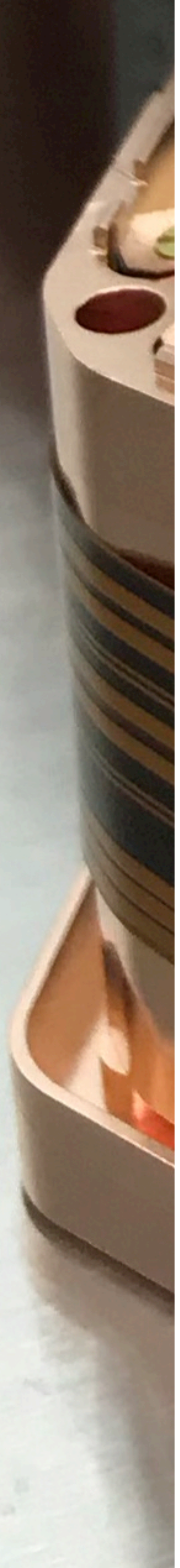

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Super CDMS

The SuperCDMS dark matter experiment

October 21, 2018

John L. Orrell
Research Scientist

U.S. DEPARTMENT OF ENERGY BATTELLE

PNNL-SA-138955

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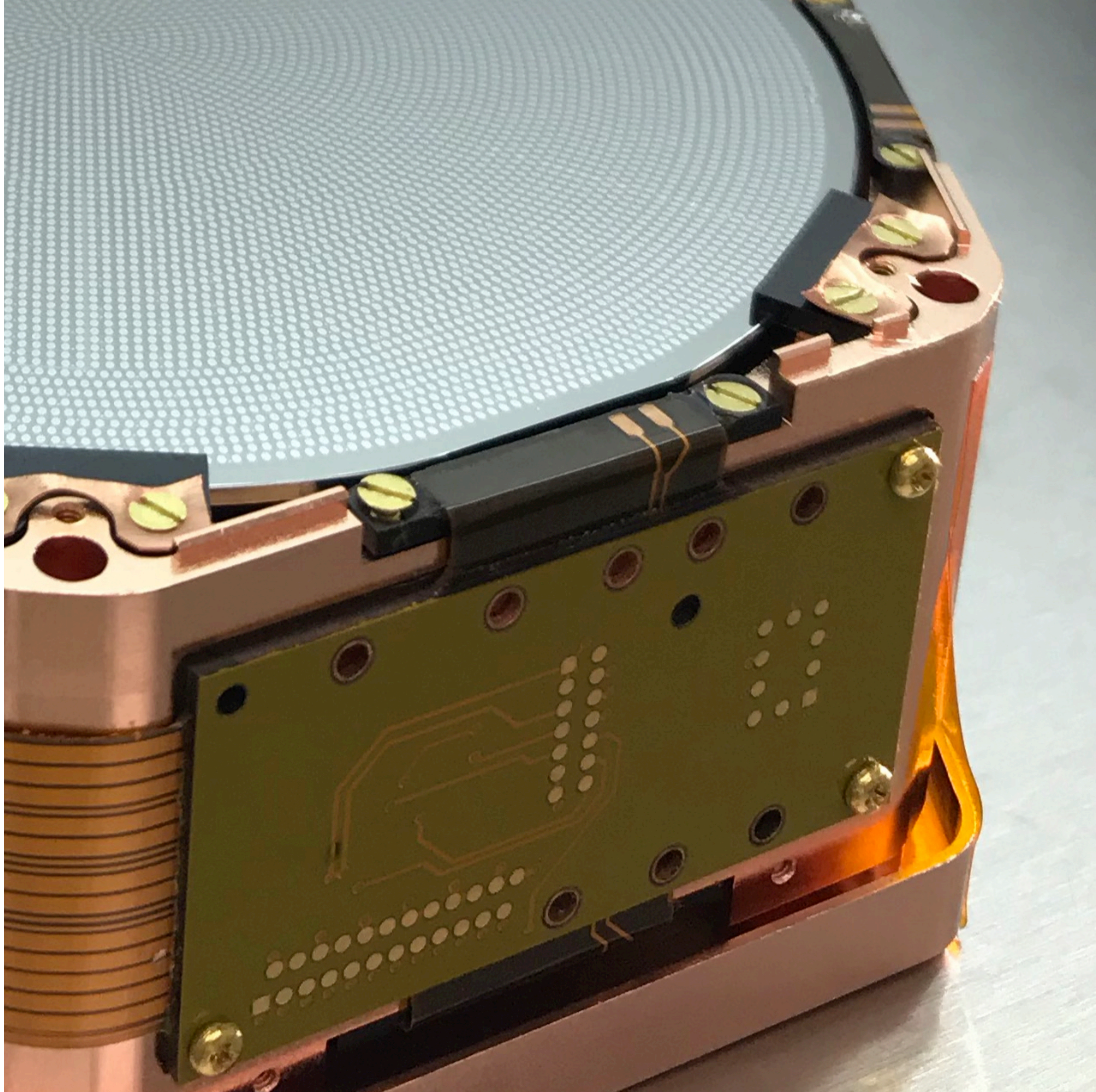

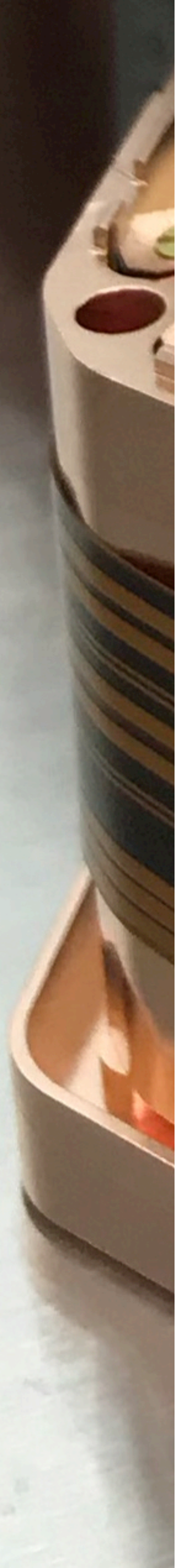

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Outline

SuperCDMS

- SuperCDMS SNOLAB
  - Design
  - Detectors
  - Sensitivity
- Backgrounds
  - Overview
  - Tritium from cosmic rays
  - Cu surfaces & bulk ^{210}Pb
  - Kapton & cirlex
- R&D detectors
  - HVeV
- Summary

SuperCDMS Collaboration

California Inst. of Tech. | CNRS-LPN* | Durham University | FNAL | NISER | NIST*

Northwestern | PNNL | Queen's University | Santa Clara University | SLAC | South Dakota SM&T

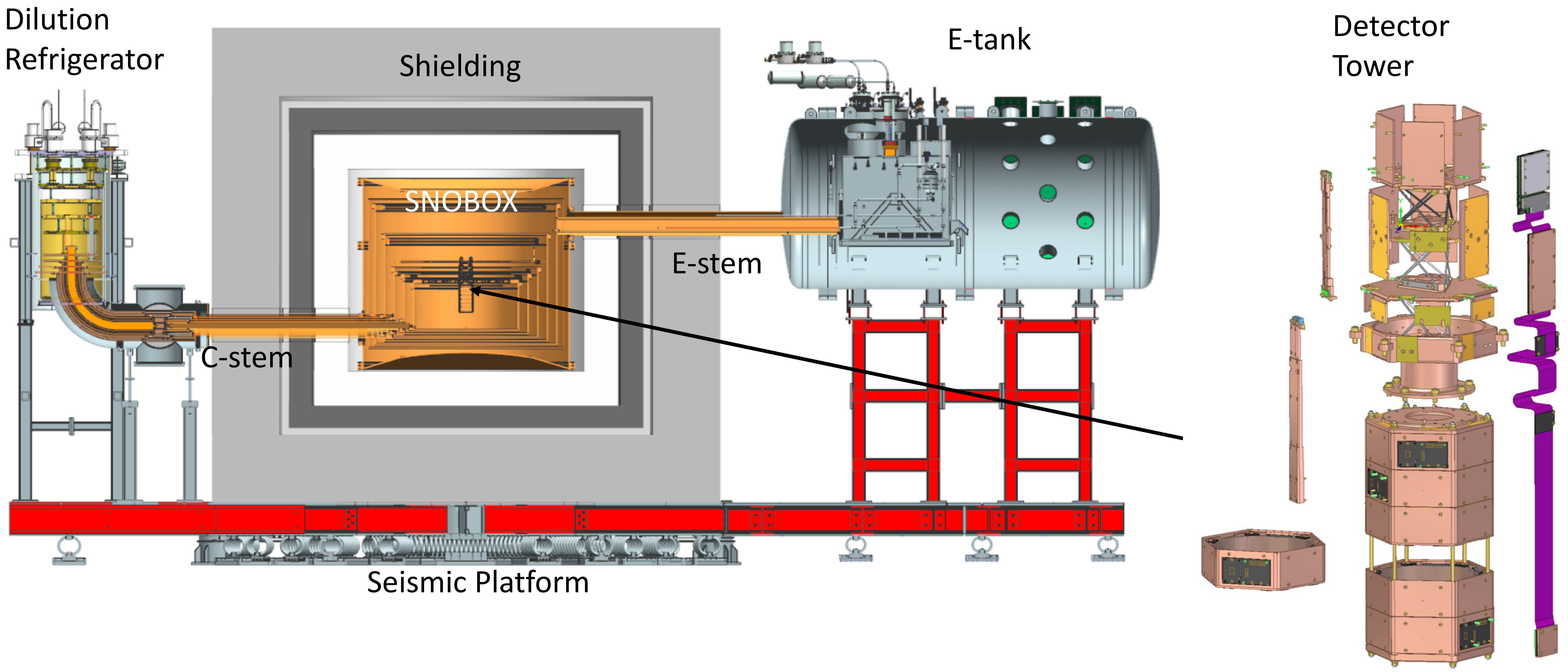
SMU | SNOLAB | Stanford University | Texas A&M University | TRIUMF | U. British Columbia

