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Cosmic Experiment Research and Operations – CDMS and SuperCDMS

Dan Bauer

Fermilab Institutional Review

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The interplay of cosmic research and operations

- Research
  - Scientists (staff and postdocs)
  - Scientist support (admins, office supplies, travel)
  - Management of the cosmic program at Fermilab

- Operations
  - Technical support (engineers, technicians, computer professionals,…) for operating experiments
  - Materials, services and equipment needed for maintenance of operating experiments
  - Computing support for operating experiments (incl. users)
  - Travel support for operating experiments (incl. users)

A Worked Example: CDMS

- CDMS = Cryogenic Dark Matter Search
  - Attempt to directly detect dark matter particles (WIMPs) using solid-state detectors cooled to cryogenic temperatures
  - But it isn't just about the detectors
    - Very complex cryogenic infrastructure required to reach <50 mK
    - Massive, layered shielding and location deep underground to protect detectors from seeing normal matter backgrounds
    - Low-noise electronics needed to distinguish very low energy signals from noise
    - Modern data acquisition and software systems to process high-rate calibration data needed to separate backgrounds from signals
    - System integration and project management
  - These are what Fermilab provides for CDMS

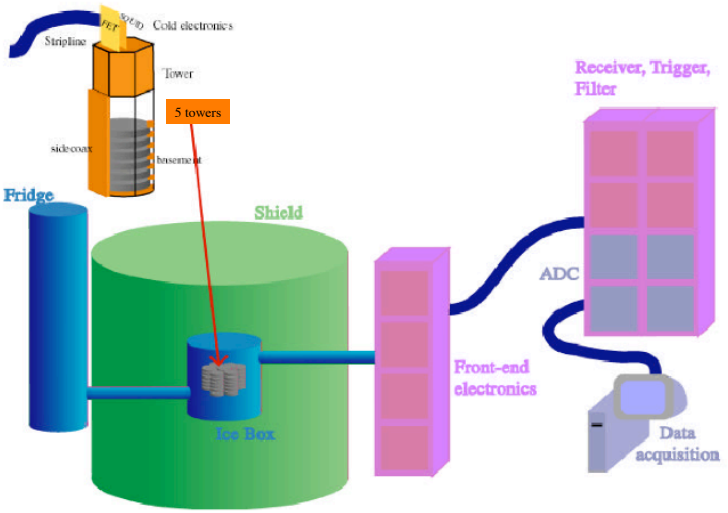
CDMS at a glance

- Science: direct detection of dark matter WIMPs (and other exotic particles)
  - 'Conventional' WIMP candidates (e.g. SUSY)
  - 'Dark sector' particles (low-mass WIMPs)
  - Axions from the sun and/or the galaxy
  - Lightly-ionizing particles

- Basic experimental setup: Ge crystals with charge and phonon sensors on both sides (iZIP), operated at cryogenic temperatures, surrounded by layered shielding in a deep underground laboratory

- Collaboration: ~90 scientists from the US, Canada, France, Spain, UK

- Funding: US (DOE, NSF) with contributions from Canada (NSERC, CFI)



