Optical Calibration of the SNO+ Detector

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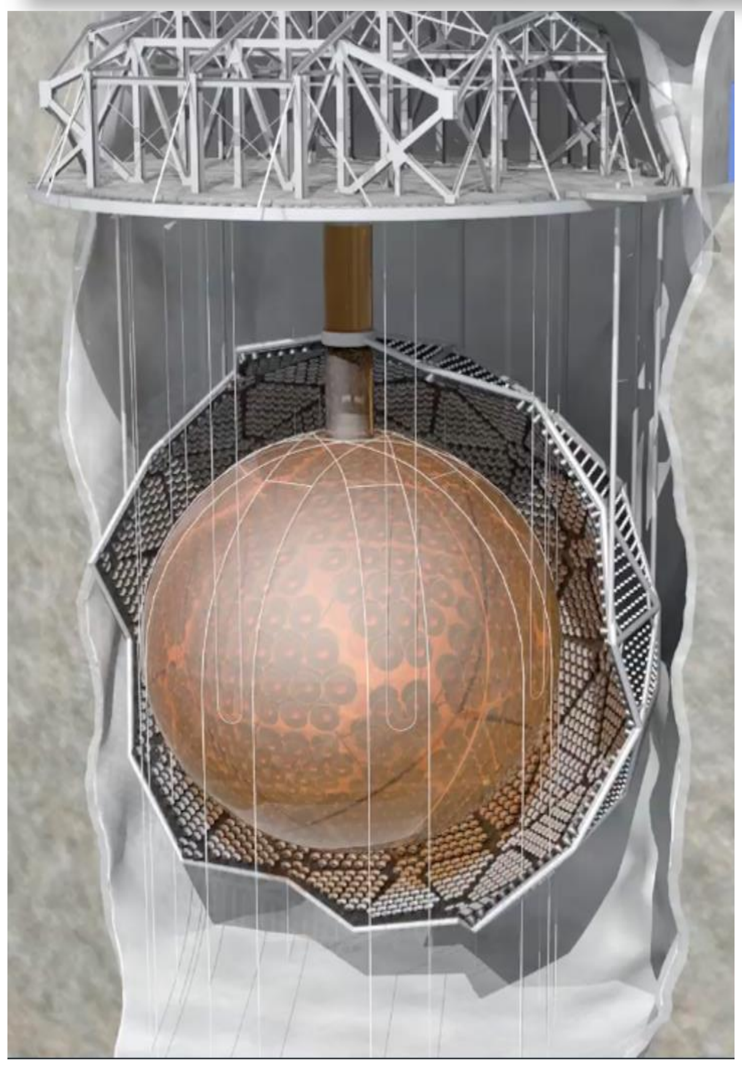
The SNO+ Experiment



SNO+ consists of a large volume liquid scintillator detector located 2 km underground at SNOLAB, Sudbury, Canada. It reuses most of the components of the SNO detector.

9400 PMTs with reflectors, ~50% coverage, supported by an 8 m radius geodesic structure (PSUP).

6 m radius Acrylic Vessel (AV)

* Currently filled with water.
* Will be filled with 780 tons of LAB+PPO (2 g/L)+bisMSB +0.5%Te-diol (1330 kg of ^{130}Te).

Hold-down and support rope systems

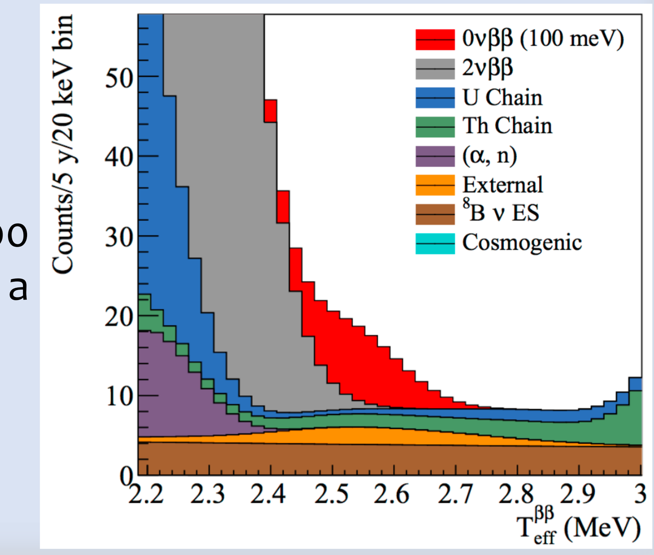
7000 tons of ultra-pure water shielding

+ **Updated read-out/trigger electronics** to accommodate higher data rates.
+ **Scintillator Purification Systems**
+ **New calibration systems**

