

# Photon Response Model of MCP-PMT

– based on the onsite PMT testing data

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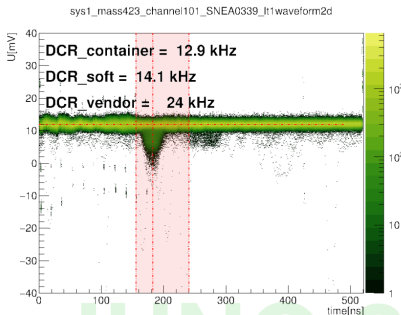


# Outline

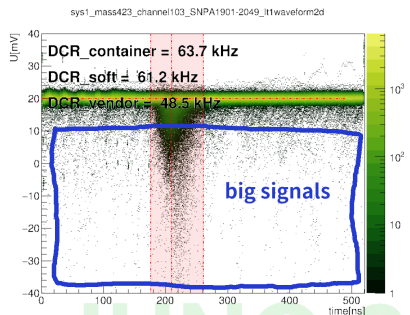
- ① Brief Introduction
- ② traing and test of CNN
- ③ Summary

# 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=  $1\text{E}7, \mu \simeq 0.1$

# the "big signals" of MCP PMT

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

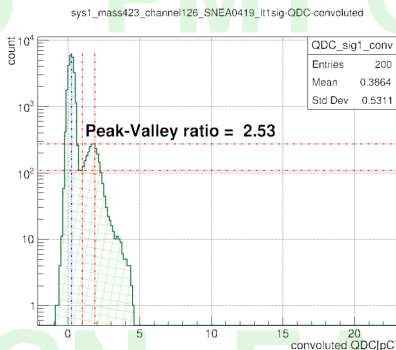


图: SPE of HAMAMATSU PMT

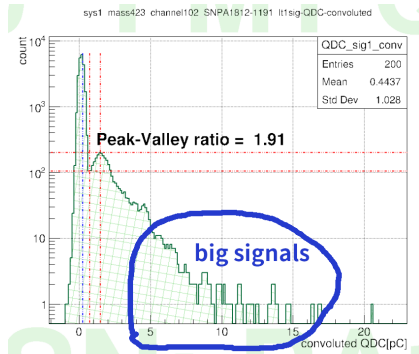


图: SPE of MCP PMT

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

# photon response characters of MCP PMT

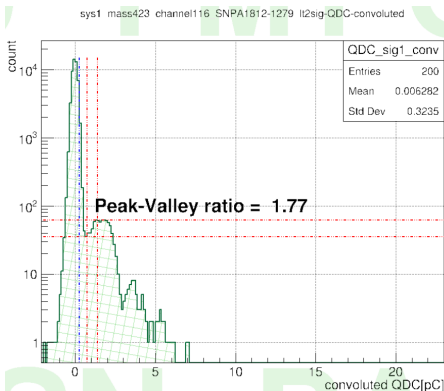
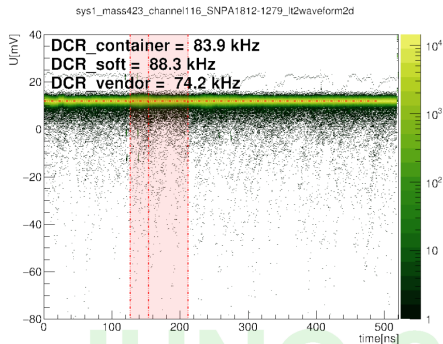
Based on the container testing data, we can acquire waveforms of the MCP PMT in 5 different illumination levels:

- 1 dark noise mode [no light incident]
- 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 =  $10^7$ .  
If we suppose all the dark counts is caused by single thermal electron,  
then those fake multi-p.e events are caused by the magnification of MCP.



# photon response characters of MCP PMT

select the time interval before "trigger window".

