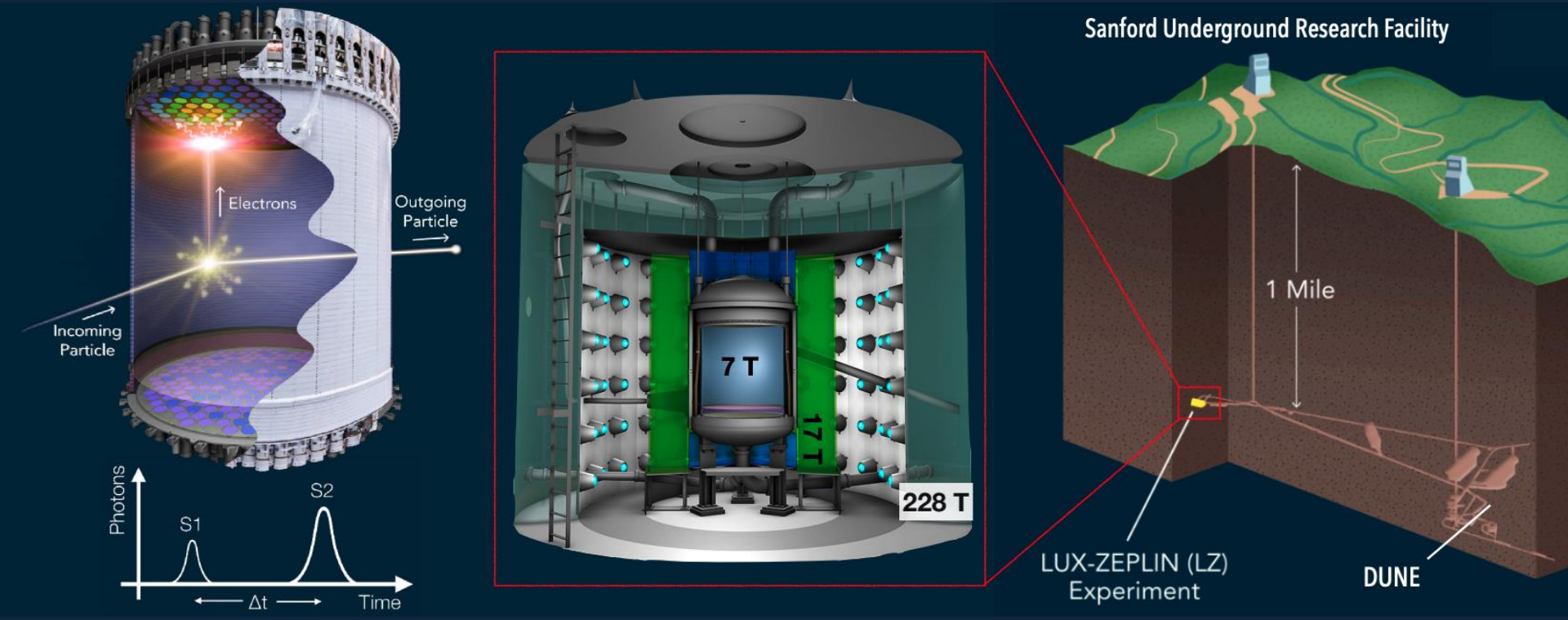
UNIVERSITY OF LIVERPOOL

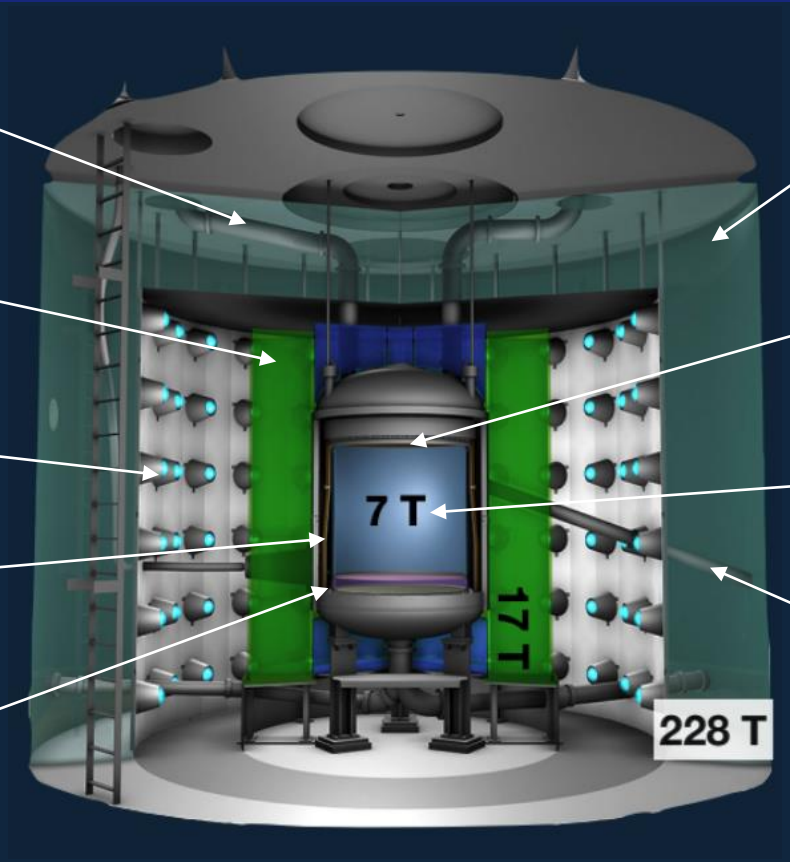
LZ Outer Detector: Calibrations, Monitoring & Performance

