SUPERCDMS DETECTOR PERFORMANCE AND EARLY SCIENCE FROM CUTE

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SuperCDMS Collaboration
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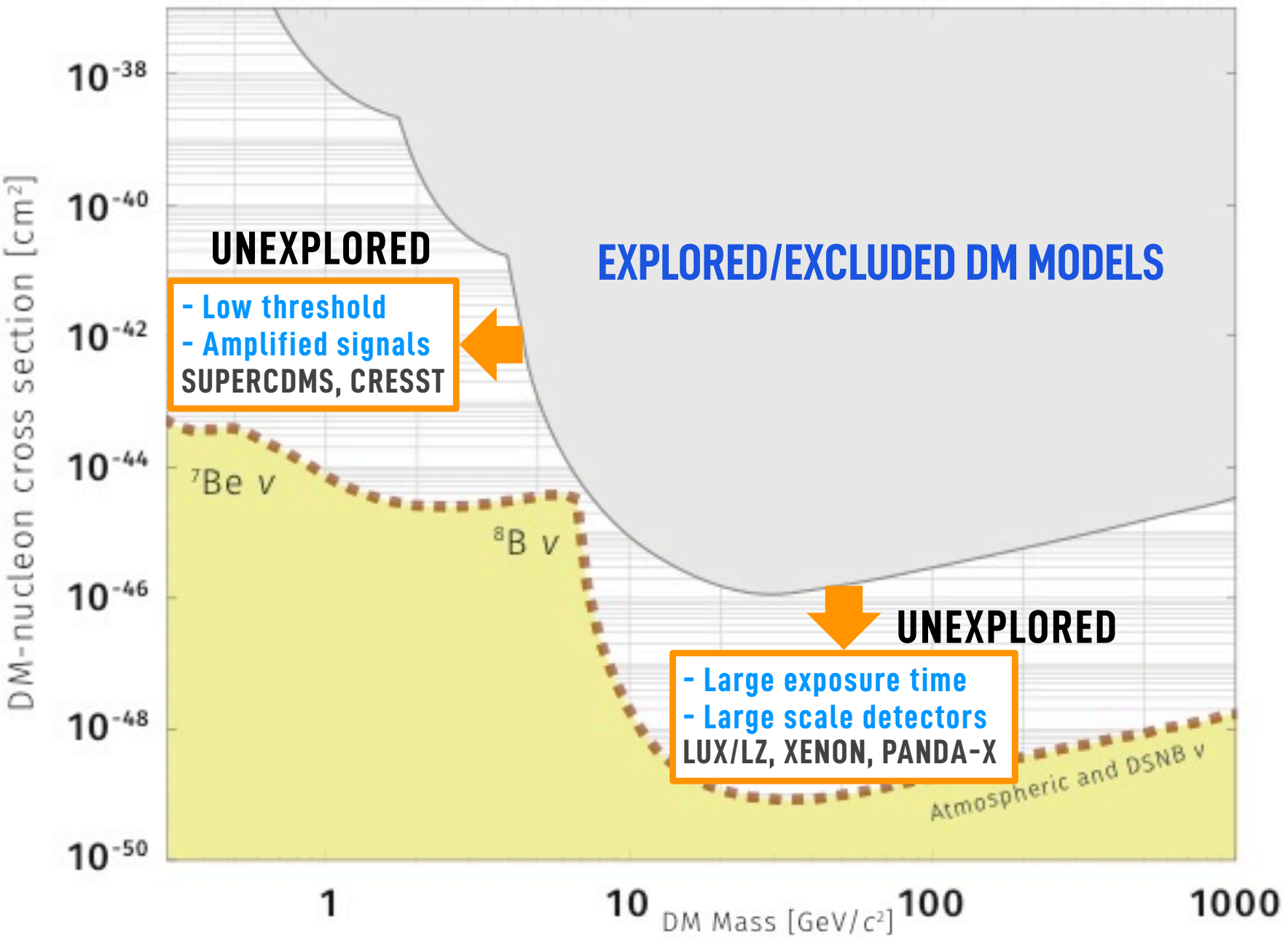
U.S. DEPARTMENT OF ENERGY
Office of Science

