

# PDE Evaluation

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# Outline

① Brief Introduction

② Waveform and Charge Spectrum

③ Statistical Sesults of Paramaters

④ Summary

## PMT testing data analysis –

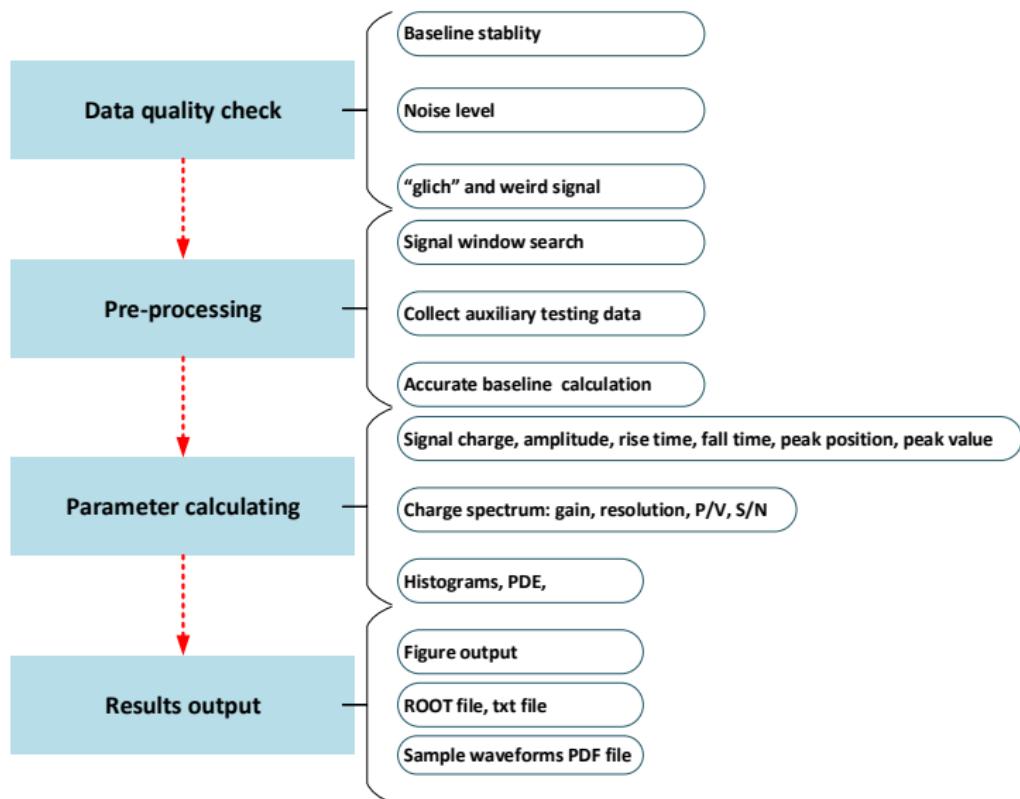
We have tested 5k HAMAMATSU PMTs and about 7k NNVT PMTs in the container system. We can obtain the following parameters:

**表:** PMT performance qualification standard

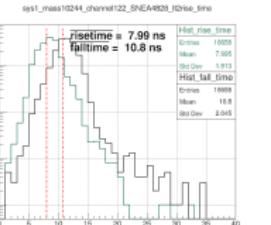
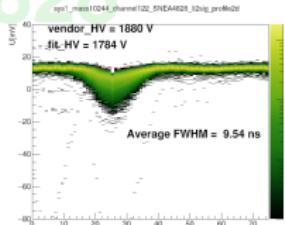
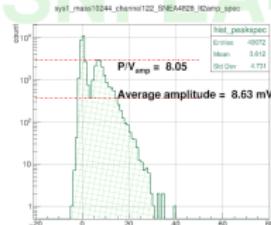
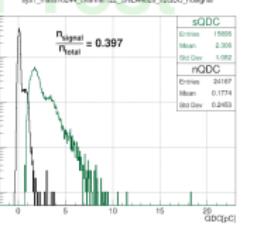
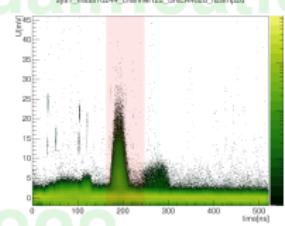
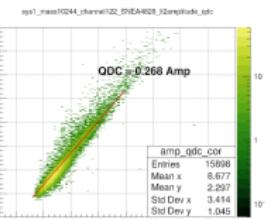
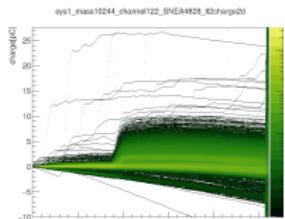
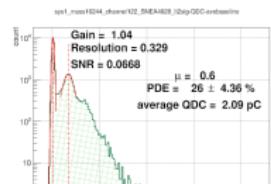
parameter	HAMAMATSU PMT	NNVT PMT
HV@Gain=10 <sup>7</sup>	<2350 V	<2800V
PDE	>24%	>24%
DCR	<50kHz	<100kHz
PV	>2.5	>2.5
rise time	<8.5ns	-
fall time	<12ns	-
FWHM	--	-
resolution	<0.4	<0.4

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



PMT testing report-pass

We have generated testing report for each qualified PMT.

QUALIFICATION TEST REPORT OF 20 INCH PMT								
<b>Test Information:</b>								
Test Date	Container#	Mass#	Drawer#	Mu	HV vendor	HV container	Gain	Sheet #
20171010	1	25	111	0.88	1670	1670	1.01	0
<b>Parameters of Performance:</b>								
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	√			
<b>Test History and Notes:</b>								
<p>This PMT was retested due to PDE problem , and then passed the test.</p>								
 								
<b>[Aux Info]</b>								
Table generated date: <b>20190102</b>								
Data quality check: <span style="color: green;">Pass</span>								
Scanning Station check: <span style="color: green;">Pass</span>								
<a href="mailto:zhaor25@mail2.sysu.edu.cn">zhaor25@mail2.sysu.edu.cn</a>								
<b>Final Qualification Tag</b>								
<b>PASS</b>								
<b>EA0283</b>								

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

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

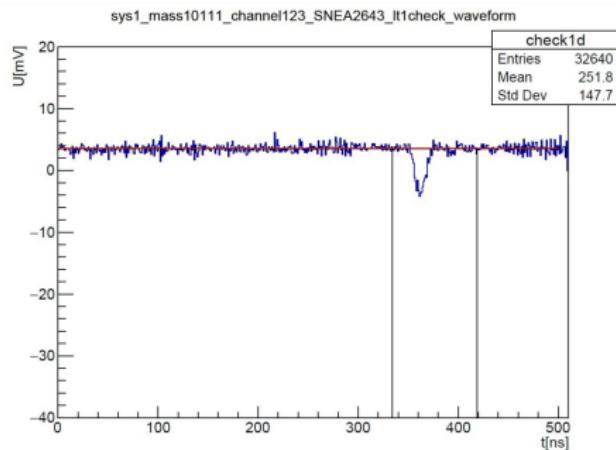


图: single photon signal waveform of HAMAMATSU PMT

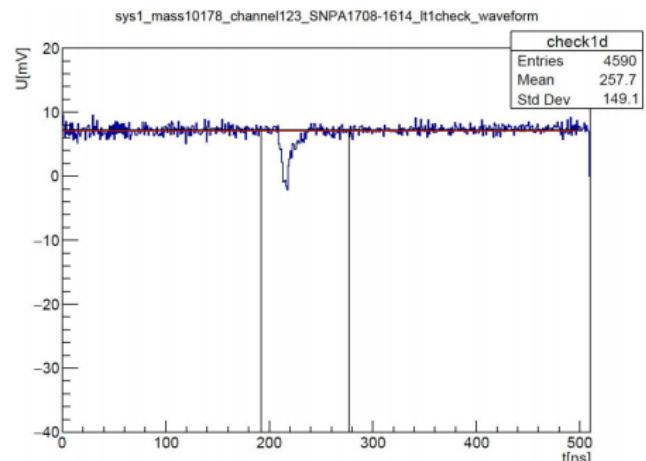
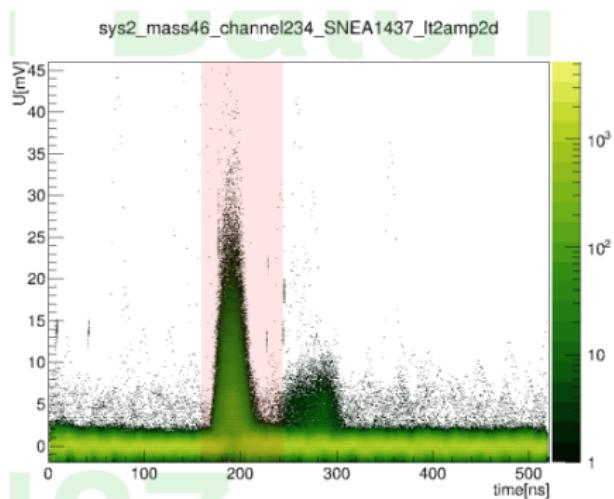


