The SuperCDMS SNOLAB Experiment

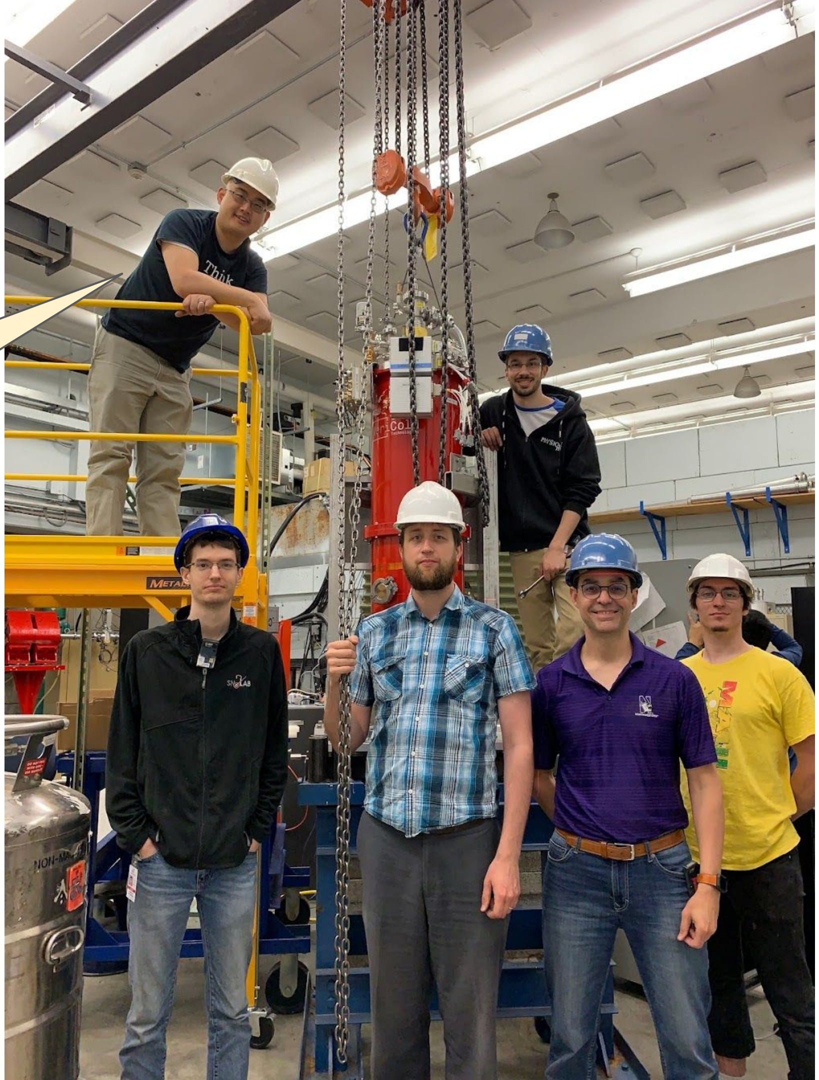
SNOLAB User's Meeting

Ziqing Hong, for the SuperCDMS Collaboration

@SuperCDMS

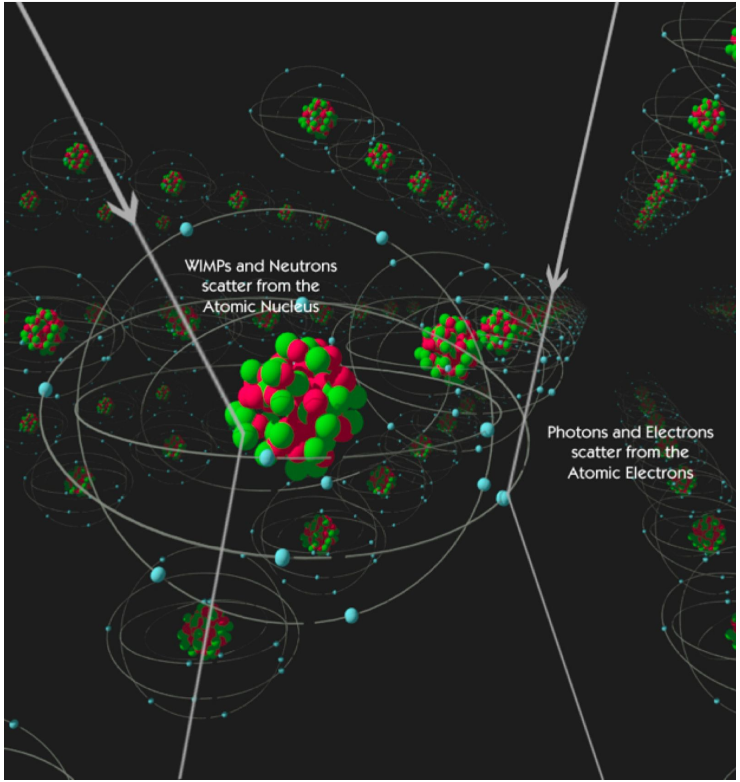
supercdms.slac.stanford.edu

- New faculty member at University of Toronto
- Interested in Dark Matter search, Coherent Neutrino Scattering, or anything that could potentially break the Standard Model
- Specialized in cryogenic systems, cryo detector R&D and calibration
- Also love burning CPU hours with simulations…



Dark Matter Interactions & Detector Physics

- Interactions fall into two categories
  - **Nuclear recoils** - particle interacts with the nucleus
    - Traditional “WIMP” Dark matter signal
    - Neutron and neutrino backgrounds
  - **Electron recoils** - particle interacts with atomic electrons
    - Electron recoil signals and Dark Photon and Axion-like particle absorption signals
