SuperCDMS in 10 minutes

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New perspectives 2023, Fermilab, USA
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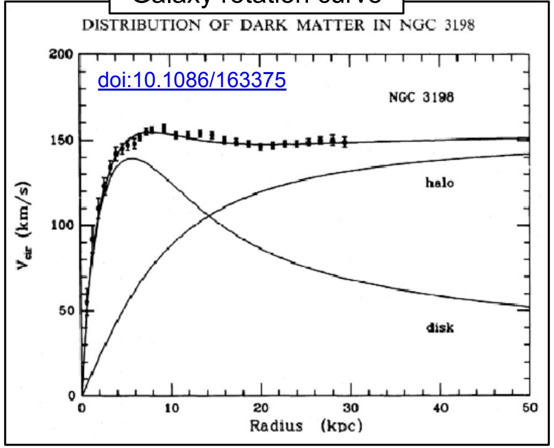
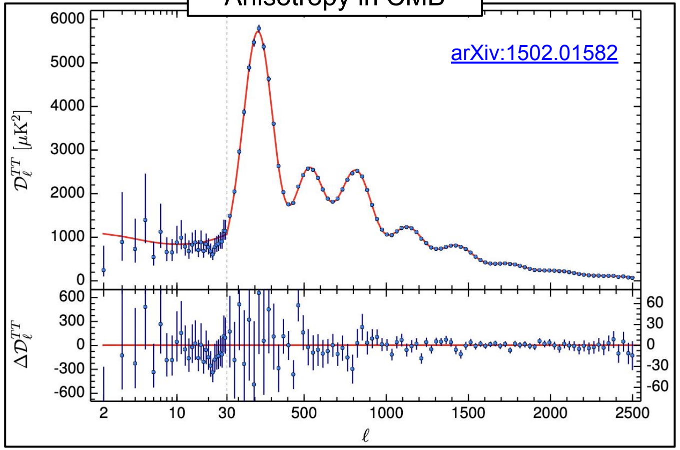
Dark matter

Astronomical observations strongly suggest that ~85% of total matter in the universe is dark matter.