图: single photon signal waveform of NNVT PMT

## 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

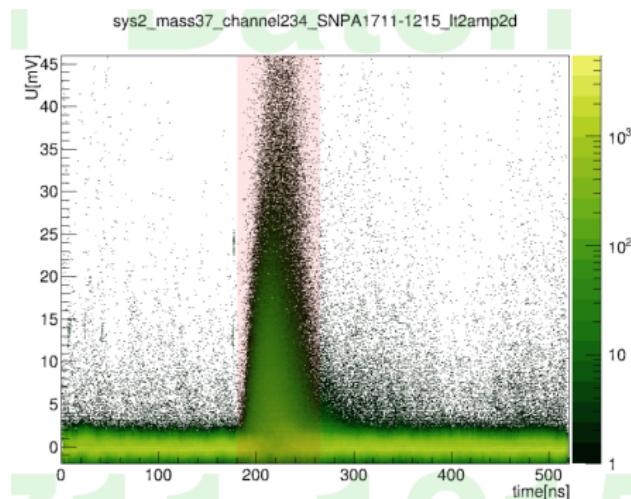


图: all frames of NNVT PMT

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

From the waveform integral histogram we acquire more information.

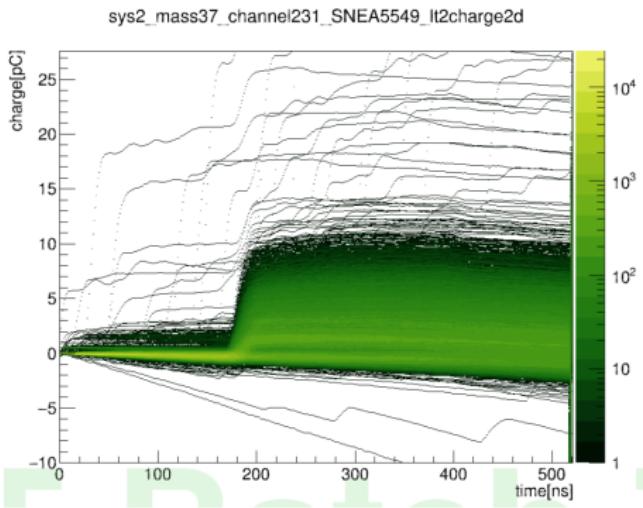
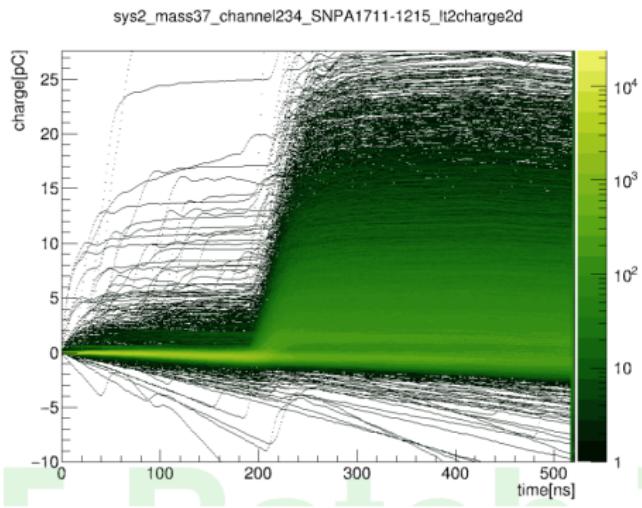


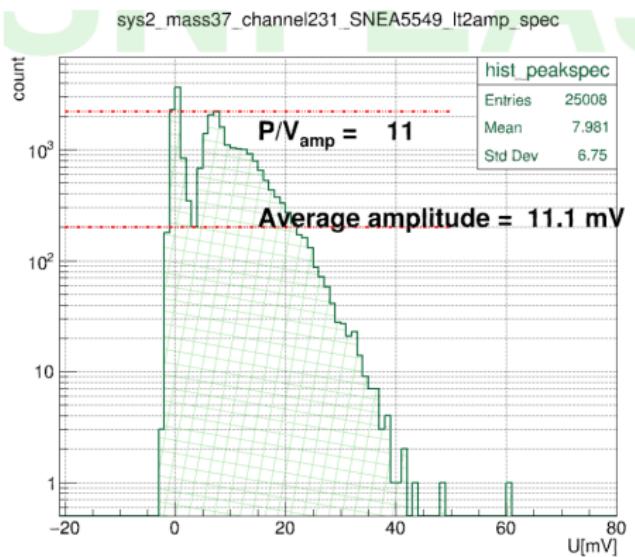
图: integrated waveforms of HAMAMATSU PMT



