

# 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

The "long tail" in charge spectrum.

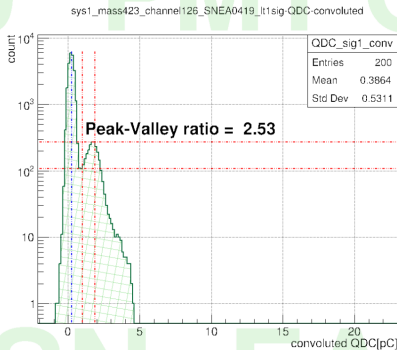


图: SPE of HAMAMATSU PMT

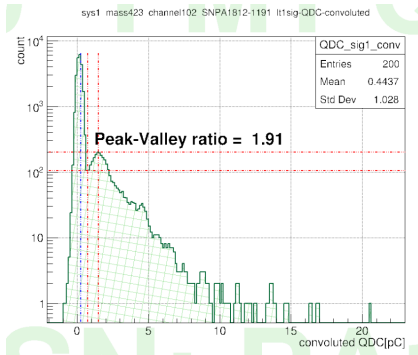


图: SPE of MCP PMT

# photon response characters of MCP PMT

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

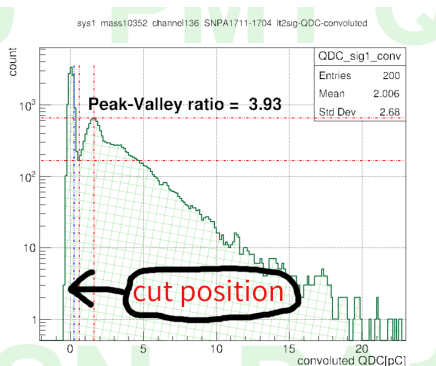


图: "cut" the charge spectrum to count pedestal events

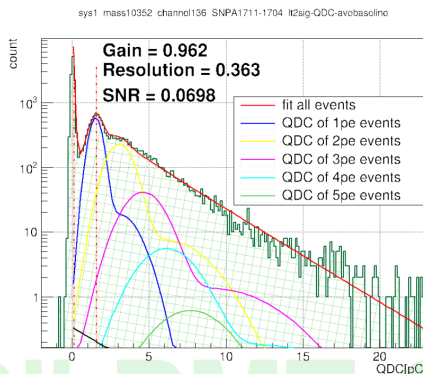


图: fit using a PMT photon response model

# CNN

select the time interval before "trigger window".

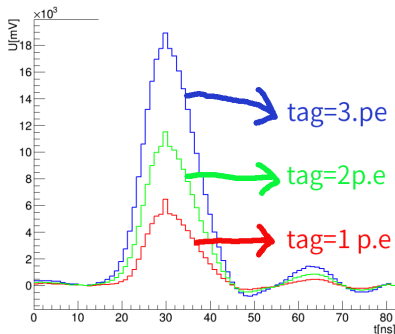


图: tags of typical waveform from CNN

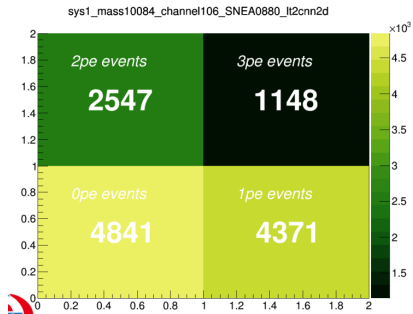
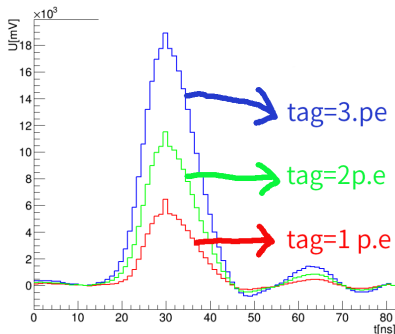



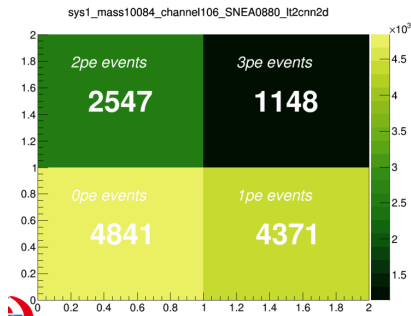
图: classification of events in one test


# 01pe

the 0.1pe case



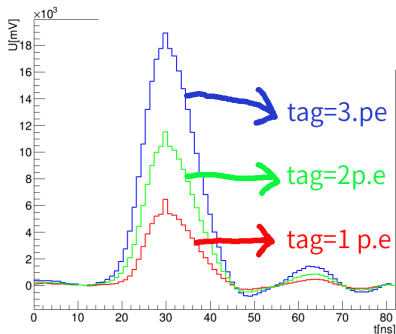
 tags of typical waveform from CNN




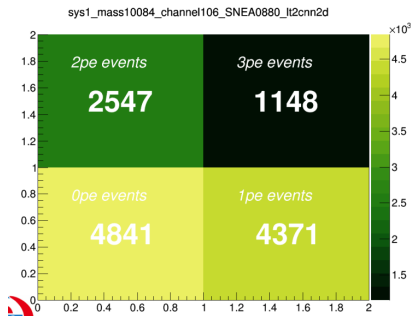
 classification of events in one test


# 01pe

the 1pe case



 tags of typical waveform from CNN



 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  $\mu$  can be acquired by<sup>1</sup>

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

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  $\mu$  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.

