Photon Response Model of MCP-PMT

– based on the onsite PMT testing data

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Outline

the ”big signals” of MCP PMT

The typical waveforms [1] of MCP PMT,compared with dynode PMT.

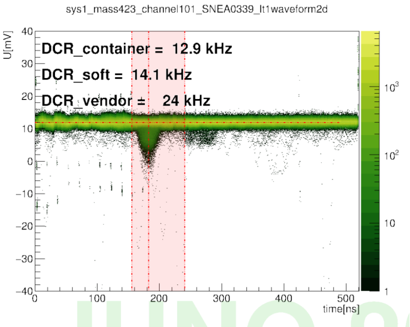


图: waveforms of HAMAMATSU PMT

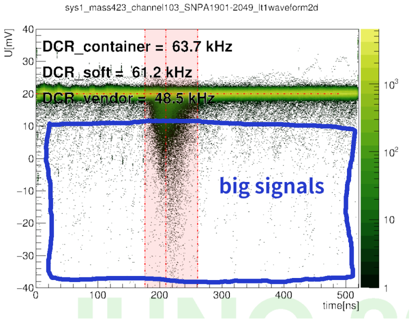


图: waveforms of MCP PMT

[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.

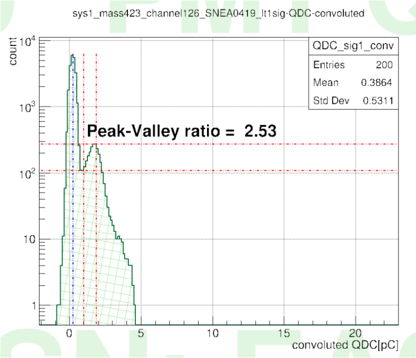


图: SPE of HAMAMATSU PMT

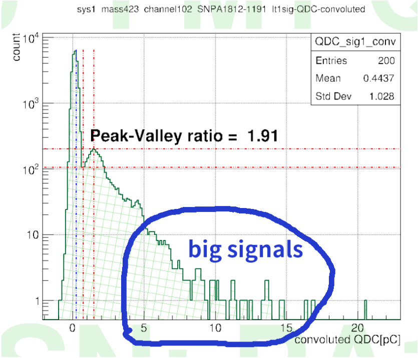


图: SPE of MCP PMT

[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:

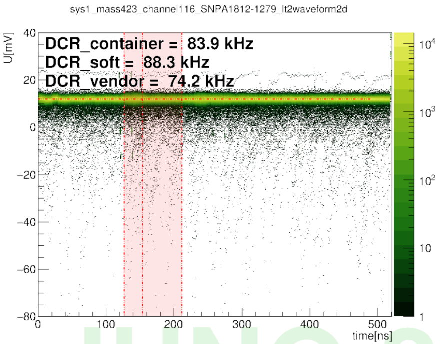
1. dark noise mode [no light incident]
2. non-trigger window @1 p.e
3. $\mu \simeq$0.1 p.e
4. $\mu \simeq$1p.e
5. $\mu =$multi-p.e [by laser]

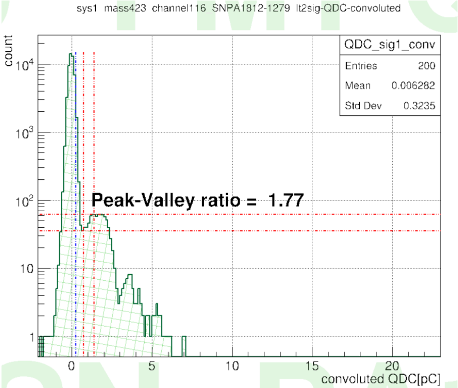
photon response characters of MCP PMT

case 1:[dark noise]

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

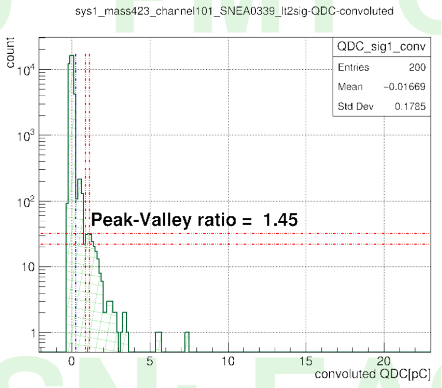
If we suppose all the dark counts is caused by single thermal electron, then those fake multi-p.e events are caused by the magnification of MCP.

