From CDMSII to SuperCDMS

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- CDMSII: Current Status
- CDMSII Perspective
- Motivation for larger exposures
- SuperCDMS 25 kg
- Beyond SuperCDMS/Perspective
CDMS is searching for WIMPs

- Looking for the low recoil energies
  - 10 keV recoil
- Very rare interaction
  - $<10^{-2}$ evt/kg/day
- Shielding is not enough
  - $10^7$ to $10^{-5}$ evt/kg/day
  - 25 cm Pb: Only $10^2$ evt/kg/day
- Event-by-event discrimination
  - Ionization and phonon
  - Scintillation and phonon
  - Scintillation and Ionization
  - Pulse shape
- Background free
  - S~1/MT but $1/(MT)^{1/2}$ with bkgnd
- Underground experiment
  - Neutrons from the $\mu$ showers
CDMS detection Principle

- Measure recoil energy via Lattice vibrations (phonons) in Ge or Si:
  - Primary excitation => phonons
  - Perfect calorimetry
  - Low temperature (0.04 K)
- Ionization:
  - Ge, Si: Semiconductor
  - Phonons/charge simultaneously
- Ionizing power (Ionization yield):
  - Nuclear Recoil > Electron Recoil
  - Event-by-event discrimination
- Near surface events:
  - Electron recoil but poor charge collection
  - Near geometrical boundaries
  - Important background: Localization!
- Catch the Phonons before equilibrium:
  - Sensitivity to event position
CDMS detectors

- Ge (250 gr), Si (100 gr)
  - $\Phi = 7.5 \text{ cm, } h = 1 \text{ cm}$
- Phonon sensors on one face
  - Litographically patterned over total surface of the detector
  - Divided into 4 quadrants
  - Each quadrant: 888 Transition Edge Sensors (TES) in parallel
  - SQUID base amplifier
- Charge readout on the other face
  - Divided into an inner electrode and guard ring.
  - Cold FET readout
Surface event discrimination: Timing Parameters

Reject 99.9998% of **Gammas**, 99.8% of **surface events**
CDMS Two tower run result (Ge 1.25 kg) : Run119

March 25, 2004 – August 8, 2004

96.8 (31.0) kg-days

0.4±0.2±0.2 Ge background expected -> 1 seen
0.4±0.9±0.5 Si background expected -> 0 seen

CDMS Two tower run result (Ge 1.25 kg): Run119

March 25, 2004 – August 8, 2004
CDMS at Soudan status: 4.5 kg

- Increased detectors
  - From 1.25 to 4.5 kg Ge
  - Newer detectors
    - Less Rn, Better performance
- Fridge warm period
  - Spring 2005 to July 2006
  - Troubleshooting
- Cold and running since July 2006
- New Phonon sensor tuning
  - Tuning for the best timing performance
- First run ended March 2007
  - ~430 kg-day acquired
  - Two neutron calibration
  - Uniform gamma calibration (2/week)
- Will run at least another year
  - 1300 kg-day
- Expected sensitivity:
  - ~1 x 10^{-44} cm^2

Cross-section [cm^2] (normalised to nucleon) vs WIMP Mass [GeV]
SuperCDMS

- CDMSII mid 2008: $\sim 1 \times 10^{-44}$ cm$^2$
  - 1300 kg-days
- Need to reach $\sim 1 \times 10^{-45}$ cm$^2$
- Interesting SUSY models yet to be explored
- SuperCDMS
  - 25 kg
  - 150 kg
  - 1000 kg
- 25kg: high scientific reach with low risk
- Need to reduce background
  - $1 \times 10^{-2}$ to $1 \times 10^{-4}$
  - Neutrons by x10
Background free: To be or Not to be?