Physics goals:

- Neutrinoless Double Beta Decay of ^{130}Te;
  - ➢ Prove Majorana nature of neutrinos.
  - ➢ Demonstrate violation of lepton number.
  - ➢ Measurement of effective neutrino mass.
- Solar neutrinos;
- Reactor anti-neutrinos;
- Geo neutrinos;
- Supernovae neutrinos;

Expected 0νββ-Decay signal for $m_{\beta\beta}$=100 meV after 5 years with 0.5% loading in a FV with 3.5 m in radius (20%).

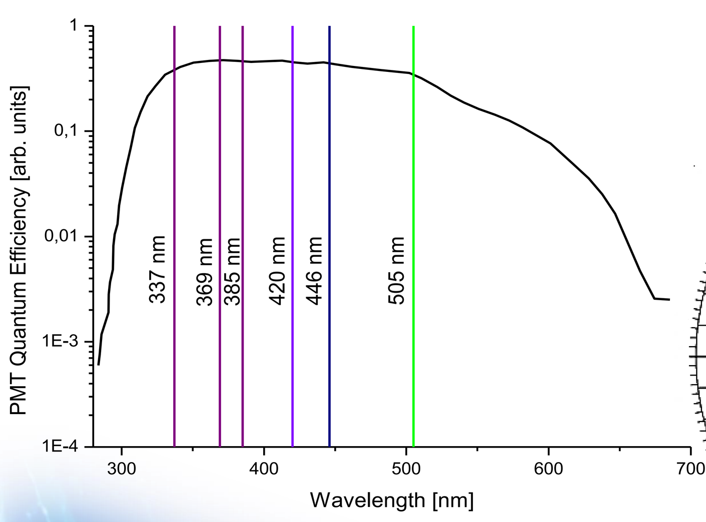


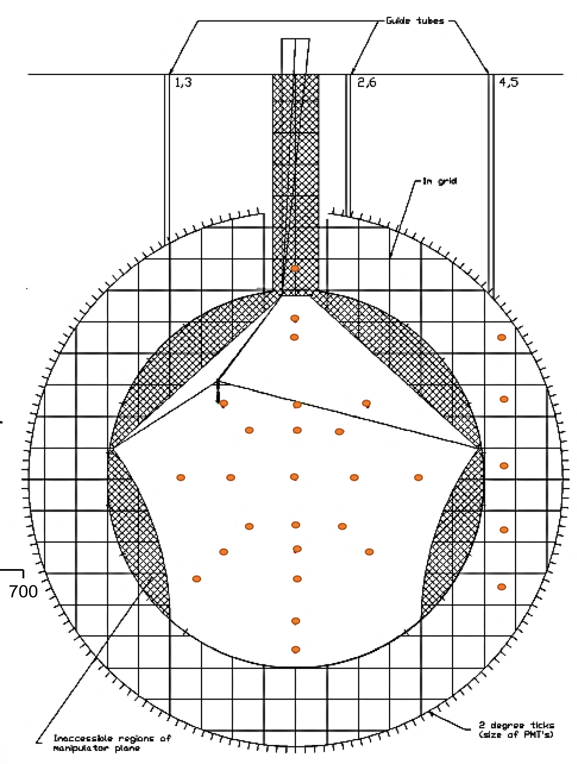
Sensitivity $T_{1/2} > 2 \times 10^{26}$ years, 90% CL
$m_{\beta\beta} \approx 40 - 90$ meV

Laserball Hardware

N2-dye laser coupled to a light diffusing sphere, deployed inside/outside the AV.

