SMELLIE: A Laser Calibration System for SNO+

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On behalf of the SNO+ collaboration

The SNO+ Experiment

- Main aim: Neutrinoless double beta decay ($0\nu\beta\beta$) in ^{130}Te.
- Three experimental phases:
  - **U**ltra-**p**ure **w**ater (UPW) - data taking since early 2017.
  - Pure scintillator (~780 tonnes LABPPO + bisMSB) – filling mid-2018.
  - Te loaded scintillator (0.5% ^{nat}Te by mass) – loading in 2019.
- Other physics aims: invisible nucleon decay, supernova neutrinos, solar neutrinos, reactor and geo antineutrinos.

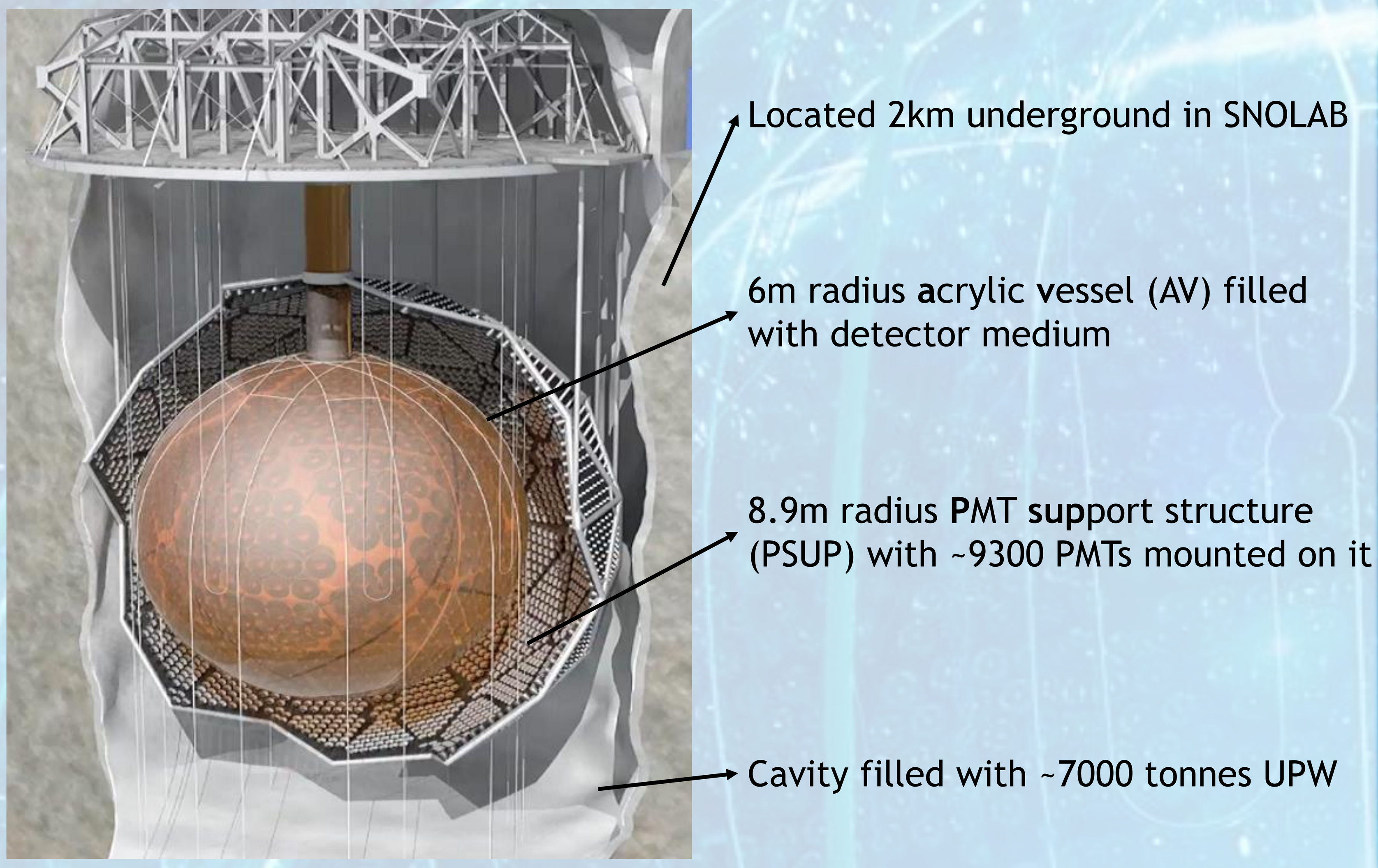

Fig. 1: An artist's impression of the SNO+ detector.

