SuperCDMS at SNOLAB

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for the
SuperCDMS Collaboration
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**Overview**

**Detectors**

**SuperCDMS History**

**Past Results**

**SuperCDMS SNOLAB**

**Conclusions**
Galactic Dark Matter

- Gravitationally bound
  \[ v_{\text{WIMP}} \leq v_{\text{esc}} \approx 600 \text{ km/s} = 2 \times 10^{-3} \text{ c} \]
  (typical \( v_{\text{WIMP}} \): 270 km/s \( \approx 10^{-3} \text{ c} \))
  \[ \rightarrow \text{Significant energy transfer only for nuclear recoils} \]
  (interact coherently with all nucleons \( \rightarrow \sigma \propto A^2 \))
- Typical WIMP mass: <1000 GeV/c²
- WIMP density at the Earth: 0.3 GeV/c²/cm³
- Expected interaction cross section: can be estimated from total amount of DM (production in early universe): \( 10^{-9} - 10^{-10} \text{ pb} \), but large uncertainty (couple orders of magnitude)
  \[ \rightarrow \text{Very rare interactions (}< 0.1 \text{ evts/kg/d}) \]
- Many more interactions from other sources (background):
  natural radioactivity (U, Th, K, ...), cosmic radiation
  \[ \rightarrow \text{Mostly ionizing: electron recoils} \]

Corresponds to 50 WIMPs\(^6\text{ GeV/ litre} \)
Or 150 g/earth
But 1 500 000/cm²/s
**Detectors**

- **Phonon signal (single crystal):** measures energy deposition
- **Ionization/scintillation signal:** quenched for nuclear recoils (lower signal efficiency)
- **Combination:** efficient rejection of electron recoil background

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**Graph 1:**

- **Graph 2:**

**Graph 3:**

- **Graph 4:**
Neganov-Luke Phonons

Electron gains kinetic energy
\[ E = q \cdot V \rightarrow 1 \text{ eV for } 1 \text{ V potential} \]

Deposited energy in crystal lattice:
Neganov-Luke phonons
\[ \propto V, \# \text{ charges} \]

- Luke phonons mix charge and phonon signal \( \rightarrow \) reduced discrimination
- Apply high voltage \( \rightarrow \) large final phonon signal, measures charge!!
- ER much more amplified than NR
  \( \rightarrow \) gain in threshold; dilute background from ER
Background Dilution

Electron Recoil Spectrum
Nuclear Recoil Spectrum

Number of Counts

Energy

0 V

HV
### History of CDMS and SuperCDMS

- **1998 - 2002**
  - CDMS @ SUF
  - 6 detectors
  - 1 kg Ge (30 kgd)
  - $\sigma < 3.5 \times 10^{-42}$ cm$^2$

- **2003 - 2009**
  - CDMS II @ Soudan
  - 30 detectors
  - ~4 kg Ge (1.1 kgy)
  - $\sigma < 2 \times 10^{-44}$ cm$^2$

- **2009 - 2014**
  - SuperCDMS @ Soudan
  - 15 (bigger) detectors
  - ~9 kg Ge (~6.5 kgy)
  - $\sigma < 3 \times 10^{-45}$ cm$^2$

- **2020**
  - SuperCDMS @ SNOLAB
  - ~30 kg Ge/Si (part HV)
  - Focus on low mass WIMPs
  - $\sigma < 1 \times 10^{-43}$ cm$^2$ (1-10 GeV)

Exposures are after all cuts!

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SuperCDMS @ SNoLAB – Wolfgang Rau – SNOLAB September 2016
Analysis Approaches

- "Classic" CDMS approach: minimize expected BG (<1 for data set under analysis) → threshold ~10 keV ($E_{\text{recoil}}$: use Q signal for Luke correction)

- Low-threshold extension: strongly rising WIMP spectrum at low E → improved sensitivity in spite of BG (no surface event discrimination; $E_{\text{NR}}$: Luke correction based on mean yield)

- CDMSlite: no discrimination, but even lower threshold; BG diluted ($E_{\text{NR}}$: based on Lindhard model)
Detectors

- **iZIP**
  - Add: charge readout (few V)
  - Background discrimination
  - Threshold < 1 keV
  - < 1 background event for whole exposure

- **HV**
  - Add: high voltage (~100 V)
  - Phonons from drifting charges
  - Threshold < 0.1 keV (phonon)
  - effective threshold: one (or few) electron-hole pairs

**Phonon Readout: Tungsten TES**

Electron recoils: background

Nuclear recoils: signal

Charging signal

- Ionization vs Recoil for a Ge ZIP: $^{55}$Cf

- Electron recoils: 0
- Nuclear recoils: 5

- + 50 V
- - 50 V

- large phonon signal from charges

- remove surface background

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Setup

- Gamma shield (Pb)
- Fridge to provide <15 mK at the detector
- 6 detectors → 1 tower
- 2 HV tower (4 Ge/2Si)
- 1 Ge/Si iZIP tower (4/2)
- 1 Ge iZIP towers
- Inner neutron shield (PE)
- Outer neutron shield (PE and water)
- Mounted on spring-loaded platform (earthquake)
- Signal vacuum feedthroughs

(space for up to 31 towers)
Development

- Detectors: larger crystals; iZIP: design ready, prototypes exist and have been tested; HV detectors: close to final design, first test anticipated later this year

- Detector tower (mechanical structure, wiring): design ready, mechanical prototype exists; some delay for wiring prototype; first thermal tests later this year

- Readout electronics:
  Preamp: thermal readout design ready; charge readout: circuits are being tested
  “Warm electronics” (outside cryostat): prototype exists, tests underway

- DAQ: MIDAS based, being developed at UBC with help from TRIUMF and Toronto (version for detector test facilities already in use)

- Cryogenics and shielding: design advanced, but not ready yet
  Procurement of dilution refrigerator under way

- Backgrounds: devised extensive material screening program; tracking and monitoring program being developed; radon filter to be installed for detector assembly cleanroom at SNOLAB.
Lead institution: UBC, with assistance from Toronto, the TRIUMF DAQ group, and several US institutions

Goal: design a deadtime-free DAQ system for new SuperCDMS electronics, including:

- Optimal filtering of noise in trigger
- Integrated data quality system
- Integrated environmental monitoring
- Fully usable and tested at SuperCDMS test facilities (Queen’s, CUTE, SLAC, UMN, Berkeley)
- Built on MIDAS DAQ system

New prototype SNOLAB readout card, and noise measurements from prototype DAQ (May 2016)
SuperCDMS SNOLAB

- Funding approved (CFI: 2012, DOE/NSF: 2014)
- DOE/NSF review process:
  First step passed (CD 1: conceptual design review)
  Next steps in 2017: status review (spring) technical design review (CD 2/3, fall 2017)
- Reviews at SNOLAB:
  passed Gateway 1 (space allocation) in fall 2015;
  GW2A (early deployment) in December 2016; GW2 probably summer 2017
- Total project costs ~$30M
The details of our projected sensitivity are presently under review. An updated projection can likely be found on the arXiv later this fall.

Sorry for the inconvenience.
Conclusions

- SuperCDMS SNOLAB aims at detecting dark matter WIMPs
- Main focus are low-mass WIMPs (< 10 GeV/c^2)
- Project planning well under way
- Main R&D is done, full technical design expected for spring 2017
- Start of operation expected in 2020
- Upgrades (improved HV detectors, EURECA detectors, ...) will allow us to reach the neutrino floor at low mass and/or check discovery claims at high mass