LUX-ZEPLIN(LZ) and Super Cryogenic Dark Matter Search(SCDMS) Status

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HEPAP
## Overview

<table>
<thead>
<tr>
<th></th>
<th>LZ</th>
<th>SCDMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>SURF</td>
<td>SNOLAB</td>
</tr>
<tr>
<td>Countries</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Institutions</td>
<td>37</td>
<td>25</td>
</tr>
<tr>
<td>Collaboration Size</td>
<td>(~ \sim 250)</td>
<td>(~ \sim 90)</td>
</tr>
<tr>
<td>Cost</td>
<td>DOE $55.5M</td>
<td>DOE $18.6M</td>
</tr>
<tr>
<td></td>
<td>Overall \sim $75M</td>
<td>Overall \sim $34M</td>
</tr>
<tr>
<td>Detection Medium</td>
<td>\sim 10 tonnes LXe</td>
<td>25 kg Ge</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.6 kg Si</td>
</tr>
</tbody>
</table>
## Project Timelines

<table>
<thead>
<tr>
<th>Event</th>
<th>LZ</th>
<th>SCDMS</th>
</tr>
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<tbody>
<tr>
<td>CD-0</td>
<td>Sep 2012(A)</td>
<td>Sep 2012(A)</td>
</tr>
<tr>
<td>CD-1</td>
<td>Apr 2015(A)</td>
<td>Dec 2015(A)</td>
</tr>
<tr>
<td>CD-2</td>
<td>Aug 2016(A)</td>
<td>May 2018(A)</td>
</tr>
<tr>
<td>CD-3</td>
<td>Feb 2017(A)</td>
<td></td>
</tr>
<tr>
<td>CD-4(Early Finish/ Milestone)</td>
<td>Jul 2020/ Mar 2022</td>
<td>Sep 2020/ Sep 2021</td>
</tr>
<tr>
<td>Start 1\textsuperscript{st} Science Run</td>
<td>Aug 2020</td>
<td>Jan 2021</td>
</tr>
<tr>
<td>Decomm. or Upgrade</td>
<td>2026</td>
<td>2026</td>
</tr>
</tbody>
</table>
SuperCDMS Collaboration: ~ 90 physicists at 25 institutions worldwide, 3 US national labs, 2 Canadian labs

- Caltech
- Northwestern
- CNRS-LPN*
- PNNL
- Durham University
- Queen’s University
- Santa Clara University
- SMU
- SNOLAB
- Stanford University
- Texas A&M University
- U. California, Berkeley
- U. Colorado Denver
- U. Florida
- U. Montréal
- U. Minnesota
- U. South Dakota
- U. Toronto

* Associate members
SuperCDMS Detector Overview

To be located in class 2000 ladder lab cleanroom, 6800 foot level at SNOLAB
Infrastructure Status at SNOLAB

- Cable Tray
- Clean Room
- Seismic Platform
- Gantry Crane installed
Initial 4-Tower payload to meet G2 DM science goals

Complementary Targets and Multiple Functionality

<table>
<thead>
<tr>
<th></th>
<th>Germanium</th>
<th>Silicon</th>
</tr>
</thead>
<tbody>
<tr>
<td>HV</td>
<td>Lowest threshold for low mass DM</td>
<td>Lowest threshold for low mass DM</td>
</tr>
<tr>
<td></td>
<td>Larger exposure, no $^{32}$Si bkgd</td>
<td>Sensitive to lowest DM masses</td>
</tr>
<tr>
<td>iZIP</td>
<td>Nuclear Recoil Discrimination</td>
<td>Nuclear Recoil Discrimination</td>
</tr>
<tr>
<td></td>
<td>Understand Ge Backgrounds</td>
<td>Understand Si Backgrounds</td>
</tr>
<tr>
<td></td>
<td>Sensitive to $^8$B $\nu$-scatter</td>
<td>Sensitive to $^8$B $\nu$-scatter</td>
</tr>
</tbody>
</table>

For new crystals, (Towers 2,3,4), cosmogenic activation is limited to < 60 days surface exposure $[90$ $^3$H atoms/kg/day in Ge$]$

Stored in N$_2$ purged containers, Rn exposure tracked for all detectors
Detector Tower Status

• Completed the Transition Edge Sensor (TES) deposition and photolithography for the Tower 2 & 4 endcap detectors

• Completed the solid model for the lids, standoffs, and IR shields and began preparation of fabrication drawings

• Held in-person meeting at vendor to review plans for horizontal and vertical flex cable fabrication → critical path driver for Tower subsystem

• Test wafers for Si HV detectors showed higher $T_C$ than expected
  – Developed multi-pronged R&D plan to reduce $T_C$ for the inner detectors in Towers 2-4
  – Expect main production to start in November
SuperCDMS at SNOLAB: Detector Characterization and Yield Studies Underway

Program to calibrate, characterize, & test detectors well-underway

- Newly-commissioned underground test facilities are up and running
  - NEXUS at MINOS underground Hall at FNAL
  - CUTE facility co-located in SuperCDMS hall at SNOLAB
- First measurement of the intrinsic ionization yield of Si at 50 mK
- Single e-h detectors with 3 eV resolution in TUNL (=Triangle Universities Nuclear Laboratory) neutron beam
- Crucial for low mass dark matter reach
- Si paper published this spring, Ge measurement next year
- Full-size SuperCDMS detectors at NEXUS using DD generator
Cryostat Design & Bid Status