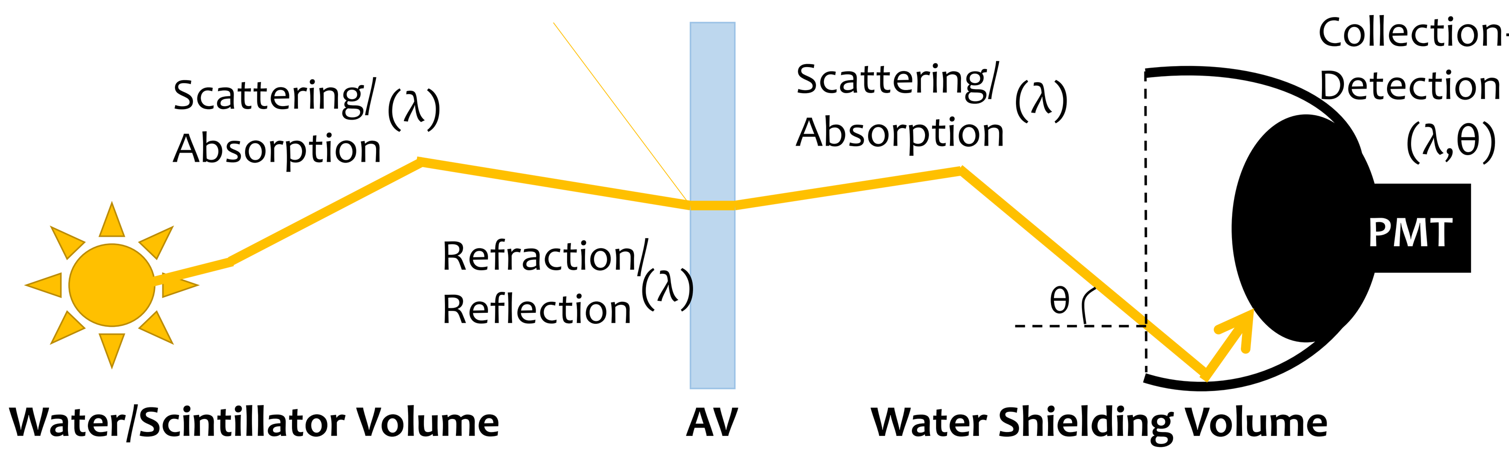
- ~60 positions inside and outside the AV.
- 6 wavelengths covering the PMT sensitivity range.
- Allows a full characterization of the optical effects in the detector.

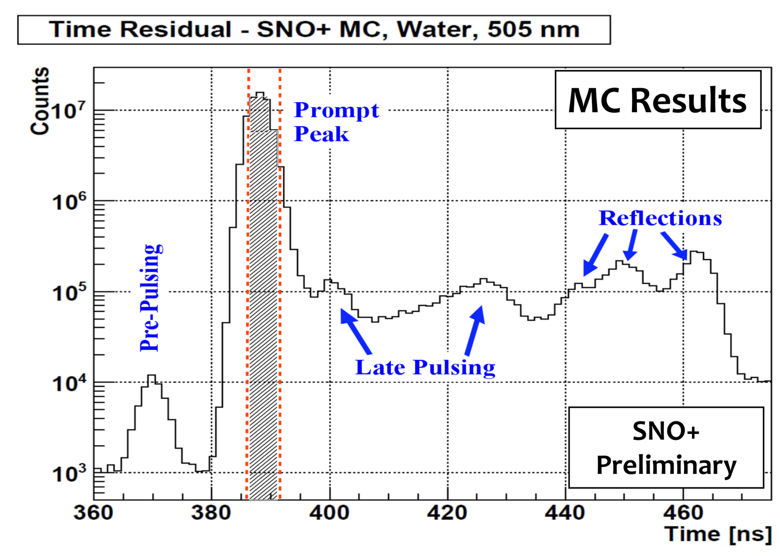




Optical Calibration Analysis

To understand the observed signals and correctly associate them with the underlying physics processes, the energy scale and optical properties of the detector must be well understood. That is accomplished by a detailed Optical Calibration using in-situ sources.





