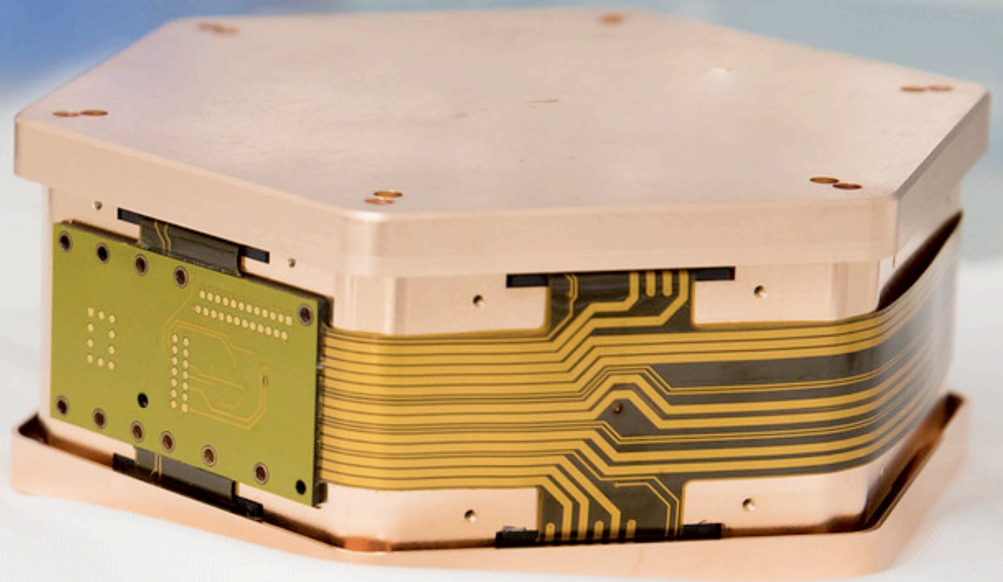
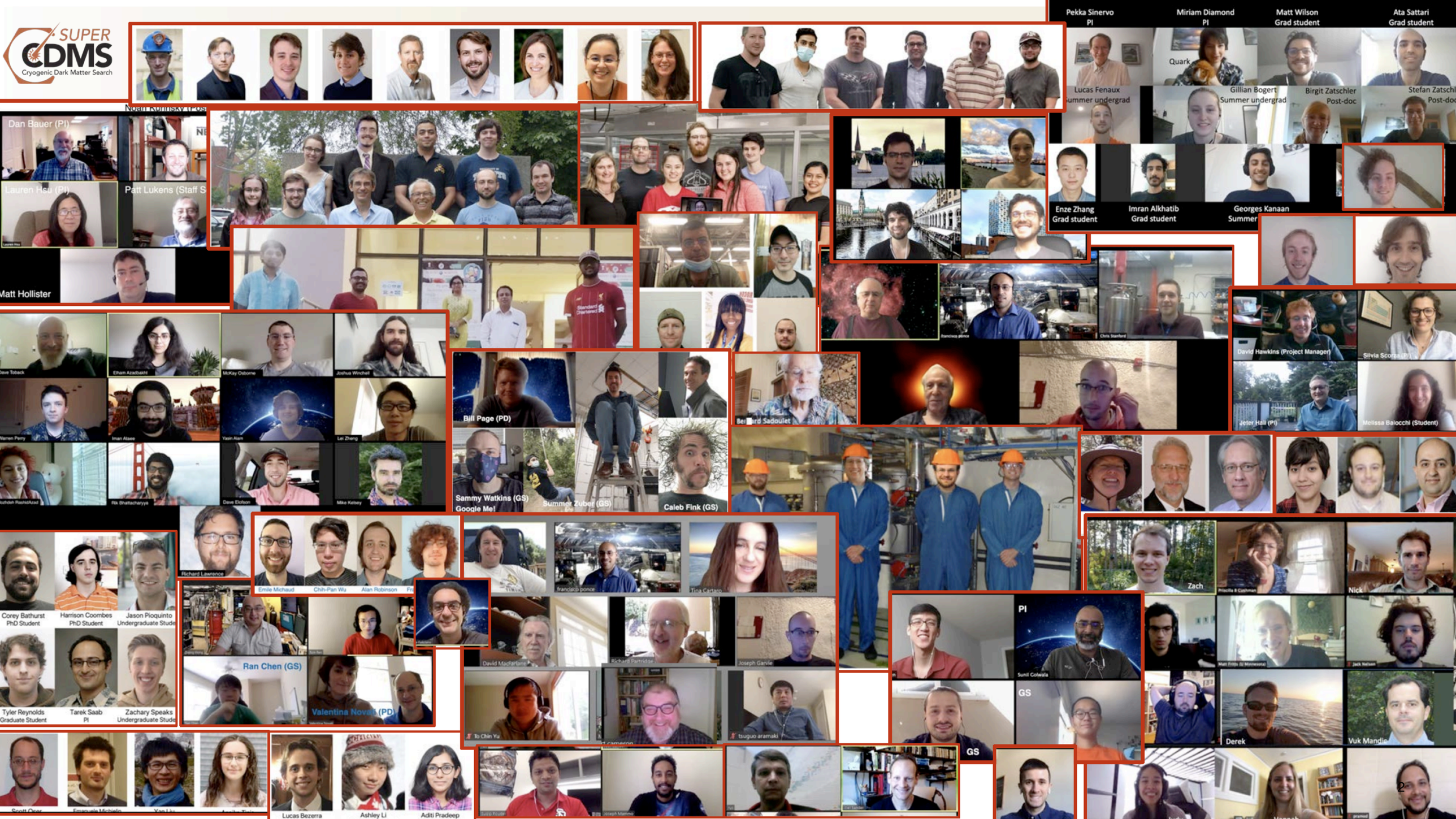


SUPER CDMS
Cryogenic Dark Matter Search

EIEIOO 2021

Eleanor Fascione, May 7th 2021


SUPER CDMS
Cryogenic Dark Matter Search
Pekka Sinervo PI
Miriam Diamond PI
Matt Wilson Grad student
Ata Sattari Grad student
Quark
Lucas Fenaux summer undergrad
Gillian Bogert Summer undergrad
Birgit Zatschler Post-doc
Stefan Zatschl Post-doc
Enze Zhang Grad student
Imran Alkhatib Grad student
Georges Kanaan Summer
Dan Bauer (PI)
Lauren Hsu (PI)
Patt Lukens (Staff S
Matt Hollister
Bill Page (PD)
Sammy Watkins (GS) Google Me!
Summer Zuber (GS)
Caleb Fink (GS)
Bernard Sadoulet
David Hawkins (Project Manager)
Silvia Scorza (PI)
Jeter Hall (PI)
Melissa Balocchi (Student)
Zach
Nick
PI
Sunil Golwala
GS
Derek
Vuk Mandic
Ran Chen (GS)
Valentina Novati (PD)
Corey Bathurst PhD Student
Harrison Coombes PhD Student
Jason Pioquinto Undergraduate Stude
Tyler Reynolds Graduate Student
Tarek Saab PI
Zachary Speaks Undergraduate Stude
Lucas Bezerra
Ashley Li
Aditi Pradeep
2

Super Cryogenic Dark Matter Search (SuperCDMS)

- Use cryogenic detectors to search for dark matter interactions with standard model matter
- Previously operated at Soudan, Minnesota
- Currently undergoing installation of the next generation at SNOLAB
  - Improving upon detector technologies
  - Lower backgrounds

