SuperCDMS
Cryogenic Dark Matter Search

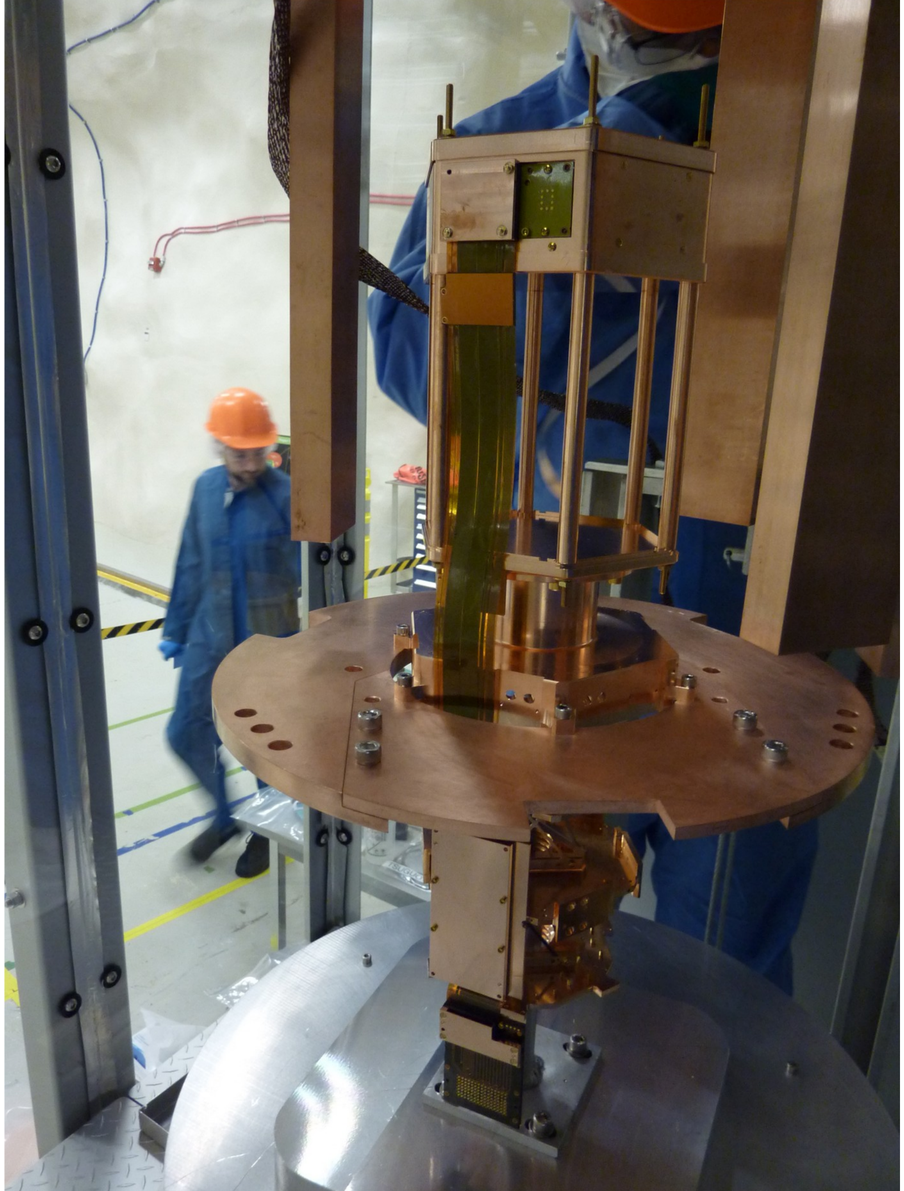
at SNOLAB

Université de Montréal

Alan Robinson

May 29 2022

IPP 50th Anniversary Symp.

