The SuperCDMS Experimental Program

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UCLA Dark Matter 2012

For the SuperCDMS Collaboration
The SuperCDMS Experimental Program

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For the SuperCDMS Collaboration
The Landscape

The graph shows the WIMP-nucleon cross section in units of $\text{cm}^2$ versus WIMP mass in units of $\text{GeV/c}^2$. The lines represent different experimental results and theories, including CDMS II, CDMS II Low-E, CDMS-EDELWEISS (2011), XENON100 (2011), Cogent, CDMS-EDELWEISS (2011), XENON100 (2011), Cogent, DAMA/Na no no channeling, SCDMS 10, 100, 1.5T, XENON 100, 1T, and Buchmueller LHC CMSSM.

Access to LHC is indicated by vertical lines. The graph includes annotations for 1 event/kg/year*, 1 event/10 kg/year*, 1 event/100 kg/year*, and 1 event/ton/year* for a 100 GeV/c$^2$ WIMP on a Ge target with a 10 keV low-energy threshold.
SuperCDMS

Use discrimination and shielding to maintain a **Nearly Background Free** experiment with cryogenic semiconductor detectors

**Strategy:**

1. **Suppress all backgrounds** (factor of millions)

2. **Discriminate between remaining background and desired signal** (make your detector as smart possible)
New SuperCDMS Detectors: iZIP
Interleaved Z-measuring Ionization and Phonon

Top and bottom surfaces contain interleaved ionization and phonon sensors

Each phonon sensor contains 458 transition-edge sensors in parallel.

Sensors are combined into 8 phonon channels and 4 charge channels
New SuperCDMS Detectors: iZIP
8 phonon channels, 4 charge channels
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8 phonon channels, 4 charge channels
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4 charge channels, 8 phonon channels
New SuperCDMS Detectors: iZIP
Intrinsic Charge Surface Rejection

Interleaved Phonon (0) and Ionization (+) Sensors on Top Surface

Interleaved Phonon (0) and Ionization (-) Sensors on Bottom Surface
New SuperCDMS Detectors: iZIP

Intrinsic Charge Surface Rejection

Interleaved Phonon (0) and Ionization (+) Sensors on Top Surface

Interleaved Phonon (0) and Ionization (-) Sensors on Bottom Surface

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New SuperCDMS Detectors: iZIP
Intrinsic Charge Surface Rejection

Bulk events create ionization signals on both sides.

iZIP detectors collect both holes and electrons.
New SuperCDMS Detectors: iZIP
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Bulk events create ionization signals on both sides.

iZIP detectors collect both holes and electrons.
When an event happens near the surface, the iZIP collects all the charge on one side only.

Charge-based Surface Rejection!

Phonon Sensors

Charge Sensors

Crystal Bulk

Vacuum
Charge-based Surface Rejection!

When an event happens near the surface, the iZIP collects all the charge on one side only.
Charge-based Surface Rejection!

When an event happens near the surface, the iZIP collects all the charge on one side only.
Charge vs Charge Plot

3x10^{-5} surface discrimination from ionization signal alone!

Additional discrimination from phonon signals
SuperCDMS Soudan: first iZIPs

5STs each 3 iZIPs

$^{210}\text{Pb}$ source used to confirm rejection
2000 decays/day (only on one Tower)

Fiducial Volume Estimates
SuperCDMS Soudan: first iZIPs

- Total mass is ~ 9 kg
  (~ 6 kg fiducial due to ~ 2 times higher fiducial fraction than CDMS II)
- Now cold, starting to take science data soon!
- Will run for at least two years
- Expect between 5 and 8e-45 cm$^2$ sensitivity with 10 keV nuclear discrimination threshold (depending on Soudan neutron background)
- Also plan to run in CDMS-lite (Luke Amplification) mode with ~ 1 keV threshold

5STs each 3 iZIPs

$^{210}$Pb source used to confirm rejection 2000 decays/day (only on one Tower)

Fiducial Volume Estimates
The SuperCDMS Program

CDMS II
7.5 x 1 cm  0.23 kg
Cross section sensitivity (cm²)
3.8e-44

SuperCDMS Soudan (G1)
7.5 x 2.5 cm  0.60 kg
x 15
3.5 kg
x 15
9 kg

SuperCDMS SNOLAB (G2)
10 x 3.3 cm  1.4 kg
x 84
120 kg

GEODM (G3)
Ge Observatory for Dark Matter
15 x 5 cm  5 kg
x 300
1500 kg

Cross section sensitivity (cm²)
3.8e-44
5e-45
3e-46
2e-47
SNOLAB Challenges

• Demonstrating larger mass detectors
• Scaling up detector fabrication and testing
• (time * $ * yield)
100 mm Detectors

