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 R&D of Microchannel-Plate-Based Large Area Photomultiplier (MCP-PMT) at IHEP

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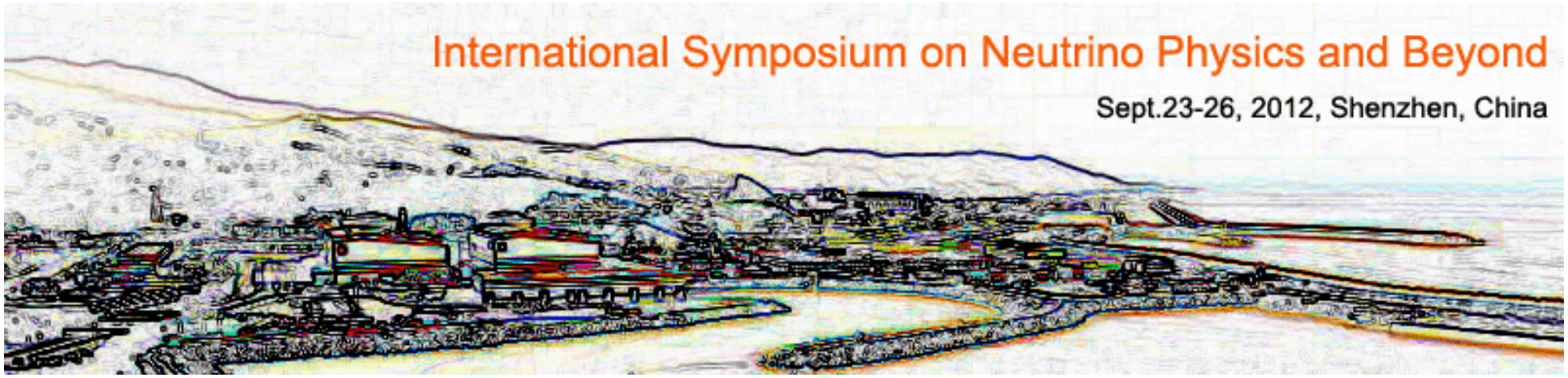
On Behalf of the Workgroup



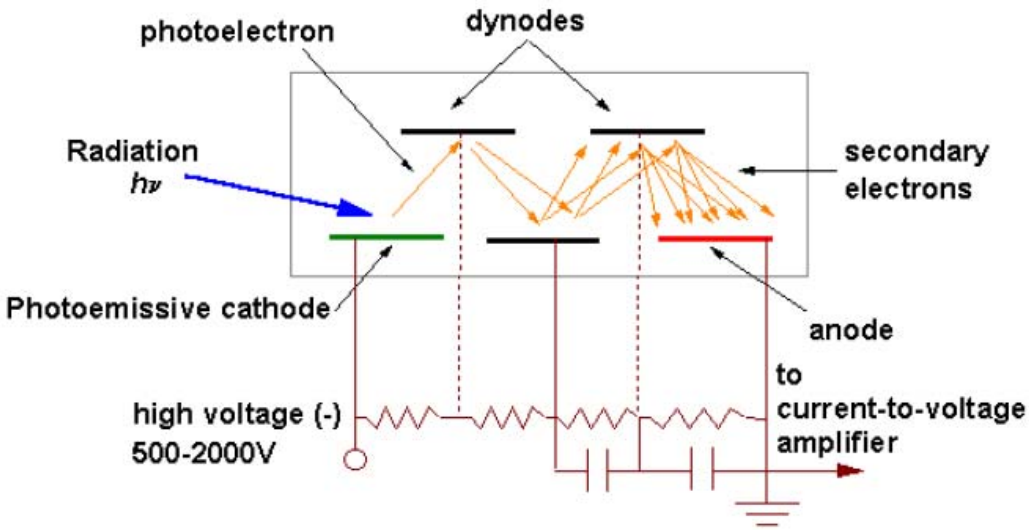
Outline

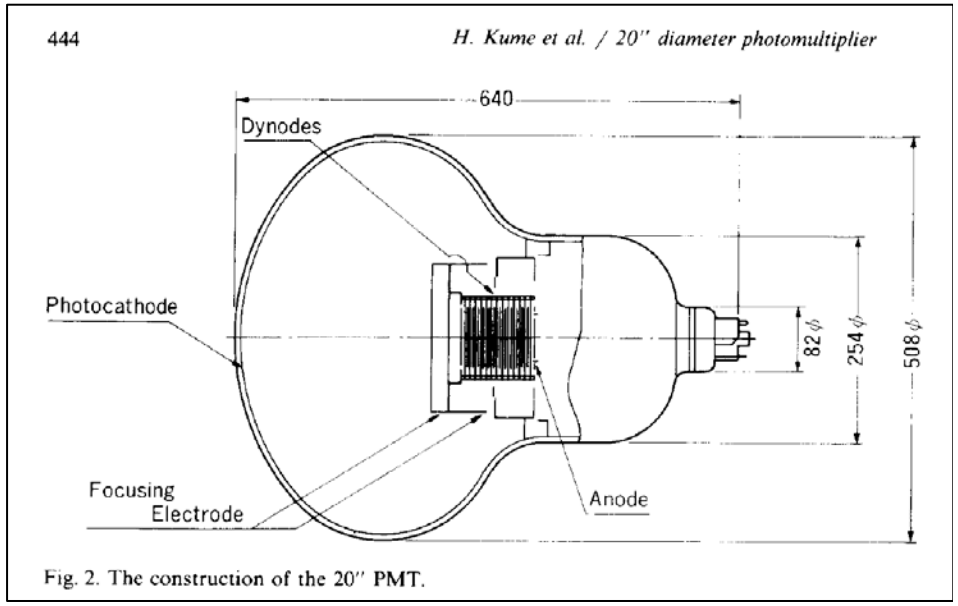
- 1. The Motivation;
- 2. The Design of the new MCP-PMT;
- 3. The Research project;
- 4. The Status of the Prototypes ;
- 5. Summary.

Outline

- 1. The Motivation;
  - 1.1 What is photomultiplier Tube (PMT)?
  - 1.2 The relationship between the PMT and neutrino detection ;
  - 1.3 The requirements of the PMT for the neutrino detection project

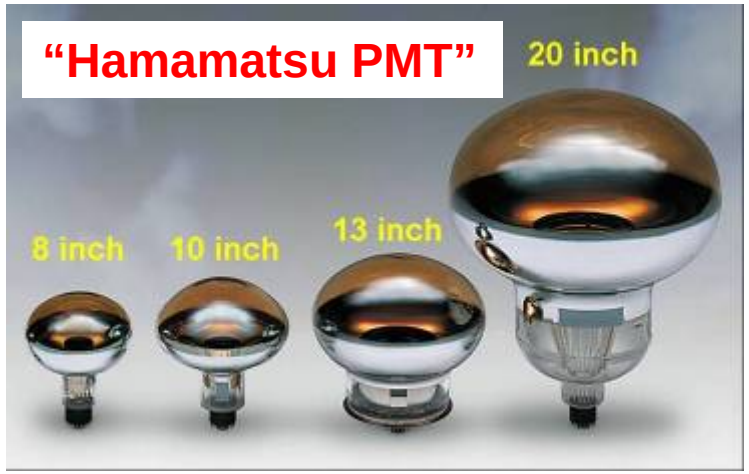
➢ 1.1 What is photomultiplier Tube (PMT)?





