# Performance of 20inch PMTs Based on the Container Testing Data

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# Outline

# PMT testing data analysis

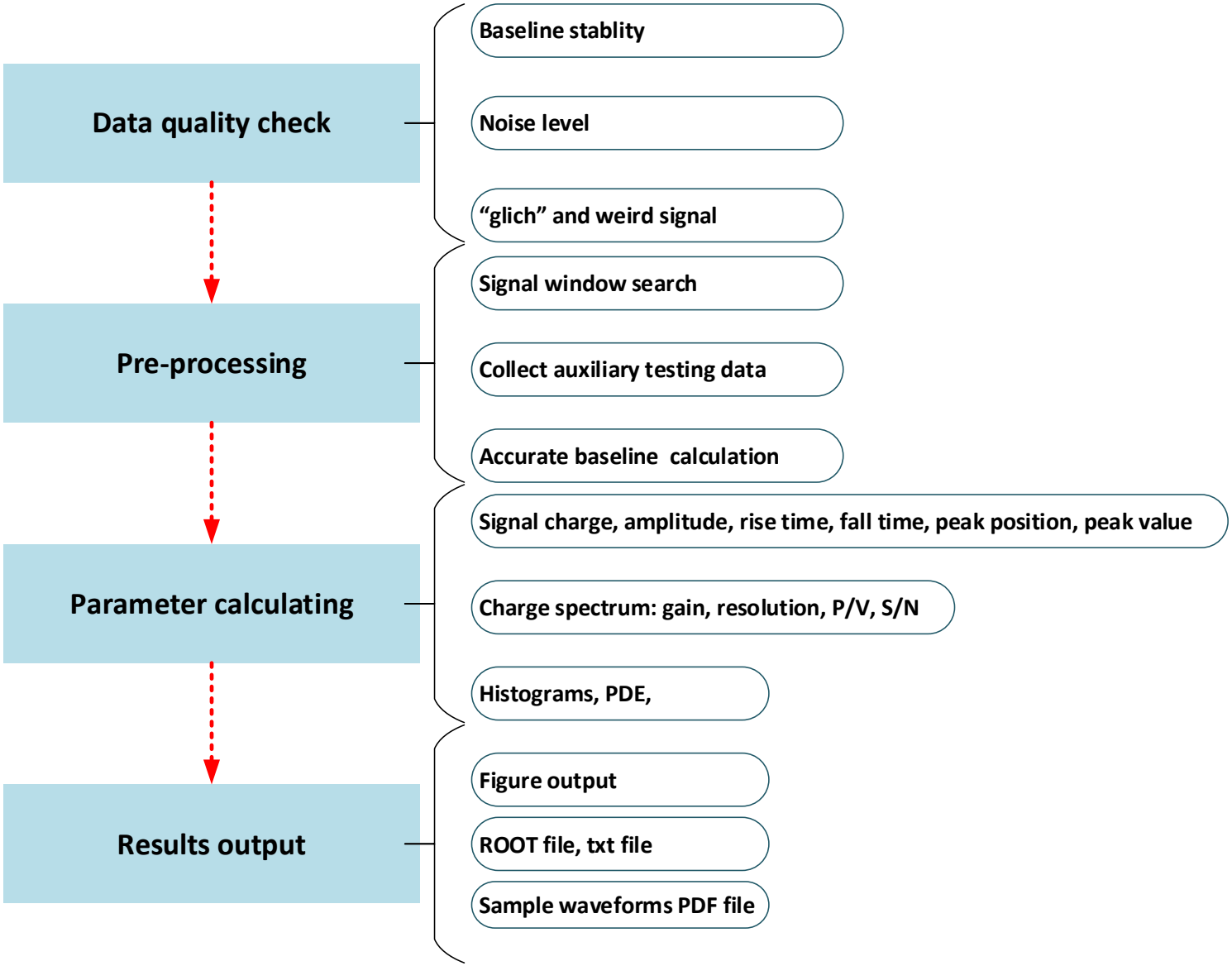
We have tested 5k HAMAMATSU PMTs and about 7k NNVT PMTs in the container system. We can obtain the following paramaters:

**表:** PMT performance qualification standard

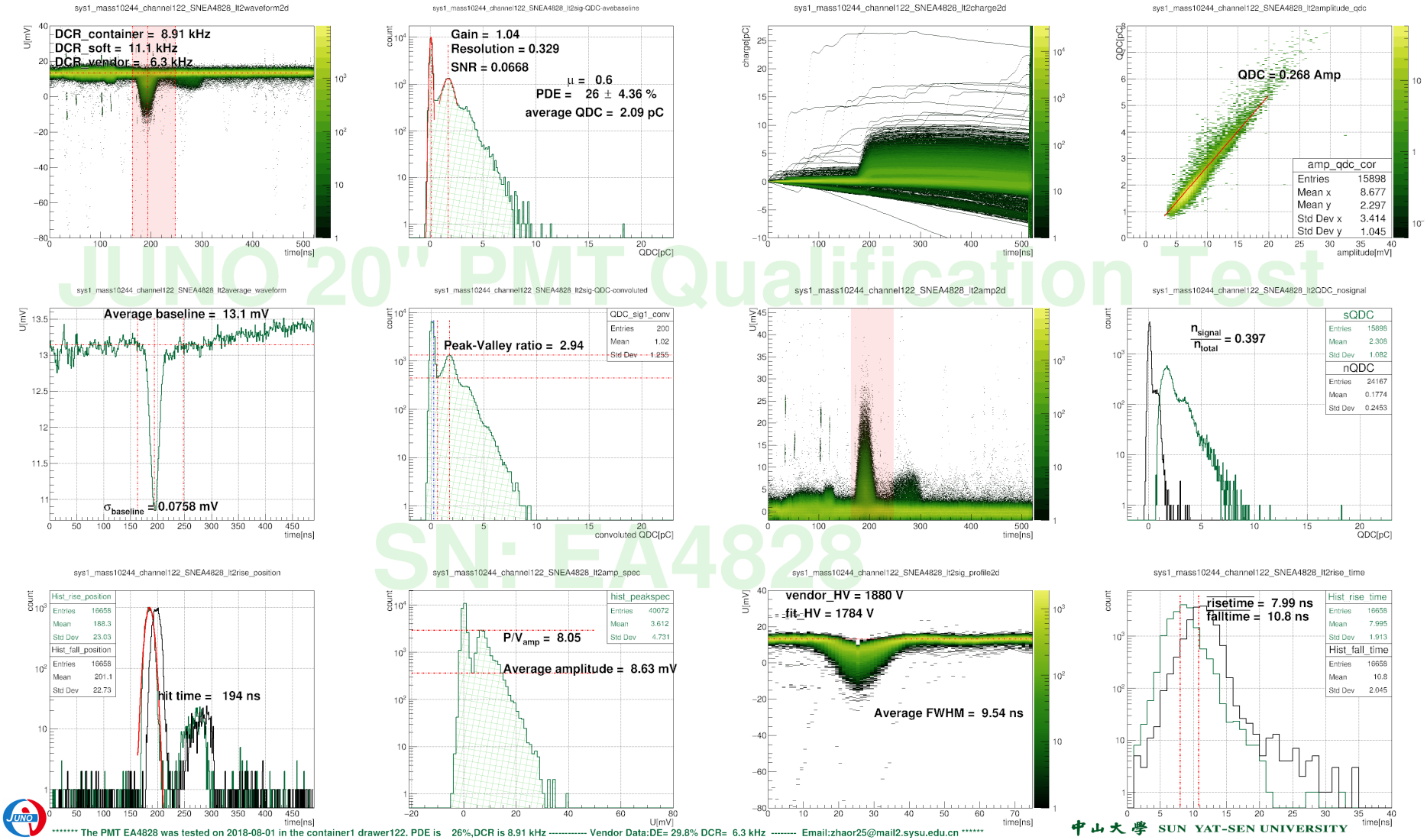
| parameter | HAMAMATSU PMT | NNVT PMT |
|---|---|---|
| HV@Gain=$10^7$ | <2350 V | <2800V |
| PDE | >24% | >24% |
| DCR | <50kHz | <100kHz |
| PV | >2.5 | >2.5 |
| rise time | <8.5ns | – |
| fall time | <12ns | – |
| FWHM | —- | – |
| resolution | <0.4 | <0.4 |

The Main aim of testing data analysis is to evaluate theses parameters and check wave quality of one PMT.

# Flowchart of analysis procedure



# Testing results output






******* The PMT EA4828 was tested on 2018-08-01 in the container1 drawer122. PDE is 26%,DCR is 8.91 kHz ---------- Vendor Data:DE= 29.8% DCR= 6.3 kHz -------- Email:zhaor25@mail2.sysu.edu.cn ******

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# PMT testing report-pass

We have generated testing report for each qualified PMT.

## QUALIFICATION TEST REPORT OF 20 INCH PMT

Test Information:

| Test Date | Container# | Mass# | Drawer# | Mu | HV vendor | HV container | Gain | Sheet # |
|---|---|---|---|---|---|---|---|---|
| 20171010 | 1 | 25 | 111 | 0.88 | 1670 | 1670 | 1.01 | 0 |

Parameters of Performance:

| Par | Value | Tag | Par | Value | Tag |
|---|---|---|---|---|---|
| PDE[%] | 27.27 | √ | Ristime[ns] | 7.63 | √ |
| DCR[kHz] | 10.25 | √ | Falltime[ns] | 10.50 | √ |
| PV | 3.23 | √ | FWHM[ns] | 9.29 | √ |
| TTS[ns] | | | SNR | 0.06 | √ |
| AP[%] | | | Resolution | 0.28 | √ |

Test History and Notes:

**This PMT was retested due to PDE problem , and then passed the test.**

[Aux Info]

Table generated date: 20190102

Data quality check:

Scanning Station check:

zhaor25@mail2.sysu.edu.cn

Final Qualification Tag

**EA0283**

**PASS**

# Typical waveform of PMT(@$gain = 10^7$)

Typical signal waveform when working @$gain = 10^7$

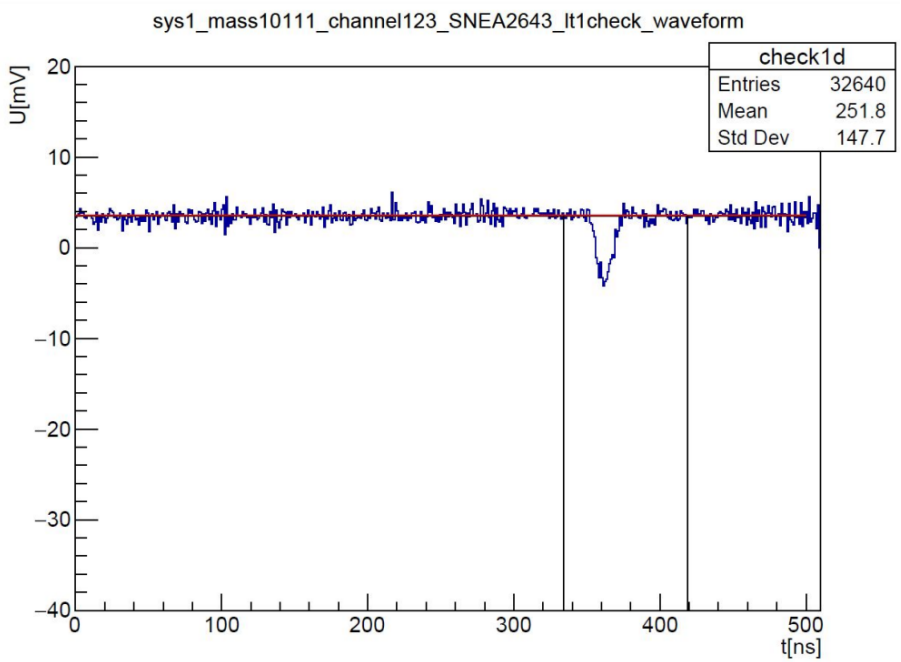



图: single photon signal waveform of HAMAMATSU PMT

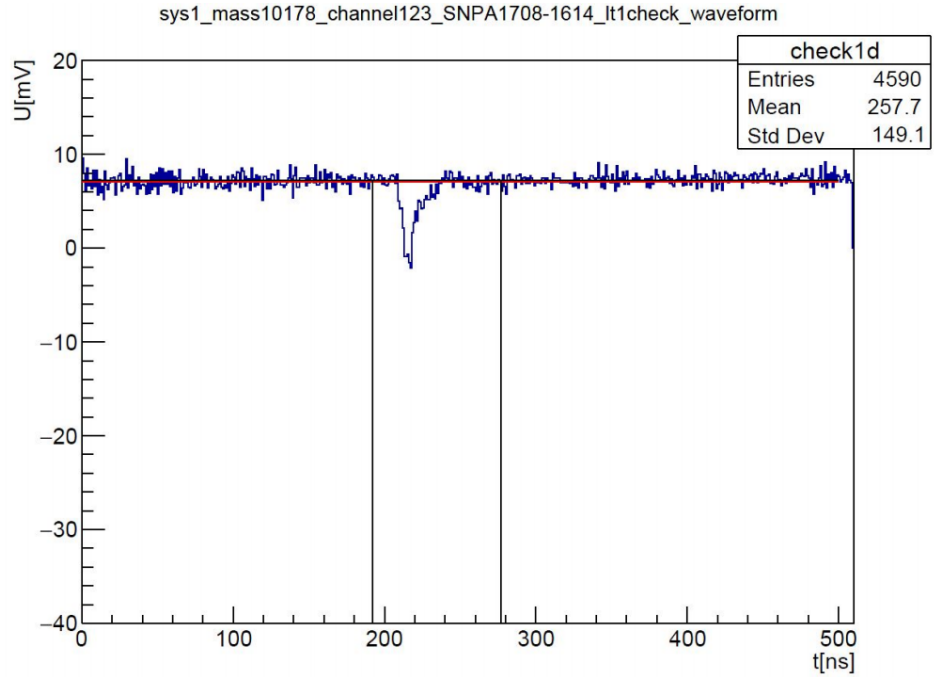



图: single photon signal waveform of NNVT PMT

# Output waveforms of PMT @$Gain = 10^7$

The 2-D waveform histogram contains all the recorded waveforms, we can clearly see the ”delayed signals” of HAMMATSU PMT and ”big signals” of NNVT PMTs.

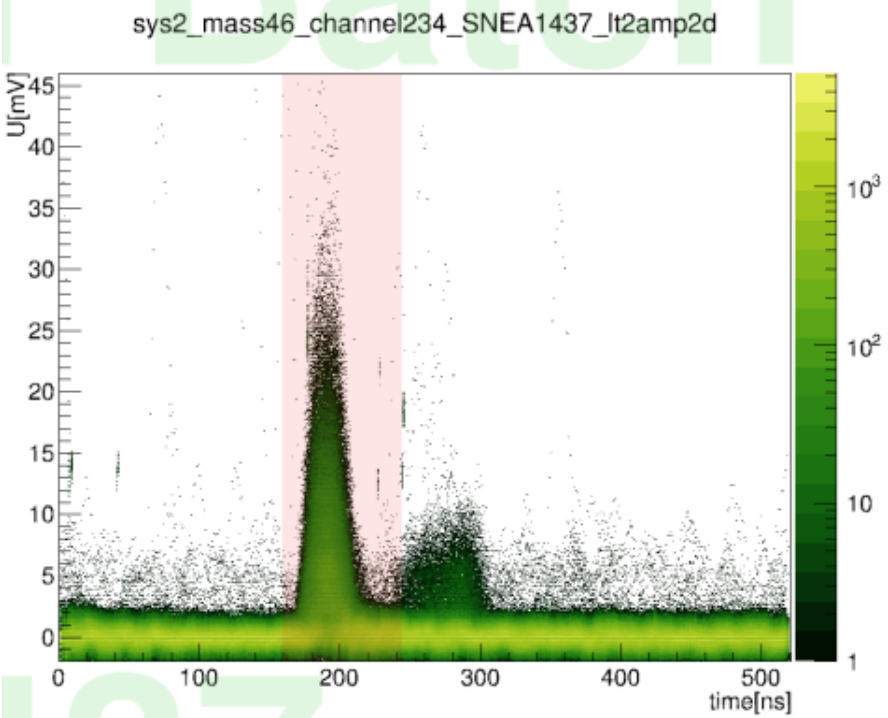



图: all frames of HAMAMATSU PMT

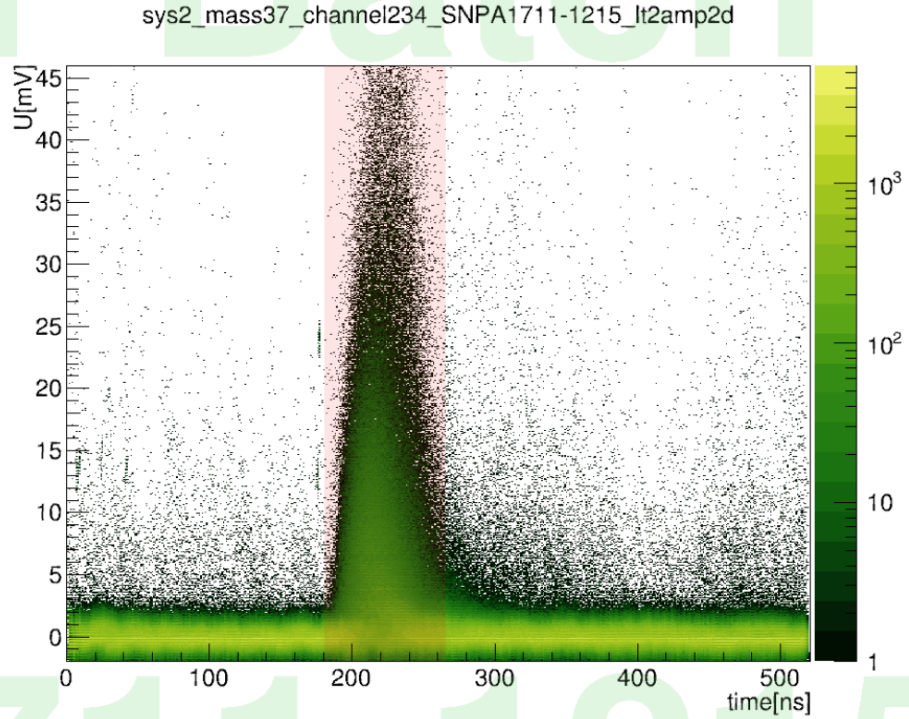



图: all frames of NNVT PMT

# Output integrated waveforms of PMT(@$gain = 10^7$)

From the waveform integral histogram we acquire more information.

