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SuperCDMS

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Dark Matter

- Come to the darkside…

(we have cookies)

SuperCDMS Collaboration

Pacific Northwest
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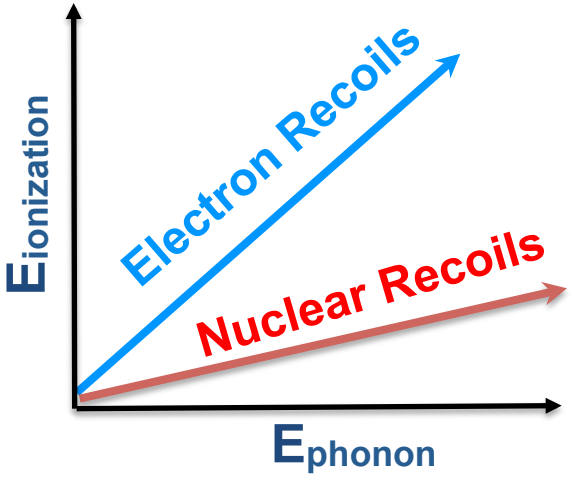
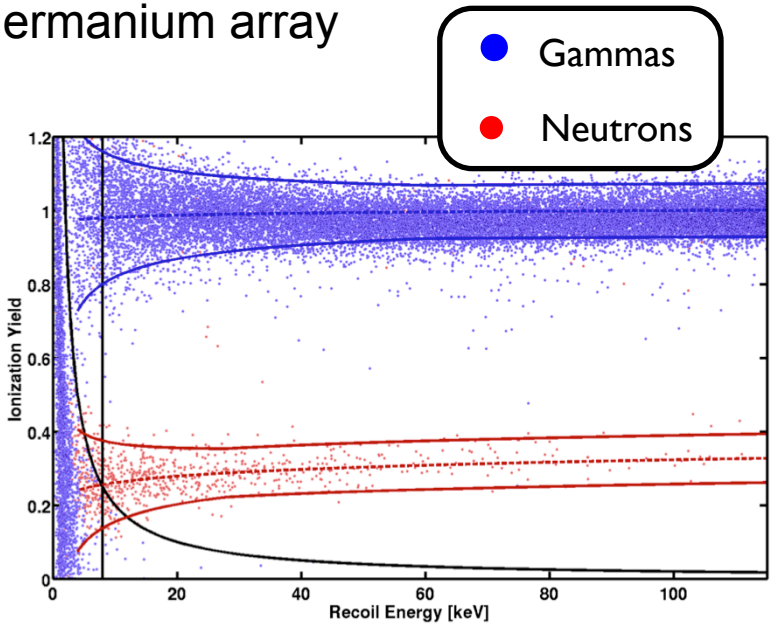
- California Institute of Technology
- Fermi National Accelerator Laboratory
- Massachusetts Institute of Technology
- Queen's University
- Santa Clara University
- SLAC / Kavli Institute for Particle Astrophysics and Cosmology
- Southern Methodist University
- Stanford University
- Syracuse University
- Texas A&M University
- Universidad Autónoma de Madrid
- University of British Columbia
- University of California, Berkeley
- Pacific Northwest National Laboratory
- University of Colorado, Denver
- University of Evansville
- University of Florida
- University of Minnesota

The Cryogenic Dark Matter Search

- The CDMS Collaboration has developed and deployed cryogenic semi-conductor detectors for rare event searches
- CDMS-II at the Soudan Underground Laboratory completed operations in 2009
  - Expect new and interesting results from CDMS-II on LIPs, silicon, annual modulation, …
- SuperCDMS consists of two experiments with substantial detector improvements
  - SuperCDMS-Soudan, an operating 10 kg germanium array
  - SuperCDMS-SNOLAB, a proposed 200 kg germanium array

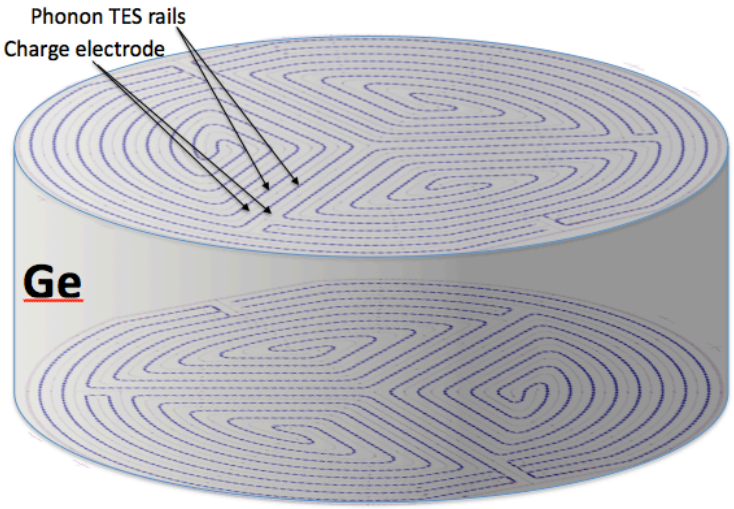


CDMS measures both the heat deposition and the ionization from particle scattering. This allows event-by-event identification the interaction as a nuclear or electron recoil down to energies below 10 keVr.