PS:The data and Picture come from the reports by Hamamatsu

➢ 1.2 The relationship between the PMT and neutrino detection



Large Format PMTs for Neutrino Experiments

- **Atmospheric neutrino exp.**
  - **SuperK**,
  - HyperK/UNO,
  - INO,TITAND,…
- **Solar neutrino exp.**
  - **SNO,**
  - GALLEX/SAGE,
  - Borexino, XMASS, …
- **Accelerator neutrino exp.**
  - **T2K,**
  - **Nova**,
  - Minos, OPERA,
  - MiniBooNE,
- **Reactor neutrino exp.**
  - **KamLAND** (Japan),
  - **Daya Bay** (China),
  - **Reno** (Korea),
  - **Double Chooz** (France)
  - **…**

➢ 1.3 The requirements of the PMT for the neutrino detection

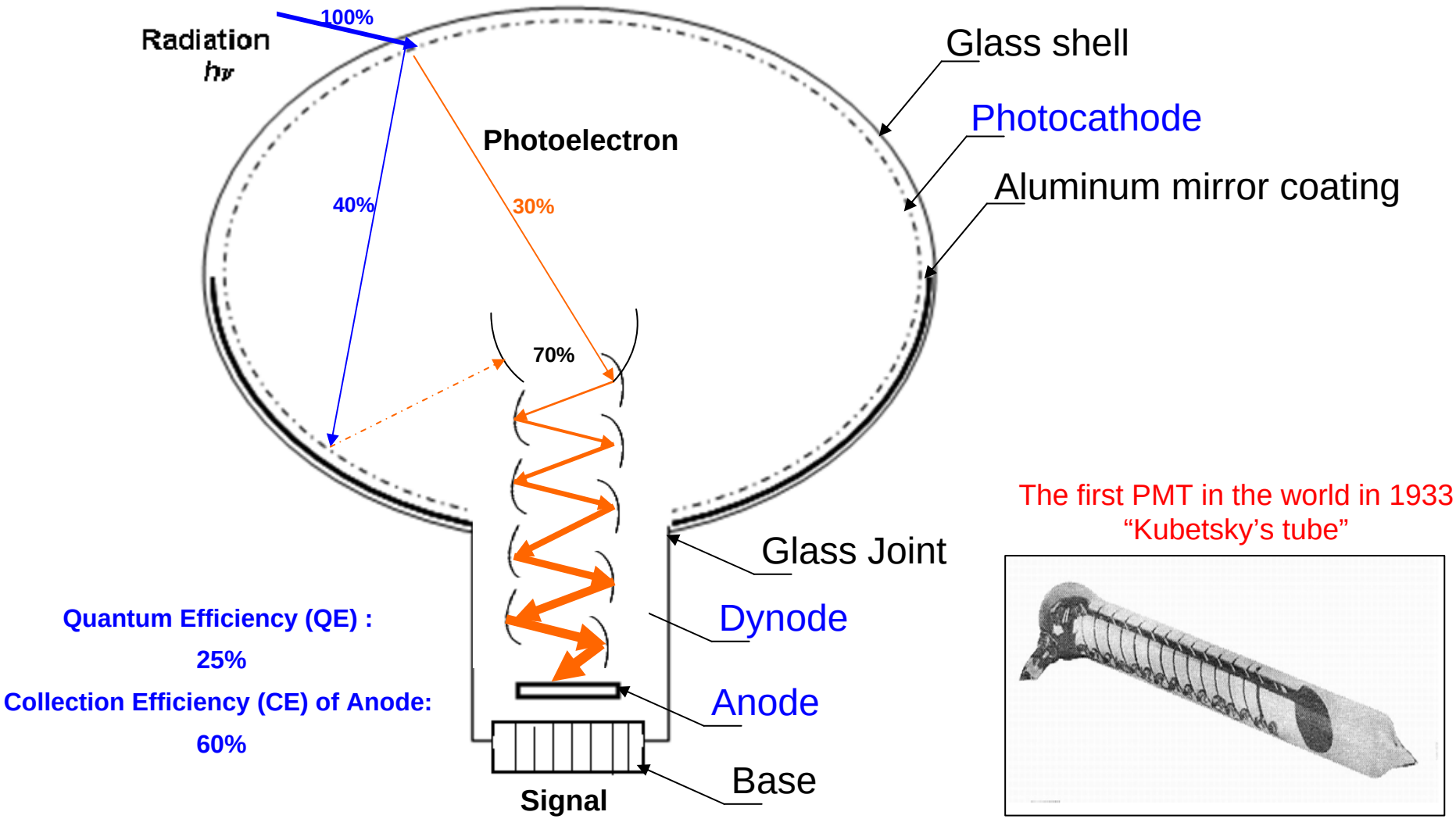
Status	Project	PMT	Number	Company
Work	ANTARES（mediterranean sea）	10”	1000	Hamamatsu
Work	IceCube（South Pole）	10”	4800	Hamamatsu
Work	KamLADE (Japan)	17” 20”	1325 554+250	Hamamatsu
Work	Super K (Japan)	20”	11146	Hamamatsu
Work	Sudbury SNO (Canada)	8”	9600	Hamamatsu
Work	DayaBay (China)	8”	2000	Hamamatsu
Plan	**DayaBay II (China)**	**20”**	**20000**	**China?**
Plan	KM3Net	Large small	10000 300000	? ?
Plan	LEAN (France)	8”	53000	?
Plan	LBNE (American)	12”	30000	?
Plan	MEMPHYS(Europe)	12”	81000	?
Plan	Hyper K	20”	Super K*20	Hamamatsu
Plan	Hanohano (Hawaii)	10”	20000	?

PS:The statistical data come from the NDIP,TIPP,APS,SPCS,NNN et.al conference reports.

Outline

- 2. The Design of the new MCP-PMT;
  - 2.1 The Conventional PMT;
  - 2.2 The Quantum Efficiency of PMT;
  - 2.3 The R&D of the new type of PMT;
  - 2.4 The new design of a large area PMT ;
  - 2.5 The performance of the MCP-PMT;

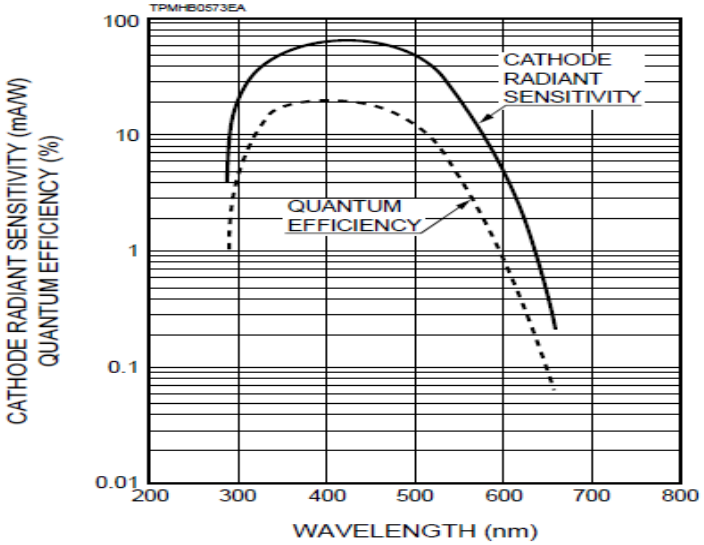
➢2.1 The Conventional PMT



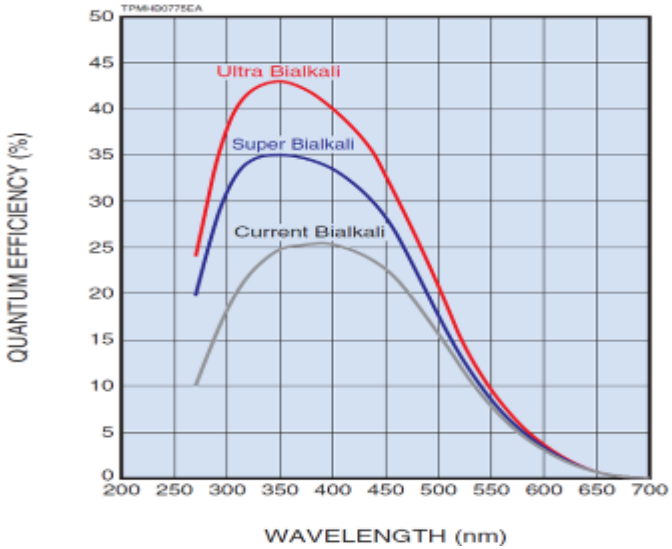
Photon Detection Efficiency (PE)= QE_{Trans} * CE = 25% * 60% = 15%

➢ 2.2 The Quantum Efficiency of PMT

The QE of 20“ PMT-R3600



The QE of SBA/UBA



➢**High QE PMTs: SBA (35%) and UBA (43%)**

are only available in small format (< 5" diameter ?)

