HEP Annual Meeting 2022

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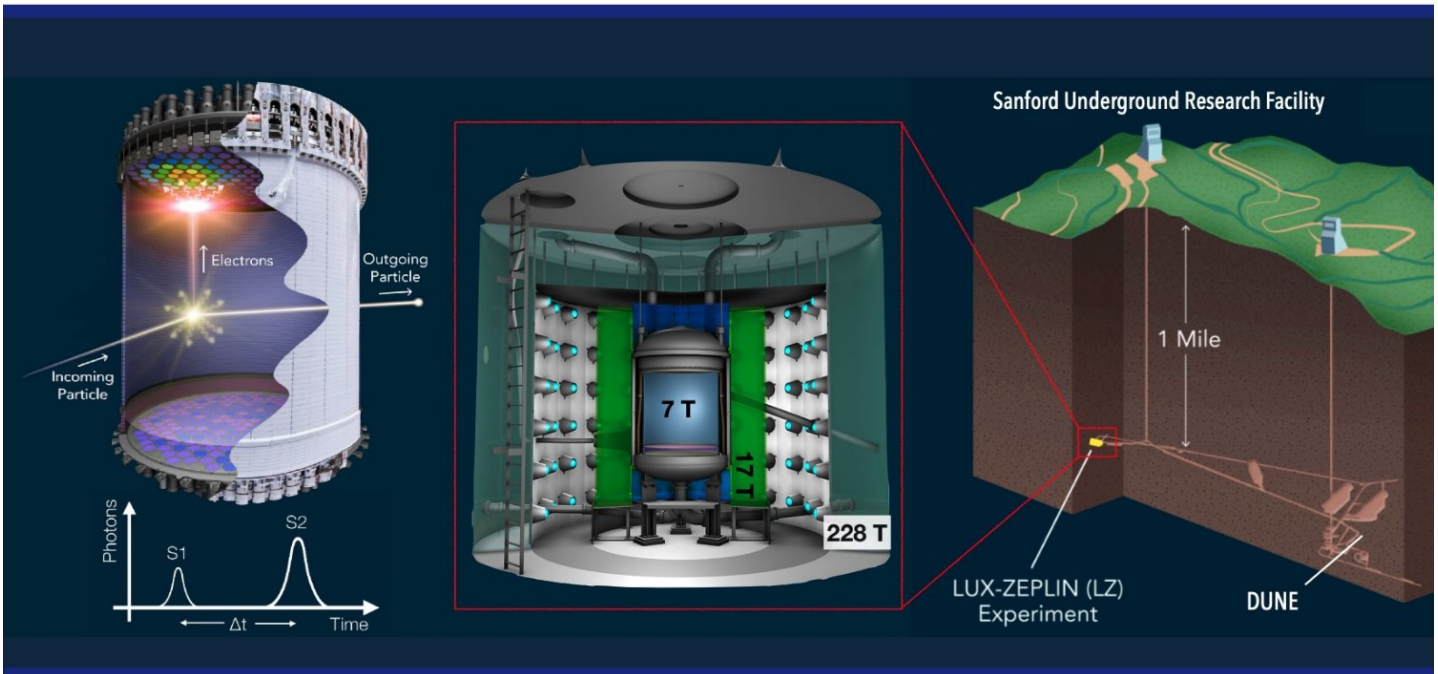
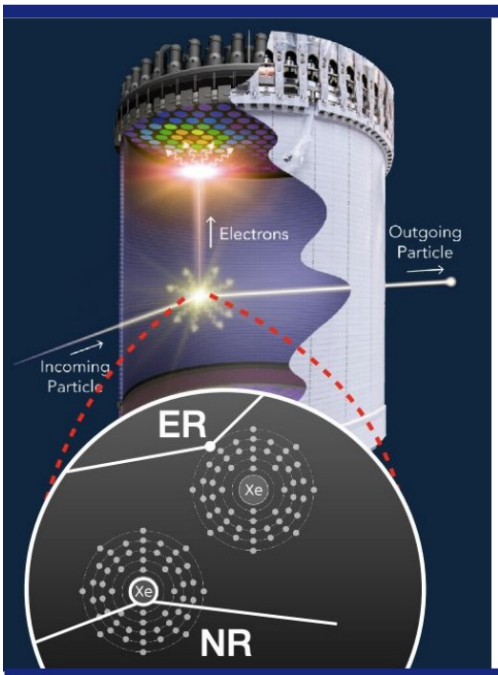
Overview

