Converting the PMT Container Testing Raw Data to ROOT File Format

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School of Physics

Outline

motivation

1. The Raw data of PMT testing is significant for the evaluation of PMT performance.
2. **While,Currently, the raw data of container system is not well organized and it is not convinent for people to get a quikly access.**
3. It is useful to convert all the testing raw data to ROOT format.
   - decrease the file size
   - easy to analysis and manage.
   - shadow the hardware details.

requirements

1. sotre the raw waveform data(.1pe, 1pe, TTS).
2. store the auxilary testing information(container , mass, HV, DCR. etc).
3. easy to manage (create, modify and update) and analyze.
4. one ane acquire almost all the data needed for analysis(of one PMT) from only one file. rather than collecting the details from server.

prliminary structure

- each PMT have one root file named in ”SN_rawdata.root”
- In a specific root file, we have several trees and a auxilary data class

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.

JUNO 中山大學 SUN YAT-SEN UNIVERSITY

[Aux Info]

Table generated date:

20190102

Data quality check:

Scanning Station check:

zhaor25@mail2.sysu.edu.cn

EA0283

Final Qualification Tag

PASS

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

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

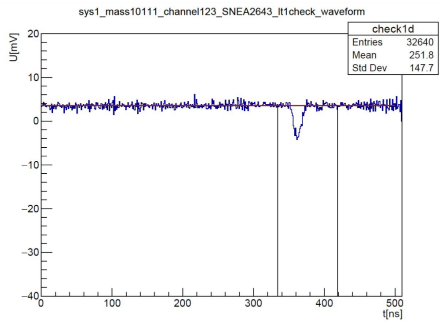


图: single photon signal waveform of HAMAMATSU PMT

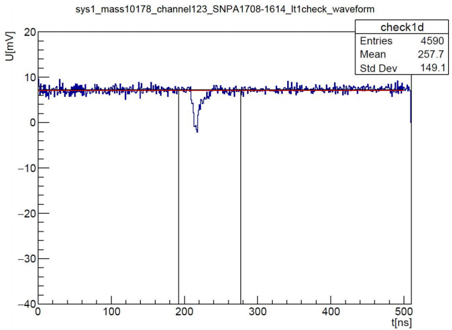


图: single photon signal waveform of NNVT PMT

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.

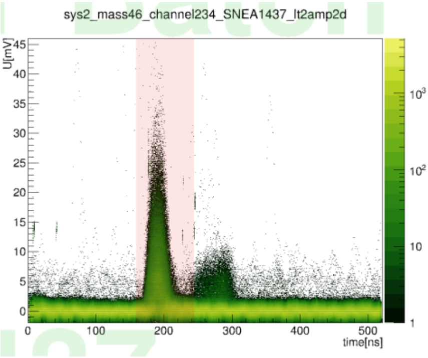


图: all frames of HAMAMATSU PMT

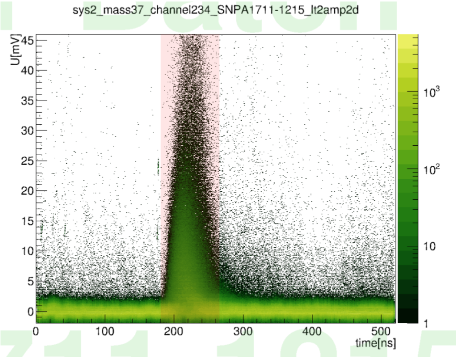


图: all frames of NNVT PMT

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

From the waveform integral histogram we acquire more information.

