The SuperCDMS Soudan High Threshold WIMP Search and the Planned SuperCDMS SNOLAB Experiment

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on behalf of the SuperCDMS collaboration

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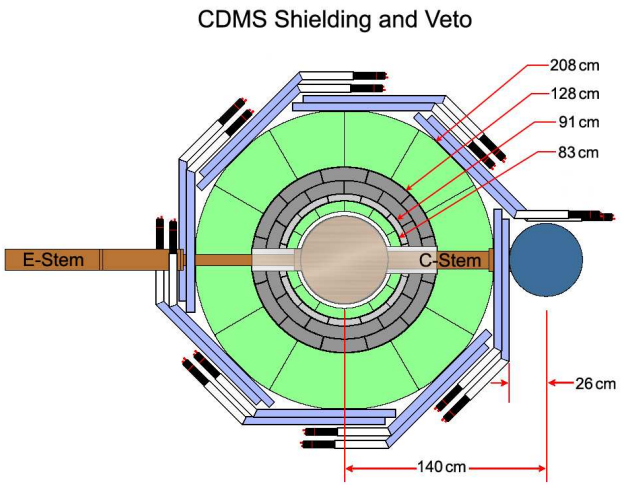
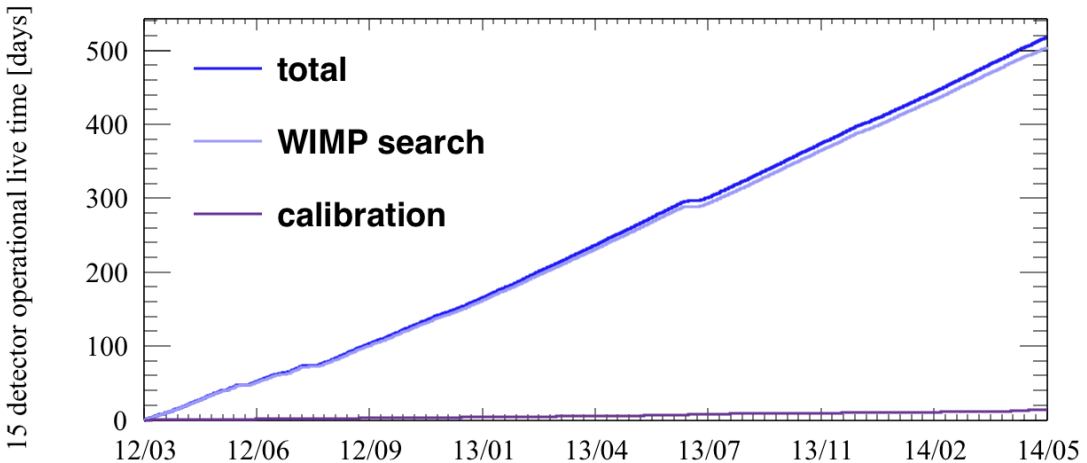
Introduction

1. SuperCDMS Soudan high threshold analysis
   - The detectors
   - Performance
   - Backgrounds and modeling
   - Projected reach
2. SuperCDMS SNOLAB project
   - Experiment design
   - Science goals
   - Estimated backgrounds
   - Projected sensitivity

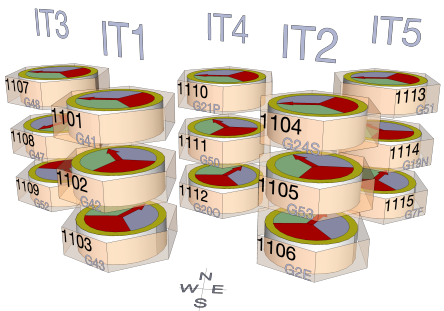
SuperCDMS Soudan

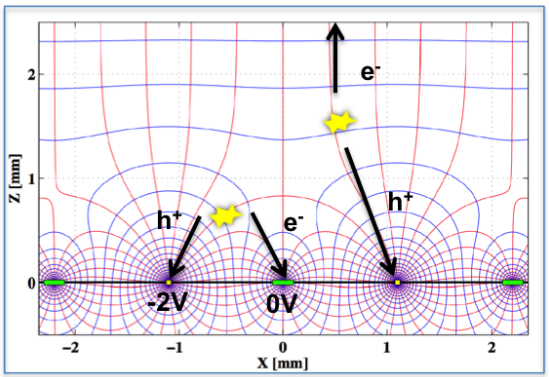


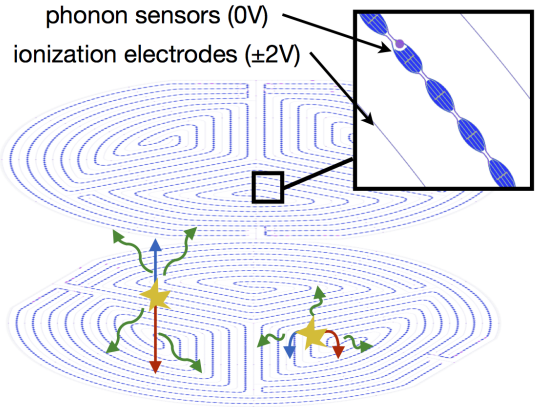


- Located in Soudan Underground Lab, $\approx \frac{1}{2}$ mile underground with 2090 M.W.E. of overburden
- Utilizes the shielding and cryostat from CDMS-II experiment (see Peter Redl's talk)
- Collected about 2500 kg-days of raw exposure