## integrated waveforms of NNVT PMT

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

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



**图:** Amplitude spectrum of HAMAMATSU PMT

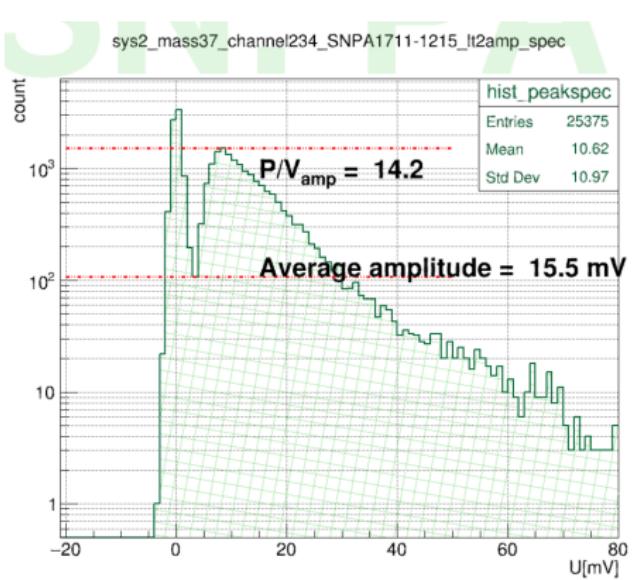


图: Amplitude spectrum of NNVT PMT

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

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

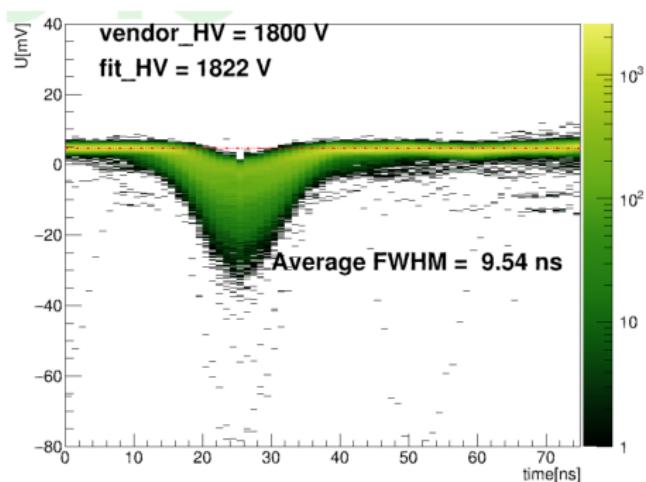


图: Aligned frames of HAMAMATSU PMT

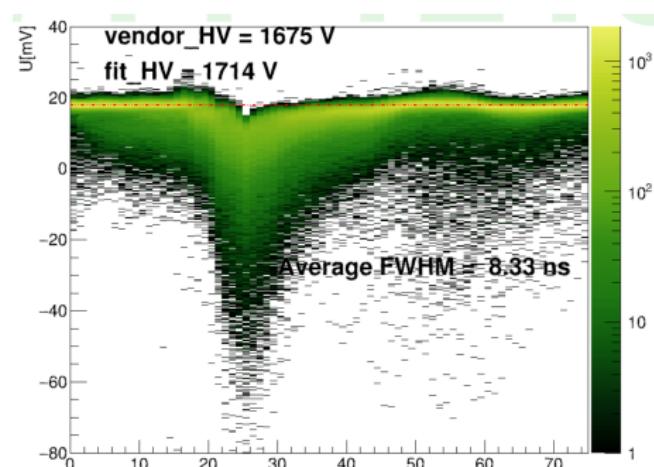


图: Aligned frames of NNVT PMT

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

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

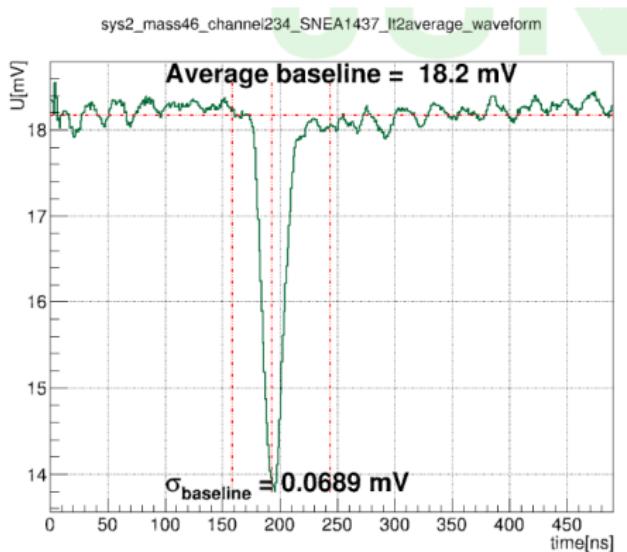


图: average waveform of HAMAMATSU PMT

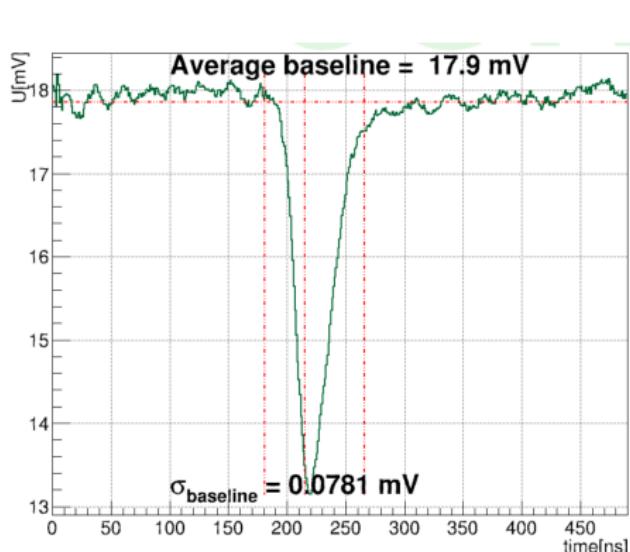
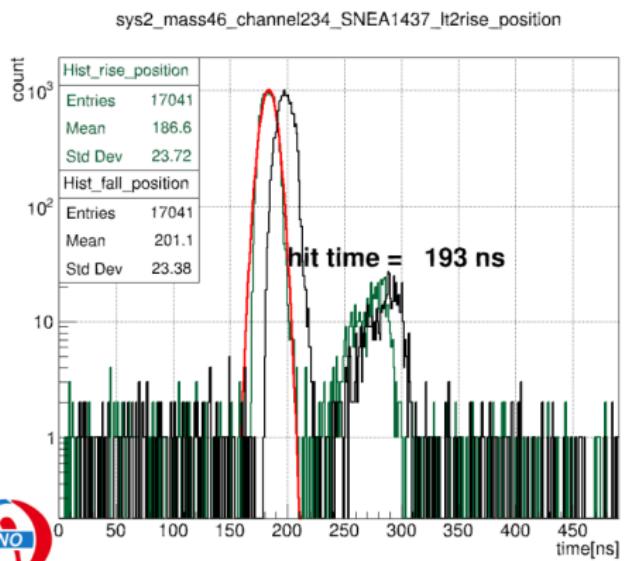


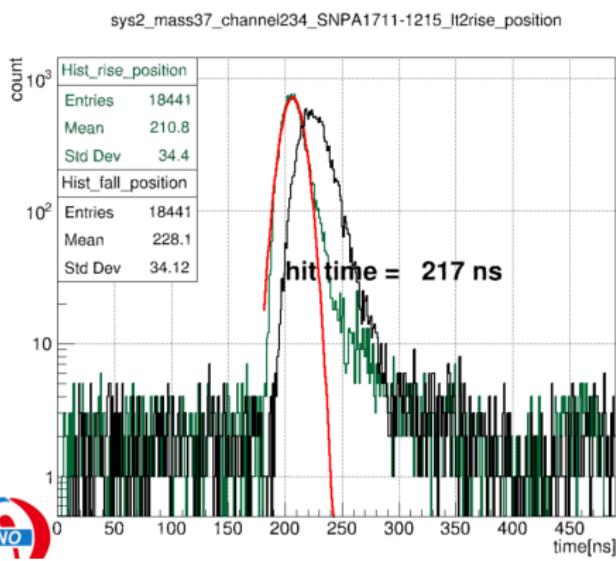
图: average waveform of NNVT PMT

## 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 (@ $gain = 10^7$  &  $\mu \approx 1.3$ )**

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

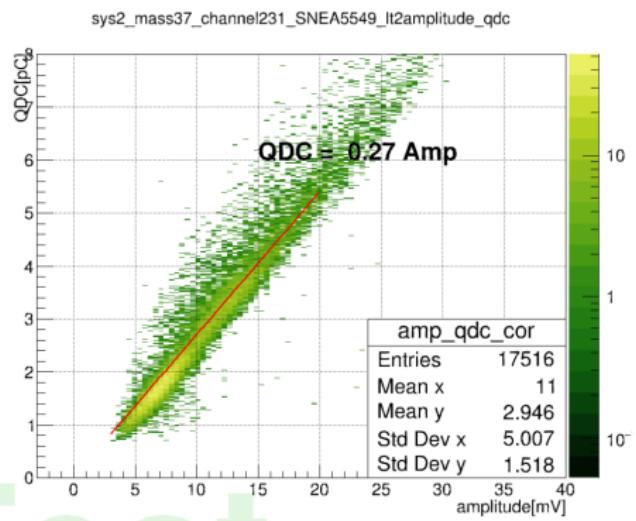
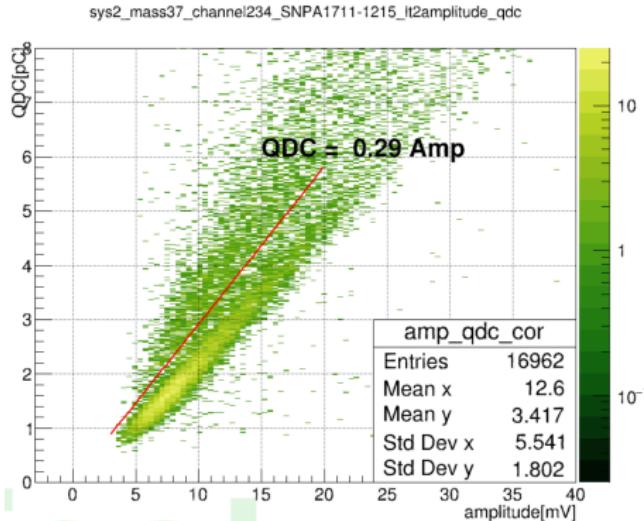