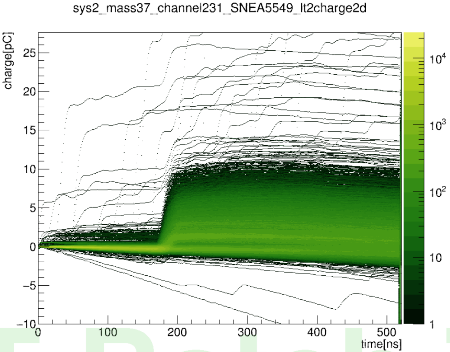


图: integrated waveforms of HAMAMATSU PMT

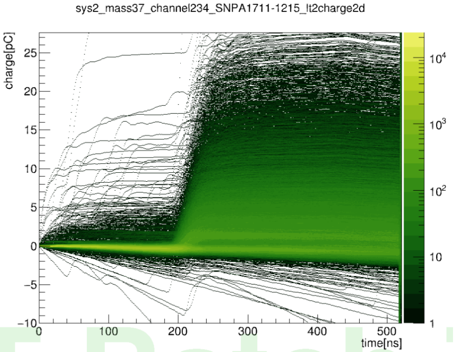


图: integrated waveforms of NNVT PMT

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

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

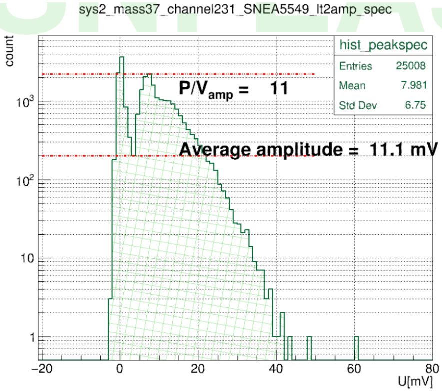


图: Amplitude spectrum of HAMAMATSU PMT

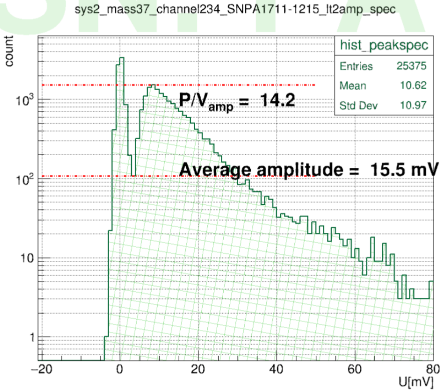


图: Amplitude spectrum of NNVT PMT

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

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

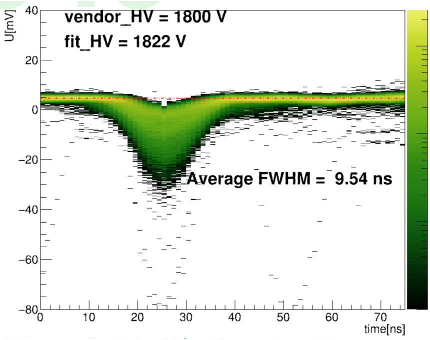


图: Aligned frames of HAMAMATSU PMT

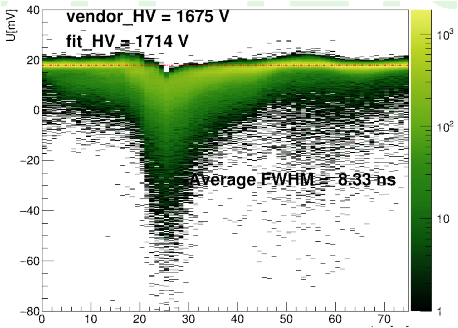


图: Aligned frames of NNVT PMT

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

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

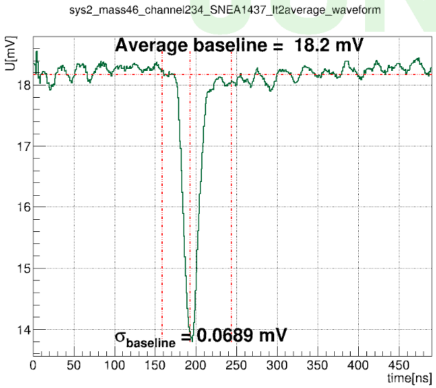


图: average waveform of HAMAMATSU PMT

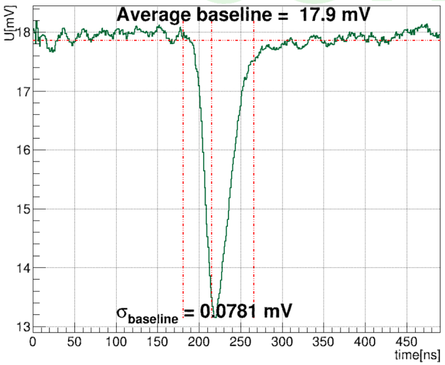


图: average waveform of NNVT PMT

Signal hit time distribution

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

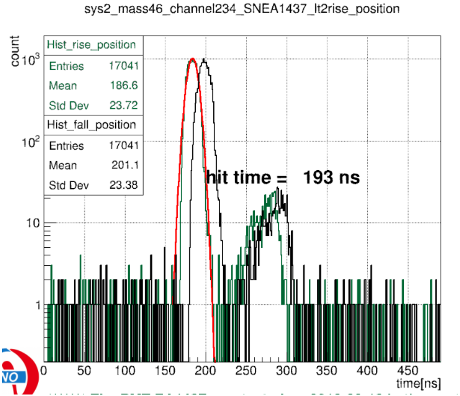


图: hit time of HAMAMATSU PMT

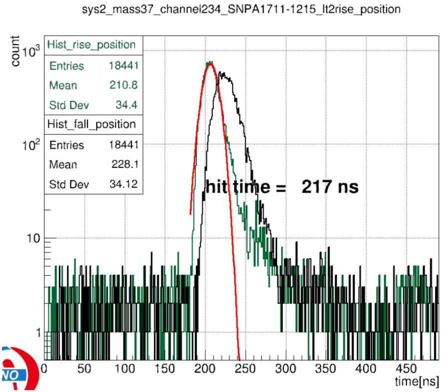


图: hit time of NNVT PMT

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.

