SuperCDMS and CUTE at SNOLAB

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for the
SuperCDMS Collaboration
SuperCDMS Collaboration

California Institute of Technology
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South Dakota School of Mines & Technology
Southern Methodist University
University of British Columbia/TRIUMF
University of Colorado Denver
University of Minnesota

CNRS/LPN
NISER
Santa Clara University
SNOLAB/Laurentian University
Stanford University
University of California, Berkeley
University of Evansville
University of South Dakota

Durham University
Northwestern University
SLAC/KIPA
Texas A&M
University of Florida
University of Toronto
SuperCDMS

- Detector technology
- Detector generations
- Experimental Setup
- Goals for SNOLAB
- Status

CUTE

- Motivation
- Design
- Status

Analysis Projects

- Detector Calibration
- Backgrounds
- Rare interactions
- Dark Matter searches

Conclusions
Overview

**SuperCDMS**

**CUTE**

**Analysis**

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**Detectors**

- SuperCDMS & CUTE
- Wolfgang Rau
- Dark Matter from a to Z, Durham

- ZIP

- Phonon Readout: Tungsten TES

- Add: charge readout (few V)
- Background discrimination
- Threshold < 10 keV

- Semiconductor operated at few 10s of mK

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**CDMS**

- Ionization vs Recoil for a Ge ZIP: $^{252}$Cf
- Electron recoils: background
- Nuclear recoils: signal
- Phonon signal
Overview

SuperCDMS

CUTE

Analysis

Detectors

Semiconductor operated at few 10s of mK

Phonon Readout: Tungsten TES

Add: charge readout (few V)
Background discrimination
Threshold < 10 keV

< 1 background event for whole exposure

Add: high voltage (~70 V)
Phonons from drifting charges
Threshold < 0.1 keV (phonon)

large phonon signal from charges

effective threshold: few hundred eV (NR)

Electron recoils: background

Nuclear recoils: signal

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

Charge signal

0 V

- 70 V

SuperCDMS Soudan

SuperCDMS & CUTE – Wolfgang Rau – Dark Matter from a to Z, Durham
Detectors

SuperCDMS & CUTE – Wolfgang Rau – Dark Matter from a to Z, Durham

Overview

SuperCDMS

CUTE

Analysis

Detectors

Phonon Readout: Tungsten TES

Add: charge readout (few V)
Background discrimination
Threshold < 1 keV

Add: high voltage (~100 V)
Phonons from drifting charges
Threshold < 0.1 keV (phonon)

< 1 background event for whole exposure

effective threshold: one (or few) electron-hole pairs

Nuclear recoils:
signal

Electron recoils:
background

large phonon signal from charges

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

Electron recoils: background

Nuclear recoils: signal

Phonon signal
Background dilution with Luke Effect

Number of Counts

Energy

Electron Recoil Spectrum
Nuclear Recoil Spectrum

No amplification
Background dilution with Luke Effect

Effect of amplification

Electron Recoil Spectrum
Nuclear Recoil Spectrum

Number of Counts vs. Energy
Background dilution with Luke Effect

Effect of amplification stronger for ER than NR
→ ER background is diluted
CDMS History

1998 - 2002
SUF, 10 mwe

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

2003 - 2009
Soudan, 2000 mwe

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

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

2020
SNOLAB, 6000 mwe

2020
SuperCDMS @ SNOLAB
30-180 detectors
30-200 kg Ge/Si (part HV)
focus on low mass WIMPs
$\sigma < 10^{-43} \text{ cm}^2$ (1-10 GeV)

exposures are after all cuts!
Implementation (Soudan setup)

- Stack detectors (3) to mount (“tower”)
- 5 towers deployed in cryostat (~9 kg Ge)
- Shielded with PE (for neutrons), Pb (gammas) and muon veto (cosmic radiation)
- Located at Soudan Underground Lab (Minnesota) to shield from cosmic radiation (~700 m below ground)
Implementation (Soudan setup)

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Implementation (SNOLAB setup)

- Fridge to provide <15 mK at the detector
- Gamma shield (Pb)
- Outer neutron shield (PE and water)
- Mounted on spring-loaded platform (earthquake)
- Signal vacuum feedthroughs

