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

基于MCP的大面积PMT研制

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On Behalf of the Workgroup

第十七届核电子学与核探测技术学术年会 2014年8月14日 兰州

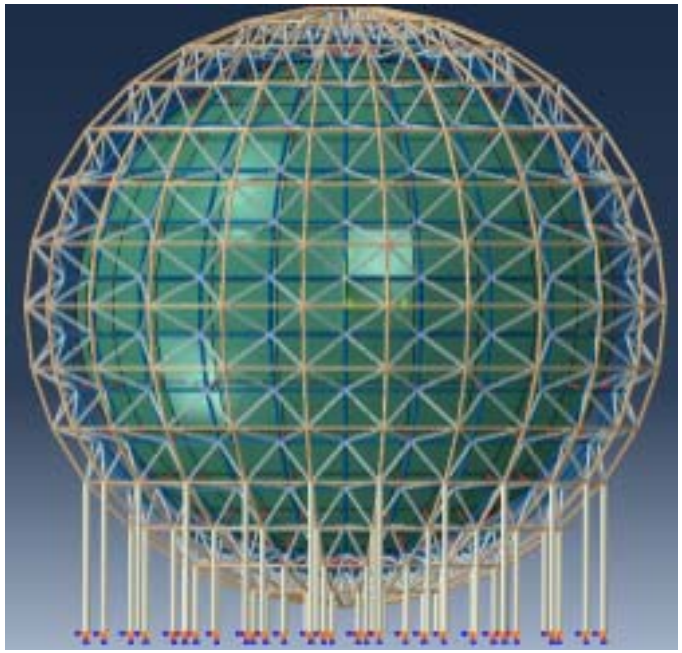
Outline

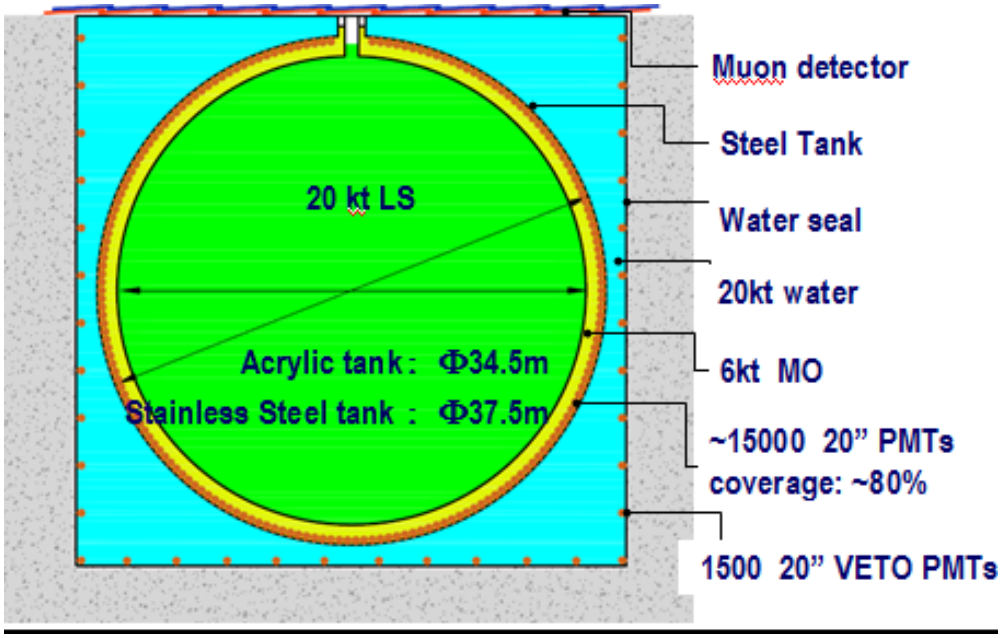
- **1.** 研制目的;
- **2.** 新型大面积**MCP-PMT**样管研制;
- **3.** 新型**8**吋**MCP-PMT**性能测试;
- **4.** 总计及计划

➢ 研制背景

《江门中微子实验》 大会报告: Prof. 张家文(中国科学院高能物理研究所)

《江门中微子观测站(JUNO)液体闪烁体研制进展》大会报告: 俞伯祥 (中国科学院高能物理研究所)





- LS volume: × 20 ➔ for more statistics (40 events/day)
- Light (PE) × 5 ➔ for better resolution (ΔM^2_{12}/ ΔM^2_{23} ~ 3%)