Bernard Sadoulet
# Background budget

<table>
<thead>
<tr>
<th>Background Events</th>
<th>Before Veto Rate</th>
<th>Before Veto No. Evts</th>
<th>After Veto Rate</th>
<th>After Veto No. Evts</th>
<th>Rejection Inefficiency</th>
<th>Not Rejected Rate</th>
<th>Not Rejected No. Evts</th>
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</thead>
<tbody>
<tr>
<td><strong>CDMS II T 1-5 at Soudan</strong> 4.5 kg × 485 d (raw 1,300 kg-d)</td>
<td></td>
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<tr>
<td>Gammas</td>
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<td>n/a</td>
<td>147</td>
<td>130,000</td>
<td>2E-6</td>
<td>4.2E-4</td>
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<tr>
<td>Betas</td>
<td>n/a</td>
<td>n/a</td>
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<td>370</td>
<td>2.1E-3</td>
<td>1.2E-3</td>
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<td>Neutrons</td>
<td>1.1E-2</td>
<td>7</td>
<td>1.5E-4</td>
<td>0.09</td>
<td>1</td>
<td>1.5E-4</td>
<td>0.09</td>
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<td><strong>SuperCDMS ST_0 1-2 at Soudan</strong> 7.5 kg × 550 d (raw 2,800 kg-d)</td>
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<tr>
<td>Gammas</td>
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<td>n/a</td>
<td>147</td>
<td>290,000</td>
<td>1E-7</td>
<td>2.1E-5</td>
<td>0.03</td>
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<td>Betas</td>
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<td>n/a</td>
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<td>1</td>
<td>1.5E-4</td>
<td>0.2</td>
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<tr>
<td><strong>SuperCDMS ST_8 1-7 at SNOLAB</strong> 27 kg × 1000 d (raw 18000 kg-d)</td>
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<tr>
<td>Gammas</td>
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<tr>
<td>Betas</td>
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<td>Neutrons</td>
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<td>1</td>
<td>5.0E-7</td>
<td>0.004</td>
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</tbody>
</table>

**Background rejection** ×4
**Analysis discrimination** ×2
**Background reduction** ×5
**Total Improvement** = ×40
**Production rate per kg** ×5

*From SuperCDMS 25 kg proposal*
Detector improvements: x10 sensitivity

x2 surface improvements

x2.5 gain on Volume/surface

x2 gain on timing rejection
Analysis improvement (x2)

- We have not used all the timing parameters to discriminate near surface events:
  - Phonon rise time, phonon delay, relative amplitude distribution, relative timing distribution…
- More advanced analysis methods:
  - Likelihood, z-reconstruction, neural network…
- X 4 already in hand w.r.t our previous analysis (First run at Soudan)
Radioactive Backgrounds

- Mainly near surface events:
  - CDMSII: $1.4 \times 10^{-3}$ to $2.5 \times 10^{-3}$ evt/kg/day
  - New detectors cleaner: T3, T4, T5
  - Need $1 \times 10^{-4}$ evt/kg/day for SuperCDMS 25 kg

- From surface contamination (e⁻ emitters):
  - 45-80% of the surface events
  - Mostly $^{222}$Rn to $^{210}$Pb (e⁻ 63 keV), $^{40}$K
  - Will be down to $5 \times 10^{-5}$ evt/kg/day

- From Gamma:
  - 0-40% from gamma-electron
  - High Rn in the mine: Old Air purge
  - Inner ancient Pb.
  - With other improvements: $1 \times 10^{-5}$ evt/kg/day
Deeper: Soudan to Sudbury

- Muon showers -> 2MeV neutron
  - Neutrons mimic WIMPs
- Soudan 2040 m watter equivalent:
  - $4 \times 10^{-4}$ evt/kg/day
  - Need < $4 \times 10^{-4}$ evt/kg/day
- SnoLab Sudbury Ontario:
  - 6000 mwe deep
  - $x1000$ less Muons -> $n/1000$
- CDMS space is approved
Conclusion

• With 4.5 kg Ge running for two years at Soudan CDMSII expects to reach $\sigma=2 \times 10^{-44}$ cm$^2$ at 60 GeV/c.

• With 25 kg Ge (7 x 6 x 0.625 kg) running for two years (2010 - 2012) in SNOLab we expect to lower our limit to $\sigma=2 \times 10^{-45}$ cm$^2$.

• We can explore the core of many SUSY models.

• We can achieve the required background $\sim 1 \times 10^{-4}$ evt/kg/day by slight improvements to our current methods.

• We pursue the R&D for beyond SuperCDMS 25 kg phases:
  • 150 and 1000 kg
  • Kinetic inductance Detectors
  • Phonon readout multiplexing. Double sided phonon readout...
  • Various readout schemes to simplify the production
Kinetic Intuctance Detectors (KIDs)
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