

Performance of 20inch PMTs Based on the Container Testing Data

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School of Physics



Outline

① Brief Introduction

② Typical waveform and charge spectrum

③ statistical results of paramaters

④ 总结

PMT testingi data analysis

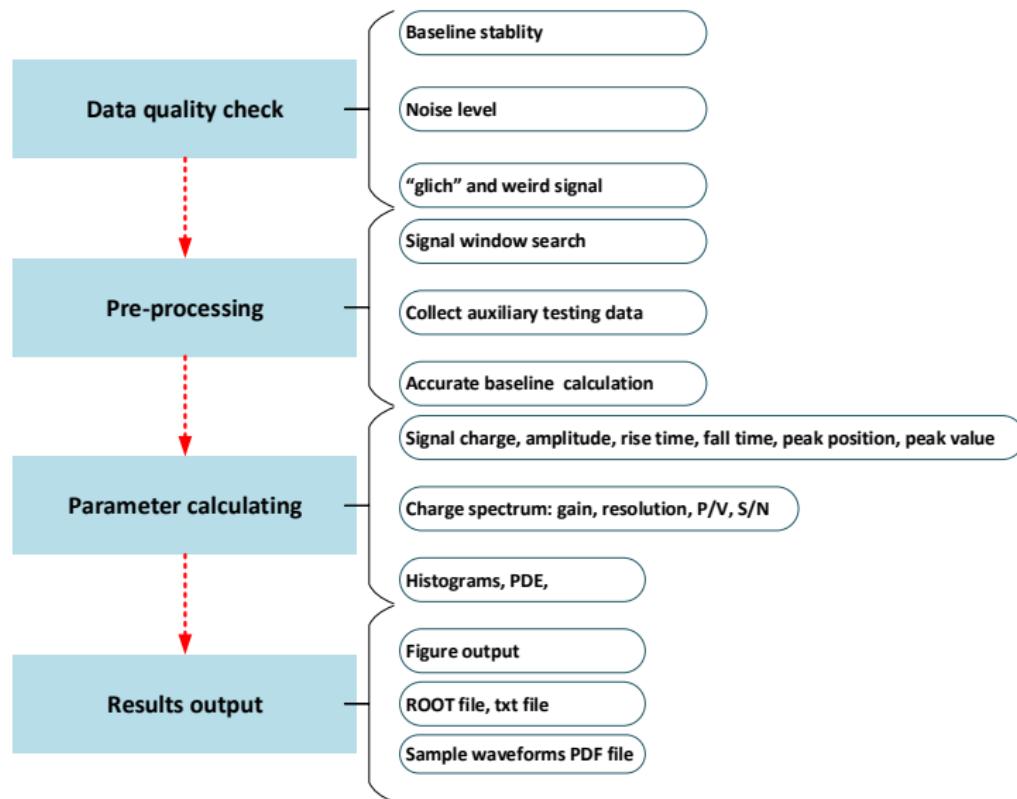
We have tested 5k HAMAMATSU PMTs and about 7k NNVT PMTs in the container system. We can obtain the following paramaters:

表: PMT performance qualification standard

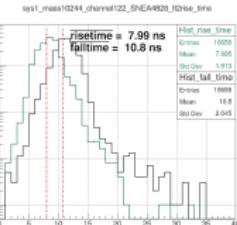
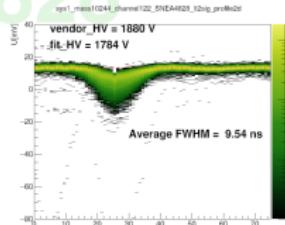
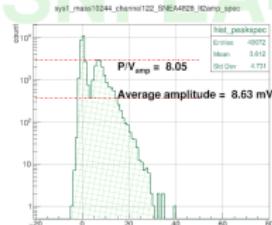
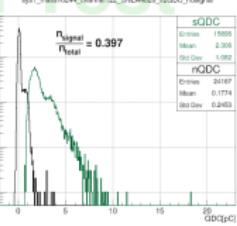
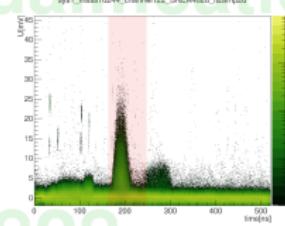
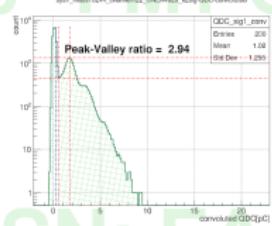
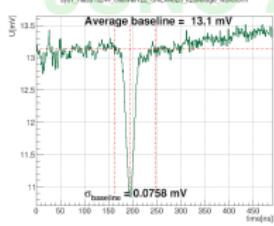
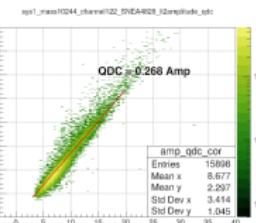
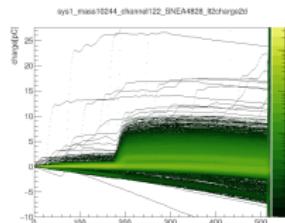
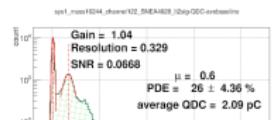
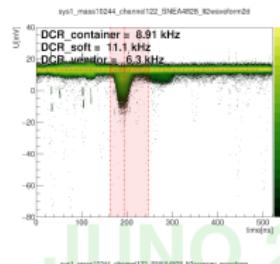
parameter	HAMAMATSU PMT	NNVT PMT
HV@Gain=10 ⁷	<2350 V	123
PDE	>24%	
DCR	<50kHz	
PV	>2.5	
rise time	<8ns	
fall time	<12ns	
FWHM	--	
resolution	<0.4	

The Main aim of testing data analysis is to evaluate theses paramters 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									
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:									
<p>This PMT was retested due to PDE problem , and then passed the test.</p>									
  									
[Aux Info]									
Table generated date: 20190102									
Data quality check: 									
Scanning Station check: 									
zhaor25@mail2.sysu.edu.cn									
Final Qualification Tag									
PASS									
EA0283									

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

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

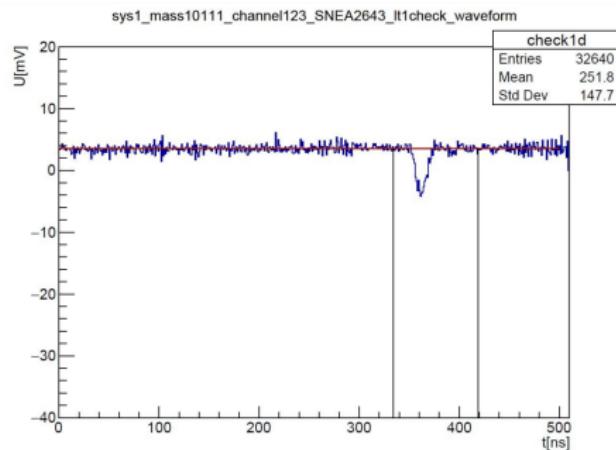


图: single photon signal waveform of HAMAMATSU PMT

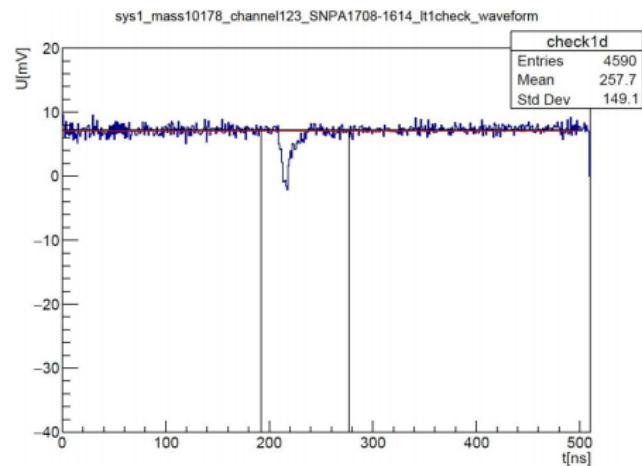


图: single photon signal waveform of NNVT PMT

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.

