The SuperCDMS SNOLAB Experiment

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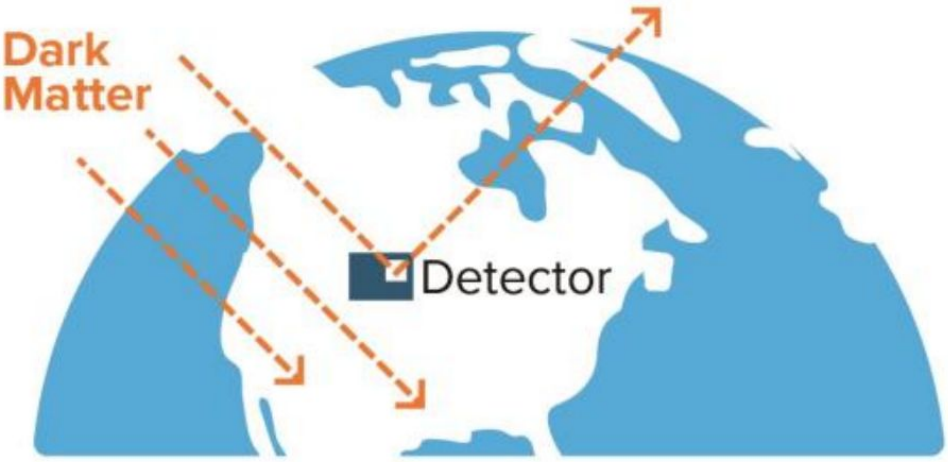
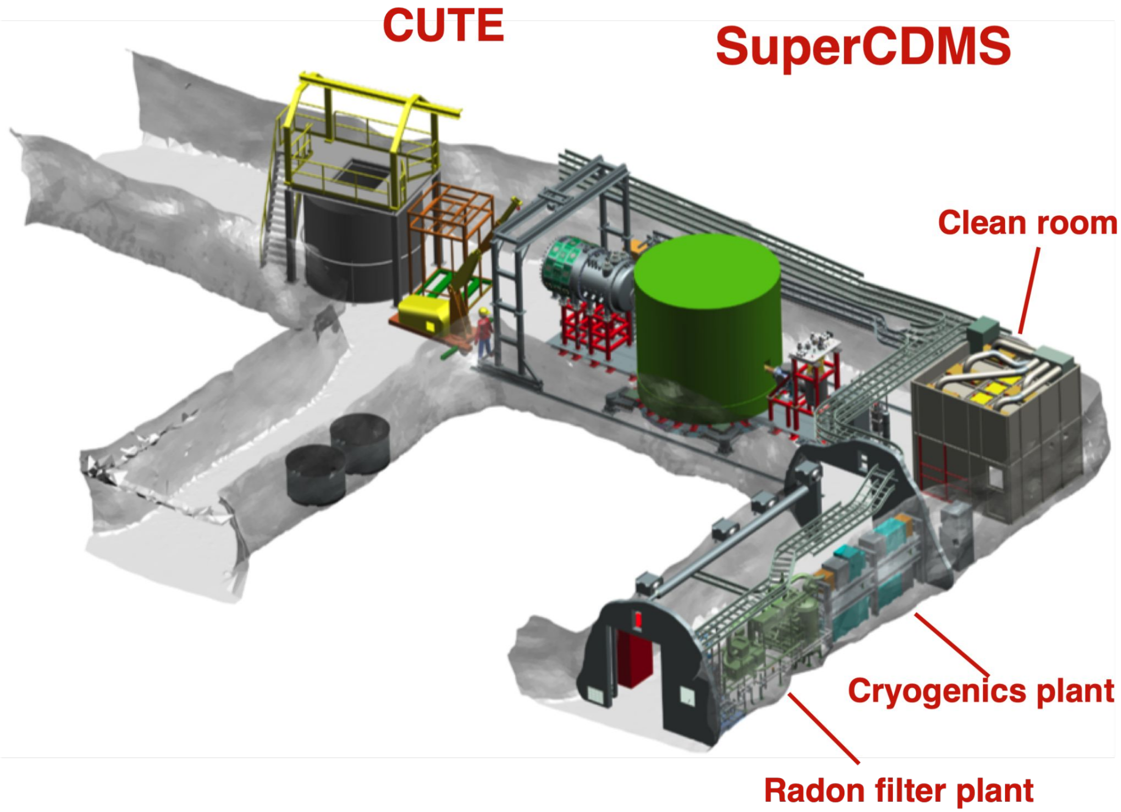
For the SuperCDMS Collaboration

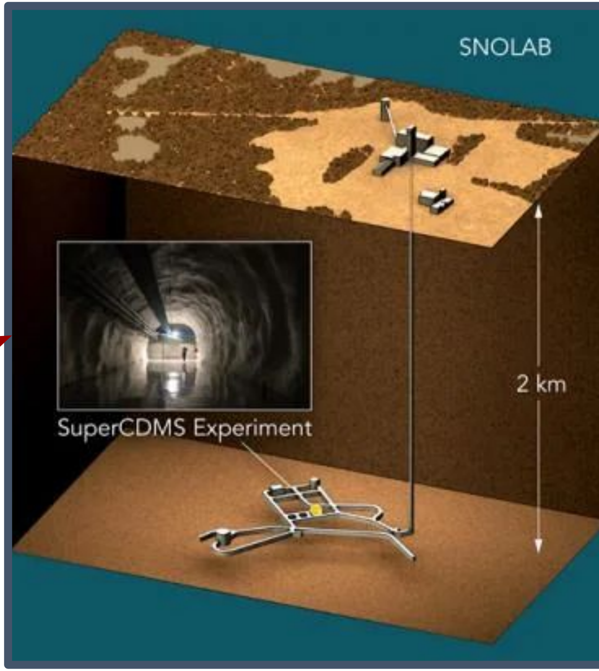
LOW RADIOACTIVITY TECHNIQUES
2026
WORKSHOP X

Dark matter direct detection



SuperCDMS @ SNOLAB

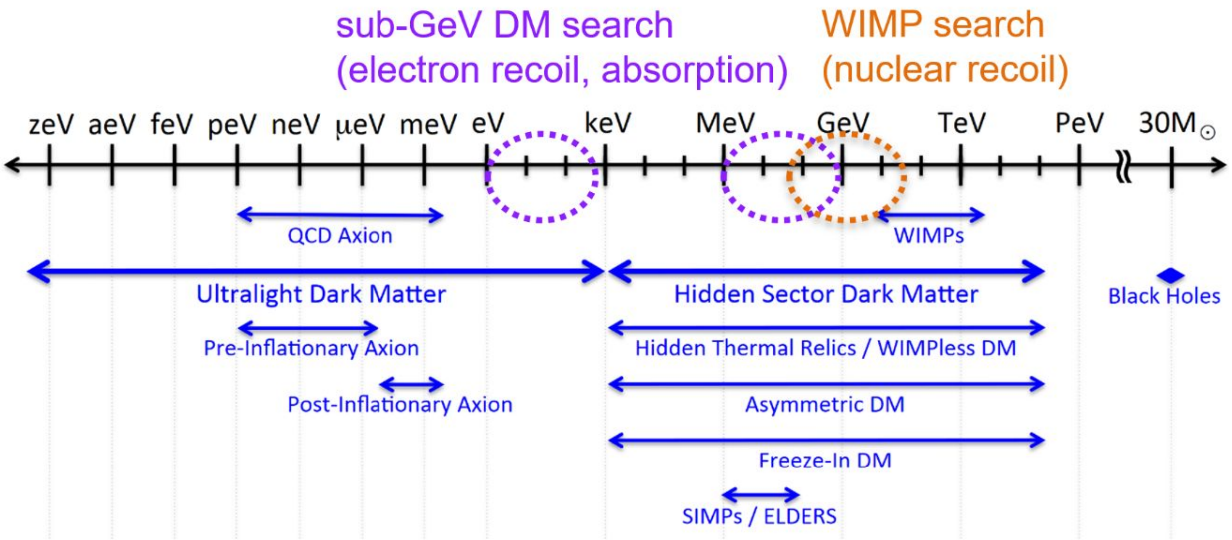




Dark Matter Candidates

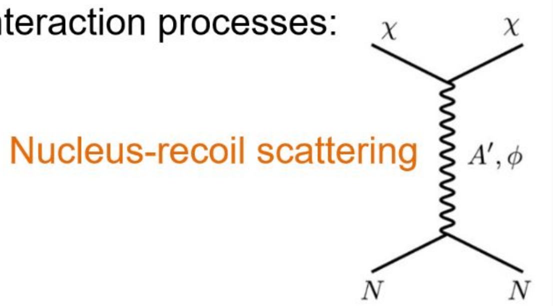
Looking for a wide range of DM candidates

