Status of SuperCDMS
Dan Bauer
All Experimenters Meeting
February 4, 2013

What is SuperCDMS Soudan?
Physics goals for SuperCDMS Soudan
Recent history
SuperCDMS Soudan operations
R&D towards SuperCDMS SNOLAB
SuperCDMS Soudan Experiment Design

Detectors
- Pure germanium crystals with interleaved charge and phonon sensors on both sides to provide excellent background rejection

Cryogenics
- Cool to near absolute zero in order to see single particle interactions

Shielding and Veto
- Reduce flux of radioactive decay particles near the detectors
- Actively tag any interactions associated with cosmic rays

Electronics and Data Acquisition
- Custom cold and warm electronics with commercial readout electronics and trigger
- DAQ software with custom fast event builder and Java-based run control and monitoring

Uses the existing CDMS II Infrastructure but with new detectors
Goals for SuperCDMS Soudan

We now have a new detector technology (iZIP) that will provide control of backgrounds for the foreseeable future.

The SuperCDMS Soudan experiment is already operating with 9 kg of Ge detectors using this new technology and has initial results which promise background-free WIMP sensitivity for three years of operation.

The experiment is competitive with, and complementary to, other G1 experiments and will also validate the designs for a second generation SuperCDMS SNOLAB experiment.
SuperCDMS Soudan Physics Reach

Best sensitivity for low (<10 GeV) and high (> 1 TeV) mass WIMPS
Requirements to meet science goals

Stable data taking for at least 3 years is the requirement for achieving high-mass (>100 GeV) WIMP sensitivity and studying annual modulation. Would need to run until March 2015.

Much shorter exposures (<200 kg-days) are needed to achieve world leading sensitivity to low-mass (<10 GeV) WIMPS. Will have sufficient exposure by fall 2013.

Already have enough data to demonstrate that iZIP detectors provide excellent surface background rejection.
Recent History of SuperCDMS Soudan

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soudan shaft fire</td>
<td>Mar 17, 2011</td>
</tr>
<tr>
<td>Install iZIP detectors</td>
<td>Oct 25, 2011</td>
</tr>
<tr>
<td>Cool to 50 mK</td>
<td>Nov 29, 2011</td>
</tr>
<tr>
<td>Start of operations</td>
<td>Mar 1, 2012</td>
</tr>
<tr>
<td>Stable data taking</td>
<td>Apr 9, 2012</td>
</tr>
<tr>
<td>Data set with very low energy threshold</td>
<td>Aug/Sep 2012</td>
</tr>
<tr>
<td>One year continuously at 50 mK!</td>
<td>Nov 29, 2012</td>
</tr>
<tr>
<td>Reliquefiers operational</td>
<td>Jan 21, 2013</td>
</tr>
</tbody>
</table>
Aftermath of the shaft fire
All better three months later

New larger underground diesel generator backs up the entire CDMS experiment
What’s an iZIP?
(no, it’s not made by Apple)

Measure both phonons and ionization for each particle interaction; ratio used to identify nuclear recoils

Interleaved phonon and charge sensors on both sides of the Ge crystal

Charge asymmetry between surfaces used to reject surface events (x100 better than in CDMS II!)

Phonon asymmetry and timing provides additional discrimination against electron recoils

surface and bulk events experience different electric fields
Ionization surface event discrimination

- ~80,000 surface events analyzed
- 0 events in signal region after ionization symmetry & yield selection
- 60% efficiency (~50% better than CDMSII)
- *phonon discrimination not exploited in this analysis*

> 10X what’s needed for 9 kg SuperCDMS!

Analyzed region [8, 100] keV$_{nr}$
iZIP Detector Installation
15 Ge detectors, each 0.6 kg, arranged in 5 towers
Reliquefier retrofit

• CDMS uses a dilution refrigerator for cooling
  – Requires daily transfers of LHe and LN
  – Very expensive (~$250K/year) and time consuming
    • 1.5 hours/day with no data, or about 16% of livetime
• Retrofitted a relicquefier system at Soudan
  – Based on 3 Cryomech two-stage LHe relicquefiers and 1 single stage LN relicquefier
  – Very limited space to fit this in; requires low-loss transfer line to return cryogens to dilution fridge
  – Rich Schmitt designed this and commissioned with Mark Ruschman and Soudan technical staff
  – It is now working and saves ~$600/day, and livetime!
Reliquefiers
SuperCDMS Soudan Status

- Mostly stable running
  - 10% of livetime used for in-situ gamma calibration with 133 Ba
  - Neutron calibration every few months with 252Cf source
  - Occasional interruptions for maintenance, low threshold studies, ....