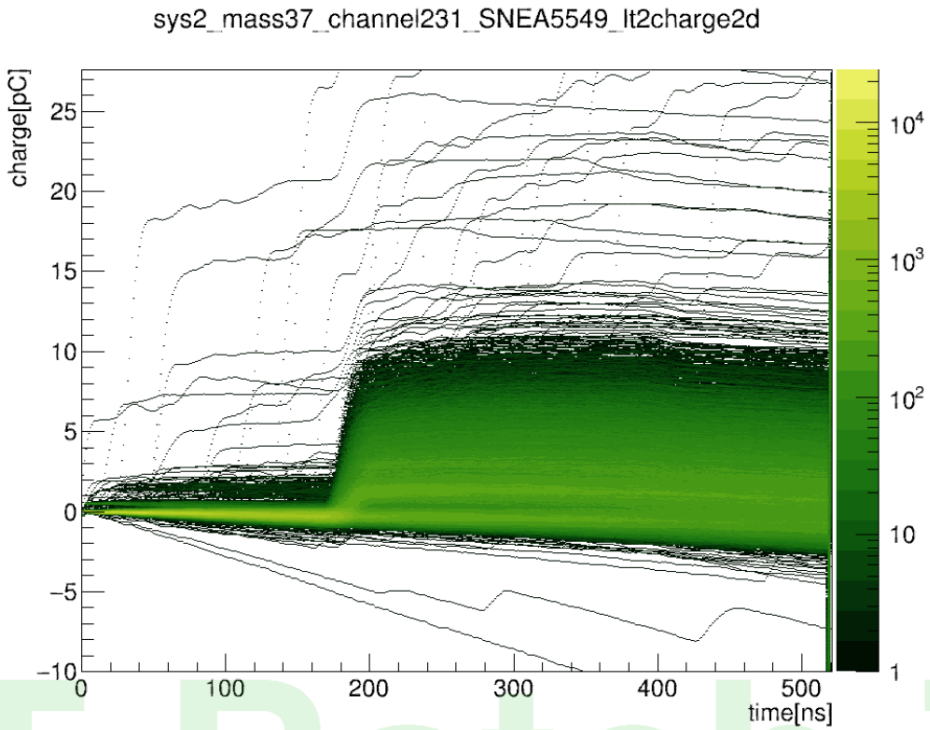



图: integrated waveforms of HAMAMATSU PMT

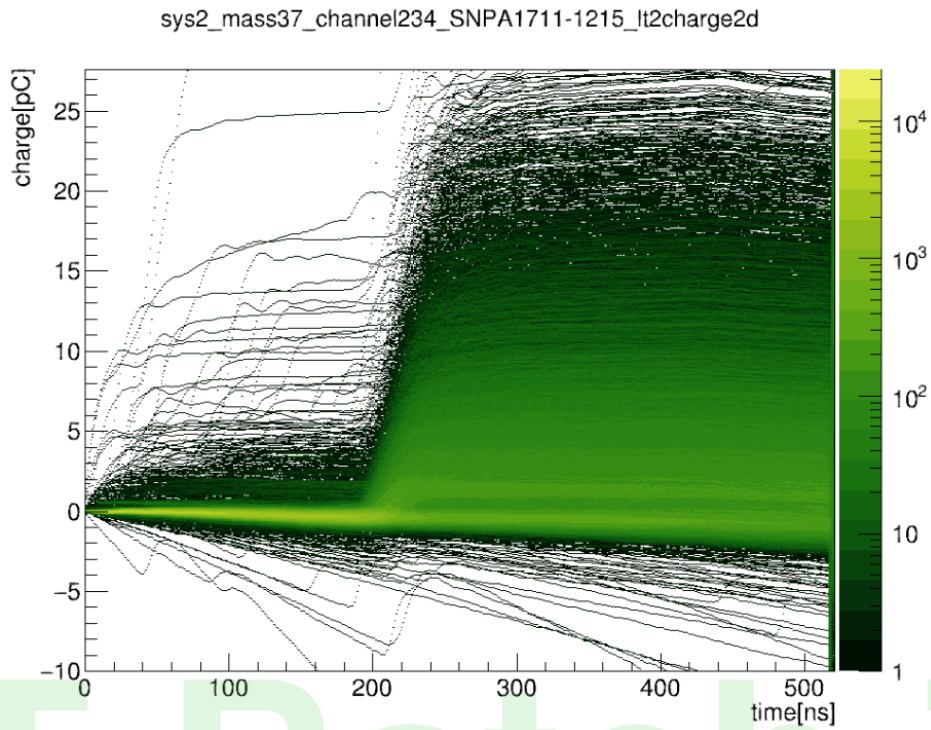



图: integrated waveforms of NNVT PMT

# Amplitude spectrum (@$gain = 10^7 \&\& \mu \simeq 1.3$)

Signal amplitude stability of NNVT PMT is worse than HAMAMATSU PMT.

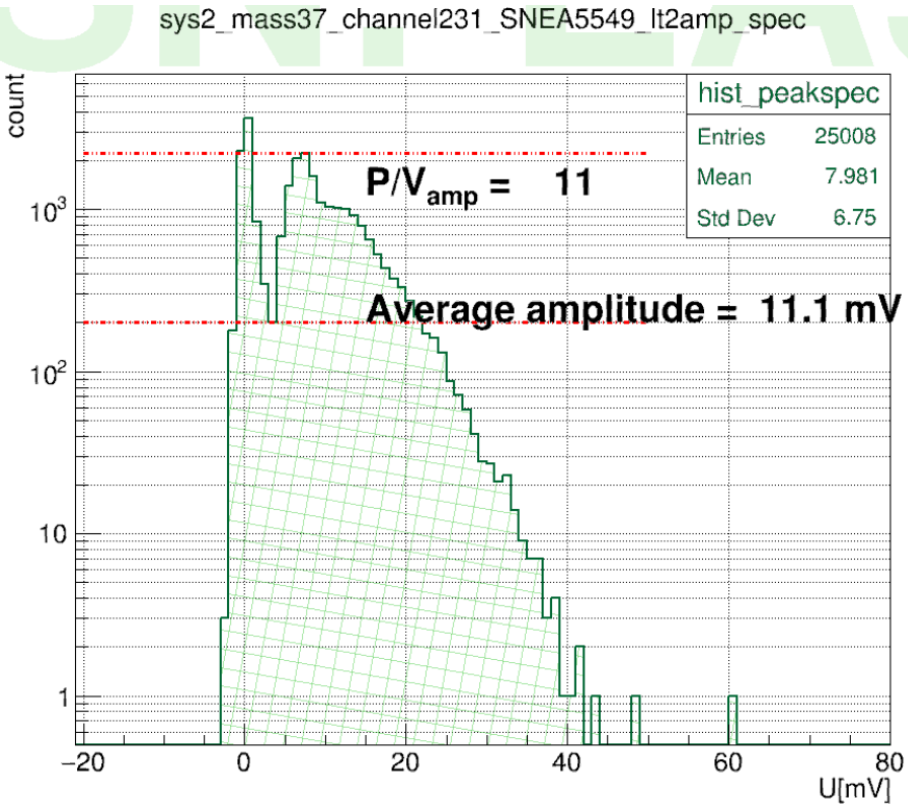



图: Amplitude spectrum of HAMAMATSU PMT

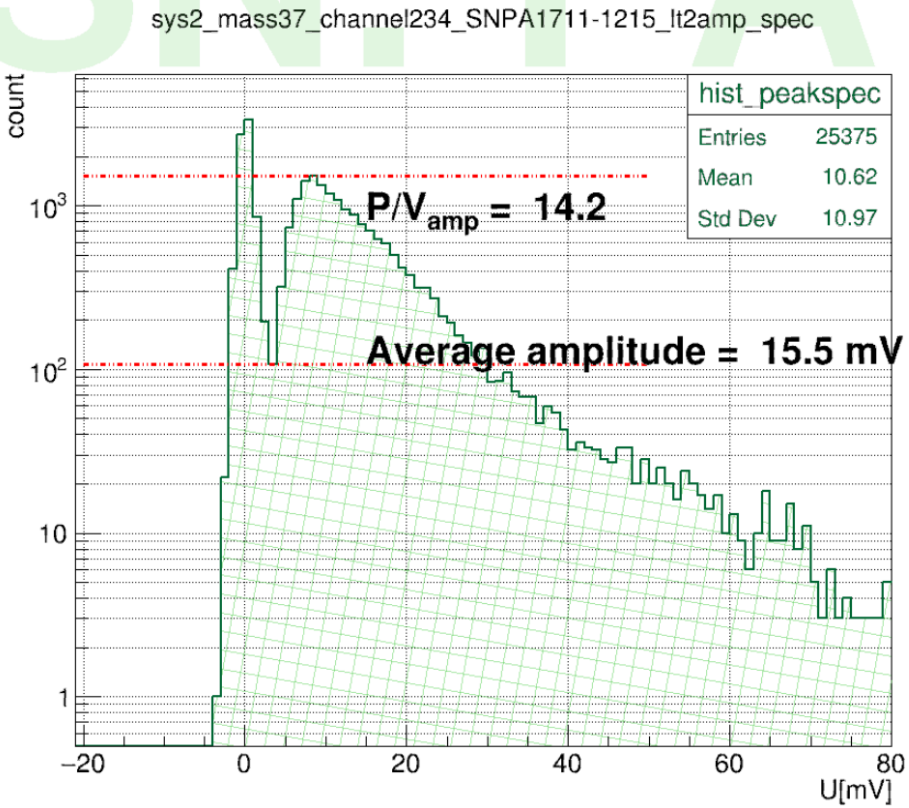



图: Amplitude spectrum of NNVT PMT

# Aligned waveforms (@$gain = 10^7 \&\& \mu \simeq 1.3$)

Aligning all signals according to their maximum: signal profile of HAMAMATSU PMT have better symetry.

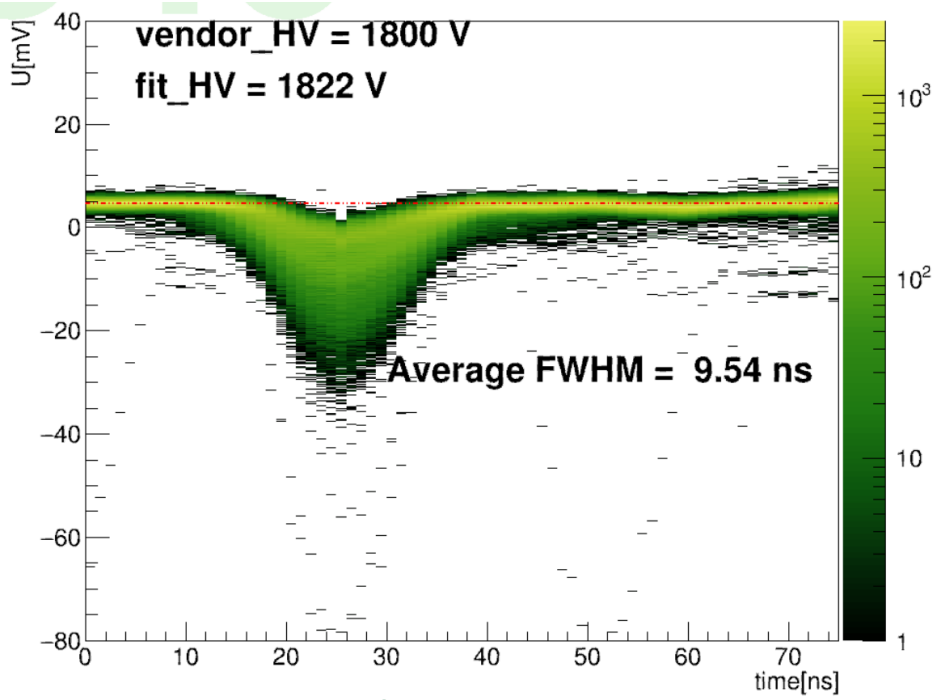



图: Aligned frames of HAMAMATSU PMT

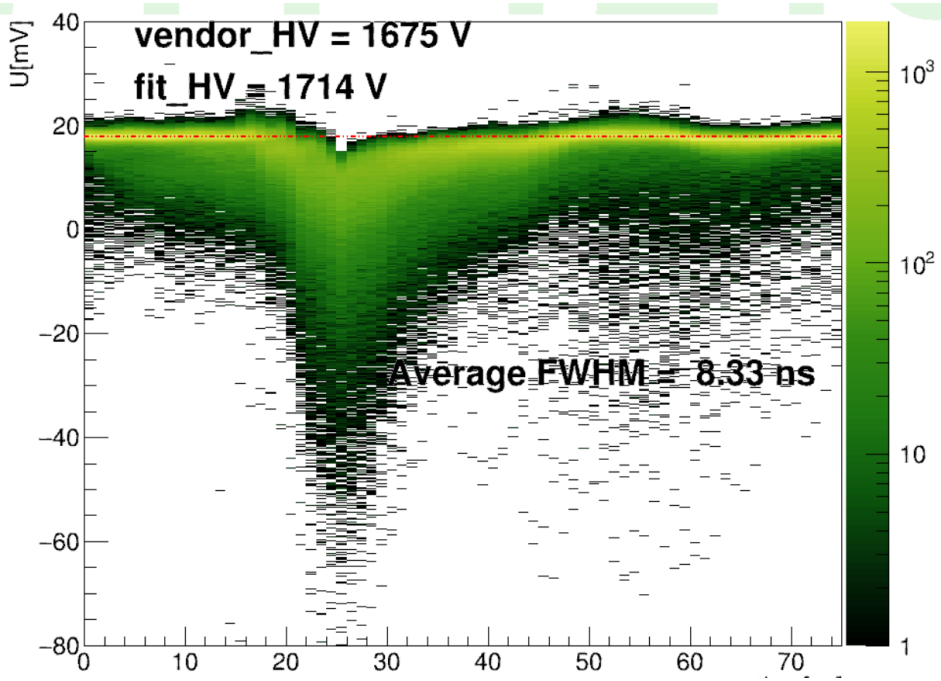



图: Aligned frames of NNVT PMT

# Average waveform (@$gain = 10^7 \&\& \mu \simeq 1.3$)

The average waveform of NNVT PMT has faster rising edge and lower falling edge.