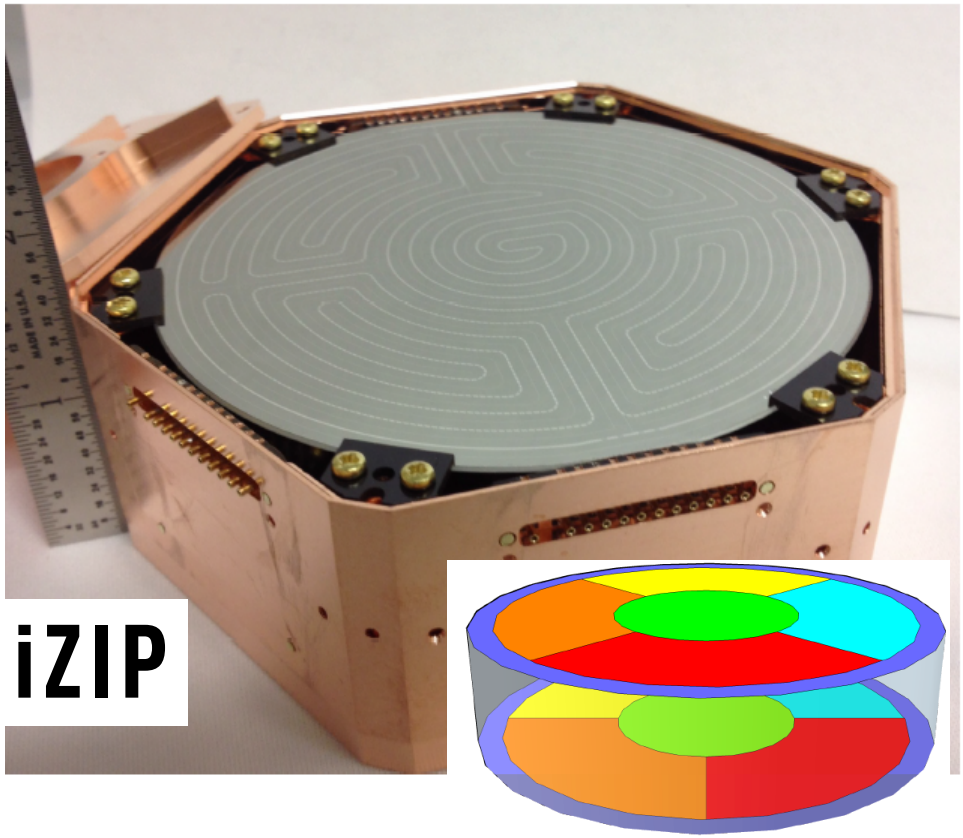
SLAC NATIONAL ACCELERATOR LABORATORY

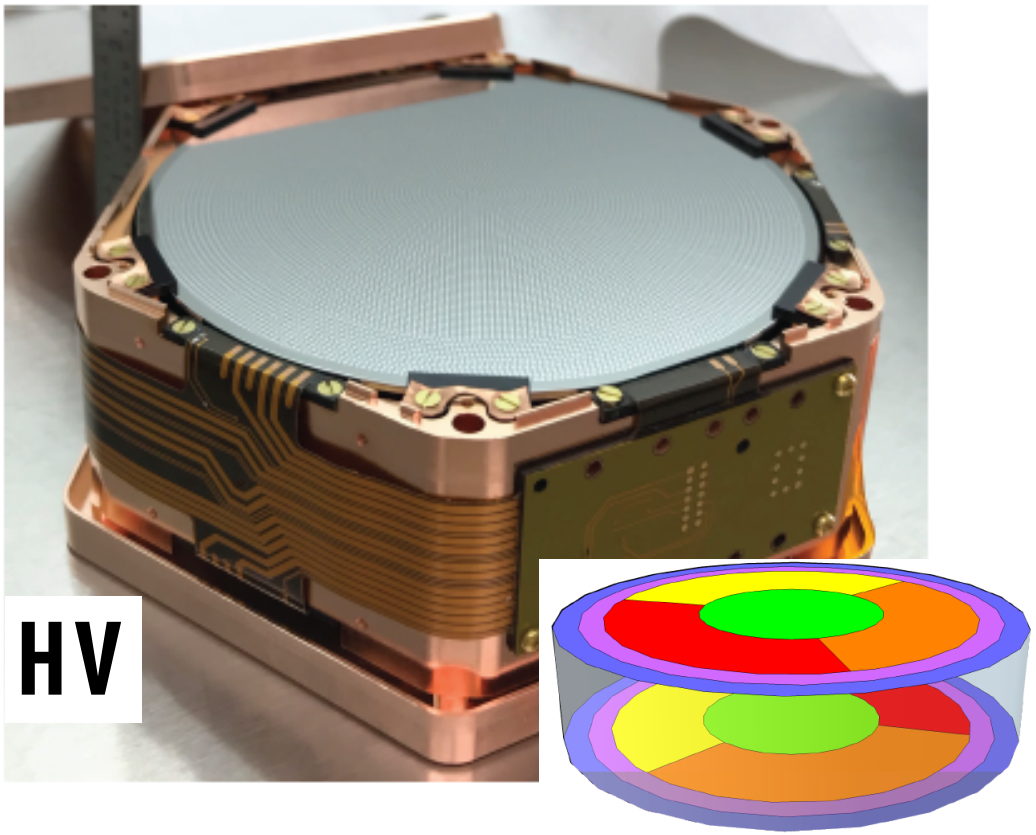
Direct DM Search: Current Status



SUPERCDMS FOCUSES ON LOW-MASS DM

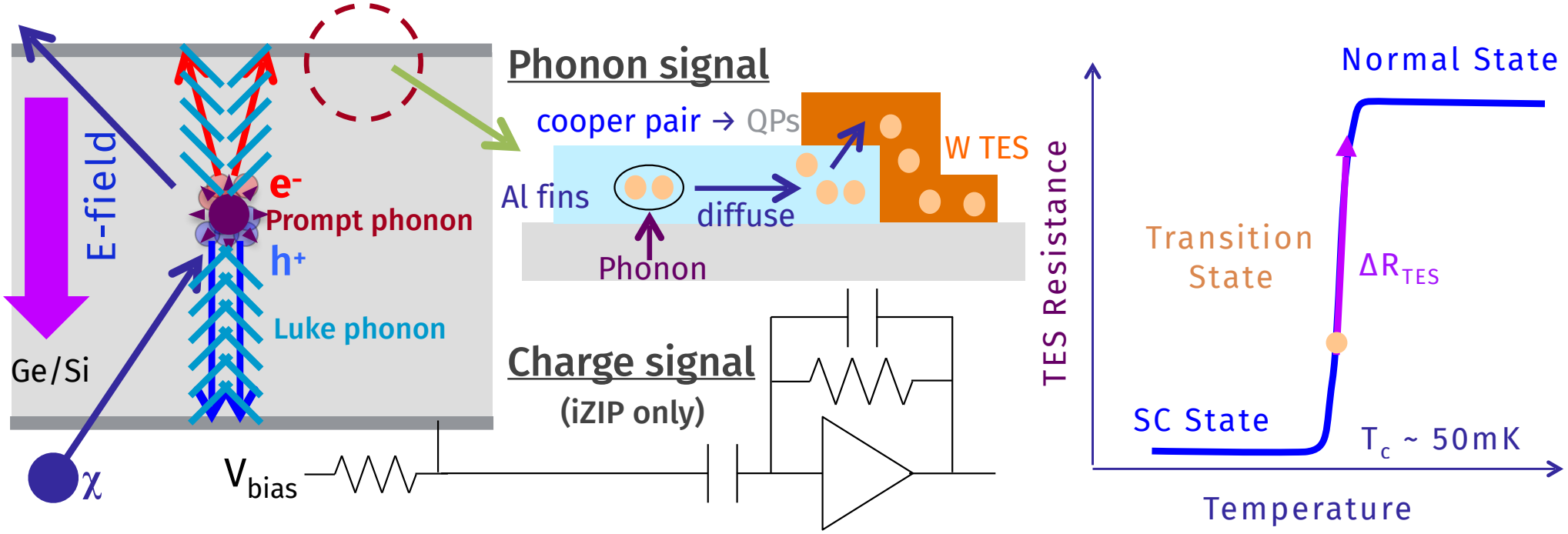
SuperCDMS Detector Technology





- Detectors made of high-purity **Ge** and **Si** Crystals
- Low operation temperature: **~15mK**
- **Athermal phonon** measurement with **transition edge sensors** (TESs)
- **Multiple channels** per detector to identify event position
- Two detector types
  - **iZIP**: **background rejection** with phonon + ionization signals
  - **HV**: **low energy threshold** with amplified Luke phonons

