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 [1] of MCP PMT,compared with dynode PMT.

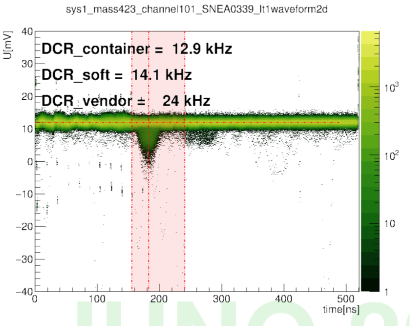


图: waveforms of HAMAMATSU PMT

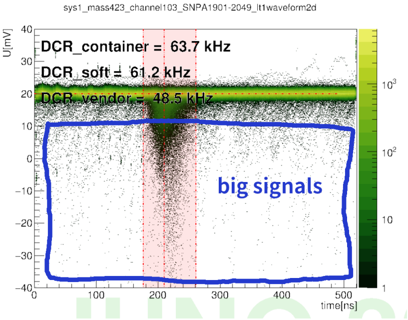


图: waveforms of MCP PMT

[1] gain= 1E7,$\mu \simeq 0.1$

the "big signals" of MCP PMT

The "long tail" in charge spectrum[2] of MCP PMT,compared with dynode PMT.

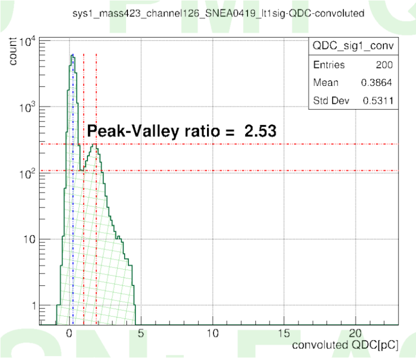


图: SPE of HAMAMATSU PMT

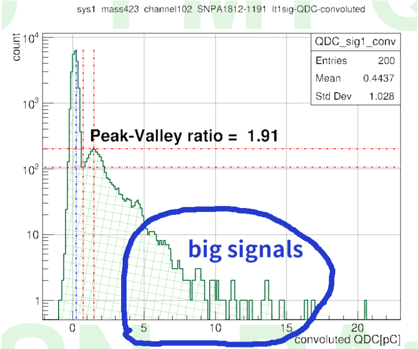


图: SPE of MCP PMT

[2] gain= 1E7,$\mu \simeq 0.1$

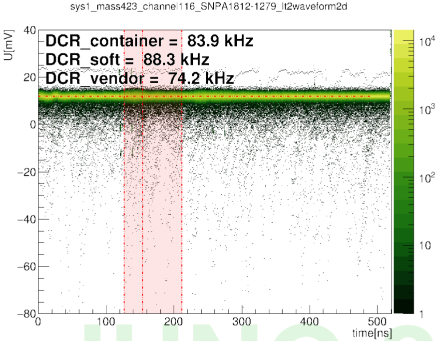
photon response characters of MCP PMT

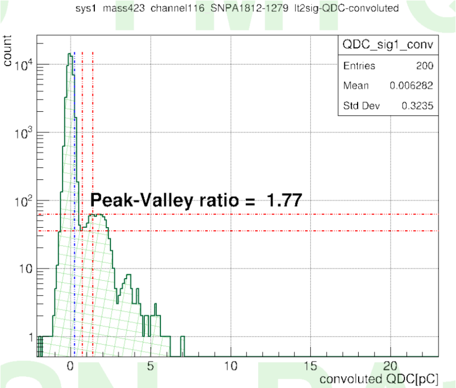
Based on the container testing data, we can acquire wavefroms of the MCP PMT in 5 different illumination levels:

1. dark noise mode [no light incident]
2. non-trigger window @1 p.e
3. $\mu \simeq$0.1 p.e
4. $\mu \simeq$1p.e
5. $\mu =$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".

