Results from the Final Runs of the CDMSII Experiment

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Detect energy deposited from WIMP-nucleus scattering

Discriminate between nuclear and electron recoils

CDMS: Z-sensitive Ionization and Phonon detectors
About 50 people from 15 institutions in the US, Canada, and Switzerland.
Experimental Setup

MINOS
CDMS
2090mwe
WIMP detection and background rejection

- Separate readout of phonon and charge channels
- Nuclear recoil interactions (like WIMPs) deposit most of their energy as phonons
- Electromagnetic recoils have higher charge signal

**Yield** = $E_{\text{charge}}/E_{\text{phonon}}$
Better than 1:10000 rejection based on ionization yield

Yield based rejection

\[ \text{Yield} = \frac{E_{\text{charge}}}{E_{\text{phonon}}} \]
- Events near surface can have reduced charge collection
- Discrimination handle is timing of phonon pulses
• Analysis of data runs beginning July 2007 and ending September 2008

• New data pipeline: Complete revamp of reconstruction software, migrated processing to ROOT. Processed 8TB of data in 1 month, much faster than before!

• Analysis tuned to keep expected background at <1 event
Candidate event criteria:

- Data quality + fiducial volume cuts
- Muon-veto anticoincident
- Single scatter
- Ionization yield within $2\sigma$ nuclear recoil band
- Phonon timing cuts to get rid of surface events

All cuts developed before unblinding using WIMP-search sidebands and calibration data!
We optimized for the best sensitivity (results in < 1 expected background).

Rejection based on phonon timing is 200:1
Unblinding the WS data
150 events in NR band fail timing cut

Events failing timing cut
Events passing timing cut

Event 1:
Tower 1, ZIP 5
Sat. Oct. 27, 2007
9:48pm EDT

Event 2:
Tower 3, ZIP 4
3:41 pm EDT
Big question: signal or background?

Post-unblinding studies:

- Data quality (re-checks) -- passed
- Reconstruction quality (re-checks)
- Cut varying studies
- Likelihood analysis

Closeup of template fit to ionization pulse for event 2

Reconstructed start time
The final surface event background estimate is:

$$0.8 \pm 0.1 \text{(stat)} \pm 0.2 \text{(sys)} \text{ events}$$

The probability to observe 2 or more surface events based on the estimated background is 20%

After including the neutron background, the probability to observe 2 or more events is 23%

Likelihood analysis encourages suspicion about event in T1Z5, and reconstruction makes us suspicious of event in T3Z4

Comments about surface events
What is the probability that a true nuclear recoil in the acceptance region is as close to the cut boundaries as the candidate events are?

<table>
<thead>
<tr>
<th>Tower 1, zip 5</th>
<th>3D unbinned (timing, energy, yield)</th>
<th>2D fit (yield, timing) with fit</th>
<th>2D no fit (yield, timing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event 1 T1Z5</td>
<td>1%</td>
<td>3%</td>
<td>4%</td>
</tr>
<tr>
<td>Event 2 T3Z4</td>
<td>12%</td>
<td>2%</td>
<td>19%</td>
</tr>
</tbody>
</table>

Likelihood Analysis
CDMS 2009@WIMP mass 70 GeV
\[ \sigma = 7.0 \times 10^{-44} \text{ cm}^2 \ (90\% \text{ C.L.}) \]

CDMS Combined Soudan Data @WIMP mass 70 GeV
\[ \sigma = 3.8 \times 10^{-44} \text{ cm}^2 \ (90\% \text{ C.L.}) \]

Science vol. 327 p.1619
Inelastic dark matter

Has been invoked by Weiner et al. to explain DAMA/LIBRA data, among other things. [Phys. Rev. D 64, 043502 (2001)]

Scattering occurs via transition of WIMP to excited state (with mass splitting $\delta$)

DAMA, allowed regions (at 90% C.L.) computed from $\chi^2$ goodness-of-fit and standard truncated halo-model [JCAP 04 (2009) 010]

Inelastic dark matter
New detectors are 2.5 times thicker
Installed in Soudan and successful engineering run Oct 2009-Dec 2009

Based on backgrounds, surface discrimination, and neutron efficiency determined from the engineering run, a 2yr mZIP exposure would result in a 4X improvement in sensitivity compared to CDMS II (~1 x 10^{-44} cm^2)

Next step: SuperCDMS mZIPs
Next generation of detector design: iZIP

**iZIP = interleaved charge and phonon channels**

1/3000 rejection of surface events in NR band based only on charge collection

If we include phonon timing the surface event rejection may be \(~10^3-10^6 \times\) better!

