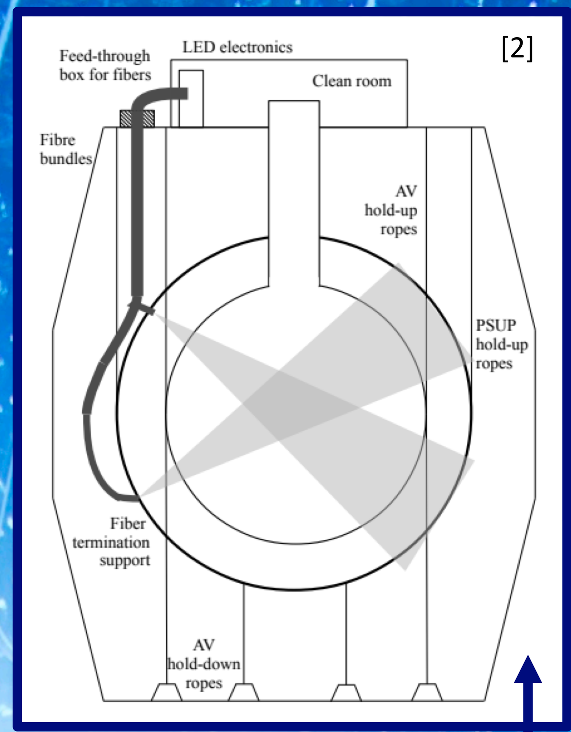
Calibrating the SNO+ PMT Array

Lorna Nolan for the SNO+ collaboration

The SNO+ Detector

SNO+ [1] is a multipurpose neutrino detector with a main goal to search for neutrinoless double beta decay. Located 2km underground in the Creighton mine in Sudbury Ontario, it is an upgrade of the Nobel prize winning SNO detector. A 6m radius Acrylic Vessel (AV) is surrounded by the 9m radius PMT Support System (PSUP) which contains ~9300 inward looking 8" PMTs and around 100 PMTs facing the external water volume to identify muons. It is essential that the output from all of these PMTs can be trusted, requiring regular calibrations particularly of timing and charge, which are outlined in this poster.



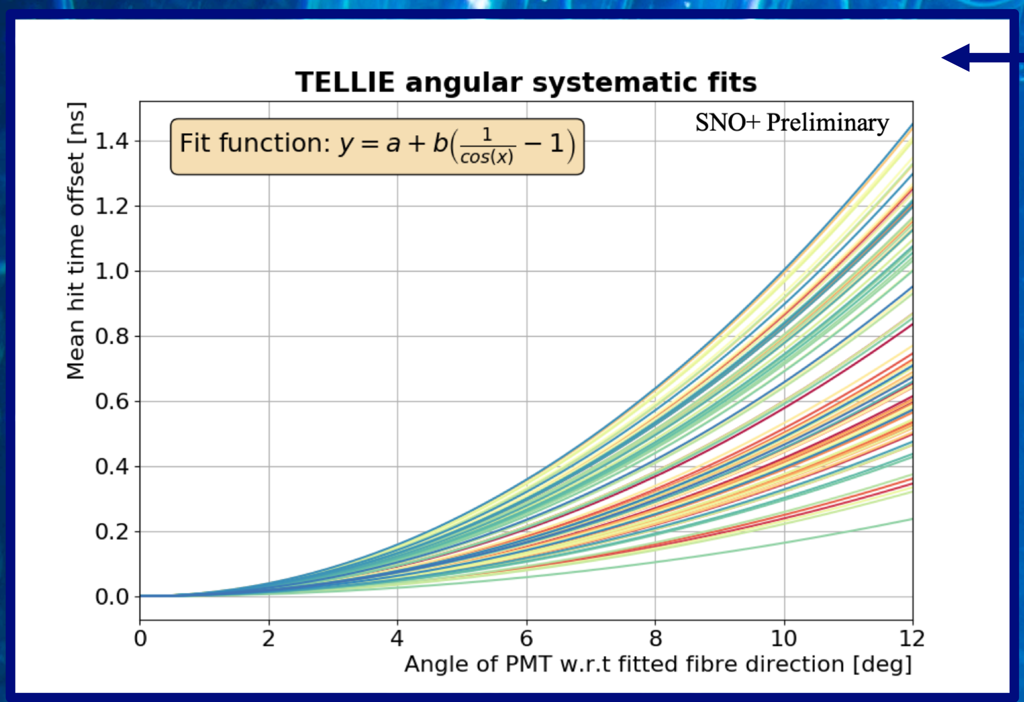
Photomultiplier CAlibration (PCA) with TELLIE [4]