SuperCDMS Detection Concept

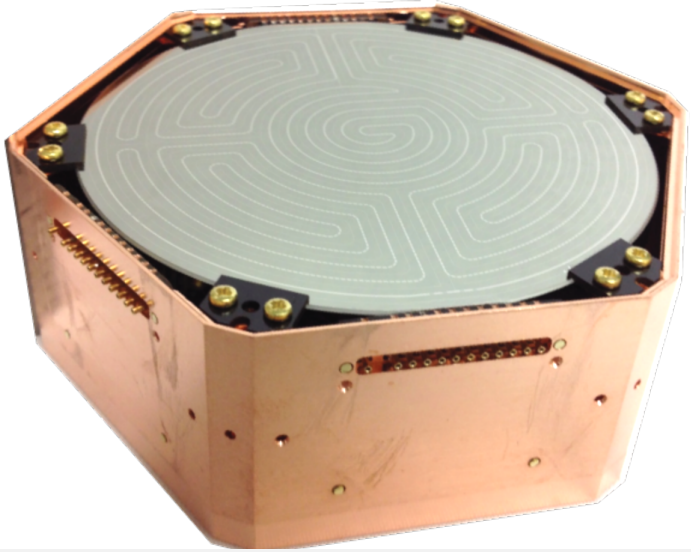


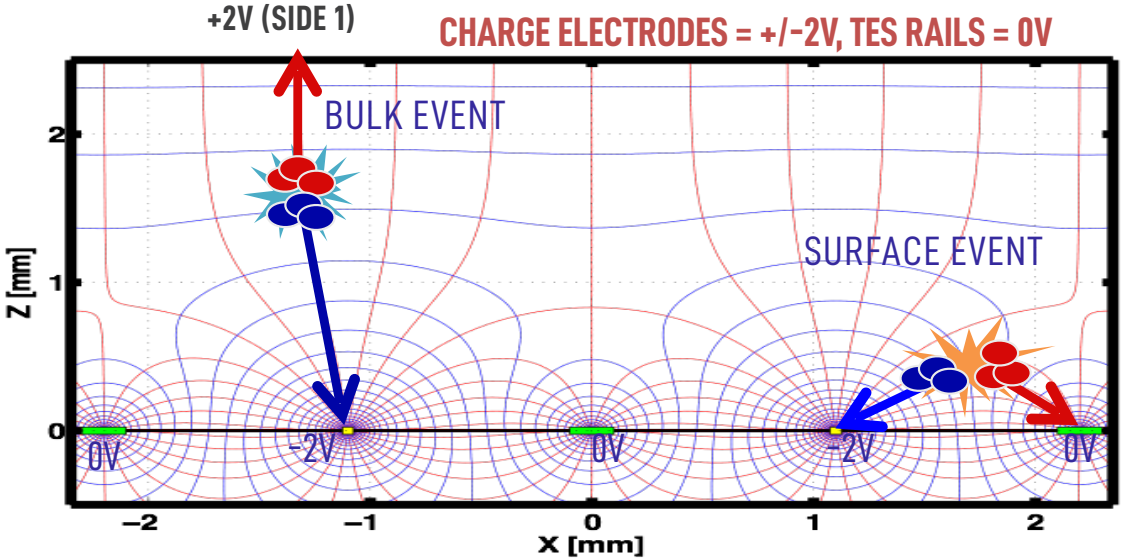
1. Dark matter particle scatters off target nucleus (Ge/Si)
   -> **Prompt phonons** & **e^-/h^+** pairs produced
2. **e^-/h^+** separated by E-field and drifted to electrodes
   -> **Luke phonons** produced due to Neganov-Luke effect
3. **e^-/h^+** read out with charge sensitive amplifiers
4. **Phonons** break **Cooper pairs** in Al fins, create quasi-particles (QP)
5. **QPs** diffuse into Tungsten (W) **Transition Edge Sensors** (TESs)
6. Current change due to ΔR_{TES} read out by **SQUID** amplifiers

   SQUID: Superconducting Quantum Interference Device (= magnetometer)

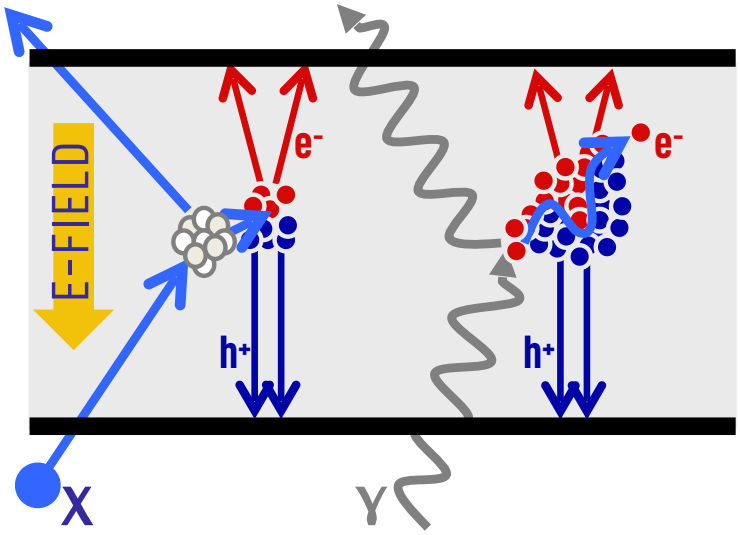
iZIP Detector

- **Interleaved** TES/electrode design to **identify/reject** **surface events**





- **Phonon** + **Ionization** signals to **identify/reject** **electron recoil events**



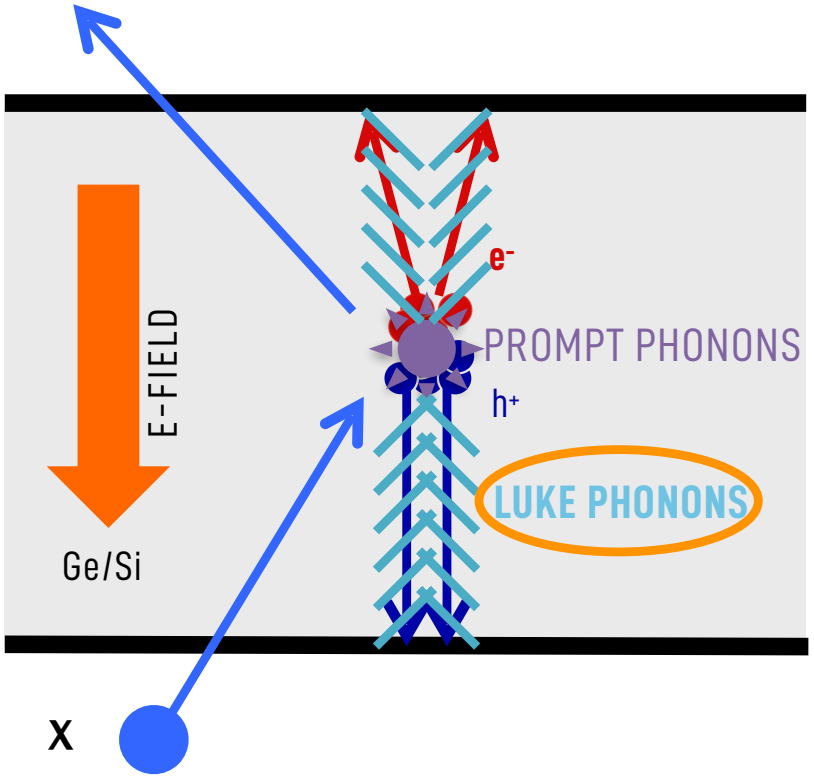
Electron recoil (**ER: $e^{+/-}$, γ**) events creates **more** e^-/h^+ pairs

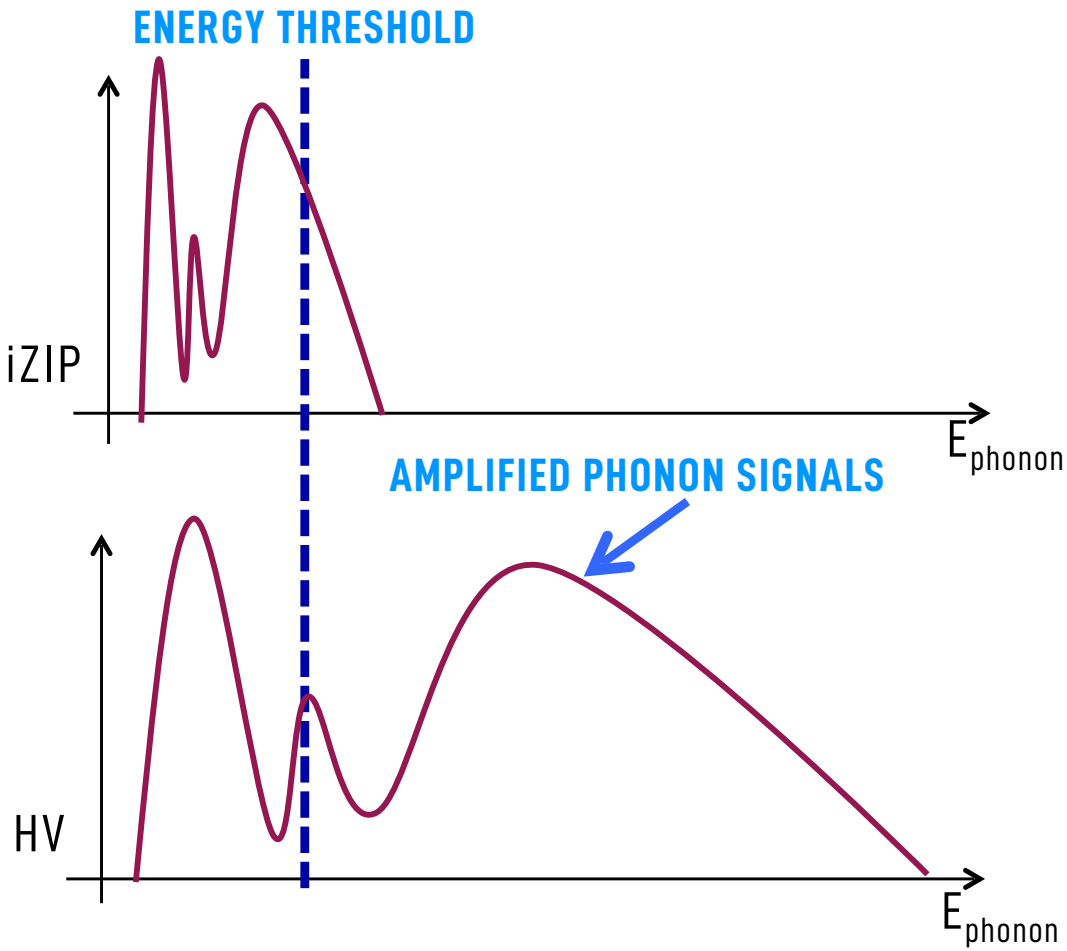
Nuclear recoil (**NR: DM, ν, n**) events create **less** e^-/h^+ pairs

