



中国科学院高能物理研究所  
Institute of High Energy Physics  
Chinese Academy of Sciences

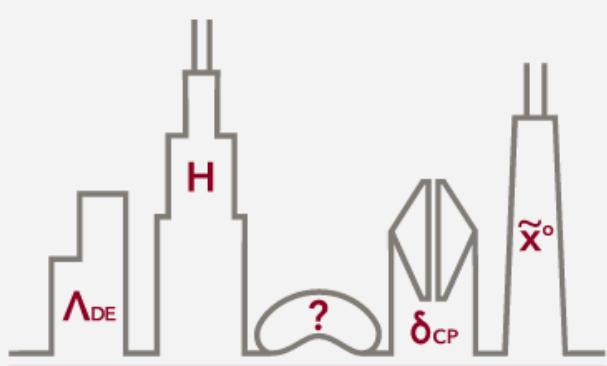


The Chinese Academy  
of Sciences

# The 20 inch MCP-PMT R&D in China

Sen Qian, Shulin Liu , On Behalf of the Workgroup

Institute of High energy Physics, Chinese Academy of Science  
[qians@ihep.ac.cn](mailto:qians@ihep.ac.cn)

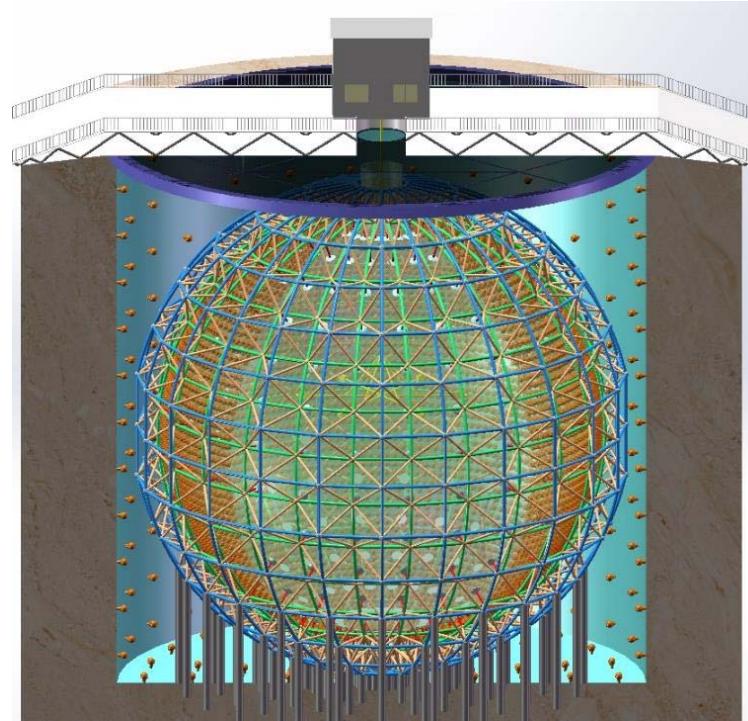


**ICHEP2016CHICAGO**

**38th INTERNATIONAL CONFERENCE  
ON HIGH ENERGY PHYSICS**

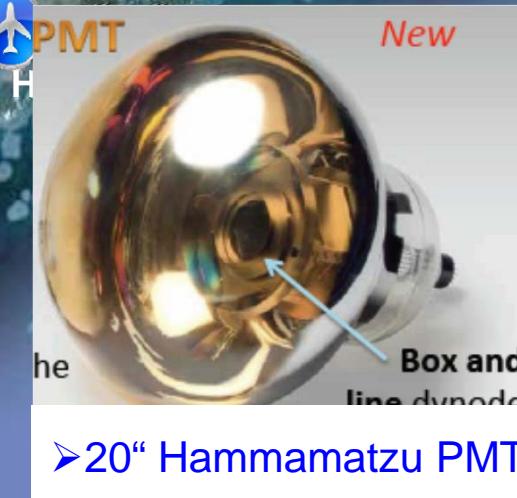
AUGUST 3 - 10, 2016  
CHICAGO

## ➤ 1. The JUNO and MCP-PMT



### ◆ High QE 20" PMTs for JUNO:

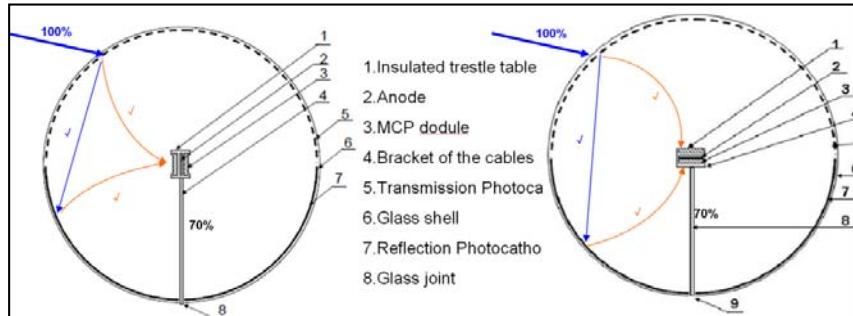
- ⇒ Hammamatsu PMT with SBA photocathode
- ⇒ A new design using MCP:  $4\pi$  collection



**Requirement:** High QE 20 inch PMT; Good SPE detection capability; Wide dynamic range; Low radioactive background; More than 20 years lifetime; Can withstand 0.4MPa Pressure; > 20000 pieces;

## ➤ 2. The new design of the MCP-PMT prototypes;

The researchers (Microchannel-Plate-Based Large Area Photomultiplier Collaboration (**MLAPC**) in IHEP designed a new type of MCP-PMT for **JUNO** (Jiangmen Underground Neutrino Observatory)



The small MCP unit instead of the large Dynode, the transmission and reflection photocathode were assembled in the same glass shell to form nearly  $4\pi$  photocathode effective area to enhance the efficiency of the photoelectron detecting.

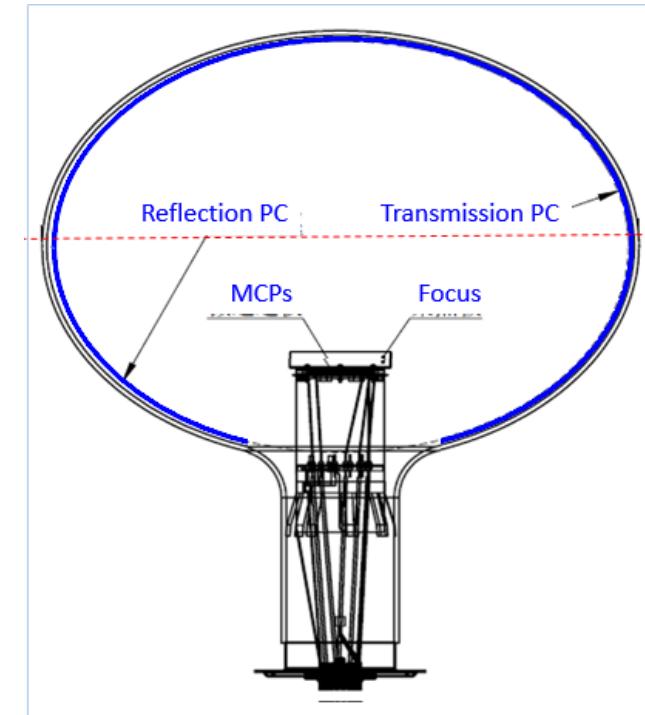
- 2009: the design of the MCP-PMT;
- 2010~2011: 5" MCP-PMT prototype without SPE;
- 2012: 8" MCP-PMT prototype without SPE;
- 2013: 8" prototypes with normal performance;
- 2014: 20" prototypes with normal performance;

QE ~ 25%@410nm; CE ~ 60%; P/V of SPE > 2.0;

