SHMS NGC Calibration and Performance Updates

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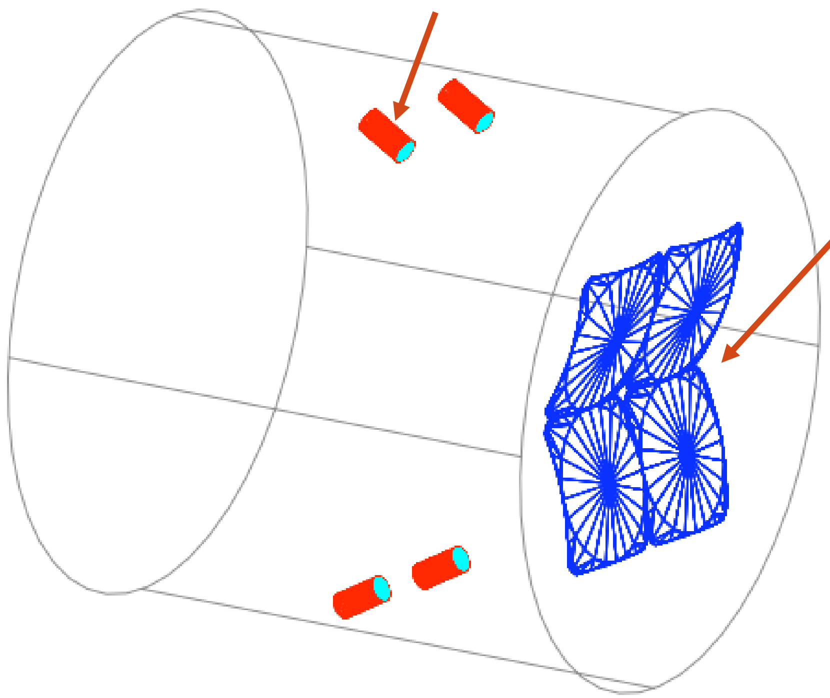
Outline

- Role of the SHMS NGC
- NGC Calibration Purpose
- NGC Calibration Process & Challenges
- Calibration Results & Performance

Role of the SHMS NGC

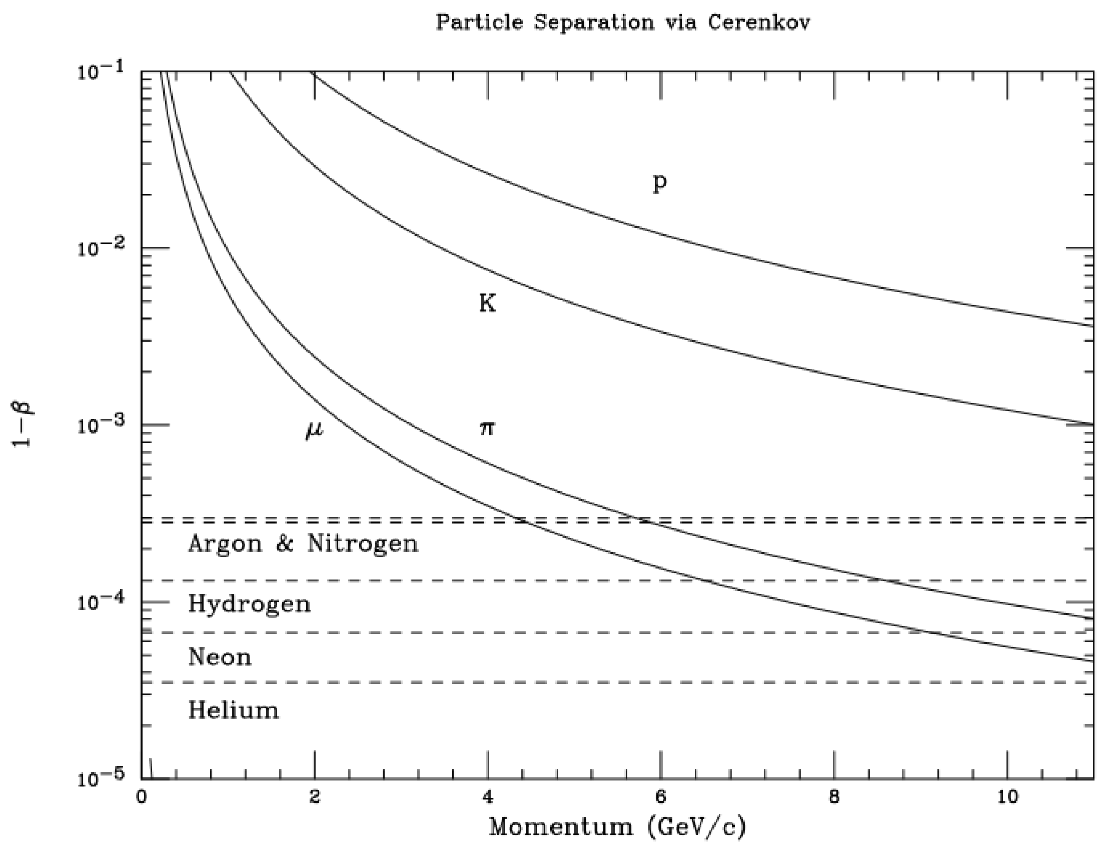
- Cerenkov detectors in nuclear and particle physics experiments are primarily used for particle identification (PID).
- As pion background rates can be over 1000 times larger than electron rates at our kinematics, it is important to suppress this background to be able to produce a clean electron signal.