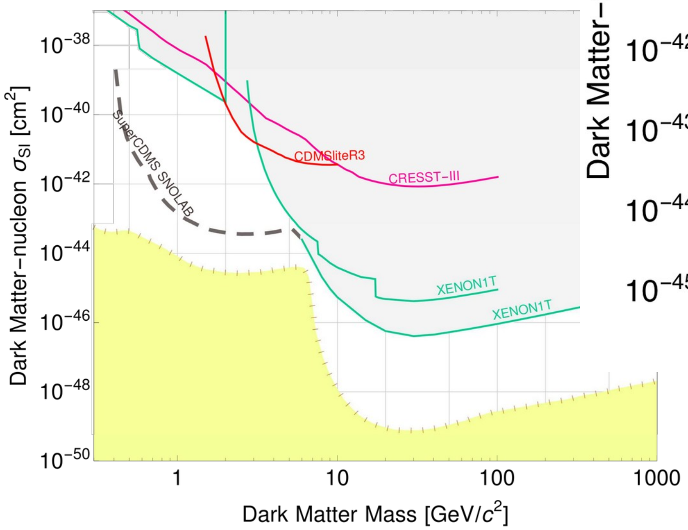


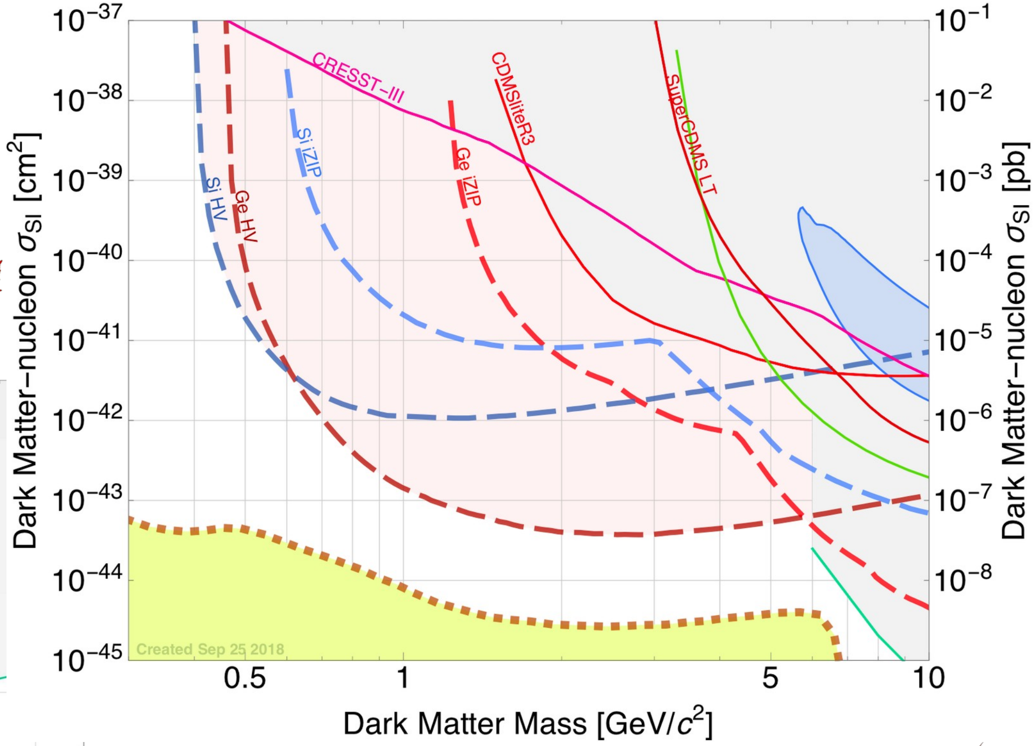
First Installation of a SuperCDMS detector at SNOLAB
Prototype HV Ge into CUTE

Generation 2 search for low-mass dark matter

Mission:
Vastly improve dark matter-nucleon scattering sensitivity for masses below 10 GeV/c²

- Funded 2016 (DOE, NSF, CFI)





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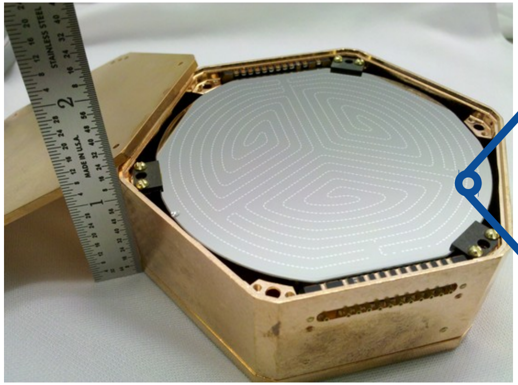
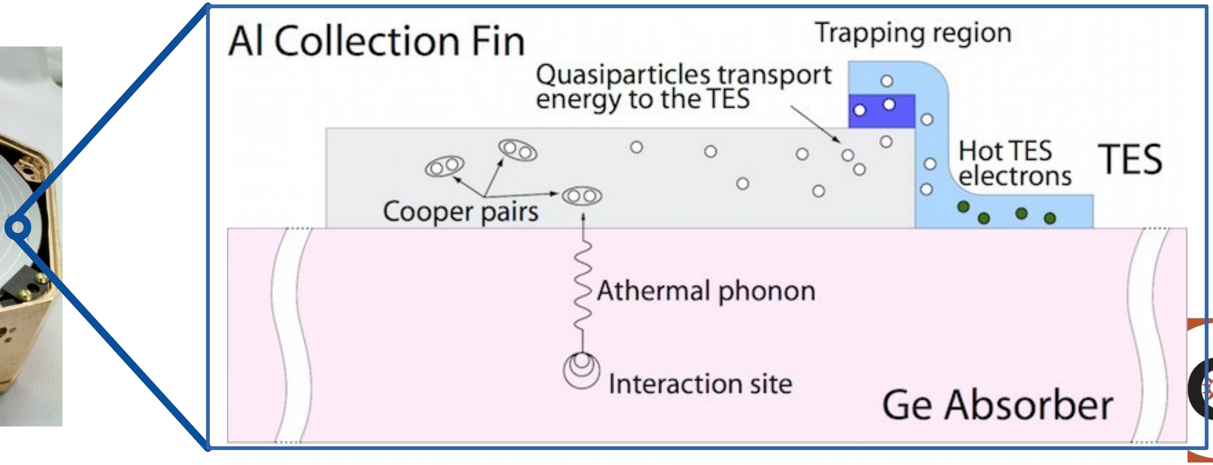
SUPER CDMS

SuperCDMS detector technology

QET – Quasi-particle trap assisted Electrothermal feedback Transition edge sensor