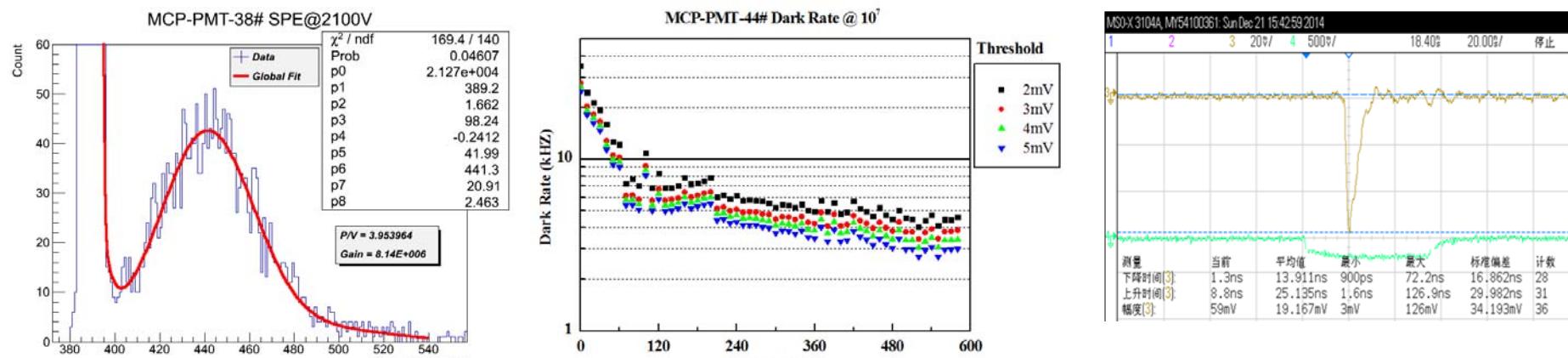
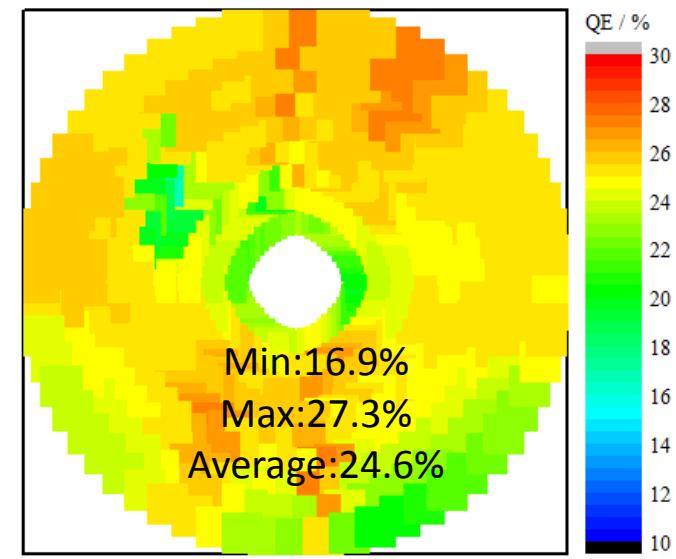
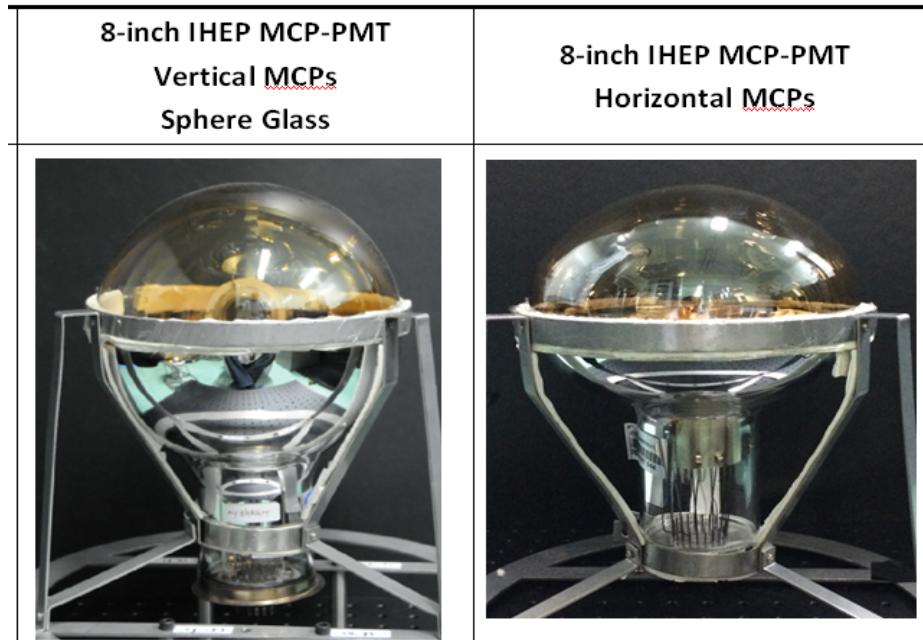
- 2015: 20" prototypes with HDE performance;

QE ~ 26%@410nm; CE ~ 100%; P/V of SPE > 3.0;

- 2016: for the high QE improvement.

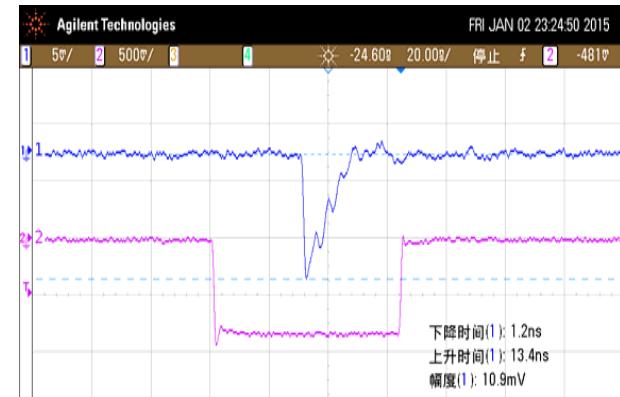
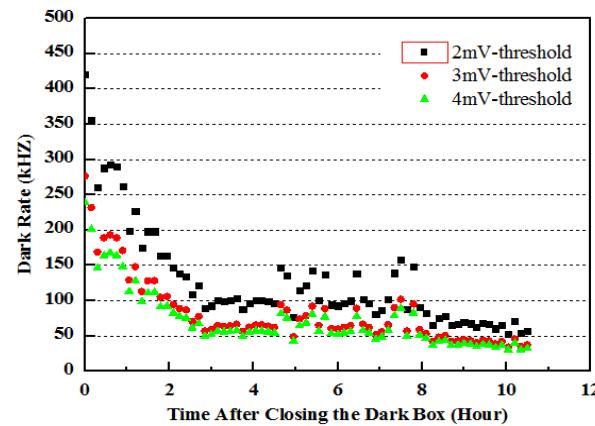
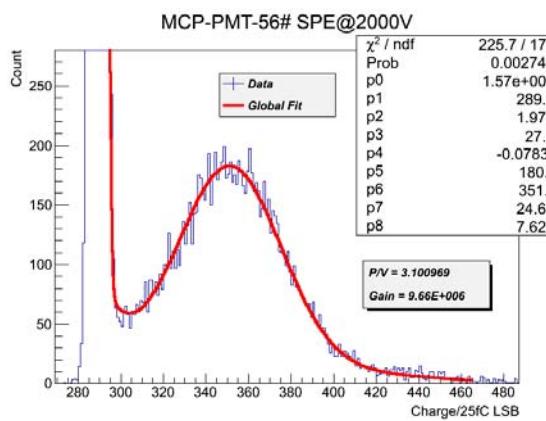
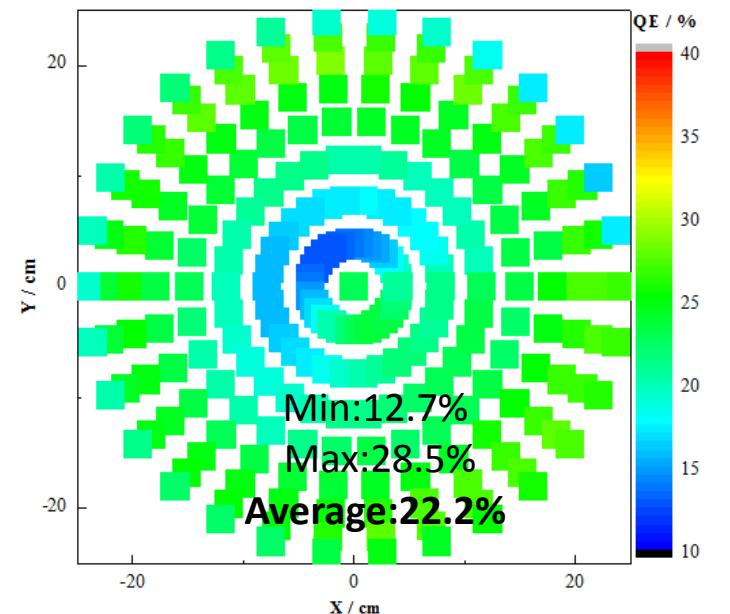
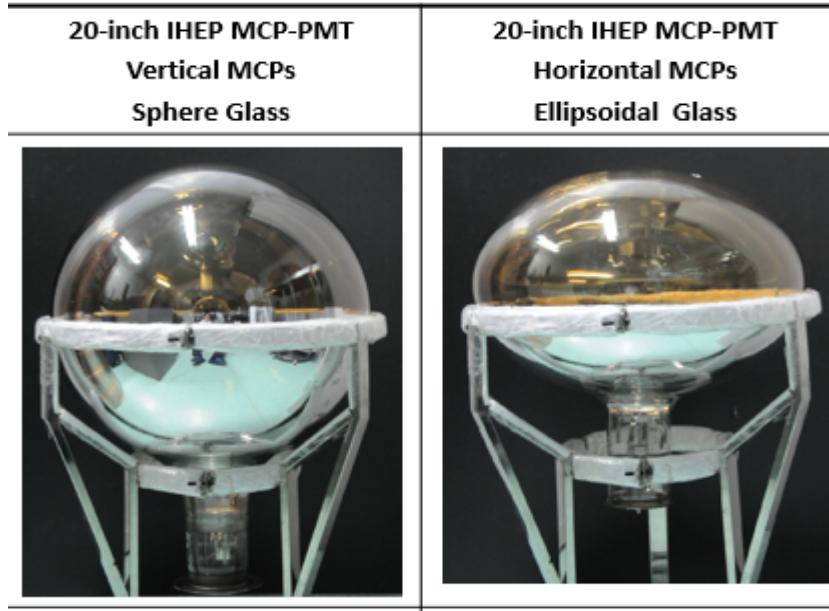


