

# Photon Response Model of MCP-PMT

– based on the onsite PMT testing data

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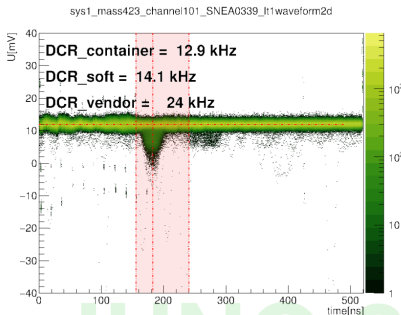


# Outline

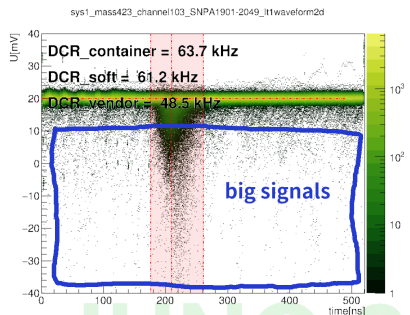
- ① Brief Introduction
- ② traing and test of CNN
- ③ Summary

# the "big signals" of MCP PMT

The typical waveforms <sup>1</sup> of MCP PMT, compared with dynode PMT.



: waveforms of HAMAMATSU PMT



: waveforms of MCP PMT

<sup>1</sup>gain =  $1E7, \mu \simeq 0.1$

# the "big signals" of MCP PMT

The "long tail" in charge spectrum<sup>2</sup> of MCP PMT, compared with dynode PMT.

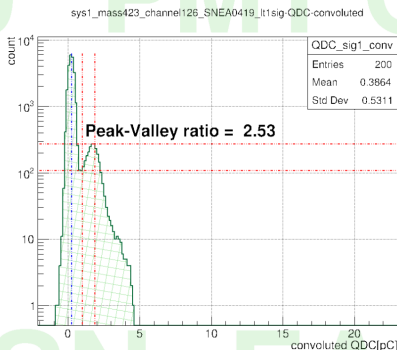


图: SPE of HAMAMATSU PMT

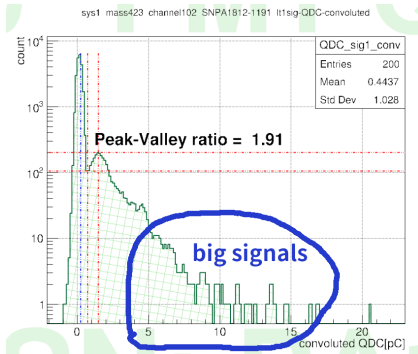


图: SPE of MCP PMT

$$^2\text{gain} = 1\text{E}7, \mu \simeq 0.1$$

# photon response characters of MCP PMT

waveforms of the MCP PMT in 5 different illumination cases:

- 1 dark noise mode
- 2 non-trigger window @1 p.e
- 3  $\mu \simeq 0.1$  p.e
- 4  $\mu \simeq 1$  p.e
- 5  $\mu = \text{multi-p.e}$  [by laser]

# photon response characters of MCP PMT

case 1:[dark noise]

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

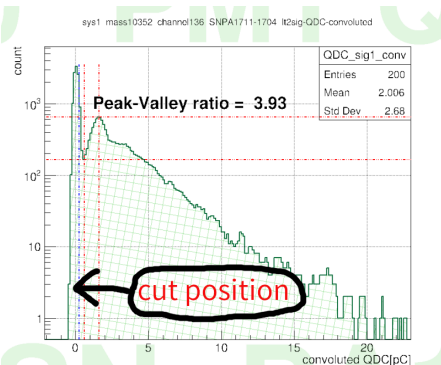


图: "cut" the charge spectrum to count pedestal events

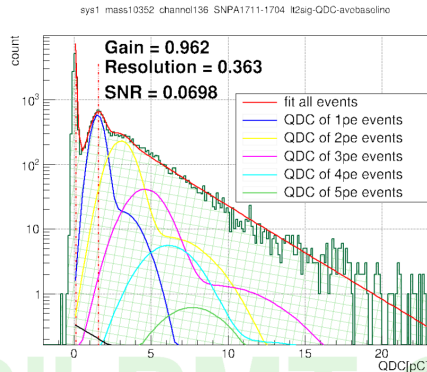


图: fit using a PMT photon response model

# CNN

select the time interval before "trigger window".