U. California, Berkeley | U. Colorado Denver | U. Evansville | U. Florida

U. Montréal | U. Minnesota | U. South Dakota | U. Toronto

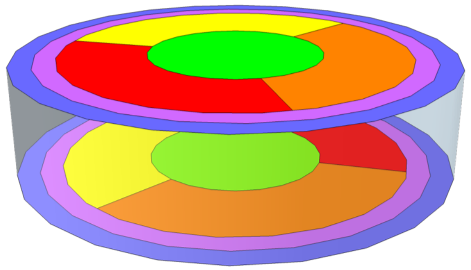
* Associate members

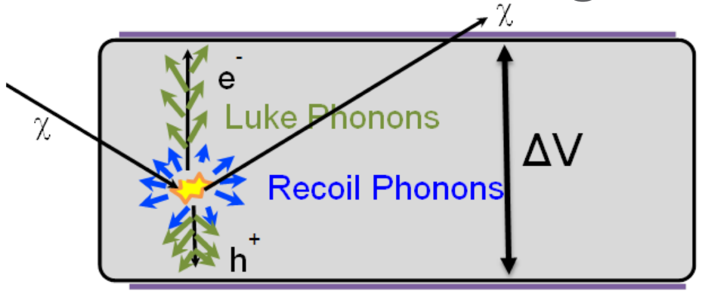
Experimental design, located at SNOLAB

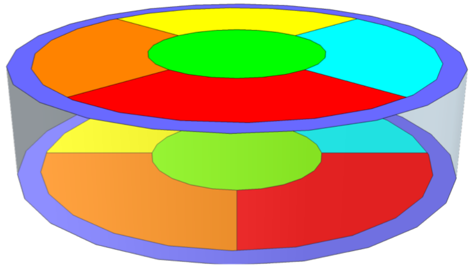


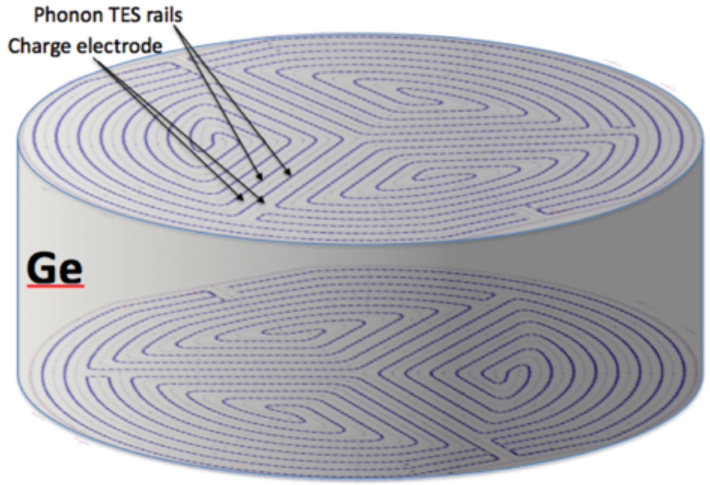
Ge & Si solid-state cryogenic detectors

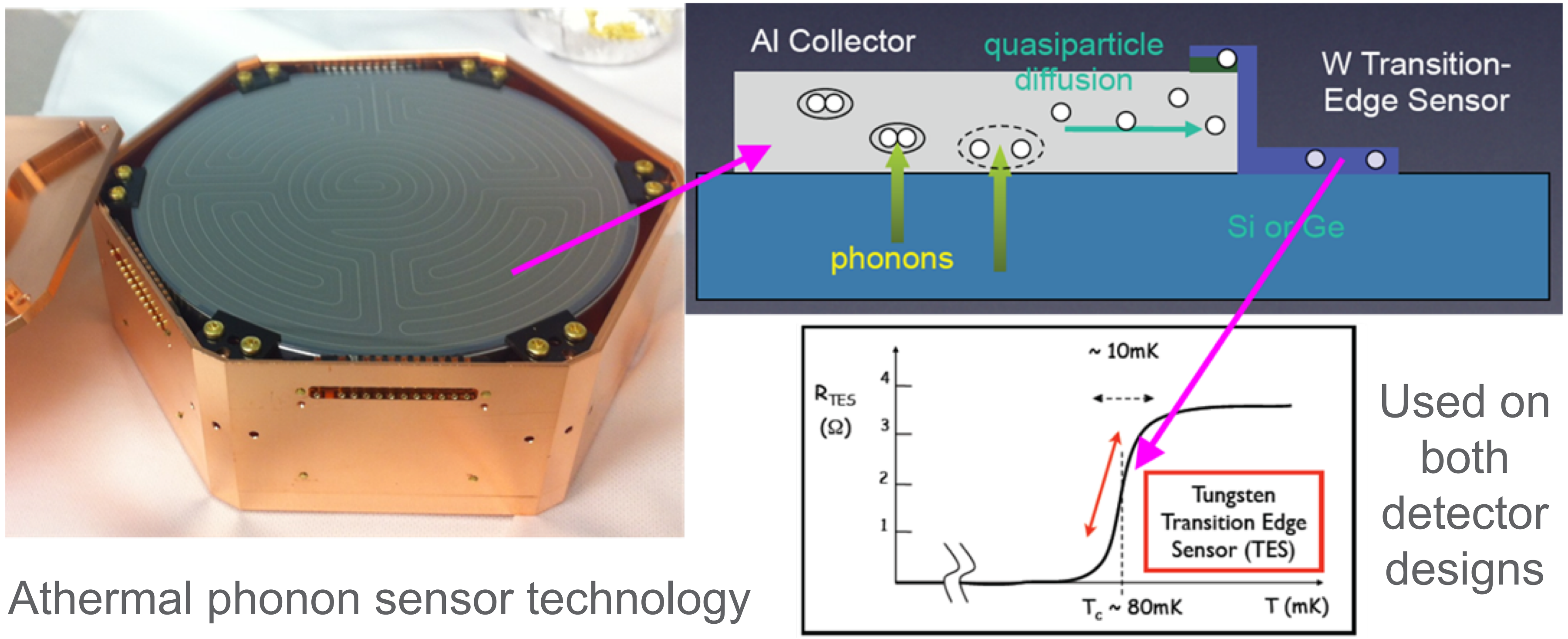
- High Voltage (HV) – Phonon-only measurement of ionization charge
- interleaved Z-dependent Ionization & Phonon (iZIP) – NR/ER discrimination