- Dark matter masses from ~10 GeV down to eV

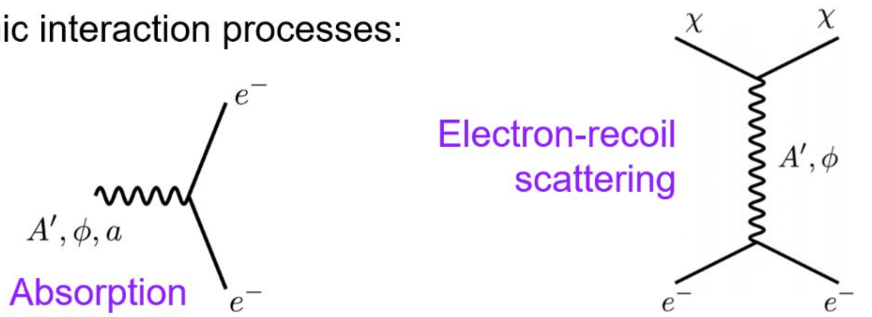


US Cosmic vision ArXiv:1707.04591

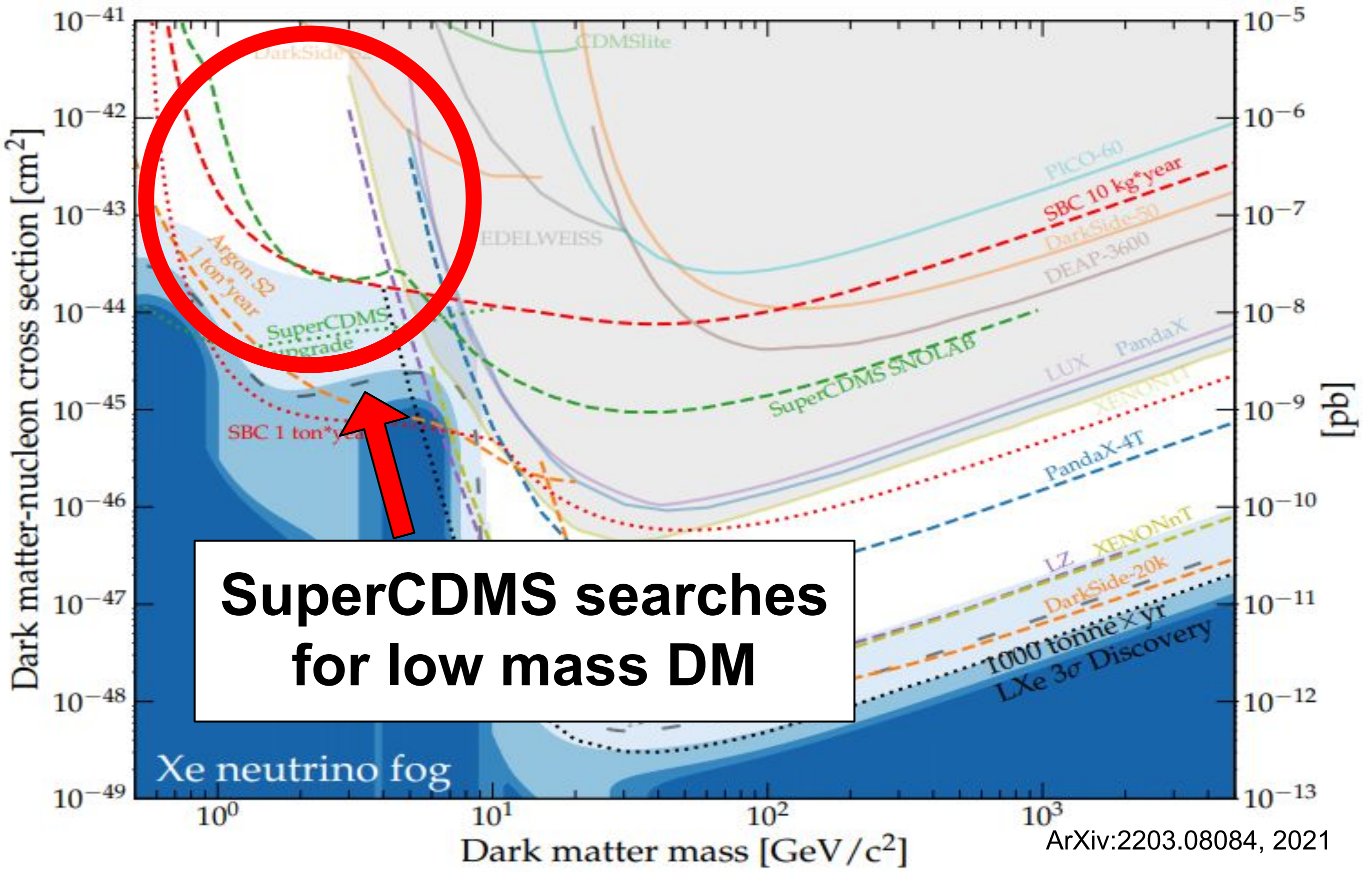
Nuclear interaction processes:



Electronic interaction processes:

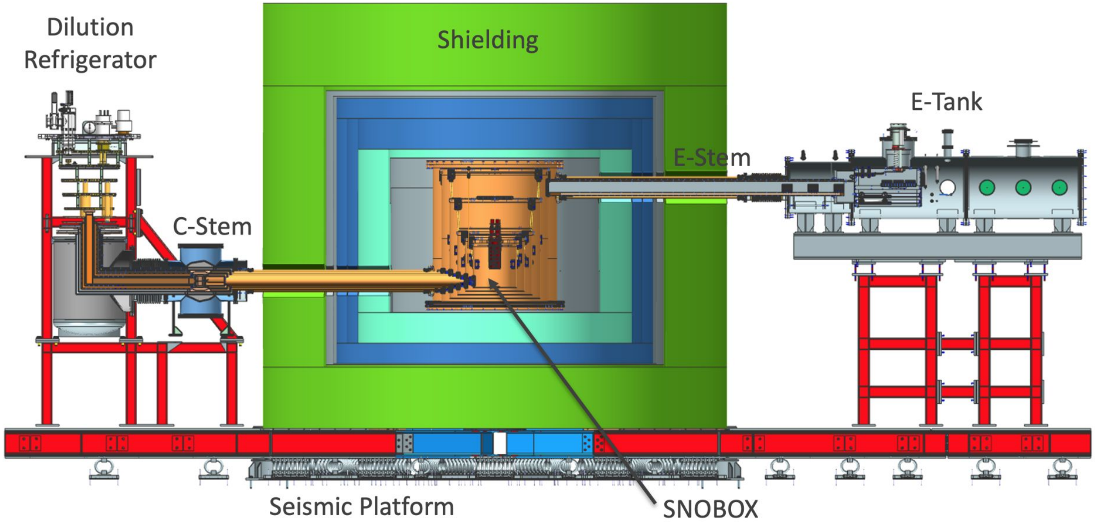


Dark Matter Search Playground



ArXiv:2203.08084, 2021

The SuperCDMS SNOLAB Experiment



Facility:

- 6000 m.w.e. overburden
- 15 mK base temperature
- Initial Payload: ~30 kg total
  - 4 stacks of six detectors ("towers")
  - 2 iZIP: 10 Ge / 2 Si
  - 2 HV: 8 Ge / 4 Si

Electron Recoil Backgrounds:

