SuperCDMS in 10 minutes

Valentina Novati on the behalf of the SuperCDMS collaboration

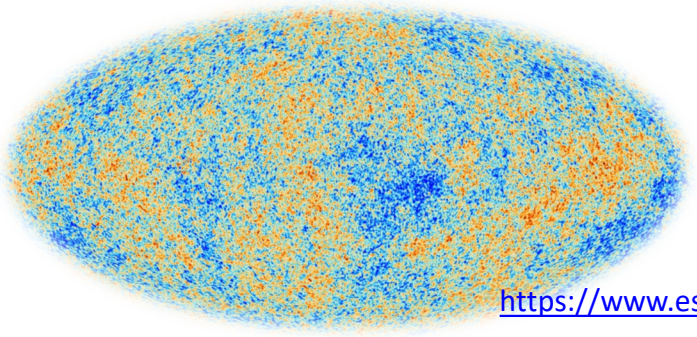
New Perspectives 2022, Fermilab

FERMILAB-SLIDES-22-085-PPD

Dark matter

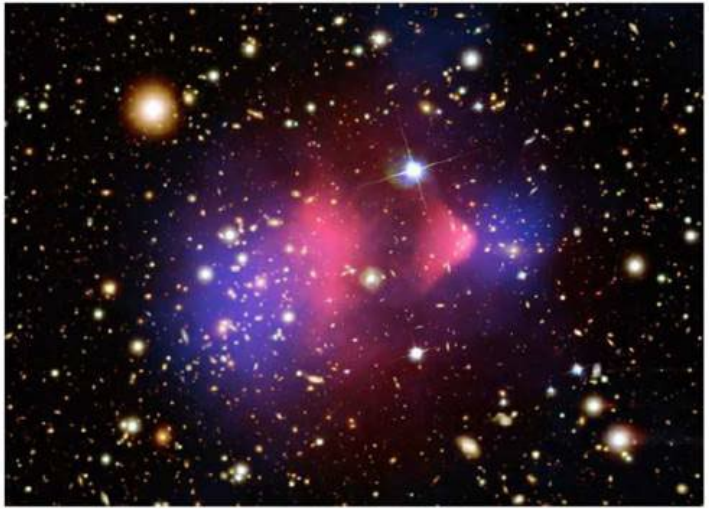
Astrophysical observations give strong evidence for dark matter (DM):

Cosmic Microwave Background



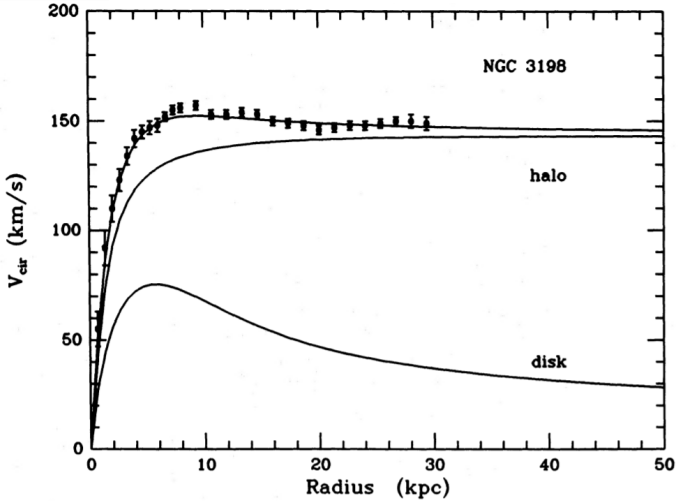
https://www.esa.int/

Gravitational lensing



Arnaud *et al.*, arXiv:0902.4890 (2009)

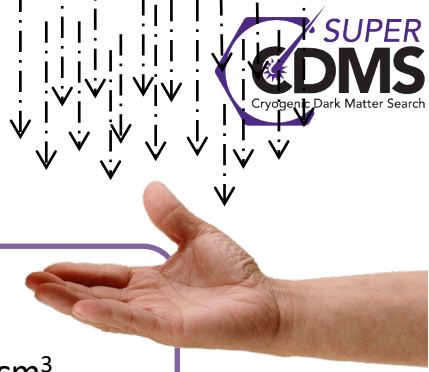
Galaxy rotation curves



T. S. van Albada et al, ApJ, 295:305,1985

And many others …

Dark matter direct detection



- Dark matter passes through the Earth all the time
  - ~100 000 dark matter particles / cm^2 / second
    About **20 million** dark matter particles / hand /second
  - but very small probability of interaction…

