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 ^{130}Te (see the other SNO+ posters presented here). This isotope is loaded into the 780-tonne liquid scintillator target. As the radio-purity requirements for SNO+ are much more stringent than for SNO, several new optical calibration systems have been developed in order to provide a detailed understanding of the response of the surrounding PMT array. 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 ^{8}Li source [2], creating a well understood amount of Cherenkov light. Both sources were frequently deployed for a dedicated calibration campaign.
The SNO+ allowed radon level (^{238}U: 10^{-18} g/g or 13.4 decays/day) is two orders of magnitude more stringent than in SNO. To ensure the required radio-purity, source deployments will have to be kept to a minimum. The **ELLIE** system is embedded on the PMT array surrounding the SNO+ target for this reason.
The **laserball** will be deployed to verify both the position dependence of the optical response throughout the target volume, as well as a cross check with the ELLIE system. The laserball will specifically calibrate the PMT (and light concentrator) angular response, the scintillator extinction length and the relative PMT efficiencies. The laserball design has been optimised, based on the SNO experience.
The **Cherenkov source** is a modification of the SNO 16[N] 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 16[N].

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 ran 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 ran 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 points from the PMT array. From each location two different beams are sent through the detector at 0 and 10 degrees w.r.t. the radial direction. This system will be used for monitoring the optical attenuation light.