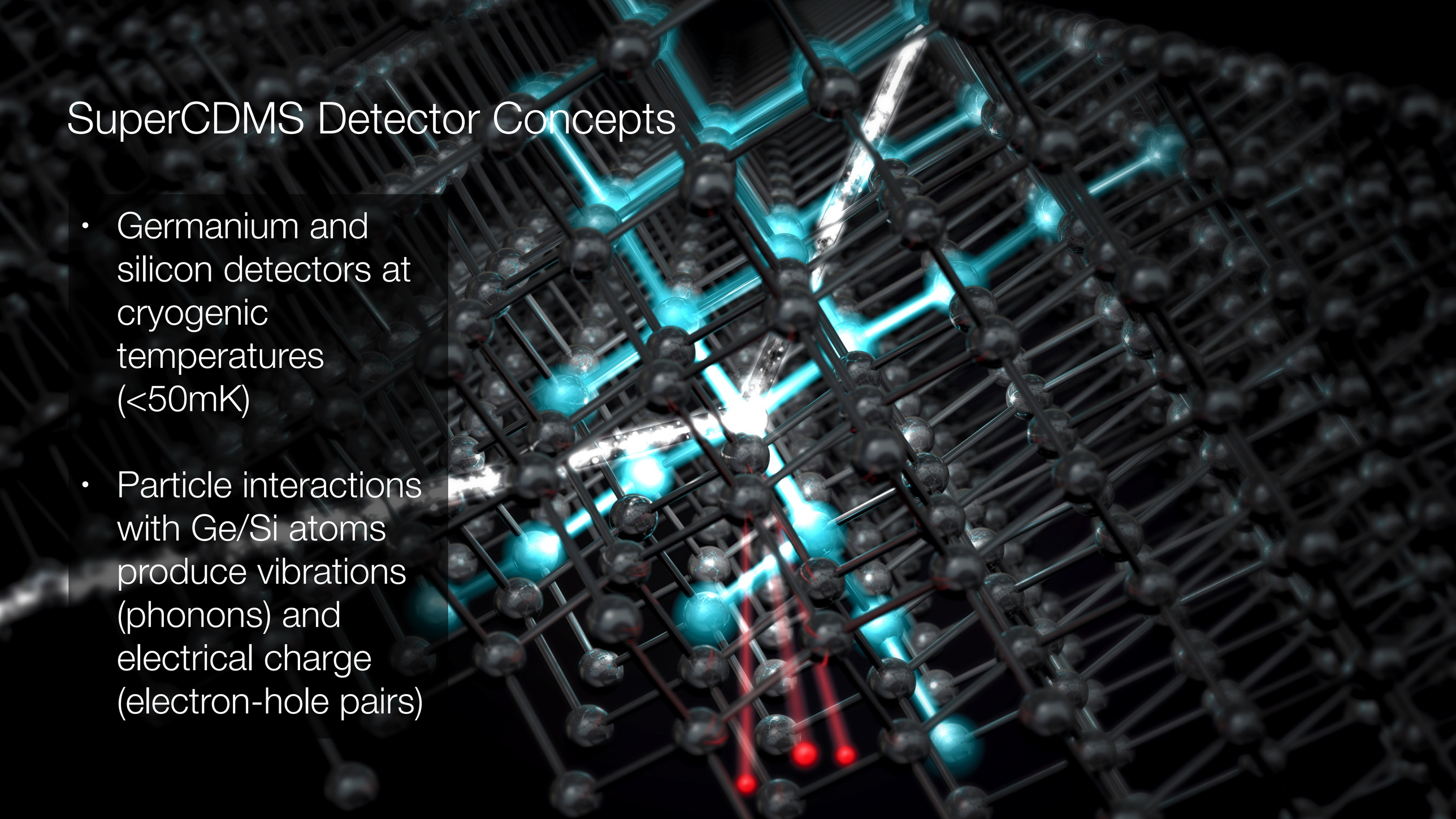
Talk Overview

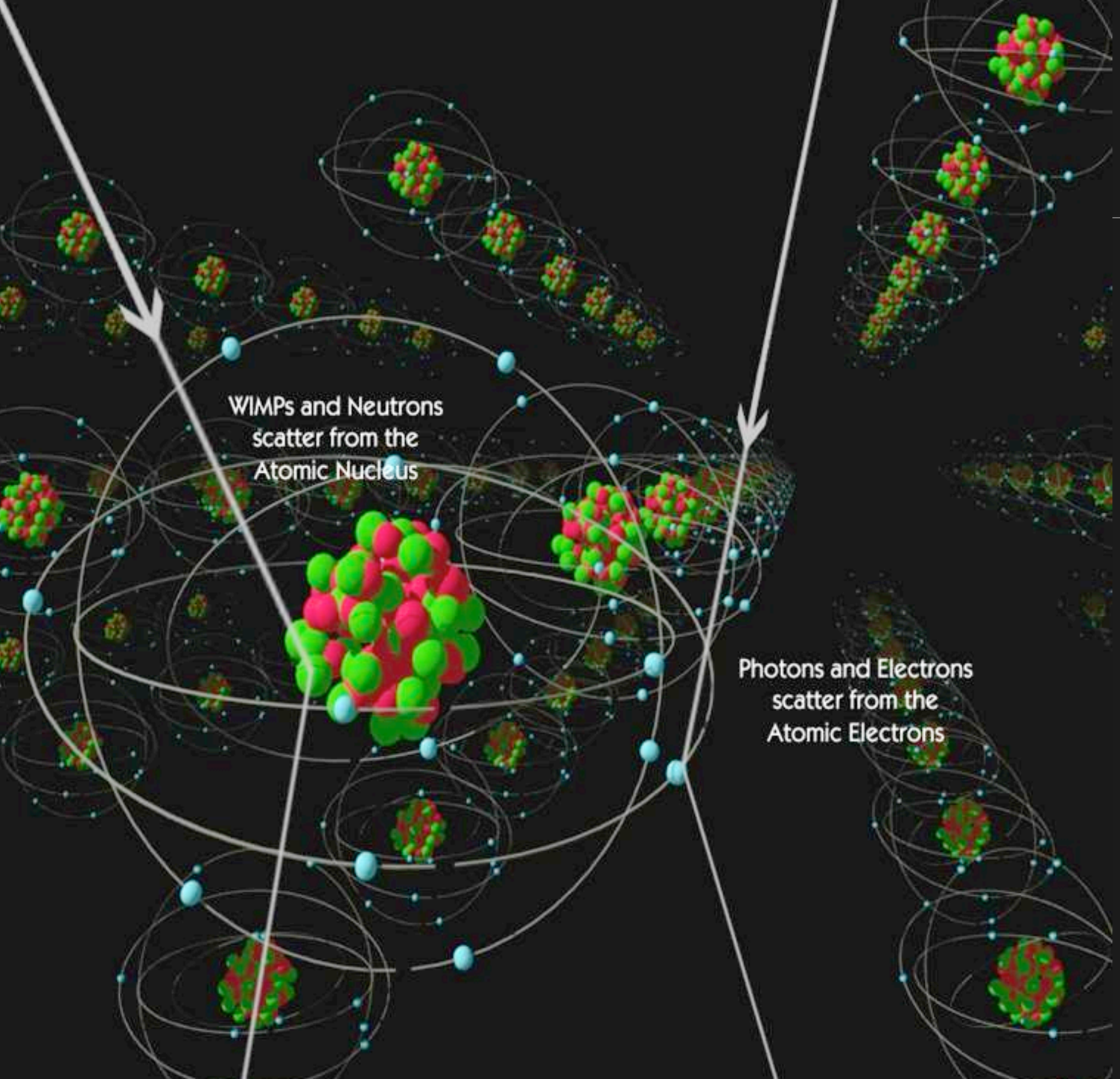
- Detector physics and technologies
- SuperCDMS SNOLAB
- R&D Devices and the CUTE Facility

Detector Physics and Technologies

SuperCDMS Detector Concepts

- Germanium and silicon detectors at cryogenic temperatures (<50mK)
- Particle interactions with Ge/Si atoms produce vibrations (phonons) and electrical charge (electron-hole pairs)



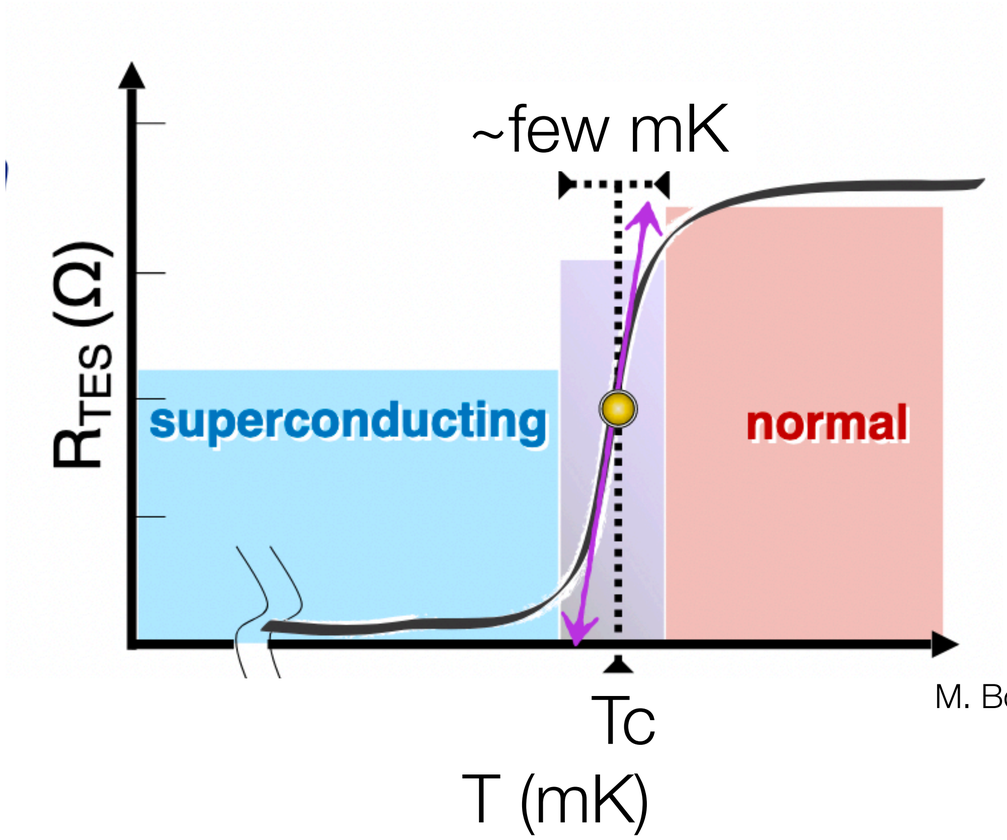


Recoil Type

- Nuclear recoils: WIMPs, neutrons
- Electron recoils: most backgrounds, some DM candidates (e.g. ALPs, dark photons)