Sam Woodford

Introduction to LZ



LZ: Detector Overview



Calibration Source Deployment Tubes

17t Gd-loaded Liquid Scintillator

120 Outer Detector PMTs

2t LXe Skin Veto

131 Skin PMTs

128t of ultrapure water

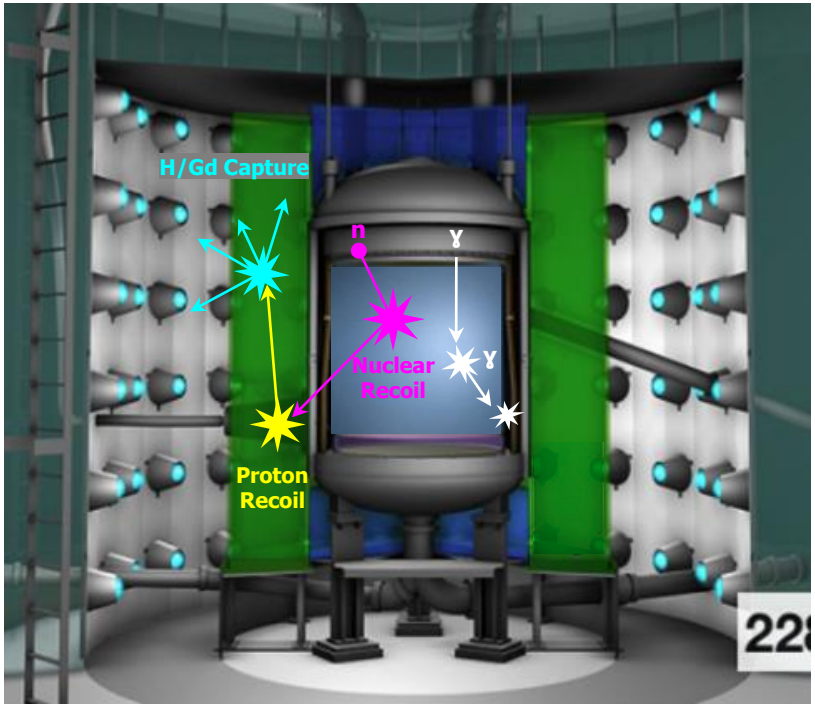
494 LXe TPC PMTs

7t Active LXe Target

Neutron Calibration Conduit

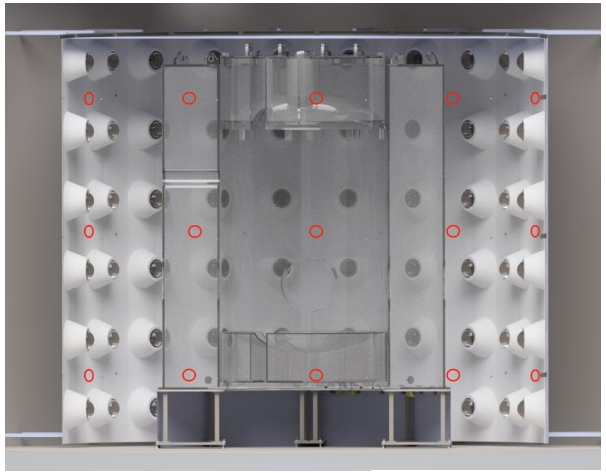
Motivation for Outer Detector

- A dark matter particle that scatters with LXe will only deposit energy in the TPC, not in surrounding materials.
- Surrounding materials produce backgrounds that can mimic WIMP-like signals:
  - Nuclear recoils via neutron scattering
  - Electron recoils via γ-ray scattering
- To account for the backgrounds, a veto system (skin + OD veto) was designed to surround the TPC:
  - Verify any dark matter signal was not induced by a background
  - Increase the fiducial volume in the TPC (simulation studies show veto cuts see up to a 70% increase to the FV)

