Optical calibration of SNO+
Overview and first results

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Abstract
This poster describes the status of the optical calibration programme for SNO+, which has as its main goal the search for neutrinoless double-beta decay of $^{76}$Ge (see the other SNO+ posters presented here). This isotope is used as a source to test the PMT performance. The optical calibration is primarily done using external sources. Here we describe these systems, the overall programme and show results from commissioning data that has been acquired recently.

Introduction
The optical calibration of SNO was based on a uniformly emitting light source, the laserball [1], and an $^{7}$Li source [2], creating a well understood amount of Cherenkov light. Both sources were frequently deployed for a dedicated calibration campaign. The $^{7}$Li source promised to a minimum. The laserball design has been optimised, based on the SNO experience. The Cherenkov source is a modification of the $^{7}$Li source. In scintillator, the Cherenkov light is overwhelmed by scintillation light and an acrylic sphere is added to act as the Cherenkov medium for the high-energy electrons emitted by $^{7}$Li.

Embedded optical calibration: the ELLIE system
ELLIE consists for three systems (TELLIE, SMELLIE, and AMELLIE) that inject light from the PMT array into the detector. The light is generated outside and fed into the detector using optical fibres. The system can be run continuously at a low rate of several Hertz. In this mode, the events are interspersed with physics data and tagged with a dedicated trigger. Alternatively, it can be run at a high rate (kHz) for dedicated calibration runs.

TELLIE injects ultra-fast (1 ns risetime) light pulses generated by 510 nm wavelength LEDs in a wide beam along the radial direction. The light is injected from 92 points on the PMT array that are evenly distributed around the scintillator target. This system is used for the timing calibration, gain calibration and monitoring of the scintillator optical transparency.

SMELLIE injects mildly collimated, sub-ns laser pulses of four different wavelengths into the detector from four different locations on the PMT support structure. From each location three beams are sent through the detector at 0, 10 and 20 degrees w.r.t. the radial direction. This system will be used to measure the scattering properties of the detector medium.

AMELLIE injects ultra-fast LED pulses generated by different wavelength LEDs from four different locations on the PMT support structure. From each location three beams are sent through the detector at 0, 10 and 20 degrees w.r.t. the radial direction. This system will be used for monitoring the optical attenuation light.

TELLIE commissioning
Figure 1: Illustration (a) of ELLIE injection point (green wide beam) and SMELLIE injection point (three multi-colour narrow beams). Photo (b) of the mounting plate with fibres on the PMT array, injecting light into the detector.

SMELLIE commissioning
The central SMELLIE system has been preliminarily commissioned using its fibre switching system to direct light into the first six installed SMELLIE fibres. The very low time dispersion of the pulses was verified across the wide range of available laser intensities that can utilise the full charge capability of the PMTs. Each laser pulse is recorded with high time resolution by the dedicated monitoring PMT and added to the event data stream. The system was integrated with the SNO+ DAQ and interlock system. Commissioning will complete after the cavity is completely filled with water.

Laserball
The laserball is a 10 cm diameter quartz flask, filled with a diffuser gel, which is coupled to a nitrogen laser. The wavelengths can be altered by inserting special dyes into the beamline. The laserball has been optimised by using fully synthetic quartz with very low radon emanation (less than 30 atoms per day) for the flask and lowering the neck diameter to the minimal possible value, to minimise shadowing. The final laserball for SNO+ is being constructed now.

Cherenkov source
The Cherenkov light source is based on a modification of the $^{7}$Li electron source used successfully in SNO. This source consists of a 4-cm thick acrylic sphere, into which $^{7}$Li is transported and allowed to decay. The decay cumbber will be lined with opaque paint and a reflective wavelength-shifting layer. The resulting light will be used to tag the event. A prototype has been successfully constructed and the final source is under construction now.

Conclusions
The optical hardware for SNO has been significantly expanded and optimised for the use in SNO+. The embedded optical sources are being commissioned at SNO+, and the other sources are in the final production stages.

References