Commissioning the SNO+ Detector

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Abstract. SNO+ is a multipurpose liquid scintillator neutrino experiment based at SNOLAB in Sudbury, Ontario, Canada. The experiment’s main physics goal is a search for neutrinoless double beta decay in Tellurium-130, but SNO+ will also study low energy solar neutrinos, geo- and reactor- antineutrinos, among other topics. We are reusing much of the hardware from the original SNO experiment, but significant work has taken place to transform the heavy water detector into a liquid scintillator detector. We present upgrades and improvements to the read-out electronics and trigger system to handle the higher data rates expected by a scintillator experiment. We show the successful installation and testing of a hold-down rope net for the acrylic vessel to counter-act the buoyancy of organic liquid scintillator. We also describe the new scintillator process plant and cover gas systems that have been constructed to achieve the purification necessary to meet our physics goals. We are currently commissioning the experiment with ultra-pure water in preparation for filling with scintillator in early 2017 and present the current status of this work.

1. SNO+ Detector
SNO+ is a liquid scintillator experiment currently being commissioned in SNOLAB, Canada. Its physics goals include neutrinoless double beta decay using $^{130}$Te, solar neutrinos, reactor anti-neutrinos, geo anti-neutrinos, supernova neutrinos and exotic searches such as invisible nucleon decay [1]. SNO+ reuses the existing infrastructure of SNO, consisting of a 6 m radius acrylic vessel (AV) surrounded by almost 10,000 photomultiplier tubes. A depth of 6000 m.w.e provides shielding from cosmic muons. In SNO+, the acrylic vessel will be filled with liquid scintillator and surrounded with a shielding of ultra-pure water. Significant work has taken place to transform the heavy water detector of SNO into a liquid scintillator detector.

2. Electronics & Trigger Upgrades
SNO+ is re-using the front-end from SNO but has improved the read-out electronics in order to compensate for the higher data rates and light output expected by a scintillator experiment.

- New XL3 readout cards will handle the higher data rates while also providing ethernet controls for the front-end boards.
- MTC/A+ trigger cards have the ability to handle the larger current load created by the greater number of PMT hits. These also provide baseline stabilisation and monitoring of triggers as well as the ability to introduce reprogrammable trigger logic.
- The CAEN v1720 digitizer adds the triggered waveforms to the event data, which will be used in the tagging of instrumental backgrounds.
• TUBii is an additional trigger utility board providing a variety of useful tools including pulser and delays for calibration sources, extra trigger ports and a backup clock. This uses a MicroZed development board containing a Zynq chip capable of running an FPGA alongside a Linux processing system. This allows on the fly reprogrammable logic of triggers. These have been commissioned during the initial air-fill and partial water-fill runs.

3. Data Acquisition Upgrades
A new DAQ system has been developed for SNO+. This uses a modular approach which decouples the data flow from the detector control (ORCA) and monitoring tools, providing more stability and increased control. This has been stress-tested at high rates during air-fill and partial water-fill running. Graphical tools have been developed allowing realtime time-series monitoring of data up to an event rate of 20kHz. A slow control system provides web-based monitoring and alarms. The detector state for each run is recorded in a database, allowing for clear reproducibility of individual runs.

“Mock Data Challenges” have provided tests of the data flow from detector hardware, through the data processing system, to storage on the Grid and point of use of analysis. A graphical user interface has been implemented for both expert and non-expert operators, with a varying amount of control. The development of standard run scripts was used successfully to take both production and calibration data.

4. Hold-Down Ropes
The SNO+ hold-down rope net was installed in 2012. This is required to counteract the buoyancy effect of the scintillator in the acrylic vessel [2]. In 2016, tests were carried out to ensure this system responded correctly by mimicking the density change that will come when filling the AV with scintillator. This was achieved by filling the outer cavity water level higher than the water level within the AV. The outer cavity water level was slowly raised to be 1.2 m above the water level in the AV, causing the AV to rise, testing the stretch of the hold-down rope net. The ropes behaved exactly as expected under the full upward force of 1260 kN.

5. Scintillator Plant & Cover Gas
A new scintillator process plant has been constructed to achieve the purification of scintillator necessary for a double beta decay search. Major tasks completed include:

• Helium Leak Checking
• Cleaning and Passivation
• Fire Suppression System
• Piping Insulation
• Water Commissioning.

We are preparing to next commission the plant with scintillator.

A new Universal Interface (UI) controls access to the detector while maintaining a clean volume. It provides glove box control of deployed calibration sources, level sensors for the scintillator, PMTs for vetoing background events, and other vital instrumentation. Installation of lower UI was completed in May 2013 and a protective sliding floor was added in October 2014. The upper UI will be installed in October 2016.

An improved Cover Gas System provides a $^{14}$N barrier to prevent radon gas from the mine air entering the detector. Redesigned from SNO to cope with the more stringent radon requirements of SNO+, it uses flexible bags to compensate for the changes in pressure between the detector and on deck. The system connects to the Upper UI through ultra clean vacuum flanges. This was installed and commissioned in 2014.
6. Summary
Much work has been done to upgrade the SNO D$_2$O experiment to SNO+, a liquid scintillator experiment. This includes new electronics and trigger systems, a hold-down rope net, a new ultra clean process plant and a radon barrier cover gas system. We are currently filling SNO+ with ultra pure water in preparation for water-fill running beginning in October. A leak in the cavity wall was encountered but has been repaired. The initial water phase allows commissioning of electronics, DAQ, calibration systems as well as physics searches including invisible nucleon decay. The scintillator phase will begin in 2017, and we will add tellurium in late 2017.

References
[1] Andringa S, et al. 2016 Advances in High Energy Physics 2016 Article ID 6194250
[2] Bialek A, et al. 2016 NIMA 827 152-160