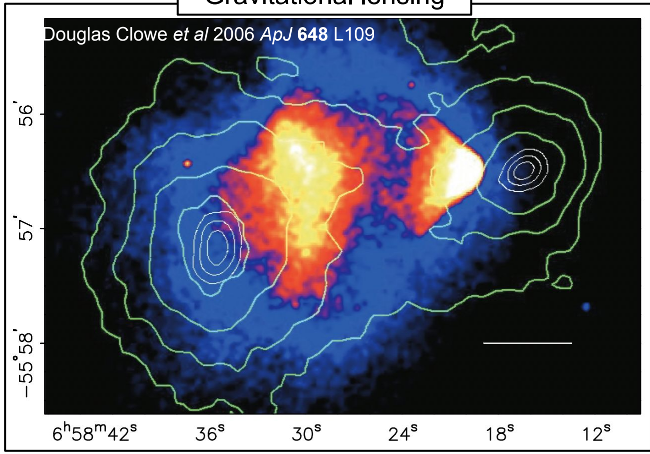
Galaxy rotation curve

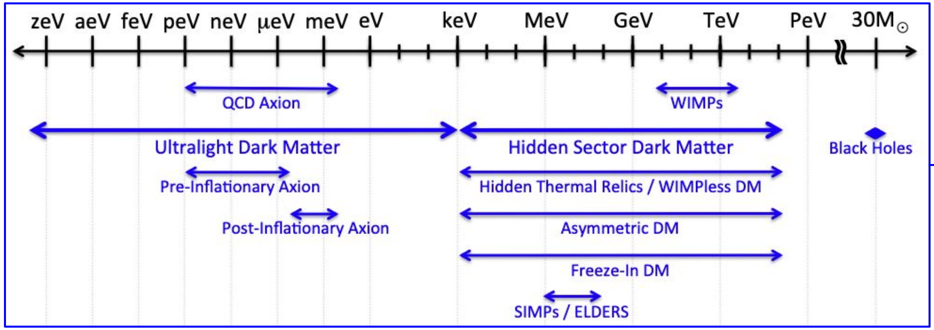


Anisotropy in CMB



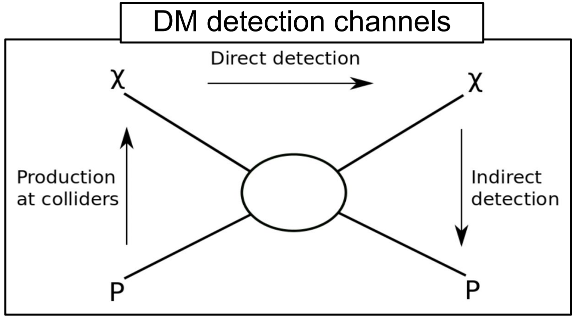
Gravitational lensing



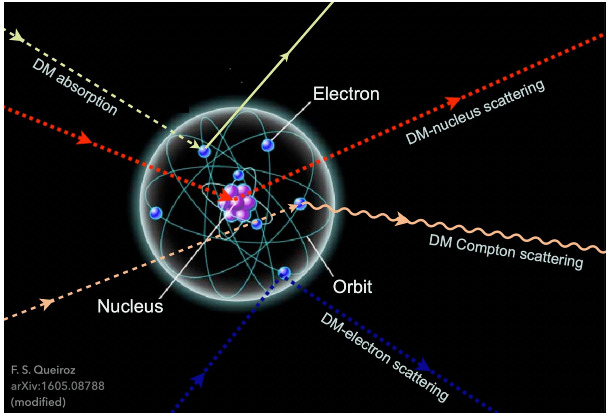


New physics models or extensions of standard model propose various DM candidates.

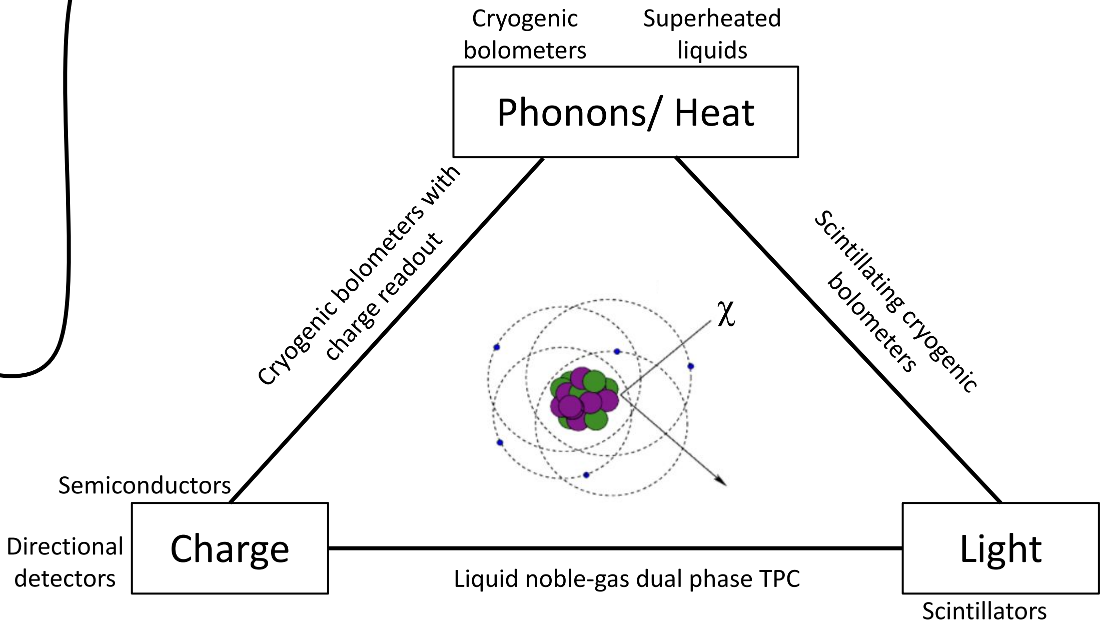
Detection techniques



In direct searches, DM interacts with the atom of detector material → producing signal