Charge near surface is collected by electrodes on only one side

*surface and bulk events experience different electric fields*
- Analysis of 612 (raw) kg-days of data, last of the CDMS-II data

- 2 events were observed in the signal region (0.8 surface events and < 0.1 neutrons were expected)

- We cannot interpret this result as a statistically significant signal but, within the blind analysis, we cannot exclude either event as signal

- World leading limit on spin-independent WIMP-nucleon cross-section
  \[3.8 \times 10^{-44} \text{cm}^2 \text{ at } 90\% \text{ CL (for 70 GeV/c}^2 \text{ WIMP mass)}\]

- **Successful good quality data run of first SuperTower!** Next run at Soudan will be a mixture of iZIP and mZIP detectors (~10X improvement over CDMSII)
Backup
Expected surface leakage = \[ \frac{N_{\text{Passing cut}}}{N_{\text{Sideband failing cut}}} \times N_{\text{failing cut}} \]

3 independent sidebands for estimating the passing/failing ratio

**SIDEBAND 1**
Use multiple-scatters in NR band

**SIDEBAND 2**
Use singles and multiples just outside NR band

**SIDEBAND 3**
Use singles and multiples from Ba calibration in wide region
Neutron Background Estimates

From GEANT4 and FLUKA simulations

3 vetoed, single NR (in Soudan dataset)
correct for efficiency and exposure

Radiogenic Neutron Estimate:
- fission, \((\alpha, n)\) in Cu, Poly, Pb

0.03 - 0.06 events

Neutron Background Estimates
SuperTower installation
A preliminary look at the Alpha rate for SuperTower 1 shows we are ~2X better than our target rate.

Alpha rate is the best measure of 210Pb, our dominant source of background.
CDMS II
4 kg Ge
~ 2 yrs operation

SuperCDMS @ Soudan
15 kg Ge
~ 2 yrs operation

SuperCDMS @ Snolab
100 kg Ge
~ 3 yrs operation, interleaved charge and phonon sensors

Future projections
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
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<tbody>
<tr>
<td>2008</td>
<td>CDMS II Soudan (4 kg Ge, 2E-44)</td>
</tr>
<tr>
<td>2009</td>
<td>SuperCDMS Soudan (15 kg Ge, 5E-45)</td>
</tr>
<tr>
<td>2010</td>
<td>SuperTower Fabrication (each tower = 3.1 kg Ge)</td>
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<tr>
<td>2011</td>
<td>Larger detector R&amp;D</td>
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<tr>
<td>2012</td>
<td>Larger detector fabrication</td>
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<tr>
<td>2013</td>
<td>Design SNOLAB Infrastructure</td>
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<tr>
<td>2014</td>
<td>Build SNOLAB Infrastructure</td>
</tr>
<tr>
<td>2015</td>
<td>SuperCDMS SNOLAB (100 kg Ge, 3E-46)</td>
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<tr>
<td></td>
<td>SuperCDMS Detector Project</td>
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<td></td>
<td>Advanced Detector and DUSEL R&amp;D</td>
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<td></td>
<td>SuperCDMS Soudan</td>
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<td></td>
<td>SuperCDMS SNOLAB Construction</td>
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<tr>
<td></td>
<td>SuperCDMS SNOLAB Operations</td>
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**Timeline**
Surface events

~10 μm “dead layer”

carrier back diffusion

rapid phonon down-conversion
Phonon detection

Transition Edge Sensor

Al

phonons

Ge or Si

Electro Thermal Feedback

R

T

Tc~80mK

~10mK

(quasiparticle diffusion)