Profiling Beams

- Need to be able to simulate accurate beams.
- Aim is to characterise our beams in terns of polar and azimuthal angles with respect to the centre of the beamspot.
- Water data makes this possible due to long scattering and absorption length and no re-emission.
- Requires us to take account of all detector effects:
  - Shadowing caused by detector elements,
  - PMT efficiency,
  - Solid angle, etc.

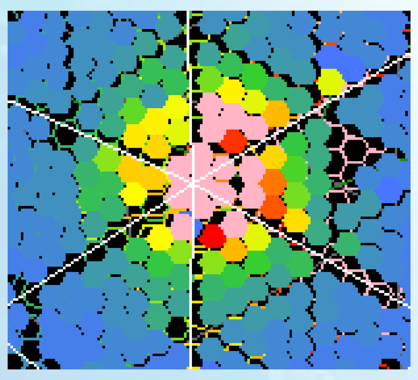

Fig. 4: An example of one of the direct beamspots in data.

- Rather than applying manual corrections for each each effect, normalise the data by MC:
  1. For a chosen SMELLIE run, calculate the occupancy in each PMT over the run.
  2. Apply a statistical correction to covert this into p.e.
  3. Simulate SMELLIE under the same detector conditions as for that run, but with a beam which is flat in the cosine of the polar angle to $\pi/2$ and flat in azimuthal angle.
  4. Calculate the p.e. in each PMT for this simulation.
  5. For each PMT, find the ratio of p.e. in data to simulation.
  6. This ratio is used to interpolate between PMTs to build a profile of the beam.

