CUTE - A Cryogenic Underground TEst facility at SNOLAB

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Abstract

A well shielded Cryogenic Underground TEst facility (CUTE) will be installed at SNOLAB with the goal to do performance tests, calibrations and background measurements with cryogenic dark matter detectors in support and preparation of the search for Weakly Interacting Massive Particles (WIMPs) with SuperCDMS at SNOLAB.

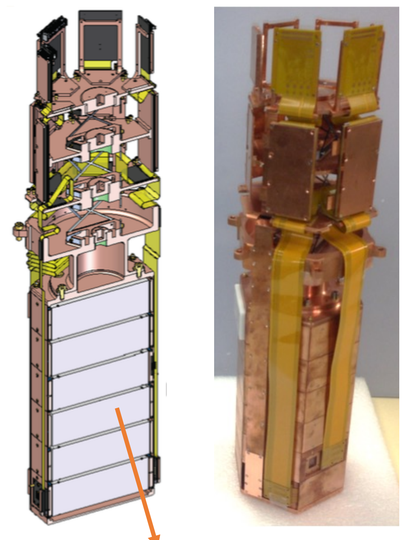
This facility will also offer the opportunity for the European Underground Rare Event Calorimeter Array (EURECA), a collaboration including the European cryogenic dark matter search experiments EDELWEISS and CRESST, to demonstrate the compatibility of their detector design with the SuperCDMS infrastructure. This in turn opens the door for bringing EURECA detectors as additional payload into SuperCDMS to increase the physics reach of the experiment.

The primary component of CUTE will be a cryogen-free dilution refrigerator mounted within a drywell in the centre of a water tank shielding. In addition, lead and polyethylene shielding will be installed in two phases to further reduce the radioactive background level at the detectors. Meanwhile, in order to minimise microphonics noise in the signal, special care will be taken to measure and suppress the level of micro-vibrations within the cryostat.

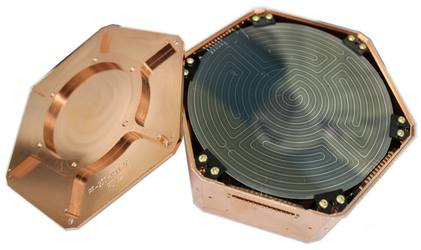
The SuperCDMS Experiment & SNOLAB

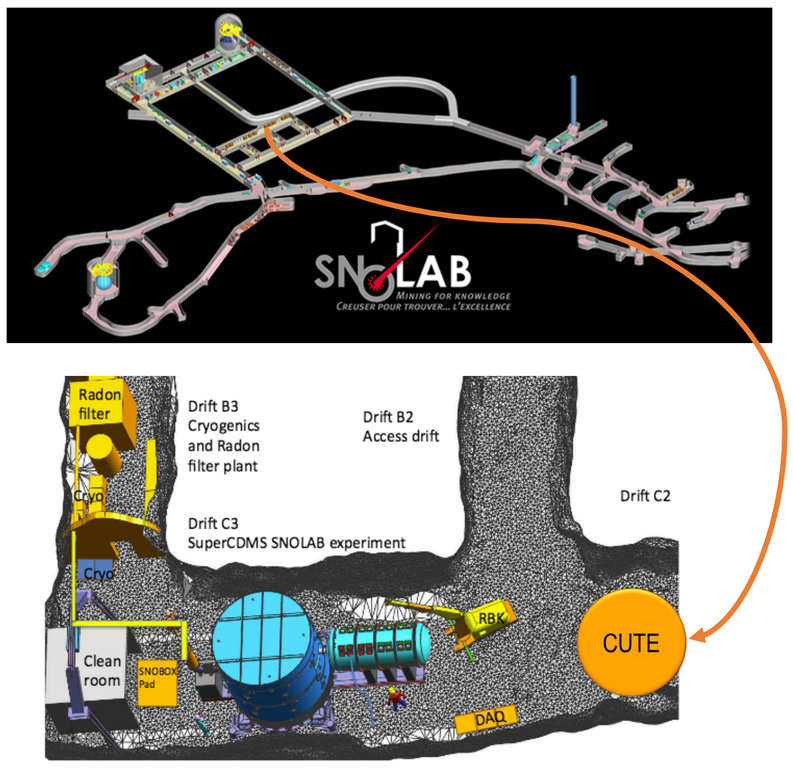
The SuperCDMS SNOLAB experiment is one of the direct search experiments. It aims to detect WIMP interactions using cryogenic germanium and silicon detectors [1]. As a next generation dark matter search experiment, it will focus on dark matter particles with mass < 10 GeV/c^2.

