CDMS-II to SuperCDMS
WIMP search at a zeptobarn

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University of Zürich
5th Patras Workshop on Axions, WIMPs and WISPs
University of Durham, 13 July 2009
CDMS-II 5 Tower setup

5 Towers a 6 detectors (Ge/Si) operated at cryogenic temperatures (~40 mk)

Underground laboratory shields well against cosmic radiation

Active veto for high energetic muons

Passive shielding against environmental radioactivity

= Ge (250g)
= Si (100g)
CDMS detectors

Ionization Signal

-3V

Vetted by guard ring

Vetted by guard ring

\[ h^+ \cdot h^+ \cdot h^+ \]

\[ e^- \cdot e^- \cdot e^- \]

\[ X \]

7.5 cm

Q_{inner} (~85%)

Q_{outer} (2.0-2.7 mm)

Gap (1 mm)

Phonon Signal

380 μm

30 nm

1 μm

W TES

Al

Ge or Si substrate (~40 mK)

Phonons

Quasiparticle Diffusion

\[ R_{TES}[\Omega] \]

\[ T [mK] \]
Primary background rejection

Dominant backgrounds ($\gamma, e^\pm$) produce electron recoils

WIMPS and neutrons produce nuclear recoils

Suppressed ionization signal for nuclear recoils

Define ionization yield:

$$y = \frac{E_{\text{charge}}}{E_{\text{phonon}}}$$
Yield based rejection

Primary electron recoil rejection
10,000 : 1

Low yield surface event population remains.

Signal region: 2σ nuclear recoil band

Ionization suppression in good agreement with Lindhard theory
Backgrounds in CDMS-II

Coadded lowbackground data for Ge detectors before timing cut

Low yield surface events are the dominating background
Surface contaminations of the crystals

Environmental $^{222}$Rn deposits $^{210}$Pb $\beta$ source on the surface of the crystals

Expected signature: Low energy $\beta$ decay  ➜ detect the ~46 keV peak
Second signature of $^{210}$Pb

$^{210}$Bi $\rightarrow$ $^{210}$Po $\rightarrow$ $^{206}$Pb + $\alpha$

Select alphas from NND:
low yield $\alpha$ + recoiling $^{206}$Pb nucleus

Correlation of $^{210}$Pb surface NND and $^{210}$Po $\alpha$/recoiling $^{206}$Pb strongly supports $^{210}$Pb theory

Build full surface event model to determine the $\beta$ rate from $^{210}$Pb contamination
### Break down of numbers

<table>
<thead>
<tr>
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<th>$^{210}\text{Pb}$ decays</th>
<th>10-100 keV surface event singles</th>
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<td>black $= 10^{-3}$ counts/detector/day</td>
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Old towers: Factor 2.5 ± 2.5 improvement

New towers
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Remanent β rate not associated with 210Pb decays

Photons can knock off electrons from materials

Additional source of β events

Rate can be measured from calibration data
Timing of phonon signals

Surface events are faster in timing than bulk nuclear recoils

Timing is a powerful discriminator for surface events
Surface event rejection cut

Defined on calibration data

Applied to low background data

Surface event rejection ~ 200:1

Cut set to allow ~0.5 events total leakage to WIMP candidates
Unblinding the signal region

Use singles and multiples in the signal region to measure the expected leakage

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

No events observed in the 2\(\sigma\) NR band

R123/124: 397 kg-d Ge exposure

Likely \(\alpha\)-induced NR

Consistent with leakage outside the signal region
Recent results

Spin-independent

- $6.6 \times 10^{-44}$ cm$^2$ @ 60 GeV
- $4.6 \times 10^{-44}$ cm$^2$ @ 60 GeV

(combined with previous CDMS data)

Spin-dependent

- $2.7 \times 10^{-38}$ cm$^2$ @ 60 GeV
- $1.8 \times 10^{-38}$ cm$^2$ @ 60 GeV

(combined with previous CDMS data)
Electromagnetic Dark Matter signatures?

What if we miss a dark matter signal due to an electron recoil interaction?