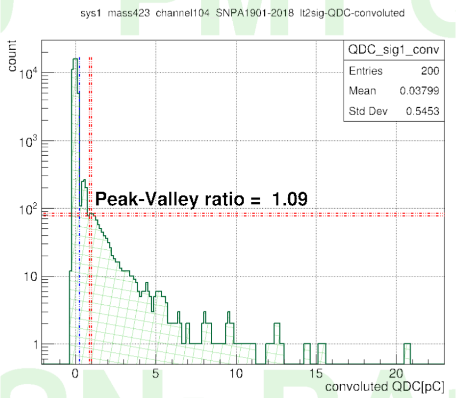




photon response characters of MCP PMT

case 1:[dark noise]
The typical charge spectrum of HAMAMATSU and MCP PMT@gain $=10^7$, with time window 521ns.





photon response characters of MCP PMT

select the time interval before ”trigger window”,we can see similar QDC spectrum with dark noise case.

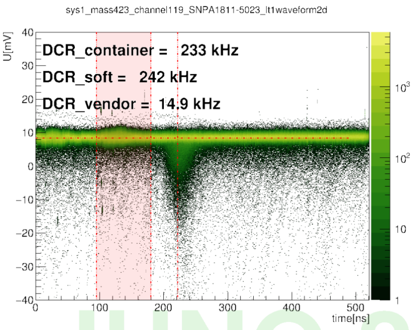


图: slect non-trigger ROI

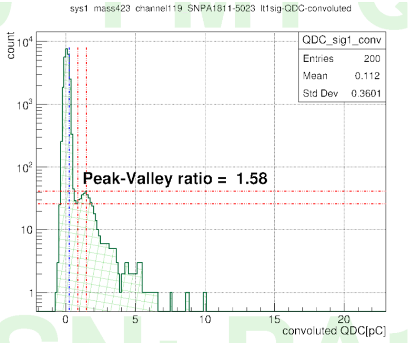


图: QDC of non-trigger ROI

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.

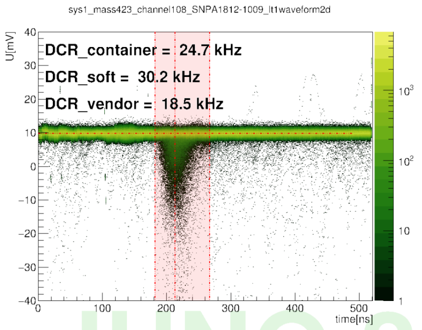


图: waeforms @ $\mu \simeq 0.1$

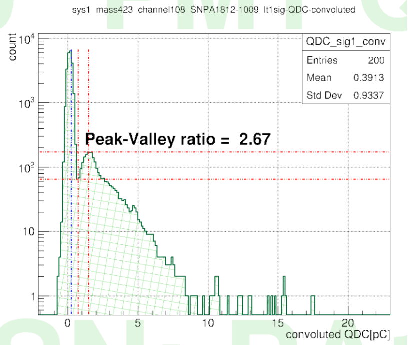
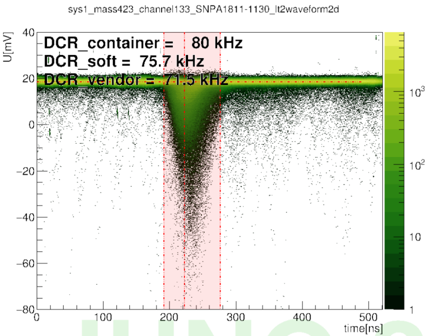
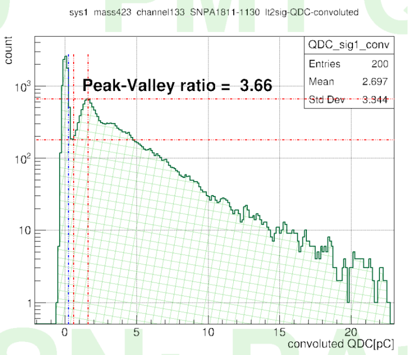


