FIRST DARK MATTER RESULTS
FROM THE CDMS 5-TOWER RUN AND THE PATH TOWARDS
$\sigma = 10^{-45}$ CM$^2$ WIMP SENSITIVITY

Tarek Saab
for the CDMS Collaboration

SUSY 08
<table>
<thead>
<tr>
<th>Institution</th>
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<tr>
<td>Caltech</td>
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<td>Case Western Reserve</td>
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<td>UC Santa Barbara</td>
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WIMP HUNTING

- Elastic scattering of a WIMP from a nucleus deposits a small, but detectable amount of energy ~ few x 10 keV
- Featureless exponential energy spectrum
  - no obvious peak, knee, break, ... that determines $M\chi$
- Expected rate $<< 0.01$/kg-day
- Radioactive background million times higher
- Background Reduction/Rejection is key

Low→no Background a Must for WIMP Discovery
DETECTOR PHYSICS TO THE RESCUE

image by Mike Attisha - Brown University
TWO TYPES OF RECOIL

Signal

Nuclear Recoils

\[ E_r \approx 10 \text{ keV} \]
\[ v/c \approx 10^{-3} \]

Dense Energy Deposition

Background

Electron Recoils

\[ v/c \approx 0.3 \]

Sparse Energy Deposition

Density/Sparsity: Basis of Discrimination
DISCRIMINATION STRATEGIES

Phonons
10 meV/ph
100% energy

Ionization
~ 10 eV/e
20% energy

Scintillation
~ 1 keV/γ
few % energy

CUORE
CRESST I
TeO₂, Al₂O₃, LiF

CDMS
EDELWEISS
Ge, Si

DRIFT, DM-TPC,
IGEX, COUPP
COSME, ANAIS
Ge, CS₂, C₃F₈

CRESST
ROSEBUD
CaWO₄, BGO
ZnWO₄, Al₂O₃ ...

NAIAD
DAMA
ZEPLIN I
DEAP
CLEAN
XMASS

ZEPLIN II, III
XENON, LUX
WArP, ArDM
SIGN
Xe, Ar, Ne
CDMS: THE BIG PICTURE

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

- **Shielding**
  - Passive: Mine Depth, Pb, Poly
  - Active: muon veto shield

- **Energy Measurement**
  - Phonon (True recoil energy)
  - Charge (Reduced for Nuclear)

- **Position measurement (x,y,z)**
  - From phonon pulse timing
CDMS APPARATUS

- Surround detectors with active muon veto
- Use passive shielding to reduce $\gamma/n$
  - Overburden reduces $\mu$-induced neutrons
  - Polyethylene for low-energy neutron
  - Lead and Copper for gammas
- 5 Towers now installed and taking data
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Z-SENSITIVE IONIZATION PHONON DETECTORS

Phonon side: 4 quadrants of athermal phonon sensors
Energy & Position (Timing)

Charge side: 2 concentric electrodes (Inner & Outer)
Energy (& Veto)

Transition Edge Sensors (TES)
Operated at ~40 mK for good phonon signal-to-noise

3” (7.6 cm)
Ge: 250 g
Si: 100 g
EXCELLENT ENERGY, POSITION RESOLUTION

Am$^{241}$: 
$\gamma$ 14, 18, 20, 26, 60 kev

Cd$^{109}$ + Al foil: 
$\gamma$ 22 kev
EXCELLENT ENERGY, POSITION RESOLUTION

Detector Calibration

Am$^{241}$:
$\gamma$ 14, 18, 20, 26, 60 keV

Cd$^{109}$ + Al foil:
$\gamma$ 22 keV
Radioactive source data defines the signal (NR) and background (ER)

Yield = Ionization/Phonon
Most effective Particle ID

$>10^4$ Rejection of $\gamma$

Drooping events from $\beta$ Ionization collection incomplete on surface. Yield can be sufficiently low to pollute the signal region
EXCELLENT PRIMARY ($\gamma$) BACKGROUND REJECTION

- Radioactive source data defines the signal (NR) and background (ER)
- Yield = Ionization/Phonon
  Most effective Particle ID
- $>10^4$ Rejection of $\gamma$
- Drooping events from $\beta$ Ionization collection incomplete on surface. Yield can be sufficiently low to pollute the signal region

Need extra handle to reject $\beta$s in signal region
SURFACE $\beta$ REJECTION

Faster down conversion of athermal phonons at surface provides faster phonon signal for $\beta$s.