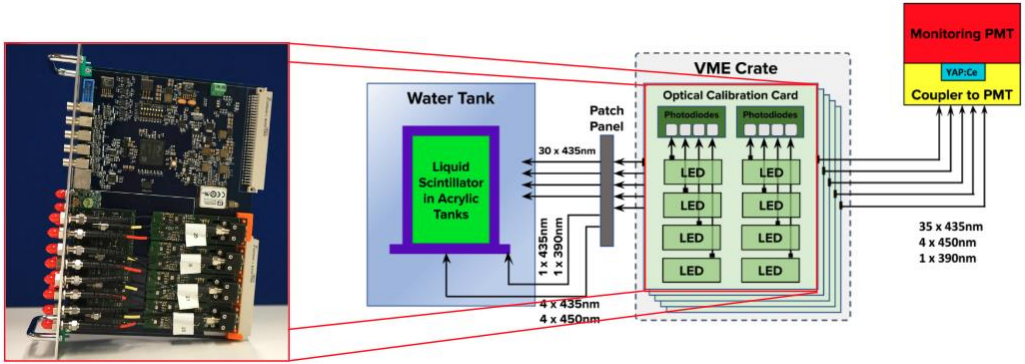


Outer Detector

Outer Detector PMT Calibration: OCS

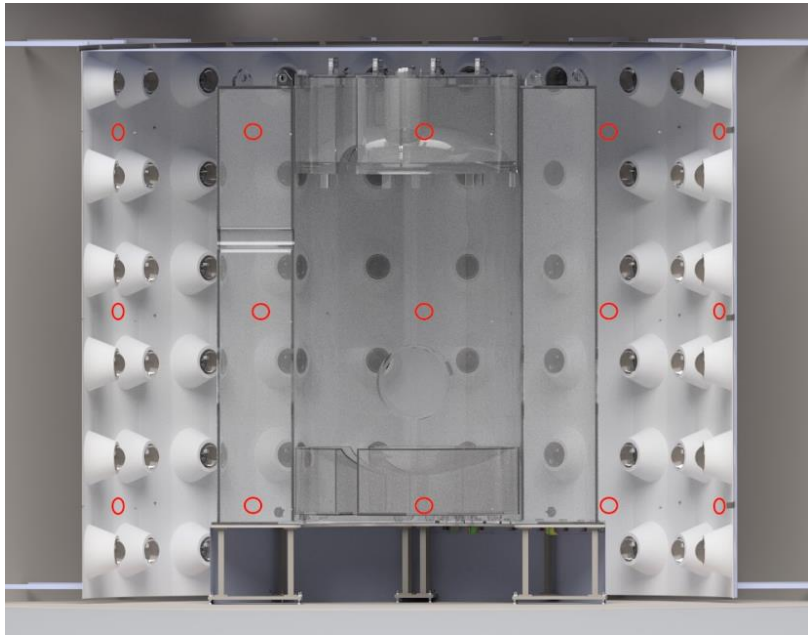


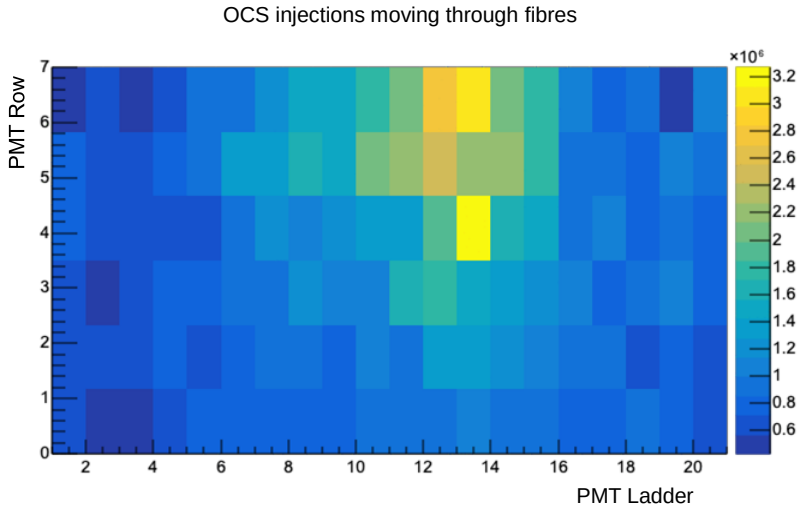
- Calibration and monitoring of the 120 8” R5912 OD PMTs achieved via LZ’s LED-driven Optical Calibration System (OCS)
- 30 optical fibre injection points situated within the OD PMT array
- LEDs of wavelength 435nm used to match the peak wavelength and quantum efficiency of the OD PMTs
- A ‘Monitoring PMT’ is also used to observe the long-term stability of the OCS.



