Analysis of the Nov 2019 data

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Fitting the charge distributions

- The ideal response:

100

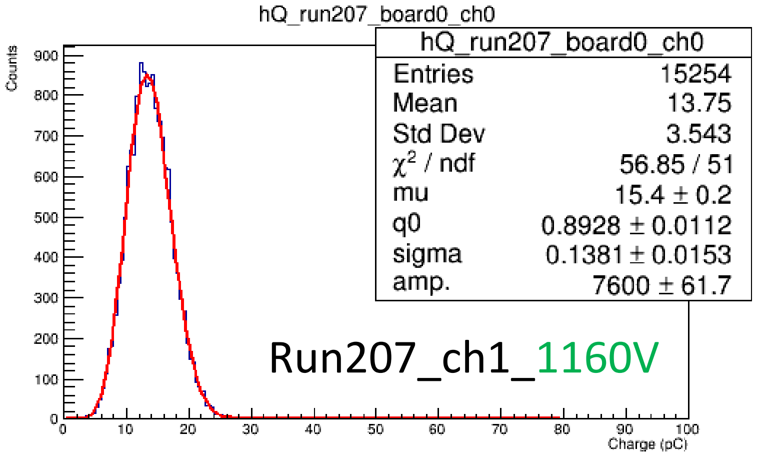
$$S_{\text{ideal}}(x) = \sum_{n=0}^{\infty} \frac{\mu^n e^{-\mu}}{n!} \frac{1}{\sigma_1\sqrt{2\pi n}} \exp\left(-\frac{(x-nQ_1)^2}{2n\sigma_1^2}\right),$$

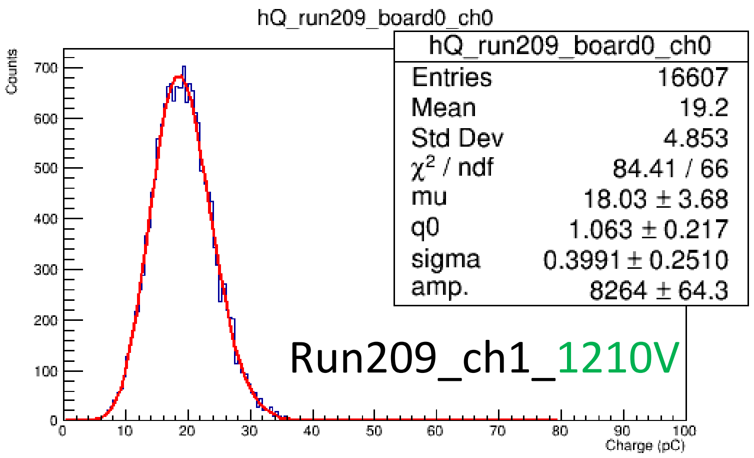
1

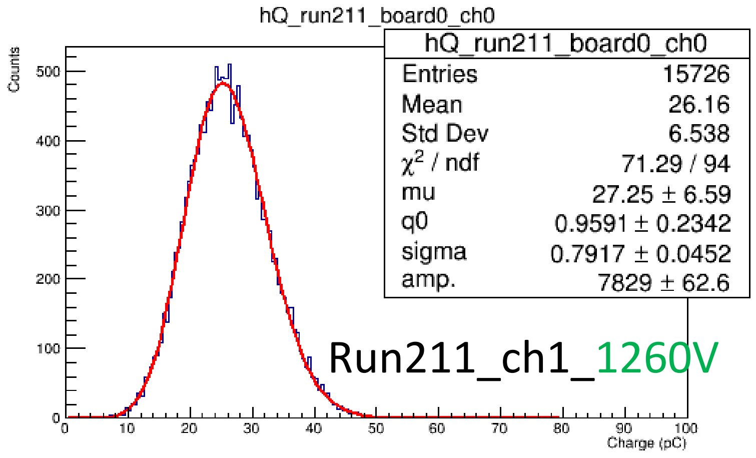
μ: mean n p.e.
Q_1: charge peaking at single p.e. (measure of gain)
σ_1: width of the single p.e. spectrum