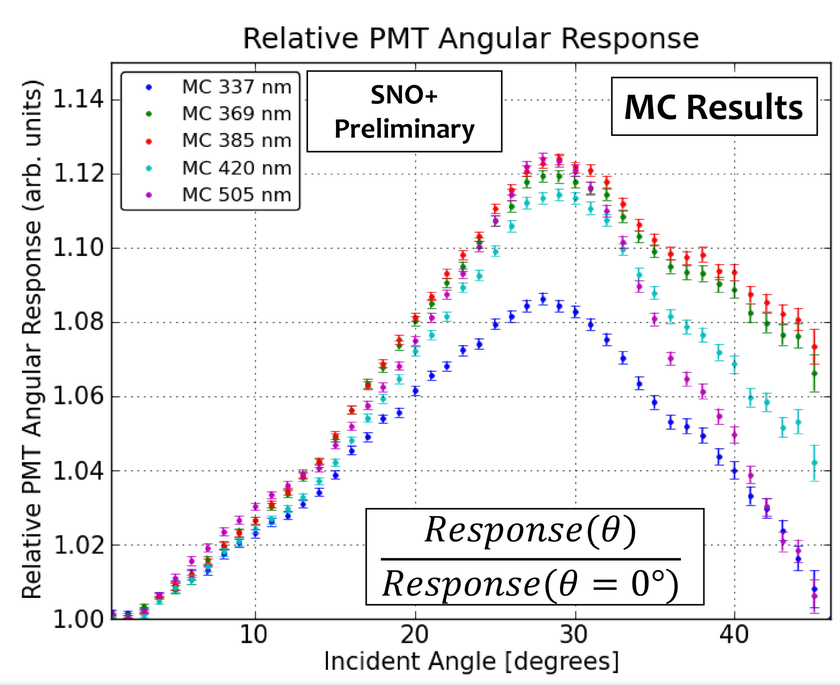
$$O_{ij} = N_i L_{ij} \Omega_{ij} T_{ij} R_{ij} \epsilon_j exp\left(-\sum_{Medium\ k} d_{ij,k}\alpha_k\right)$$

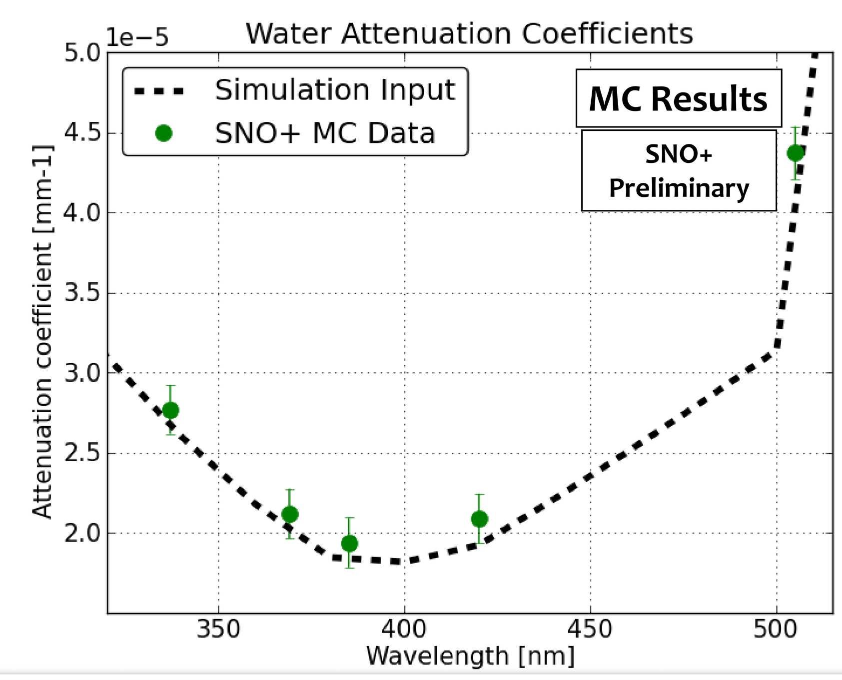
Source; Direct light detected; Solid Angle; Fresnel; PMT Response; PMT Efficiency; Distance travelled; Attenuation

Calibration uses a simplified Optical Model that excludes PMTs partially shadowed by detector components, such as ropes, and uses only the direct light detected by the PMTs, identified by the prompt peak.

The parameters of the model are extracted from Laserball data through a multiparameter fit.

PMT Angular Response changes with time due to degradation of the PMT reflectors.