    - Most background sources
- Detector response often is different for the two categories.
  - Can be used to reject some backgrounds
- Energy scale of the interaction dictates detection approach
- Backgrounds and detection techniques drive science reach



SuperCDMS Detector Technology

Discriminating

~~iZIP~~ **Detector:**

- Prompt phonon and ionization signals allow for discrimination between nuclear and electron recoil events

Low Threshold

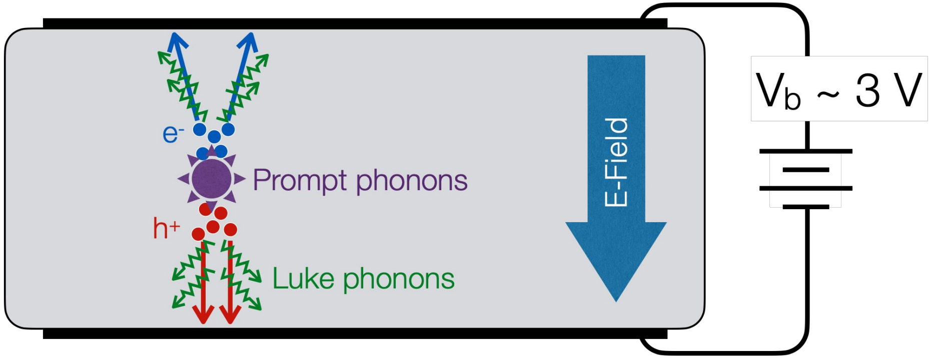
~~HV~~ **detector:**

- Drifting electrons/holes across a potential (V_b) generates a large number of phonons (Luke phonons).
  - Enables very low thresholds!
  - Trade-off: No event-by-event NR/ER discrimination

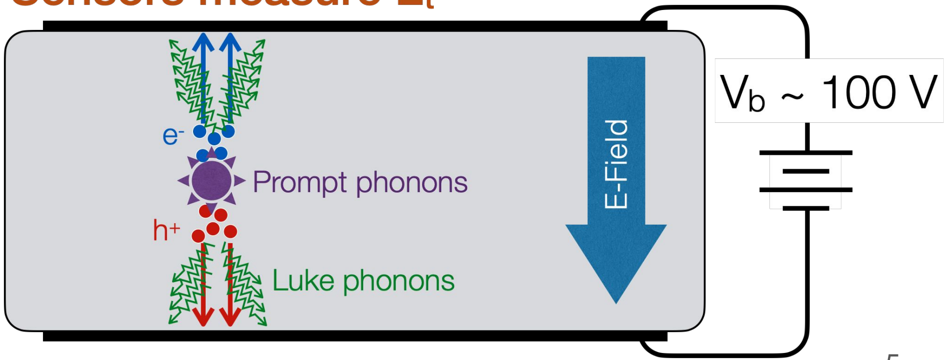
$$E_t = E_r + N_{eh} e V_b$$

total phonon energy (E_t), *primary recoil energy* (E_r), *Luke phonon energy* ($N_{eh} e V_b$)