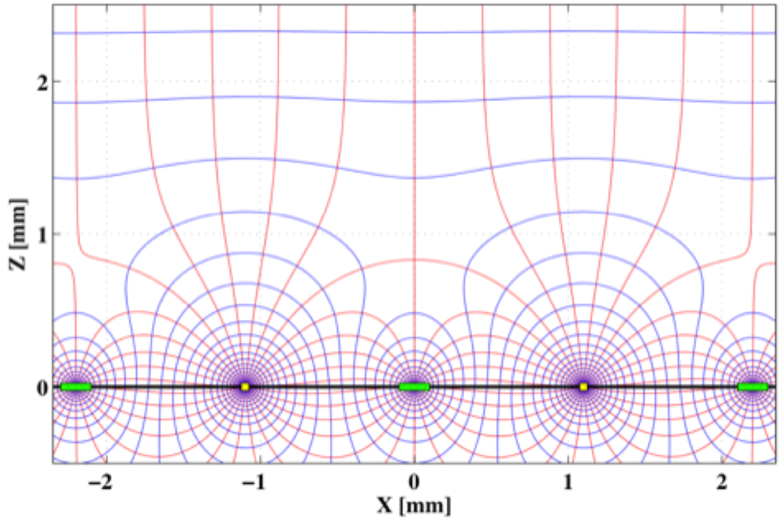






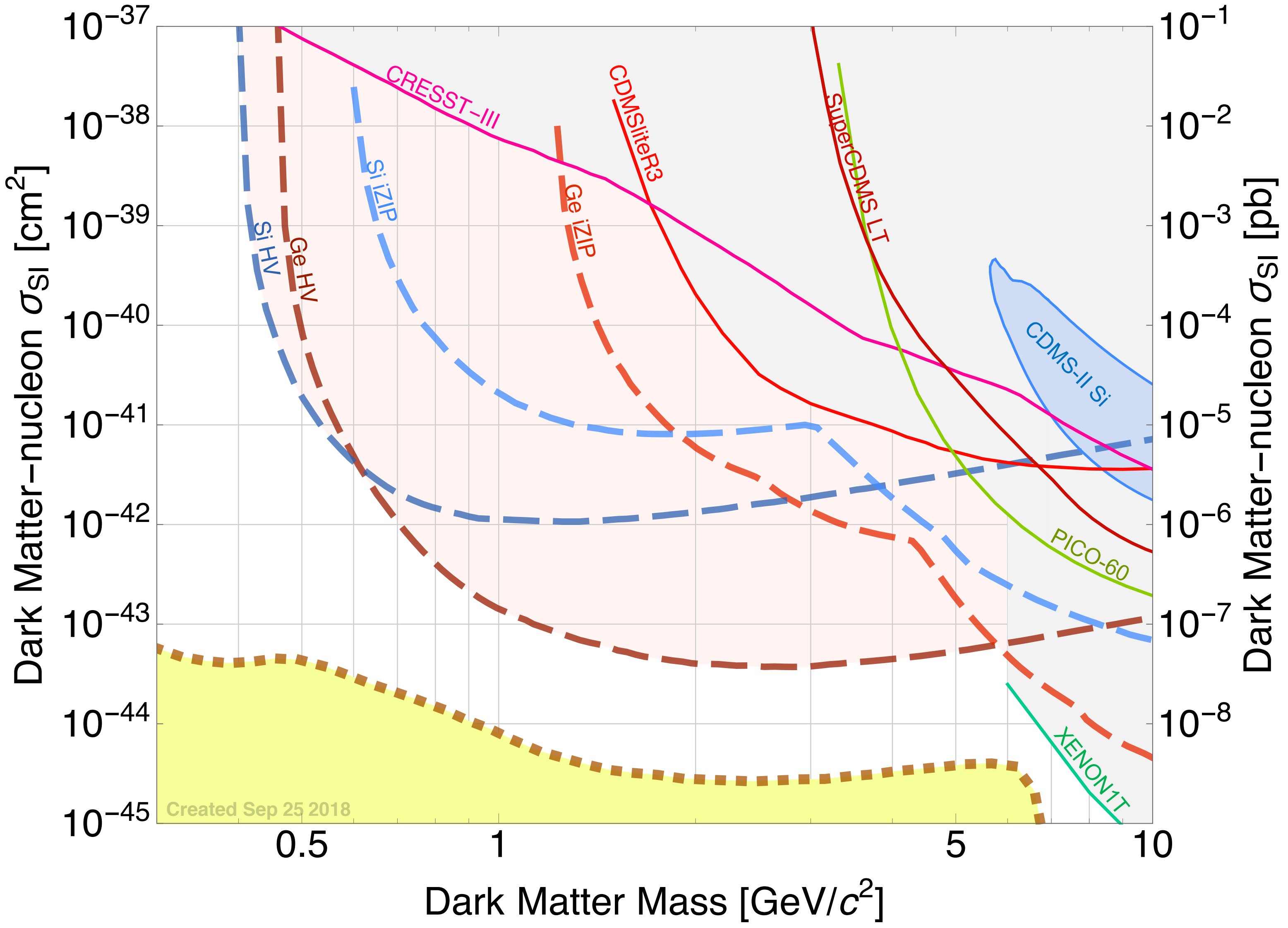
Athermal phonon sensor technology

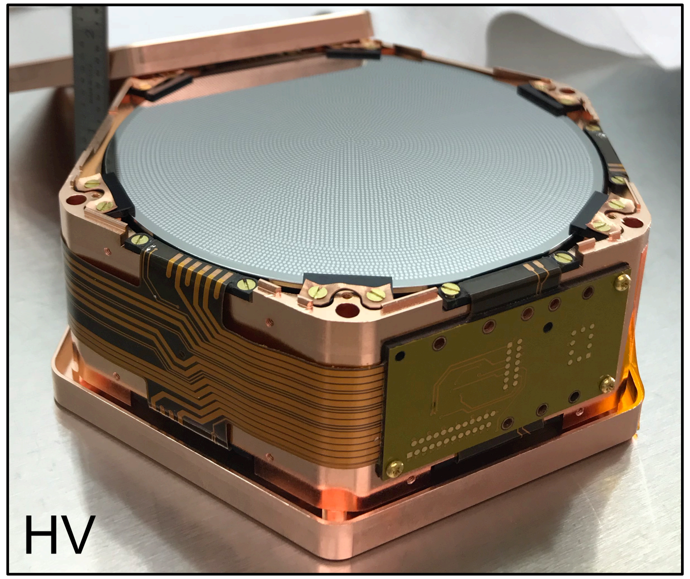
Used on both detector designs

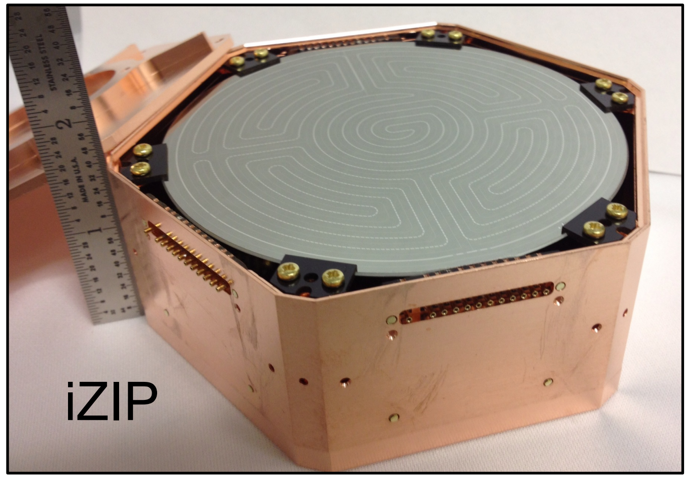


Sensitivity reach of SuperCDMS SNOLAB

- Direct detection search for spin-independent dark matter interactions

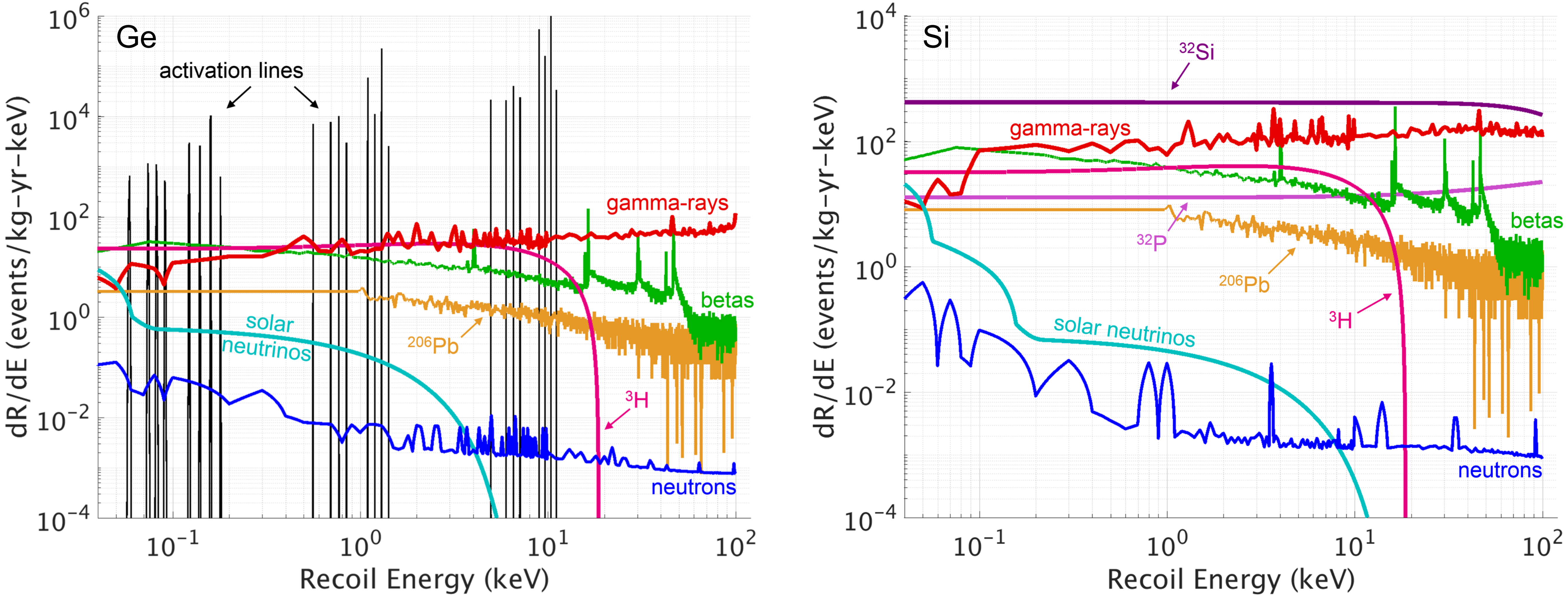




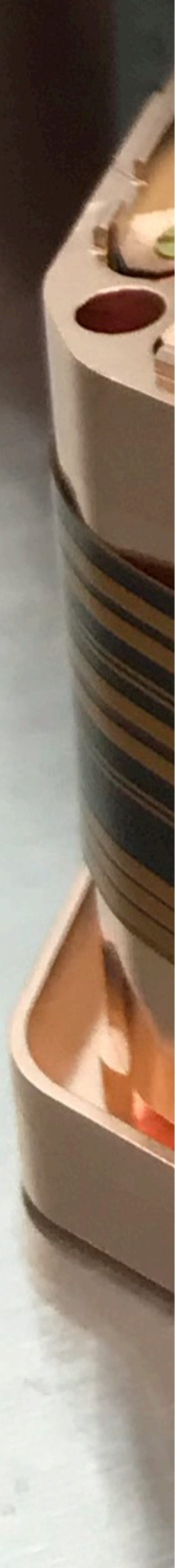


Backgrounds overview

- Anticipated: Tritium, ^{32}Si (only in Si), surface Rn daughters, material impurities

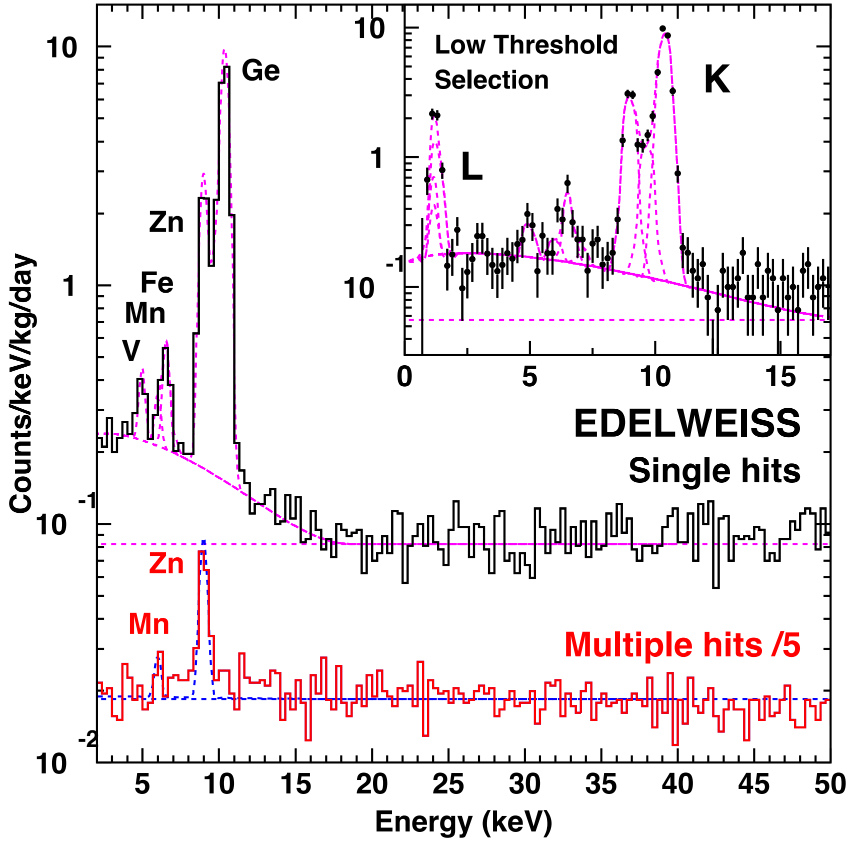


Spectra shown before detector resolution and application of single-scatter, fiducial volume, and nuclear recoil cuts

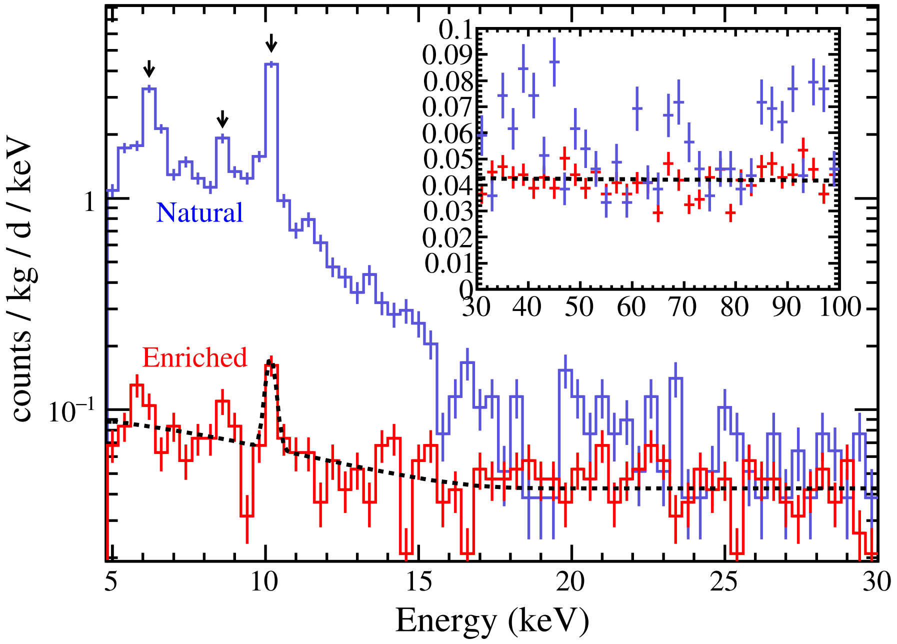


Tritium from cosmic ray spallation

- Exposure of Ge & Si crystals to secondary cosmic rays (*e.g.*, *n*, *p*, μ) causes nuclear spallation producing a variety of long-lived, unstable nuclei
  - Tritium (^{3}H) is especially problematic: $t_{1/2}$ = 12.3 yr, pure β-decay, E_β^{End} = 18.6 keV

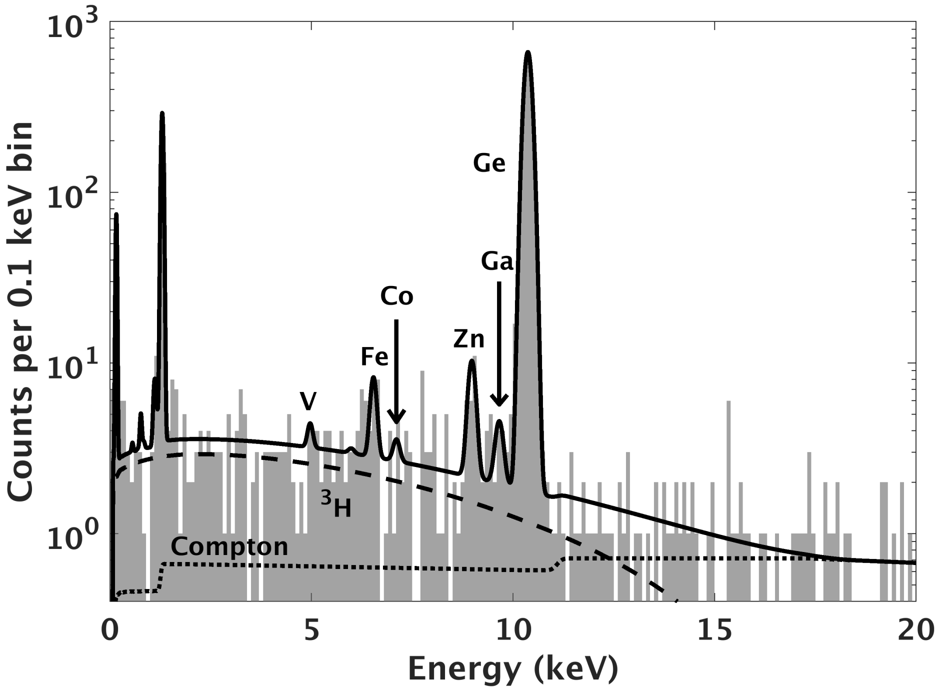


E. Armengaud *et al.*,
Astropart. Phys. 91 (2017) 51-64



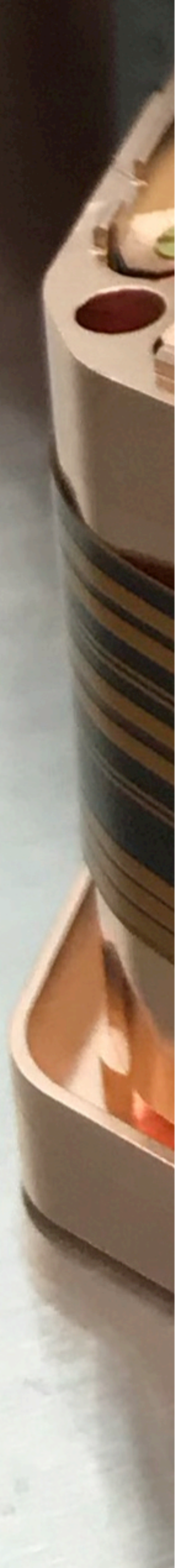
MAJORANA DEMONSTRATOR

N. Abgrall *et al.*,
NIM A 877 (2018) 314-322



CDMSlite Run 2 (Soudan)