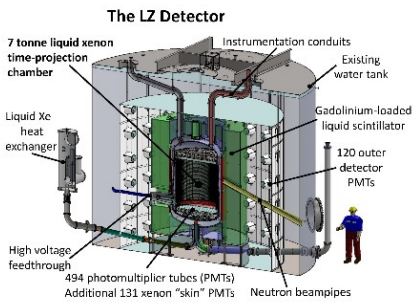
- Introduction to LZ
- Roles in LZ
- Data analysis and technical tasks
- PREM
- Future contributions

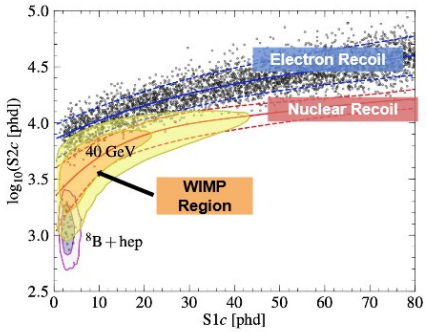
Introduction to LZ



Introduction to LZ: Interactions







- Interactions are characterised by the ratio of S2 to S1 pulse areas in an event
- Larger ratios indicate ER
- Smaller ratios indicate NR
- LZ aims to look for anomalous NR events in an ultra-low background detector
- Most background events are ER-like, but any background NR events must be vetoed by the outer detector (OD)

My roles in LZ

Data Analysis and Technical Tasks

- Liverpool group has a focus on the neutron and gamma background veto in the LZ Outer Detector (OD).
  - Conducted veto efficiency studies for the OD using data from known radioactive calibration sources.
- Also responsible for maintaining and using the OD's Optical Calibration System (OCS), designed and produced here in Liverpool.
  - Studied a new fit which better describes the single photoelectron peaks at lower pulse areas in the OD PMTs.

Data Quality Monitoring

- Liverpool group is instrumental in maintaining and developing LZ's data quality monitoring activity.
- Liverpool group produced the Physics Readiness Monitor (PREM), a user-friendly website that allows easy interaction with plots and figures from processed data runs.
  - Developed aesthetic and practical changes to the website
- Responsible for evaluating overall data quality of processed runs that can be used in WIMP search analysis post-SR1

Changes to SPE Fit

Standard LZ SPE fit in PREM uses ideal PMT response function: a convolution of a gaussian distribution with poisson statistics.

Adding an exponential term into the model may achieve a fit closer to that of a 'real' single electron response in the PMTs.

Would including this term improve overall SPE fit parameters across the range of outer detector PMT channels, and hence increase detector stability?

Fitting LED data from the OD OCS.

Ideal PMT response model to n phe:

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

- μ - mean number of photoelectrons seen.
- Q_1 - Average charge at PMT output for 1 photoelectron.
- σ - Corresponding StD.

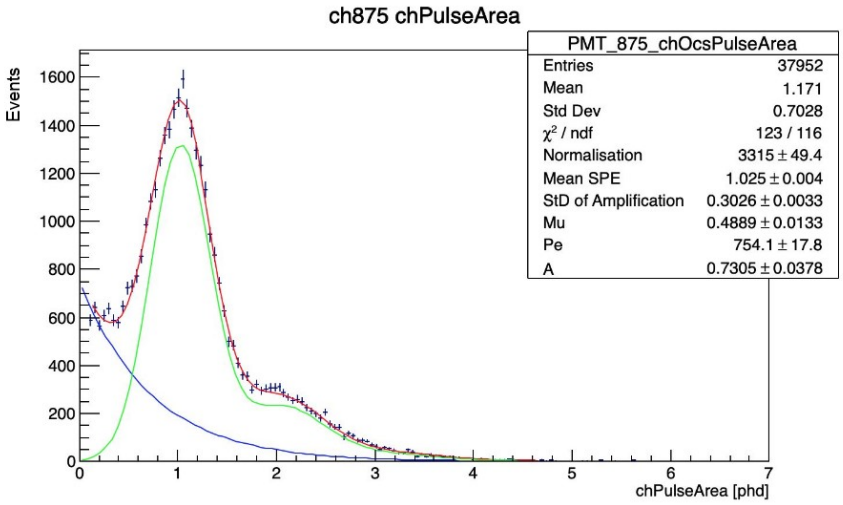
Real PMT response model:

$$\frac{p_E}{A} e^{-\frac{x-x_p}{A}} + \sum_{n=2}^{N_M} \frac{P(n;\mu)}{\sqrt{2n\pi}\sigma_1} e^{-(1/2n)\left(\frac{x-nx_1-x_p}{\sigma_1}\right)^2}$$

- A - slope of exponential part of the single electron response.
- P_E - fraction of events under the exponential function.
- x_p - pedestal position.