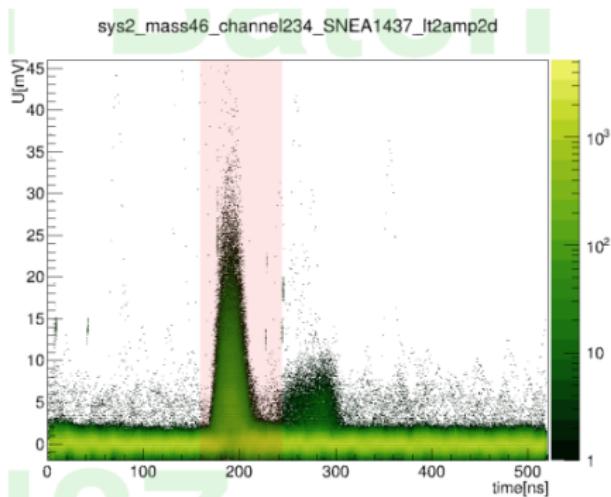


图: all frames of HAMAMATSU PMT

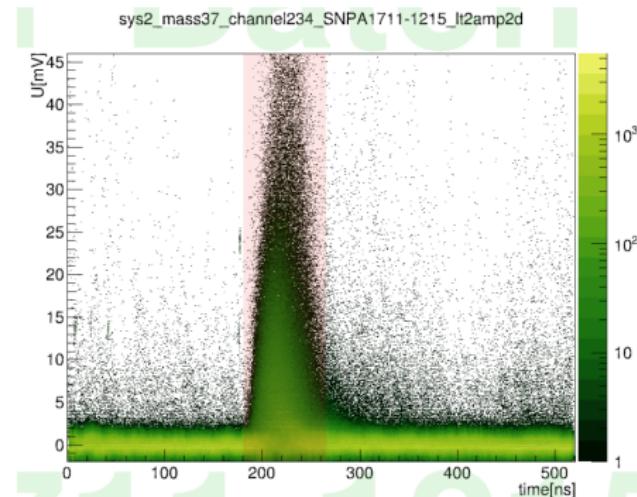


图: all frames of NNVT PMT

Output integrated waveforms of PMT(@gain = 10⁷)

From the waveform integral histogram we acquire more information.