Issues with fitting individual charge distributions:
- Mean npe varies
- Single p.e. charge at higher voltage turns to be smaller than at lower voltage

Example charge distributions for one PMT at different voltages







Fitting the charge distributions

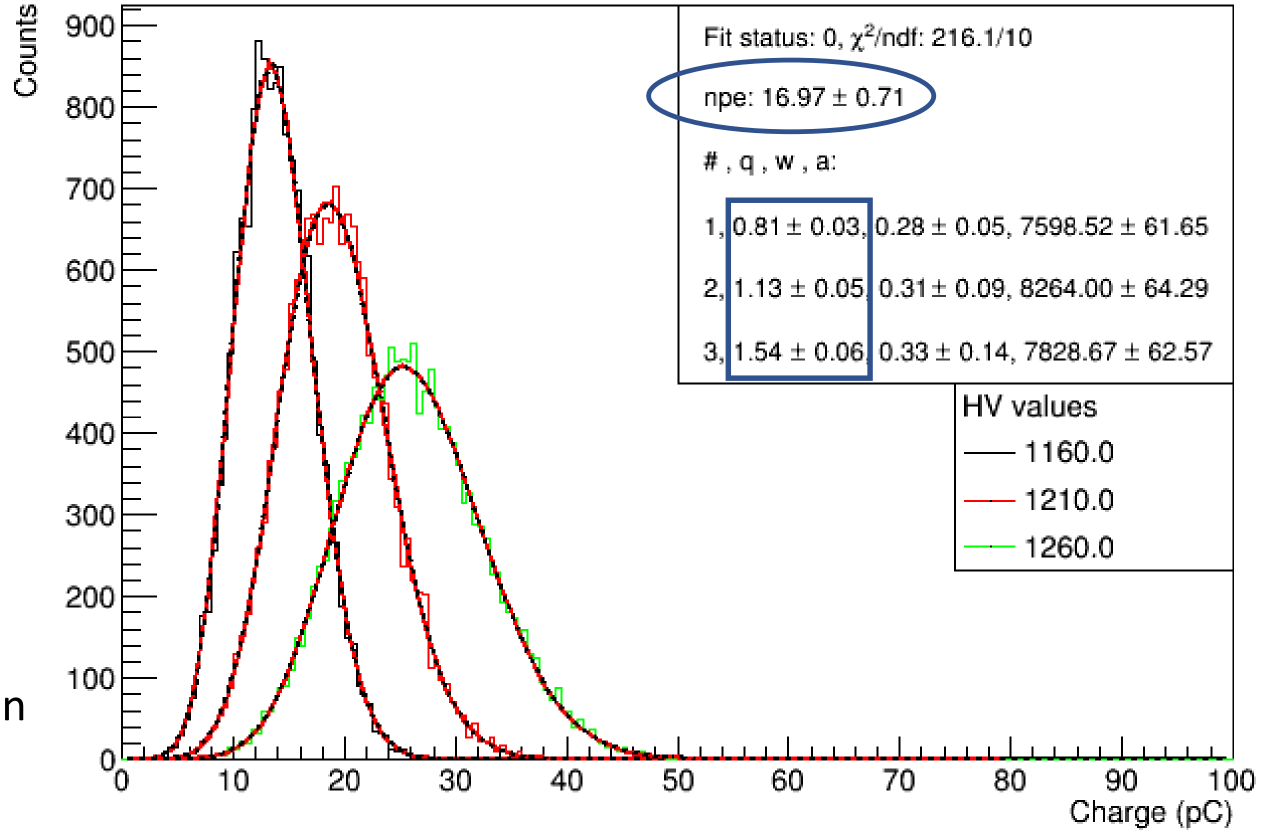
The global fit:

- Assume the same npe for different voltage
- Allow the other parameters to change
- Define the following χ^2

$$\chi^2 = \sum_{m=1}^{N_{hist}} \sum_{j=1}^{N_{bin}} \frac{\left(N_{ij} - P_{ij}(\mu, q_i, \sigma_i, a_i)\right)^2}{N_{ij}}$$

