Is Dark Matter a WIMP?

Particles with mass and annihilation cross section at the weak scale naturally yield correct relic density of CDM.

\[ \frac{N}{N_{\text{EQ}}} \]

Increasing \( \langle \sigma_\chi v \rangle \)

Look for nuclear recoil from WIMP scatter

\[ \chi \rightarrow q \bar{q} \]

Kolb & Turner, “The Early Universe”

M. Attisha

TeVPA 2009
CDMS Experiment

**CDMSII at Soudan:**
*Five Towers (30 ZIPS) operating since June '06*

Most sensitive to spin-independent scattering: $\sigma \propto A^2$
- 4.75 kg Ge\((A=73)\)
- 1.1 kg Si\((A=28)\)
Detection Strategy
discrimination and shielding maintain a <1 event background experiment

19 Ge zips (250 g each)
11 Si zips (100 g each)
1 cm thick crystals

Signature of a Nuclear Recoil:
reduced ionization signal relative to phonon signal

Major Backgrounds:
- Gammas/Betas (electron recoils)
- Neutrons (nuclear recoils)
- Surface Events
Gamma Rejection

BETTER THAN $1:10^4$ rejection of gammas based on ionization yield alone.

$$\text{ionization yield} = \frac{E_{\text{charge}}}{E_{\text{phonon}}}$$

ultra-clean materials and careful handling
ancient lead shielding
Neutron Backgrounds

1. Go Deep:
   - Soudan Mine: 2090 mwe
   - (muon rate reduced by $>10^4$)

2. Use Active Shielding:
   - Muon veto ~98% efficient

3. Use Passive Shielding:
   - 2 layers polyethylene - shields from cosmogenic and radiogenic neutrons

4. Use Event Topology
   - Neutrons may double scatter or be accompanied by EM shower

5. Run Extensive Simulations:
   - GEANT4
   - FLUKA+MCNPX
   - MUSIC
Surface Events

10 µm “dead layer” results in reduced ionization collection

Phonon pulse shape (timing) distinguishes surface events

Both yield and “timing” rejects these events

These events are primarily electrons, gammas and x-rays originating from surfaces of the detectors and surrounding materials
Analysis Technique

All cuts established before unblinding!

Candidate Criteria:

- Data Quality + Fiducial Volume Cut
- Muon-veto anticoincident
- Single Scatter (only 1 zip w/ signal)
- Ionization yield within 2σ nuclear recoil band
- Phonon “timing” cut - reject surface events

Cut Efficiencies

CDMSII 2008 result
Our Current Limit

CDMS II 2008: 1st Five Tower Result

398 raw kg-d
121 kg-d (for 60 GeV/c^2 WIMP)
10 - 100 keV analysis range

Expected Surface Events:

\[ \frac{0.6^{+0.5}_{-0.3}}{\text{(stat.)}} + \frac{0.3}{\text{(syst.)}} \]

Expected Neutrons:

\( (\alpha, n): < 0.03 \)
\( \text{(fission)}: < 0.1 \)
\( \text{Cosmogenic:} < 0.1 \) (MC 0.03-0.05)

ZERO Events Observed in Signal Region!

4.6x10^{-44} cm^2 @90% CL
coming soon...
CDMS II 2009
Projected Sensitivity

~2.5X more total exposure

Ge Exposures:
- CDMS II T1+T2 ~120 kg-d
- CDMS II 2008 ~400 kg-d
- CDMS II 2009 ~750 kg-d
  (after nominal quality cuts)

Results expected August '09
Calibration Data Preview

Initial studies indicate the data is very well behaved... even better than previously published data!

CDMS II 2008

CDMS II 2009

tighter bands!
Promising Surface Event Rejection

Aiming for ~X2 better rejection of surface events to keep up with exposure potential and stay a <1 background experiment.

Surface Event Discrimination

- 2008 $^{133}$Ba surface
- 2008 $^{252}$Cf neutron
- 2009 $^{133}$Ba surface
- 2009 $^{252}$Cf neutron

CDMS 2009 Calibration Data

- $^{133}$Ba e-recoil
- $^{133}$Ba surface
- $^{252}$Cf n-recoil

Note: Ba/Cf exposures are different between datasets and hasn’t been corrected for here.

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SuperCDMS

15 kg of Ge at Soudan, arranged as 5 SuperTowers

**SuperTower**

- 2.5X thicker (1-inch) Ge crystals
- "endcap" Ge veto detectors in each tower
- modified Al fin layout, improves phonon collection efficiency
- cleaner, simplified, and streamlined production
- "mercedes" phonon sensor layout, outer phonon "guard"

**CDMSII Tower**
First SuperTower Installation

CDMS II data-taking ended March 2009

First SuperTower installation is now complete!

Testing currently underway
SuperCDMS Future

CDMS II
4 kg Ge
~ 2 yrs operation

SuperCDMS @ Soudan
15 kg Ge
~ 2 yrs operation

SuperCDMS @ Snolab
100 kg Ge
~ 3 yrs operation

DUSEL/GEODM
1.5T

~LHC projected limit
CDMS has a world-leading limit on the spin-independent WIMP annihilation cross section:

$$4.6 \times 10^{-44} \text{cm}^2 \text{ at } 90\% \text{ CL (for 60 GeV/c}^2 \text{ WIMP mass)}$$

~750 kg-days of five-tower data is currently being analyzed. Results expected by end of summer

First SuperCDMS tower is installed and is nearly ready for data-taking

Steady progress to zeptobarn cross sections and smaller!
Thank You


(CDMS Collaboration)

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backup slides
Other CDMS Results for 2009


“Search for Axions with the CDMS Experiment” - arXiv:0902.4693 [hep-ex]
Energy Resolution

Ionization Energy [keV]

Phonon Energy [keV]

10.4 keV

μ: 10.316±0.014
σ: 0.287±0.013
χ²/dof: 0.96726

10.4 keV

μ: 10.432±0.018
σ: 0.324±0.017
χ²/dof: 1.3326
Signal Region CDMS II 2008

Without Timing Cut

With Timing Cut

PRL 102, 011301 (2009)
What are Surface Events?

Reduced charge yield due to charge carrier back-diffusion in surface events.

~10 µm “dead layer”

carrier back diffusion

Correlations to $^{210}$Pb contamination observed, most likely from beta decays on surface of detectors.
What is Dark Matter?

Bullet Cluster

Rotational Curves

Strong Lensing

WMAP 5-year

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