The CUTE Facility

Cryogenic Underground TEst facility

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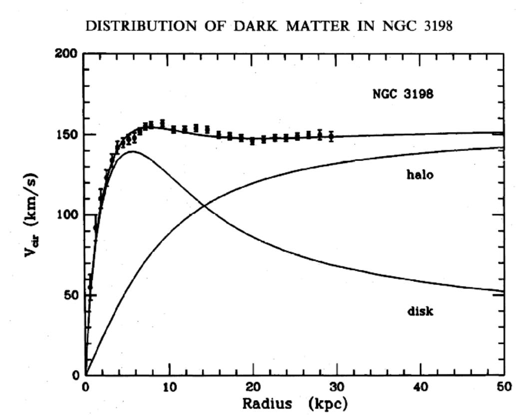
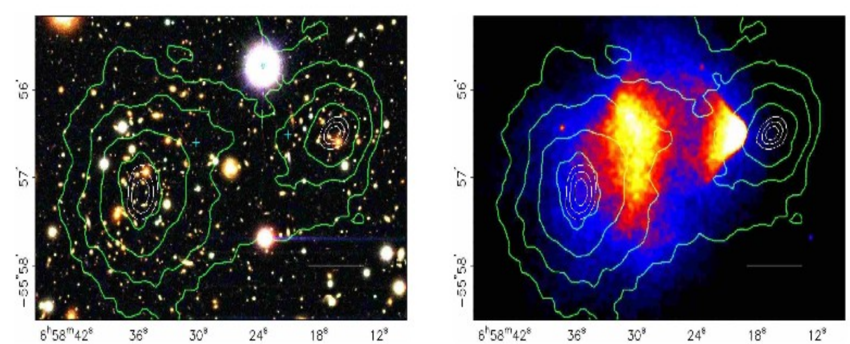
Dark Matter

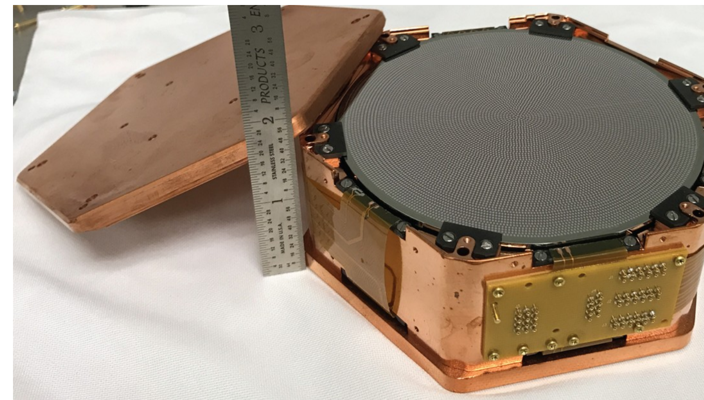
- Strong evidence for a non-luminous, gravitationally interacting kind of matter; “Dark Matter”
- Interaction with normal matter is very weak
- Look for signal from dark matter in terrestrial detectors

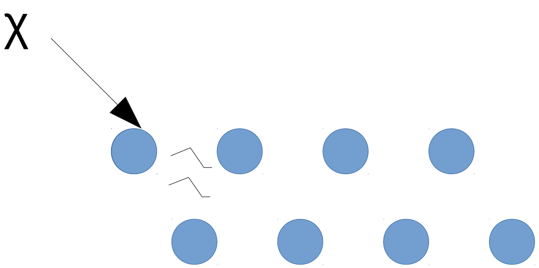




SuperCDMS

- **Super C**ryogenic **D**ark **M**atter **S**earch
- SuperCDMS uses cryogenic Ge/Si semiconductor detectors to search for dark matter interactions
- Interacting particles liberate charges and deposit energy in the lattice, which can be measured as phonons

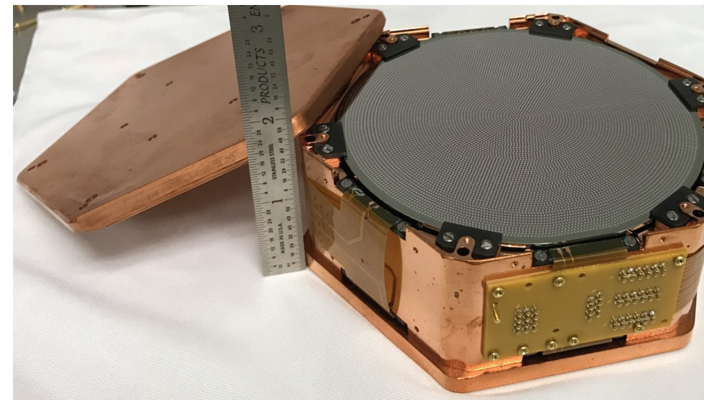


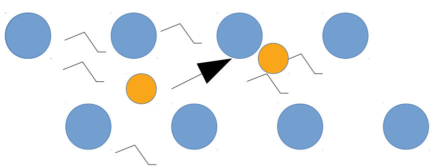


- Main Challenges:
  - Low rate (need to minimize background)
  - Low energy (need low threshold detectors)
  - Long lived cosmogenic backgrounds (need to minimize detectors' time above ground)
  - 2 km underground at SNOLAB (to reduce cosmogenic background)