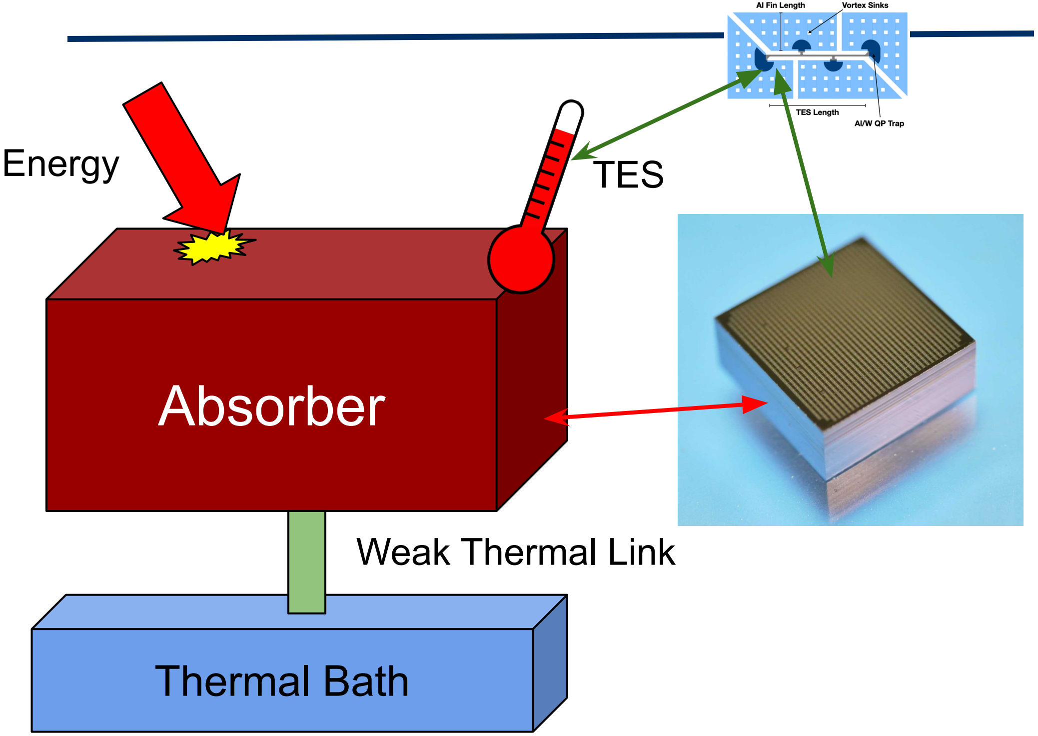
- External and facility: O(0.1 /keV/kg/d)
- Det. setup: O(0.1(Ge)-1(Si) /keV/kg/d)
- Total: O(0.1-1 /keV/kg/d)

Facility designed to be dominated by solar neutrinos in NR background

Vibration isolation:

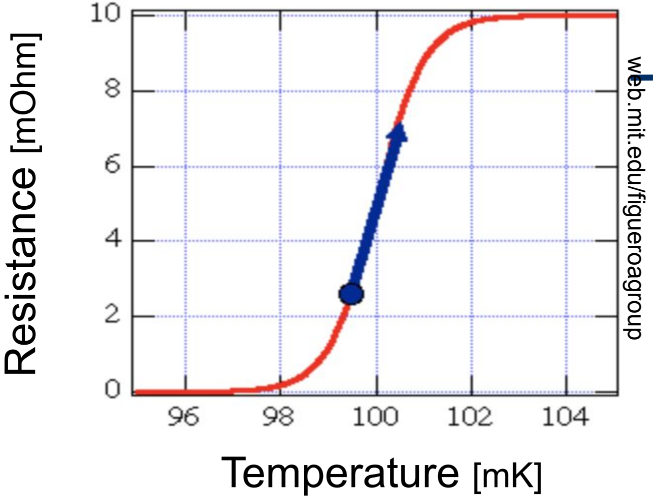
- Seismic: spring loaded platform
- Fridge on active vibration damper
- Cryo coolers: soft couplings
  - Braids, bellows
- Copper cans: hanging on Kevlar ropes

Cryogenic Calorimeter Detector Schematic

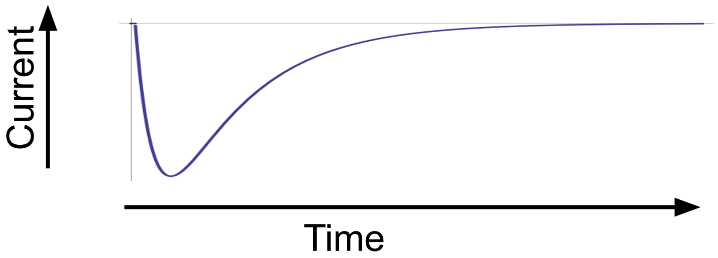


Cryogenically cooled in dilution fridge

Transition-Edge Sensor (TES)



Response of TES



SuperCDMS Detector Technology

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

total phonon energy · *primary recoil energy* · *Luke phonon energy*

Discriminating

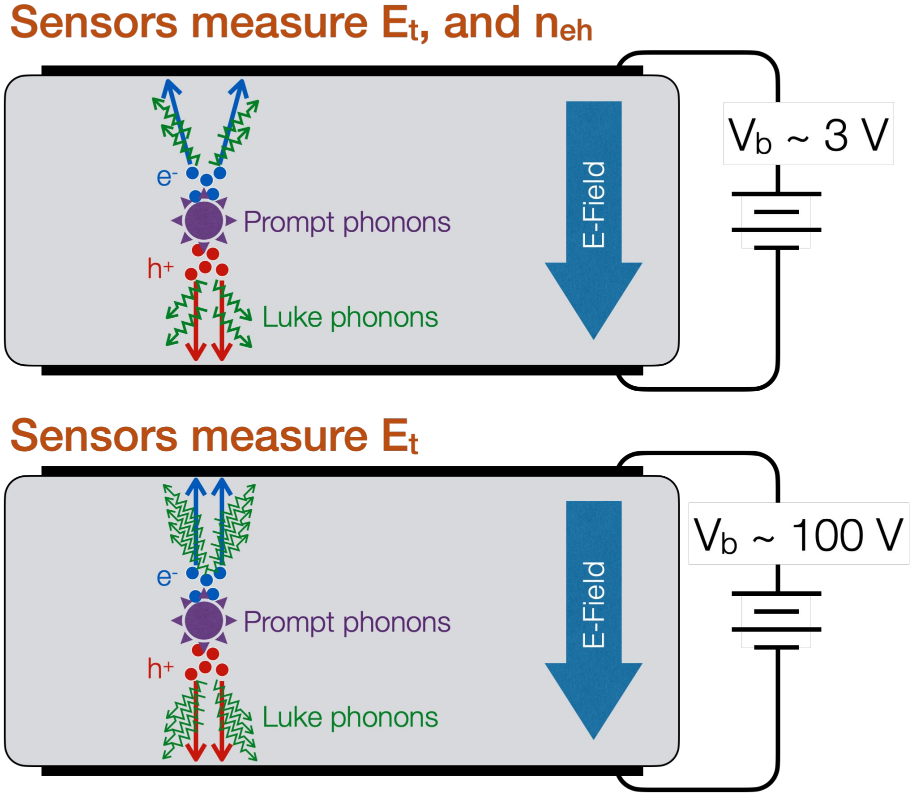
~~iZIP~~ Detector:

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

Low Threshold

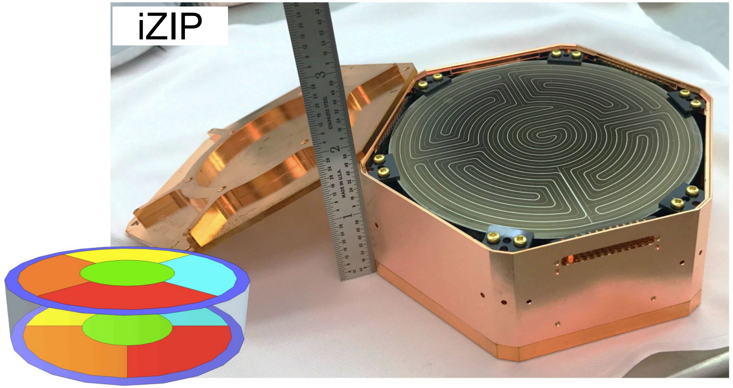
~~HV~~ detector:

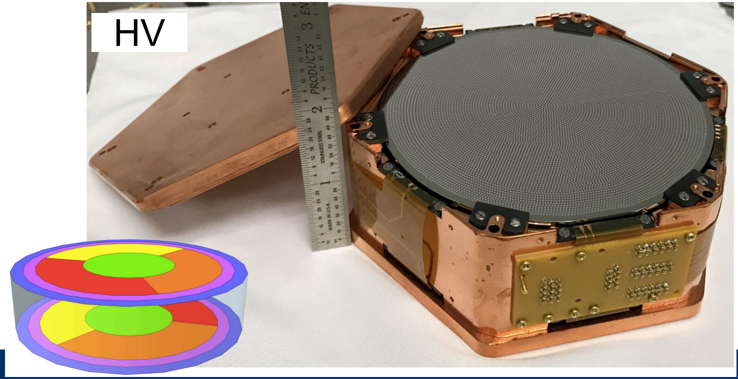
- Drifting electrons/holes across a potential (V_b) generates a large number of phonons (Luke phonons).
  - Enables <100 eV low thresholds!
  - Trade-off: No event-by-event NR/ER discrimination



SuperCDMS Detectors: Posing for the Cameras

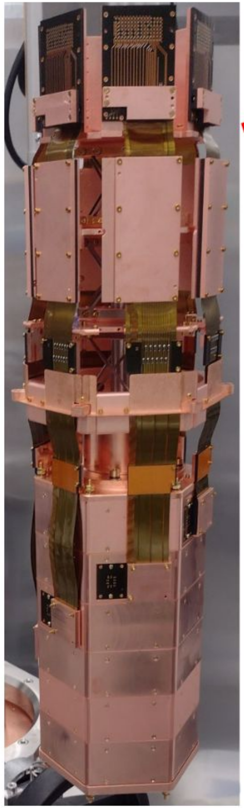
- Detectors made of high-purity Ge and Si Crystals
  - Si (0.6 kg each) provides sensitivity to lower dark matter masses
  - Ge (1.4 kg each) provides sensitivity to lower dark matter cross-sections
- Low operating temperature: ~15mK
  - Athermal phonon measurement with TESs
  - Ionization measurement (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: 8 Ge / 4 Si



