

Photon Response Model of MCP-PMT

– based on the onsite PMT testing data

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Outline

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

the "big signals" of MCP PMT

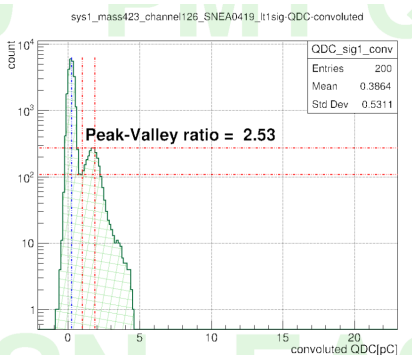


图: HAMAMATSU

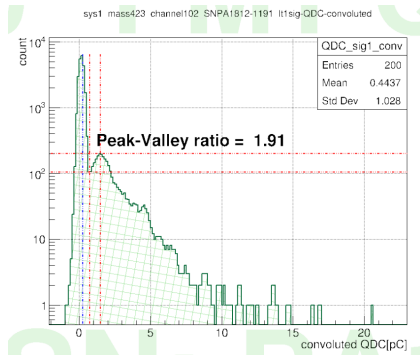


图: MCP

photon response characters of MCP PMT

The typical waveform and charge spectrum of MCP PMT@gain = 10^7
[dark noise]

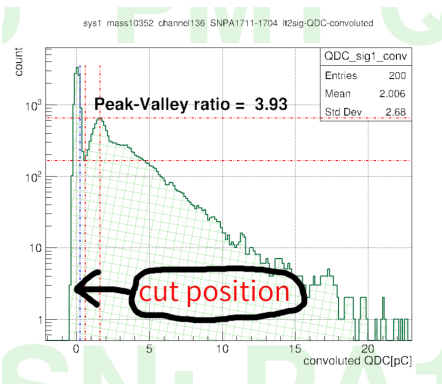


图: "cut" the charge spectrum to count pedestal events

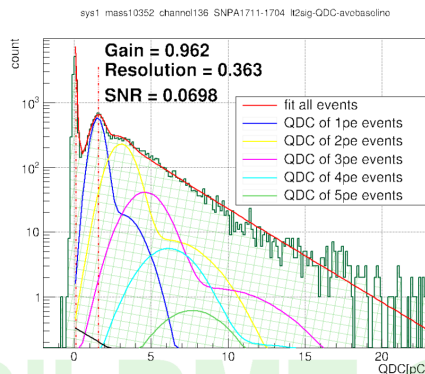
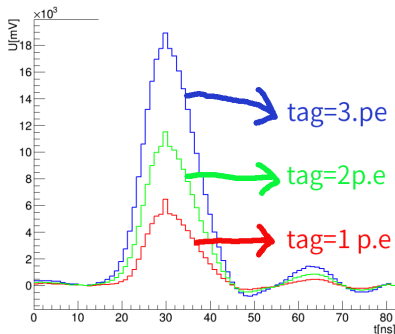



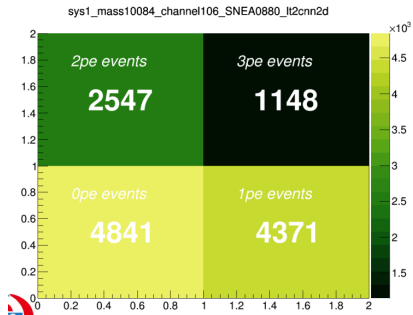
图: fit using a PMT photon response model


CNN

select the time interval before "trigger window".



 tags of typical waveform from CNN



 classification of events in one test

01pe

the 0.1pe case

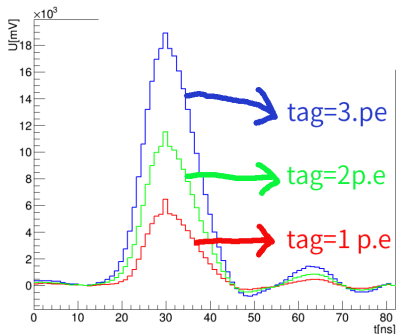


图: tags of typical waveform from CNN

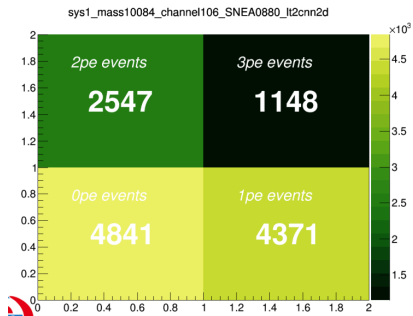


图: classification of events in one test

01pe

the 1pe case

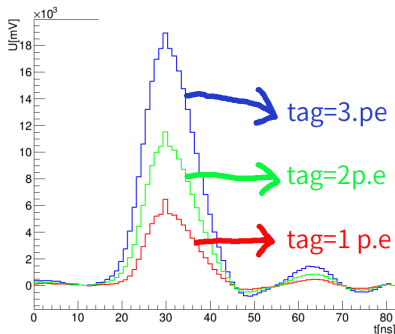


图: tags of typical waveform from CNN

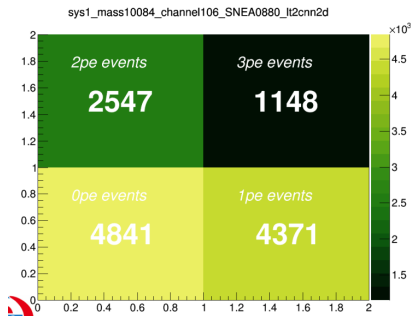


图: classification of events in one test

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 :