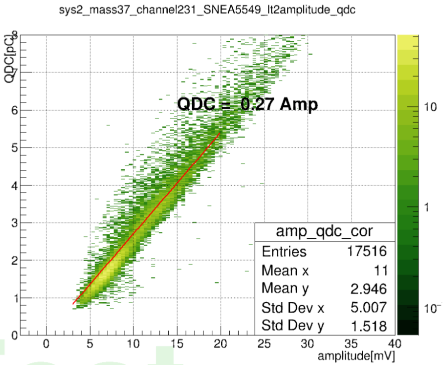


图: charge and amplitude correlation of HAMAMATSU PMT

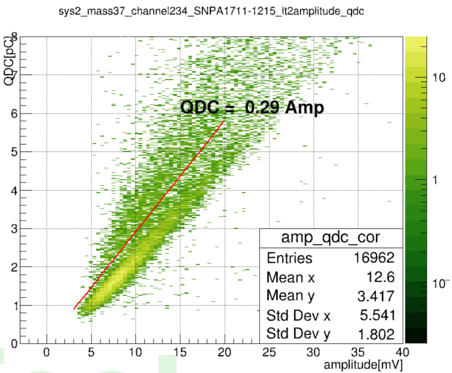


图: charge and amplitude correlation of NNVT PMT

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

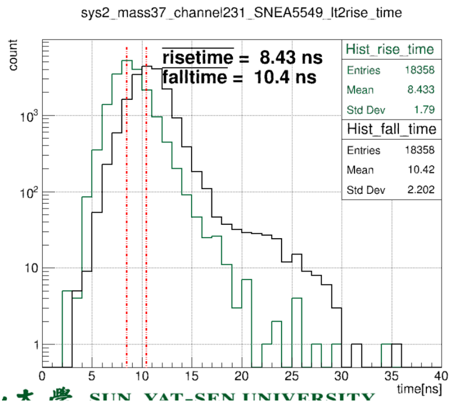


图: rise-time and fall-time of HAMAMATSU PMT

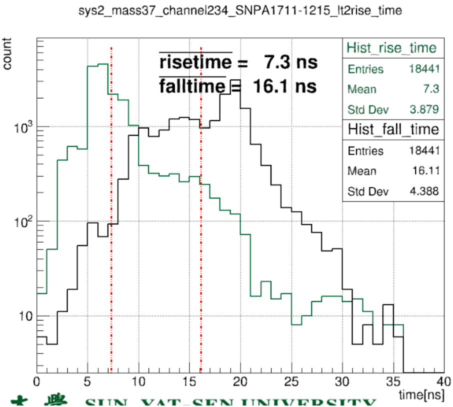


图: rise-time and fall-time of NNVT PMT

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

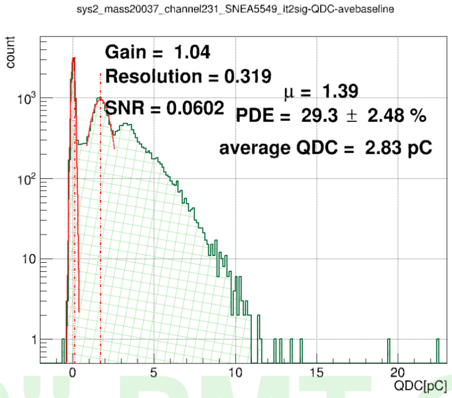


图: signal charge spectrum of HAMAMATSU PMT

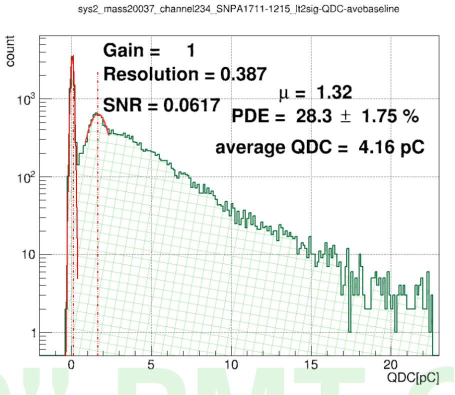


图: rise-time and fall-time of NNVT PMT

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 $drawer_{factor}$

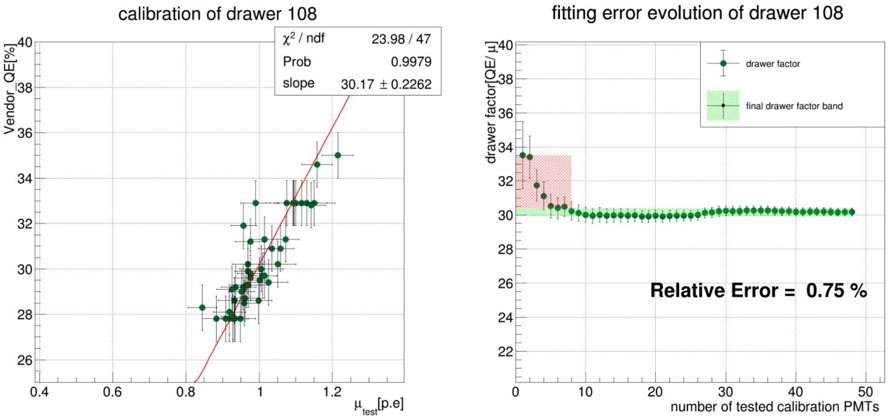


图: fitting the drawer factor in one drawer

calculation of *PDE*

we can obtain the average photon number μ_{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%.

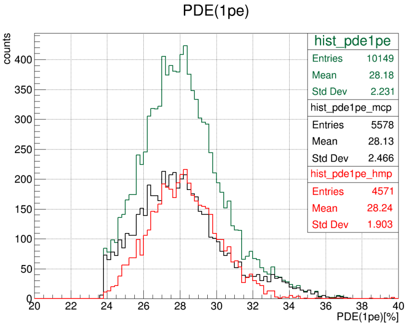


图: PDE of tested PMT

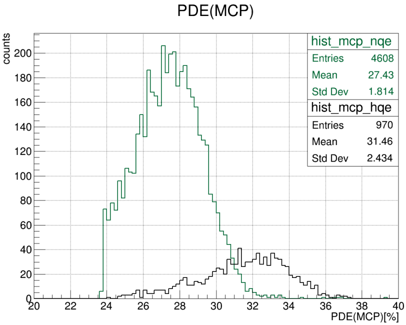


图: PDE of tested NNVT PMT

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:

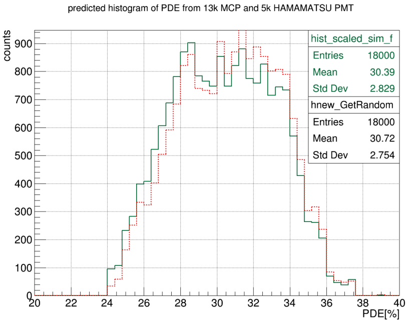


图: predicted PDE in CD

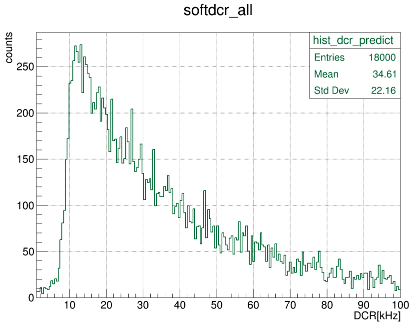


图: predicted DCR in CD

[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

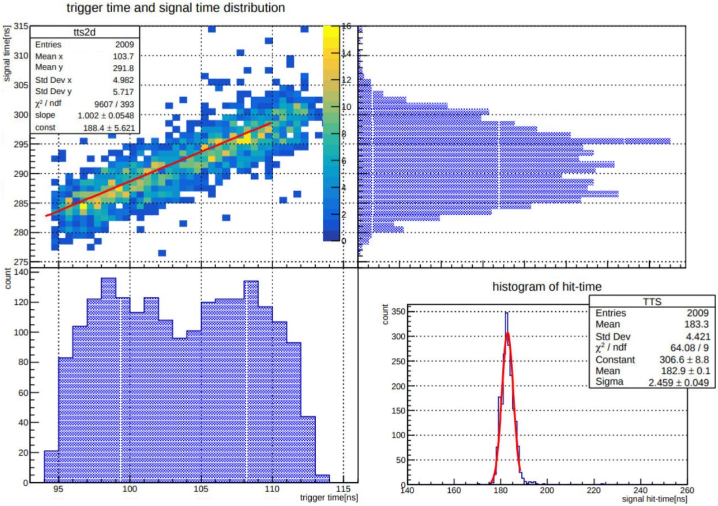


图: hittime and trigger time

TTS calculation of NNVT PMT

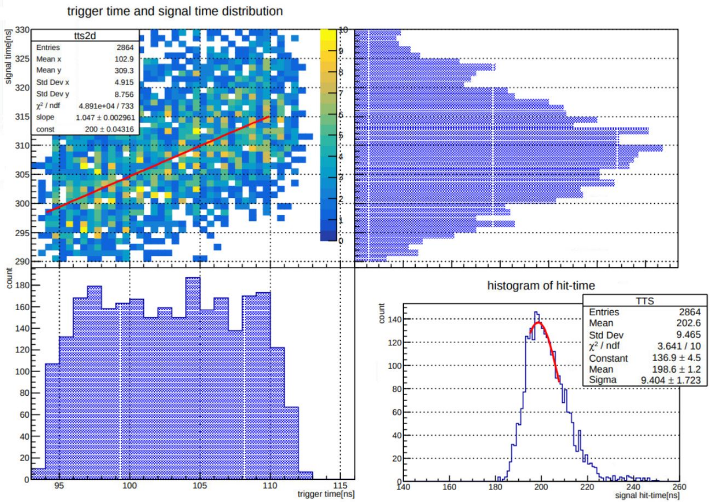
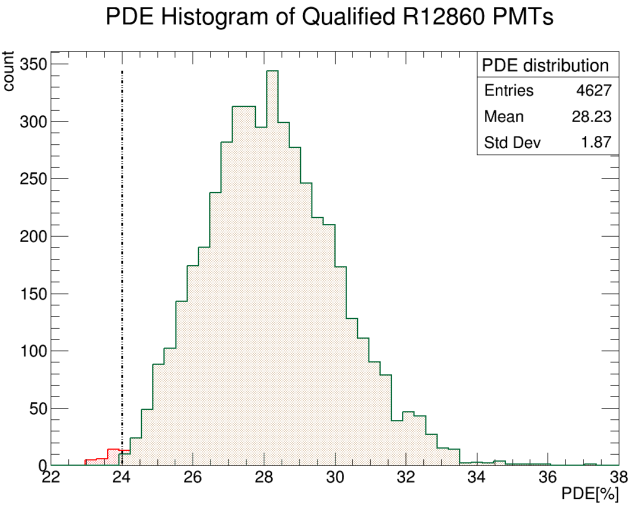