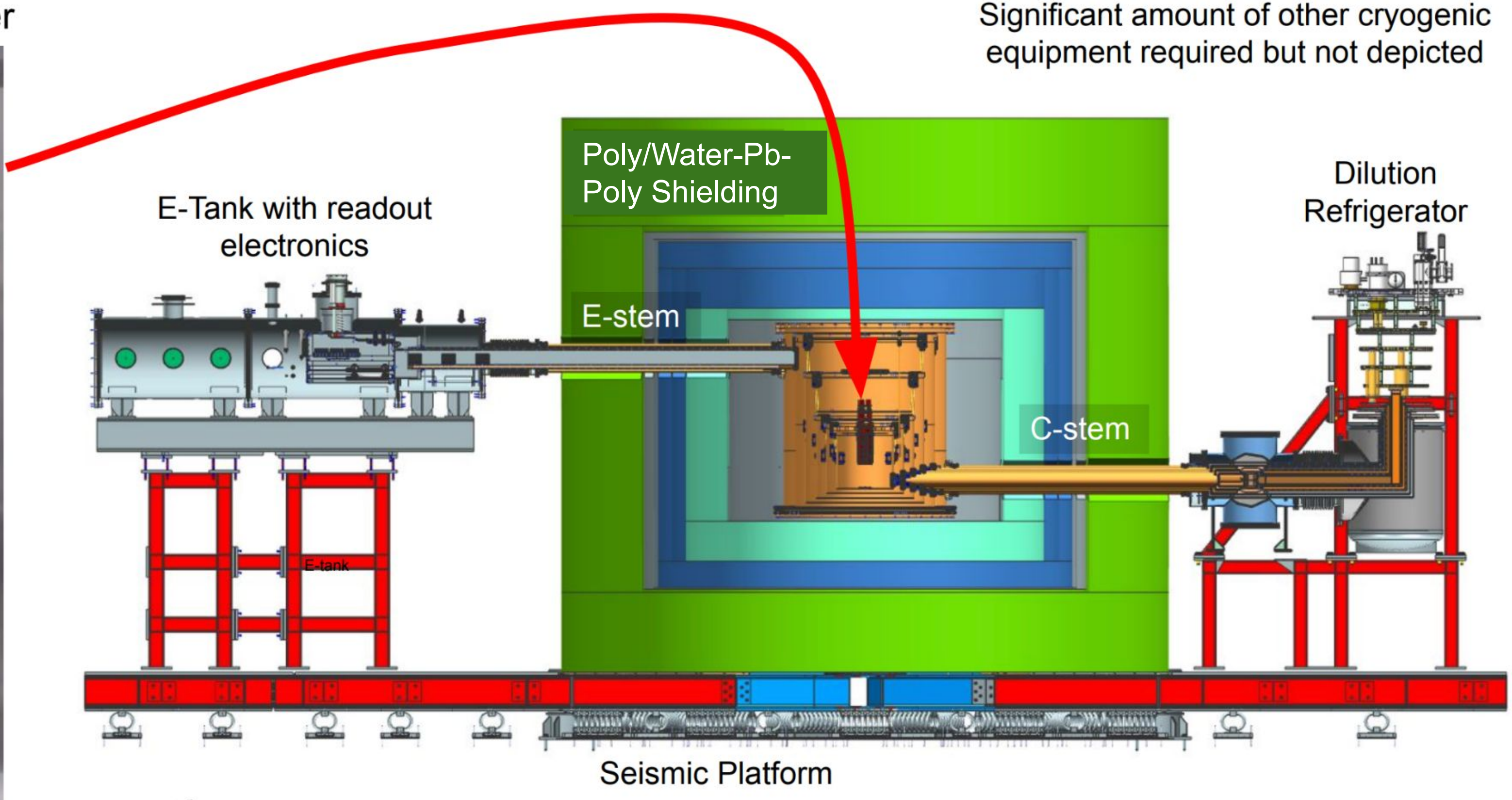


SuperCDMS @ SNOLAB Status

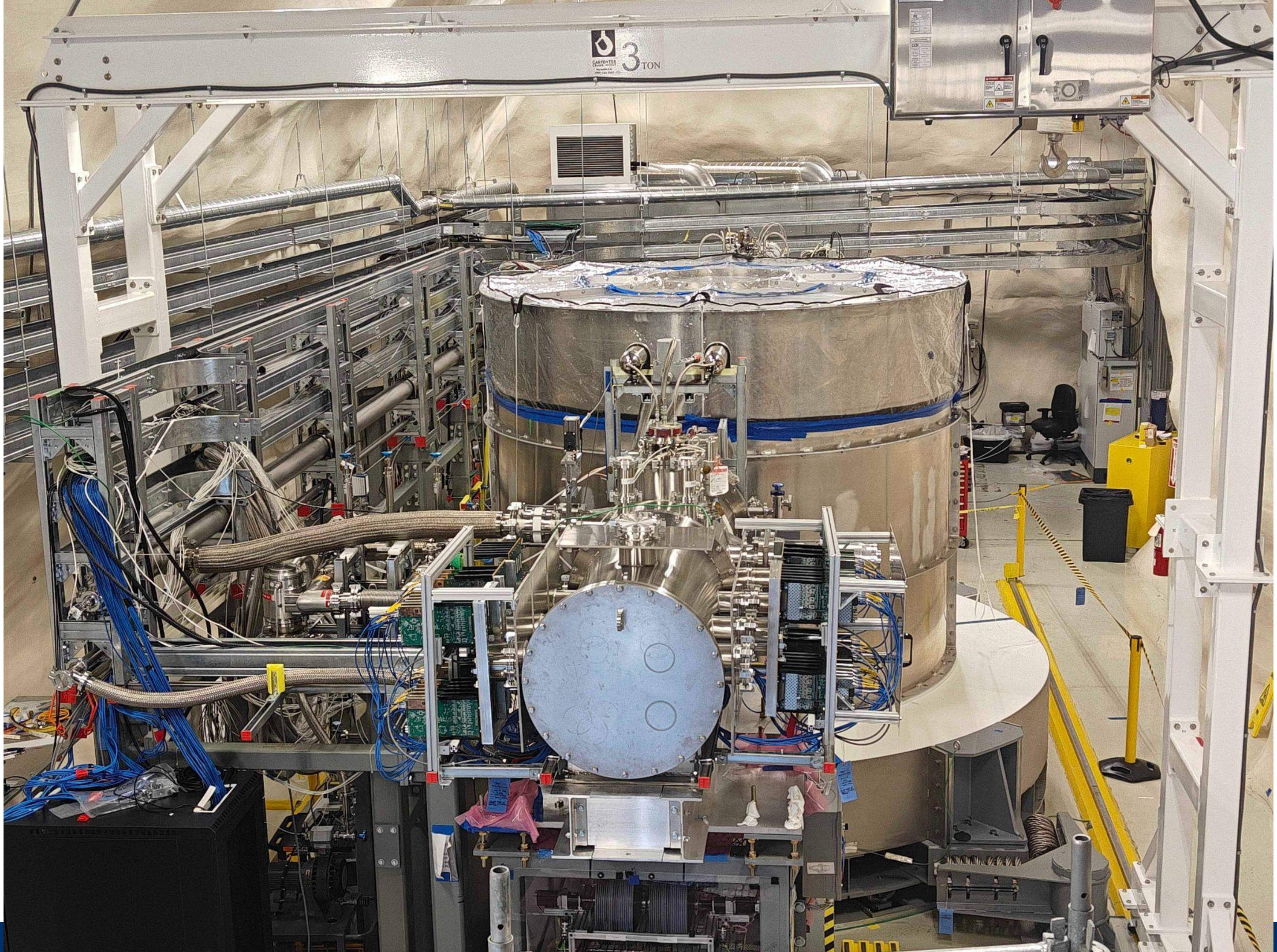
Detector Tower



Significant amount of other cryogenic equipment required but not depicted




FIRE
EXTINGUISHER


3 TON

Expected background sources

Expected # DM events: **<5 hits every year** in each detector!

Need to **reduce and model interactions from non-DM** particles for conclusive observation

Material contamination

Material activation

Environmental backgrounds

Material contamination: ~40% of background

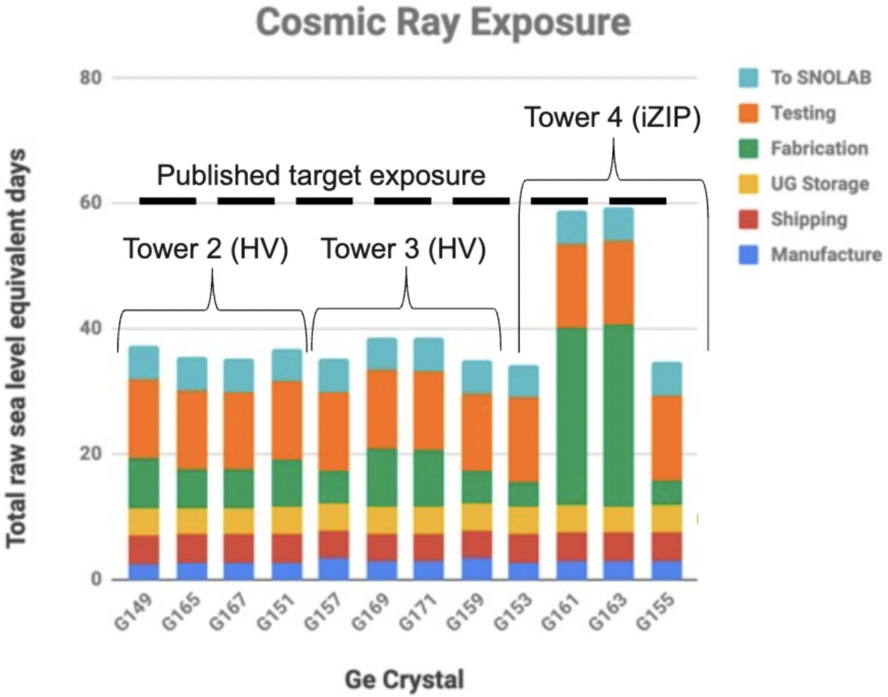
All materials have low levels of ^{238}**U**, ^{232}**Th**, and ^{40}**K**

Measure many (many!) samples and **select lowest radioactivity** then **clean carefully** before install

No.	Sample	#	Mass (g)	U	Th
1	Copper, commercial, post nitric etch	1	0.39	0.093 ± 0.012	< 0.0644
2	Copper, commercial, post nitric etch	1	2.23	0.0400 ± 0.0008	0.034 ± 0.009
3	Copper, Aurubis high purity OFHC sample 1	1	1.16	<0.0117	<0.0202
		2	0.92	<0.0147	<0.0254
4	Copper, Aurubis high purity OFHC sample 2	1	0.94	<0.0145	<0.0249
		2	0.95	<0.0142	<0.0246
5	Copper, Aurubis high purity OFHC sample 3	1	0.95	<0.0142	<0.0245
		2	0.95	<0.0143	0.037 ± 0.010
6	Copper, Aurubis high purity OFHC sample 4	1	0.93	<0.0146	<0.0252
		2	0.93	<0.0146	<0.0251
		3	0.93	<0.0146	<0.0252
7	Copper, Aurubis high purity OFHC sample 5	1	0.93	<0.0146	<0.0252
8	Copper, Southern Copper MKM Plate", Piece 1	1	3.67	0.011 ± 0.001	0.012 ± 0.003
		2	3.67	0.01 ± 0.003	0.012 ± 0.003
		3	3.67	0.011 ± 0.003	0.015 ± 0.005
9	Copper, Southern Copper MKM Plate", Piece 2	1	3.30	0.012 ± 0.003	0.020 ± 0.004
		2	3.30	0.011 ± 0.002	0.021 ± 0.005
		3	3.30	0.01 ± 0.002	0.017 ± 0.007
10	Copper, Southern Copper MKM Plate", Piece 2	1	2.16	0.081 ± 0.006	0.010 ± 0.005
		2	2.16	0.275 ± 0.028	0.008 ± 0.005
11	Copper, 17 mm x 17 mm x 5 mm cube	1	5.68	275 ± 17	236 ± 17
12	Copper, 18 mm x 17 mm x 7 mm cube	1	6.50	267 ± 15	196 ± 16
13	Copper, Sequoia Brass and Copper inc, IR shielding	1	0.66	< 0.14	< 0.59
		2	0.64	< 0.14	< 0.59
		3	0.75	0.24 ± 0.21	< 0.60
14	Copper, SC5 from Southern Copper	1	0.34	<0.9	<0.9
		2	0.51	<0.9	<0.9
		3	0.25	<0.9	<0.9
15	Copper, SC5 from Southern Copper	1	0.46	<1.0	<0.9
		2	0.27	<1.0	<0.9
		3	0.27	<0.9	<0.9
16	Copper, PR2125 inner bulk	1	0.95	<0.9	<0.9
		2	0.72	<0.9	<0.9
		3	0.63	<1.0	<0.9
17	Copper, VA326516 inner bulk	1	0.86	1.10 ± 0.40	<0.9
		2	0.43	<0.9	<0.9
		3	0.41	<0.9	<0.9
18	Copper, VA326517 inner bulk	1	0.52	<1.0	<0.9
		2	0.23	<0.9	<0.9
		3	0.36	<0.9	<0.9
19	Copper, VA326518 inner bulk	1	0.87	1.0 ± 0.5	<1
		2	0.94	<1.0	<1
		3	0.77	<0.9	<0.9
20	Copper, Luvata Tubing	1	0.55	<1.0	<0.9
		2	0.54	<1.0	<0.9
		3	0.62	<1.0	<0.9
21	Copper block, Aurubis grade OF01	1	0.44	0.37 ± 0.14	0.17 ± 0.17
		2	0.53	0.48 ± 0.15	0.36 ± 0.17
		3	0.58	0.3 ± 0.2	0.3 ± 0.4