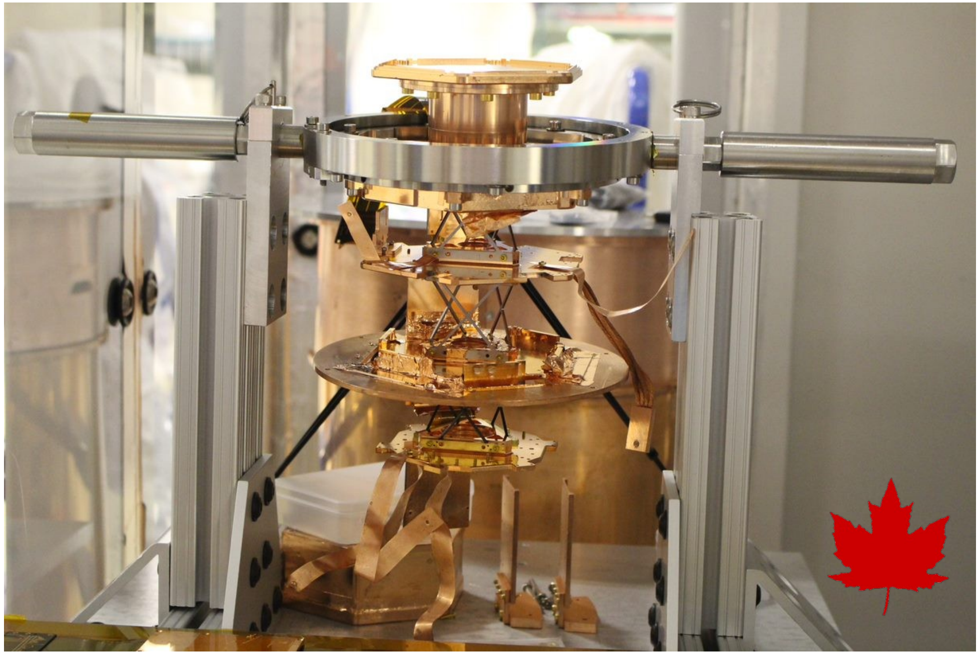
- Energy deposited in kg-scale detector concentrated on mg-scale sensors
- 5-10 eV resolution for athermal phonons



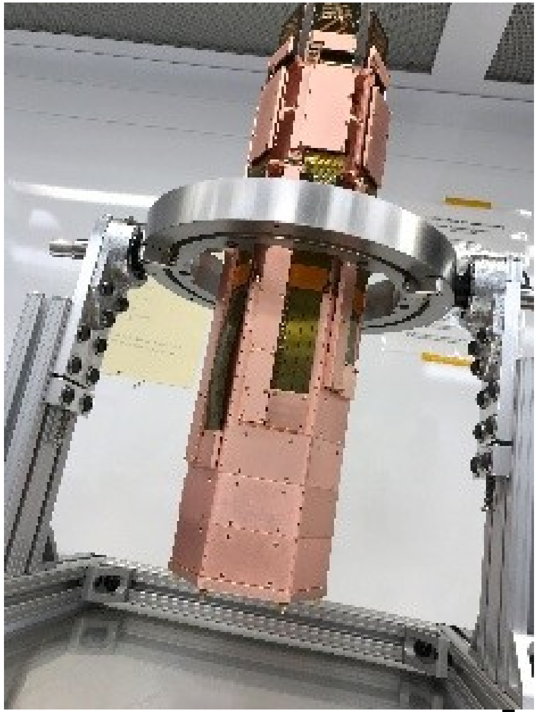


SuperCDMS detector technology

SuperCDMS Tower : Up to 6 detectors stacked on a cryogenic stage



CUTE tower ready for detector installation on Thursday



First production tower in March

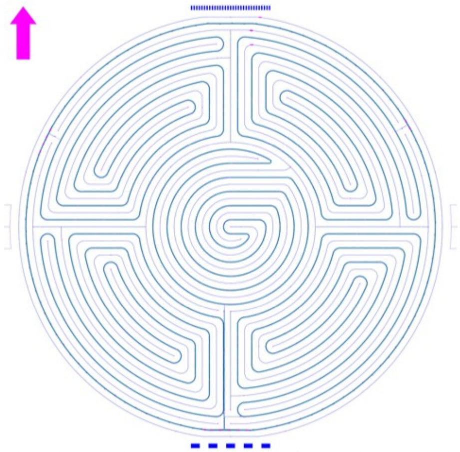
SuperCDMS detector technology

2 flavours

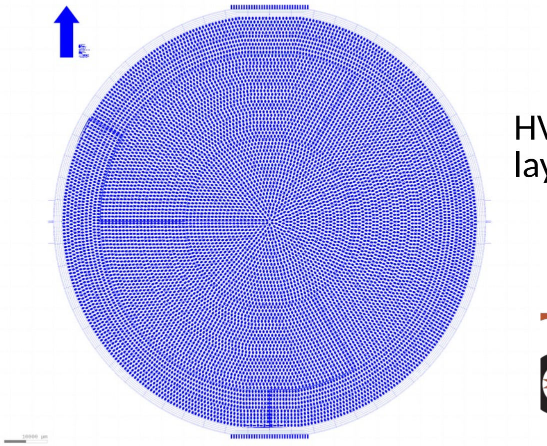
- iZIP: independant charge readout
- HV: new optimized phonon resolution