  (Currently set to 0 as no way of knowing where the pedestal lies, may be suppressed by the gain and bias in the DAQ).

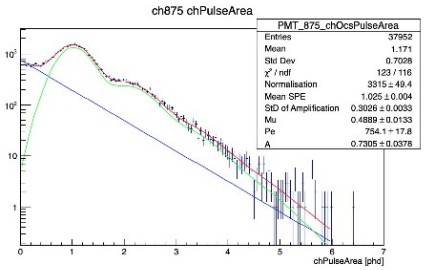
Plotting full fit



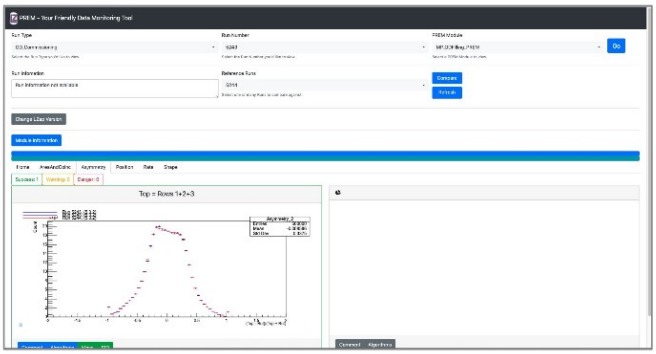
Exponential

Poisson-Gaussian

Full fit



Data Quality Monitoring

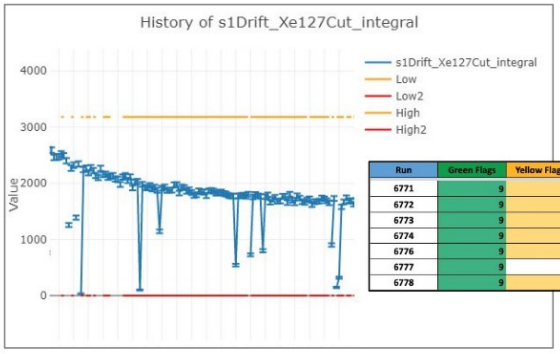


Alongside PREM-dev team, made aesthetic and practical changes to the site.

Created coding framework for evaluating the quality of data runs that may be used for WIMP search analysis post-SR1 based on PREM algorithm flags.

PREM

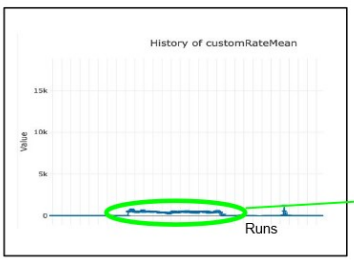
- The official offline Data Quality Monitor
- Creates JSON objects containing the analysis outputs and pushes these to a website
- Website allows quick and easy viewing of data modules for monitoring and comparisons over different data runs

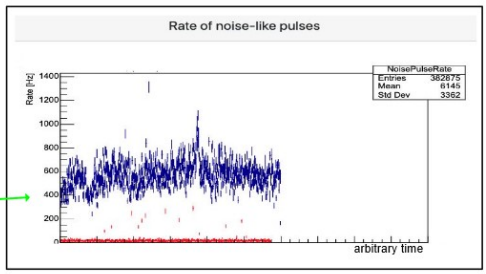


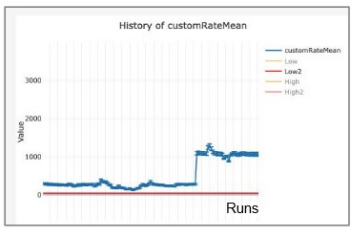
Run	Green Flags	Yellow Flags	Red Flags
6771	9	1	0
6772	9	1	0
6773	9	1	0
6774	9	1	0
6776	9	1	0
6777	9	0	1
6778	9	1	0

Data Quality Monitoring

Created coding framework for evaluating the quality of data runs that may be used for WIMP search analysis post-SR1 based on PREM algorithm flags.