Outer Detector PMT Calibration: OCS

Example of fibre injections during PMT QA:



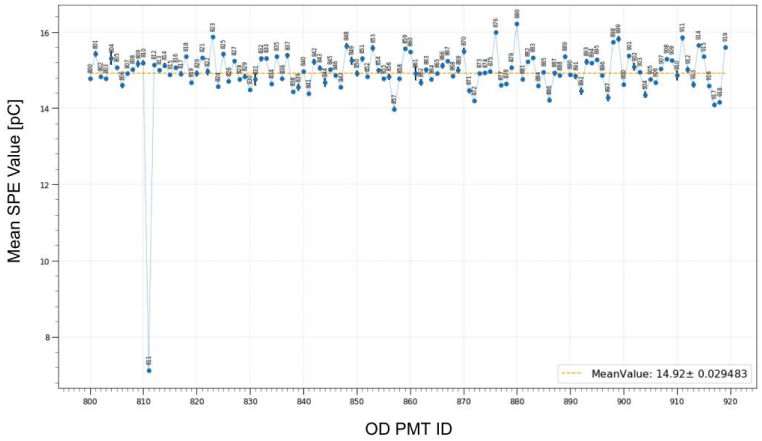


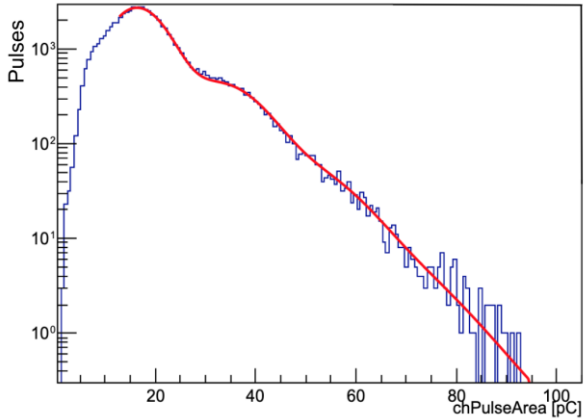
OD PMT Calibration: SPE Response

Outer Detector PMT calibrations are quantified by each channel's single-photoelectron response.

Assuming the light source is steady and the mean number of photons incident on the PMT is constant, then PMT SPE response may be modelled as a convolution of Poisson and Gaussian distributions.

Takes into account both the Poisson distribution of incident photons and the quantum efficiency that these photons are converted into electrons.