interleaved Z-sensitive Ionization and Phonon (iZIP) Detectors

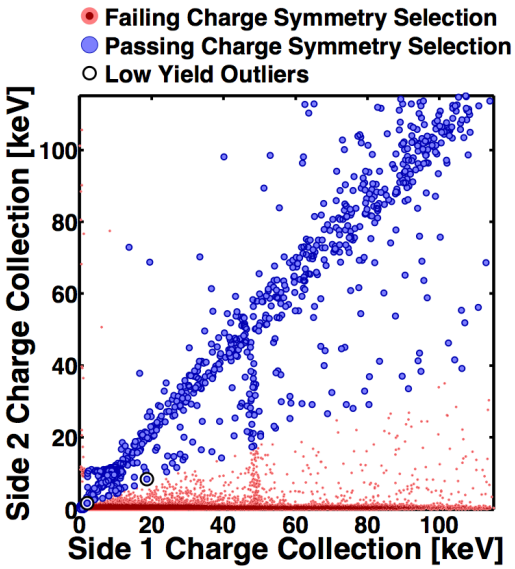


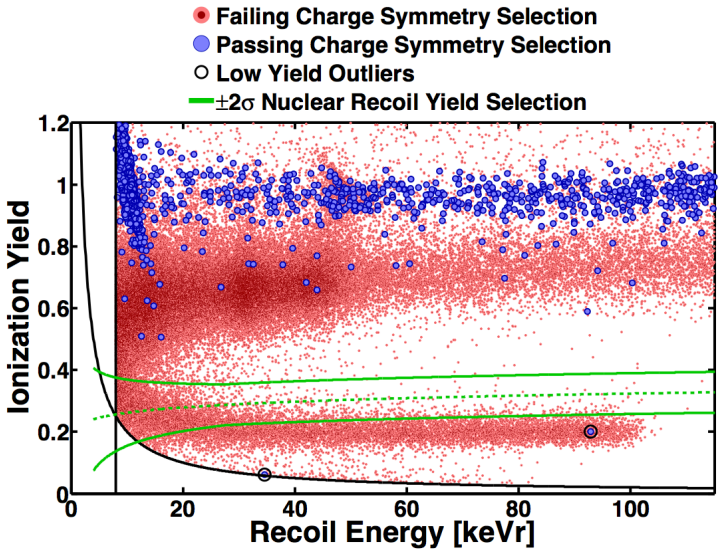


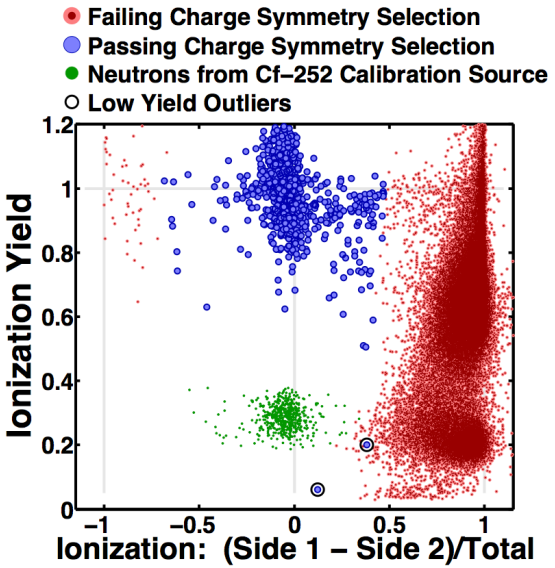


- Detector array :15 Ge iZIP detectors (0.6 kg each) held at 50 mK
- 4 phonon and 2 charge channels on each detector face
- Phonon channels are grounded, charge channels are biased at $\pm$ 2 V
- Field configuration causes events near surface to have charge collection localized to one side