IZIP DETECTORS CAPABLE OF BACKGROUND REJECTION

HV Detector

- **HV bias applied** to **amplify phonon signals** with Neganov-Luke effect
  - **Very low Energy** threshold achievable
  - Sensitive to measure **small signals** from **low-mass DM**

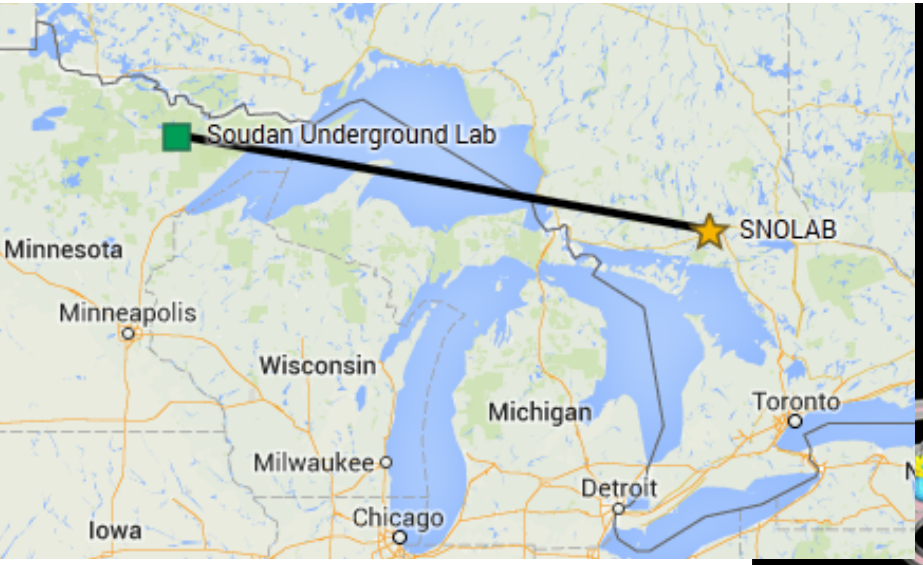


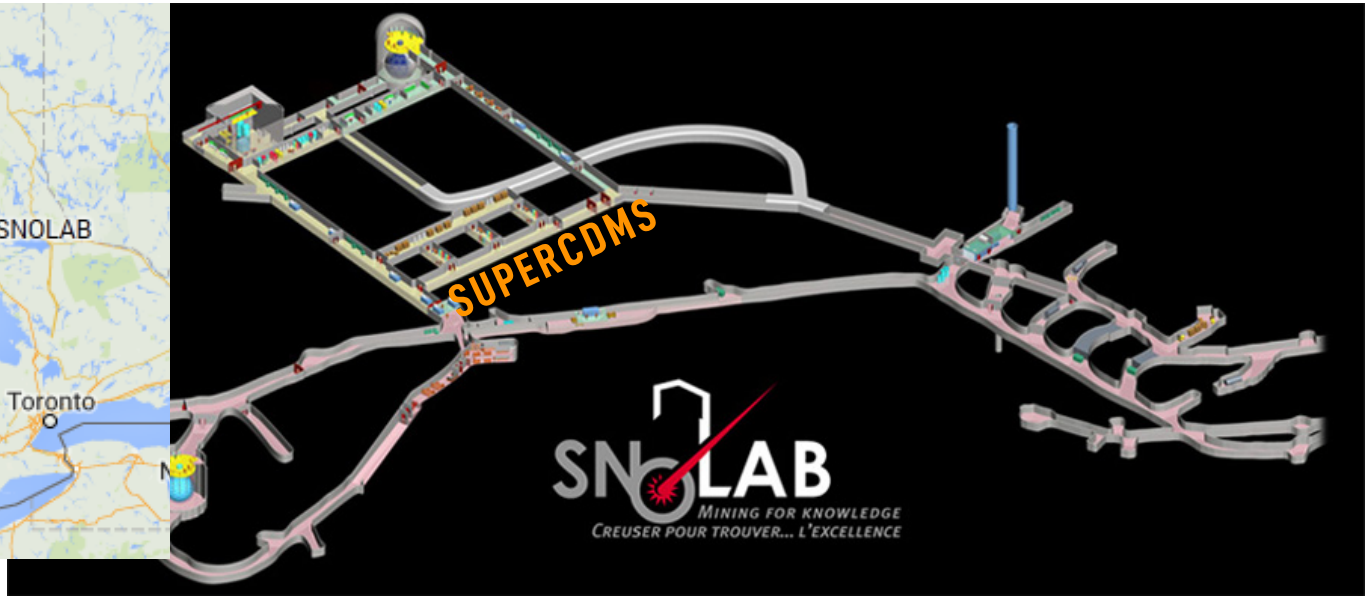


HV DETECTORS OPTIMIZED FOR LOW-MASS DM SEARCH

SuperCDMS SNOLAB Project

- A DOE/NSF G2 DM search program, 4th generation of CDMS project
- Complementary **target nuclei (Ge/Si)** & **detection techniques (iZIP/HV)**
- Optimized for **low-mass DM** (< 10GeV) search