} 大面积高量子效率**PMT**

➢ 研制背景

◆ **20吋高量子效率PMT研制的三个可能的方案:**

⇨ **Hammamatsu PMT with SBA photocathode**

⇨ **A new design using MCP: 4π collection**

⇨ **Photonics-type PMT**

需求目标:

- ✓ 高量子效率（High QE）;
- ✓ 好的单光电子分辨能力（SPE）
- ✓ 大动态范围（dynamic range）;
- ✓ 低本底（radioactive background）;
- ✓ 长寿命（20年）;
- ✓ 抗水压（ 0.4MPa Pressure）;
- ✓ 大批量（~2万只）;

➢20“ Hammamatzu PMT

➢20” MCP- PMT

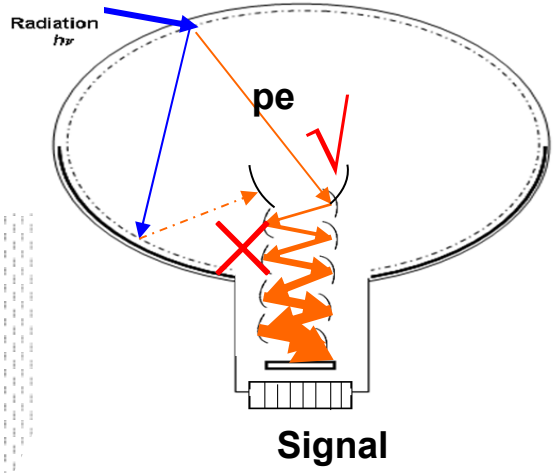
- 全球对称电场设计
- 全球面光阴极

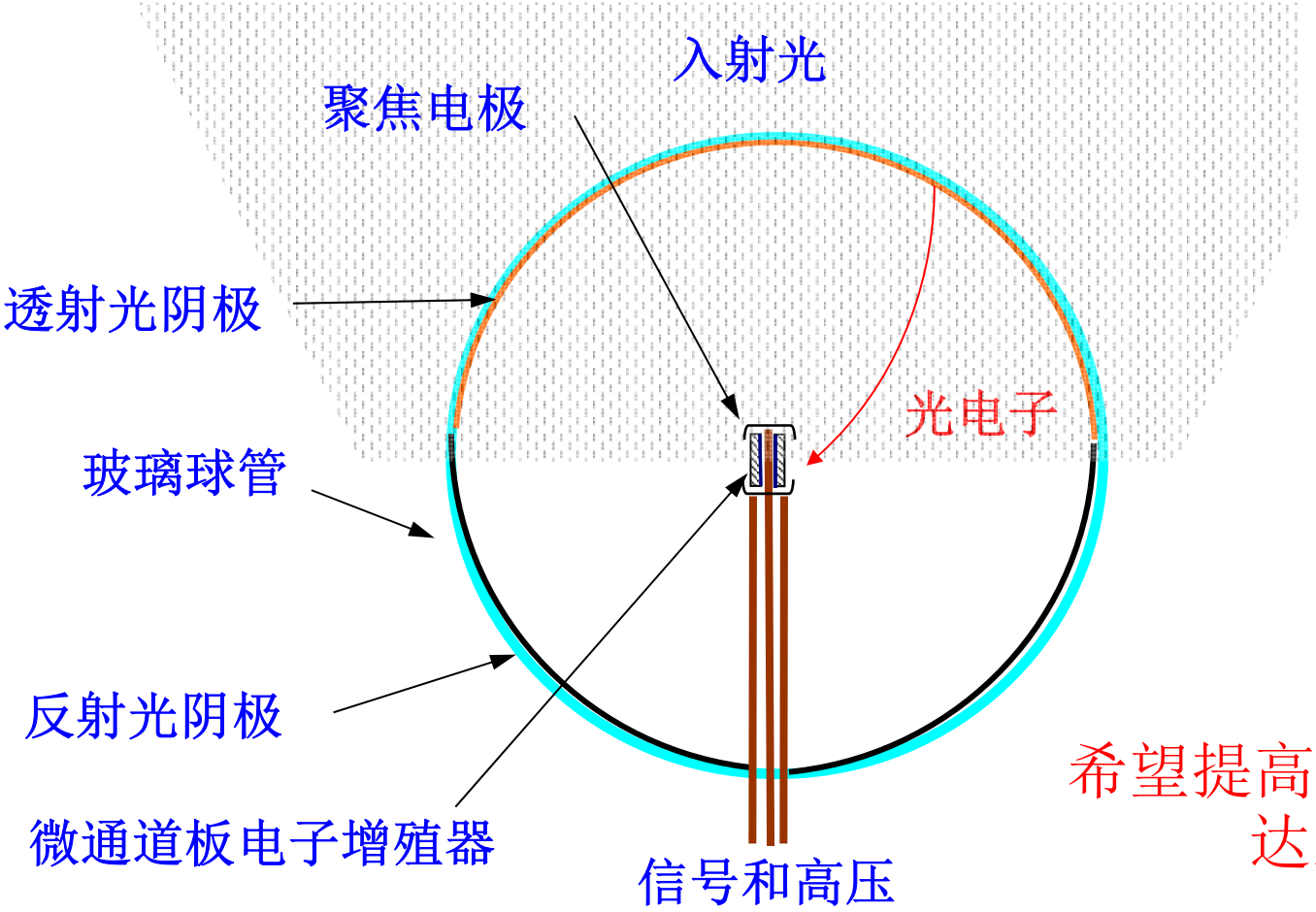
  上半球透射式：探测效率30~40%

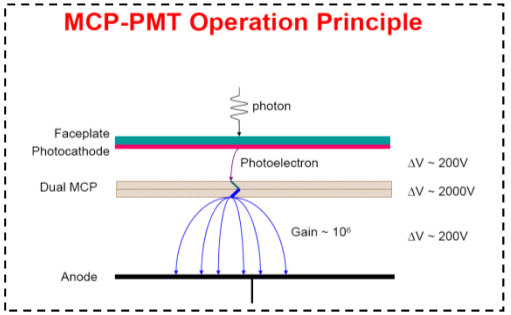
  下半球反射式：探测效率10~20%
- 两组紧凑的MCP电子放大器置于球心，

  取代传统打拿电极，

  光电子收集效率 > 80%







希望提高光子探测效率，
达到 > 40%

Outline

- 1. 研制目的;
- 2. 新型大面积MCP-PMT样管研制;
- 2.1 样管一览图;
- 2.2 8吋样管（水平MCP组件）;
- 2.3 8吋样管（竖直MCP组件）;
- 2.4 20吋样管（竖直MCP组件）;
- 3. 新型8吋MCP-PMT性能测试;
- 4. 总计及计划