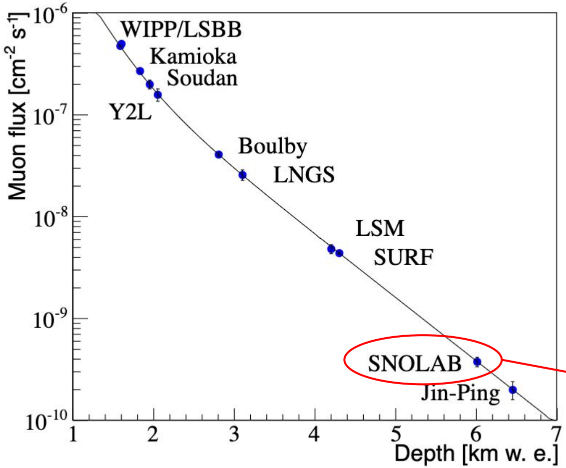


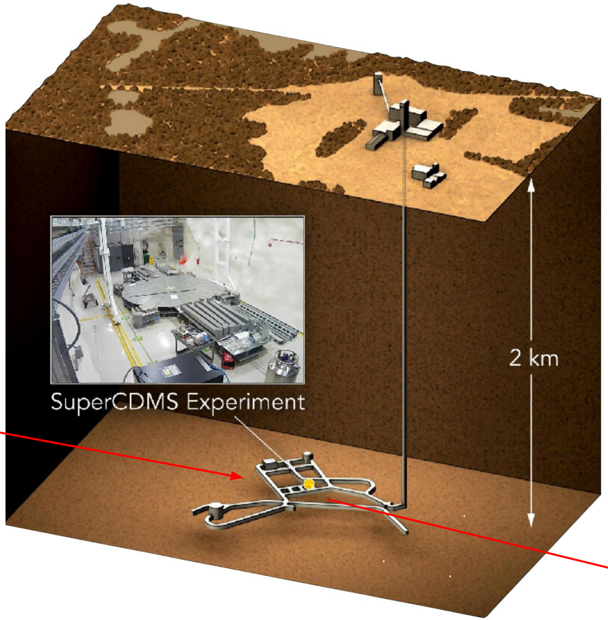
Variety of materials & sensors can be employed to measure the signal in the detector



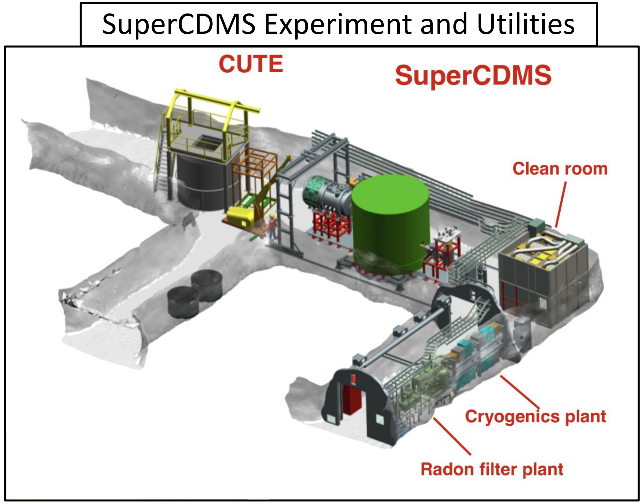
SuperCDMS : charge + phonon readout for DM search

