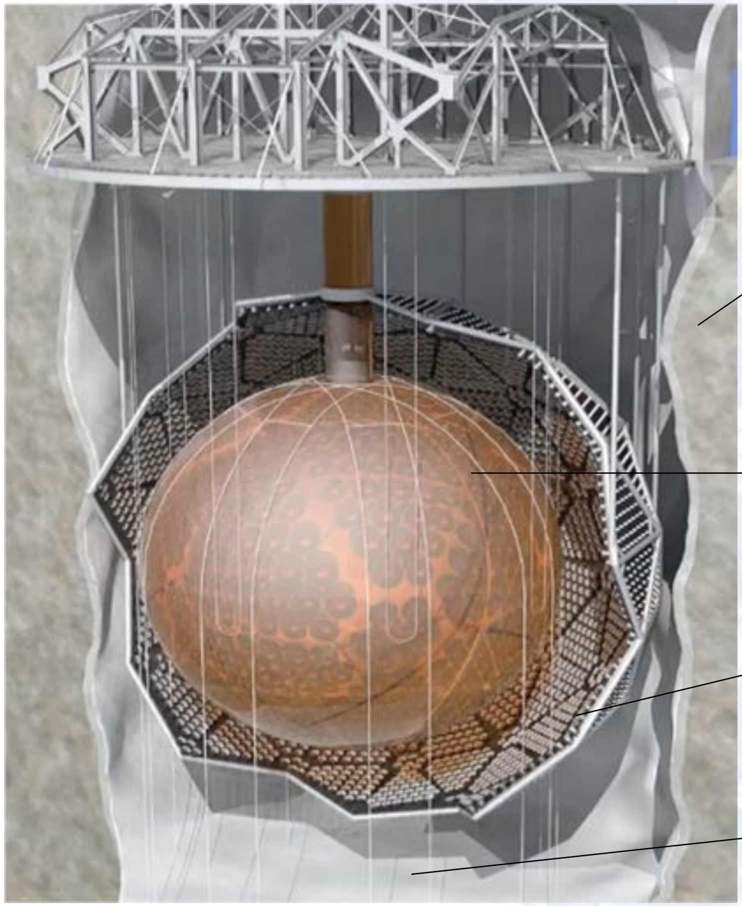
A Laser Calibration System for SNO+

A Brief Introduction to SNO+

Repurposing and upgrade of the SNO experiment



- 2km underground in SNOLAB (6000 m.w.e overburden)
- 6m radius acrylic vessel (AV) filled with detection medium (currently UPW)
- 8.9m radius PMT support structure (PSUP) with ~9300 PMTs mounted on it
- Cavity filled with ~7000 tonnes UPW

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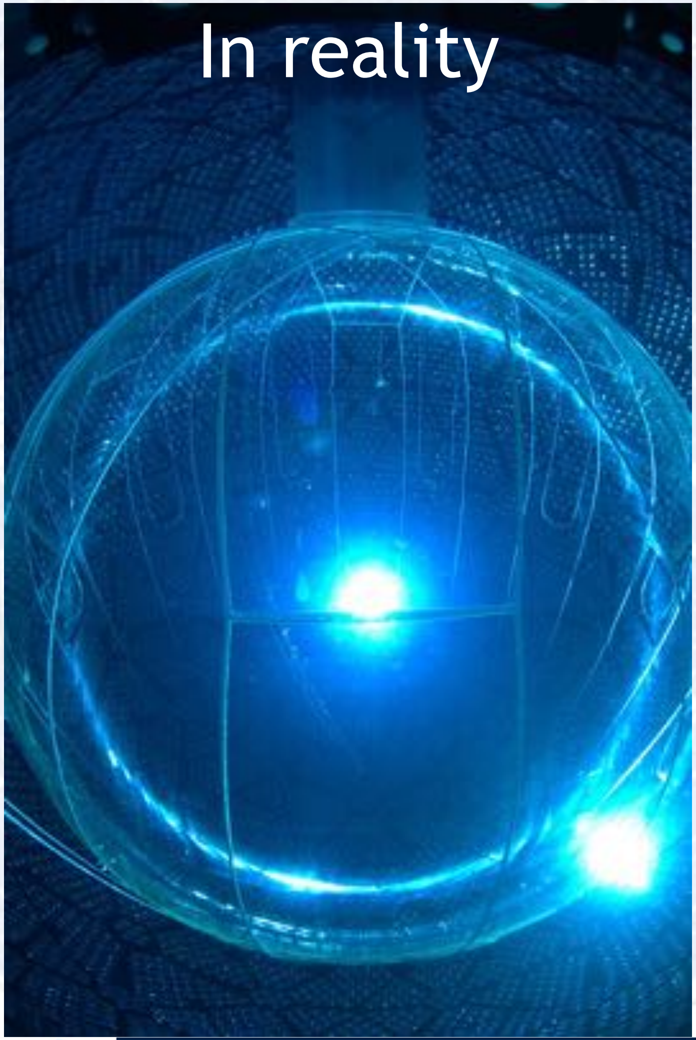
In reality