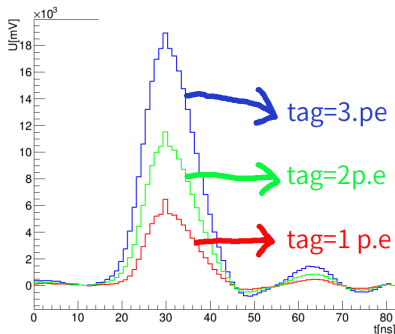


图: tags of typical waveform from CNN

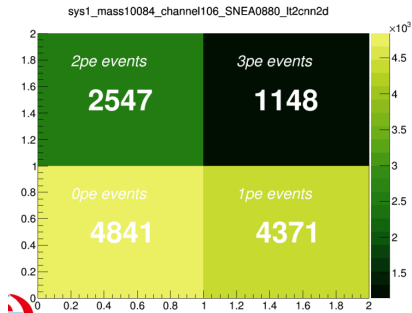


图: classification of events in one test

# 01pe

the 0.1pe case

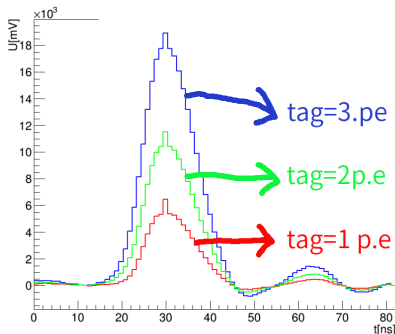


图: tags of typical waveform from CNN

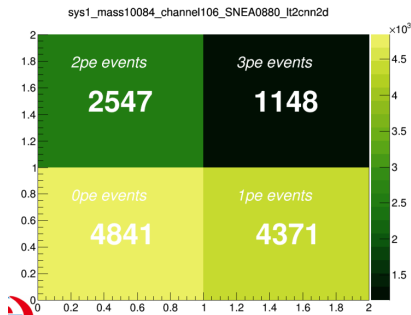


图: classification of events in one test



# 01pe

the 1pe case

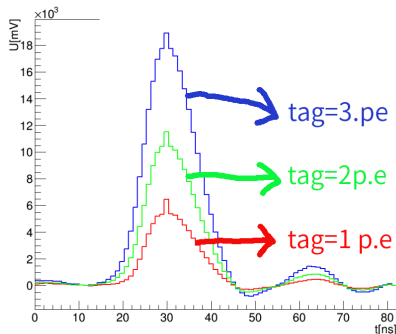


图: tags of typical waveform from CNN

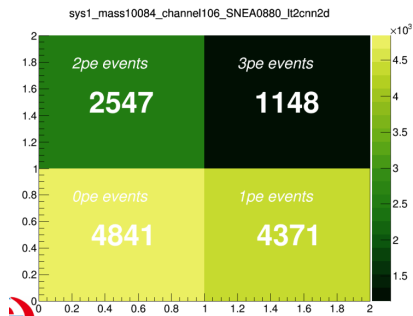


图: classification of events in one test

## the expected photon number

If we do a "cut" is the charge spectrum@0.25 spe, the averager photon number  $\mu$  can be acquired by<sup>3</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 :

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

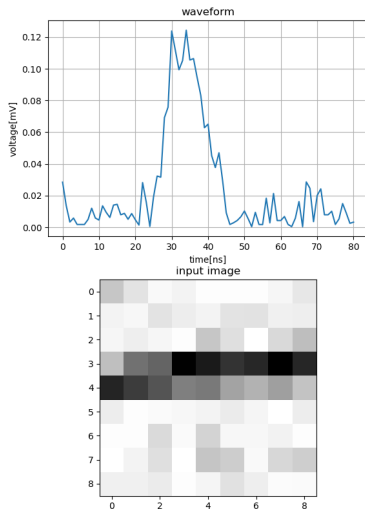
where  $n_N$  is the number of  $N$  p.e events.