Discrimination

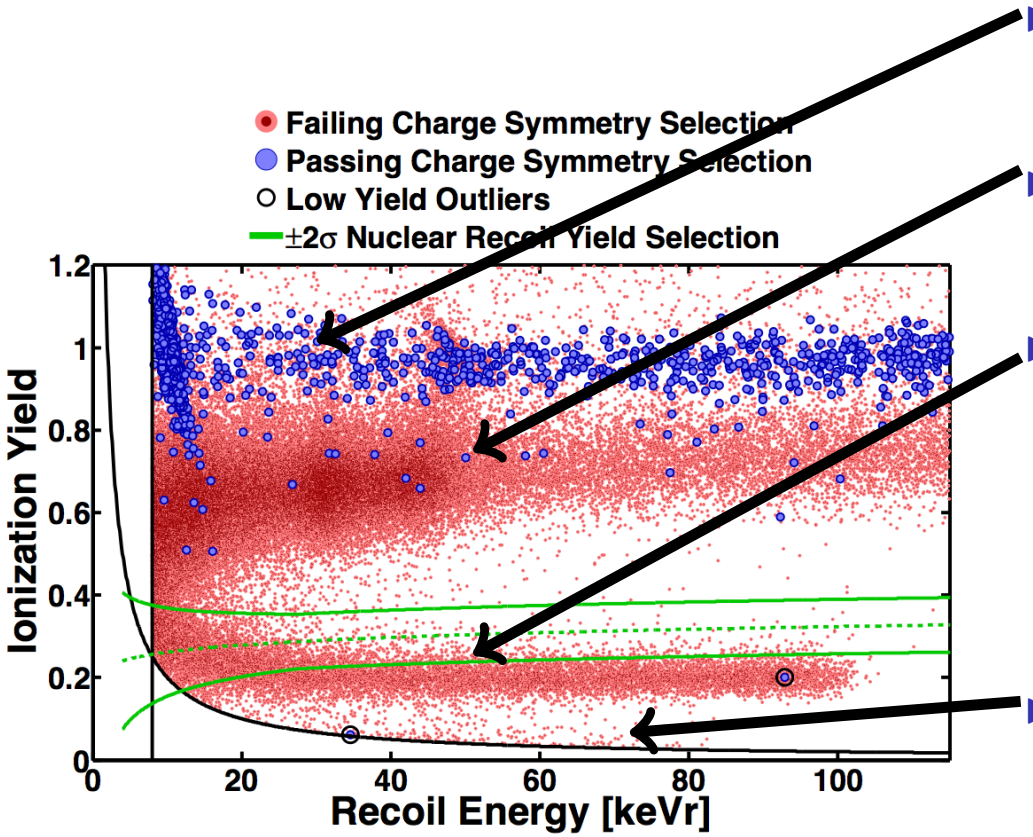






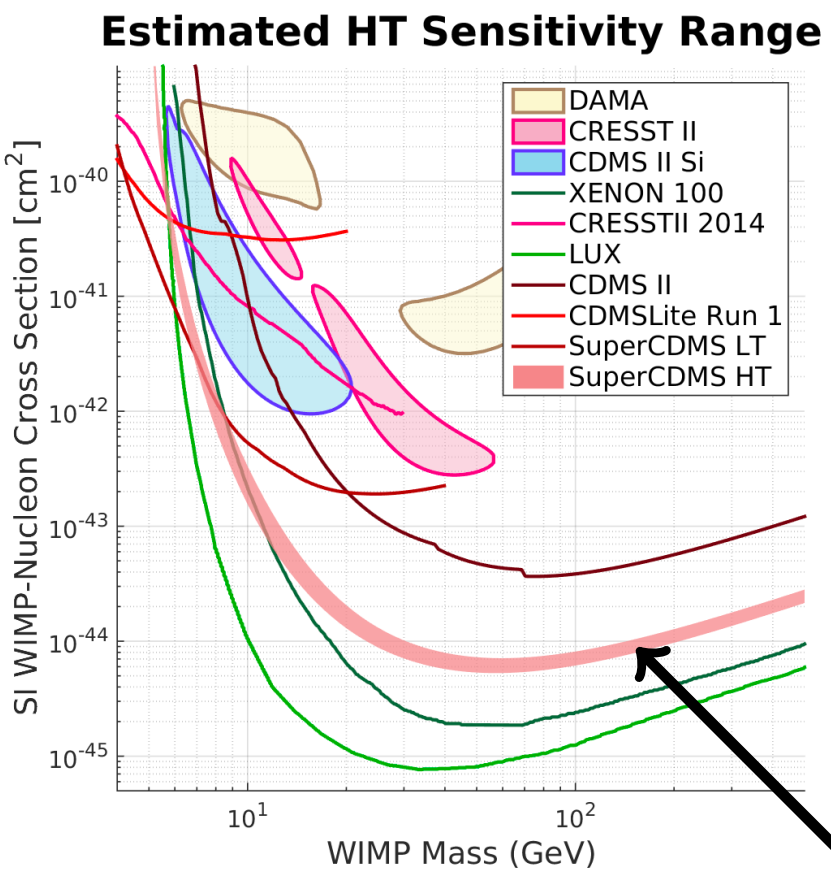
- Two of the detectors are faced with a ^{210}Pb implanted Si wafer as a calibration source for ^{206}Pb nuclei and low-energy betas
- Yield is still a powerful discriminant but can be combined with charge asymmetry to improve rejection of surface events
- Set an upper limit of 1.3×10^{-5} for surface event rejection power in the nuclear recoil signal region

Sources of Backgrounds



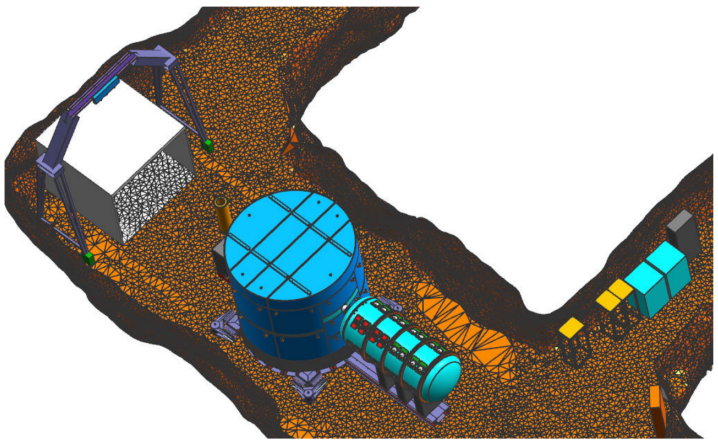
- Bulk gammas - modeled with ^{133}Ba gamma calibration data
- Betas - modeled from ^{210}Pb source and Ba data
- ^{210}Pb induced surface events - rates can be measured through alphas, modeling based on controlled sources (calibration plates, test facilities)
- Zero charge - originate from gammas interactions in regions with weak E-field at high radius, traditionally removed through ionization threshold