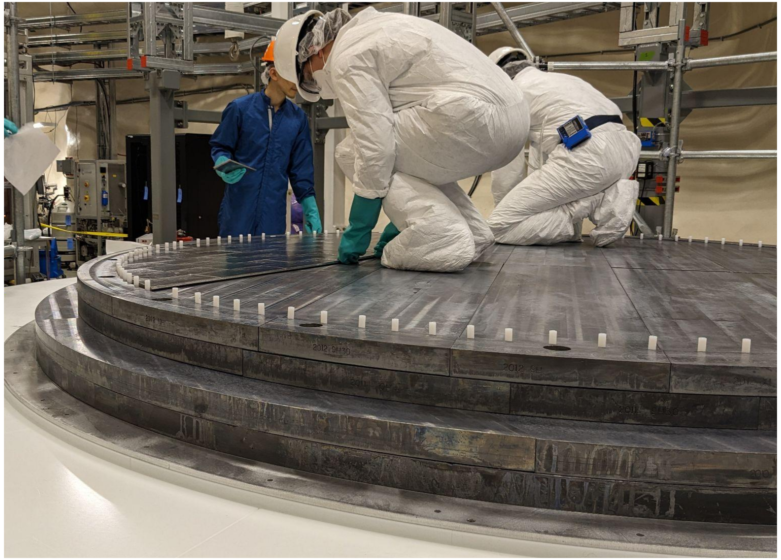
Material activation: ~40% of background

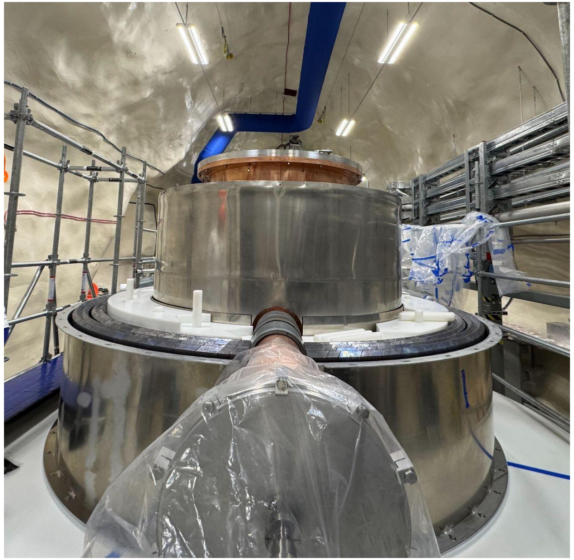
Exposure to cosmic rays produces radioactive isotopes in copper, germanium, and silicon
Carefully **track exposure at sea level**, and **use shielding** where needed for shipping



Environmental sources: ~20% of background

Dust, rock in lab walls and human activity carry trace amounts of ^{238}**U**, ^{232}**Th**, and ^{40}**K**
Radon gas underground produces ^{210}**Pb**
Can't prevent any of these from occuring, so **protect and shield** as best we can





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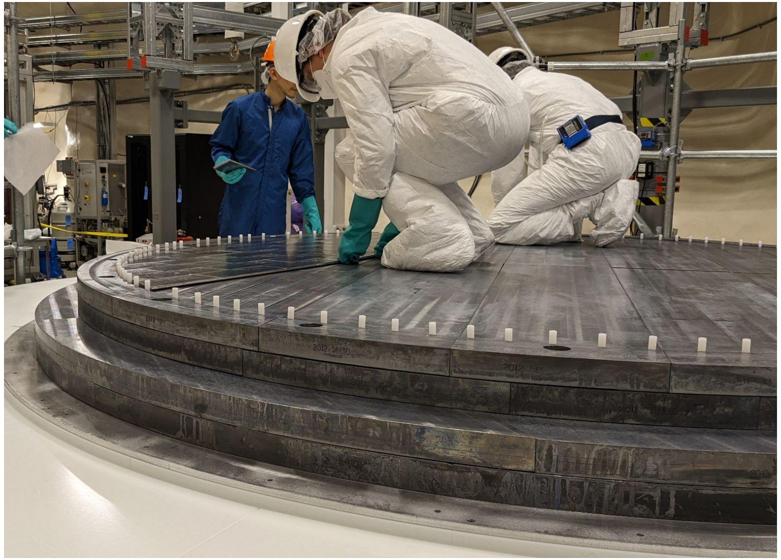


See poster on radon purge by Nevena

Backgrounds at SuperCDMS

Relevant SuperCDMS operational goals:

1. <100 (1100) events/kg/keV/year for Ge (Si) while maximising detector mass and live time
2. Search for DM that includes an understanding of residual backgrounds

Three pronged backgrounds approach:

1. Background reduction
   How can we reduce our total background rate during installation?

2. Background studies
   Can we constrain our expected backgrounds from ancillary studies?

3. Background modelling
   How do we distinguish signal from background during analysis?

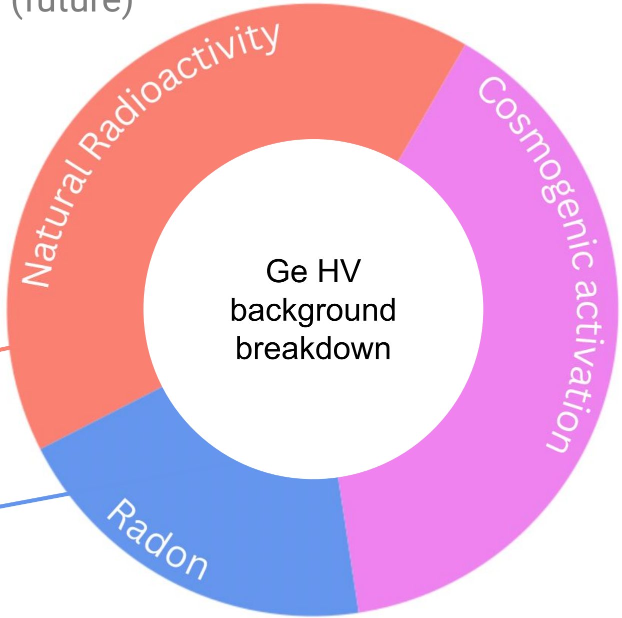
Interface Control Level and Assignment:	*goal*		*requirement*	
Background Category for events in the detector bulk	Ge HV (ER)	Si HV (ER)	Ge HV (ER)	Si HV (ER)
Total Rate (counts/keV/kg/year)	**50**	**550**	**100**	**1100**
2. Detector Internal Contamination	**25**	**460**	**50**	**920**
Tritium (^{3}H)	25	35	50	70
^{32}Si		425		850
3. Material Internal Contamination	**16**	**68**	**32**	**136**
Housing and Towers	6	35	12	70
Readout Cables*	0.5	1	1	2
SNOBOX Cans & Stems, Kevlar	4.5	18	9	36
Calibration System Materials	1	3	2	6
Shield Materials	4	11	8	22
4. Material Internal Activation	**3**	**10**	**6**	**20**
Housing and Towers	1	4	2	8
SNOBOX Cans & Stems	2	6	4	12
5. Non-line-of-sight Surfaces	**2**	**6**	**4**	**12**
6. Prompt Interstitial Radon	**1**	**2**	**2**	**4**
7. Cavern Environment	**3**	**4**	**6**	**8**

Background reduction - assay program

SuperCDMS assay program reaches back to 2011 and includes several methods to assess materials:

- Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) → PNNL
- High Purity Ge counting (HPGe) → UMN (previously), SNOLAB (present)
- Radon permeability and emissivity → SDSMT
- Alpha counting (radon plate out) → SMU (previously), SNOLAB (future)

	Ge HV (cpd/kg/keV)	Si HV (cpd/kg/keV)
Total Background	**0.19**	**1.10**
^{238}U	0.01	0.06
^{232}Th	0.01	0.05
^{40}K	0.02	0.05
^{210}Pb	0.06	0.06
^{222}Rn	0.01	0.03