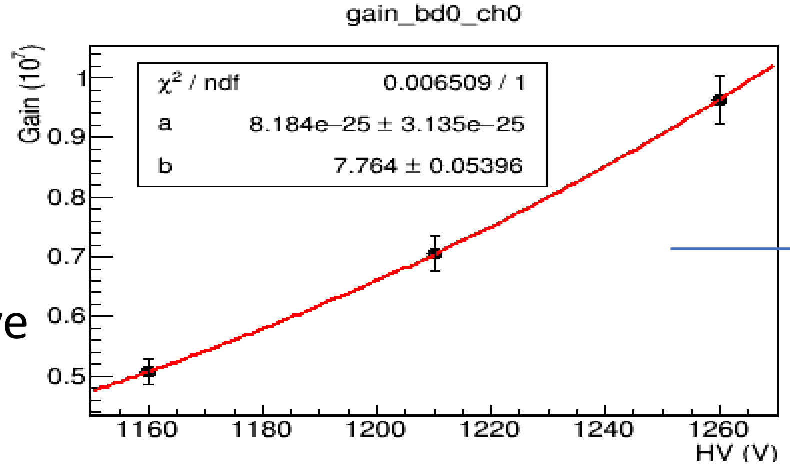
N_{hist}: number of charge distributions
N_{bin}: number of bins in the charge distributions
N_{ij}: number of events in the j-th bin in the i-th distribution
$P_{ij}(\mu, q_i, \sigma_i, a_i)$: the calculation based on the ideal response for charge distribution, with parameters μ, q_i, σ_i, a_i.

Run 207/209/211 _ board0_ch0



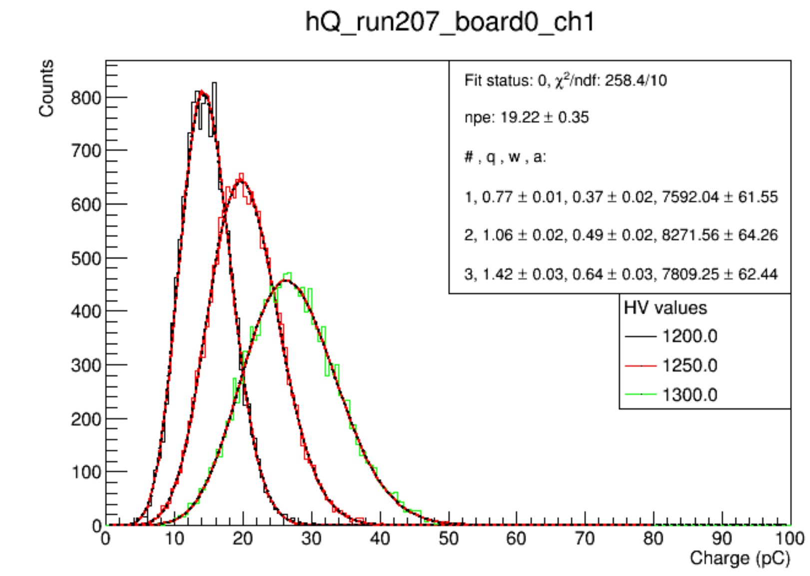
- This global fit appears to work well. the PMT's gain can be calculated by $g = a \cdot V^b$
  b: physical meaning?