2 materials

- Si
  - Lower mass sensitivity
- Ge
  - Larger exposure



iZIP sensor layout

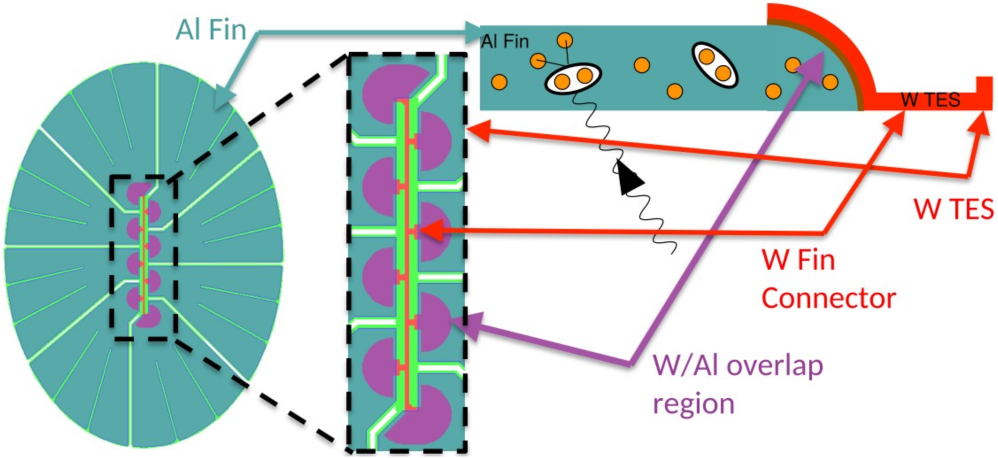


HV sensor layout

Optimizing QETs

vs. previous SuperCDMS Soudan

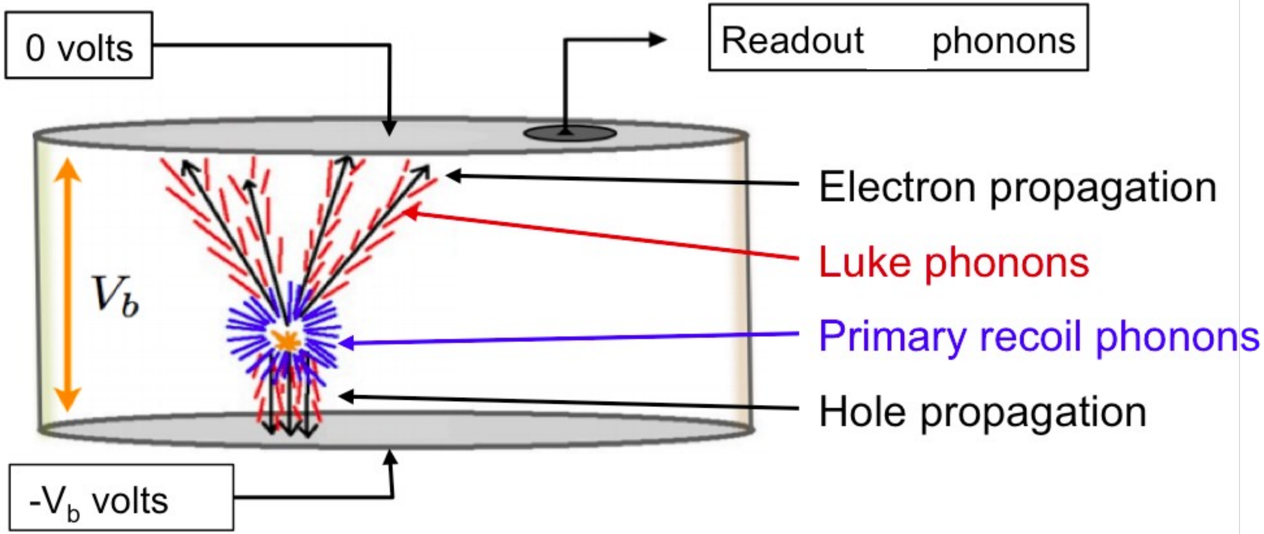
- Lower Tc
  - Resolution scales as T_c^3
  - $(40\ mK/90\ mK)^3 = 0.09$
- Optimize geometry
  - More overlap between Al and W
  - Optimization for lower T_c
- Eliminate charge readout (HV)



Ionization in HV mode

Athermal (high-frequency) phonons produced by

- Heavy ion stopping
- Neganov-Trofimov-Luke (NTL) effect
  - Energy released from charge drifted across the potential of the crystal.

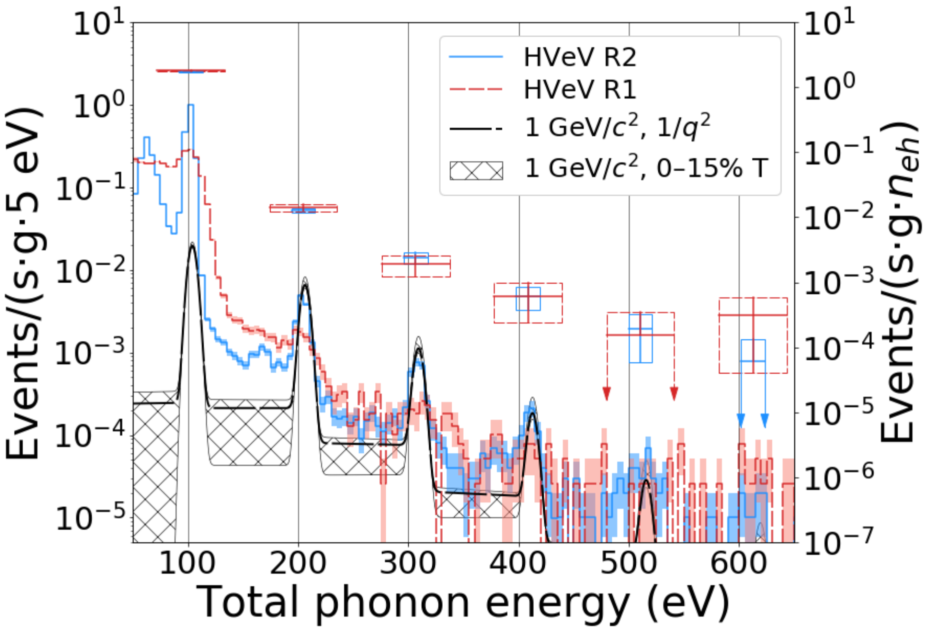


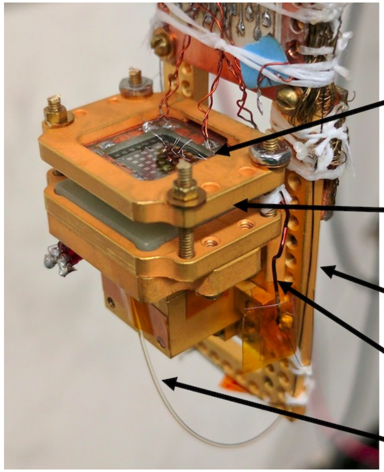
$$E_{phonon} = E_{recoil} + V \times n_{eh}$$