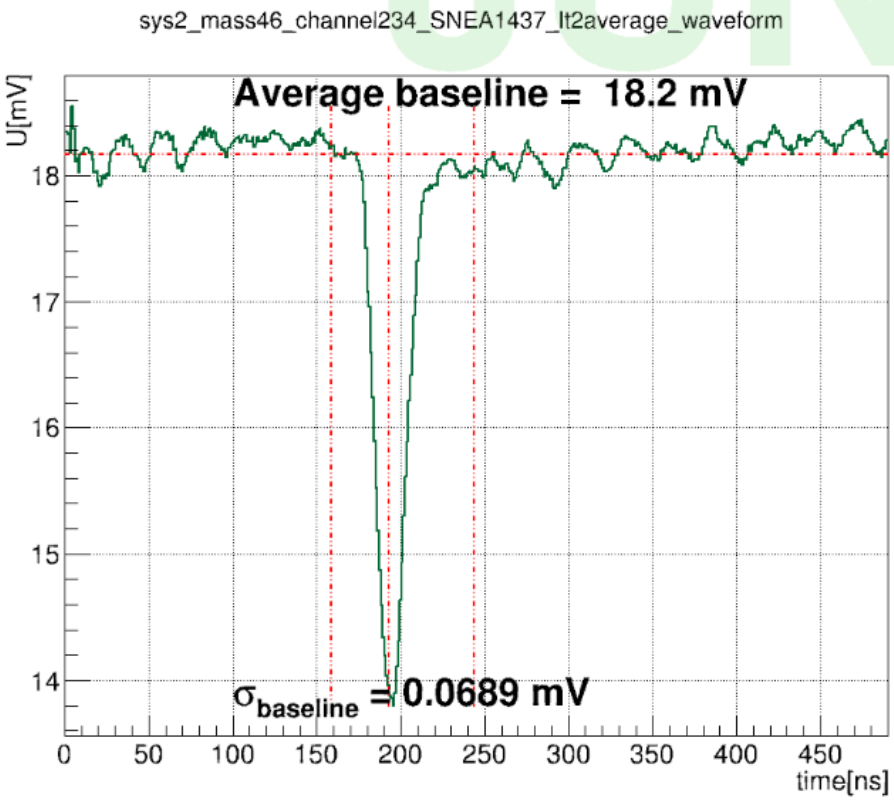



图: average waveform of HAMAMATSU PMT

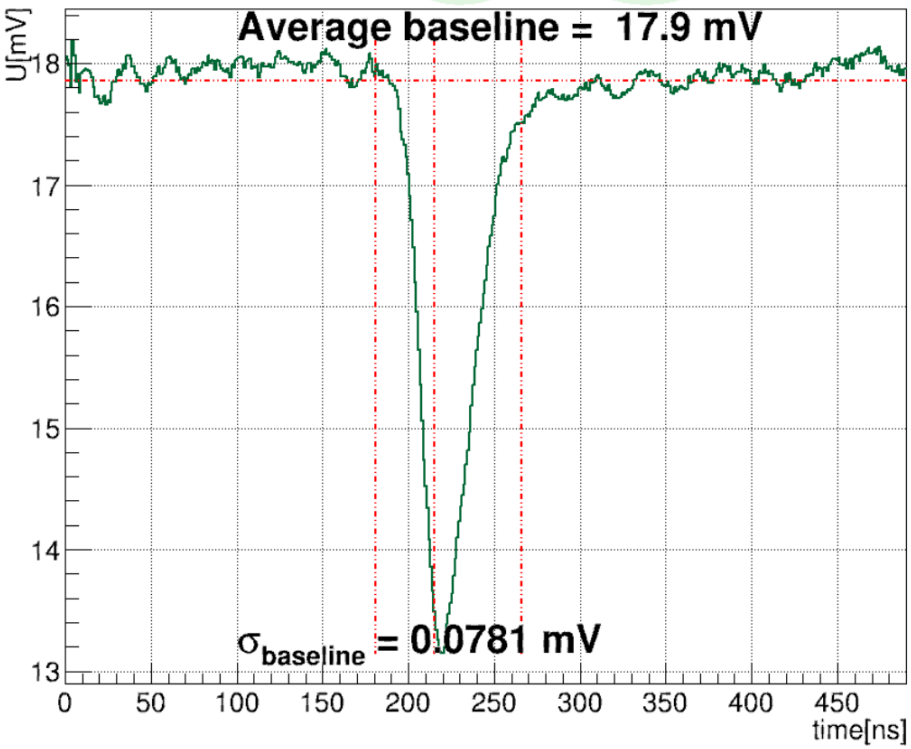



图: average waveform of NNVT PMT

# Signal hit time distribution

The hittime response of NNVT PMT is about 20ns slower than the HAMAMATSU PMT.

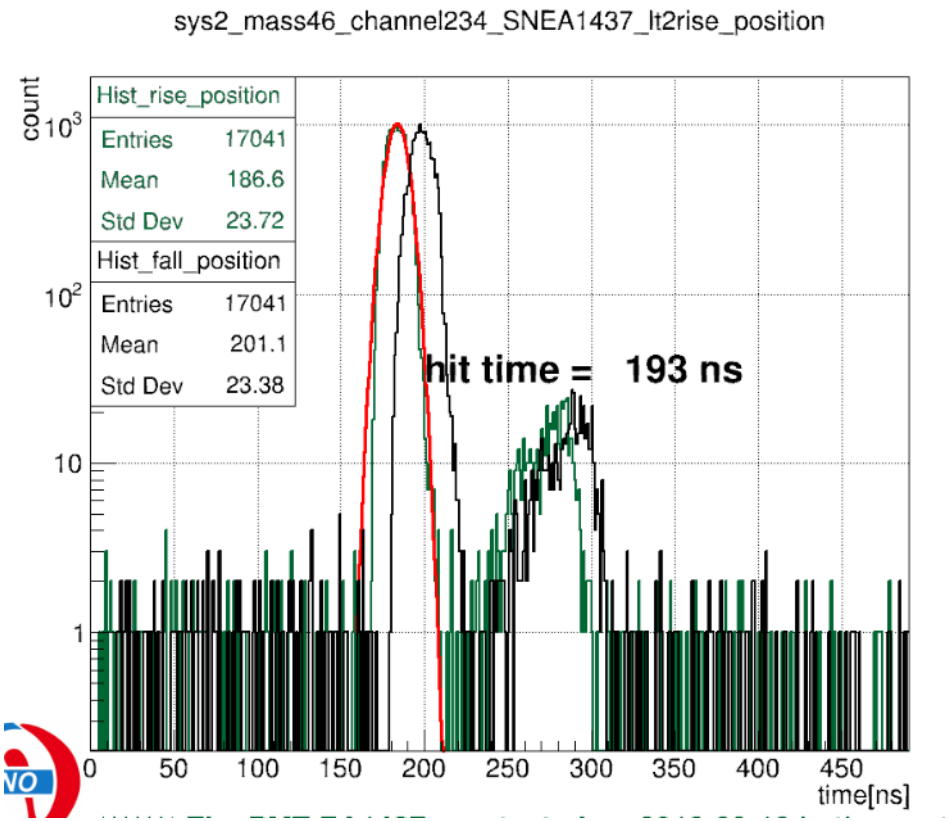



图: hit time of HAMAMATSU PMT

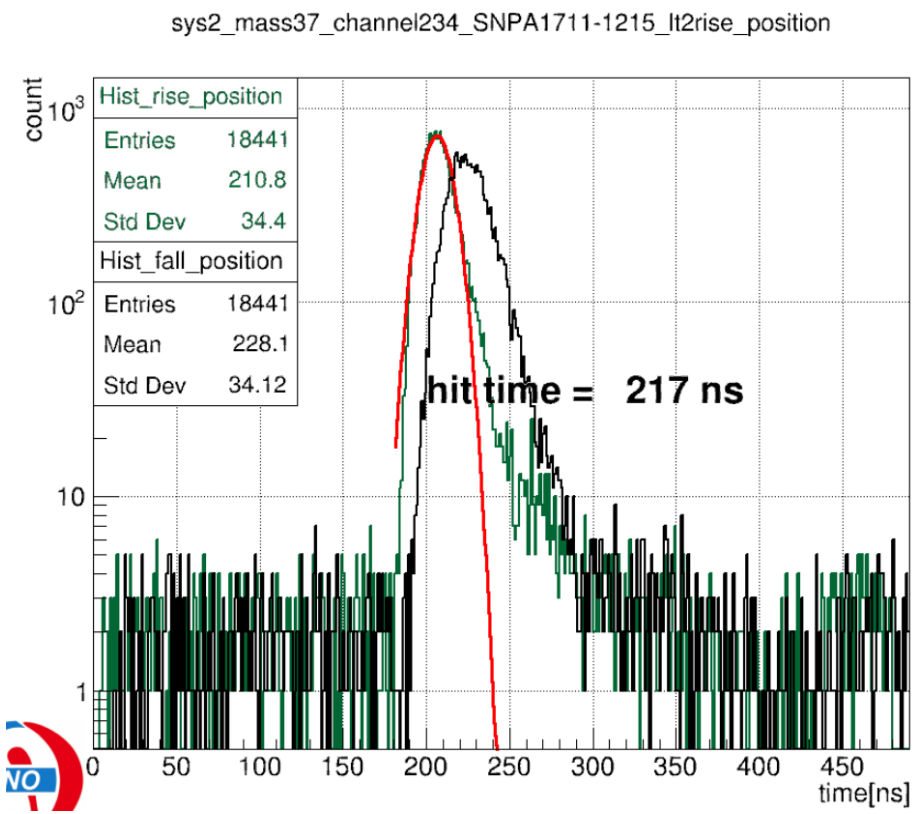



图: hit time of NNVT PMT

# charge and amplitude (@$gain = 10^7 \&\& \mu \simeq 1.3$)

amplitudes and and charge intergrals of NNVT PMT is not as stable as HAMAMATSU PMT.