Old Mock-up of the SHMS NGC Geometry

Role of the SHMS NGC

- By cleverly choosing what gas mixture is used in the NGC, you can ensure that electrons passing through your detector at a given energy produce Cerenkov radiation, while pions (and other hadrons) do not. This allows a cut to be made on the Cerenkov signal to get a clean sample of electron events.



NGC Calibration Purpose

- The purpose of the NGC calibration is to determine the conversion factor between the charge output by the PMT (in pC) to the number of photo-electrons extracted from the photo-cathode (NPE). We can then cut out pions by requiring NPE > 2 (electrons produce ~12 photo-electrons in current configuration).
- This calibration must be done any time the PMTs High Voltage changes, and should be done periodically to check for consistency.
- A good dataset to do a NGC Calibration has:
  - Low pion background
  - Good distribution of events covering all 4 PMTs
  - On the order of millions of events

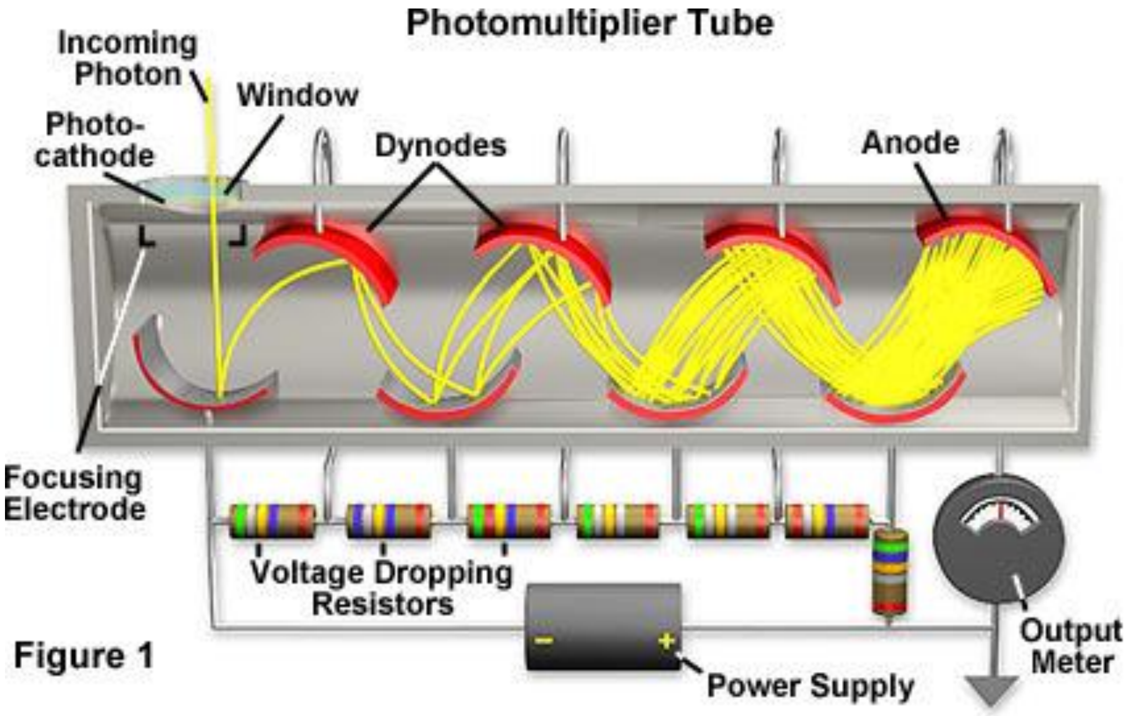


Figure 1

NGC Calibration Process & Challenges

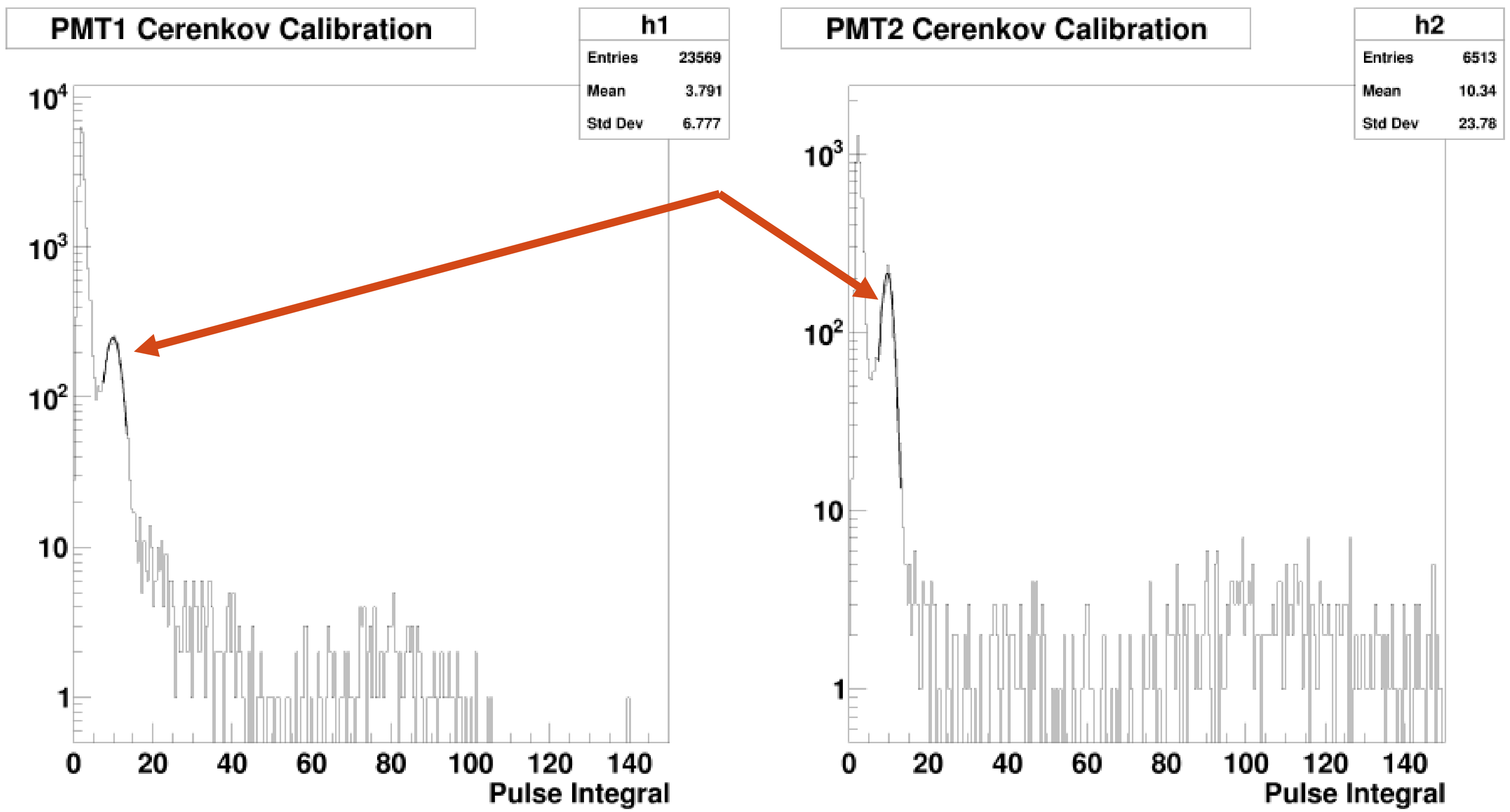
- First challenge in "updating" the SHMS NGCER calibration code – There is no existing code in hallc_replay to update.