SuperCDMS at SNOLAB



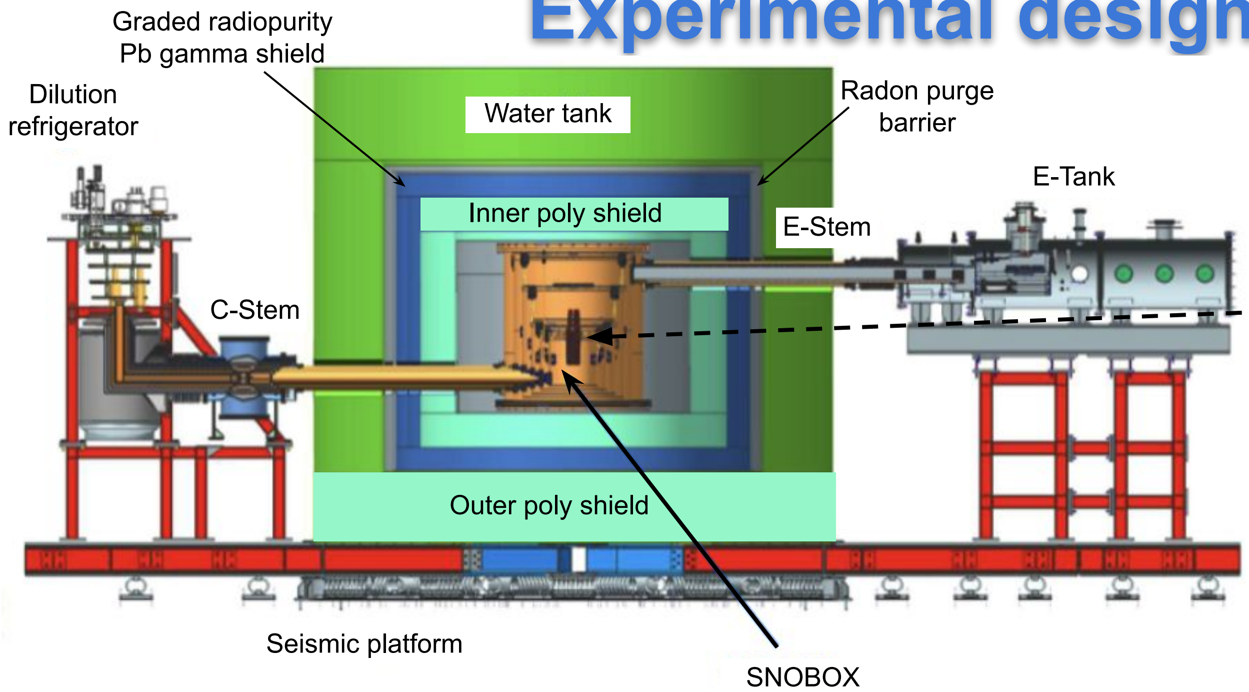


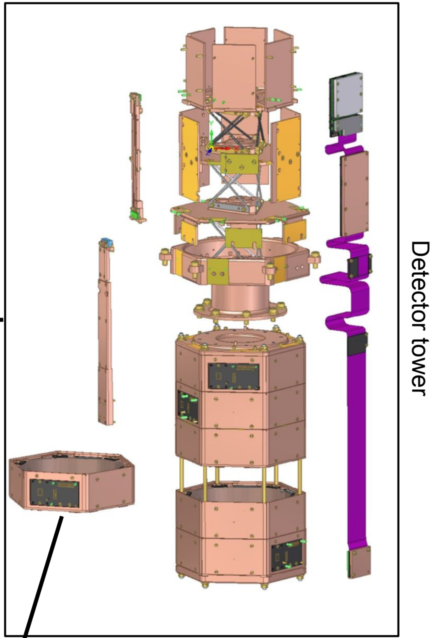
- ➢ Located at SNOLAB facility, Sudbury, Canada
- ➢ Provides 2 km rock overburden
- ➢ Natural shielding from cosmic rays

