Ngcer Calibration Update

I have been working on the noble gas calibration.

I looked at two methods,
1. The Poisson fit that that Cameroon Cotton developed
2. The multi-Gaussian fit that was used to calibrate the aerogel.

I have concluded that the Poisson method is much easier to get working properly, and has given me one set of parameters for both 2021, and 2022.

Poisson Method

Uses a modified Poisson function: $$f(x) = A\frac{\frac{\lambda}{\mu}^{\frac{x}{\mu}} e^{-\frac{\lambda}{\mu}}}{\Gamma(\frac{x}{\mu}+1)}$$

- Where the λ/μ term is the calibration parameter of interest
- Cameron has a full write up, including the derivation here:
  - https://github.com/heinricn/hallc_replay_lt/blob/LTSep_Analysis_2022/CALIBRATION/shms_ngcer_calib/SHMS_NGCER_CALIBRATION.pdf
- I left all the stuff he wrote about here the same, only changing some of the cut values and fit windows.

Gaussian Method

Background

This method cites the paper: https://doi.org/10.1016/0168-9002(94)90183-X

The function as it is written in the paper is: $S_{real} = B + S$

$$S_{\mathrm{real}}(x) \approx \left\{ \frac{(1-w)}{\sigma_0\sqrt{2\pi}} \exp\left(-\frac{(x-Q_0)^2}{2\sigma_0^2} \right) + w\theta(x-Q_0) \times \alpha \exp[-\alpha(x-Q_0)] \right\} e^{-\mu} + \sum_{n=1}^{\infty} \frac{\mu^n e^{-\mu}}{n!} \times \frac{1}{\sigma_1\sqrt{2\pi n}} \times \exp\left(-\frac{(x-Q_0-Q_{\mathrm{sh}}-nQ_1)^2}{2n\sigma_1^2} \right), \quad (10)$$

Spectrum

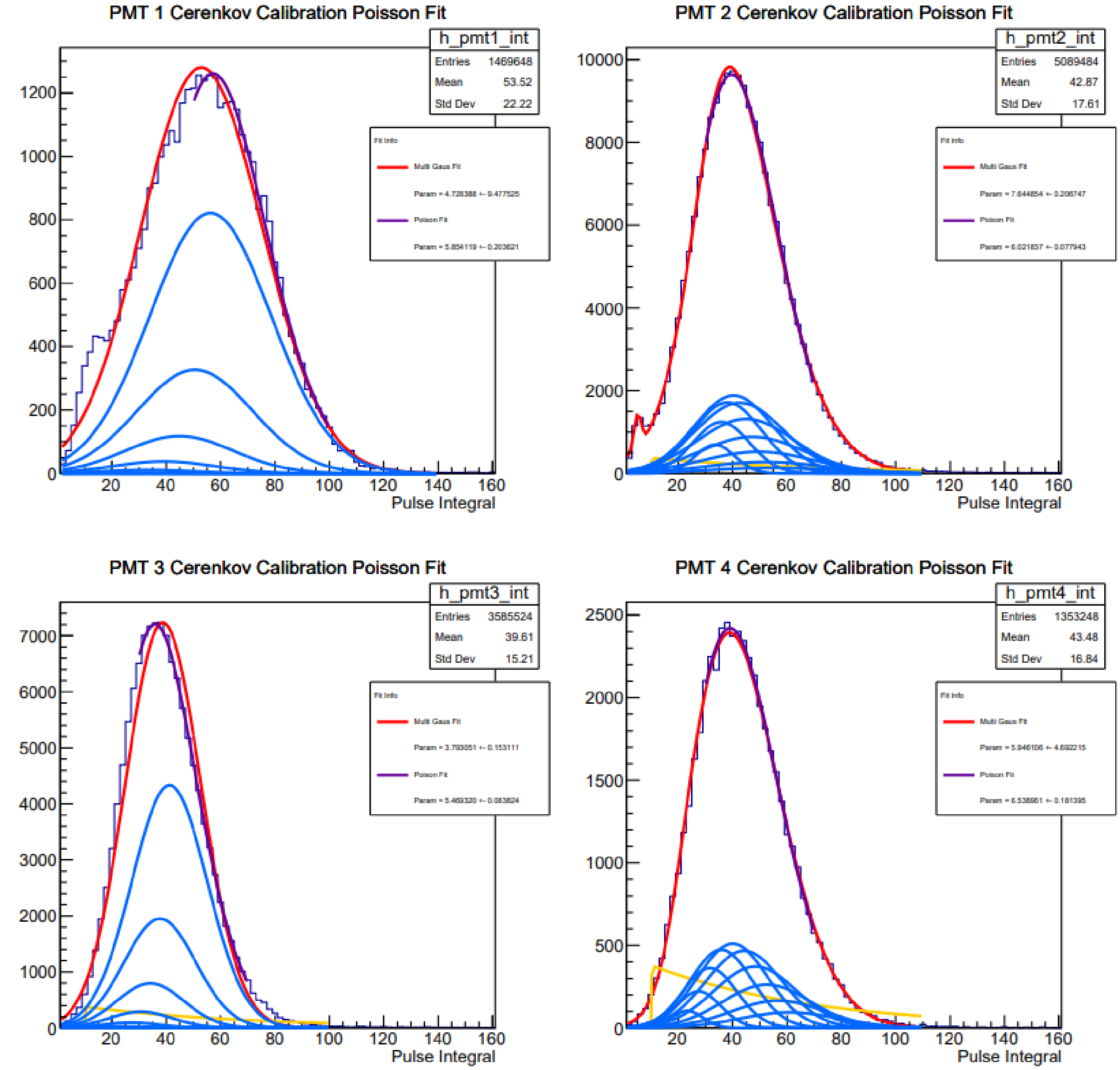
This is noramized to 1, so I added 2 additional parameters to make: f = c1*B + c2*S

Root did not like my implementation of this function as a for loop (would not fit at all), so I had to hard code the function up to the desired number of terms.

I used 10 Gaussians in what I’m showing, although I tried 15 and that had little effect, but 7 is too few.

Calibration

- I calibrated 6 π- settings from across 2021 and 2022, combining the entire setting to get good stats.
- The Gaussian fit often failed, perhaps it is possible to get them to fit properly by fiddling with the parameter limits, and initial values, but I am satisfied with the performance of the Poisson method.