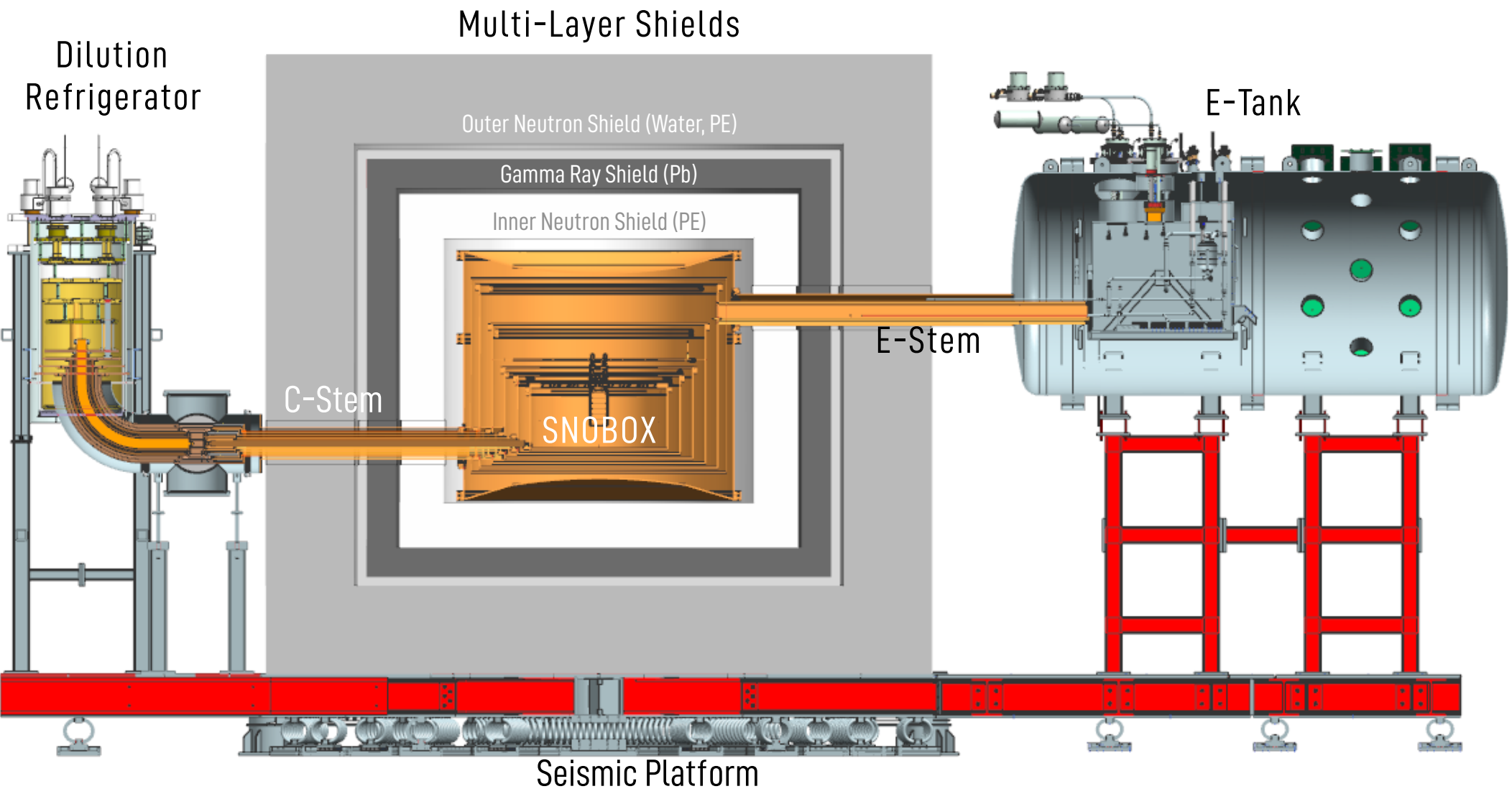




- **4 detector towers**, (6 detectors per tower), operated at **~15mK**
  - Tower 1: 6 Ge iZIP
  - Tower 2: 4 Ge HV + 2 Si HV
  - Tower 3: 4 Ge HV + 2 Si HV
  - Tower 4: 4 Ge iZIP + 2 Si iZIP
- Full operation will start in 2020

Twins:
Fabricated/assembled at the same time
Identical cosmogenic activation, radon exposure
Tower 4 will be used to estimate Tower 3 background

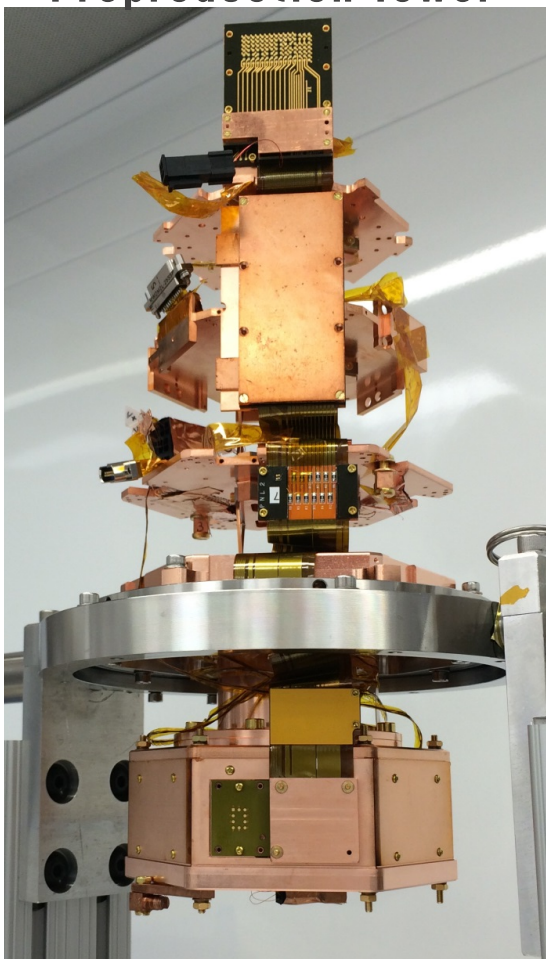
SNOLAB Infrastructure

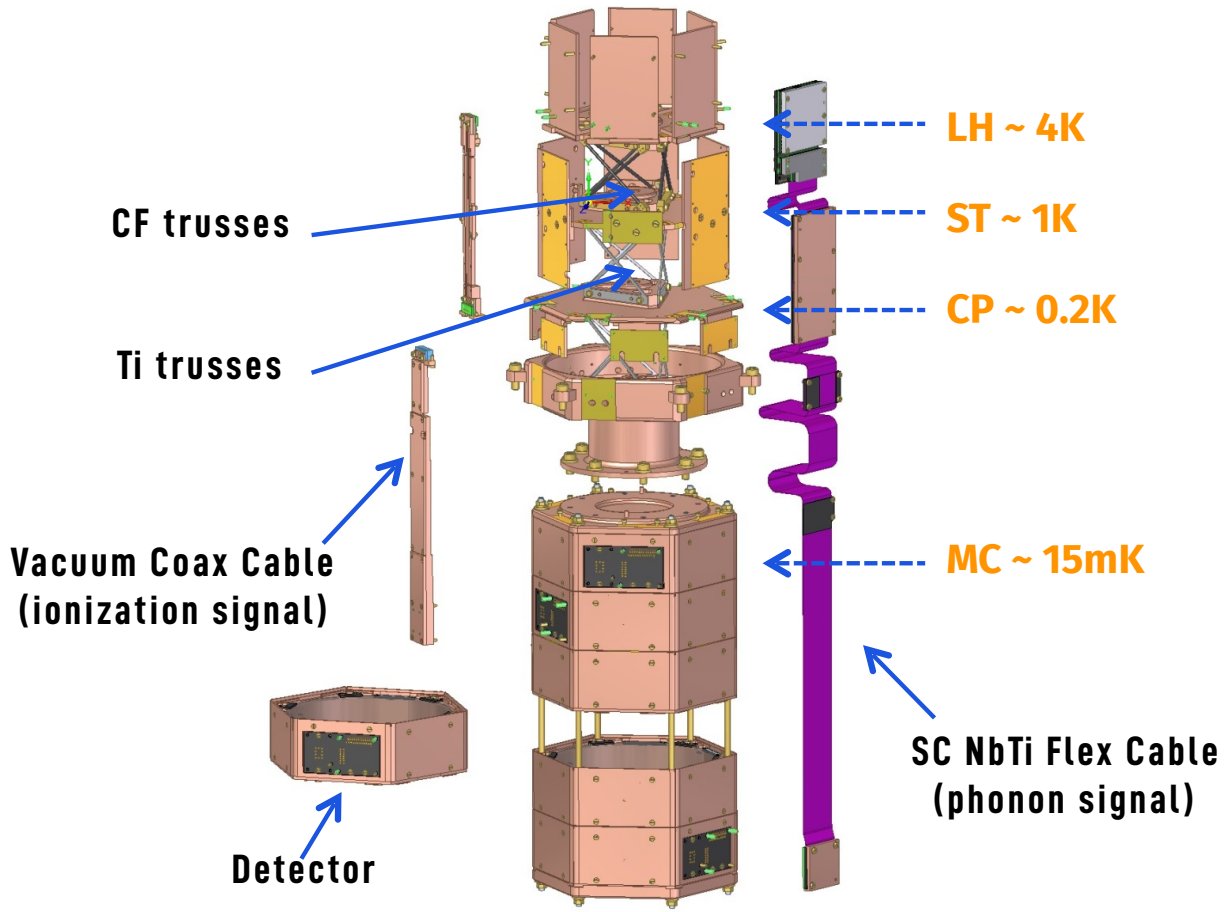


- 6000 m.w.e (**x10³ less cosmic rays**), class-2000 cleanroom
- **Multi-layer shields** for background reduction
- Very quiet, low-radioactive environment

