



中國科學院高能物理研究所
Institute of High Energy Physics
Chinese Academy of Sciences



The Chinese Academy
of Sciences

The 20 inch MCP-PMT R&D in China

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Technology and Instrumentation in Particle Physics

May 22-26, 2017, Beijing, China

Organized by

Institute of High Energy Physics, CAS

State Key Laboratory of Particle Detection and Electronics



Outline

➤ 1. The new design of the MCP-PMT for JUNO; (2009-2011)

the 4 π design; the MCP-PMT collaboration group; roadmap;

➤ 2. The MCP-PMT prototypes production; (2011-2015)

the 8 inch prototypes; the 20 inch prototypes; the high PDE;

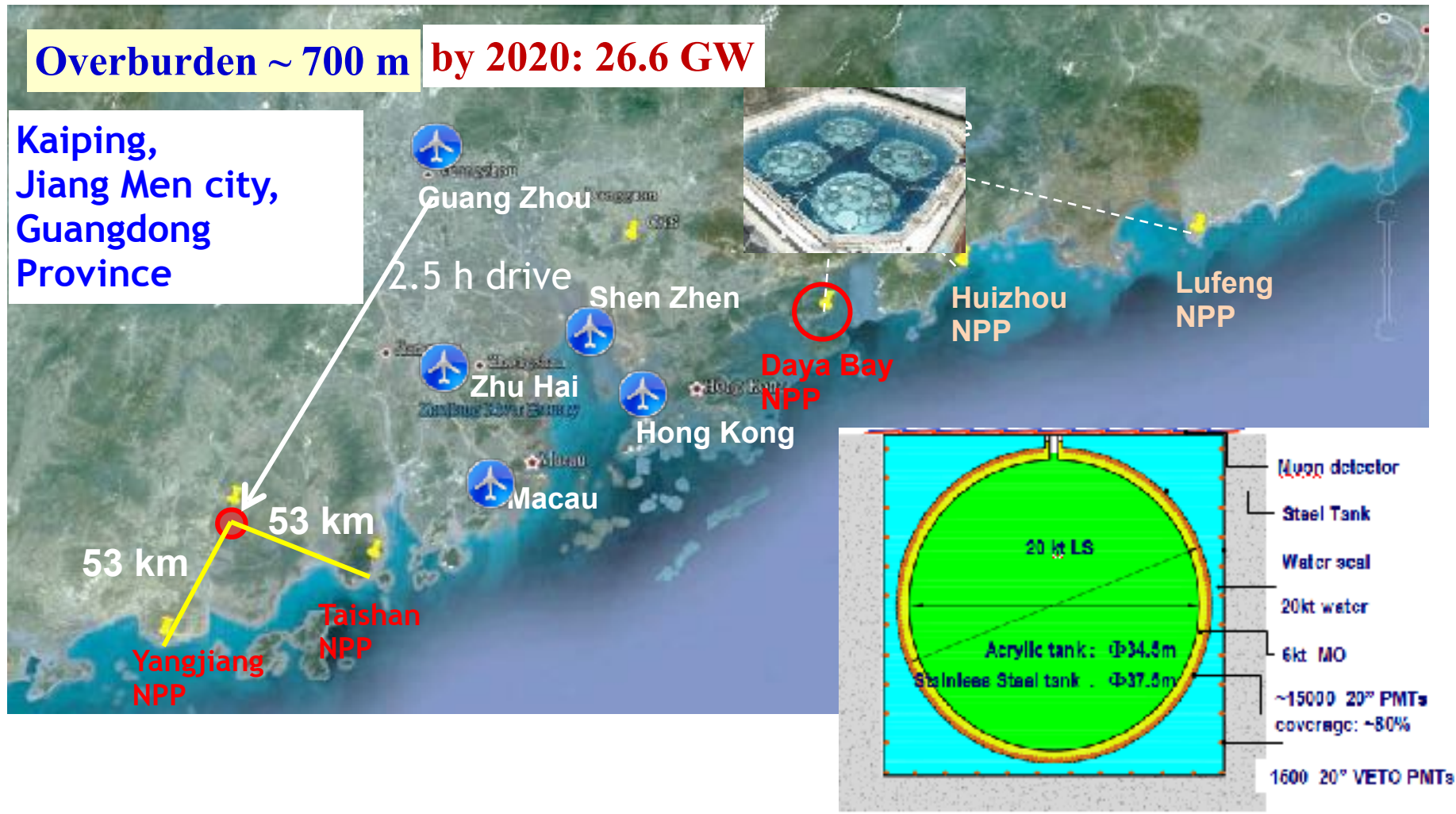
➤ 3. The Mass production and Batch test; (2016-2019)

the mass production, the batch test system, the plan;

➤ 1.0 Jiangmen Underground Neutrino Observatory (JUNO)

Overburden ~ 700 m by 2020: 26.6 GW

Kaiping,
Jiang Men city,
Guangdong
Province

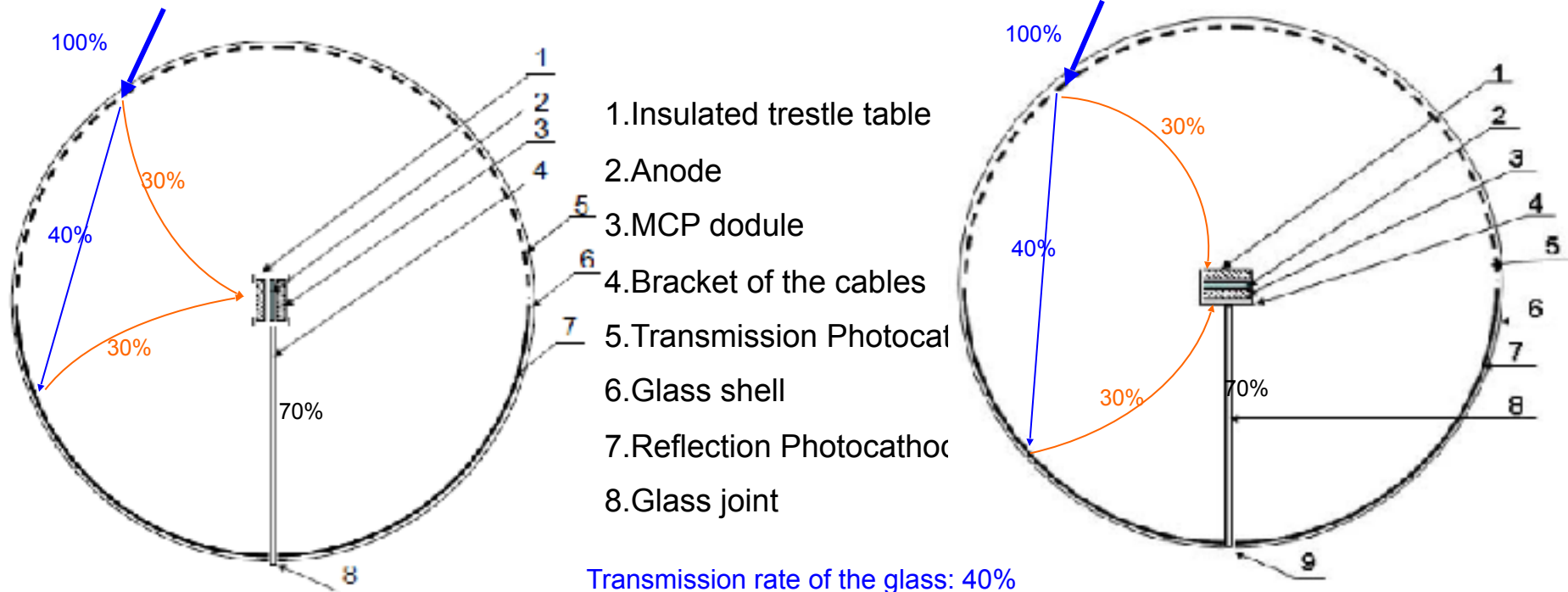


Requirement: High QE 20 inch PMT; Good SPE detection capability; Wide dynamic range;
Low radioactive background; Can withstand 0.4MPa Pressure;
> 20000 pieces; More than 20 years lifetime;

➤ 1.1 the primary design of the MCP-PMT in 2009

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)
- } ~ 4π viewing angle!



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 !