mrcmor100 Add reference time and timing window setup scripts. Add specific DEF-... ... 93b4b18 on Jul 13, 2022 History

..		
bcm_current_map	Fix when writing the event number in BCM param files. Values > 1E6 in...	2 years ago
bpm_calib	Modified CALIBRATION/bpm_calib	4 years ago
dc_calib/scripts	turned on the shms ngc in the shms calo calibration script	4 years ago
hms_cal_calib	hms cal. calib. clearer comments in input file	last year
hms_cer_calib	Added HMS Calibration script (#481)	4 years ago
hms_dc_calib	modified script to produce 'new_tzero.param' containing only the HMS ...	6 years ago
hms_hodo_calib	Updated HMS Hodo Calib:	4 years ago
hodo_calib	Small correction to PARAM/SHMS/HODO/CALIB/ptofcalib.param	5 years ago
set_peddefault	Add set_peddefault to CALIBRATION directory	2 years ago
set_reftimes	Add reference time and timing window setup scripts. Add specific DEF-...	6 months ago
set_timing_windows	Add reference time and timing window setup scripts. Add specific DEF-...	6 months ago
shms_aero_calib	Fall 2018 ver1 (#507)	4 years ago
shms_cal_calib	shms cal. calib. change default sigma range	last year
shms_hgcer_calib	Updates to the SHMS HGC calibration script by Vijay Kumar. The instru...	2 years ago
shms_hodo_calib	On branch shms_hodo_work (#539)	10 months ago
README.md	Add set_peddefault to CALIBRATION directory	2 years ago

NGC Calibration Process & Challenges

- Unlike the HMS Cerenkov and the SHMS HGC, the single photo-electron peak is typically not visible in the NGC PMT signal distribution, so it is not as simple as fitting the peak and setting the calibration constant to 1/mean.



NGC Calibration Process & Challenges

- With a clean electron sample, we can use statistics to determine the calibration constant for each PMT.
- The number of photo-electrons extracted from the photo-cathode follows a Poisson distribution (discrete, uncorrelated probabilistic event), so we start there.
- We need to fit a “continuous” signal distribution, so we use the Gamma function to generalize the factorial to all real positive numbers.
- We are also fitting a distribution of millions of real events, so we can introduce an overall scale factor (A) to account for this.
- Finally, the “discrete” increments of our signal distribution are not unity like the photo-electron distribution, but are equal to the nominal signal output by the PMT per photo-electron, which is precisely the calibration constant we are after (μ).