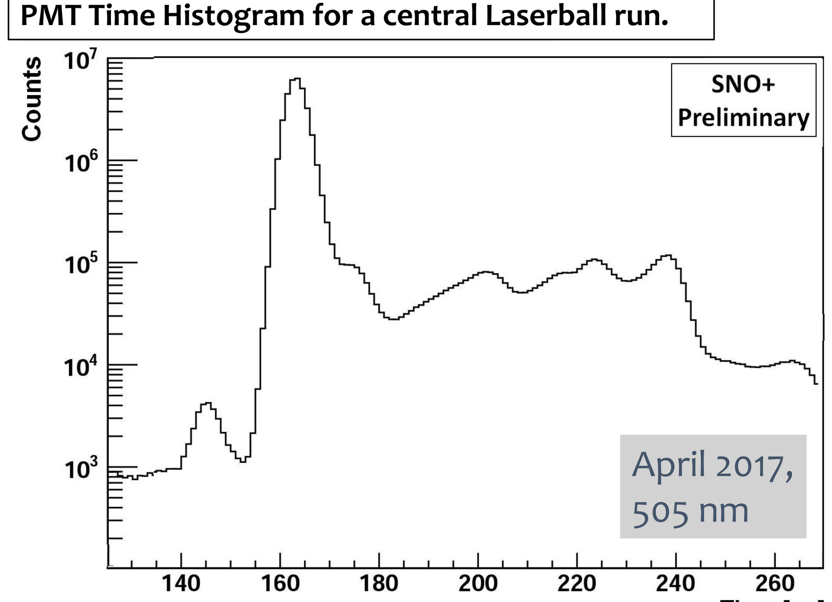


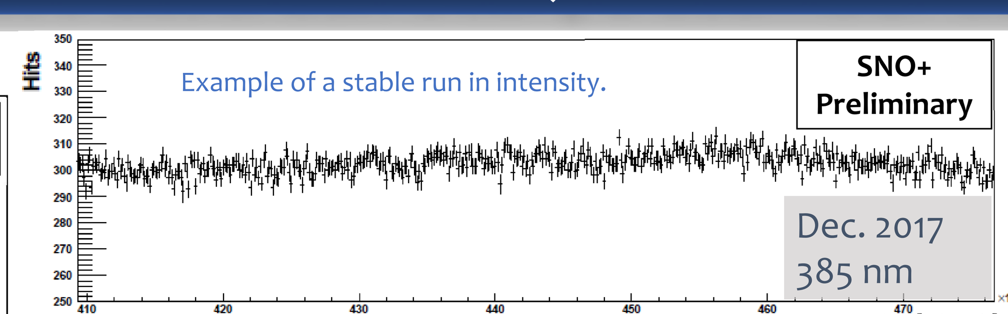


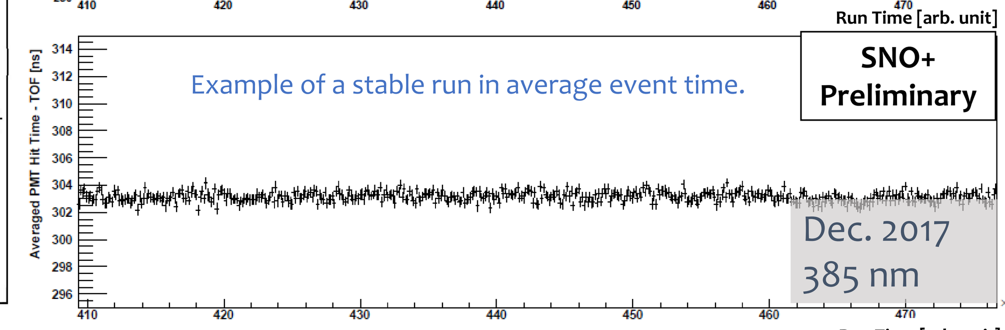
PMT Angular Responses and Water Attenuation coefficients from MC Laserball data.