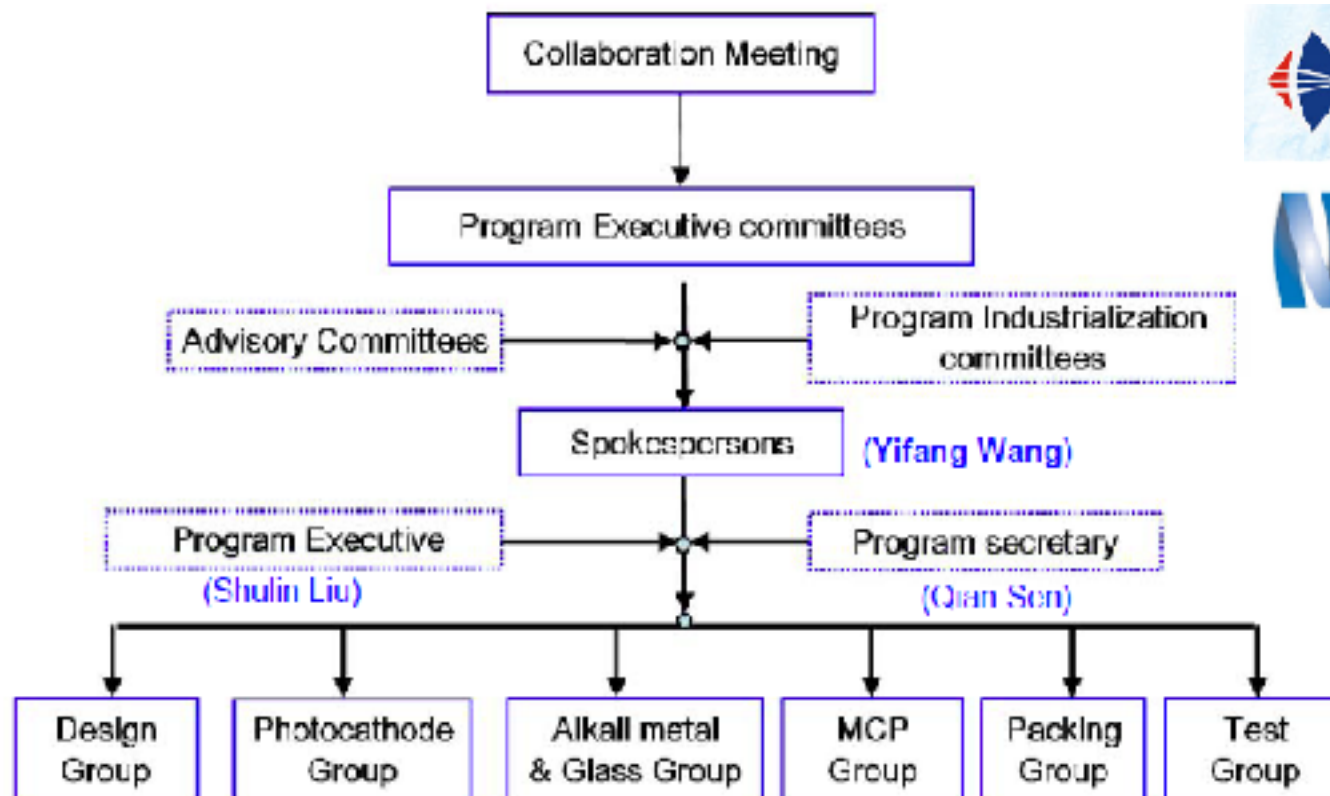
➤ 1.2 Project team and Collaborators



Institute of High Energy Physics, CAS

effort by Yifang Wang;

Microchannel-Plate-Based Large Area Photomultiplier Collaboration (MLAPC)



中国科学院西安光学精密机械研究所
XI'AN INSTITUTE OF OPTICS AND PRECISION MECHANICS OF CAS



北方夜视技术股份有限公司
NORTH NIGHT VISION TECHNOLOGY CO.,LTD

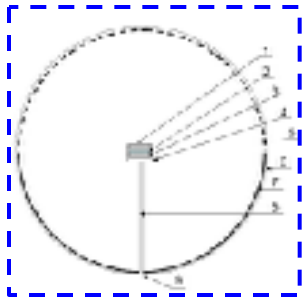
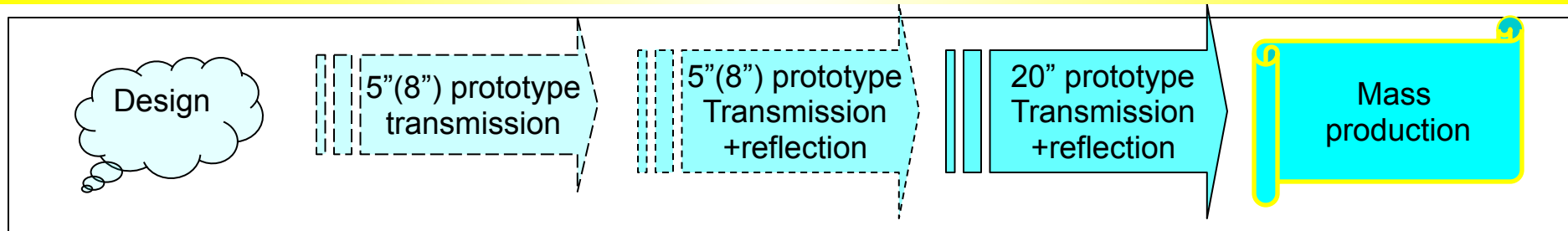


中核(北京)核仪器厂
CNMC Beijing Nuclear Instrument Factory



南京大学

➤ 1.3 The R&D plan of MCP-PMT (Roadmap —time)



The design of the
IHEP-MCP-PMT

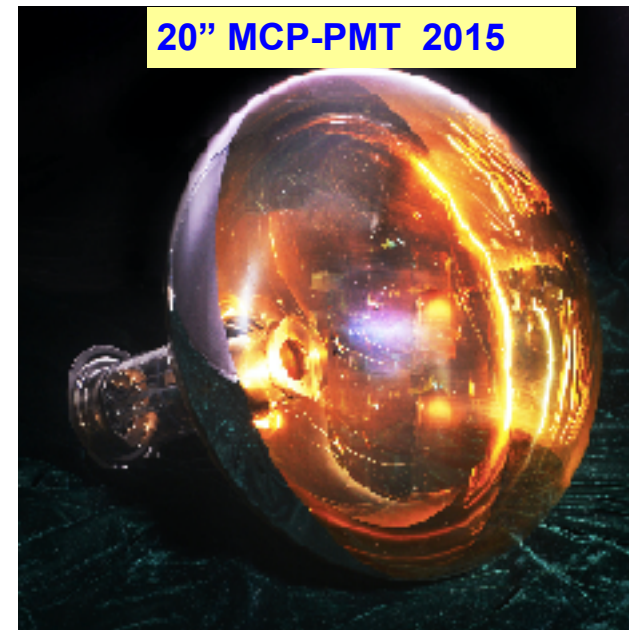
The project of
DayaBay /JUNO



2" MCP-PMT



8" MCP-PMT 2013



20" MCP-PMT 2015

5" MCP-PMT 2010年

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the mass production, the batch test system, the plan;

➤ 2.1 8" prototypes with normal performance--2013

8-inch IHEP MCP-PMT

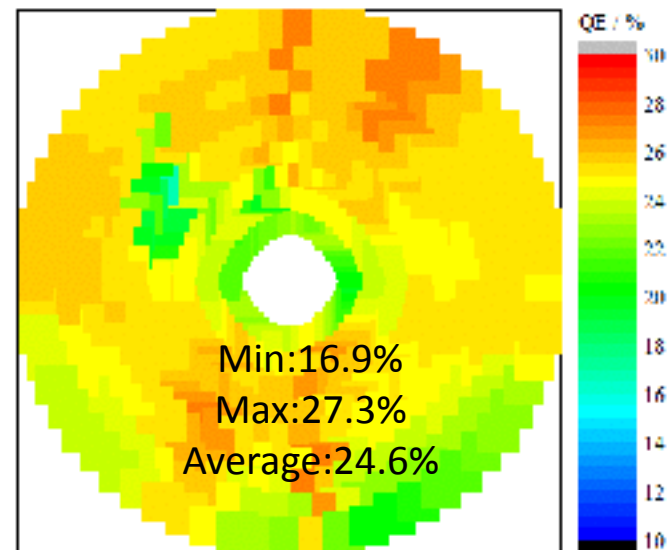
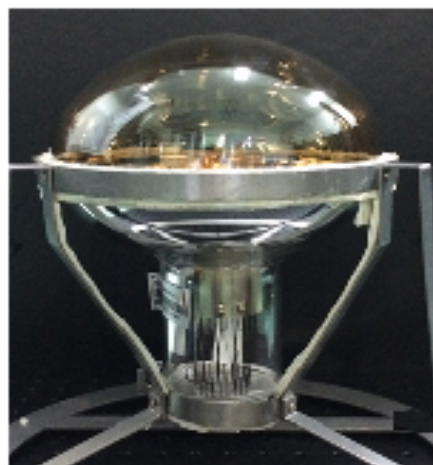
Vertical MCPs

Sphere Glass

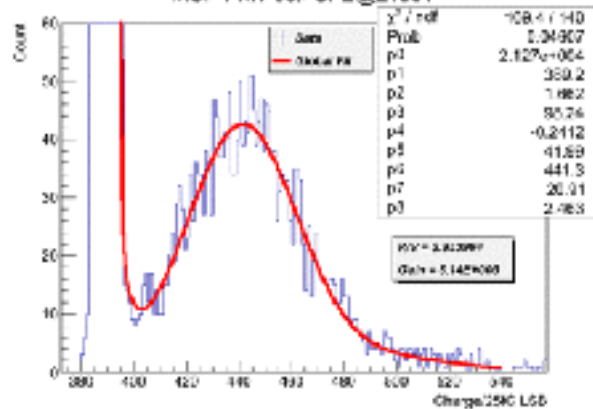


8-inch IHEP MCP-PMT

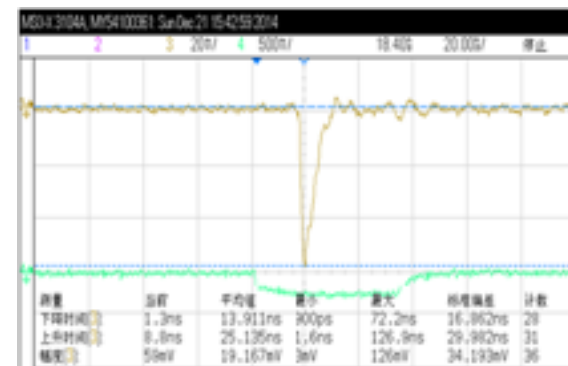
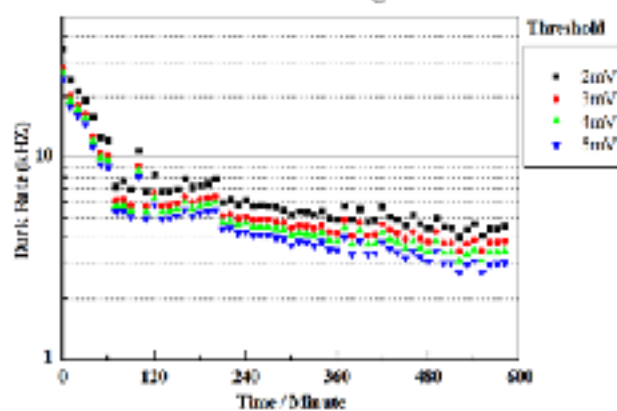
Horizontal MCPs