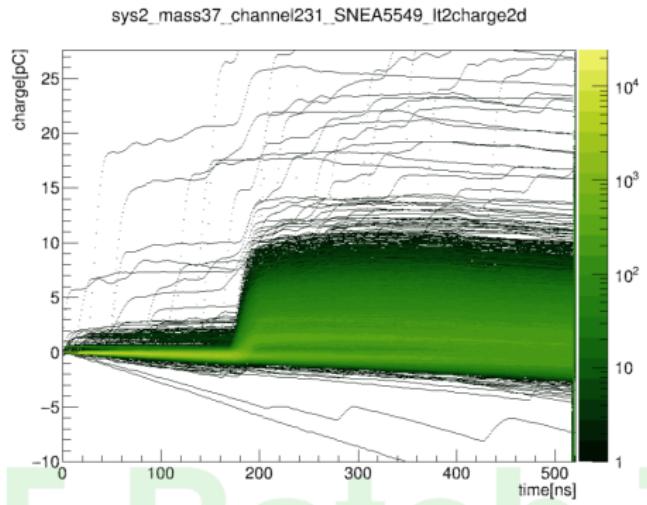


图: integrated waveforms of HAMAMATSU PMT

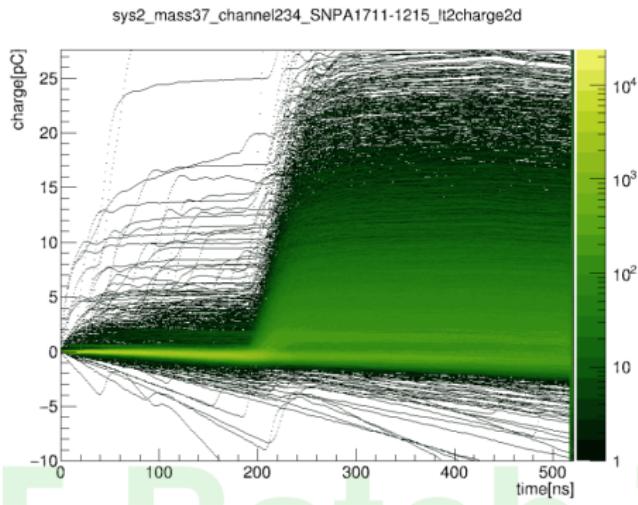


图: integrated waveforms of NNVT PMT

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

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

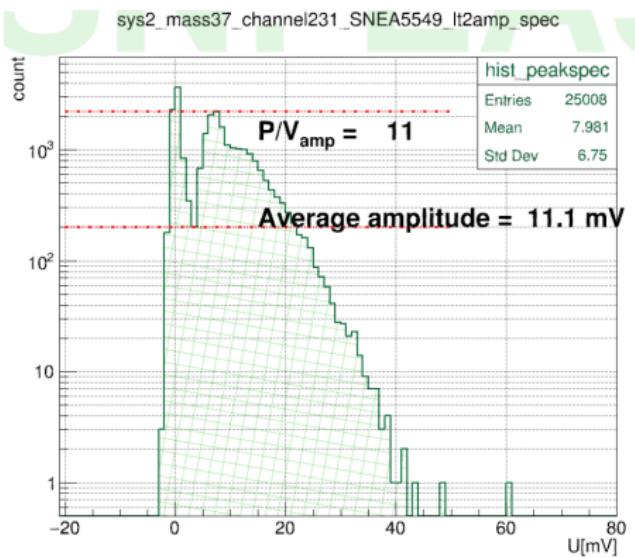


图: Amplitude spectrum of HAMAMATSU PMT

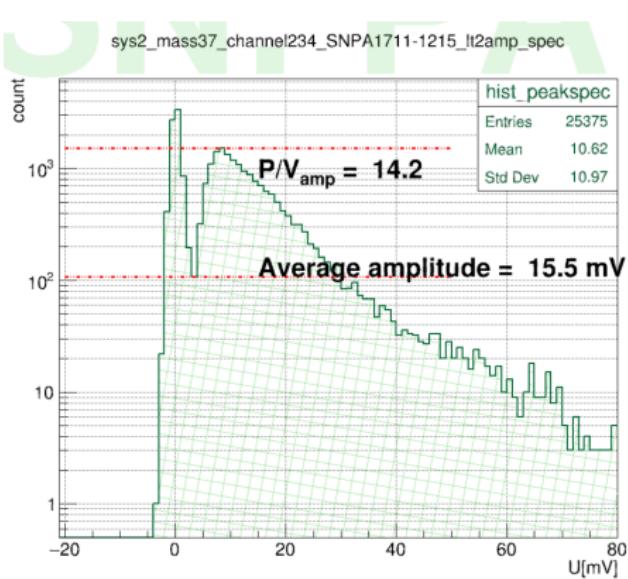


图: Amplitude spectrum of NNVT PMT

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

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

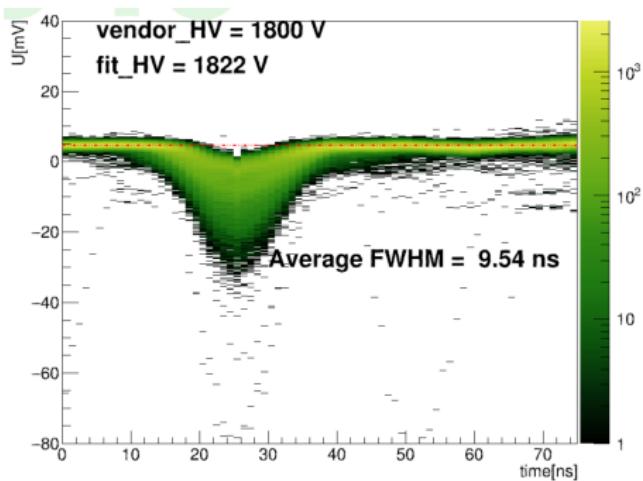


图: Aligned frames of HAMAMATSU PMT

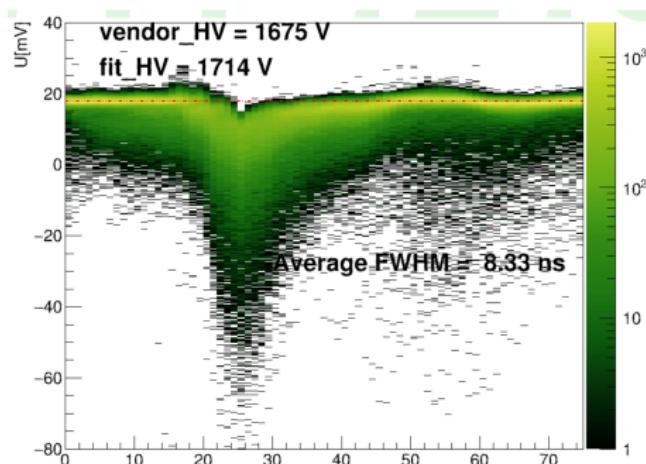


图: Aligned frames of NNVT PMT

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

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

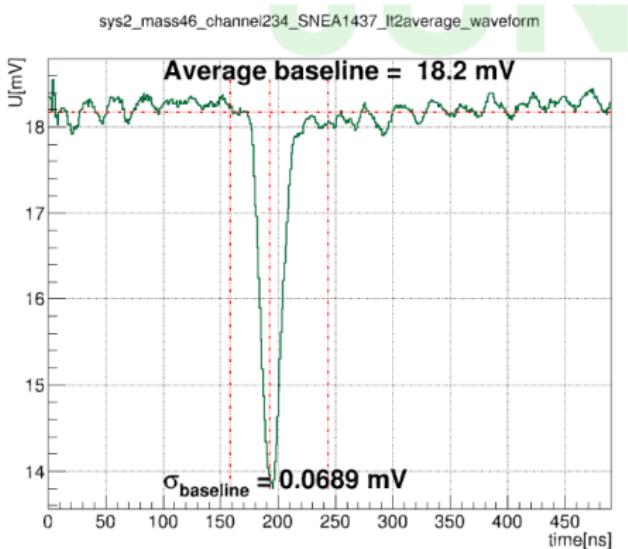


图: average waveform of HAMAMATSU PMT

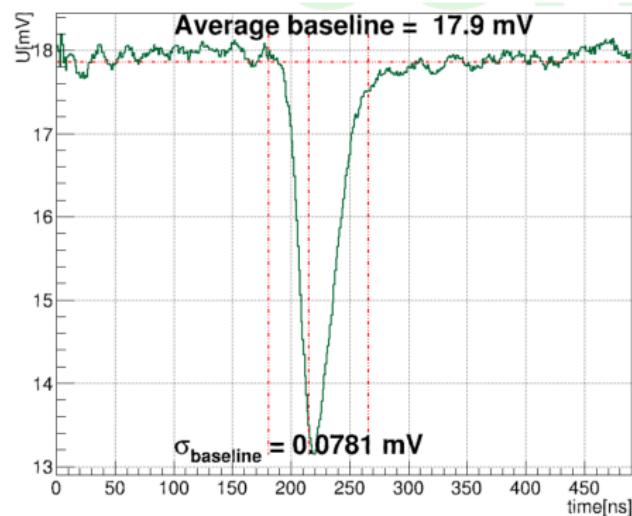


图: average waveform of NNVT PMT

Signal hit time distribution

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

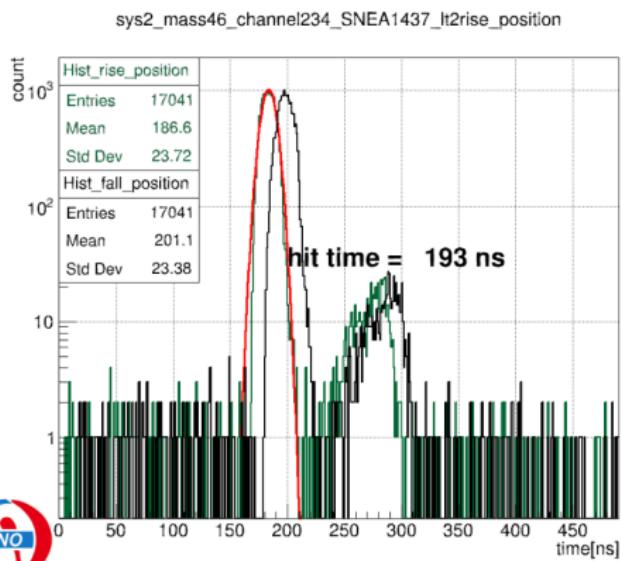


图: hit time of HAMAMATSU PMT

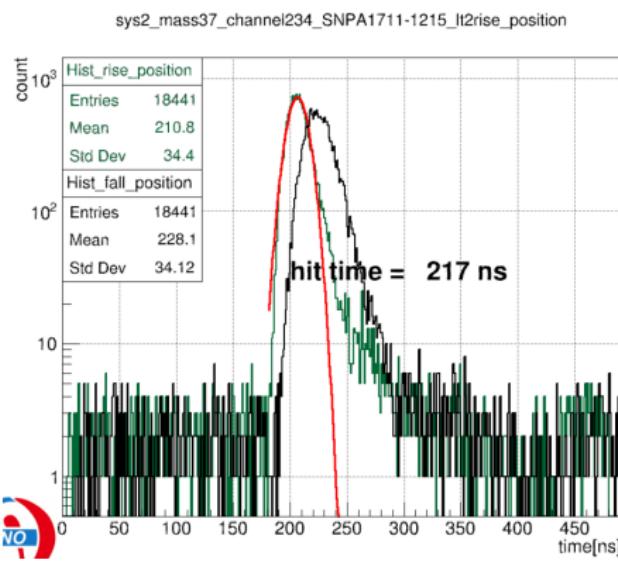