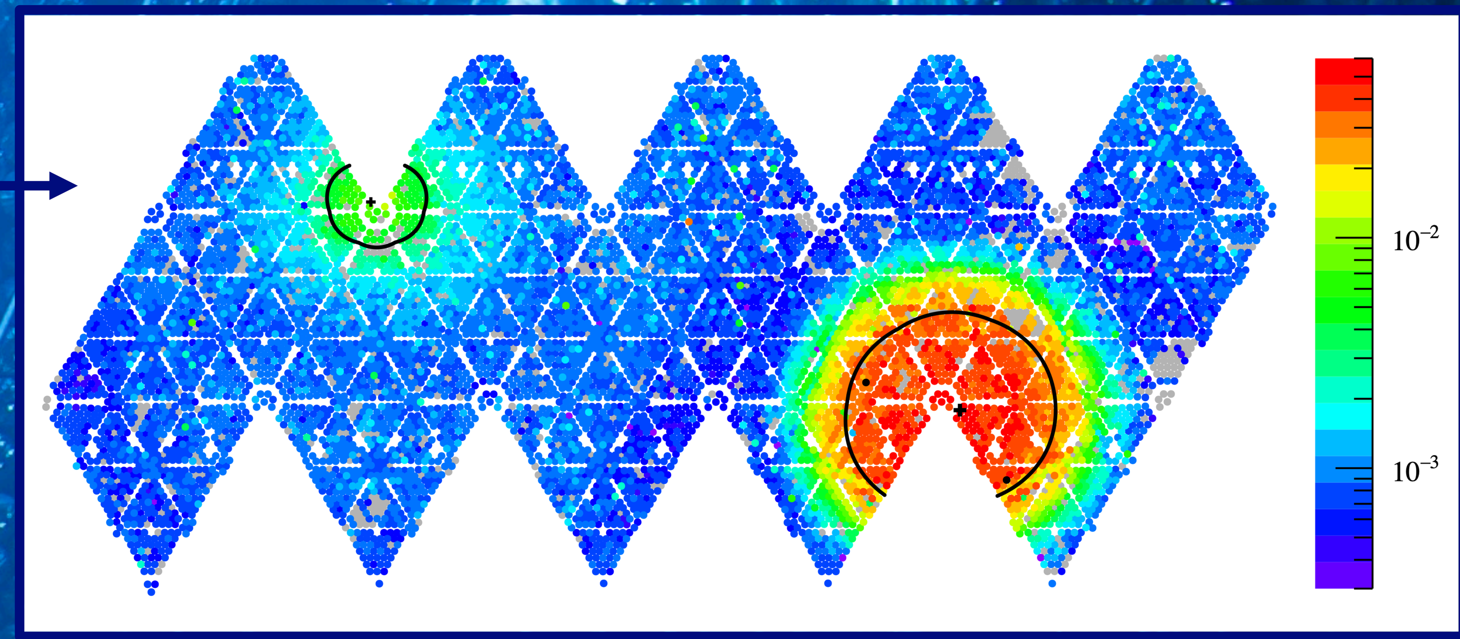
The timing module of the External LED/Laser Light Injection Entity (TELLIE) is mounted on the PSUP (shown above) and measures the time delay from electronic effects (cable delays, PMT transit time and time-walk).

- 95 channels, each with 2 fibres, meaning each PMT is covered by several fibres
- Fire short LED light pulses of ~505nm from each fibre in turn. An example run for one fibre can be seen on the right.

To find the time delay, light is injected to the detector at the exact same time, corrected by a channel-dependant software delay. Three small corrections are then made to the hit time measurement:

- Time of flight of the photon, the time the photon takes to reach the PMT from the fibre is the largest correction at ~76ns.
- The 'bucket time' of the photon is the time that the photon spends within the PMT geometry. This is a much smaller correction, ~0.47ns.
- Due to the angles of the fibres, some of the light is slightly delayed within the fibre. This is the angular systematic and is a very small constant for each fibre as can be seen on the left.