Schematic of the CDMS experiment

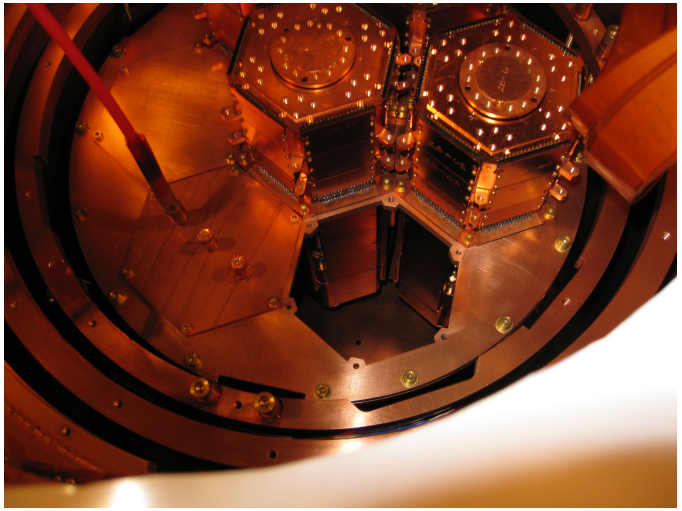


Photo showing iZIP detector towers at Soudan

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Operational Challenges

- Working in remote underground laboratories
  - Even getting there reliably can be challenging
  - Limited access to underground lab (10 hours/day, weekdays)
  - Must have everything you need underground => advance planning
- 50 mK cryogenics is challenging even at the surface
  - Underground operation requires huge investment in monitoring, process control and remote operation
  - Getting reliable cryogen deliveries takes considerable planning
- Backup power and cooling are a must
  - Power often unreliable, so UPS/generator required
- Electronics, DAQ and data quality must be robust
  - Remote monitoring and control are vital
- These are all things that Fermilab provides

Fermilab's roles in CDMS operations

- Project and Operations Management
  - For the last 16 years, Fermilab has provided management of the DOE/NSF projects to build and operate the Soudan experiment
  - Operational experience of our scientists, engineers and technicians have been key to the success of CDMS II, and SuperCDMS Soudan
    - Dan Bauer – Project and Operations Manager, Cryogenics, Shielding
    - Lauren Hsu – Data Quality and Analysis coordination
    - Ben Loer – Data Quality and operations
    - Rich Schmitt and Sten Hansen – Lead cryogenics and electronics engineers
    - Mark Ruschmann – Lead technician
    - Don Holmgren – Computing and DAQ support
  - Also very important to work closely with onsite Soudan staff
    - Dan Bauer has been Fermilab contact with Soudan for many years

Manpower for the experiment

- Soudan lab staff (University of Minnesota) trained to handle routine operation and maintenance
  - Key technicians are Dan DeVaney and Jeff Gunderson, networking/computing Dave Saranen
- Fermilab staff are on call for unusual situations (24/7/365)
  - Dan Bauer, Rich Schmitt for cryogenics, lab issues
  - Don Holmgren for DAQ, computing
  - Lauren Hsu and Ben Loer for data quality
- Onsite shift physicists handle routine data taking and testing
  - Presence enabled by Fermilab support for Soudan house rental and travel to Soudan
  - Provide training and hands-on experience to students, postdocs
- Offsite shift physicists monitor data quality

Data Analysis and Extraction of the Science

- Fermilab has played both leadership and enabling roles in CDMS analysis and science
  - Jonghee Yoo (former postdoc) developed improved pulse fitting algorithms and did interesting axion search with CDMS detectors
  - Lauren Hsu was a leader in the much-anticipated 2009 CDMS-II result and was analysis coordinator during much of SuperCDMS Soudan. Key to the recent low-threshold result. Developed data quality monitoring system.
  - Jeter Hall and Ritoban Basu Thakur have been leaders in CDMSlite (very low mass WIMP search)
  - Ben Loer oversees data processing (FermiGrid) and provides important trigger efficiency and database support work

Computing

- CDMSII/SuperCDMS raw datasets redundantly housed on tape in Enstore at Fermilab. Additionally, several hundred TB of data (raw and processed) stored on CDMS disk servers operated by the Scientific Computing Division.
- All raw data reconstructed on general purpose FermiGrid and distributed to universities for analysis
  - 330 khrs consumed in FY2014 (for data reconstruction and simulation)
  - Similar usage anticipated for the next few years as analysis of Soudan data draws to a close
- SuperCDMS SNOLAB data to be housed at Fermilab. Data rates still being determined, anticipated data storage starting FY~2018
- Collaboration will make extensive use of DocDB for design phase of SuperCDMS SNOLAB.
- Don Holmgren is key to the use of Fermilab computing facilities