MCP-PMT-39# SPE@2100V

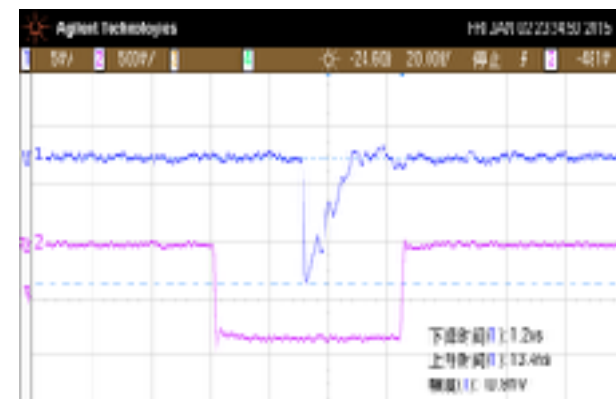
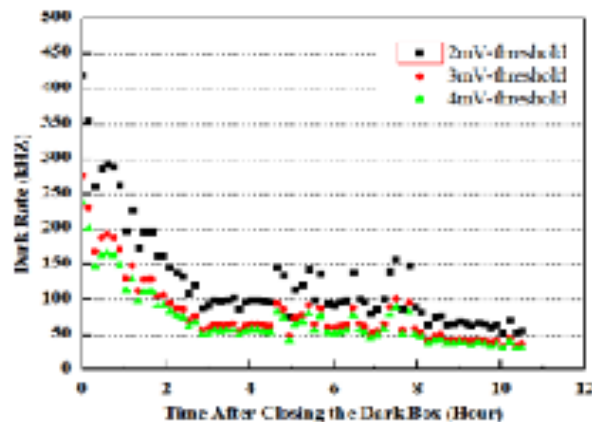
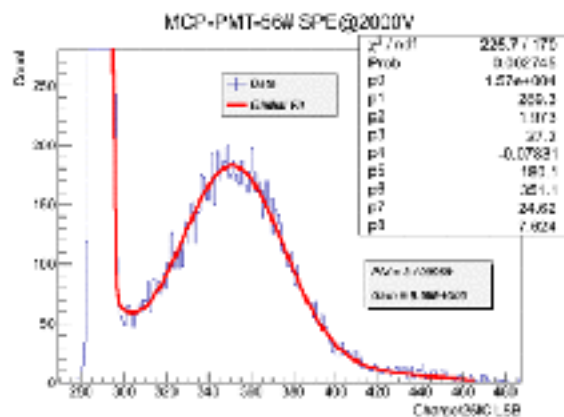
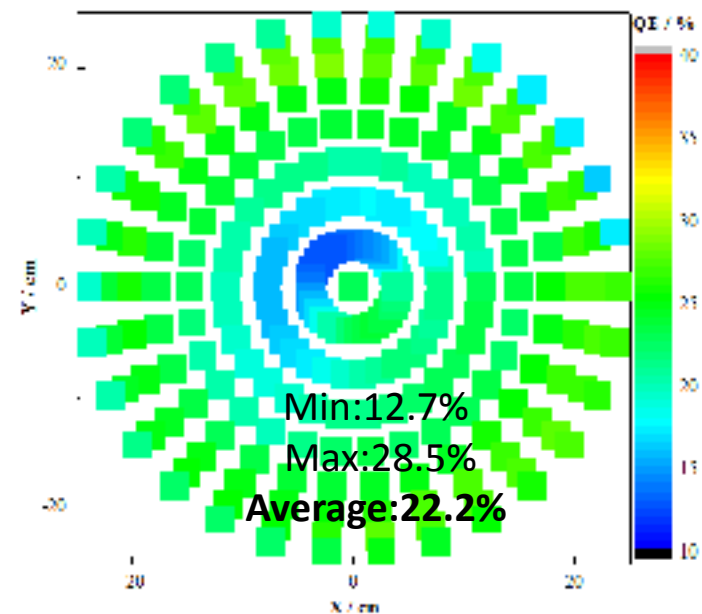
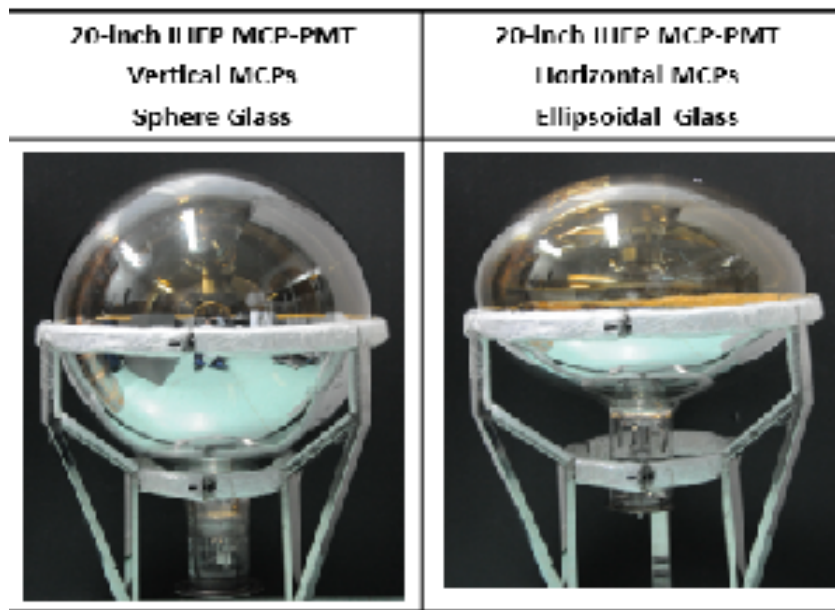


MCP-PMT-44# Dark Rate @ 10°



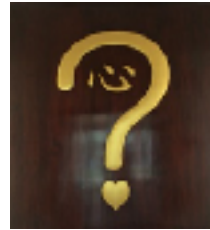
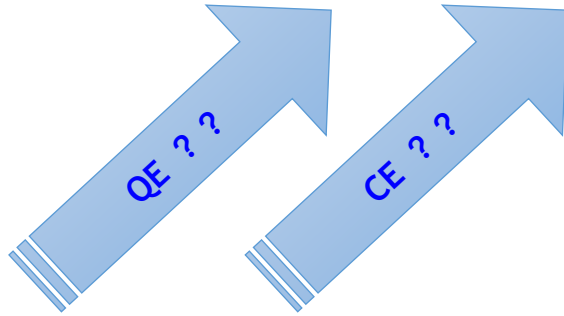
HV	Gain	P/V	Rise Time	Fall Time	Dark rate @1E7 Gain(0.25PE)
2100V	~1E7	~4	~1.3ns	~8.8ns	~3kHz

➤ 2.2 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

➤ 2.3 The improvement of the MCP-PMT (2015)



2014: 1st 20" prototype, with normal performance

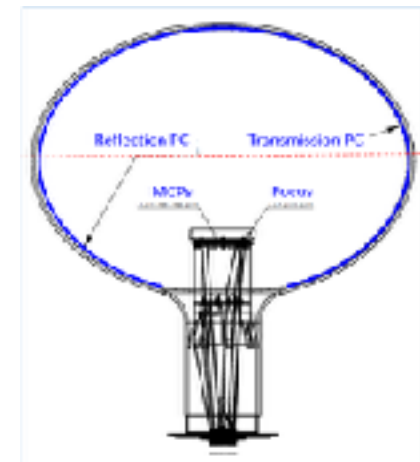
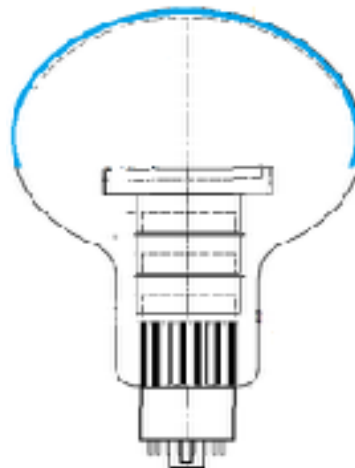
⇒ QE ~ 25% @ 410nm; CE ~ 60%; P/V of SPE > 2