- 6 detectors → 1 tower
- 1 HV tower (4 Ge/2Si)
- 3 Ge iZIP towers
- 1 Si iZIP tower

(space for up to 31 towers)

Inner neutron shield (PE)
SNOLAB

- Radon filter
- Cryogenics and radon filter plant
- Experimental area
- Access drift
- Clean room
- DAQ
- CUTE
Goal

The diagram shows a plot of WIMP-nucleon cross section vs. WIMP mass, with shaded regions representing different experimental constraints and sensitivities. The axes are labeled as follows:

- Y-axis: WIMP-nucleon cross section [cm^2]
- X-axis: WIMP mass [GeV/c^2]

Key features include:
- Solar Neutrinos
- Atmospheric Neutrinos
- DEAP
- LZ
- LUX 2013
- CDMS II 2015
- DAMIC 2016
- SI\text{ZIP} 2015
- Ge\text{ZIP} 2015
- DAMA
- SuperCDMS LT 2014

The goal of the SuperCDMS & CUTE collaboration is to explore the dark matter spectrum from 0.2 to 200 GeV/c^2, with an emphasis on the region of overlap between different experimental sensitivities.
Goal
• Funding approved (CFI: 2012, DOE/NSF: 2014)

• DOE/NSF review process:
  First step passed (CD 1: conceptual design review)
  Next step in fall 2017: technical design review/ready for construction (CD 2/3)

• Reviews at SNOLAB:
  passed Gateway 1 (space allocation) in fall 2015;
  GW2a (early construction) in December 2016 / GW2 (construction) summer 2017

• Total project costs ~$30M
Development

- Detectors: larger crystals; iZIP: design ready, prototypes exist and have been tested; HV detectors: first prototypes built; testing has started
- Detector tower (mechanical structure, wiring): design ready, mechanical prototype exists; wiring prototype expected in early 2017
- 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 (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.
Cryogenic Underground TEst facility (CUTE)

Motivation

• Detector performance:
  Detector integrity after transportation
  Background discrimination
  Noise performance (impact of background)

• Background studies
  Confirm that screening program
  and handling procedures are appropriate
  Study cosmogenic backgrounds ($^3$H, $^{32}$Si)

• Test EURECA detectors in a SuperCDMS environment (possibly join forces)

• Opportunity for early science! ($BG\;\Theta$ (few evt/keV/kg/d below 100 keV))

Schedule

• Cryostat ordered
• Infrastructure (water tank, cleanroom, services): in early 2017
• May 2017: test at Queen’s; summer installation underground
• Commissioning: early fall 2017 (~2-3 years ahead of SuperCDMS)
Cryogenic Underground TEst facility (CUTE)

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## Analysis Projects

- Photo-Neutron calibration (low-energy nuclear recoil calibration)
  Last “physics” measurement from Soudan (summer/fall 2015)
  Analysis under way, publication ‘sometime next year’

- Backgrounds: Analysis of cosmogenic backgrounds in CDMSlite ($^3$H and others)
  Analysis in good shape; hope to publish early next year

- Backgrounds: radioactivity from the setup/environment – improved MC simulations to inform ongoing analysis of dark matter data and learn for SNOLAB

- Rare interactions: follow-up of LIPs analysis (can we use CDMSlite data to improve our sensitivity for lower fractional charges?)

- Annual modulation analysis – long time coming; hopefully ready within the next 2-3 months

- Standard WIMP search from SuperCDMS (full discrimination, intermediate to high mass range): not competitive with Xe for ‘vanilla WIMP’, but still important for non-standard models (EFT ...); first half of next year (?)

- Last CDMSlite data set – develop blinding scheme, consider background modeling
CDMSlite R2

- Reduced threshold
- New pulse fitting
- Improved resolution
- Fiducialization
CDMSlite R2

No background model
Optimum interval analysis
CDMSlite R2

- No background model
- Optimum interval analysis

CDMSlite R3
- Less exposure
- Moderately lower threshold
- Background model?
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
- CUTE: Queen’s initiative for an underground test facility, operational in about a year (detector performance studies, background checks, early dark matter science)
- Analysis: many updates in the pipeline; small steps until new facilities come online