

Performance of CNN in PMT PDE Evaluation

– based on the onsite PMT testing data

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Outline

- ① Brief Introduction
- ② traing and test of CNN
- ③ Summary

traditional methods of PDE evaluation

Calculate the expected p.e by "cut" or "fitting" of charge spectrum.

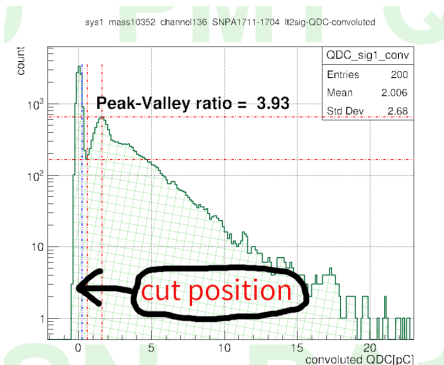


图: "cut" the charge spectrum to count pedestal events

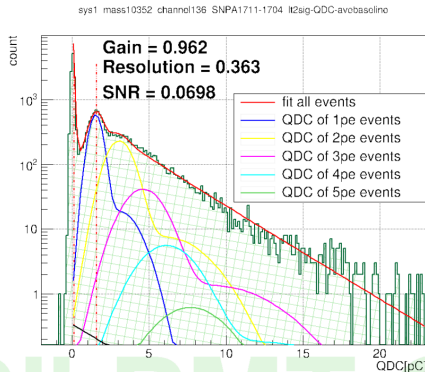


图: fit using a PMT photon response model

waveform classification using CNN

CNN can perform a powerful PSD and classify the waveforms, then we could get explicit p.e during one test.

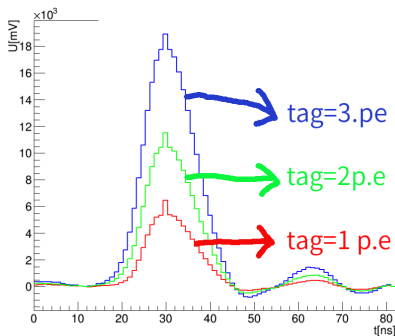


图: tags of typical waveform from CNN

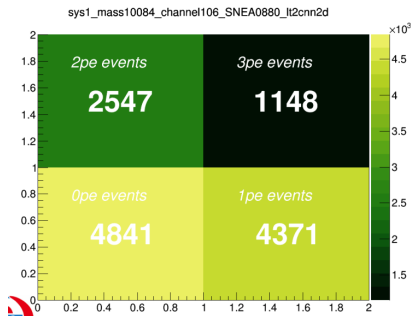


图: classification of events in one test

the expected photon number

If we do a "cut" is the charge spectrum@0.25 spe, the averager photon number μ can be acquired by¹

$$\mu = -\ln\left(\frac{N_0}{N}\right) \quad (1)$$

where N_0 is the number of pedestal(0 p.e) events, N is the total event number.

However, if we know explicitly the photon number of specific event, the μ value is :

$$\mu = 1 \times n_1 + 2 \times n_2 + \cdots + N \times n_N \quad (2)$$

where n_N is the number of N p.e events.

¹E. H. Bellamy et al /Nucl. Instr. and Meth. in Phys. Res. A 339 (1994) 468-476

input of CNN

training data selection:

- random selection from different PMTs(NNVT and HAMAMATSU)
- $1.5 < \text{QDC} < 1.7$ for 1p.e
- $3.1 < \text{QDC} < 3.3$ for 2p.e
- $4.7 < \text{QDC} < 4.9$ for 3p.e
- 81ns ROI $\rightarrow 9 \times 9$ 2D map

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 NNVN PMTs.

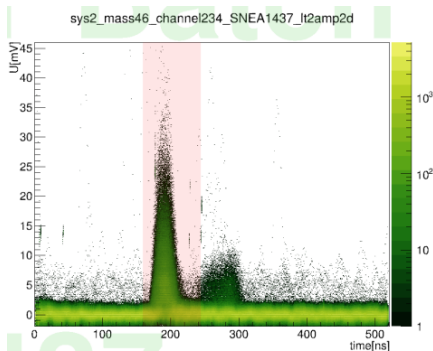


图: all frames of HAMAMATSU PMT

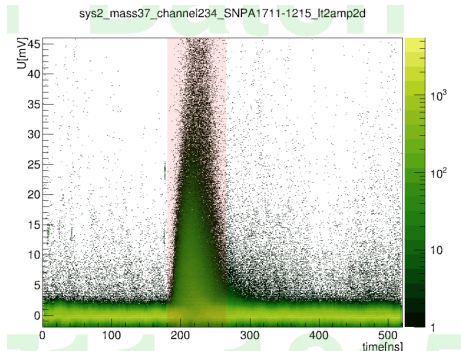


图: all frames of NNVN PMT

calculation of PDE

we can obtain the average photon number μ_{test} from charge spectrum, along with the $drawer_{factor}^2$, the PDE result from container system is:

$$PDE_c = \mu_{test} \times drawer_{factor} \quad (3)$$

Then we map the PDE from container to the final PDE value with the help of container f_{cs}^3 :

$$PDE = PDE_c \cdot f_{cs} + constant \quad (4)$$

²Calibrate the drawer factor using PMT tested in the drawer which has vendor QE value.

³linear correlation factor

statistical results

Mean value of parameters for HAMAMATSU-PMT and NNVT-PMT⁴:

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

⁴For the parameter TTS, we need to test the internal time resolution firstly, since we found the TTS results is highly drawer related.

summary

- the charge and amplitude stability of HAMAMATSU PMT is better.
- $\sim 6k$ NNV T PMTs and $5k$ HAMAMATSU PMTs has been tested in container system, test results and test reports are available from PMTDataBase⁵.
- we reject or accept one PMT according to its performance test results from container and scanning station.
- we need to study the "delay signal" of HAMAMATSU PMT and "big signal" of NNV T PMT⁶ in detail⁷.
- the expected mean PDE value is 30.4% and mean DCR value is $\sim 34kHz$ ⁸ in CD.

⁵ pmtddb.juno.ihep.ac.cn

⁶ especially when PMT working in the multi-photon case

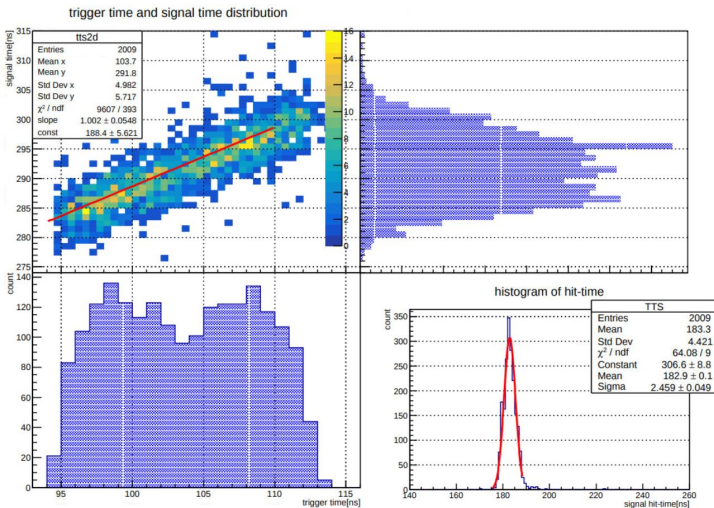
⁷ one option is to transport several PMTs to SYSU for detailed study

⁸ will decrease after installation

THANKS

BACK-UP

TTS of HAMAMATSU PMT



hit-time and trigger time

TTS calculation of NNVT PMT

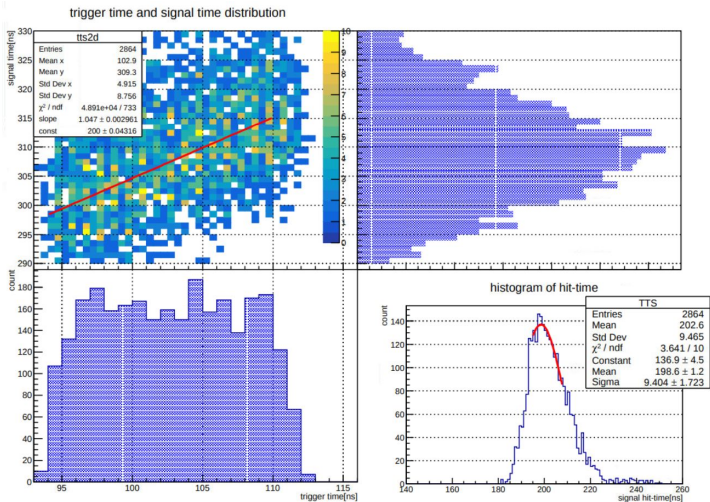


图 • hittime and trigger time