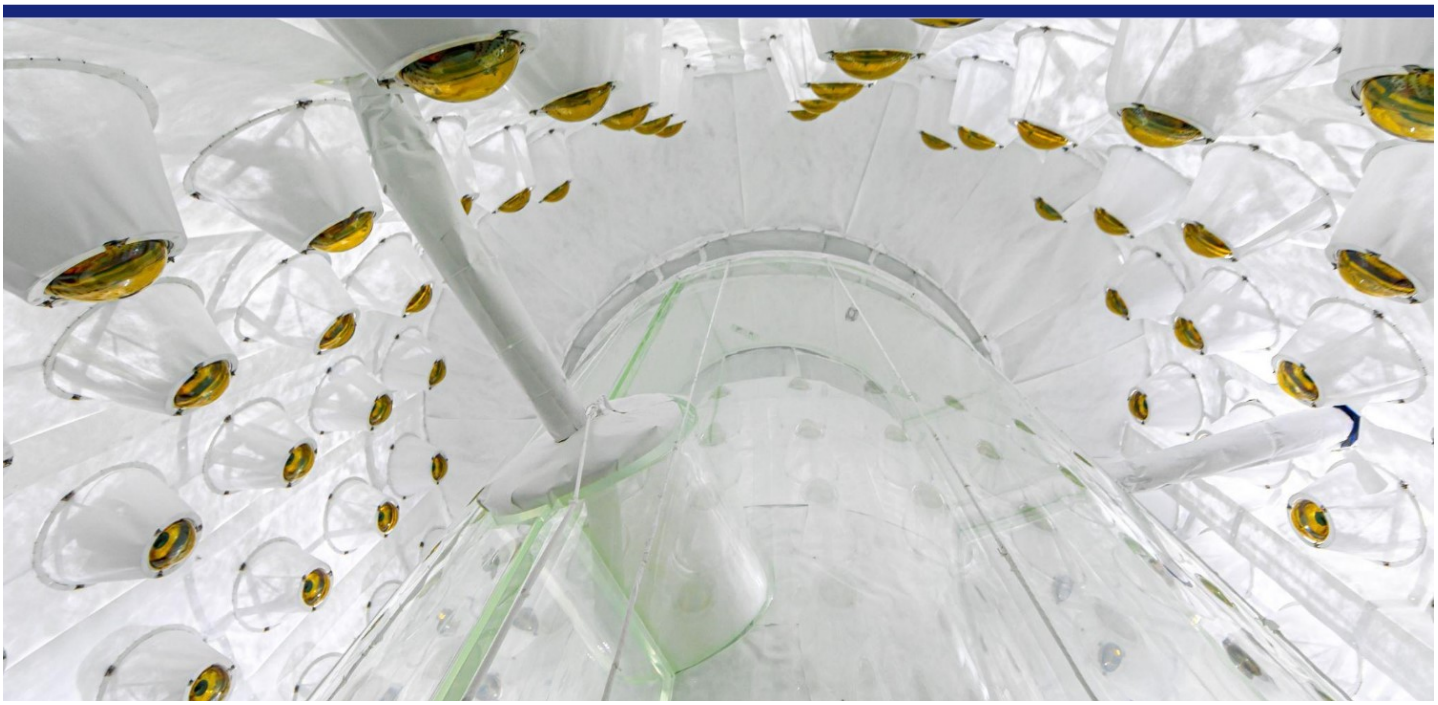
Can identify runs with that show PMT flare ups or electronic noise, to cross check with the data acquisition info

Future work

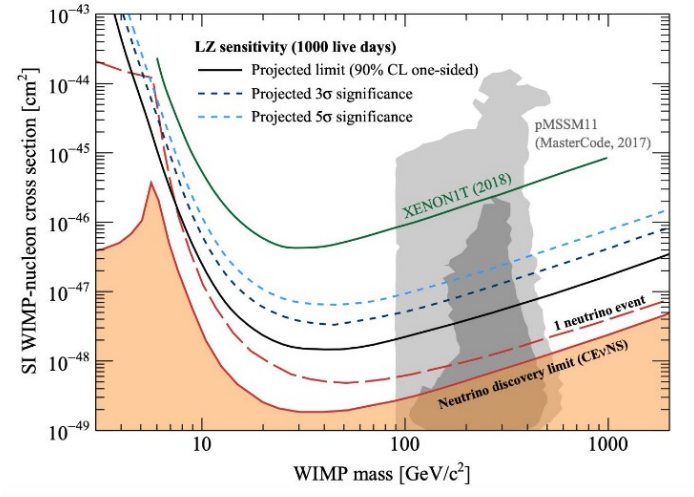
- Further improve the PMT response model for SPE peaks by extracting parameters of the pedestal (where the DAQ accrues data at zero-suppression). Currently the new exponential term covers both the dynode noise and the pedestal information.
- Take a lead with data quality analysis for post-SR1 data
  - Optimise algorithm thresholds within the PREM modules to better tune runs into categories, e.g. ‘gold’, ‘green’, ‘yellow’, and ‘red’.
- LTA planned from next month to the winter: hardware tasks may include upgrading parts of the OCS and taking a lead with commissioning the OD for future science runs.