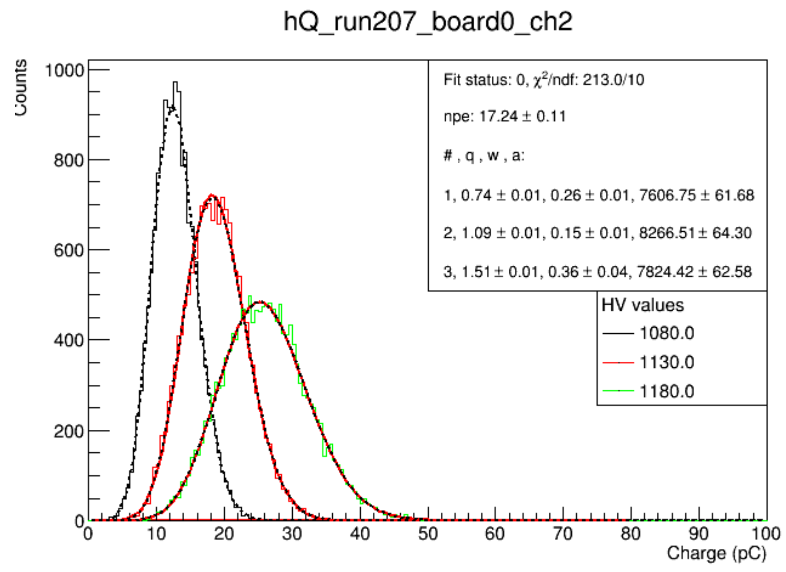
Gain curve

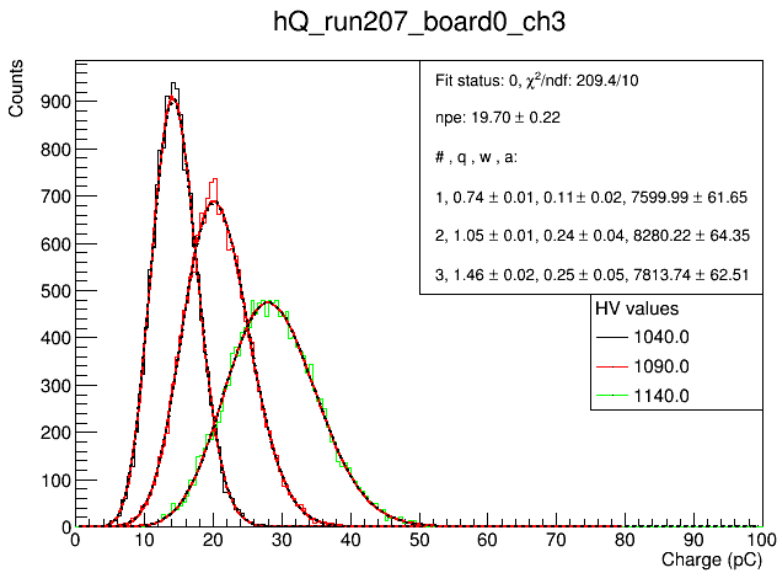


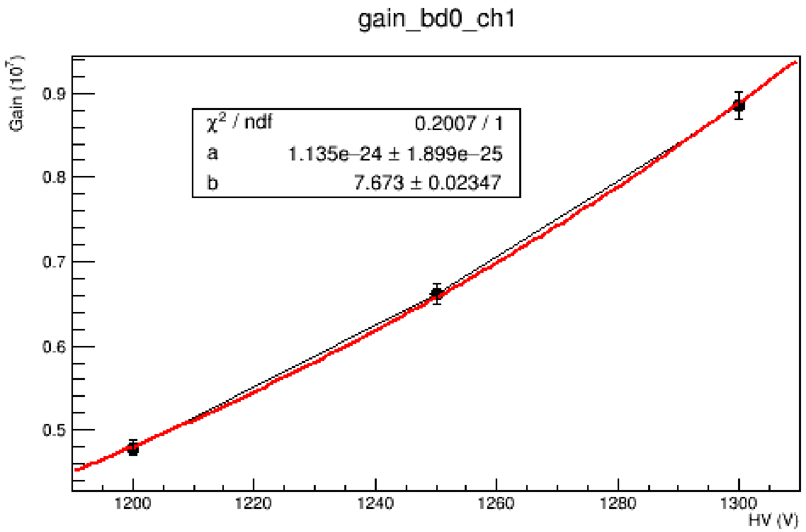
For gain 10^7