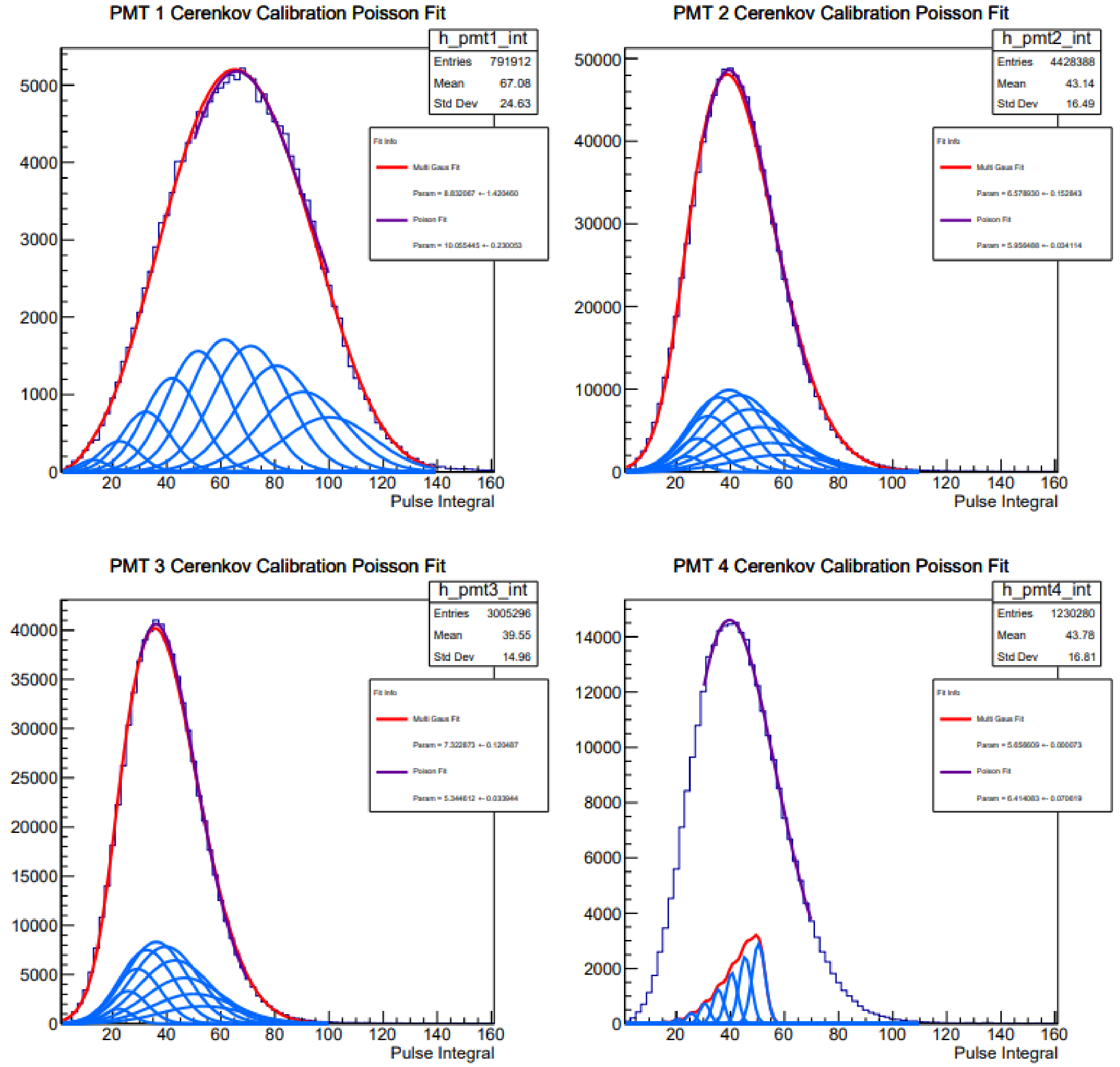
12052

This Run had the fix to the ngcer happen part of the way through the run, so PMTs 1 and 2 have untrustworthy spectrums

Also, Red line is multi-Gaussian fit

Purple line is the Poisson fit

Blue and yellow are the spectrum and background for the multi-Gauss fit (for debugging)



PMT 1 Cerenkov Calibration Poisson Fit
h_pmt1_int
Entries 791912
Mean 67.08
Std Dev 24.63
Fit Info
Multi Gaus Fit
Poison Fit
Pulse Integral
PMT 2 Cerenkov Calibration Poisson Fit
h_pmt2_int
Entries 4428388
Mean 43.14
Std Dev 16.49
Fit Info
Multi Gaus Fit
Poison Fit
Pulse Integral
PMT 3 Cerenkov Calibration Poisson Fit
h_pmt3_int
Entries 3005296
Mean 39.55
Std Dev 14.96
Fit Info
Multi Gaus Fit
Poison Fit
Pulse Integral
PMT 4 Cerenkov Calibration Poisson Fit
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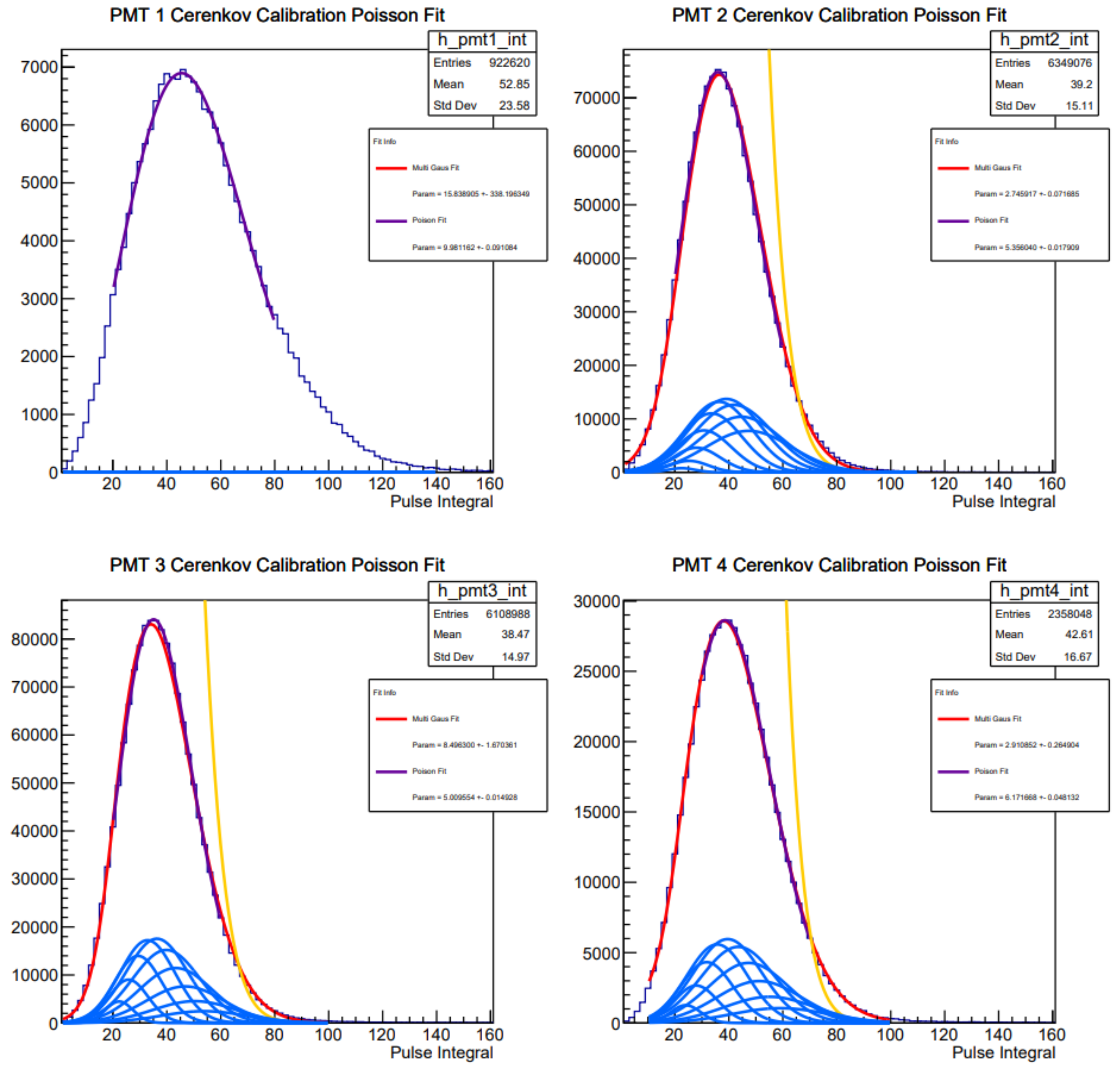
Entries 1230280
Mean 43.78
Std Dev 16.81
Fit Info
Multi Gaus Fit
Poison Fit
Pulse Integral