Assuming:
mass = 60 GeV/c^2
density = 0.3 GeV/cm^3
relative velocity 220 km/s

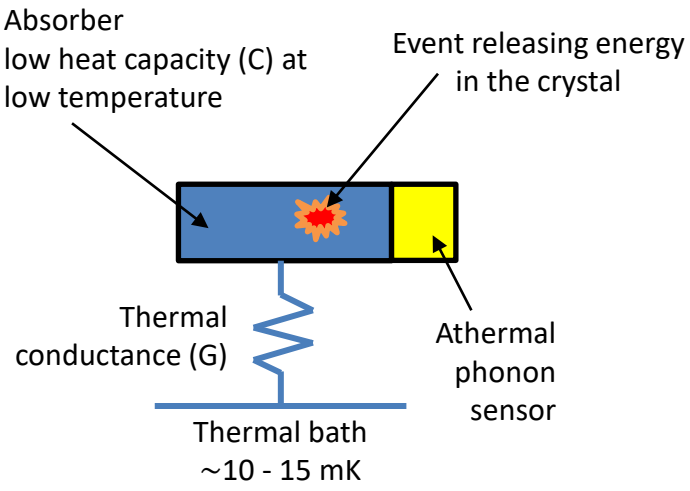
- Direct detection dark matter (DM) experiments
  weakly interacting massive particles (WIMPs) ⟶
  elastically scattering on target nucleus

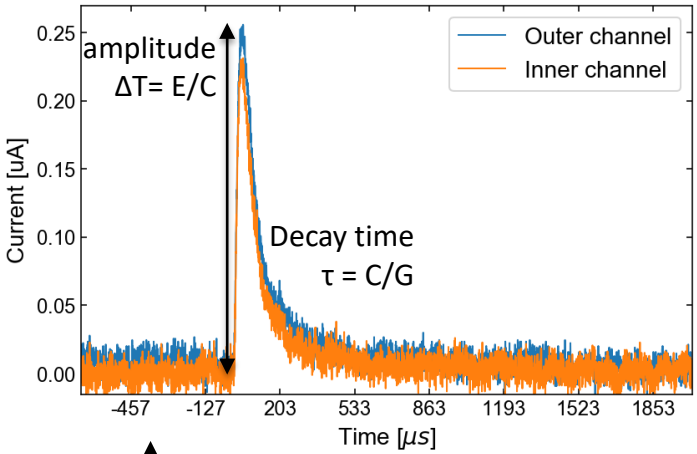
- Experimental requirements
  - Ultra sensitive detectors
  - Low backgrounds
  - Long exposure

Ultra sensitive detectors: Calorimetric technique

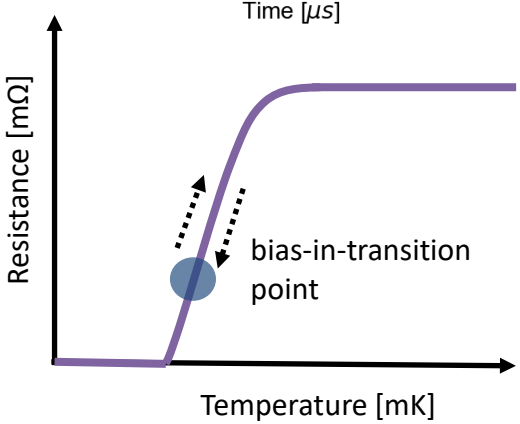
We want to measure the energy of a dark matter particle recoiling on detector lattice

- Cryogenic calorimeters – temperatures ~10 - 15 mK
- Phonon mediated detectors





Temperature variations are measured with transition-edge sensors (TES)



Ultra sensitive detectors: Neganov-Trofimov-Luke effect

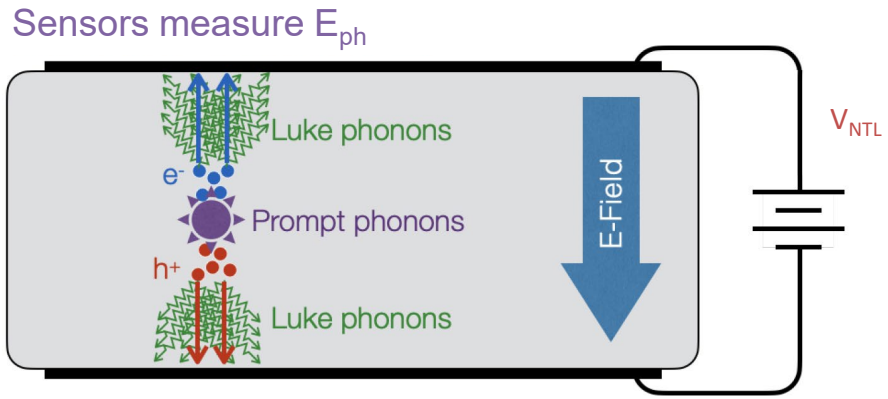
Charge signals are amplified
with an electric field across the crystal