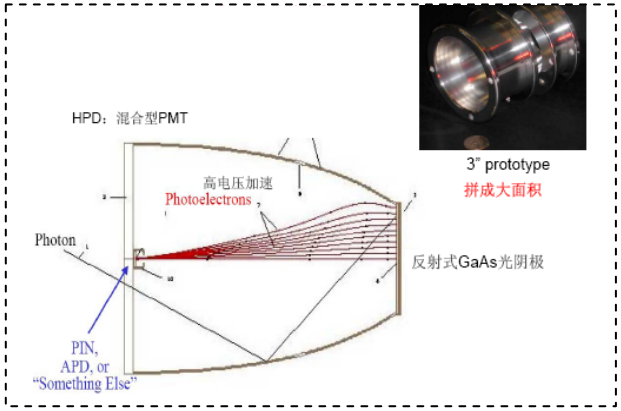
➢**Can we improve the Quantum Efficiency of Photocathode or Photon Detection Efficiency for the large area 20” PMT ?**

?? 20” UBA/SBA photocathode PMT from Hamamatzu ? QE: 20% → 40%

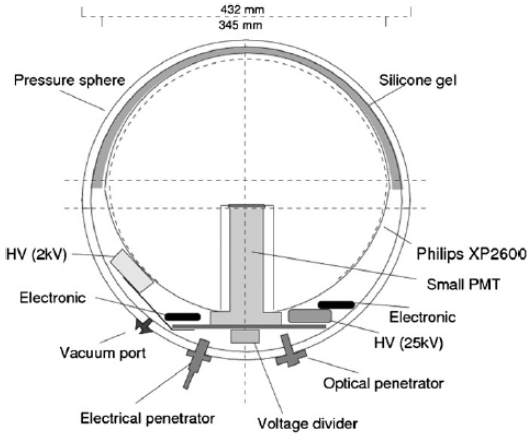
?? 20” New large area PMT ? Quantum Efficiency > 40% ?

or **Photon Detection Efficiency:** 15% → 30%

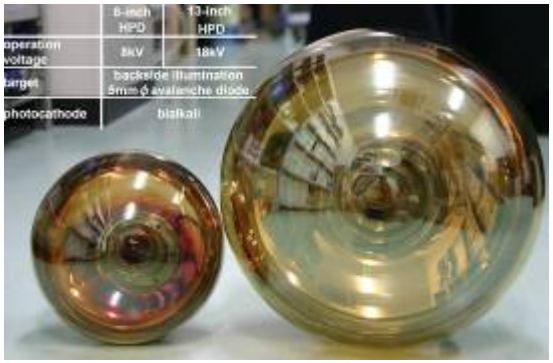
➢ 2.3 The R&D of the new type of PMT



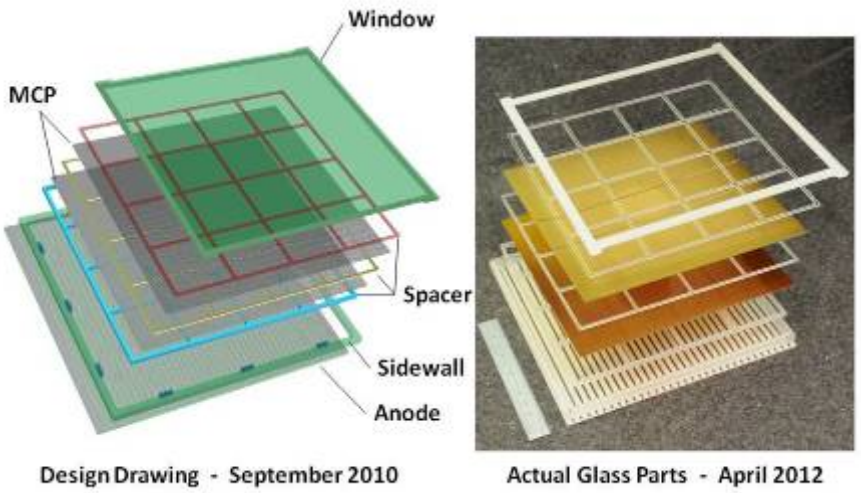
HPD--U.C. Davis



HPD—of DUMAND
European optical module



HPD--Hamamatzu



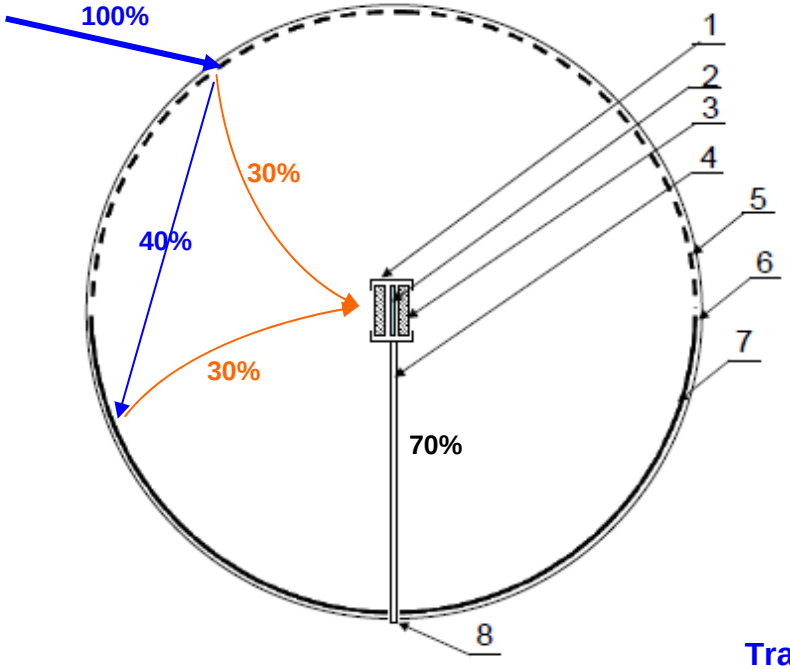
LAPPD project – ANL, Chicago

12" PMT with SBA photocathode--Hamamatzu

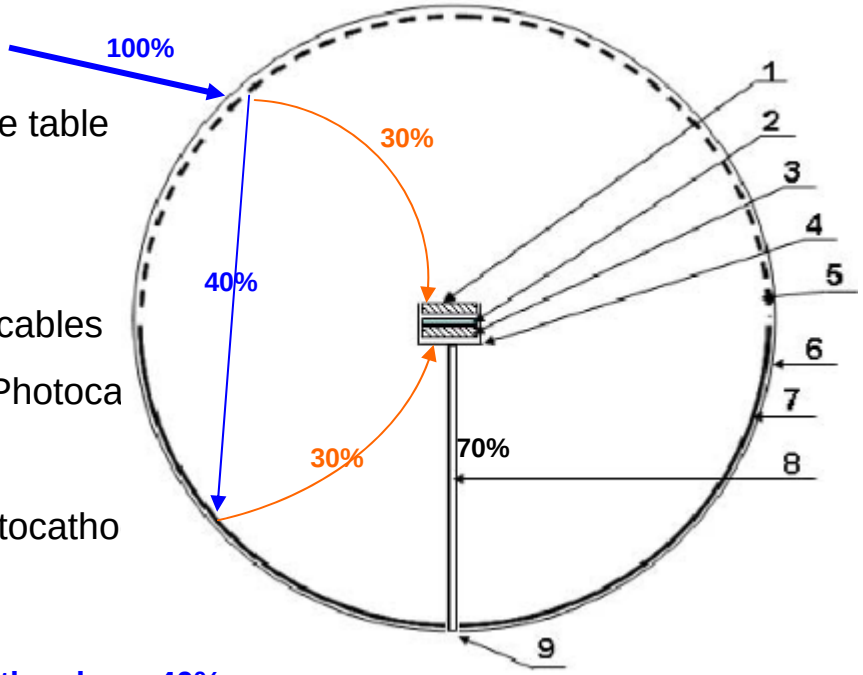
➢2.4 The new design of a large area PMT

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) } ~ 4π 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 !

