

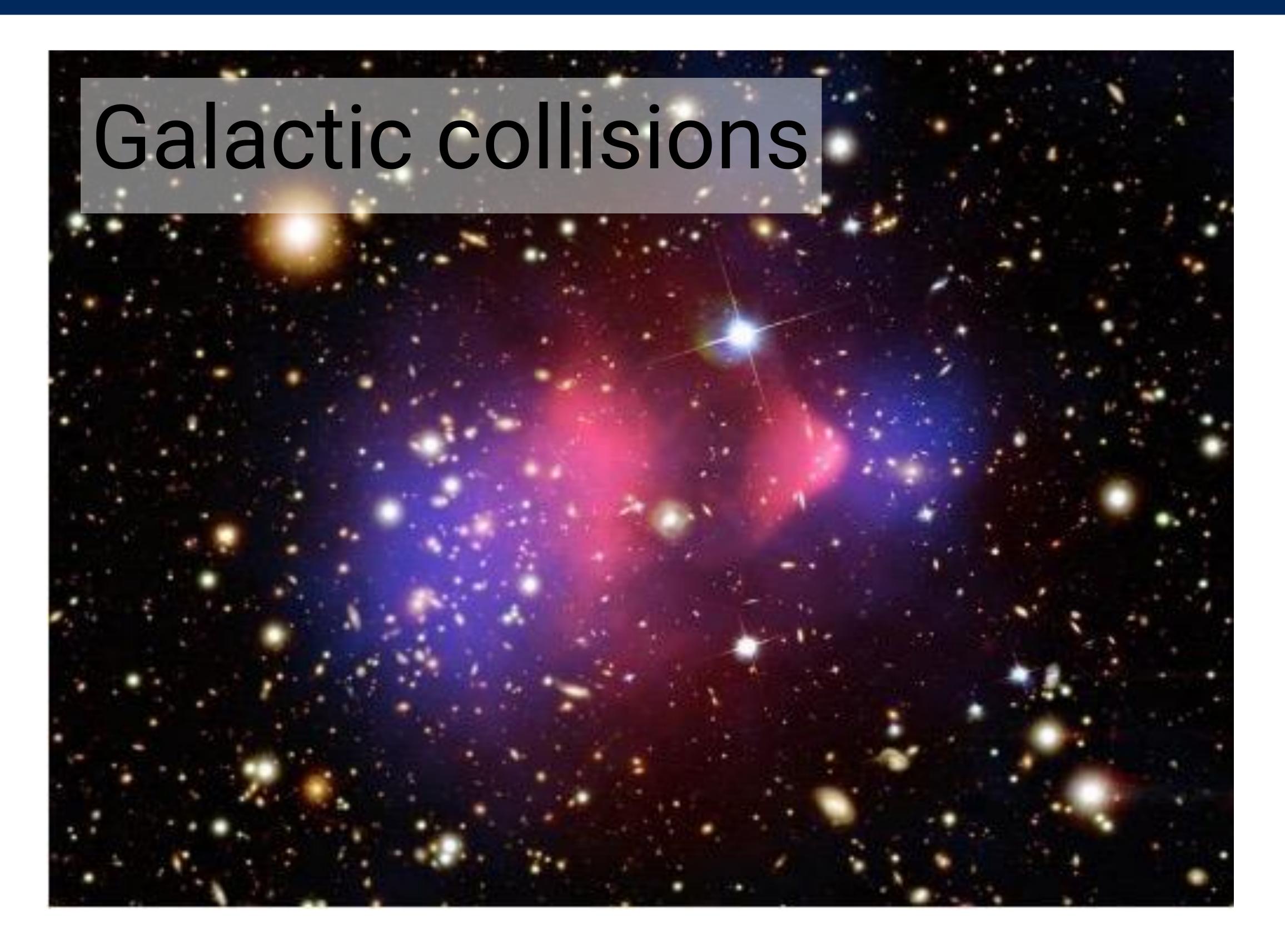
SuperCDMS Overview and Status

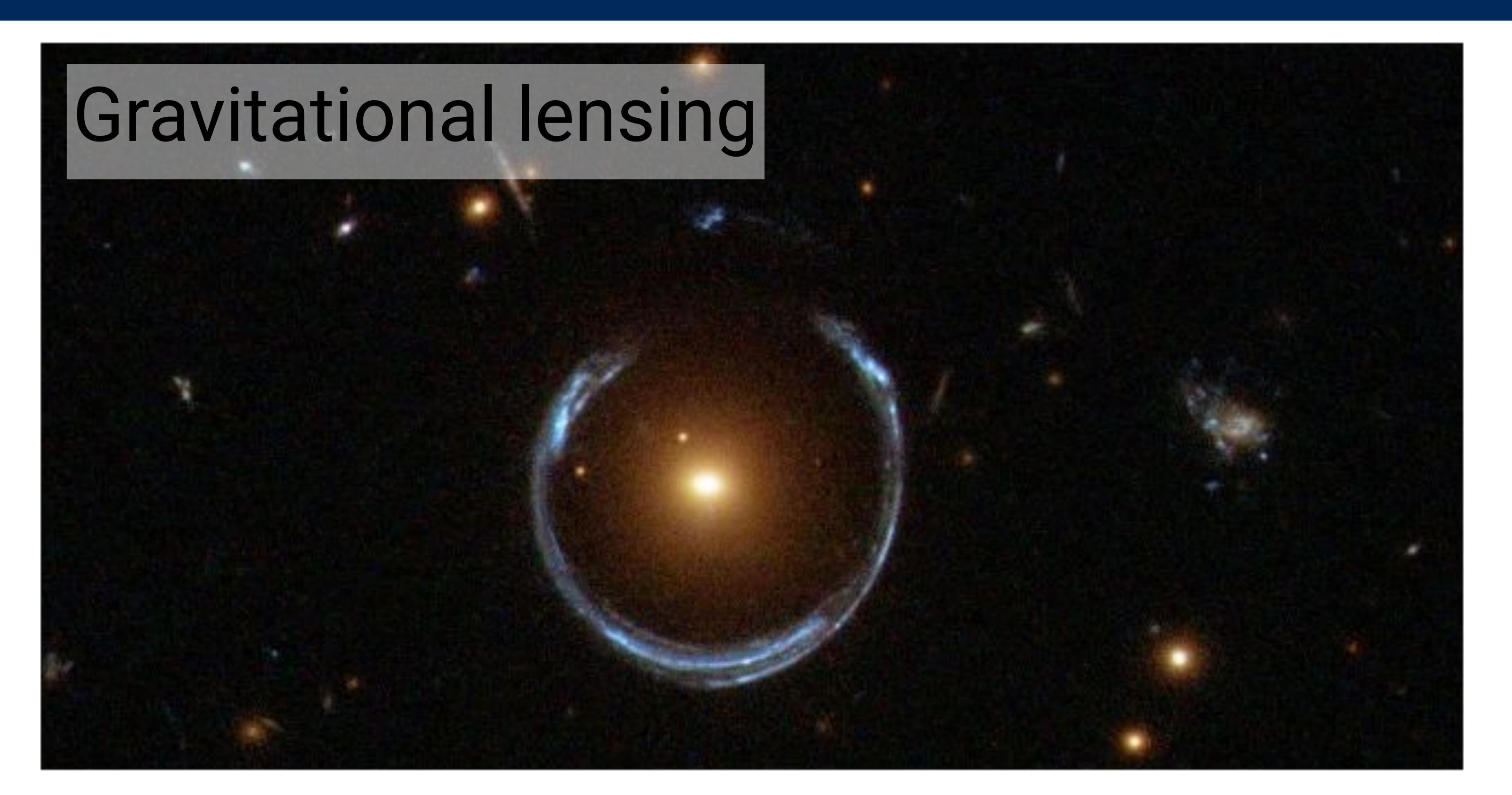
Madeleine J. Zurowski | University of Toronto

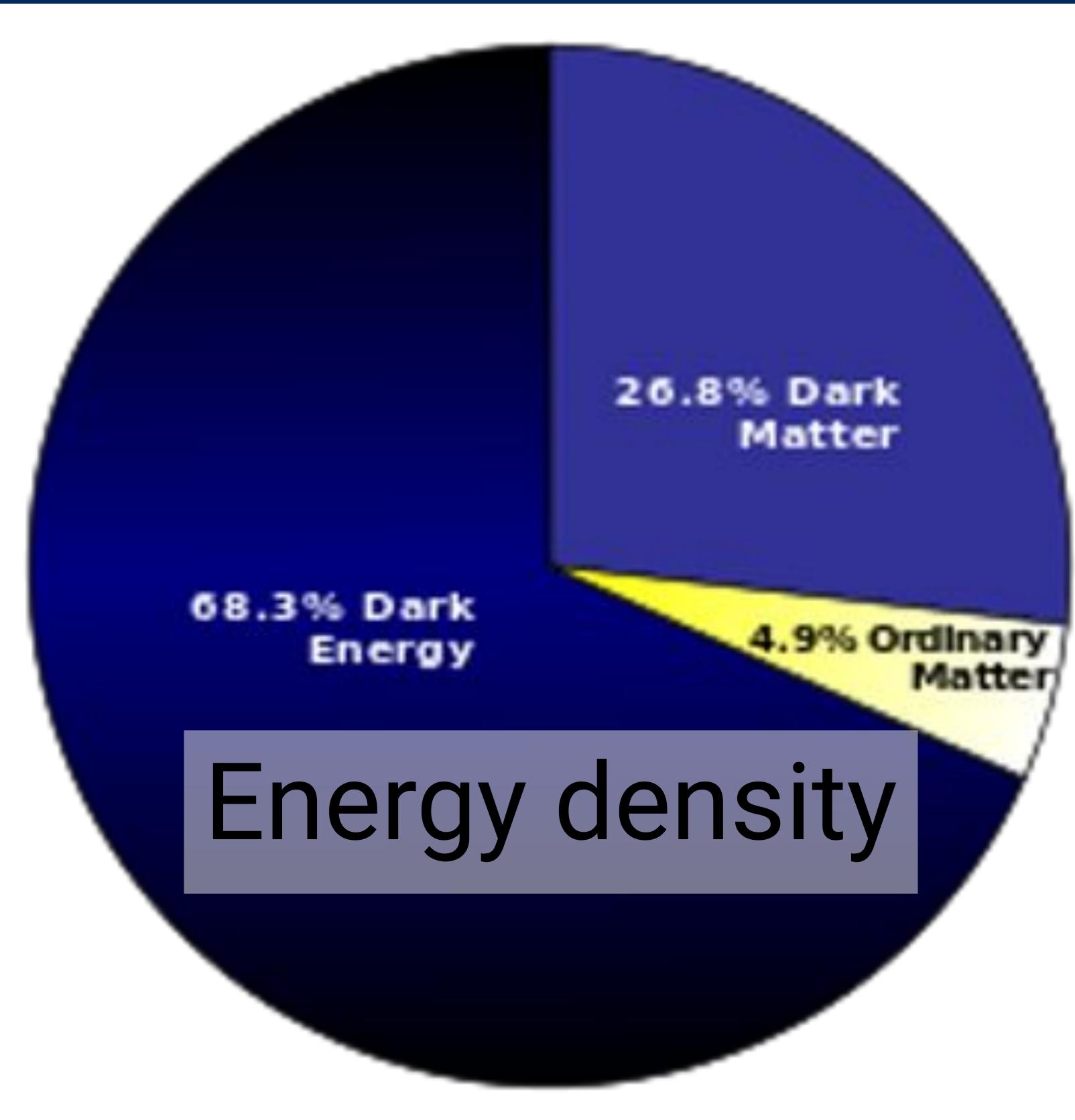
On behalf of the SuperCDMS Collaboration madeleine.zurowski@utoronto.ca