$$P(k) = \frac{\lambda^k e^{-\lambda}}{k!}$$

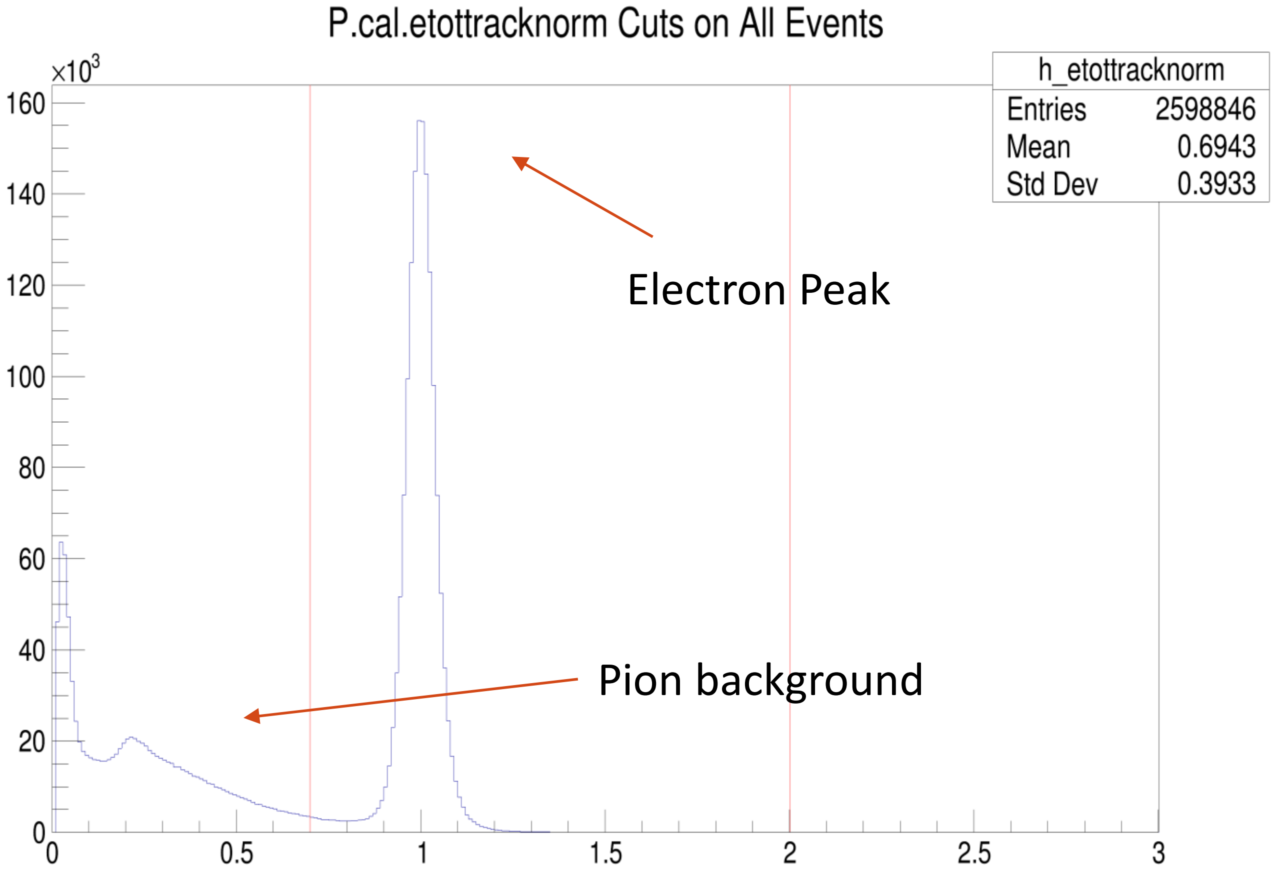
$$P(x) = \frac{\lambda^x e^{-\lambda}}{\Gamma(x+1)}$$

$$\mathrm{f}(x) = A\frac{\lambda^x e^{-\lambda}}{\Gamma(x+1)}$$

$$\mathrm{f}(x) = A\frac{\frac{\lambda}{\mu}^{\frac{x}{\mu}} e^{-\frac{\lambda}{\mu}}}{\Gamma(\frac{x}{\mu}+1)}$$