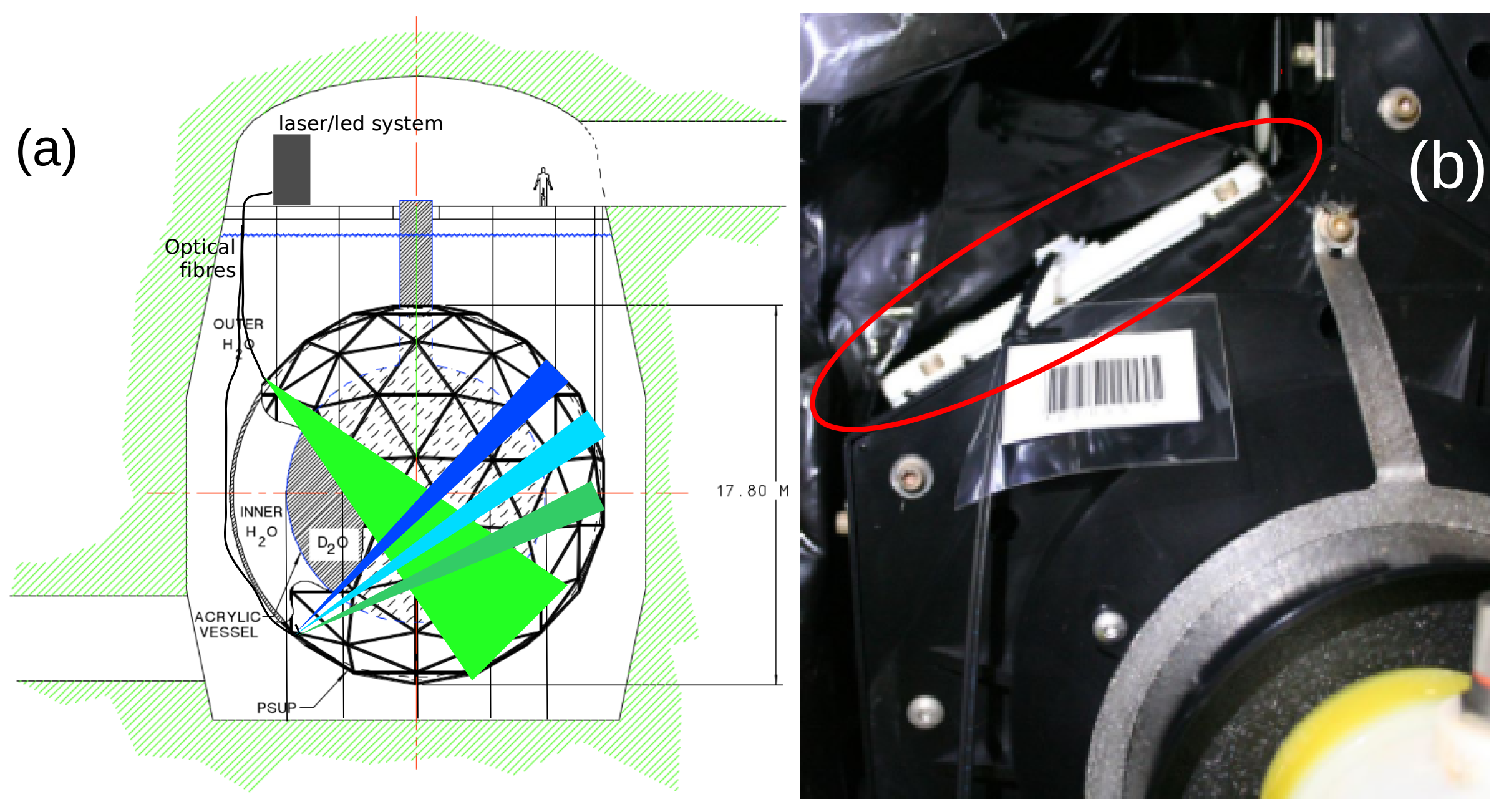

Figure 1: *Illustration (a) of ELLIE injection point (green wide beam) and SMELLIE injection point (three multi-colour narrow beams). Photo (b) of the mounting plate with fibres on the PMT array, injecting light into the detector.*