## ➤ 3.1 8"prototypes with normal performance--2013



HV	Gain	P/V	Rise Time	Fall Time	Dark rate @1E7 Gain(0.25PE)
2100V	~1E7	~4	~1.3ns	~8.8ns	~3kHz

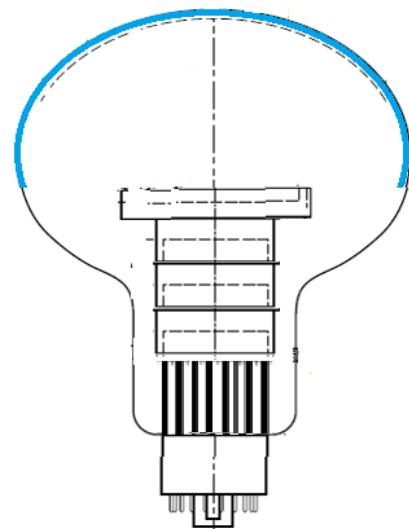
## ➤ 3.2 20"prototypes with normal performance--2014



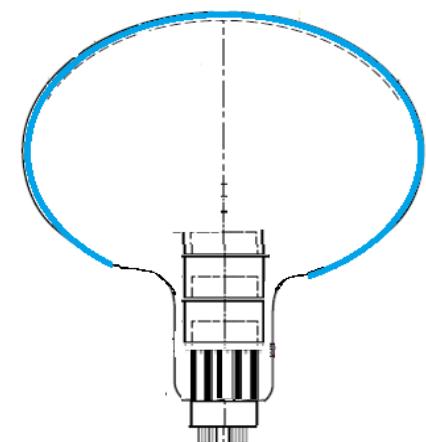
HV	Gain	P/V	Rise Time	Fall Time	Dark rate @1E7 Gain(0.25PE)
2000V	~1E7	~3	~1.2ns	~15ns	~50kHz