图: hit time of NNVT PMT

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

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

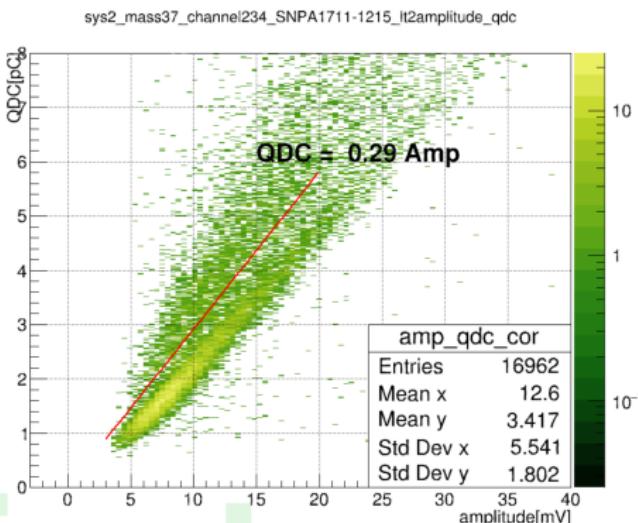
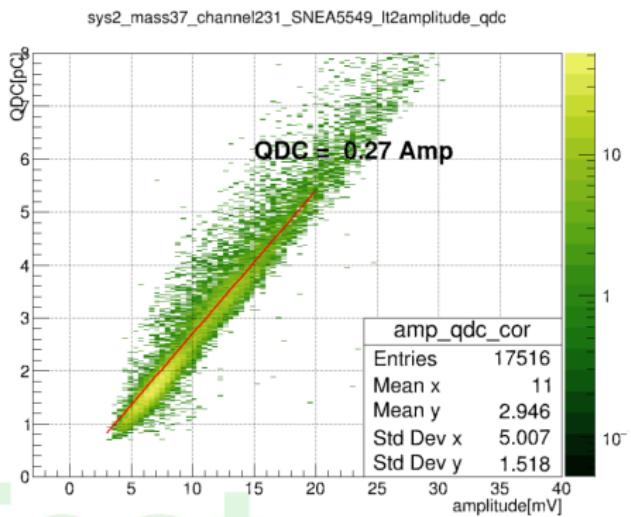
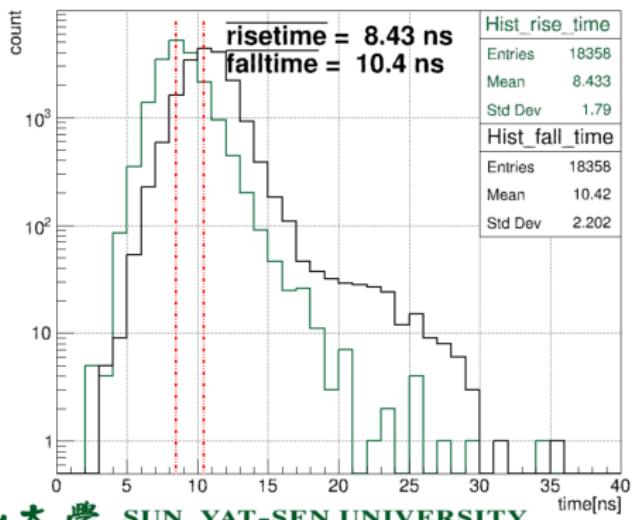


图: charge and amplitude correlation of HAMAMATSU PMT

图: charge and amplitude correlation of NNVT PMT

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

sys2_mass37_channel231_SNEA5549_lt2rise_time



sys2_mass37_channel234_SNPA1711-1215_lt2rise_time

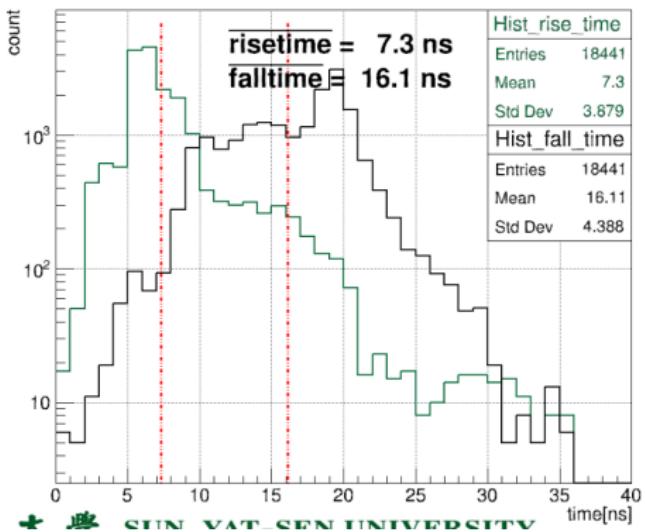
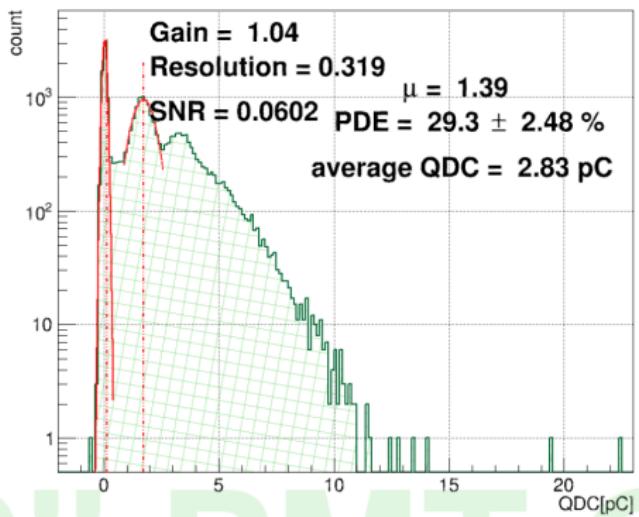


图: rise-time and fall-time of HAMAMATSU PMT

图: rise-time and fall-time of NVT 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

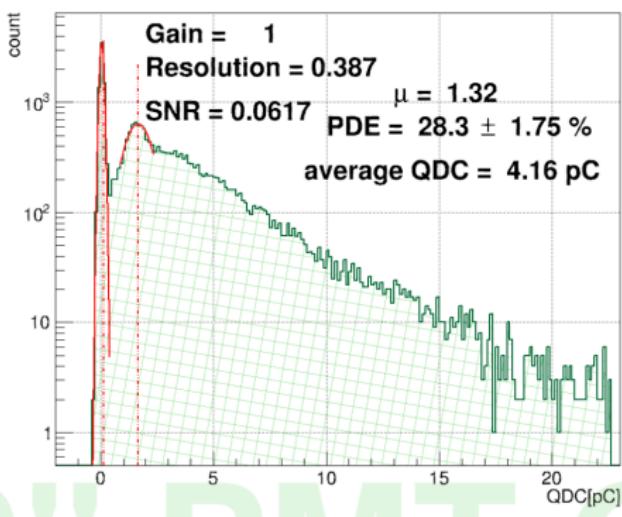


图: signal charge spectrum of HAMAMATSU PMT

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

PDE 的计算

根据电荷谱可以得到平均光子数 μ_{test} , 刻度数据 $drawer_{factor}$ ¹, 计算出集装箱系统的 PDE 结果:

$$PDE_c = \mu_{test} \times drawer_{factor} \quad (1)$$

利用集装箱系统和扫描站系统的 PDE 线性关联系数 f_{cs} ², 得到最终的 PDE 结果:

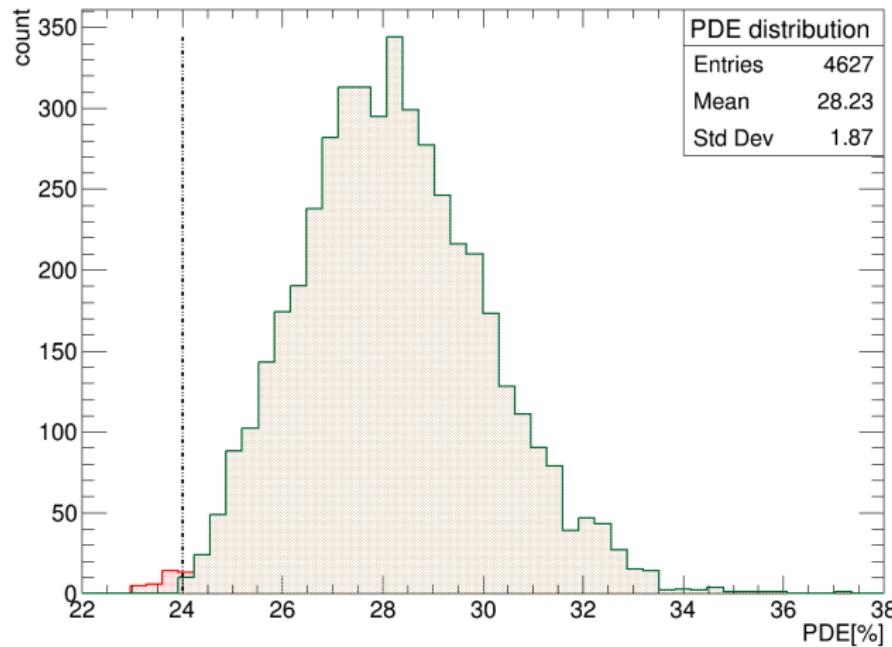
$$PDE = PDE_c \cdot f_{cs} + constant \quad (2)$$