Sensors measure E_t, and n_{eh}

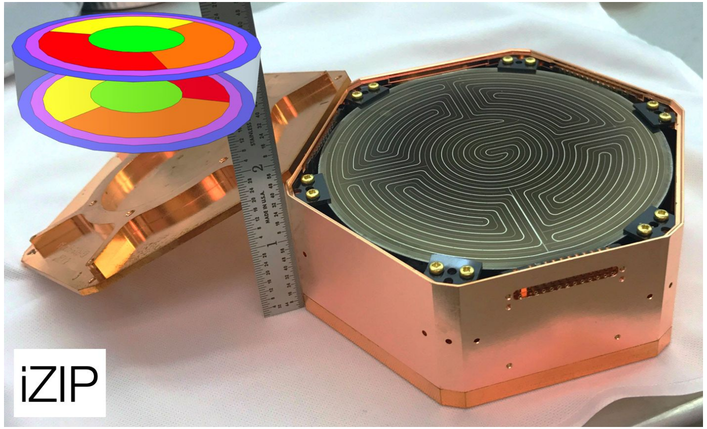


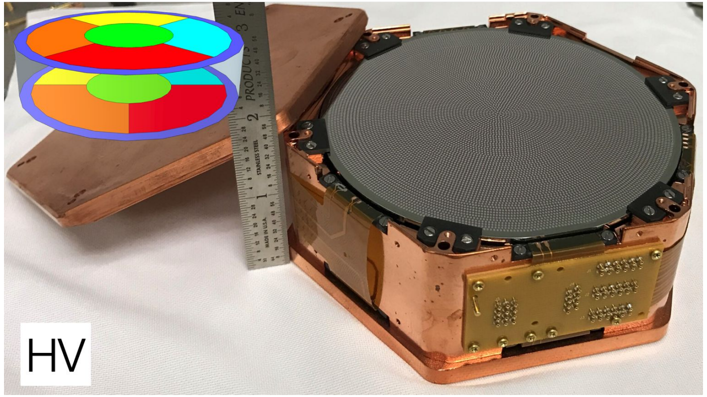
Sensors measure E_t



SuperCDMS Detectors: Posing for the Cameras

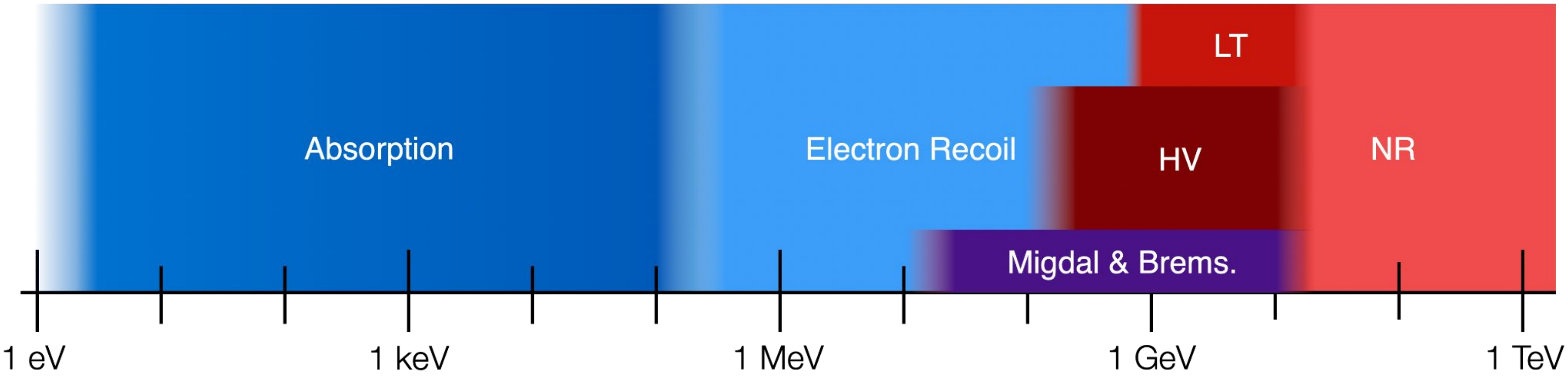
- Detectors made of high-purity Ge and Si Crystals
  - Si (0.6 kg each) provides sensitivity to lower dark matter masses
  - Ge (1.5 kg each) provides sensitivity to lower dark matter cross-sections
- Low operation temperature: ~15mK
  - Athermal phonon measurement with TESs
  - Ionization measurement (iZIP) with HEMTs
- Multiple channels per detector to identify event position
- Initial payload will consist of 4 stacks of six detectors ("towers")
  - 2 iZIP: 10 Ge / 2 Si
  - 2 HV: 4 Ge / 8 Si