2015: 20" prototypes with normal performance

⇒ QE ~ 26% @ 410nm; CE ~ 100%; P/V of SPE > 3

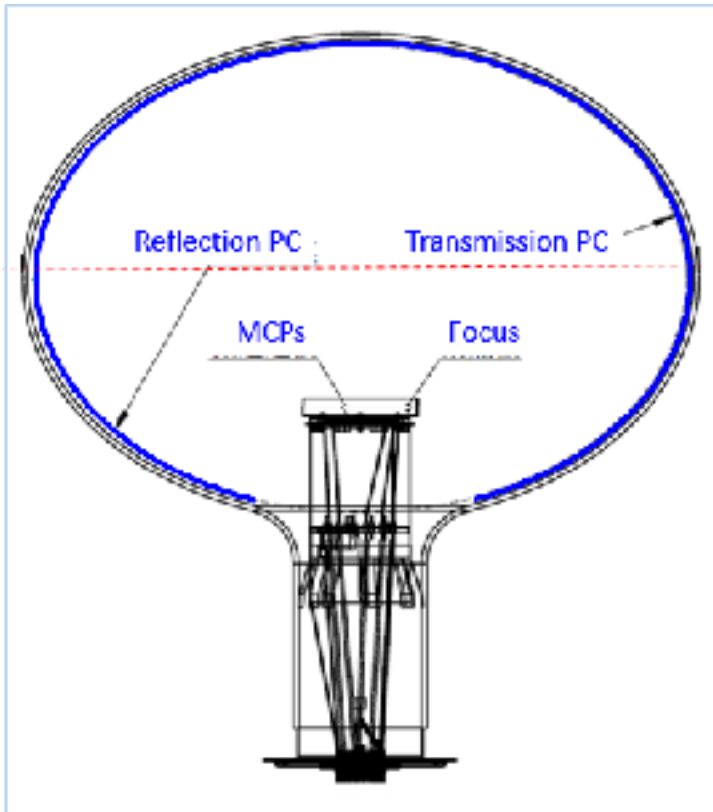
20-inch Hamamatus PMT-Dynode Ellipsoidal Glass

20-inch IHEP-MCP-PMT-Ellipsoidal Glass

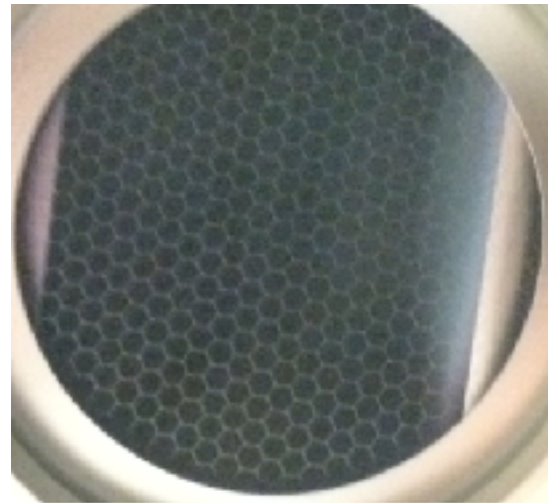


> The Transmission + Reflection QE of the Photocathode

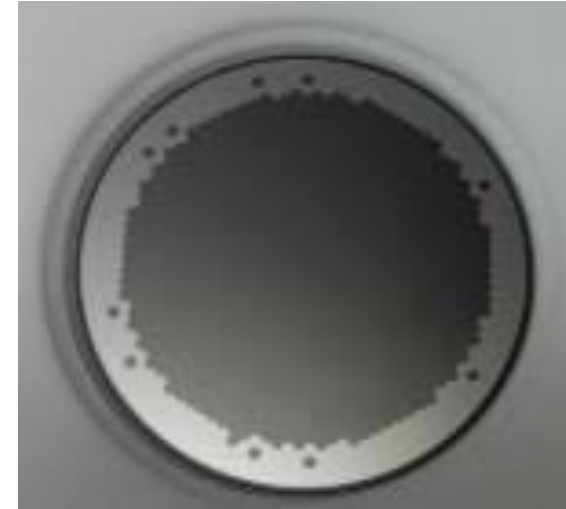
The High Collection Efficiency MCP



> **Dynode: A mesh covering the dynode**



> **MCP: Special MCP for CE~100%**



Good situation:

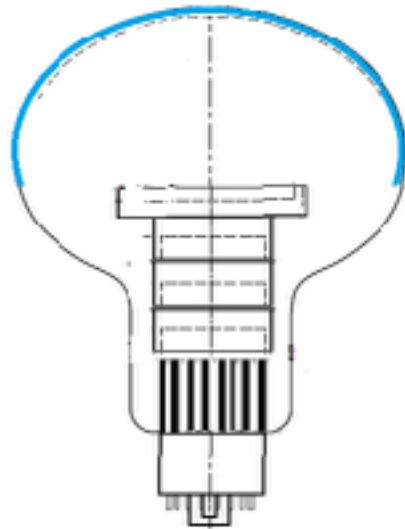
- Improve the total QE;
- Improve the Detection Efficiency;

Bad situation:

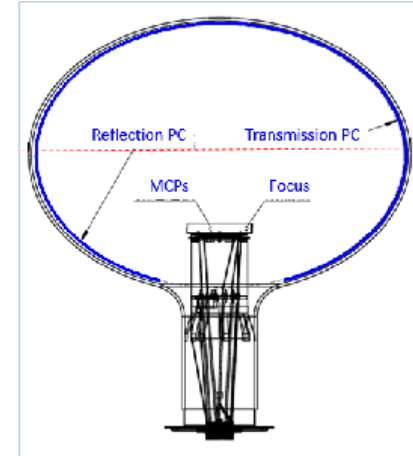
- Larger Dark count;
- larger TTS;

