SuperCDMS Soudan
Ray Bunker
for the SuperCDMS Collaboration
Detection Technique

Ionization & Phonons

Nuclear Recoil (NR) yields ≈20–30% ionization vs. Electron Recoil (ER)

Phonons provide equal measure of NR & ER recoil energies
Detection Technique

Ionization & Phonons

Residual backgrounds are near surfaces:
- U/Th/K decays → γ-induced electrons, sidewall γ’s
- $^{210}$Pb decay chain → betas, x-rays, $^{206}$Pb recoils

Low-energy region, all of the above plus:
- U/Th/K decays → γ-induced bulk ERs
- Internal activation (e.g., $^{68}$Ge) → bulk ERs
The SuperCDMS iZIP

Interleaved ionization & phonon sensors

**Bulk event** → Side-symmetric ionization signal

**Surface event** → Asymmetric ionization signal

Significantly improved surface-event rejection

Phonon sensors @ 0V

Ionization electrodes @ ±2V
SuperCDMS Soudan

15 detector array of germanium iZIPs:
- 0.6 kg per detector
- \textit{in situ} $^{210}\text{Pb}$ sources
- Installed in CDMS II shielding
- In operation since early 2012
- Primary iZIP science run ended summer 2014
- More CDMSlite & calibrations through fall 2015

Broad science program:
- Demonstration of surface-event discrimination
- WIMP-search analyses:
  - 3 CDMSlite runs $\rightarrow M_{\text{WIMP}} < 5 \text{ GeV}/c^2$
  - Low-threshold iZIP $\rightarrow M_{\text{WIMP}} = 5–10 \text{ GeV}/c^2$
  - High-threshold iZIP $\rightarrow M_{\text{WIMP}} > 10 \text{ GeV}/c^2$
- Y/Be & Sb/Be photoneutron calibrations
- In general, high degree of experimentation to inform SuperCDMS SNOLAB

see talk by Sunil Golwala (next session)
Surface-event Discrimination

$^{210}$Pb sources placed above and below 2 detector faces:

- 50 live days $\rightarrow$ 0 of 132,968 leaked surface events in (symmetric) NR signal region
- More than sufficient face-event discrimination for SNOLAB iZIP payload

![Graph showing ionization-derived side-symmetry parameter vs. recoil energy (keV) and ionization yield for bulk ERs, surface betas & X-rays, bulk NRs, and $^{206}$Pb recoils.](APL 103, 164105 (2013))
Low-threshold Analysis

Low-energy WIMP search:

- Use 7 iZIPs w/ best low-energy performance
- Data period = Oct 2012 – July 2013
- 577 kg-day exposure (2.4x CDMS II)
- Range of thresholds: 1.6–5 keV
- Improved discrimination of sidewall events via phonon-derived fiducial volume

Further LT studies:

- Maximum likelihood analysis using background model from 2014 PRL
- Understand anomalous high-energy candidates using Detector Monte Carlo

→ Stay tuned… PRD long paper in progress

PRL 112, 241302 (2014)
High-threshold Analysis

High-energy WIMP search:

- Different strategy: target high-mass WIMPs
- Higher thresholds to prevent background at low energy due to resolution smearing
- Use 10 iZIPs w/ fully operational charge channels
- Mix of WIMP search and $\gamma$ & neutron calibrations
High-threshold Analysis

Analysis challenges:
- Exposure-limited → maximize fiducial volume with near-zero background
- Surface events ($\gamma$-induced electrons & $^{210}$Pb decay chain):
  - Faces: expect a few hundred such events → demonstrated $\approx 10^{-5}$ rejection more than sufficient!
  - Sidewalls: more challenging to understand low-yield event rate vs. radial-position estimator (ongoing)
High-threshold Analysis

Projected sensitivity for:
- 1700 kg-day exposure ($\approx 2.75 \times$ CDMS II)
- 7-15 keV thresholds
- 50-65% fiducial volume

Nice improvement vs. CDMS II considering modest exposure

Important demonstration of iZIP technology in advance of SuperCDMS SNOLAB
Background Measurements

Global $\gamma$ background:
- Geant4 simulation of U/Th/K in materials of construction
- Simultaneous fit for activities using measured ionization spectrum
- Mystery: dominated by U/Th gammas coming from below!
- Attempting to understand with forensic assay → e.g. dust?

Surface $\alpha$ background:
- Alphas are easily identified!
- Primary contribution from $^{210}$Po at 5.3 MeV
  → Normalizes $^{210}$Pb surface contamination
- Decay rate indicates more Po vs. Pb at start
- Ge crystal faces show $\approx$50 nBq/cm$^2$
- >10x higher rate at sidewalls
  → Copper housings or crystal sidewalls?
  → Planning to directly $\alpha$ assay both!

![Graph showing measured and simulated spectra for $\gamma$ and $\alpha$ backgrounds]
Photoneutron Calibration

Purpose:
• Improve understanding of nuclear-recoil energy scale for CDMSlite & iZIP modes

Technique:
• Pair $^{88}\text{Y}$ and $^{124}\text{Sb}$ $\gamma$ sources with Be wafer $\rightarrow \approx$ mono-energetic neutrons (152 & 23 keV)
• Look for maximum elastic scattering shoulder off Ge at 8.1 & 1.3 keV
• SuperCDMS Soudan is a rich source of data for improving WIMP-search sensitivity and understanding SuperCDMS detectors

• The iZIP technology significantly improves rejection of the CDMS II limiting backgrounds
  • *e.g.*, demonstrated face-event rejection better than needed for SuperCDMS SNOLAB & improved phonon-sensor layout enables >10x reduction of low-energy backgrounds

• High-threshold analysis is ongoing (expect result this year) + backgrounds & calibrations
Backup Slides
CDMS II → Background-Limited

High-threshold analysis:
- Final CDMS II dataset
- 612 kg-day Ge exposure
- 10 keV threshold
- Limited by near-face ERs in high-energy region

Low-threshold analysis:
- Final CDMS II dataset
- 241 kg-day Ge exposure
- 2 keV threshold
- Limited by sidewall events in low-energy region
Charged-based radial preselection not effective on top side
Phonon-based radial fiducialization less effective near top corner
Photoneutron Calibration

Plots shown here are result after subtracting neutron-off from neutron-on spectra; these plots are not efficiency corrected.

Events per hour

\( ^{88}\text{Y}\, ^{9}\text{Be} \) subtracted

\( ^{124}\text{Sb}\, ^{9}\text{Be} \) subtracted

x-axis units are not calibrated...but they are the same scale shown on previous slide.

error bars shown are statistical;
data shown is 5 weeks of Sb and 4 weeks of Y (additional data not yet analyzed)