Energy Measurement

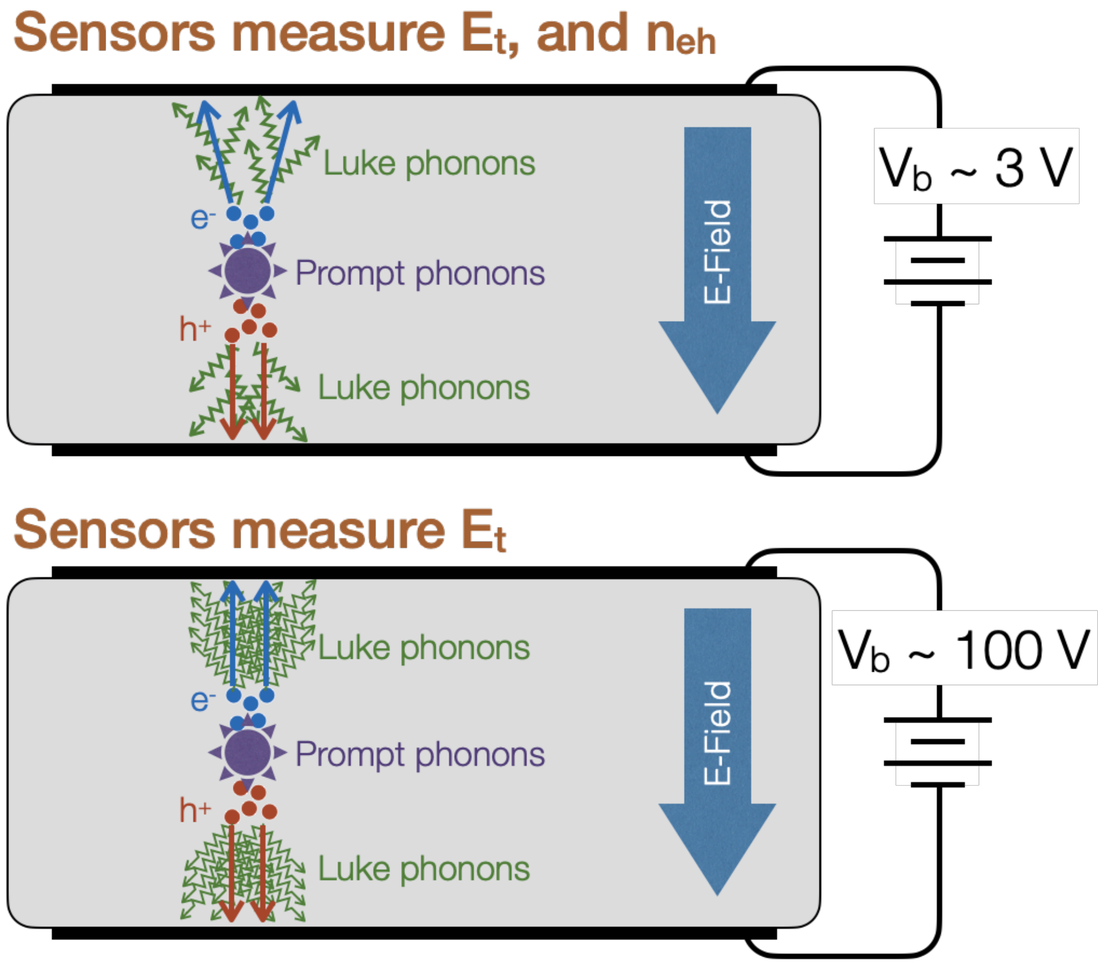
- Phonons are measured via Quasiparticle trap assisted Electrothermal feedback Transition edge sensors (QETs)



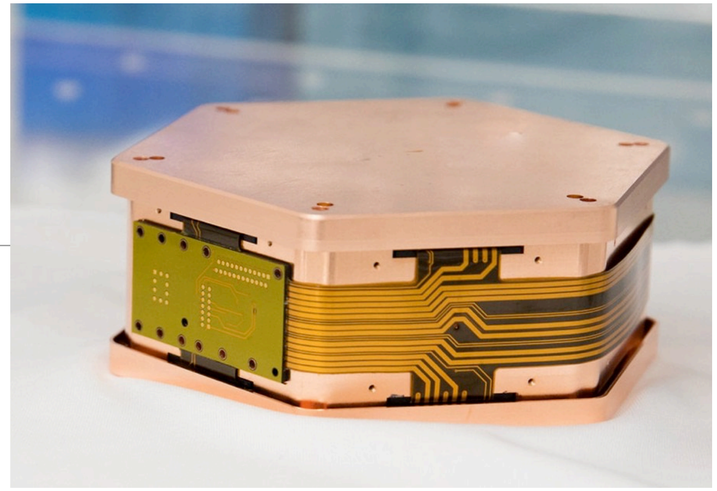
M. Bowles PhD thesis

Neganov-Trofimov-Luke (NTL) Effect

- Charges in the crystal lattice drifting across an applied potential will produce additional phonons called NTL phonons
- Energy in NTL phonons is proportional to applied voltage across the detector
- Results in sensitivity to much lower energies



SuperCDMS SNOLAB Detectors



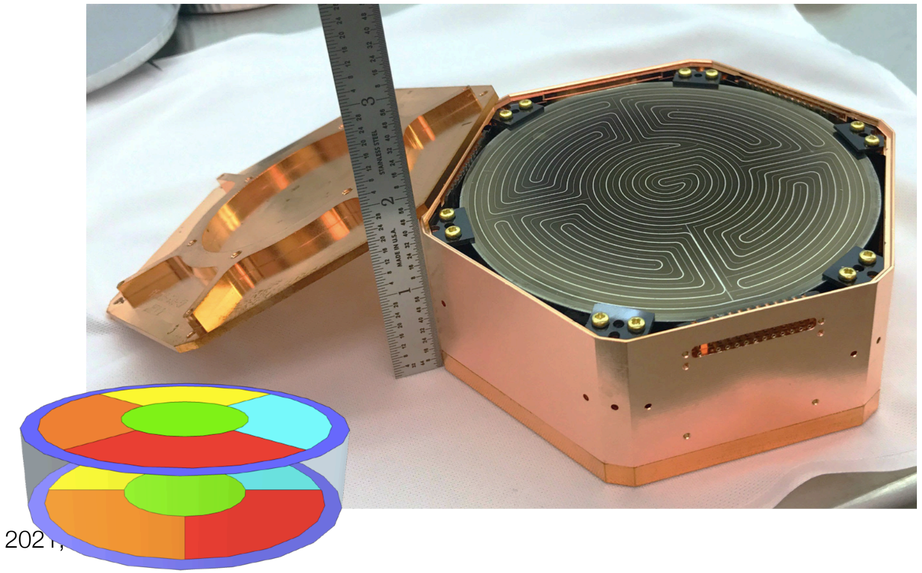
iZIP and HV detectors with new sensor layout in two materials:

- Ge - lower DM cross section sensitivity
- Si - lower DM mass sensitivity

Larger than Soudan detectors (100mm diameter, 33mm thick)

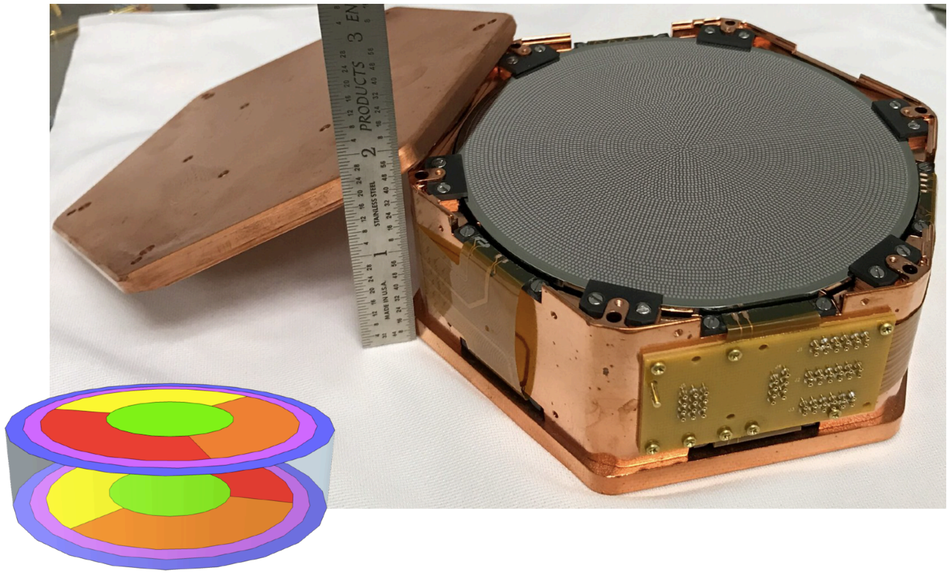
iZIP

- 6-8V bias (minimal NTL phonon contribution)
- NR/ER discrimination
- Surface event removal



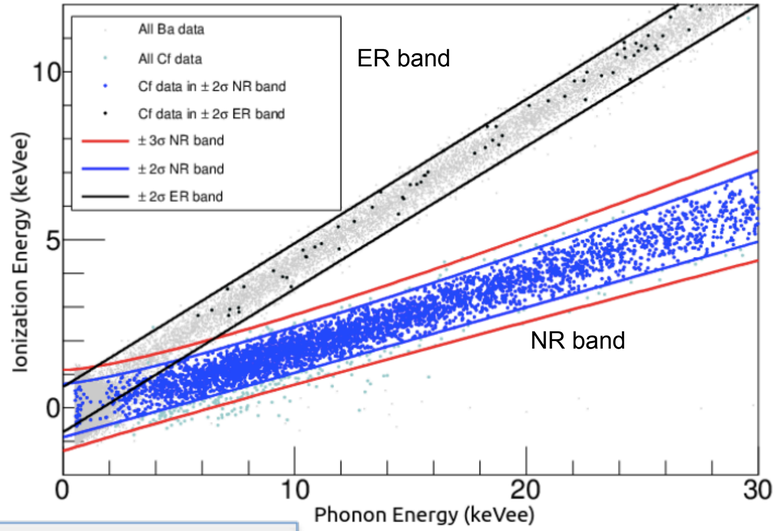
High Voltage (HV)

- 100V bias (NTL phonons dominate)
- Much lower threshold
- No recoil type discrimination