R. Agnese *et al.*,
Astropart. Phys. (2019) 1-12



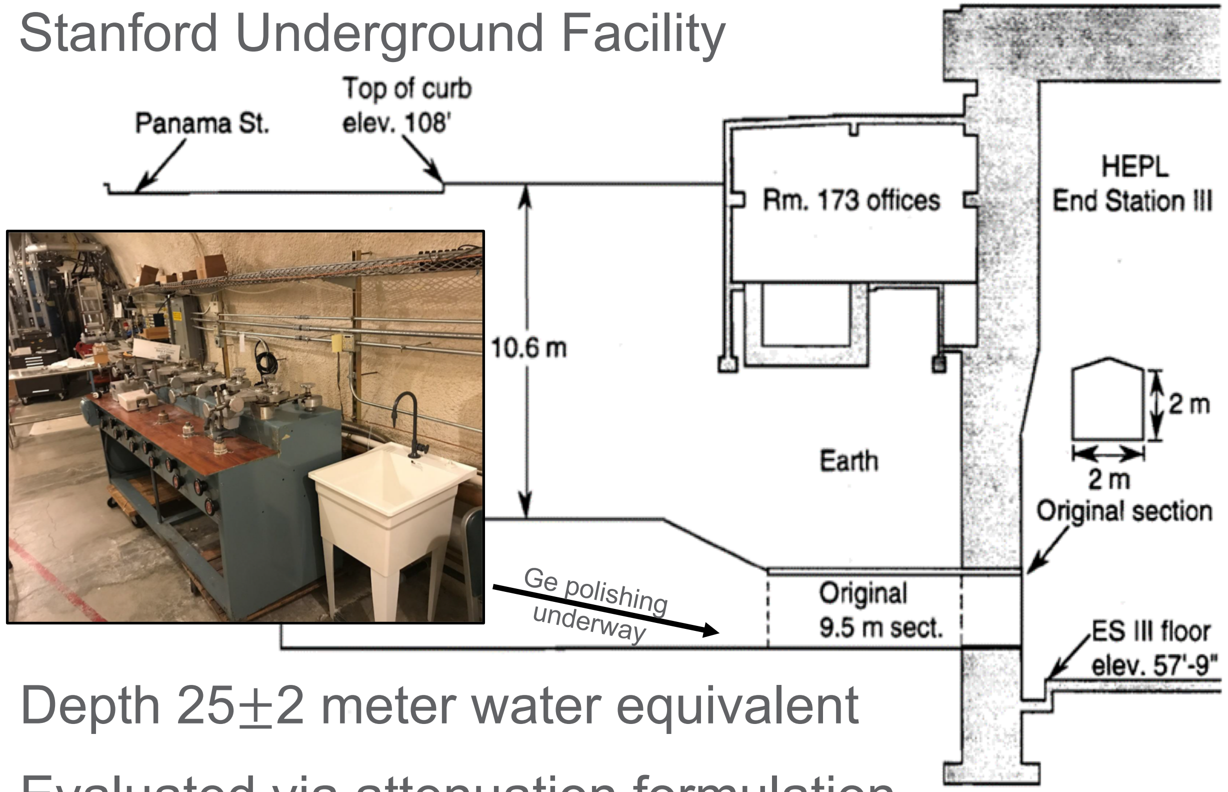
Tritium from cosmic ray spallation

- SuperCDMS SNOLAB Goal: Less than 60 days sea level equivalent exposure
  - One of four towers is composed of iZIPs with longer surface exposure
  - Currently crystals have < 8 days sea level equivalent – shipped from Europe to SLAC

Thank you
MAJORANA & GERDA!

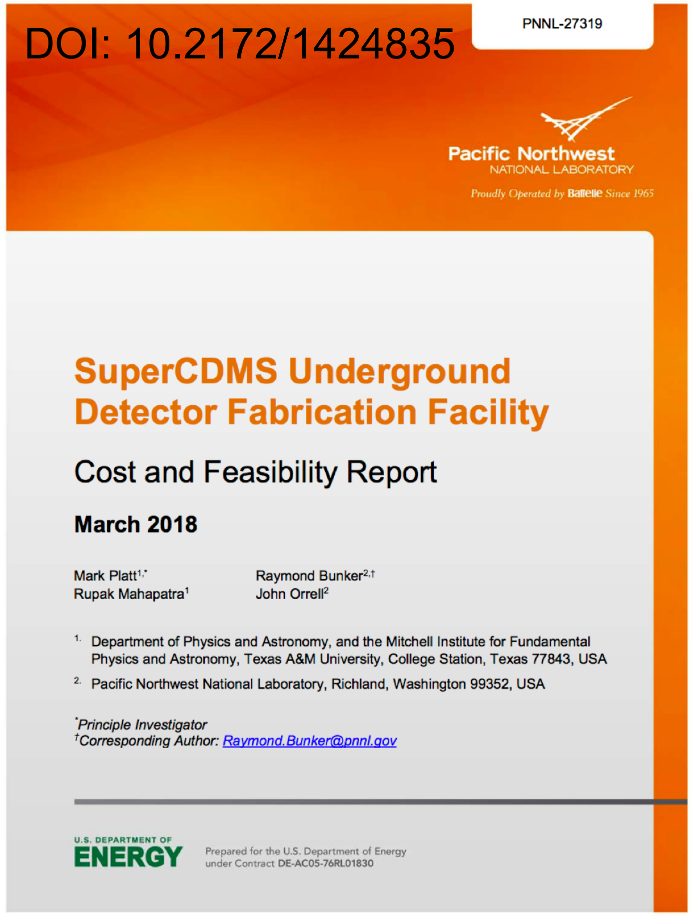
Shielded shipping container critical to meet exposure goal

Underground storage & polishing at Stanford Underground Facility



Depth 25±2 meter water equivalent

Evaluated via attenuation formulation employed by muon-tomographers → Barbouti & Rastin J. Phys. G 9 (1983)1577


DOI: 10.2172/1424835

PNNL-27319

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SuperCDMS Underground Detector Fabrication Facility

Cost and Feasibility Report

March 2018

Mark Platt[1,*] Raymond Bunker[2,†]
Rupak Mahapatra[1] John Orrell[2]

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2. Pacific Northwest National Laboratory, Richland, Washington 99352, USA

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U.S. DEPARTMENT OF ENERGY
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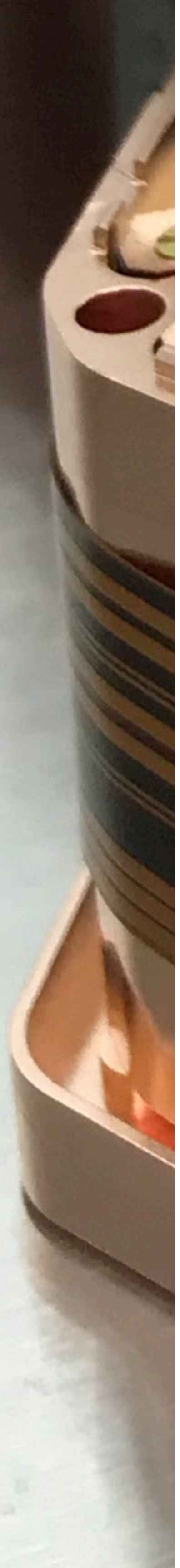
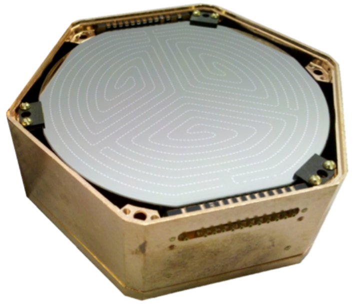
Available on www.OSTI.gov

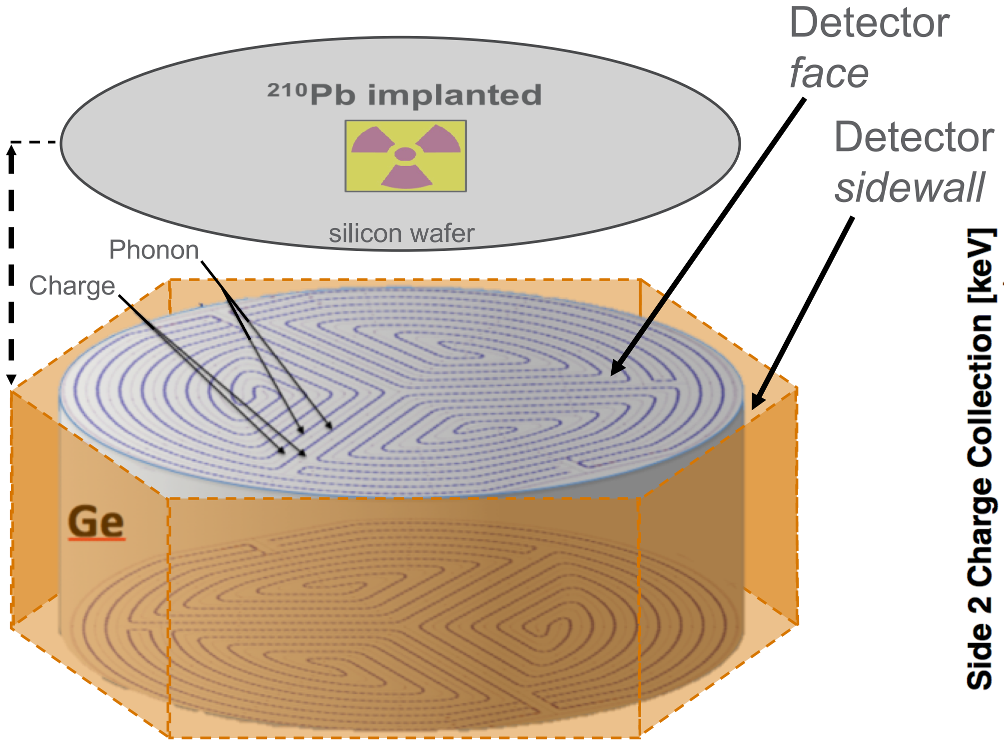


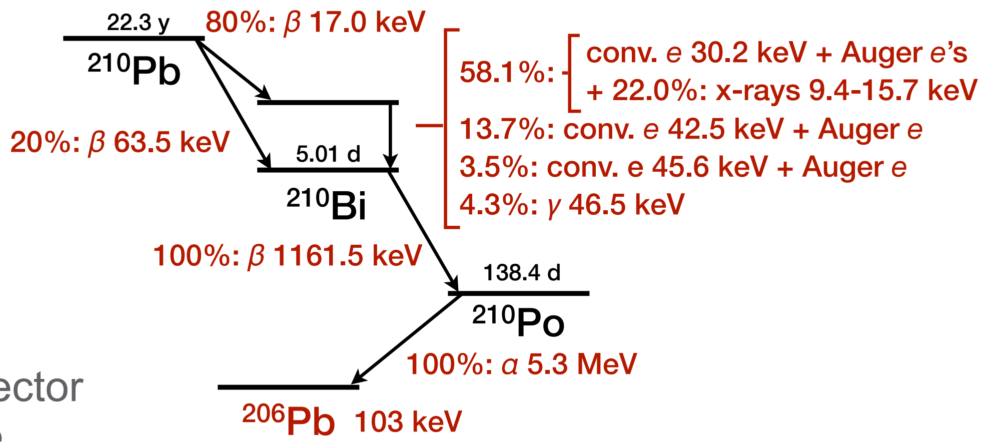
Surface backgrounds (Rn daughters)