Analysis motivated by the DAMA/LIBRA modulation signature.
Low energy spectrum

DAMA

Energy = 3.15 ± 0.02 keV
Width = 0.611 ± 0.025 keV
Rate = 0.698 ± 0.051 cpd kg⁻¹

Excess in detected rate in the DAMA low energy spectrum

Contribution from $^{40}$K (3.2 keV)
unknown

Assumption: conversion of dark matter particle to electromagnetic energy

No excess rate above background detected

CDMS-II

Energy = 8.98 keV ($^{65}$Zn)
Rate = 0.73 ± 0.1 cpd kg⁻¹

likely $^{55}$Mn

Energy = 6.54 ± 0.1 keV
Rate = 0.44 ± 0.09 cpd kg⁻¹

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Comparison with DAMA/LIBRA

\[ Z^2 \text{ scaling of the CDMS upper limits is an arbitrary toy model} \]

In need of an actual particle model to perform physical interpretation
5 Towers - the second part

→ Second run with the 5 Tower setup since July 2007

→ Factor ~2.5 more exposure

→ Improved data processing

→ New phonon pulse information yielding possible discrimination potential

→ Aim to keep expected backgrounds at the same (better lower) level as for the most recent analysis

Analysis of the data is ongoing while we speak
Surface event discrimination

Timing for the new data looks promising in obtaining higher nuclear recoil detection efficiency.
CDMS-II sensitivity till 2009

Raw Exposures

R118-119  ~120 kgd
R123-124  ~400 kgd
R118-124  ~520 kgd
R125-128  ~750 kgd

Total of ~1300 kgd

Final CDMS-II results expected in August
The dawn of a new age

Improved active Al coverage
⇒ better phonon collection

Final tuning of the first super tower last week
⇒ ready for taking data
Improved timing information

CDMS-II configuration

ST-I configuration

New phonon sensor configuration strongly improves the timing discrimination

Detectors used in the next Stage of CDMS
CDMS-II to SuperCDMS 100kg

August this year
5 ST @ Soudan
~2 year sensitivity
SuperCDMS 100kg
zeptobarn sensitivity
• Excellent knowledge of the backgrounds and discrimination make the CDMS-II experiment to a zero background experiment

• Latest CDMS-II results set an world leading 90%CL exclusion limit on the WIMP nucleon cross-section for masses > 42 GeV

• Started to look not only for “standard” dark matter interactions

• Final CDMS-II data has been taken and is currently under analysis with final results expected in August this year

• Successful development and integration of the first SuperTower used in the next stage of the CDMS experiment

• Continuous improvements of the CDMS collaboration in reaching the zeptobarn sensitivity
The CDMS-II Collaboration

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Case Western Reserve University

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S. Arrenberg, T. Bruch, L. Baudis
BACKUP SLIDES
Understanding the origin of our backgrounds

Gamma spectrum, T4 germanium ZIPs only

- Run123 T4 (84.8 kg d)
- MC Sum
- 238U+232Th MC cans
- 238U+232Th MC T4
- 238U+232Th MC T1,2,3,5
- 60Co MC
- 40K MC
- 238U+232Th MC inner poly
Backgrounds for the new data

Gamma spectrum, T4 germanium ZIPS only

Counts / (kg d keV)

Energy [keV]

238 [keV] 60Co
352 [keV] 60Co
511 [keV] 60Co
609 [keV] 60Co
911 [keV] 60Co
969 [keV] 60Co
1120 [keV] 228Ac + 1592 [keV] DE 208Tl
1238 [keV] 228Ac + 1592 [keV] DE 208Tl
1335 [keV] 60Co
1464 [keV] 40K
1588 [keV] 228Ac + 1592 [keV] DE 208Tl
1765 [keV]
2204 [keV]
2448 [keV]
2615 [keV]

R123 84.8 kgd
R125 95.19 kgd
R126 55.72 kgd
R127 43.94 kgd
R128 18.73 kgd
Expected signature: Low energy beta decay -> detect the ~46 keV peak