$$E_{ph} = E_{recoil} + E_{NTL} = E_{recoil}\left(1 + Y(E_{recoil})\frac{e \cdot V_{NTL}}{\varepsilon}\right)$$

Total phonon energy

Initial energy deposited in the absorber

Neganov-Trofimov-Luke (NTL) gain



B. S. Neganov and V. N. Trofimov, Otkryt. Izobret., 146, 215 (1985)
P. N. Luke, J. Applied Phys. 64,6858 (1988)

Ultra sensitive detectors: SuperCDMS detectors

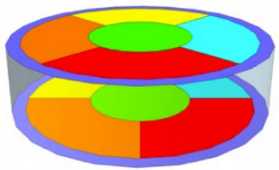
Two absorber materials: germanium (1.4 kg) and silicon (0.6 kg)
10 cm diameter and 3.3 cm thick
Two detector designs:

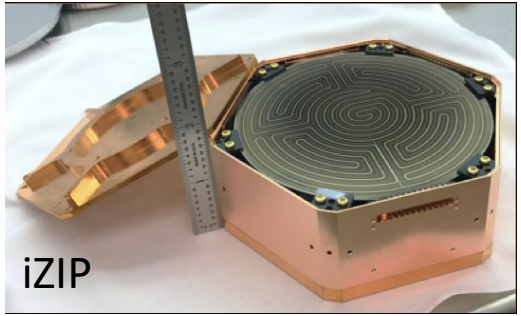
Agnese, R. et al., Phys. Rev. D 95 (2017)
https://arxiv.org/pdf/2203.08463.pdf

iZIP

Low NTL bias voltage (~6-8 V) gives background-free mode

- Charge and phonon readout
- Provides 10^6 electron and nuclear recoil discrimination and surface rejection

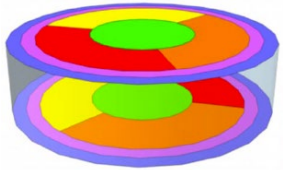


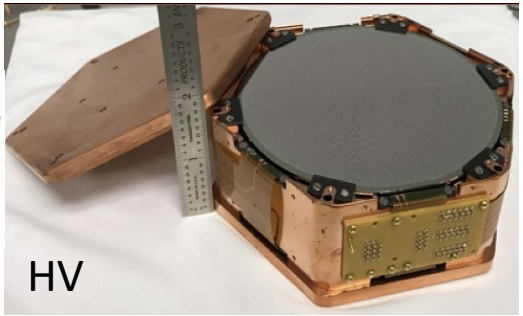


HV

High NTL bias voltage (~100 V) pushes to lower thresholds

- Only phonon signal readout
- Optimized for phonon energy resolution and collection efficiency