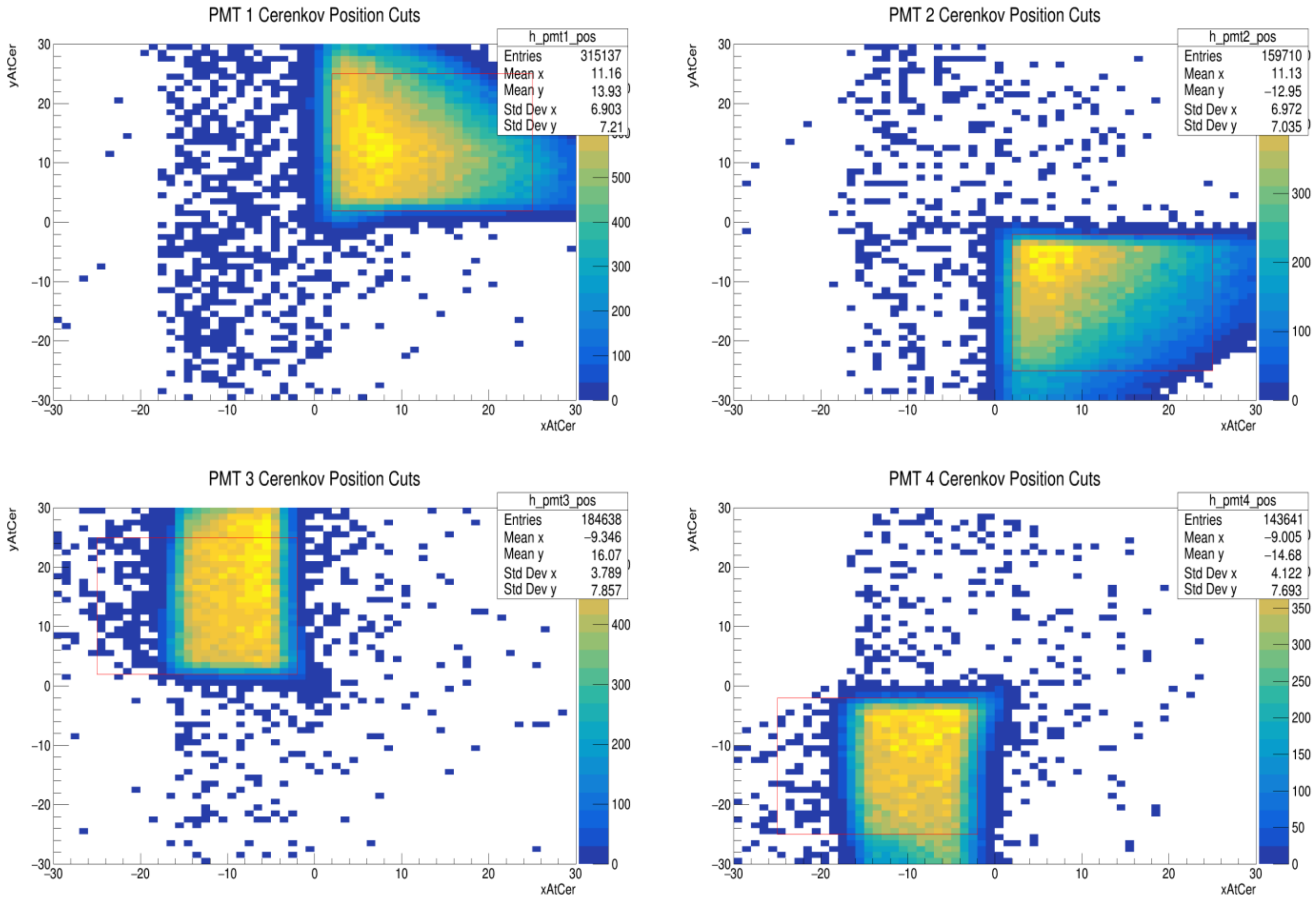
NGC Calibration Process & Challenges

- Now that we have our equation, we need a clean electron sample to fit.
- First, we apply a calorimeter cut to a data set with a large fraction of electron events. This gives us a reasonably clean electron sample.
  - Timing window and reference time cuts should already be done.