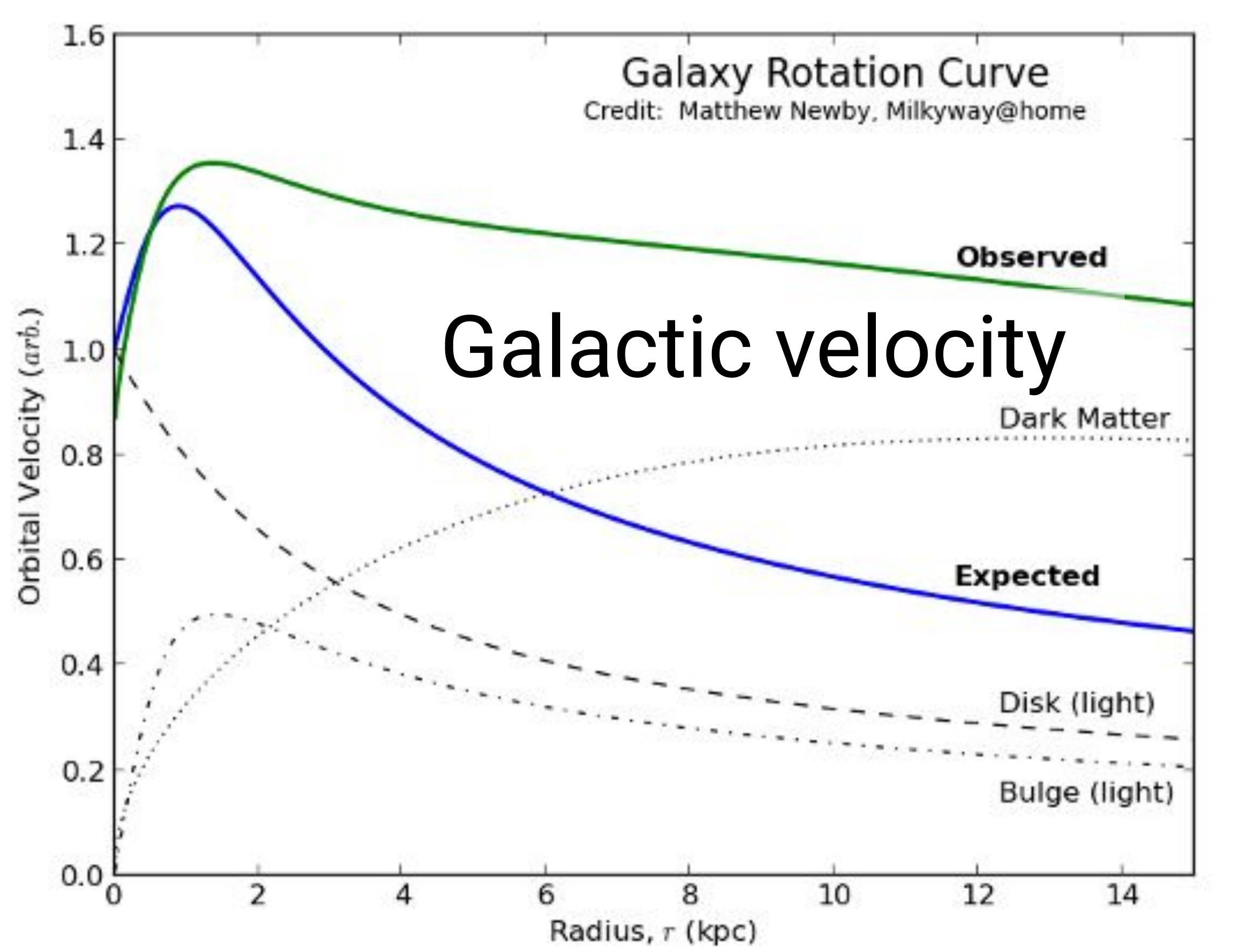


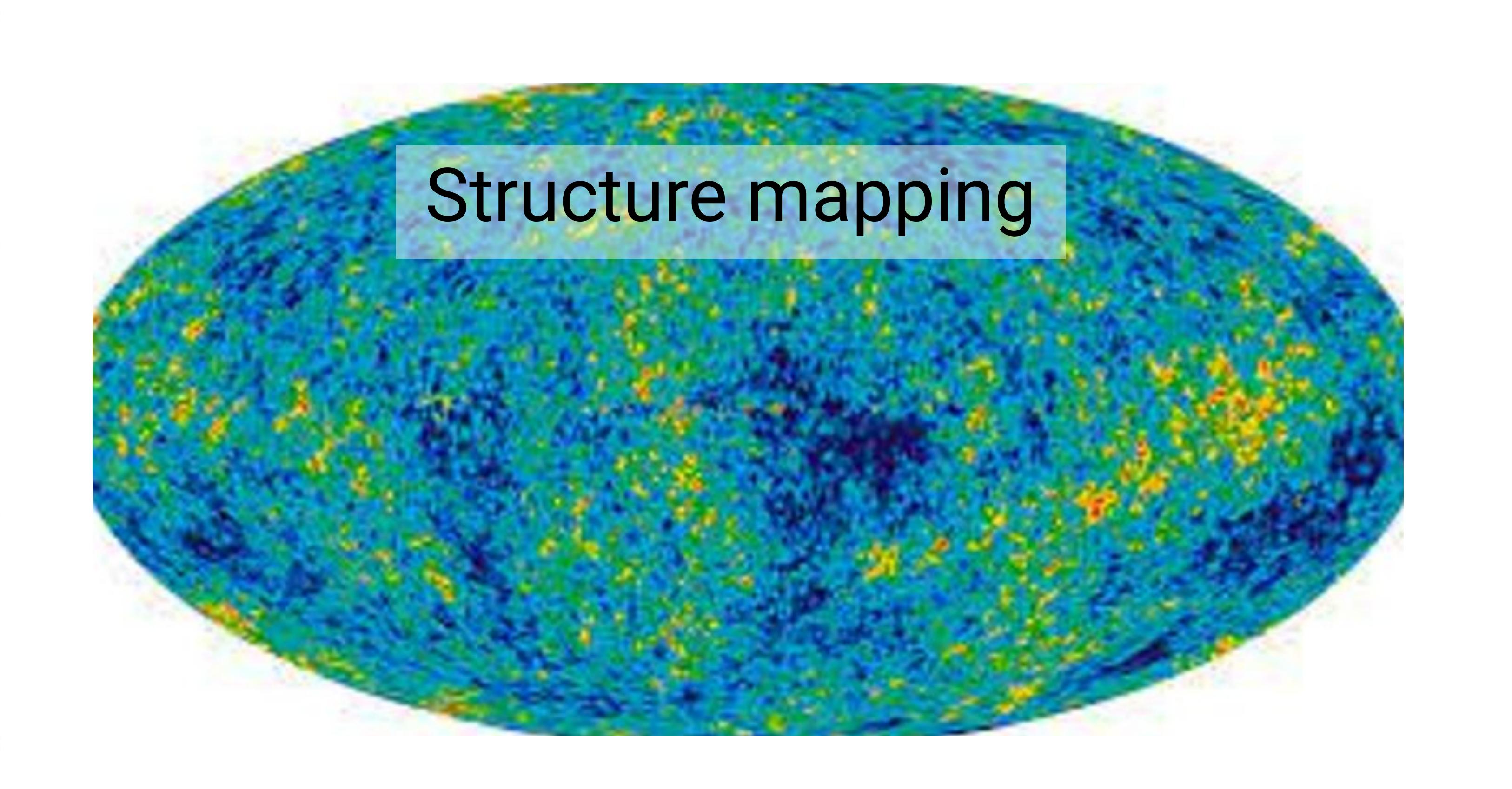
Dark Matter

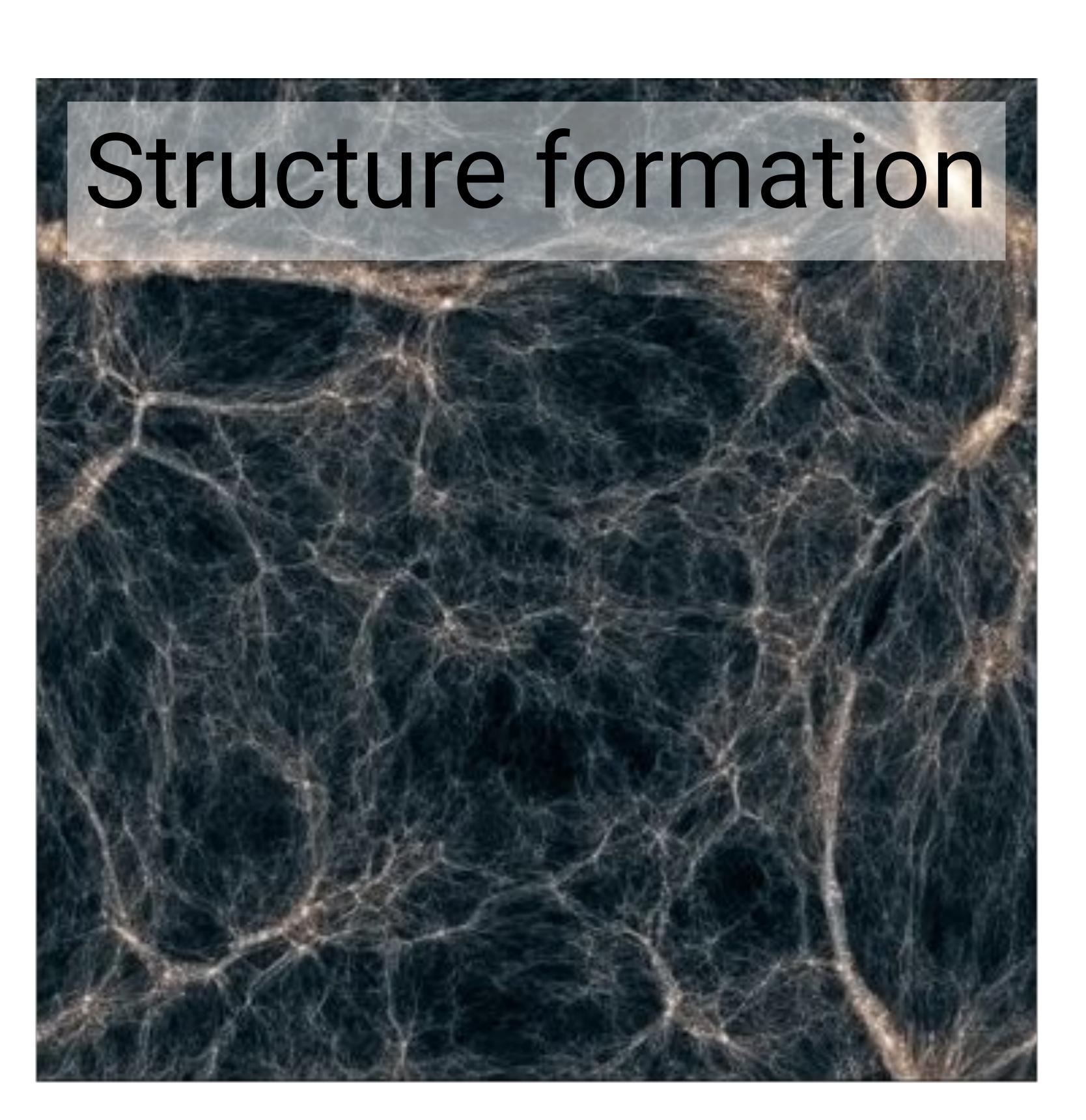








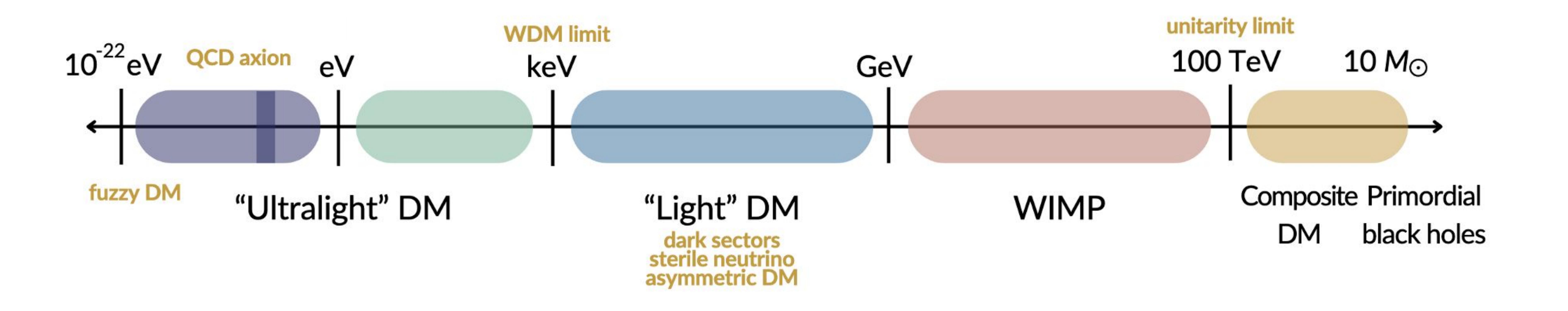




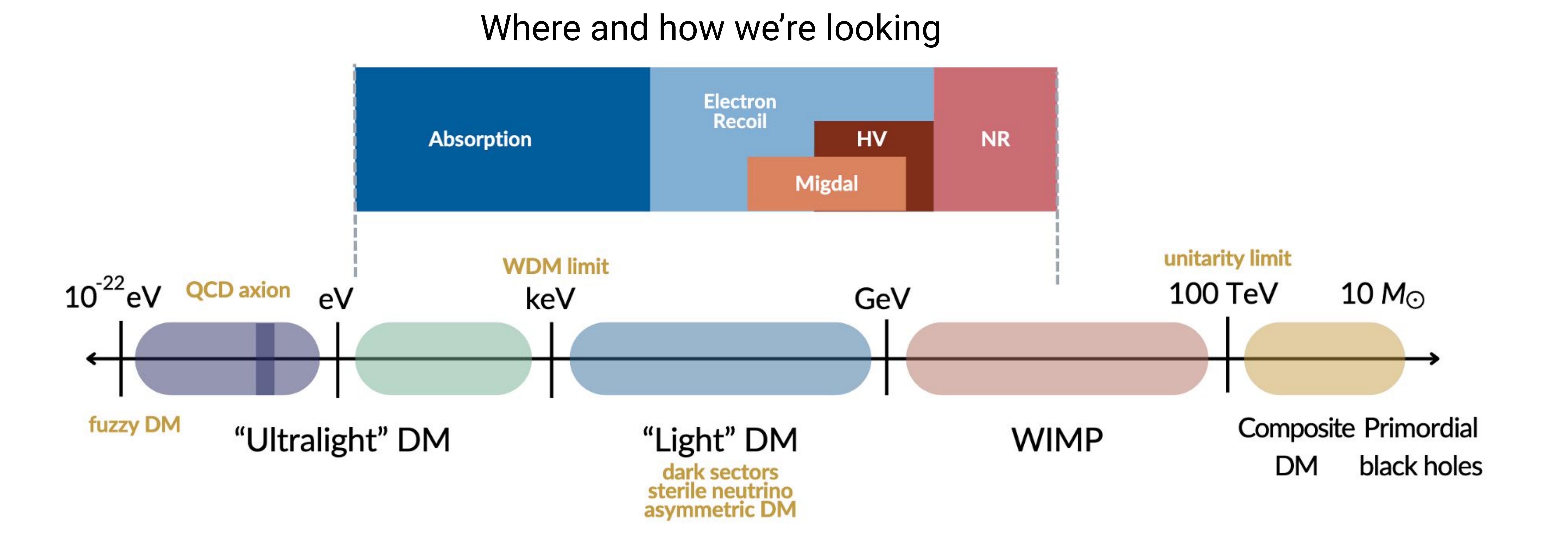
Dark Matter

We're pretty sure it's out there, but where to look...

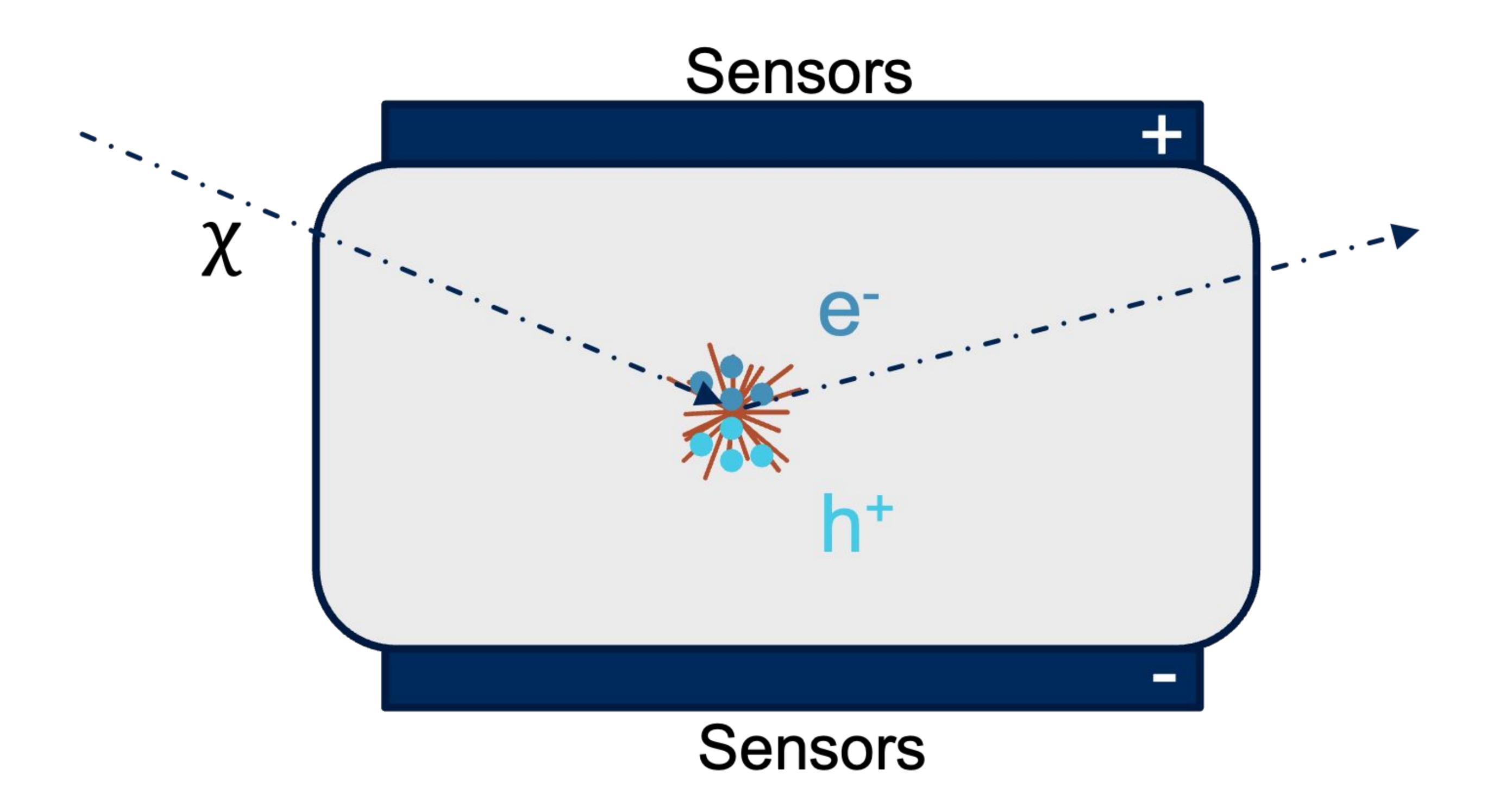
Lots of well motivated theories and experimental techniques

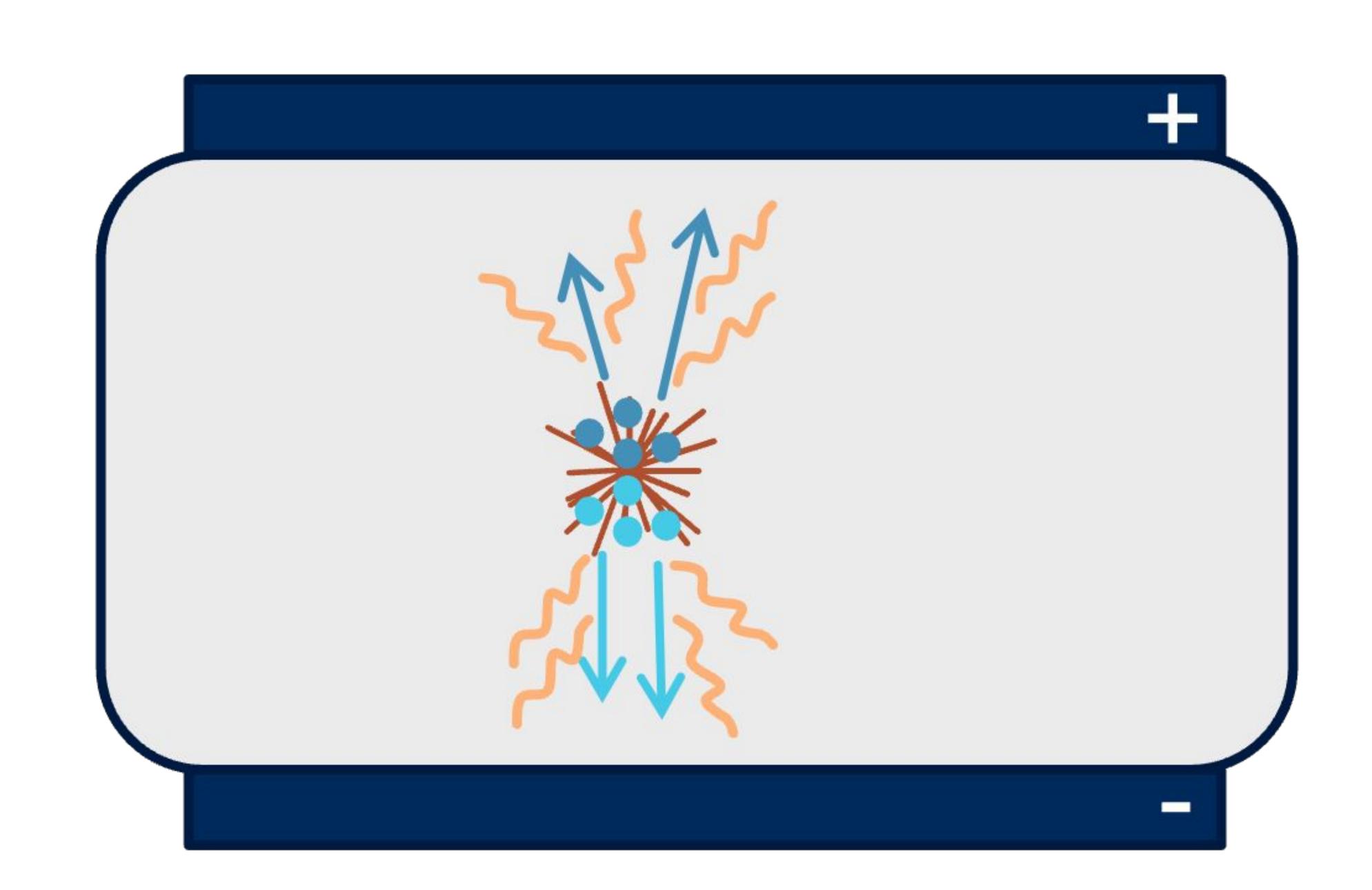


Dark Matter + SuperCDMS



Detector Concepts



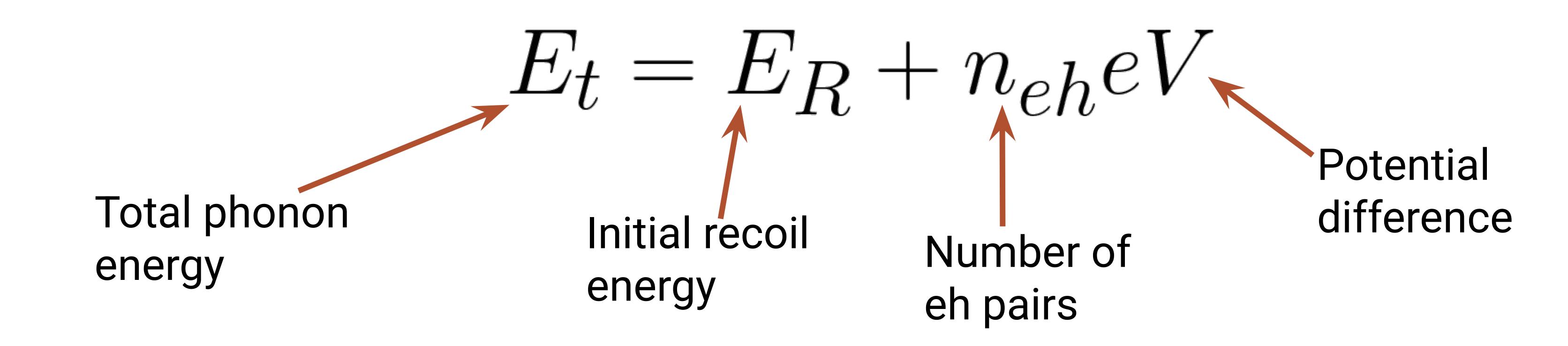


- DM scatters in crystal and produces recoil in lattice
- Energy deposition produces two observables:
 - o Electron-hole pairs
 - Prompt and Neganov-Trofimov-Luke (NTL) phonons
- Charges drifted with electric field to sensors for collection of signals
 - Interleaved electrodes for ionisation
 - OQETs for athermal phonons
- Combine these in different ways depending on what we want:
 - Low energy threshold: HV
 - o NR/ER discrimination: iZIP