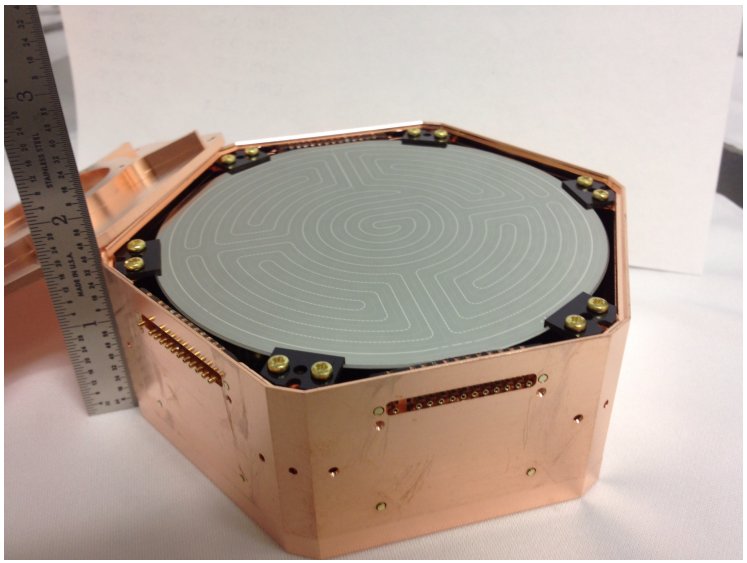
Projected Sensitivity



- Analysis will focus on a subset of our best detectors
- Several techniques being persued such as aBDT, cut-and-count and profile likelihood
- Assumptions used to derive sensitivity estimate
  1. 60-65% fiducial volume
  2. 95% data quality efficiency
  3. Phonon thresholds as measured for the individual detectors
  4. 11-14 detectors used
- Limits will be improved by an order of magnitude over CDMS-II analysis

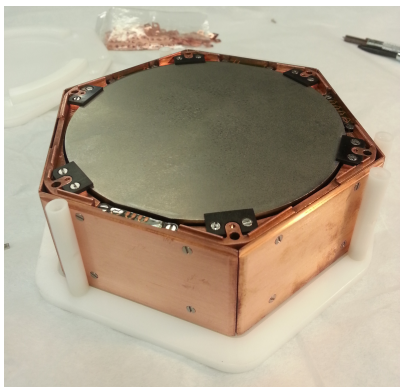
SuperCDMS SNOLAB

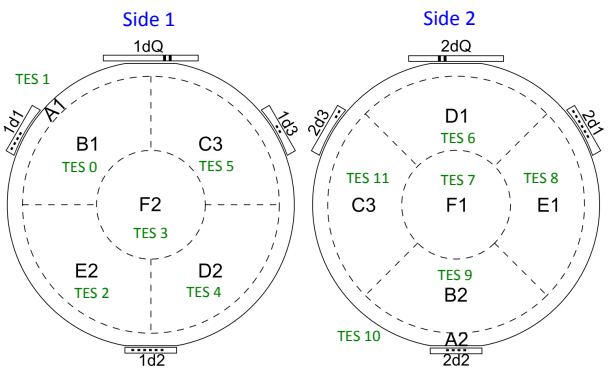


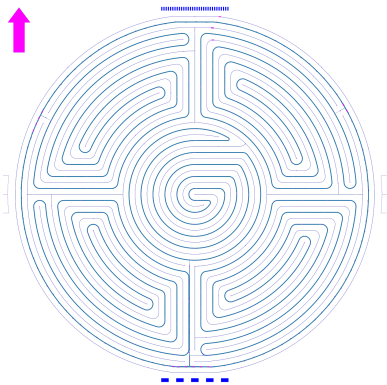


- One of three G-2 experiment selected to go forward
- SuperCDMS SNOLAB, whole new experiment at Creighton Mine, Sudbury, Canada
- SNOLAB : $\approx$ 2 km underground; 6010 mwe of shielding from cosmics; entire lab is class 2000 cleanroom
- Space at SNOLAB is reserved in ladder labs