Outline

- 3. The Research project;
  - 3.1 Project team and Collaborators;
  - 3.2 The Organization Chart;
  - 3.3 The Technical Workshop & Collaboration Meeting;
  - 3.4 The R&D plan of MCP-PMT （schedule）;
  - 3.5 The New PMT factory in China;
  - 3.6 How to produce the MCP-PMT;
  - 3.7 The R&D plan of MCP-PMT （method）;
  - 3.8 The Challenge of the Research Project ;

➢3.1 Project team and Collaborators

中国科学院高能物理研究所

Institute of High Energy Physics, CAS

effort by **Yifang Wang;**

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

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

南京大学

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

宝光股份
BAOGUANG

HZC PHOTONICS

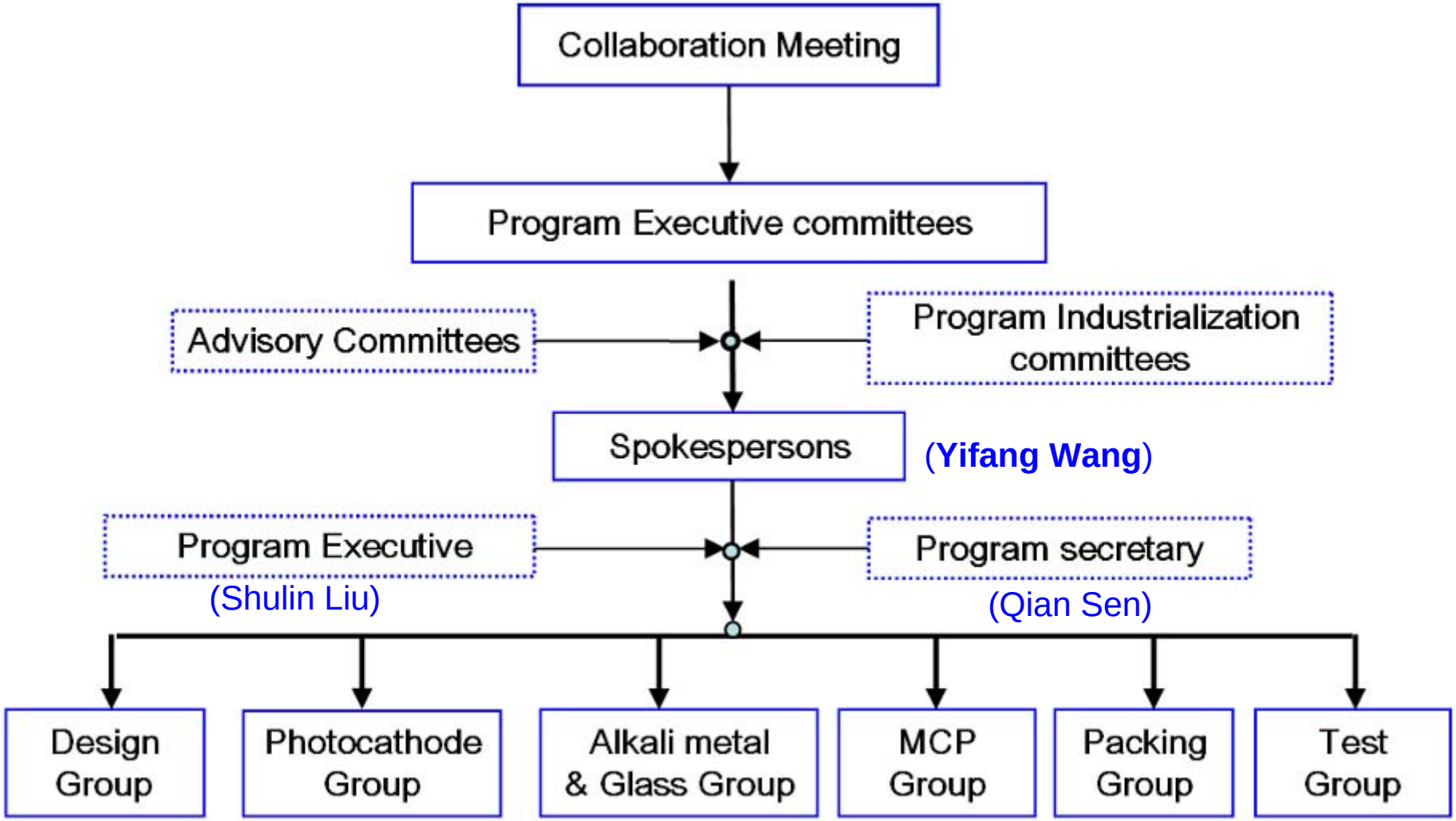
Other company and institute (not join us yet)： ……

