Calibrations in SNO+

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Introduction

Using the infrastructure of the Sudbury Neutrino Observatory, SNO+ is intended to provide a scalable measurement of neutrino-less double beta decay[1]. Located in SNOLAB in the Vale Creighton Mine, SNO+ is in an excellent location for low background neutrino detection. Measurements of reactor, solar, and geo neutrinos may be conducted. At present the detector is half full of Linear Alkylbenzene (LAB). Understanding the response of the LAB detector is essential for proper evaluation of physics measurements. The first calibration activities for SNO+ with scintillator are described here.

The SNO+ Detector

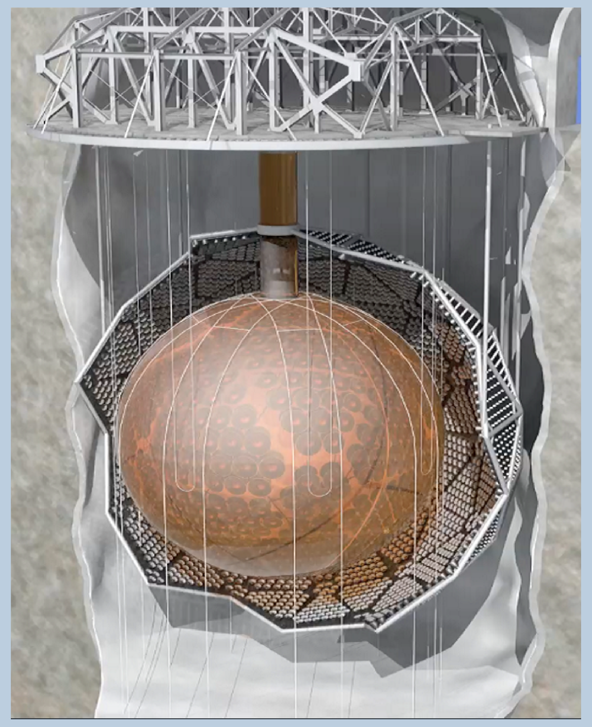

Figure 1: Rendering of SNO+

- Located under 6 km water equivalent rock overburden.
- Acrylic vessel (AV) 6 meters in radius
- Suspended in a cavern 30.5 meters in height.
- SNO+ scintillator fill at 364 t out of 780 t.
- ~9300 Photo multiplier tubes with a 54% coverage supported by an 8 m radius geodesic structure(PSUP).
- Anticipate 2 g/L final PPO loading
- PMT light yield, efficiency, and angular response needs to be evaluated.