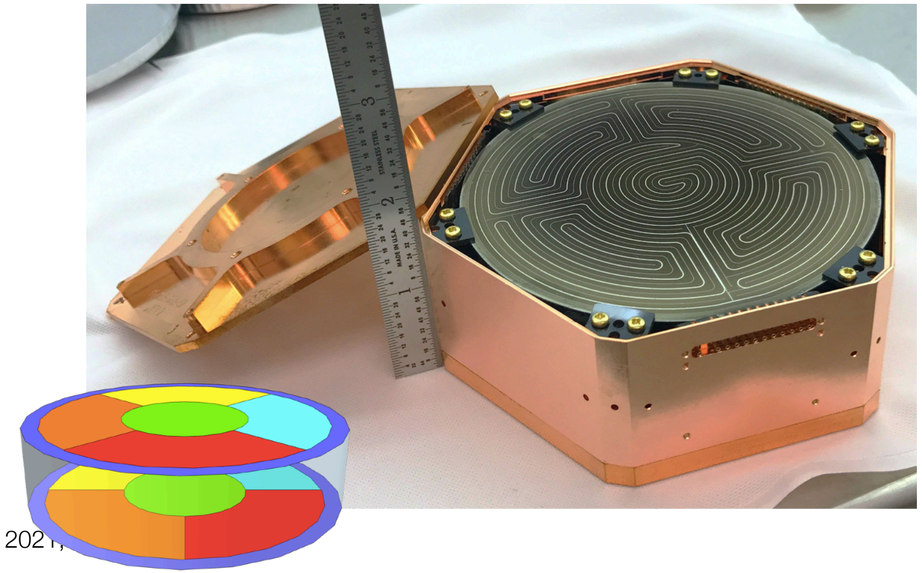


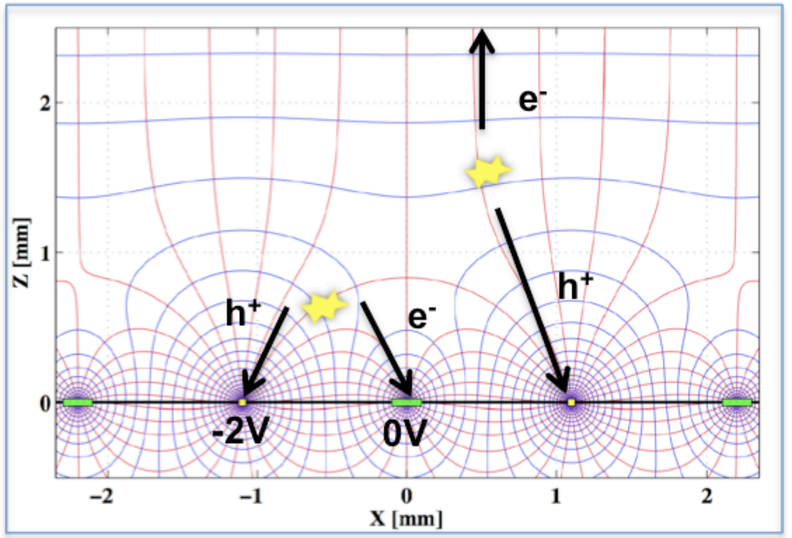
interleaved Z-sensitive Ionization and Phonon (iZIP) Detectors

- iZIP detectors measure phonons and charge - gives recoil type discrimination
  - WIMP DM does not interact electromagnetically, and will interact with the nucleus in a ‘nuclear recoil’
  - Most backgrounds will interact electromagnetically in an ‘electron recoil’
  - The charge yield of each recoil type is different
- Surface events are a problem - are usually background events and have incomplete charge collection (can mistake ERs for NRs)
- Interleaved electrode and phonon sensor layout gives electric field that allows for z-sensitivity and surface event rejection



Recoil type discrimination



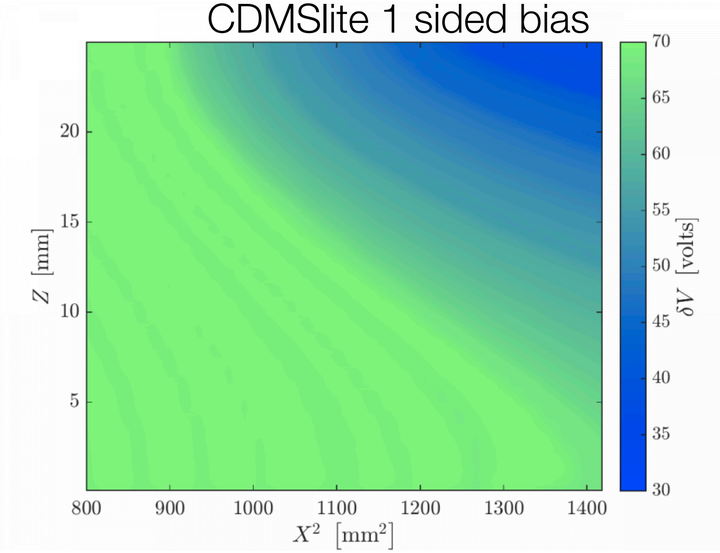


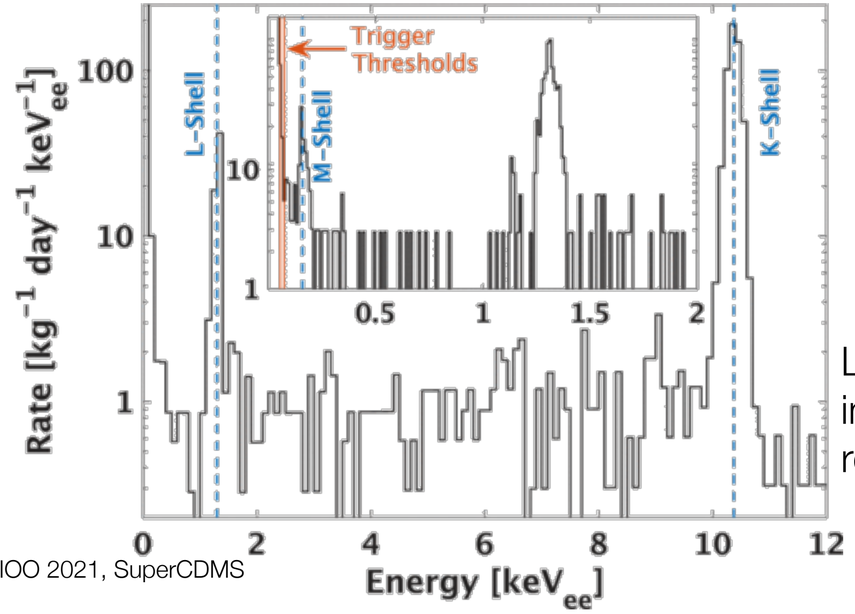
Electric field and z-sensitivity

High Voltage (HV) Detectors

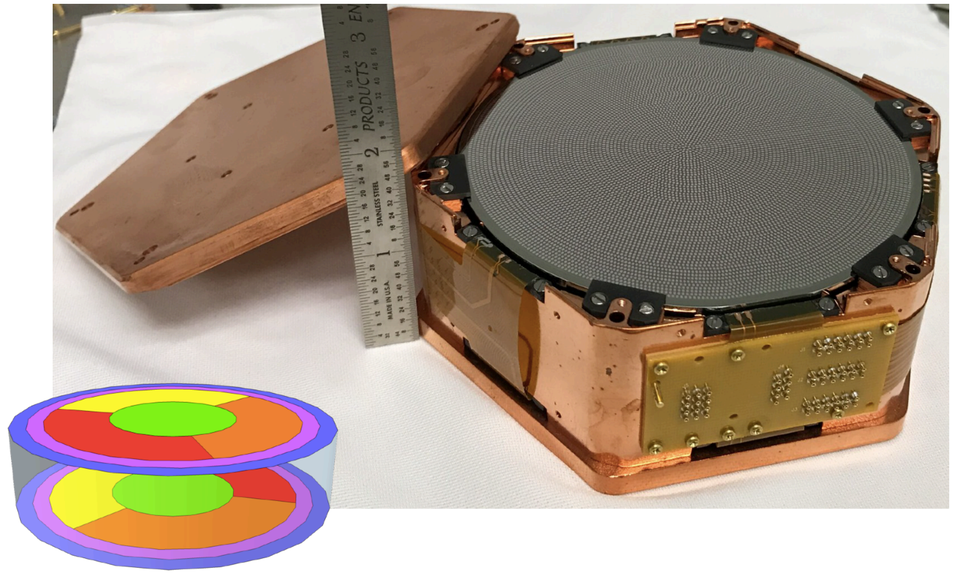
- New detector type based on operation of SuperCDMS Soudan iZIP detectors at high (~70 V) bias (called CDMSlite mode)
  - 2 sided bias for uniform E-field
  - Channel layout optimized for position sensitivity
  - No charge readout
- Higher density phonon sensor coverage (35%) compared to iZIP (4%) - decreased phonon collection time
- Improved energy resolution and lower threshold