SuperCDMS Tower Prototype



100 mm iZIP Detector





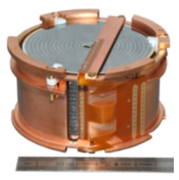
To shield against cosmogenic backgrounds, the detectors are operated in the low radioactivity environment of the SNOLAB [2], which is located deep underground in the operational Vale Creighton nickel mine, near Sudbury, Ontario in Canada. With a rock overburden of roughly 2 km, it provides a shielding equivalent to ~6000 m of water.

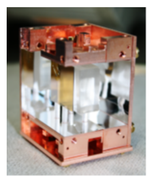
Motivations for CUTE

The original and most important motivation for CUTE is the need for a well shielded test facility which can be used to study detectors under low-background conditions, but there are a number of other goals that can be achieved with such a facility. Some of the studies for which CUTE would be ideally suited are:

- Detector Performance
  - Electron recoil vs. nuclear recoil discrimination efficiency of the 100 mm iZIP detector
  - Surface event discrimination efficiency of the 100 mm iZIP detectors
  - Origin of elevated noise when operating detectors at high voltage
  - Confirming reliability of detector tower transportation procedures to SNOLAB
- Background Studies
  - Cosmogenic production rate of ^{3}H in Ge and Si
  - ^{32}Si content in SuperCDMS Si substrates
  - Confirming SuperCDMS detector production, handling and transportation procedures do not introduce significant contamination
  - Confirming SuperCDMS screening program does not overlook major contaminants
- Nuclear Recoil Energy Scale
  - Improved photo-neutron calibration with optimized source geometry

EDELWEISS Ge Detector





CRESST $CaWO_4$ Detector

- EURECA
  - First operation of EURECA detectors within a SuperCDMS compatible tower configuration
  - Basic detector performance studies within this new environment
  - Confirming these detectors do not bring in significant contamination
  - Verifying the transportation procedures, in particular the trans-Atlantic shipping
- Physics
  - First peek at very low-mass WIMPs with SuperCDMS HV detectors

The CUTE Facility & Shielding

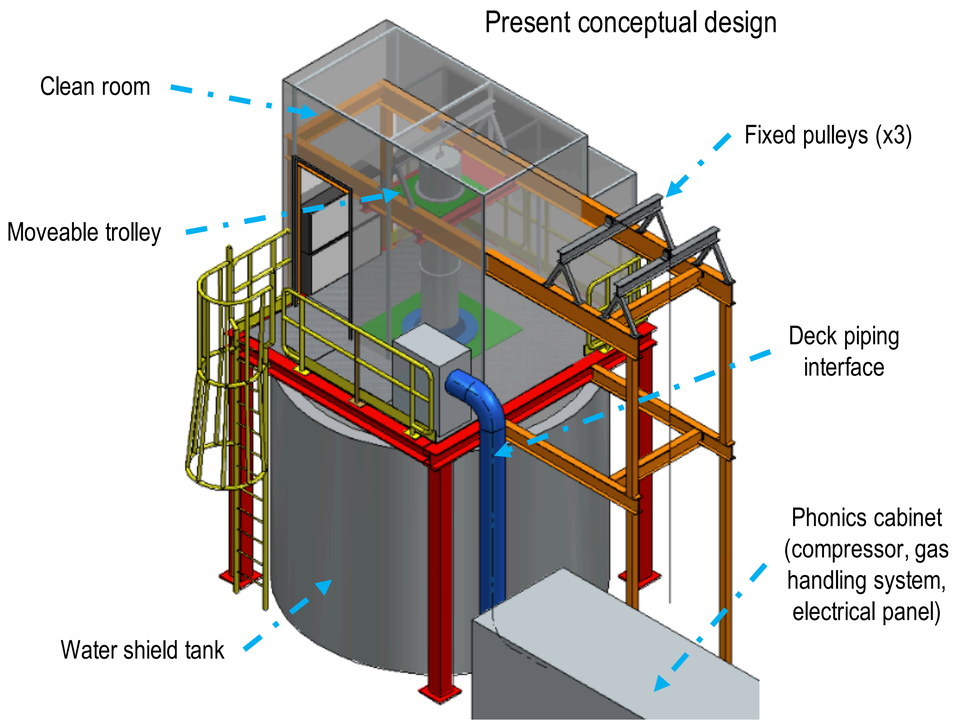
Primary goal of radioactivity background level [3, 4]