图: charge and amplitude correlation of HAMAMATSU PMT



 charge and amplitude correlation of NNVT PMT

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

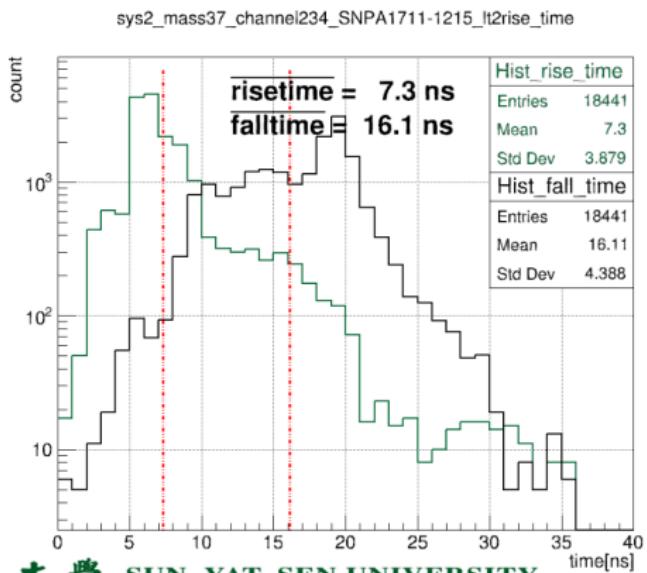
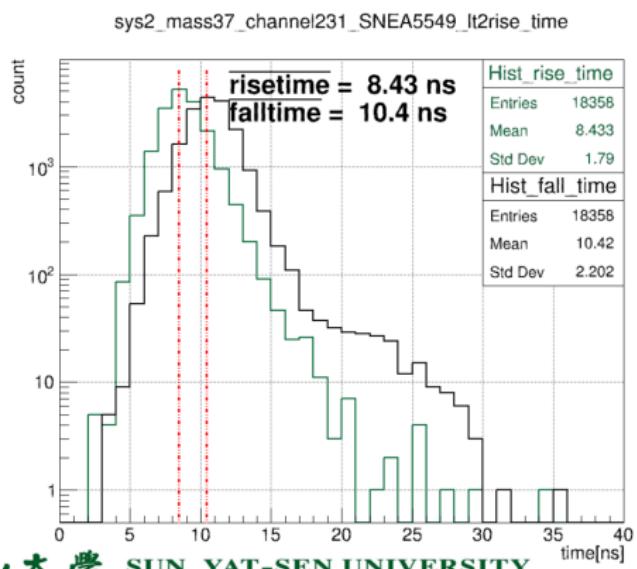
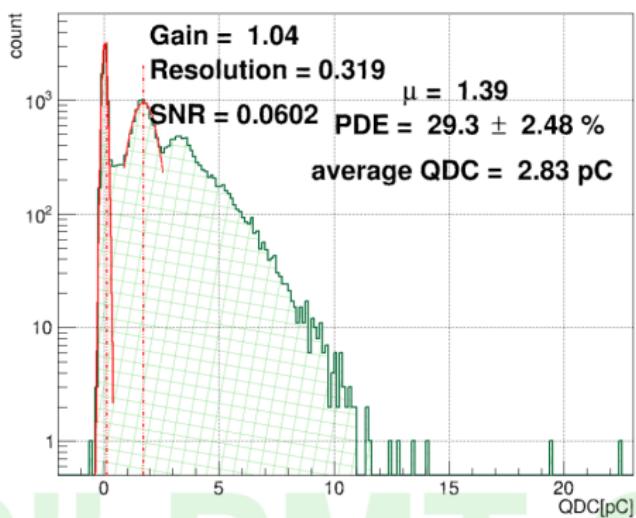


图: rise-time and fall-time of HAMAMATSU PMT

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

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

sys2\_mass20037\_channel231\_SNPA5549\_lt2sig-QDC-avebaseline



sys2\_mass20037\_channel234\_SNPA1711-1215\_lt2sig-QDC-avebaseline

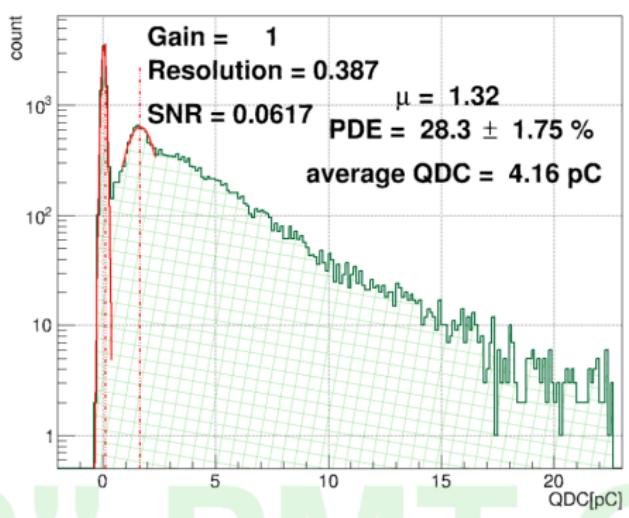


图: signal charge spectrum of HAMAMATSU PMT

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

# calculation of parameters

## signal waveform

- $\text{rise time} = t_{.9r\text{Maximum}} - t_{.1r\text{Maximum}}$
- $\text{fall time} = t_{.1f\text{Maximum}} - t_{.9f\text{Maximum}}$
- $\text{FWHM} = t_{+1/2\text{Maximum}} - t_{-1/2\text{Maximum}}$

## charge spectrum

- $\text{Gain} = \frac{Q_{1pe} - Q_{0pe}}{Q_e}$
- $\text{PV} = \frac{\text{Peak}_{spe}}{\text{Valley}_{spe}}$
- $S/N = \frac{\sigma_{0pe}}{Q_{1pe} - Q_{0pe}}$
- $\text{Resolution} = \frac{\sigma_{1pe}}{Q_{1pe} - Q_{0pe}}$

# calculation of drawer<sub>factor</sub>

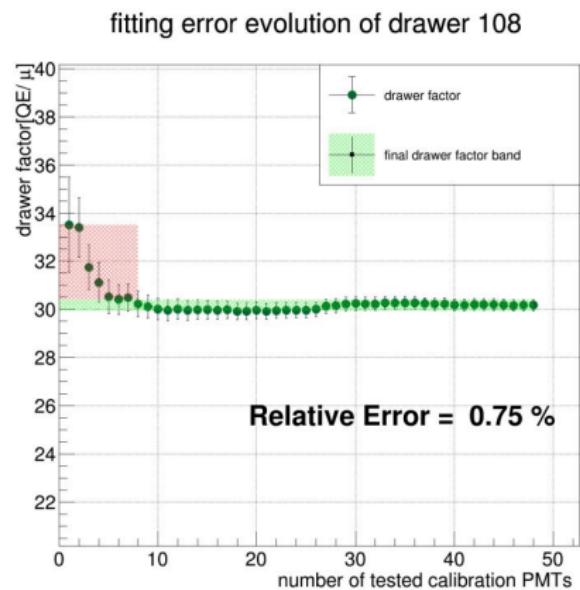


图: fitting the drawer factor in one drawer

## 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:

$$PDE_c = \mu_{test} \times \text{drawer}_{\text{factor}} \quad (1)$$

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

$$PDE = PDE_c \cdot f_{cs} + \text{constant} \quad (2)$$

<sup>1</sup>Calibrate the drawer factor using PMT tested in the drawer which has vendor QE value.