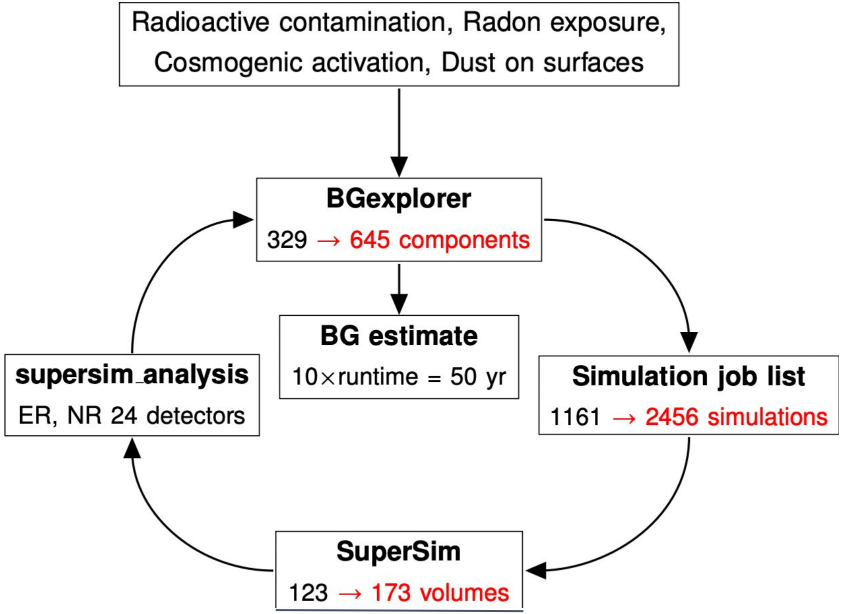


Background modelling - simulation

Significant effort over last year to improve fidelity of simulation with as-built detector. Provides more refined selection and categorisation of components in background model

Production pipeline

- **BGExplorer**
  - Calculates component emission rates from assays, mass and surface area
- **SNOLABBackgroundMacros**
  - Macros for each component
  - Scripts for file/directory management, job submission, validation, processing
- **SuperSim**
  - Propagates particle tracks, records hits
- **supersim_analysis**
  - ROOT and Python utilities for event selection and ROI counting
- **BGExplorer**
  - Calculates expected BG rate in ROI from simulated spectra



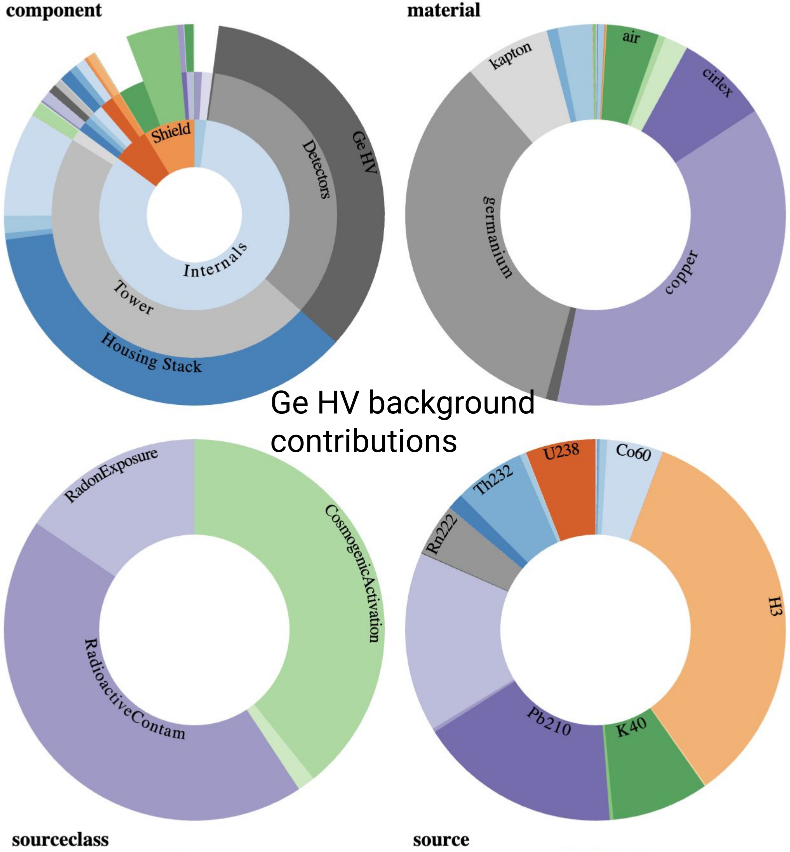
https://github.com/bloer/bgexplorer-demo

Background bookkeeping

- Several 1000 background simulations
- Make use of Background Explorer to assess
  - Combines spectra based on normalisation and provides tools to show spectra, percentage contributions, and overall projection
- Allows us to understand which sources can be combined, and which need individual modelling

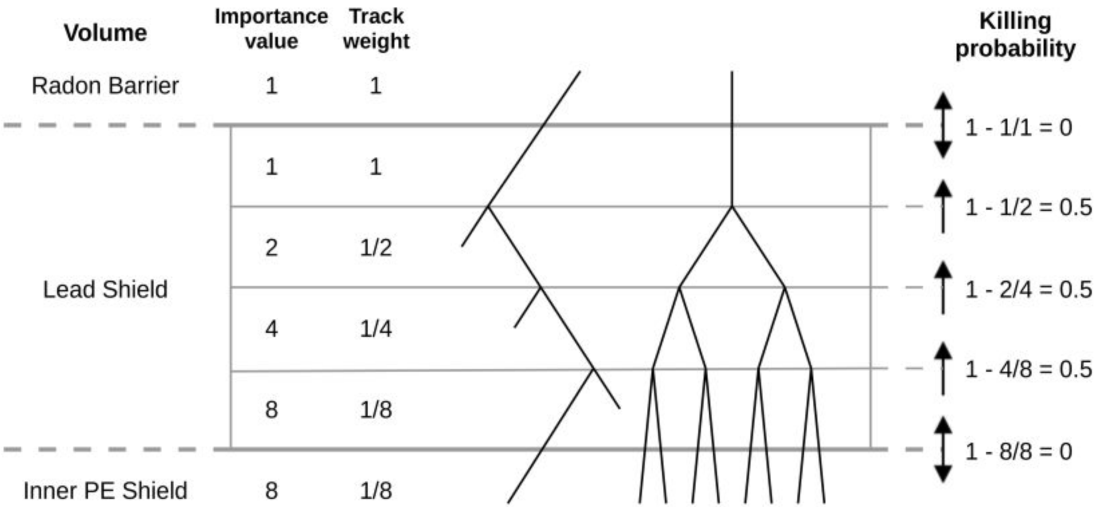
-Material Internal Contamination	26.
-Housing and Towers	21.
+brass	0.33
+copper	10.
+SiBr	0.01
+cirlex	5.3
+epoxy	0.00
+kapton	4.9
+electronic_component	0.01