## ➤ 4. The High PDE MCP-PMT--2015

20-inch Hamamatus PMT-Dynode Ellipsoidal Glass

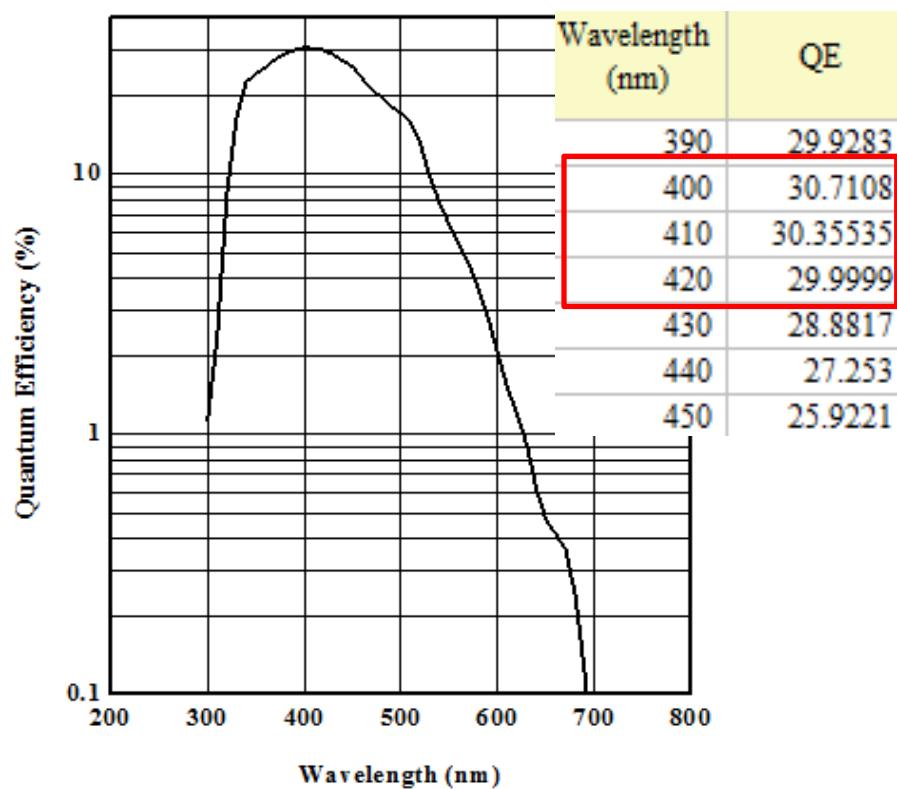


20-inch IHEP-MCP-PMT-Ellipsoidal Glass

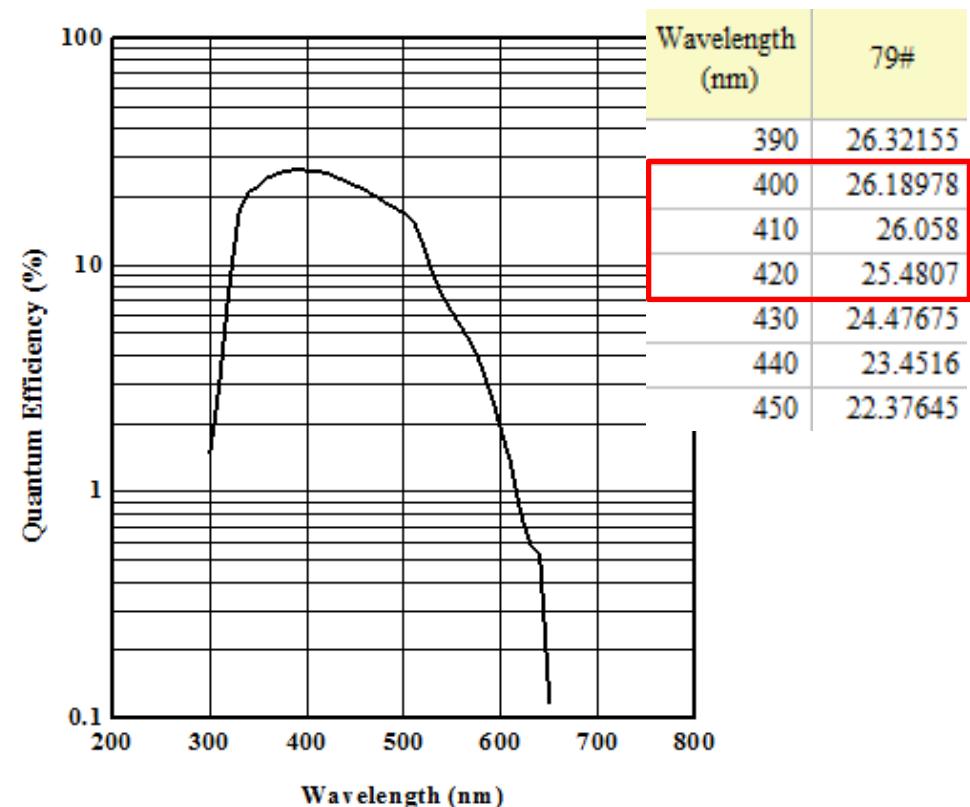


## ➤ 4.1 The QE of the Photocathode

20 inch Prototype	R12860	MCP-PMT
QE@410nm	~30%	~26%



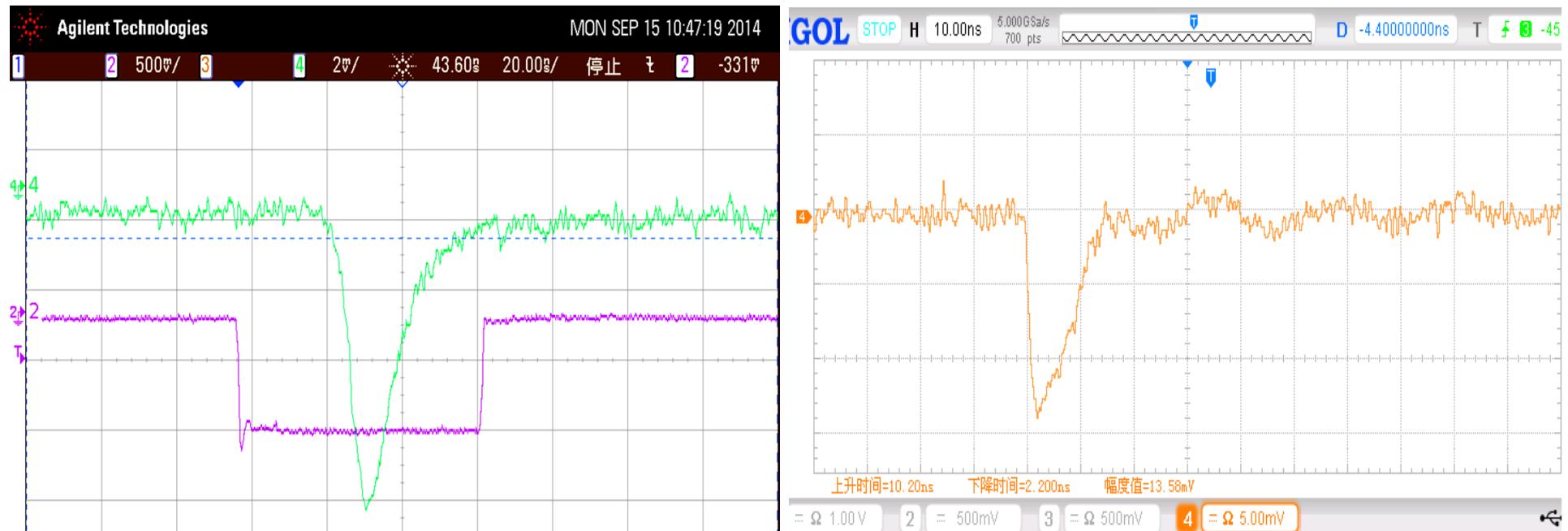
Hamamatsu R12860



MCP-PMT