A Brief Introduction to SNO+

Water phase:

- Data taking now, since early 2017
- Physics:
  - Invisible nucleon decay
  - Supernova neutrinos

Te loaded scintillator phase:

- Starting in 2019
- Loading ~1330kg ^{130}Te
- Physics:
  - **Neutrinoless double beta decay**
  - ^{8}B solar neutrinos
  - Reactor and geo antineutrinos
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Pure scintillator phase:

- Starting mid-2018
- AV filled with ~780 tonnes LABPPO + bisMSB
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After 5 years:

$T_{\frac{1}{2}} > 1.9 \times 10^{26}$ years, 90% CL

$m_{\beta\beta}$: 41 – 99 meV

Using g_A = 1.269, M = 2.06 – 4.98 and G = 3.688×10^{-14} years^{-1}.

Calibration in SNO+

Electronic:

- Pedestal and timing amplitude conversion for each channel

PMT:

- Time walk and gain of each PMT, angular responses, relative efficiencies

Energy:

- Detector response at different energies and to different particle interactions, performance of reconstruction algorithms

Optical:

- Optical effects between generation and detection of photons

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The Embedded Laser/LED Light Injection Entity (ELLIE)

- Part of the in-situ optical and PMT calibration system
- Consists of optical fibres mounted on PSUP and connected to lasers/LEDs, with beam directed through AV
- Enables continuous monitoring (no deployment of sources necessary)
- Three subsystems:
  - **T**iming Module (TELLIE)
  - **A**ttenuation **M**odule (AMELLIE)
  - **S**cattering **M**odule (SMELLIE)

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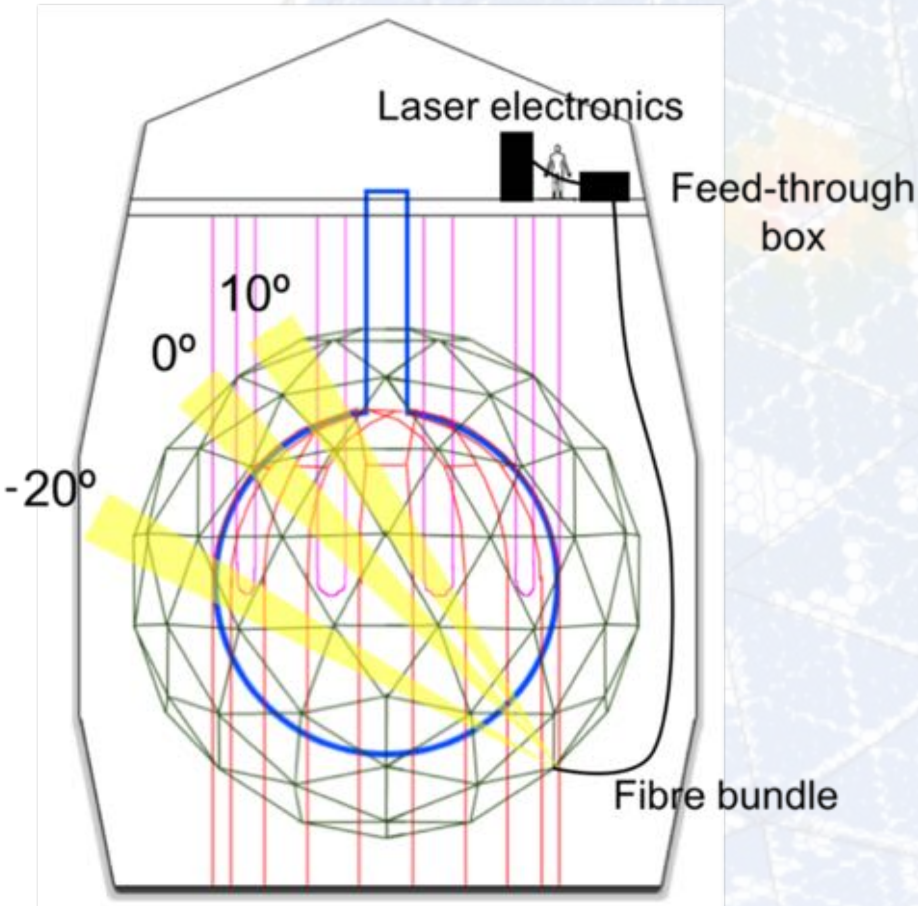
The Scattering Module for ELLIE (SMELLIE)