¹集装箱 1 使用每个抽屉的测试过滨松 PMT 的厂家 QE 进行刻度, 集装箱 2 使用选择的刻度管进行刻度。具体细节在 DOCDB 文件 3921

²王俊和王耀光模拟结果, 以及胡航的数据拟合

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。

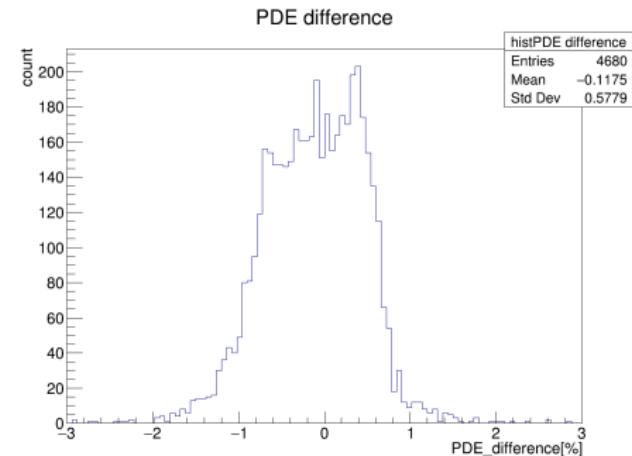
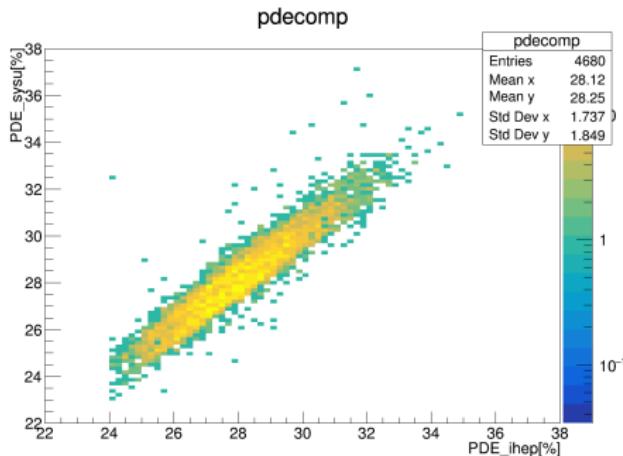
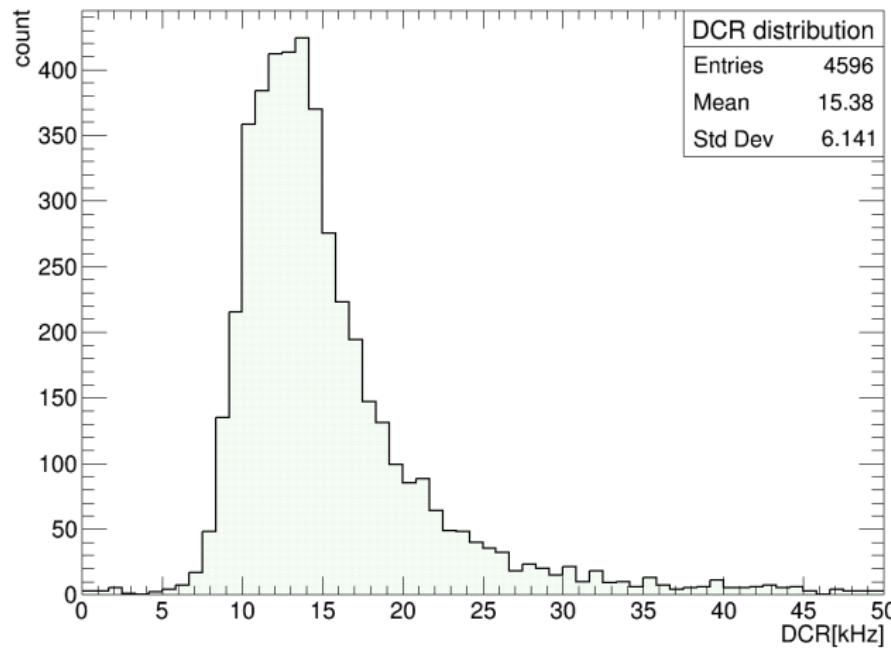