12068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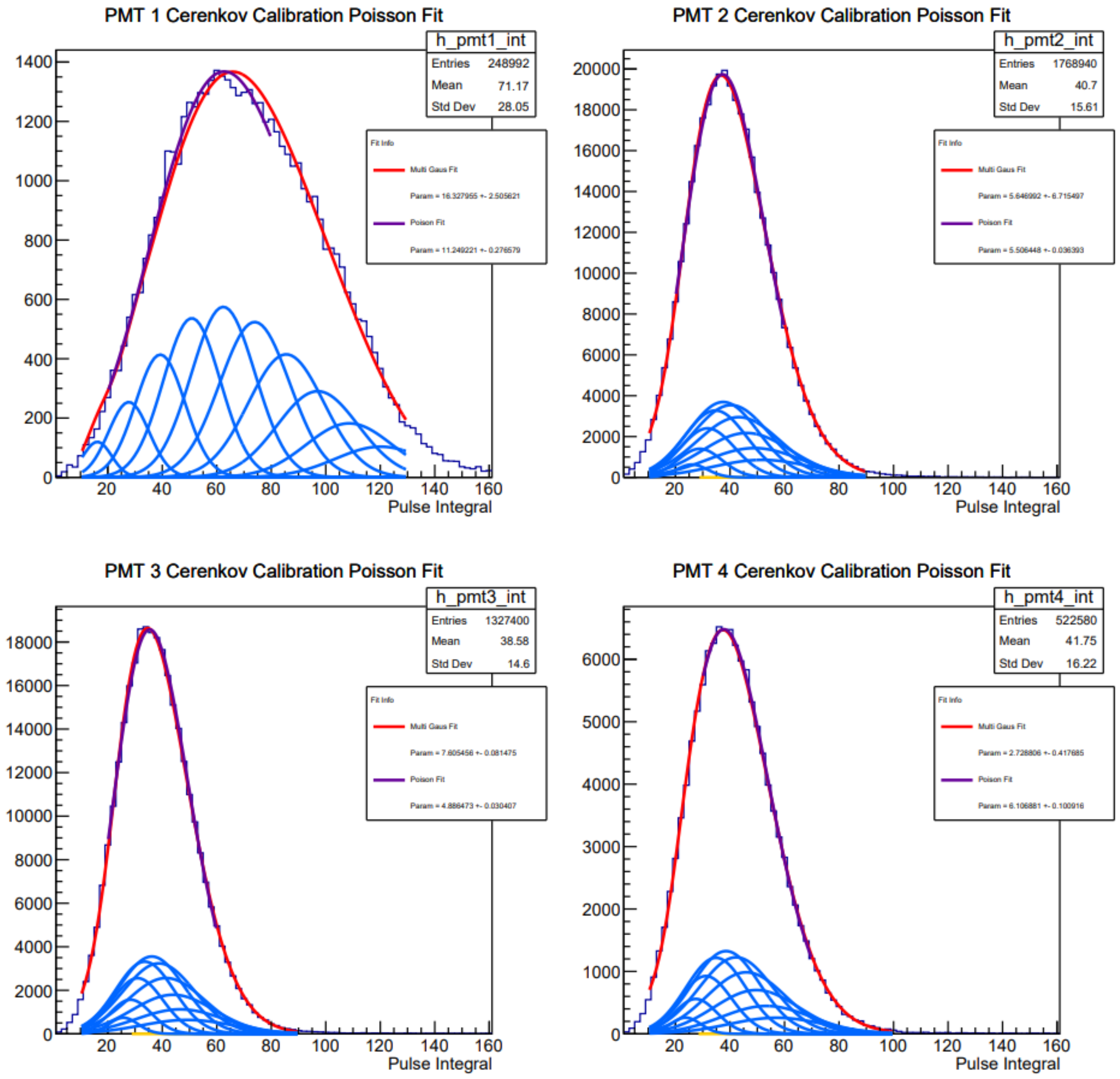
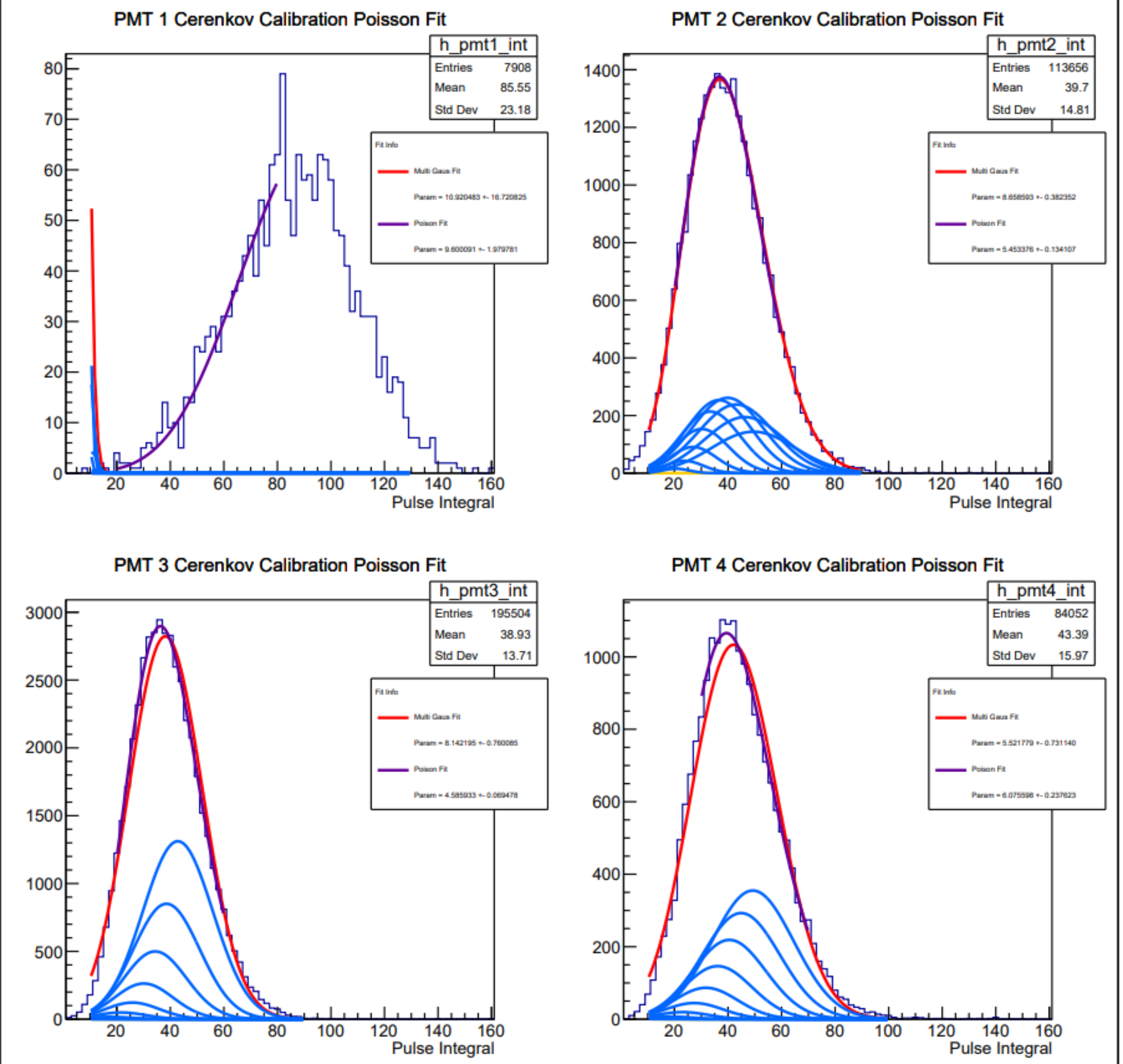
h_pmt1_int
Entries 922620
Mean 52.85
Std Dev 23.58
Fit Info
Multi Gaus Fit
Param = 15.838905 +- 338.196349
Poison Fit
Param = 9.981162 +- 0.091084
Pulse Integral
PMT 2 Cerenkov Calibration Poisson Fit
h_pmt2_int
Entries 6349076
Mean 39.2
Std Dev 15.11
Fit Info
Multi Gaus Fit
Param = 2.745917 +- 0.071685
Poison Fit
Param = 5.356040 +- 0.017909
Pulse Integral
PMT 3 Cerenkov Calibration Poisson Fit
h_pmt3_int
Entries 6108988
Mean 38.47
Std Dev 14.97
Fit Info
Multi Gaus Fit
Param = 8.496300 +- 1.670361
Poison Fit
Param = 5.009554 +- 0.014928
Pulse Integral
PMT 4 Cerenkov Calibration Poisson Fit
h_pmt4_int
Entries 2358048
Mean 42.61
Std Dev 16.67
Fit Info
Multi Gaus Fit
Param = 2.910852 +- 0.264904
Poison Fit
Param = 6.171668 +- 0.048132
Pulse Integral