Non-uniform E-field from CDMSlite 1 sided bias





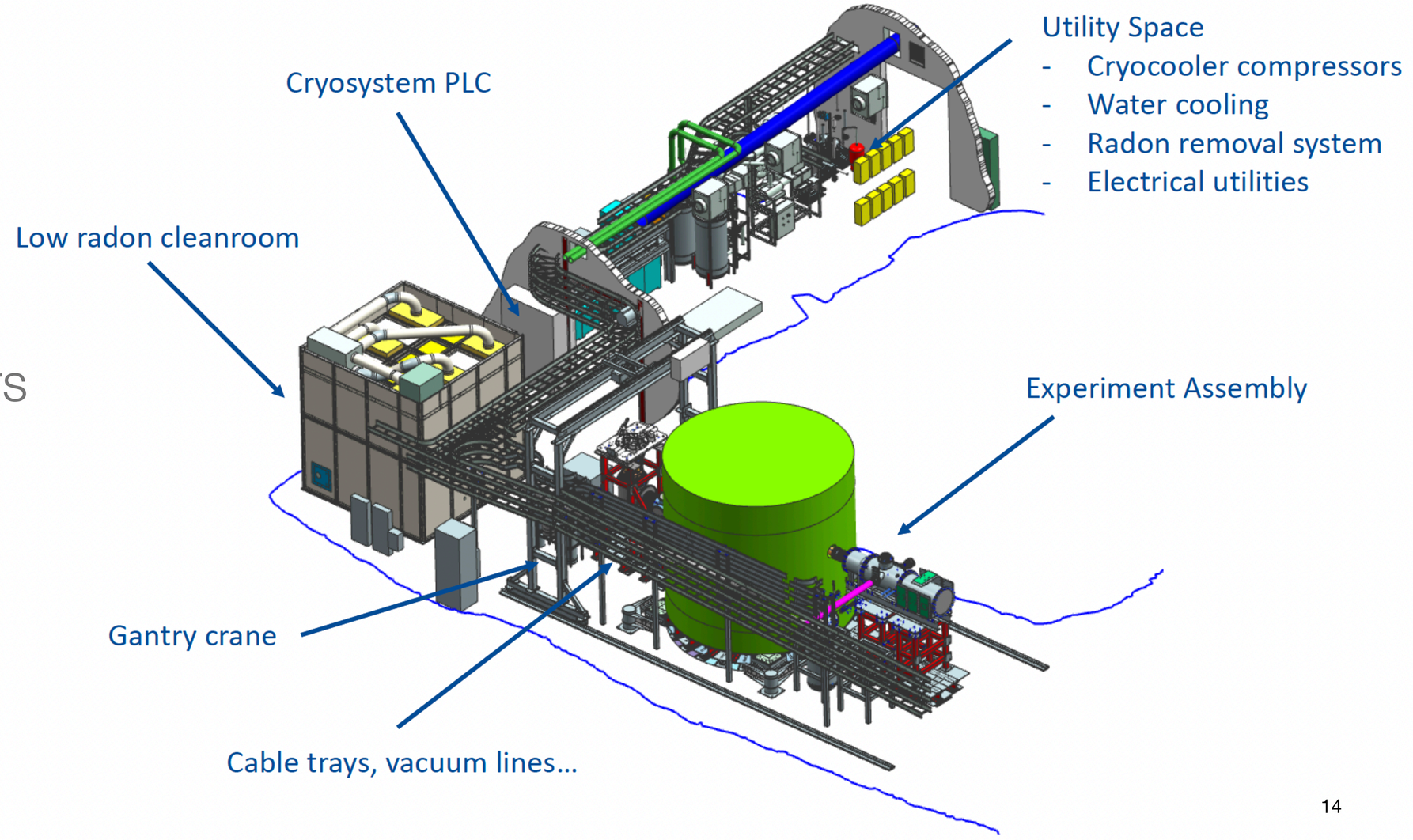
Low threshold and improved energy resolution in CDMSlite



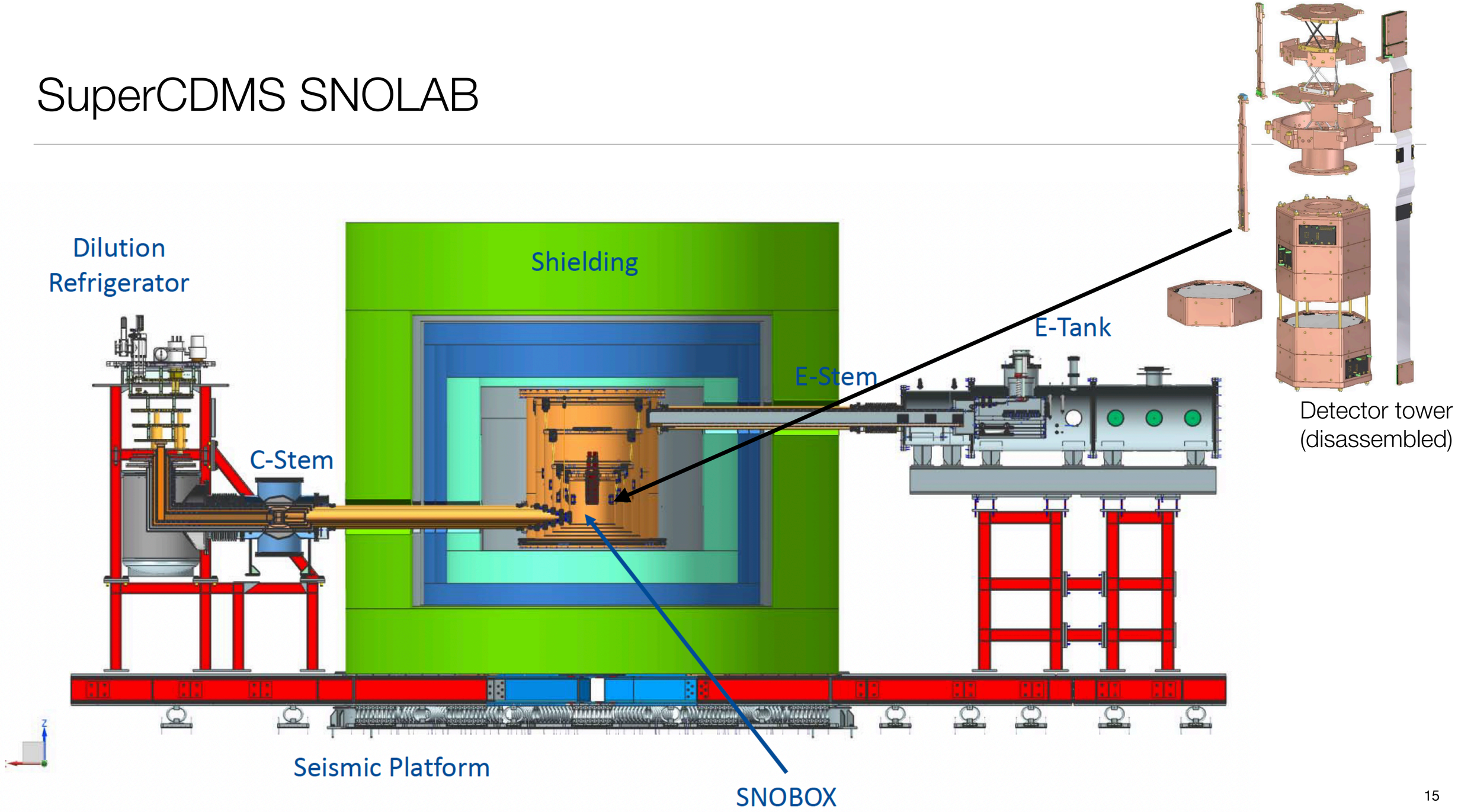
SuperCDMS SNOLAB

SuperCDMS SNOLAB

- 7 tower capacity, 6 detectors per tower
- Commissioning planned for 2022
- First run with 4 towers



SuperCDMS SNOLAB



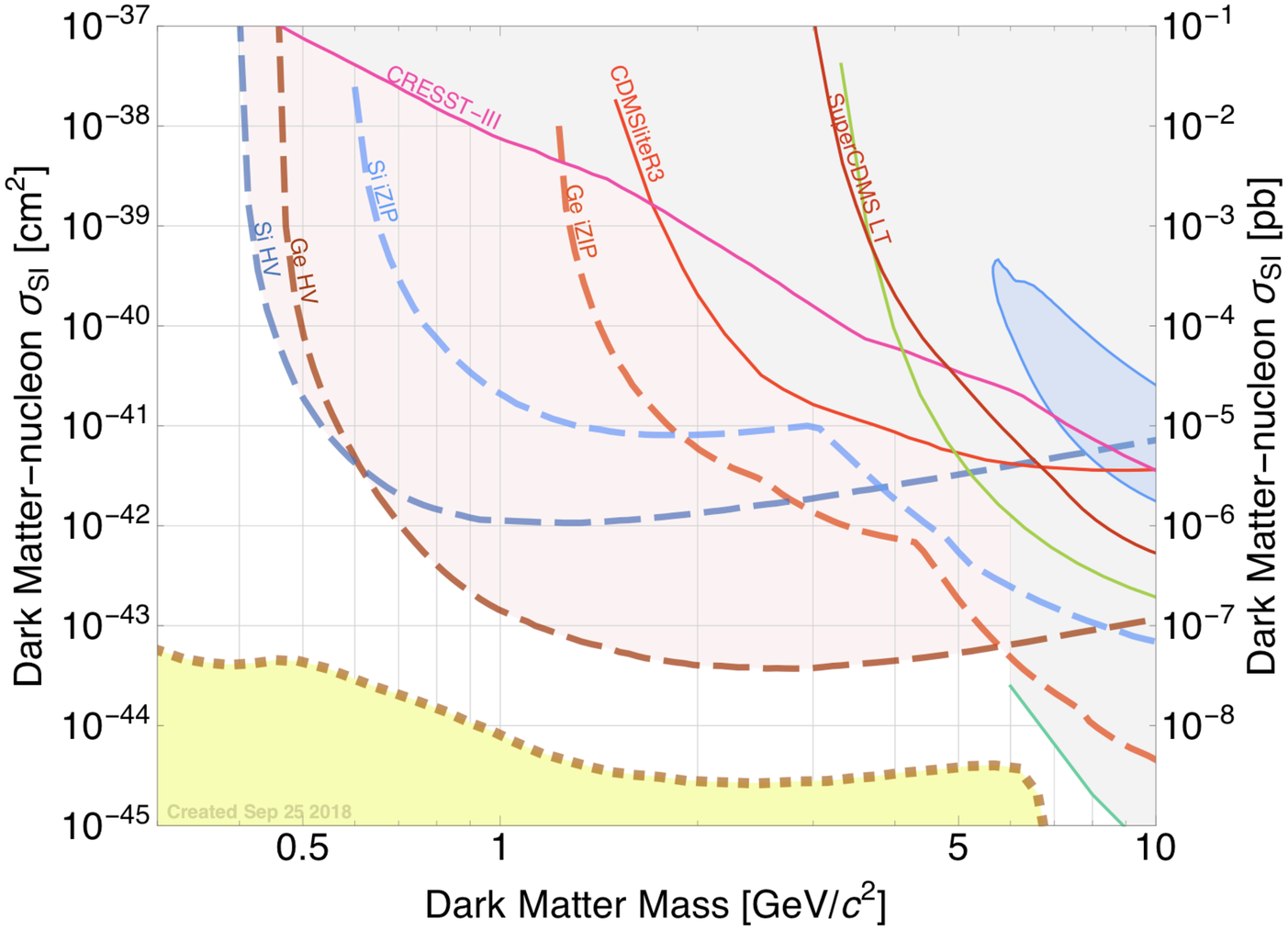
SuperCDMS SNOLAB Construction

- Construction is progressing!