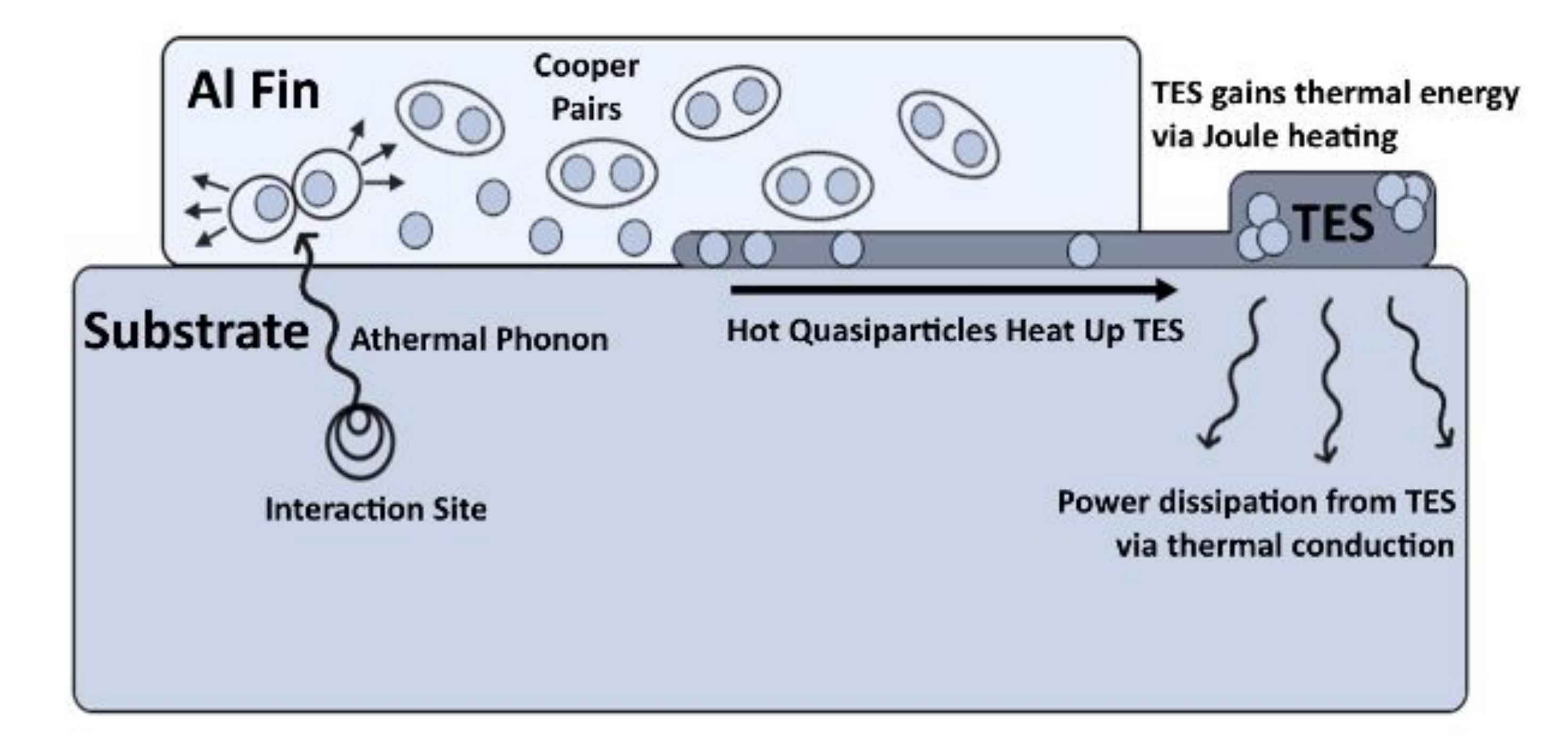
HV detectors

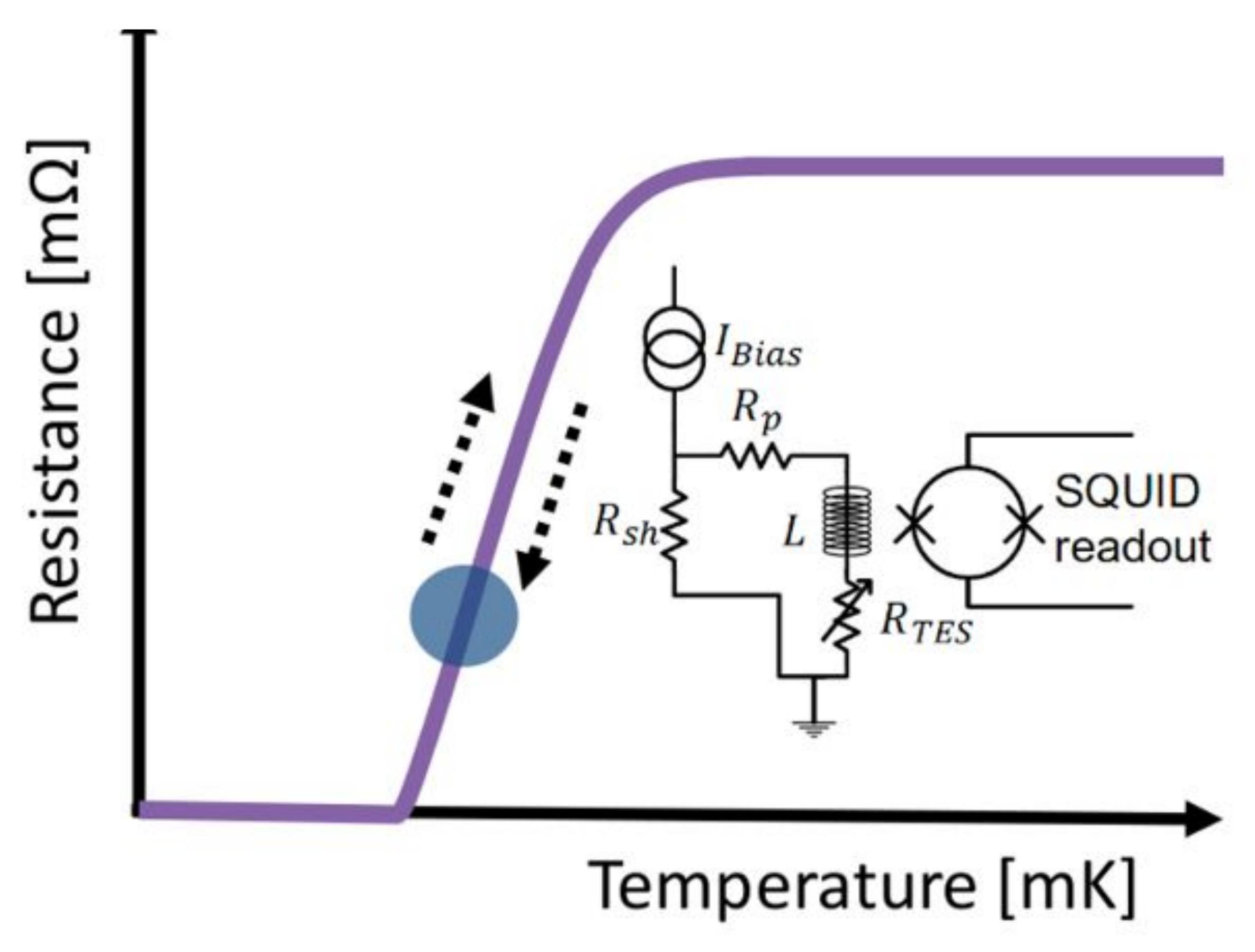
Key concept: use NTL effect to reduce energy threshold.

 NTL effect: drifting electron-hole pairs across potential produces phonons:



- Increased potential ⇒ increased total energy for the same recoil
- Phonons detected using TES at ~50% bias point
- 12 total channels across each HV detector

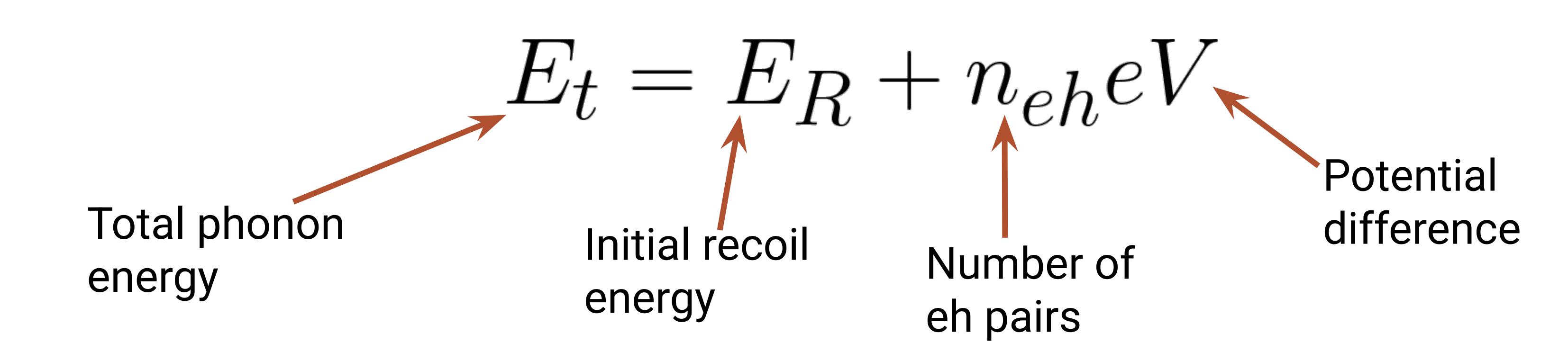




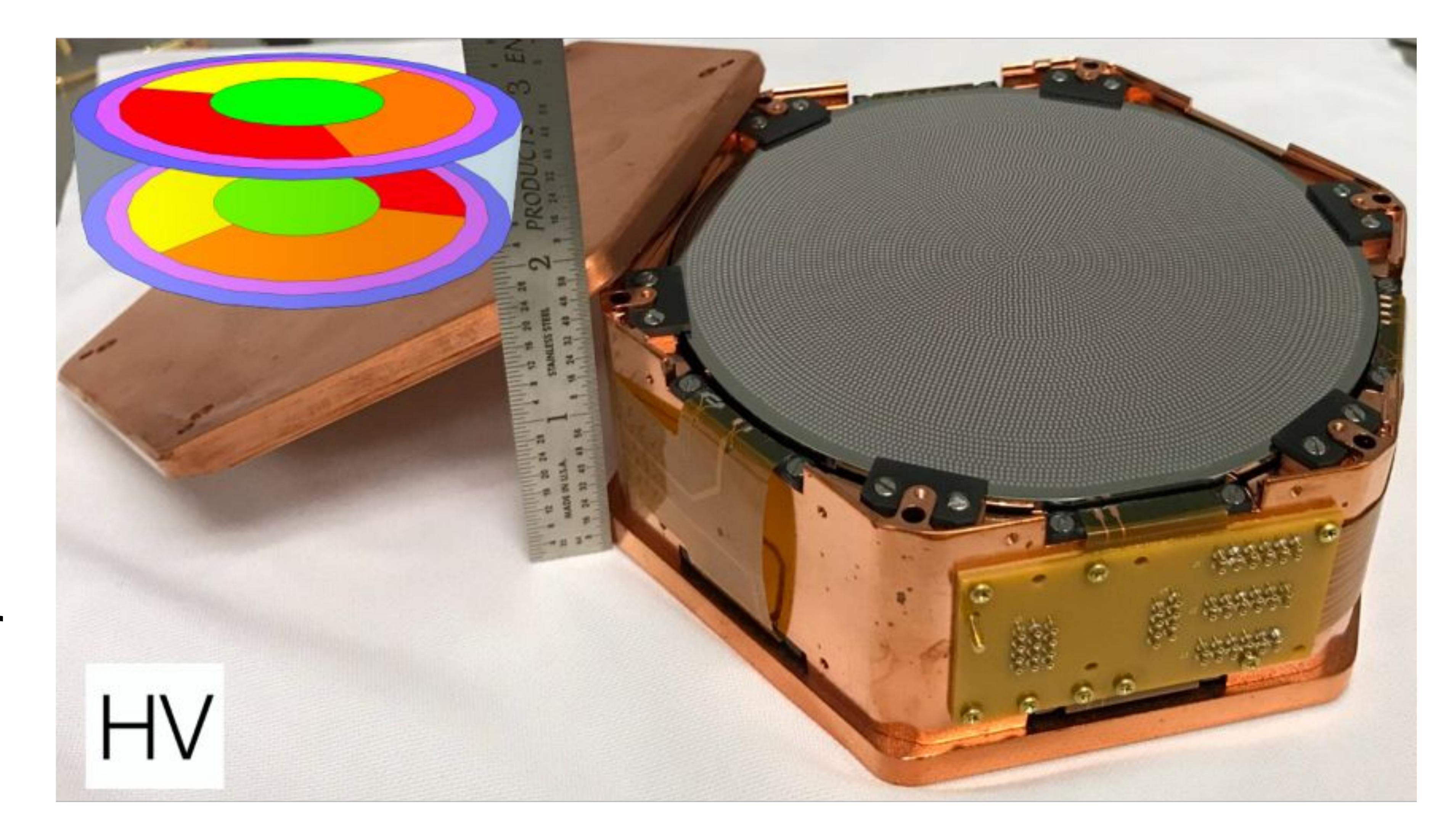
HV detectors

Key concept: use NTL effect to reduce energy threshold.

 NTL effect: drifting electron-hole pairs across potential produces phonons:



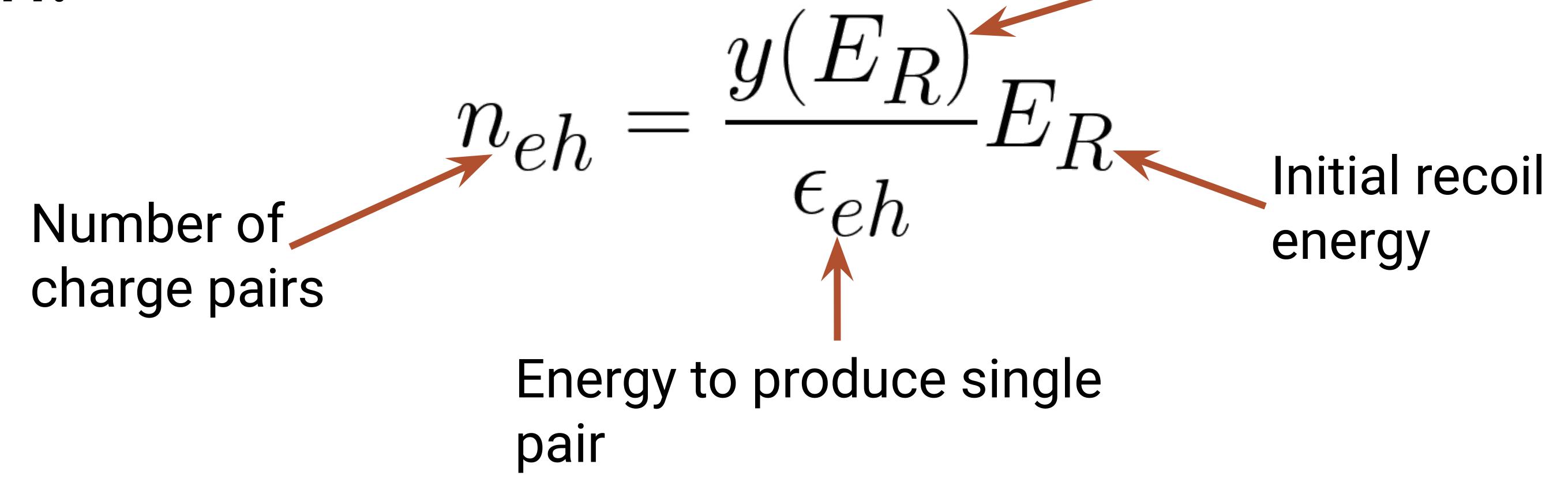
- Increased potential ⇒ increased total energy for the same recoil
- Phonons detected using TES at ~50% bias point
- 12 total channels across each HV detector



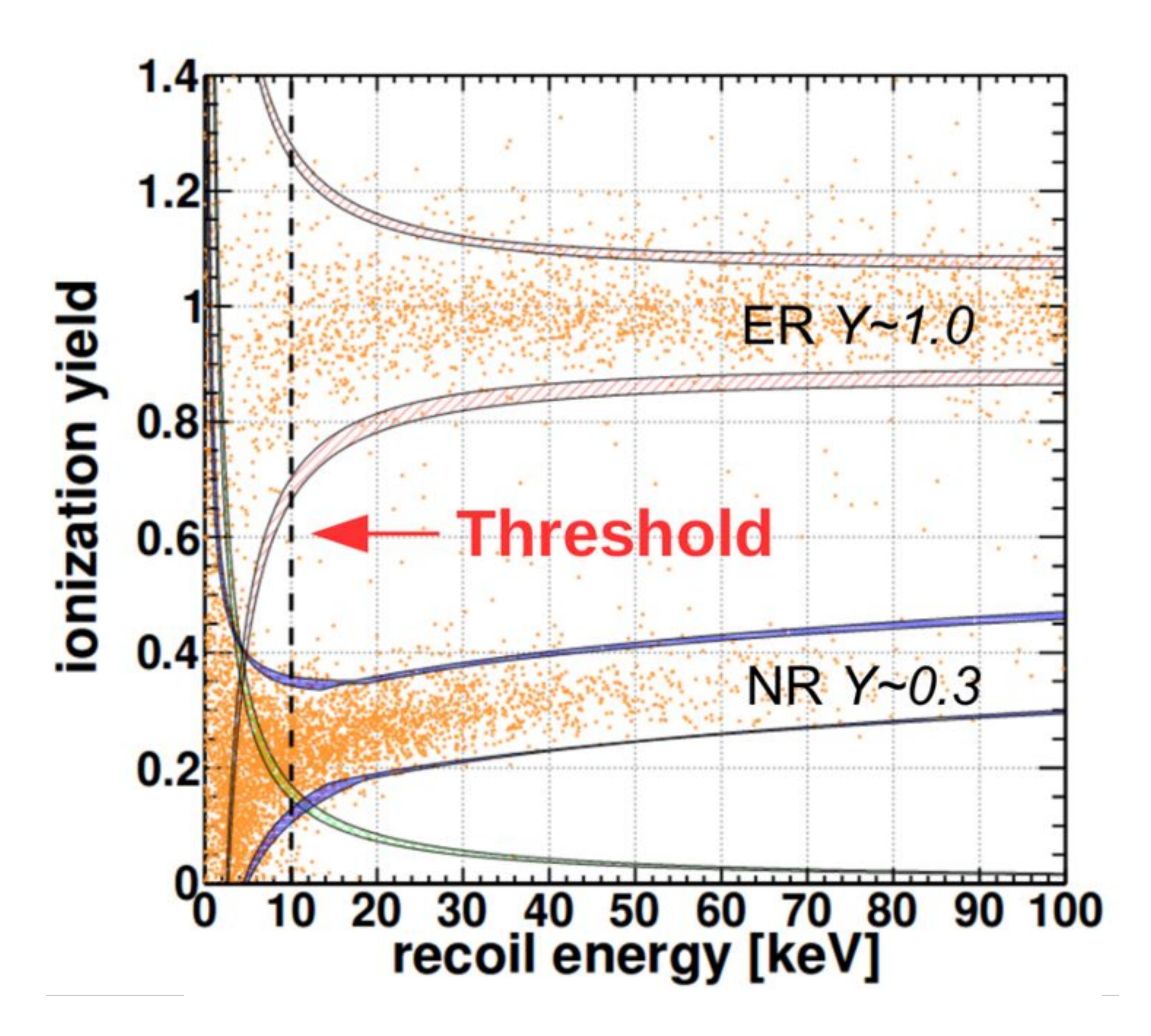
iZIP detectors

Key concept: use charge and phonon signals for electron (ER) and nuclear (NR) recoil discrimination.

• Amount of charge generated depends on <u>ionisation yield</u> of interaction:



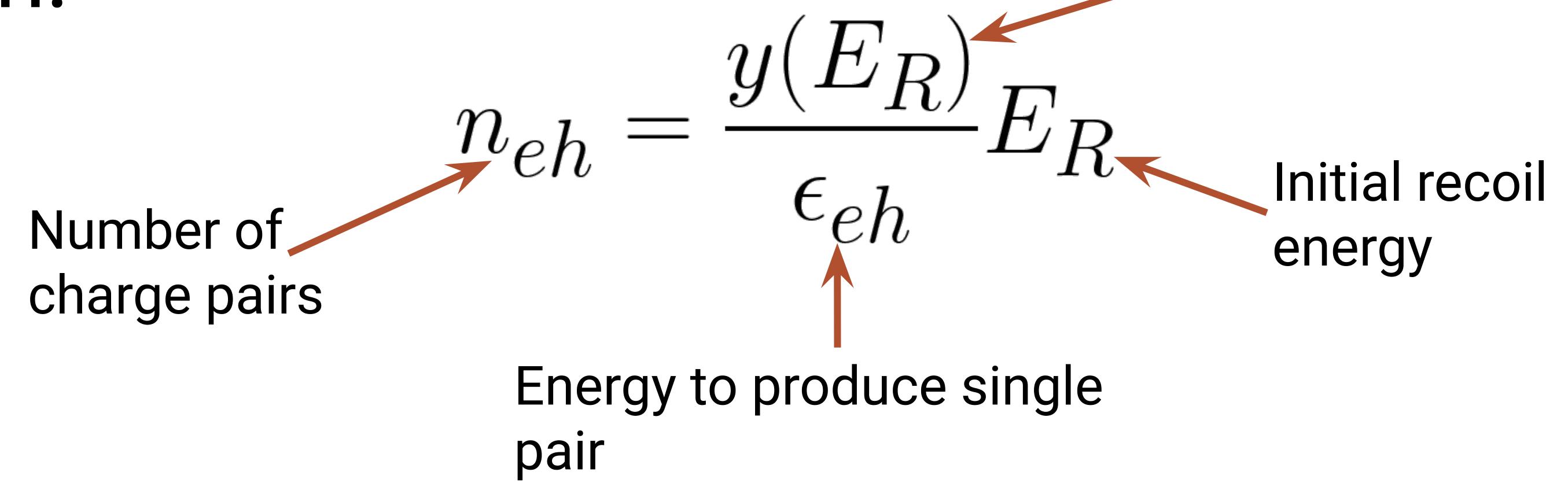
- Ionisation for ER is 1, for NR<1. Comparing the ratio of this to phonons gives discriminant metric
- Charge detected using electrodes on crystal as part of HEMTs (charge amplifier circuit)
- 4 charge channels, 12 phonon channels for each detector



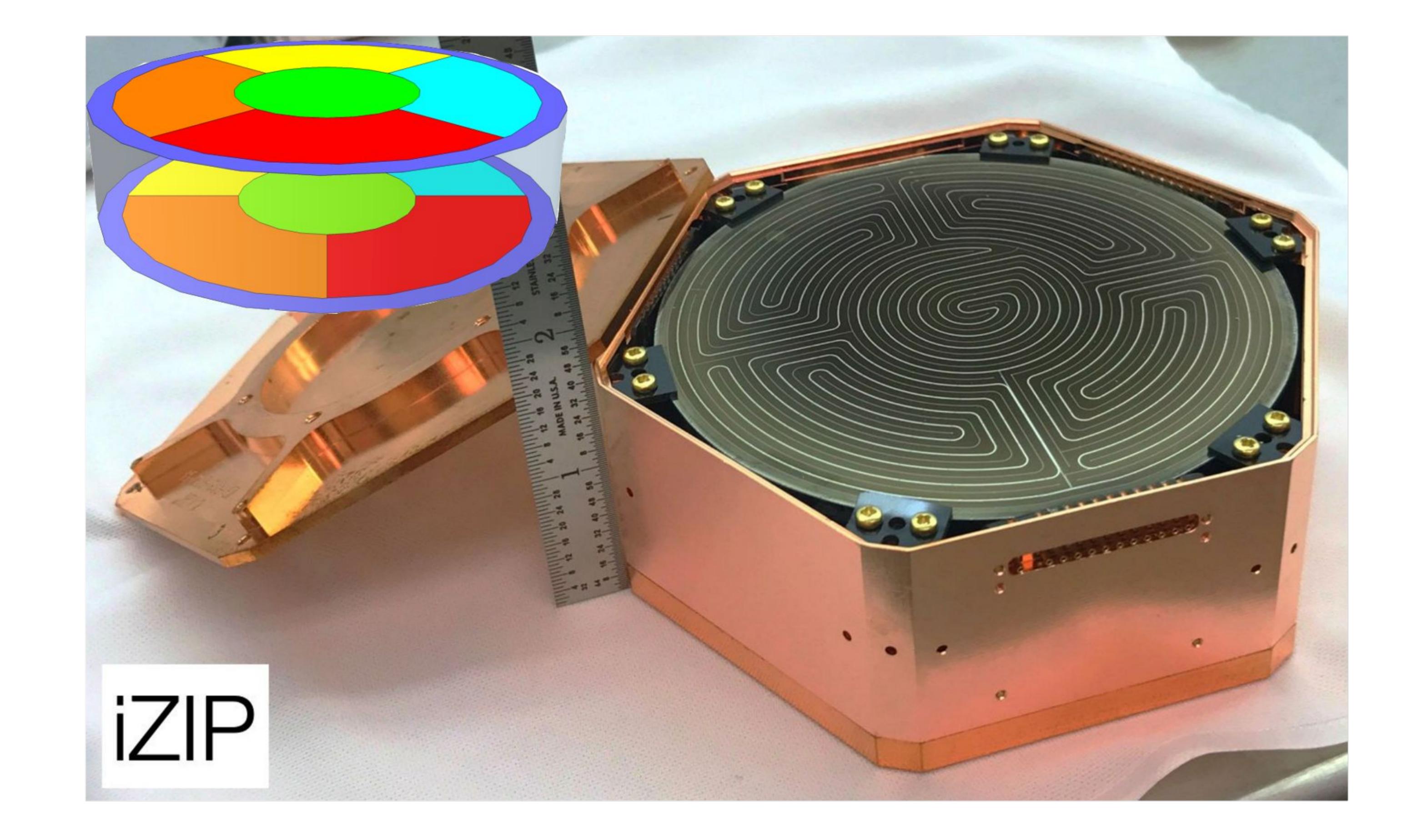
iZIP detectors

Key concept: use charge and phonon signals for ER/NR discrimination.