图: hittime and trigger time

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。

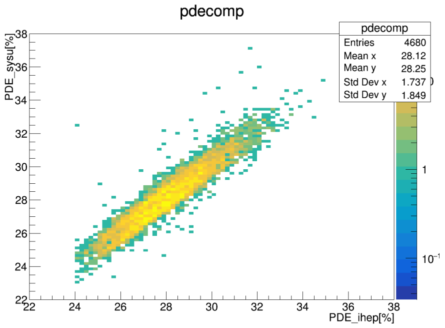


图: PDE 结果的关联对比

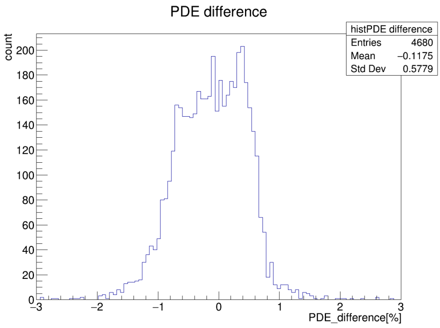
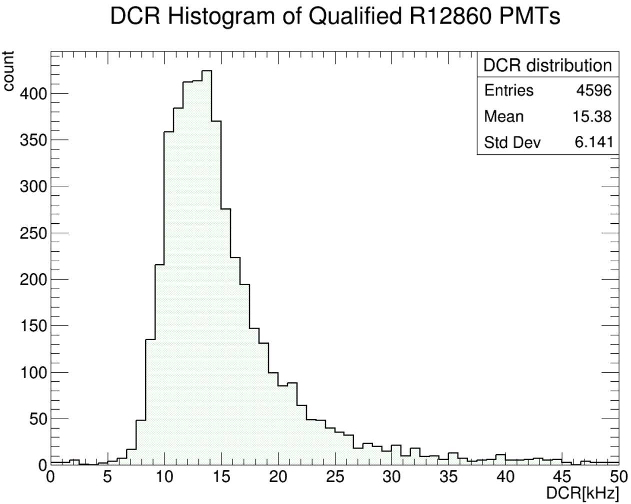
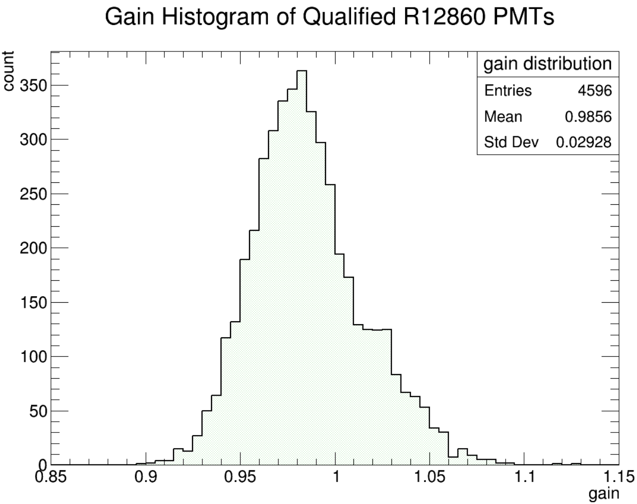