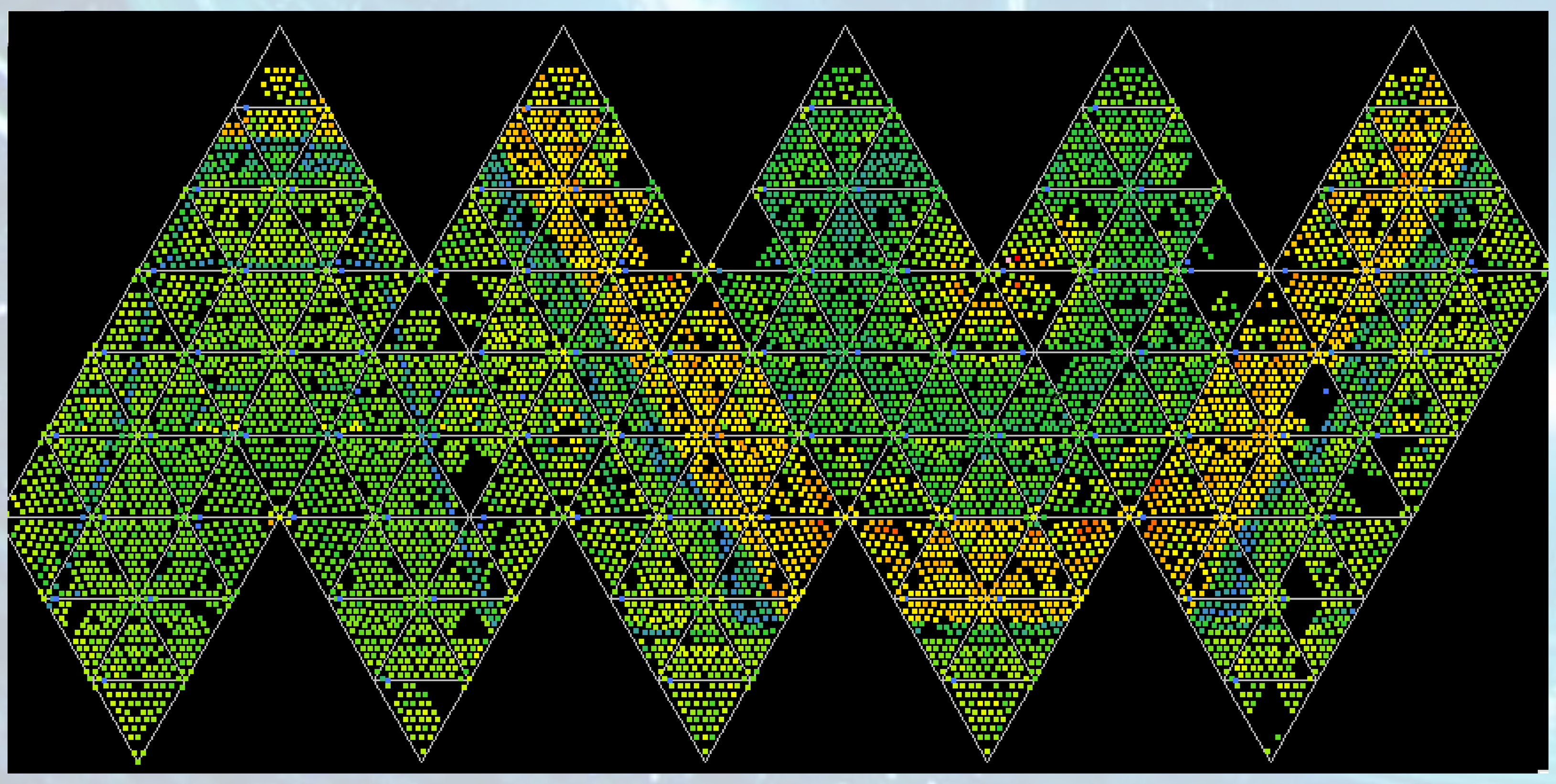

Fig. 5: A flatmap of one of the simulations to normalise by, demonstrating how the geometry of the detector creates many features in a flat profile.

SMELLIE

- Part of the in-situ optical and PMT calibration system ELLIE (**E**mbedded **L**aser/LED **L**ight **I**njection **E**ntity).
- SMELLIE is the **S**cattering **M**odule for ELLIE.
- Designed to measure and characterise the optical scattering in the detector media.
- External to AV to meet stringent radiopurity requirements and to enable continuous monitoring.

Hardware:
- 15 collimated optical fibres
- 5 injection points on PSUP
- 3 fibres at each
- 4 fixed wavelength lasers (375nm, 405nm, 440nm, 495nm)
- 1 supercontinuum laser (400 – 700nm)
- 1 **m**onitoring **P**MT **u**nit (MPU)
- Uses an external asynchronous trigger

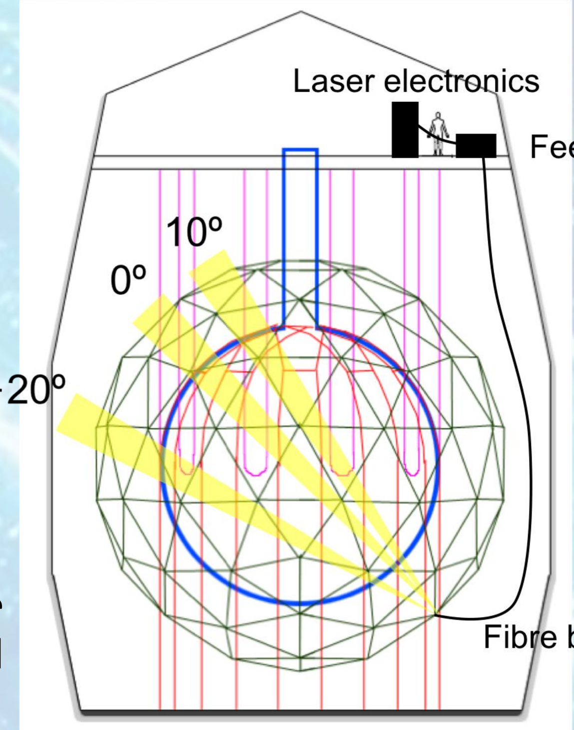

Fig. 2: A diagram showing a single injection node of SMELLIE. Adapted from [1].