• Amount of charge generated depends on <u>ionisation yield</u> of interaction:



- Ionisation for ER is 1, for NR<1. Comparing the ratio of this to phonons gives discriminant metric
- Charge detected using electrodes on crystal as part of HEMTs (charge amplifier circuit)
- 4 charge channels, 12 phonon channels for each detector

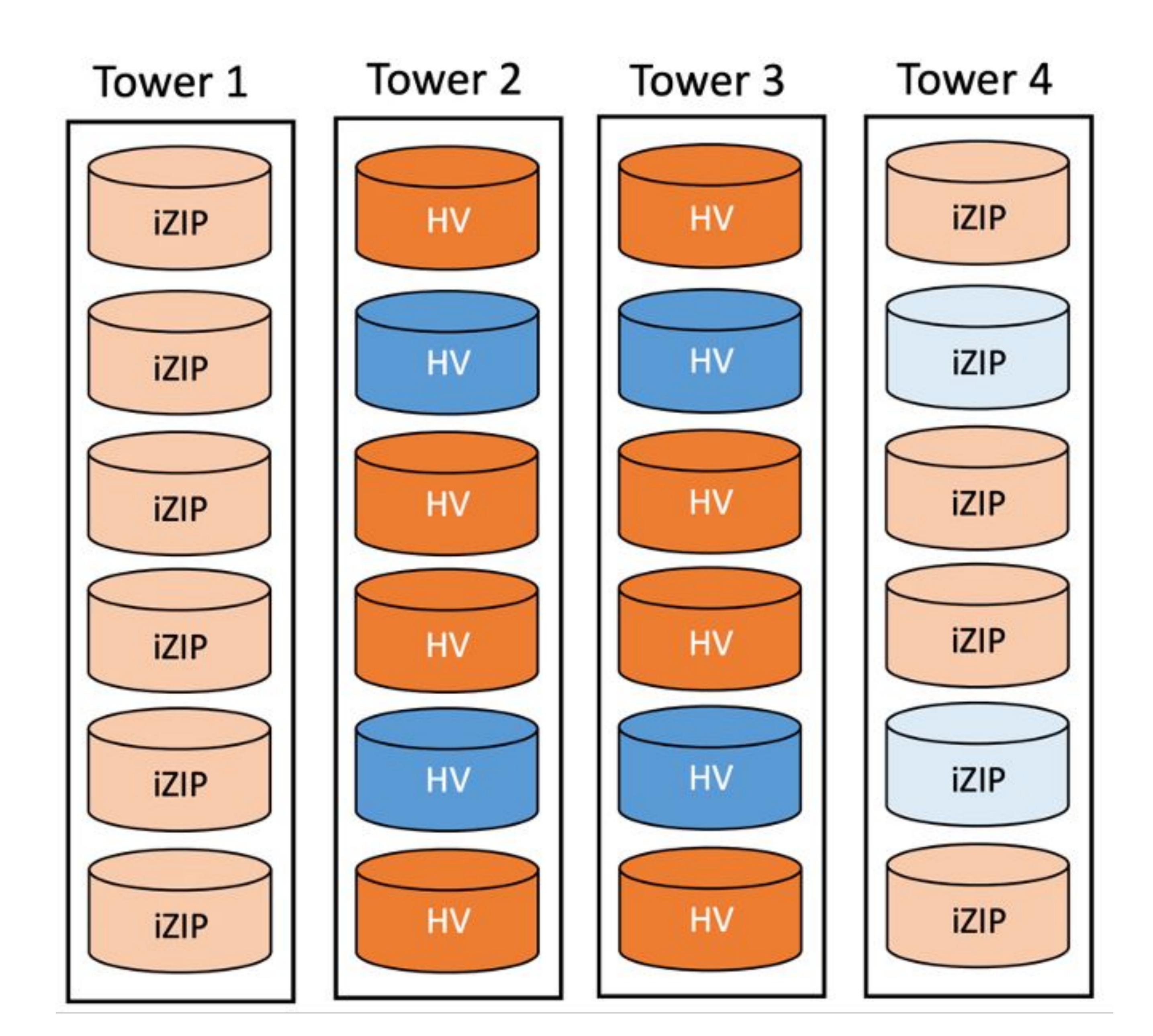


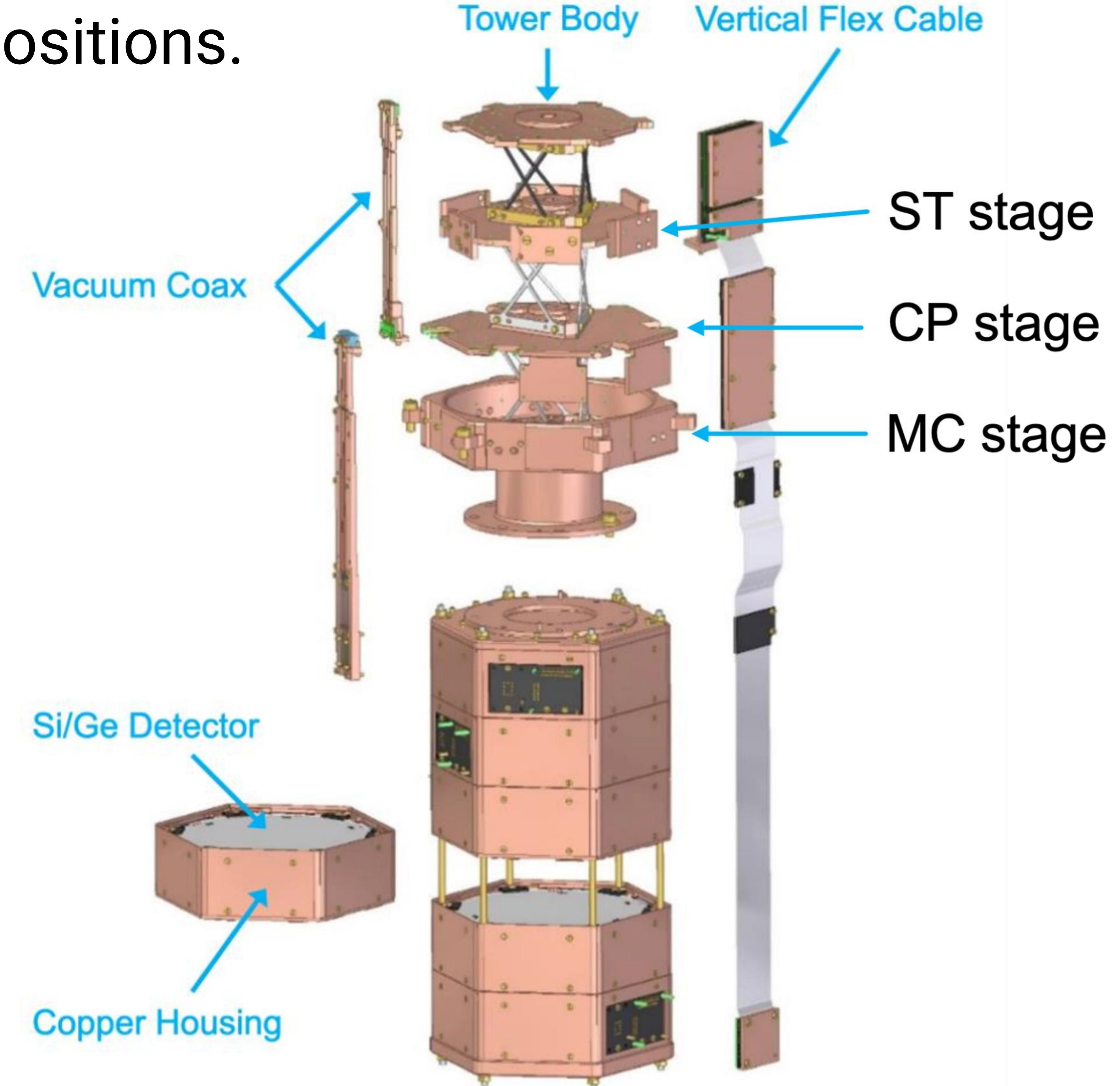
SuperCDMS

Detectors organised into 4 towers with layouts designed based

on detector type and shielding/veto for different positions.

Orange ⇒ Ge, blue ⇒ Si

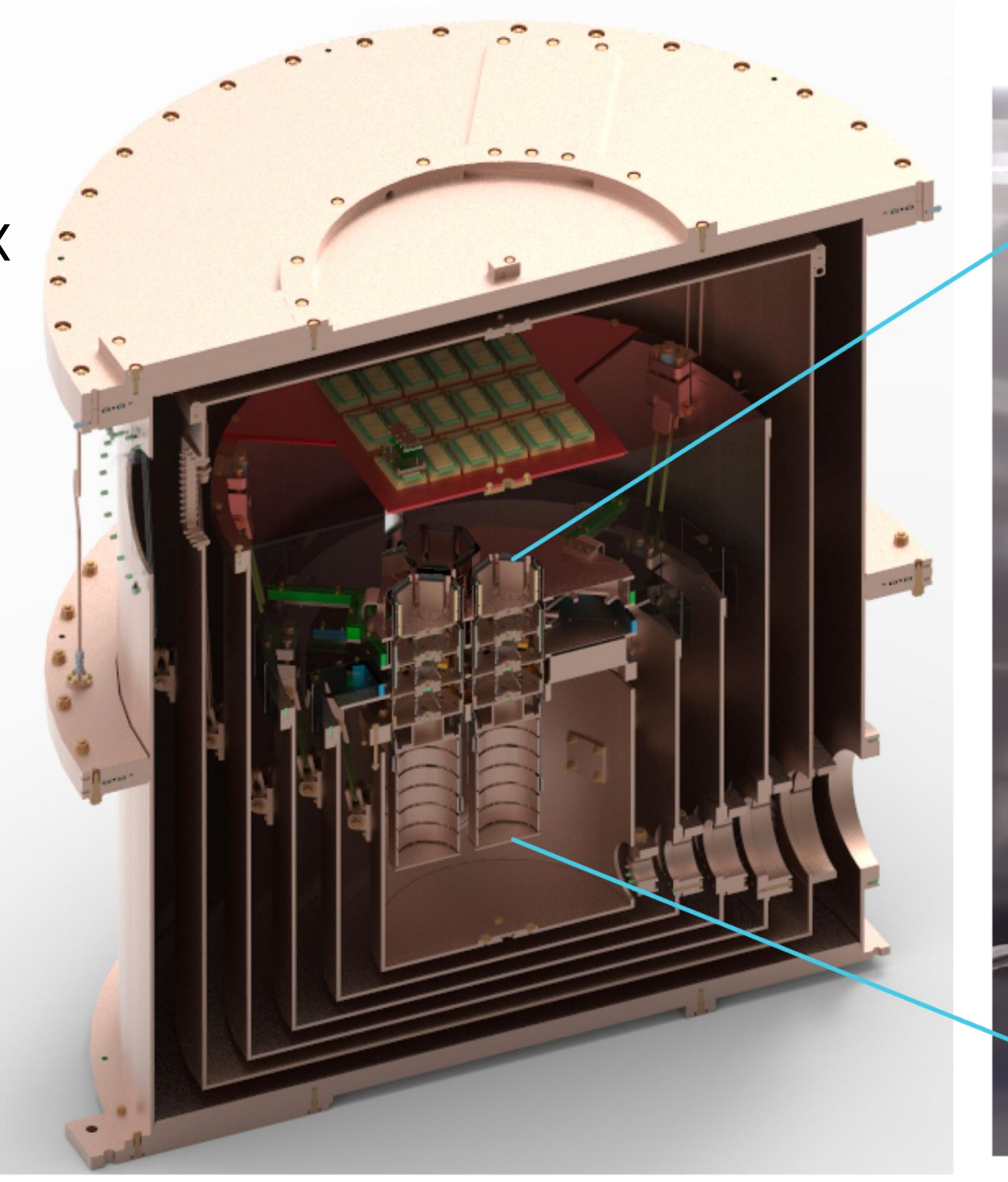




SuperCDMS

Towers placed in SNOBOX

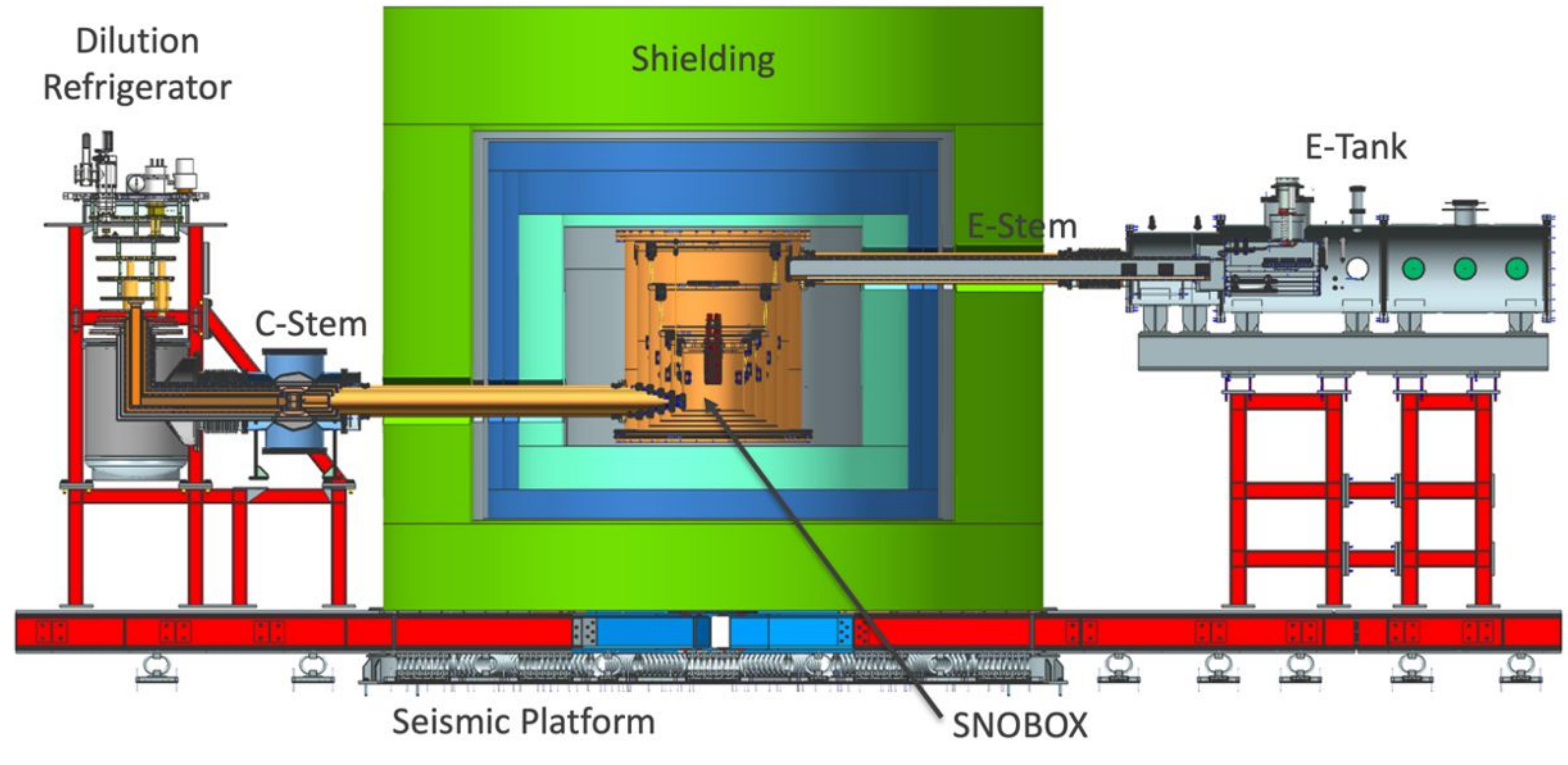
- 6 cans forming giant dilution fridge:
 - OVC Room temp
 - SH < 50 K
 - LH < 5 K
 - ST 1 K
 - CP <230 mK
 - MC <30 mK





Detectors assembled in 4 towers, thermally coupled to each of the fridge stages

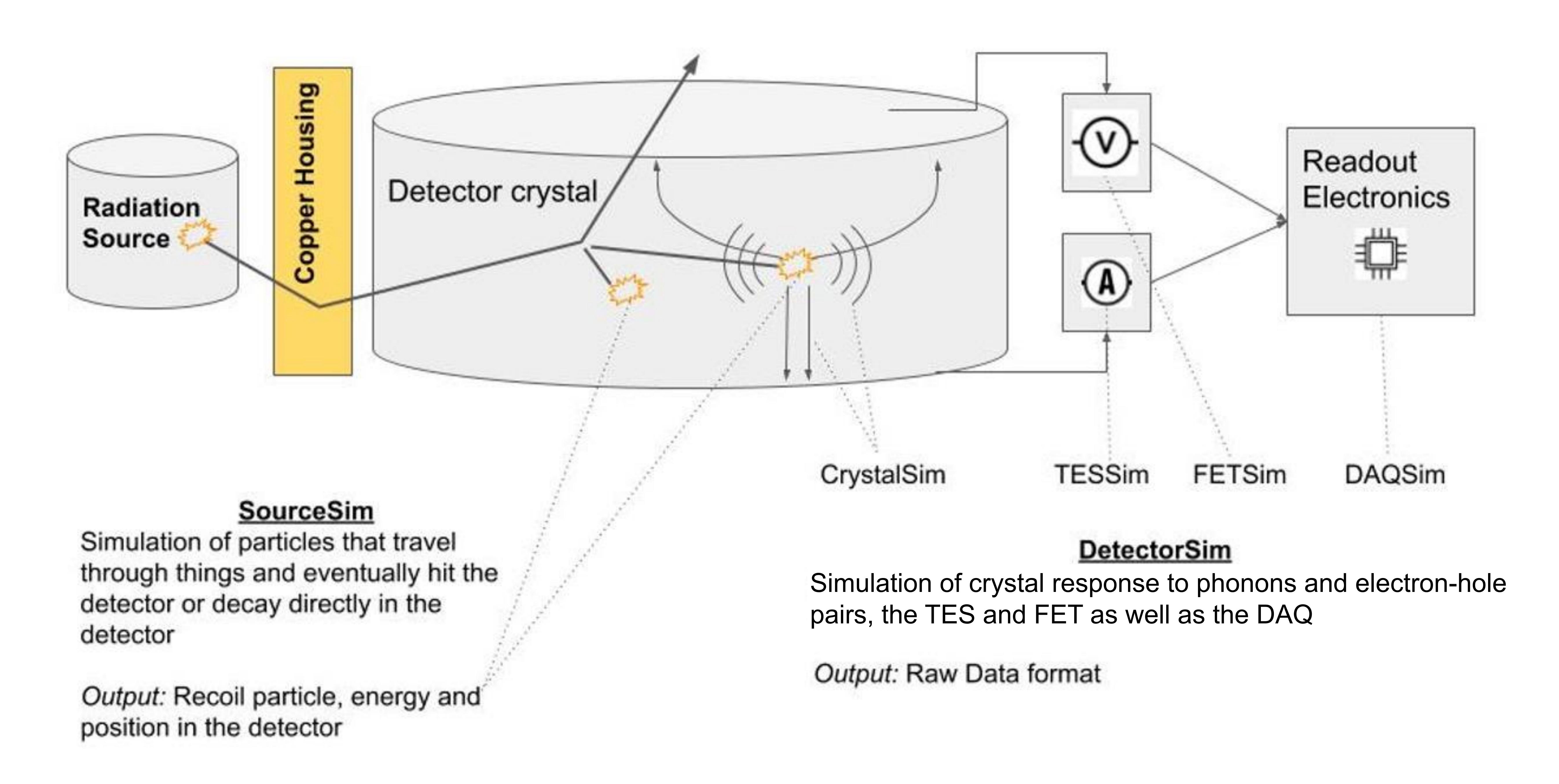
SuperCDMS



Located 2 km underground at SNOLAB

Simulation Program

GEANT4 based framework (G4CMP) that captures detector geometry and response, allowing matching to data and prototyping of analysis