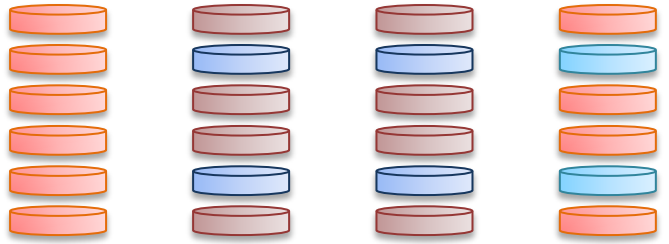




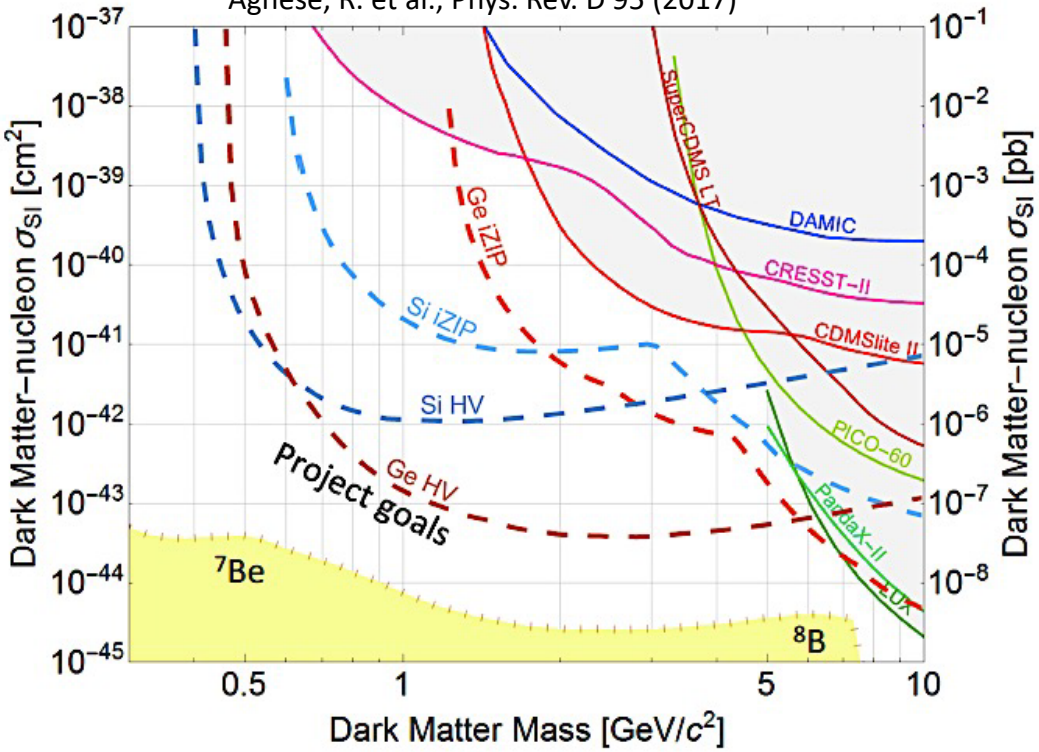
SuperCDMS sensitivity

4 detector towers with 6 detectors each operated in the first run

	iZIP		HV	
	Ge	Si	Ge	Si
number of detectors	10	2	8	4
Voltage bias (V)	6	8	100	100



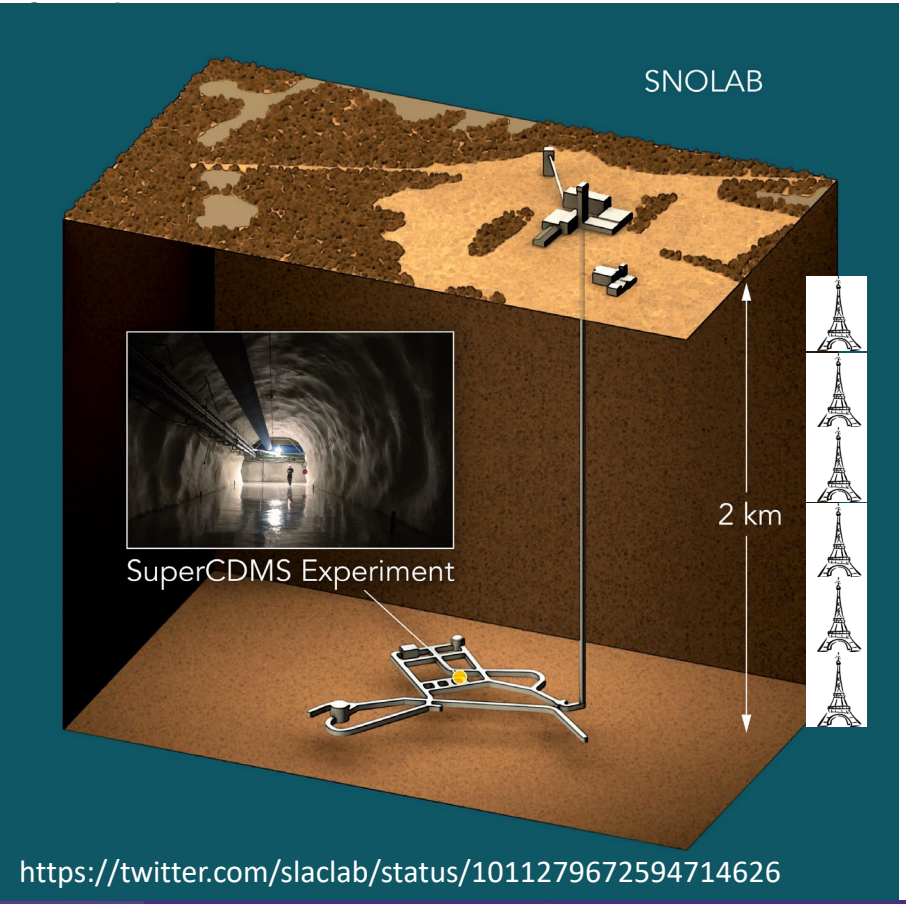
Agnese, R. et al., Phys. Rev. D 95 (2017)