图: PDE 结果的关联对比

图: 两种分析的差值分布

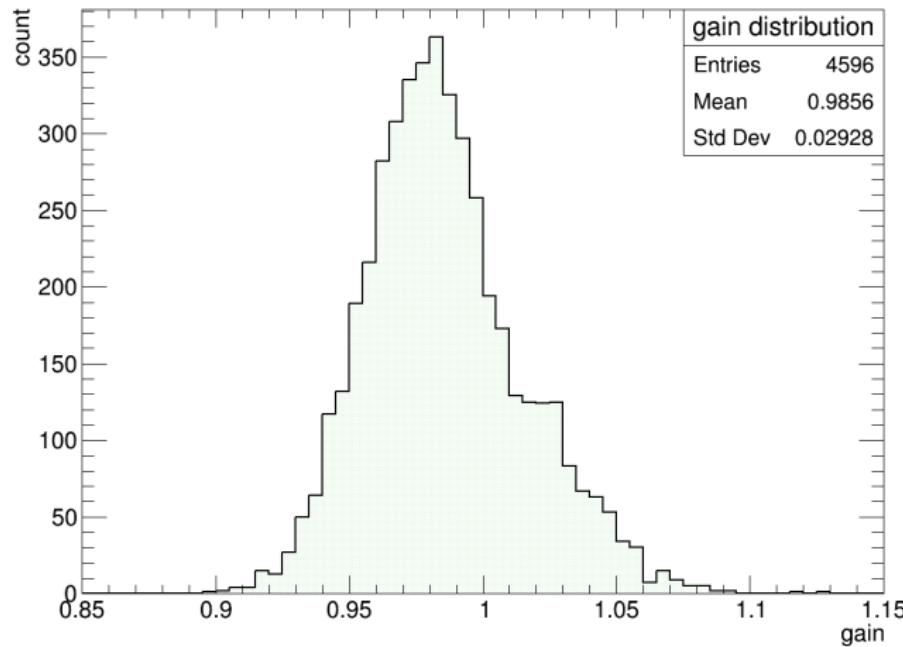
各个参数的统计结果-DCR

DCR Histogram of Qualified R12860 PMTs



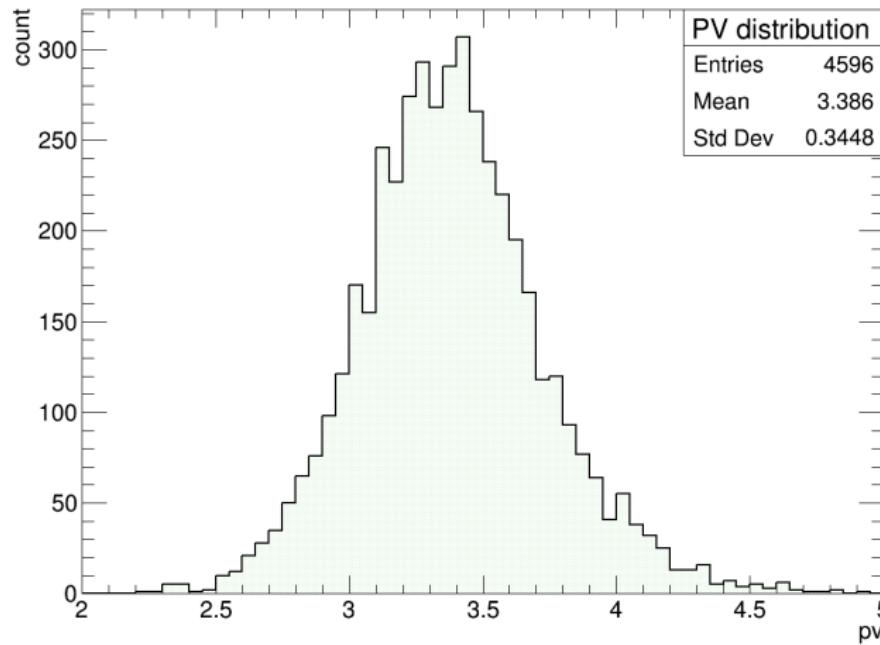
各个参数的统计结果-Gain

Gain Histogram of Qualified R12860 PMTs



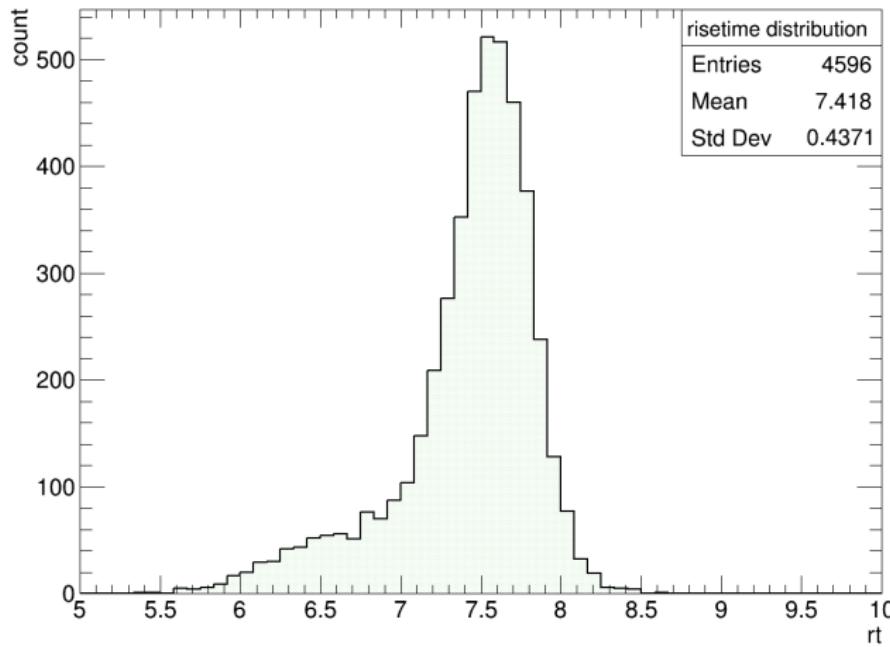
各个参数的统计结果-P/V

PV ratio Histogram of Qualified R12860 PMTs



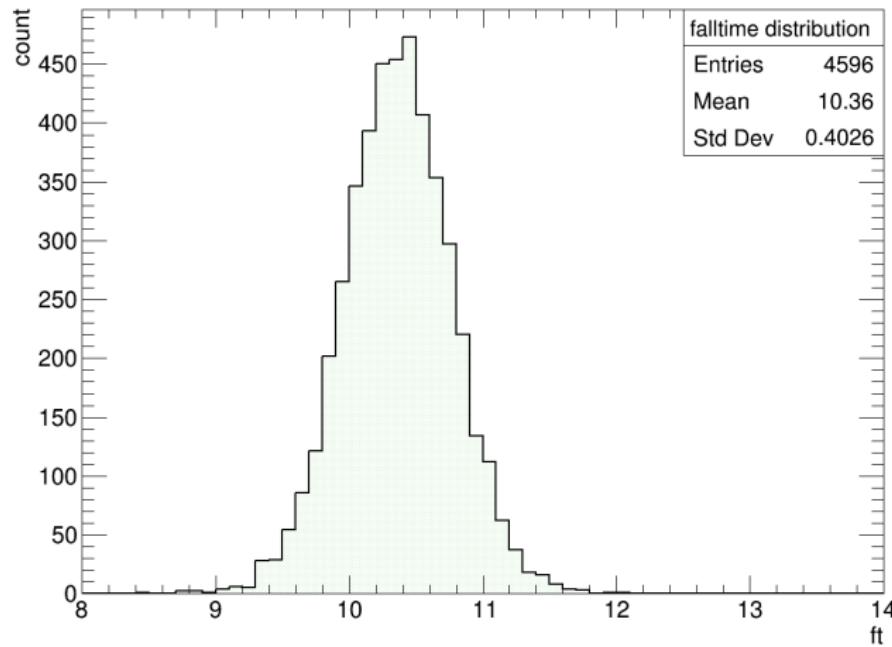
各个参数的统计结果-rise time

Risetime Histogram of Qualified R12860 PMTs



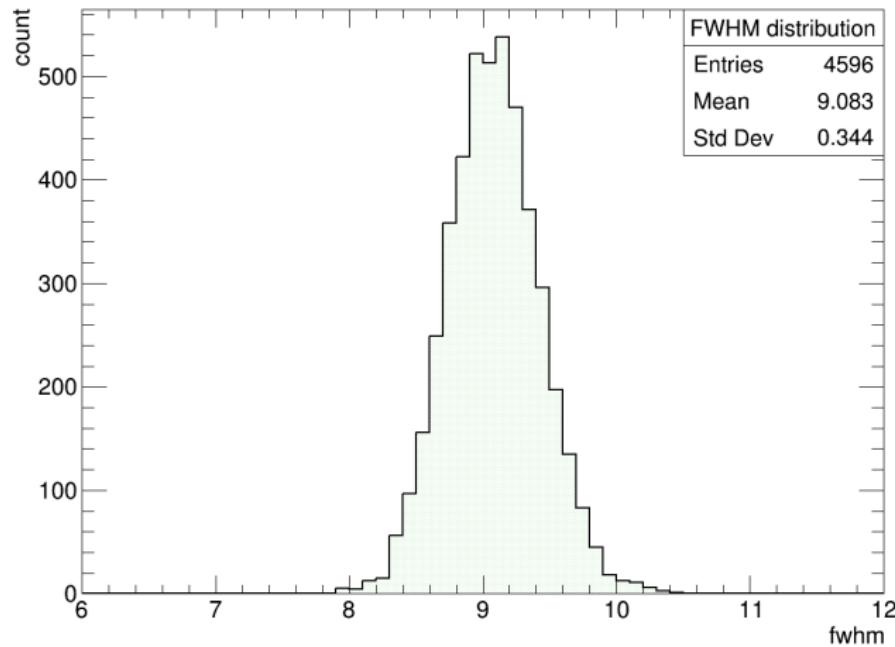
各个参数的统计结果-fall time

Falltime Histogram of Qualified R12860 PMTs



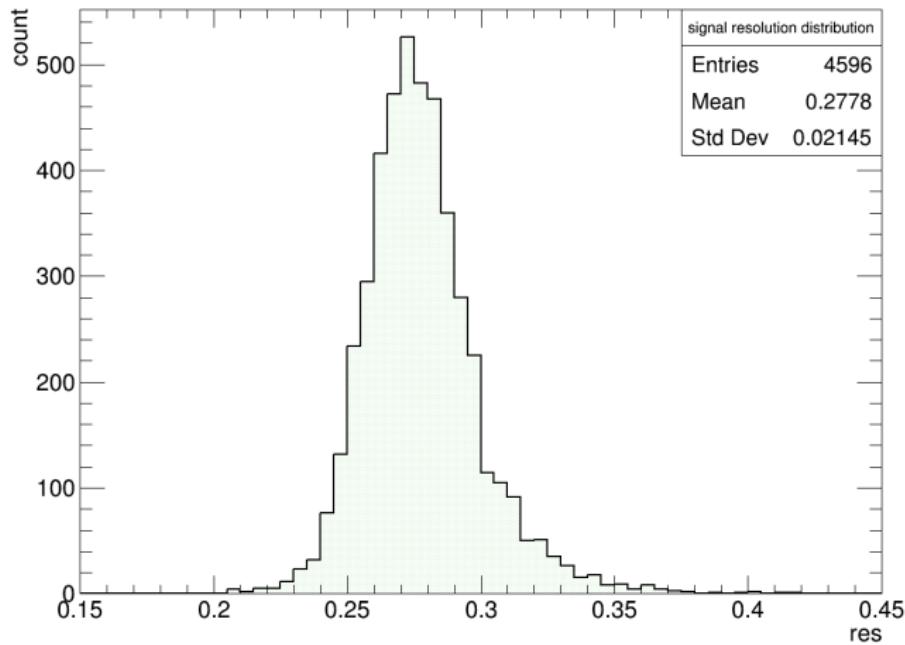
各个参数的统计结果-FWHM

FWHM Histogram of Qualified R12860 PMTs



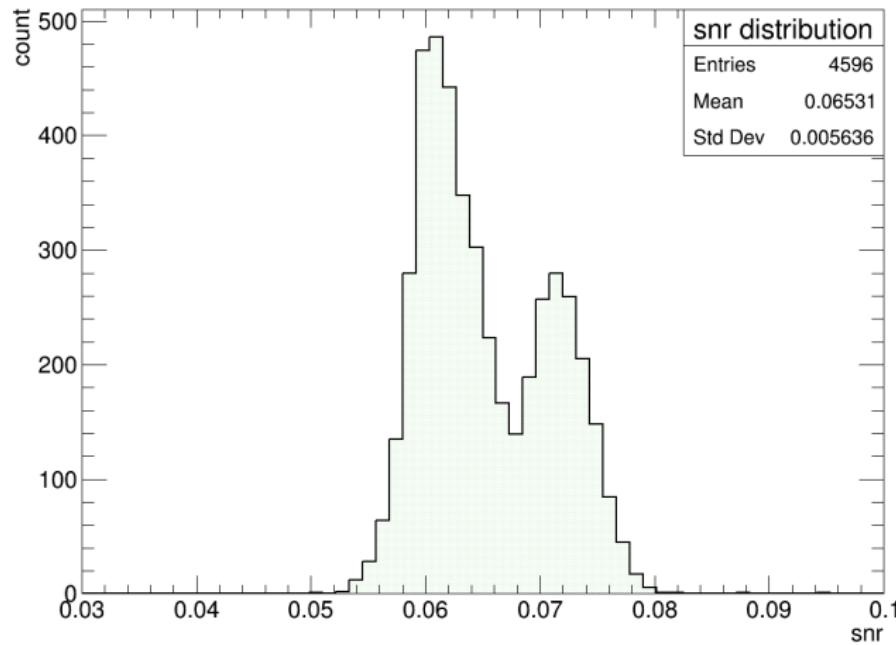
各个参数的统计结果-Resolution

Signal Resolution Histogram of Qualified R12860 PMTs



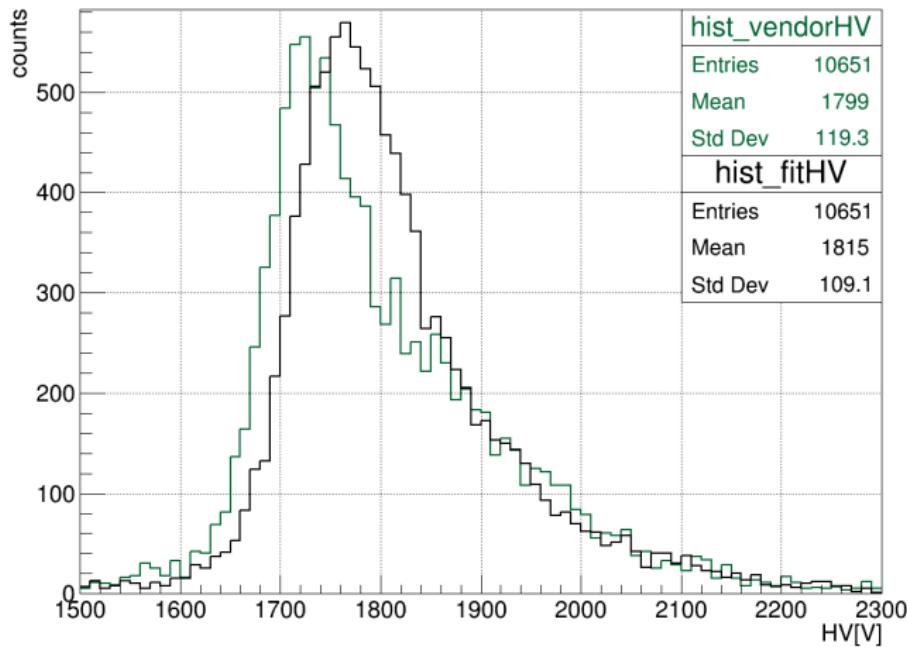