<sup>2</sup>linear correlation factor

## statistical results

Mean value of parameters for HAMAMATSU-PMT and NNVT-PMT<sup>3</sup>:

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

<sup>3</sup>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%.

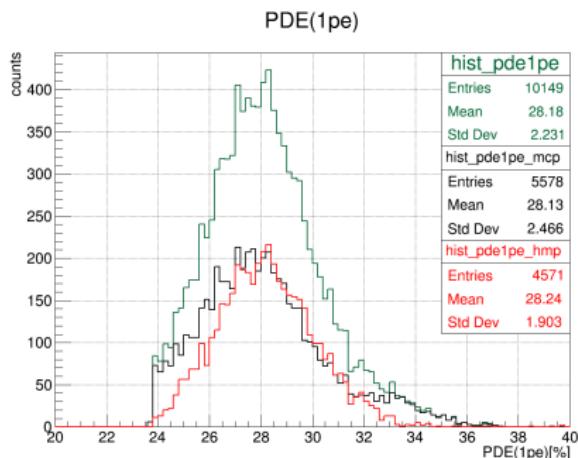


图: PDE of tested PMT

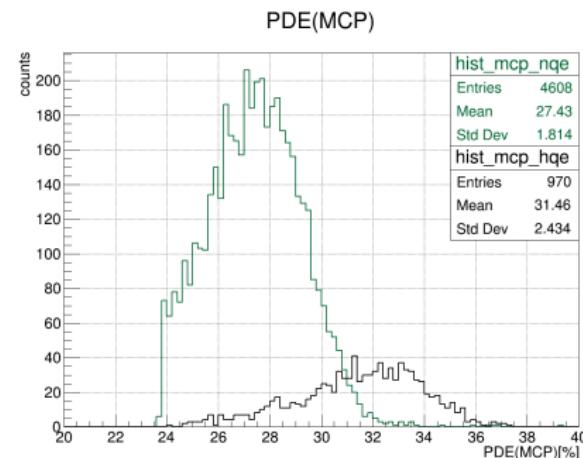
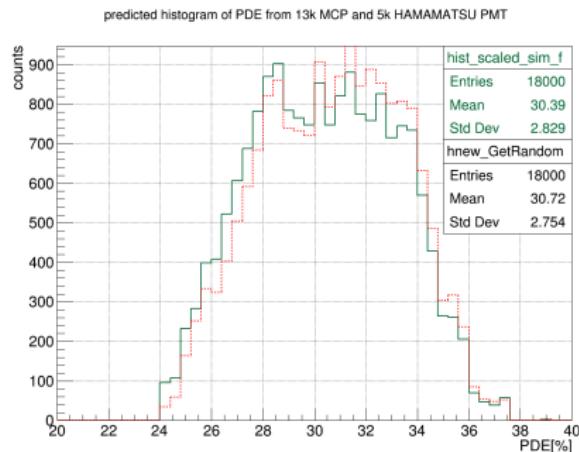


图: PDE of tested NNVT PMT

## **predicted PDE statistical results**

CD will use ~13k NNVT<sup>4</sup> PMT, and 5k HAMAMATSU PMT, we can predict the final PDE and DCR distribution based on the current data:



 predicted PDE in CD



## 图: predicted DCR in CD

<sup>4</sup>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 available from PMTDataBase<sup>5</sup>.
  - 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<sup>6</sup> in detail<sup>7</sup>.
  - the expected mean PDE value is 30.4% and mean DCR value is ~34kHz<sup>8</sup> in CD.

<sup>5</sup>pmtdb.juno.ihep.ac.cn

<sup>6</sup>especially when PMT working in the multi-photon case

<sup>7</sup>one option is to transport several PMTs to SYSU for detailed study

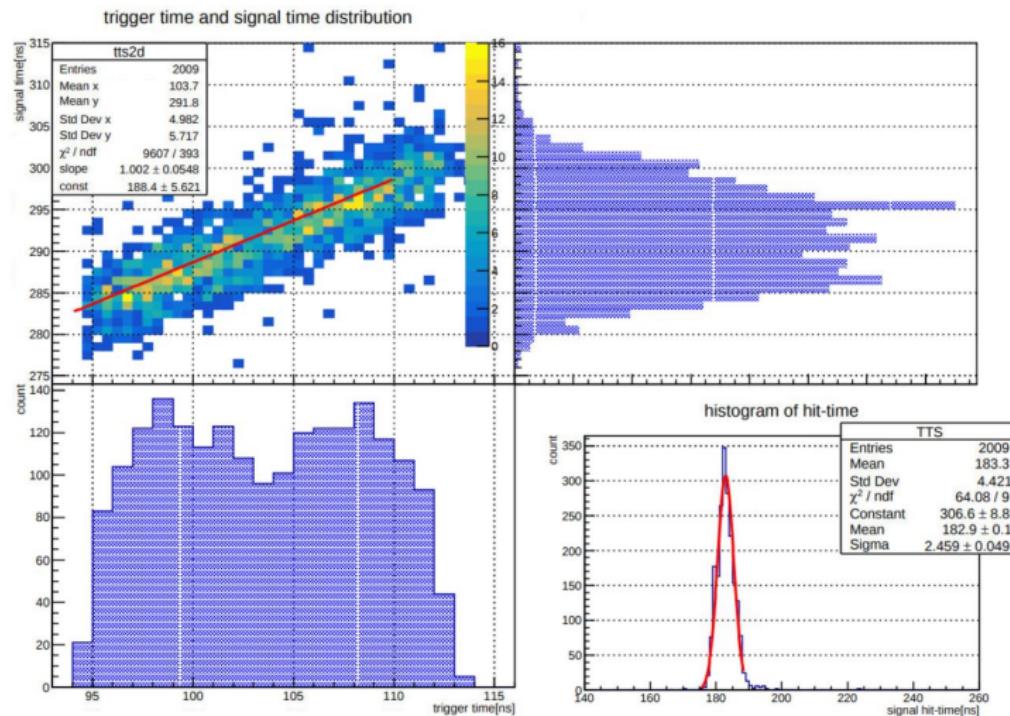
<sup>8</sup>will decrease after installation