Backup Slides

LZ OD



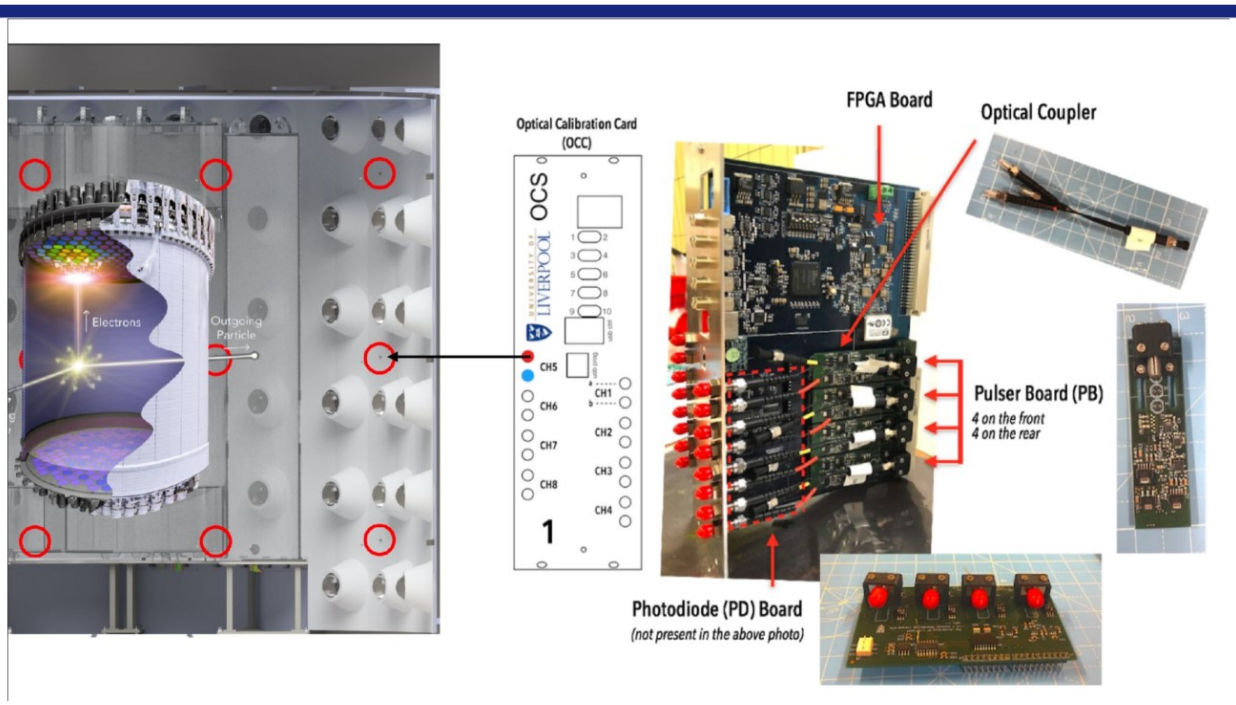
LZ Sensitivity



The most stringent constraint to date on the WIMP-neutron cross section was determined by the XENON1T collaboration, with a minimum of 6.3×10^{-42} cm^2 at 30 GeV/c^2 and 90% confidence level.

D.S. Akerib, C.W. Akerlof, S.K. Alsum, H.M. Arau´jo, M. Arthurs, X. Bai, A.J. Bailey, J. Bal- ajthy, S. Balashov, D. Bauer, and et al. Projected WIMP sensitivity of the LUX-ZEPLIN dark matter experiment. Physical Review D, 101(5), Mar 2020.