<sup>3</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  $\simeq 0.95$

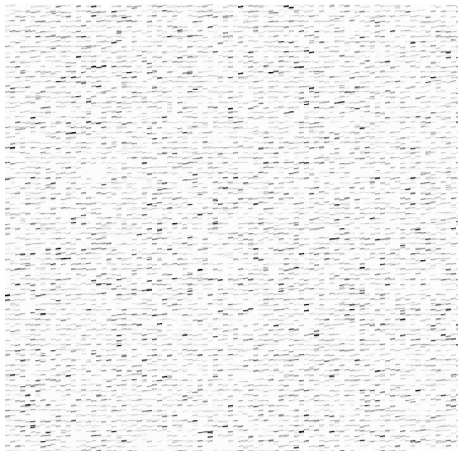
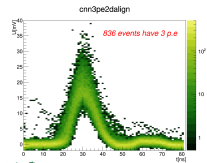
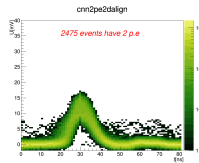
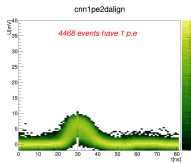
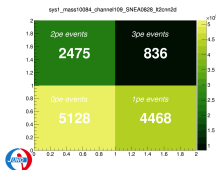
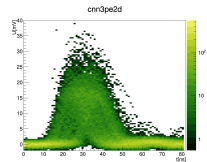
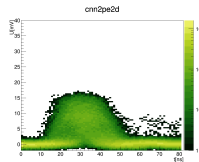
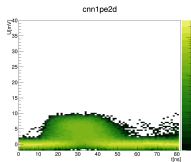
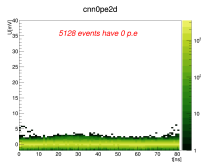
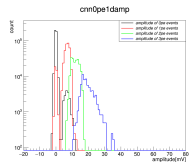
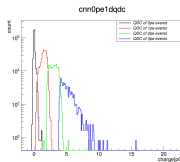
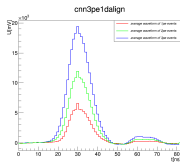
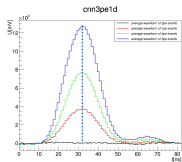


图: input data

# results of cnn



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图: HAMAMATSU PMT

# results of cnn

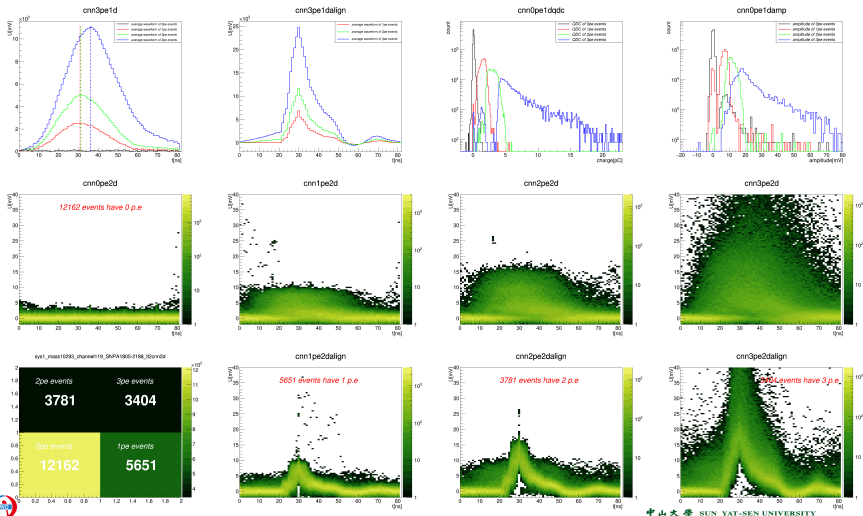


图: NNVT PMT

## 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