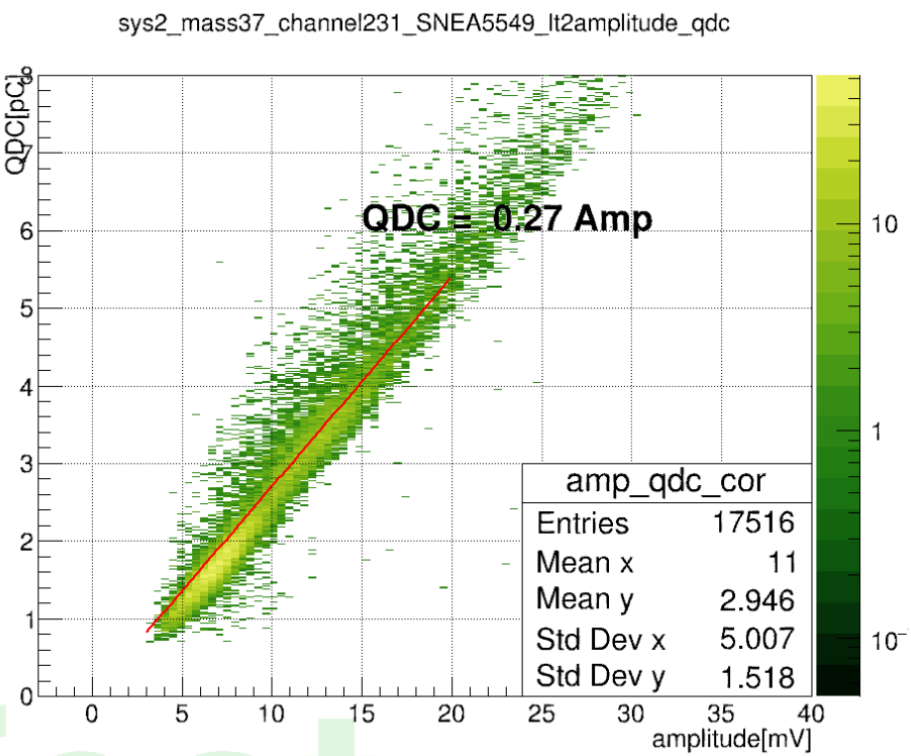



图: charge and amplitude correlation of HAMAMATSU PMT

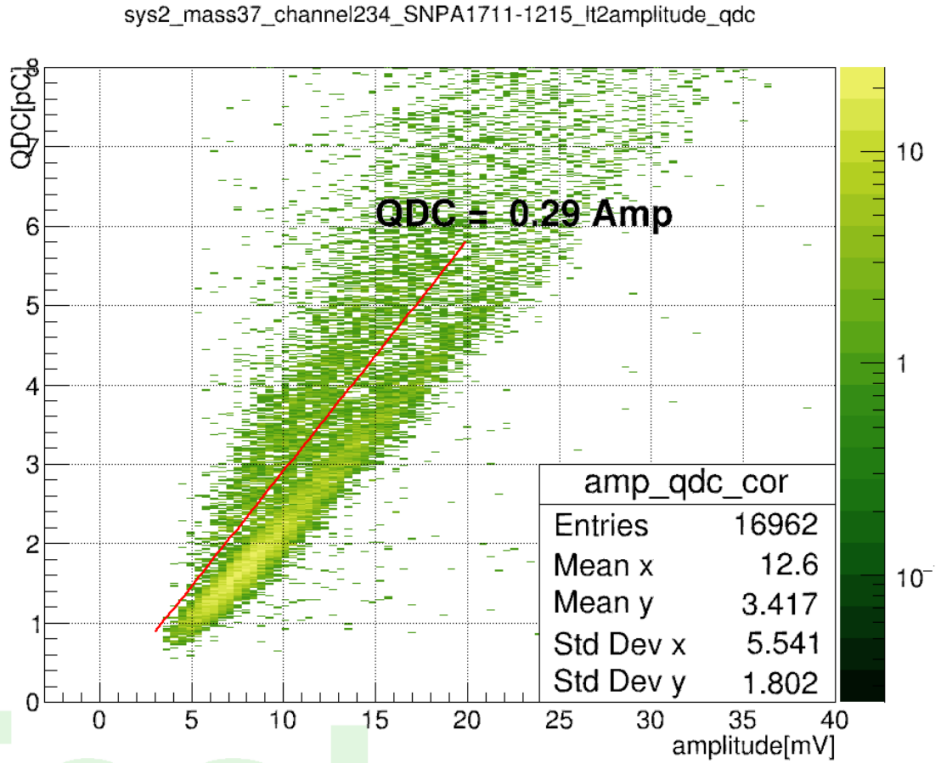



图: charge and amplitude correlation of NNVT PMT

# rise-time and fall-time (@$gain = 10^7 \&\& \mu \simeq 1.3$)

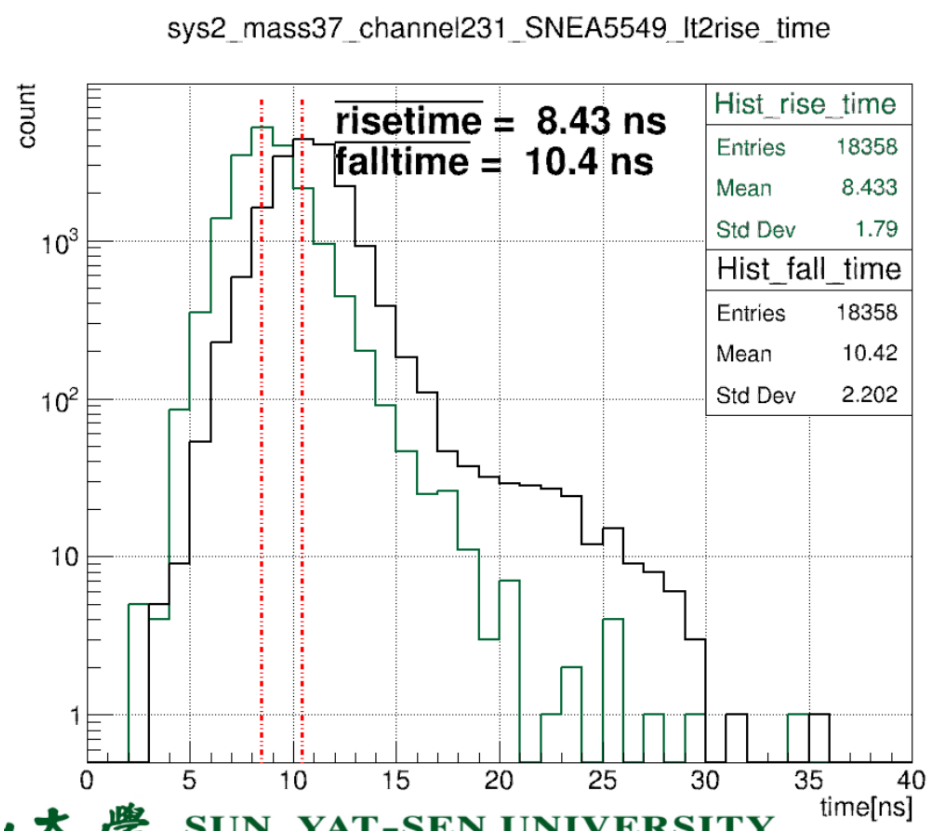



图: rise-time and fall-time of HAMAMATSU PMT

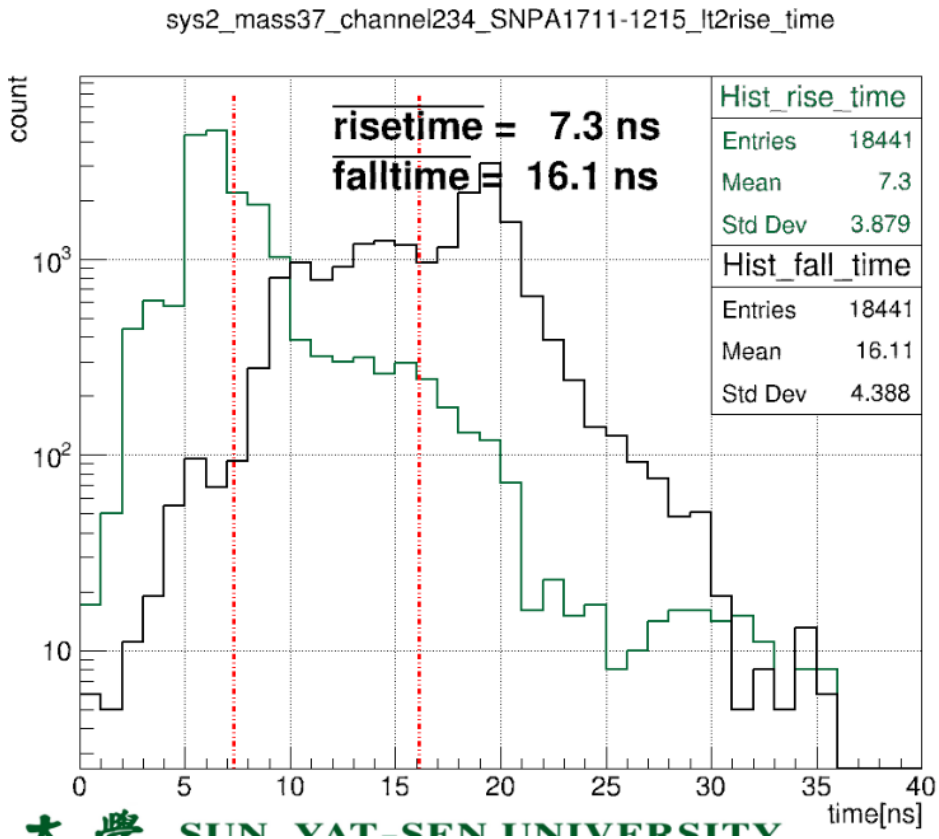



图: rise-time and fall-time of NNVT PMT

# Signal charge spectrum(@$gain = 10^7 \&\& \mu \simeq 1.3$)

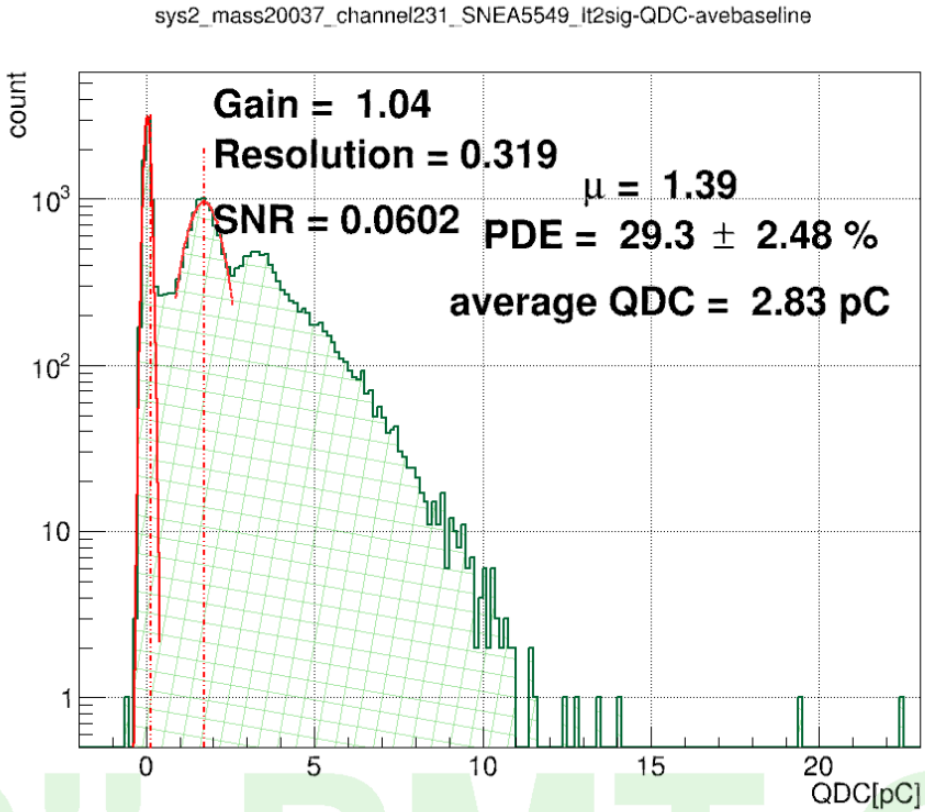



图: signal charge spectrum of HAMAMATSU PMT

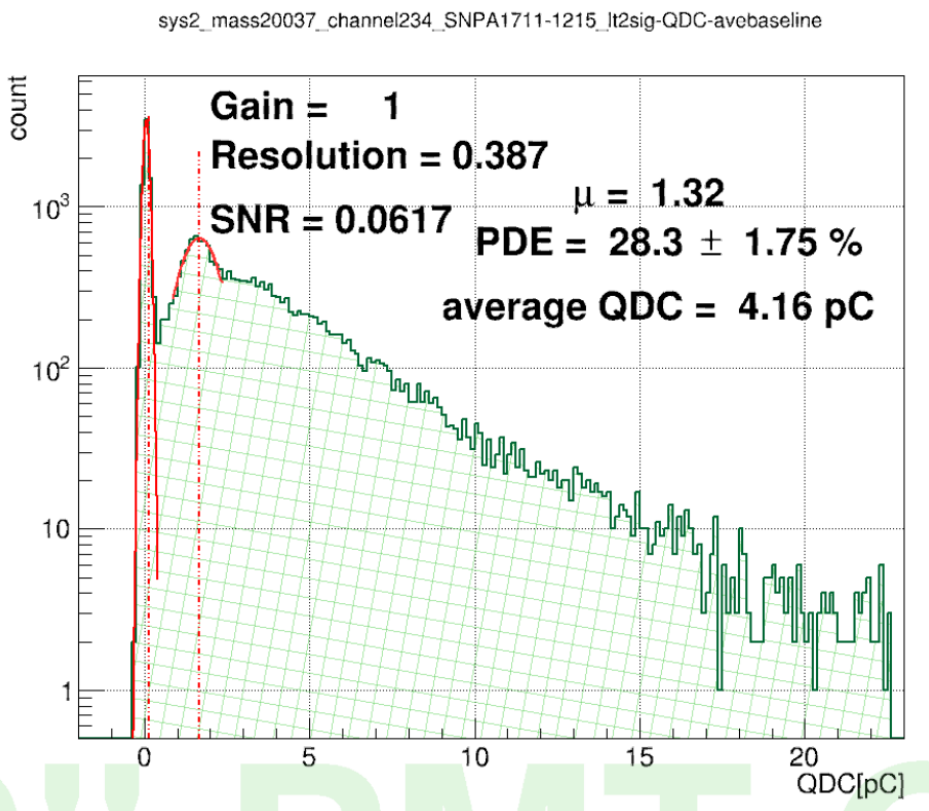



图: rise-time and fall-time of NNVT PMT

# calculation of parameters

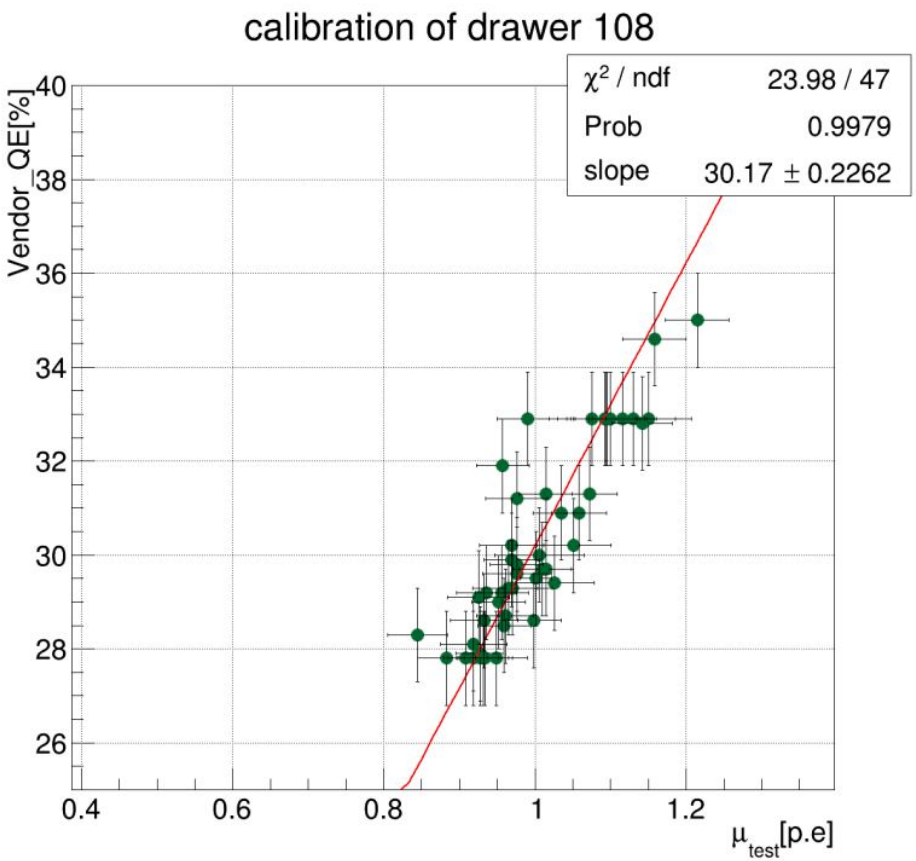
signal waveform

- $rise\ time = t_{.9rMaximum} - t_{.1rMaximum}$
- $fall\ time = t_{.1fMaximum} - t_{.9fMaximum}$
- $FWHM = t_{+1/2Maximum} - t_{-1/2Maximum}$

charge spectrum

- $Gain = \frac{Q_{1pe} - Q_{0pe}}{Q_e}$
- $PV = \frac{Peak_{spe}}{Valley_{spe}}$
- $S/N = \frac{\sigma_{0pe}}{Q_{1pe} - Q_{0pe}}$
- $Resolution = \frac{\sigma_{1pe}}{Q_{1pe} - Q_{0pe}}$

# calculation of $drawer_{factor}$



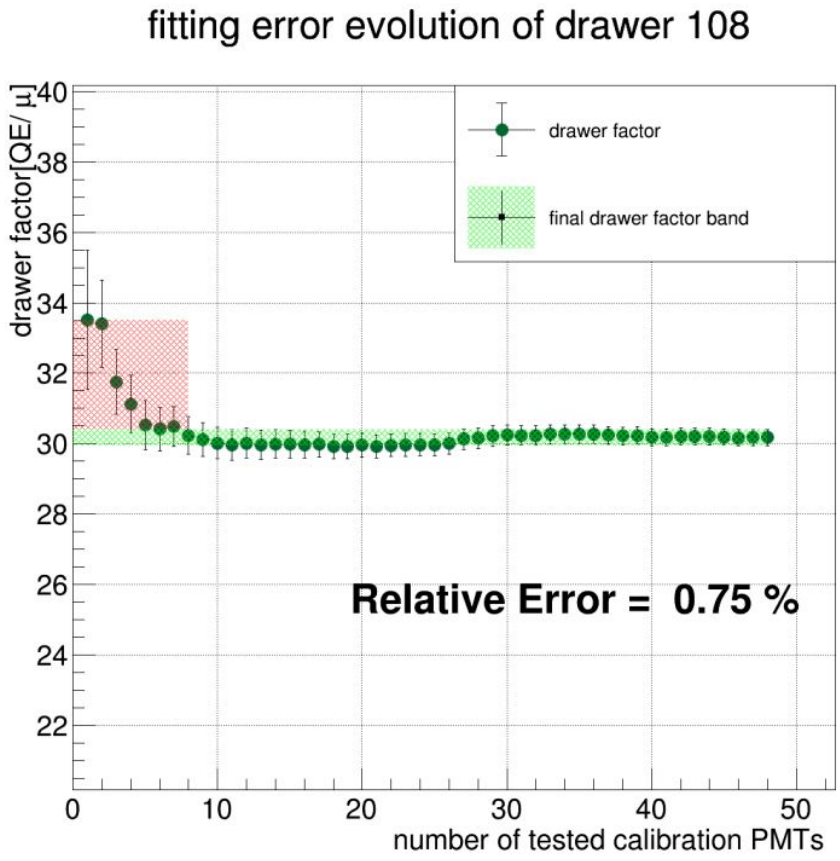




图: fitting the drawer factor in one drawer

# calculation of *PDE*

we can obtain the average photon number $\mu_{test}$ from charge spectrum, along with the $drawer_{factor}$[1], the PDE result from container system is:

$$PDE_c = \mu_{test} \times drawer_{factor} \tag{1}$$

Then we map the PDE from container to the final PDE value with the help of container $f_{cs}$[2] :

$$PDE = PDE_c.f_{cs} + constant \tag{2}$$

[1] Calibrate the drawer factor using PMT tested in the drawer which has vendor QE value.

[2] linear correlation factor

# statistical results

Mean value of parameters for HAMAMATSU-PMT and NNVT-PMT[3] :

| parameters（mean） | HAMAMATSU | NNVT |
|---|---|---|
| DCR(kHz) | 15.38 | 41.24 |
| rise time(ns) | 7.4 | 3.2 |
| fall time(ns) | 10.36 | 15.9 |
| PV | 3.39 | 3.19 |
| resolution | 0.28 | 0.35 |
| HV@1E7(V) | 1861 | 1783 |
| FWHM(ns) | 9.08 | 5.8 |

[3]For the parameter TTS, we need to test the internal time resolution firstly, since we found the TTS results is highly drawer related.

# current PDE statistical results

For NNVT PMT, the new version High-QE tubes have higher PDE with mean value about 30.5%.

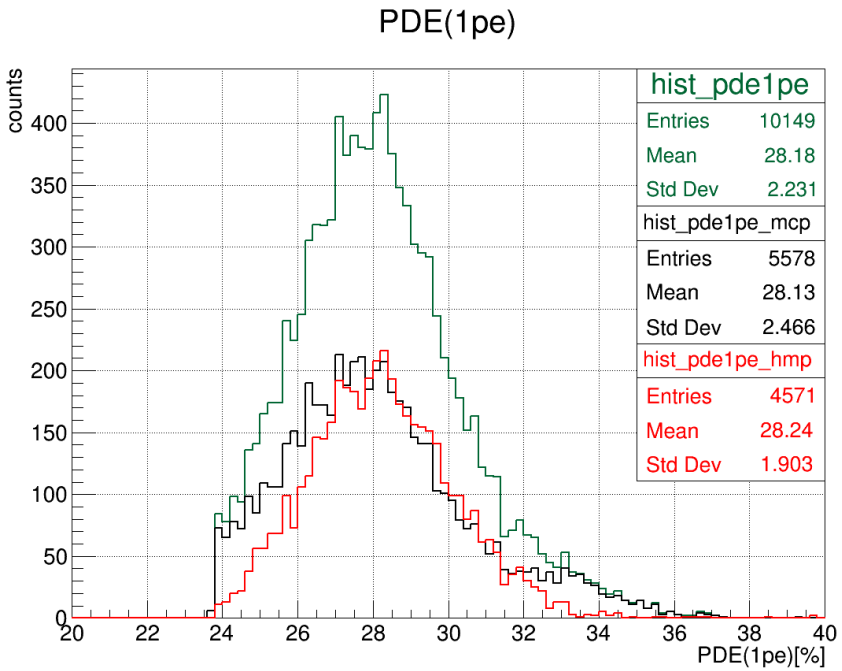



图: PDE of tested PMT

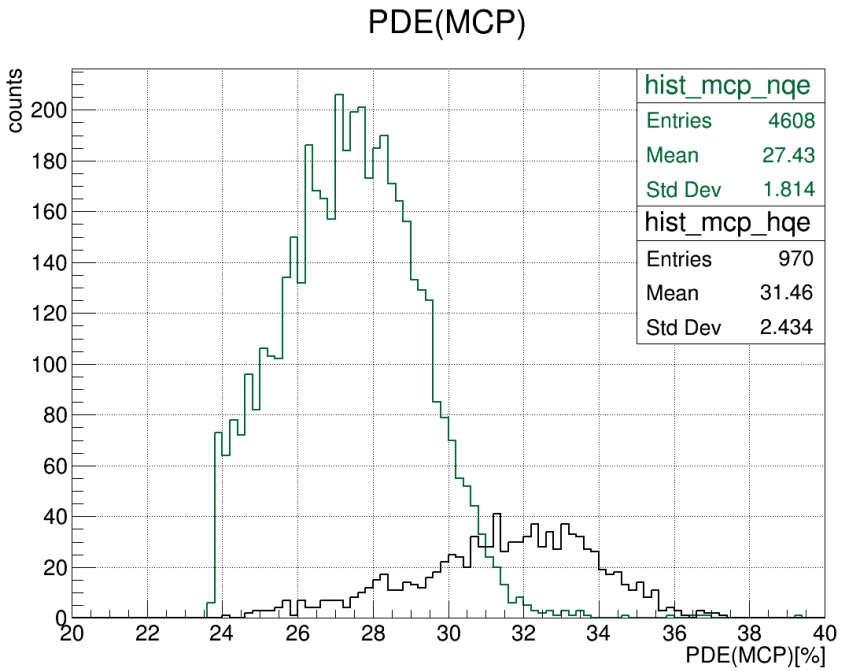
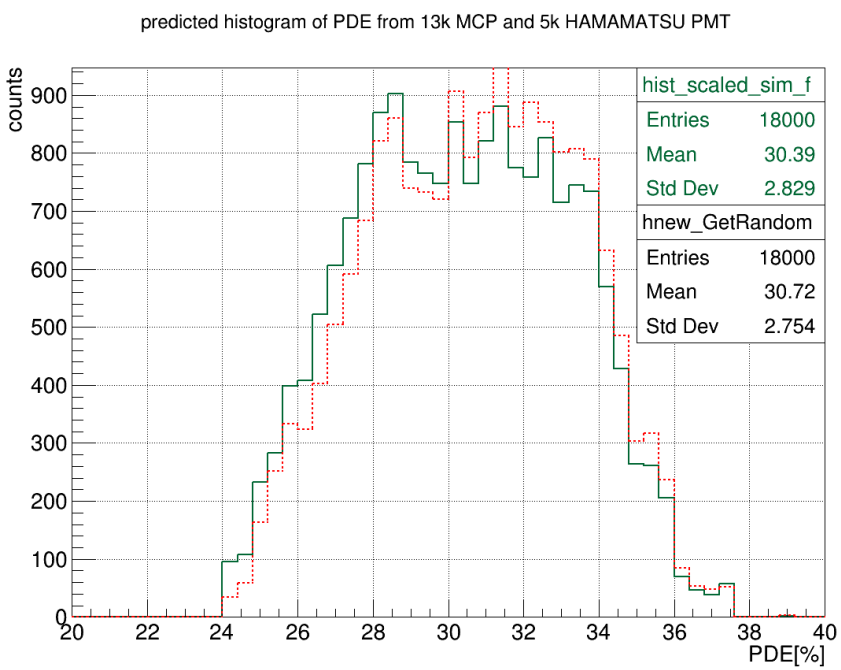