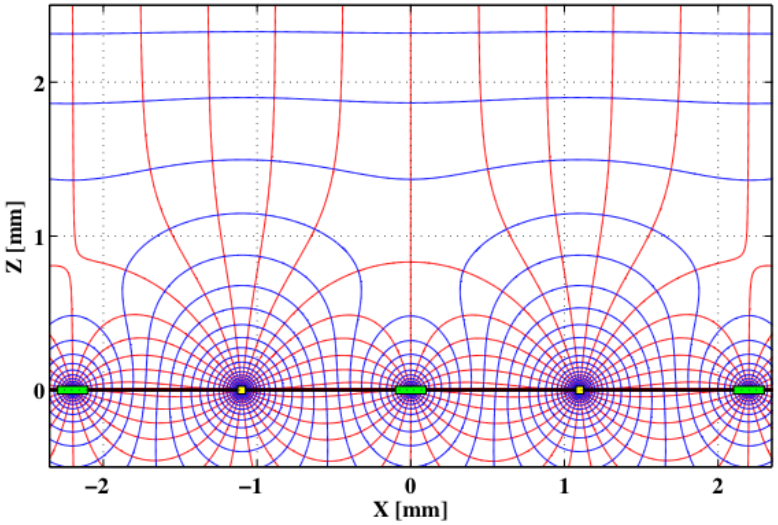


SuperCDMS

- Search with germanium iZIP detectors
- Operating at ~50 mK
  - Enables phonon and charge readout
  - Charge to phonon ratio separates nuclear and electron scatters
- interleaved Z-sensitive ionization and phonon sensors on both faces
  - Surface event identification
  - Outer phonon guard ring



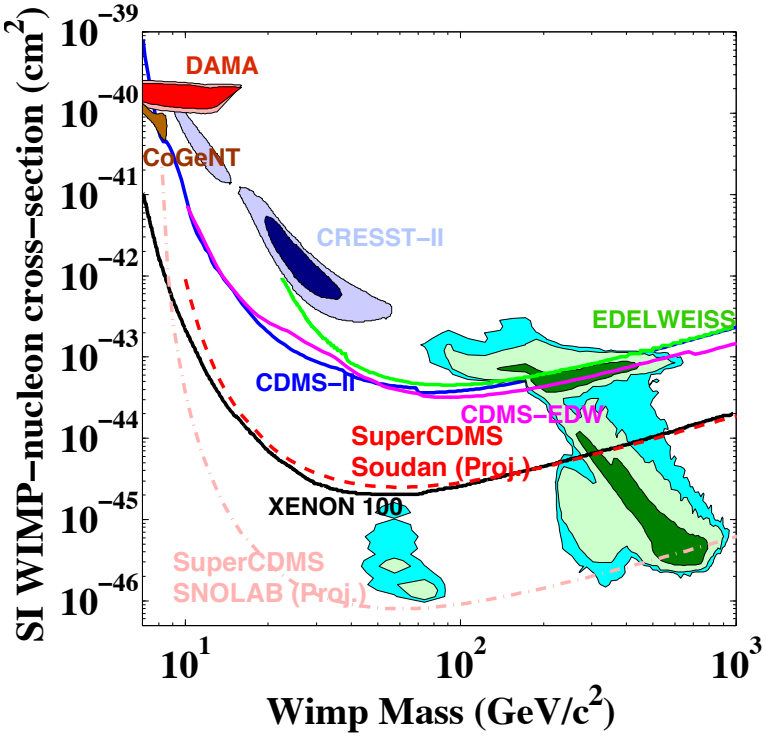
SuperCDMS iZIP detectors have phonon and ionization instrumentation on both faces allowing superior z-sensitivity.