seismic platform

low radon cleanroom

SuperCDMS SNOLAB Goal (SI WIMP DM)



Tower and Detector Arrangement

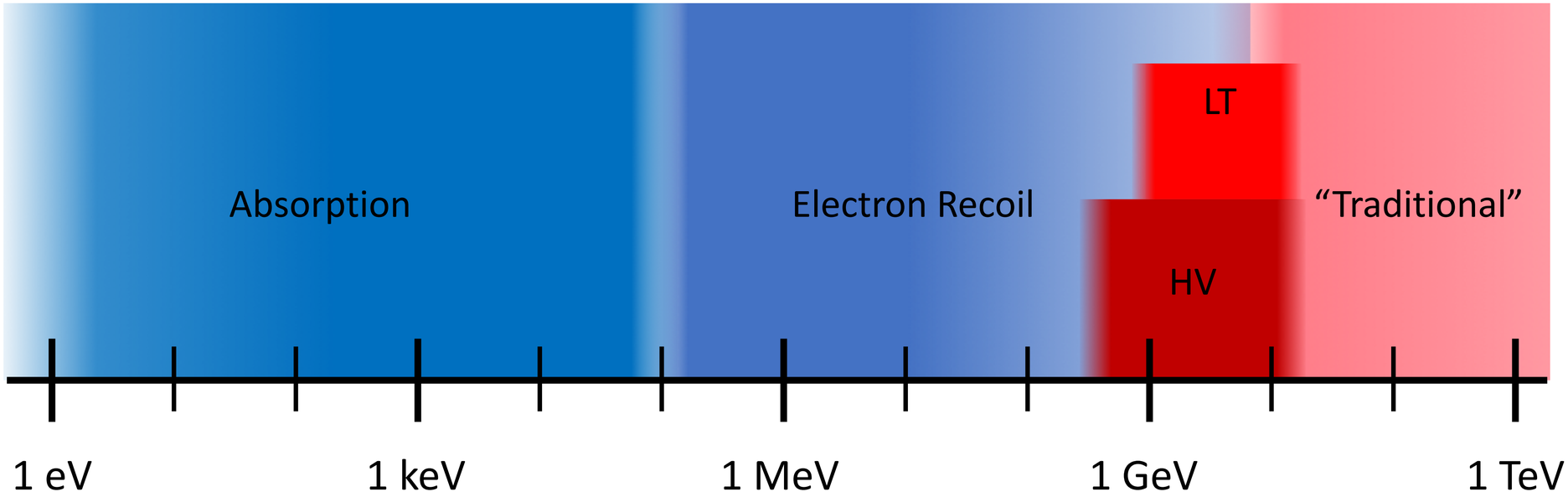
T1 iZIP | T2 HV | T3 HV | T4 iZIP

	Germanium	Silicon
HV	Low mass sensitivity No ^{32}Si background	Lowest mass sensitivity
iZIP	NR discrimination	NR discrimination

SuperCDMS Collaboration (2016)
10.1103/PhysRevD.95.082002

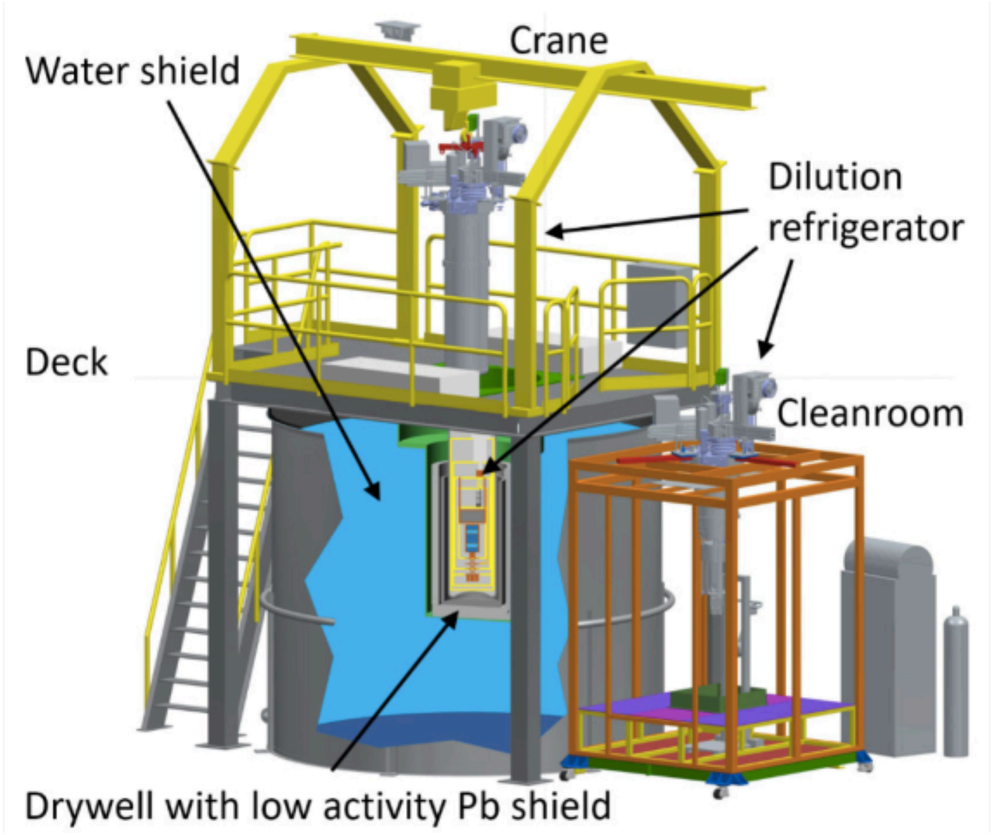
SuperCDMS SNOLAB Sensitivity

Dark Matter Mass Ranges		
Traditional NR	iZIP, “background free”	$\gtrsim$ 5 GeV
Low Threshold NR	iZIP, limited discrimination	$\gtrsim$ 1 GeV
HV NR	HV, no discrimination	~0.3 – 10 GeV
Electron recoil	HV, no discrimination	~0.5MeV – 10 GeV
Absorption (dark photons, ALPs)	HV, no discrimination	~1 eV – 500 keV (“peak search”)



R&D Devices and CUTE Facility

Cryogenic Underground TEst (CUTE) Facility



A low background test facility at SNOLAB

- Cryogen-free dilution refrigerator
- Capable of operating a single SuperCDMS tower
- Goal: characterize SuperCDMS SNOLAB detectors

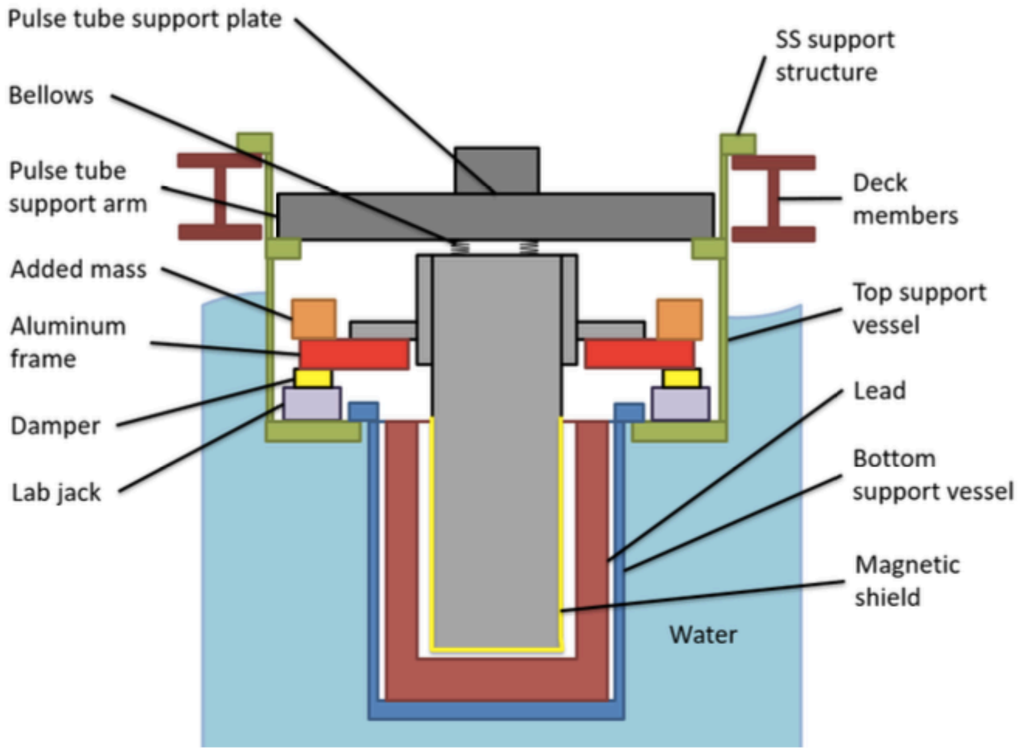
Shielding

- Rock overburden
- Water tank (1.5m radius)
- Polyethylene shield
- Internal and external lead shields