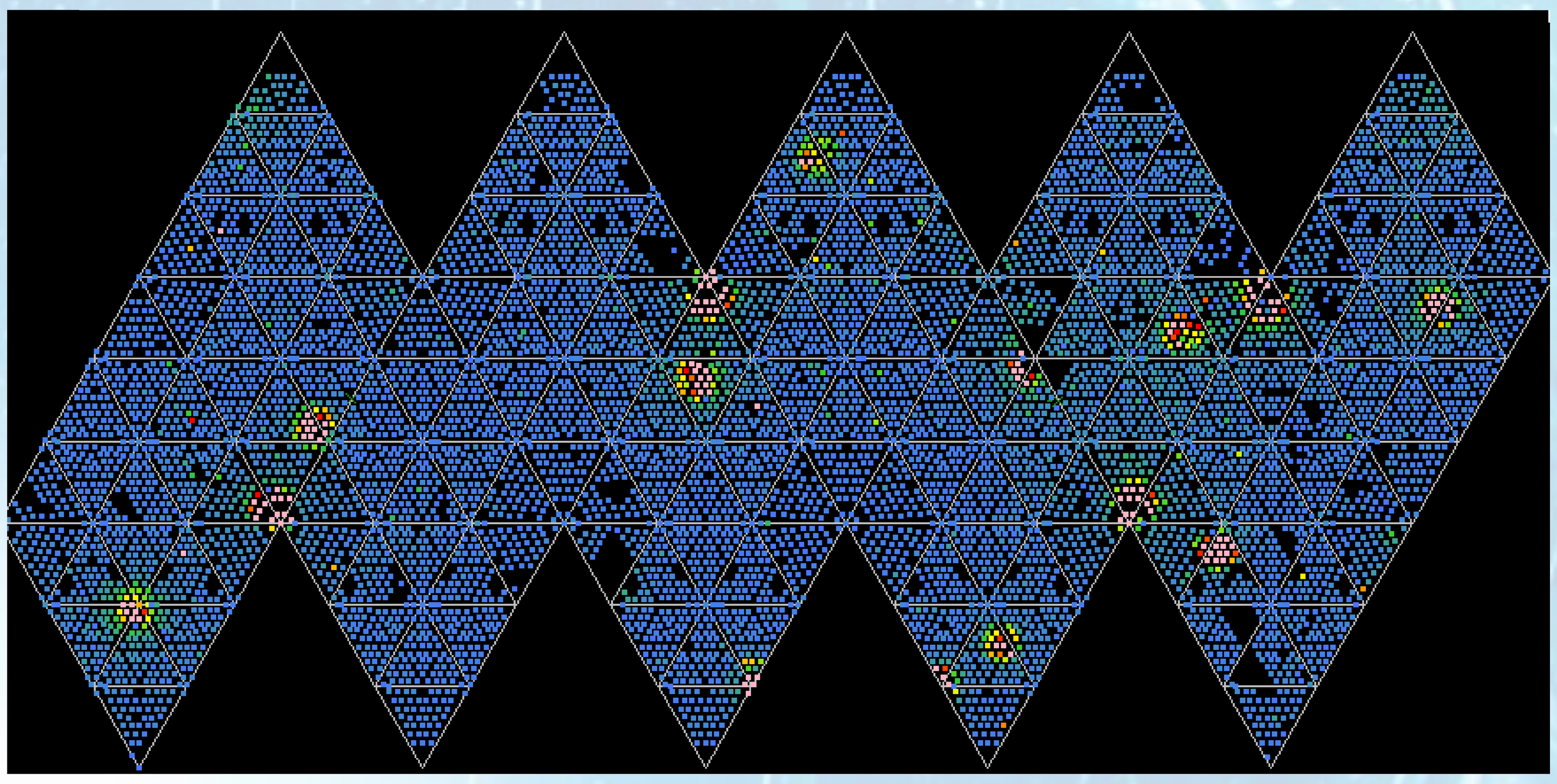

Fig. 3: A flat map of the water-filled detector summed over a SMELLIE run, in which the superK was fired down 14 of the fibres. Each point is a PMT, where the colour represents the number of times it was hit. Pink is saturated. This shows the direct beamspot locations spread over the detector.

[1] K. Majumdar, Ph.D. thesis, University of Oxford (2015).