图: PDE of tested NNVT PMT

# predicted PDE statistical results

CD will use ∼13k NNVT[4] PMT, and 5k HAMAMATSU PMT, we can predict the final PDE and DCR distribution based on the current data:



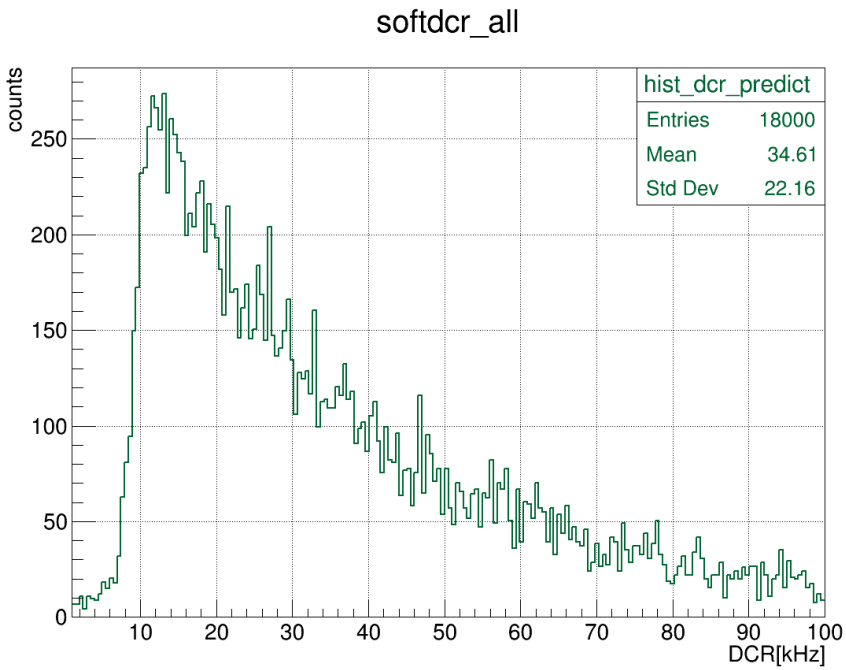




图: predicted PDE in CD

图: predicted DCR in CD

[4]with ∼11k high QE PMT and 2k low QE PMT

# summary

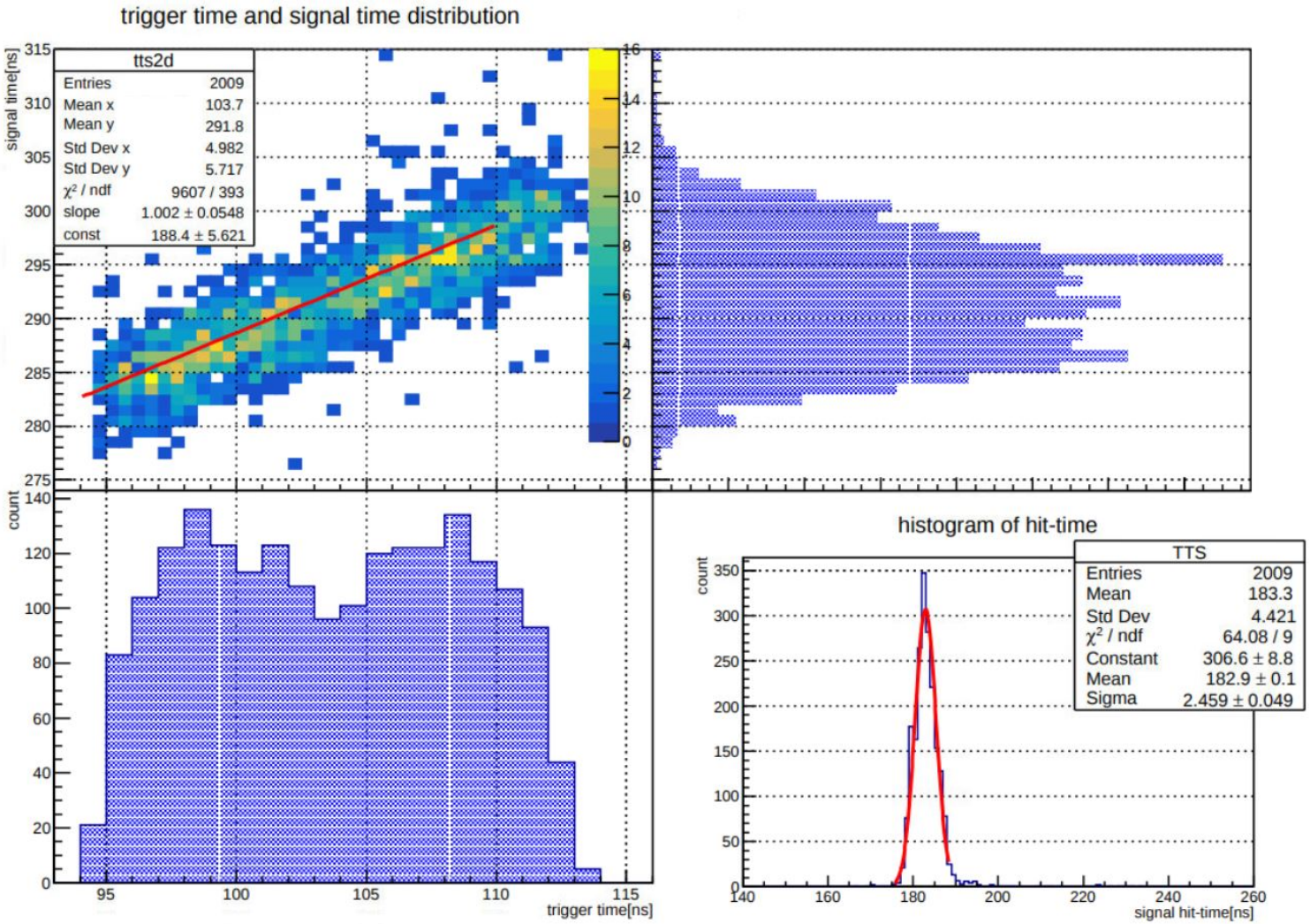
- the charge and amplitude stability of HAMAMATSU PMT is better.
- ∼6k NNVT PMTs and 5k HAMAMATSU PMTs has been tested in container system, test results and test reports are avaliable from PMTDataBase[5].
- we reject or accept one PMT according to its perfomance test results from container and scanning station.
- we need to study the ”delay signal” of HAMAMATSU PMT and ”big signal” of NNVT PMT[6] in detail[7].
- the expected mean PDE value is 30.4% and mean DCR value is ∼34kHz[8] in CD.

[5] pmtdb.juno.ihep.ac.cn
[6] especially when PMT working in the multi-photon case
[7] one option is to transport several PMTs to SYSU for detailed study
[8] will decrease after installation