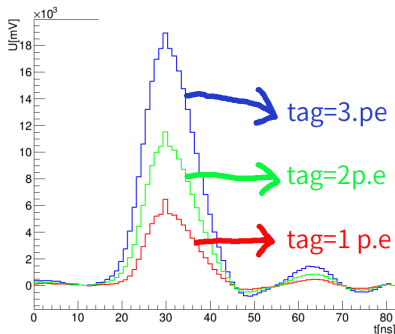


图: tags of typical waveform from CNN

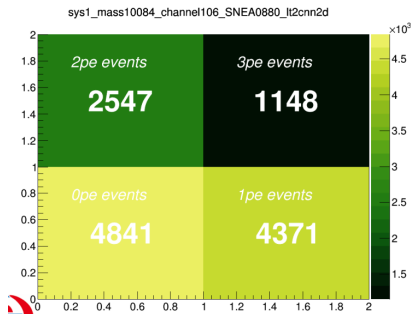


图: classification of events in one test

# photon response characters of MCP PMT @ $\mu \simeq 0.1$

case 3:  $\mu \simeq 0.1$

In the trigger window, we can still see those "big signals" with charge  $> 3\text{p.e.}$

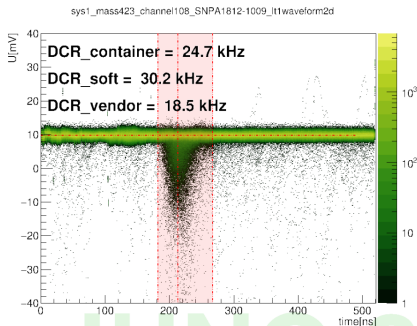


图: waveforms @  $\mu \simeq 0.1$

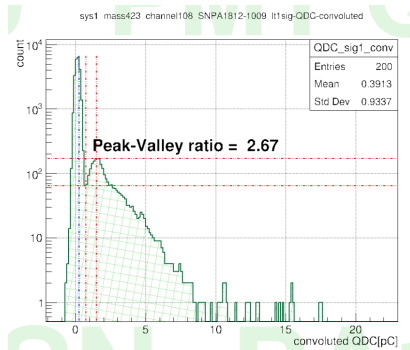


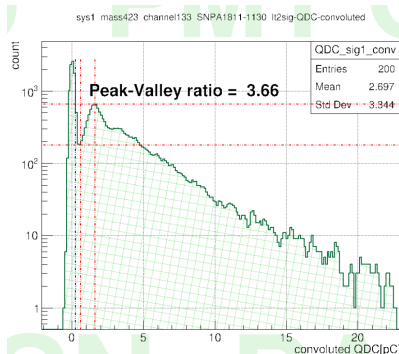
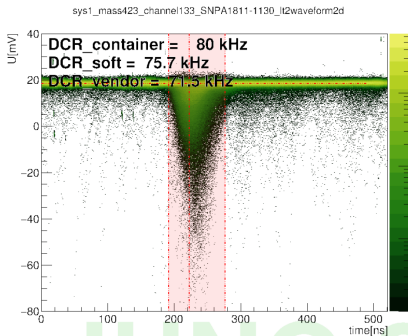
图: QDC @  $\mu \simeq 0.1$



# photon response characters of MCP PMT @ $\mu \simeq 1$

case 4:  $\mu \simeq 1$

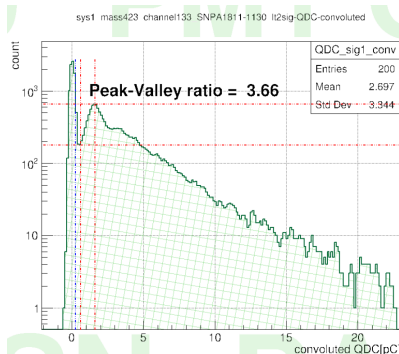
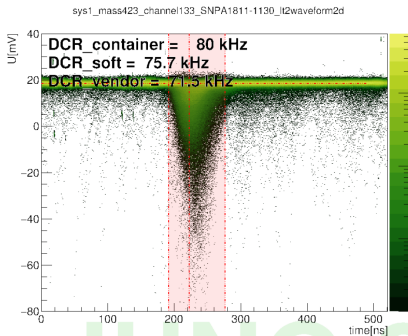
When the light intensity increase to  $\mu \simeq 1$  we can see a continuous "long tail" with charge  $> 5p.e$ ; this is a clear clue that MCP will magnify little part of electrons with abnormal large gain.



# photon response characters of MCP PMT @ $\mu > 2$

case 4:  $\mu > 2p.e.$

When the light intensity increase to  $\mu \simeq 1$  we can see a continuous "long tail" with charge  $> 5p.e.$ ; this is a clear clue that MCP will magnify little part of electrons with abnormal large gain.



