Function to Fit PMT Charge Distribution

Generative NN for Water Cherenkov Detector

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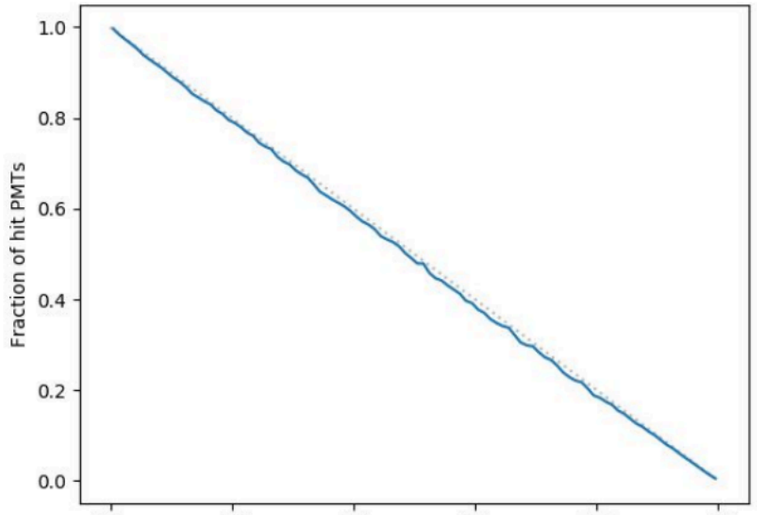
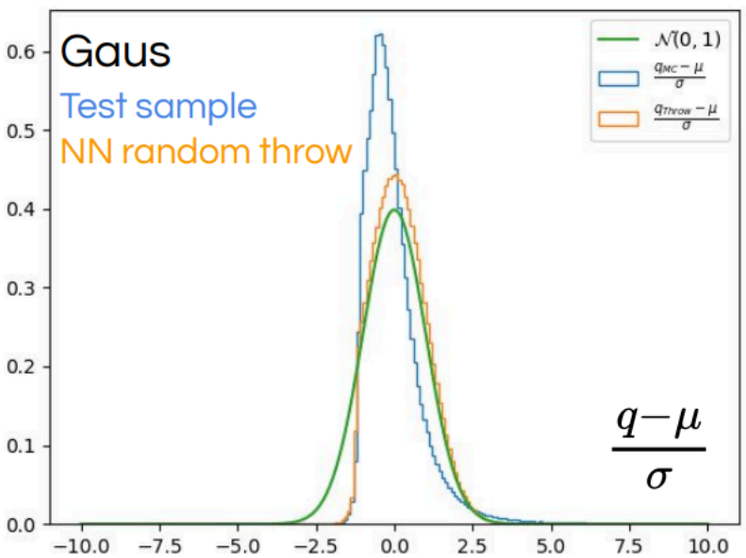
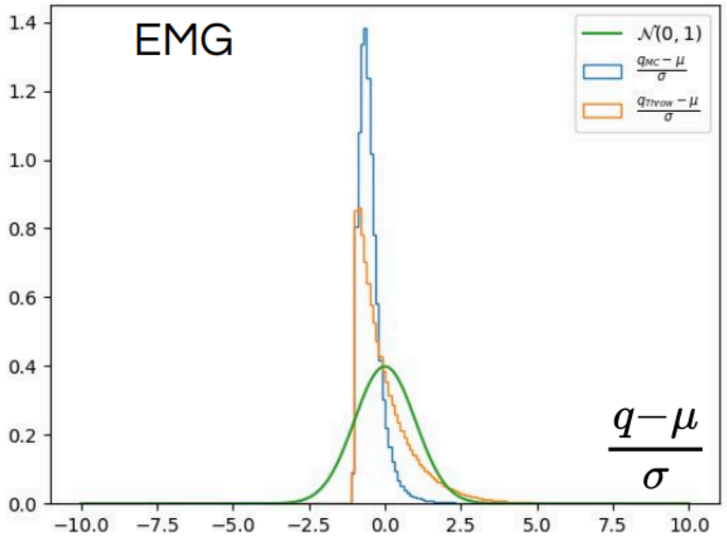
Background