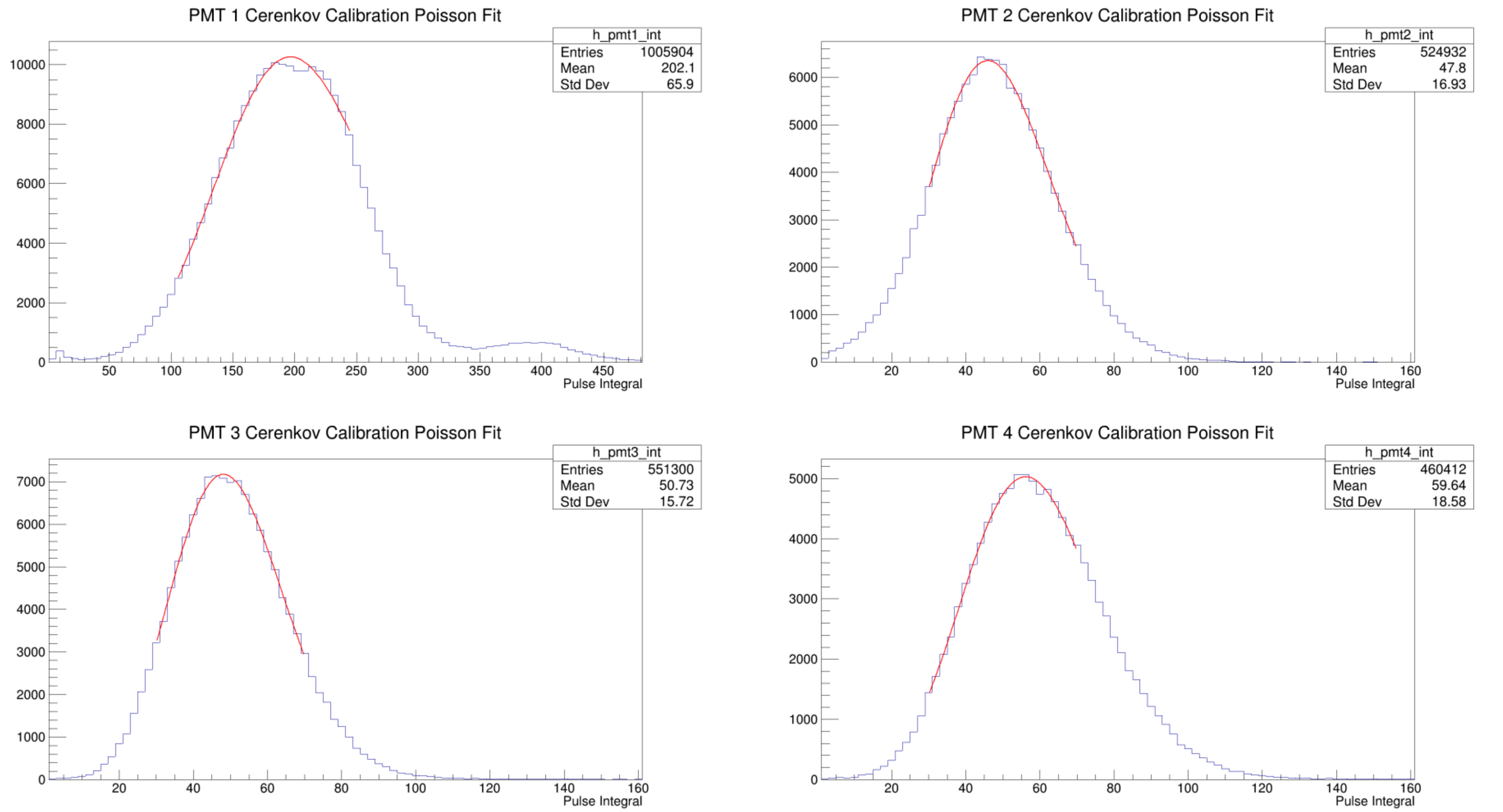


NGC Calibration Process & Challenges

- Now that we have our equation, we need a clean electron sample to fit.
- First, we apply a calorimeter cut to a data set with a large fraction of electron events. This gives us a reasonably clean electron sample.
  - Timing window and reference time cuts should already be done.
- Then, we perform a multiplicity cut on each of the PMTs such that a signal was only detected in one of the PMTs, and that there was only one “hit” in that event. This ensures we are only looking at the signal from a clean single electron event that deposited all of its energy into a single PMT. Finally, we cut on the particle’s position in the Cerenkov detector to ensure that the particle was not on the edge of any one of the mirrors.



NGC Calibration Process & Challenges



Calibration Results & Performance

- Calibration Constant:
  - PMT 1: 1/18.67*
  - PMT 2: 1/5.33
  - PMT 3: 1/4.63
  - PMT 4: 1/5.46
- Mean NPE (Gas chosen to give ~12):
  - PMT 1: 11.38
  - PMT 2: 9.05
  - PMT 3: 10.88
  - PMT 4: 10.76
- Current Gas Mixture (XEM2):
  - ~23% Neon and ~77% Argon (originally planned to be 20:80)
  - This mixture has a pion threshold of ~6.4 GeV

PMT 1 is noisy and has issues. Calibration surprisingly looks ok for now, but studies need to be done to determine how to handle this.

Hopefully once this issue is solved, my calibration code can be added to the online git repository for use in upcoming experiments.

Code runs fast thanks to a relatively new (2018) object in root called the RDataFrame – Multithreading!

Questions?