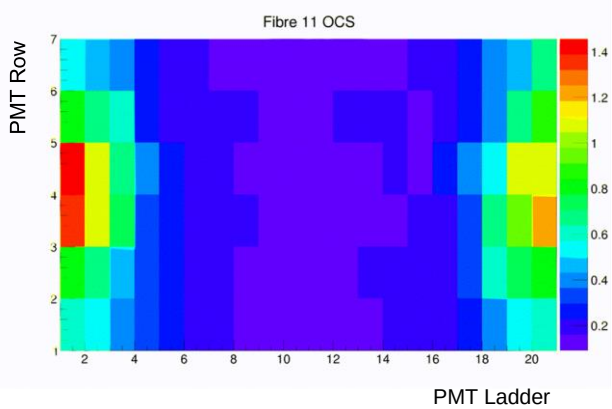


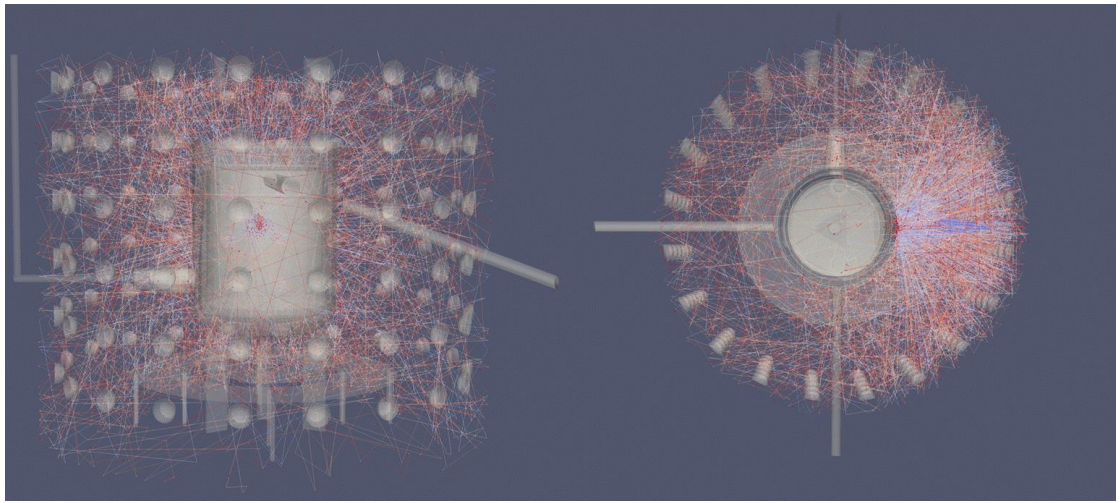
$$S_{ideal}(x) = P(n;\mu) \otimes G_n(x) = \sum_{n=0}^{\infty} \frac{\mu^n e^{-\mu}}{n!} \frac{1}{\sigma_1 \sqrt{2n\pi}} \exp\left(-\frac{(x - nQ_1)^2}{2n\sigma_1^2}\right).$$

- μ - mean number of photoelectrons collected at first dynode.
- Q_1 - Average charge at PMT output for 1 photoelectron.

OD PMT Calibration: SPE Response

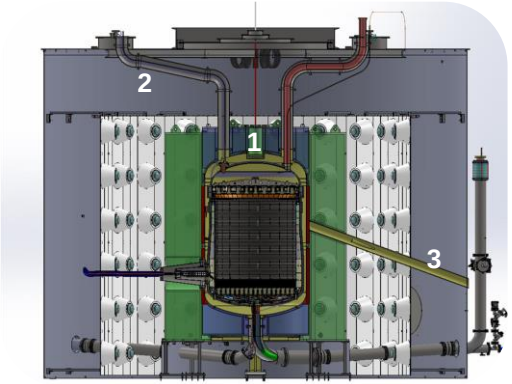
Example of SPE calibration injections:



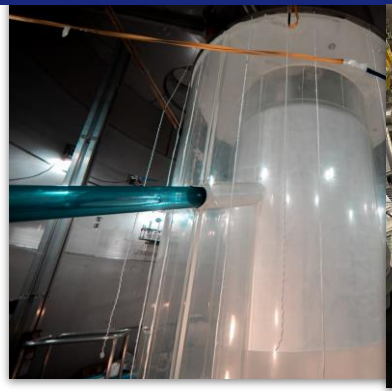


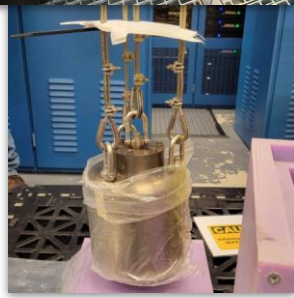
OD Calibration: Source Deployment

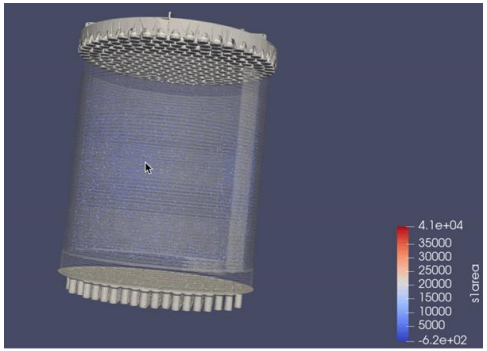
Three types of controlled radioactive source deployment used in LZ:

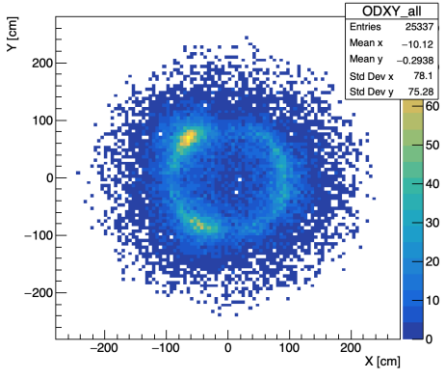


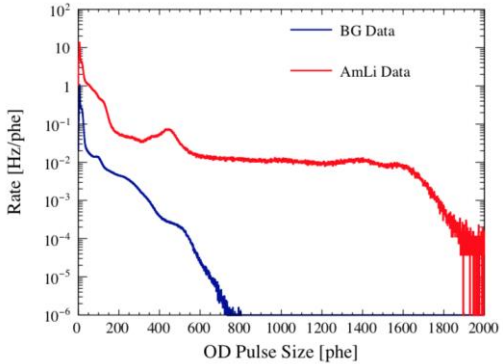
1. Photoneutron sources: YBe. Lowered into the detector above the tungsten shield.
2. Three external CSD tubes - neutrons and gammas (AmLi, Cf-252 and Th-228). Lowered to various fixed Z positions.
3. 2 neutron conduits: one horizontal, one angled, used for localised NR calibrations using DD neutron generator.





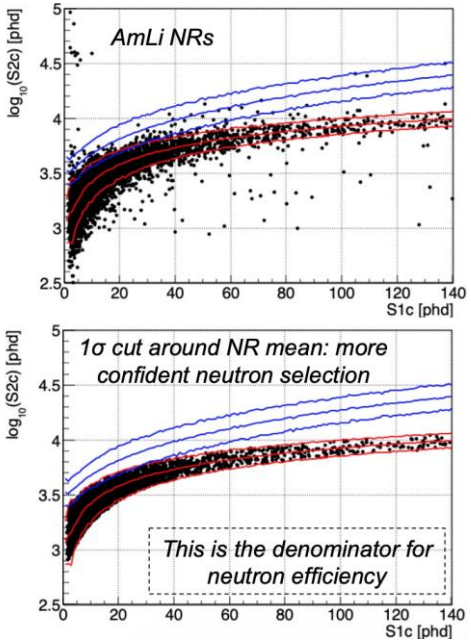




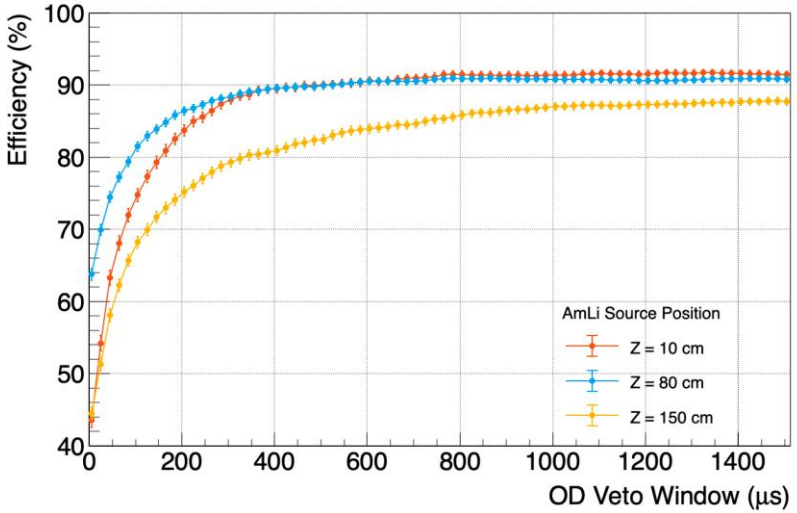


OD Neutron Tagging

Efficiency and false veto fraction is assessed using different windows and thresholds while also accounting for detector geometry.



After factoring for accidental coincidences of AmLi gammas and neutrons with single scatter nuclear recoils in the TPC, we have a tagging efficiency of **(89 ± 3)** %.

