Photon Response Model of MCP-PMT

– based on the onsite PMT testing data

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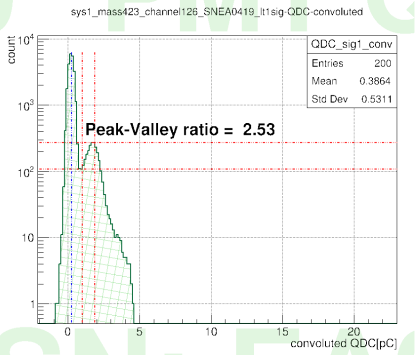
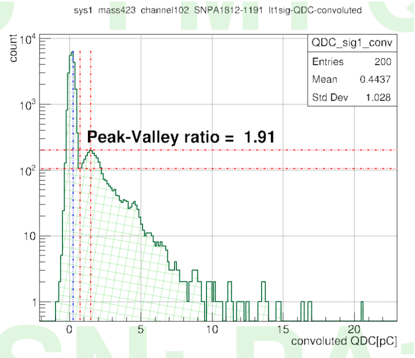
Outline

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

the ”big signals” of MCP PMT

From the JUNO PMT testing data, we found thay when illumiated with single p.e phtons[1][$\mu = 0.1$],MCP PMT will, typicaly ,output more multi-pe signals than dynode PMT. This phenomenon is depicted in the bellow figures as the ”long tail ” in the charge spectrum. the MCP manification factor is not so stable.





photon response characters of MCP PMT

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

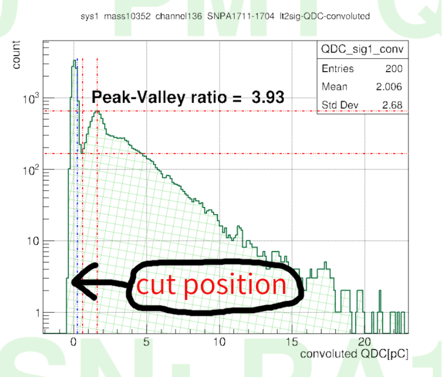


图: "cut" the charge spectrum to count pedestal events

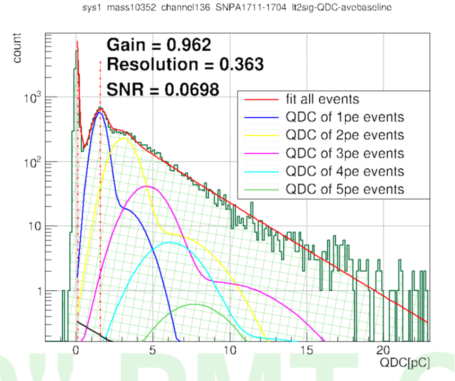


图: fit using a PMT photon response model

CNN

select the time interval before ”trigger window”.

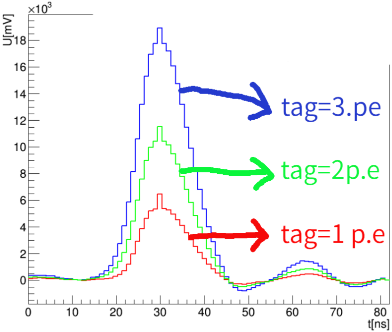


图: tags of typical waveform from CNN

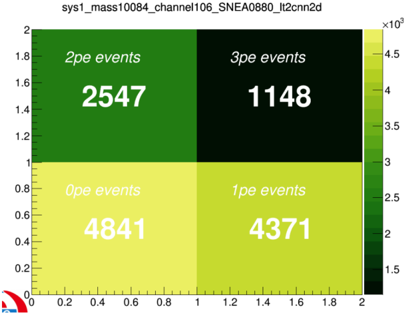


图: classification of events in one test

01pe

the 0.1pe case

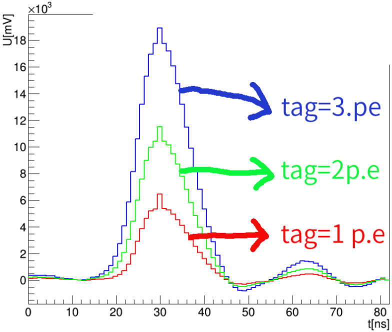


图: tags of typical waveform from CNN

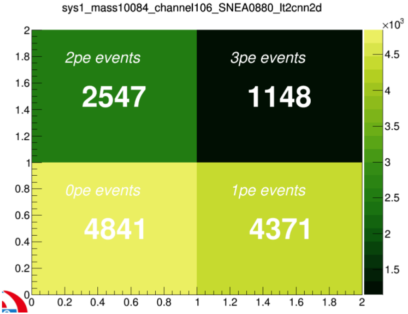


图: classification of events in one test

01pe

the 1pe case

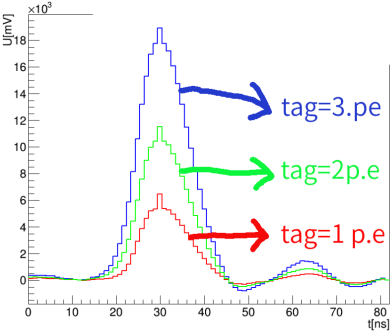


图: tags of typical waveform from CNN

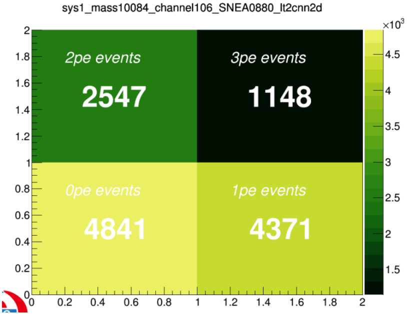


图: classification of events in one test

the expected photon number

If we do a "cut" is the charge spectrum@0.25 spe, the averager photon number μ can be acquired by[2]