## 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 :

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

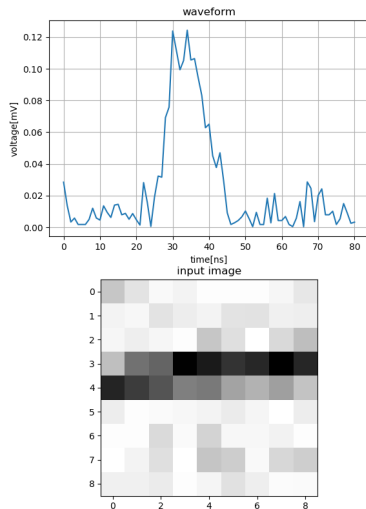
where  $n_N$  is the number of  $N$  p.e events.

<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  $\simeq 0.95$

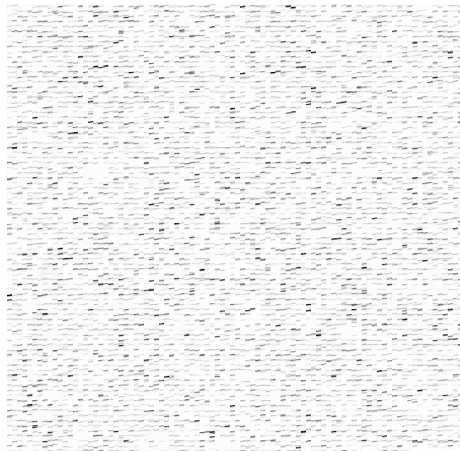
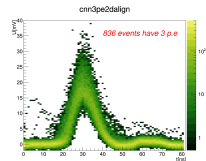
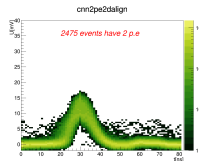
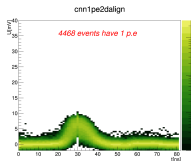
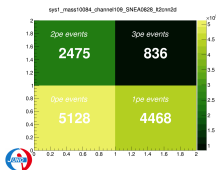
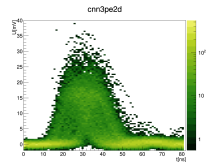
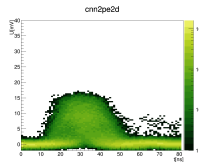
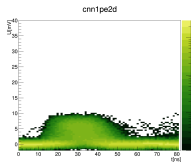
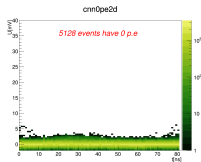
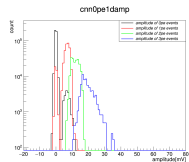
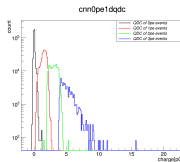
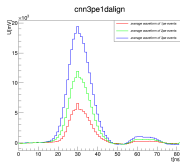
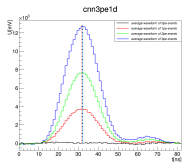


图: input data

# results of cnn



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HAMAMATSU PMT

# results of cnn

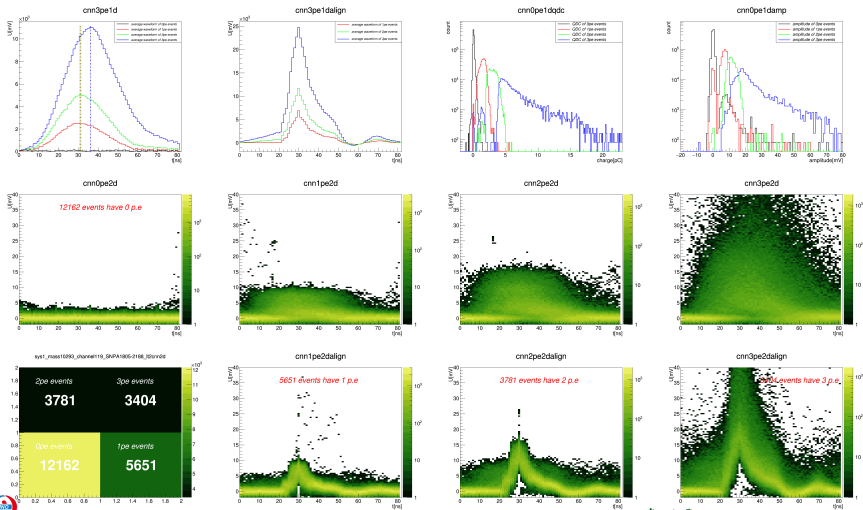


图: NNVT PMT

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## 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