各个参数的统计结果-S/N

SNR Histogram of Qualified R12860 PMTs



各个参数的统计结果-HV

vendor and fit HV of all PMT



测试结果的输出

在完成每一只 PMT 的数据分析之后，输出重要的信息和数据：

- 测试信息：测试时间、集装箱编号、抽屉编号、mass number 等
- 性能测试信息：各种波形图、参数计算的中间 histogram
- 各个参数的计算结果、拟合信息
- 集装箱测试的历史记录、扫描站的测试结果
- 最终合格与否的结论标签

对于每一只 PMT，结合集装箱的多次测量结果以及扫描站复测结果，确保给出正确的最终结论。

测试结果报告-reject

QUALIFICATION TEST REPORT OF 20 INCH PMT

Test Information:

Test Date	Container#	Mass#	Drawer#	Mu	HV vendor	HV container	Gain	Sheet #
20171017	1	31	111	0.72	1710	1719	1.04	0

Parameters of Performance:

Par	Value	Tag	Par	Value	Tag
PDE[%]	22.38	✗	Ristime[ns]	7.65	✓
DCR[kHz]	10.44	✓	Falltime[ns]	9.90	✓
PV	2.30	✗	FWHM[ns]	9.28	✓
TTS[ns]			SNR	0.06	✓
AP[%]			Resolution	0.28	✓

Test History and Notes:

This PMT failed the container test due to low PDE but passed the scanning station test.



