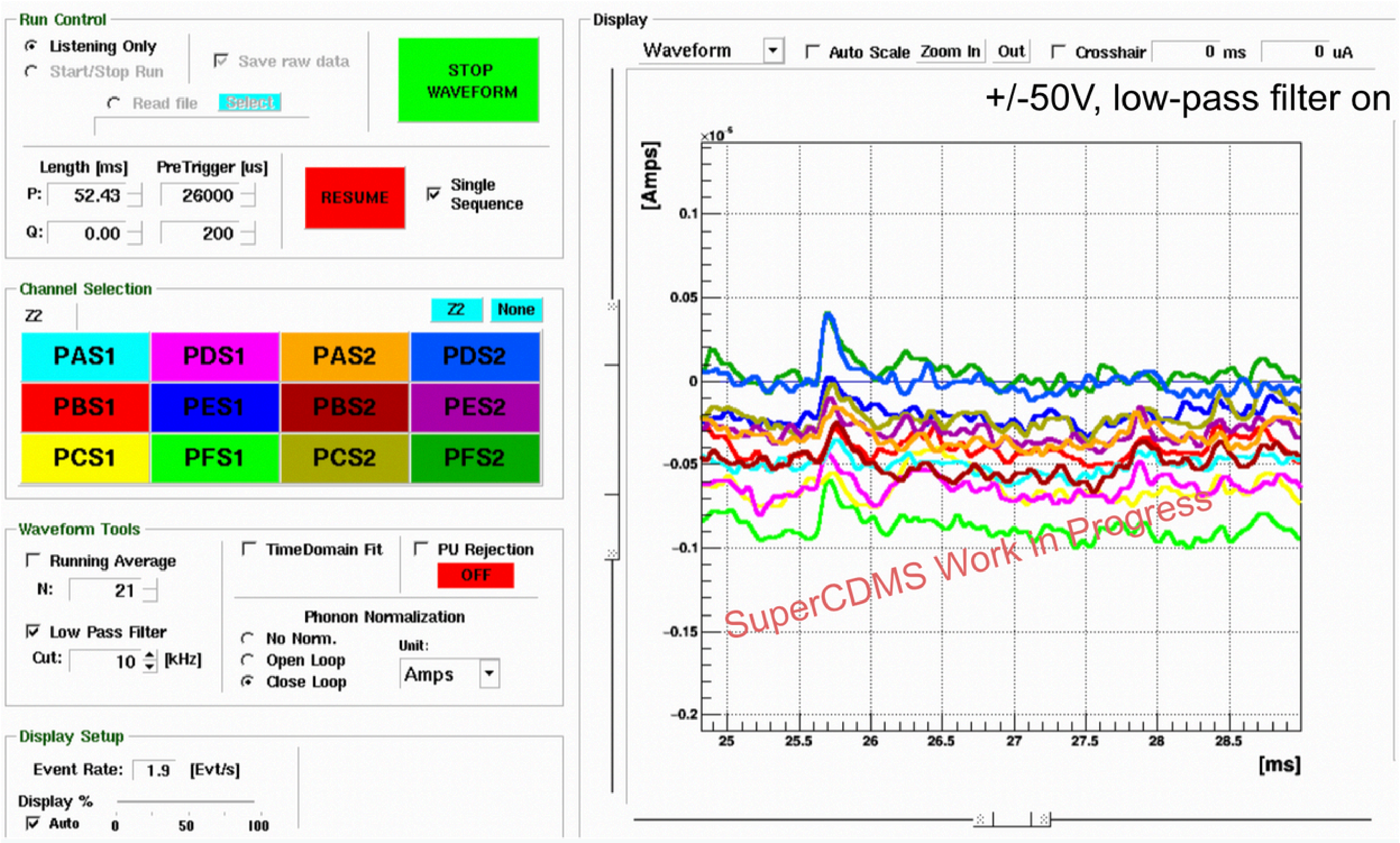
Tower Testing at CUTE: Statistics

151 days covering 4 thermal cycles

Total data volume: 400 detector days

~2 month of calibration data

~2 weeks of low background data



Run Control

● Listening Only

○ Start/Stop Run

☑ Save raw data

○ Read file

Length [ms] P: 52.43 Q: 0.00

PreTrigger [us] P: 26000 Q: 200

☑ Single Sequence

Channel Selection Z2

Waveform Tools

☐ Running Average N: 21

☑ Low Pass Filter Cut: 10 [kHz]

☐ TimeDomain Fit

☐ PU Rejection OFF

Phonon Normalization

○ No Norm.