- 15 collimated fibres
- 5 injection points on PSUP
- 3 fibres at each (0°, 10°, and -20° pointing angles with respect to detector centre)
- 4 fixed wavelength lasers (375nm, 405nm, 440nm, 495nm)
- 1 supercontinuum laser (400 – 700nm)
- 1 monitoring PMT unit (MPU)
- Uses an external asynchronous trigger

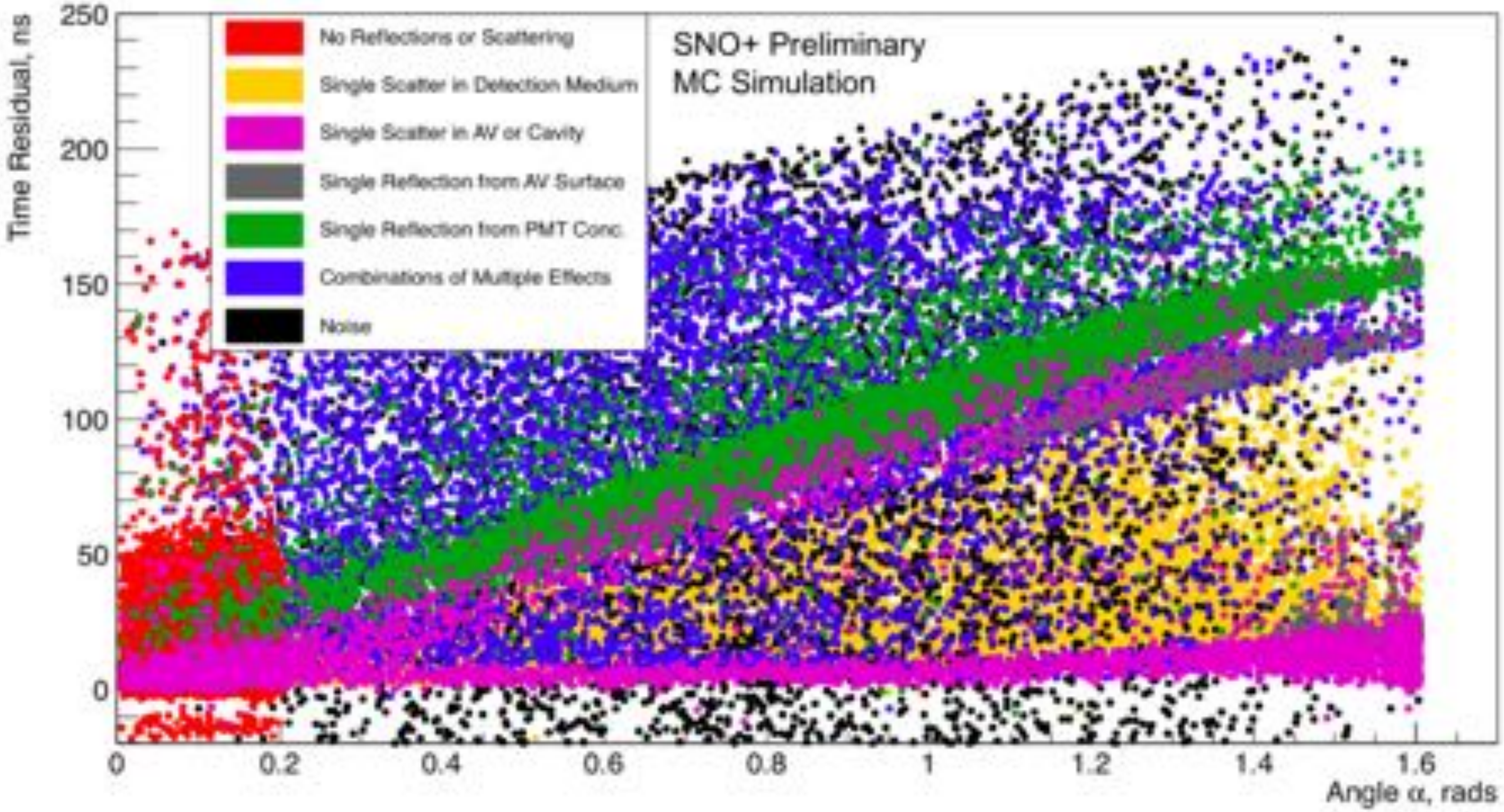
A Scattering Analysis

Designed to measure and characterise the scattering properties of the detector medium.

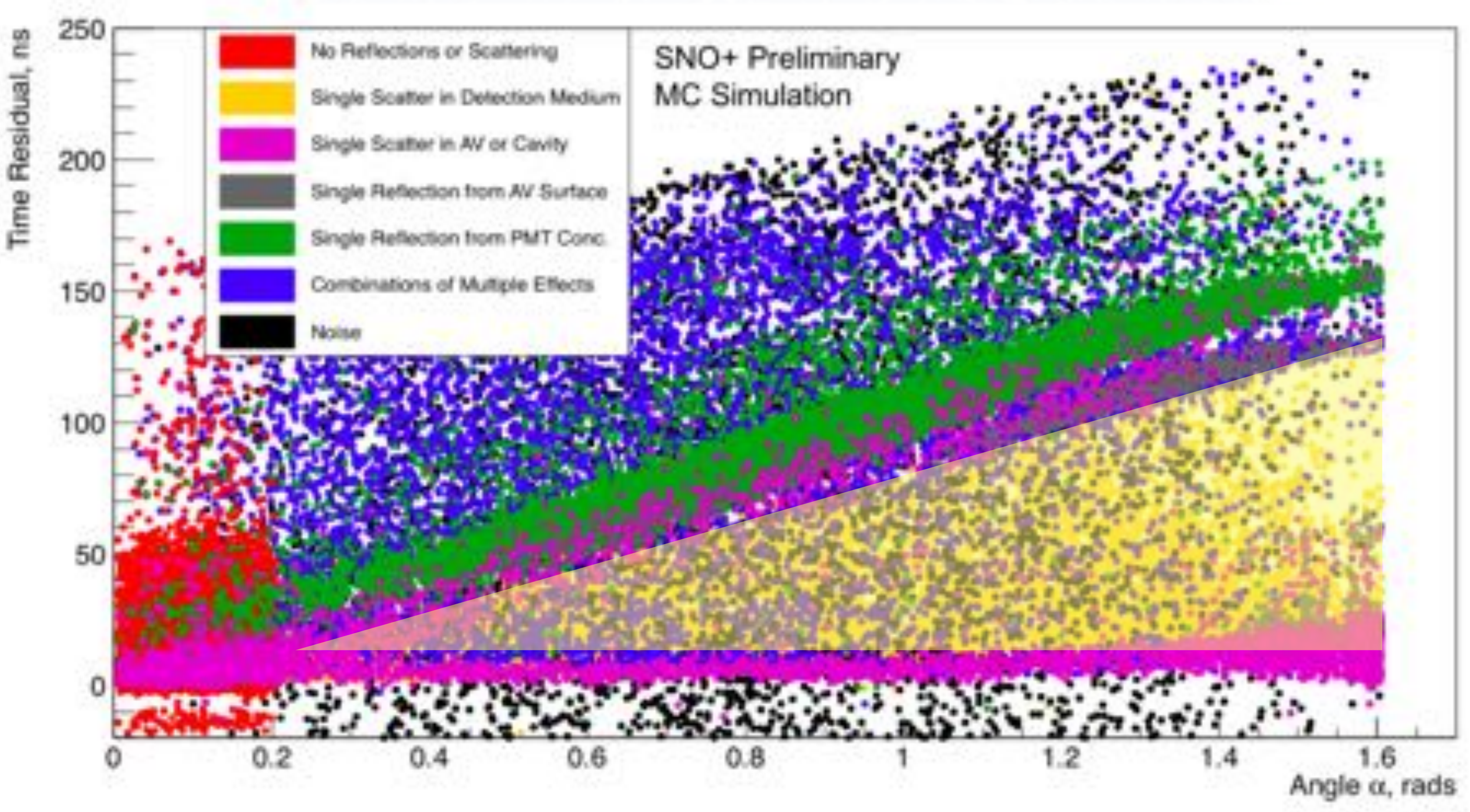
For example, to measure the scattering length of the detector medium:

1. Simulate a run, using the nominal scattering length.
2. Isolate the region of photons singly scattered within the detection medium.

A Scattering Analysis



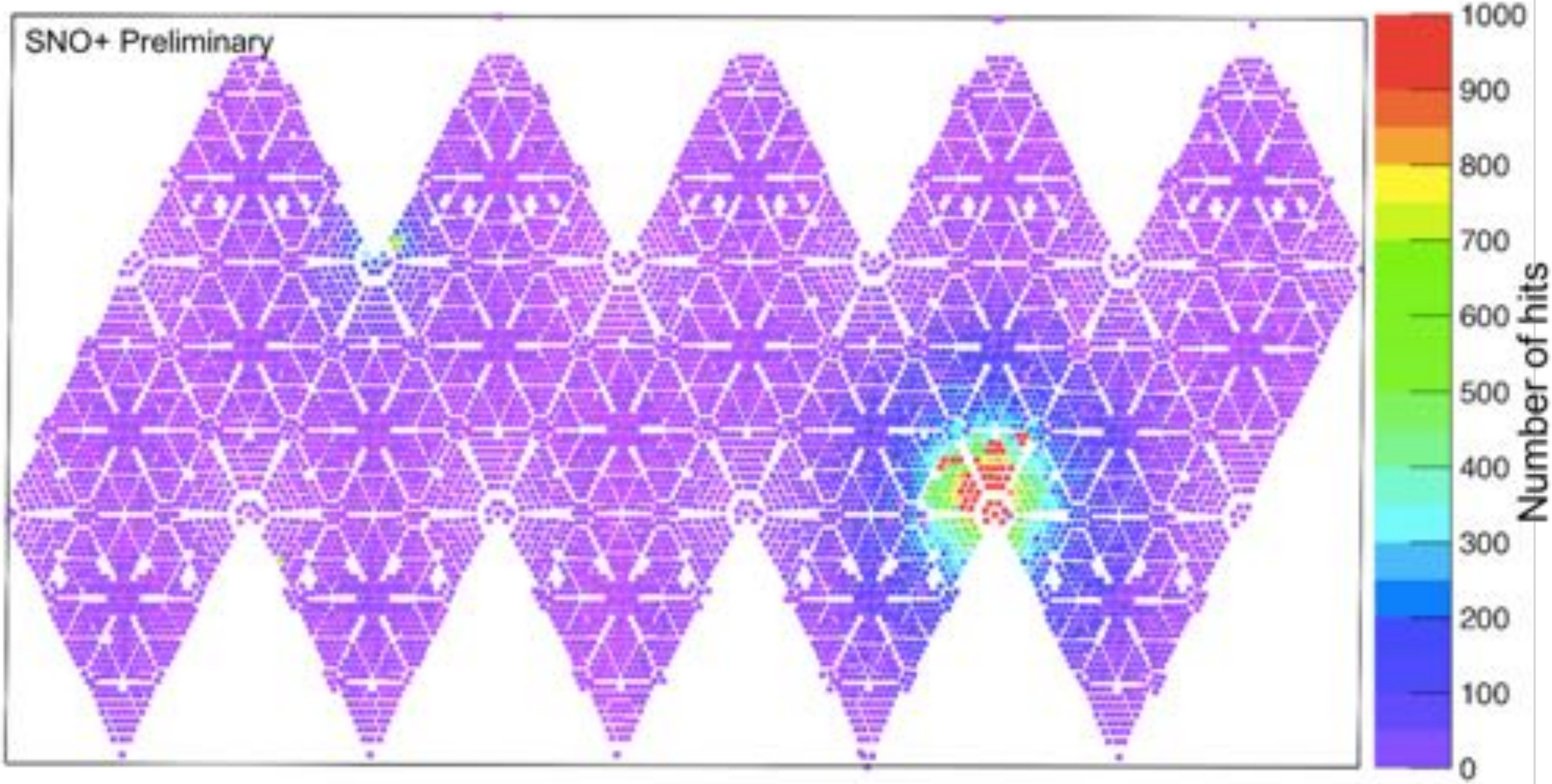
A Scattering Analysis



A Scattering Analysis

3. Apply the same cuts to the matching data run.
4. Find the ratio of photoelectrons (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 correlates with scattering length.