![Graph](chart.png)
SuperCDMS Soudan Operations Issues

• Soudan infrastructure Issues
  – Relying on aging power feed in shaft
    • Working on better measurements of power usage
  – Air handlers causing vibrations
    • Replace motors with two-speed versions
  – Networking is outdated
    • Keep patching it up but needs new equipment
  – Cryogenics and electronics are 15 years old
    • Upgrading parts that fail and vigilant maintenance
SuperCDMS Soudan Operations Issues

• Detector Issues
  – Failed channels
    • Several detectors have bad channels (cold shorts)
    • Source is believed to stem from quality control issues
    • Redundancy of charge/phonon channels means we can work around these issues in analysis
  – Low frequency noise
    • Combination of vibration sensitivity and 60 Hz harmonics
    • Have achieved 2 keV thresholds on enough detectors to do low threshold WIMP search
    • Super-low (<150 eV) threshold on one detector biased in a special manner (CDMSlite)
Low-mass WIMP search with SuperCDMS Soudan

- Data set from one detector in CDMSlite mode
  - Analysis ongoing; results by spring
The next stage: SuperCDMS SNOLAB?

• A next-generation (G2) experiment designed for < 0.5 event background WIMP-nucleon cross section sensitivity x10 better than Soudan

• Essential parameters:
  – 200 kg Ge target mass (150 kg fiducial)
  – Cryogenics system designed for up to 400 kg of detectors at <40 mK
  – Active and passive shielding to achieve < 1 event background in 4 years of operation
  – Location at 6000 mwe SNOLAB ladder lab
SuperCDMS SNOLAB R&D

- Currently doing R&D towards conceptual design
  - Have developed larger (1.2 kg) iZIPs
  - Streamlining detector fab and testing
  - Developing more robust towers and reduced heat load electronics (FETs -> HEMTs)
  - Modern DAQ and single-card warm electronics in place of 9U/6U chain
  - New cryogenics design to reach lower temps
  - Cleaner passive shielding and active neutron veto to reduce backgrounds
  - Automated calibration system
100 mm iZIP performance

From Paul Brink, TIPP 2011
General Layout

COUPP 60kg

Detector Electronics

Vacuum Feed Through

Snobox & Shielding

Fridge

Test Facility

Mechanical Equipment
Snobox w/removable MC

- MC
  - 47 inch ID
  - 21 inch high

- OVC
  - 69 inch OD
  - 49 inch high

2/4/13 Dan Bauer, All Experimenter's Meeting
Redesigned tower structure

4K-to-300K cable (not shown)

HEMT BOARD

SQUID BOARD
(actually probably internal)

SHUNT BOARD

Q lines
(vacuum coax or flex)

phonon flex

SCAB

detector-end stiffener

PT2 (~4K)
ST (0.6-1 K)
CP (100-200 mK)
MC (<50 mK)

drawings courtesy of Marco Oriunno/SLAC
SuperCDMS SNOLAB Physics Reach

Sensitivity comparable to other proposed G2 experiments
# SuperCDMS Experiment Schedule

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CDMS II</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected Sensitivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SuperCDMS Soudan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detector R&amp;D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected Sensitivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SuperCDMS SNOLAB</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&amp;D</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Critical Design Milestones</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CD-0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CD-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CD-2/3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CD-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SNOLAB facility</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ge Towers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 years</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected Sensitivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **4kg, 4E-44 cm^2**
- **10 kg, 5E-45 cm^2**
- **200 kg, 8E-47 cm^2**
Summary

• SuperCDMS Soudan is operating well
  – iZIPs demonstrate excellent control of backgrounds
  – Low (high) mass WIMP results by 2013 (2015)
• SuperCDMS SNOLAB in full R&D
  – Expect MIE project to start in 2014
  – Construction finished in 2016/2017
  – We hope this might be the discovery generation of dark matter direct detection experiments!