图: QDC @ $\mu \simeq 0.1$

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: $\mu > 2p.e.$
with $\mu = 3.48$, we can get signals with almost > 15p.e.

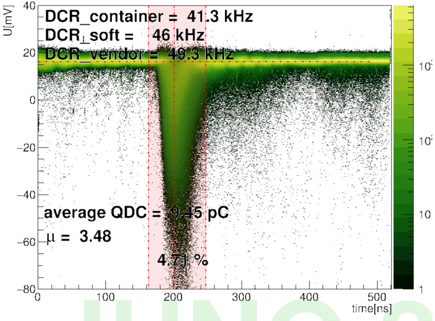


图: waeforms @ $\mu \simeq 1$

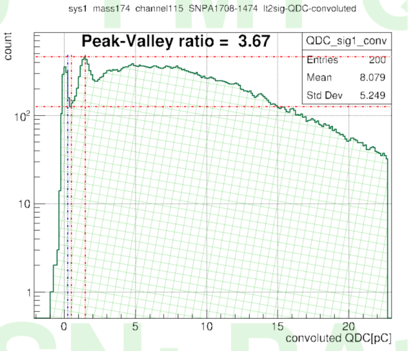


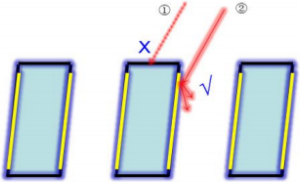
图: waeforms @ $\mu \simeq 1$

what we found

To conclude the above information, we find:

- The Gain of MCP-PMT is not stable enough, It has small propobilty to magnify single p.e to unreasonable large charge.
- the charge of ”big signals” is proportional to incident light.the more incident phtons, the more ”bgi signals”. So, the charge of ”bigsignals” is closely related to the light intensty rather and a fix charge sum.

possible reason



CE = 70%

The p.e. into the channel directly ~70%

change

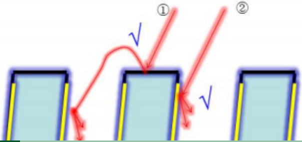
The Diameter of the MCP: 33mm; 50mm;

The Diameter of the Hole: 6um; 8um; 10um; 12um;

The Inclined Angle: 0°; 8°; 12°;

The Open Area Ratio: 60%; 77%;

The Special Film by ALD for the same SEE material ……



CE = 100%

The p.e. into the channel directly ~70%

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 :

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

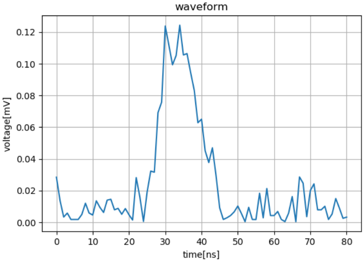
where n_N is the number of N p.e events.