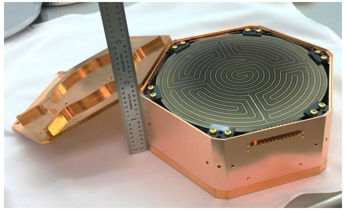


- ➢ **Ambient background at SNOLAB:**
  - 0.27 muons $\mathrm{m^{-2}d^{-1}}$
  - ~ 4000 fast neutrons $\mathrm{m^{-2}d^{-1}}$
  - 4145 ± 50 thermal neutrons $\mathrm{m^{-2}d^{-1}}$
  - Radon: 130 $\mathrm{Bq/m^3}$

Experimental design







Si (0.6 kg) or Ge (1.4 kg) crystal instrumented with phonon and charge sensors

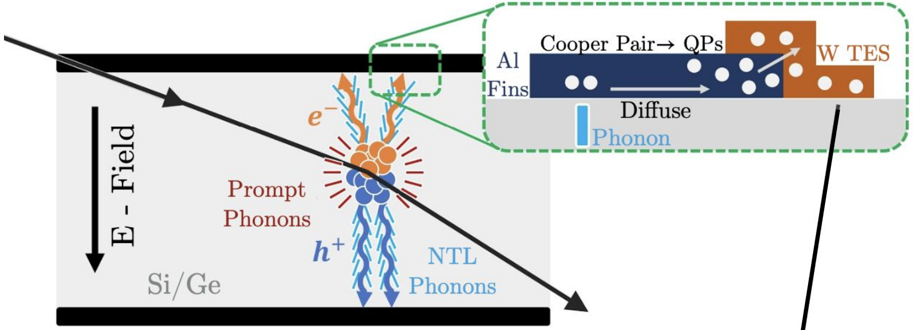
- ➢ **Dilution refrigerator** : cools down to 15 mK
- ➢ **C-stem** : thermal connection to SNOBOX
- ➢ **Layered shielding** : ultra-low background
- ➢ **E-stem** : electrical connection to DAQ
- ➢ **E-tank** : houses readout electronics

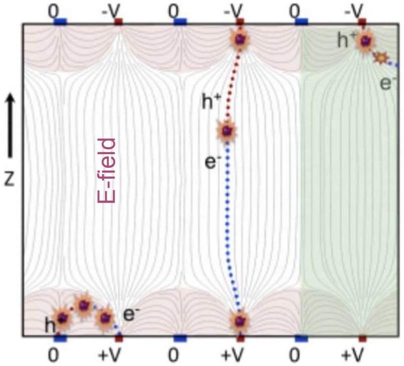
SuperCDMS detection technology

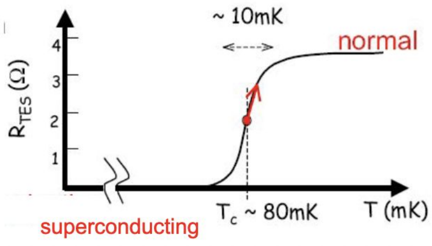
- Particle interacts in the crystal recoils off of either electron (ER) or nucleus (NR), generates heat (phonons) and ionization (charge) signal
- **Phonon** : Measured by **Q**uasiparticle trap-assisted **E**lectrothermal feedback **T**ransition edge sensors
- **Charge** : Measured using interleaved electrodes
- Also, charges drift through E-field producing secondary phonons, amplifying phonon signal: **Neganov-Trofimov-Luke (NTL) effect**

$$E_{tot} = E_r + \underbrace{N_{eh}\, e\, V_b}_{} = E_r \left(1 + Y(E_r) \frac{e\, V_b}{\varepsilon} \right)$$

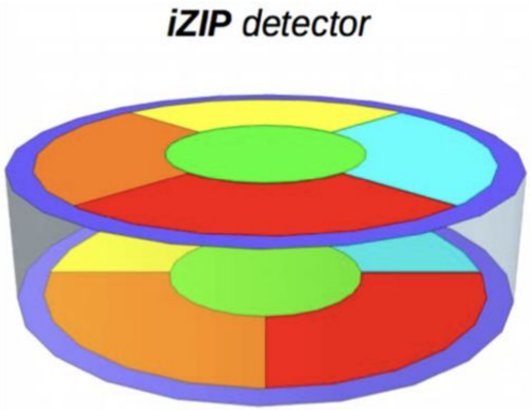
E_{tot}: Total phonon energy; E_r: Recoil energy; $N_{eh}\, e\, V_b$: NTL-amplified phonon energy; $Y(E_r)$: Ionization yield $Y_{ER} \sim 1$; $Y_{NR} < 1$ (energy dep.)