Demonstrated sensitivity

Testing with g-sized detectors

- Electron/hole counting





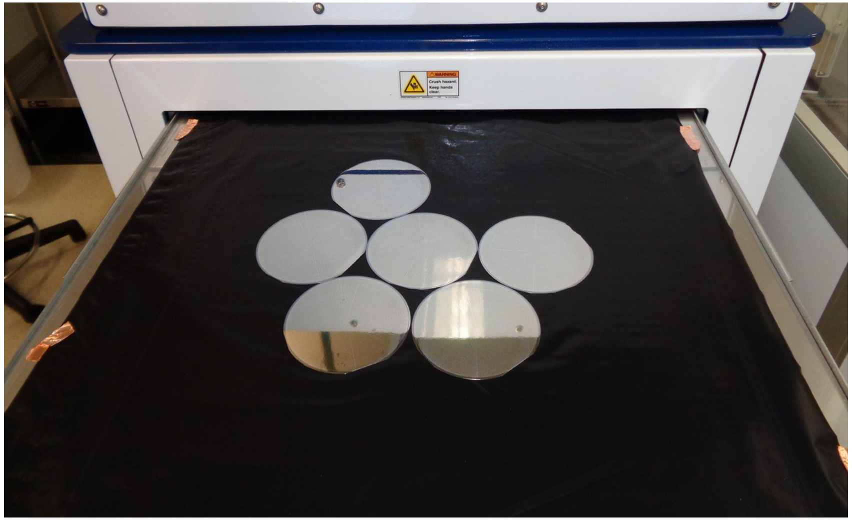
$$E_{phonon} = E_{recoil} + V \times n_{eh}$$

PRD **102** 091101 (2020)

SUPER CDMS

SuperCDMS SNOLAB backgrounds

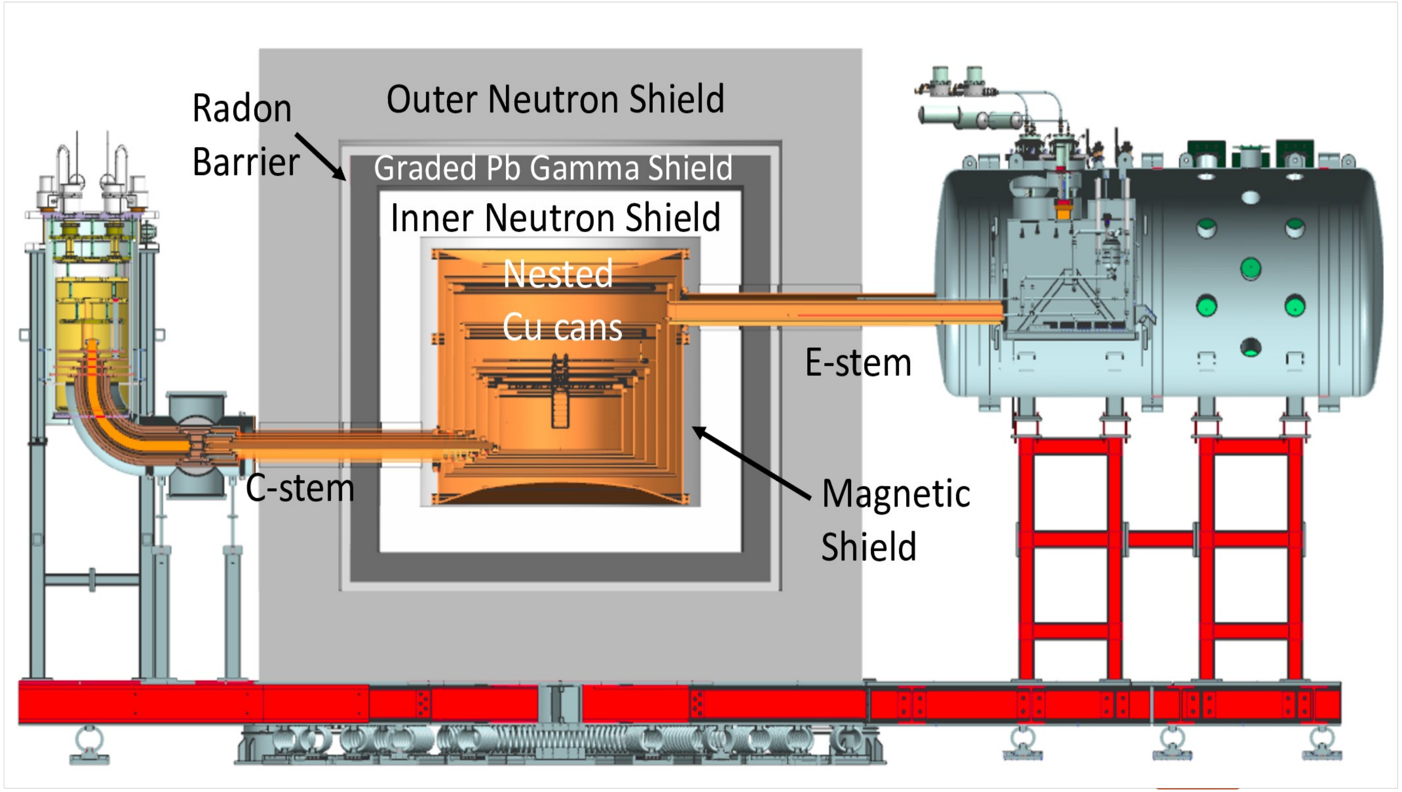
- Electron recoils (for which HV detectors are sensitive)
  - ^{3}H, ^{60}Co from cosmogenic activation
  - ^{32}Si from atmospheric deposition
  - Background energy differential rate reduced by ER/NR energy scale ratio
- Radon deposition
- Neutrons, cosmic rays
  - Minimized by shielding and siting at SNOLAB.