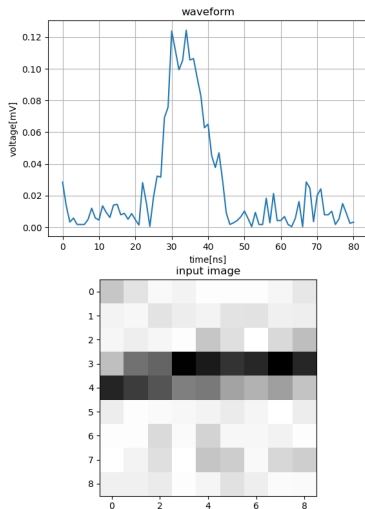
<sup>1</sup>E. H. Bellamy et al /Nucl. Instr. and Meth. in Phys. Res. A 339 (1994) 468-476



# 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  $\simeq 0.95$

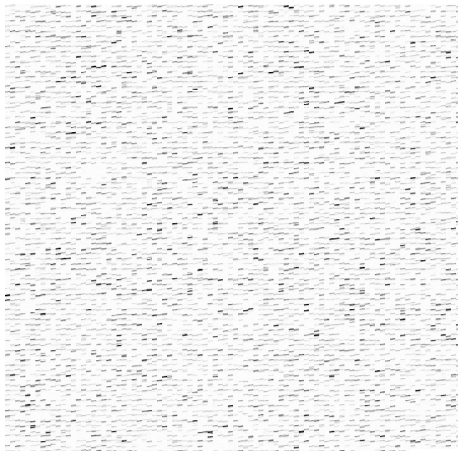
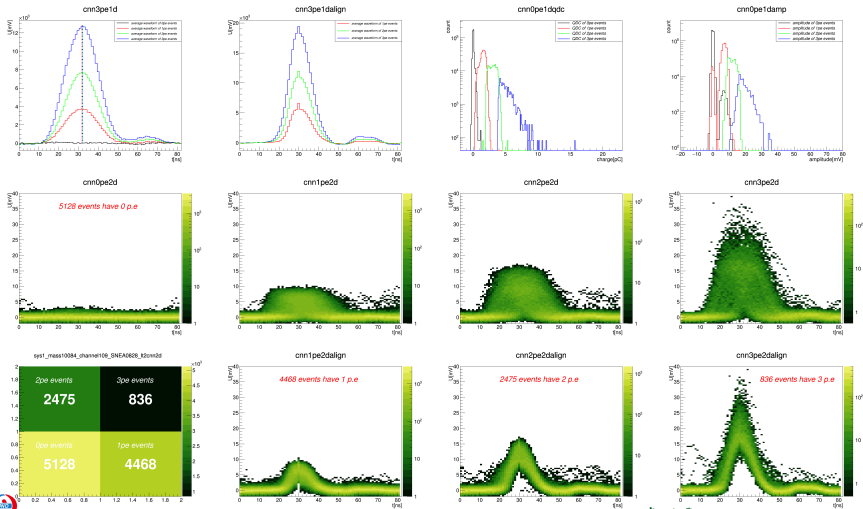


图: input data

# results of cnn



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图: HAMAMATSU PMT

# results of cnn

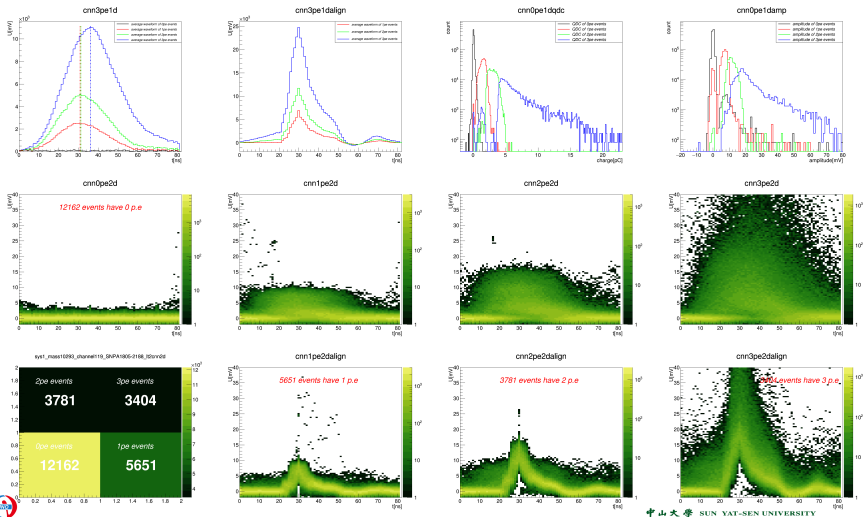


图: NNVT PMT

## 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