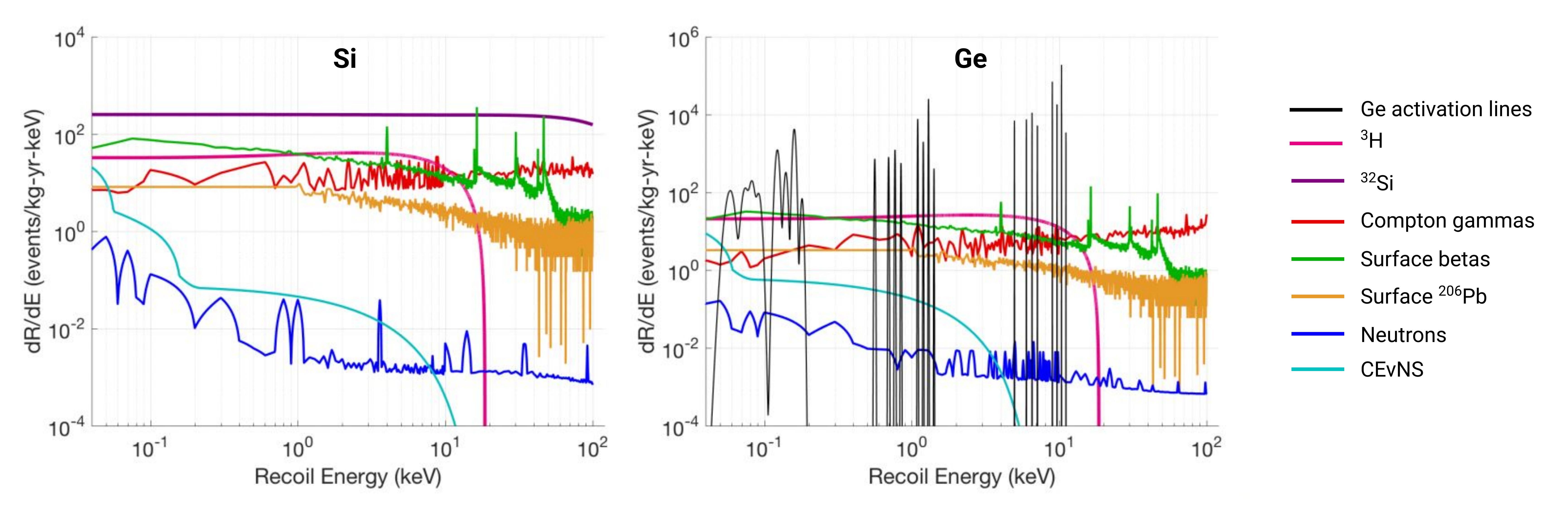
Background studies

Detailed bookkeeping done using eTraveller and BGExplorer:

βαck Yroμnd EXplorer

- 329 components catalogued
- 32 sources considered
- Tracking of location for cosmogenic and radon exposure

Challenge now is to turn this information into a background model suitable for analysis

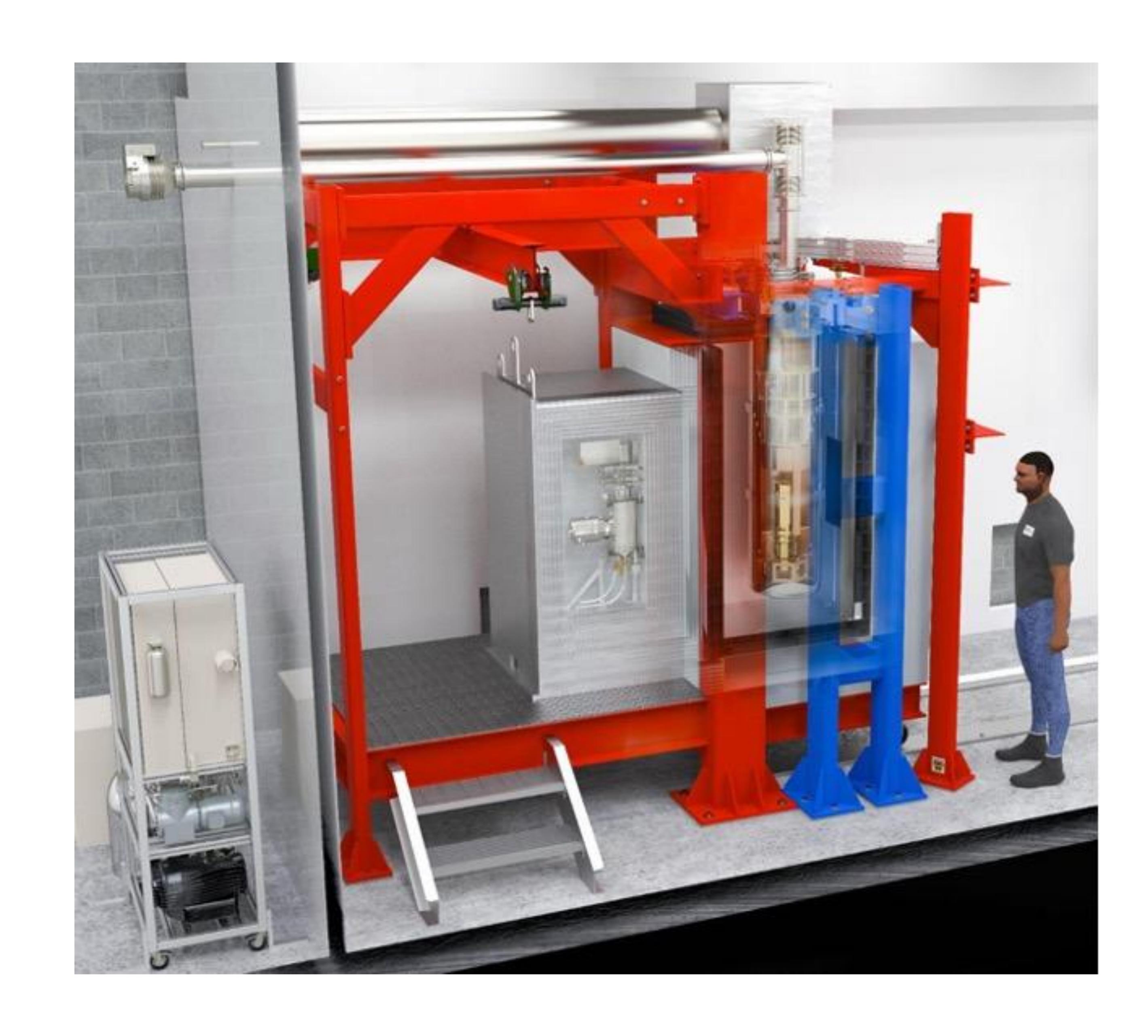


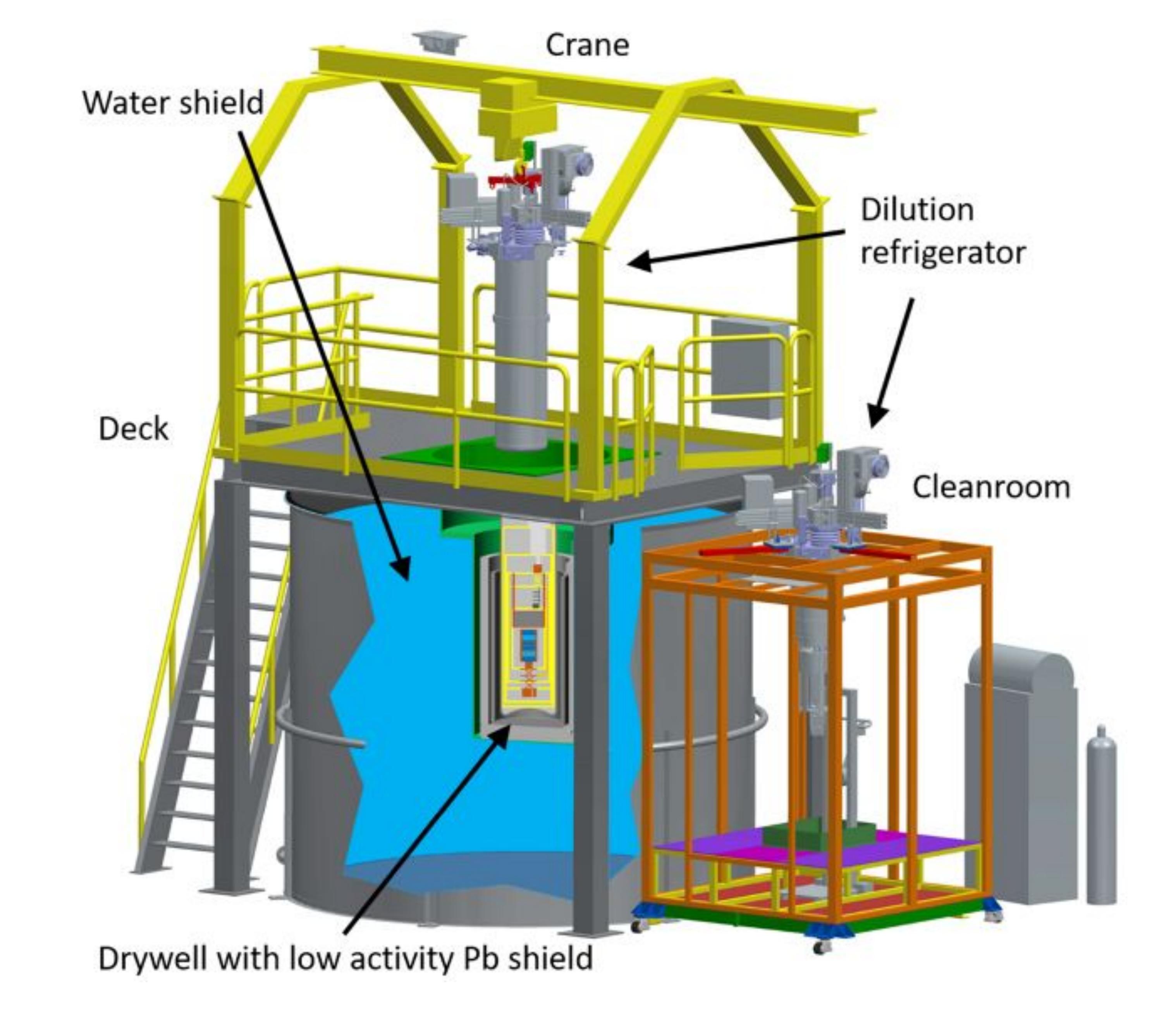
Test Facilities





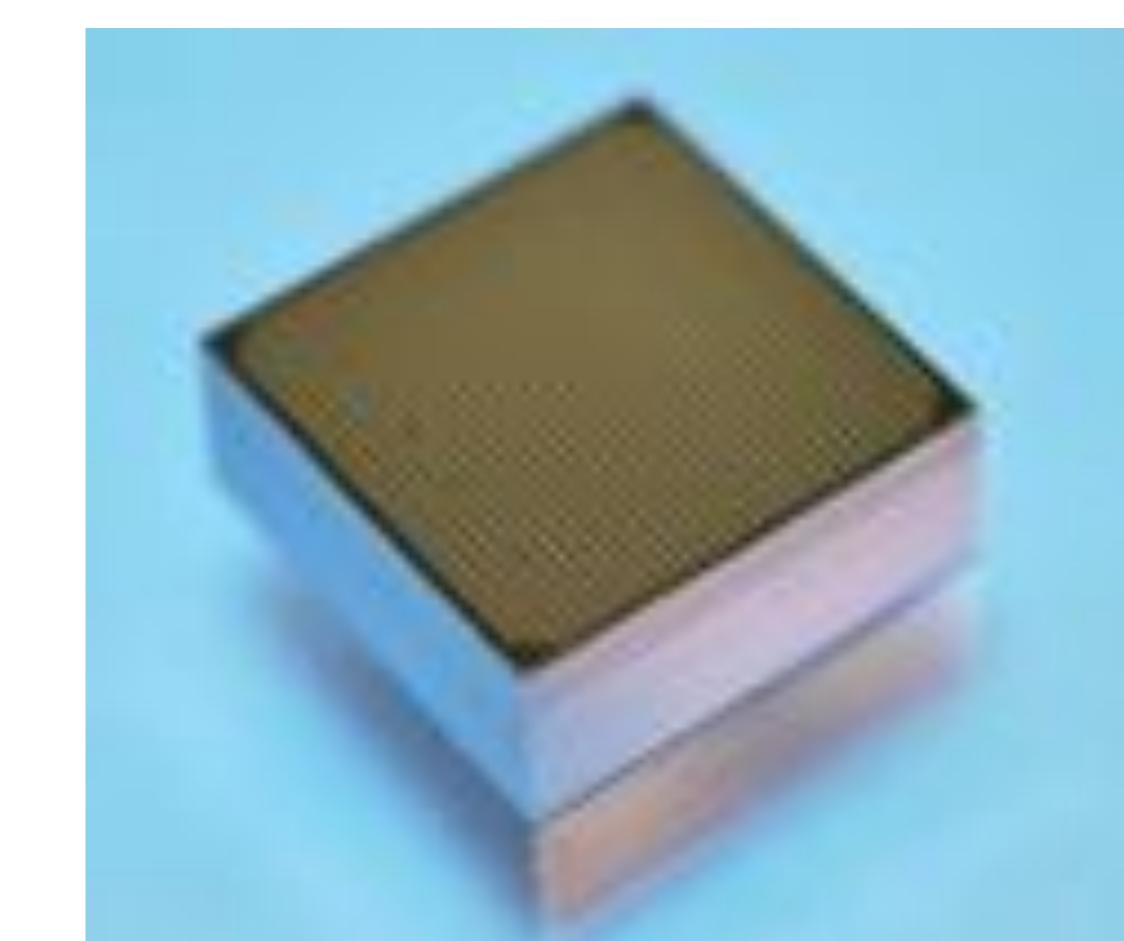
~100 m underground at Fermilab
Used for HVeV studies
~2 km underground at SNOLAB
Used for HVeV studies, pathfinders, detector characterisation





HVeV @ NEXUS

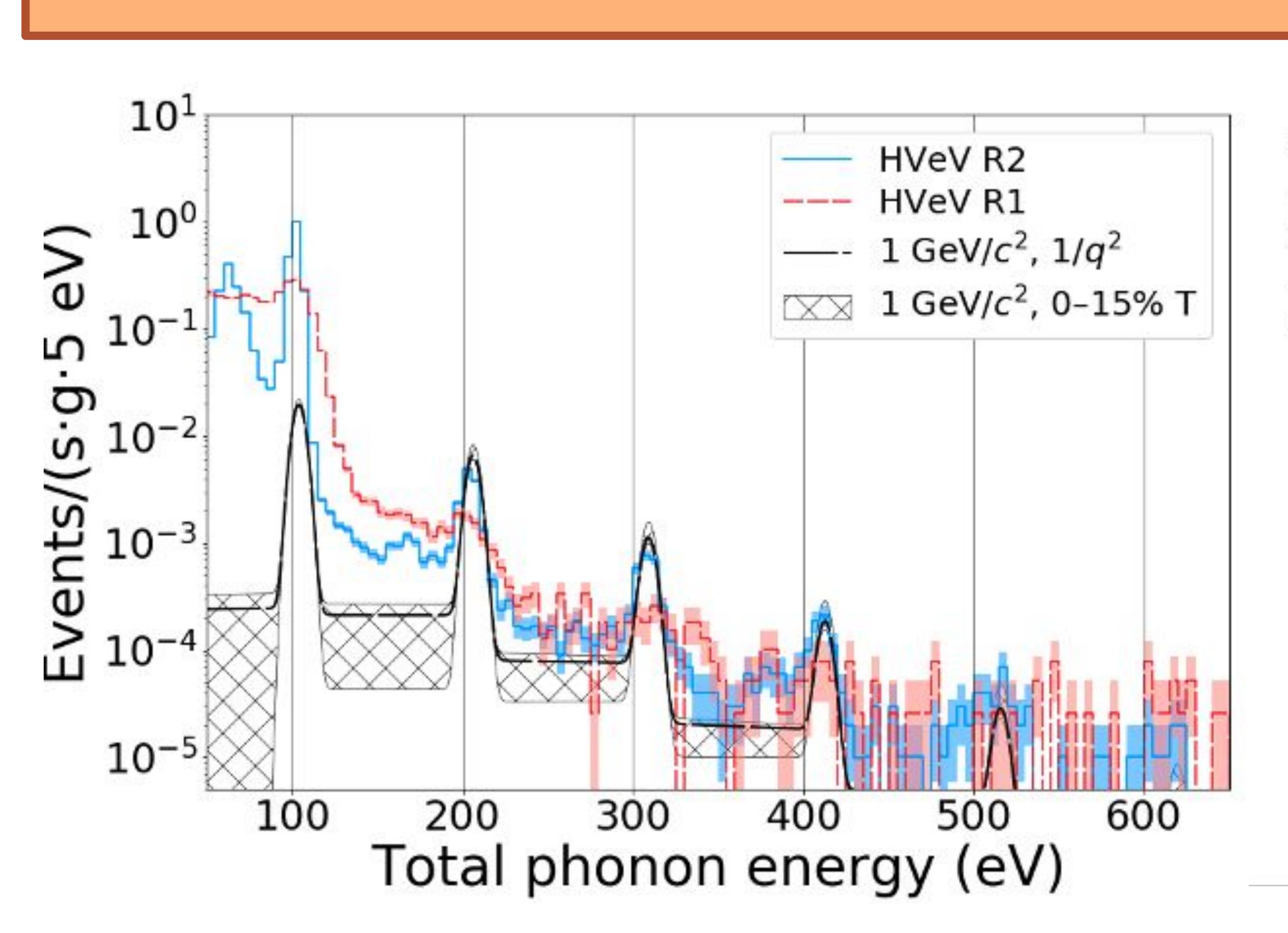
- Gram scale versions of SuperCDMS HV with eV resolution
- Opportunity to test sensor limits, calibration processes, resolution and more
- Clear improvement demonstrated over iterations, especially at low energy
- Currently taking data in CUTE