图: 两种分析的差值分布

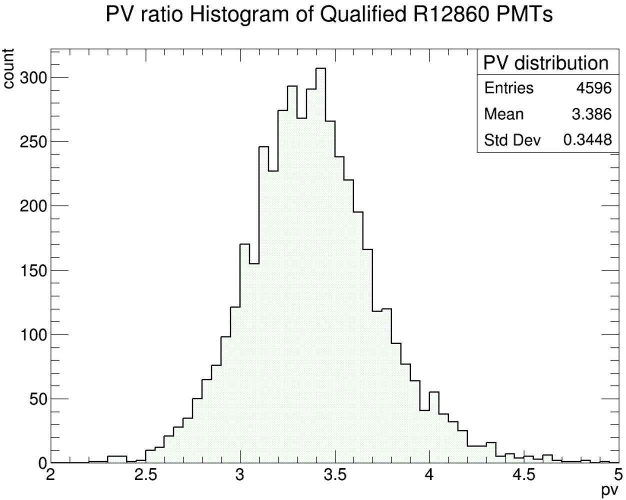
各个参数的统计结果-DCR



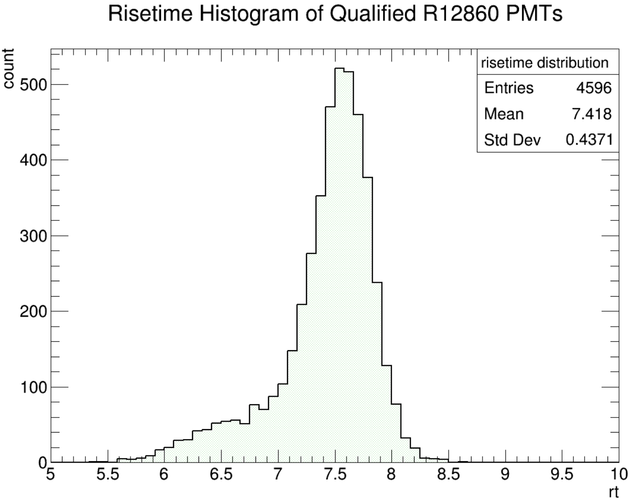
各个参数的统计结果-Gain



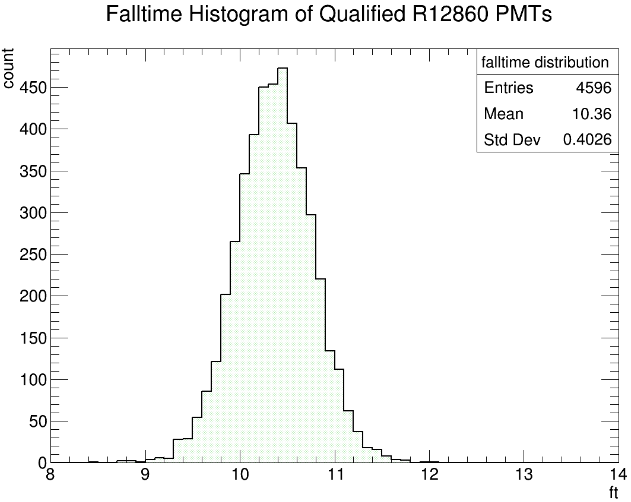
各个参数的统计结果-P/V



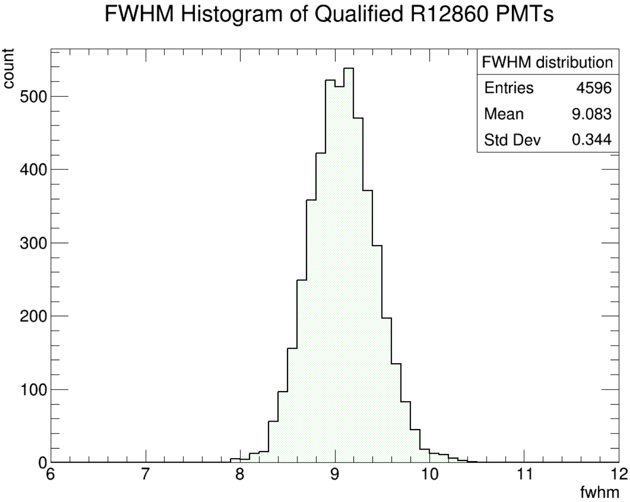
各个参数的统计结果-rise time



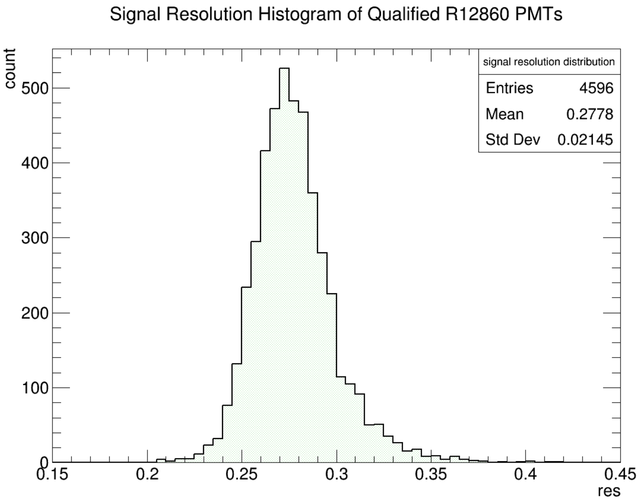
各个参数的统计结果-fall time



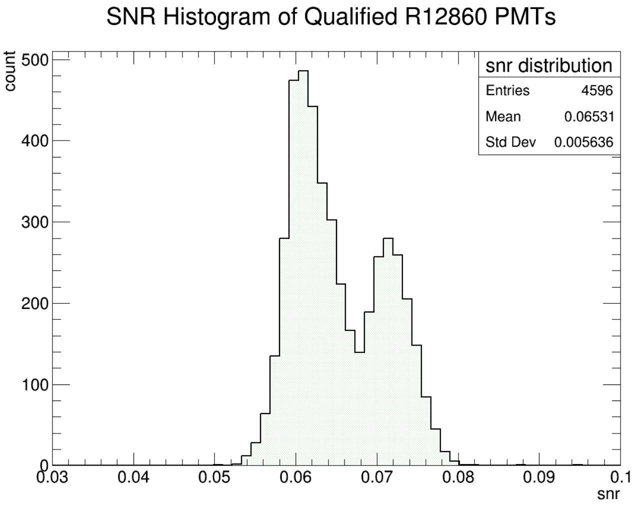
各个参数的统计结果-FWHM