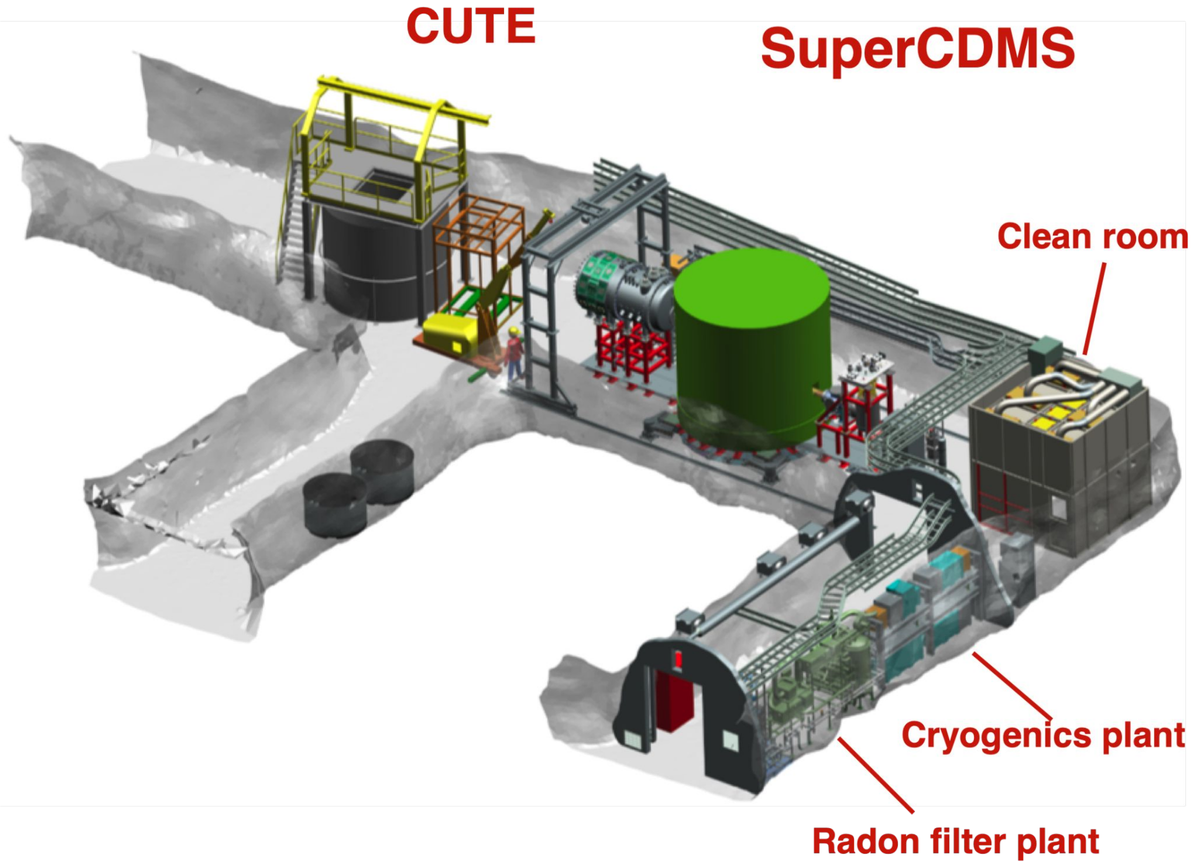


SuperCDMS Detectors & Dark Matter Mass Scales

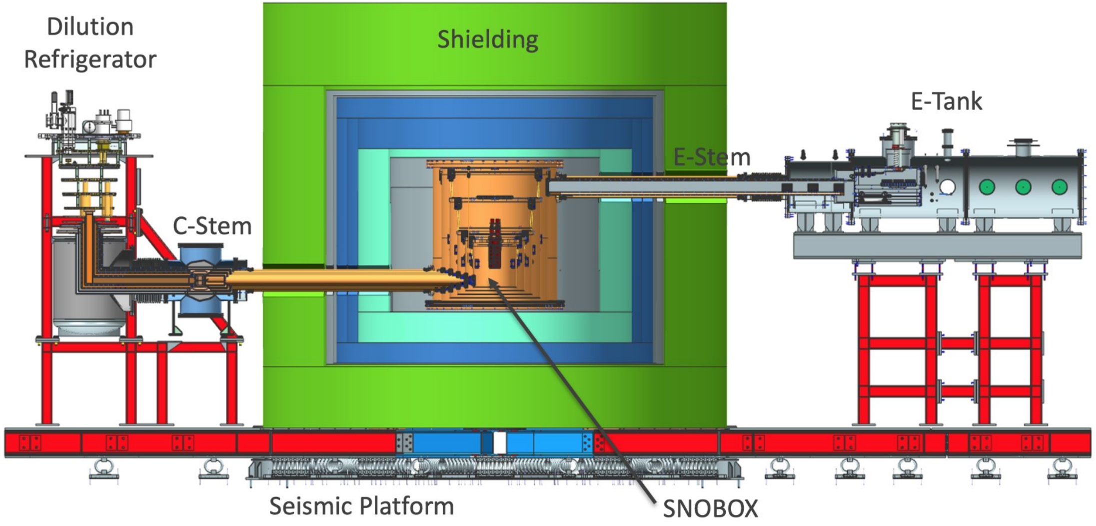
- Dark Matter Mass Ranges
  - "Traditional" Nuclear Recoil: Full discrimination, ≳ 5 GeV
  - Low Threshold NR: Limited discrimination, ≳ 1 GeV
  - HV Detector: HV, no discrimination, ~0.3 – 10 GeV
  - Migdal & Bremsstrahlung: no discrimination, ~0.01 – 10 GeV
  - Electron recoil: HV, no discrimination, ~0.5 MeV – 10 GeV
  - Absorption (Dark Photons, ALPs): HV, no discrimination, ~1 eV – 500 keV ("peak search")



SuperCDMS @ SNOLAB



The SuperCDMS SNOLAB Experiment



Facility:

- 6800 m.w.e. overburden
- 15 mK base temperature
- Initial Payload: ~30 kg total
  4 towers (2 iZIP, 2 HV)

Electron Recoil Backgrounds:

- External and facility: O(0.1 /keV/kg/d)
- Det. setup: O(0.1(Ge)-1(Si) /keV/kg/d)
- Total: O(0.1-1 /keV/kg/d)