SuperCDMS SNOLAB iZIP Detectors





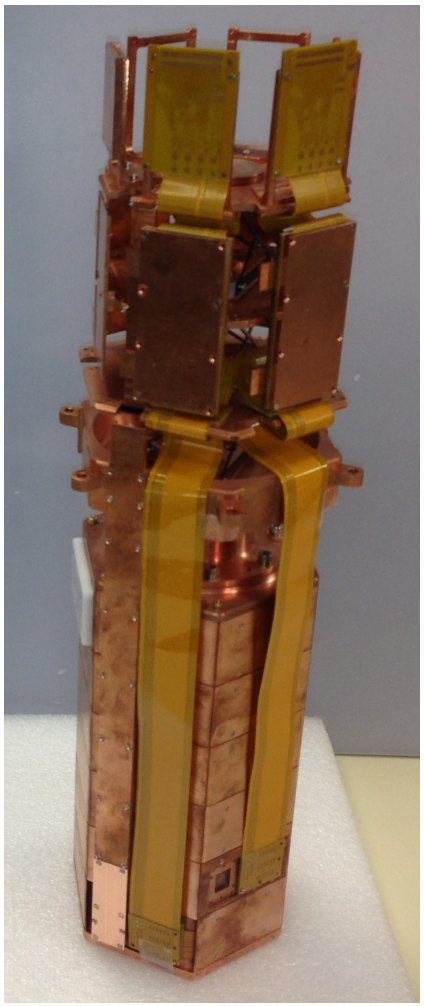


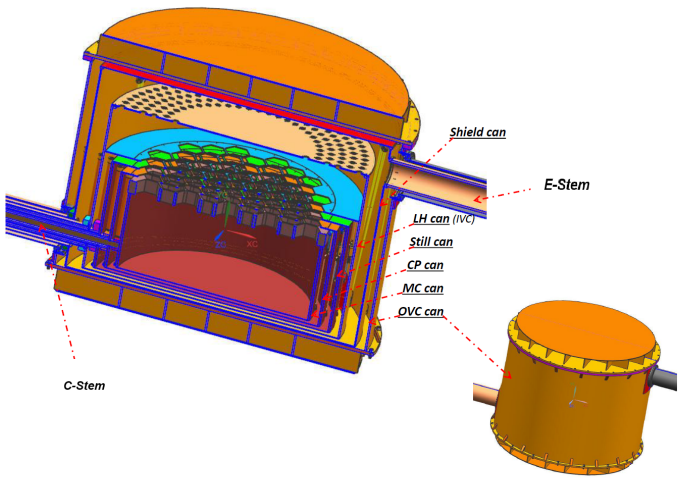
- Crystal dimensions : 33 mm thick, 100 mm diameter
- Two target materials : Ge (1.39 kg/detector) and Si (0.6 kg/detector)
- 6 phonon channels and 2 charge channels on each detector face (interleaved like in SuperCDMS Soudan detectors)

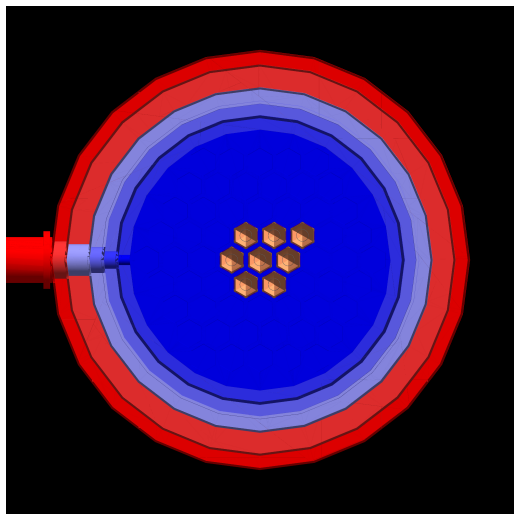
HV Biasing

- Phonons are created from charges passing through a crystal through Luke-Neganov effect
- The contribution to total phonon energy goes as $N_{e/h} e V_b$: proportional to bias voltage V_b
- High bias voltage allows us to measure small amount of charges through phonon signal (low ionization threshold, see Mark Pepin's talk)
- Trade-off: no separate measurement of primary phonon signal, sacrifices ER/NR discrimination
- Soudan HV mode: 70 V; plans for SNOLAB: 100 V
- Expected trigger threshold for SNOLAB: 70 eVt (total phonon energy); at 100 V bias this corresponds to single electron-hole pairs

