Background rejection with the SuperCDMS iZIP detector

Silvia Scorza
Southern Methodist University
SuperCDMS Collaboration
California Institute of Technology
Z. Ahmed, B. Dougherty, J. Filippini, S.R. Golwala,
D. Moore, R. Nelson, R.W. Ogburn

Fermi National Accelerator Laboratory
D. A. Bauer, F. De Jongh, J. Hall, S. Hansen, D. Holmgren,
L. Hsu, R.L. Schmitt, R. B. Thakur, J. Yoo

Massachusetts Institute of Technology
A. Anderson, E. Figueroa-Feliciano, S. Hertel,
S.W. Leman, K.A. McCarthy, P. Wikus

NIST
K. Irwin

Queen's University
C.H. Crewdson, P. Di Stefano, J. Fox, O. Kamaev,
S. Liu, C. Martinez, P. Nadeau, K. Page, W. Rau,
Y. Ricci, M.A. Verdier

Santa Clara University
B. A. Young

Southern Methodist University
J. Cooley, B. Karabuga, H. Qiu, S. Scorza

SLAC/KIPAC
M. Asai, A. Borgia, D. Brandt, P.L. Brink, W. Craddock,
E. do Couto e Silva, G.G. Godfrey, J. Hasi, M. Kelsey, C. J. Kenney,
P. C. Kim, R. Partridge, R. Resch, D. Wright

Stanford University
B. Cabrera, M. Cherry, R. Moffatt, L. Novak, M. Pyle, M. Razeti,
B. Shank, A. Tomada, S. Yellin, J. Yen

Syracuse University
M. Kos, M. Kiveni, R. W. Schnee

Texas A&M
R. Harris, A. Jastram, K. Koch, R. Mahapatra, M. Platt,
K. Prasad, J. Sander

University of California, Berkeley
M. Daal, T. Doughty, N. Mirabolfathi, A. Phipps, B. Sadoulet,
D. Seitz, B. Serfass, D. Speller, K.M. Sundqvist

University of California, Santa Barbara
R. Bunker, D.O. Caldwell, H. Nelson

University of Colorado Denver
B.A. Hines, M.E. Huber

University of Florida
D. Balakishiyeva, T. Saab, B. Welliver

University of Minnesota
J. Beaty, H. Chagani, P. Cushman, S. Fallows, M. Fritts,
T. Hoffer, V. Mandic, X. Qiu, R. Radpour, A. Reisetter,
A. Villano, J. Zhang
Direct Detection of WIMPs
(Weakly Interacting Massive Particles)

- Recoil Energy ~ 10s of keV
- Interaction Rate < 1 ev/kg/y
- Background Discrimination
  - α, β, γ
  - Neutrons
  - μ - induced events

- Large Detector Mass
- Low Energy Threshold
- Excellent Resolutions
- Low radioactivity
- Powerful Rejection
- Background knowledge
iZIP detector design - I
(interleaved Z-measuring Ionization and Phonon)

New Layout Phonon Sensors

Three inner phonon channels and one outer phonon “ring” channel to provide better radius determination in the phonon signal.

Bottom channels are rotated 60 degrees from top channels.
iZIP detector design - II

Electrode Scheme

- NEW interleaved layout of ionization and phonon sensors

- We now have phonon sensors and ionization sensors on BOTH the top and bottom of the detector

- Major improvements in discrimination from this new technology

SuperCDMS Soudan iZIP:
76 mm x 25 mm
0.6 kg

Silvia Scorza
Primary Background (γ) Rejection

Electron Recoils (133Ba)

β $^{109}$Cd Internal source

Nuclear Recoils (252Cf source (external) + 7evt/hr background)

- Radioactive source data defines the signal (NR) and background (ER)
- The simultaneous measurement of phonon and charge signals allows an event by event identification by $\text{Yield} = \text{Ionization/Phonon}$

ER/NR well separated

- $E > 6$ keV
- $\sigma_q \sim 300$ eV (measured)
- $\sigma_p \sim 192$ eV (measured)
- $\rightarrow$ underground $\sigma_p \sim 72$ eV
Charge-based Surface event rejection

Complex E-fields produced by interleaving +2V/0V electrodes encode Position Information

$1:10^4$ surface discrimination from ionization signal!

Outer charge electrodes separately measured for radial information
Yield-based Surface Event Rejection
(Test Facility Data)
Electron Recoil Position Resolution Based on Energy Deposited in Different Phonon Channels

Surface Events = Low Yield

Bulk Events = High Yield

No Source on Bottom Surface
### Bulk Electron Recoil Rejection

<table>
<thead>
<tr>
<th>Discrimination Type</th>
<th>iZIP power rejection</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yield</strong></td>
<td>Expected to be the same as CDMS II ( &gt; 1:10⁶)</td>
</tr>
<tr>
<td><strong>Phonon Pulse Shape ER/NR</strong></td>
<td>&gt;1: 10³ but this will improve significantly</td>
</tr>
</tbody>
</table>

Silvia Scorza  
9/6/11
## Surface Electron Recoil Rejection

<table>
<thead>
<tr>
<th>Discrimination Type</th>
<th>iZIP Power rejection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Charge-based Surface Cut</td>
<td>$&gt;1 \times 10^4$</td>
</tr>
<tr>
<td>Phonon-based Surface Cut</td>
<td>$&gt;1 \times 10^3$</td>
</tr>
<tr>
<td>Low Yield Surface Events</td>
<td>$&gt;1 \times 10^3$</td>
</tr>
<tr>
<td>Total Surface Event Rejection</td>
<td>$&gt;1 \times 10^6$</td>
</tr>
</tbody>
</table>

For 1ton scale experiment $\rightarrow 2 \times 10^5$
Deeper Underground
Cosmic Background

Soudan:
2090 mwe
~75 /yr/ton

SNOLAB:
6060 mwe
< 1 /yr/ton
The new iZIP detector technology is vastly superior to CDMS II devices.

Current 100 kg SuperCDMS SNOLAB and future 1.5 ton GEODM plans.
Backup Slides
NR/SE Phonon Pulse Shape Discrimination

- NR/SE discrimination seen in both pulse shape differences and z partition
Phonon Pulse Shape Discrimination

- NR/SE discrimination
- \(1:10^4\) Rejection down to \(15\text{keV}_{\text{ne}}\) with \(\sim60\%\) total efficiency (15\% additional loss after Q radial cut)

- NR/ER discrimination
- Current Algorithms have sizeable energy degradation
- Nonlinear pulse shape fitting currently being pursued.