➤ 2.4 The High PDE MCP-PMT--2015

20-inch Hamamatus PMT-Dynode Ellipsoidal Glass

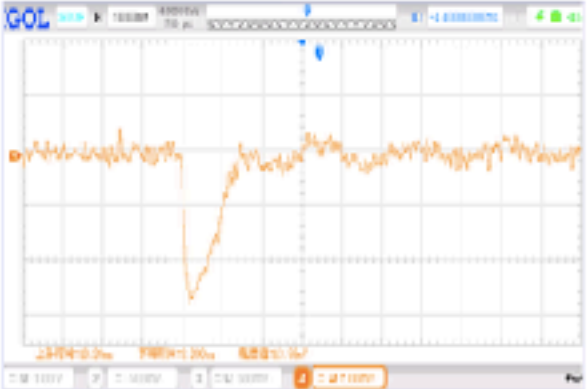


20-inch IHEP-MCP-PMT-Ellipsoidal Glass

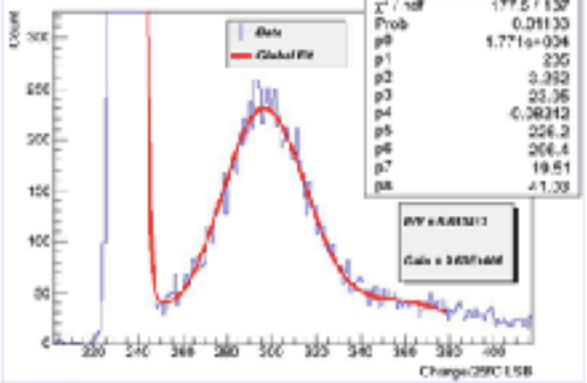


The typical performance of the 20 inch MCP-PMT

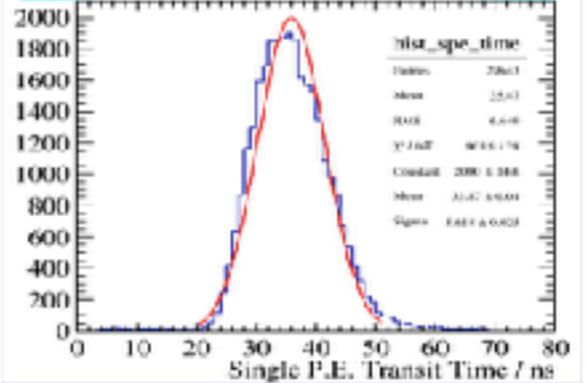
Waveform of the Prototype



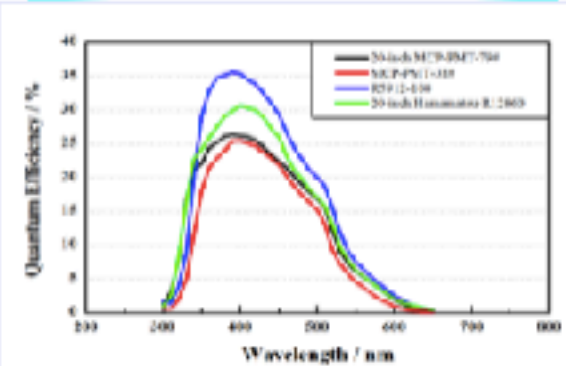
The SPE of the Prototype



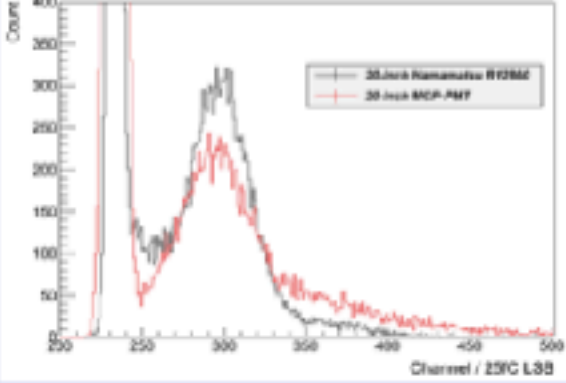
TTS of the Prototype



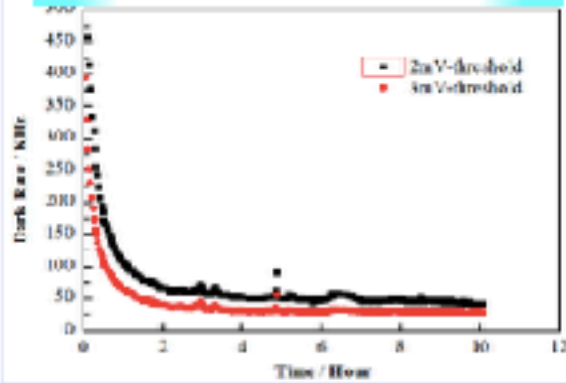
QE of the Photocathode



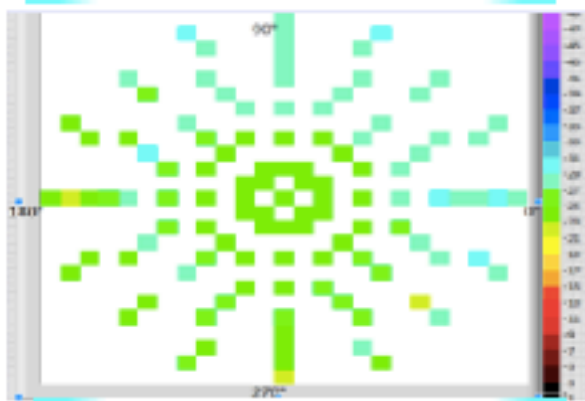
Relative Collection Efficiency



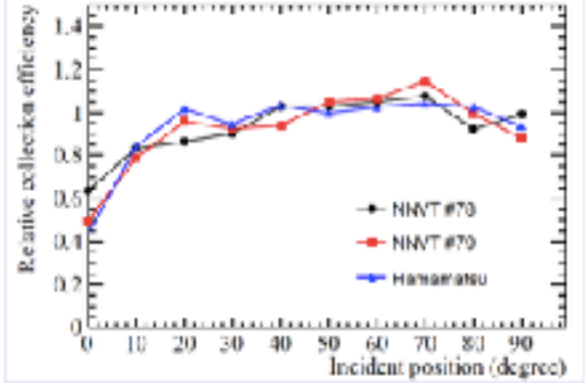
Dark rate of the Prototype



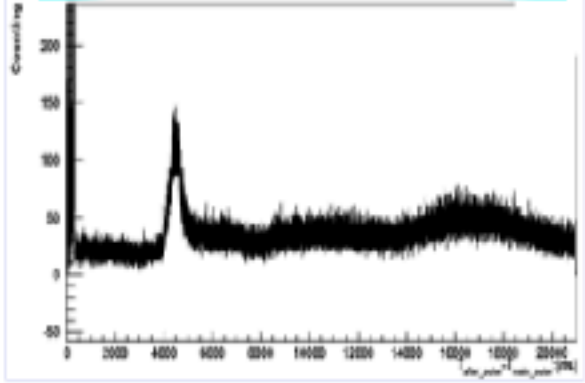
Uniformity of the Photocathode



Uniformity of the Collection Efficiency



After Pulse of the Prototype



➤ 2.5 The performance of the 20 inch prototypes

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

Outline

➤ 1. The new design of the MCP-PMT for JUNO; (2009-2011)

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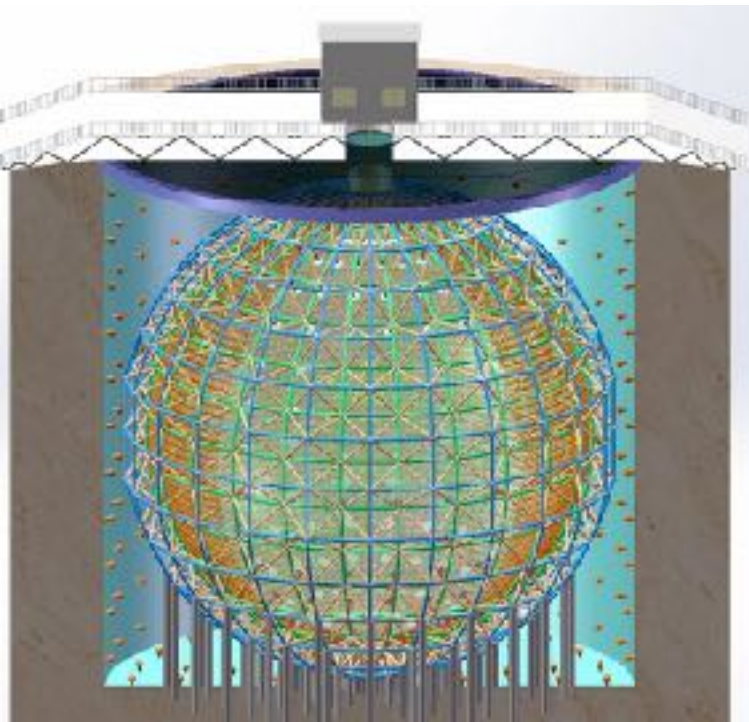
➤ 2. The MCP-PMT prototypes production; (2011-2015)

the 8 inch prototypes; the 20 inch prototypes; the high PDE;

➤ 3. The Mass production and Batch test; (2016-2019)

the mass production, the batch test system, the plan;

➤ 3.0 . The PMT purchase of JUNO



◆ High QE 20" PMTs for JUNO:

- ⇒ Hamamatsu PMT with SBA photocathode
- ⇒ A new design using MCP: 4π collection



➤ 20" Hamamatsu PMT



➤ 20" MCP- PMT-IHEP

➤ the 75% order of PMT for JUNO (2015)



Specification in the Contracts

Characteristics	unit	MCP PMT (NNVC)	R12860 (Hamamatsu)
Detection Eff.(QE*CF*area)	%	27%, > 24%	27%, > 24%
1/V of SPE		3.5, > 2.8	3, > 2.5
TTS on the top point	ns	~12, < 15	2.7, < 3.5
Rise time/ Fall time	ns	R ^{~2} , F ^{~12}	R ^{~5} , < 7; F ^{~9} , < 12
Anode Dark Count	/Hz	20K, < 30K	10K, < 50K
After Pulse Rate	%	1, < 2	10, < 15
Radioactivity of glass	ppb	238U: 50 232Th: 50 40K: 20	238U: 400 232Th: 400 40K: 40

15k MCP-PMT (75%)

Contract for JUNO

Signed with NNVT

on Dec.16, 2015



➤ 3.1 . The 20 inch MCP – PMT production line (2016)

- 2 units were working already in 2015; ★
- 6 units were ready on the summer 2016; ☆
- 14 units were ready on the winter 2016; ☆

One Unit could produce 3PMTs in Two days;

——> 22 Units for the mass production;

——> 33 PMTs / 1 day;



The Production line was operated on Dec.25, 2016



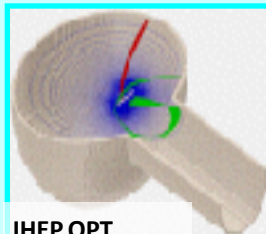
30 pic PMTs per day!

The Bunch test system
will be finished Jan.20,2017
32 pic PMT together per day!

➤ 3.2 The plan of MCP-PMT batch test



电场设计



收集效率 (CE)

渡越时间涨落 (TTS)

信号波形 (RT/FT)

抗地磁场能力 (EM)

MCP组件



增益 (Gain)

单光子探测 (SPE)

后脉冲率 (APR)

探测效率 (DE)

渡越时间涨落 (TTS)

非线性 (Linearity)



标准碱源

量子效率 (QE)

后脉冲率 (APR)

均匀性 (Uniformity)

暗计数率 (DR)



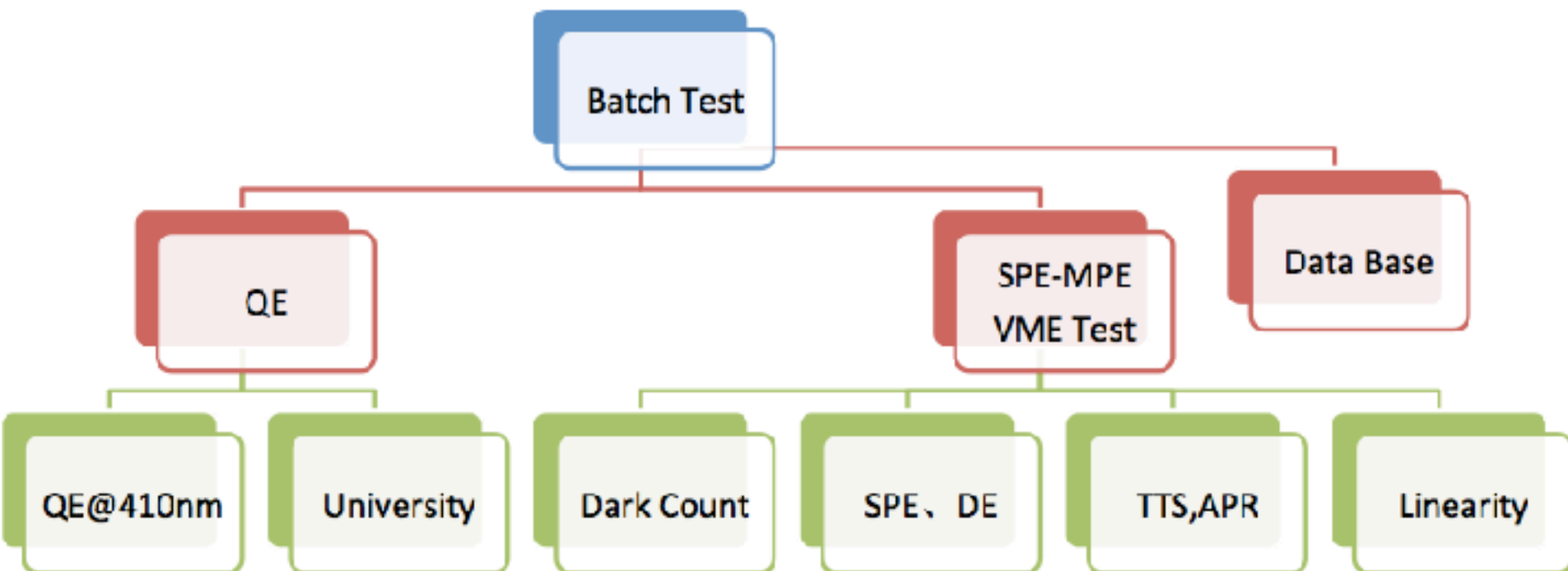
低本底玻壳

放射性本底 (Radioactive background)

机械尺寸 (Size)

机械强度 (mechanical strength)

➤ the design of the batch test system in NNVT



➤ the Review of the batch test system in NNVT

The Batch test system was reviewed on Feb.10,2017

The mass production Line: 30 pic PMTs per day.