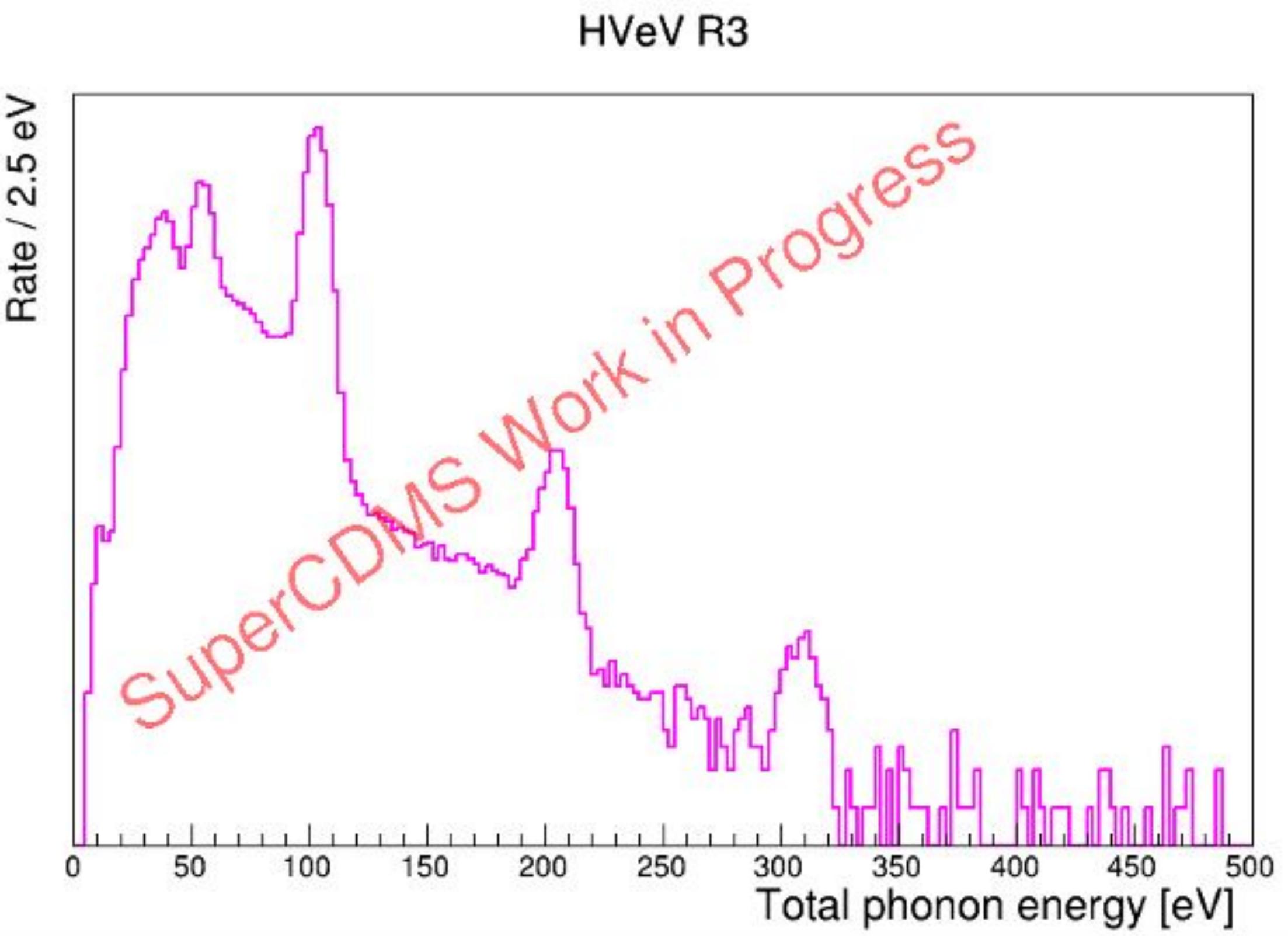


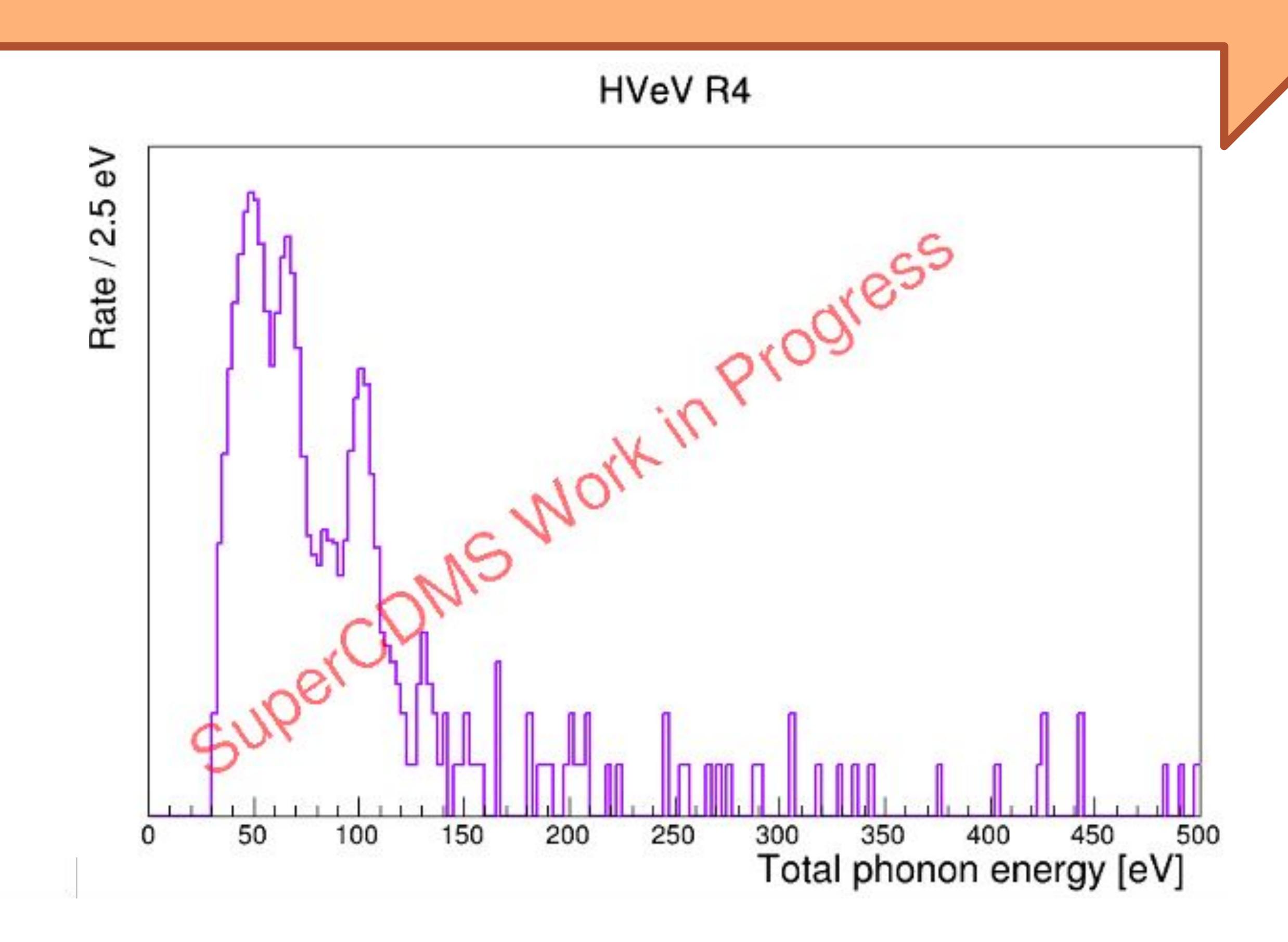
Runs 1&2: backgrounds from external

Run 3: employed coincident detectors

Run 4: found and eliminated source







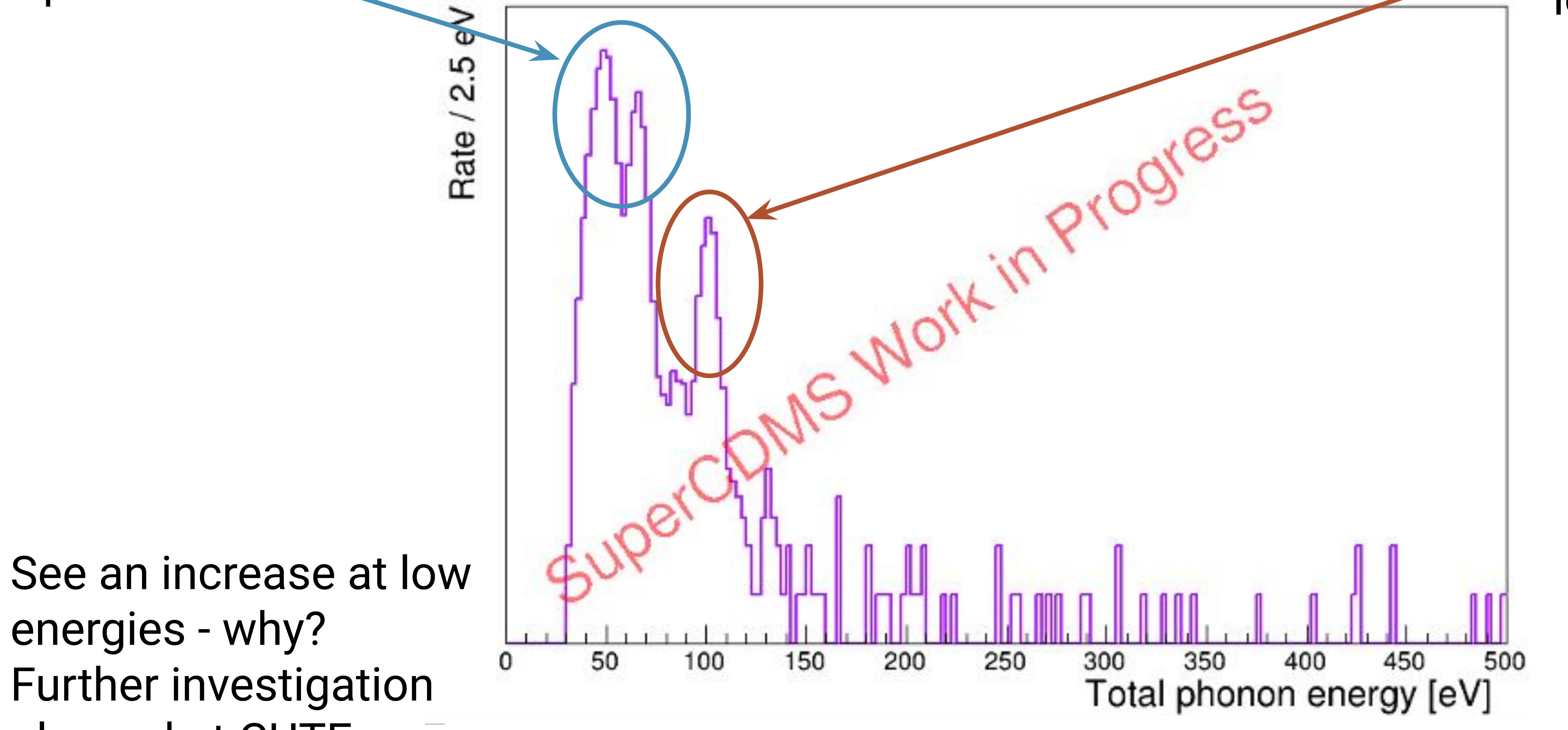
16

HVeV open questions

Why are there sub 1 eh peaks?

Detector imperfections to be

improved?



HVeV R4

Pronounced 1 eh peak -- do we have light leakage?

How can we calibrate detectors?

Further investigation

energies - why?

planned at CUTE

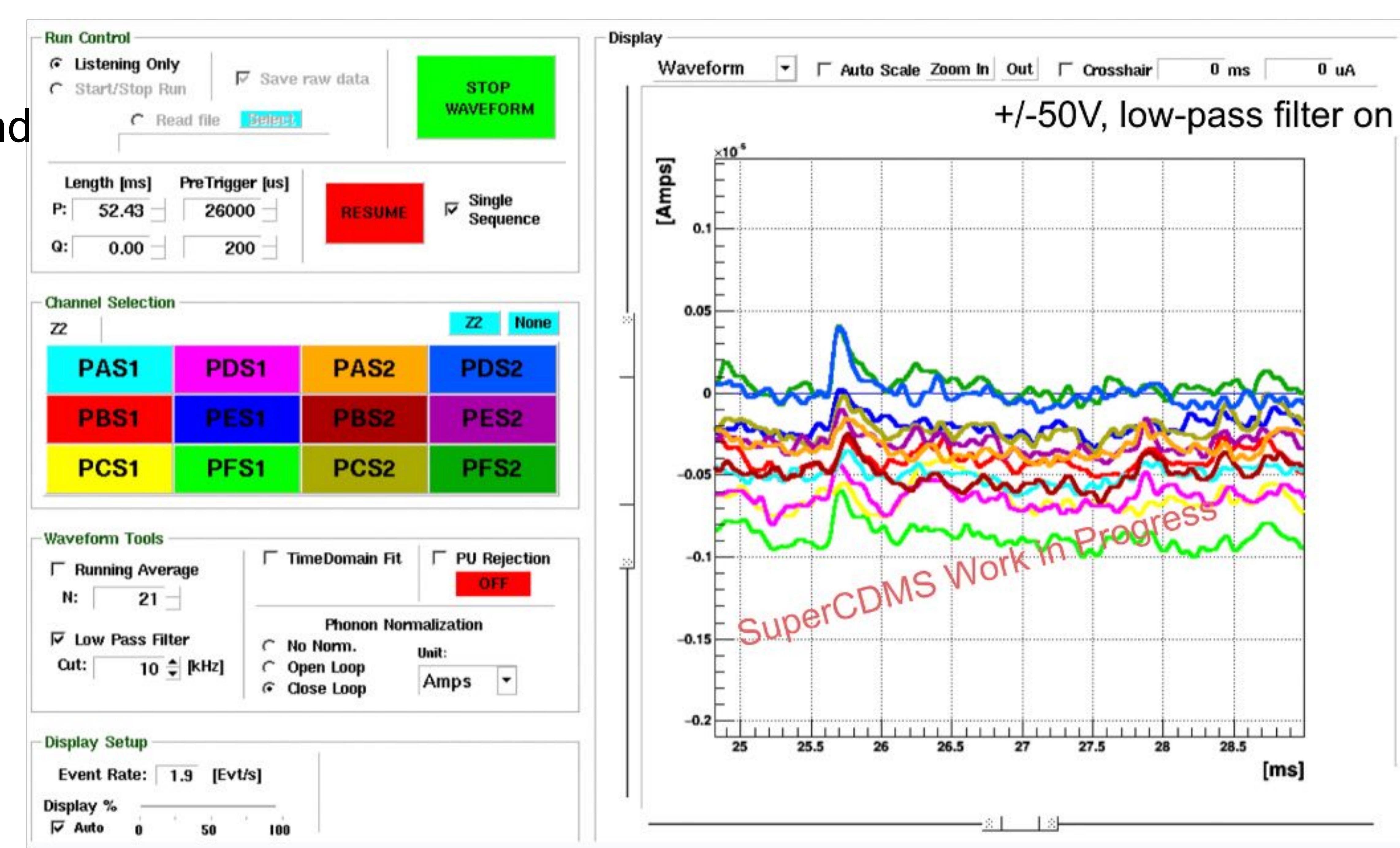
CUTE Tower Testing

Tower 3 installed in CUTE in Nov 2023:

- First time detectors operated underground
- First chance to calibrate detectors
- First HV application
- Development of operating procedures
- Training of new operators

Highlights:

- 151 day run (4 thermal cycles)
- 400 detector days of data
- 2 months of calibration data
- 2 weeks of low background data

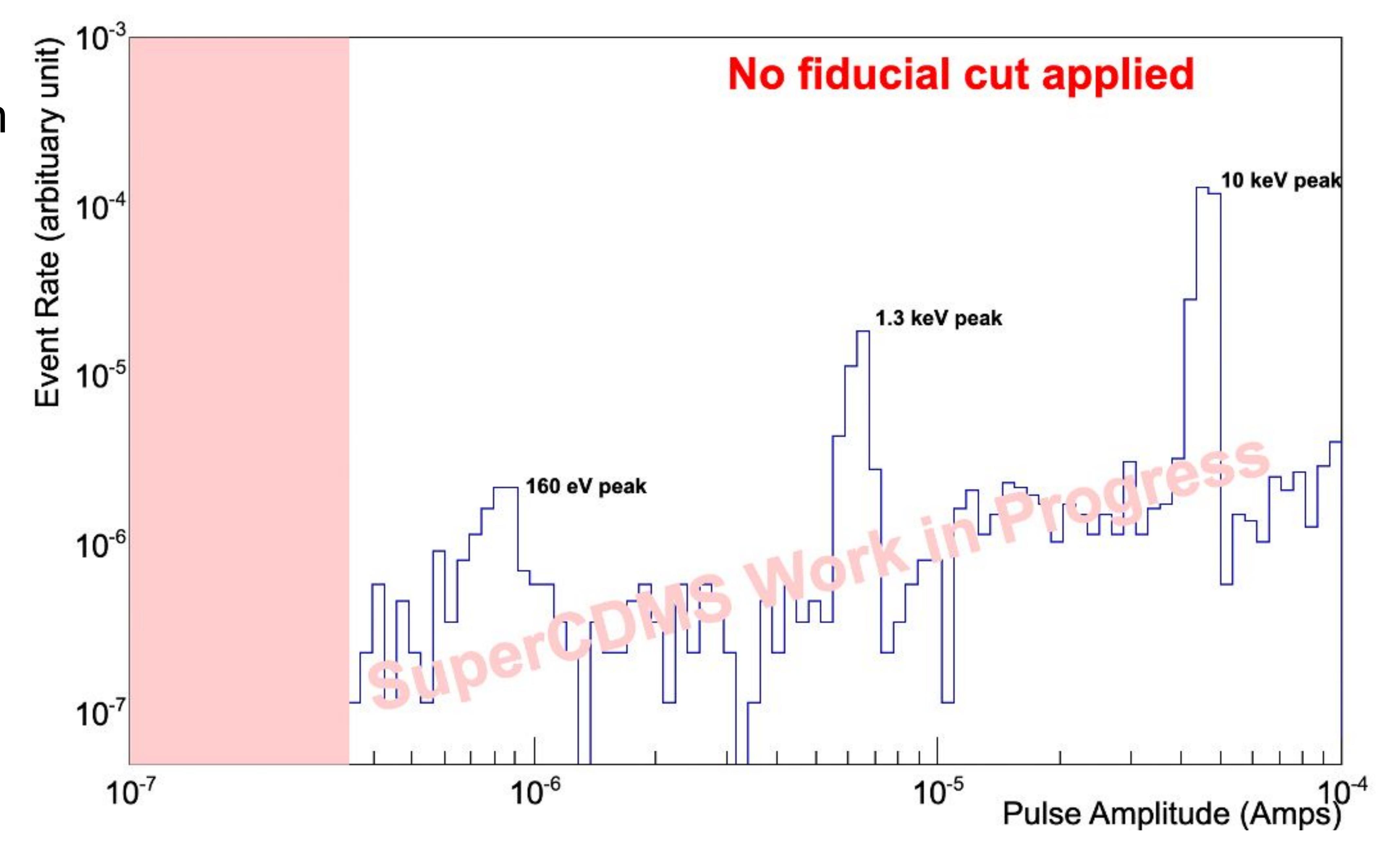


CUTE Tower Testing: Ge calibration

Low energy calibration of Ge can be done with activation peaks

- Irradiating Ge with neutrons produces ⁷¹Ge
- Undergoes electron capture producing lines at:
 - o 160 eV
 - o 1.3 keV
 - o 10 keV
- ~90 hrs of data taken in Dec 2023

Ge activation peaks in Tower 3 Detector 3 +/-25V (preliminary data quality cuts)

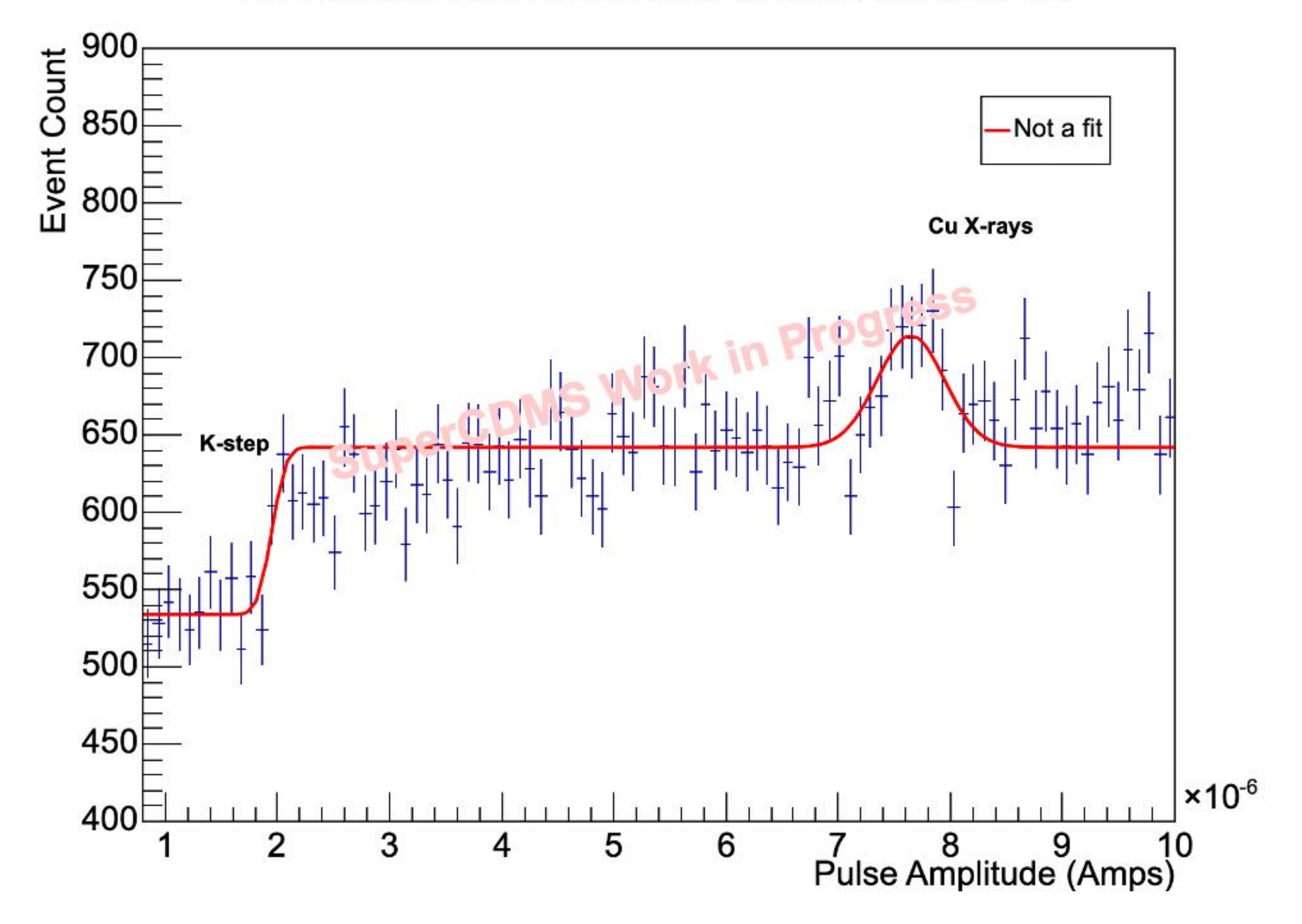


CUTE Tower Testing: Si calibration

Low energy calibration of silicon is difficult. One proposal: Compton steps

- Scattering below binding energy of electrons decreases interaction rate
- Expect to see step features at these values:
 - o 1.84 keV (K step)
 - o150 eV(L₁ step)
 - o 100 eV (L, step)
- ◆ ~90 hrs of ¹³³Ba data taken to test viability

Ba calibration for Tower 3 Detector 2 at 0V (preliminary data quality cuts)



Coming up...