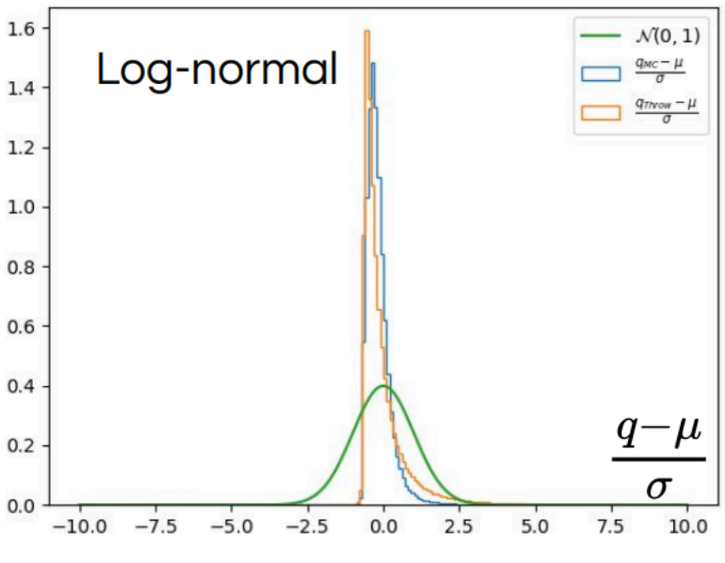
Loss function studies

- Hit probability component of the loss function works well.
- However, charge distribution is not gaussian.
  - Might get some improvement by using a more “taily” distribution.
  - Currently investigating mixture of Gaussians.