TELLIE commissioning

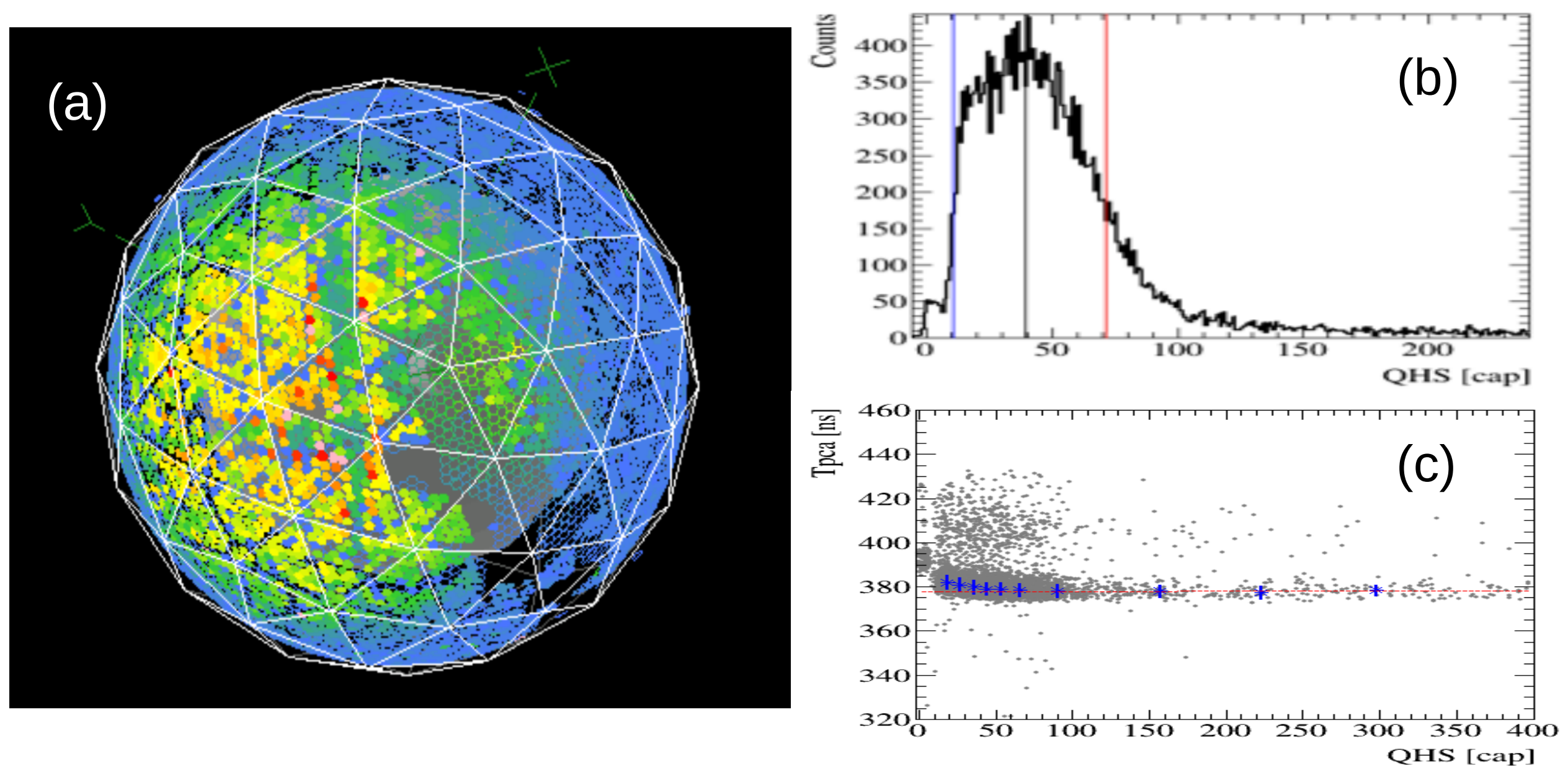

Figure 2: *Picture (a) shows a hit map of the PMT array of an TELLIE commissioning run, with only air in the cavity and the detector. The system is able to verify the position of the hold-down ropes. The graphs show, as an example, the charge (QHS) spectrum (b) and the timing calibration, including the charge dependence (c) for one PMT. The three lines in the charge spectrum (b) indicate the fitted parameters for the gain calibration. The red line in the time calibration (c) shows the timing offset.*

The TELLIE system has been installed at SNO+. Most of the bottom fibres have been installed on the PMT array, as these are relatively easy to access from the cavity floor. The rest of the fibre installation will be completed during the water fill (currently in progress) of the cavity. The system has already been extensively used for electronics commissioning and it has been shown that the performance meets the specification.

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.