南京电子器件研究所
Nanjing Electronic Devices Institute

華東電子

➢ 3.2 The Organization Chart

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



➢ 3.3 The Technical Workshop & Collaboration Meeting

Technical Workshop

Kunming 20110911

Xian 20120227

Nanjing 20120620

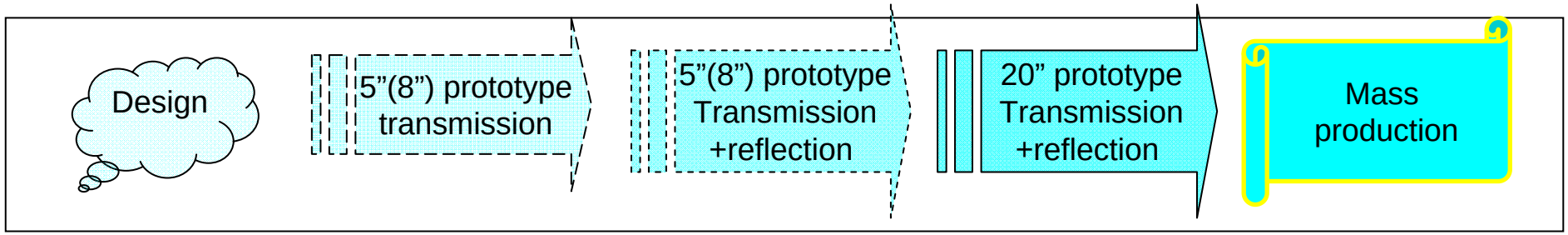
Collaboration Meeting

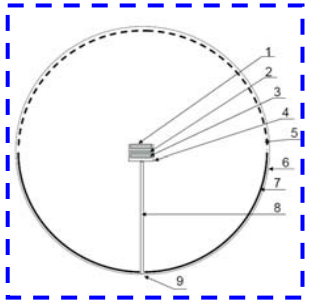
Beijing 20111118

Xian 20120301

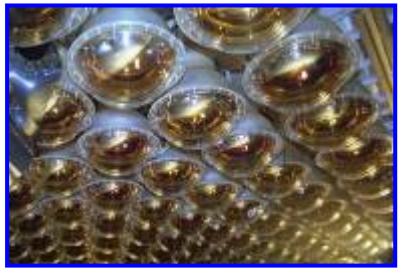
Nanjing 20120621

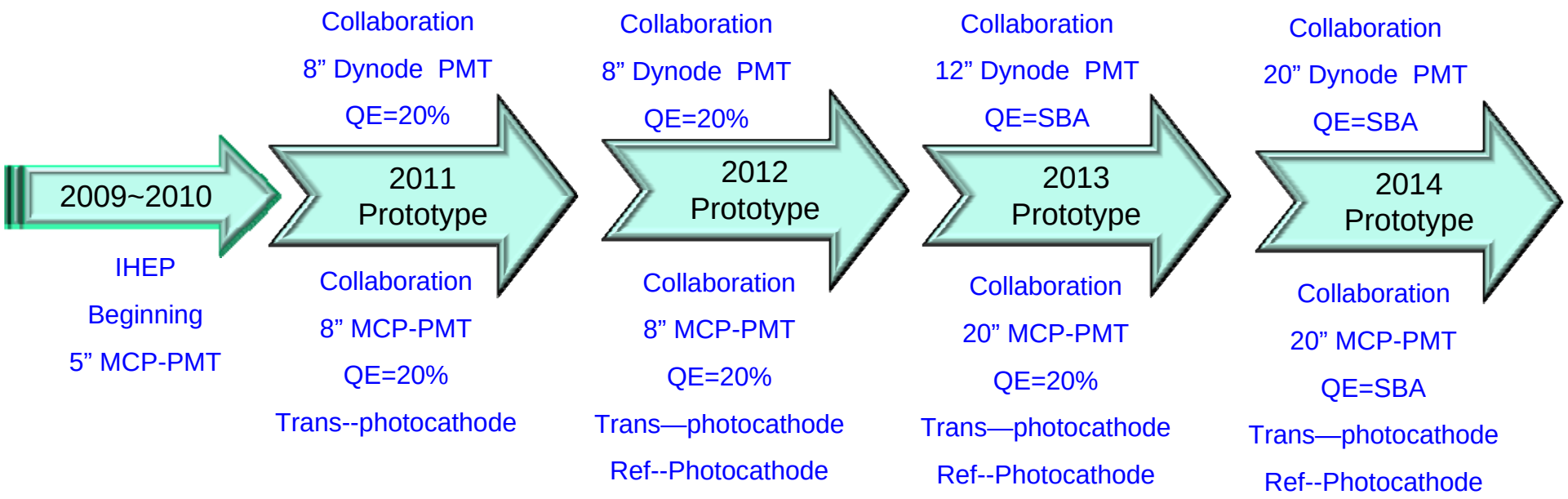
➢3.4 The R&D plan of MCP-PMT （schedule）





The design of the IHEP-MCP-PMT → The project of Daya Bay II





➢3.5 The New PMT factory in China

HZC has bought the PMT production Line from Photonis in 2011, and will produce the first prototype in the end of this year in Hainan province in China.

PHOTONIS

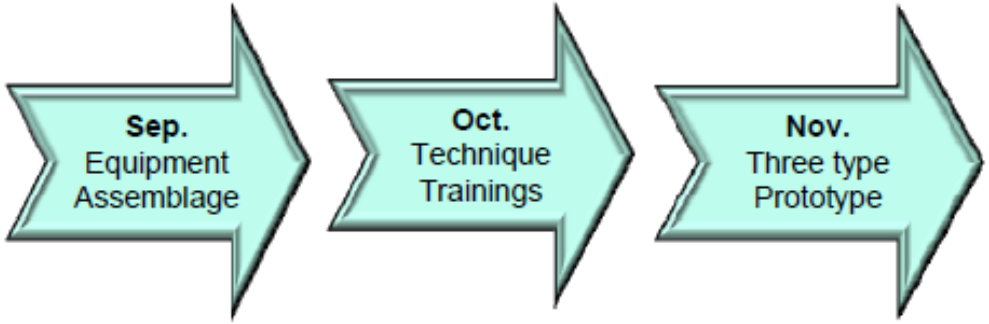
- ➢Production Equipment for PMT；
- ➢Patents and Technique documents；
- ➢Technique Trainings；
- ➢Technique Support for R&D;
- ➢User authentication & product certification

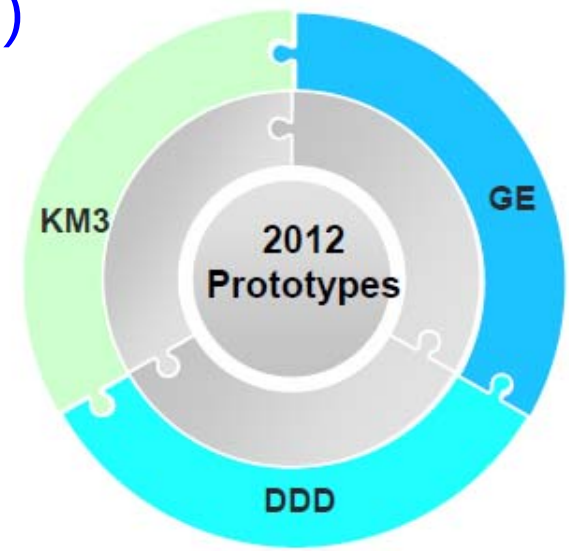
HZC PHOTONICS

Office Building

Factory Building

PMT Production Plan for the Market (2012)