Towers and Payload

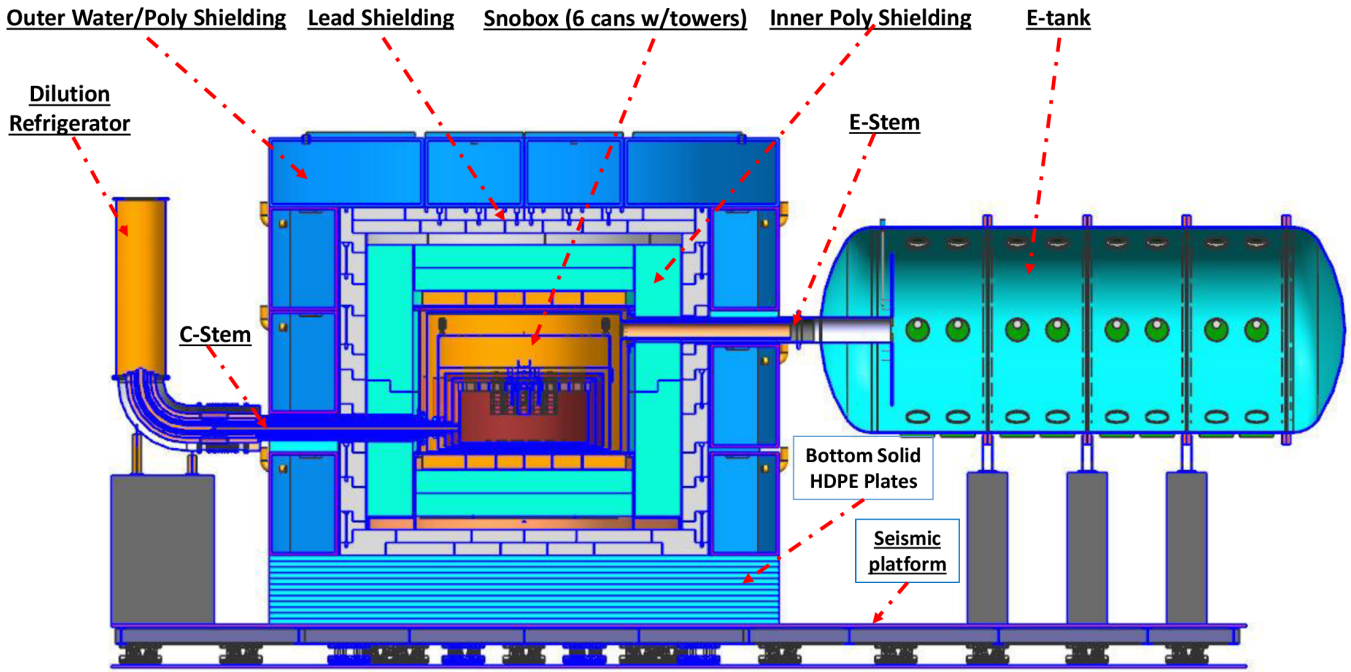






- Baseline design consists of 8 towers
- One tower will be entirely HV biased, with a mix of Ge and Si detectors
- One tower will consist of Si detectors
- Optimization of exact payload is still on-going

Shielding Design



- Similar to Soudan design, water tanks instead of poly in outer layers
- Lead shielding will consist of two layers, outer lead and an inner ancient Pb liner
- Inner poly maybe replaced with an active neutron veto in a future upgrade after initial deployment

Science Goals

- Mix of Ge/Si and HV/iZIP gives four WIMP search configurations
  1. Ge iZIP - 36 detectors, 50 kg
  2. Si iZIP - 6 detectors, 4.1 kg
  3. Ge HV - 4 detectors, 5.6 kg
  4. Si HV - 2 detectors, 1.4 kg
- HV detectors provide sensitivity to lowest masses while iZIP detectors cover above $\approx$5 GeV/c^2
- Different targets let us study non-standard interactions
- Can search for axions and lightly ionizing particles
- Expect to observe coherent scattering of ^{8}B solar neutrinos
- Cryostat will allow for future payload upgrades

Background Sources

- Same sources as Soudan HT analysis will also be present at SuperCDMS SNOLAB
- Neutrons are a dominant background for high mass WIMP searches, electron recoils dominate low mass search
- Lack of background discrimination in HV detectors means we need to get low energy background rates down during construction
- The lower background means that new background sources become important like ^{3}H