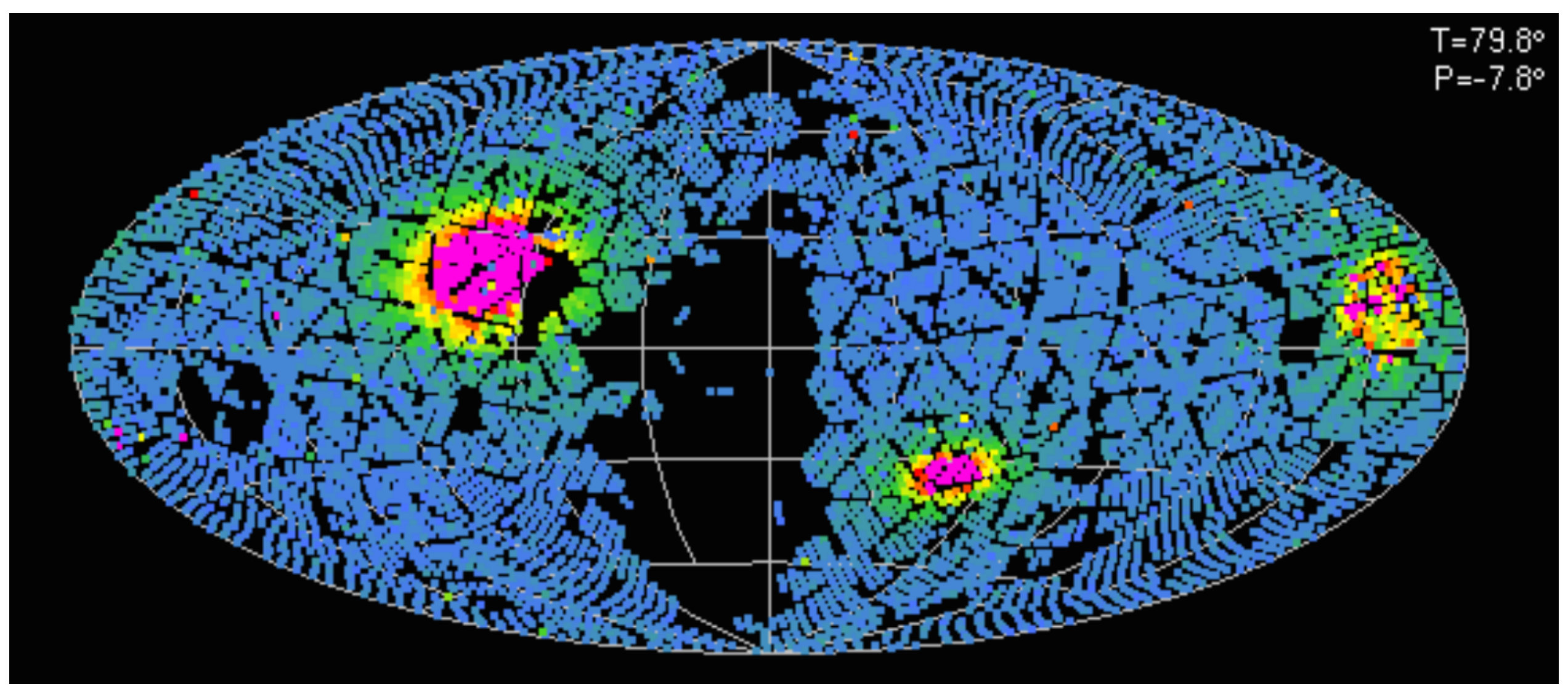

Figure 3: *Event display showing the integral of many events for the recent commissioning of the system at SNO+ (with only air in the cavity and the detector).*

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.