Detector Tower

Preproduction Tower



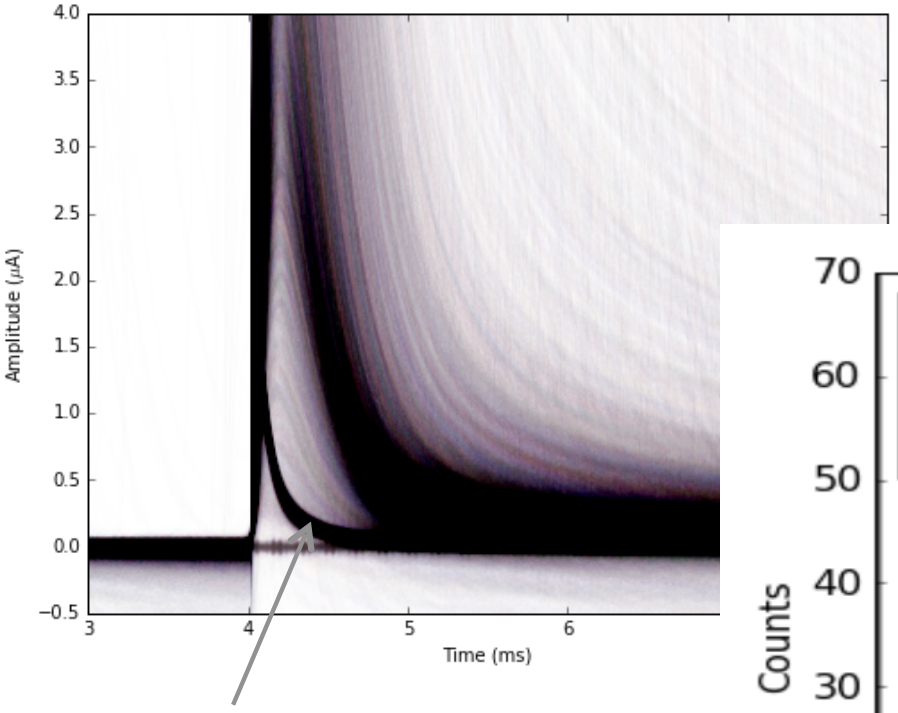


4 Thermal Stages: MC = Mixing Chamber, CP = Cold Plate, ST = Still, LH = Liquid Helium

- **6 detectors** and **4 thermal stages** per tower
- **Detector** at **MC**, R_S at **CP**. **SQUID amplifier** at **ST**, **Charge amplifier** at **LH**
- **Ti/CF trusses** to **thermally isolate**, **mechanically support** each stage
- **SC cables** to read signals, **avoid thermal short** between stages
- **Tower 1** will be assembled **this Fall**

Detector Performance

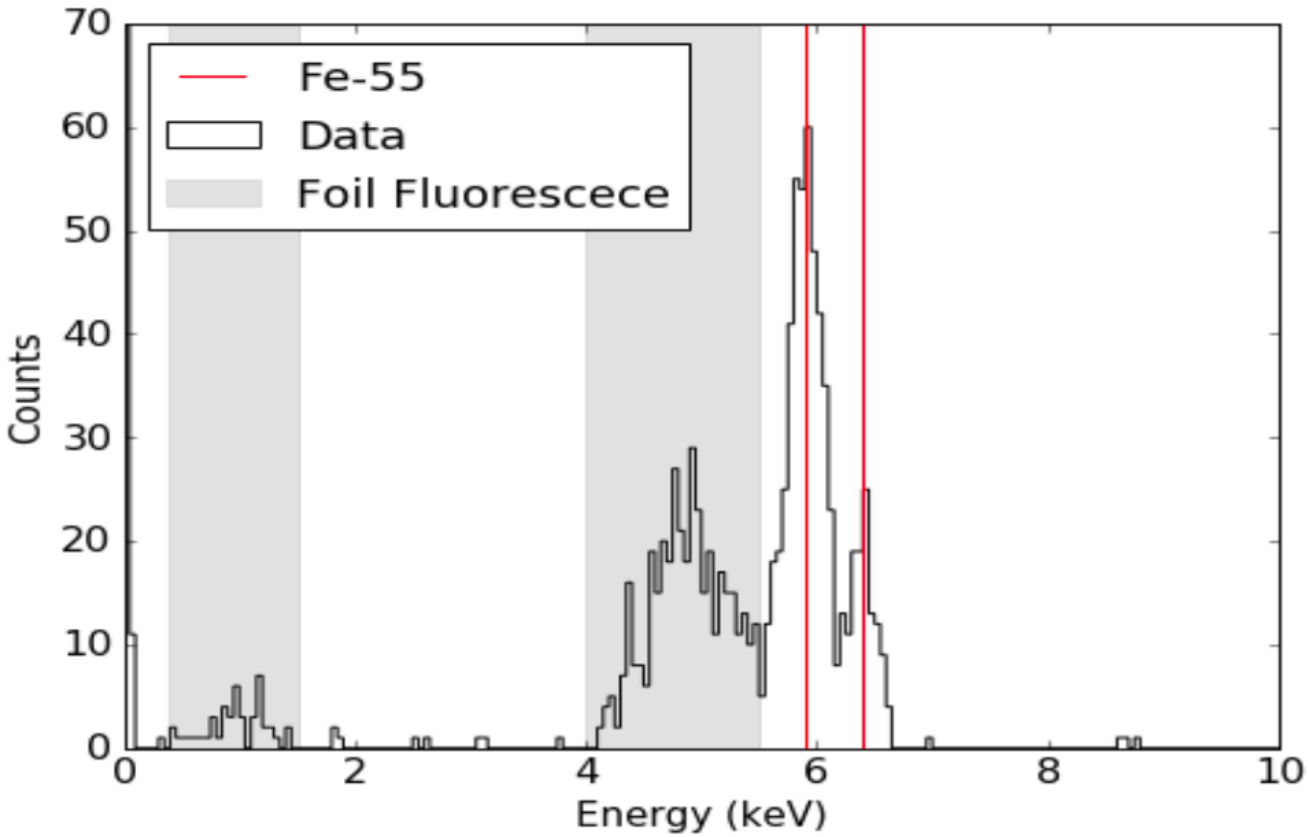
- **Successfully** demonstrated detector performance
  - Preproduction tower with **SC Ti cables**, **SQUID** and **charge amplifiers**
  - **^{55}Fe source** above detector