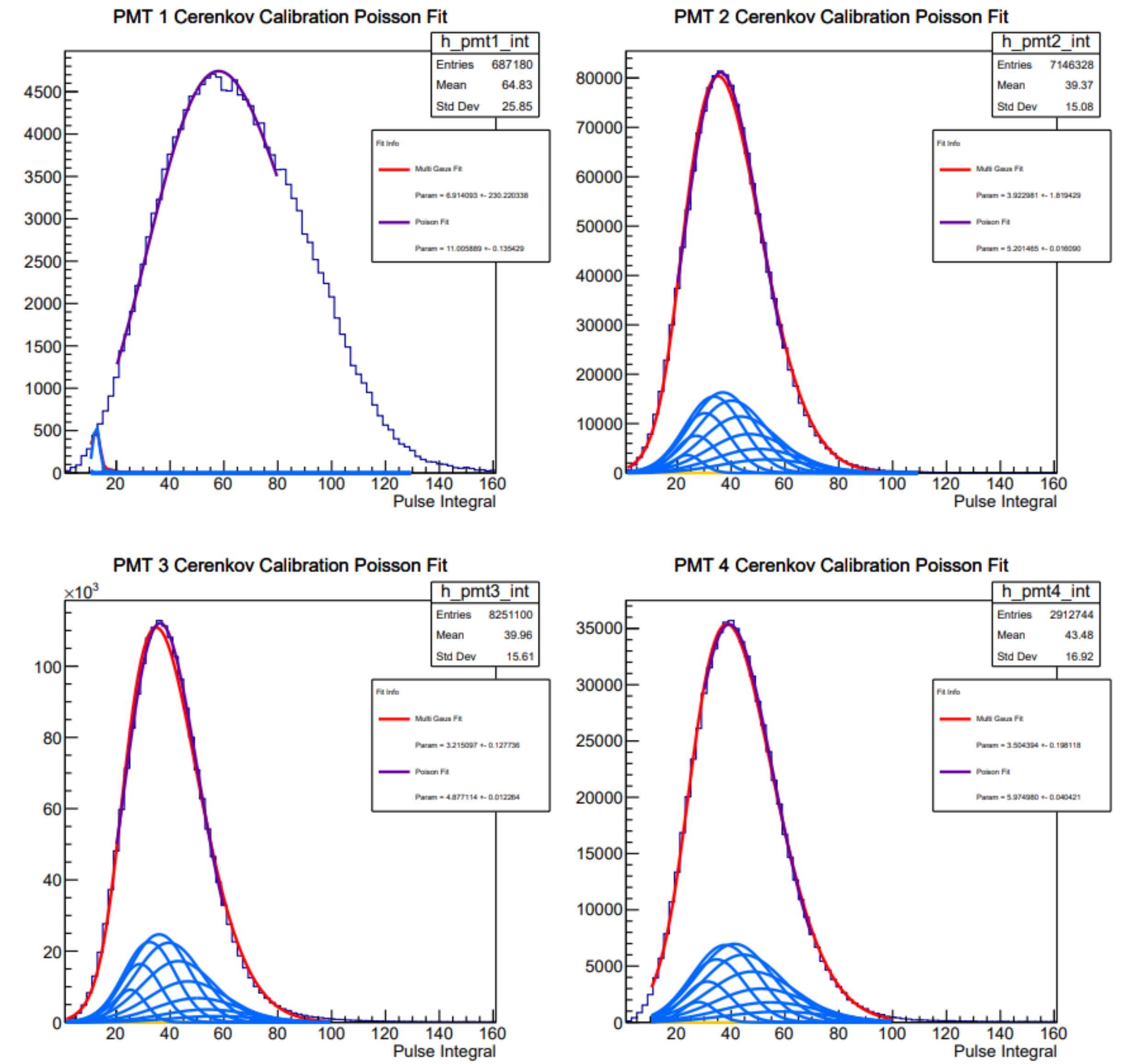
13472


PMT 1 Cerenkov Calibration Poisson Fit
h_pmt1_int
Entries 248992
Mean 71.17
Std Dev 28.05
Fit Info
Multi Gaus Fit
Param = 16.327955 +- 2.505621
Poison Fit
Param = 11.249221 +- 0.276579
Pulse Integral
PMT 2 Cerenkov Calibration Poisson Fit
h_pmt2_int
Entries 1768940
Mean 40.7
Std Dev 15.61
Fit Info
Multi Gaus Fit
Param = 5.646992 +- 6.715497
Poison Fit
Param = 5.506448 +- 0.036393
Pulse Integral
PMT 3 Cerenkov Calibration Poisson Fit
h_pmt3_int
Entries 1327400
Mean 38.58
Std Dev 14.6
Fit Info
Multi Gaus Fit
Param = 7.605456 +- 0.081475
Poison Fit
Param = 4.888473 +- 0.030407
Pulse Integral
PMT 4 Cerenkov Calibration Poisson Fit
h_pmt4_int
Entries 522580
Mean 41.75
Std Dev 16.22
Fit Info
Multi Gaus Fit
Param = 2.728806 +- 0.417685
Poison Fit
Param = 6.106881 +- 0.100916
Pulse Integral

15198


PMT 1 Cerenkov Calibration Poisson Fit
h_pmt1_int
Entries 7908
Mean 85.55
Std Dev 23.18
Fit Info
Multi Gaus Fit
Param = 10.920483 +- 16.720825
Poison Fit
Param = 9.600091 +- 1.979781
Pulse Integral
PMT 2 Cerenkov Calibration Poisson Fit
h_pmt2_int
Entries 113656
Mean 39.7
Std Dev 14.81
Fit Info
Multi Gaus Fit
Param = 8.658593 +- 0.382352
Poison Fit
Param = 5.453376 +- 0.134107
Pulse Integral
PMT 3 Cerenkov Calibration Poisson Fit
h_pmt3_int
Entries 195504
Mean 38.93
Std Dev 13.71
Fit Info
Multi Gaus Fit
Param = 8.142195 +- 0.760085
Poison Fit
Param = 4.585933 +- 0.069478
Pulse Integral
PMT 4 Cerenkov Calibration Poisson Fit
h_pmt4_int
Entries 84052
Mean 43.39
Std Dev 15.97
Fit Info
Multi Gaus Fit
Param = 5.521779 +- 0.731140
Poison Fit
Param = 6.075598 +- 0.237623
Pulse Integral