7. Use a fit of this correlation to find scattering length of detector medium.

Commissioning SMELLIE



Commissioning SMELLIE

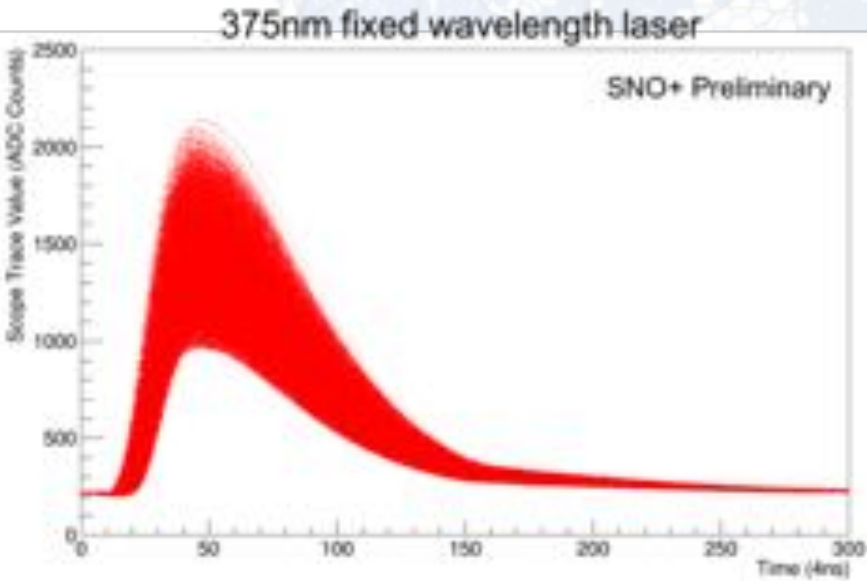
With water data:

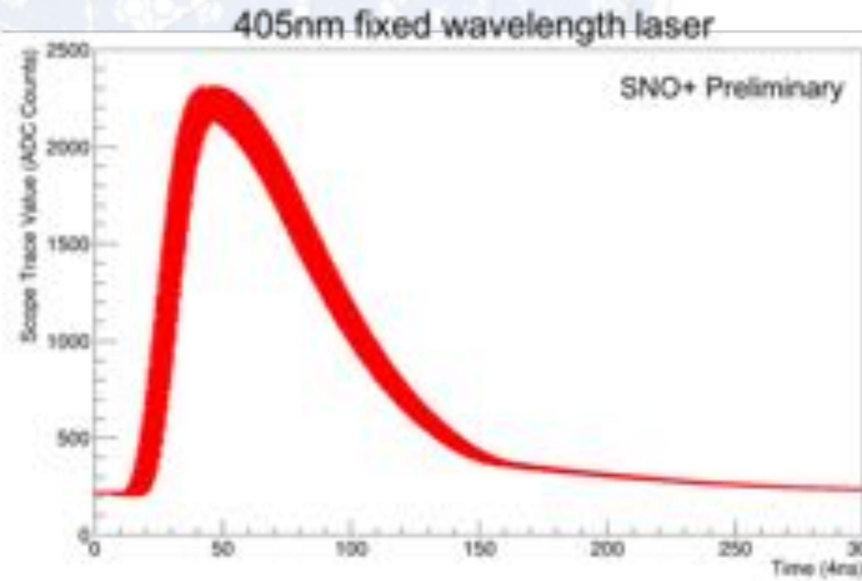
- Characterise SNO+ UPW scattering
- Confirm analysis method
- Extract beam profiles
- Understand MPU response