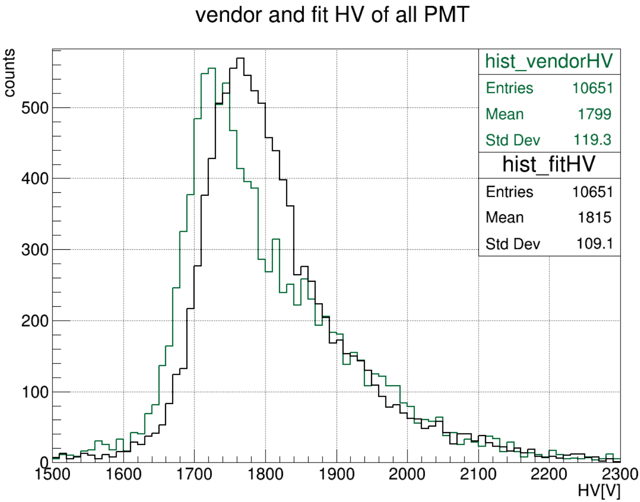
各个参数的统计结果-Resolution



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。$y = 1.148x + 0.998$

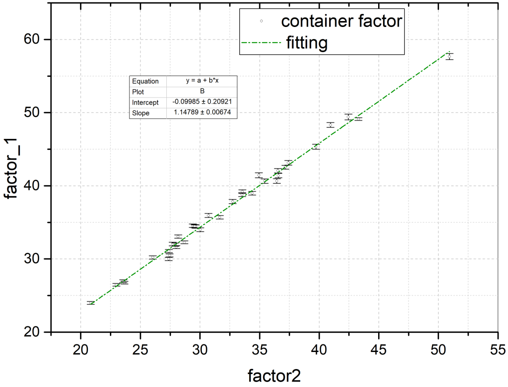
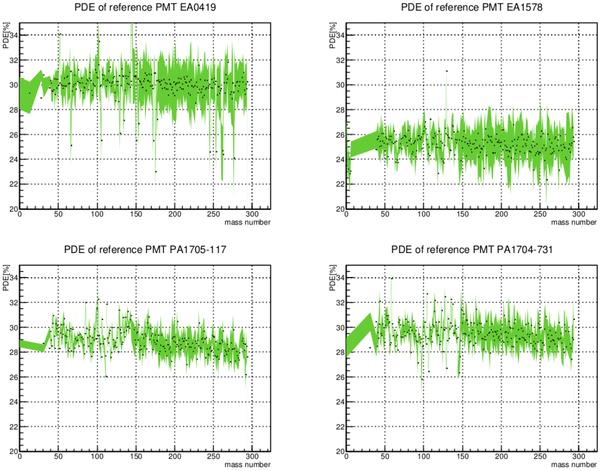


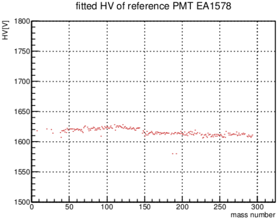
图: 抽屉因子和现场使用值的对比

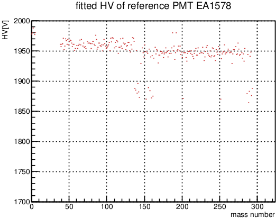
参考管稳定性

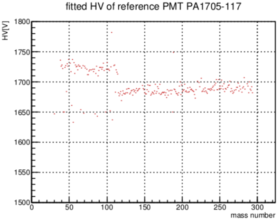