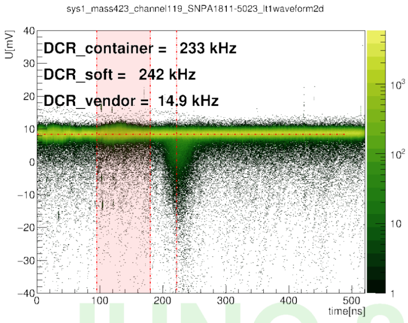


图: tags of typical waveform from CNN

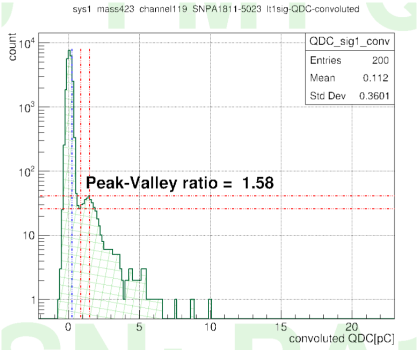


图: classification of events in one test

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 >3p.e.

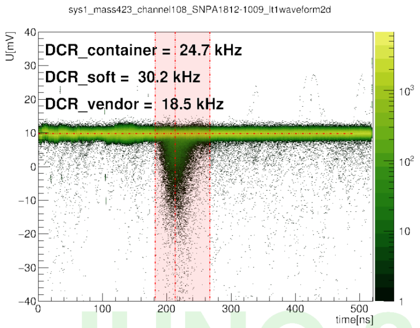


图: waeforms @ $\mu \simeq 0.1$

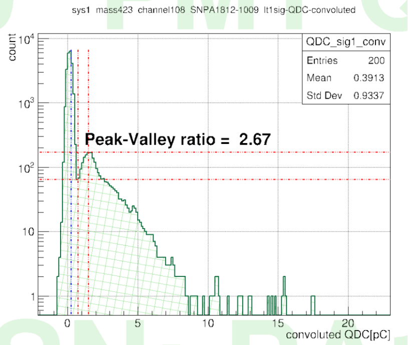
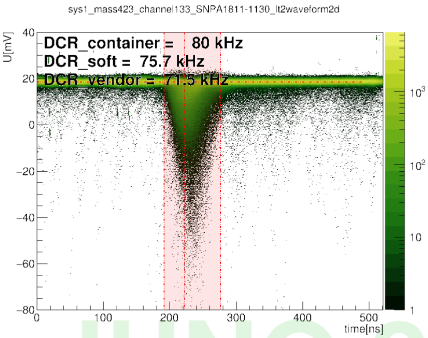
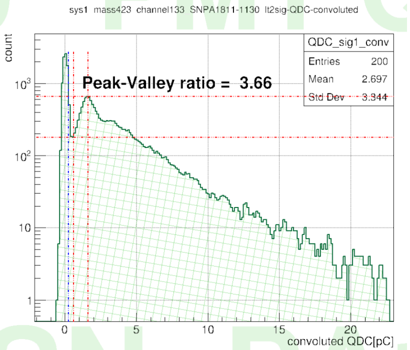


图: QDC @ $\mu \simeq 0.1$

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

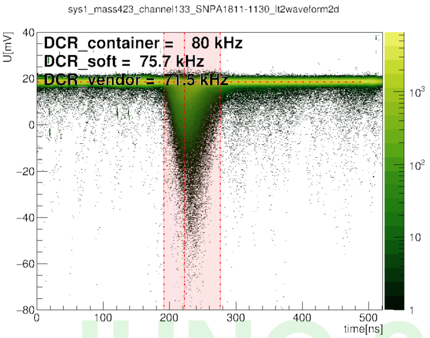
case 4: $\mu \simeq 1$
When the light intensity increase to $\mu \simeq 1$ we can see a continuous "long tail " with charge >5p.e; this is a clear clue that MCP will magnify little part of electrons with abnornal large gain.

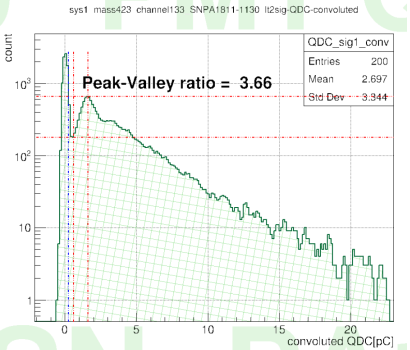




photon response characters of MCP PMT @$\mu > 2$

case 5: $\mu > 2$*p.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 abnornal large gain.