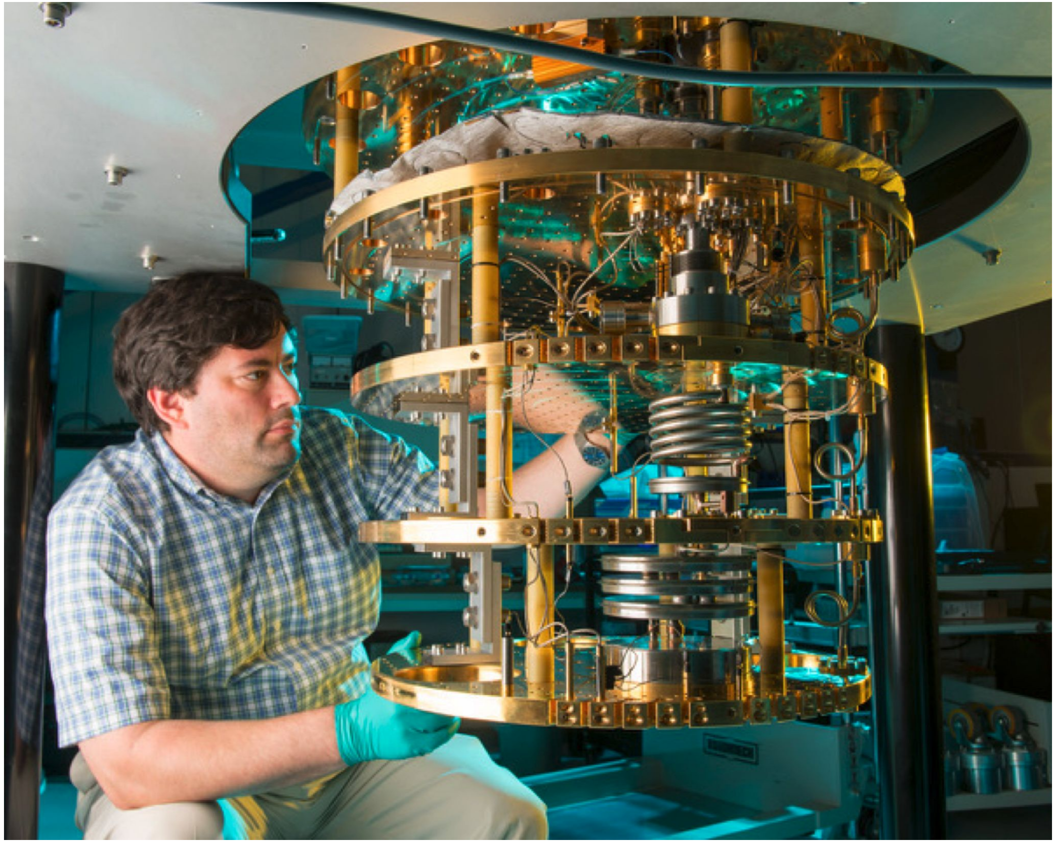
Facility designed to be dominated by solar neutrinos in NR background

Vibration isolation:

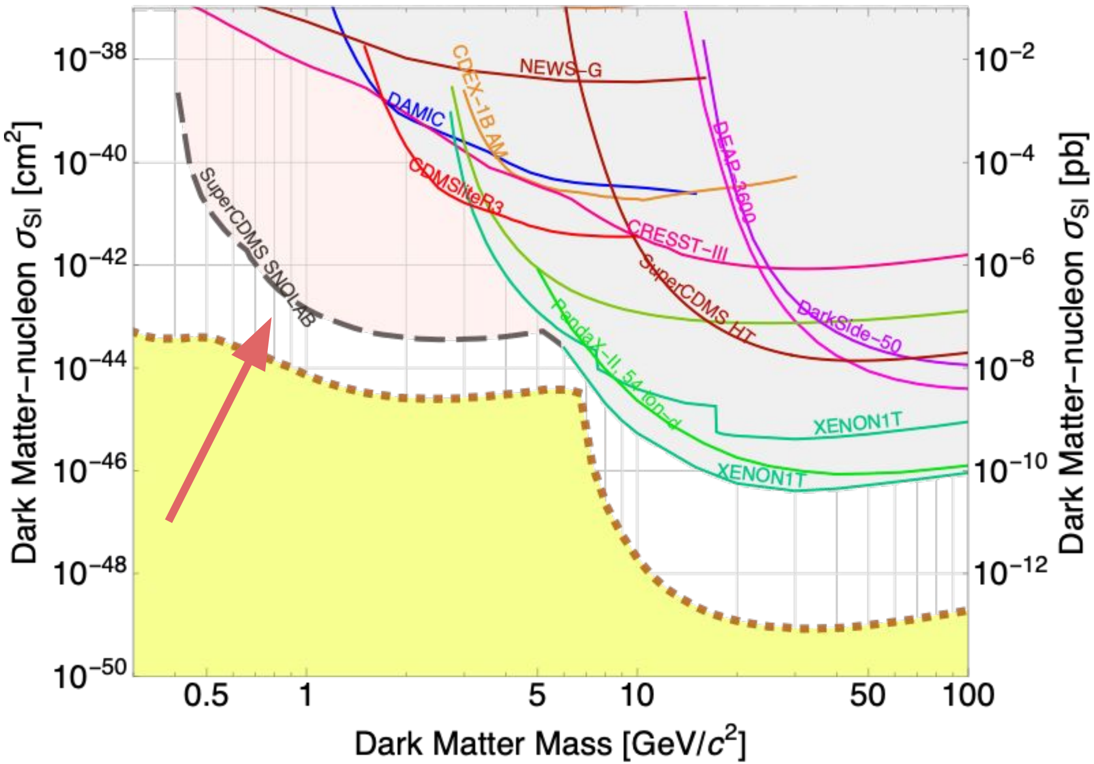
- Seismic: spring loaded platform
- Cryo coolers: soft couplings
  - Braids, bellows
- Copper cans: hanging on Kevlar ropes