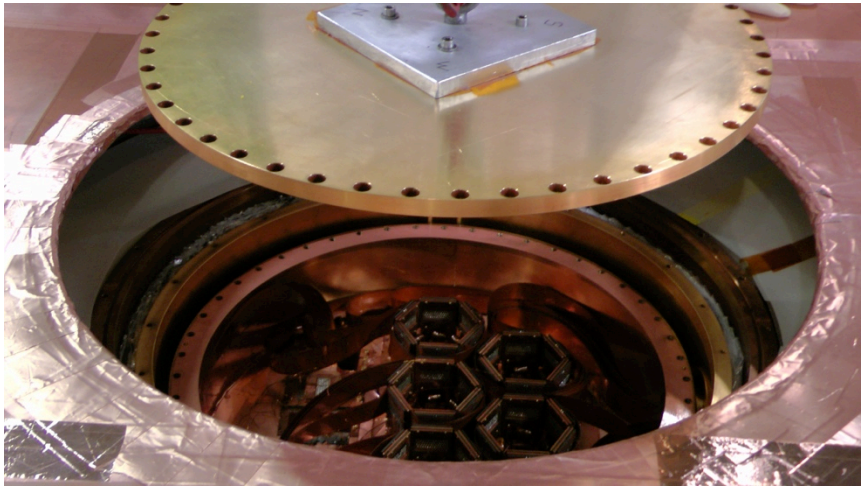
By holding a potential between ionization and phonon electrodes, a more complex electric field is created. Charge near the surface of the detector is collected on only one side. Charge in the bulk of the detector is collected on both faces.

SuperCDMS-Soudan

- Array of 15 iZIPs in the Soudan infrastructure built for CDMS-II
- >X10 sensitivity increase over CDMS-II
  - Larger detector mass (x2.5 thicker detectors)
  - Fiducial fraction improved to 67% from 35%
  - Surface background negligible



Projected WIMP sensitivity for SuperCDMS-Soudan after 3 calendar years (Spring 2015).

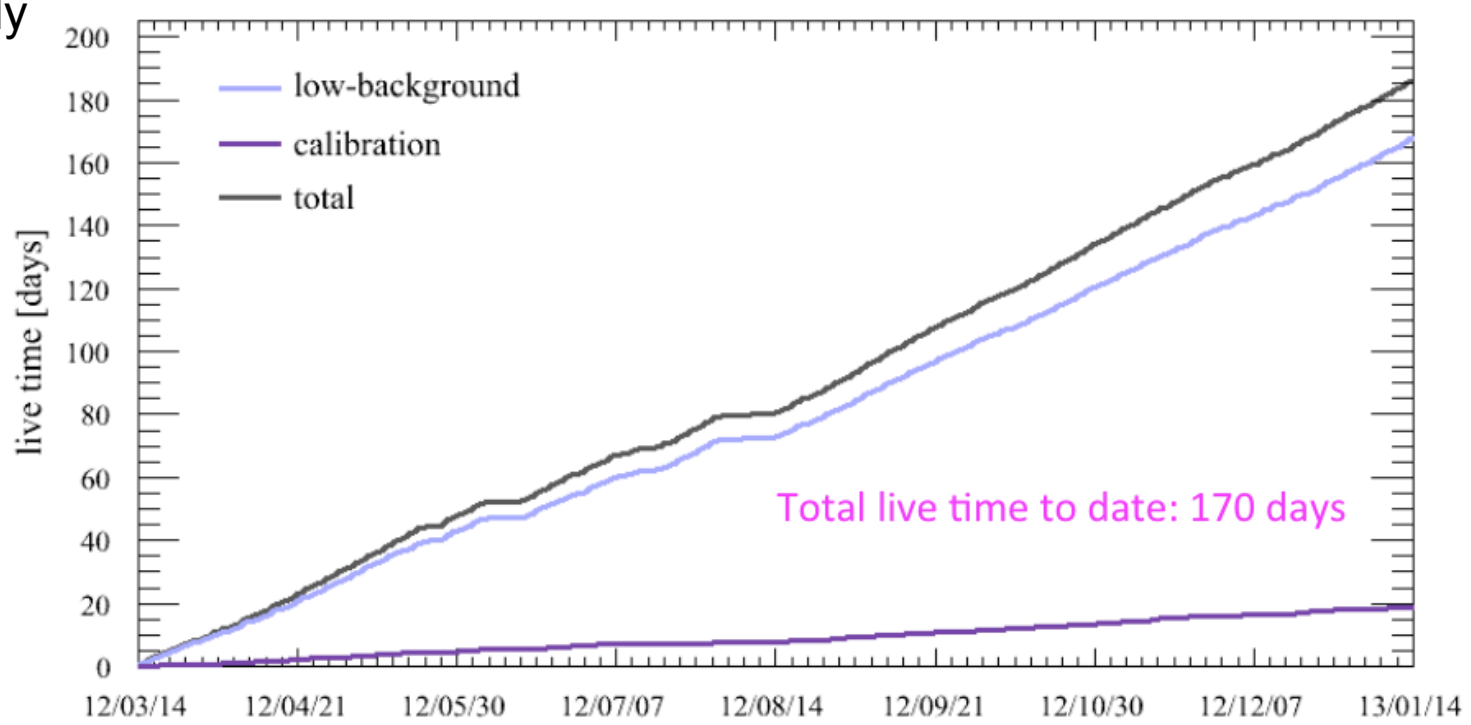


SuperCDMS detector installation was completed 8 Nov 2011. Detectors have been operating with final settings since March 2012.