## ➤ 4.2 Waveform of the Prototype

	Rise Time	Fall Time
R12860	~6.7ns	~17.7ns
MCP-PMT	~2.2ns	~10.2ns

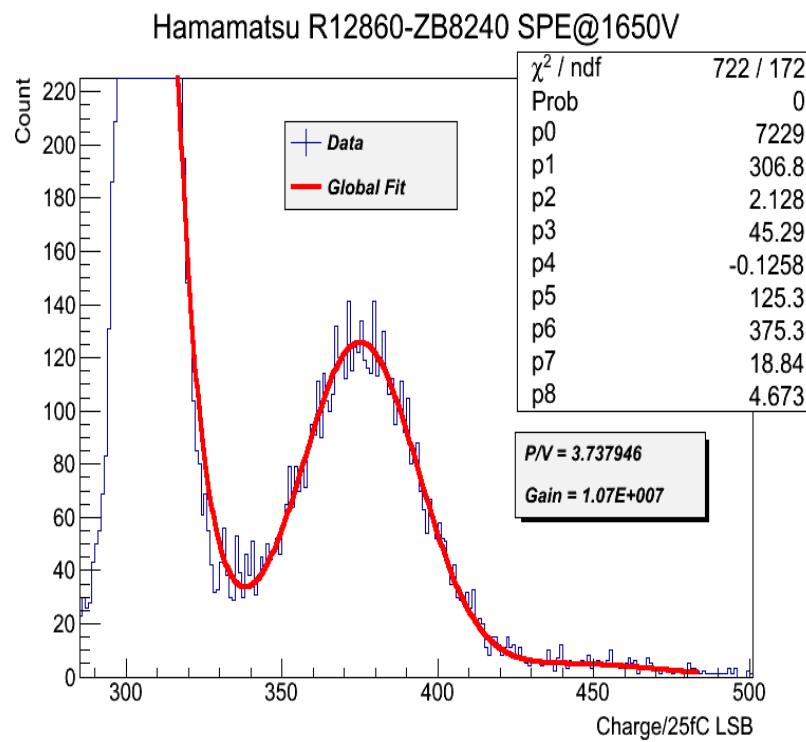


Hamamatsu R12860

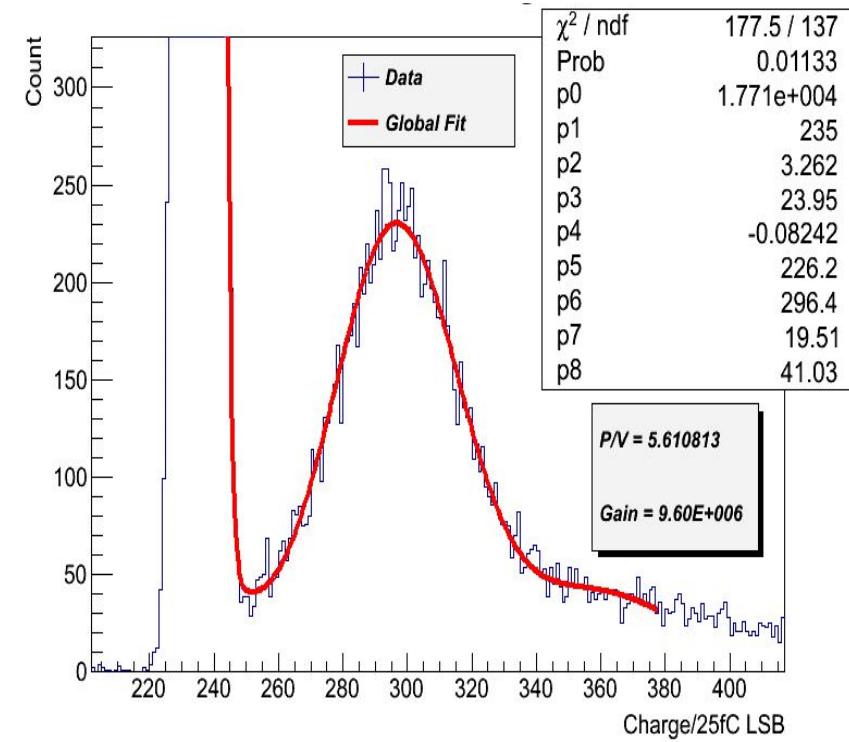
MCP-PMT

## ➤ 4.3. The SPE of the Prototype;

	HV	Gain	P/V
R12860	1650V	~1.1E7	~3.7
MCP-PMT	1930V	~9.6E6	~5.6



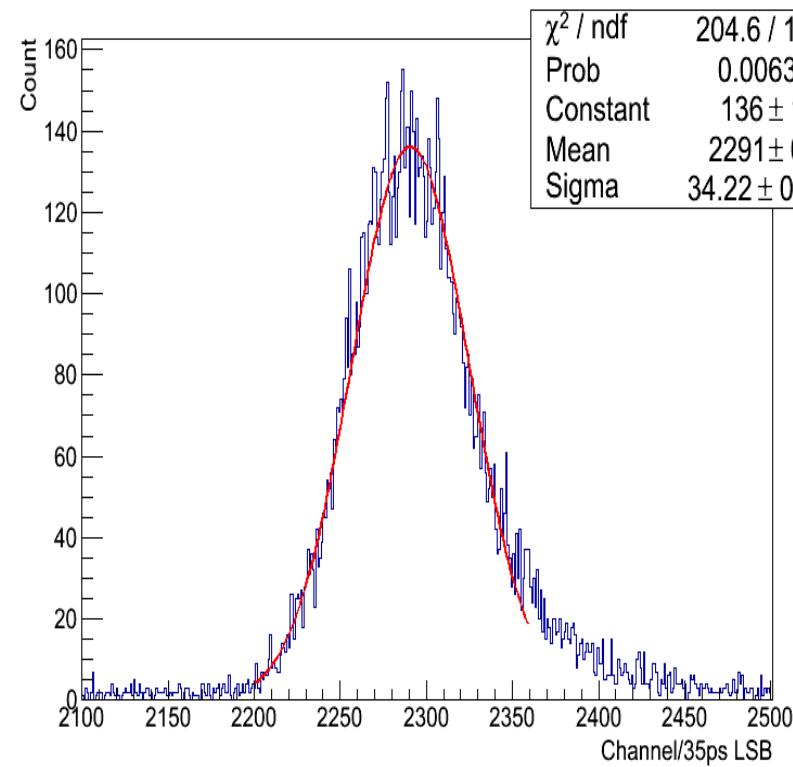
Hamamatsu R12860



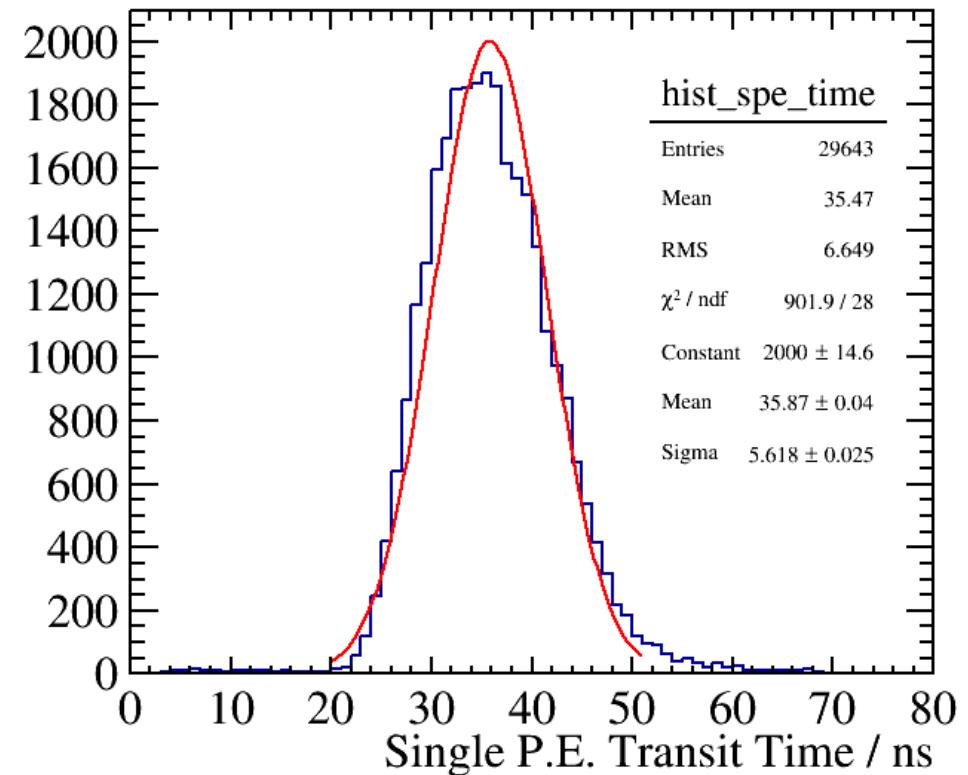