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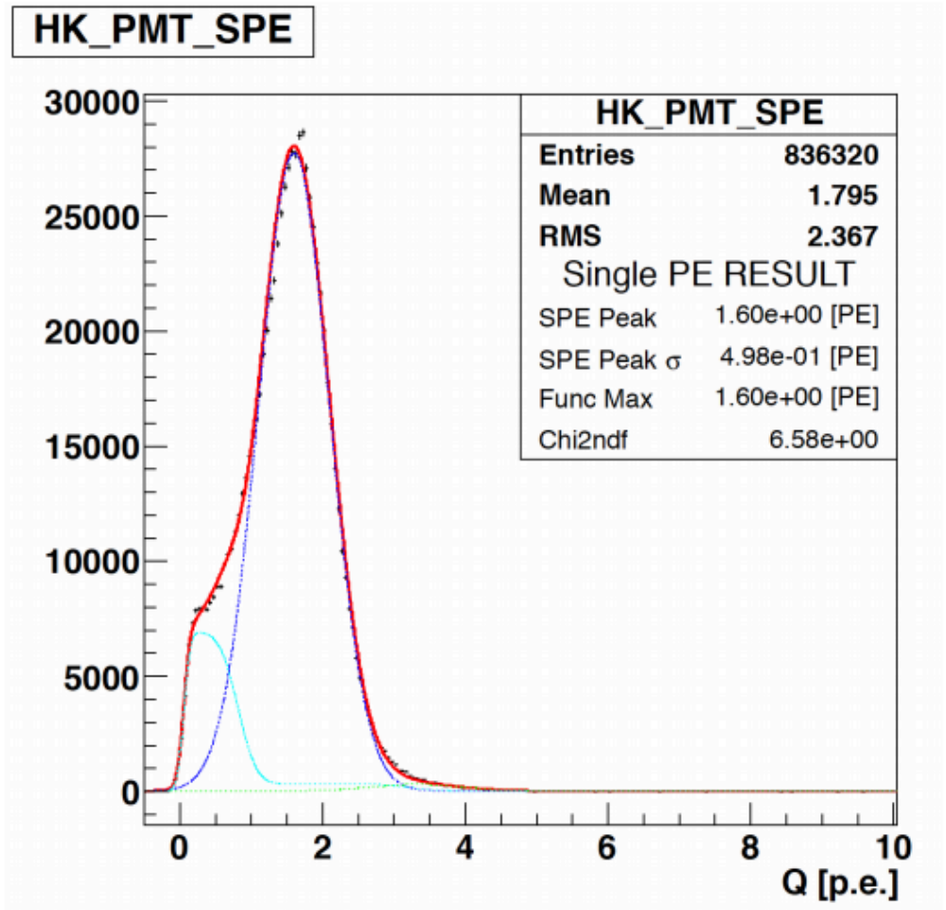
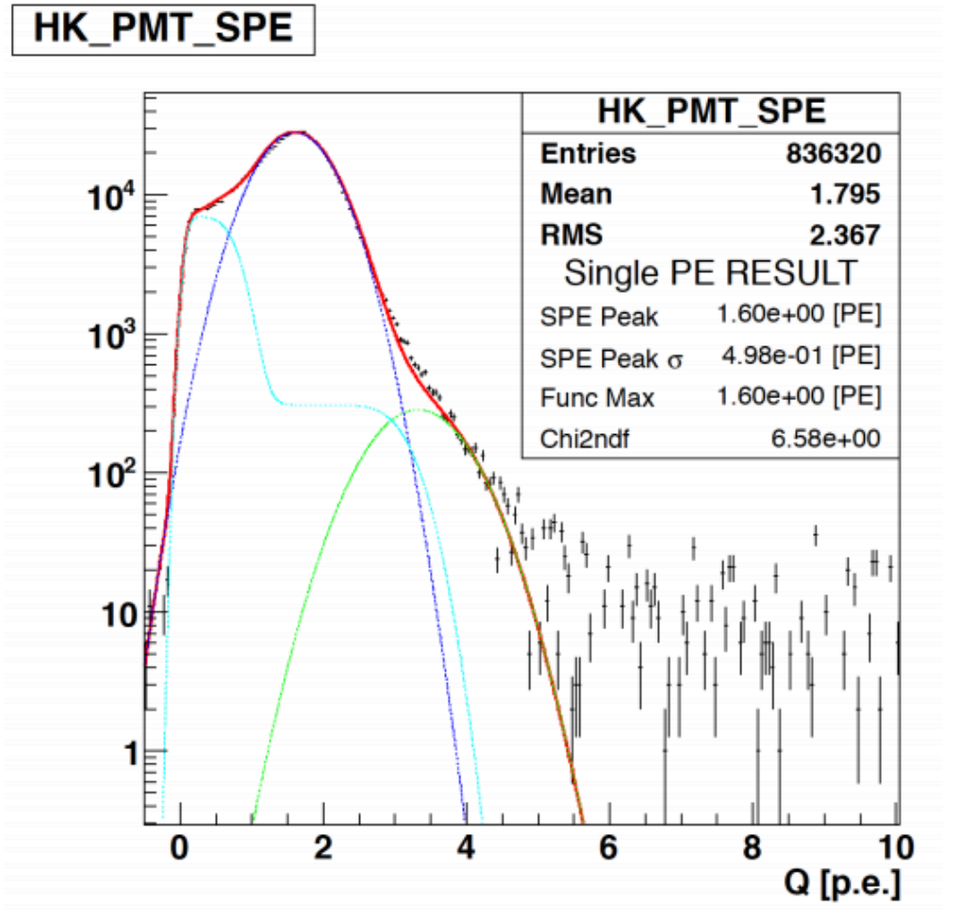
Cris’ Talk @ NPML 2020

Which Reminds Me of the Days of SK Calibration…



(a) Fitting on the Hyper-K SPE charge distribution from Ni-Cf data



(b) Fitting on the Hyper-K SPE charge distribution from Ni-Cf data in logarithmic scale

Figure 6.2: The fitting of the SPE charge distribution of Hyper-K PMTs with Ni-Cf data. The blue curve represents the SPE peak, green the 2PE peak, and cyan the integrated back scattering components. The red curve shows the overall fitting result.