4-tower payload (in blue) is offset vertically and horizontally from the penetrations

31 Tower capacity to fulfill ultimate Science Goal of reaching the neutrino floor in a future upgrade

Low-background copper material on order, two machining bids within budget, working on developing welding contract
Pb Shield Pre-assembly at Lemer Pax in France: first shipment now at SNOLAB
4-Tower payload meets project science goals; order of magnitude improvement with background subtraction.
LZ Collaboration

250 scientists & engineers from 37 institutes in the US, UK, Portugal, South Korea & Russia

Black Hills State University ◊ Bristol University ◊ Brookhaven National Laboratory ◊ Brown University ◊ Center for Underground Physics, Korea ◊ Edinburgh University ◊ Fermi National Accelerator Laboratory ◊ Imperial College London ◊ Lawrence Berkeley National Laboratory ◊ Lawrence Livermore National Laboratory ◊ LIP-Coimbra, Portugal ◊ University of Liverpool ◊ MEPhI Moscow, Russia ◊ Northwestern University ◊ Oxford University ◊ Penn State University ◊ Rutherford Appleton Laboratory ◊ Royal Holloway, University of London ◊ SLAC National Accelerator Laboratory ◊ South Dakota School of Mines & Technology ◊ South Dakota Science and Technology Authority ◊ SUNY University at Albany ◊ Texas A&M University ◊ University of Alabama ◊ University of California Berkeley ◊ University of California Davis ◊ University of California Santa Barbara ◊ University College London ◊ University of Maryland ◊ University of Massachusetts ◊ University of Michigan ◊ University of Rochester ◊ University of Sheffield ◊ University of South Dakota ◊ University of Wisconsin
LZ Detector Overview

- Cathode high voltage connection
- Instrumentation conduits
- Outer detector PMTs
- 7 tonne active volume liquid Xe TPC. 10.3 tonnes total
- Instrumentation conduits
- Existing water tank
- Gadolinium-loaded liquid scintillator veto
- Liquid Xe heat exchanger

About 1 mile deep at the Sanford Underground Research Facility (SURF) in South Dakota

Paper on arXiv
Xe Status

- 10.7 tonnes procured
- 97% of Xe gas in hand
- Last 3% delivered in two weeks.
- Xe gas is at SLAC for removal of trace amounts of Kr, a radioactive contaminant, to achieve ≤ 0.3 parts-per-trillion of Kr.
- Production processing imminent.
- To SURF by April 2020
Xe and Cryogenic Systems

• Underground installation at SURF largely done
• About to begin operation at 100kg Xe scale using “dummy” cryostat and final circulation system to debug system
Inner Detector Status

- Time Projection Chamber fully assembled and checked out in custom low Rn clean room on surface at SURF.
TPC/ICV Underground

- The TPC was installed into the Inner Cryostat Vessel (ICV) and the assembly lowered through the Yates shaft at SURF and transported underground on Oct. 21, 2019.
- Next step: put into Outer Cryostat Vessel, already in place in water tank, Dec 2019. Followed by months of hookup & checkout.
Outer Detector Status

- Acrylic tanks fabricated and delivered to SURF but issues with 2 of 10, now back at vendor for repair by year’s end.
- Liquid scintillator production 95% complete at BNL
- All phototubes in hand, production of supports underway
Electronics and Controls Systems

- All significant production is complete
- Underground installation long underway and on track to meet needs as equipment comes online
Computing and Software

• Operational challenge complete, data transfer from SURF to US data center (NERSC at LBNL) successful.
• Mock Data Challenges (MDCs) used to validate software and computing model
• In last stages of MDC3, simulate first few months of data taking, including calibration, and analysis
• Utilizing NERSC resources and UK data centre (roughly equal to NERSC resources)
• Next steps: more operational challenges, code development, leading to computing & software readiness review by April 2020
Expected WIMP Sensitivity

- Plot below based on 1000 live days, ~5 years
- Better than XENON1T (2018) in few months of running
- Goal to publish from 1st run in early 2021
Summary

• LZ and SCDMS Projects preparing for completion in the 2\textsuperscript{nd} half of CY2020
• Plan to begin science operations by end CY2020 – early CY2021
• First science results by CY2021
• Planning for data taking of \sim 5 years
Axion Dark-Matter eXperiment Generation 2 (ADMX-G2)

**ADMX-G2** is located at University of Washington, managed by Fermilab
- Primarily DOE supported with contributions from the UK, Germany and Australia; R&D support from the Heising-Simons Foundation
- **Uses a strong magnetic field and resonant cavity to convert dark matter axions into detectable microwave photons**

**Operating**: Series of runs (1a-2b) with detector modifications cover range 0.5 to 2 GHz (≈ 2 to 8 micro-eV mass) – started Aug. 2016; planned to complete ~ 202
- **Run 1A** (2017) & **Run 1B** (2018) - both reached “invisible” axion (DFSZ model) sensitivity!
- Run 1C running; Run 2 Cavities under development.

**ADMX-Extended being planned (a Dark Matter New Initiative) → 2 - 4 GHz**

![Graph showing ADMX Run 1B Sensitivity](image)

**Pierre Sikivie**, inventor of the axion haloscope and recipient of the 2020 Sakurai prize, helping assemble the ADMX experiment.