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[3]

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

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 :

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

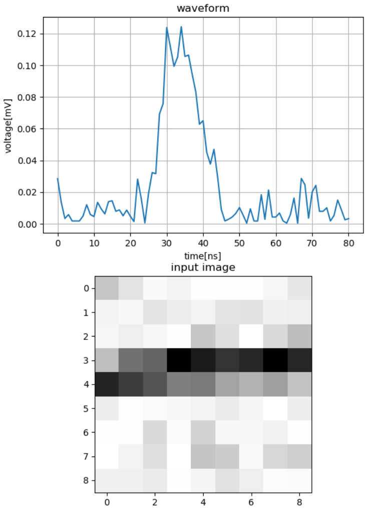
where n_N is the number of N p.e events.

[3] 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$\simeq 0.95$

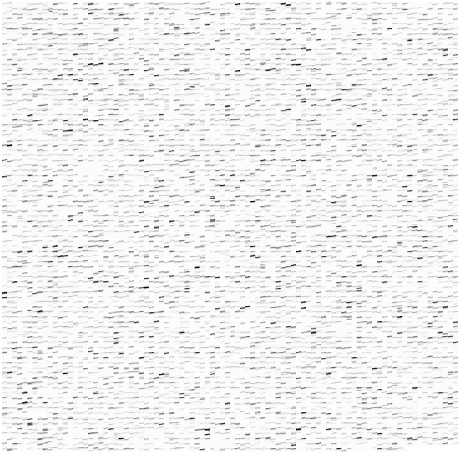


图: input data

results of cnn

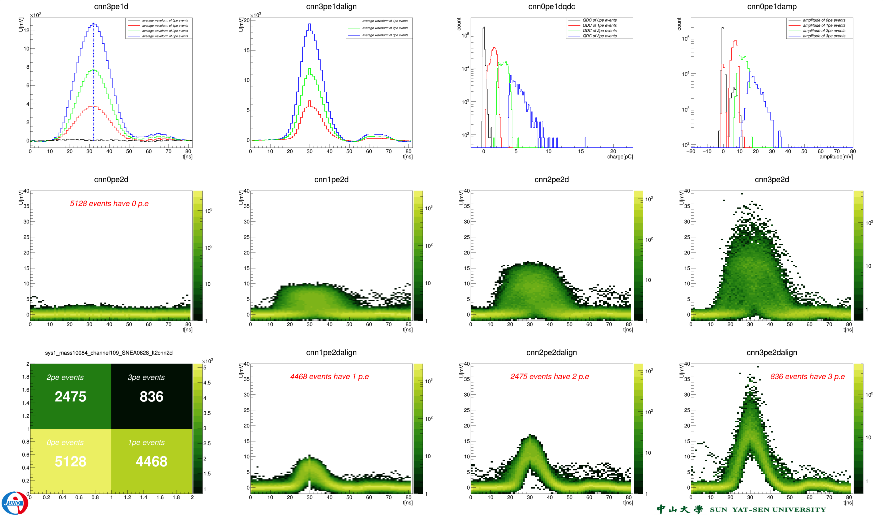


图: HAMAMATSU PMT

results of cnn

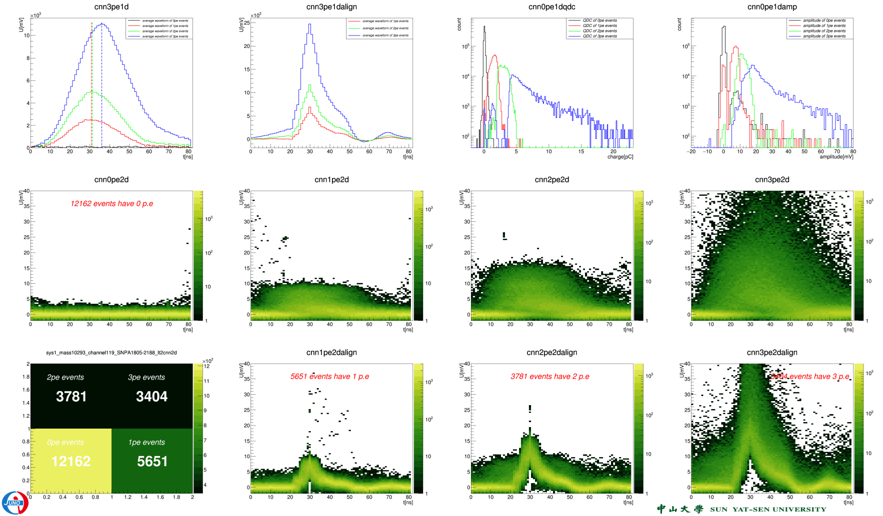


图: NNVT PMT

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