CDMS II Status
+ CDMS I / III / CryoArray
Direct Detection of SUSY
Cold Dark Matter

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see information at
http://cdms.brown.edu/
http://gaitskell.brown.edu/
STATUS: CDMS II - Cold & Running “First Dark” achieved

- 12 detectors - cold & checked out @ SOUDAN
  - 6 Ge+6 Si
  - Cryo / DAQ / Electronics / Analysis operating
- Tower 1 - currently calib
  - Prev. 1/2 year @ Stanford - b/g well understood
    - 120 live days (50 kg-days Ge)
    - Tower not changed -> Soudan
    - Will be some improvement at depth
      - Need stats to study bg (Prelim looks good)
- Tower 2
  - All New detectors
    - Some improvements made in b/g handling
    - Not yet measured b/g for this tower
- Initial Goal @ SOUDAN
  - Similar run to Stanford: 50 Ge kg-days
  - Looking for Zero background (ZBG) >10 keV
    - Expect very clean analysis
Direct Detection: History & Future
90% CL Limit on Cross section for 60 GeV WIMP (scalar coupling)

m = ?? GeV - if significantly better limit obtained at different mass

Limit Scalar Cross-section cm$^2$ [60 GeV WIMP]

Year


-~1 event kg$^{-1}$ day$^{-1}$

-~1 event kg$^{-1}$ yr$^{-1}$

-~1 event 100 kg$^{-1}$ yr$^{-1}$

CDMS Dark Matter - Aachen EPS - 17 July 2003

Not meant to be a complete list - see http://dmtools.brown.edu

[Image of a graph showing data points and technologies related to direct detection of dark matter.]

Rick Gaitskell
Latest & Greatest Limits on Scalar C-S for WIMPs

- Latest Edelweiss result (updated May 2003)
- ZEPLIN I result (announced Sept 2002)
- CDMS I result (updated June 2003)

http://dmtools.brown.edu
CDMS Background Discrimination
Explanation of basics (...On-going improvements in rejection)

• Ionization Yield (ionization energy per unit recoil energy) depends strongly on type of recoil
• Most background sources (photons, electrons, alphas) produce electron recoils
• Particles (electrons) that interact in surface “dead layer” of detector result in reduced ionization yield
• WIMPs (and neutrons) produce nuclear recoils

• Detectors provide near-perfect event-by-event discrimination against otherwise dominant bulk electron-recoil backgrounds
  very good (\(>98\%\) against surface electron-recoil backgrounds

NOT A SIMULATION!

1334 Photons (external source)
233 Electrons (tagged contamination)
616 Neutrons (external source)

>\(1/2\) year’s background

>>\(1/2\) year’s signal!!
CDMS II - Calibrations at Stanford

- ZIP Detector (250g Ge, or 100 g Si)
  - 20,400 gamma events (5-100 keV) ~ 1 week continuous calibration with $^{60}$Co source
  - = ~one count in 12 years of gamma background
    (assuming project background level of 0.25 counts/keV/kg/day at CDMSII Soudan. Calibration still Poisson stats/neutron background limited)
  - Sensitivity better than 1 WIMP per year per detector

![Graph showing gamma and neutron events](image)

- Trigger Threshold
  - 1334 gamma events, 616 neutron events

- Calibration Results
  - Yield (Q/Ph rg) vs. Recoil for $^{60}$Co Calibration
  - Gamma leakage vs Recoil: Z3 $^{60}$Co Calibration

- Project Background Level
  - 0.25 counts/keV/kg/day at CDMSII Soudan

- Sensitivity
  - Better than 1 WIMP per year per detector
ZIP Detector Phonon Sensor Close-up

- Photolithographic patterning like CMOS but 1 big chip
- 37 cells per quadrant
- 7x4 array of W transition-edge sensors per cell, with Al “collector” fins covering only fraction of surface

Si or Ge surface
2 µm wide W transition edge sensor

W - Al overlap

380 µm Al fins
60 µm wide
Demonstration of xyZIP Position Sensitivity

Delay Plot

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

Cd$^{109}$:
- 22 kev
- i.c. electr 63, 84 KeV

Cd$^{109}$ + Al foil:
- 22 kev
Working at Soudan
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Expected Backgrounds for CDMS II at Soudan

On track for 0.0003 events/kg/keV/day at 15 keV?

- Depth of 2000 mwe reduces neutron background from ~1 / kg / day to ~1 / kg / year
  - Also better neutron shielding

500 Hz muons in 4 m² shield
Expected Backgrounds for CDMS II at Soudan

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- Depth of 2000 mwe reduces neutron background from ~1 / kg / day to ~1 / kg / year
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- Photon background is already 0.7 events/(kg keV day) x 10^{-3} expected leakage, despite the shallow site (good enough with background subtraction)
Expected Backgrounds for CDMS II at Soudan

On track for 0.0003 events/kg/keV/day at 15 keV?

