

NuPhys2016-Liggins
April 28, 2017

SNO+ Commissioning Status

BILLY LIGGINS ON BEHALF OF THE SNO+ COLLABORATION

PPRC

Queen Mary University of London, London, UK

SNO+ inherits much of its infrastructure from the Noble prize winning SNO detector. However due to the two orders of magnitude increase in light output in liquid scintillator many upgrades have been made. Details of these upgrades and their commissioning status are presented, along with a update on the current status of SNO+.

PRESENTED AT

NuPhys2016, Prospects in Neutrino Physics Barbican
Centre, London, UK, December 12–14, 2016

1 SNO+

SNO+ is general purpose neutrino detector which will search for neutrinoless double beta decay ($0\nu\beta\beta$) in 1.3T of ^{130}Te loaded in 780kT of LABPPO [1]. SNO+ is situated at SNOLAB in Sudbury, Ontario, Canada. SNOLAB is 2 km (6000 m.w.e) below ground in shaft 9 of the active Creighton Nickel mine. At this depth cosmogenic backgrounds are reduced; with the total muon flux less than $10^{-9} \text{ cm}^{-2} \text{ s}^{-1}$. SNO+ uses the same 6 m radius acrylic vessel (AV) as SNO and is observed by the same ~ 9300 8 inch Hamamatsu R1408 photomultiplier tubes providing a coverage of 54%. The detector is housed in a cavity filled with ultra pure water. While commissioning the detector for $0\nu\beta\beta$ phase SNO+ will be sensitive to invisible nucleon decay and solar axions during the initial water phase. During the second phase, with a detector full of scintillator, SNO+ will search for low energy solar neutrinos as well as Geo and reactor anti-neutrinos. A supernova would be seen across all three phases of running. A substantial amount of work has been done to transform the detector from a heavy water based detector to a liquid scintillator detector.

2 Detector and Processing Plant Upgrades

2.1 Hold Down Ropes

As the LABPPO is less dense than water, the AV will experience a significant buoyant force during scintillator fill. A hold down rope system was designed and installed in 2012 and has been tested at various points throughout commissioning. Testing was achieved by filling the cavity to a level above that of the AV fill level thus manufacturing a buoyant force. The ropes system was found to work as expected under an upward force of 1260 kN.

2.2 Scintillator Plant

A new processing plant had been constructed to achieve the purity of scintillator needed to ensure the low backgrounds required, $> 10^{-17} \text{ g/g}_{\text{LAB}}$. Many tasks have been undertaken and completed; Helium leak checking, cleaning and passivation, fire suppression system installation, pipe insulation and water commissioning. The plant is currently being commissioned with 40 tonnes of LABPPO.

2.3 Cover Gas

The nitrogen cover gas that existed on SNO, has been upgraded to satisfy the cleanliness requirements for low background. The cover gas seals the detector from high levels of Radon gas in the mine air. The system also adjusts for pressure differentials

between the detector and the mine. The upgrades were installed and commissioned in 2014.

2.4 Universal Interface

A new universal interface (UI) was designed and installed in late 2016. The UI controls access to within the detector allowing the deployment of various calibration sources, see §5.2. The UI also includes various level sensors and veto PMTs.

3 Electronic Updates

With the increased light output of liquid scintillator, the SNO+ electronics have been upgraded to deal with the increase in current and trigger rate. New XL3 readout cards can deal with the expected trigger rates, while also providing ethernet communication with the front end boards. The MTC/A+ trigger cards can handle the increase in PMT hits, as well as providing better baseline stability and monitoring. The ability to introduce reprogrammable trigger logic has also been added. The CAEN v1720 digitizer aids in instrumental background reduction through outputting the triggered waveforms on each event. An additional trigger utility board, TUBii, adds an extensive suite of tools tying many parts of the experiment together. TUBii is built around a MicroZed development board containing a Zynq chip running a FPGA alongside a Linux processing system. Features include synchronisation of calibration systems with detector readout, extra trigger ports and detector wide timing verification. TUBii also introduces on the fly reprogrammable trigger logic. The full electronics system (with upgrades) has been testing and commissioned in all phases to date.

4 Data Acquisition Upgrades

The data acquisition system (DAQ) has undergone a complete overhaul, which saw data flow decoupled from detector controls (ORCA). Taking this modular approach provides improved detector control and stability. Stress tests have taken place on various occasions throughout air and partial water fill phases. The detector control GUI provides both user and expert operation modes, giving increased confidence in detector output. Online monitoring tools have been developed capable of displaying data at 20 kHz. These tools offer the possibility of monitoring the detector from anywhere in the world, added to a potential remote shifters tool box. An extensive alarm sever with accompanying GUI, which monitors both short and long time changes has been implemented. Improved detector readout during ramping the detector to high voltage has been implemented, providing a responsive GUI allowing controllers to check for abnormalities channel to channel. The detector state is committed to a database on

a run by run bases, allowing for individual run reproducibility during offline analyses. Grid based processing and storage channels have been updated accounting for the increased trigger rate. The full DAQ has been stress tested in various “mock data challenges” which have helped in finding potential bottle necks and speed ups.

5 Calibration

5.1 In situ sources

The Embedded LED/Laser Light Injection Entity (ELLIE) is a new multi purpose optical calibration system. It consists of three sub systems, AMELLIE, SMELLIE and TELLIE. AMELLIE will measure attenuation in scintillator, thus monitoring scintillator quality, and is due to come online for scintillator phase. SMELLIE uses a super continuum laser to measure the scattering length of the detecting medium. SMELLIE will run across all phases of data taking and at the time of writing is currently being commissioned. TELLIE uses high frequency LEDs to measure the timing response of the PMTs and was fully commissioned in the spring of 2017. For more details on the in suit calibration in SNO+ see [2].

5.2 Deployed sources

Substantial effort has gone into updating the deployed calibration sources from SNO ready for the SNO+ scintillator phase. Due to the increased cleanliness requirements new deployment mechanisms have been developed, machined and shipped to SNO-LAB. A new “laserball” reducing the self shadowing angle from 30° to 7° has also been designed and constructed.

6 Current Status

SNO+ is currently in operational mode currently undergoing water calibration. The detector electronics were switched on in early 2017 and have been are functioning and stable. Water fill is due to finish in late spring 2017, however the water level has been above the PMTs for some time allowing for calibration to take place. Both in situ and deployed source calibration is on going.

7 Outlook

With calibration complete SNO+ will search for invisible nucleon decay as well as characterising the state of the detector. Scintillator fill is scheduled to commence in

August 2017 and to be completed by the end of the year. The Scintillator phase will build upon the work done in the previous phase and assess the background levels present in the detector, optical studies will also take place. Reactor and Geo anti-neutrino studies will be undertaken and background level permitting low energy Solar signals will be measured. With the background studies complete, loading with ^{130}Te will begin, thus commencing the $0\nu\beta\beta$ phase. This is scheduled for early 2018.

References

- [1] Andringa S, et al. 2016 Advances in High Energy Physics 2016 Article ID 6194250
- [2] E. Falk, et al. “Commissioning of ELLIE for SNO+” NuPhy2016 conference proceedings.