The SuperCDMS Dilution Refrigerator

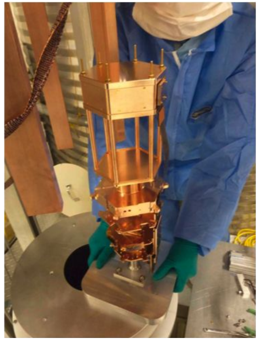
- Big machine!
- Will show up at SNOLAB at the beginning of 2022!
- The rest of the cryostat will follow and get integrated
- Full cryogenic system commissioning early 2023
- Expect cold detectors fall 2023



SuperCDMS SNOLAB Projected Sensitivity



R&D and Detector Testing in Parallel



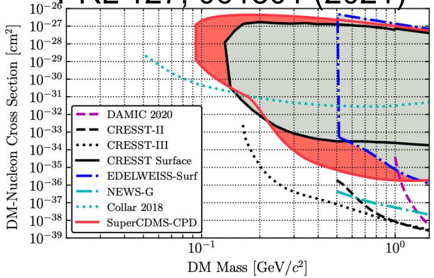
- Testing prototype detectors at CUTE
  - Please refer to the CUTE status talk by Silvia yesterday
- R&D of smaller devices achieving new sensitivities to low mass DM models

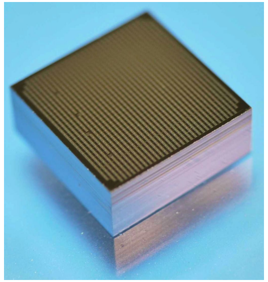
10 gram silicon

3.9 eV resolution

0 V operation

PRL 127, 061801 (2021)





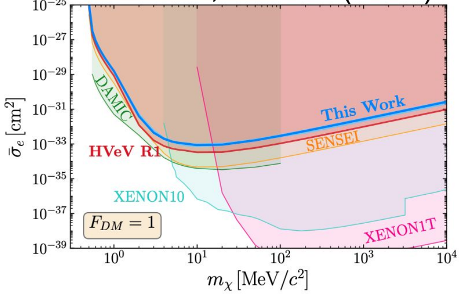
1 gram silicon

2.6 eV resolution

100 V operation

→ 0.03 charge resolution

PRD 102, 091101 (2020)



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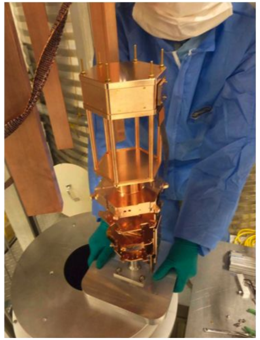

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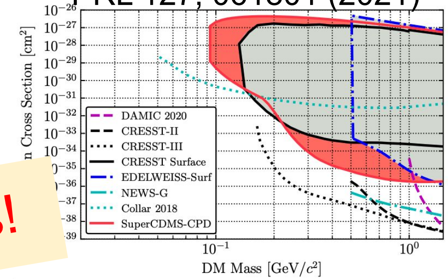
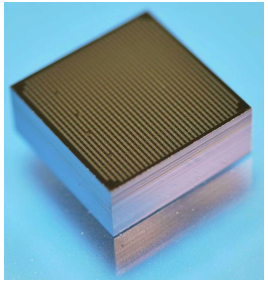


Candidates for future upgrades!