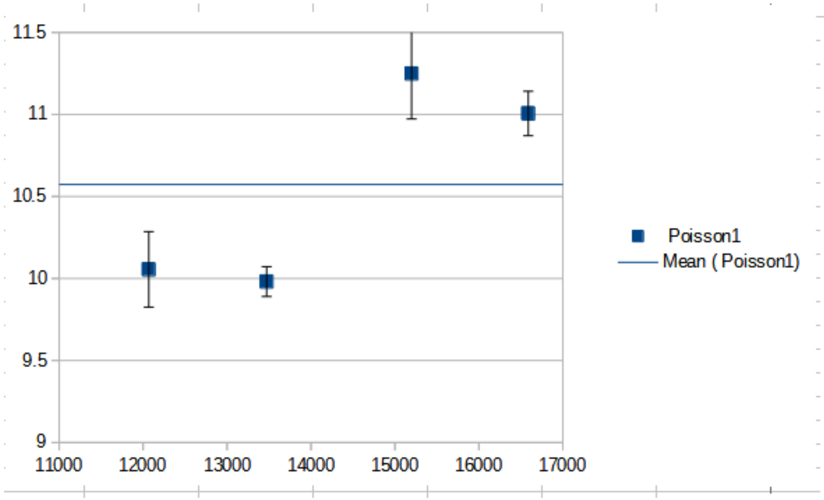
16005

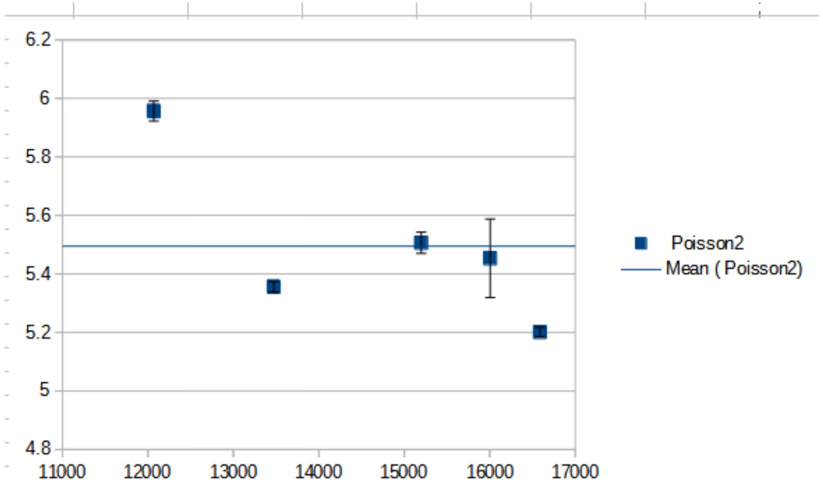


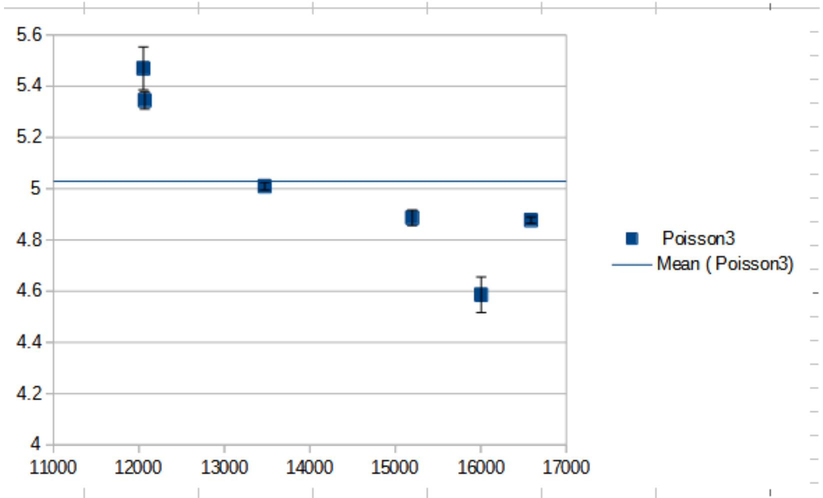
PMT 1 Cerenkov Calibration Poisson Fit
h_pmt1_int
Entries 687180
Mean 64.83
Std Dev 25.85
Fit Info
Multi Gaus Fit
Param = 6.914093 +- 230.220338
Poison Fit
Param = 11.005889 +- 0.135429
Pulse Integral
PMT 2 Cerenkov Calibration Poisson Fit
h_pmt2_int
Entries 7146328
Mean 39.37
Std Dev 15.08
Fit Info
Multi Gaus Fit
Param = 3.922981 +- 1.819429
Poison Fit
Param = 5.201465 +- 0.016090
Pulse Integral
PMT 3 Cerenkov Calibration Poisson Fit
$\times 10^3$
h_pmt3_int
Entries 8251100
Mean 39.96
Std Dev 15.61
Fit Info
Multi Gaus Fit
Param = 3.215097 +- 0.127736
Poison Fit
Param = 4.877114 +- 0.012264
Pulse Integral
PMT 4 Cerenkov Calibration Poisson Fit
h_pmt4_int
Entries 2912744
Mean 43.48
Std Dev 16.92
Fit Info
Multi Gaus Fit
Param = 3.504394 +- 0.198118
Poison Fit
Param = 5.974980 +- 0.040421
Pulse Integral