OD OCS



Full PMT Response

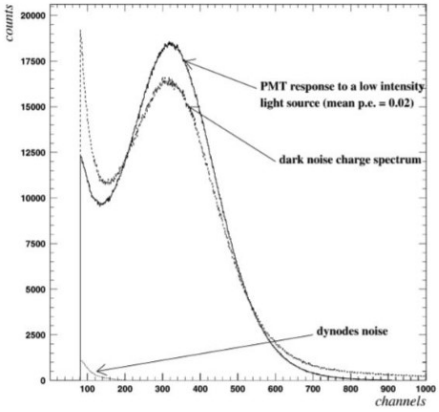


Fig. 2. Dark noise and PMT response to a low intensity light source. The dynodes noise distribution is also shown.

R. Dossi, A. Ianni, G. Ranucci, O.Ju. Smirnov,
Methods for precise photoelectron counting with photomultipliers,
Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment

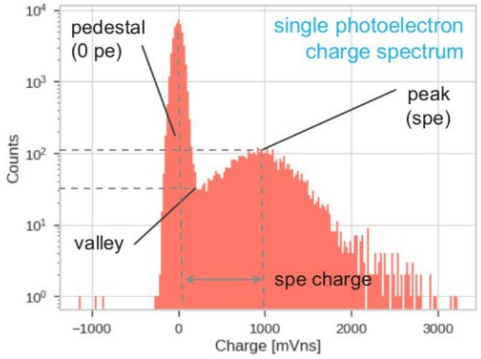
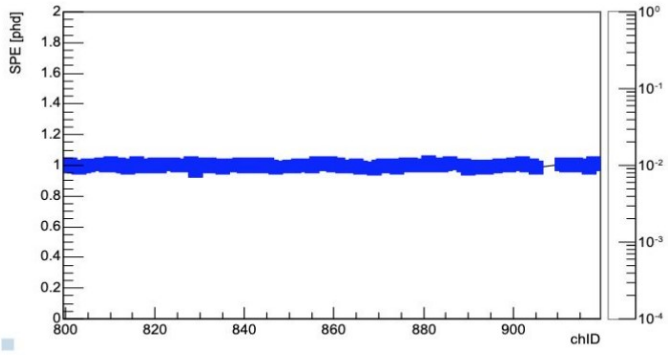


Figure 3. Single photoelectron (SPE) charge spectrum. Features used for gain and peak-to-valley ratio determination are highlighted.

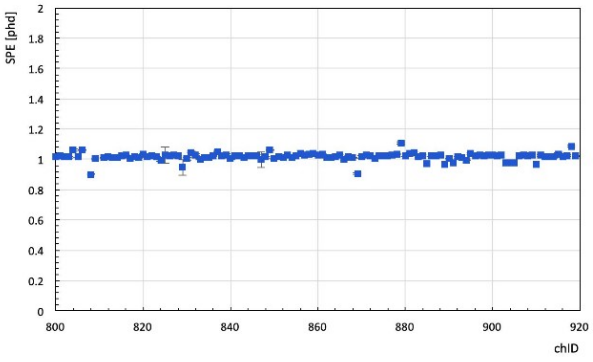
Classen, Lew & Kappes, Alexander. (2019). The multi-PMT optical module for the IceCube-Upgrade. EPJ Web of Conferences. 207. 06004. 10.1051/epjconf/201920706004.

Effect of fit on mean SPE value

Current fit on PREM



With new fit



SPE Fit Discussion points

- After applying the new fit we notice a 2-3% difference in mean SPE values output by the fit in most of the OD PMTs
- This is more stark in 'badly performing' PMTs like ch918 (more like a 8% difference)
- The range of the fit needs to be considered. The new fit range is hard-coded while Ewan's previous range is $\pm 0.75\sigma$ from the mean:

```
Hists[k-800]->Fit("GaussPoissonSum","","",chMean-(chStD*0.75), chMean+(chStD*0.75));
```

Will need to consider best range to use to optimise the mean SPE values.

SPE Fit Next Steps

- Currently we don't have a pedestal term, as we don't know any parameters, so the exponential term covers both the dynode noise and the pedestal. We're using 2e6 gain, so SPE peak will be closer to the pedestal, and more noise leaks into the SPE region.
- Could possibly improve this fit if we had some access to the pedestal parameters -- at the moment we think this information is being suppressed by the DAQ.