Source Deployment Systems

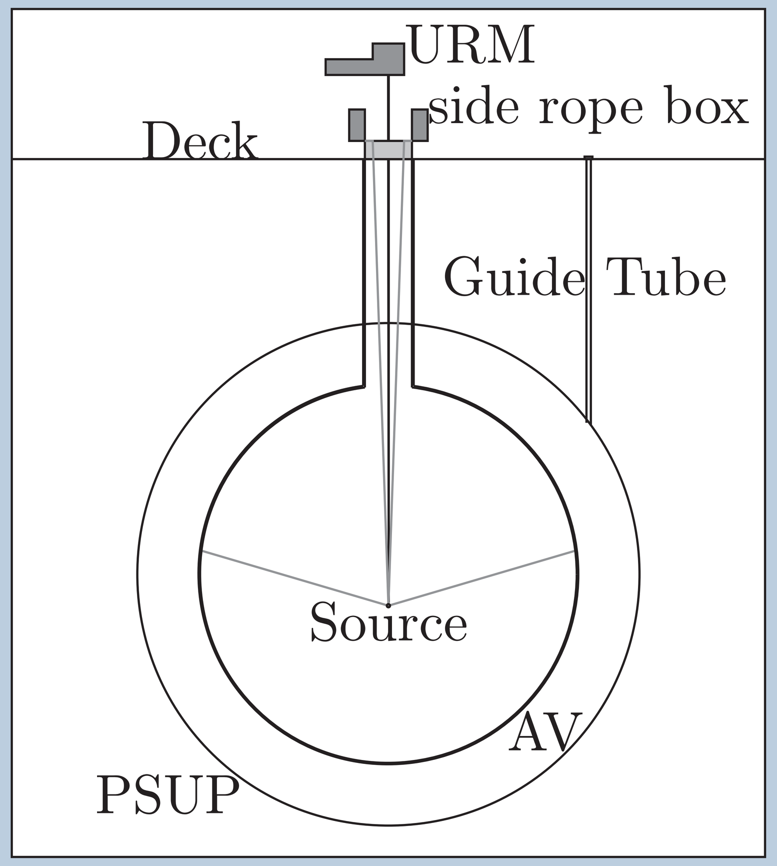

Figure 2: Schematic of SNO+ detector in XZ plane with calibration mechanisms

- Source retrieved from AV using mechanisms which store the umbilical and measure the source position (URM).
- Services are supplied to deployed sources via umbilical tubes.
- Off-axis positions in a plane reached with side rope systems.
- Calibration sources can also be deployed externally via guide tubes avoiding contact with the detector medium internal to the AV

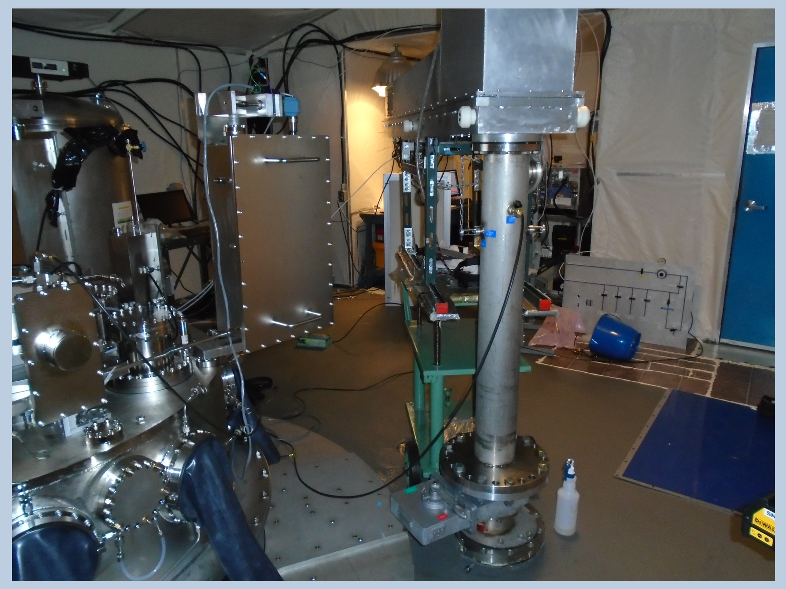

Figure 3: URM mounted on a guide tube next to the SNO+ Universal Interface

Radioactive Sources

Figure 5: N16 source

- Energy calibration uses AmBe source to provide coincident γ [2]
  - Prompt signal (4.4 MeV) followed by neutron capture (2.2 MeV on ^{1}H)
  - Neutron detection efficiency measured
- Supported by a tagged gamma source.
  - ^{16}N gas injected via the umbilical [3]
  - $^{16}N \rightarrow ^{16}O^{*} + e^{-} + \bar{\nu}_{e}$ and $^{16}O^{*} \rightarrow ^{16}O + \gamma(6.1\text{MeV})$

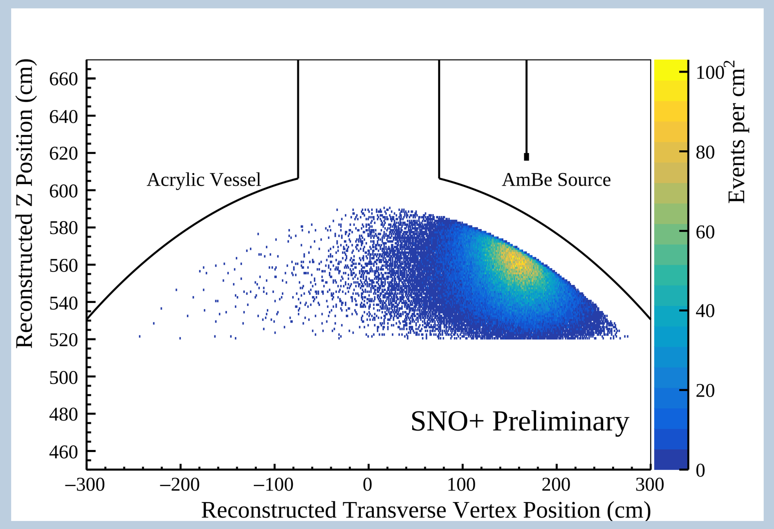

Figure 6: Reconstructed AmBe calibration events reconstructed in 22 t of LAB with 0.5 g/L PPO loading from a source deployment external to the SNO+ AV.