Suspension system

- Vibration isolation
- Active damper system to account for lab pressure changes

Cryogenic Underground TEst (CUTE) Facility



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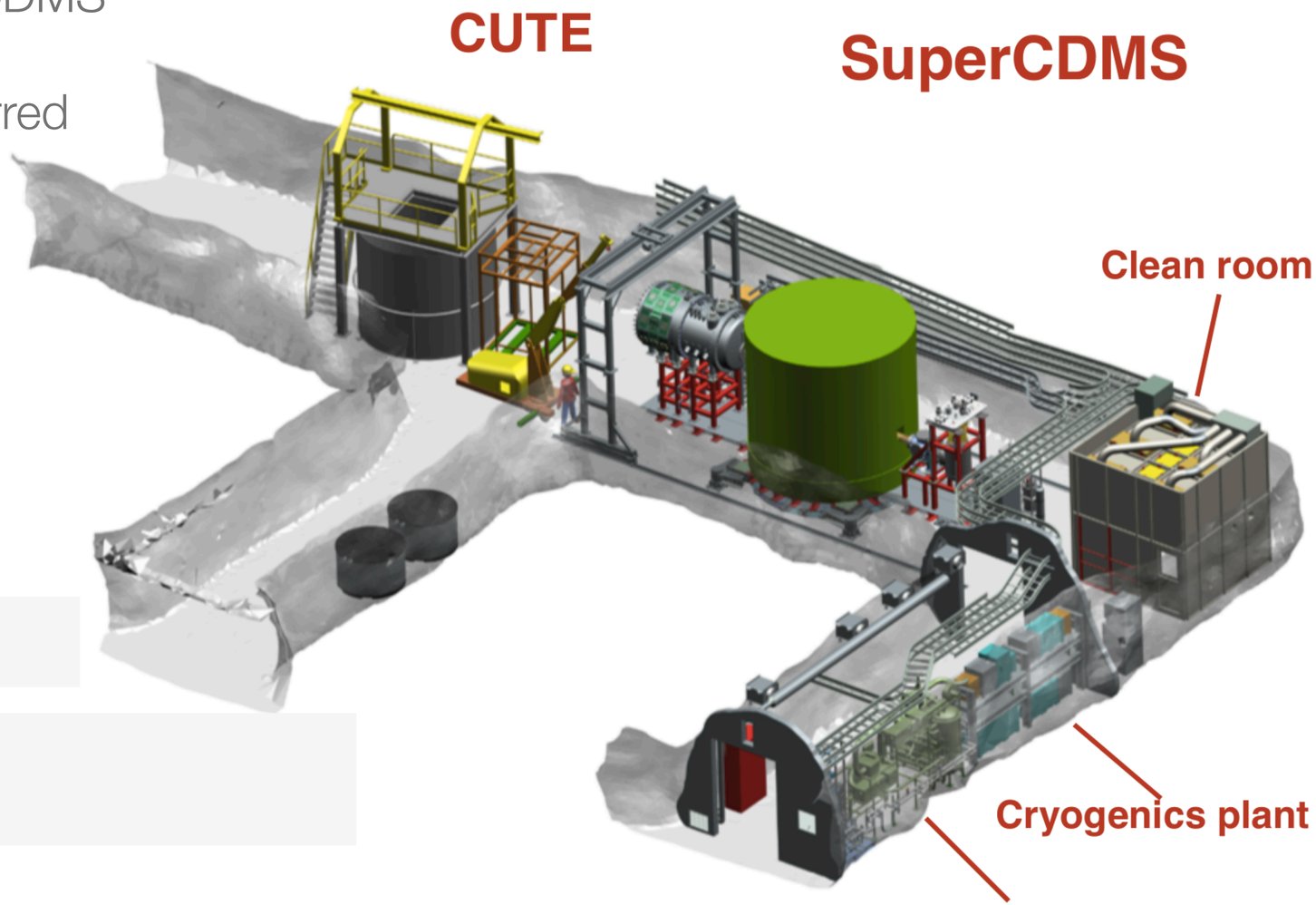
CUTE and SuperCDMS

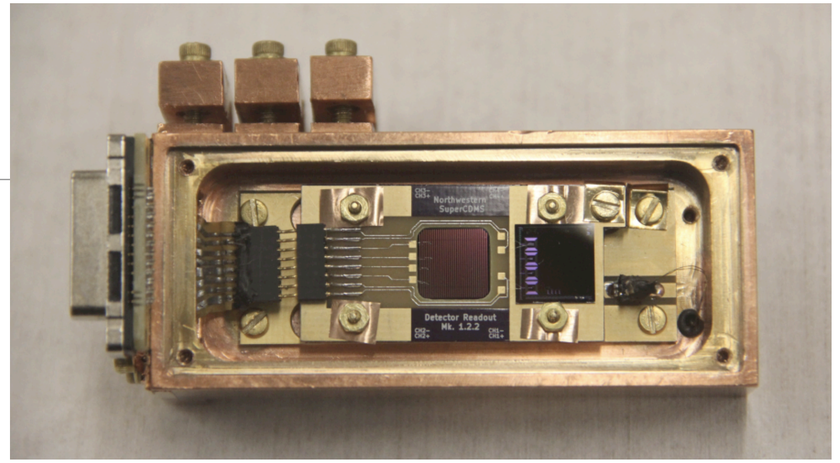
- CUTE is currently managed by SuperCDMS
- Management will eventually be transferred to SNOLAB

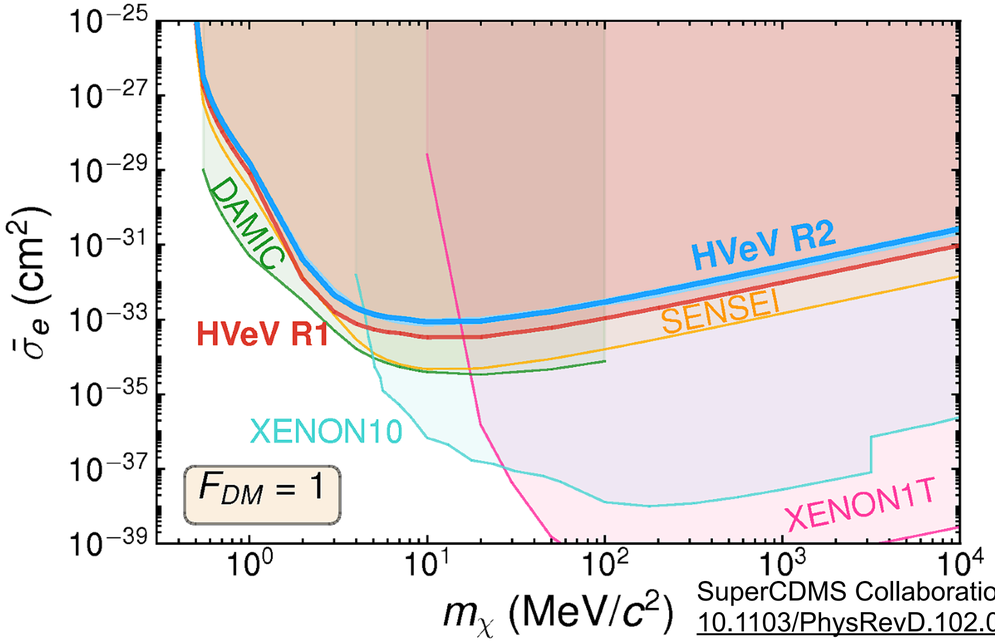
CUTE at SNOLAB



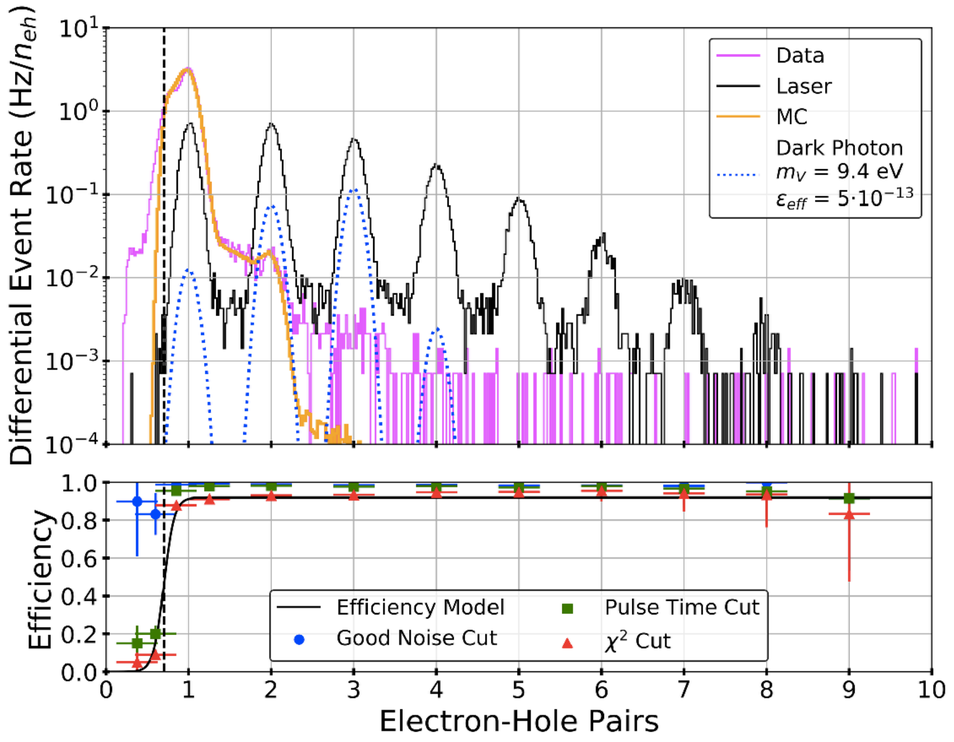
HVeV Detectors

- Small Si HV (1cm x 1 cm$_2$x 4 mm) @ 100-140 V bias
- Very low energy resolution, can resolve single electron-hole pairs
- Can set competitive dark matter limits even at surface facilities