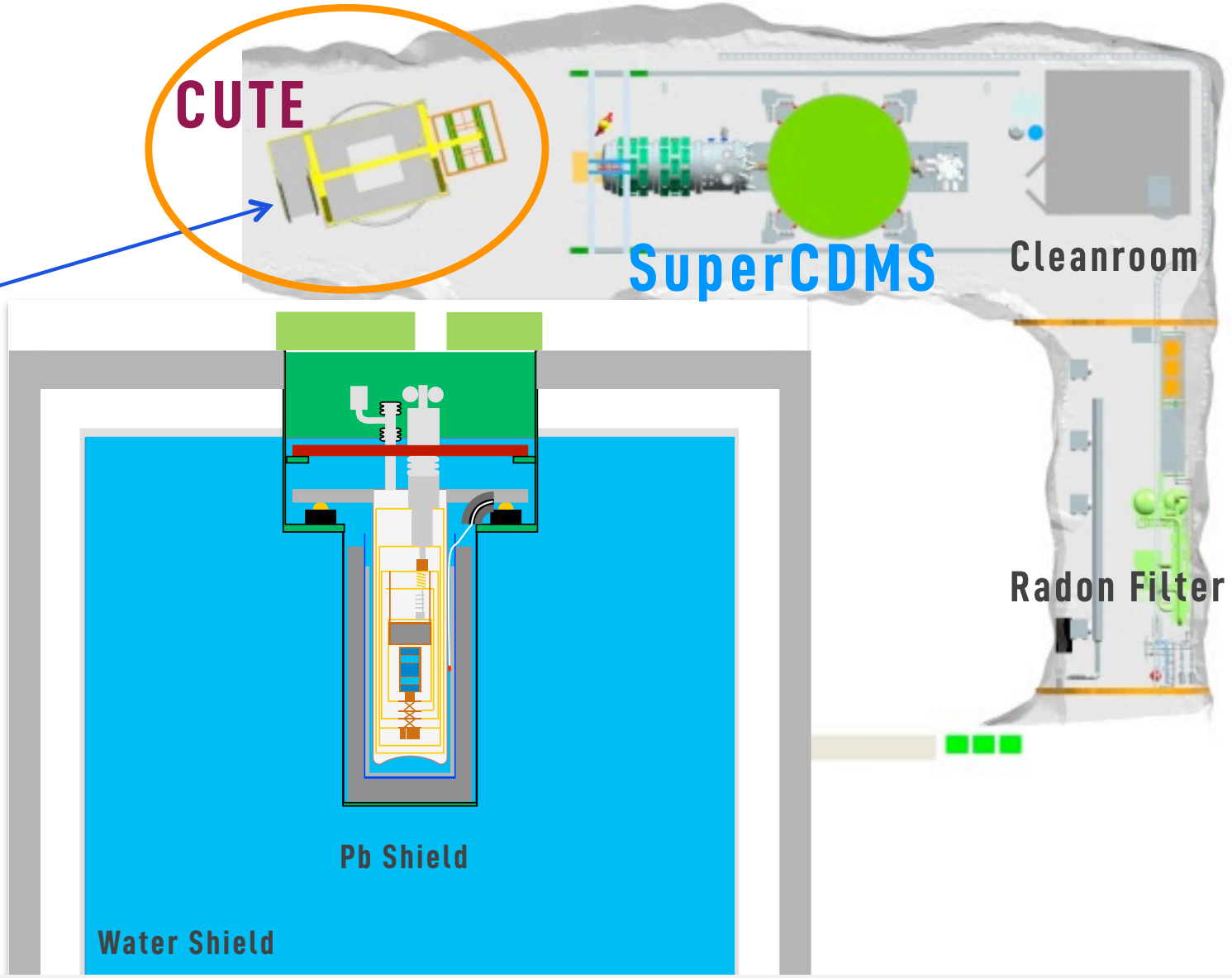
Signals from ^{55}Fe source

Phonon collection efficiency ~20%

σ_E ~ 17eV for 5.9 keV line



CUTE (Cryogenic Underground TEst) Facility

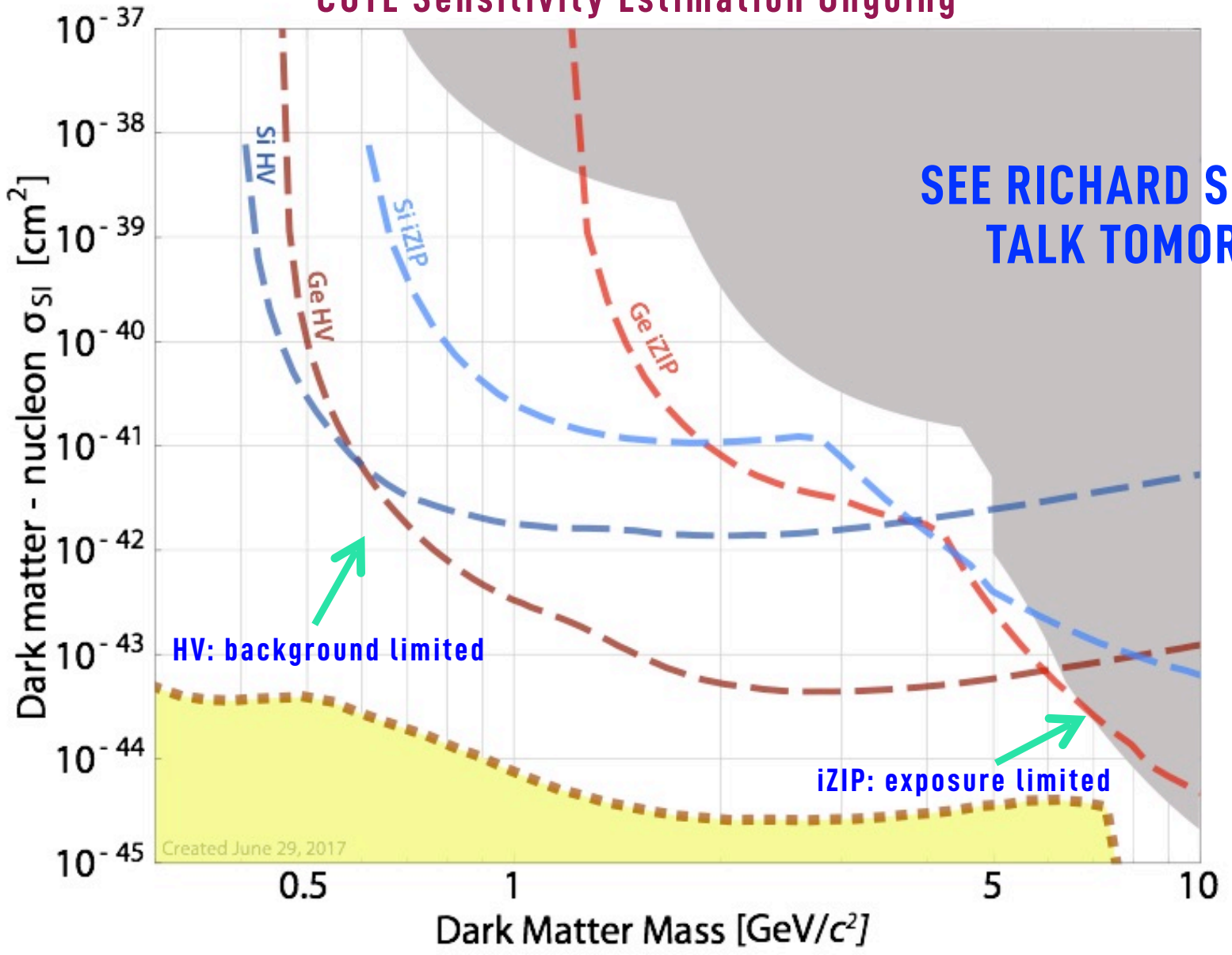


- SuperCDMS SNOLAB **pre-operation phase** with **one detector tower**
  - Detailed detector **characteristic test** with **low-background**
  - Explore **new dark matter parameter space**