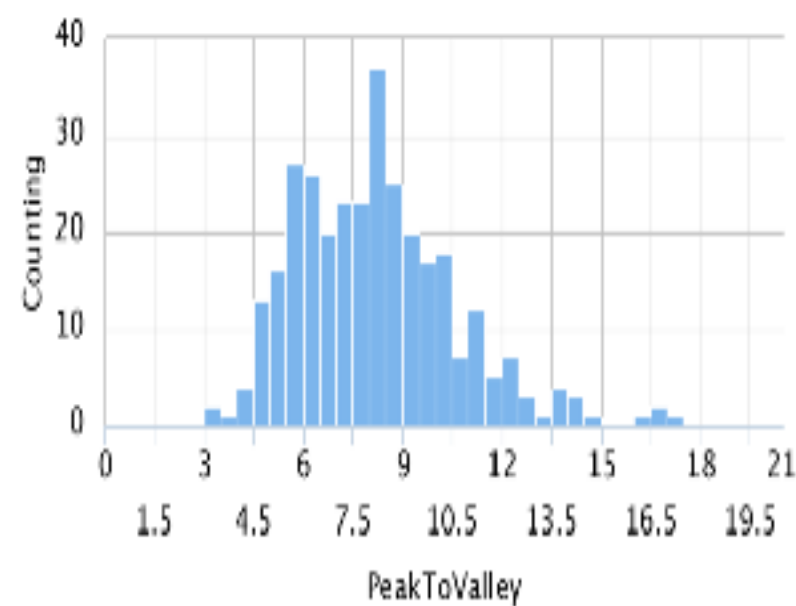
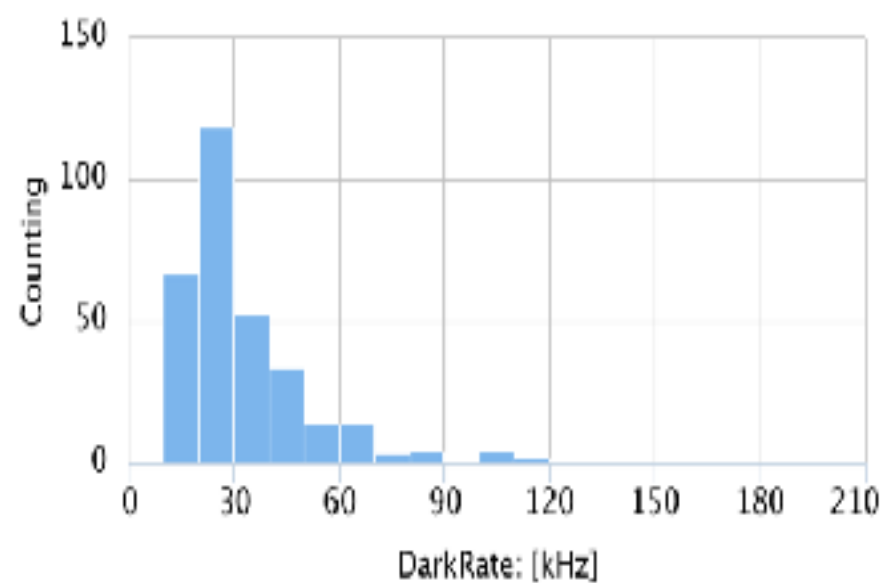
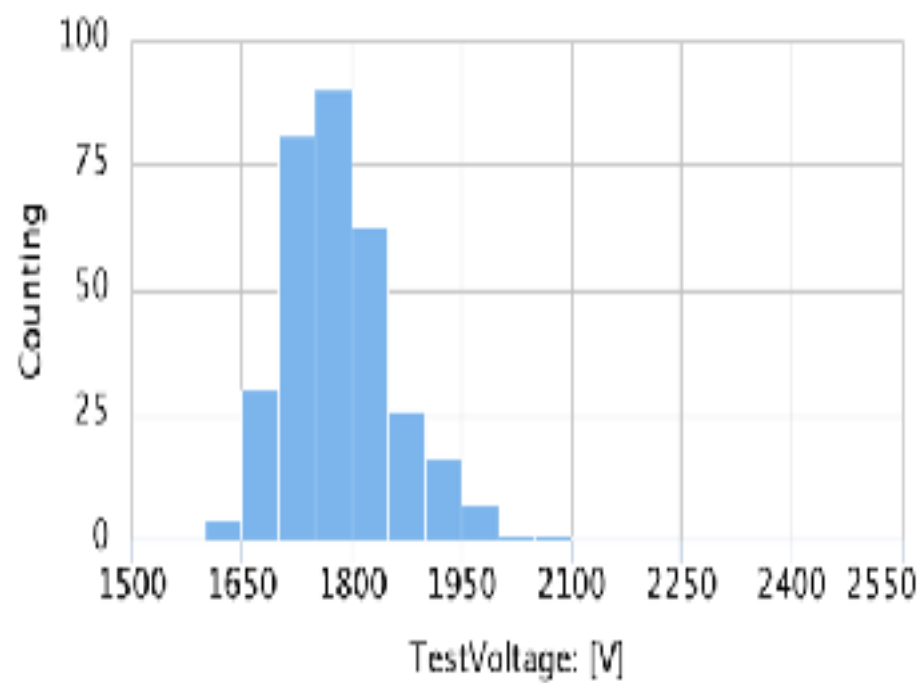
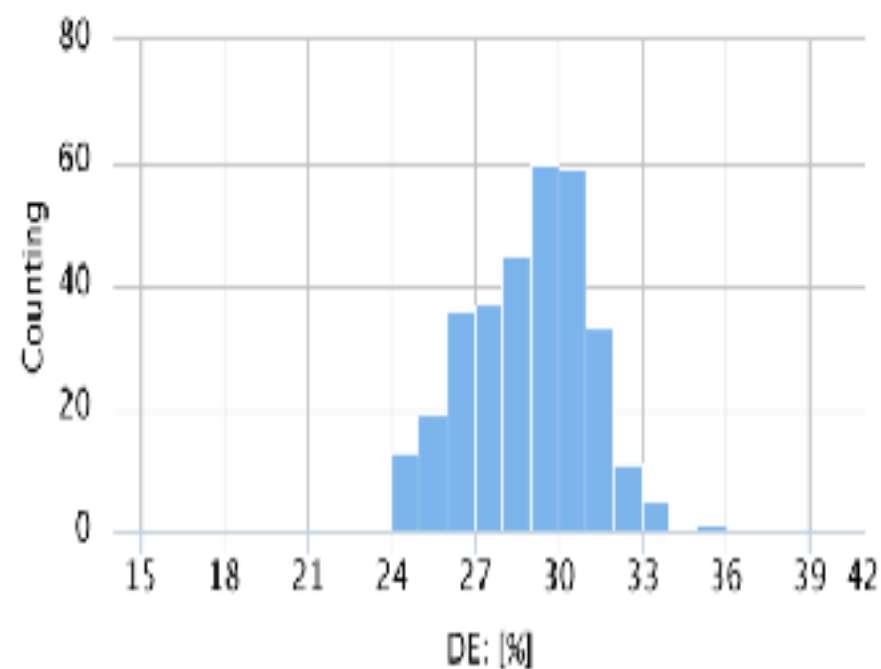
The Batch test system: 32 pic PMTs per day.