SuperCDMS SNOLAB facility

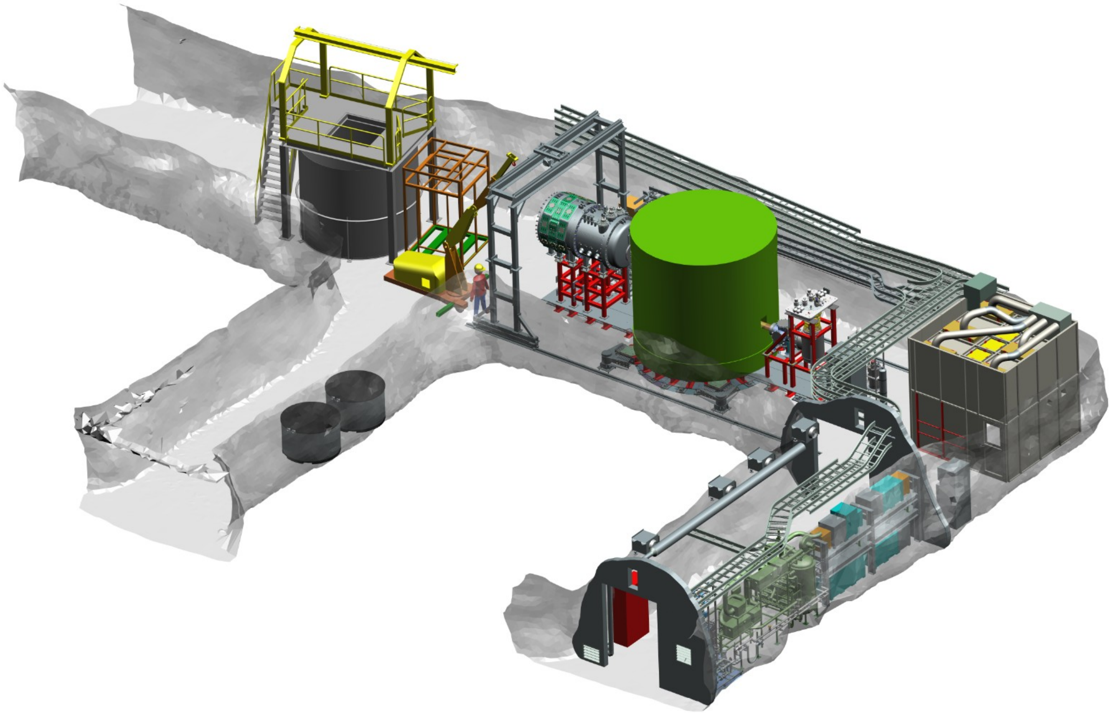
A campus for cryogenic dark matter detectors.

- 6800 m.w.e. overburden
- Capacity for 7 towers (4 initially, 31 w/ upgrades)
- ν-dominated NR bg
- O(0.1) dru γ background
- 15 mK base temperature



A campus for cryogenic dark matter detectors

- Low-radon clean-room
- Collaborating with Cryogenic Underground TEst facility (CUTE)
  - Rapid-turn around detector testing
  - First data from SuperCDMS SNOLAB towers.



- Pushing detector sensitivity
  - SNOWMASS CF1 arxiv: 2203.08463

Quantity	Detector		Detector Upgrade Scenario					
			A		B		C	
	Type	Size	Si	Ge	Si	Ge	Si	Ge
phonon energy resolution [eV]	0V	1 cm^3	0.5		0.13	0.28	0.013	
		10 cm^3	2.5	4.5	0.7	1.5	0.07	0.14
	HV	10 cm^3	3.3	4.5				
		SNOLAB-sized	12.	21.	4.	6.	0.6	0.7
	iZIP	10 cm^3	2.5	4.5	0.7	1.5		
		SNOLAB-sized	12.	21.	3.4	6.		
	piZIP	10 cm^3	3.3	4.5	1.2	1.5	0.19	0.21
		SNOLAB-sized	12.	21.	4.	6.	0.6	0.7
ionization energy resolution [eV_{ee}]	iZIP	10 cm^3	50.	60.	17.	17.		
	piZIP	10 cm^3	8.	11.	3.	6.	0.5	0.5
		SNOLAB-sized	30.	53.	10.	15.	1.5	1.8
ionization leakage current [Hz/gm]	HV		1.0		0.1		0.01	
impact ionization probability	HV		0.02		0.01		0.01	
charge trapping probability	HV		0.01		0.01		0.001	

Table 2: ***Detector upgrade scenarios.*** *We provide the quantitative improvements for each detector type and size and for each scenario (*`Det A`*,* `Det B`*,* `Det C`*). These improvements are described in detail in §2.1.4. The detector sizes are explained in §2.1.2. The* `Det C` *10 cm^3 piZIP scenarios are greyed out because the continuous ionization model used for the piZIP becomes invalid for such good effective ionization resolution.*