# THANKS

# BACK-UP



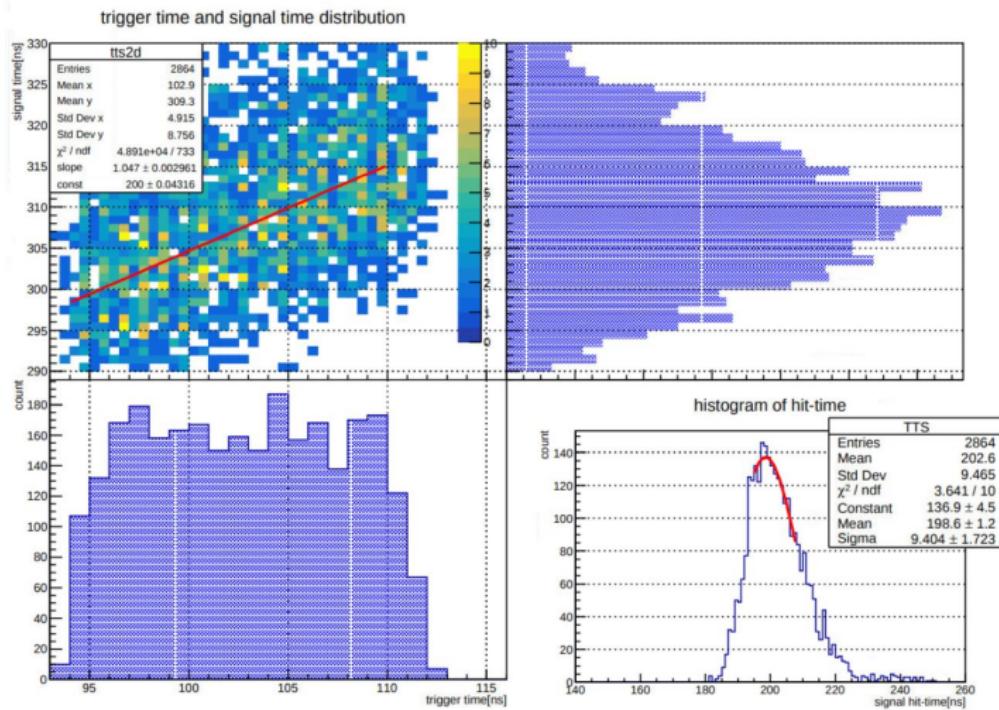
# TTS of HAMAMATSU PMT



图· hittime and trigger time



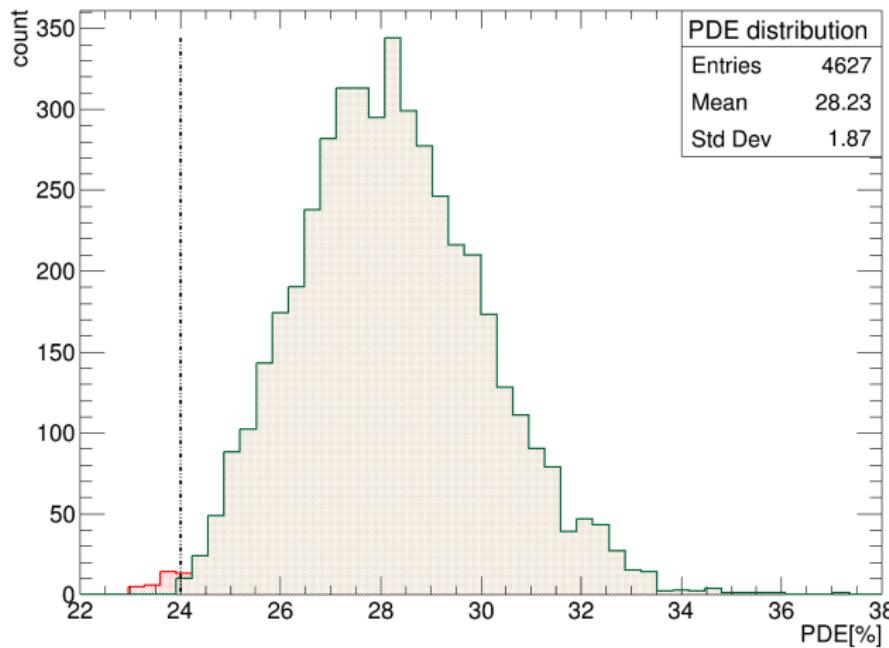
# TTS calculation of NNVT PMT



图· hittime and trigger time

## 各个参数的统计结果-PDE

PDE Histogram of Qualified R12860 PMTs



## 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。

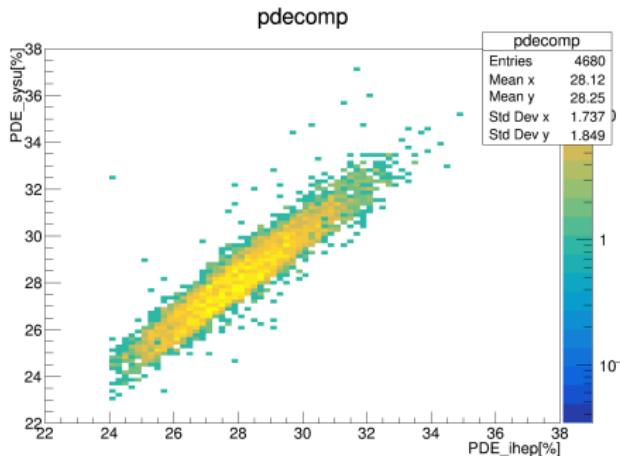
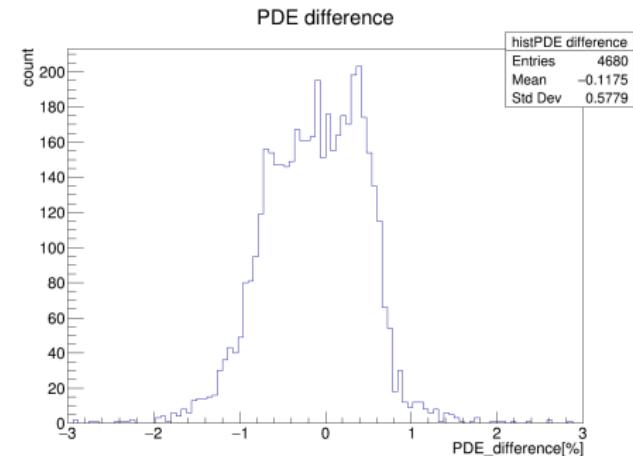