PMT Prototype R&D Plan for the DayaBay II

3” QE= 38.4%

XP53B20

+

8” QE= 23.6%

XP1805

+

XP1807 12” QE= 24%

=

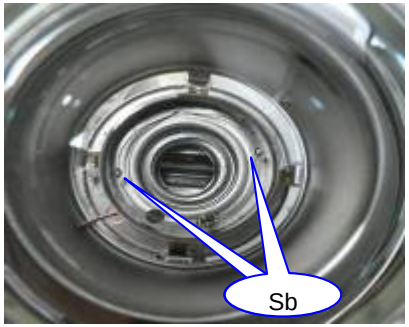
20” QE= 30%

➢ 3.6 How to produce the PMT

The reflection film --**Al**

The anode and electrode –**MCP/ Cu / stainless steel**

The electric film --**Sb**

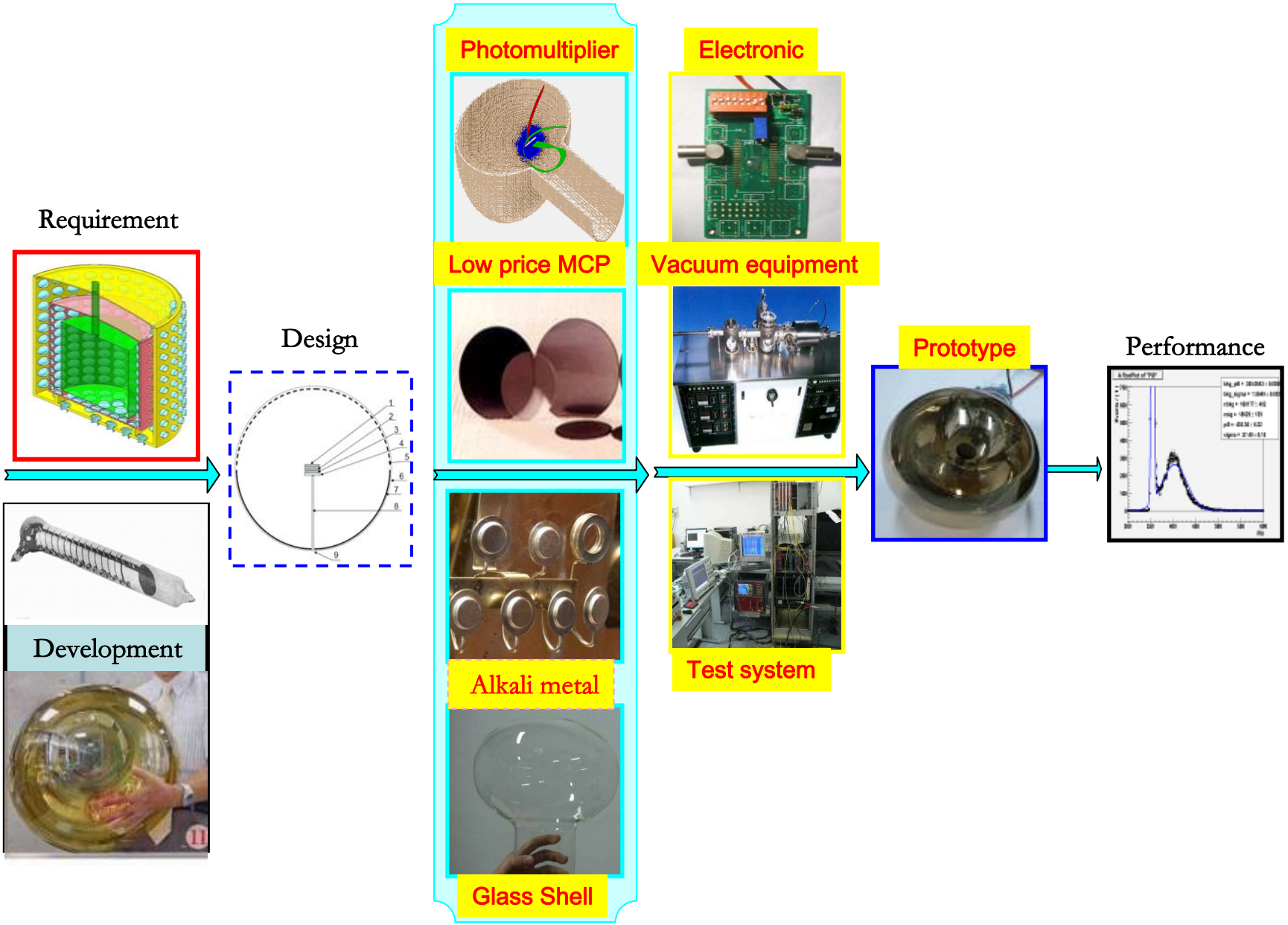


The **Photocathode**

The alkali metal –**K/Cs**

The **oxgen plasma**

➢ 3.7 The R&D plan of MCP-PMT （method）



➢ 3.8 The Challenge of the Research Project

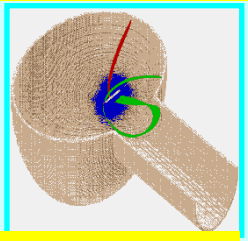
➢Simulate the best place for MCP unit ;
➢Simulate the best assemblage;

➢Low cost not for imagine device ;
➢High gain/ low noise for SPE detection ;
➢enhance the performance by ALD

➢The alkali metal dispensers (AMD)?;
➢For high QE photocathode;
➢Control the quality of mass production;

➢Large size (8" , 20");
➢Superb water-resistance characteristics;
➢Low radioactive background glass;

Photomultiplier

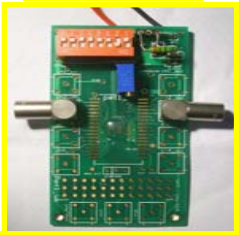


Low price MCP

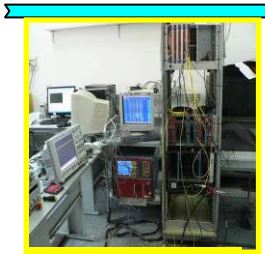
Alkali metal

Glass Shell

Electronic



Vacuum equipment



Test system

➢The Pre-Amplifier;
➢Improve the gain ;
➢Current-sensitive preamplifier;

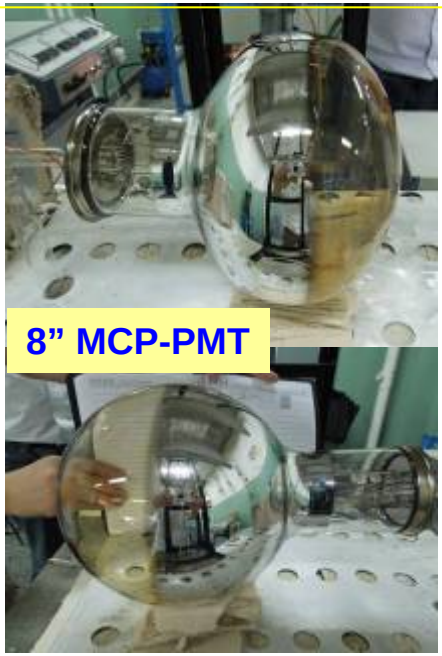
➢MCP Test equipment;
➢The Transfer equipment for MCP-PMT prototypes;
➢The Atomic Layer Deposition System (ALD)

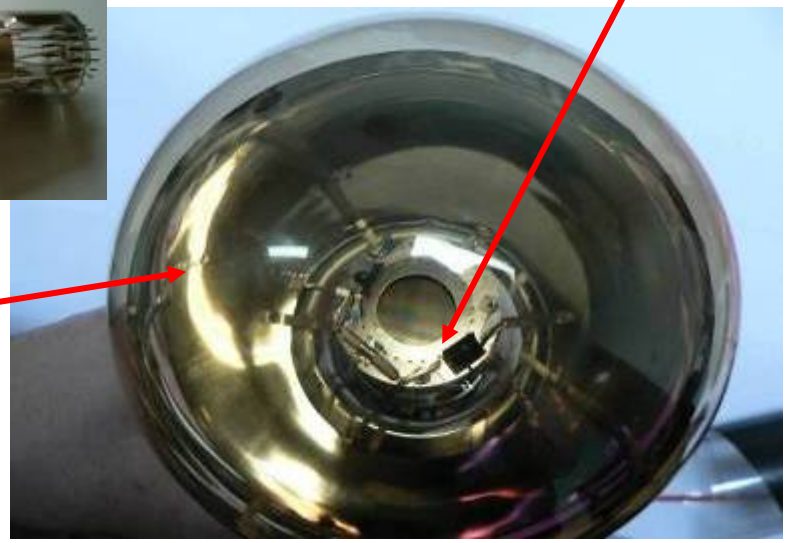
➢Large PMT evaluation system;
➢Single photoelectron spectrum;
➢System for QE measurement;

Outline

- 4. The Status of the Prototypes ;
  - 4.1 The prototypes；
  - 4.2 The performance of 5” MCP-PMT；
  - 4.3 The performance of 8” MCP-PMT；