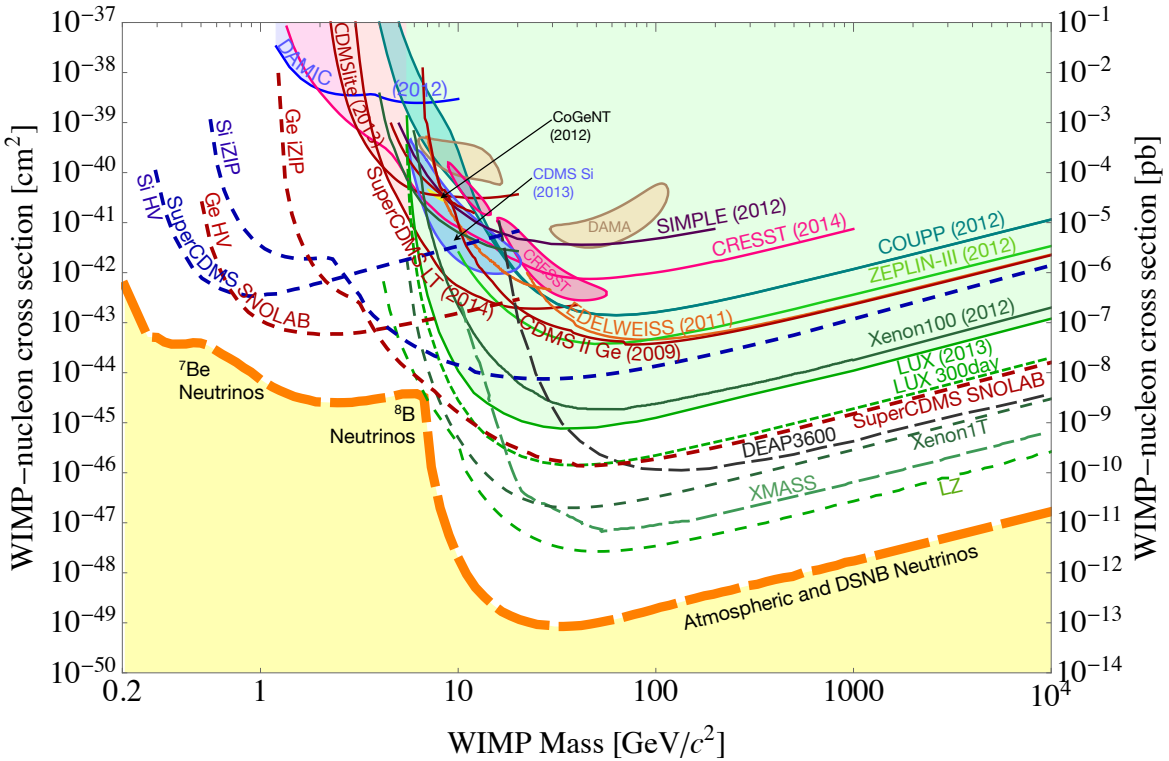
Background Rates

Material	^{238}U	^{232}Th	^{40}K	Reference
Polyethylene	0.03 mBq/kg	0.02 mBq/kg	0.1 mBq/kg	DEAP
Copper	0.07 mBq/kg	0.02 mBq/kg	0.04 mBq/kg	XENON100
Lead	0.66 mBq/kg	0.5 mBq/kg	7.0 mBq/kg	XENON100
Detector and Housing surfaces		^{206}Pb: 25 nBq/cm^2		SuperCDMS Soudan

Type	Soudan Calculated Singles Rate events/keVr/kg/yr	SNOLAB Assumed Singles Rate events/keVr/kg/yr
Cosmogenic Neutrons	1.5×10^{-4}	2.8×10^{-5}
Radiogenic Neutrons	8×10^{-4}	2.5×10^{-5}
Bulk Gammas	1.1×10^{3}	2.2
Top/bottom Surface β	1.2	1.2
Radial Surface β	114	4.4
Top/Bottom Surface ^{206}Pb	0.18	0.18
Radial Surface ^{206}Pb	23	1
Cosmogenic Activation (^{3}H)	-	16.4 (Ge), 93.3 (Si)

- Backgrounds are simulated using a GEANT4 based framework
- Contamination rates are taken from literature
- Gamma rate is driven by contamination in Cu cryostat

Projected Reach - 5 years exposure



- SuperCDMS SNOLAB will be leading the way at for low mass WIMPS using HV biased detectors
- Standard detectors will give sensitivity to intermediate mass range; expect to reach neutrino floor around 10 GeV/c^2

Conclusion/Summary

- We have collected $\approx$ 2500 kg-days of raw exposure with SuperCDMS Soudan
- Aim is to have a high mass result by end of the year
- As Soudan operations shut down, focus turns to SuperCDMS SNOLAB project
- SuperCDMS SNOLAB will have superior sensitivity to low mass WIMPs
- Agency review proces ongoing; CD-1 planned for later this fall
- We hope to start collecting data in a few years at SNOLAB!