Installation

- All detectors are currently underground
- Fridge installed and tested
- SNOBOX components being shipped over and cleaned
- Shield wall partially constructed
- E tank prepped for install
- Low radon cleanroom shown to be working



Software

- Simulation geometry updated for 'as built' experiment
- Continued development of G4CMP and detector response
- Analysis pipeline and processing taking learnings from CUTE tower run



Analysis

- Background modelling underway for PLR sensitivity
- Ongoing analysis of CUTE calibration and science data
- HVeV studies ongoing to understand calibration and low energy excess
- ERDM and NRDM modelling tools under development

Coming up...

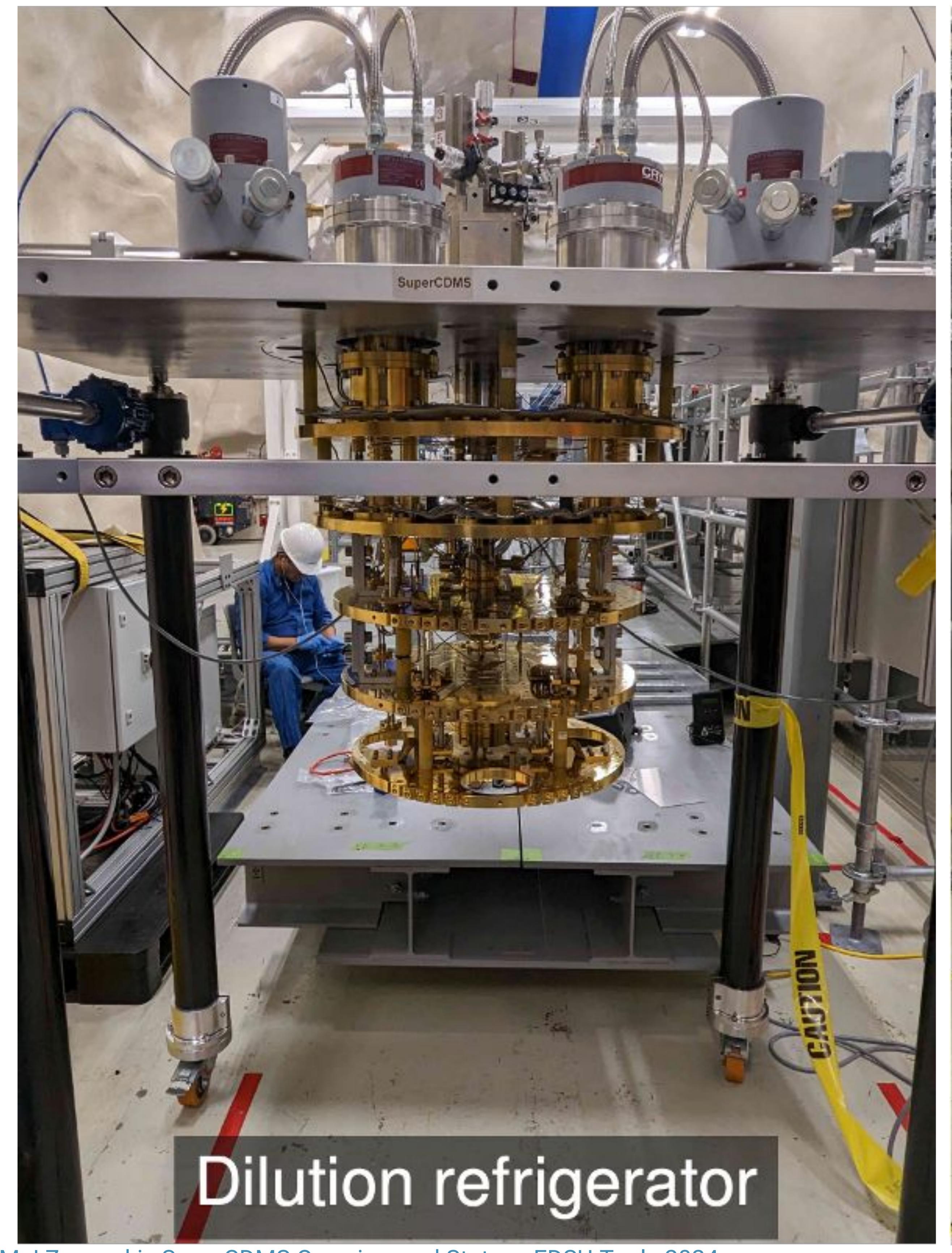


Installation

- All detectors are currently underground
- Fridge installed and tested
- SNOBOX components being shipped over and cleaned
- Shield wall partially constructed
- E tank prepped for install
- Low radon cleanroom shown to be working