➢ 5.1 The Prototypes

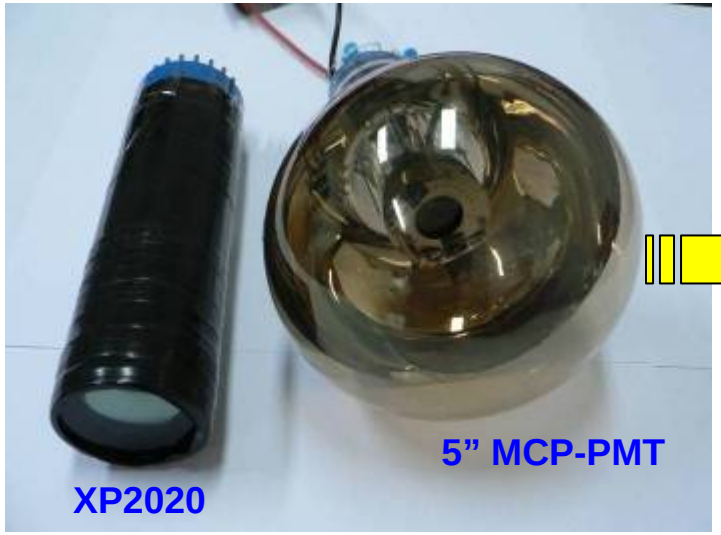


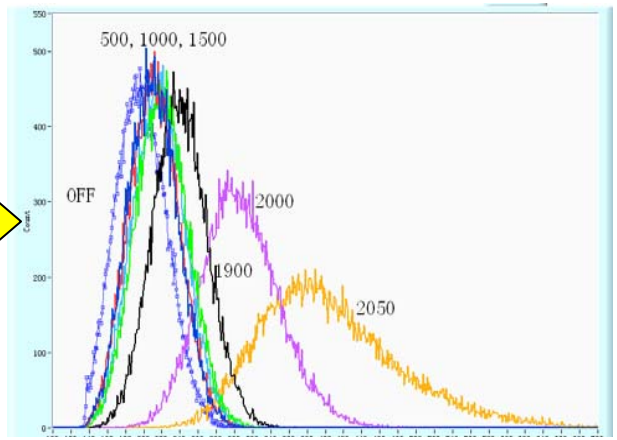


transmission photocathode

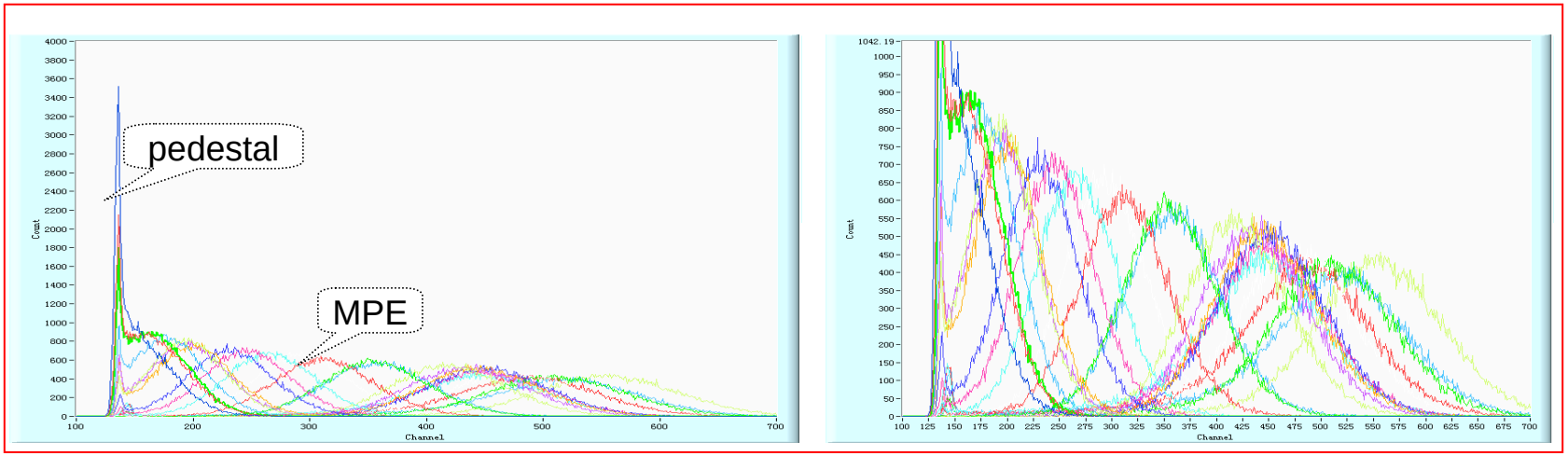
➢ 5.2 Performance of the 5”MCP-PMT prototype