➤ 3.3 The first ship for the MCP-PMT to JUNO

- first 336 pics 20 inch MCP-PMT already send to JUNO on 15th.May 2017





➤ 4. Summary of the Design and Production of the MCP-PMT



2010-2011

5"(8") prototype
transmission

2009

Design

2012-2013

5"(8") prototype
Transmission
+reflection

2014-2015

20" prototype
Transmission
+reflection

2016

HQE
Production line
bunch test sys

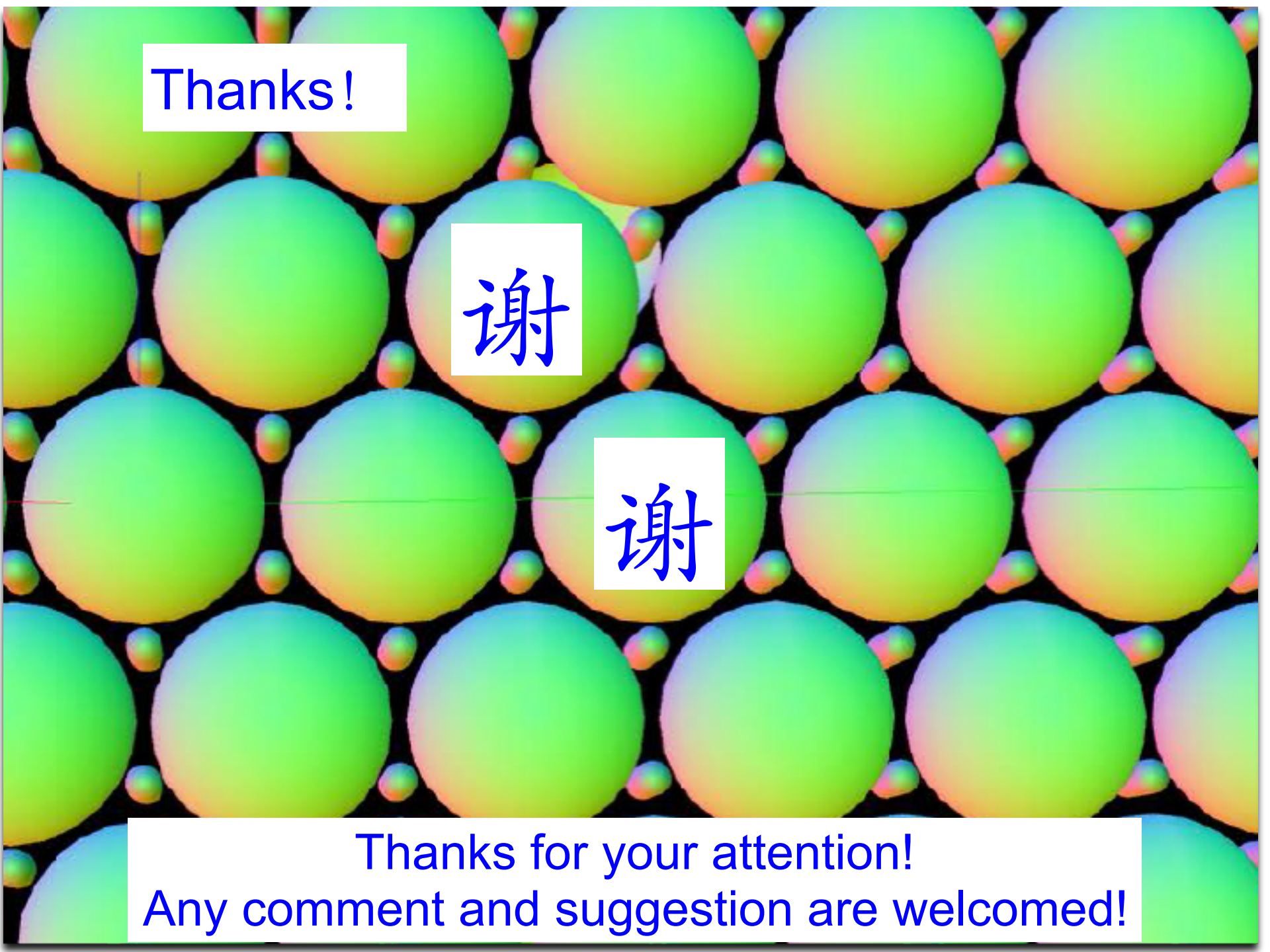
Mass
production

2017-2018

Bunch
test

30 pic/ day for 2 years,





Thanks!

谢

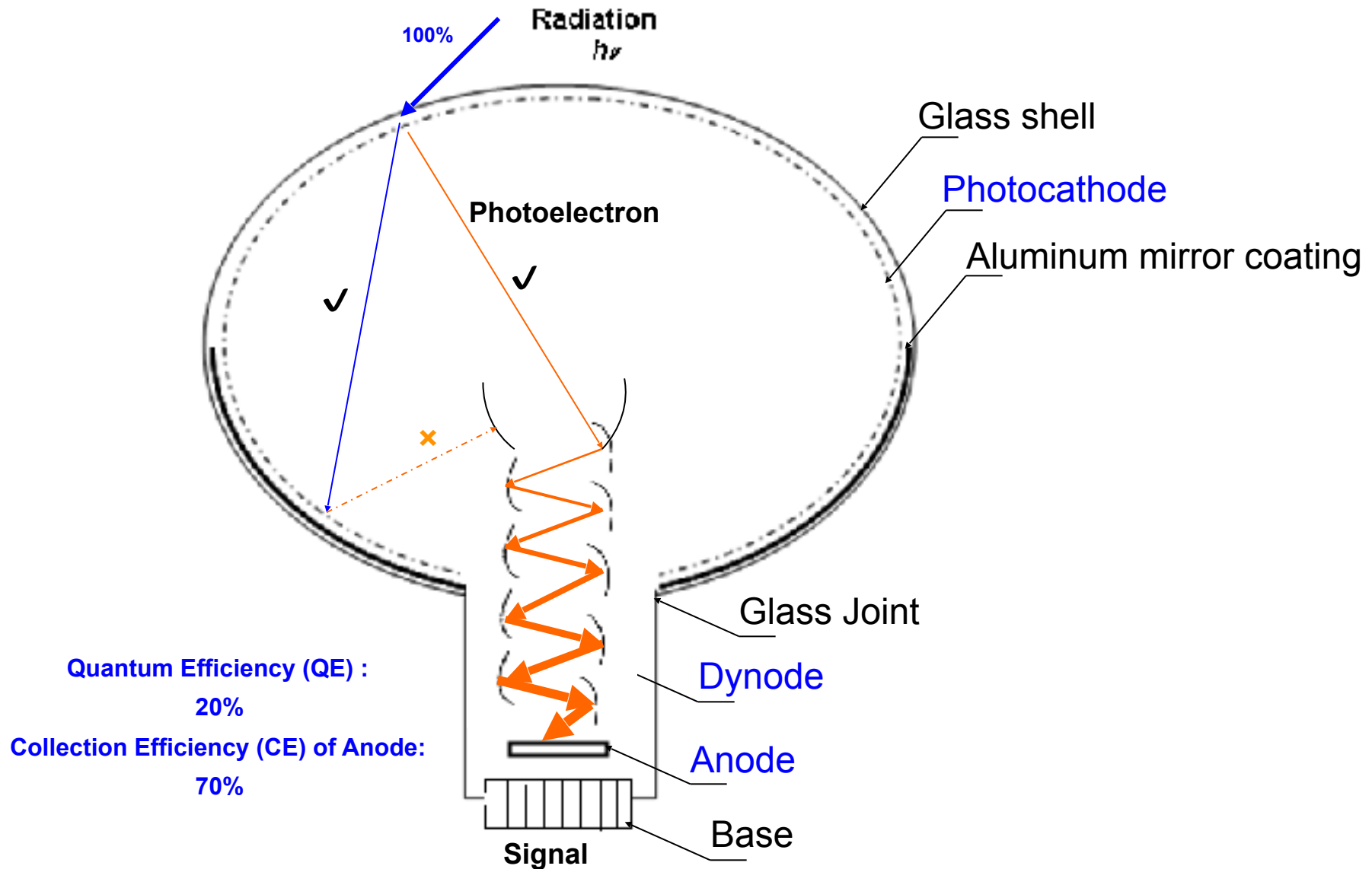
谢

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

Thank! 谢谢!