Electronics CAlibration (ECA) [3]

- Run ~every 2 weeks, checks for significant changes since last ECA
- Fire 512 channels at once
- 2 types of calibration: time-slopes and charge pedestal

ECA time-slopes

- Time-to-amplitude converter (TAC) begins ramping when channel is hit and stops if global trigger received
- Smaller amplitude means later hit time
- Each channel repeatedly fired, scanning over delay of the global trigger

ECA pedestals

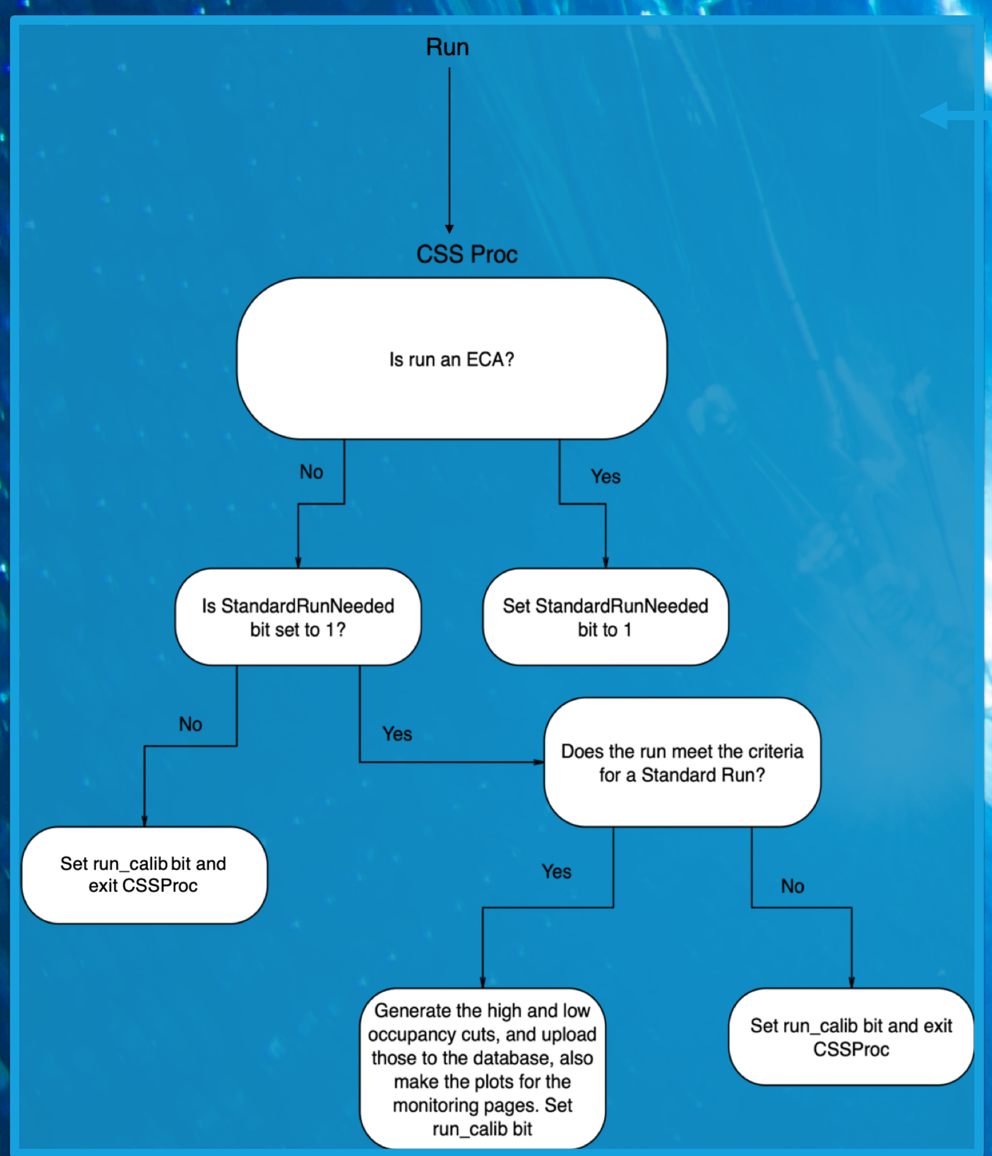
- Charge is measured by the ADC, analogue-to- digital converter, which can have an offset from zero known as the pedestal level.
- ECA force short trigger (150ns) to read out pedestal level.
- subtract pedestal from charges recorded in physics events.