The first SuperCDMS tower consisting of 6 Ge iZIP detectors has been tested successfully at SLAC, the other 3 towers will follow shortly

https://arxiv.org/pdf/2203.08463.pdf

Low backgrounds: deep-underground SNOLAB facility



https://twitter.com/slaclab/status/1011279672594714626

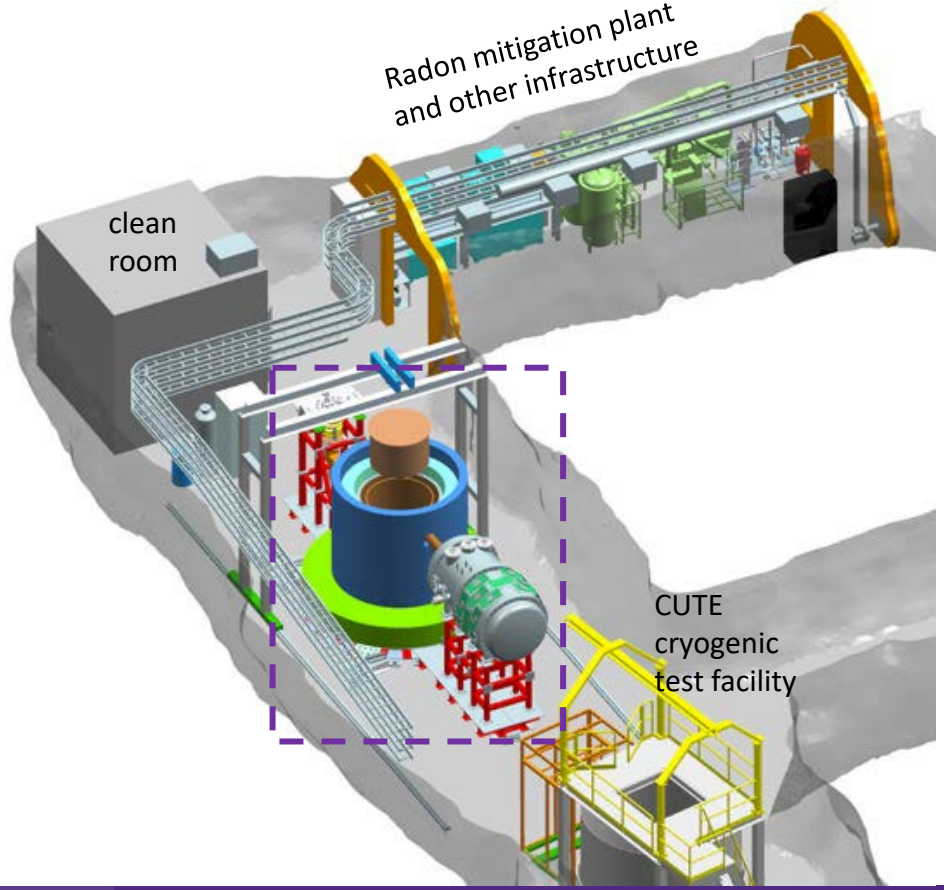
The SuperCDMS experiment is hosted at SNOLAB (Lively, Canada), a class-2000 clean room 2 km deep underground.