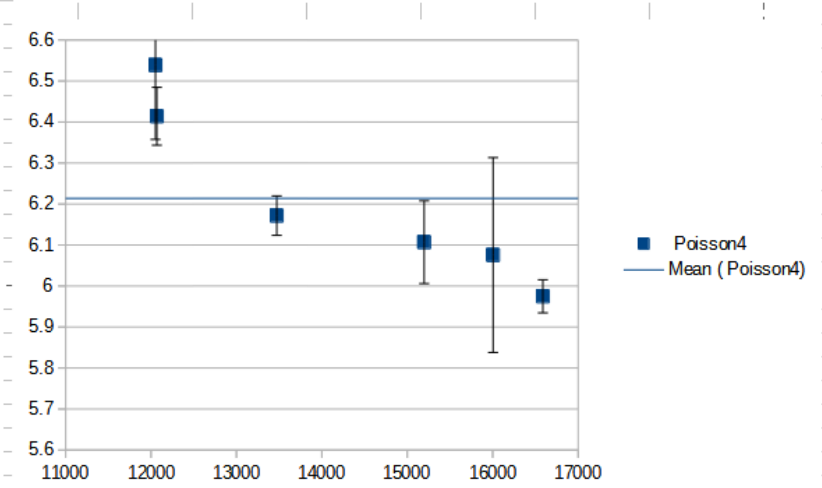
16588

Fit Overview







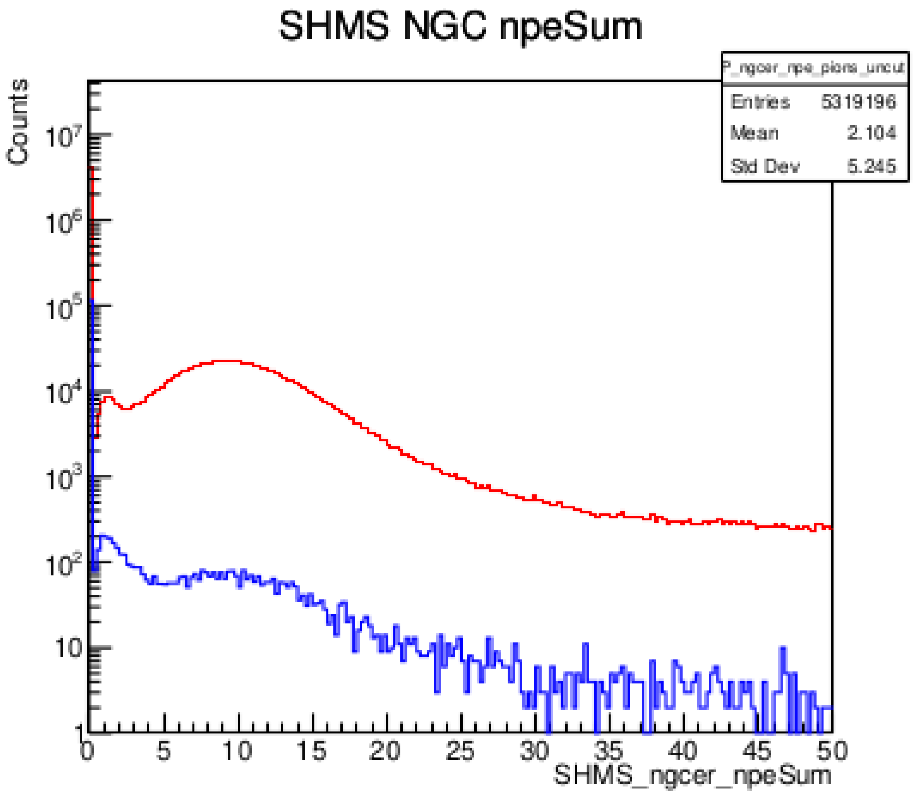


Calibration Conclusions

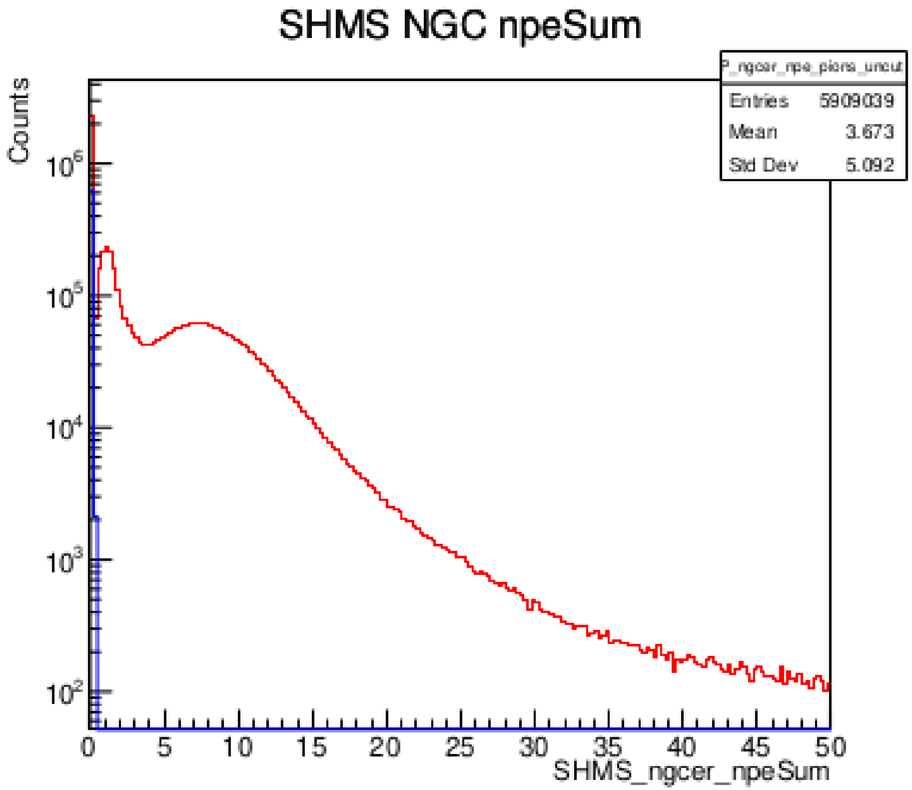
- I excluded the values from pmts 1 and 2 from 12052, as well as from pmt 1 in 16005. then took the average of the rest.
- The parameters look very stable, so I don’t think any further investigation is needed.
- Next is comparison with online, which we expect to be very different as we had a very old set of parameters while we were running.