- Radon daughters (long-lived ^{210}Pb) are potential surface background sources



Soudan iZIP



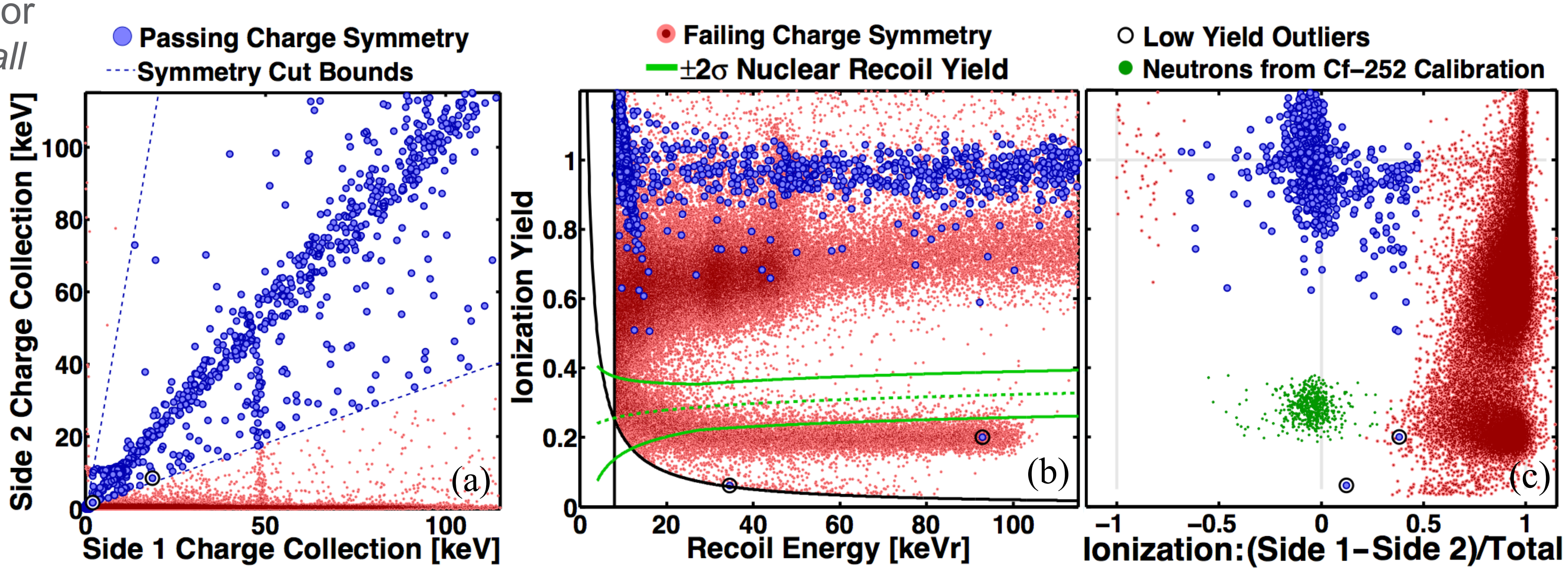


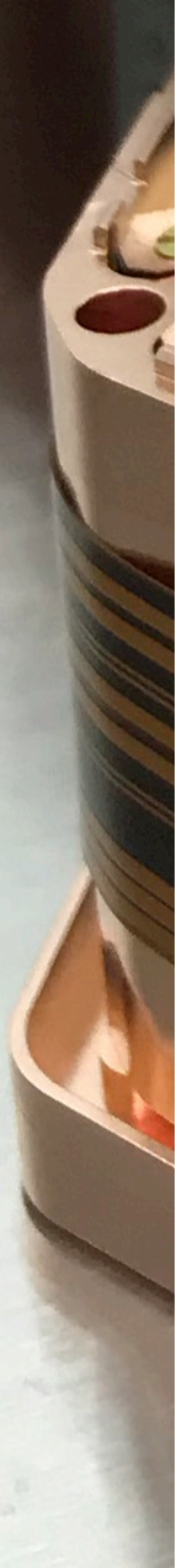
Demonstration of surface electron rejection with interleaved germanium detectors for dark matter searches

R. Agnese *et al.*,
Appl. Phys. Lett. 103 (2013) 164105

Caveats

Performed with iZIP, not HV detector
Surface source only irradiated detector *face*





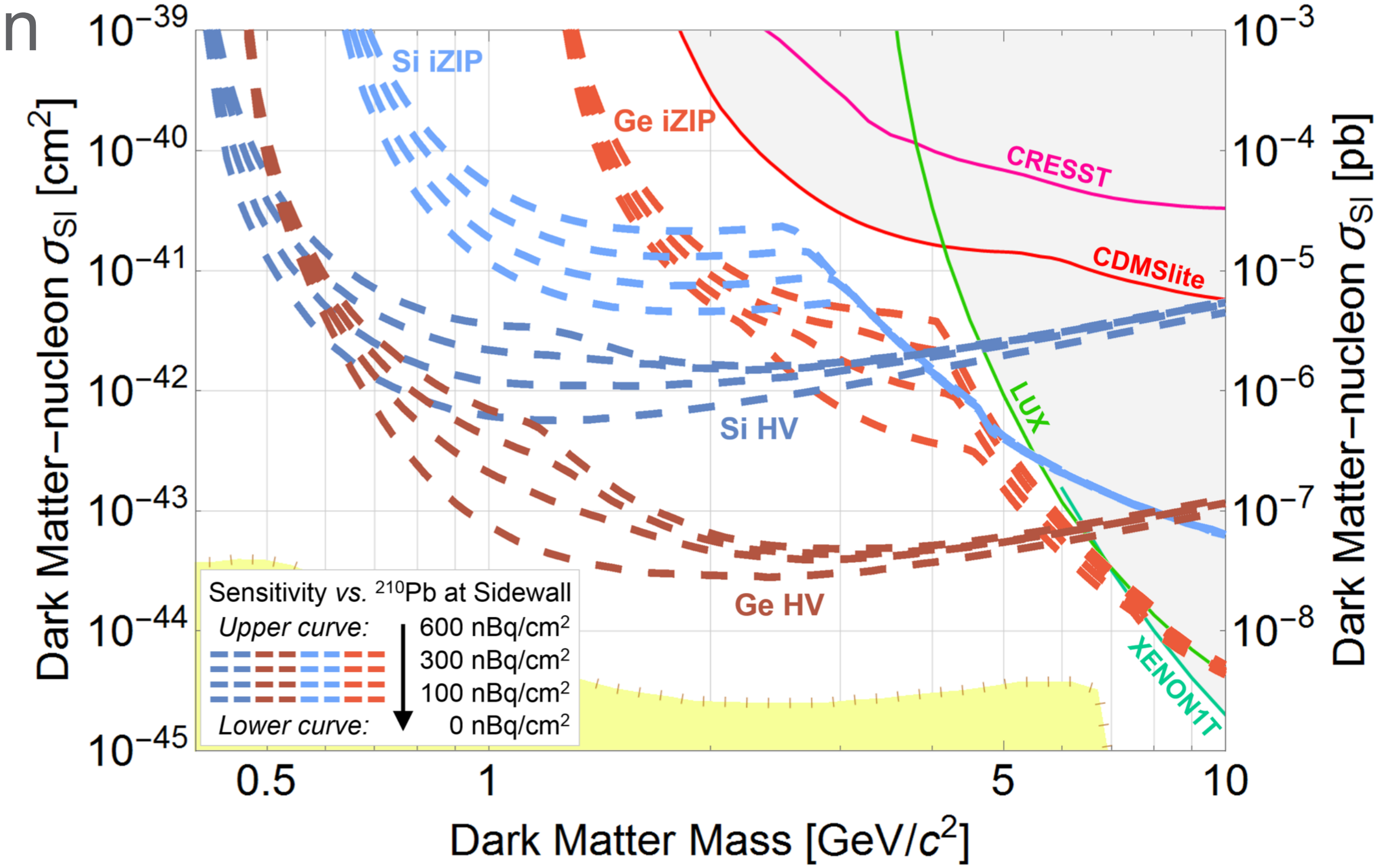
Cu surface background at detector sidewall

- SuperCDMS progressing from Soudan

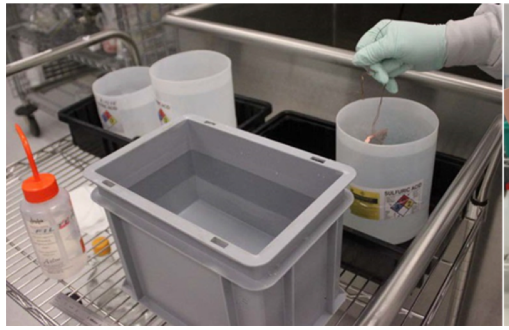
  At Soudan: (based on T2Z1)
  - Bottom face: 20 nBq/cm²
  - Sidewall total: 1000 nBq/cm²

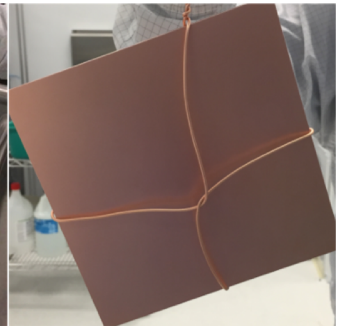
  SNOLAB Goals:
  - Detector faces: 25 nBq/cm²
  - Sidewalls: 50 nBq/cm²

Sensitivity study vs. sidewall activity



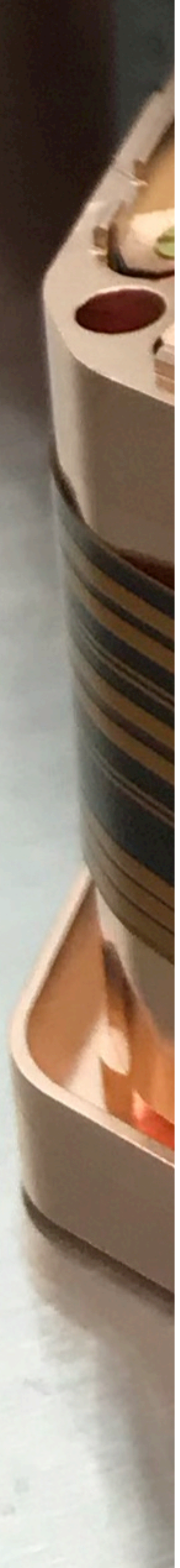
- Summary concern → Cu cleanliness
  - Using acidified-peroxide etching followed by acetic acid passivation





  - Tested on McMaster and Aurubis copper

Cleanliness tested with XIA Ultra-Lo1800 alpha counter by measuring polonium (^{210}Po), not lead (^{210}Pb) !!!