SuperCDMS Detectors

- SuperCDMS has two main detector types: iZIP, and HV
  - iZIP- Best discrimination of radioactive background using charge to phonon ratio
  - In HV mode, charges are drifted across the detector using the bias voltage, amplifying the phonon signal, to lower threshold

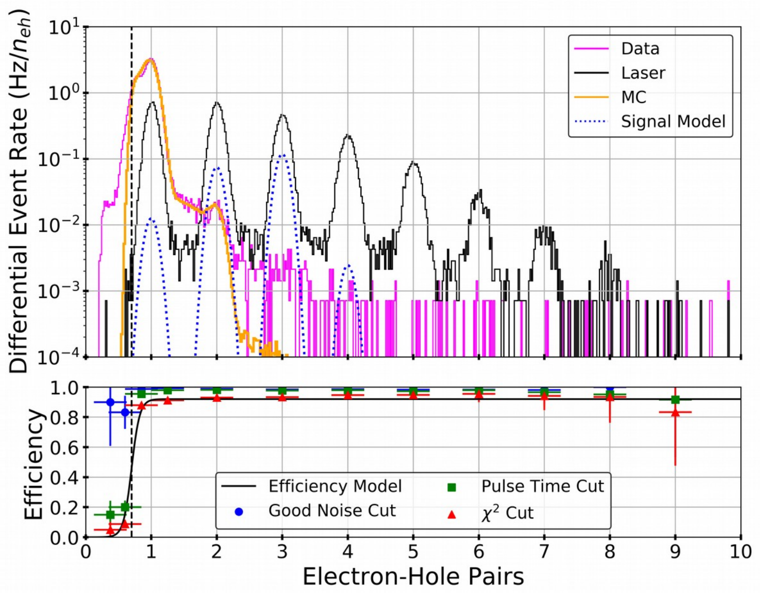




	iZIP		HV	
	Ge	Si	Ge	Si
Number of detectors	10	2	8	4
Total exposure (kg · yr)	56	4.8	44	9.6
Phonon resolution (eV)	50	25	10	5
Ionization resolution (eV)	100	110	–	–
Voltage bias (V)	6	8	100	100

Very low threshold prototype detector

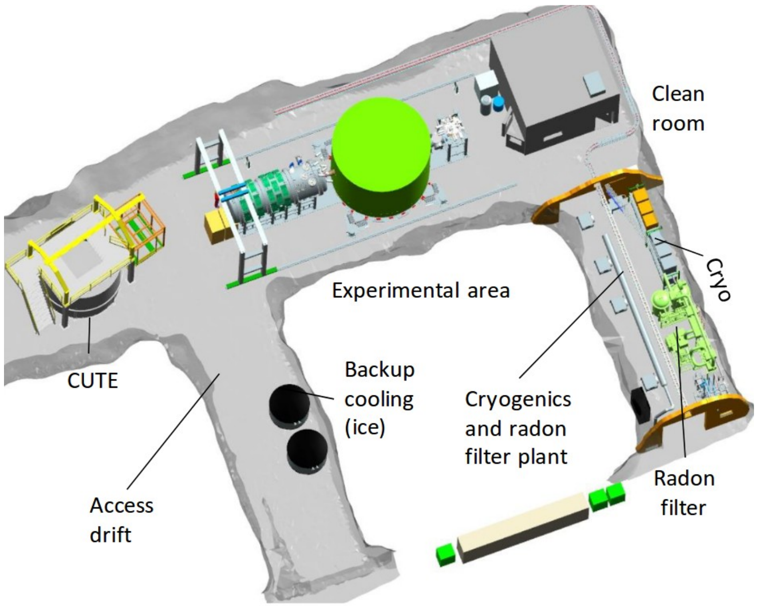
- Prototype "HVeV" devices (https://arxiv.org/abs/1804.10697) push down sensitivity for even lower masses
- Low mass, low threshold devices sensitive to single electron-hole pairs
- Has a limiting background: leakage current. Source is unclear, may improve underground



Above ground results with HVeV device show clear separation of small numbers of electron-hole pairs, giving competitive sensitivity for electron-interacting dark matter searches.