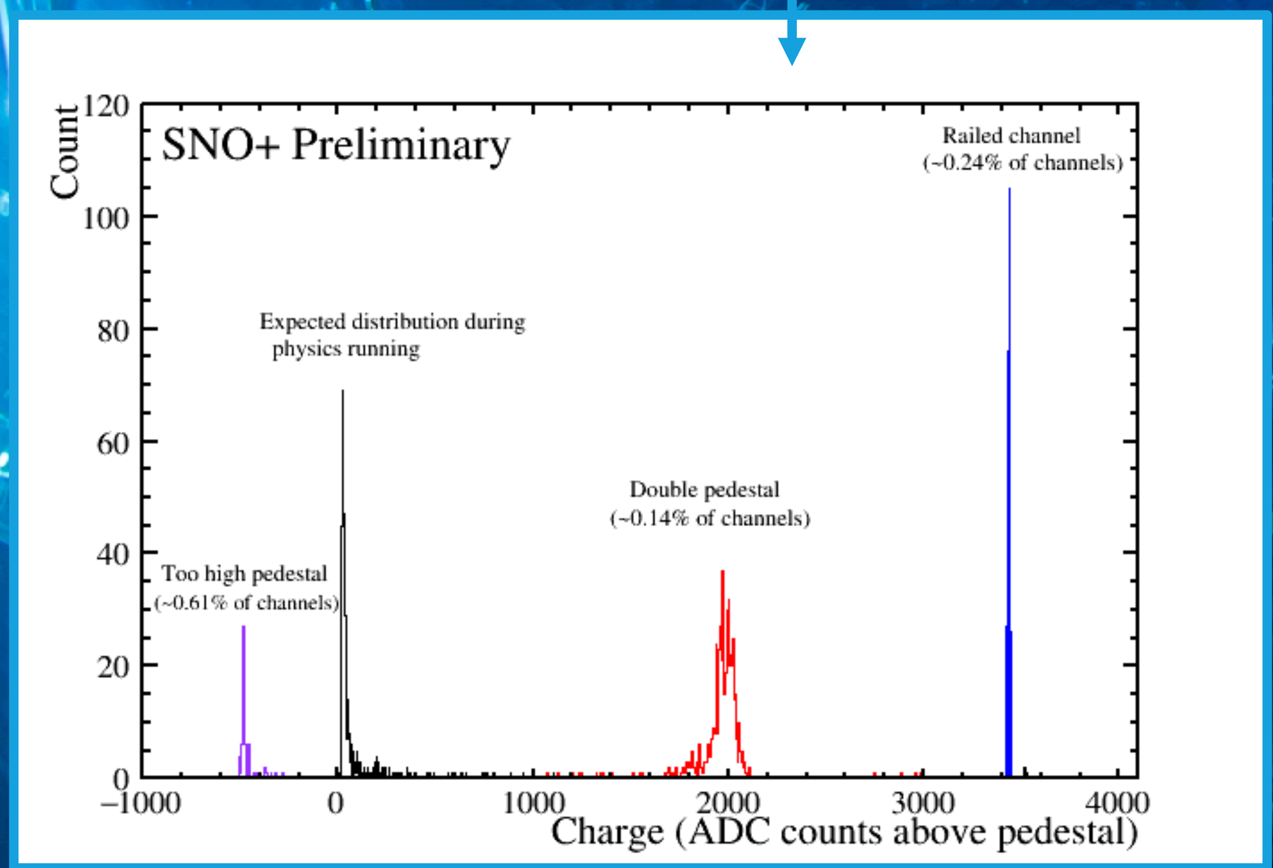
Channel Software Status (CSS)

Channel Software Status (CSS) [5] is a run-by-run software based calibration to identify channels that are behaving anomalously between calibrations.

- Processor (below) reassesses occupancy criteria after every ECA Calibrator
- Flags channels that fail checks on: Charge, High Occupancy, Low Occupancy

A machine learning approach to CSS is currently being developed that will not need to retune the cuts after every ECA