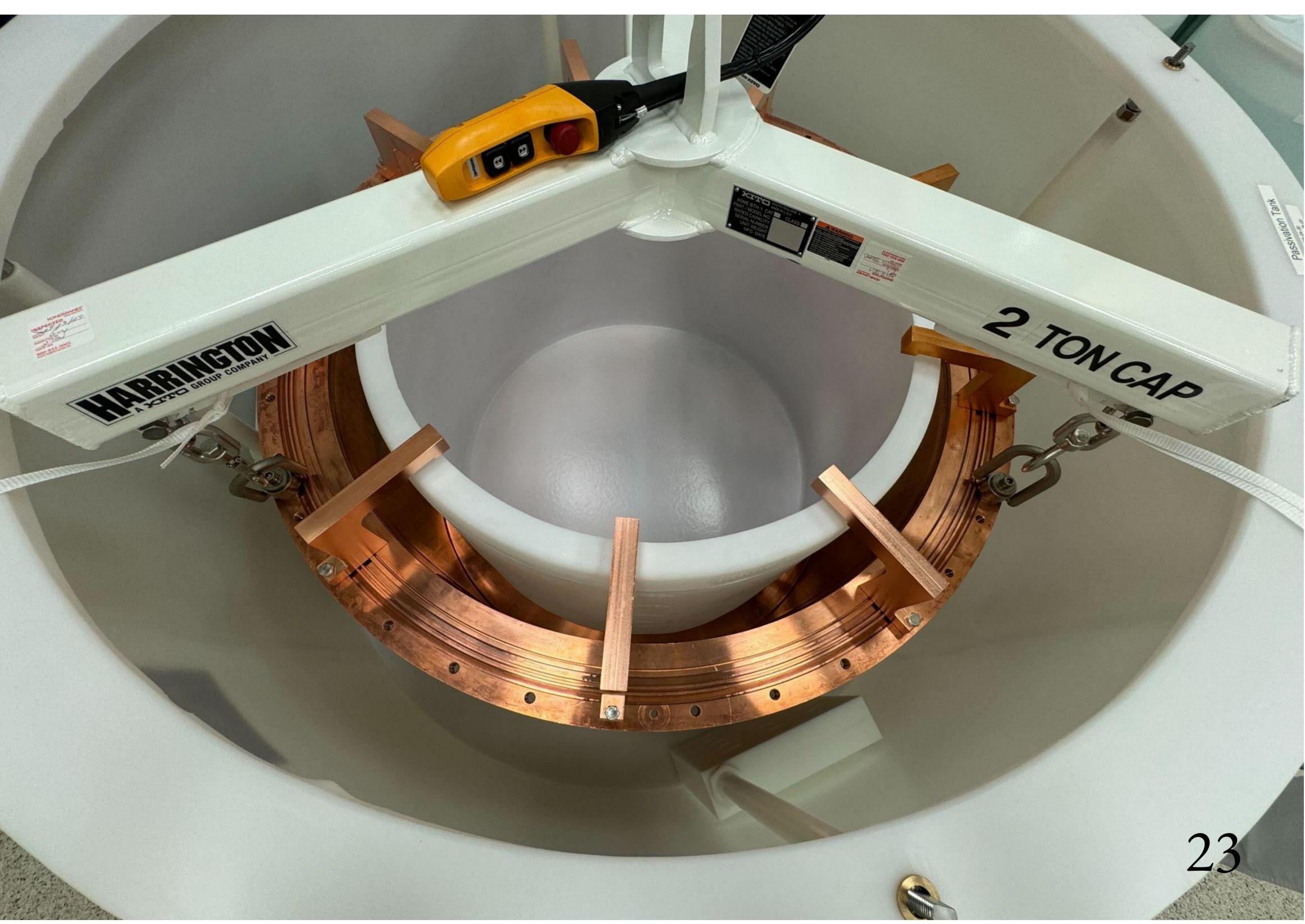


Installation activities



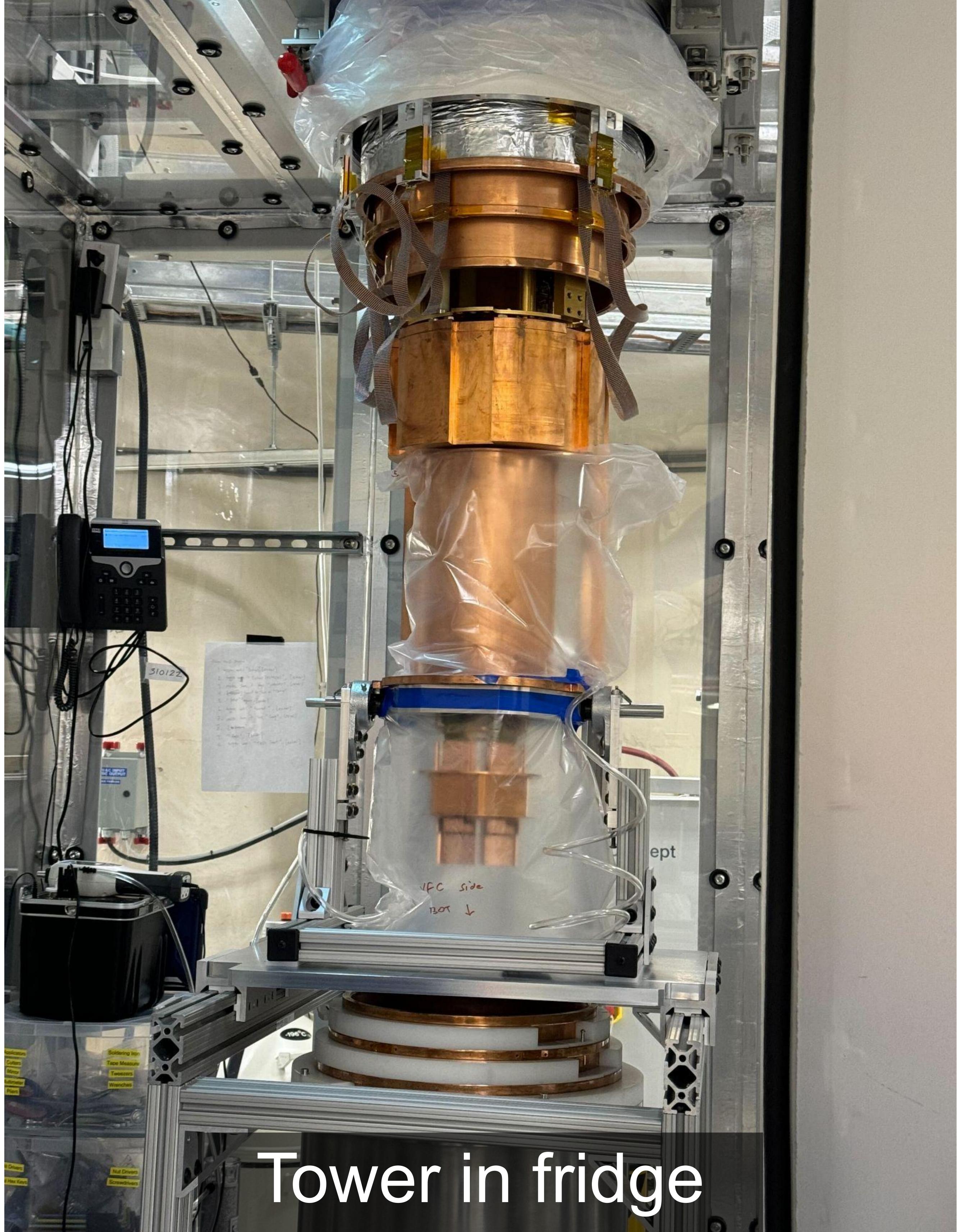


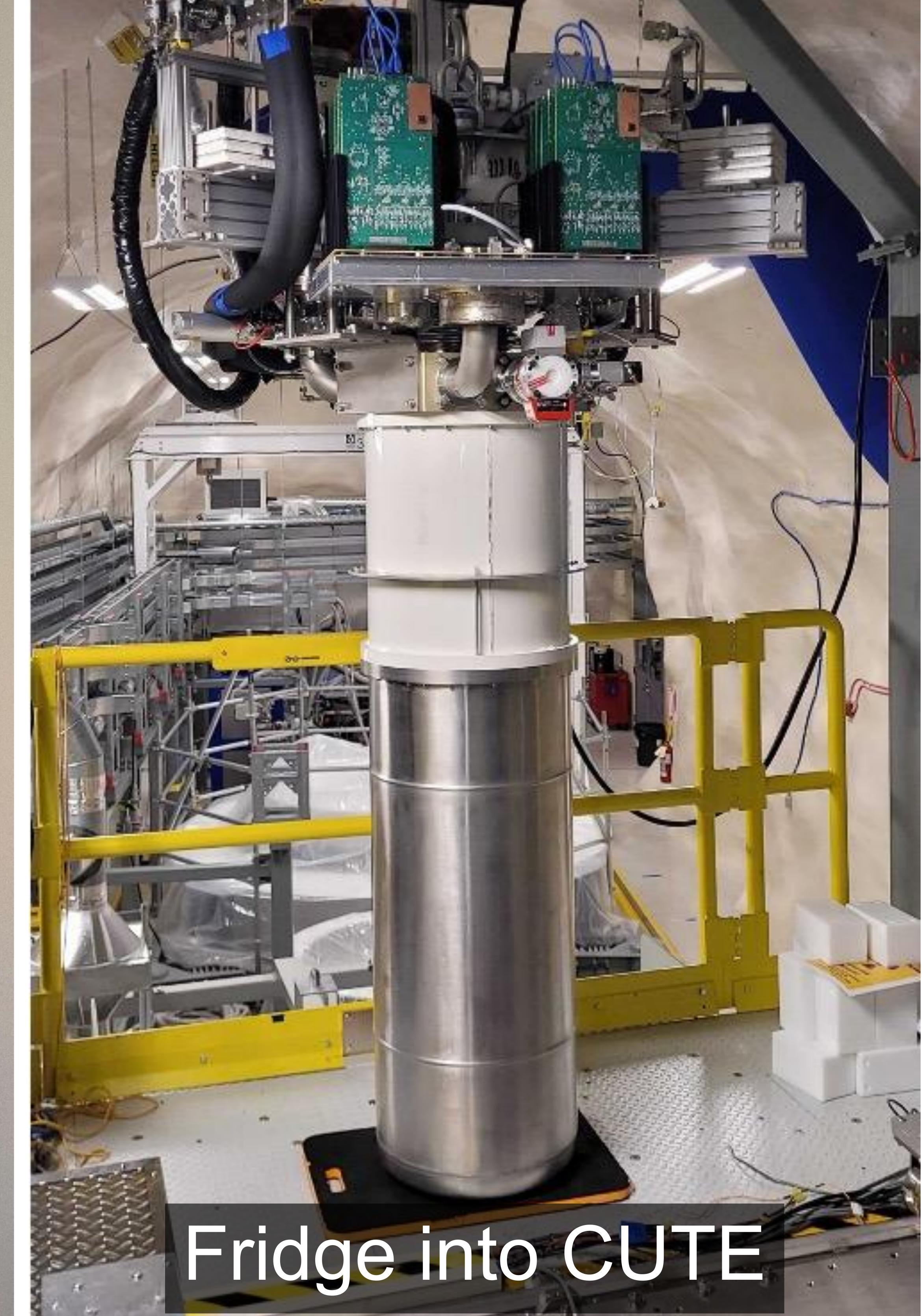




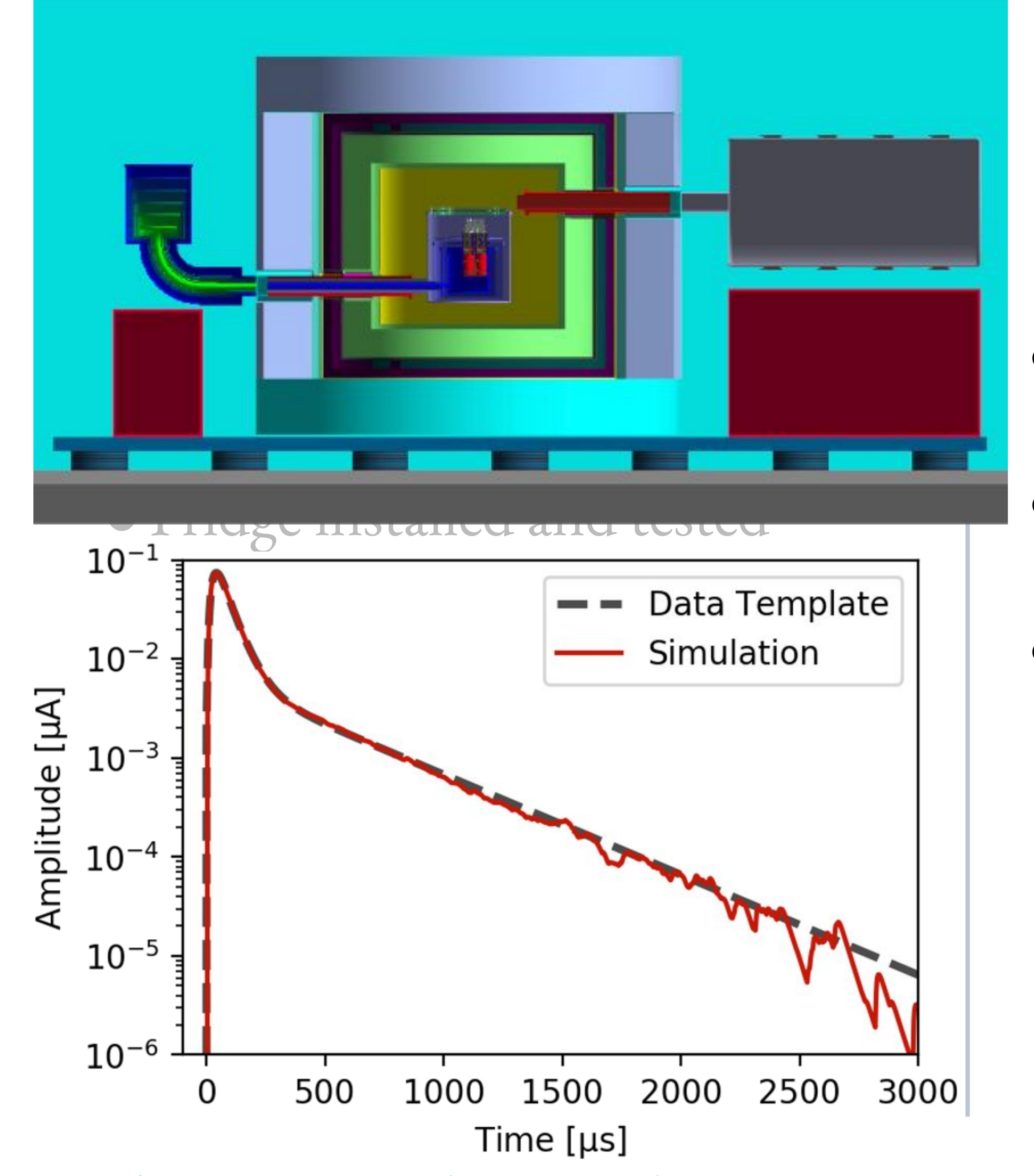
Installation activities







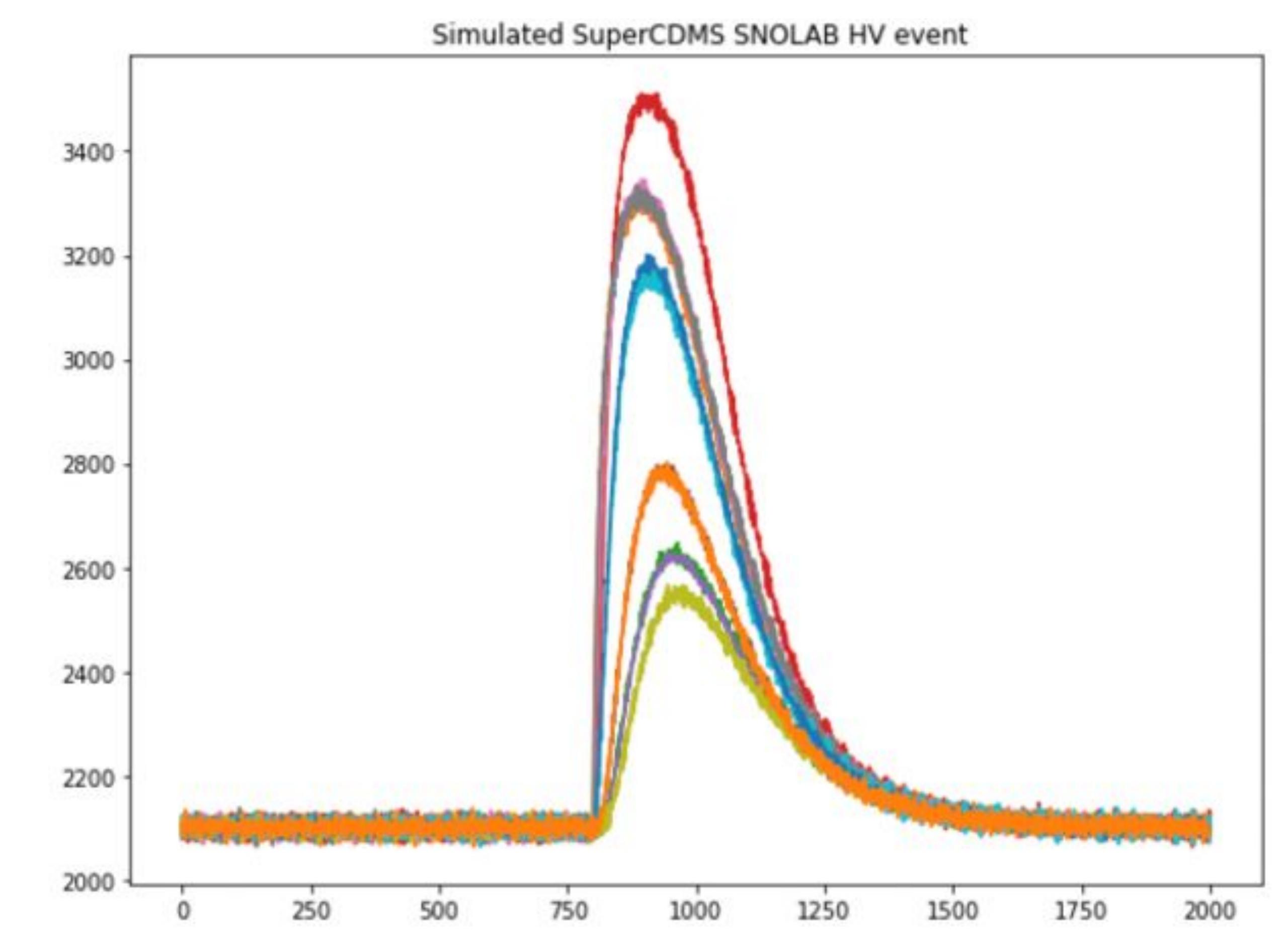
Coming up...

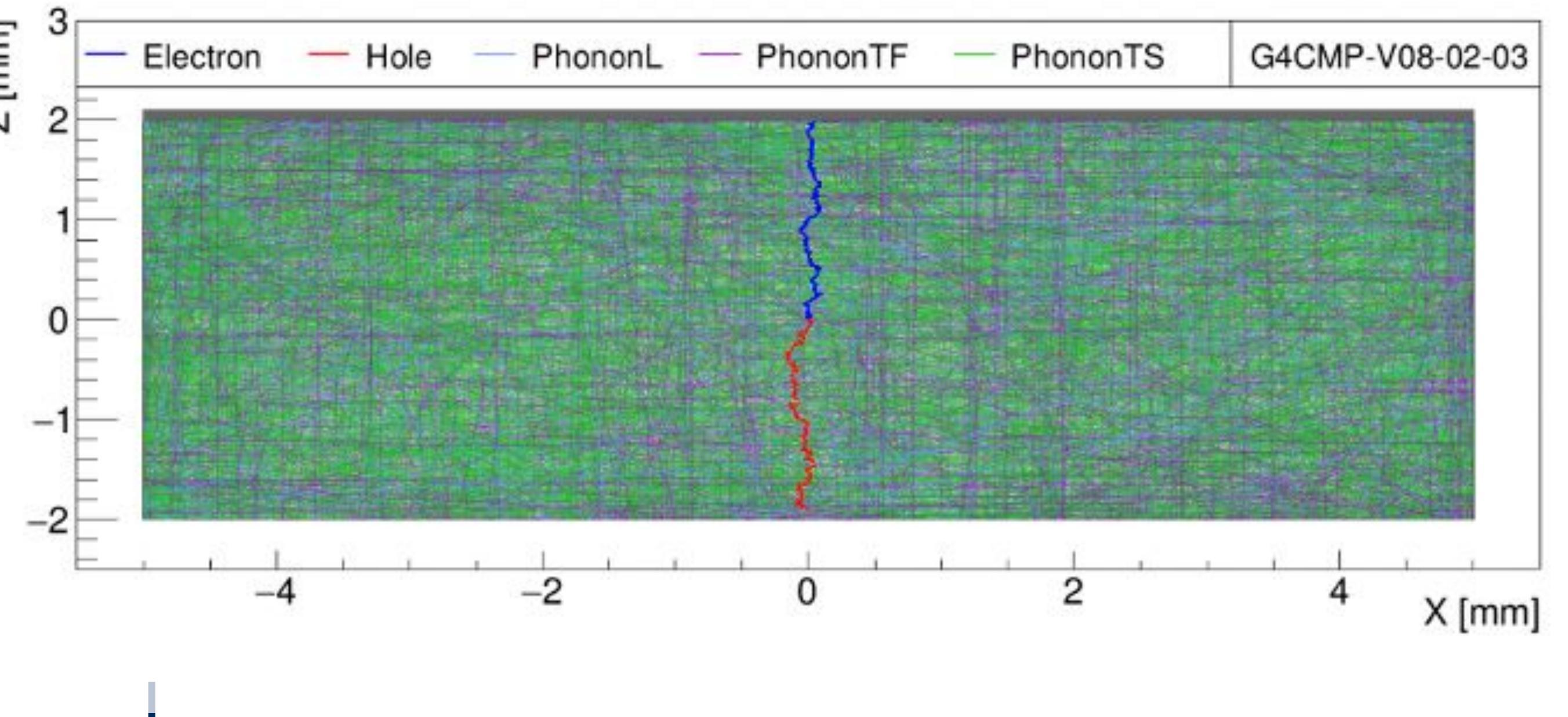




Software

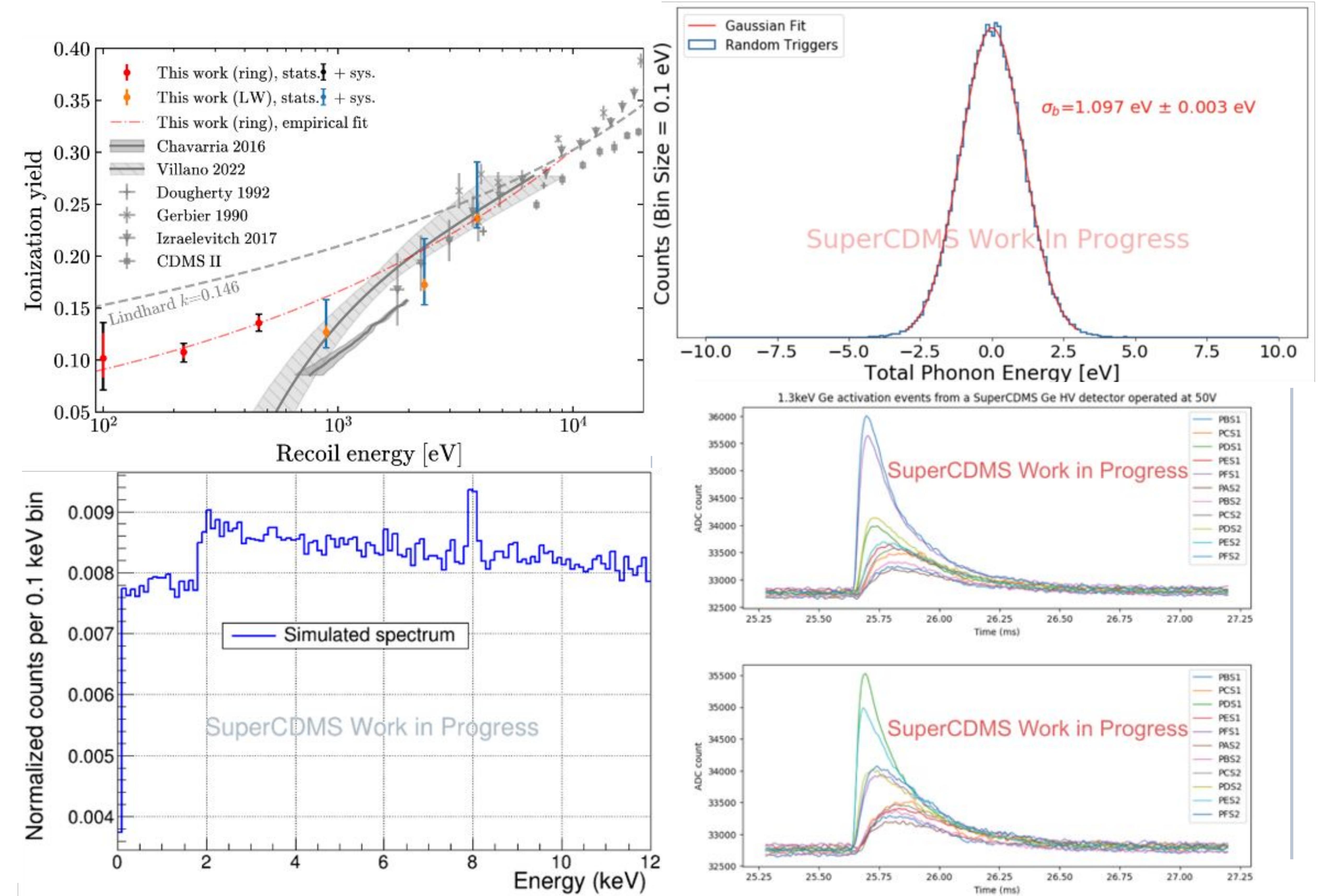
- Simulation geometry updated for 'as built' experiment
- Continued development of
 G4CMP and detector response
- Analysis pipeline and processing taking learnings from CUTE tower run





25

Coming up...





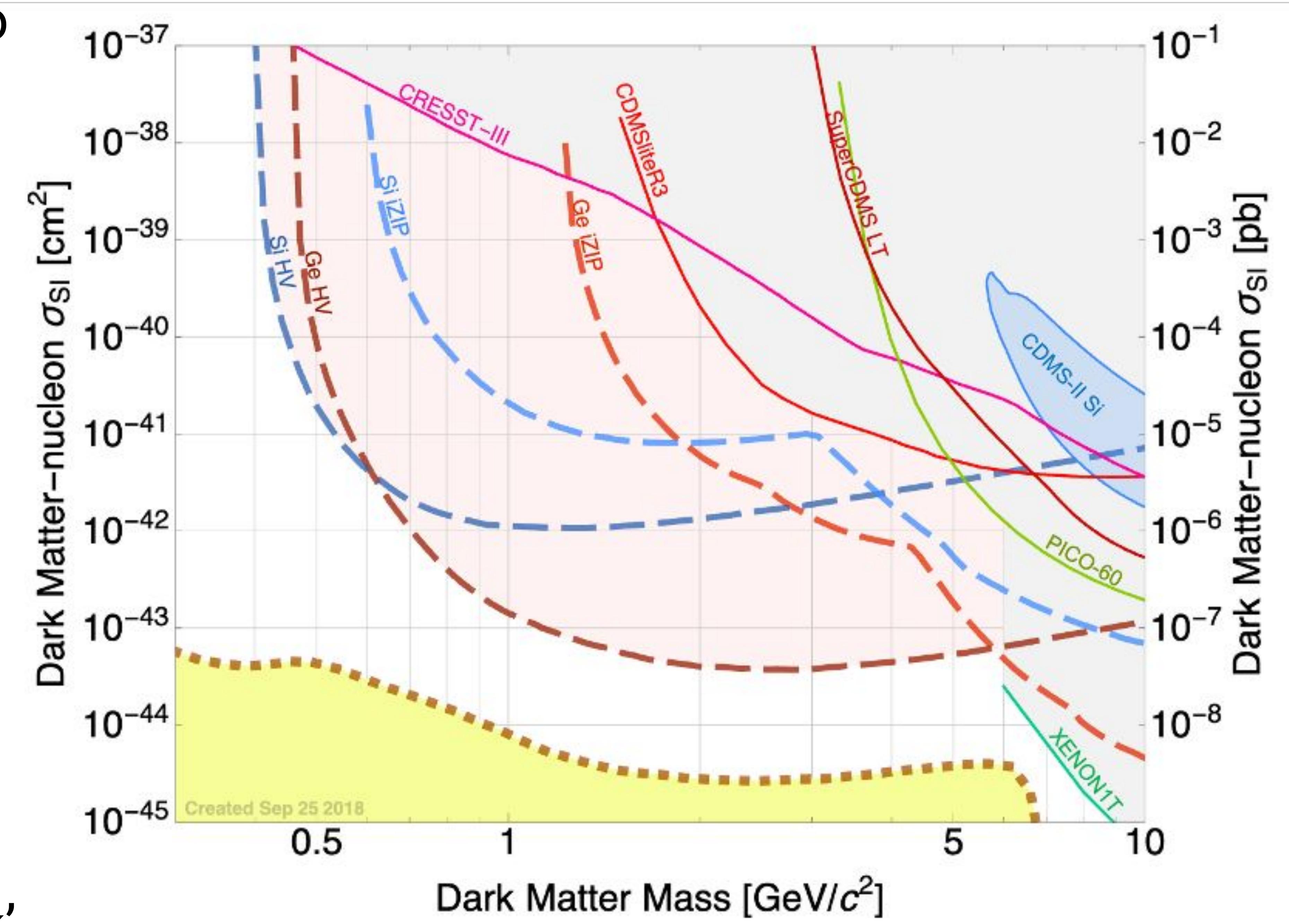
Analysis

- Background modelling underway for PLR sensitivity
- Ongoing analysis of CUTE calibration and science data
- HVeV studies ongoing to understand calibration and low energy excess
- ERDM and NRDM modelling tools under development

26

Summary

- SuperCDMS is well suited for low mass DM due to
 - o Multiple targets
 - Dual, complementary detector technologies
 - Sensitivity to a range of different DM models
- SNOLAB commissioning is well underway
- Exciting results expected soon from our test facilities (NEXUS and CUTE)
 - Successfully demonstrated operation of HV detectors in low background environment
 - Testbed for calibration processes and simulation program
 - Will help prepare the collaboration for 'first dark'



Acknowledgements



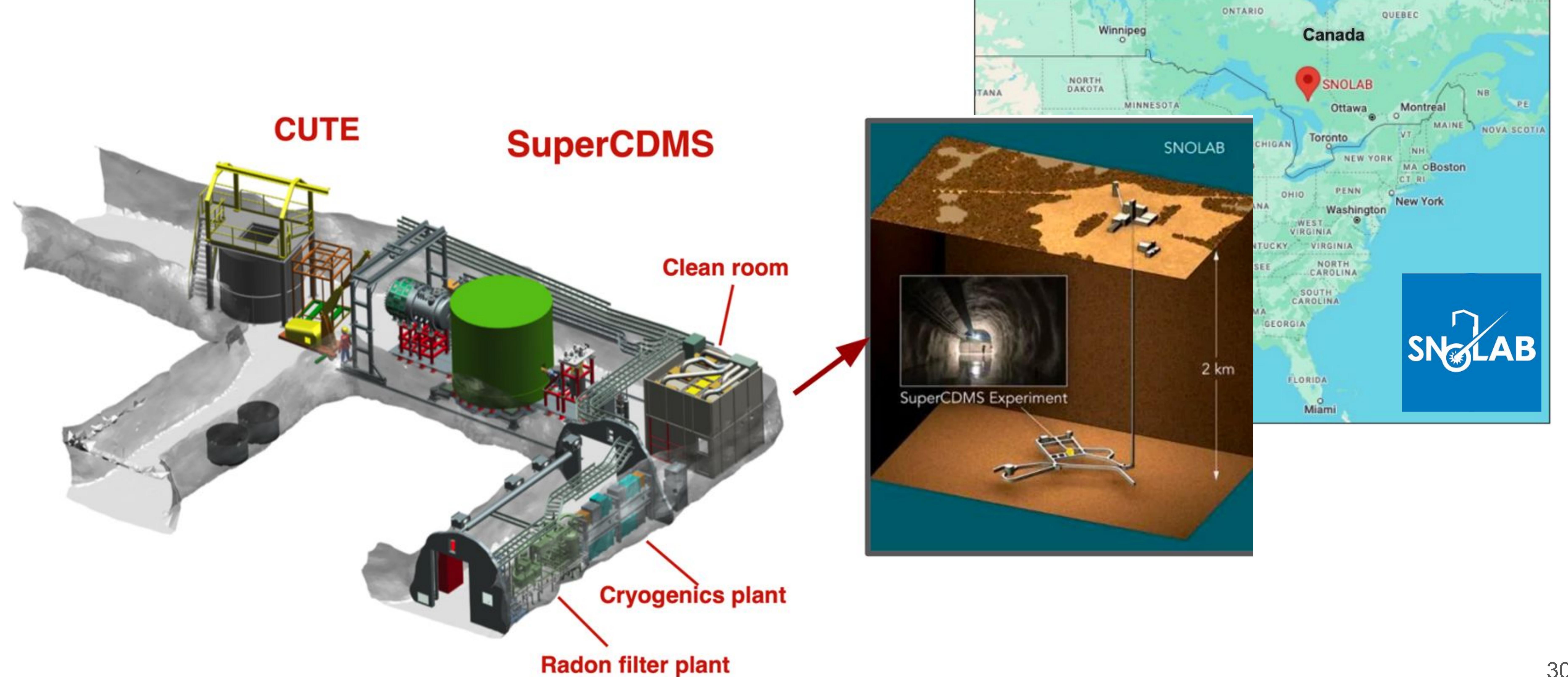


supercdms.slac.stanford.edu





Back up slides



SuperCDMS search methods

- "Traditional" Nuclear Recoil:
- Low Threshold NR:
- HV Detector:
- Migdal & Bremsstrahlung:
- Electron recoil:
- Absorption (Dark Photons, ALPs): HV, no discrimination,

Full discrimination,

Limited discrimination,

HV, no discrimination,

no discrimination,

HV, no discrimination,

≥ 5 GeV

≥ 1 GeV

 $\sim 0.3 - 10 \, \text{GeV}$

~0.01 - 10 GeV

~0.5 MeV - 10 GeV

~1 eV - 500 keV ("peak search")