SuperCDMS-Soudan

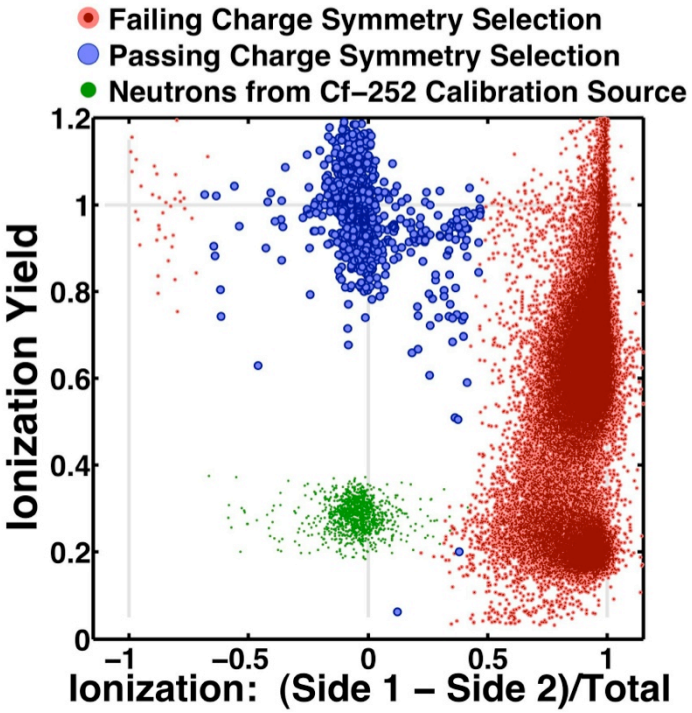
- 170 live days as of mid-January
  - Some 'dead-time' to pursue optimization and other physics searches
  - 10% of running time used for calibration
- Cryogenics upgrades are performing
  - Dilution refrigerator has been at base temperature for 14 months continuously

Cooling down the cryostat and detectors was accomplished in three weeks following installation. The cryogenics performance has proven that these cryogenic detectors can be operated for years at a time. SuperCDMS-Soudan live-time goals may be accomplished with one cool-down. CDMS-II took 7 cool-downs.



Soudan iZIP Surface Calibration

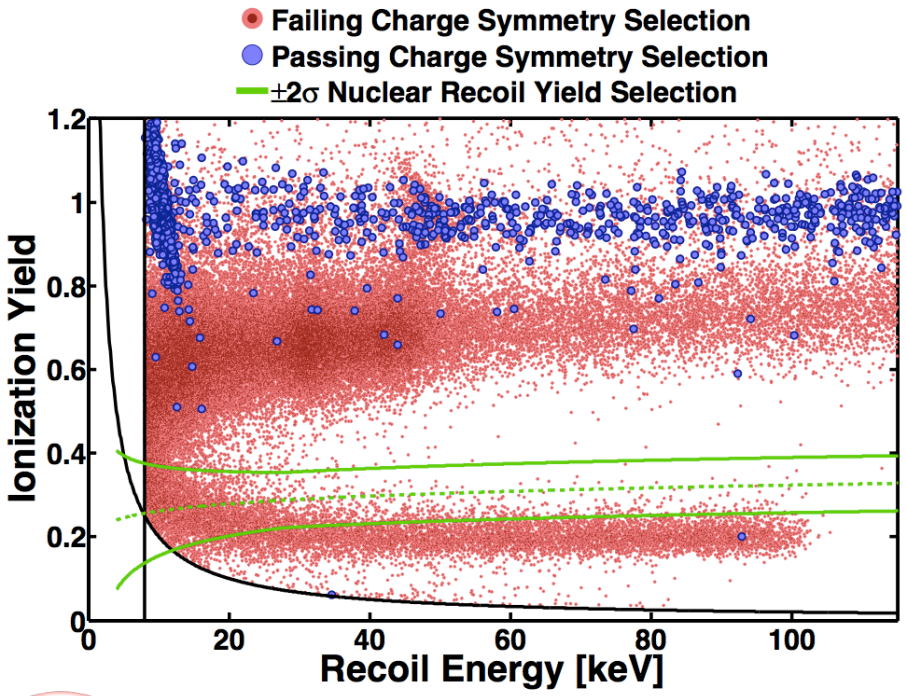
- Installed ^{210}Pb implanted Si wafers facing two detectors
- Activity of 1000 Pb decays per day
- Allows performance verification of surface event identification
  - Complex electric field creates asymmetry in both phonon and ionization signals for surface events
- CDMS-II achieved 1:1200 rejection with a 35% fiducial volume
- The goal for a 200 kg array of iZIPs (SuperCDMS-SNOLAB) is 70 times better rejection with twice the fiducial volume