Q^2 1.60 W 3.08 center high ε LD-

Offline

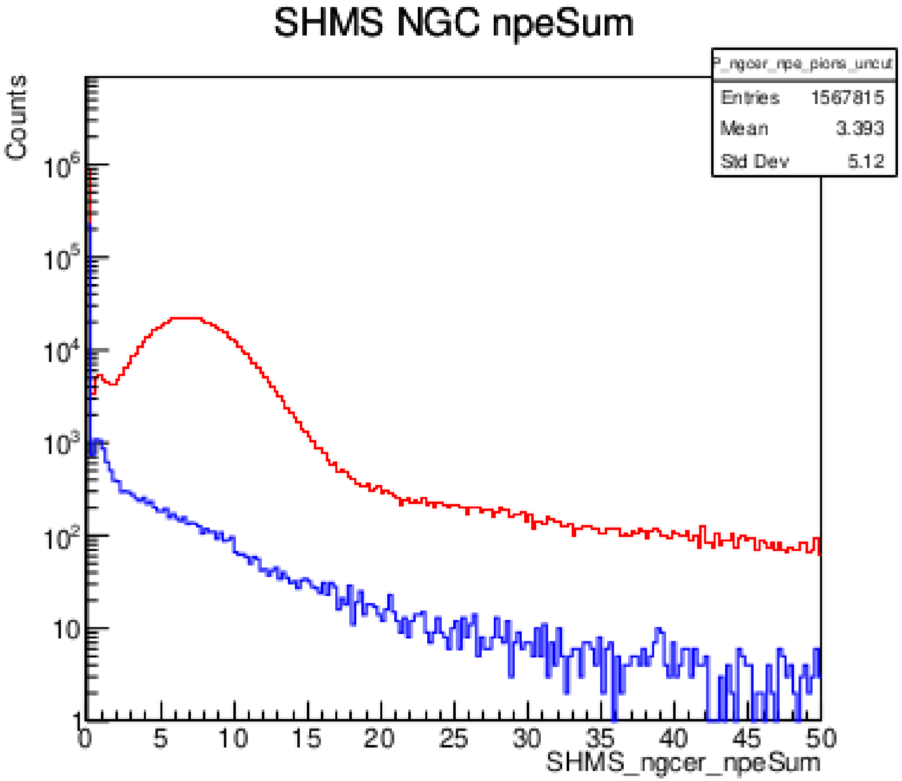


Online

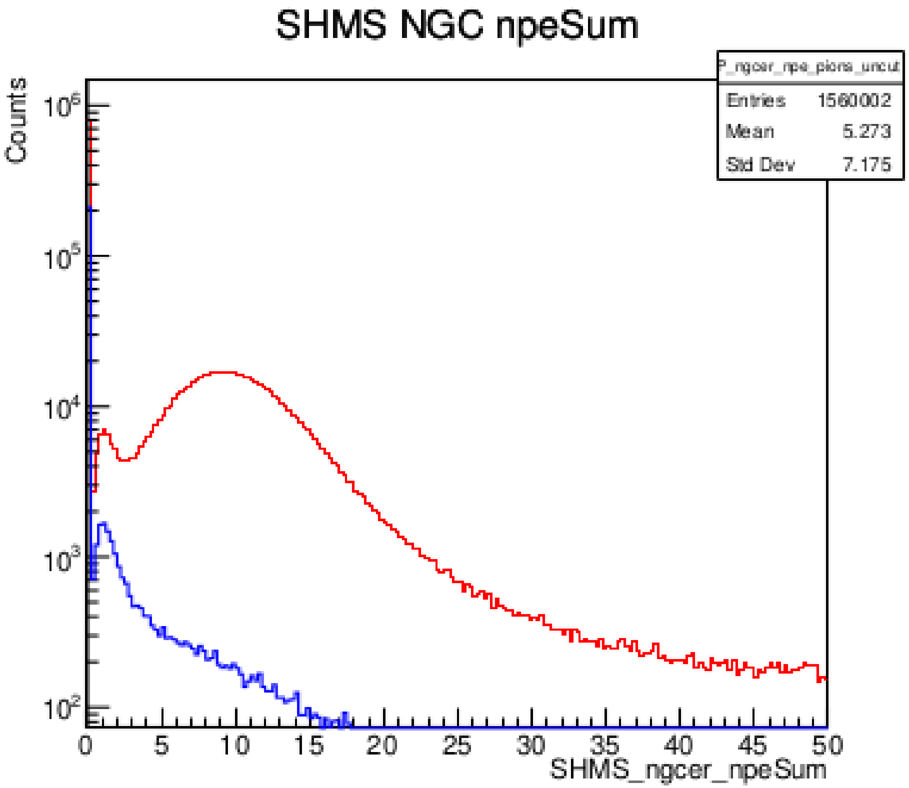


Q^2 3.85 W 2.62 center high ε LD-

Offline

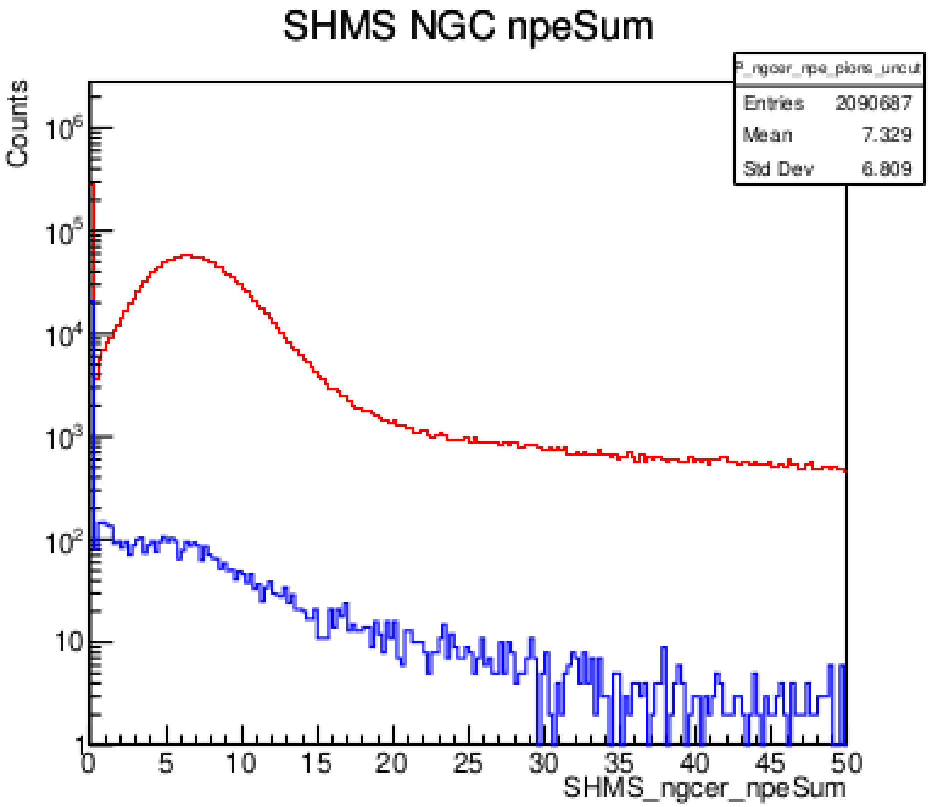


Online

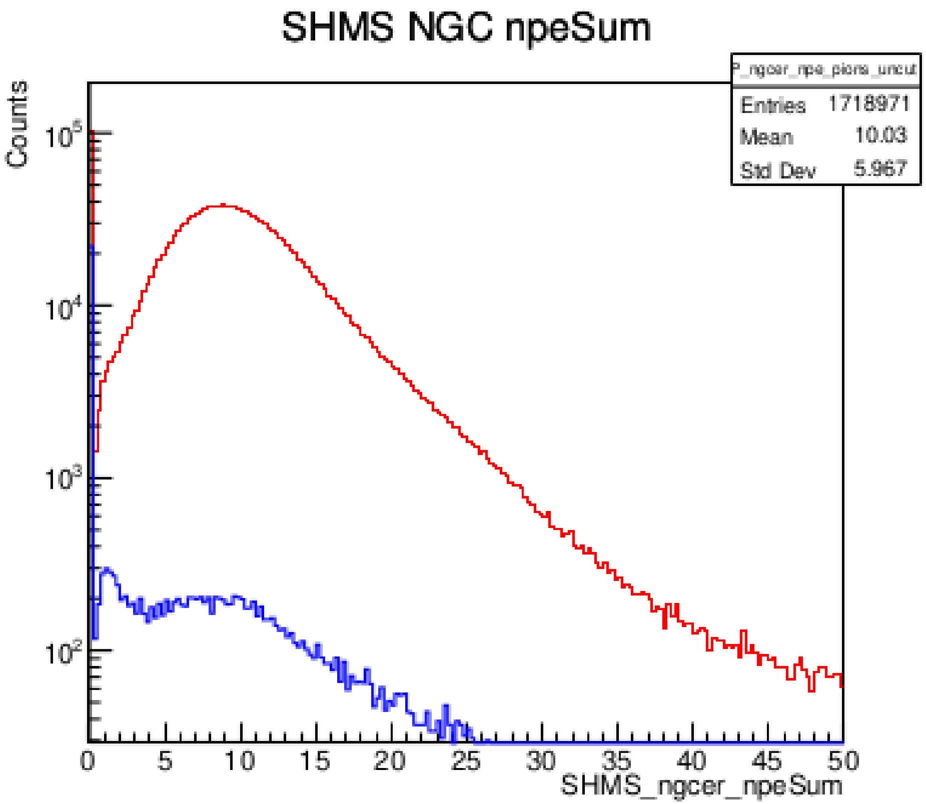


Q^2 3.85 W 3.07 center low ε LD-

Offline

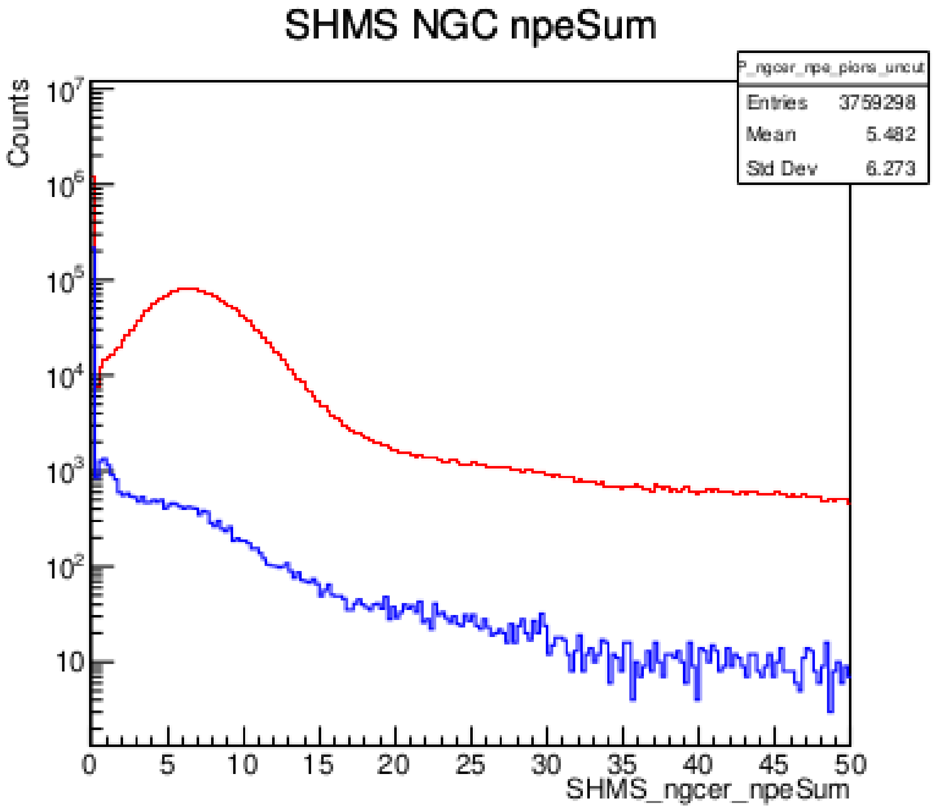


Online

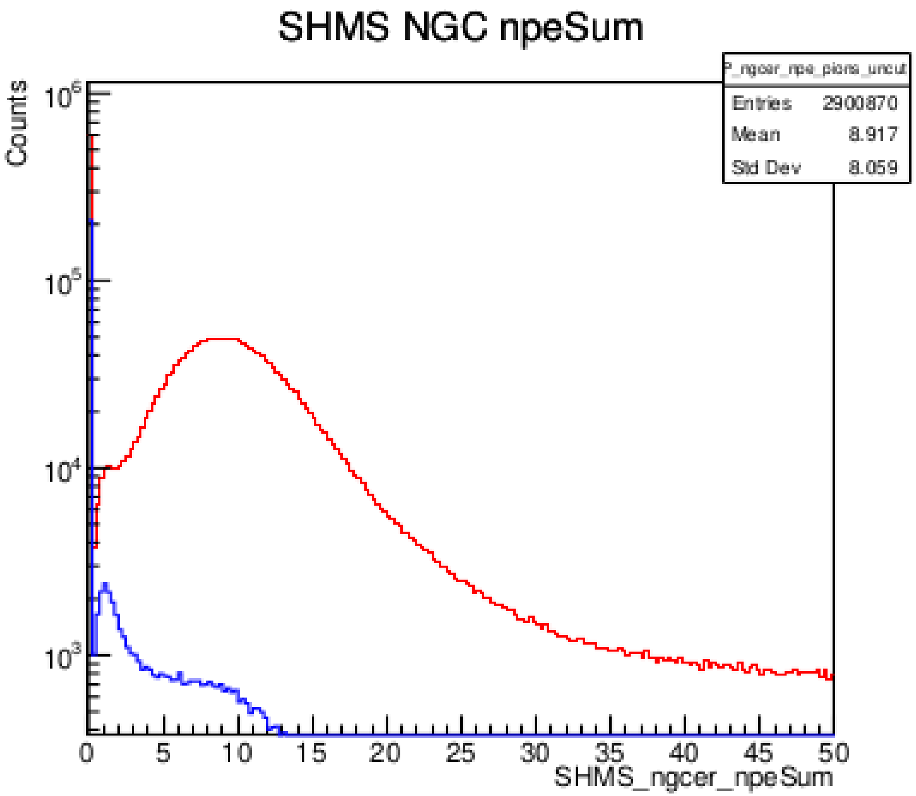


Q^2 3.85 W 3.07 Right high ε LD-