- Gamma rate << 1 Hz per detector
- Neutron rate < 1 neutron/day/detector

Shielding implementation plan

- Initial Phase
  - ~1-1.5 m water shielding all around (water tank with drywell for the dilution refrigerator)
  - 15 cm internal Pb shielding above the detector tower
- Upgraded Phase
  - 10-15 cm of Pb shielding directly around the cryostat, within the drywell
  - Potentially replace all the cryostat cans by low-radioactivity copper ones
  - Potentially 30-50 cm polyethylene shielding above the cryostat

Present conceptual design

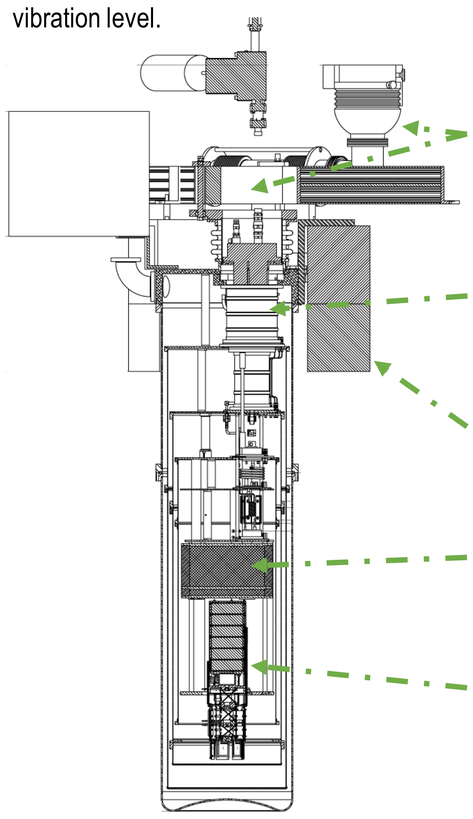


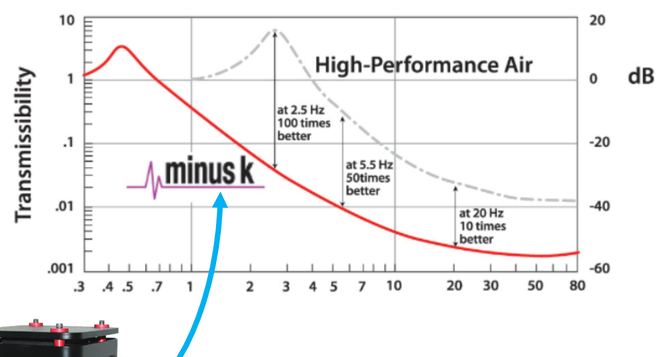
Schedule

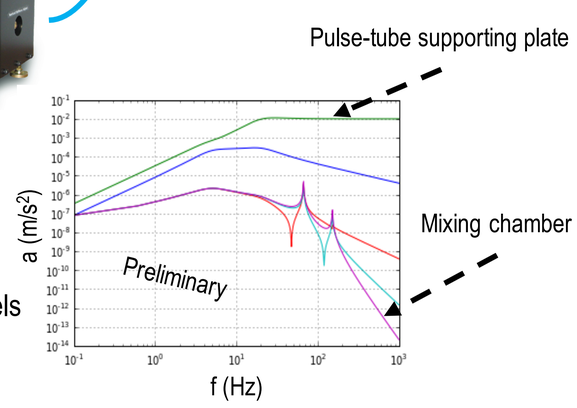
The schedule is driven by the fridge design and production: the first test at the manufacturer site is expected in January 2017. It will then be delivered to Queen's for a few basic tests before being moved to SNOLAB. The fridge will be integrated within the shielded setup there. The goal is to commission CUTE underground at SNOLAB in summer 2017.

Micro-vibration Suppression

Careful consideration is given to minimising micro-vibrations. The cryostat will be mounted on "negative-k" dampers [5] and the pulse-tube cooler and the circulation turbo pump will be mechanically separated from the cryostat itself to achieve the lowest possible vibration level.







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- Xiaohe Zhang, Postdoc
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References

[1] The SuperCDMS Collaboration, SuperCDMS SNOLAB Conceptual Design Report

[2] SNOLAB, https://www.snolab.ca

[3] Philippe Camus, et al., CUTE Project: Conceptual Design Report

[4] Shuo Liu, The limiting background in a detector testing facility for SuperCDMS at SNOLAB, M.Sc. Thesis, Queen's University, 2011

[5] Minus K Technology, http://www.minusk.com