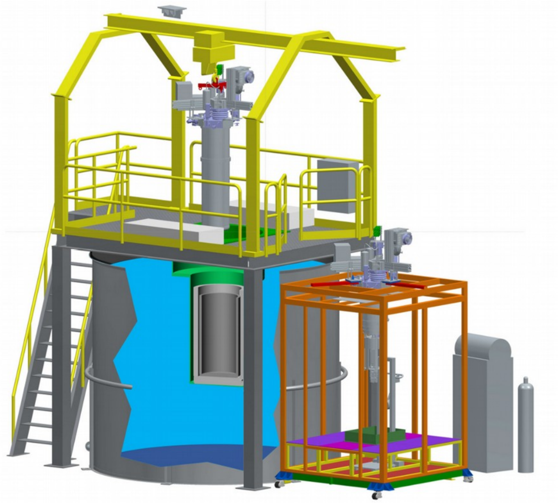
CUTE

- Need to test detector behaviour under low background conditions
- Need to test and characterize detectors without producing a cosmogenic background
- Build the **C**ryogenic **U**nderground **TE**st Facility



CUTE

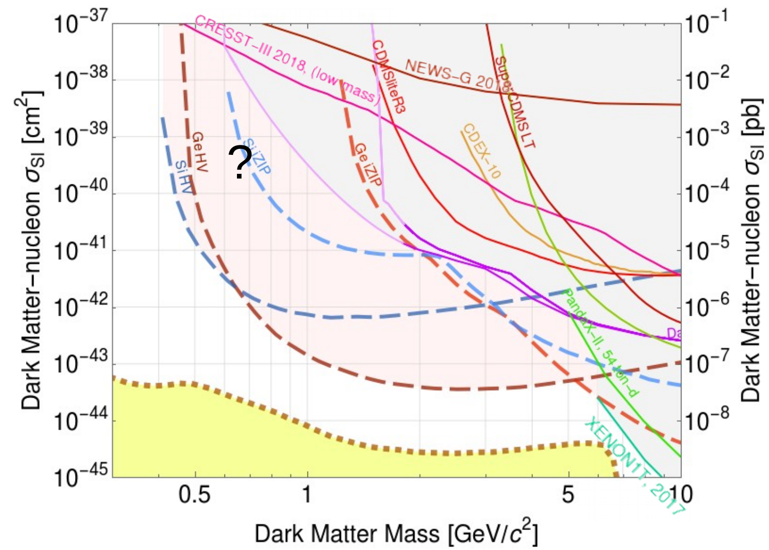
- Can hold up to 6 SuperCDMS detectors
- Well shielded (1.5 m water, ~10 cm of low-activity Pb)
- - Estimated background: few events/keV/kg/day



Background source	Material	Contributing isotopes	Induced detector rate [evts/keV/kg/d] below 1 keV
External Environment	Cavern walls	^{208}Tl, ^{40}K, n	1.10
Radon in water	Water	^{222}Rn	0.05
Lead shield, external	Low act. lead	U/Th, ^{210}Pb	0.65
Radon in air gap	Rn reduced air	^{222}Rn	0.04
Cryostat vacuum can	SS, 316L	U/Th, ^{60}Co	0.58
Cryostat inner shields	Copper, CuC2	U/Th, ^{60}Co	0.10
Brazing	AgSn	^{210}Pb	0.25
Lead shield, internal	Low act. lead	U/Th, ^{210}Pb	0.10
Total			**2.87**

CUTE Role

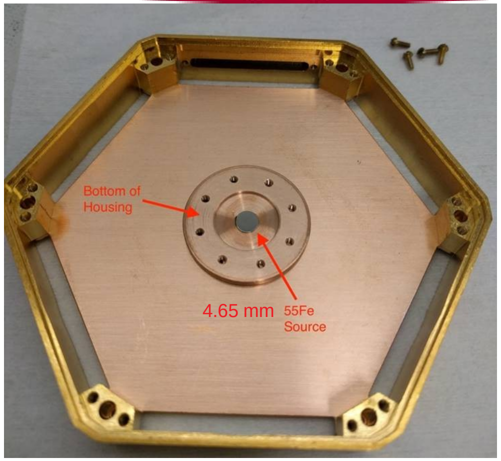
- Test SuperCDMS detectors
  - Understand the noise
    - EM interference from the lab, leakage current, detector cross talk, etc.
  - Detector setup optimization
  - Data taking/processing (end-to-end data pipeline testing from detector via electronics, to transfer of data to processing)
  - Calibration
  - IR leakage testing
- If time permits and bg low enough, probe new dark matter parameter space
  - Bg comparable to previous facility but with much lower threshold