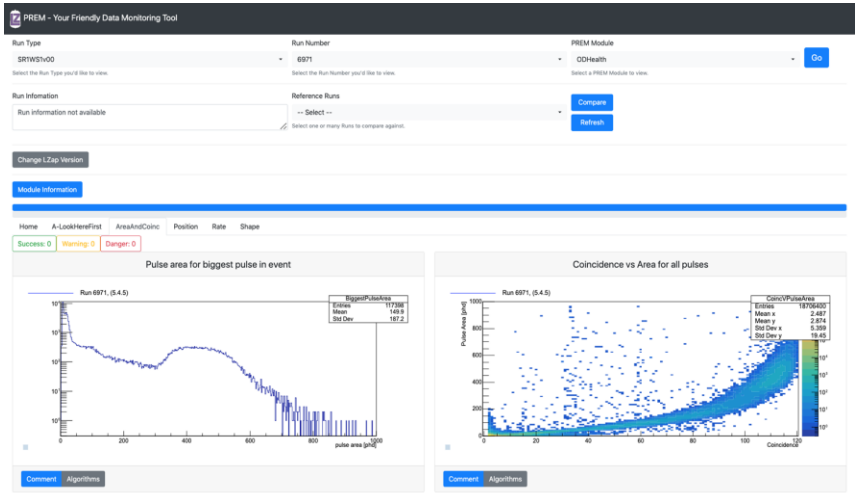


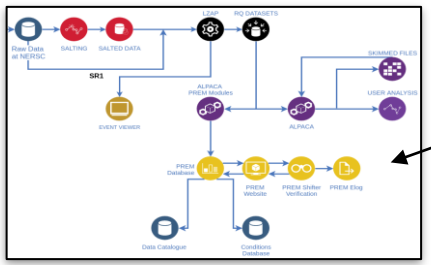
Points are corrected for accidentals using observed rate in random triggered windows.

Tracking OD Performance: PREM

Physics **RE**adiness **M**onitor

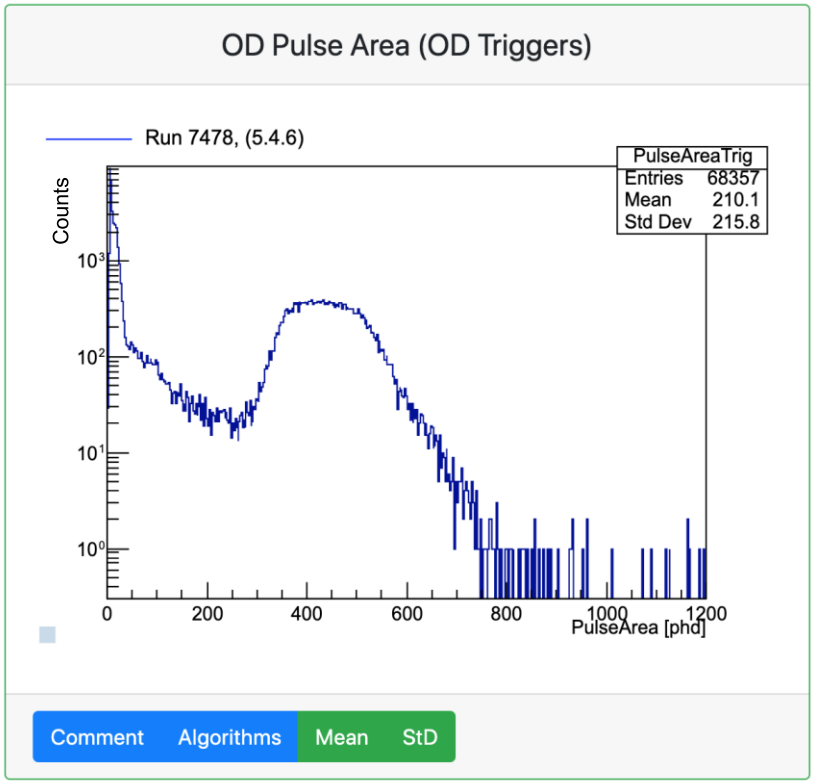
- The official offline Data Quality Monitor
- Creates JSON objects containing the analysis outputs and pushes these to a website
- Website allows quick and easy viewing of data modules for monitoring and comparisons over different data runs