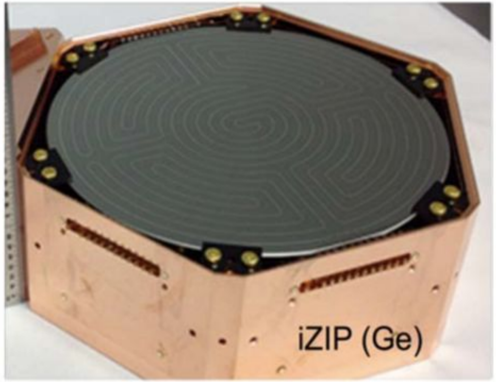




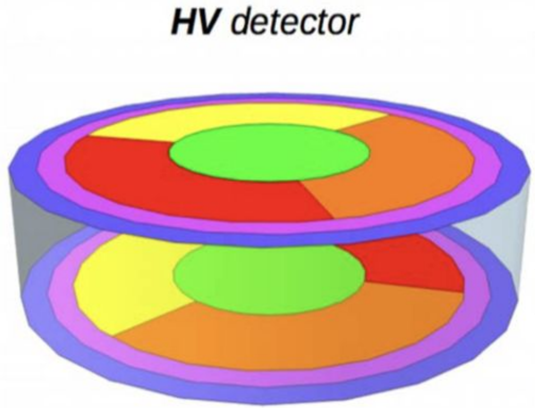


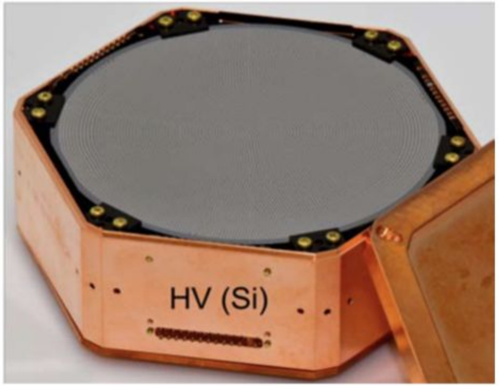
SuperCDMS detectors





- **iZIP**:
  - Interleaved charge and phonon readout on both sides
    - 12 phonon channels
    - 4 charge channels
  - Low voltage operation ($\Delta V < 10V$)
  - Capable of ER vs NR discrimination
  - E-field-shaping → Surface event rejection

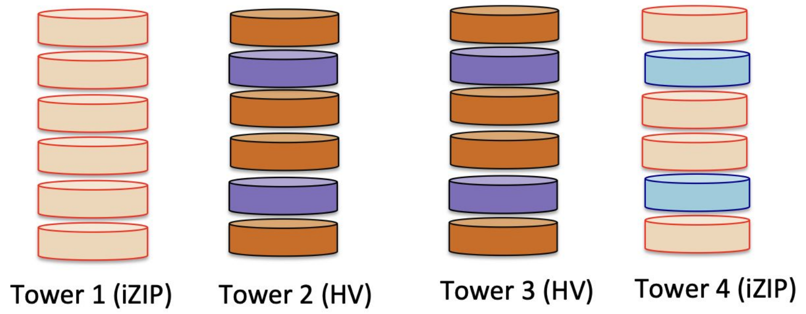




- **HV**:
  - Phonon only readout on both sides
    - 12 phonon channels
  - High voltage operation ($\Delta V \sim 100V$)
    - NTL amplification of phonon signal
    - Lower threshold readout
    - Better energy resolution
  - QET optimized for higher phonon collection efficiency