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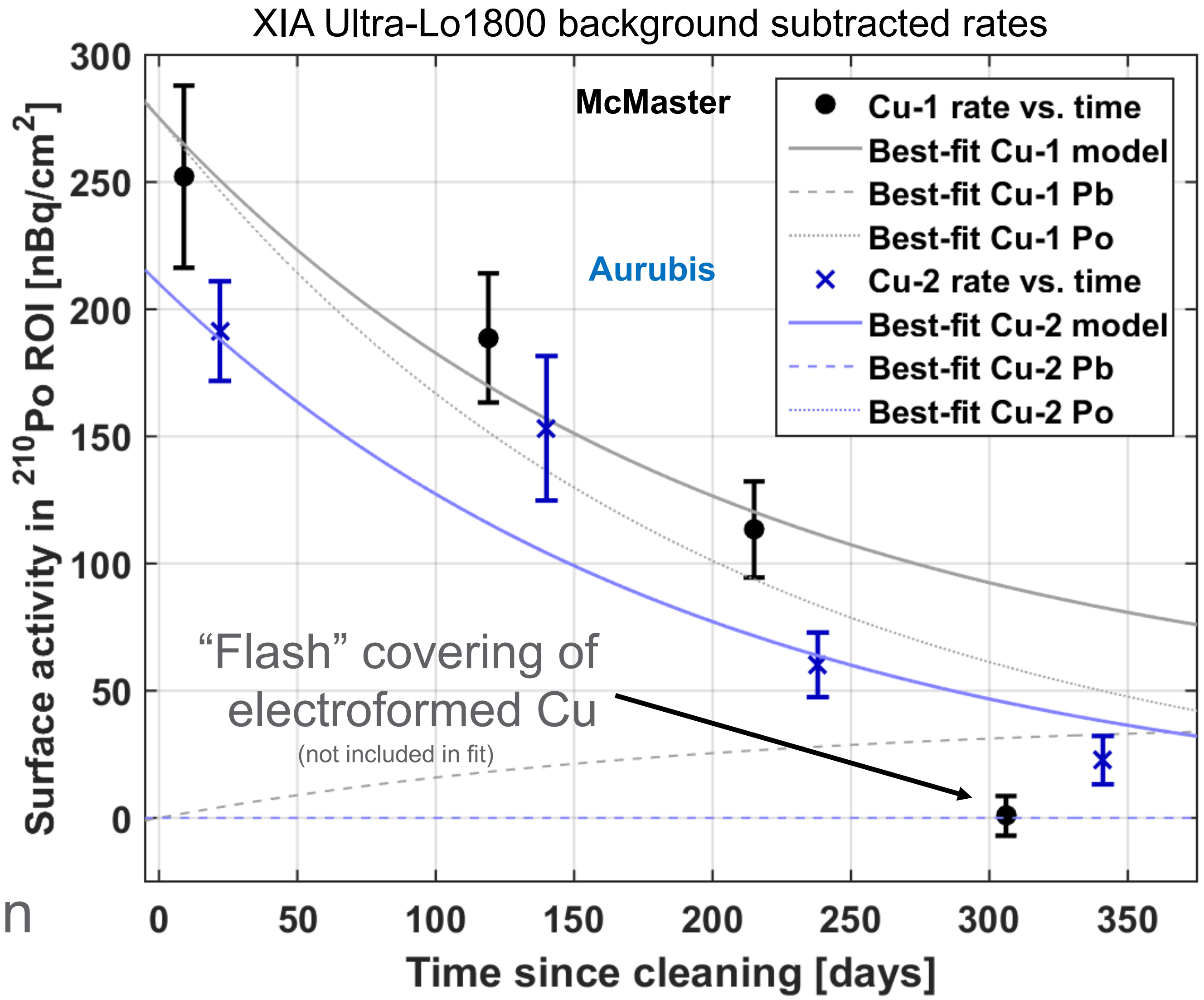
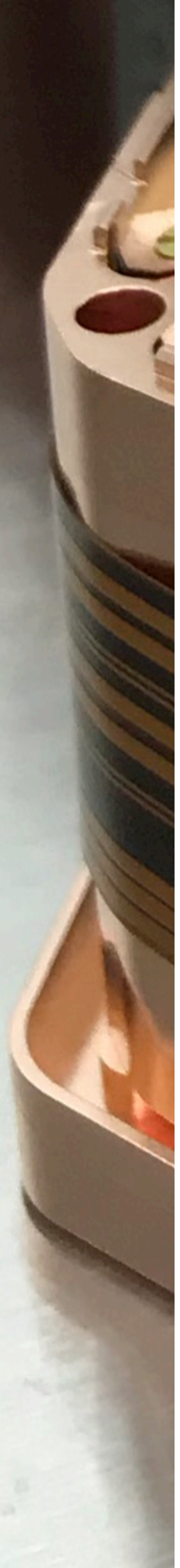
Cu surface background evaluation

- One year's worth of XIA Ultra-Lo1800 measurements on cleaned Cu surfaces
  - Shows unsupported ^{210}Po on Cu surface
  - Electroformed Cu doesn't show effect
  - Suggests ^{210}Pb in bulk of Cu



- XMASS measured ^{210}Po in bulk Cu
  - Inferring 17-40 mBq of ^{210}Pb per kg Cu
  - K. Abe *et al*., NIM A 884 (2018) 157-161

- In summary:
  - Cu surfaces are clean for SuperCDMS
  - Bulk ^{210}Pb in Cu is out of ^{238}U equilibrium
  - Pursuing bulk measurements for publication



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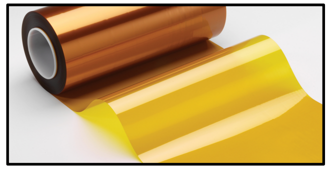
SuperCDMS

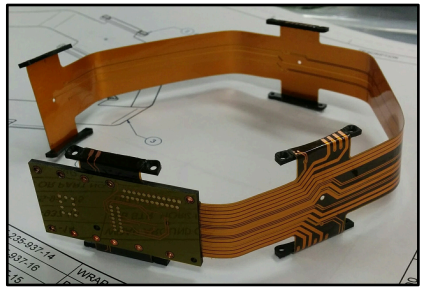
Kapton & CIRLEX trace radio-impurities

- SuperCDMS uses Kapton & cirlex in electrical readout from detector towers
  - Anticipated 17% of Ge HV background of SuperCDMS SNOLAB experiment
  - Of this 17%… 81% is from equally Th and ^{40}K
- Kapton:
  - DuPont polyimide film

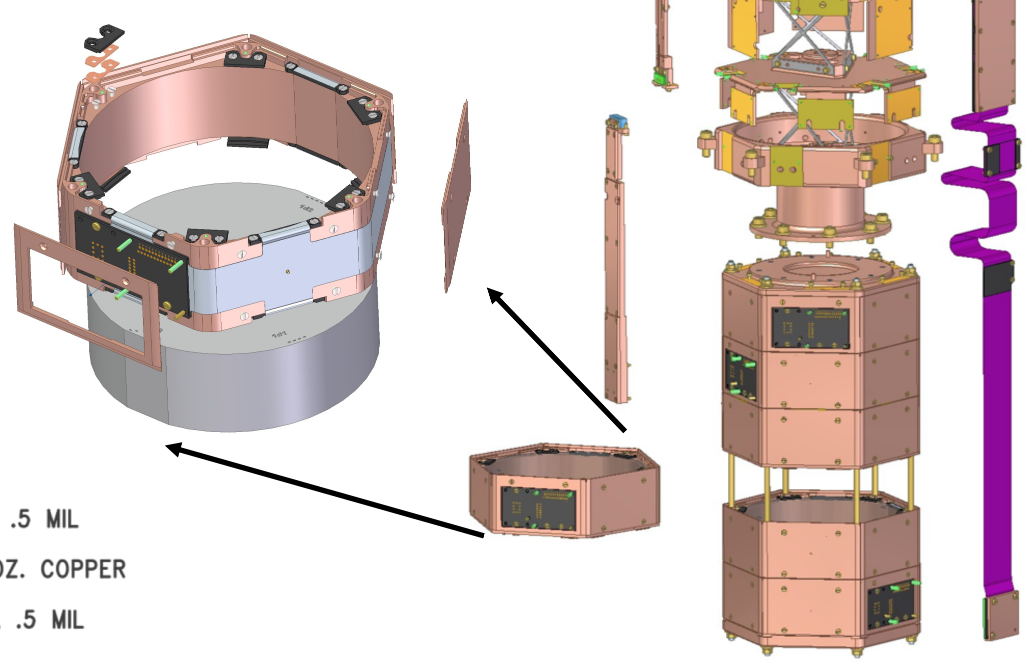


- CIRLEX
  - FRALOCK product
  - Adhesively layered Kapton

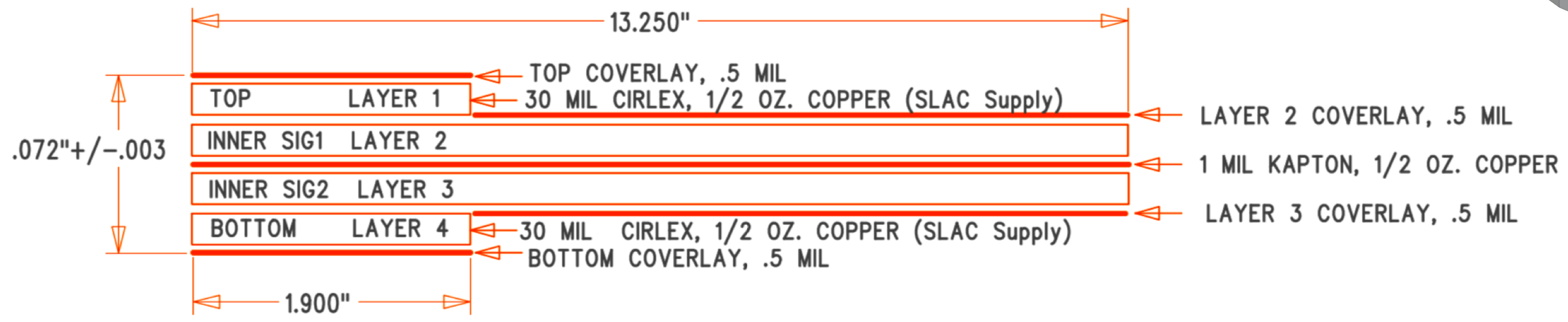
Acceptable, but a target for materials R&D