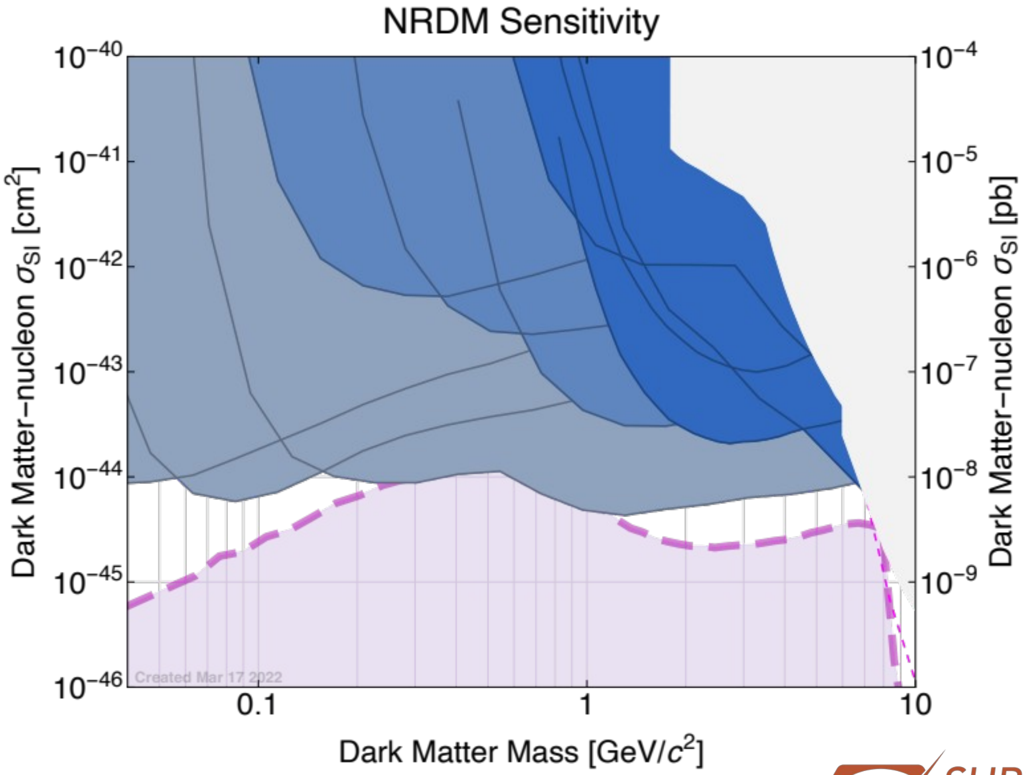
A campus for low-mass dark matter exploration

- Pushing detector sensitivity
  - will cover motivated low-mass dark matter models
  - SNOWMASS CF1 arxiv: 2203.08463

Current project

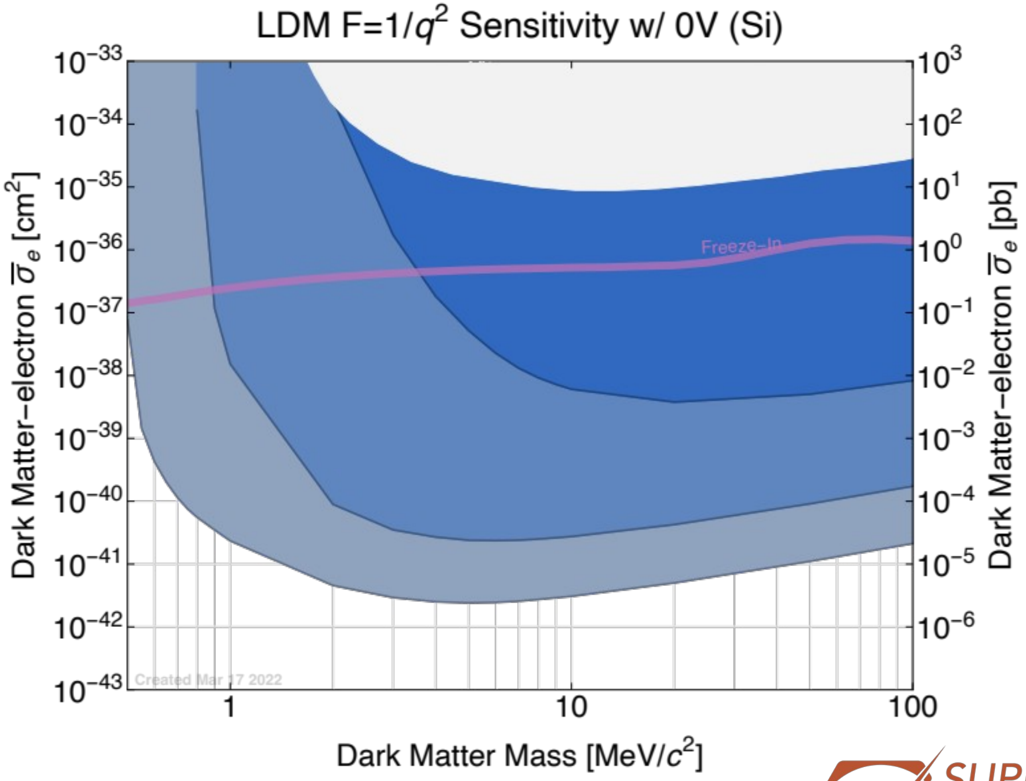
In-hand R&D

Facility potential



A campus for low-mass dark matter exploration

- Pushing detector sensitivity
  - will cover motivated light-dark matter models
  - SNOWMASS CF1 arxiv: 2203.08463