• We’ve acquired 100 mm diameter by 33 mm thick crystals
• We’ve fabricated these crystals into test devices and tested the ionization performance
• Currently designing 100 mm iZip

356 keV $^{133}$Ba $\gamma$ line
Detector Throughput Test

- SuperCDMS throughput study
- 6 3”x1” detectors in 3 weeks with 3FTE fab team
Conclusions

• New iZIP detectors meet Soudan surface event rejection requirements and are expected to exceed SNOLAB requirements.

• Soudan science running imminent

• R&D for G2 SuperCDMS SNOLAB in progress
Other SNOLAB R&D in Progress

- Phonon sensor design
- Cold electronics and mechanical design
- SNOLAB Cryostat and shield (neutron veto?)
- Warm electronics, DAQ, and software
Low-Threshold Ge Sensitivity

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The Effects of Backgrounds

Neutralino
NMSSM

WIMP-Nucleon Cross Section [cm$^2$]

WIMP Mass [GeV/c$^2$]

10 keV
5 keV
1 keV
100 eV

10$^{-47}$ 10$^{-46}$ 10$^{-45}$ 10$^{-44}$ 10$^{-43}$ 10$^{-42}$ 10$^{-41}$ 10$^{-40}$ 10$^{-39}$ 10$^{-38}$

CDMS II
XENON100 (2011)
Cogent
DAMA/Na no channeling
SCDMS 100, 1.5T
XENON 100, 1T
Buchmueller LHC CMSSM

Flat Bkgnd
The Effects of Backgrounds

WIMP-Nucleon Cross Section [cm$^2$] vs. WIMP Mass [GeV/c$^2$]

- CDMS II
- XENON100 (2011)
- Cogent
- DAMA/Na no channeling
- SCDMS 100, 1.5T
- XENON 100, 1T
- Buchmueller LHC CMSSM

Experimental Background (Exp Bkgnd)
Flat Background (Flat Bkgnd)

Neutralino NMSSM

100 eV, 1 keV, 5 keV, 10 keV
The Effects of Backgrounds

- Neutralino
- NMSSM

10 keV
5 keV
1 keV
100 eV

WIMP-Nucleon Cross Section $[\text{cm}^2]$ vs. WIMP Mass $[\text{GeV/c}^2]$
Low-Threshold Operation

- Use only the high-resolution phonon readout channel
- No yield discrimination
- Use higher voltage bias to amplify the phonon signal and attain a lower effective threshold
- Future detectors with higher resolution phonons will enable even lower thresholds
Surface Event Rejection

Test Facility Data

Yield Rejection with Symmetric Events

- Yield (Charge/Phonon)
- Phonon Recoil Energy [keV]

Yield Rejection with Symmetric Events

- cCdOnly_ucl
- cQsym_g48
Surface Event Rejection
Test Facility Data

Yield Rejection

Red
Green = 3 \times 10^4
## Bulk Electron Recoil Rejection

<table>
<thead>
<tr>
<th>Discrimination Type</th>
<th>CDMS II Rejection</th>
<th>iZIP Rejection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electron Energy / Phonon Energy (Yield)</td>
<td>$&gt;1: 1 \times 10^6$</td>
<td>Expected to be the same as CDMS II</td>
</tr>
<tr>
<td>Phonon Pulse Shape ER/NR Discrimination</td>
<td>1:10</td>
<td>$&gt;1: 1 \times 10^3$, but this will improve significantly</td>
</tr>
<tr>
<td>Discrimination Type</td>
<td>CDMS II Rejection</td>
<td>iZIP Rejection</td>
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<tr>
<td>Charge-based</td>
<td>Not Possible with CDMS II Detectors</td>
<td>$&gt;3 \times 10^{-5}$</td>
</tr>
<tr>
<td>Phonon-based</td>
<td>1:20</td>
<td>$&gt;1: 1 \times 10^3$</td>
</tr>
<tr>
<td>Low Yield Surface Events</td>
<td>1:10</td>
<td>$&gt;1: 1 \times 10^3$</td>
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