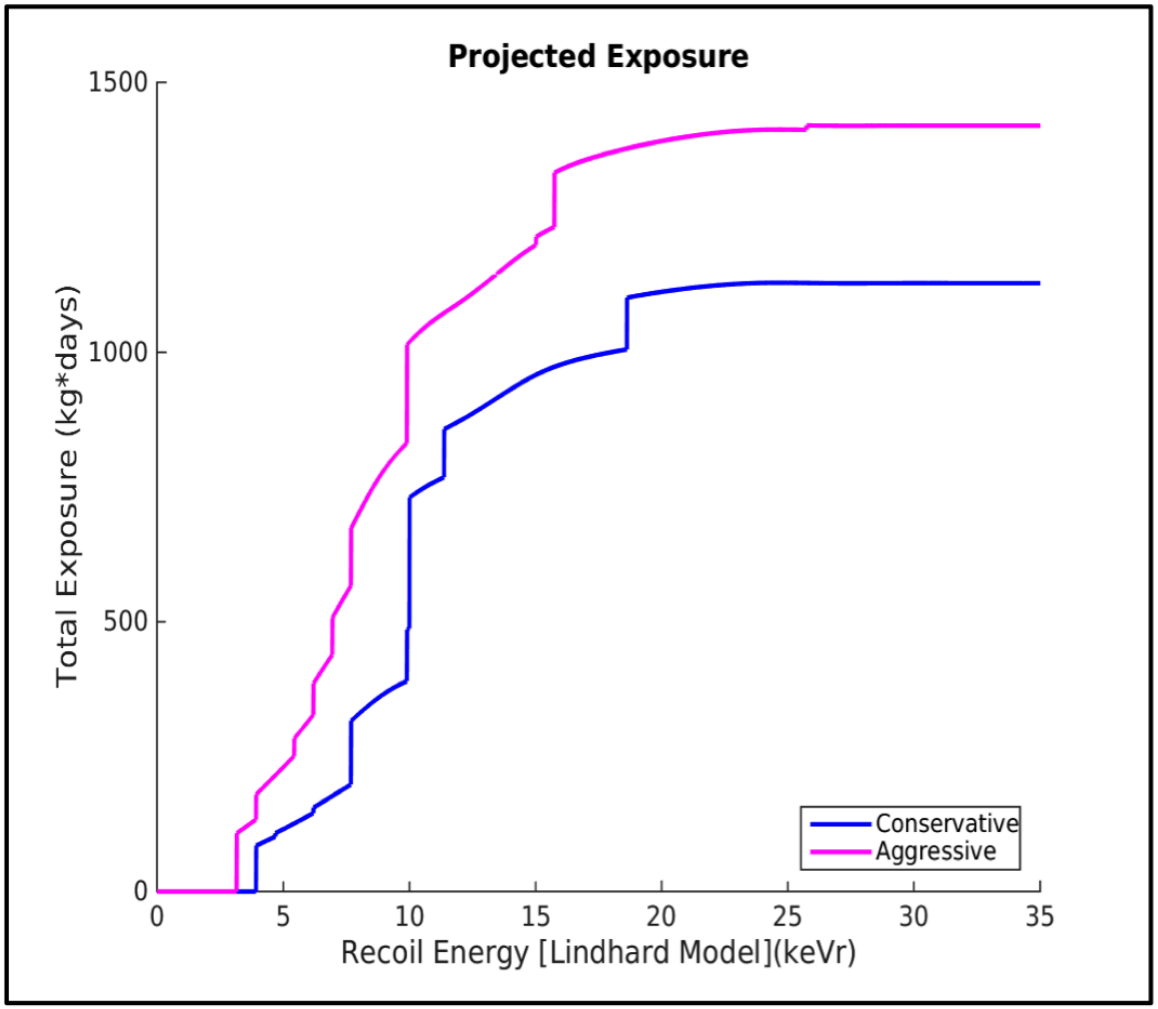
The SuperCDMS Collaboration - 2015

California Inst. of Tech.
CNRS-LPN*
Durham University
FNAL
NIST*
Northwestern
PNNL
Queen's University
SLAC
Southern Methodist U.
Santa Clara University
South Dakota SM&T
Stanford University
Texas A&M University
U. British Columbia
U. California, Berkeley
U. Colorado Denver
U. Evansville
U. Florida
U. Minnesota
U. South Dakota

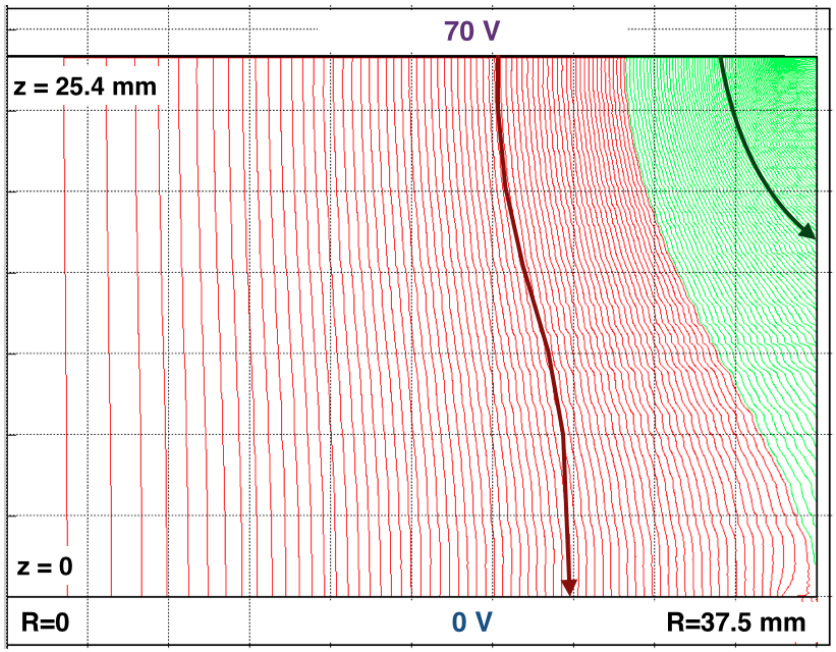
* Associate members

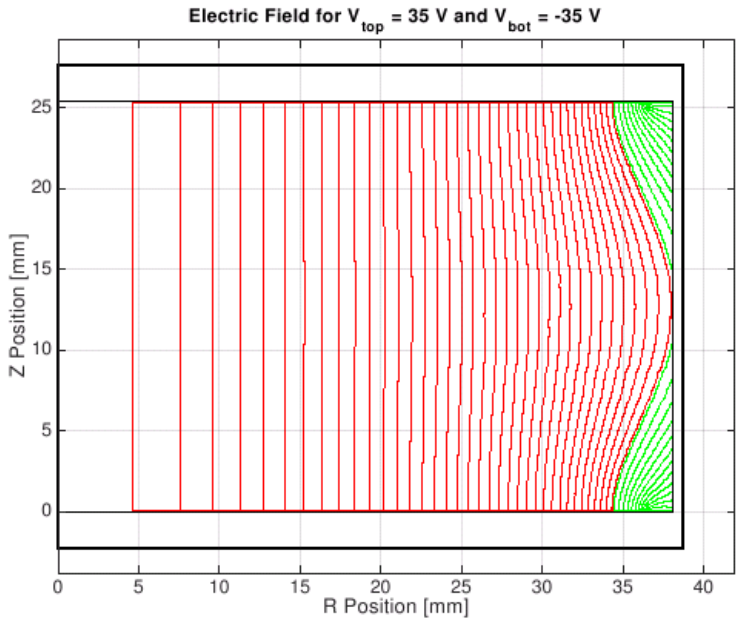
Backup slides

Projected exposure for Soudan HT analysis



CDMSlite Soudan field configurations





These plots show simulations of the electric fields generated in a CDMSlite detector. We are currently exploring a double sided mode to improve the fiducial volume.

Projected Reach - 5 years exposure details

- 80% duty cycle
- Ge iZIP : 200 kg-y
- Si iZIP : 15 kg-y
- Ge HV : 22 kg-y
- Si HV : 5 kg-y