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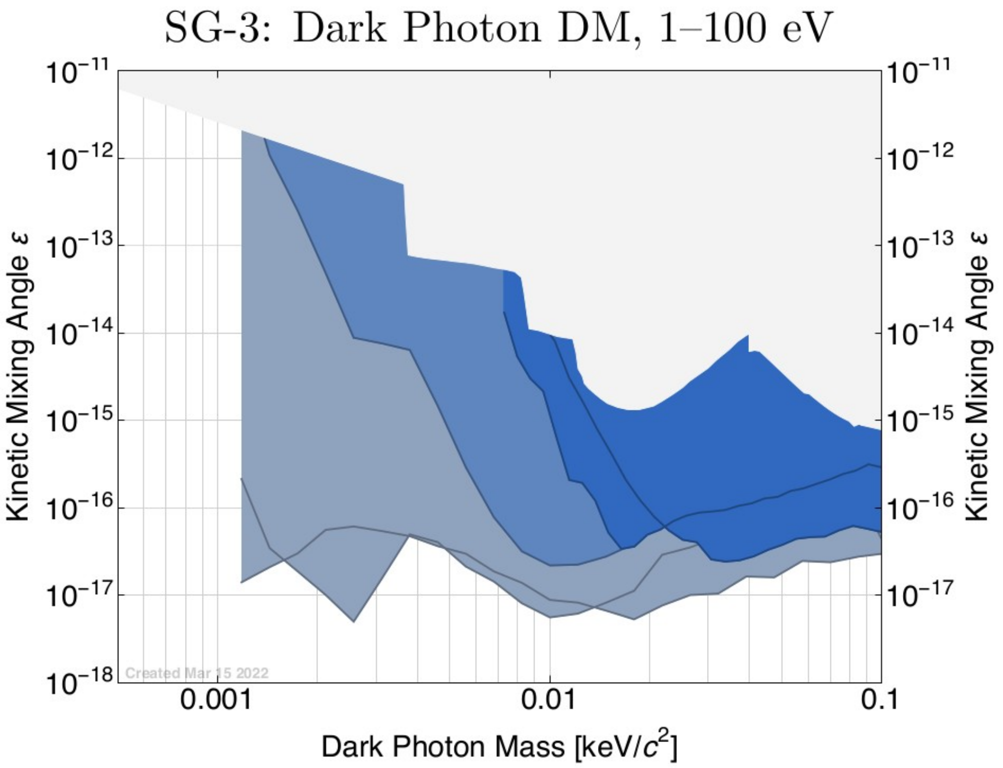
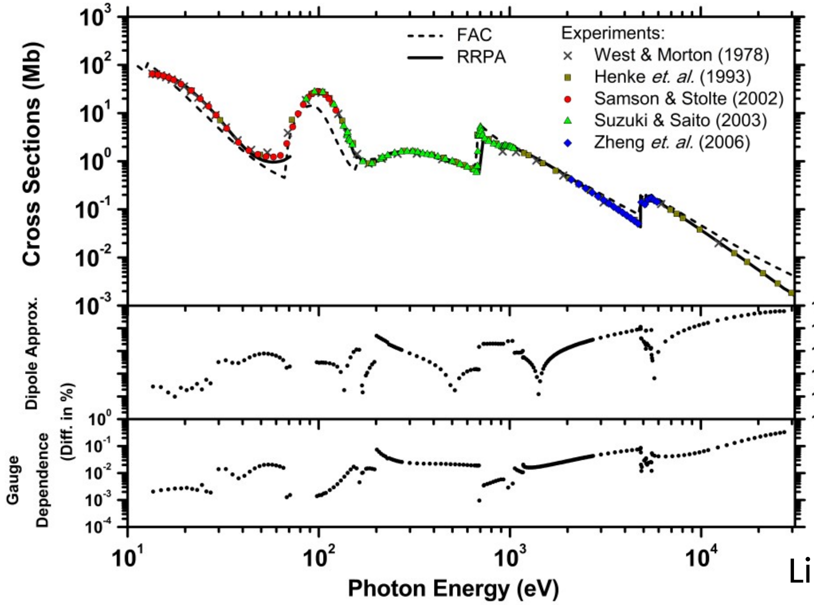


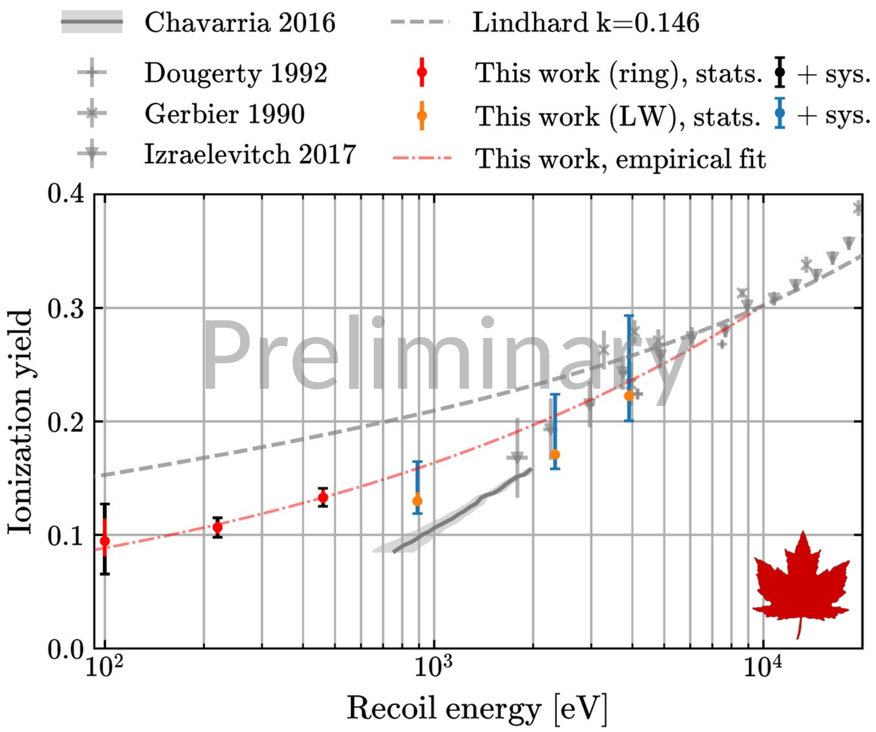
Construction Progress

Construction through 2022-23

Understanding ~eV energy depositions

- Lowest-energy calibrations of ionisation yield.
- Modelling new effects





Liu, Wu, Chi, Chen, PRD **102** 121303 (2020)

SUPER CDMS

One giant leap in sensitivity at SNOLAB

An underground cryogenic campus

- Commisioning next year

Ongoing efforts

- Comprehensive prototyping
- Off-site calibrations
- Backgrounds mitigation
- Opportunistic early DM searches