# THANKS

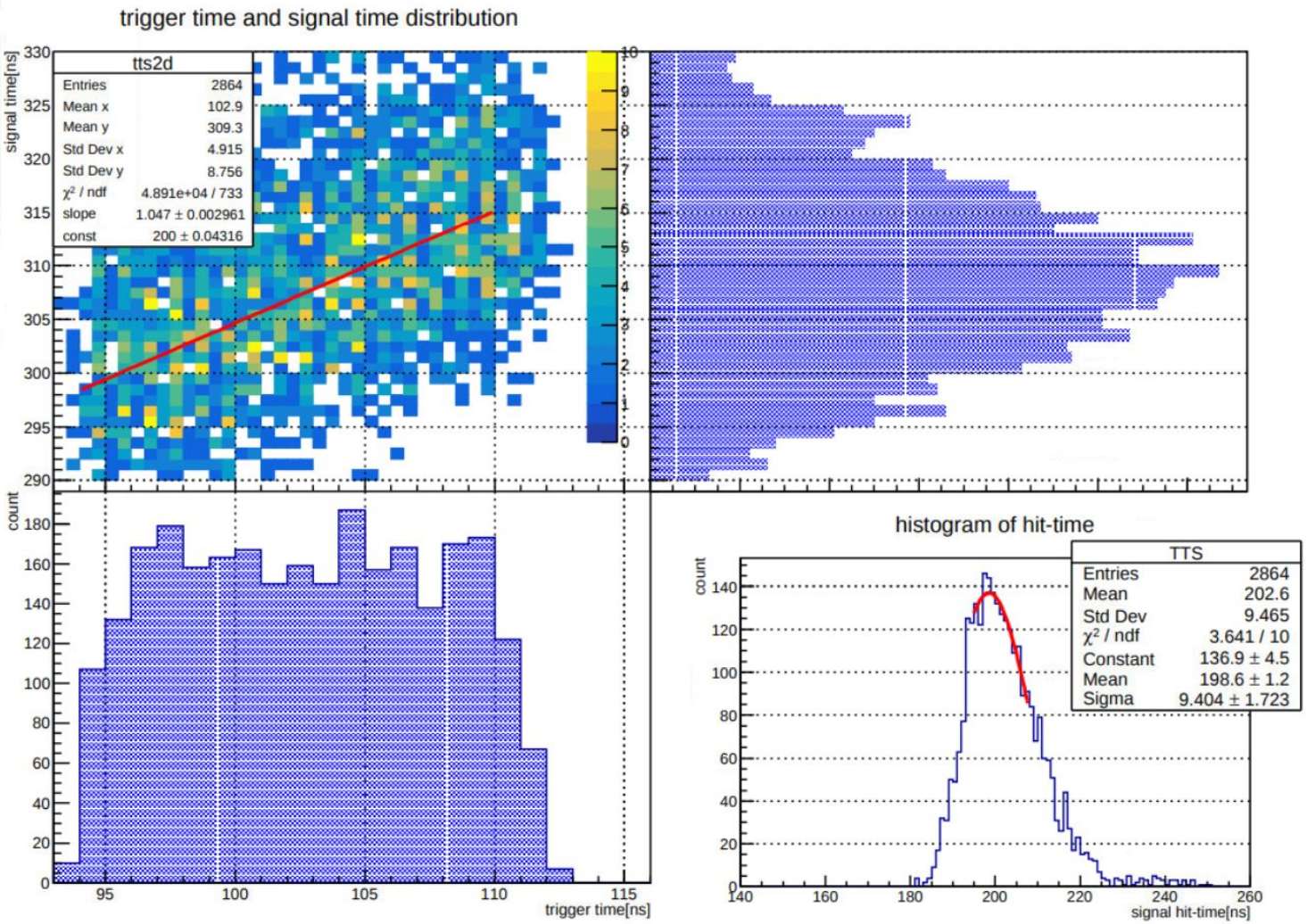
# BACK-UP

# TTS of HAMAMATSU PMT



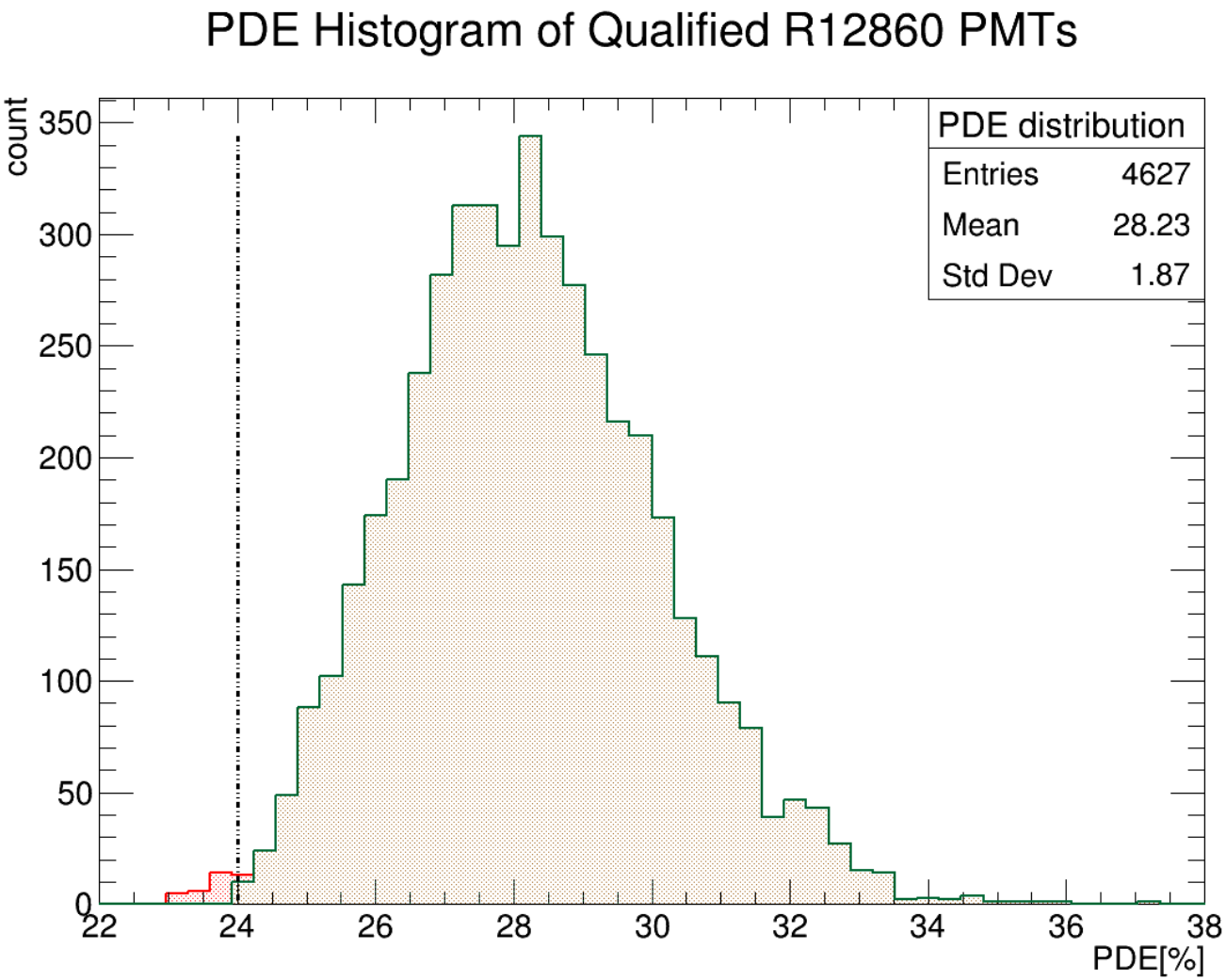

图：hittime and trigger time

# TTS calculation of NNVT PMT




图· hittime and trigger time

# 各个参数的统计结果-PDE



# PDE 计算结果的初步对比

对所有测试的 PMT 的 PDE 和测试现场的分析结果进行对比，发现存在少数 PMT 差别较大，需要进一步查找原因。

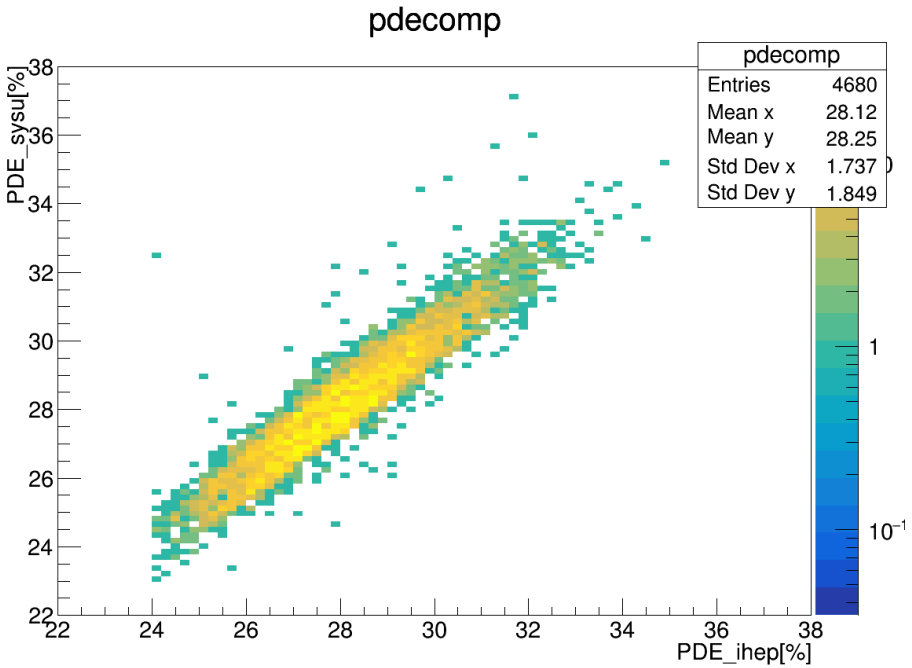



图: PDE 结果的关联对比

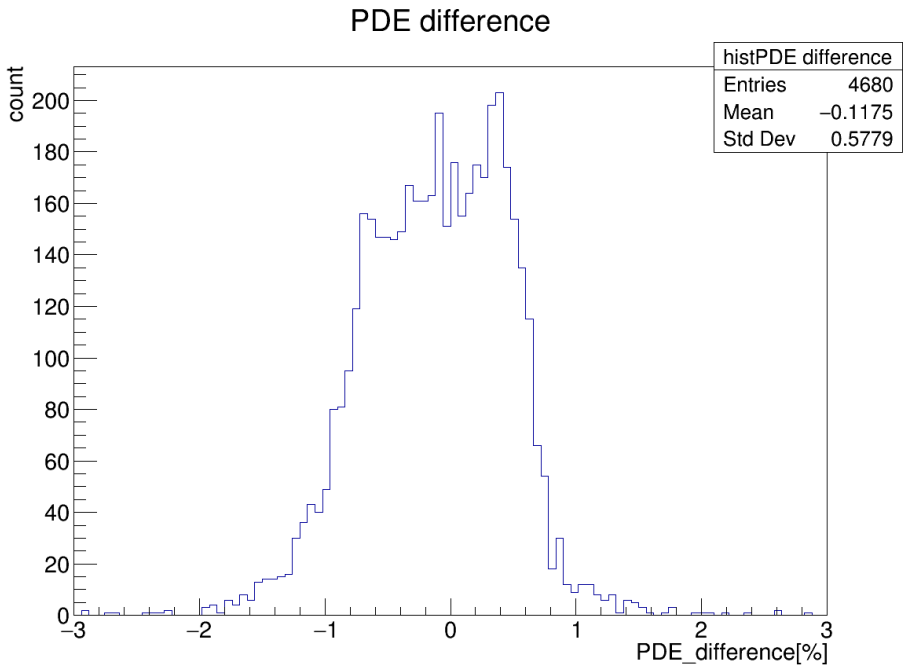
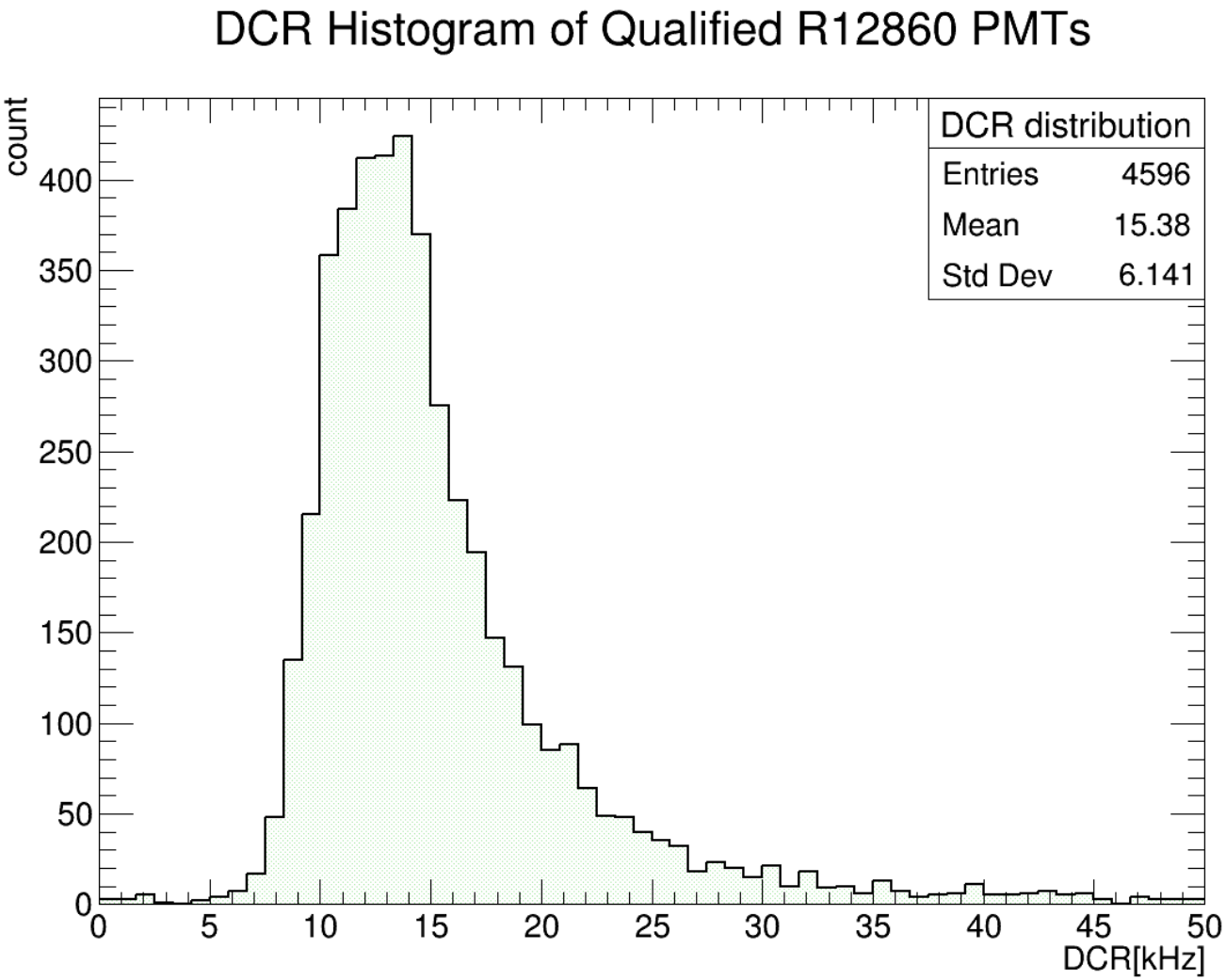
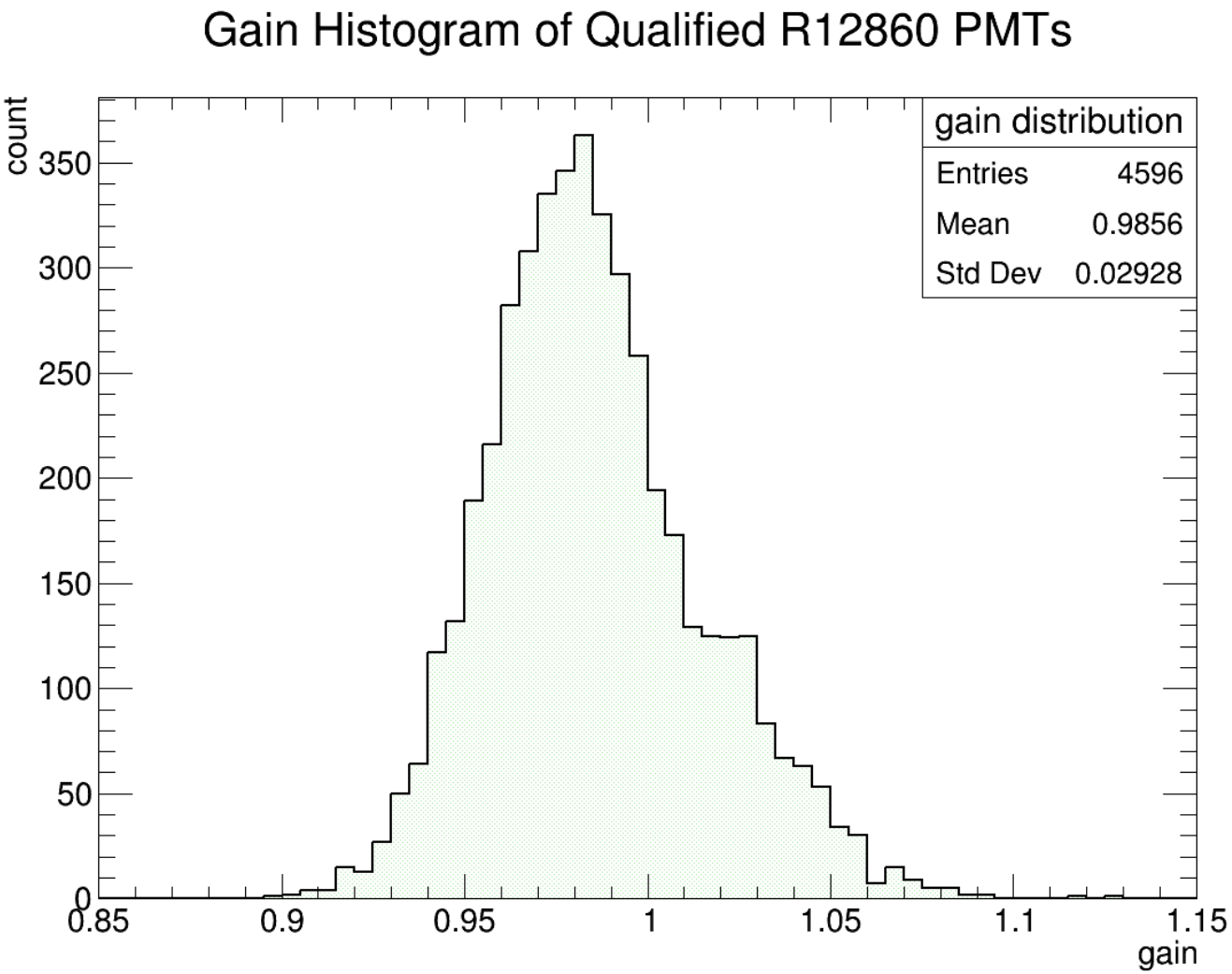



