The SNOLAB Science Program

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Abstract. SNOLAB has a rich and varied program in underground science. This report discusses the work in neutrino physics, direct dark-matter search, biology, and mining engineering. SNOLAB has recently implemented a new process for allocation of lab resources, including space allocation. This will be discussed.

1. Introduction to the SNOLAB Facility
SNOLAB is located at the Vale Creighton Mine near Sudbury, Ontario, Canada. The underground facility has a clean laboratory of area 5000 m² and volume 37000 m³. There is a 2km rock overburden (6000 m.w.e.) and the resulting muon flux is 0.27m⁻²day⁻¹. The original SNO cavity, now occupied by SNO+, is barrel shaped with a height of 34m and a diameter of 22m. The Cube Hall, the second largest hall, has a usable space of 15m a cube plus a staircase and height for a crane. The Cryopit, the third large hall, has a cylindrical shape of 15m in diameter and 15m in height plus height for a crane. A chiller can remove 1 MW of heat load from SNOLAB. There is an underground machine shop in the clean space. The low background counting facilities are being upgraded and are reported at this meeting by I Lawson. In addition to the underground facility, there is a surface building with offices, meeting rooms, laboratories, and a warehouse.

Figure 1. An overview of SNOLAB. The clean laboratories including the three large halls are on the left side of the figure. The various service drifts and the air raise for the chiller are on the right side.

Figure 2. The muon flux is shown for many underground laboratories. The figure is taken from [1].
The SNOLAB water plant produces 130 liters/minute of ultra-pure water treated with reverse-osmosis, ion exchange, two wavelengths of UV light (one to break up large organic molecules for removal by ion exchange and the second to kill bacteria), and vacuum degassing and subsequent re-gassing with boil-off nitrogen. The SNO+ collaboration and SNOLAB recently improved the reverse osmosis from the SNO-era water system with the addition of an extra polishing stage taken from the SNO heavy-water plant. In addition the SNO Uranium-chain radon-monitoring system\[2\] is available. SNO+ and SNOLAB also installed the SNO-era heavy-water HTiO radium-monitoring system\[3\] on the light water system. The water system delivers water throughout the underground laboratory.

SNOLAB has an experiment life-cycle process to help projects in all stages from design to decommissioning. Letters of interest may be sent to the SNOLAB Director at director@snolab.ca.

2. SNOLAB Science

SNOLAB has a rich and varied suite of experiments in neutrino physics, astroparticle physics, biology, and mining engineering.

The status of the SNO+ experiment is reported at this meeting by J Maneira. SNO+ is a versatile experiment\[4\] with excellent sensitivity to neutrinoless double beta decay of \(\text{^{130}Te}\), solar, geo and supernovae neutrinos. See figures 3 and 4.

![Figure 3.](image1.png)

**Figure 3.** A worker, viewed from above, cleans the outside of the SNO+ acrylic vessel. Part of the rope net for holding down the acrylic vessel as is the PMT array in the background.

![Figure 4.](image2.png)

**Figure 4.** A summary stacked plot of all backgrounds and a hypothetical \(0\nu\beta\beta\) signal for \(m_{\beta\beta} = 200meV\) with 5 years data taking. The event rate is calculated based 0.3% natural Te loading and a fiducial radius of 3.5m. This is a reproduction of figure 6 from from \[4\].

The HALO detector (Helium and Lead Observatory) is a 73-tonne lead supernova neutrino detector. HALO is appealing because it is sensitive to the neutrino (rather than antineutrino) signal and is thus complementary to the water Cherenkov detectors. Neutrino interactions in the lead produce neutrons which are measured by \(^3\)He proportional counters. The detector is operational and detailed efficiency calibrations are in preparation. Figure 5 shows the detector with one side of neutron shielding removed.

The MiniCLEAN dark matter detector is completely installed and cooling. It is a single phase liquid argon or liquid neon detector. The initial run will be with a natural argon target volume. A spike test in which \(^{39}\)Ar is added to the detector is planned. In that run the rate of...
Figure 5. The HALO detector (with one side of neutron shielding removed) is shown. The lead bricks, painted green, moderating plastic, proportional counters, and calibration tubes are shown.

$^{39}$Ar events will be increased ten-fold and pulse-shape discrimination will be studied. Figures 6 and 7 show steps in the installation.

The DEAP-3600 detector[5] has been taking commissioning data since the start of 2015. Optical calibrations have been performed. Care was taken during construction to limit backgrounds. The status of the DEAP-3600 detector was reported at this meeting by P Giampa and B Beltran. The detector assembly and installation of the process systems is complete. Studies of radon backgrounds in the DEAP-1 prototype are published [6] and a study of pulse-shape discrimination is in revision. See figures 8 and 9.

Both MiniCLEAN and DEAP-3600 hold large volumes of cryogens. A detailed set of safety systems and plans were put in place to ensure that over-pressure protection and oxygen-deficiency hazards were mitigated.

The DAMIC detector[7] searches for low-mass dark matter with CCD detectors and details were presented at this meeting by P Privitera and in the poster session by DT Machado.

The PICO collaboration[8] has two detectors at SNOLAB: PICO-2L, a 2 liter prototype bubble detector and PICO-60, a 60 kg bubble detector. Both have high sensitivity to nuclear recoil, low sensitivity to electrons and gamma rays, and can contain various liquid targets with both spin-dependent and spin-independent couplings to WIMP dark matter. Targets have included CF$_3$I and C$_3$F$_8$. Details were presented at this meeting by R Neilson. Since this meeting PICO has submitted new results for the 2L detector [9]. See figures 10 and 11.

The New Experiments with Spheres (NEWS-SNO) is being developed for a gas phase detector to allow for large target mass, simple geometry and excellent energy resolution.

SuperCDMS will locate at SNOLAB. SuperCDMS uses mature technology and will increase the mass of Ge and Si crystal detectors for the SuperCDMS-SNOLAB run. Currently detailed engineering and planning is underway.
Figure 6. MiniCLEAN is moved by crane into position. The detector is currently cooling.

Figure 7. The MiniCLEAN inner vessel is seen installed on the lower half of the outer vessel.

Figure 8. The DEAP-3600 detector viewed from the outside. The detector is in a stainless steel shell and is submerged in ultrapure water in a shielding tank.

Figure 9. The sensitivity of DEAP-3600 is shown. It is approximately 20 times more sensitive than the result from LUX (2014) at 100 GeV.

Many other neutrino and particle astrophysics experiments have expressed interest in SNOLAB including nEXO, Ge 1T (Majorana), DMTPC, and a PINGU test facility.

SNOLAB has two approved experiments in biology and medicine. Fruit-fly metabolism is studied by a Laurentian University group led by Canada Research Chair Thomas Merritt and...
underground data are compared with results of bench-top experiments on surface in which only one variable is changed. This work has the goal of understanding metabolic changes that occur in underground workers. Secondly, a group from McMaster University and the Northern Ontario School of Medicine is studying the effects of lower-than-normal doses of radiation on development of organisms. Currently experiments are in progress underground with whitefish embryos.

SNOLAB hosts the Center of Excellence in Mining Innovation, which is a hub for mining research and small-to-medium sized enterprises in the mining sector.

3. Conclusion
SNOLAB has an active scientific program in a variety of fields. The facility has undergone significant development in recent years and will continue to do so, especially in regards to low background counting and support of projects.

References
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