http://www-sk.icrr.u-tokyo.ac.jp/sk/_pdf/articles/2019/MasterThesis-XIA_JUNJIE-35176375.pdf

Function Details

$$f(x) = \underbrace{p_0 \cdot e^{-\left(\frac{x-p_1}{\sqrt{2}p_2}\right)^2}}_{\text{SPE Gaussian peak}} + \underbrace{p_3 \cdot e^{-\left(\frac{x-p_4}{\sqrt{2}p_5}\right)^2}}_{\text{2PE Gaussian peak}}$$

$$+ \underbrace{0.5 \cdot p_6 \cdot p_0 \cdot \left(\operatorname{erf}\left(\frac{x-p_7}{p_8}\right) - \operatorname{erf}\left(\frac{x-p_{11}}{p_{12}}\right)\right)}_{\text{SPE Back scattering}}$$

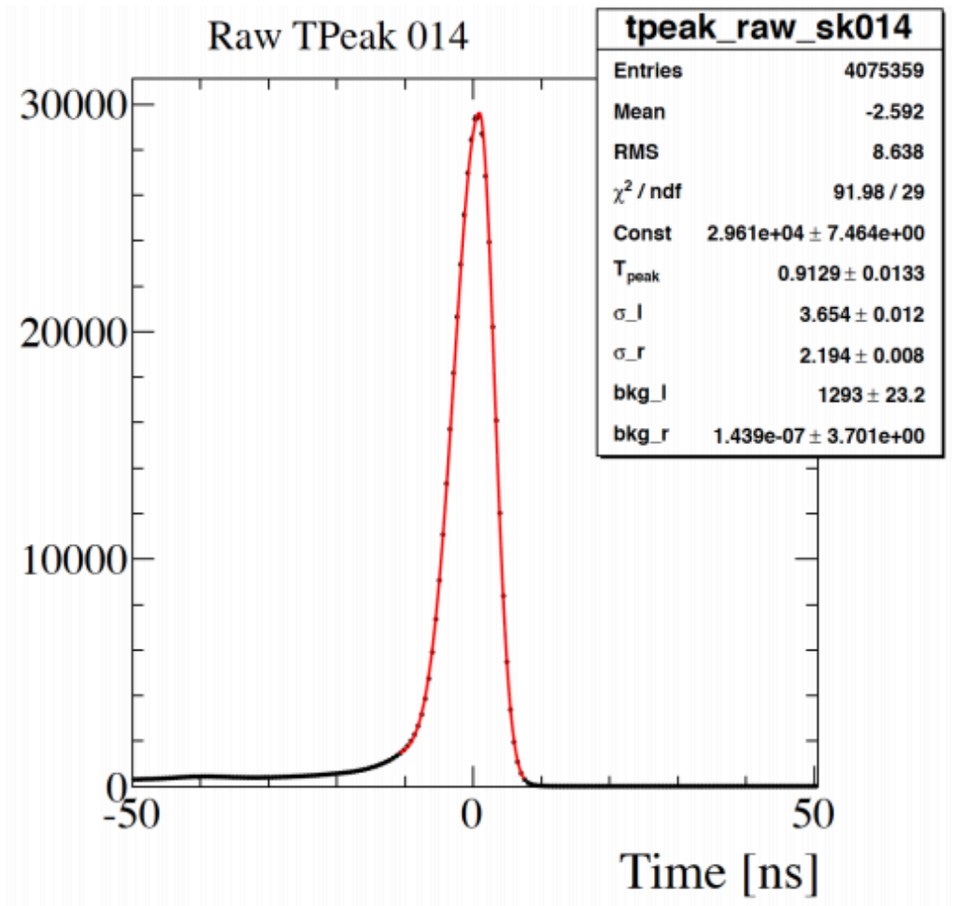
$$+ \underbrace{0.5 \cdot p_9 \cdot p_3 \cdot \left(\operatorname{erf}\left(\frac{x-p_{11}}{p_{12}}\right) - \operatorname{erf}\left(\frac{x-p_{13}}{p_{14}}\right)\right)}_{\text{SPE-2PE Back scattering}}$$