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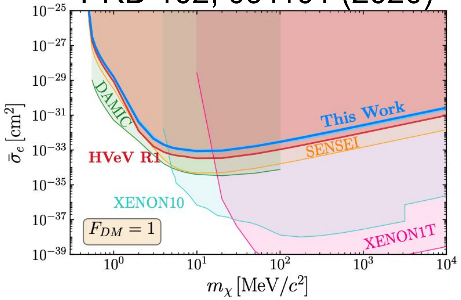
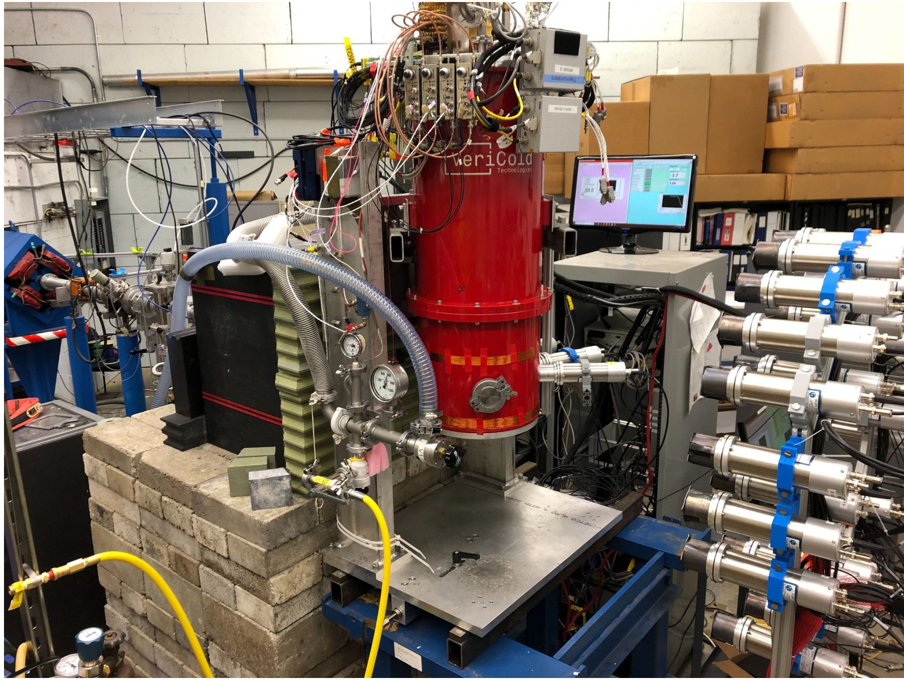


Ionization yield measurement for Si and Ge

- Measuring ionization yield of Si and Ge
    - At energy below 1 keV
    - To be ready for data interpretation as soon as the SNOLAB cryostat turns on
- Classical scattering experiment
    - A monoenergetic neutron beam
    - A Si/Ge detector in a mobile cryostat
    - An array of secondary neutron detectors to tag the recoil angles
- First Si measurement done in 2019
    - Result coming out this fall
- Ge measurement planned for 2022
    - A Canadian-led effort now



Conclusions

- SuperCDMS detectors aiming to reach “neutrino floor” in 1-10 GeV NR mass range
- Technology being adapted in smaller detectors to search for light dark matter, down to
  - **O**(10) MeV via inelastic Nuclear recoil channels (Migdal, Bremsstrahlung)
  - **O**(1) MeV via Electron recoil channels and
  - **O**(1) eV via Dark Photon and Axion-like Particle (ALP) Absorption channels
- SuperCDMS designed a powerful complex cryogenic system that is being installed at SNOLAB
  - SuperCDMS Detector installation – next spring/summer
    - Full system commissioning – beginning of 2023
    - Cold detector – fall 2023
- SuperCDMS is particularly competitive at low masses, including electronic interactions.
- R&D on small/more sensitive devices as well as ionization yield measurements are progressing
- Stay tuned! Experiments are producing results at a fast pace, more sensitive experiments are soon to come online.