- Depth of 2000 mwe reduces neutron background from ~1 / kg / day to ~1 / kg / year
  - Also better neutron shielding
- Photon background is already 0.7 events / (kg keV day) x <10^{-3} expected leakage, despite the shallow test site
- Electron background is 0.1 events / (kg keV day) x ~0.04 expected leakage, despite the shallow site (need ~2x improvement from depth, or better surface screening/cleaning)
Latest & Greatest Limits on Scalar C-S for WIMPs

- CDMS II
  Initial goal 20x improvement over CDMS I
  ZeroBG 50 kg-days Ge

Initial Goal 2003
CDMS II 20x ZBG 50 kg-days

~1 event kg⁻¹ day⁻¹

http://dmtools.brown.edu

http://dmtools.berkeley.edu
Gaitskell&Mandic

CDMS Dark Matter - Aachen EPS - 17 July 2003
Rick Gaitskell
• **CDMS I (1995-2001)**

  - SI upper limits now eclipsed by EDELWEISS, Zeplin I except at low WIMP mass.
  - CDMS data are *incompatible* with DAMA signal for standard WIMPs & halo.
  - Sensitivity limited by neutrons from muons interacting in surrounding rock.

• **CDMS II (2000-2005)**

  - 12 detectors (1.5 kg Ge, 0.6 kg Si) cold @ Soudan
    - Stanford discrimination tests of 6 dets exceeded performance expectations.
    - Stanford b/g testing showed expected reduction of neutron background by factor of ~2.3 due to installation of internal moderator (agreement with MC predictions.)
  - “First Dark” achieved Apr 2003.
    - Initial Goal ~50 kg-days Ge (similar to previous run @ Stanford, but no neutrons!)

• **CryoArray (2006 - 2017 or so…)**

  - Sensitivity to study WIMP physics down to $s \sim 10^{-46} \text{ cm}^2$ (many events if higher $s$).
  - Modest improvements over current results (shared):
    - Discrimination: \(\Box\) already good enough, \(\Box\) within factor few.
    - **Backgrounds:** x20 reductions vs CDMS II, 2-3x vs best current IGEX, H-M

Backup Slides Q&A
(Not Used in Talk)
CryoArray: A 3rd Generation Experiment

- Based on extrapolation of CDMS technology/strategy

- Basic parameters/goals
  - 1000 kg x 2 (live) years
  - ~100 WIMPs at 10^{-45}cm^2
    - ~10 WIMPs at 10^{-46}cm^2
  - ~10’s background events

- Excellent discrimination so need little background reduction
  - Internal (g, b) and external (n)

- Main challenge:
  - Increase mass (~100x) and manufacturability of detectors/cryo package
  - Maintain Performance

- Possible sites
  - Soudan (CDMS II) among shallower sites (n background problematic)
  - National Underground Facility
    - Depth
    - Shared resources (vetos, assembly, materials screening, fabrication???)
Background Projections - CryoArray (1 ton)

<table>
<thead>
<tr>
<th>Energy Range 15-45 keV</th>
<th>Event Rate (mdru)</th>
<th>Exposure (1000 kg day)</th>
<th>Raw Events (#)</th>
<th>Rejection Efficiency</th>
<th>After Reject (#)</th>
<th>After Subtraction (#) (mdru)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Photons</td>
<td>Site</td>
<td>Depth (mwe)</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>CDMS I</td>
<td>SUF</td>
<td>16</td>
<td>800</td>
<td>0.016</td>
<td>384</td>
<td>99.96%</td>
</tr>
<tr>
<td>CDMS II</td>
<td>SUF</td>
<td>16</td>
<td>800</td>
<td>0.04</td>
<td>960</td>
<td>99.97%</td>
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<tr>
<td>CDMS II</td>
<td>Soudan</td>
<td>2080</td>
<td>260</td>
<td>2.50</td>
<td>19500</td>
<td>99.97%</td>
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<tr>
<td>CryoArray</td>
<td></td>
<td></td>
<td>13</td>
<td>500</td>
<td>195000</td>
<td>99.97%</td>
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<tr>
<td>Electrons</td>
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<td></td>
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<tr>
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<td>SUF</td>
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<td>300</td>
<td>0.016</td>
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<tr>
<td>CDMS II</td>
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<td></td>
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<td>500</td>
<td>15000</td>
<td>99.90%</td>
</tr>
</tbody>
</table>

- **Photon background is very manageable**
  - Current lower limit on discrimination already good enough if raw rate reduced to 13 mdru, ~2-3 times better than best levels reached so far (by IGEX, H-M)
    - achieve via materials selection and simplification of structures (little mounting material)
  - Screening to $10^{-10}$ g/g can reveal contamination source of such a background

- **Electron background more worrisome, but certainly tractable**
  - Need to screen & clean surfaces to $2.5 \times 10^{-2}$ counts/ (keV m$^2$ day), or to 10x better if rejection remains only 95% -- novel but appears to be doable

$dru = 1 \text{ event keV}^{-1} \text{ kg}^{-1} \text{ day}^{-1}$

see Schnee, Gaitskell & Akerib astro-ph/0208326