图: 两种分析的差值分布

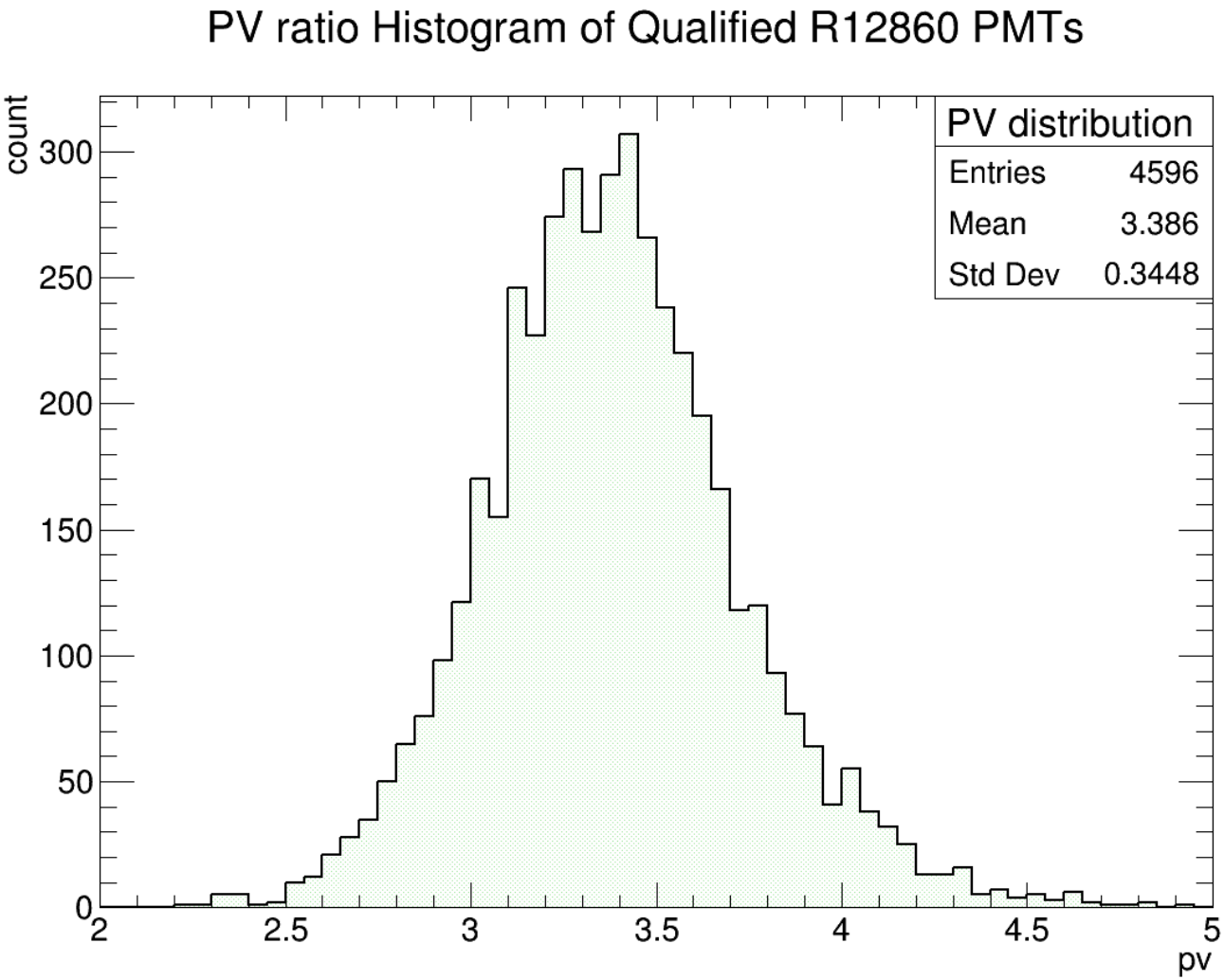
# 各个参数的统计结果-DCR



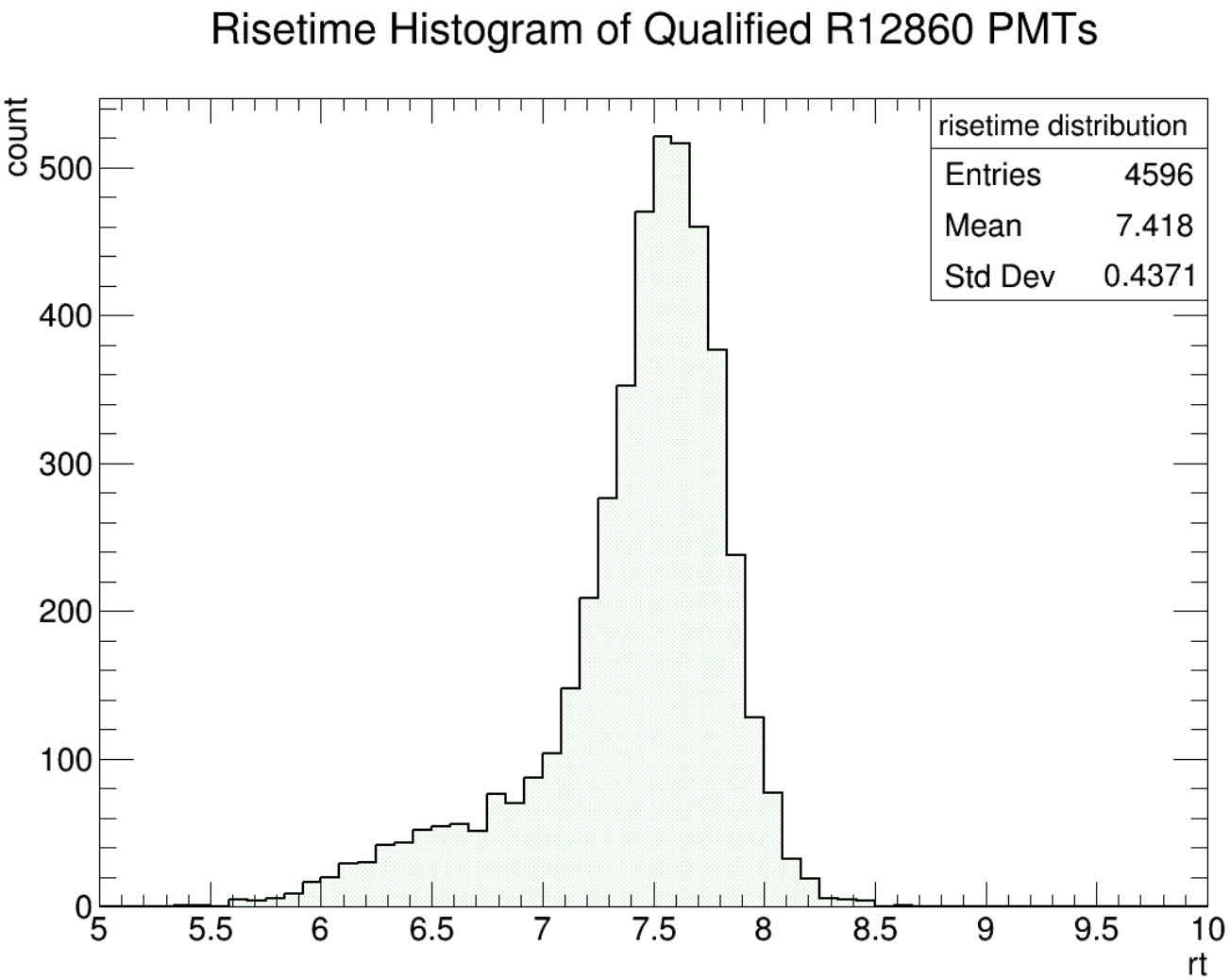
# 各个参数的统计结果-Gain



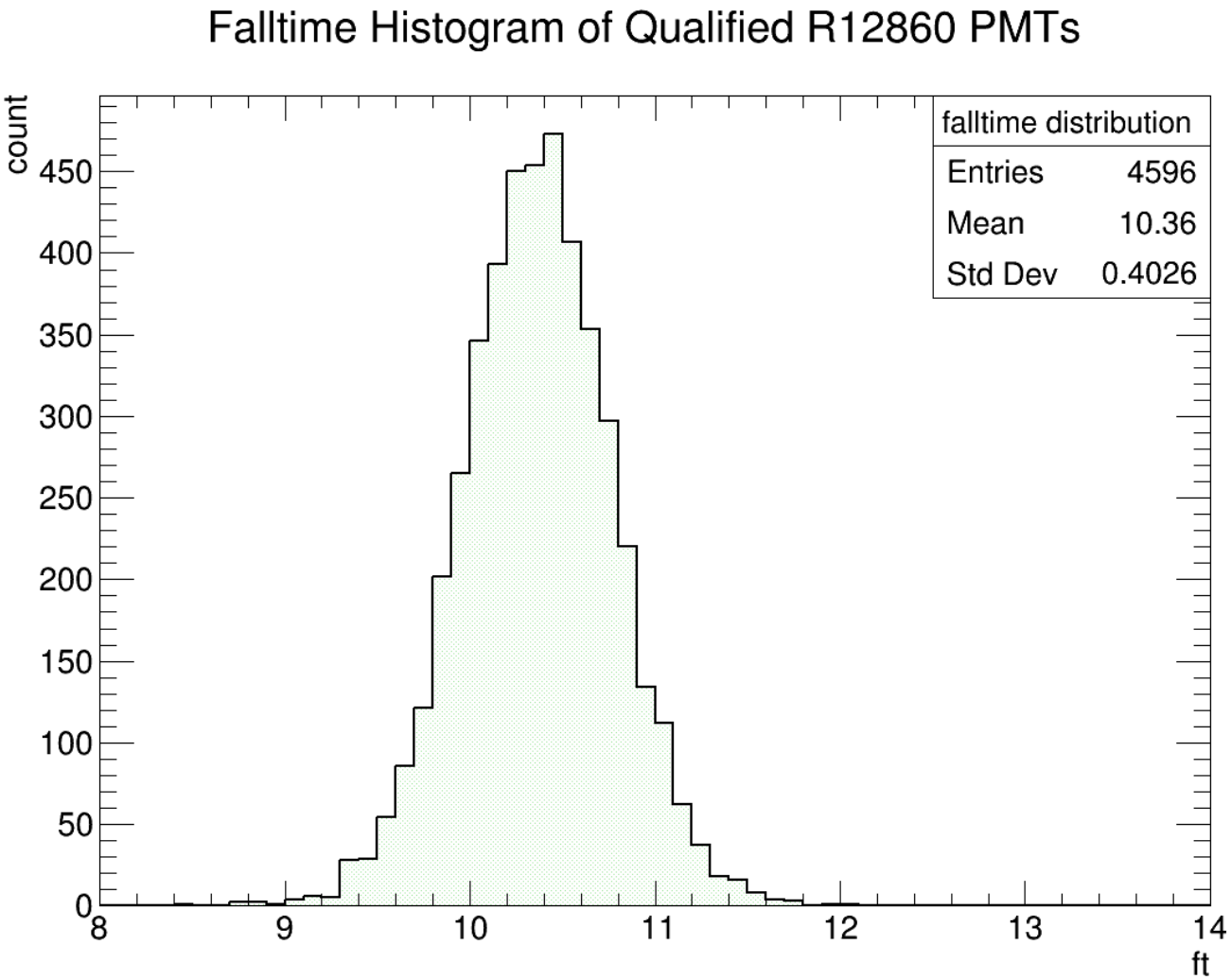
# 各个参数的统计结果-P/V



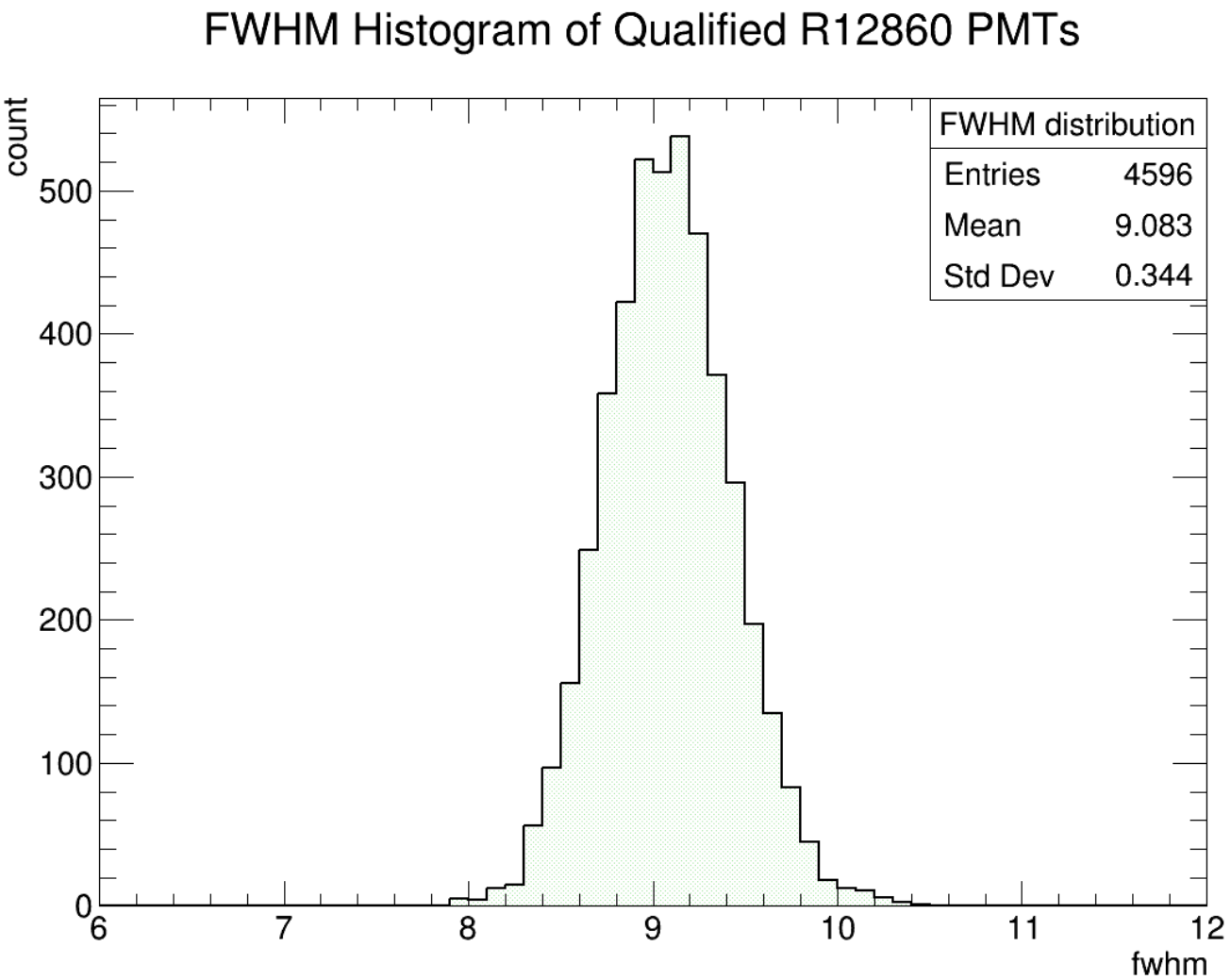
# 各个参数的统计结果-rise time



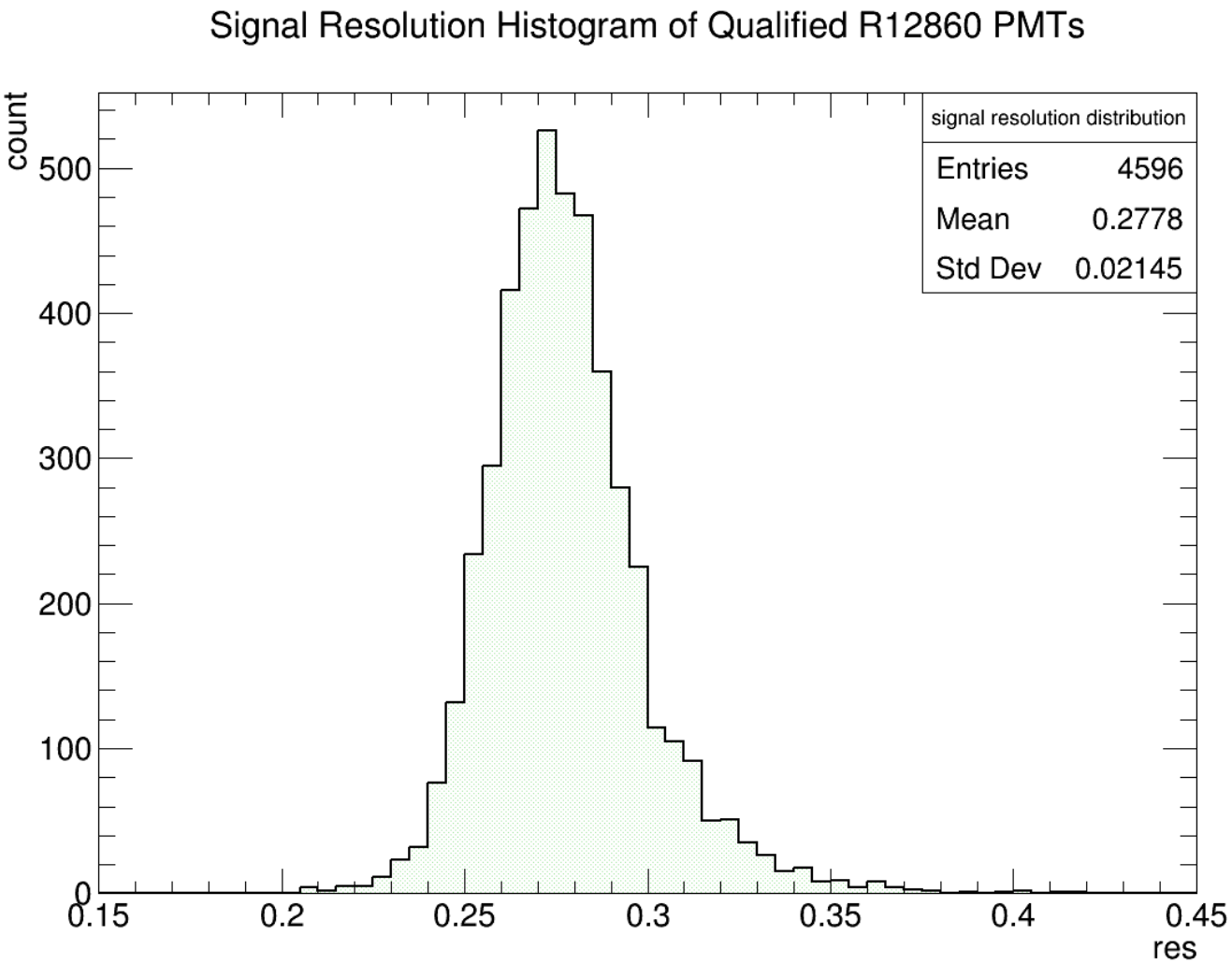
# 各个参数的统计结果-fall time



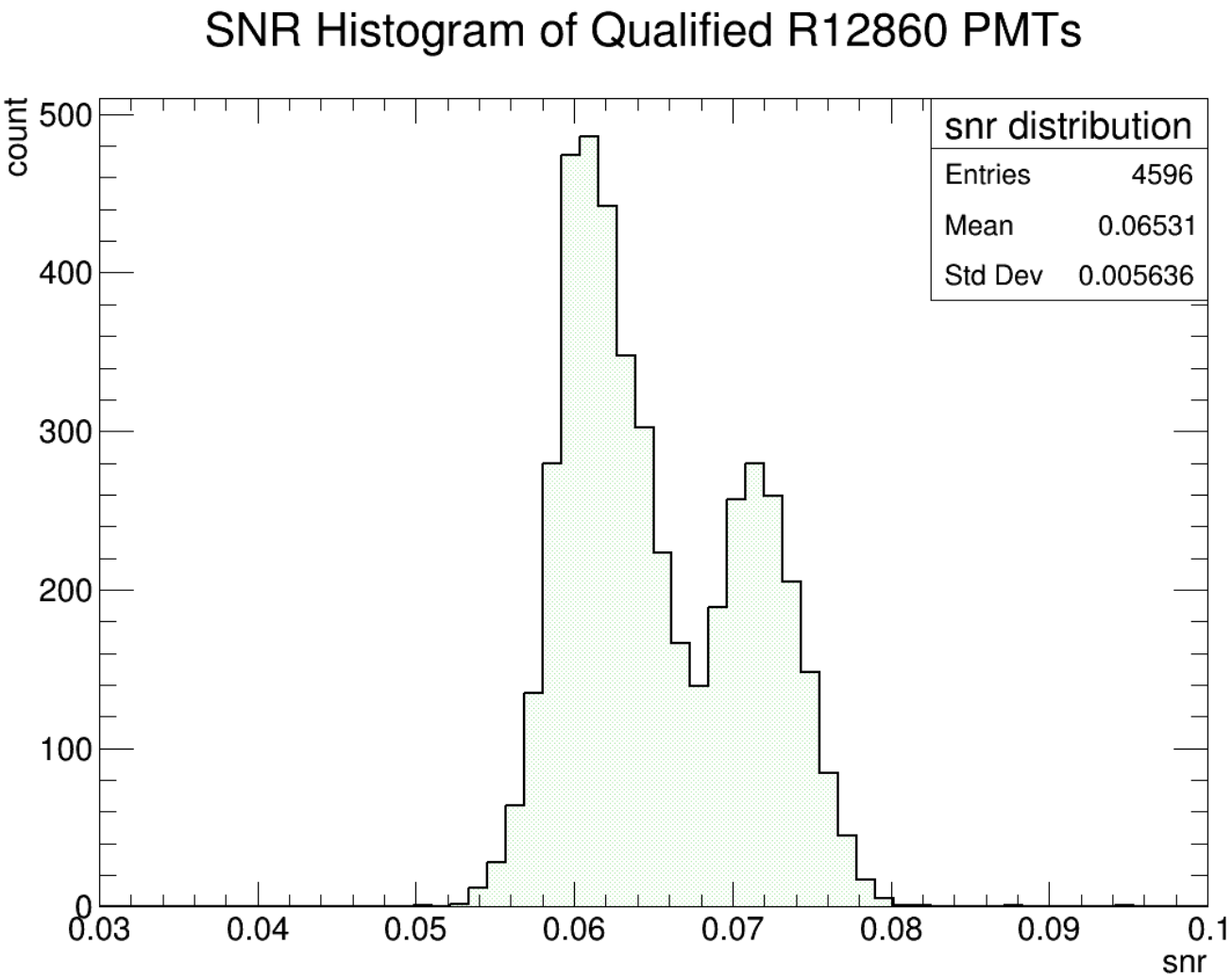
# 各个参数的统计结果-FWHM



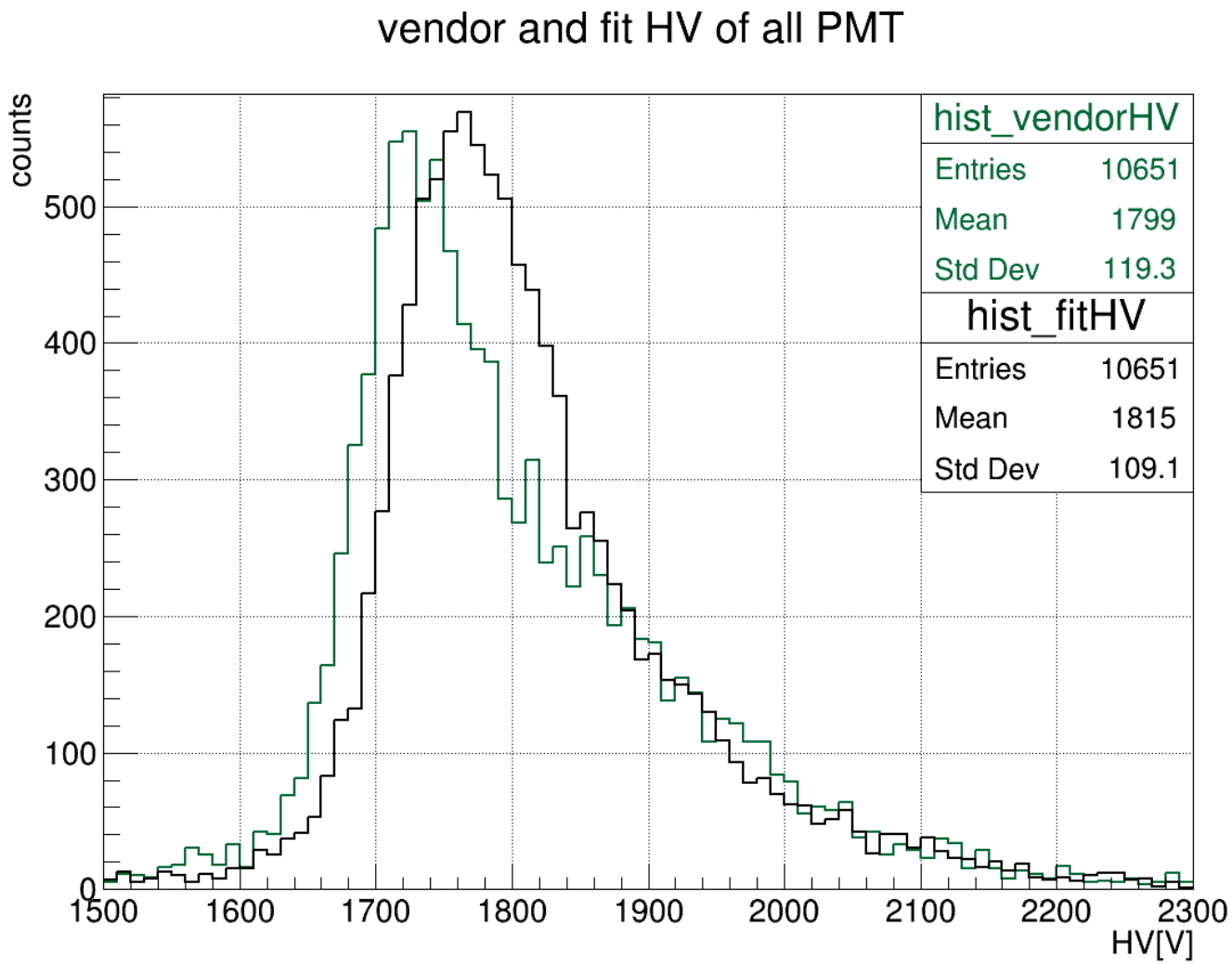
# 各个参数的统计结果-Resolution



# 各个参数的统计结果-S/N



# 各个参数的统计结果-HV



# 抽屉因子的比较

factor_1 是我的结果，factor_2 是张海琼的结果。$y = 1.148x + 0.998$

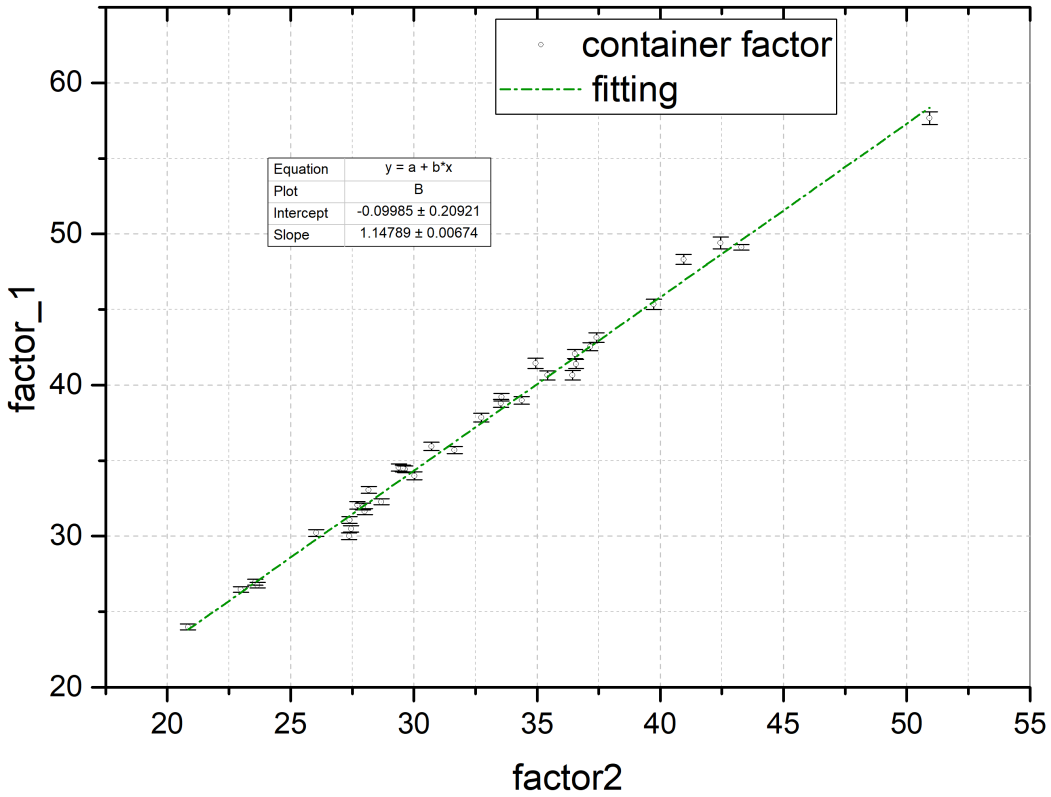
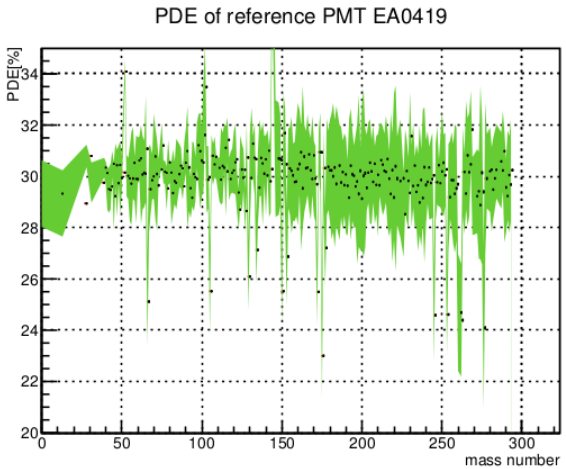
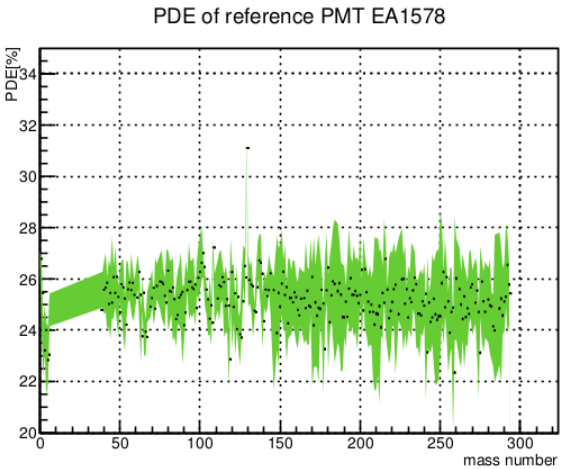
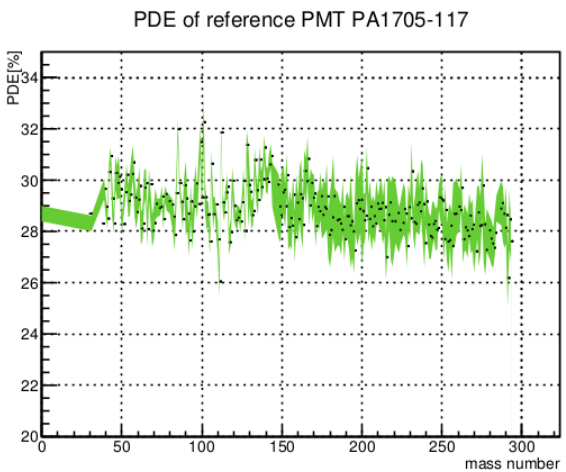


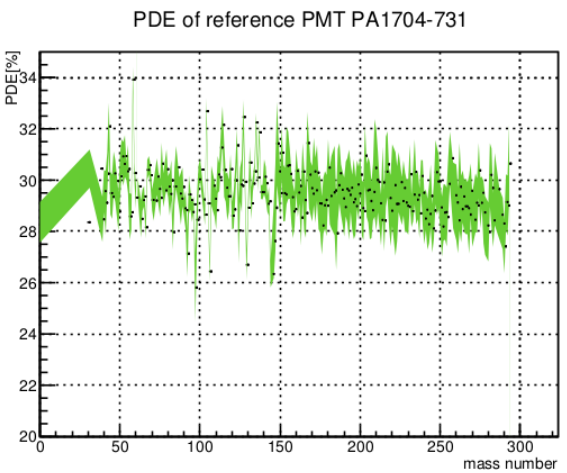

**图:** 抽屉因子和现场使用值的对比

# 参考管稳定性


PDE of reference PMT EA0419