Possible in water due to the long scattering and absorption lengths and lack of re-emission

Commissioning SMELLIE

At low shot energy (near lasing threshold), laser output can be unstable. MPU allows monitoring of this and hence correction for it.





Commissioning SMELLIE

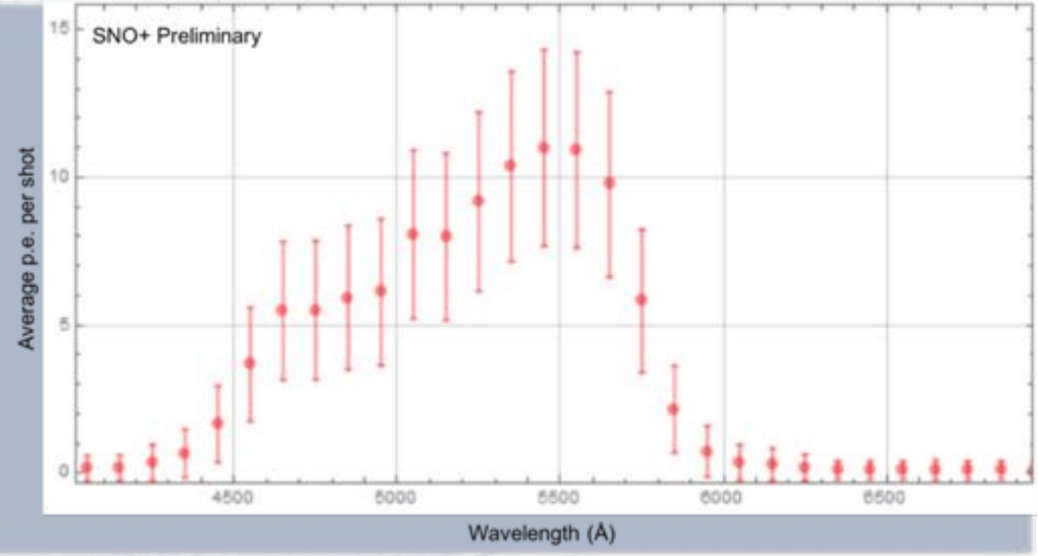
Settings for each shot:

- Laser / Wavelength
- Shot energy
- MPU gain
- Fibre

Requirements for each shot:

- Desired number of p.e.
- Tolerable MPU pulse height

The SMELLIE Tesseract:
Database of settings at which data was taken together with extrapolation and interpolation routines.



Summary

- SNO+ is currently taking data in its water phase.
- Optical calibration is crucial for understanding detector response and reconstruction.
- SMELLIE is part of the in-situ optical calibration system, designed to measure and characterise the scattering of the detector medium without the need for source deployment.
- Water data allows us to commission SMELLIE, as the scattering and absorption lengths are long and there is no re-emission.
- Once fully commissioned, we are ready to measure the scattering length of SNO+ UPW over a wide wavelength range.

Thank you!
Any questions?