[Aux Info]

Table generated date:

20190102

Data quality check:

Scanning Station check:

zhaor25@mail2.sysu.edu.cn

Final Qualification Tag

EA0302

REJECT

总结和结论

- 分析测试数据得到每只 PMT 的各个参数测量结果
- 结合扫描站系统给出每只 PMT 的最终测试结论（是否合格）
- 保存重要的测试信息和输出结果到 PMT 数据库，所有测试结果³可以直接通过 <http://pmtdb.juno.ihep.ac.cn/>⁴ 查询得到
- 初步结论：目前现场 5002 支滨松 PMT，382 支外观检测不合格，5 支 HV 不合格，2 支波形较差，24 支 DCR 不合格，9 支 PDE 不合格。

³包含集装测试历史数据

⁴Query::LPMT Tested Reports

谢谢

BACKUP

其他重要参数的 check

HAMAMATSU-PMT 的参数对比：

参数 (平均值)	我的结果	测试现场结果
暗计数 (kHz)	17.8	16.6
信号上升时间 (ns)	7.3	6.9
信号下降时间 (ns)	10.36	10.2
峰谷比	3.3	3.9
分辨率	0.28	0.277
高压 (V)	1861	1858
信号半高宽 (ns)	9.08	11.6

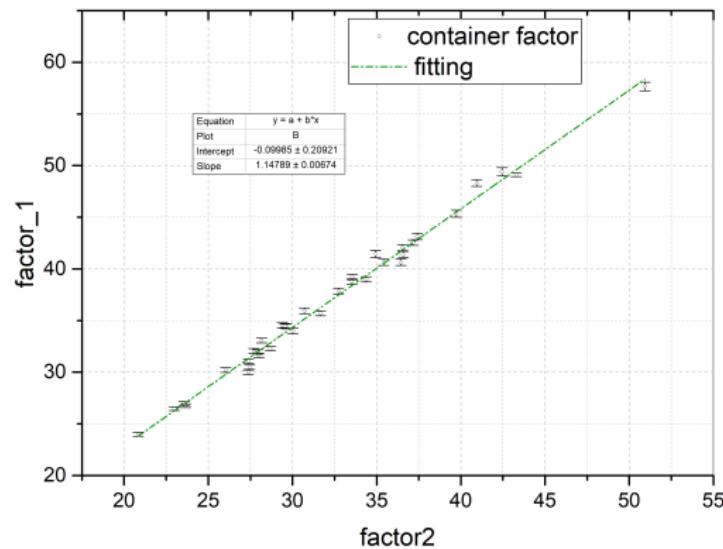
其他重要参数的 check

MCP-PMT 的参数对比：

参数 (平均值)	我的结果	测试现场结果
暗计数 (kHz)	41.4	44.3
信号上升时间 (ns)	3.2	4.6
信号下降时间 (ns)	15.9	16.2
峰谷比	3.19	4.4
分辨率	0.35	0.32
高压 (V)	1783	1784
信号半高宽 (ns)	5.8	7.7

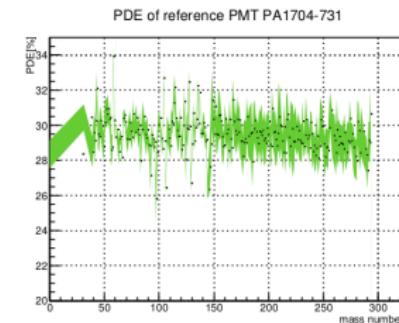
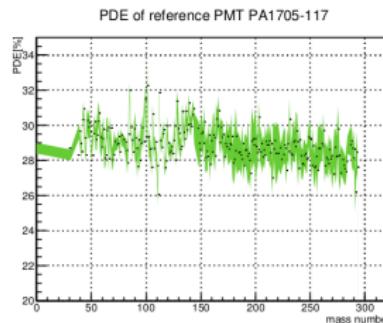
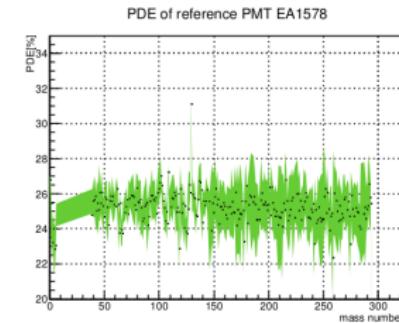
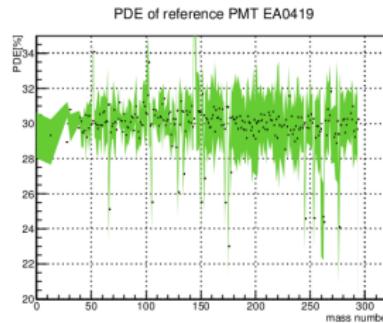
抽屉因子的比较

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



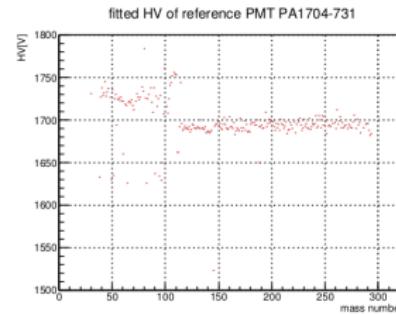
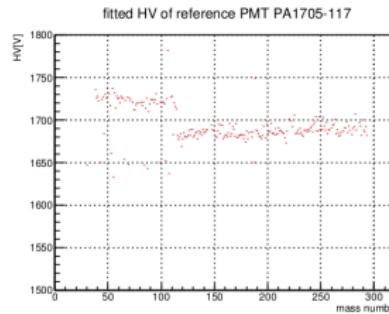
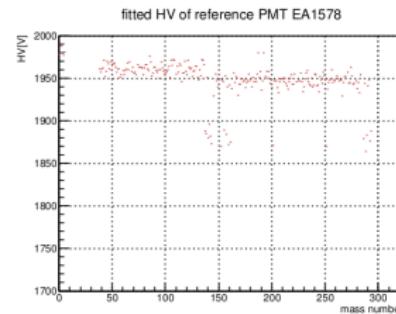
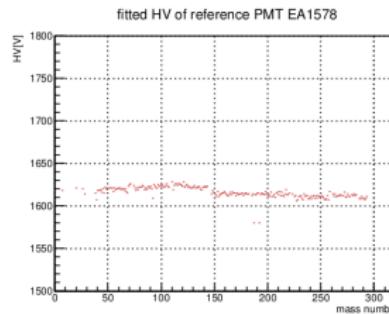
图：抽屉因子和现场使用值的对比

参考管稳定性



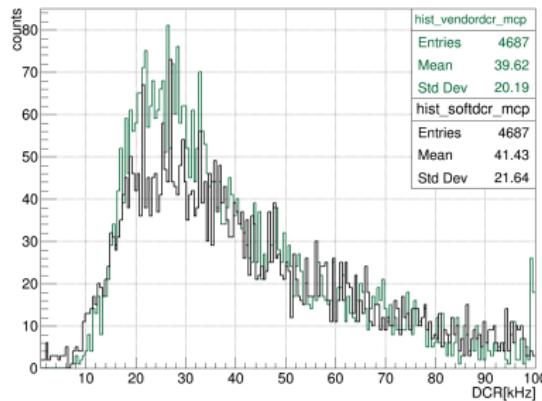
参考管电压稳定性

新DAQ对系统的性能产生了影响，高压平均值发生了变化：

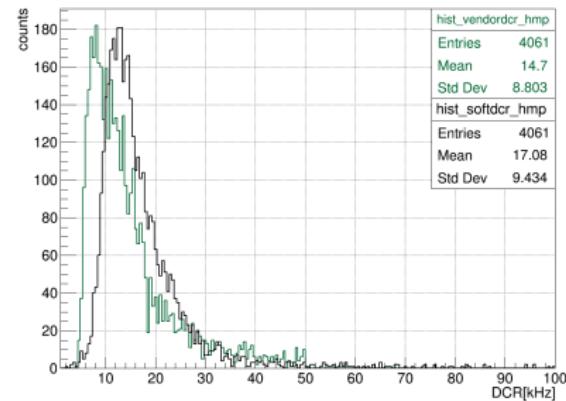


暗计数

vendor and soft dcr of MCP PMT



vendor and soft dcr of HMP PMT



上升时间和下降时间分布