Counts per kg/keV/year



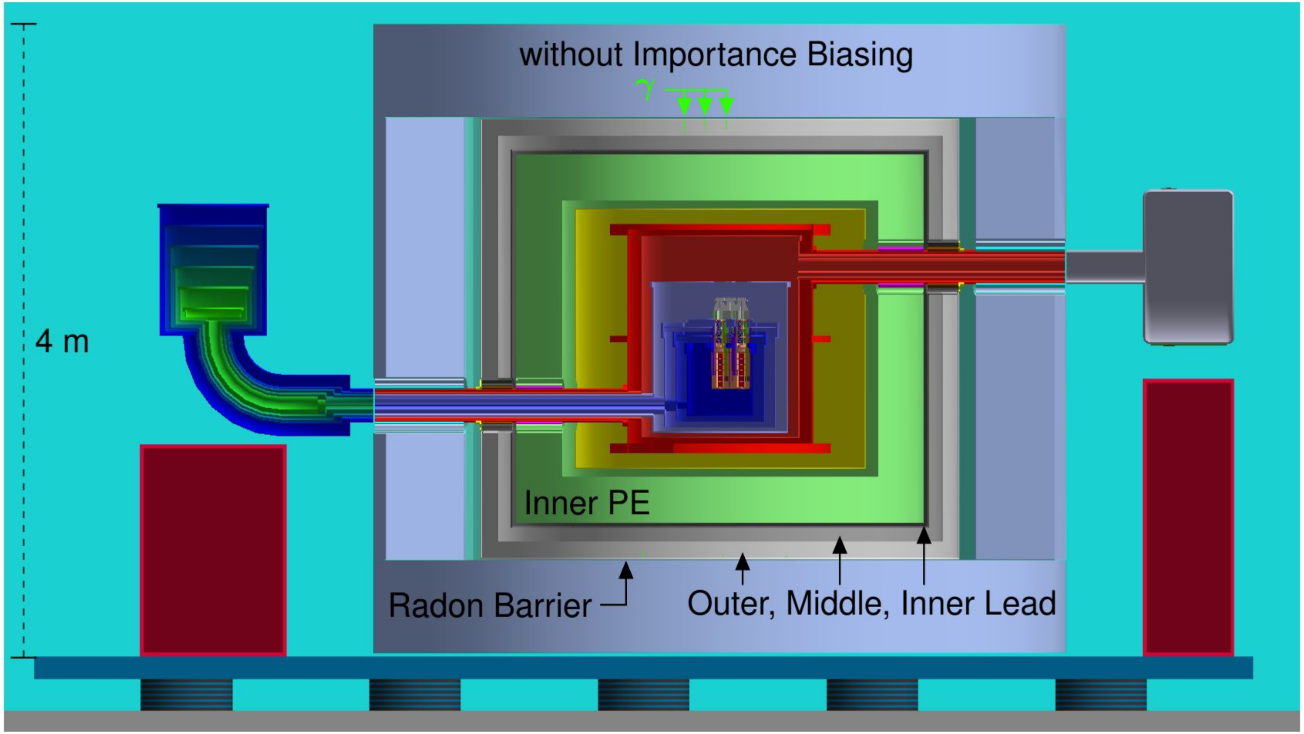
Ge HV background contributions

Importance Biasing



- Splits (kills) particles going to (away from) the detectors.
- Weights are properly adjusted
- A backwards going particle is either killed or its weight is adjusted.
- Only one particle type is biased, i.e. in our case gammas inside the lead shield.

Particle propagation in comparison



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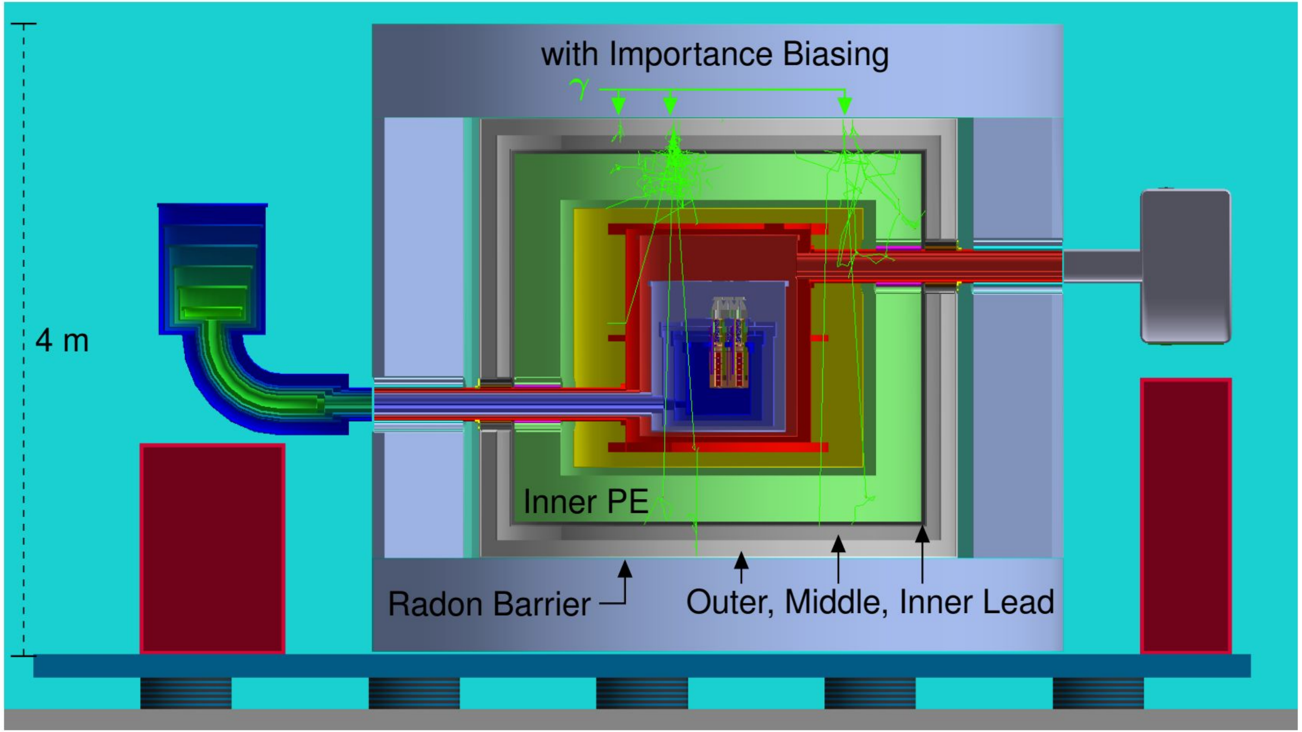
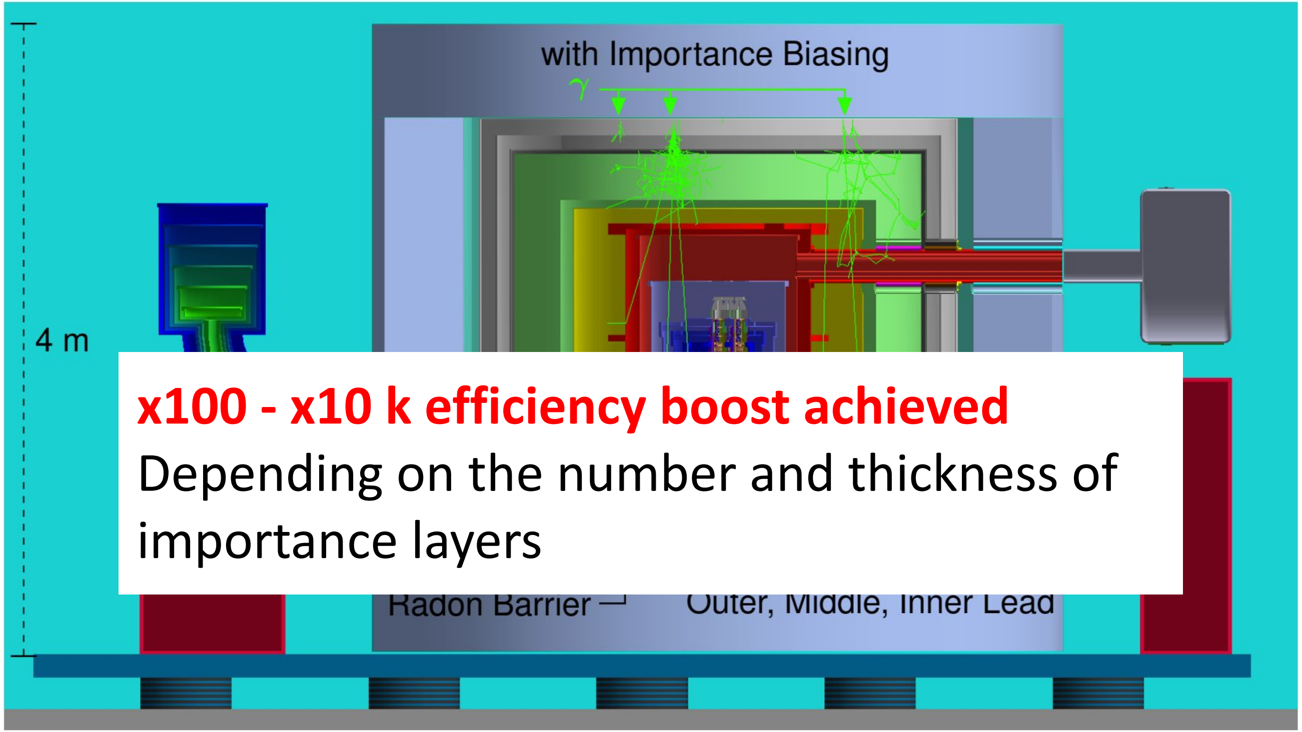


NIM A 1080 (2025) 170766

Particle propagation in comparison



x100 - x10 k efficiency boost achieved

Depending on the number and thickness of importance layers

Conclusions

- SuperCDMS in a very exciting phase. First science run ongoing
- We (think) we understand our (radioactive) backgrounds
  - Paper on 10+ years of assay results in preparation
- Polishing our tools to better model our backgrounds
  - Eg. importance biasing greatly enhances simulation efficiencies
- First in-situ background measurement on the horizon
- Then we'll see if there's dark matter in addition
- Stay tuned!