Scattering Length

To measure the scattering length of the detection medium:
1. Simulate a SMELLIE run, using the nominal scattering length.
2. Isolate the region of photons singly scattered in the detection medium. See fig. 6.
3. Apply the same cuts to the matching data run.
4. Find the ratio of **p**hoto**e**lectrons (p.e.) in this region to the total number of photons in the detector.
5. Find this ratio for further simulations with a range of different scattering lengths.
6. This ratio corresponds to scattering length. Between 0.5 and 10 × the nominal scattering length, the relationship between the ratio and the scattering length can be fitted with a quadratic.
7. Use this fit to find the scattering length of the detector medium.

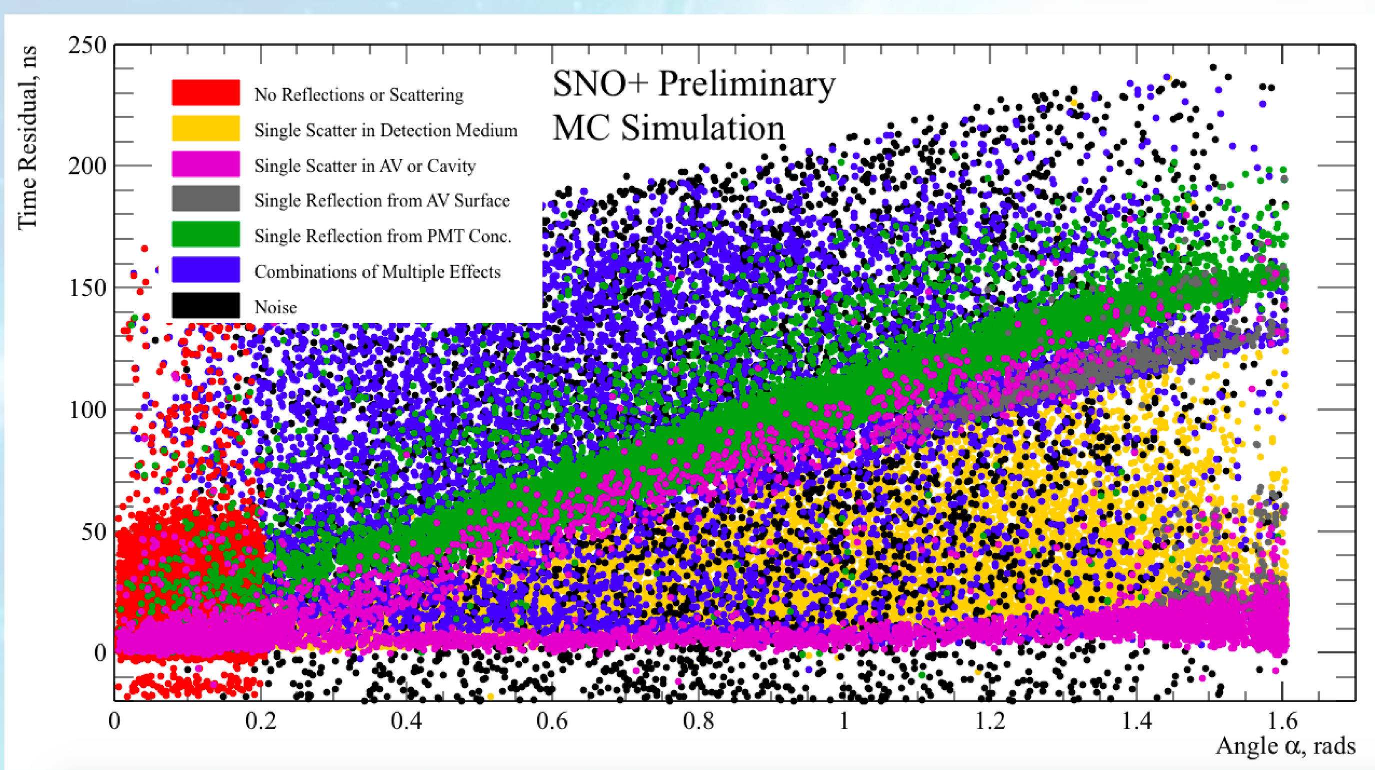

Fig. 6: The triggered PMTs in a simulated SMELLIE run in time versus angle space. The PMTs are coloured by the optical processes the photon underwent.