Eiffel Tower (Paris, France)
1063-feet height

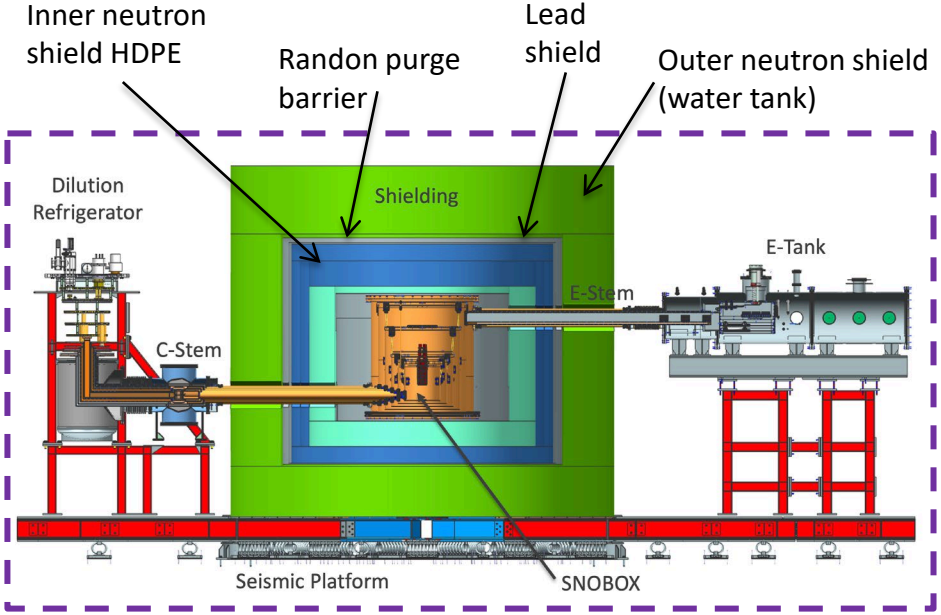
SuperCDMS is 6 Eiffel towers deep underground

Reduction of cosmic radiation background corresponding to 6010 meters of water equivalent

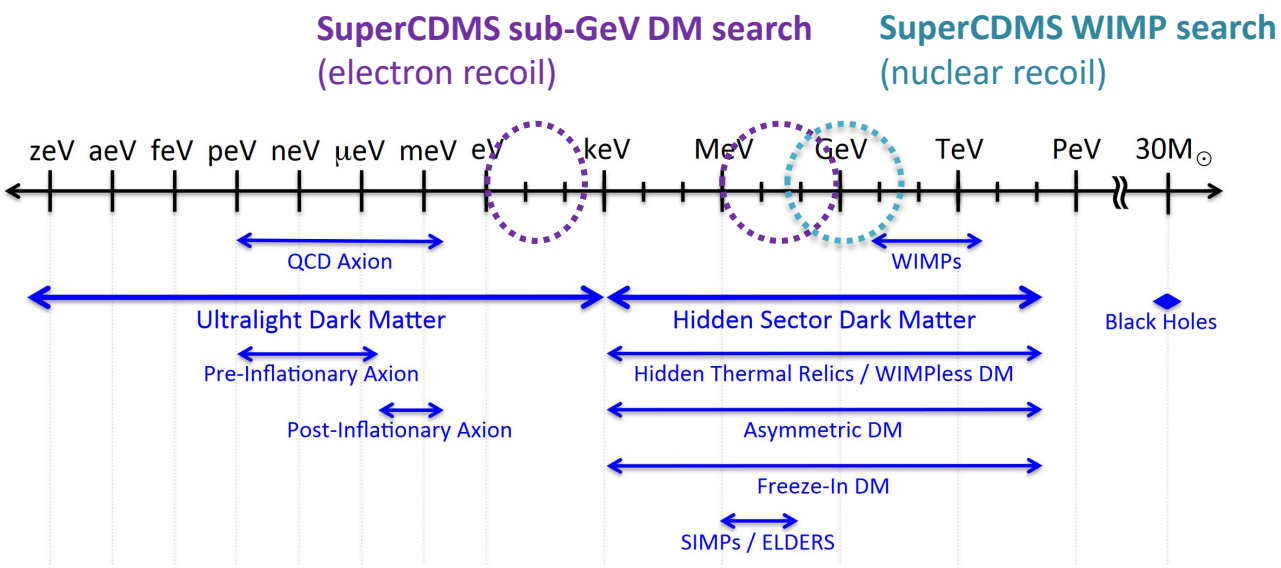
Low backgrounds: SuperCDMS cryogenic facility at SNOLAB



SuperCDMS SNOLAB Experiment is being installed now



SuperCDMS electron recoil and photon absorption



US Cosmic vision
ArXiv:1707.04591

1 gram SuperCDMS HVeV detectors are also sensitive to sub-GeV dark matter through electron recoil signal search. A lot of exciting work is done at the NEXUS facility at Fermilab

→ See Huanbo Sun's talk for more information: "SuperCDMS HVeV program at the NEXUS facility at Fermilab"

Takeaways

The SuperCDMS experiment

- will employ silicon and germanium cryogenic calorimeters equipped with transition edge sensors
- is hosted in a low-background underground cryogenic facility at SNOLAB (Lively, Canada)
- will search for direct interaction dark matter signals below 10 GeV/c^2
- is under construction… Stay tuned for new results!