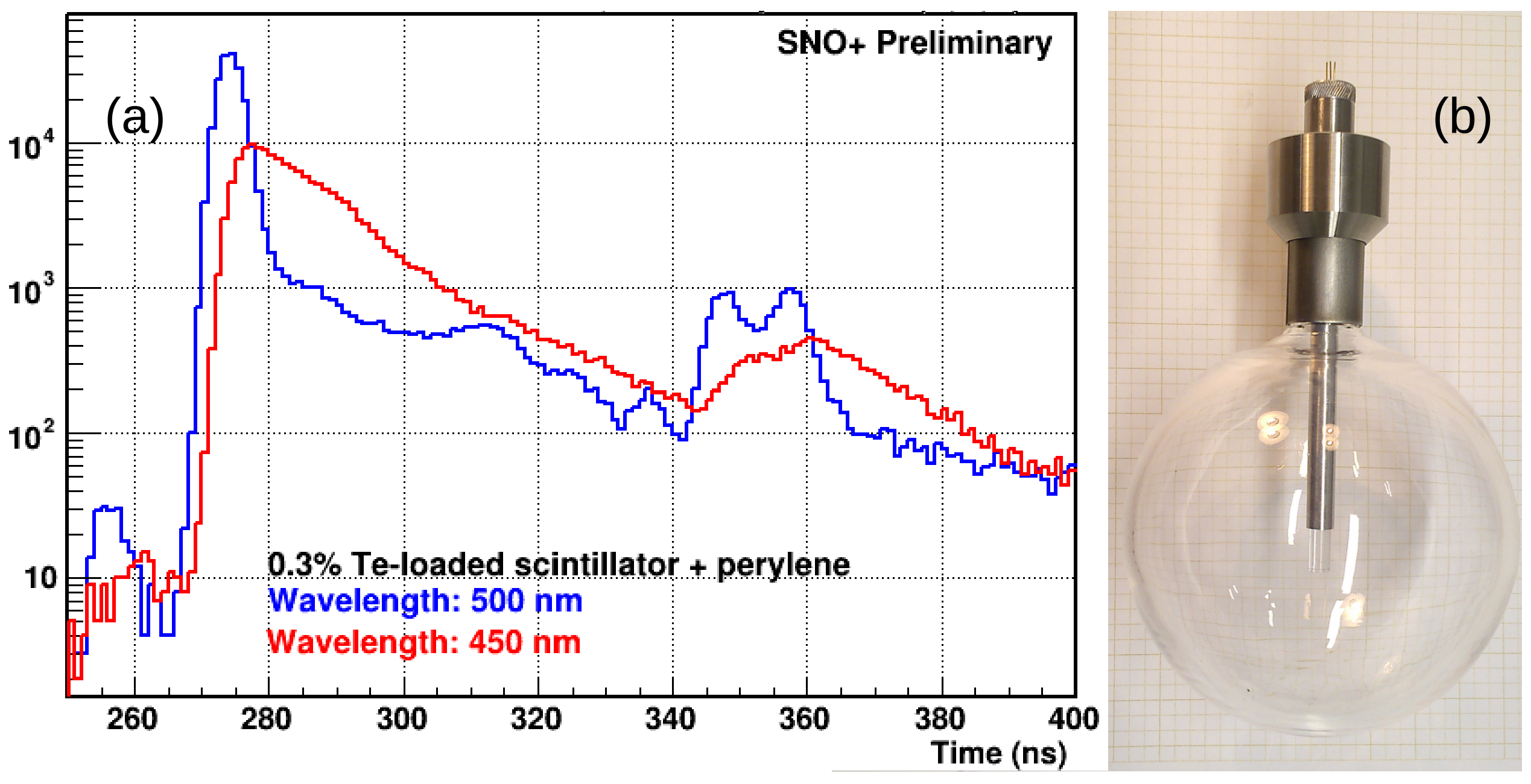

Figure 4: *Simulated PMT hit times for the laserball with a 450 nm and 500 nm dye (a) and the improved laserball with diffuser gel (b), showing the low radioactivity flask with a minimal diameter neck.*

Cherenkov source

The Cherenkov light source is based on a modification of the ^{8}Li electron source used successfully in SNO. This source consists of a 6 cm thick acrylic sphere, into which ^{8}Li is transported and allowed to decay. The decay camber will be lined with opaque paint and a reflective wavelength-shifting layer. The resulting β^- will be stopped in the acrylic wall and produce Cherenkov light. This provides a well understood source of non-isotropic light for calibrating detector response independent of the light yield of the SNO+ LAB/PPO scintillator. The subsequent αs will produce scintillation light that will be used to tag the event.
A prototype has been successfully constructed and the final source is under construction now.