Detector Tower

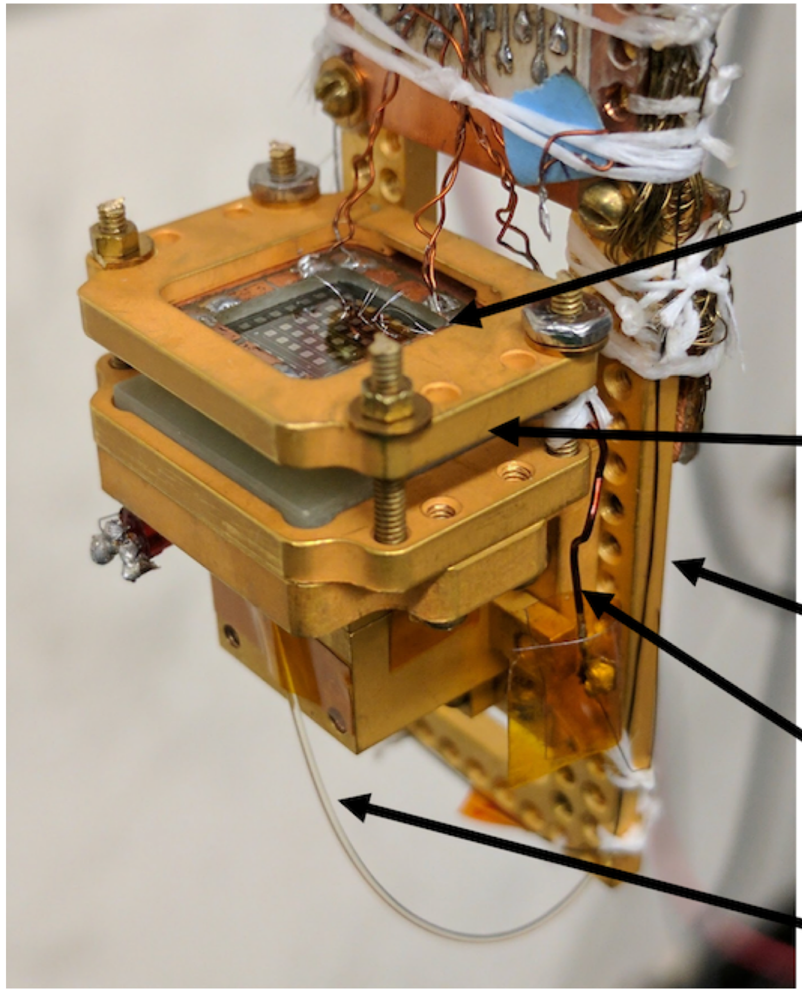


- SuperCDMS flex cable stack-up: 4–LAYERS



R&D detectors

- New developments using the athermal phonon sensor technology
  - R.K. Romani *et al.*, Appl. Phys. Lett. 112 (2018) 043501



Si crystal/ phonon sensors

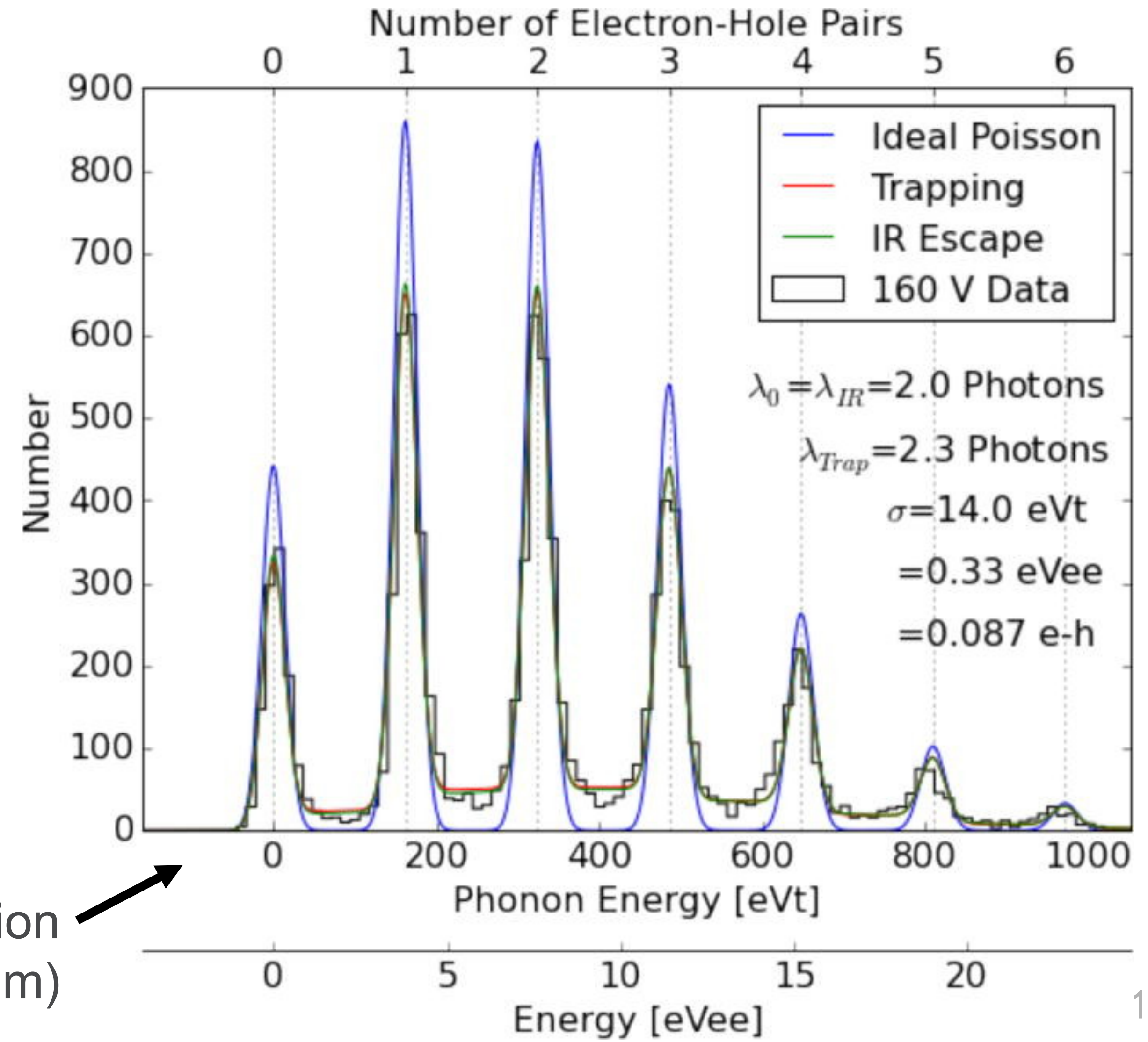
Crystal holder

Dilution refrigerator sample stage (30 mK)

Bias voltage line

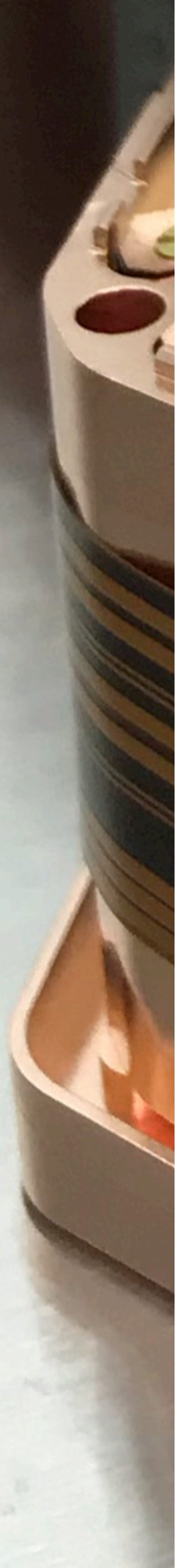
Fiber optic … Illumination (650 nm)

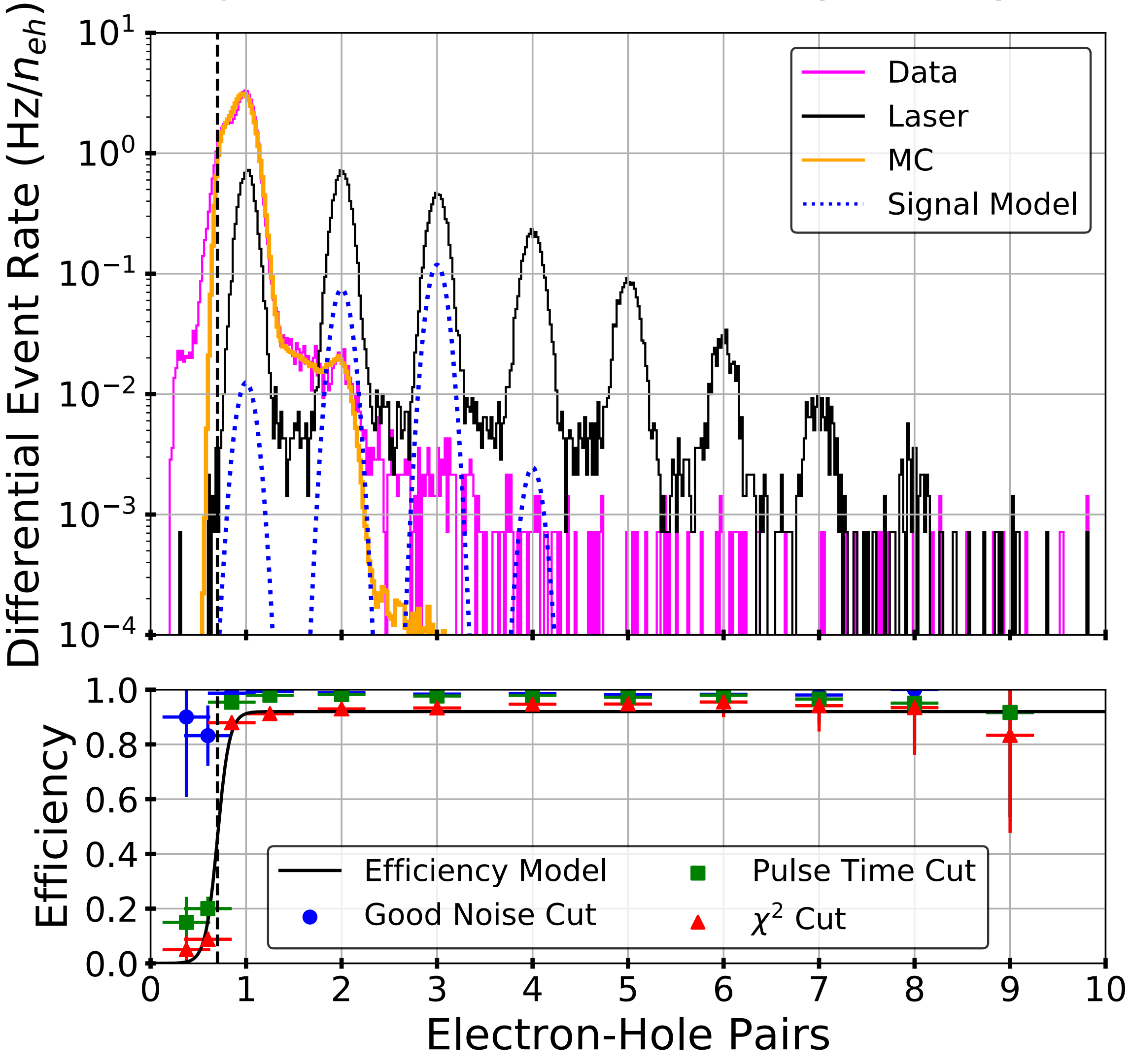
1 cm² by 4 mm thick silicon crystal (0.93 g)



