Performance of CNN in PMT PDE Evaluation

– based on the onsite PMT testing data

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Outline

traditional methods of PDE evaluation

Calculate the expected p.e by "cut" or "fiting" of chagre spectrum.

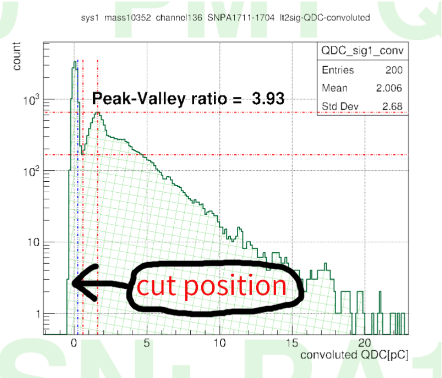

图: "cut" the charge spectrum to count pedestal events

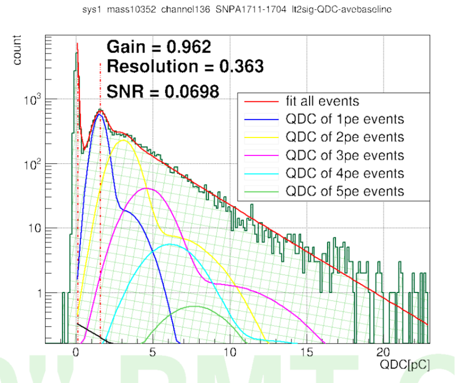

图: fit using a PMT photon response model

waveform classification using CNN

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

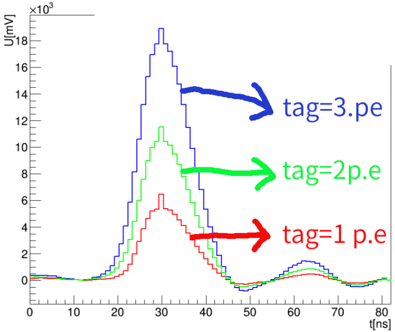

图: tags of typical waveform from CNN

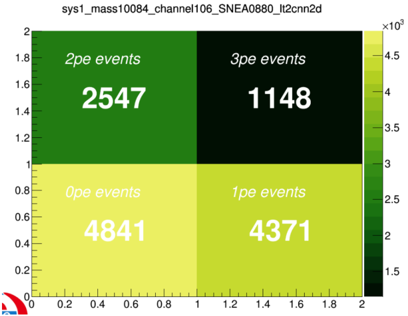

图: classification of events in one test

the expected photon number

If we do a ”cut” is the charge spectrum@0.25 spe, the averager photon number μ can be acquired by[1]

$$\mu = -ln(\frac{N_0}{N}) \tag{1}$$

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 :

$$\mu = 1 \times n_1 + 2 \times n_2 + \cdots + N \times n_N \tag{2}$$

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

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

input of CNN

training data slecetion:

- random selection from different PMTs(NNVT and HAMAMATSU)
- 1.5<QDC<1.7 for 1p.e
- 3.1<QDC<3.3 for 2p.e
- 4.7<QDC<4.9 for 3p.e

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.

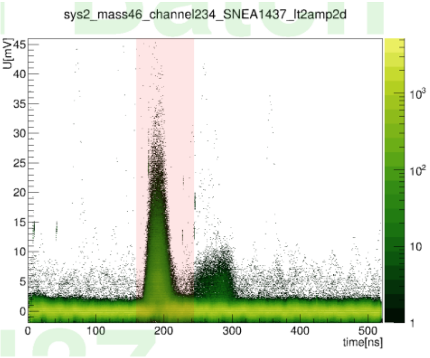

图: all frames of HAMAMATSU PMT

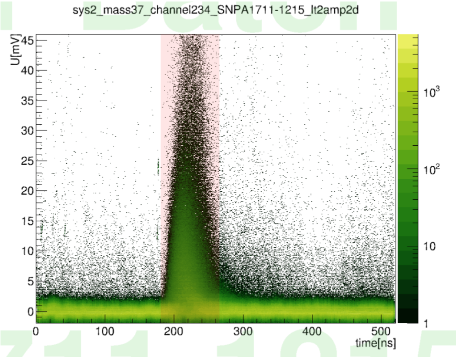

图: all frames of NNVT PMT

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:

$$PDE_c = \mu_{test} \times drawer_{factor} \tag{3}$$

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

$$PDE = PDE_c.f_{cs} + constant \tag{4}$$

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

[3] linear correlation factor

statistical results

Mean value of parameters for HAMAMATSU-PMT and NNVT-PMT[4]:

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

[4]For 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 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 $\sim$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

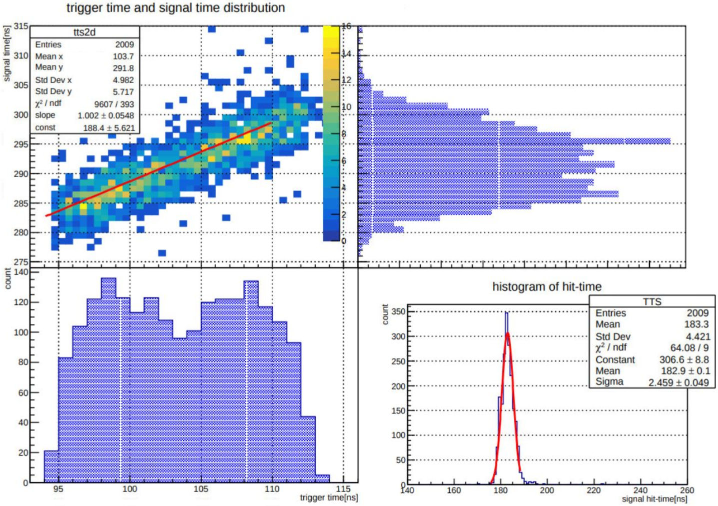

图: hittime and trigger time

TTS calculation of NNVT PMT

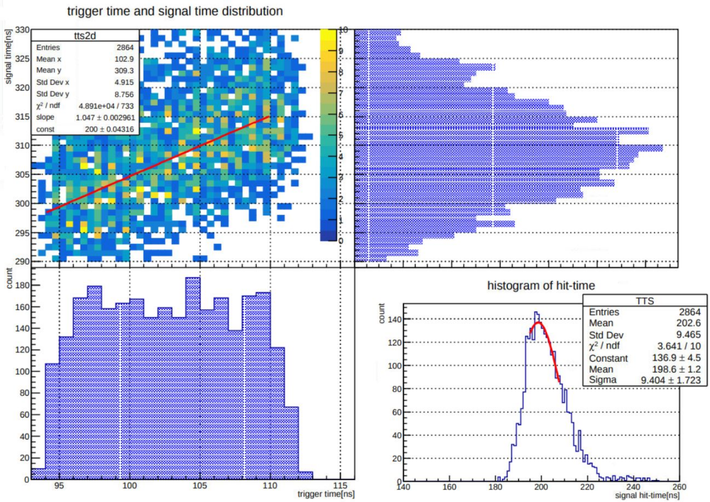

图: hittime and trigger time