MCP-PMT

## ➤ 4.4. The TTS of the Prototype;

	HV	Gain	TTS @ top center
R12860	1650V	~1.1E7	~2.8ns
MCP-PMT	1930V	~9.6E6	~12ns



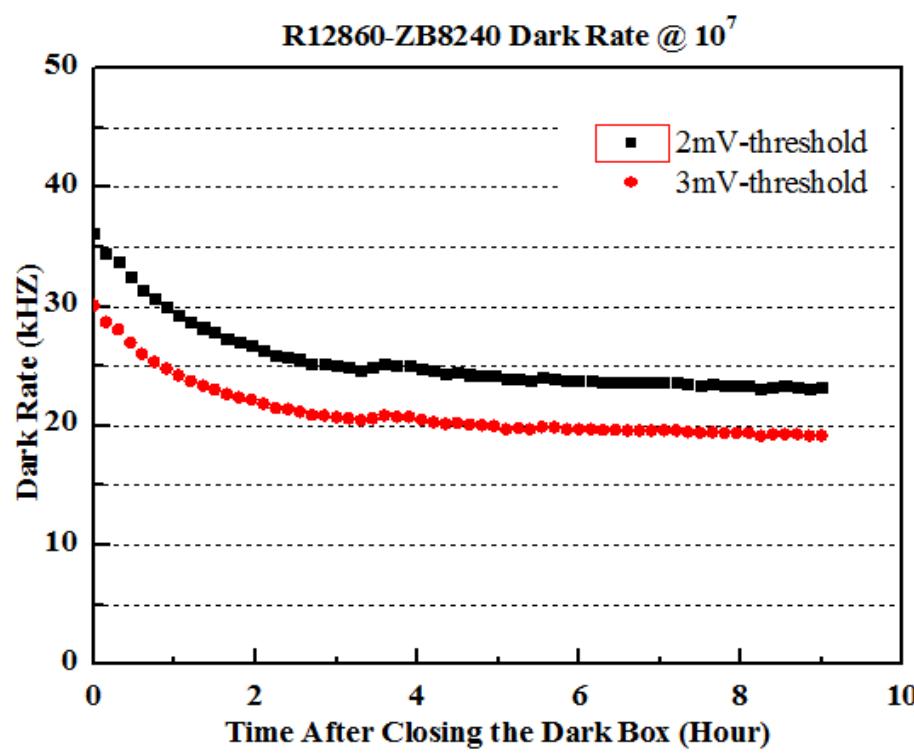
Hamamatsu R12860



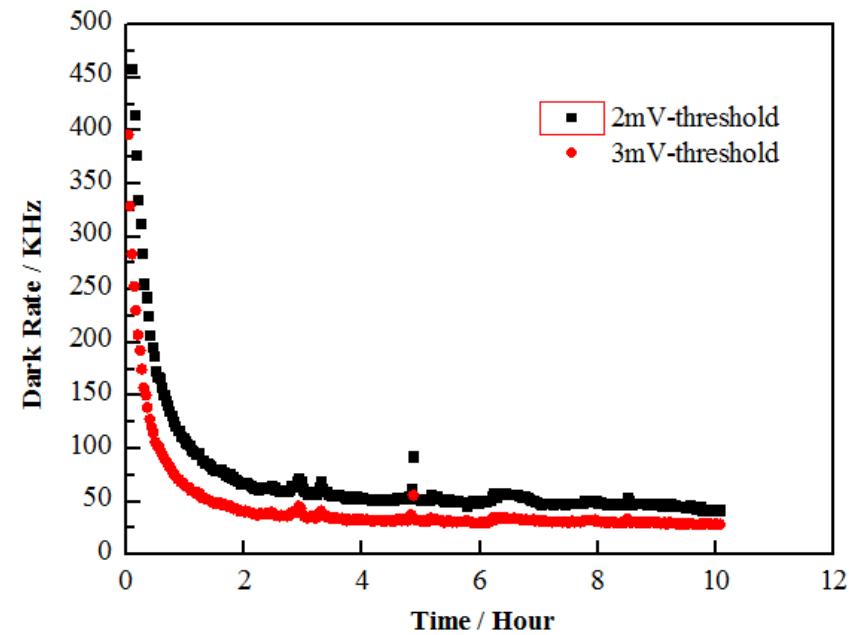
MCP-PMT

## ➤ 4.5. The Dark count of the Prototype;

	HV	Gain	Dark rate @ 0.25PE
R12860	1650V	~1.1E7	~25kHz
MCP-PMT	1930V	~9.6E6	~ 30kHz