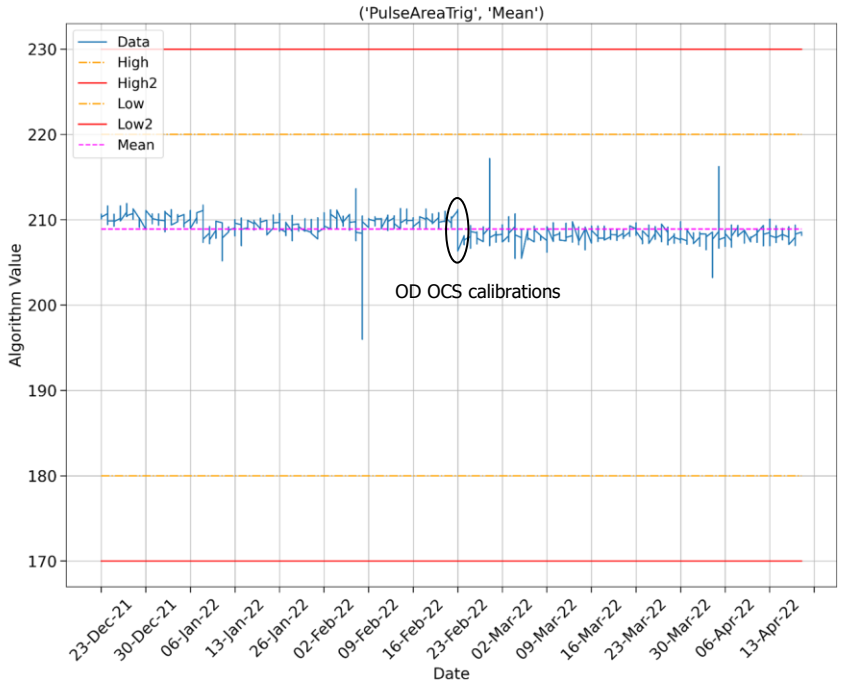


Allows us to look at SPE response and other OD behaviour over a long period of data-taking

Tracking OD Performance: PREM

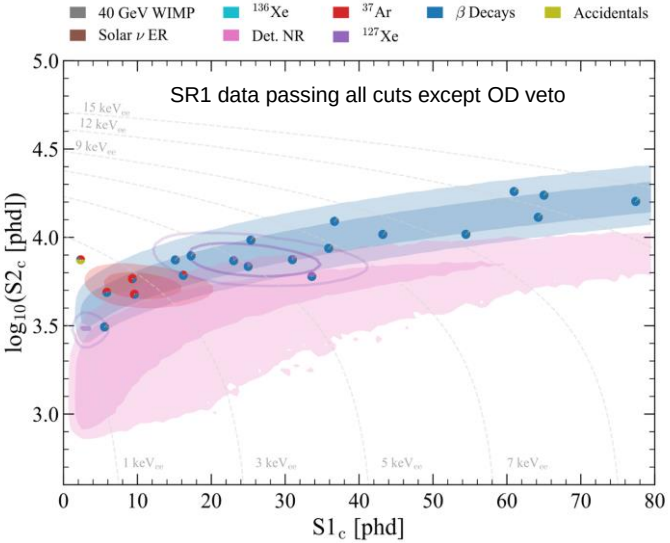


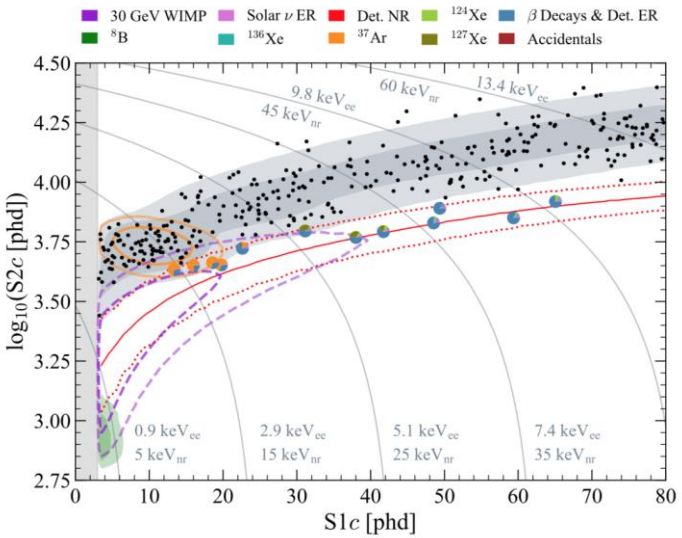
Histogram of OD pulse areas in OD triggers, only includes pulses with Coincidence > 5 (hit 5 OD PMTs)



OD Contribution to WIMP Search

- Neutron backgrounds, “Det. NR”, with OD tag are 7.7 times larger than without (tagging efficiency is 89 ± 3%).
- By design, 5% of non-neutron backgrounds have an accidental OD-tag.
- We use OD-tagged data to set data driven constraints on Det. NR rate:< 0.2 events.
- SR1 data is consistent with simulation estimate of 0.06 events in 60 live-days.
- The Outer Detector is performing well and has helped LZ to reach its first science result and increase sensitivity!





Thank You!

LZ (LUX-ZEPLIN) Collaboration, 38 Institutions

250 scientists, engineers, and technical staff

@lzdarkmatter

https://lz.lbl.gov/

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