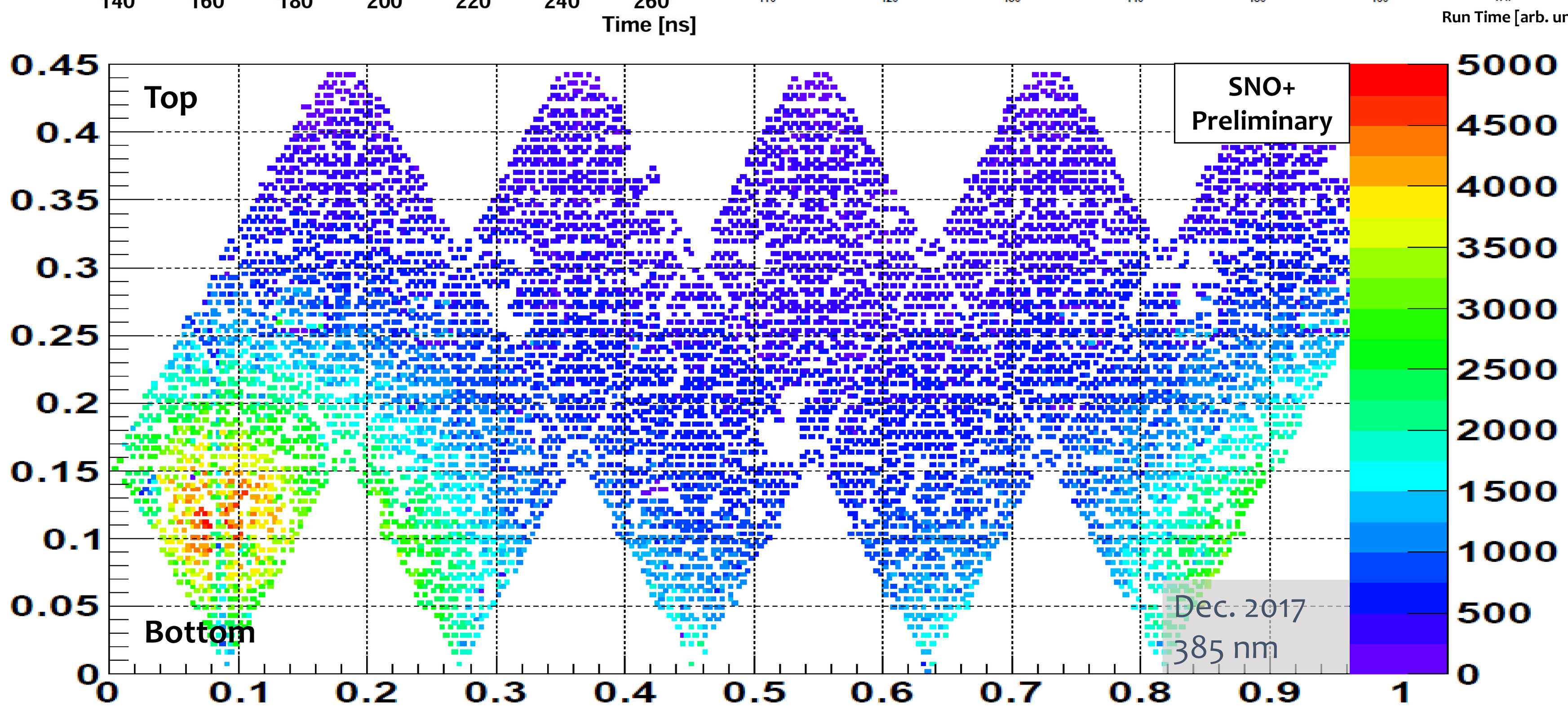
SNO+ Water Phase Laserball Scan, December 2017

PMT Time Histogram for a central Laserball run.



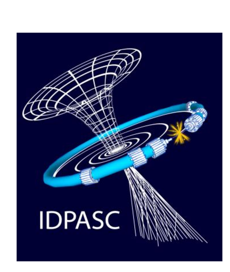






Icosahedron projection of the SNO+ detector. Shows the number of hits in each PMT, with the Laserball at the bottom of the detector.

- Laserball deployed in SNO+ detector!
  - 204 runs collected in 35 positions inside the AV, using the 6 available wavelengths.
- On-going data analysis:
  - Data quality checks of the detector and laserball hardware stability;
  - Validation of the laserball position fit algorithm;
  - Fast analysis tools:
    - Laserball Asymmetry Analysis – characterization the laserball light distribution;
    - Diagonal Scan Analysis – characterization the attenuation of the medium inside the AV;
  - Full Optical Calibration analysis – extraction of all the Optical Model parameters from the laserball data.
- Attenuations and PMT angular responses will be used when reprocessing the Water Phase data;
- PMT angular responses will also be used for the scintillator phase.



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