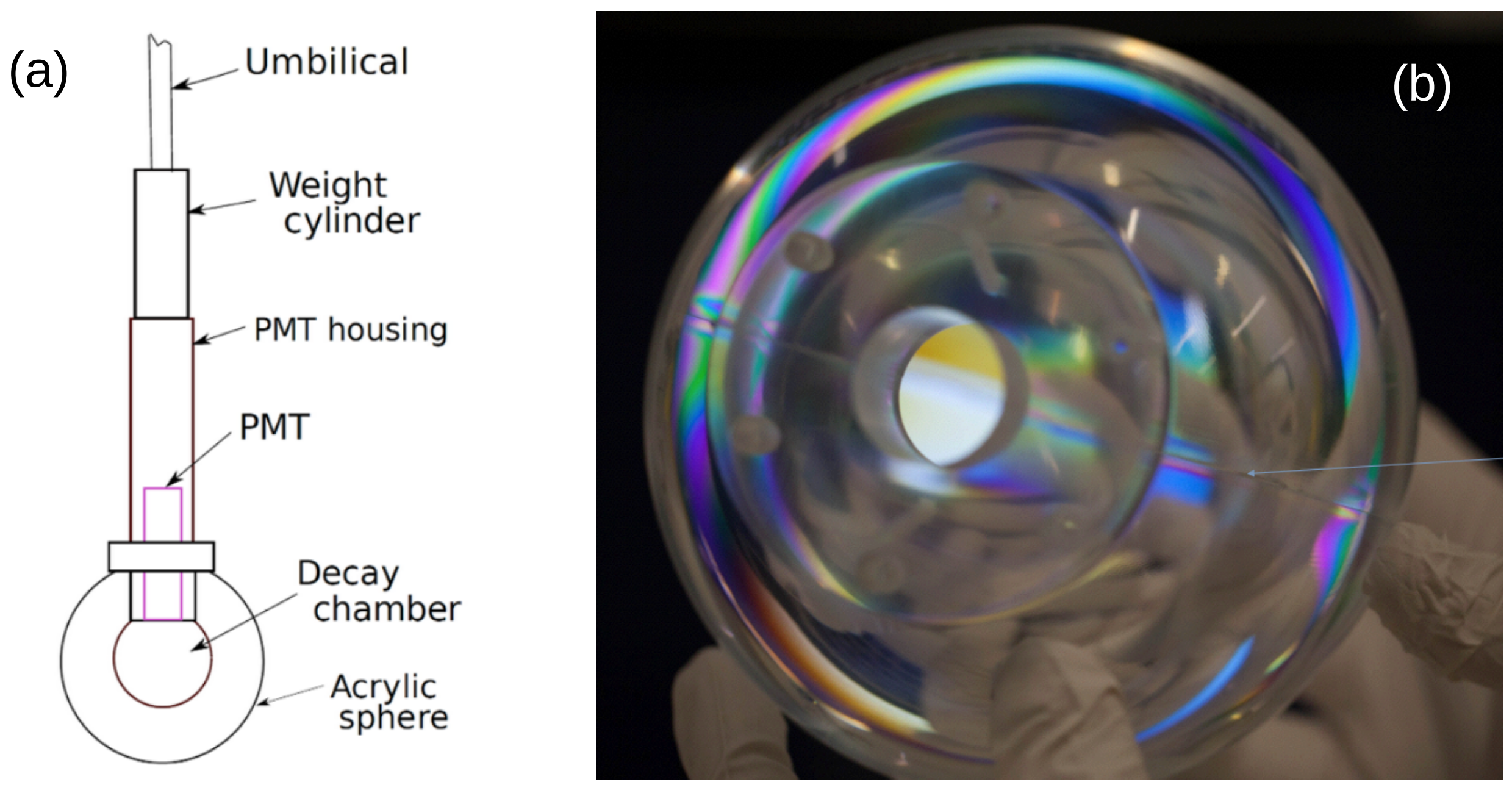

Figure 5: *The Cherenkov source design (a) and a prototype acrylic sphere (b).*

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

[1] *Optical Calibration Hardware for the Sudbury Neutrino Observatory*, B.A. Moffat, R.J. Ford, F.A. Duncan, K. Graham, A.L. Hallin, C.A.W. Hearns, J. Maneira, P. Skensved, NIMA **554** (2005) pp. 255-265

[2] *The* ^{8}Li *calibration source for the Sudbury Neutrino Observatory*, N. J. Tagg, A. Hamer, B. Sur, E. D. Earle, R. L. Helmer, G. Jonkmans, B. A. Moffat, J. J. Simpson, arXiv:nucl-ex/0202024