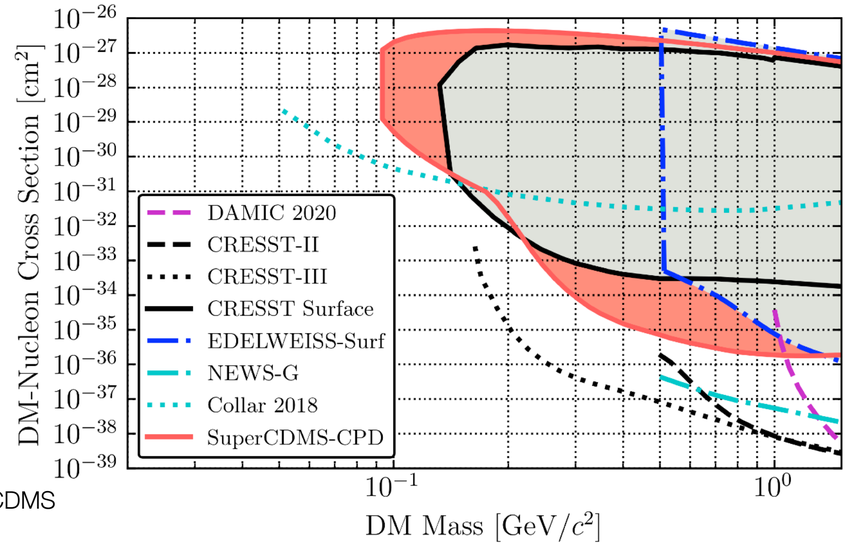
SuperCDMS Collaboration 2020
10.1103/PhysRevD.102.091101

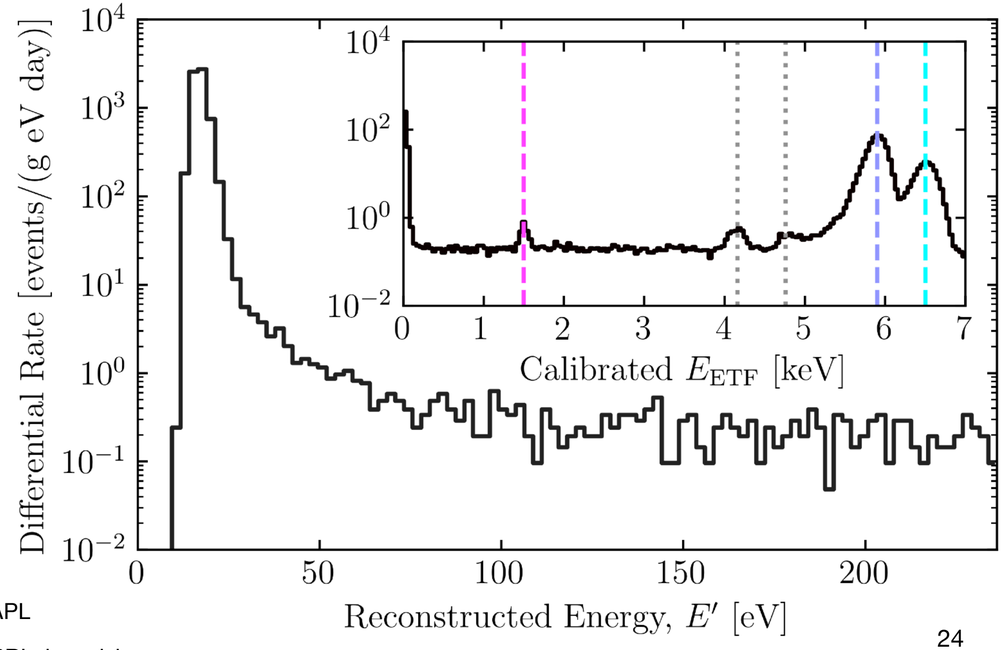


SuperCDMS Collaboration
10.1103/PhysRevLett.121.051301

Cryogenic PhotoDetectors

- Optimized for photon detection
- Single distributed channel for fast athermal phonon collection time
- No bias voltage applied
- Low threshold (~20eV) and very good energy resolution (~4eV)
- Very competitive for low mass DM search via nuclear recoils
- Two CPD devices have been operated at the CUTE facility!





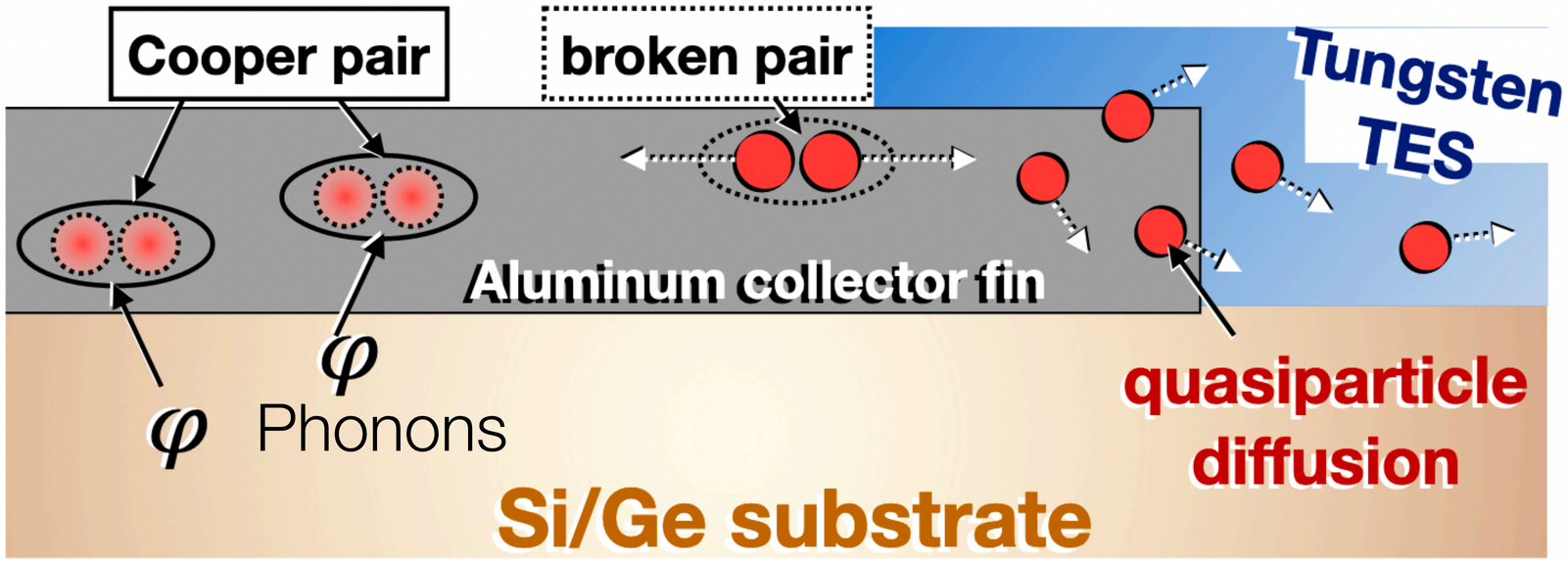
arXiv:2009.14302, submitted to APL

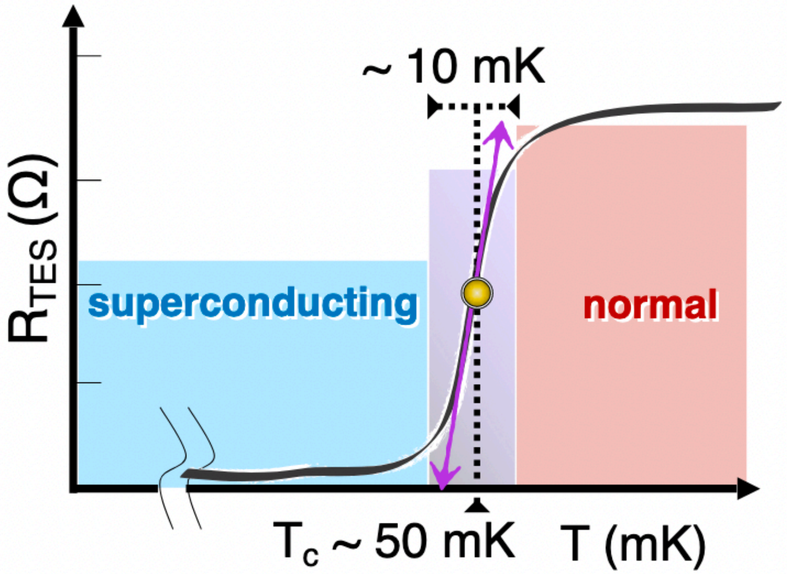
arXiv:2007.14289, submitted to PRL, in revisions

Questions?

Backup

QETs





M. Bowles PhD thesis