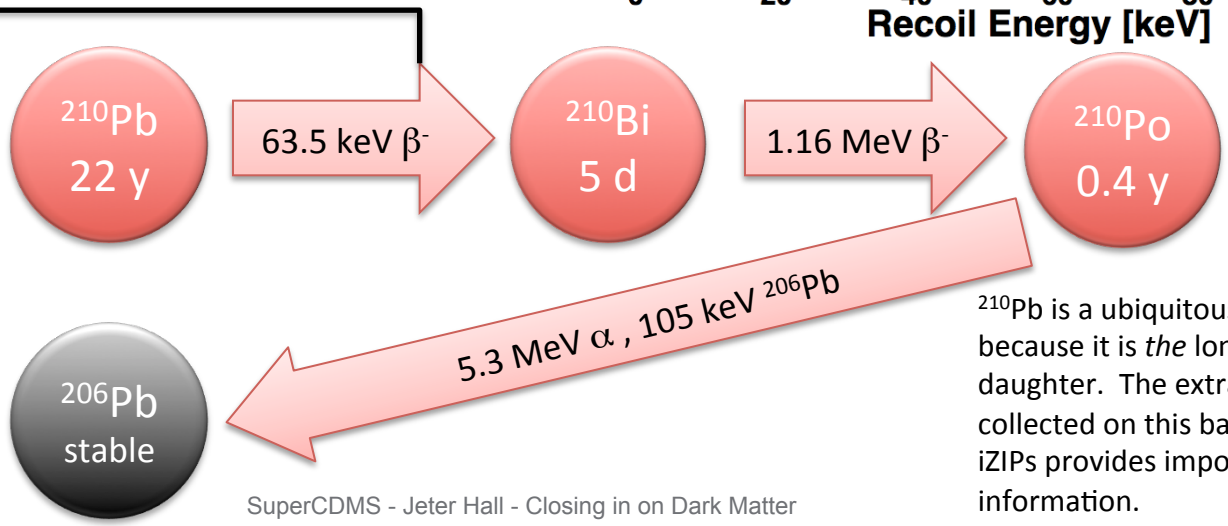
The charge is measured on both sides of the detector. With the complex electric field, the side-asymmetry in the charge collection has excellent identification of surface events. The phonon asymmetry shows similar identification of surface events.

Soudan iZIP Surface Calibration

- 65,000 beta events and 15,000 ^{206}Pb recoils analyzed
- No surface events leaking into 67% fiducial volume
- Limits surface event leakage to **<2x10^{-5} at 90% CL**
  - 80,000:1 rejection required for SNOLAB
  - 0/80,000 passing cuts in these data
- Ionization collection at the surface is significantly improved over CDMS-II detectors