➢ 2.1 样管一览图

Prototype

2” MCP-PMT

8” Dynode-PMT

8” MCP-PMT 5” MCP-PMT

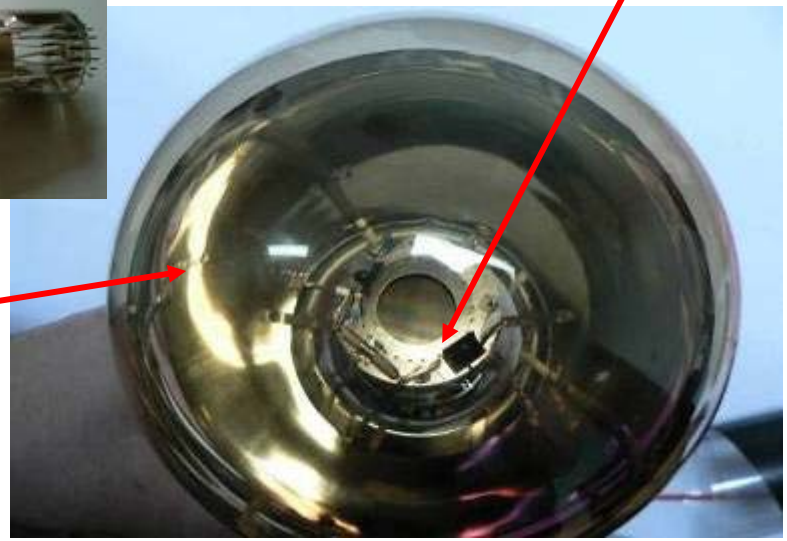
8” MCP-PMT

8” MCP-PMT

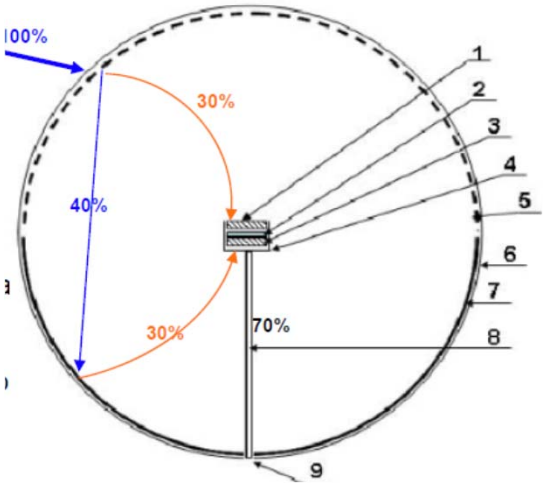
transmission photocathode

5” MCP-PMT

MCP