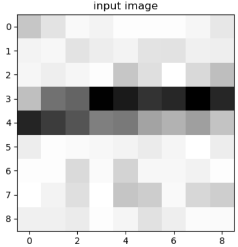
[3] E. H. Bellamy et al /Nucl. Instr. and Meth. m Phys . Res. A 339 (1994) 468-476

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$\simeq 0.95$

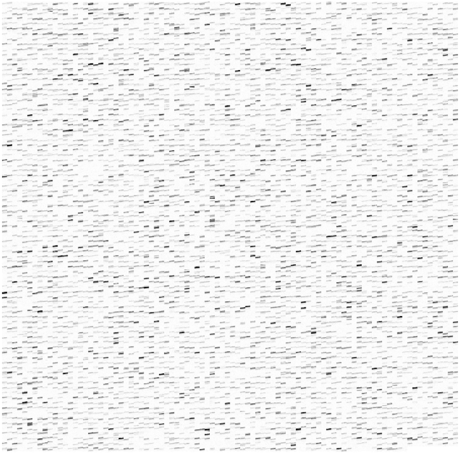


图: input data

results of cnn

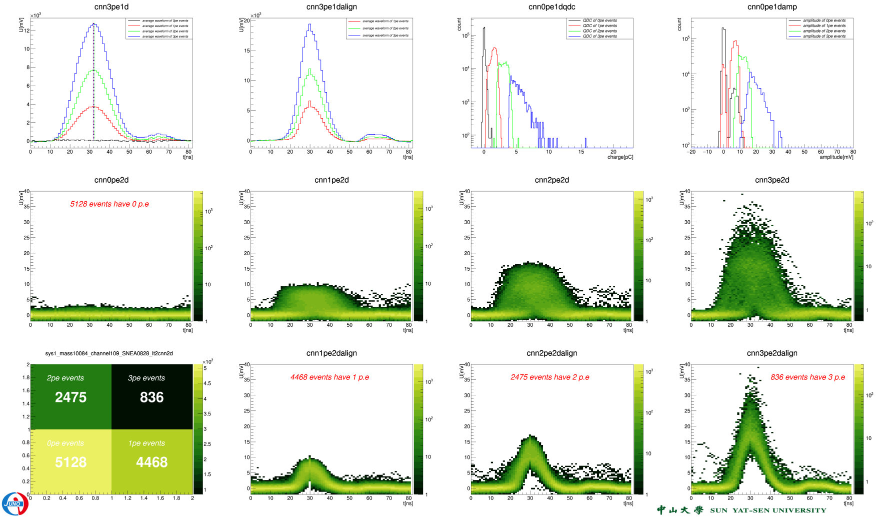


图: HAMAMATSU PMT

results of cnn

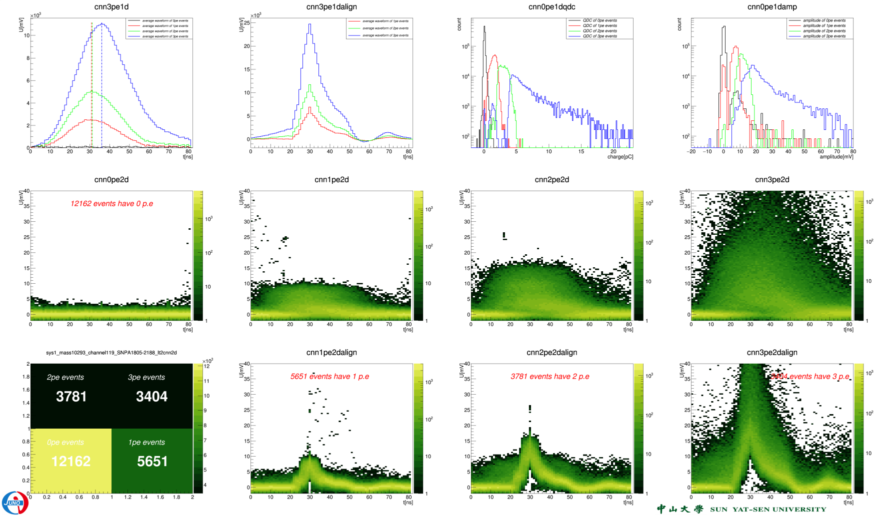


图: NNVT PMT

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