SuperCDMS : Science reach

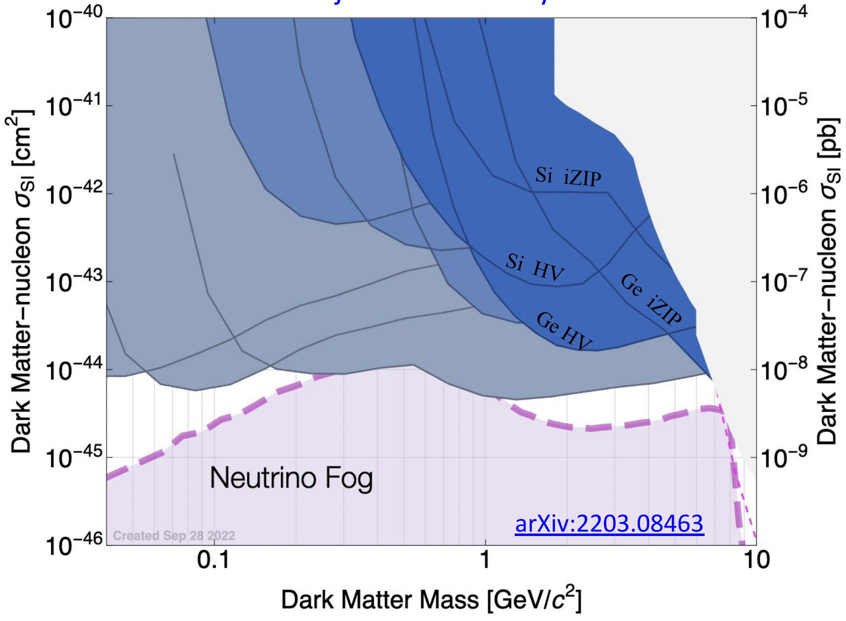
- Initial payload : 4 Towers
  - 24 Detectors : 12 iZIP, 12 HV



	Germanium	Silicon
HV	Lowest threshold for low mass DM Larger exposure, no ^{32}Si bkgd	Lowest threshold for low mass DM Sensitive to lowest DM masses
iZIP	Nuclear Recoil Discrimination Understand Ge Backgrounds	Nuclear Recoil Discrimination Understand Si Backgrounds

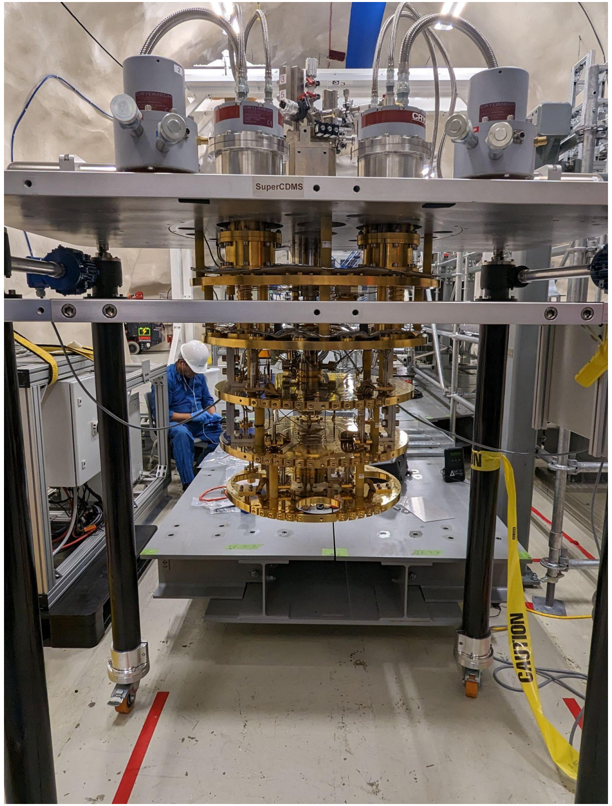
Scope of future bg improvements and detector upgrades.