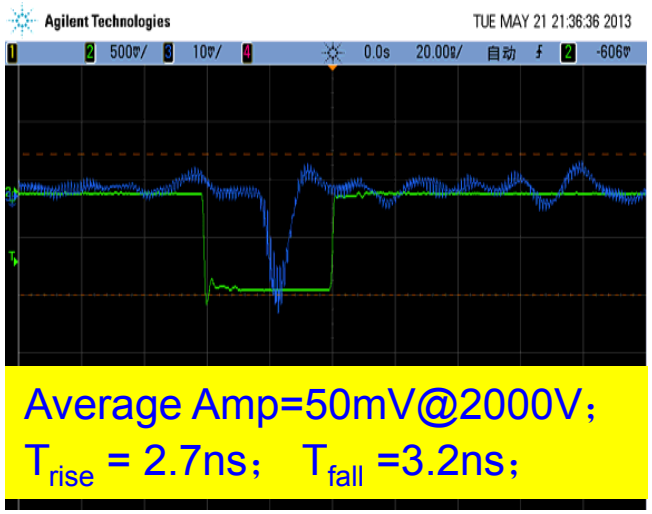


2.2 8吋样管（水平MCP组件）

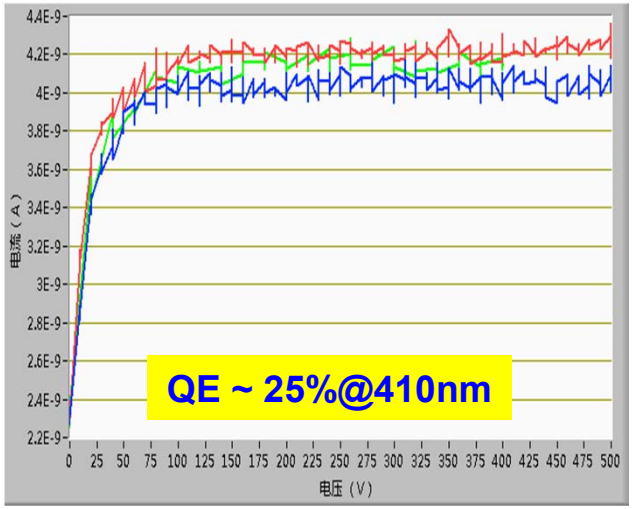


MCP-PMT设计

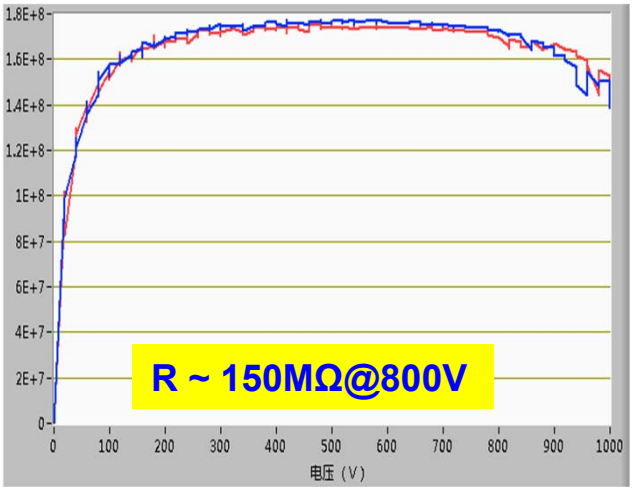
MCP-PMT 样管



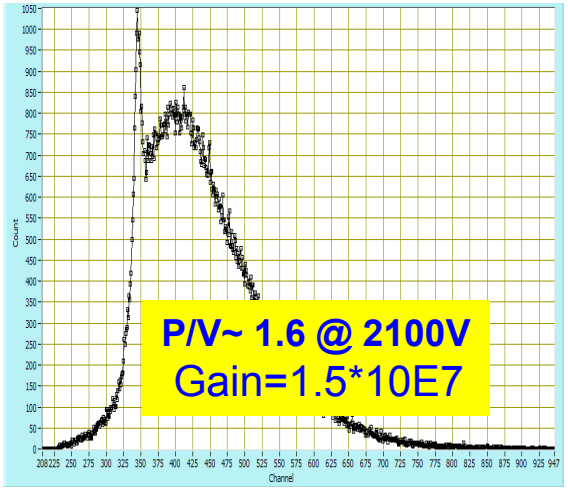
MCP-PMT 信号波形



样管光阴极 I-V 坪曲线