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

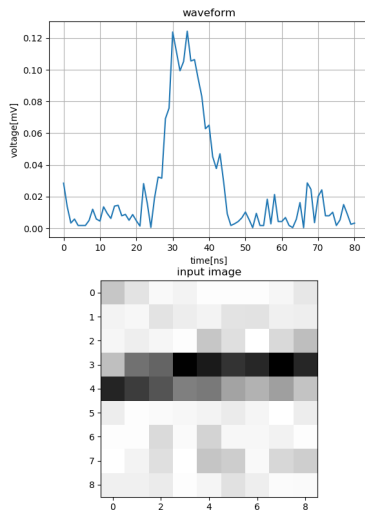
where n_N is the number of N p.e events.

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

input of CNN

training data selection and pre-process:

- random selection from different PMTs
- $1.5 < QDC < 1.7$ for 1p.e
- $3.1 < QDC < 3.3$ for 2p.e
- $4.7 < QDC < 4.9$ for 3p.e
- 81ns ROI $\rightarrow 9 \times 9$ 2D image
- normalization



CNN parameters

- 30k training waveform samples
- 2 convolution layers
- 4 output tags
- accuracy $\simeq 0.95$

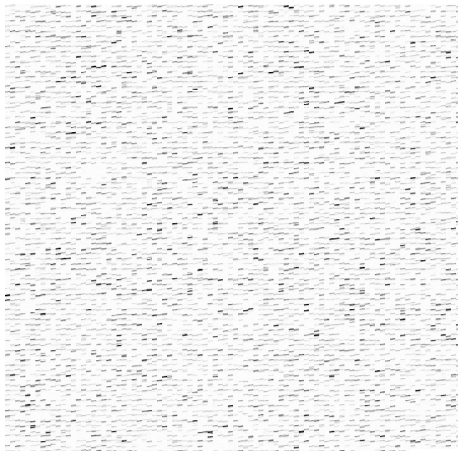
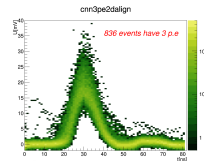
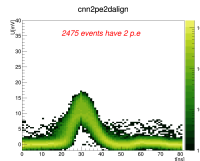
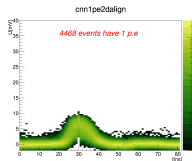
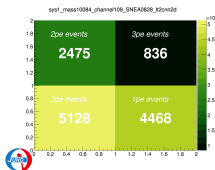
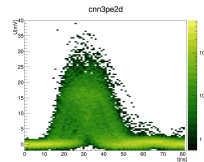
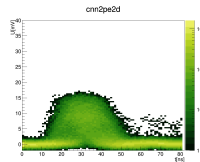
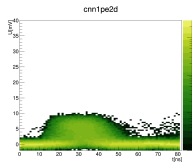
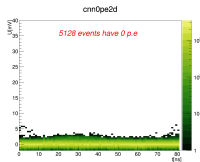
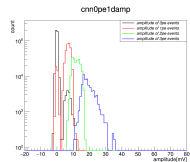
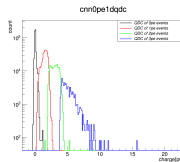
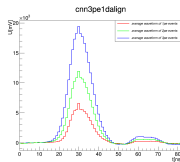
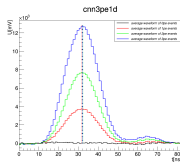


图: input data

results of cnn



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图: HAMAMATSU PMT

results of cnn

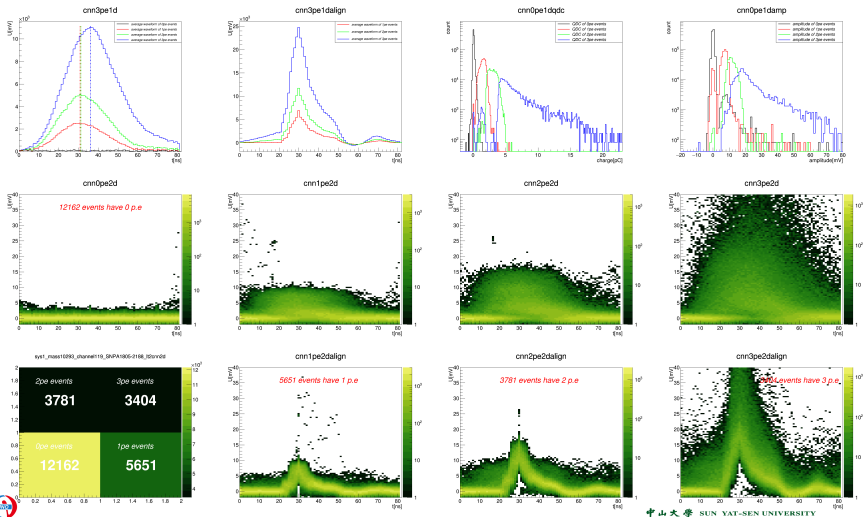


图: NNVT PMT

summary

- PSD by CNN provide a new option for PDE evaluation.
- can achieve *sim*0.95 accuracy with the traditional method using simple NN.
- much faster than traditional methods in PDE evaluation.
- CNN can extract more information from waveforms.

to list:

- refine the training samples and network structure.
- compare the accuracy in more details, for example using the reference tubes in container system.
- improve the input data quality.

THANKS

BACK-UP