○ Open Loop

● Close Loop

Unit: Amps

Display Setup

Event Rate: 1.9 [Evt/s]

Display % ☑ Auto 0 50 100

Display

Waveform ☐ Auto Scale Zoom In Out ☐ Crosshair 0 ms 0 uA

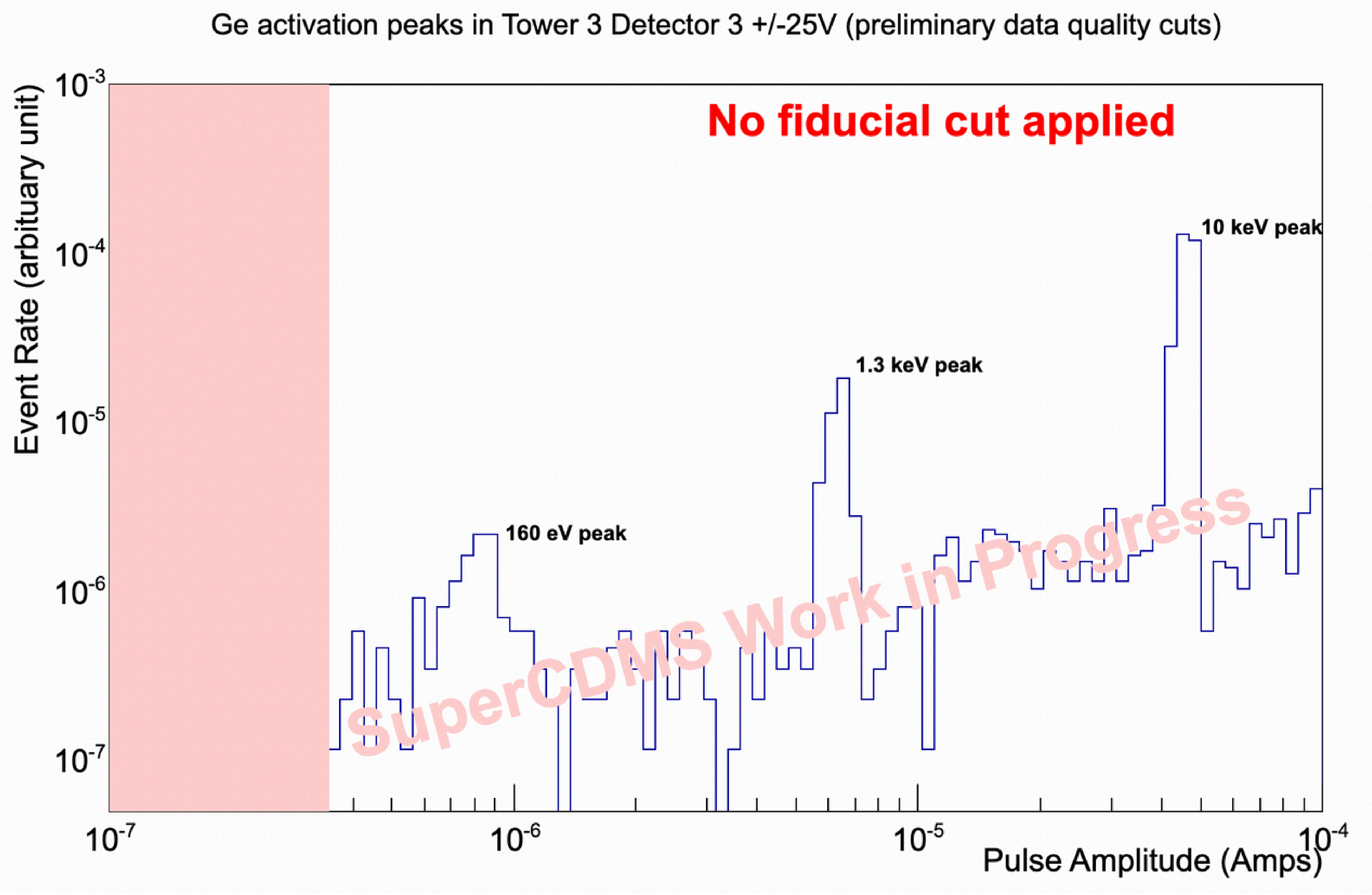
Example pulses from a Silicon detector operated at 100V

Tower Testing at CUTE: Ge Detector Calibration

- Irradiating Ge with neutrons produces ^{71}Ge (11.4 days half-life)
- The activation lines from ^{71}Ge electron captures are:

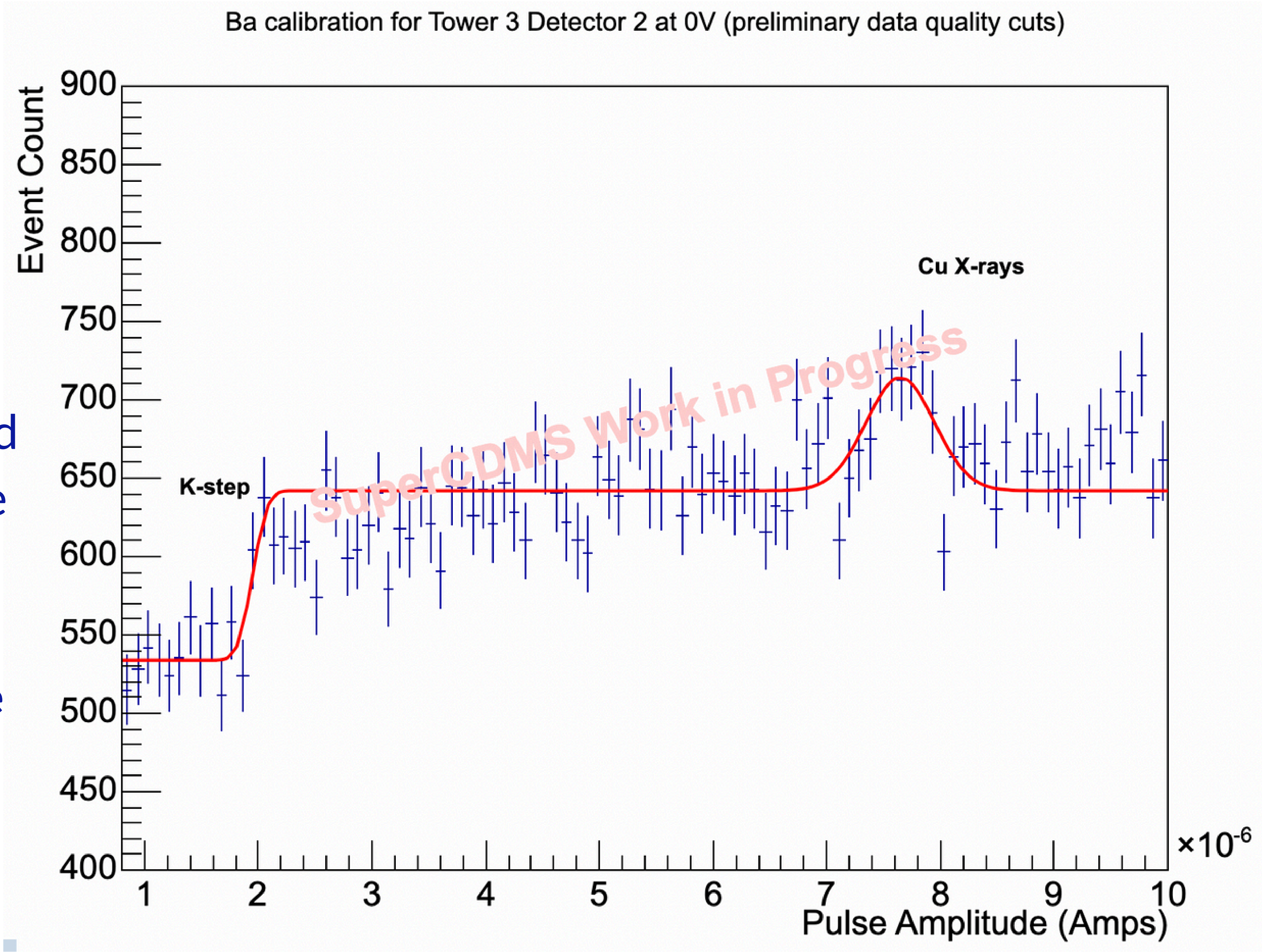
  — 10 keV, 1.3 keV, 160 eV

- From Dec. 16 to Dec. 21, ~90 hours of Ge detector calibration dataset was taken



Tower Testing at CUTE: Si Detector Calibration

- ~90 hrs of Ba source data for Si detector operated at 0V.
- Characteristic steps in energy spectrum caused by the binding energy of shell electrons can be used to calibrate the Si detector.
- **Demonstrating the calibration method for the Si detector was one of the most important goals for CUTE tower testing**



CONCLUSIONS

1. Direct detection of dark matter is one of the most promising methods we have to investigate BSM physics.
2. SuperCDMS SNOLAB is sensitive to a variety of dark matter models ranging over 10 orders of magnitude in dark matter mass.
3. SuperCDMS High Voltage tower at CUTE marks the first time these detectors are operated in an underground, low background environment.
4. Preliminary results indicate great potentials with these detectors, enabling us to explore exciting science in the coming months and beyond.

thankyou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SUPER CDMS
Cryogenic Dark Matter Search