PDE of reference PMT EA0419
PDE of reference PMT EA1578
PDE of reference PMT PA1705-117
PDE of reference PMT PA1704-731
PDE[%]
mass number

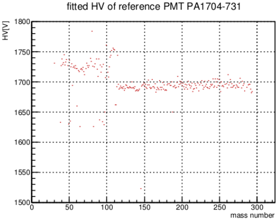
参考管电压稳定性

新 DAQ 对系统的性能产生了影响，高压平均值发生了变化：

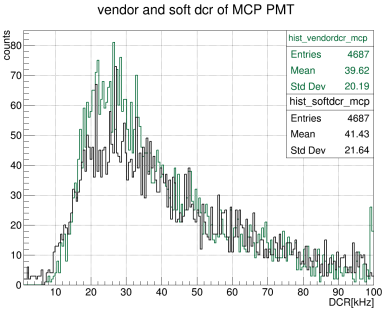


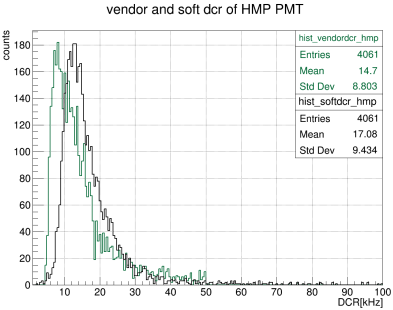






暗计数


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