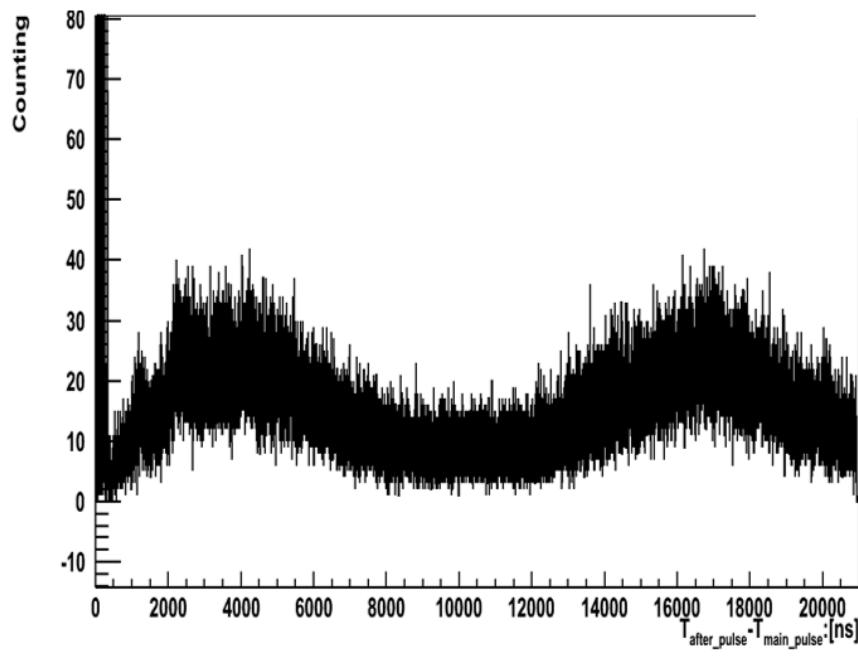
Hamamatsu R12860



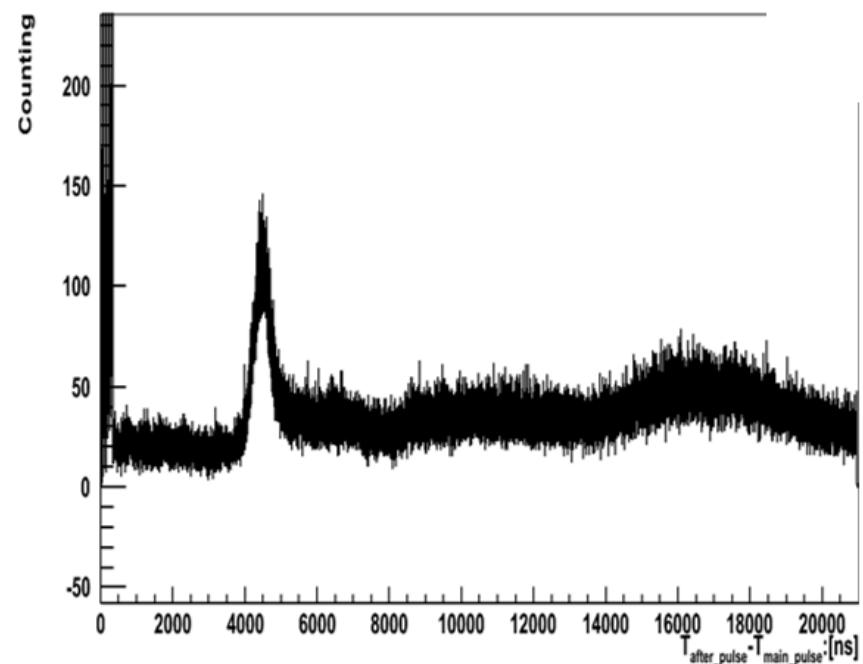
MCP-PMT

## ➤ 4.6. The After Pulse Rate of the Prototype

	Time distribution	After Pulse Rate
R12860	4us, 17us	10%
MCP-PMT	4.5us	2.5%



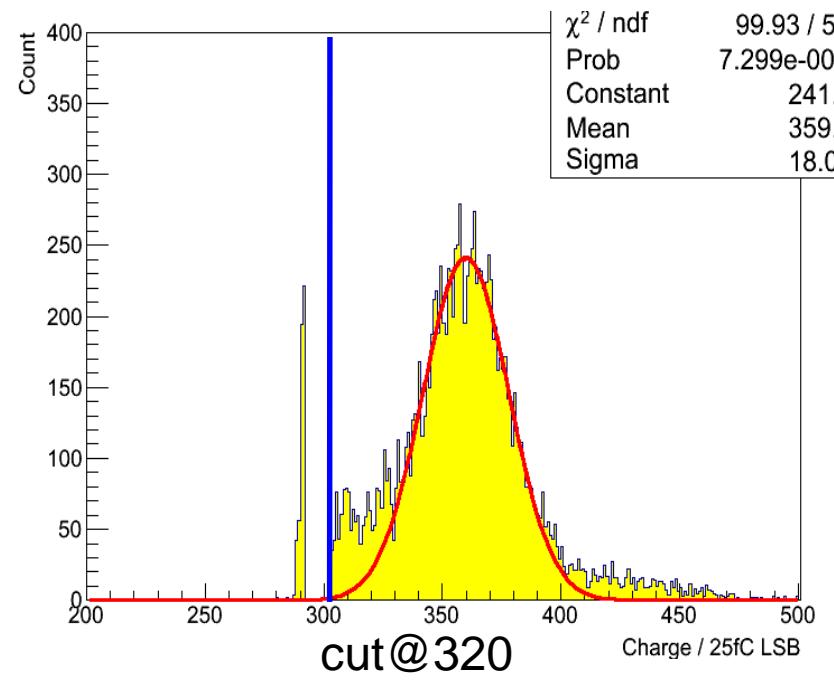
Hamamatsu R12860



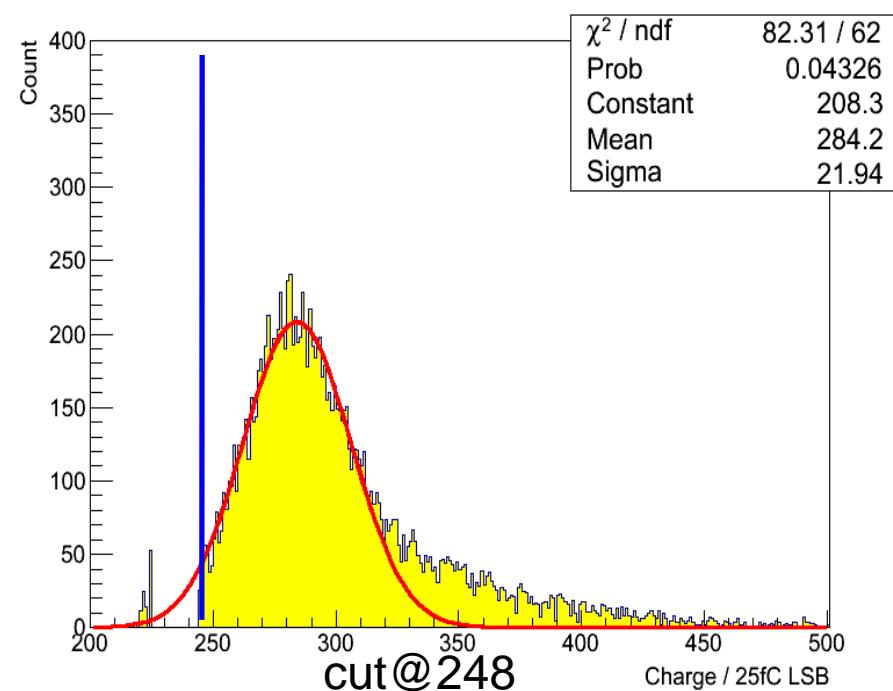
MCP-PMT

## ➤ 4.7. The Relativity Detection efficiency of the Prototype

	HV	Gain	Relativity PDE
R12860	1650V	~1.1E7	100%
MCP-PMT	1930V	~9.6E6	110%



Hamamatsu R12860



MCP-PMT

## ➤ 4.8 The performance of the 20 inch prototypes

Characteristics	unit	MCP-PMT (IHEP)	R12860 (Hamamatsu)
Electron Multiplier	--	<b>MCP</b>	Dynode
Photocathode mode	--	<b>reflection+ transmission</b>	transmission
Quantum Efficiency (400nm)	%	<b>26 (T), 30 (T+R)</b>	<b>30(T)</b>
Relativity Detection Efficiency	%	<b>~ 110%</b>	<b>~ 100%</b>
P/V of SPE		<b>&gt; 3</b>	<b>&gt; 3</b>
TTS on the top point	ns	<b>-12</b>	<b>-3</b>
Rise time/ Fall time	ns	<b>R~2 , F~10</b>	<b>R~7 , F~17</b>
Anode Dark Count	Hz	<b>~30K</b>	<b>~30K</b>
After Pulse Time distribution	us	<b>4.5</b>	<b>4, 17</b>
After Pulse Rate	%	<b>3</b>	<b>10</b>
Glass	--	<b>Low-Potassium Glass</b>	HARIO-32

## ➤ 5. The PMT purchase of JUNO

➤ Dynode-PMT- 20" from Hamamatsu

➤ MCP-PMT- 20" from NNVT



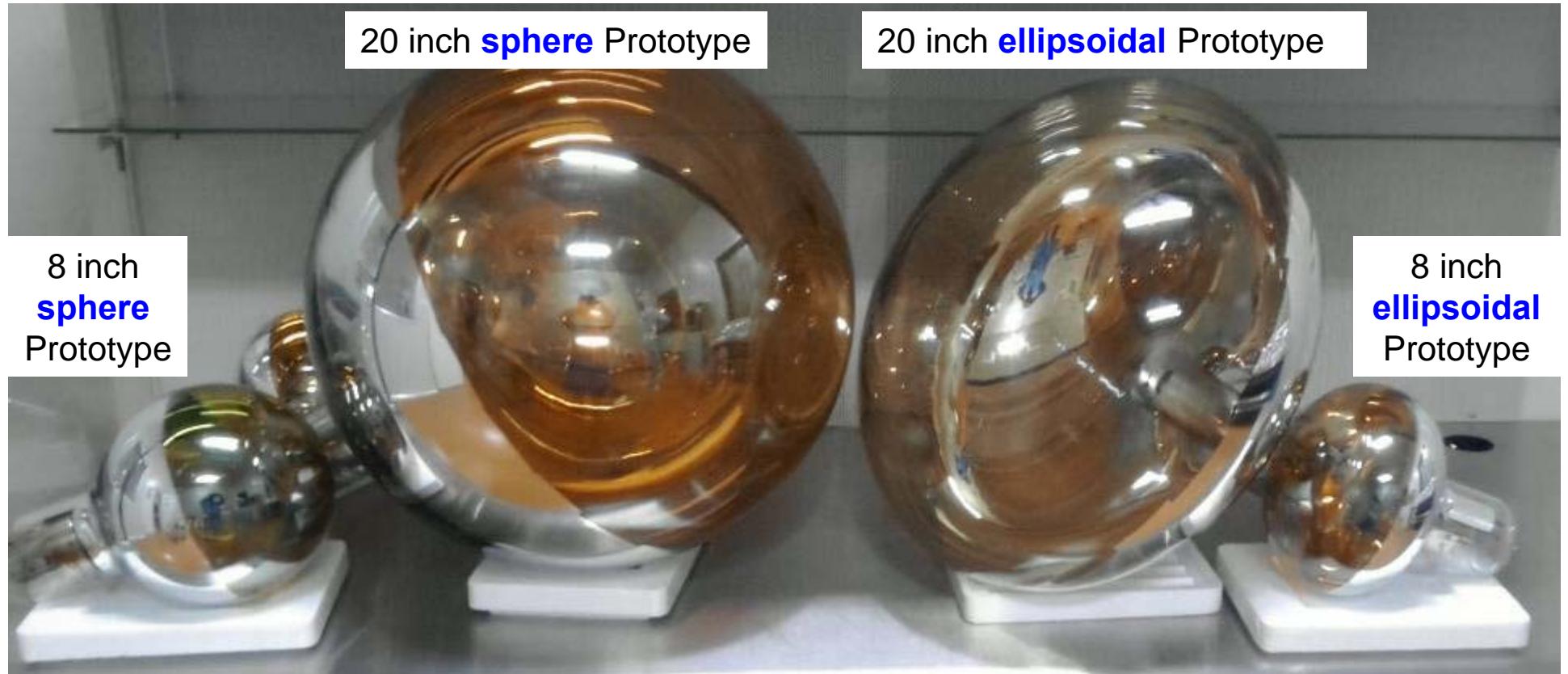
15k MCP-PMT (75%)

Contract for JUNO

Signed with NNVT  
on Dec.16, 2015



- **Prototypes:** Successful 8" and 20"prototypes with normal performance;



We could successfully produce the 8 / 20 inch MCP-PMT prototype for good SPE and QE