HV = 1266 ± 87

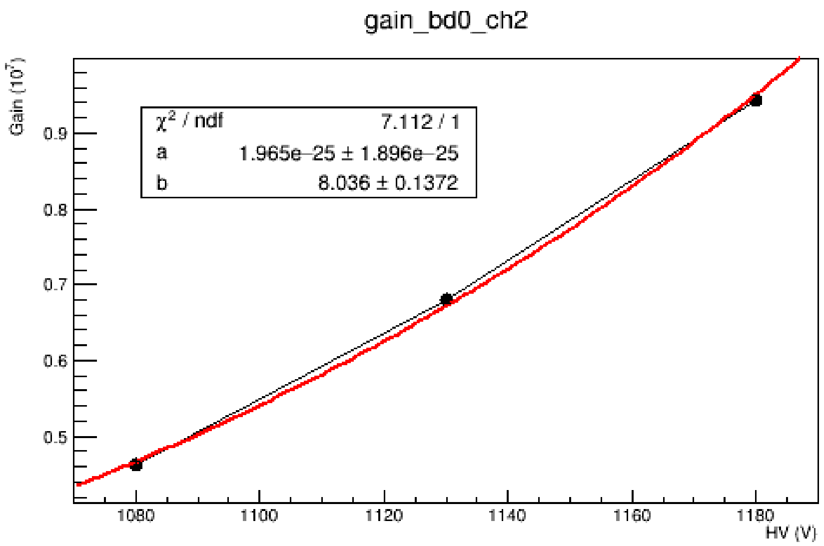
Examples of good fits

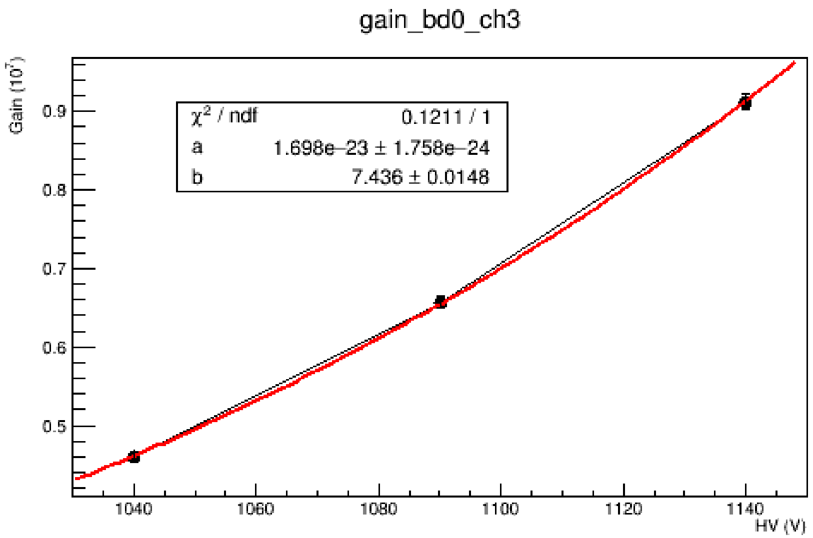




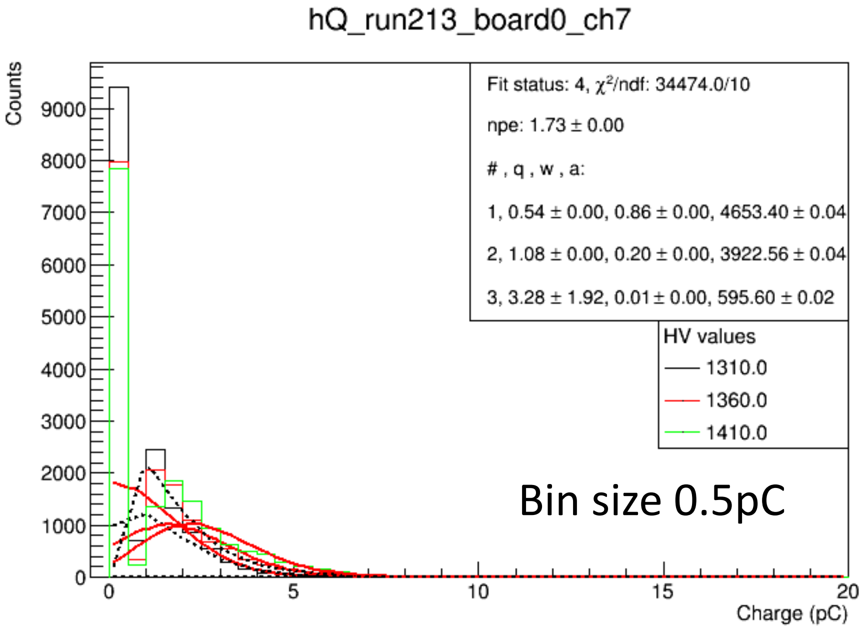