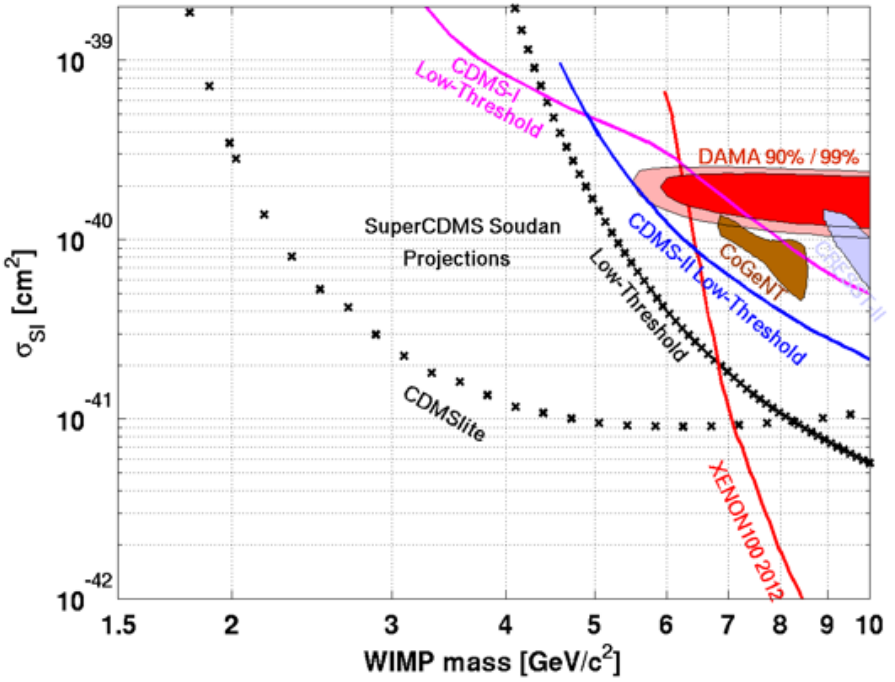
Type	E [keV]	P [%]
β-	17	84
β-	63.5	16
Aug E	8.2	37
CE	30.2	60
CE	42.5	14
X-ray	~10.8	24
X-ray	46.5	4



^{210}Pb is a ubiquitous background because it is *the* long-lived ^{222}Rn daughter. The extraordinary detail collected on this background in CDMS iZIPs provides important background information.

Low Mass WIMP Search

- Low mass WIMP search based on two strategies
- 'Low-Threshold' search, optimizing the analysis to approach the hardware trigger threshold
  - Nuclear recoil discrimination down to 2 keVr, but significant overlap of electron and nuclear recoil distributions
  - Note that this projection assumes fewer events with no ionization detected
- 'CDMSlite' search, an ionization only search strategy with lower threshold
  - Use Neganov-Luke amplification to increase the signal-to-noise for low-energy events
  - Note this projection assumes a 85 eVee threshold

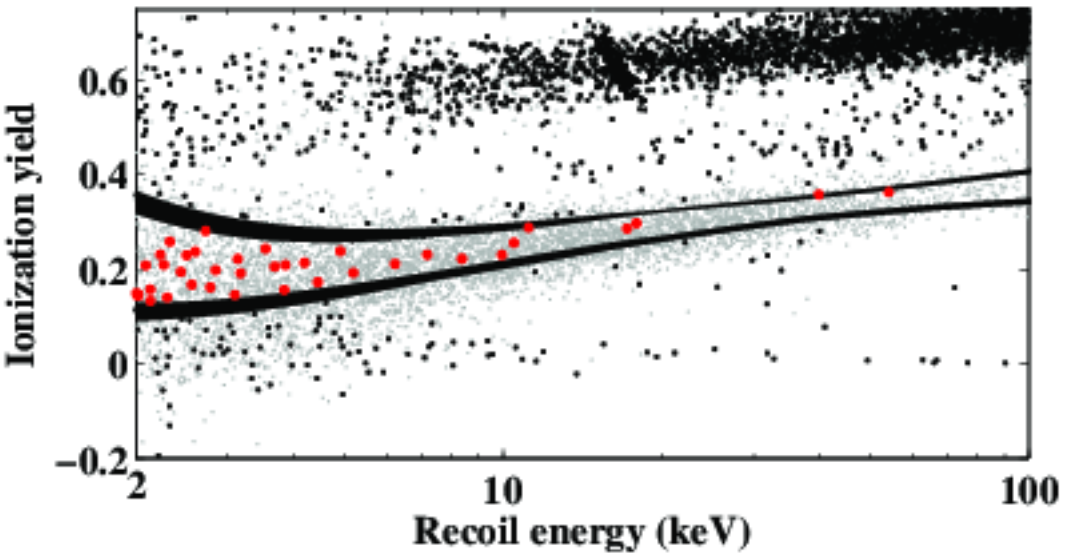


SuperCDMS-Soudan is pursuing a two-fold strategy to search for light dark matter (WIMPs with masses below 10 GeV.) The 'Low-Threshold' and 'CDMSlite' projections show the expected sensitivity of these two search strategies.