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

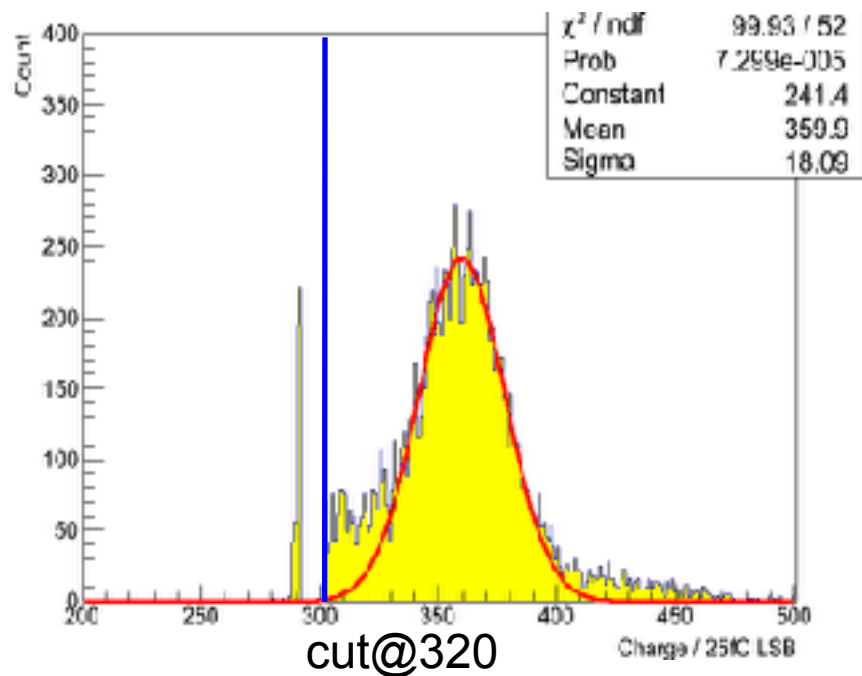
The Conventional PMT



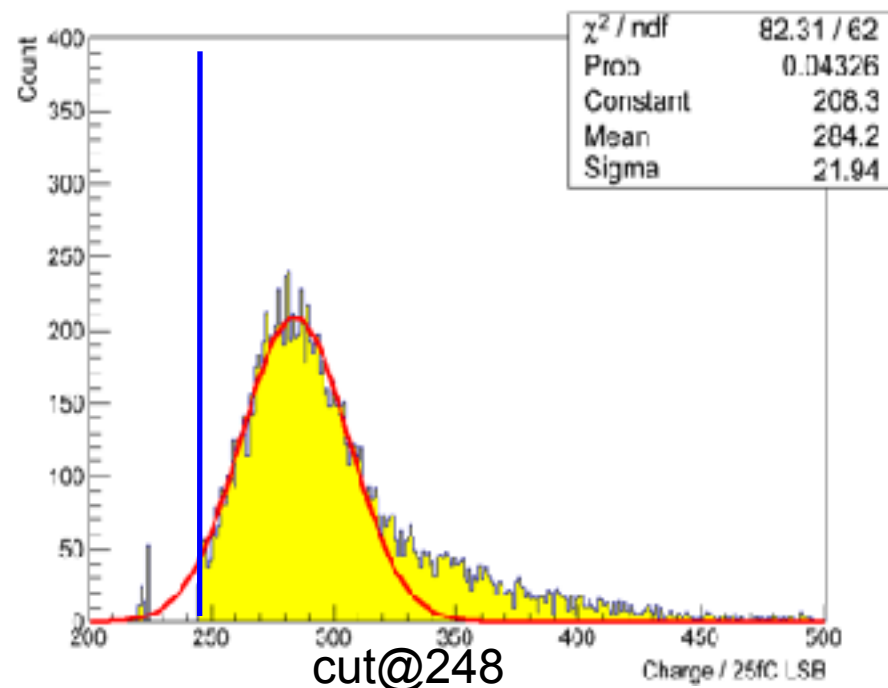
Photon Detection Efficiency (PE) = $QE_{\text{Trans}} * CE = 20\% * 70\% = 14\%$

➤ The Relativity Detection efficiency of the Prototype

	HV	Gain	Relativity PDE
R12860	1650V	$\sim 1.1\text{E}7$	100%
MCP-PMT	1930V	$\sim 9.6\text{E}6$	110%



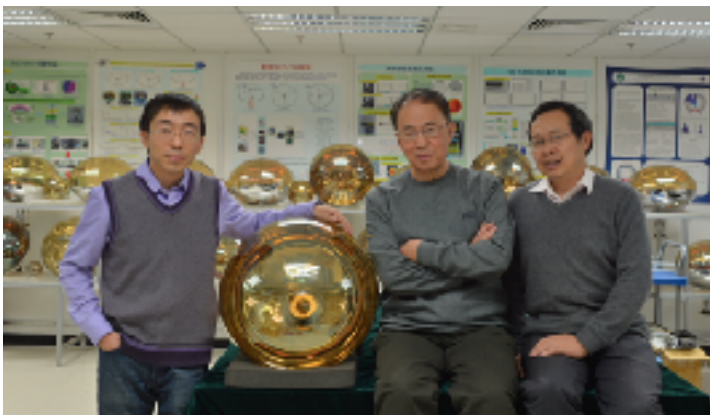
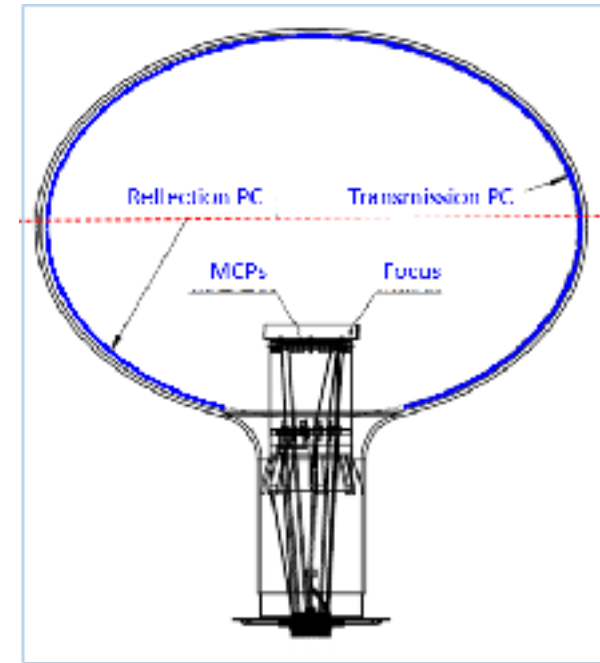
Hamamatsu R12860



MCP-PMT

➤ 4. Summary of the Design and Production of the MCP-PMT

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





TIPP2017,

Beijing, May. 22-26,2017

4h,
by train

X-PMT workshop

Nanjing, May. 27-28,2017

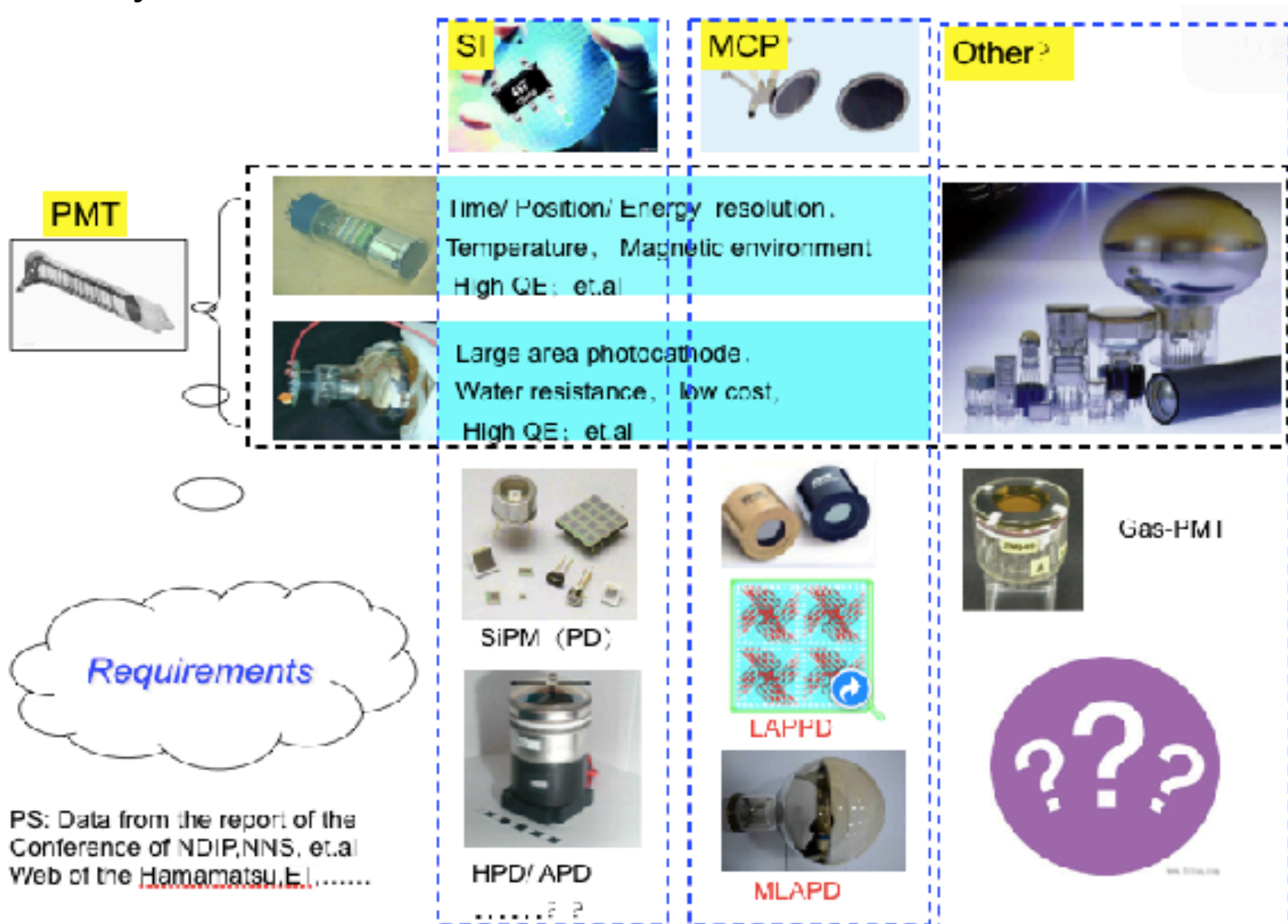


Nanjing University



X-PMT workshop

Dynode-PMT; MCP-PMT; Si-PMT; Gas-PMT; et.al





X-PMT Workshop

27-28 May 2017

Nanjing University, Gu Lou Campus (南京大学鼓楼校区)

Asia/Shanghai timezone

Overview

Committee

Scientific Programme

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Timetable

Contribution List

Author List

Book of Abstracts

Registration

Registration Form

Accommodation

Transportation

X-PMT workshop

Nanjing University
May 27th-28th, 2017

X-: Dynode-, MCP-, Si-, Gas-, APD-, HPD-, et.al

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CHINESE ACADEMY OF SCIENCES

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

南京大学
NANJING UNIVERSITY

NVT
北方夜视
NIGHT VISION
TECHNOLOGY

<http://indico.ihep.ac.cn/event/6639/overview>