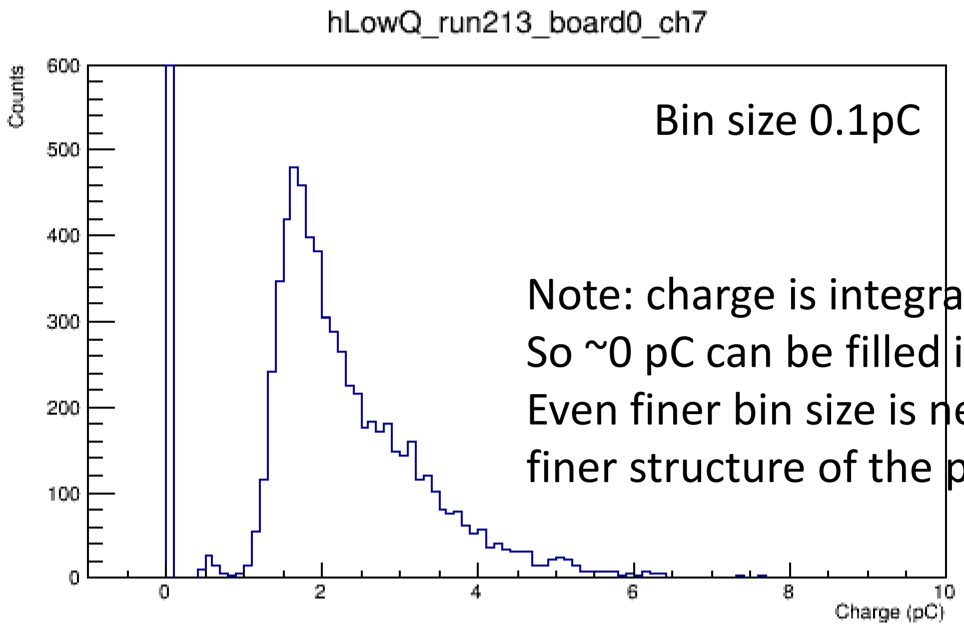




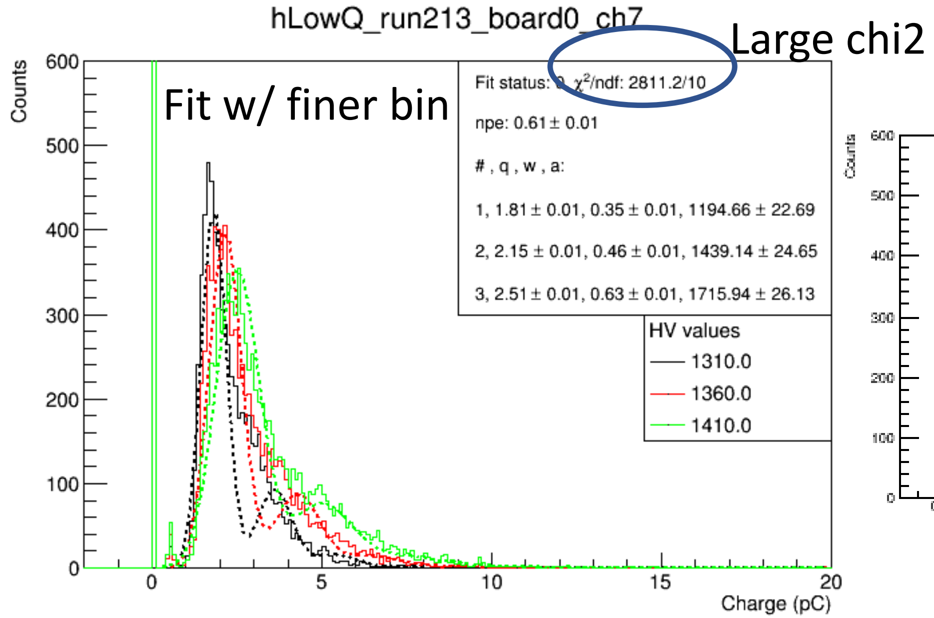
In the case of when the mean npe is small …