Projected sensitivity

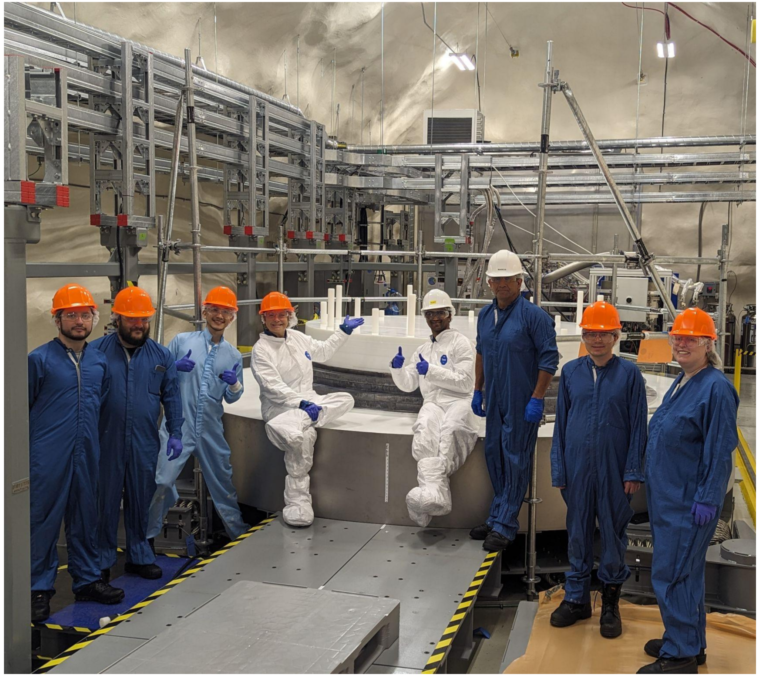


- Current experimental constraint
- Expected SuperCDMS SNOLAB sensitivity (w/ initial payload)
- Expected sensitivity with future bg improvements & in-hand detector technology
- Expected sensitivity with future bg improvements & significant detector upgrades

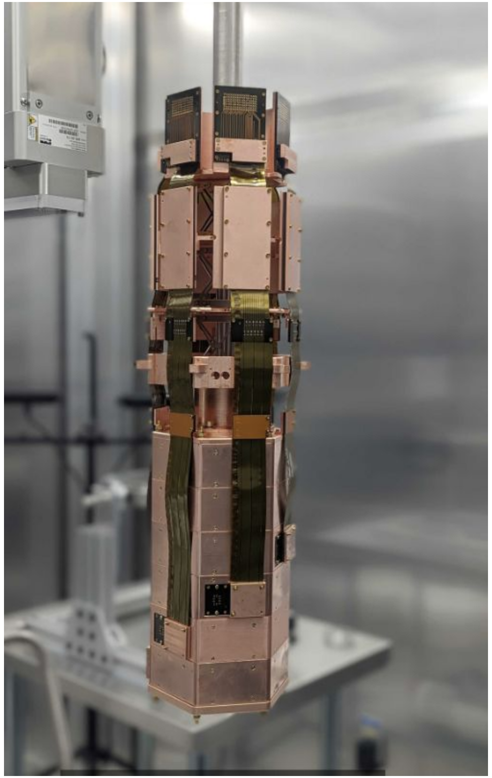
Installation in progress



Dilution refrigerator
near C-stem



Shield base assembly
on seismic platform



Detector tower in
SCDMS cleanroom

Conclusion

- SuperCDMS installation is in full swing.

- Two detector towers already arrived at SNOLAB last month → testing is ongoing.
    - Remaining two will arrive soon.

- Commissioning starts in 2024.

- Complementary detector technologies and design will provide opportunity for potential DM discovery and world leading limits.

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Backup slides