SuperCDMS SNOLAB Sensitivity

CUTE EARLY OPERATION FROM 2019, SUPERCDMS FULL OPERATION FROM 2020

CUTE Sensitivity Estimation Ongoing

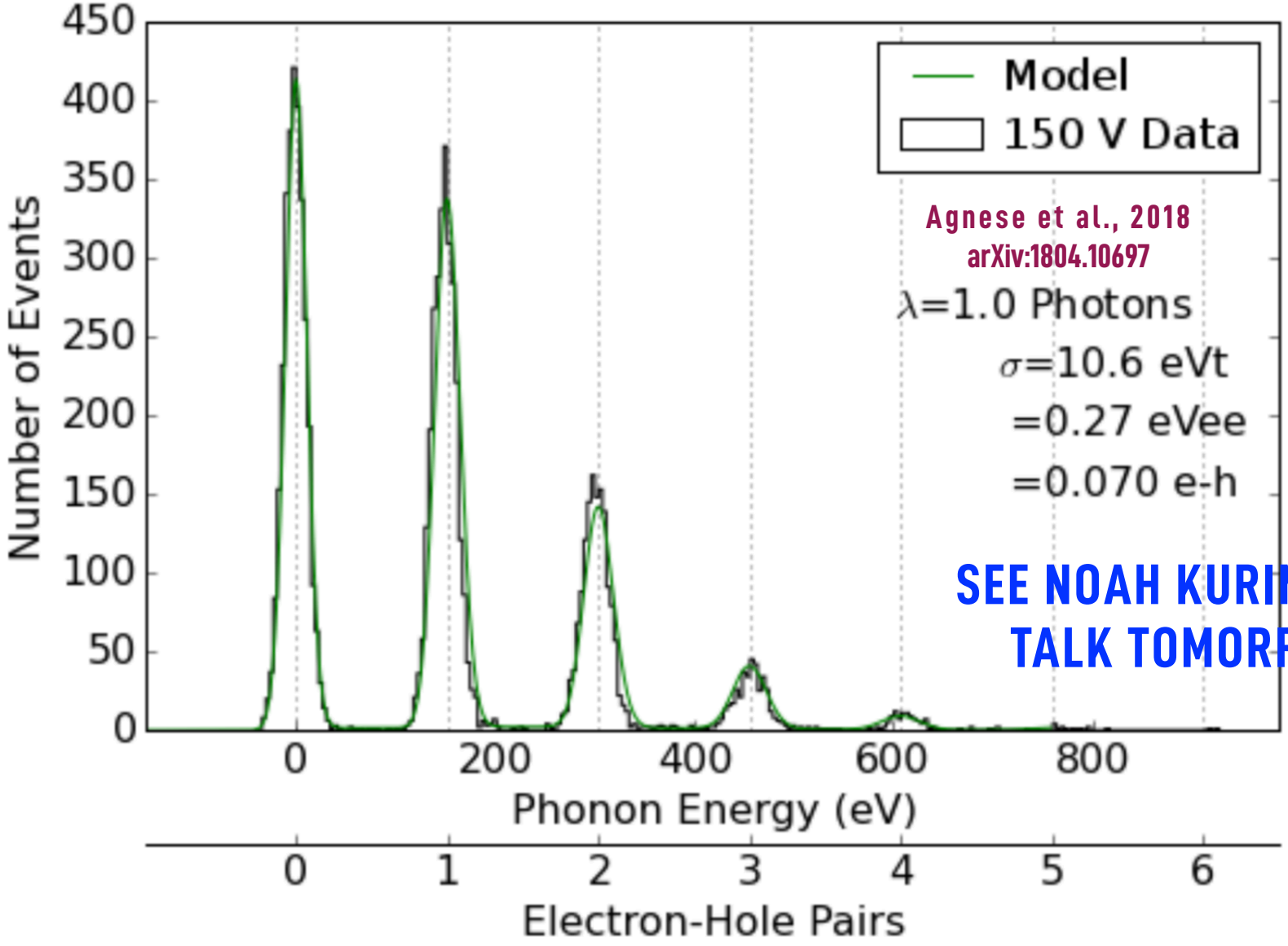


SEE RICHARD SCHNEE'S TALK TOMORROW

SUPERCDMS/CUTE WILL EXCLUSIVELY EXPLORE LOW-MASS DM MODELS

Future Upgrade (G2+)

QUANTIZED e^-/h^+ SIGNALS OBSERVED WITH STANFORD SMALL TEST CHIP

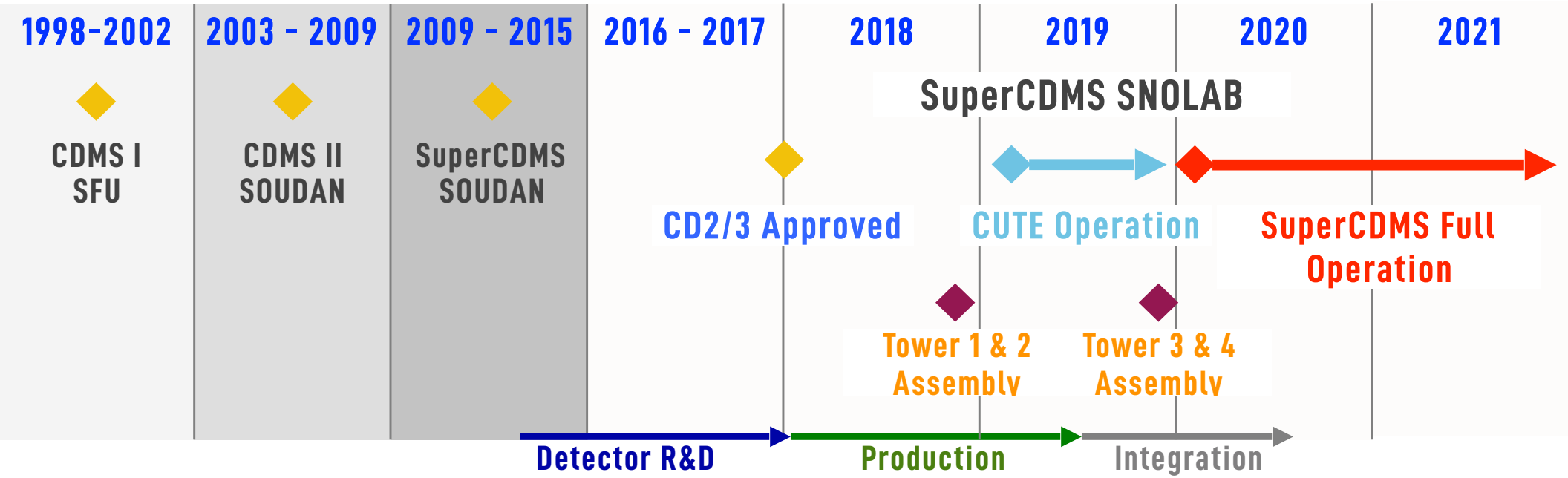


SEE NOAH KURINSKY'S TALK TOMORROW

7/25: Understanding eV-threshold calorimeters for SuperCDMS - Alan Robinson

7/27: Dark Photon Searches with SuperCDMS Technology - Belina von Krosigk

Timetable and Summary



- The SuperCDMS collaboration has been one of the leading direct DM search experiments for more than a decade
- We successfully demonstrated detector performance with SC cables and Preproduction Tower
- We are approved for CD2/3 Reviews and Tower 1 & 2 production started
- Early operation at CUTE Facility will start next year and SuperCDMS SNOLAB full operation will begin in 2020.
- SuperCDMS early/full operation will uniquely and deeply explore DM parameter space, especially for low-mass DM models

SuperCDMS Collaboration

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CNRS-LPN*
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NIST*
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Queen's University
Santa Clara University
SLAC
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SMU
SNOLAB
Stanford University
Texas A&M University
TRIUMF
U. British Columbia
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U. Evansville
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U. Montréal
U. Minnesota
U. South Dakota
U. Toronto

* Associate members