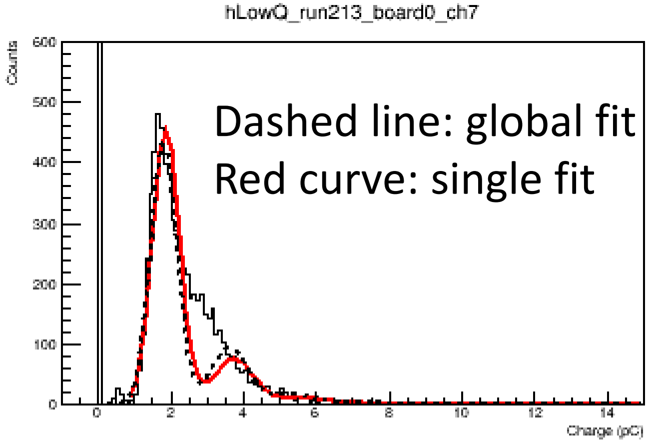


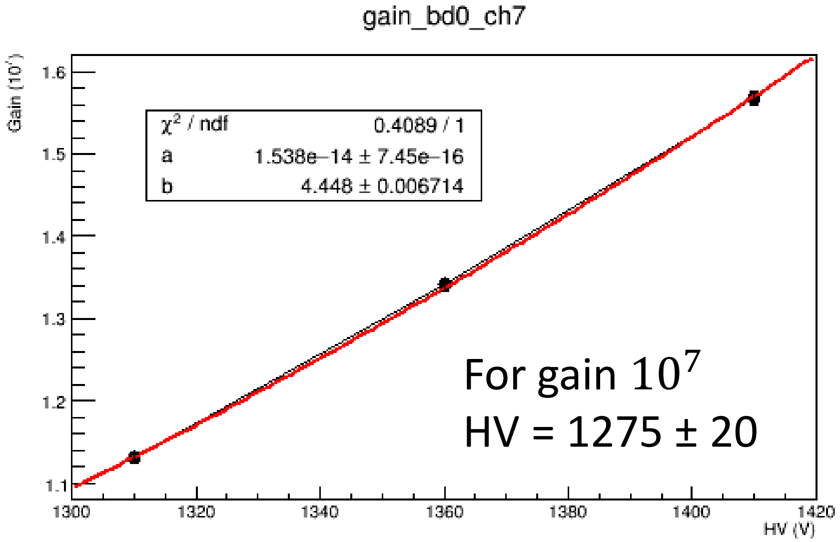
Refine binning by a factor of 5 for low charge distribution



Note: charge is integrated over fixed window
So ~0 pC can be filled in (so-called pedestal)
Even finer bin size is needed in order to see
finer structure of the pedestal







Summary

- Tool/module: the gain curve fitting module is set
  - the fitting method (eg., chi2 formula) can be tuned.
  - the fit to the low charge distributions is not as neat, probably there is extra signals to be investigated.

- Gain curves for Nov data can be produced
  - maybe Austin now can take over this and run through the Nov data (30 PMTs in 6*3 runs with HV).
  - have noticed using less events produce larger uncertainties, we could use the same data to test “how many events will be sufficient for a good calibration”

- I will continue to develop the next topic: dark pulse finding/counting