Offline

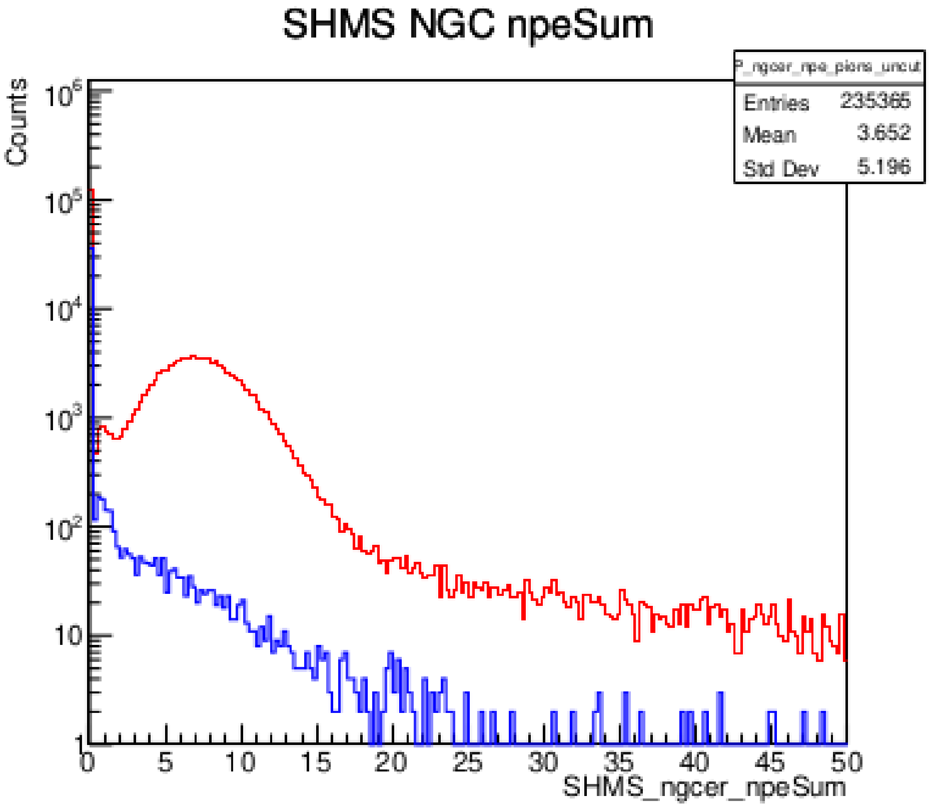


Online

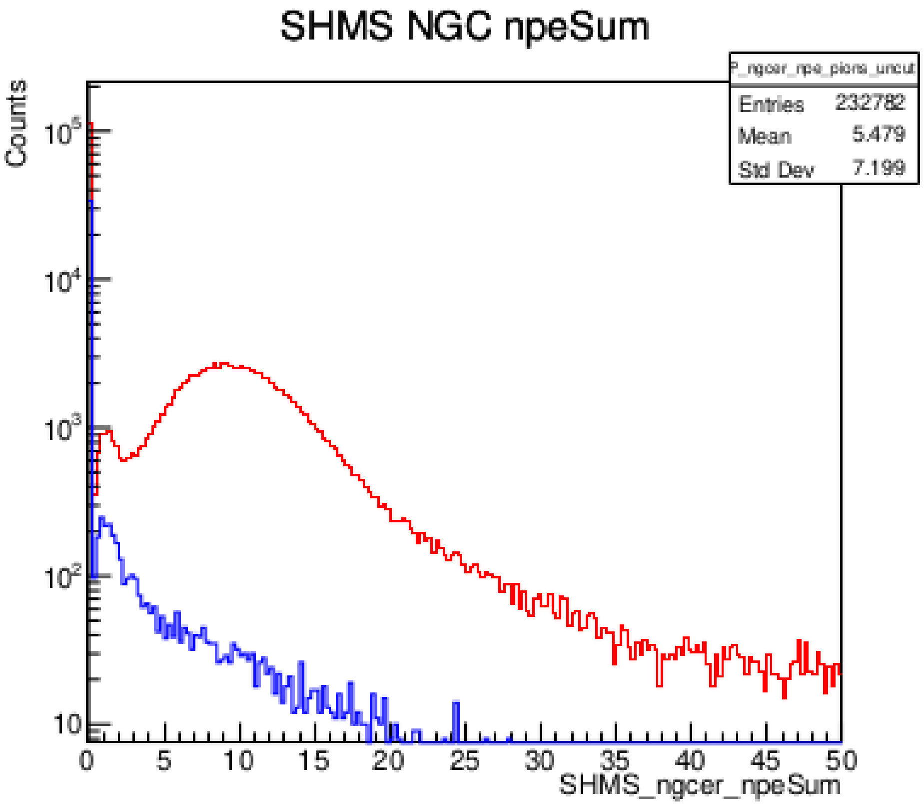


Q^2 6.00 W 2.40 center high ε LD-

Offline



Online



Conclusions

- Calibrated data looks good, by eye a pion cut of around < 3 NPE should work for the entire run period.
- A full PID cut study will have to be done, but that is for later.
- I have begun looking at the HGC calibration, hopefully that can be finished soon.