- Sources to be deployed in scintillator include AmBe, ^{46}Sc (tagged), and ^{137}Cs (untagged) sources.

Internal Optical Source

- Optical fibres embedded in PSUP inject LED or laser light into detector
- Monitors PMT timing, PMT efficiency and optical scattering. See PMT Calibration poster.
- Complement deployed optical (laserball) source.

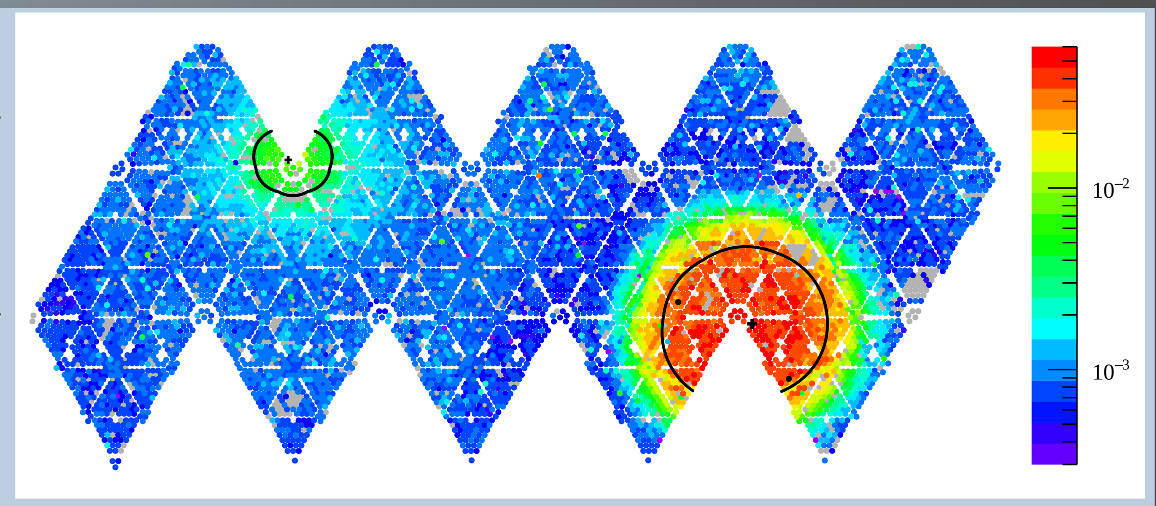

Figure 4: Light from embedded LED source

References

[1] SNO+ Collaboration. The SNO+ Experiment. In *DOE Long Range Plan Town Hall*, 2014.

[2] M.R. Anderson et al. Measurement of Neutron-Proton Capture in the SNO+ Water Phase. 2 2020.

[3] M.R. Dragowsky and others. The 16n calibration source for the sudbury neutrino observatory. *Nucl. Instr. Meth. Phys. Res*, A481:284–296, 2002.

[4] B.A. Moffat et al. "Optical Calibration Hardware for the Sudbury Neutrino Observatory". *Nucl. Instr. Meth. Phys. Res*, A554:255–265, 2005.