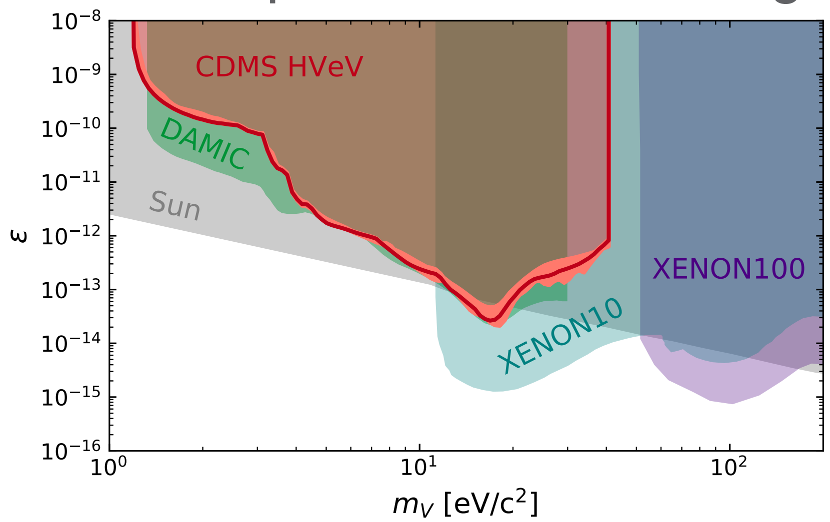
R&D detectors

- R. Agnese *et al.*,
  Phys. Rev. Lett. 121 (2018) 051301

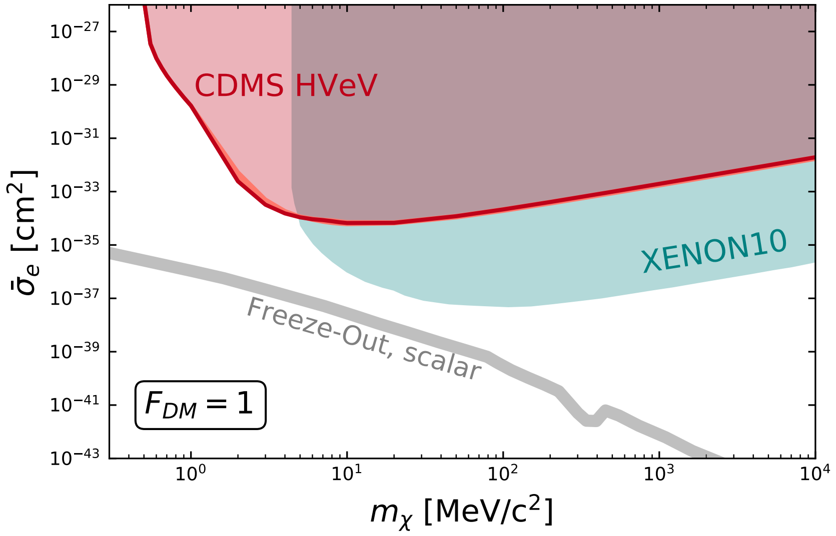




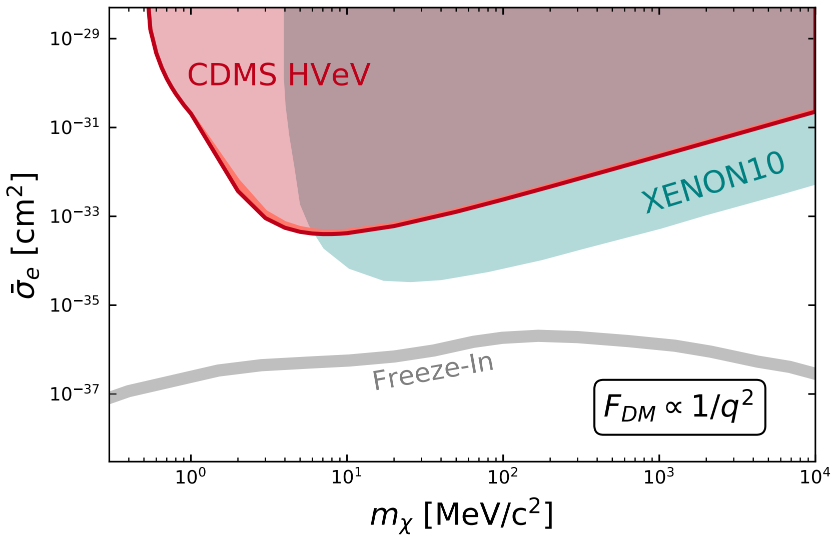
dark photon kinetic mixing



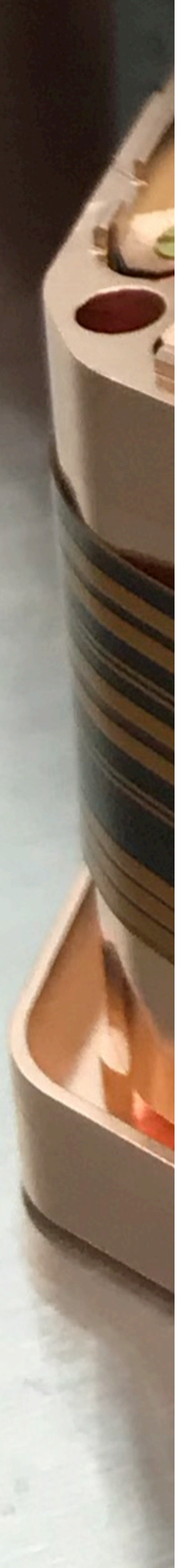
heavy dark photon



ultra-light dark photon

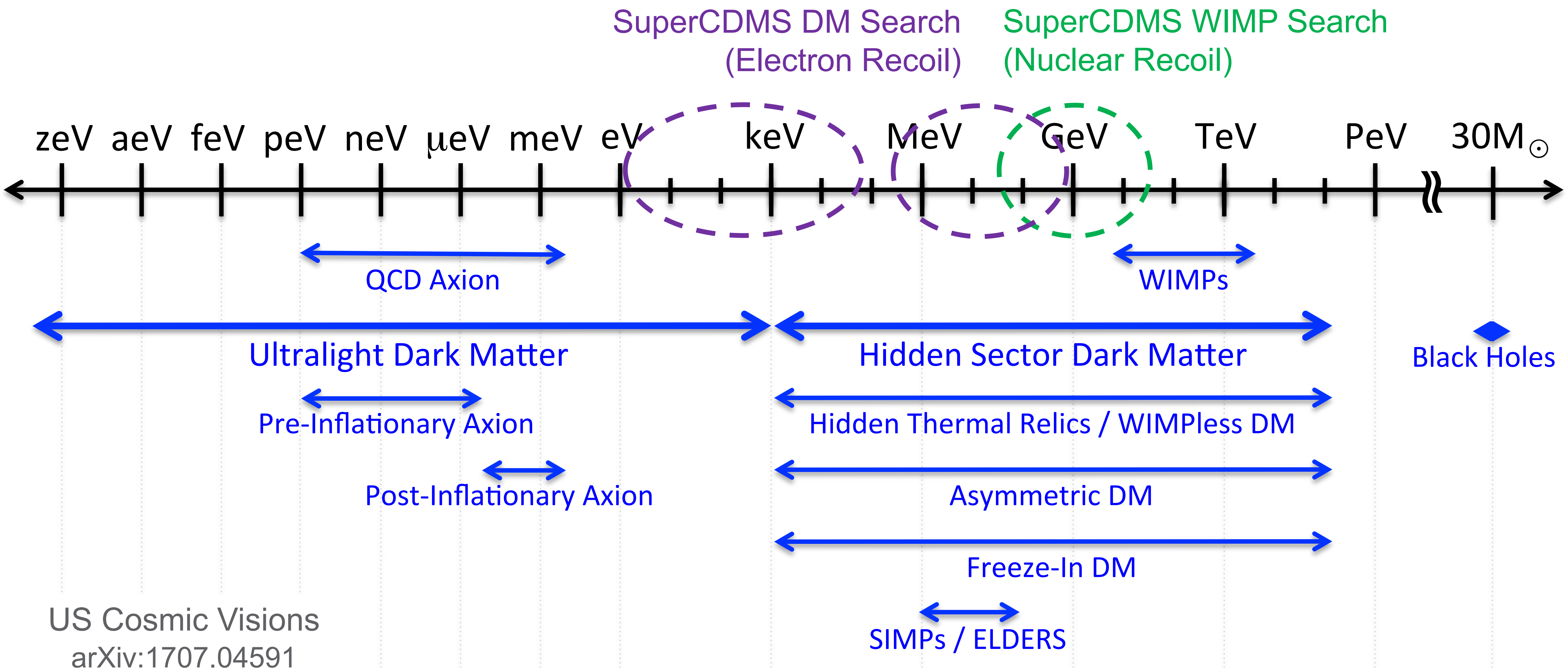


Optimum interval 90% C.L. limits
No background subtraction

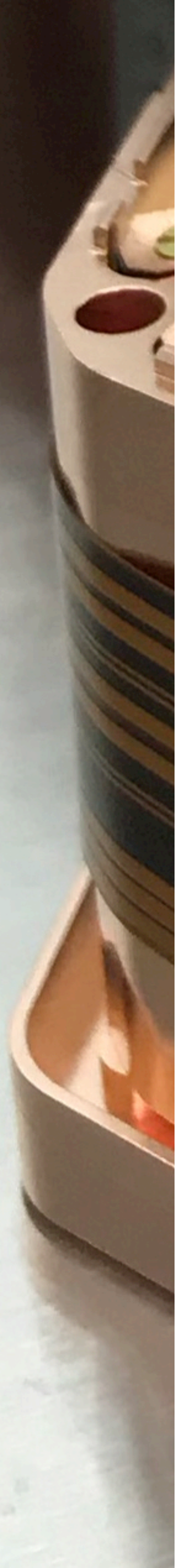


R&D detectors

- Suggests new reach for SuperCDMS

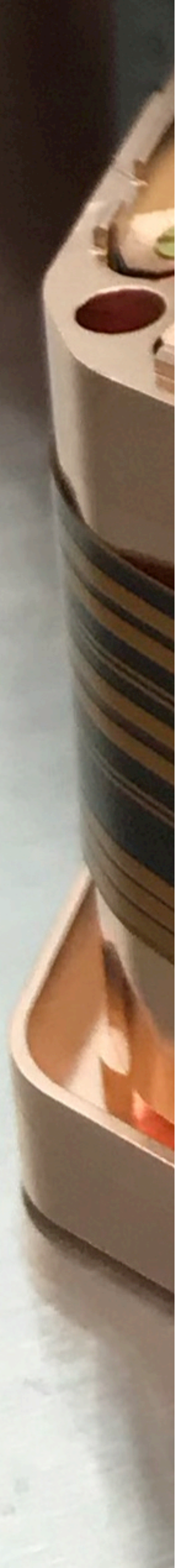


US Cosmic Visions
arXiv:1707.04591



Summary

- SuperCDMS searching for direct detection of low mass dark matter
  - Projected reach $\sigma \sim 10^{-43}$ cm^2 at 1 GeV/c^2 dark matter mass
  - Under construction now
  - Operation at SNOLAB in 2020
- Anticipated backgrounds: Tritium, ^{32}Si, Rn daughters, material impurities
  - Developments during construction show paths to further reduction in the future
  - Highlighted background sources are of relevance to neutrinoless double beta decay
- Future detectors expected to probe yet lower mass dark matter candidates
  - Anticipate further R&D detector development in parallel with SuperCDMS construction
  - Developments will likely also improve sensitivity to 1-5 GeV/c^2 dark matter candidates



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Thank you