CSS Occupancy checks

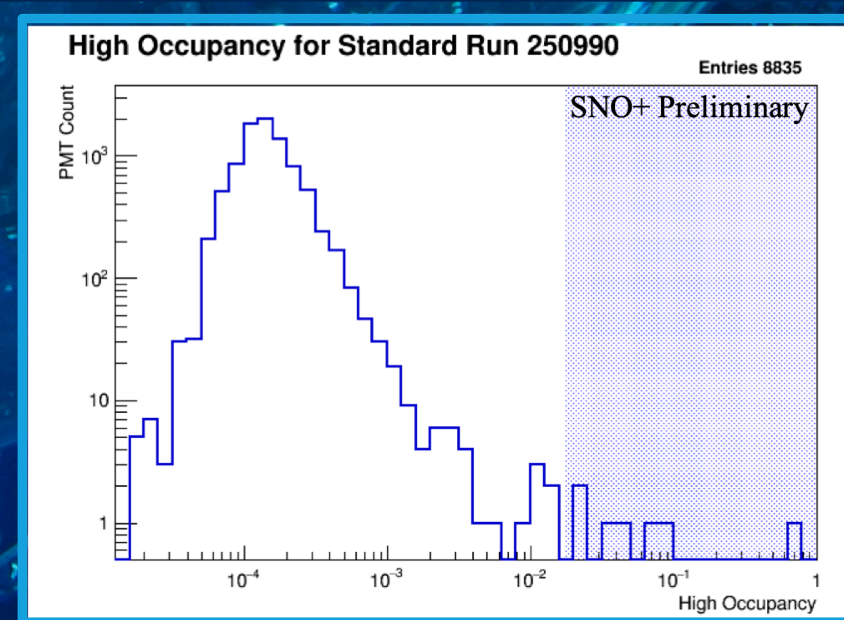
CSS occupancy criteria are retuned on the first SR (Standard Run) following every ECA. A SR must be a Physics run, over 50 minutes in duration, have over 90% of channels online and meet all DQ checks.

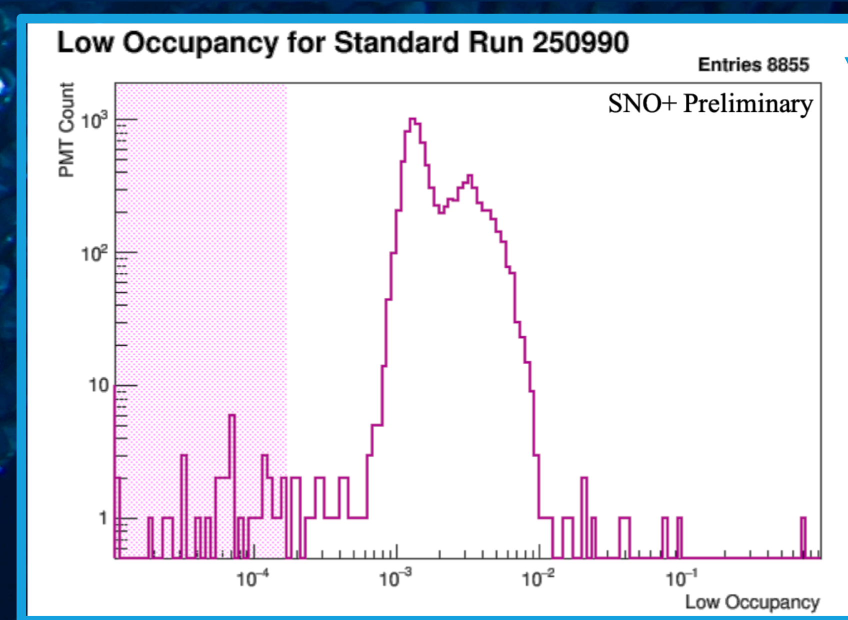
The high occupancy check identifies channels registering too many hits using the Pulsed Global Trigger (PGT), a 50Hz forced trigger on the baseline detector state.

The low occupancy check identifies channels registering significantly fewer hits than expected using all event triggers.

- Occupancy statistic = number of events on channel / total events across detector in same period
- To calculate each occupancy cut from the SR, the statistics for each channel are plotted and a cut is defined as 75 FWHMs from the peak of this distribution (examples for low and high occupancy below).

For each run after the SR, a channel is flagged as high or low occupancy if its respective occupancy statistics fail this check.





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SNO+

References:

[1] Current status and future prospects of the SNO+ experiment , Advances in High Energy Physics, vol. 2016, 6194250 (2016), SNO+ Collaboration

[2] The calibration system for the photomultiplier array of the SNO+ experiment, Journal of Instrumentation (JINST) Vol. 10, P03002 (2015), R. Alves et al.

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[5] Current contact person for CSS: Lorna Nolan, Queen Mary University of London