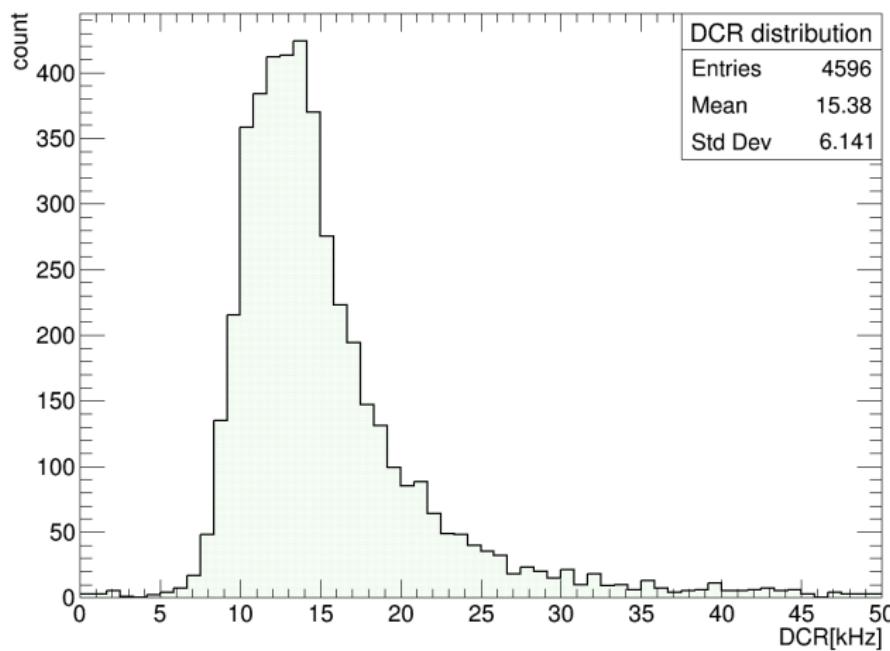
图: PDE 结果的关联对比



图：两种分析的差值分布

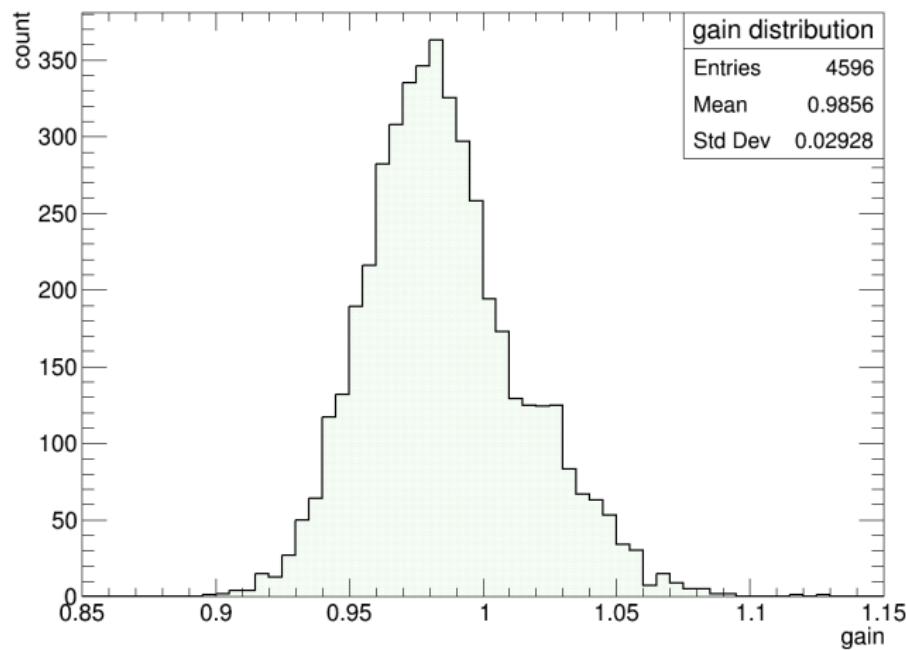
# 各个参数的统计结果-DCR

DCR Histogram of Qualified R12860 PMTs



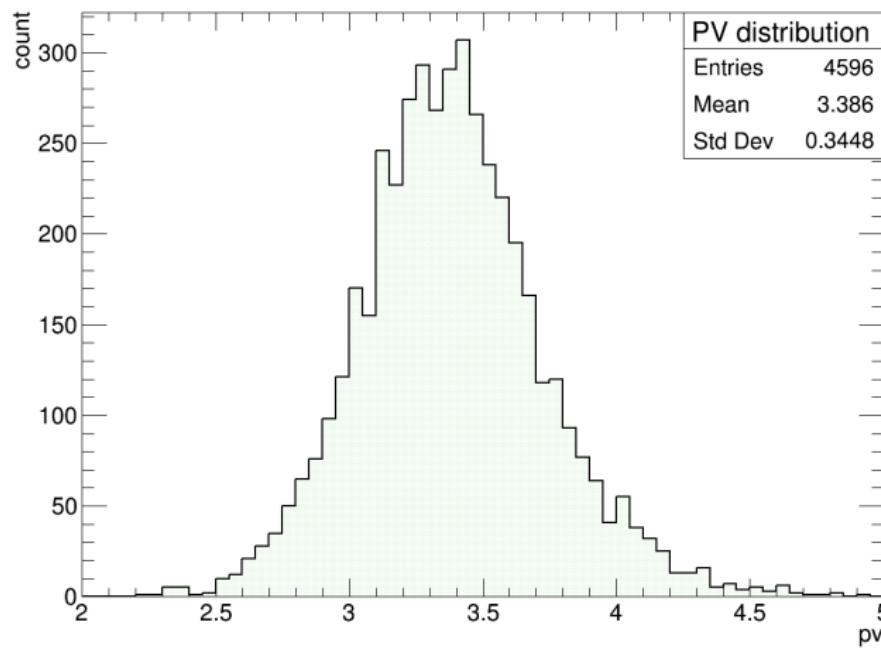
# 各个参数的统计结果-Gain

Gain Histogram of Qualified R12860 PMTs



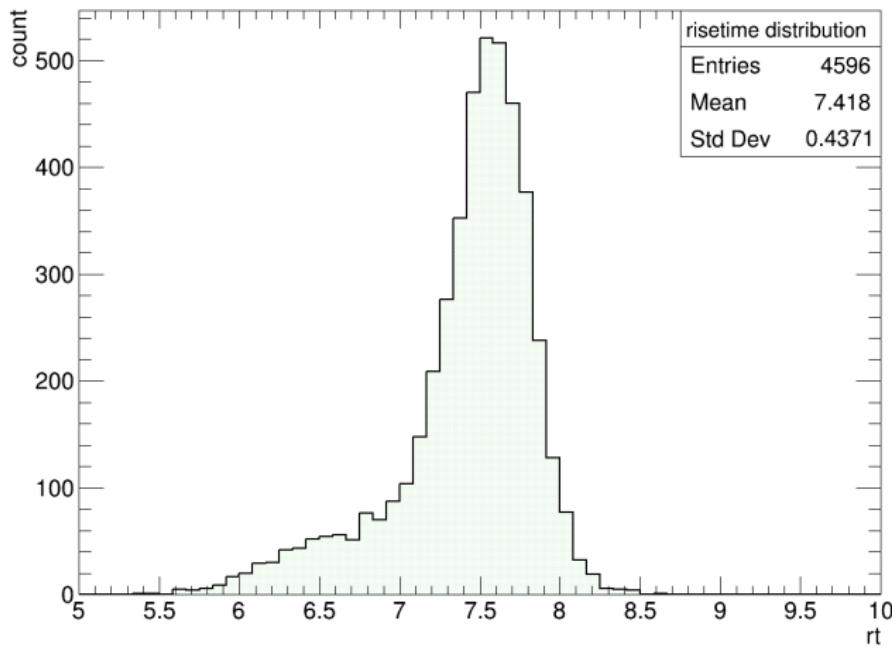
# 各个参数的统计结果-P/V

PV ratio Histogram of Qualified R12860 PMTs



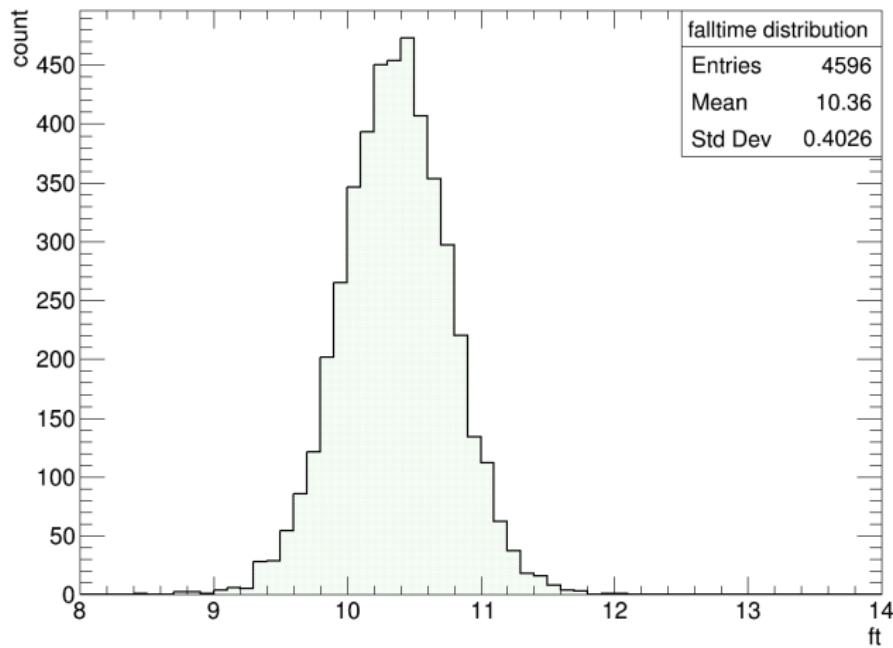
# 各个参数的统计结果-rise time

Risetime Histogram of Qualified R12860 PMTs



# 各个参数的统计结果-fall time

Falltime Histogram of Qualified R12860 PMTs



# 各个参数的统计结果-FWHM

FWHM Histogram of Qualified R12860 PMTs



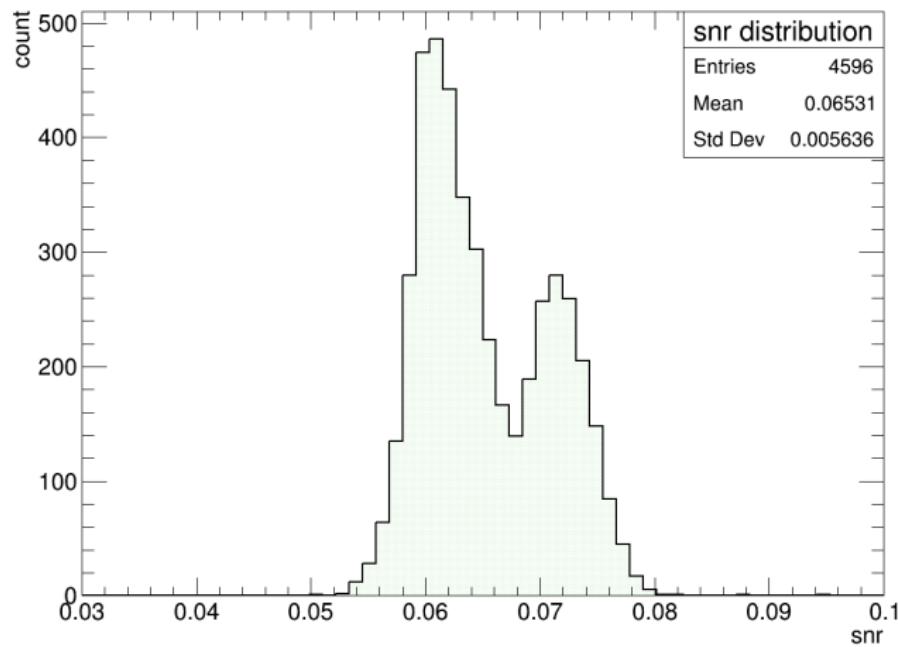