Coordination with other institutions

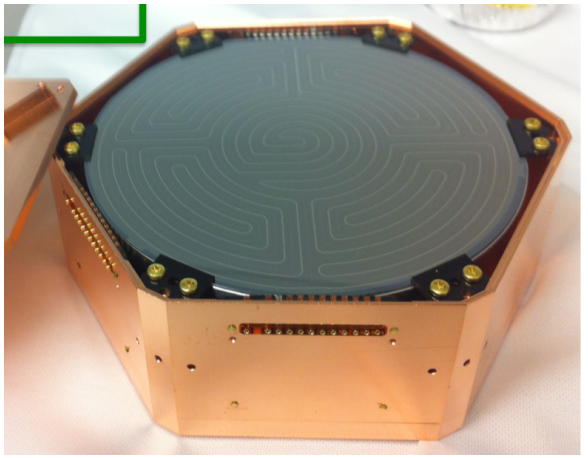
- University of Minnesota
  - Close relationship for operation at Soudan, and frequent exchange of students/postdocs, working on backgrounds, calibration, veto
- Queens University and SNOLAB
  - Cryogenics, SNOLAB infrastructure, future operations
- SLAC
  - SuperCDMS SNOLAB Project management and computing
- PNNL
  - SuperCDMS group formed by hiring former FNAL postdoc, Jeter Hall, and is working closely with us on CDMSlite, backgrounds
- UBC/TRIUMF
  - Working together on SNOLAB DAQ and onsite computing
- MIT and University of Florida
  - Cryogenics and system integration

Moving forward towards SuperCDMS SNOLAB

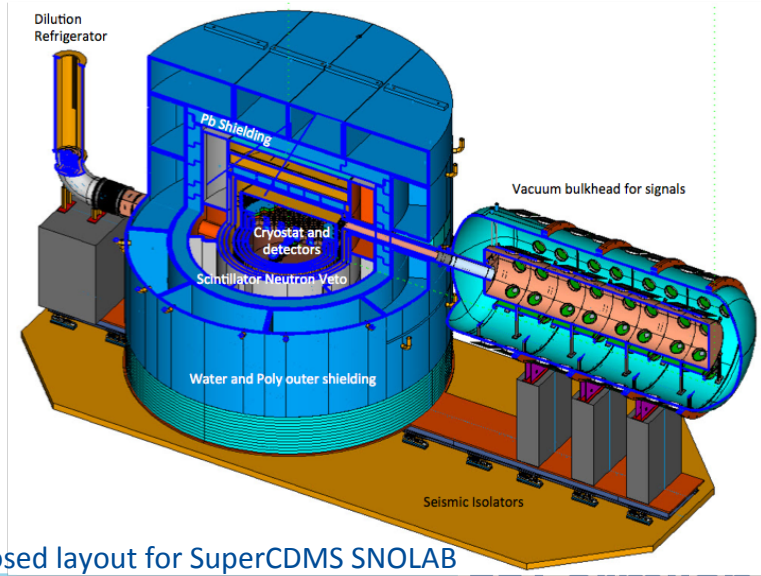
- Fermilab brings history of experience to the new SuperCDMS SNOLAB Project
  - Project Scientist (Dan Bauer), Project Manager (Pat Lukens)
  - L2 managers: Rich Schmitt (Cryogenics), Ed Chi (Shielding), Dan Bauer (System Integration and Test)
  - L3 managers: Ben Loer (Neutron Veto), Lauren Hsu (Calibration)
- Currently engaged in the vital role of pulling the collaboration and the project teams together into achieving the goals for SuperCDMS SNOLAB
  - Continued world-leading sensitivity (and hopefully discovery) of low-mass WIMPs
  - Ability to study higher mass WIMP signals with different targets and controlled backgrounds
  - Searches for new particles (axions, fractionally-charge particles) that can be done with our unique detector technology

SuperCDMS SNOLAB – The next phase

- Science: direct detection of dark matter WIMPs with focus on light masses (< 10 GeV/c^2)
  - 'Conventional' WIMPs
  - 'Dark sector' particles (low-mass WIMPs)
  - Other exotic particles (axions, LIPs,…)
- New experimental setup: New cryogenics and shielding system, with capacity for up to 400 kg of target mass
- Location: SNOLAB, Sudbury, Ontario Canada (deepest clean laboratory in North America) to avoid cosmic and radioactive backgrounds
- Timescale: R&D (FY15), Fabrication (FY16-18), Operations (FY19-22)