Backup Slides

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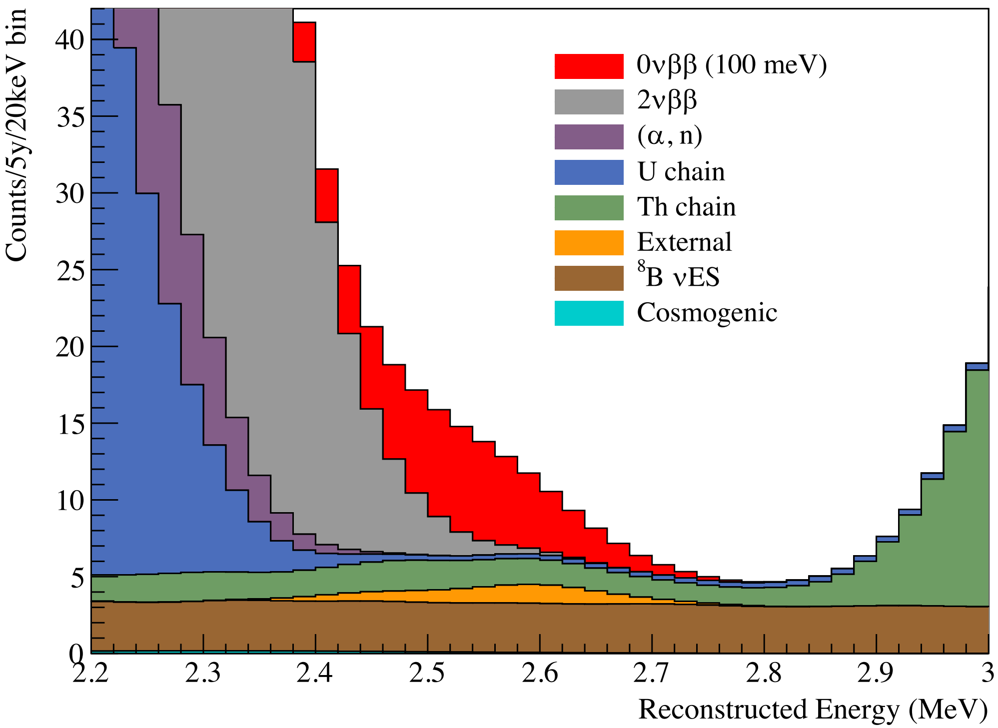
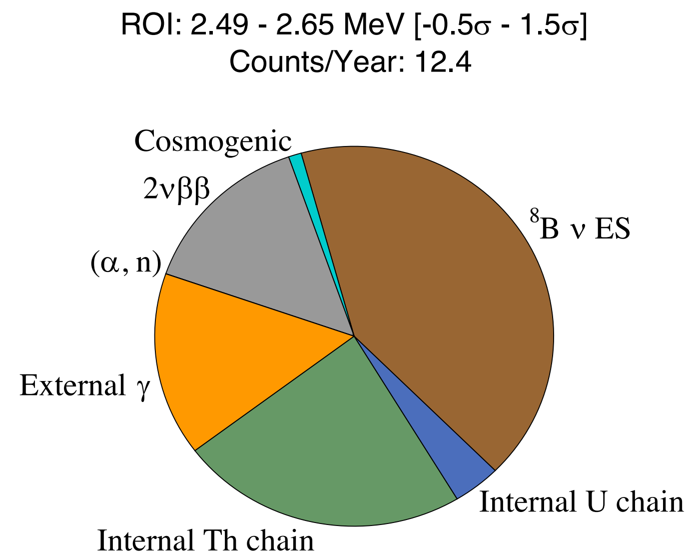
Main aim: Neutrinoless double beta decay ($0\nu\beta\beta$) search in ^{130}Te



- 0.5% ^{nat}Te by mass
- Light yield is ~390 hits/MeV
- Fiducial volume for spectrum plot is 3.3m



Estimating P.E.

- A PMT hit means at least one p.e. was present in the PMT.
- Over many hits, number of p.e. in a PMT follows a Poissonian distribution.
- $P^i = 1 - e^{-\mu^i}$, where P^i is probability of observing a hit in PMT i and μ^i is the expected number of p.e. in that PMT.
- P^i can be estimated for a specific PMT as $\frac{N_{Hits}}{N_{Shots}}$.
- $\mu = -\log(1 - P)$.
- At too high a shot energy to use this, can convert charge to p.e.

Estimating P.E.