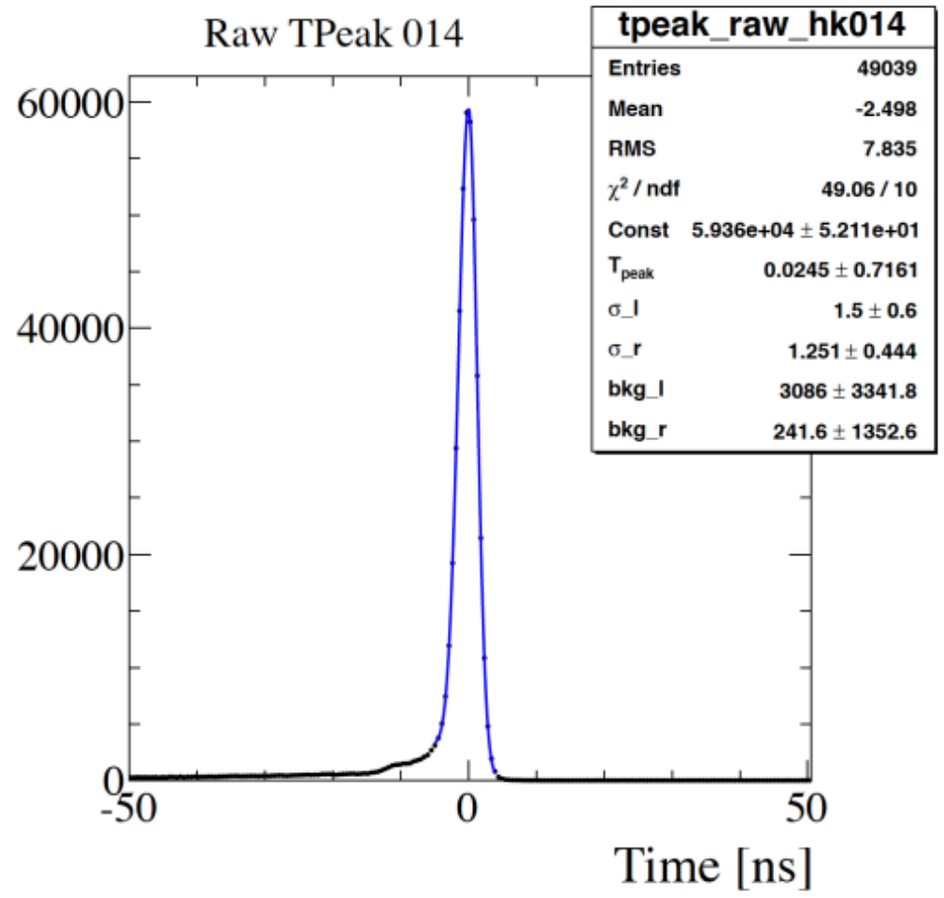
$$+ \underbrace{0.5 \cdot p_{10} \cdot p_3 \cdot \left(\operatorname{erf}\left(\frac{x-p_7}{p_8}\right) - \operatorname{erf}\left(\frac{x-p_{13}}{p_{14}}\right)\right)}_{\text{2PE Back scattering}}$$

- Erf: $\operatorname{erf} z = \frac{2}{\sqrt{\pi}} \int_0^z e^{-t^2}\, dt.$
- Can be broken into groups of 1 Gaussians + 1 Erf
- No new parameters, all are just scale, mean, & sigma
- Caution: can be computationally expensive as the number of sets increases. Need to find the optimal case.

http://www-sk.icrr.u-tokyo.ac.jp/sk/_pdf/articles/2019/MasterThesis-XIA_JUNJIE-35176375.pdf

Some Extras for PMT Timing





- The timing of SK (left) and HK (right) PMTs at ~SPE
- Non-Gaussian feature, fitted by 2 Gaussians on the left&right
- Another option is a damped Gaussian distribution, but can be too time consuming

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