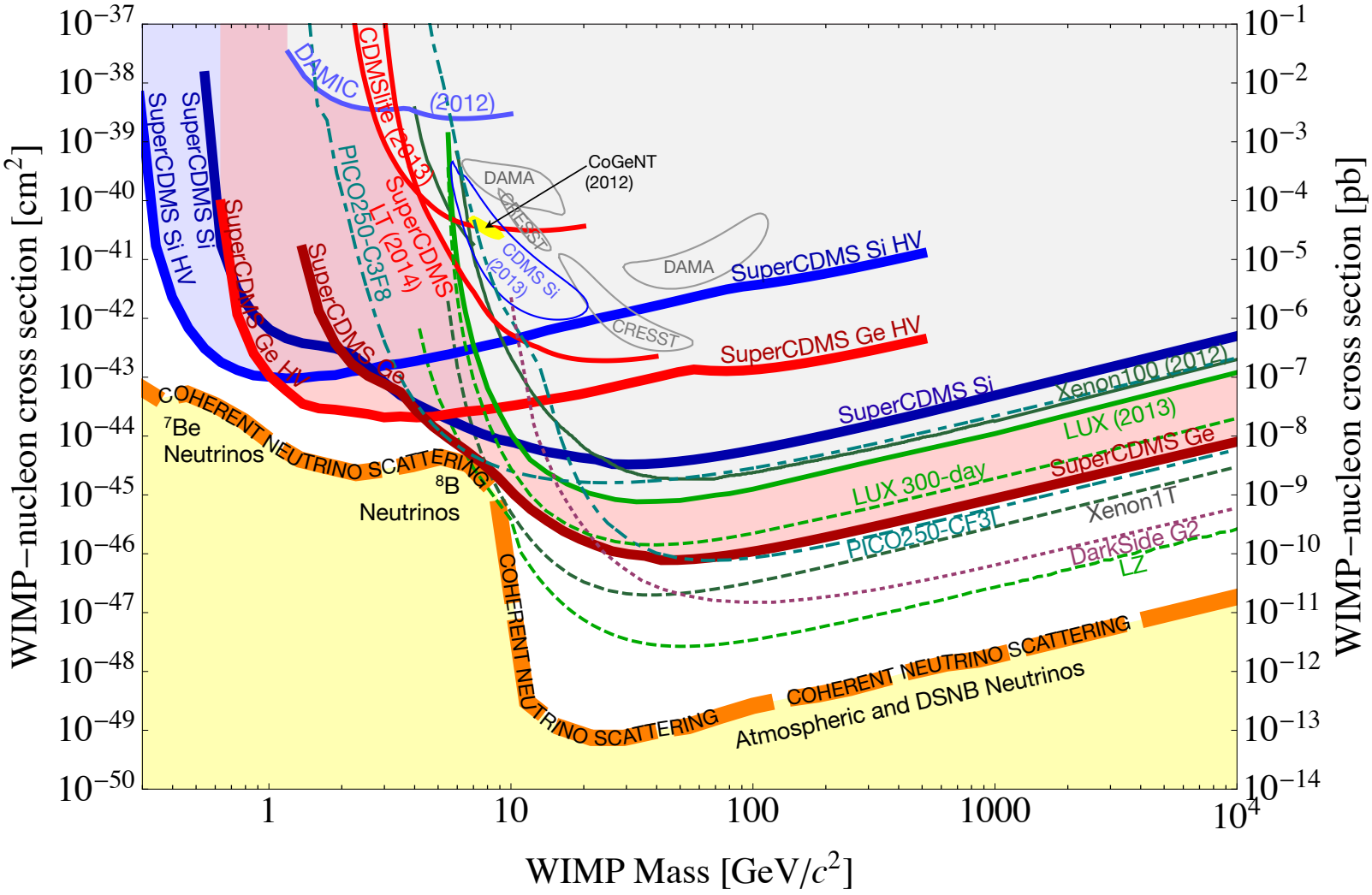


1.3 kg Ge iZIP prototype detector



Proposed layout for SuperCDMS SNOLAB

Probing to lower WIMP mass, down to the neutrino floor



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Summary

- Fermilab has long had leading roles in CDMS/SuperCDMS
  - Experimental infrastructure, cryogenics, electronics, operations, analysis, computing, analysis and many areas of science
  - Enabling universities to focus on other areas (detectors, cold hardware, data acquisition, simulations)
  - Providing operations support, facilities and mentoring for users at both Fermilab and experiment sites (Soudan, SNOLAB)

- Fermilab CDMS group is small, but effective
  - Local group needs to grow for SuperCDMS SNOLAB
  - But our user community increases our effectiveness