SuperCDMS Low-Threshold Search

- Thresholds were recently tuned by optimizing the trigger filtering
  - Lowered thresholds by factors of 1.5-2
- Four detectors operating with thresholds of ~2 keVr
- The new iZIP design has significantly reduced the quantity of interactions with no charge detected (based on a study of a multi-detector interactions)
  - Double sided readout allows improved position resolution for events in regions of poor charge collection
  - Surface fields reduces the 'dead-layer' significantly

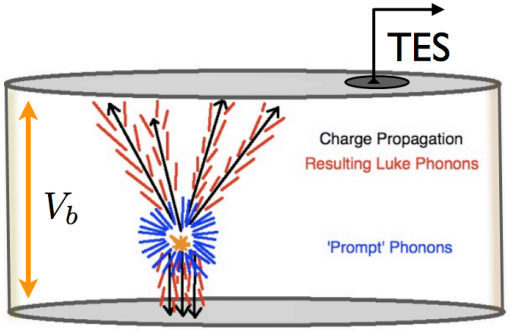
PRL 106, 131302 (2011)

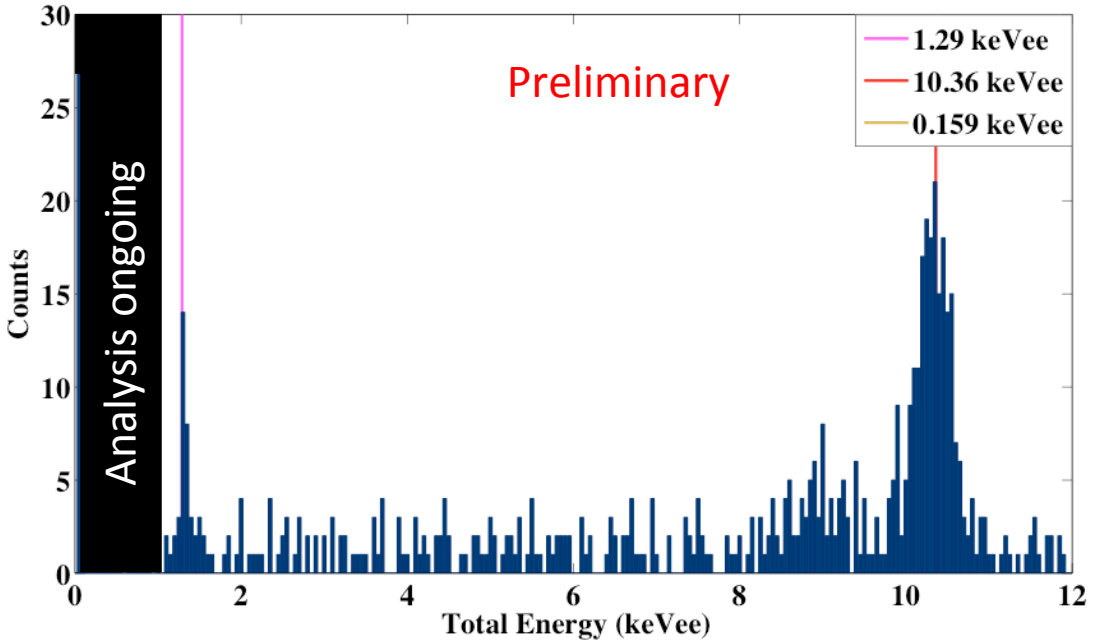


Extending the analysis of traditional WIMP search data to the trigger threshold shows that discrimination is reduced, but not eliminated at nuclear recoil energies as low as 2 keV. This figure is from CDMS-II data and the limiting background was from events where the charge signal was consistent with noise. Preliminary results show that the iZIPs have significantly reduced the quantity of events with no charge signal while retaining 2 keVr thresholds.

CDMS low ionization threshold experiment

- CDMSlite strategy leverages Neganov-Luke amplification to realize low thresholds with high-resolution
  - Ionization only, no event-by-event discrimination of nuclear recoils
- Drifting N_e electrons across a potential, V, generates N_eV electron volts of heat
- Low background data taken Fall 2012
- First results expected Spring 2013