PDE[%]
mass number

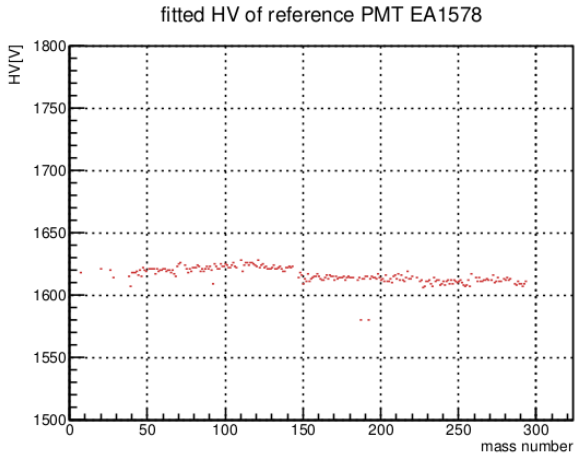

PDE of reference PMT EA1578
PDE[%]
mass number

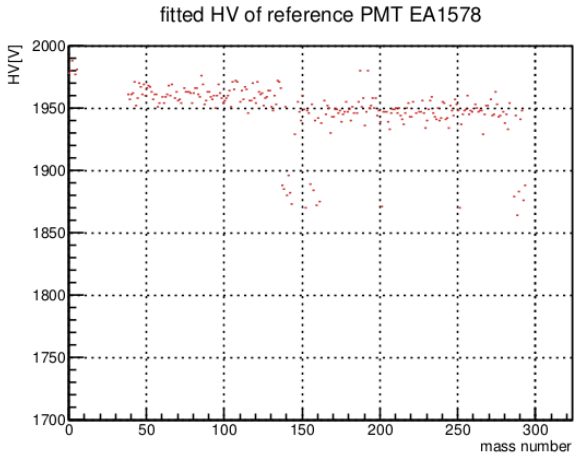

PDE of reference PMT PA1705-117
PDE[%]
mass number

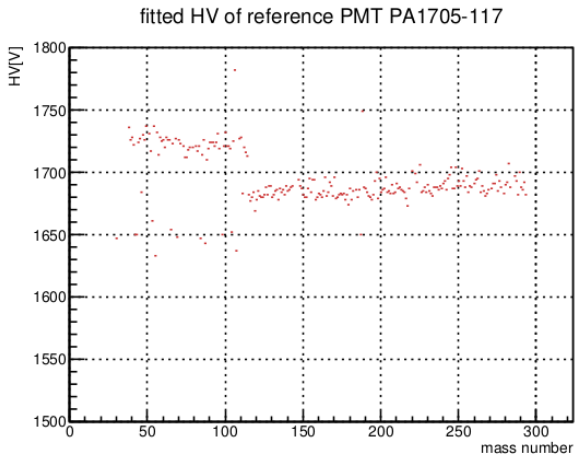

PDE of reference PMT PA1704-731
PDE[%]
mass number

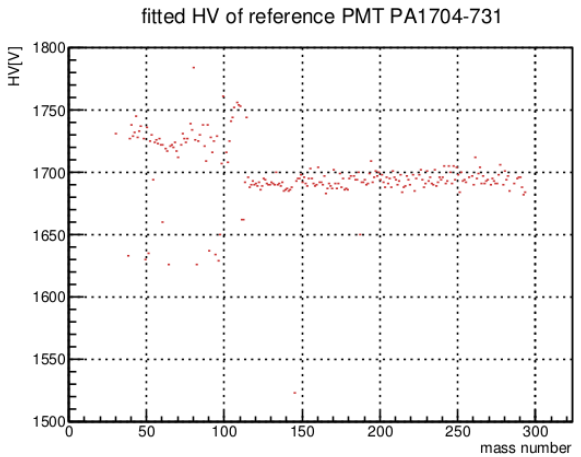
# 参考管电压稳定性

新 DAQ 对系统的性能产生了影响，高压平均值发生了变化：

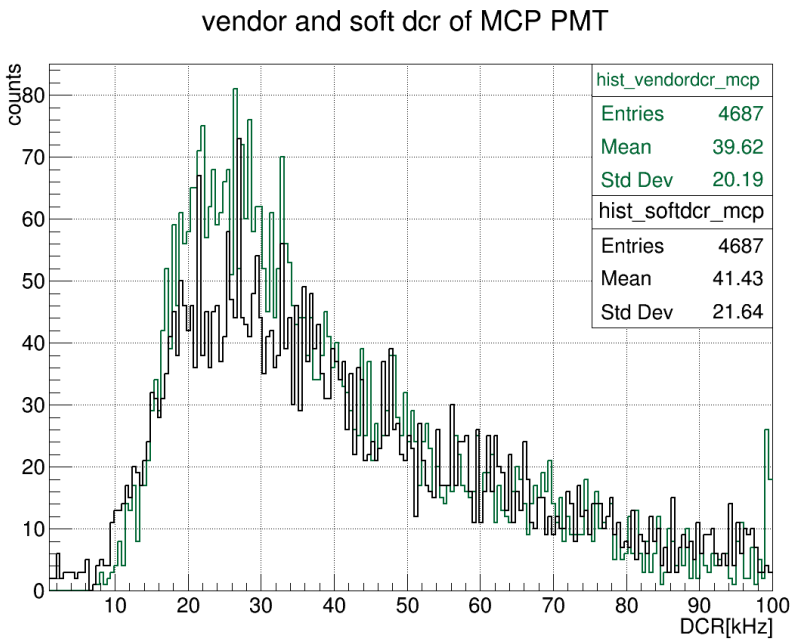


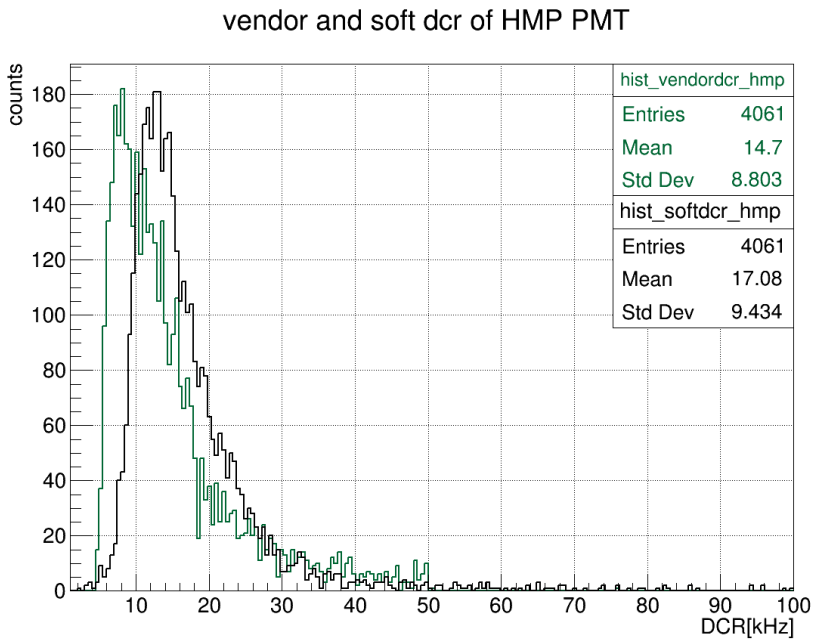



# 暗计数


vendor and soft dcr of MCP PMT
counts
DCR[kHz]
hist_vendordcr_mcp
Entries 4687
Mean 39.62
Std Dev 20.19
hist_softdcr_mcp
Entries 4687
Mean 41.43
Std Dev 21.64


vendor and soft dcr of HMP PMT
counts
DCR[kHz]
hist_vendordcr_hmp
Entries 4061
Mean 14.7
Std Dev 8.803
hist_softdcr_hmp
Entries 4061
Mean 17.08
Std Dev 9.434

# 上升时间和下降时间分布