➢**The photoelectron spectrum of a prototype: 5” IHEP-MCP-PMT**





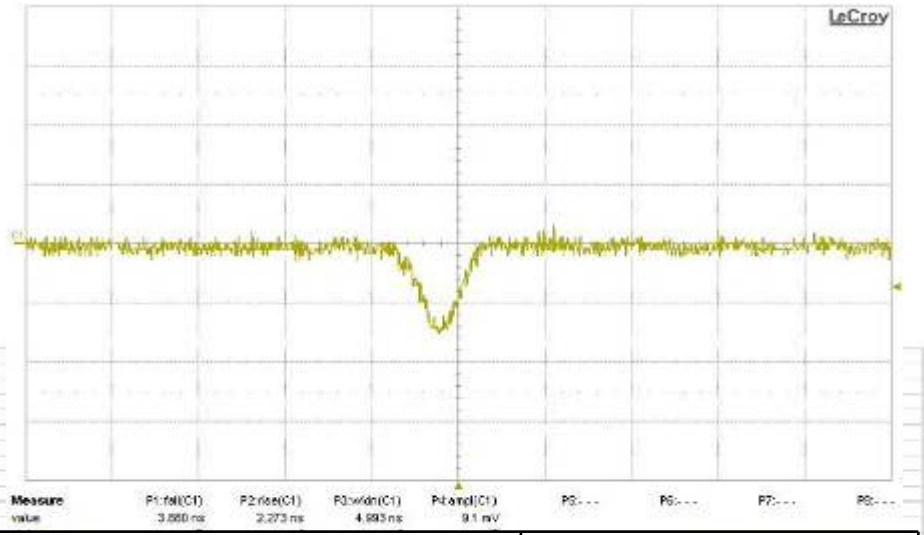
➢**SPE vs the Voltage of the PMT**

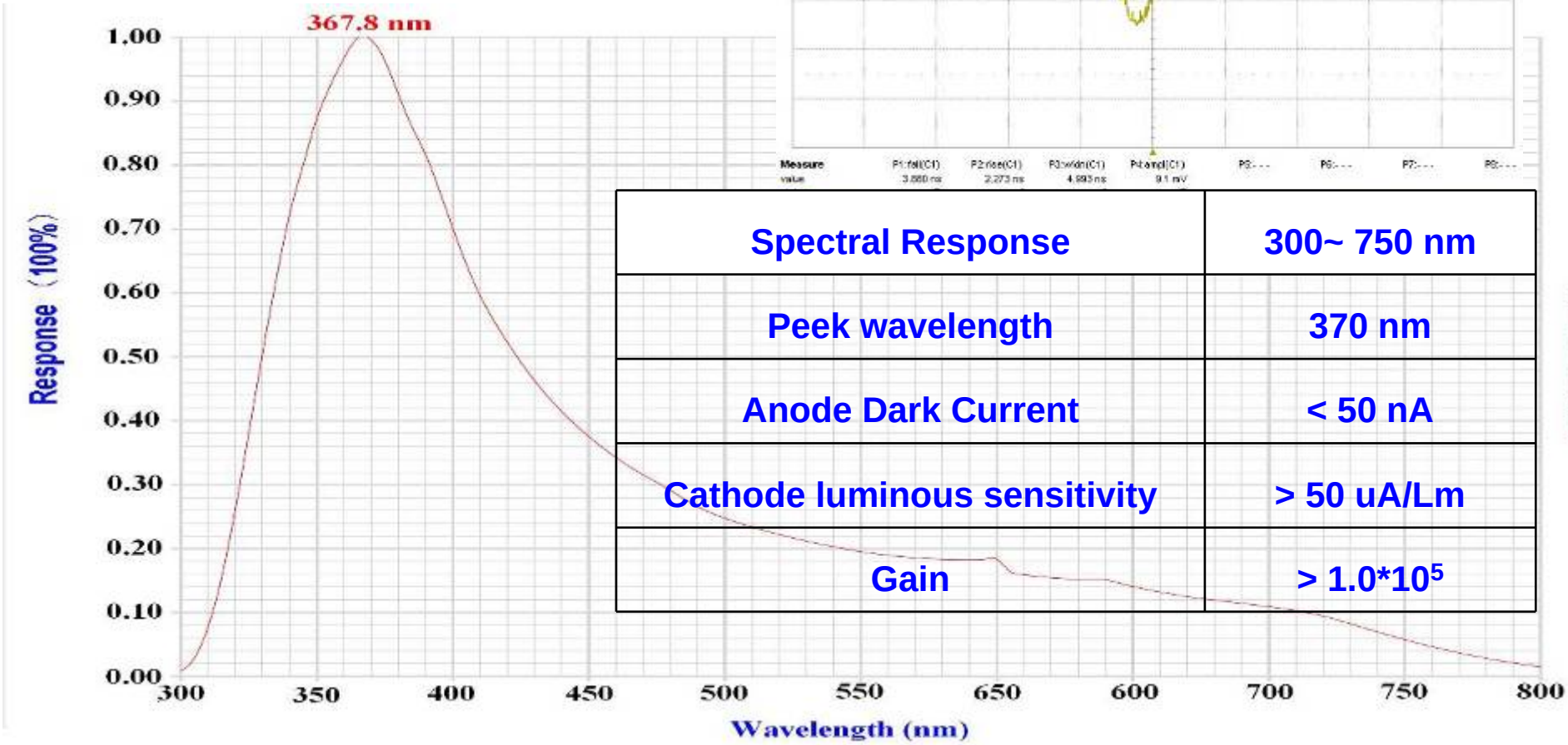


➢**MPE vs the luminance of the LED light**

**--adjust the working voltage of the LED to adjust the luminance of the LED light.

- Rise time： ~ 2ns；
- Fall time: ~3ns；
- Signal amplitude ~7mV；

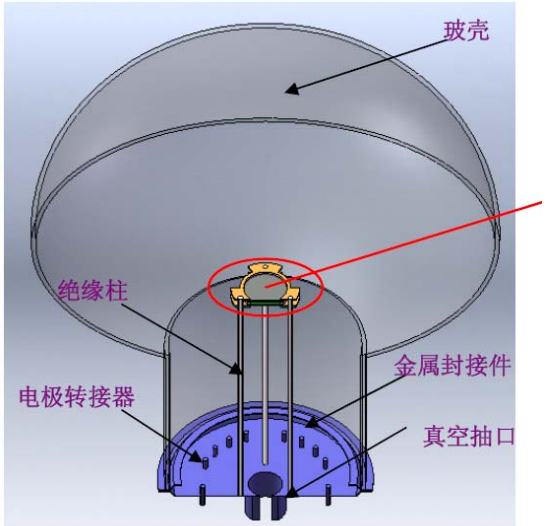




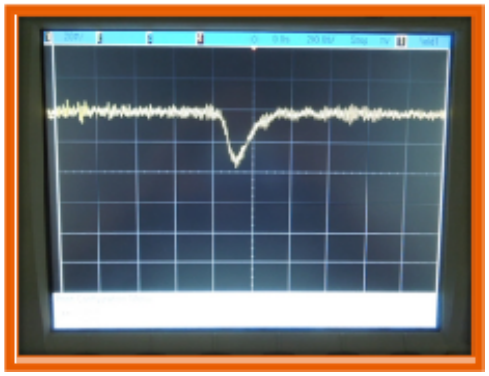
Spectral Response	**300~ 750 nm**
Peek wavelength	**370 nm**
Anode Dark Current	**< 50 nA**
Cathode luminous sensitivity	**> 50 uA/Lm**
Gain	**> $1.0*10^5$**

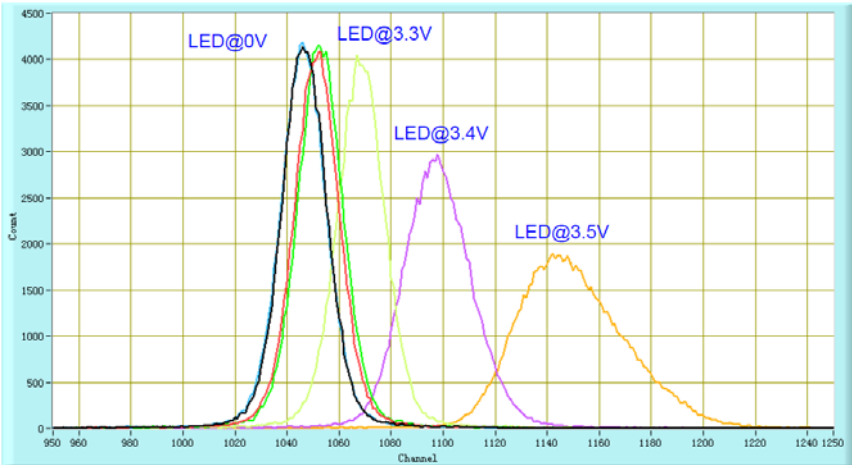
➢ 5.3 Performance of the 8” MCP-PMT prototype

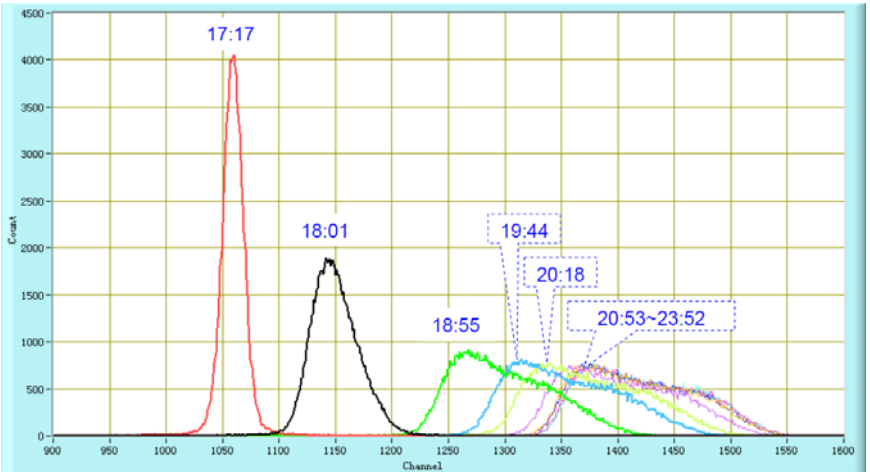
5” 8” 6”



8” ellipse 8” spherical




LED@0V
LED@3.3V
LED@3.4V
LED@3.5V
Count
Channel


17:17
18:01
18:55
19:44
20:18
20:53~23:52
Count
Channel

Summary

- **1. A new type of MCP-PMT is designed for the next generation neutrino exp.**
  - ✓ Large ares: ~ 20";
  - ✓ High photon detection efficiency: ~30%, al least ×2 than normal PMT;
  - ✓ Low coat: ~ low cost MCPs;
- **2. The R&D process is composing with 3 steps.**

  ① 5"(8") prototype with transmission photocathode;

  ② 5"(8") prototype with transmission and reflection photocathode;

  ③ 20" prototype with transmission and reflection photocathode;
- **3. The R&D work is divided into 7 Parts to product the prototype to detect SPE:**

  ①Photocathode; ②MCP; ③Glass; ④Photomultiplier;

  ⑤vacuum equipment; ⑥Electronic; ⑦Test system;

There are lots of work to do!

We need any help from other institute and company!

Thank！ 谢谢！

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

➢ 2.5 The performance of the MCP-PMT

Characteristics	unit	R3809U-50 （Hamamatsu）	R5912 （Hamamatsu）	MCP-PMT-8 （IHEP）	R3600 （Hamamatsu）	MCP-PMT-20 （IHEP）
size	inch	2	8	**8**	20	**20**
Spectral Response	nm	160~850	300~650	**300~650**	300~650	**300~650**
Photocathode Material	--	Multialkali	Bialkali	**Bialkali**	Bialkali	**Bialkali**
Electron Multiplier	--	MCP	Dynode	**MCP**	Dynode	**MCP**
Gain	--	2×10^5	$\geqslant1\times10^7$	**$\geqslant1\times10^5$**	$\geqslant1\times10^7$	**$\geqslant1\times10^5$**
Photocathode mode	--	transmission	transmission	**reflection + transmission**	transmission	**reflection + transmission**
Cathode Sensitivity	uA/lm	150	70	**70**	60	**70 ~100**
Quantum Efficiency（400nm）	%	--	22	**20~40？？**	20	**20~40？？**
Electron Multiplier Collection efficiency	%	~ 60%	~ 60%	~ 70%	~ 60%	~ 60%
Efficiency of detecting photoelectron	%	--	< 13	**> 20**	<12	**> 20**
Anode Dark Current	nA	100	⩽700	**⩽100**	⩽1000	**⩽100**
Anode Pulse Rise Time	ns	0.150	3.8	⩽ 5	10	**⩽10**
Transit Time Spread (TTS)	ns	⩽0.025	2.4	**⩽1**	5.5	**⩽2**
Anti-Magnetic characteristics	--	Good	**normal**	**normal**	**normal**	**normal**
Glass	--	--	Low-Potassium Glass	**Low-Potassium Glass CN-2#**	HARIO-32	**Low-Potassium Glass- CN-2#**