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

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 :

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

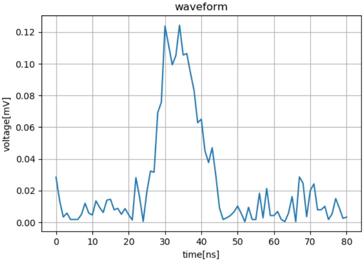
where n_N is the number of N p.e events.

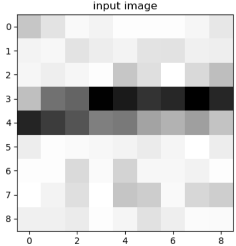
[2] E. H. Bellamy et al /Nucl. Instr. and Meth. m Phys . Res. A 339 (1994) 468-476

input of CNN

training data slecetion 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$\simeq 0.95$

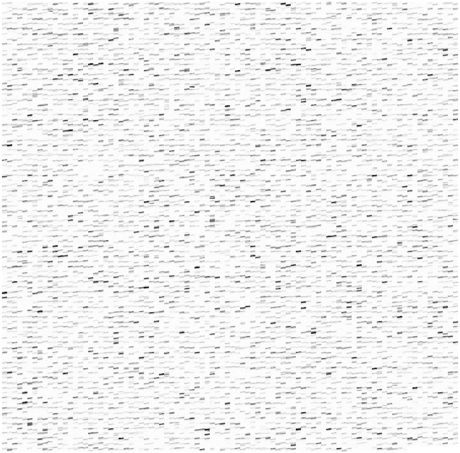


图: input data

results of cnn

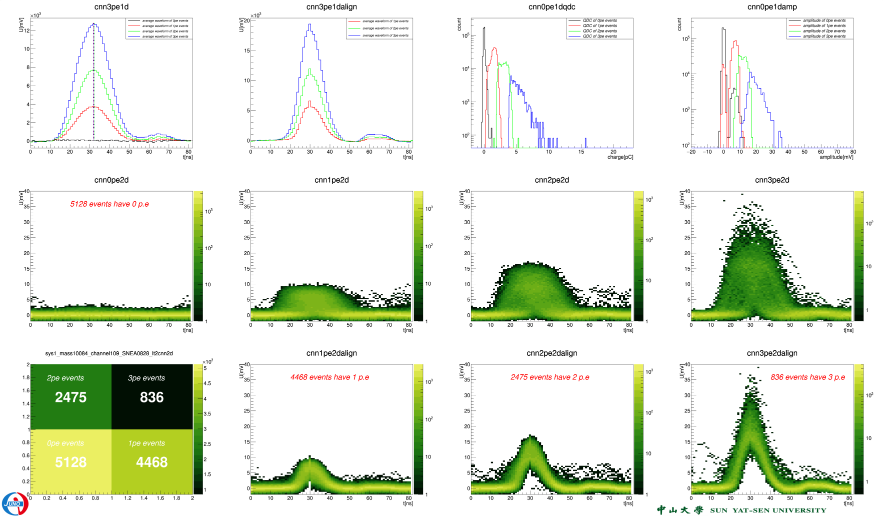


图: HAMAMATSU PMT

results of cnn

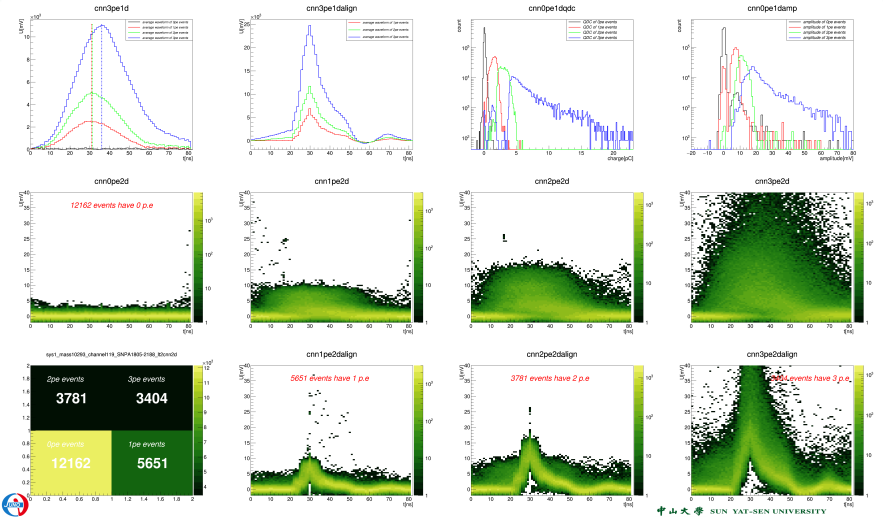


图: NNVT PMT

summary

- PSD by CNN provide a new option for PDE evaluation.
- can achieve *sim*0.95 acuuracy with the traditional method using simple NN.
- much faster than traditionl methods in PDE evaluation.
- CNN can ectract more infromation 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