# 各个参数的统计结果-Resolution

Signal Resolution Histogram of Qualified R12860 PMTs



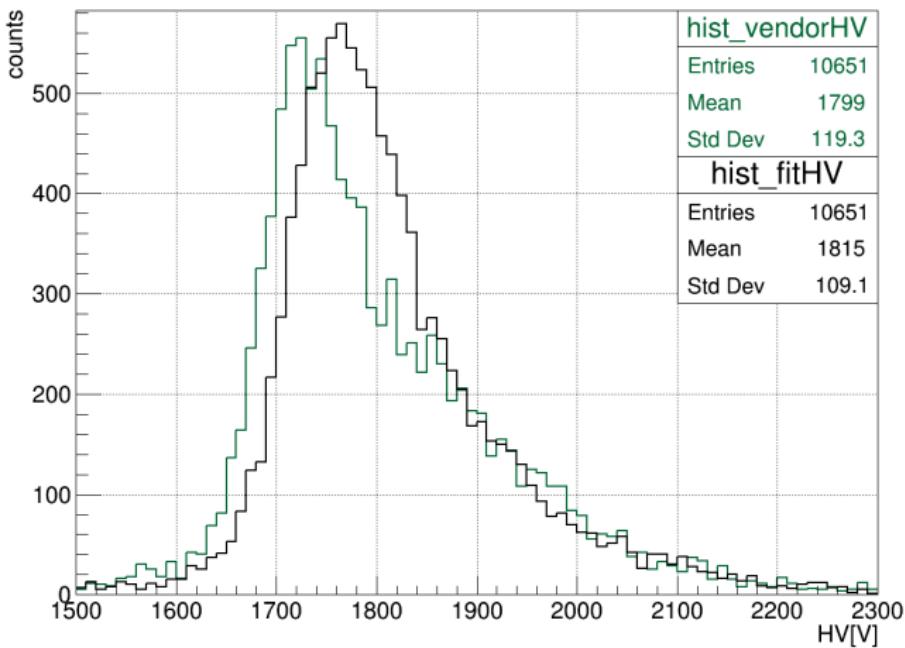
## 各个参数的统计结果-S/N

## SNR Histogram of Qualified R12860 PMTs



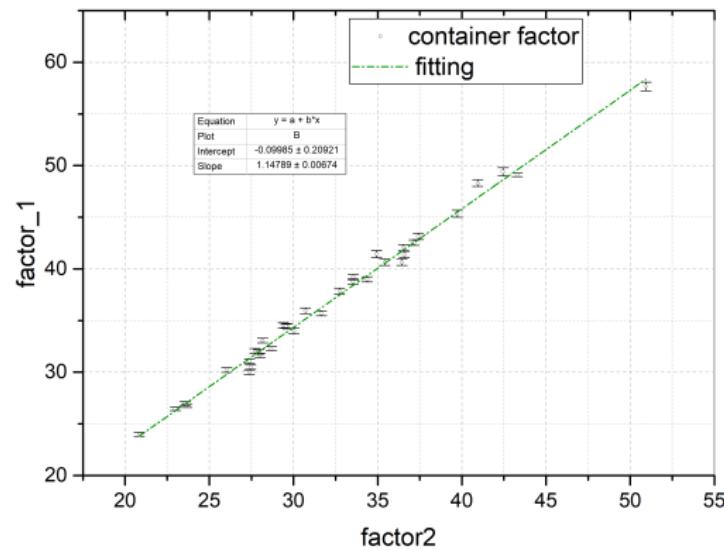
## 各个参数的统计结果-HV

vendor and fit HV of all PMT



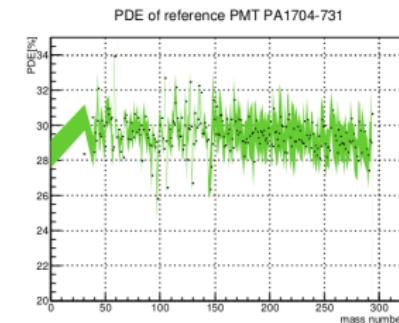
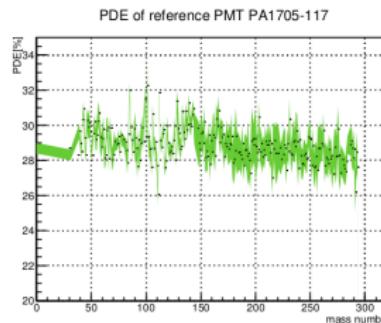
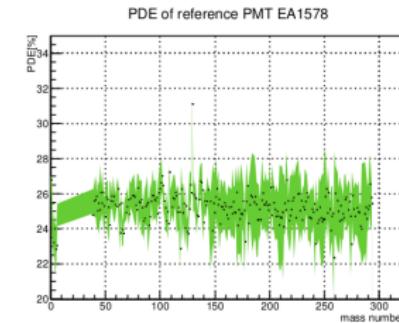
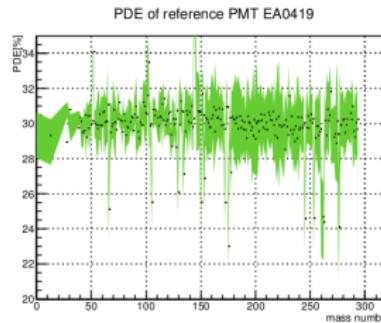
# 抽屉因子的比较

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

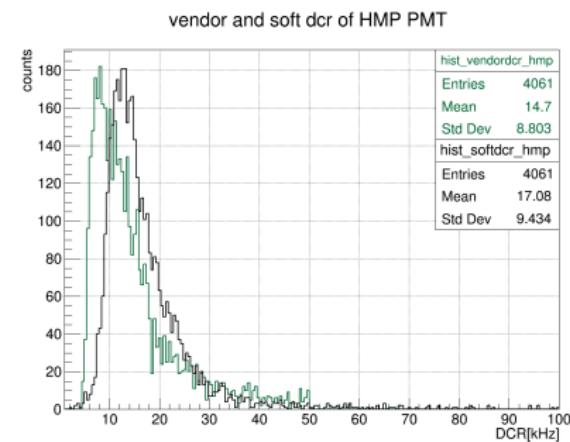
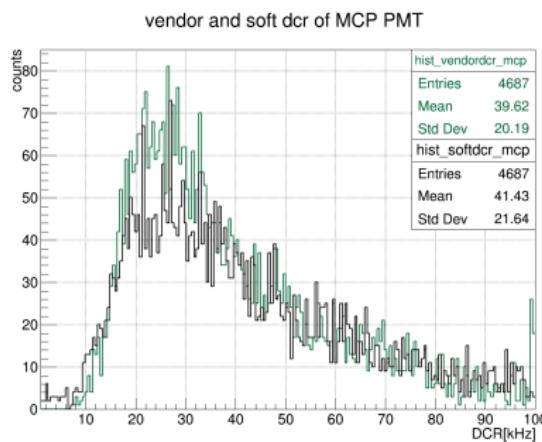


# 参考管电压稳定性

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



# 上升时间和下降时间分布