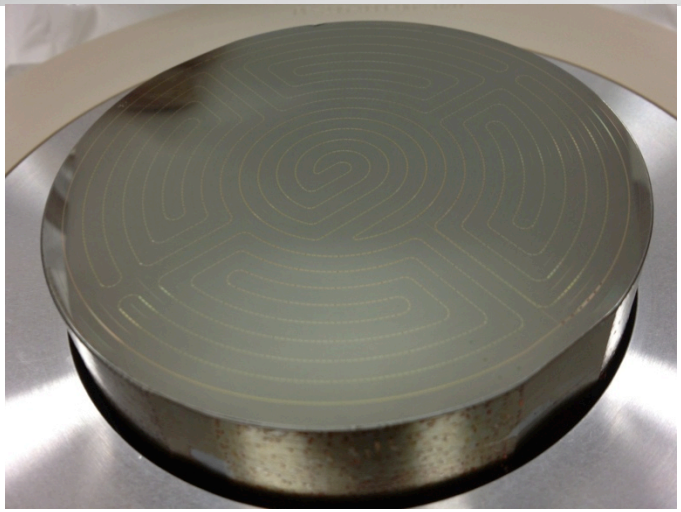


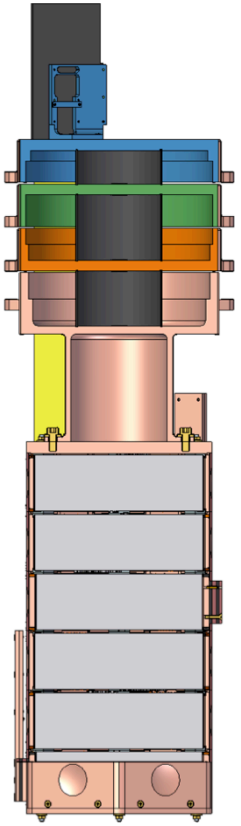


This spectrum shows the low-energy performance of SuperCDMS detectors with increased voltage. The applied bias was 69V corresponding to an order of magnitude gain in the signal. The energy resolution for the 1.29 keV gallium L-shell line is ~24 eV, the Fano limited resolution is ~20 eV. The increase at 9 keV is due to cosmic ray activation of ^{65}Zn. Note that the efficiency of the cuts used to produce this preliminary spectrum has not been applied.

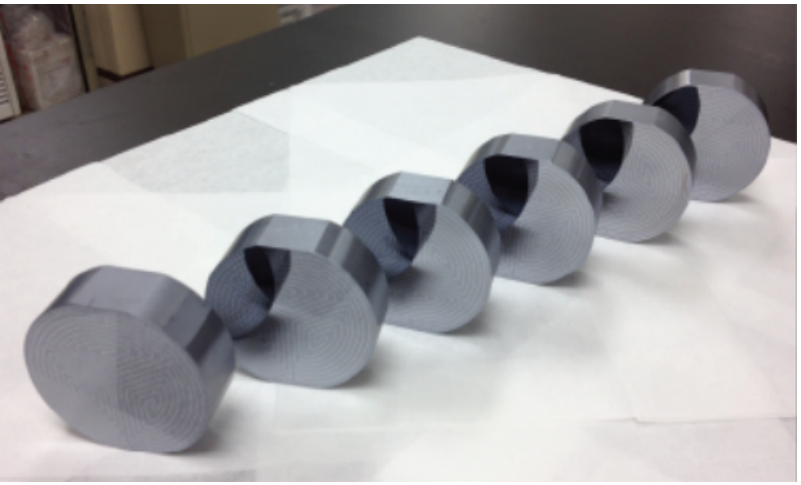
SuperCDMS-SNOLAB

- SuperCDMS has proposed a 200 kg cryogenic germanium array for the SNOLAB facility
- Projected spin-independent sensitivity of 8×10^{-47} cm^2
- See talk by R. Schnee on Saturday for more details



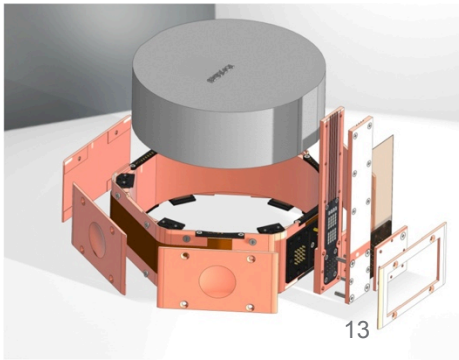


Procurement and performance testing of 100 mm x 33 mm germanium detectors is ongoing. First 100 mm iZIP has been fabricated. The proposed SuperCDMS-SNOLAB project involves fabricating and deploying 144 of these detectors.



A detector fabrication exercise demonstrated the throughput needed for SuperCDMS-SNOLAB

Cryogenic and mechanical engineering indicates it will be possible to assemble and operate this proposed experiment.



Conclusions

- SuperCDMS is producing detectors with extraordinary precision and particle identification for dark matter detection, and, eventually, elucidation of the dark matter properties
  - Precision measurements are particularly useful at the discovery phase when rejecting the background hypothesis is paramount
- SuperCDMS-Soudan is running and current results are promising for
  - Spin-independent WIMP sensitivity comparable to XENON-100 with a different nuclear target
  - Low phonon thresholds to study dark matter with masses <10 GeV
  - Low ionization thresholds providing increased sensitivity for lighter dark matter
- SuperCDMS-SNOLAB will extend the sensitivity by over an order of magnitude with an increased target mass of 200 kg and suppression of backgrounds through better shielding design, materials selection, and materials handling as well as the added depth to suppress backgrounds from cosmic-ray showers