**And better for CE of the MCP; Uniformity of CE, QE, TTS,  
we also try to improve our design of the prototype.**

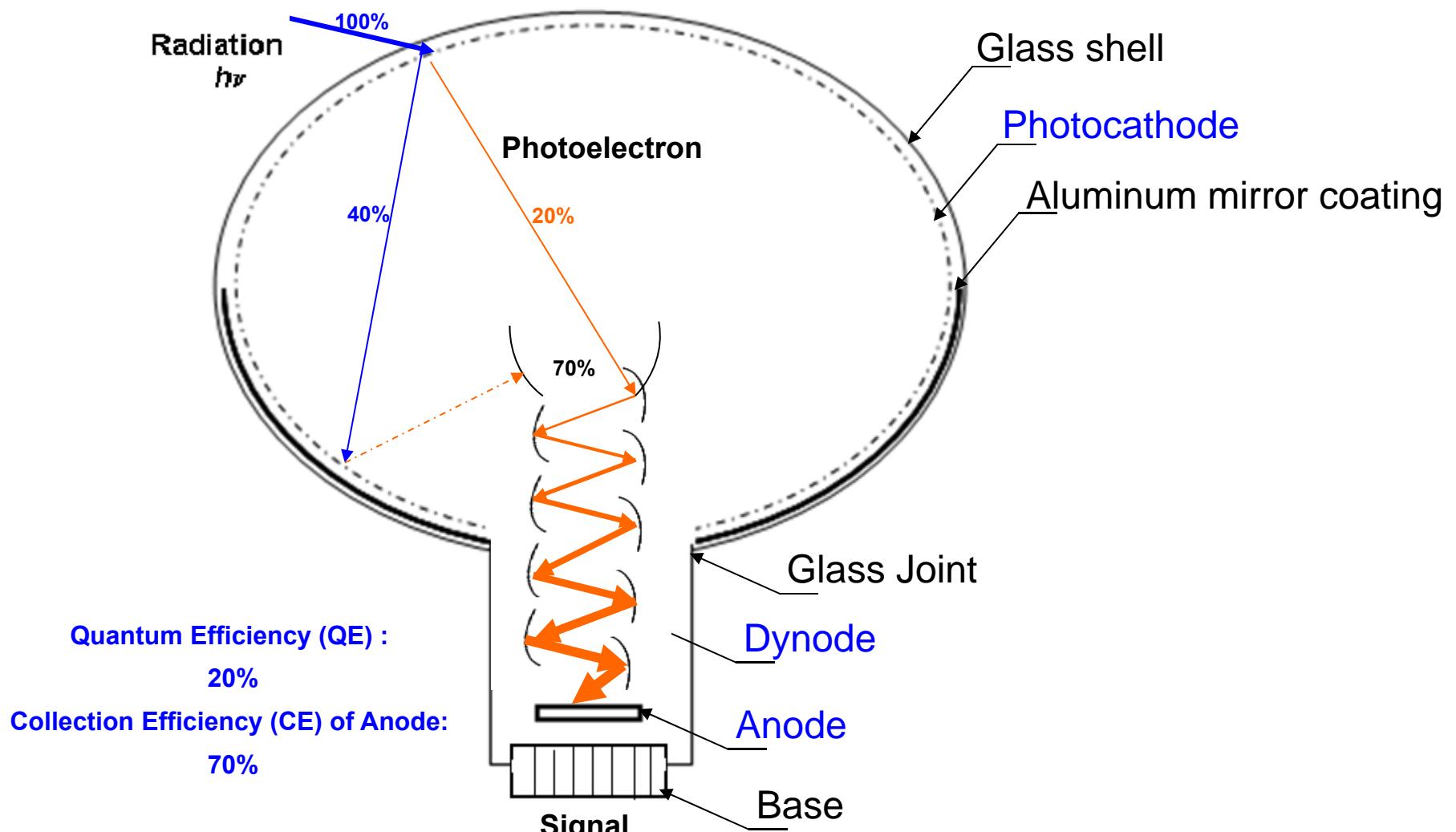
# Thank! 谢谢!

Thanks for your attention!  
Any comment and suggestion are welcomed!



# Welcome to Kaiping

## ➤ The Conventional PMT



$$\text{Photon Detection Efficiency (PE)} = \text{QE}_{\text{Trans}} * \text{CE} = 20\% * 70\% = 14\%$$

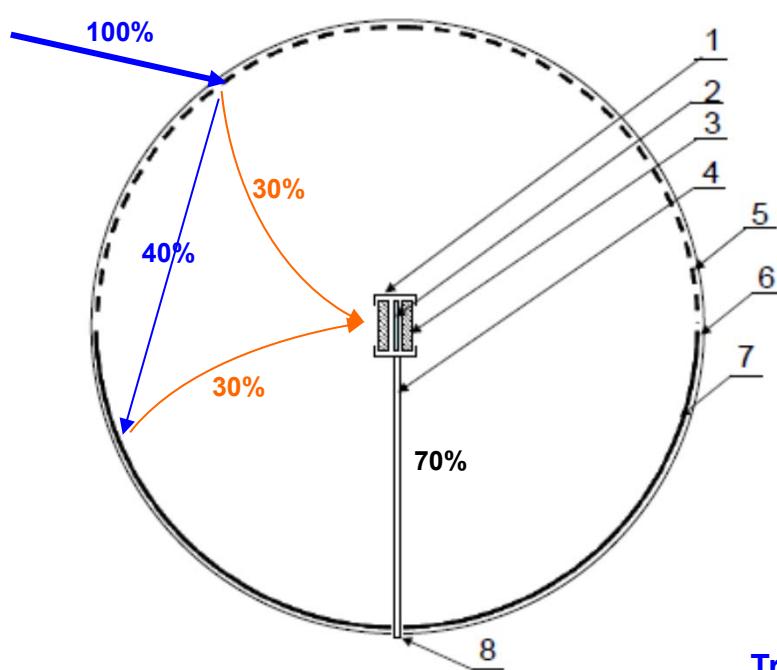
## ➤ The new design of a large area PMT

High photon detection efficiency + Single photoelectron Detection + Low cost

1) Using two sets of Microchannel plates (MCPs) to replace the dynode chain

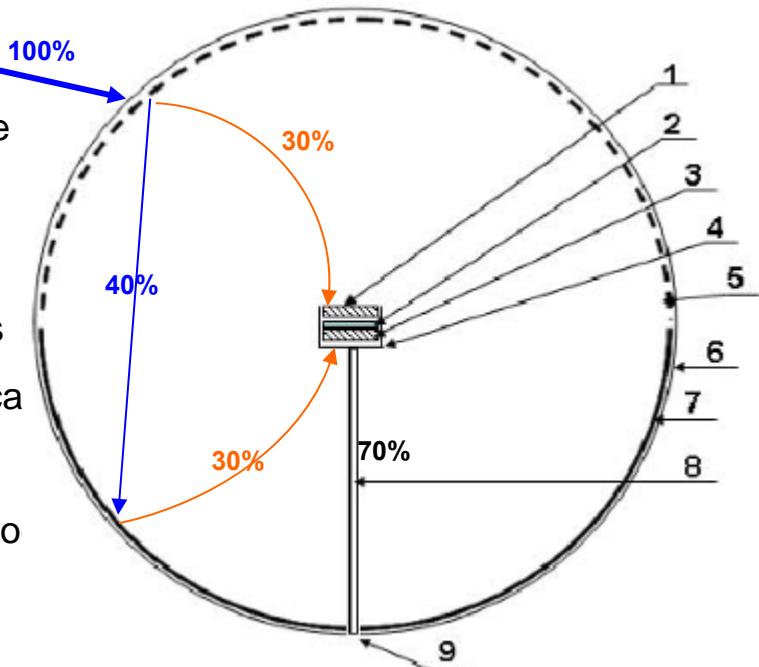
2) Using transmission photocathode (front hemisphere)  
and reflection photocathode (back hemisphere)

~  $4\pi$  viewing angle!



- 1. Insulated trestle table
- 2. Anode
- 3. MCP dodule
- 4. Bracket of the cables
- 5. Transmission Photoca
- 6. Glass shell
- 7. Reflection Photocatho
- 8. Glass joint

Transmission rate of the glass: 40%



Quantum Efficiency (QE) : of Transmission Photocathode 30% ; of Reflection Photocathode 30% ;

Collection Efficiency (CE) of MCP : 70%;

$$PD = QE_{Trans} * CE + TR_{Photo} QE_{Ref} * CE = 30\% * 70\% + 40\% * 30\% * 70\% = 30\%$$

**Photon Detection Efficiency: 15% → 30% ; ×~2 at least !**