Scintillator Energy Calibration

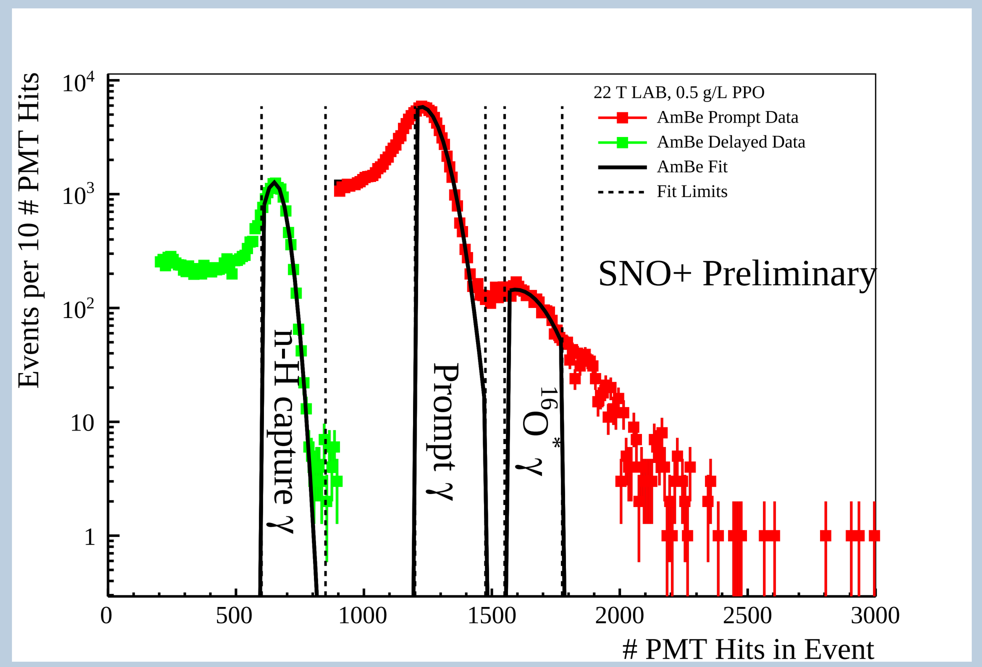

Figure 7: Data collected from an AmBe source deployment external to the SNO+ acrylic vessel.

- Fit calibration peaks to determine Number PMT Hits generated at specific energies
- Peak values plotted versus expected energy to determine energy response of scintillator

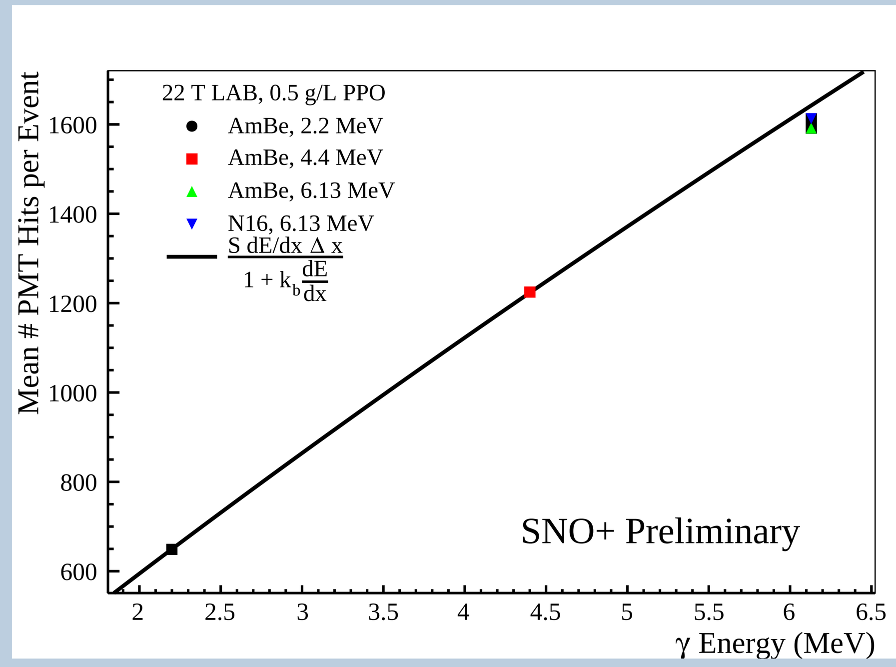

Figure 8: Light yield curve from the first SNO+ calibration data in scintillator. A light yield of ~300 PMT Hits/MeV is observed for 0.5 g/L PPO, not considering Cherenkov light and source container effects.

Outlook

- SNO+ scintillator fill is ongoing. Data collection has continued throughout
- Calibration of data is essential for potential physics studies. External deployments were conducted in Fall 2019. An estimated light yield for an interim scintillator mixture with reduced PPO loading is 300 Hits/MeV.
- Evaluation of backgrounds for calibration is ongoing. Preparations for in-situ calibrations also in progress which require new hardware to accommodate low contamination levels and new material requirements.