Cut chosen at a level to contribute $\sim 0.5$ event total leakage to WIMP candidate.
NET CDMS REJECTION

YIELD + TIMING PROVIDE EXCELLENT (>MILLION:1) REJECTION OF E-M BACKGROUNDS

~15σ Away from Signal Band
CDMS 5-TOWER DATA AT SOUDAN
SOUDAN IN THE MORNING
FIVE TOWER RUNS (2006-8)

- 30 ZIPs (5 Towers) installed in Soudan icebox:
  - 4.75 kg Ge, 1.1 kg Si

- Combination of Ge and Si Detectors
  - Neutron background measurement
  - WIMP Mass Measurement
  - Ge more sensitive to higher mass WIMPs.
  - Si to lower mass WIMPs
Published Results

Four successful 5-T data runs so far:

- Run 123 (10/06-3/07): 430 kg-d Ge (raw)
- Run 124 (4/07-7/07): 224 kg-d Ge (raw)
- Run 125 (7/07-1/08): 465 kg-d Ge (raw)
- Run 126 (1/08-05/08): 273 kg-d Ge (raw)
- Run 127 just started...

>10x the 2-Tower exposure so far!

Results shown today are for 123+124 data

Will more than double the exposure with data in the can...
All cuts set blind, without looking at the signal. i.e. we do not look at events which are:

- Inside the good fiducial volume
- In the Nuclear Recoil Band
- Not a Multiple Scatter
- Not a surface event: phonon timing cut
EXPECTED $\beta$ LEAKAGE

- $\sim 300:1$ Rejection is chosen on calibration Data
  - Provides Near Optimum Sensitivity
- WIMP side bands show 200:1 Rejection
- Difference dominated by differences in phonon/charge side rejection and $\beta$ energy spectrum in calibration
- Expected Leakage $\sim 0.6 \pm 0.5$ events
- Uncertainty on Leakage Preliminary and Conservative
EXPECTED NEUTRON BACKGROUND

Cosmogenic

- 8 Vetoed nuclear recoil multiples observed
- No Vetoed Singles Observed
- Use MC Predicted singles/multiples ratio and vetoed to unvetoed ratio
- Expect < 0.1 unvetoed neutron background

Fission/alpha-N

- Fission neutron < 0.1 from Pb counting
- Alpha-N < 0.03 from Uranium in Poly

Expect Total Neutron background < 0.2 events
EFFICIENCIES

TOTAL EFFICIENCY WITH RESPECT TO FULL DETECTOR MASS
All cuts set and frozen!

Expected Events:
77 ± 15 single scatters in NR
THE WIMP SEARCH DATA: GE
MIDNIGHT PST, 4TH OF FEB, 2008

97 singles in signal region before applying surface cut
OPEN THE BOX:
SURFACE EVENT CUT
MIDNIGHT PST, 4TH OF FEB, 2008

Expected Background: 0.6 ± 0.5 surface events and < 0.2 neutrons

0 Observed Events
SPIN-INDEPENDENT EXCLUSION LIMIT

$10^{-7}$ pb
CDMS 5-TOWER RESULTS

- Zero Events Observed! (654 kg-days of raw data)

- Best Spin-Independent limit above $40\text{GeV/c}^2$ WIMP Mass

- ~Twice the exposure of current analysis waiting in analysis pipeline. Double again by end 2008

- Will surpass target sensitivity of $2 \times 10^{-44}\text{cm}^2$

- Preprint available @ [http://cdms.berkeley.edu](http://cdms.berkeley.edu) and on arXiv article id 0802.3530
THE CDMS COLLABORATION

CDMS Institutions

National Laboratory
- Fermilab
- NIST

US University
- CalTech
- Case Western
- Colorado (Denver)
- Florida
- Minnesota
- MIT
- Stanford
- Santa Clara
- Syracuse
- UC Berkeley
- UC Santa Barbara

International
- QUEENS
- Zurich
LOOKING AHEAD TOWARDS

$\sigma = 10^{-45} \text{ CM}^2$
BASELINE DETECTOR FOR SUPERCDMS

CDMS-II ZIPs:
3” dia x 1 cm => 0.25 kg of Ge

Existing ZIPs

SuperCDMS ZIPs:
3” dia x 1” => 0.64 kg of Ge

ZIPs for SuperCDMS
<table>
<thead>
<tr>
<th>project</th>
<th>ratio</th>
<th>kg/det</th>
<th># det</th>
<th>tot kg</th>
<th>fiducial</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDMS II</td>
<td>x 1</td>
<td>0.25</td>
<td>16</td>
<td>4.0</td>
<td>50%</td>
</tr>
<tr>
<td>SCDMS 25 kg</td>
<td>x 2.5</td>
<td>0.64</td>
<td>42</td>
<td>27</td>
<td>80%</td>
</tr>
<tr>
<td>R&amp;D SCDMS 1000 kg</td>
<td>x 10</td>
<td>2.5</td>
<td>228</td>
<td>570</td>
<td>80%</td>
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<tr>
<td></td>
<td>x 20</td>
<td>5.0</td>
<td>228</td>
<td>1140</td>
<td>90%</td>
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DISLOCATION FREE GE NEEDED FOR 6 IN DETECTORS

- 1 cm thick by 30 mm diameter dislocation free crystal from E.E. Haller illuminated with $^{241}$Am source operated at $\sim 40$ mK
- Excellent resolution and charge collection efficiency
ZERO BACKGROUND NECESSARY FOR DISCOVERY
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