Material	Isotope	Production Rate (atoms/kg/day)	Concentration (decays/kg/day) HV	iZIP
Ge	^{3}H	80	0.7	1.5
Si	^{3}H	125	1	2
Si	^{32}Si	–	80	80

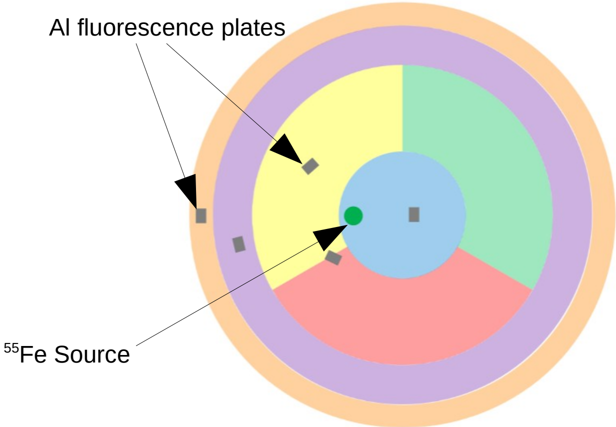
CUTE Role - Calibration

- Energy scale
  - High Energy:
    - ^{133}Ba (356 keV)
  - Low Energies
    - ^{55}Fe (5.9 keV) with Al fluorescence (1.5 keV)
    - In Ge: ^{71}Ge (0.16, 1.3, 10.4 keV; activated by a ^{252}Cf neutron source
  - Very low energies: individual optical/IR photons (single e-h pairs)
    - Internal LEDs
    - Optical Fiber
- Position dependence (ideas, but no plan defined)
  - Array of LEDs across detector surface
  - Moveable radioactive source
  - Multiple fluorescence sources

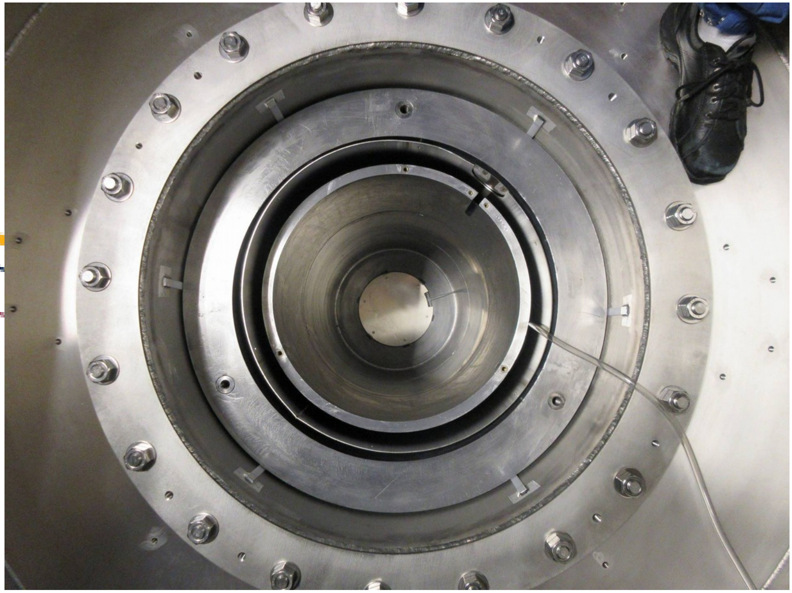


^{55}Fe source in use at SuperCDMS test facility at SLAC

Sensor layout of SuperCDMS HV detector



CUTE Status



- Already installed Underground:

CUTE Status

- Can now install:
  - Cryostat
  - Vibration isolating suspension system
  - Gas handling system
  - Electronics and rack
- All parts in hand on site, at partner institutions, or on the way
- Installation to be completed by April

Science Opportunities

- After necessary testing goals have been achieved in CUTE, there will be opportunities for competitive science results.
- If detectors behave as expected, 1-2 months of Ge or Si-HV could produce competitive DM sensitivity
- Possible to explore HVeV device underground to test if residual background can be reduced
- May test/operate other prototype detectors with potentially interesting science reach

Conclusion

- SuperCDMS searches for dark matter interactions with cryogenic Ge and Si semiconductor detectors
- SuperCDMS needs a low background and low activation environment to test its detectors
- CUTE provides this environment
- New dark matter parameter space could be explored with SuperCDMS detectors in CUTE assuming background and threshold goals are met

Thank You!

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