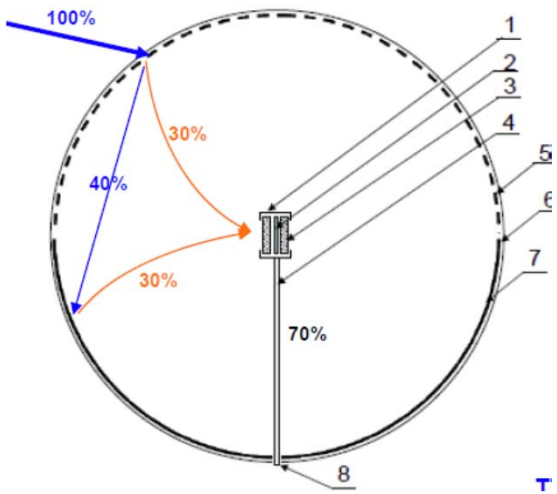


样管MCP的体电阻率



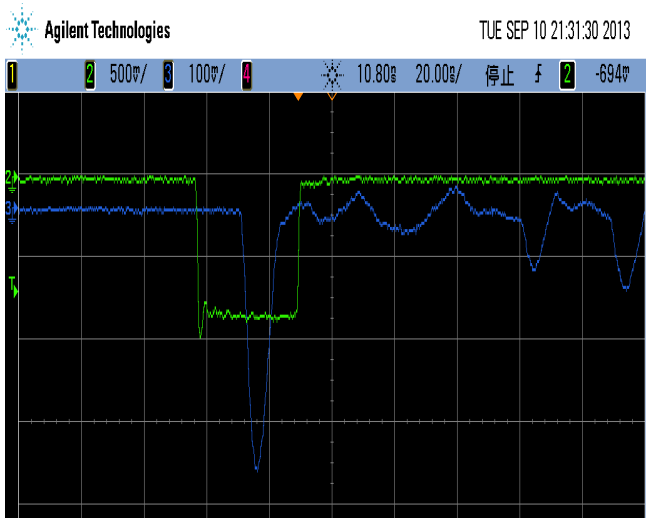
样管单光电子谱SPE

➢ 2.3 8吋样管（竖直MCP组件）

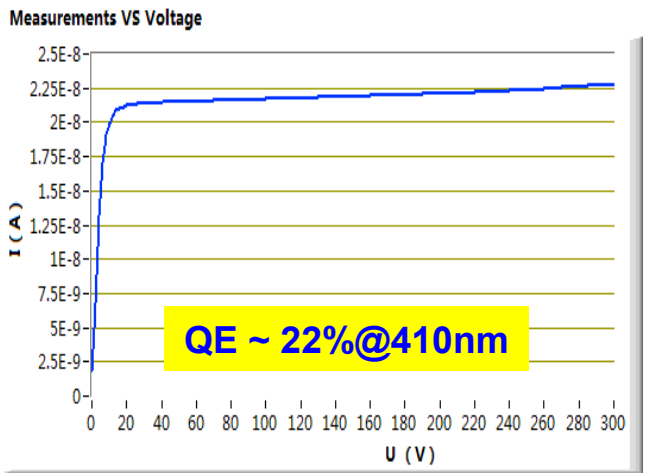


MCP-PMT设计

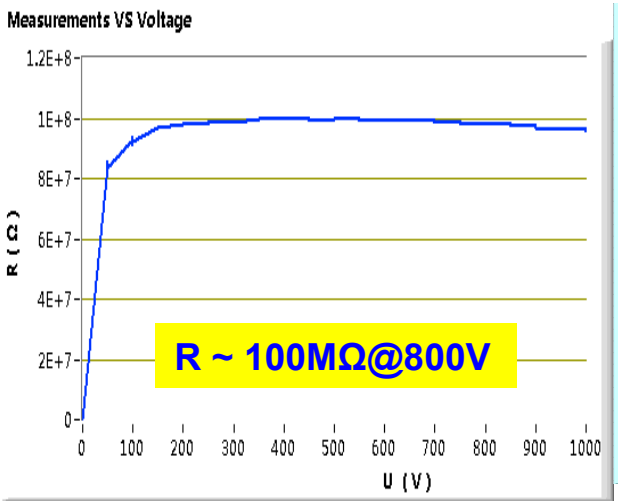
MCP-PMT 样管



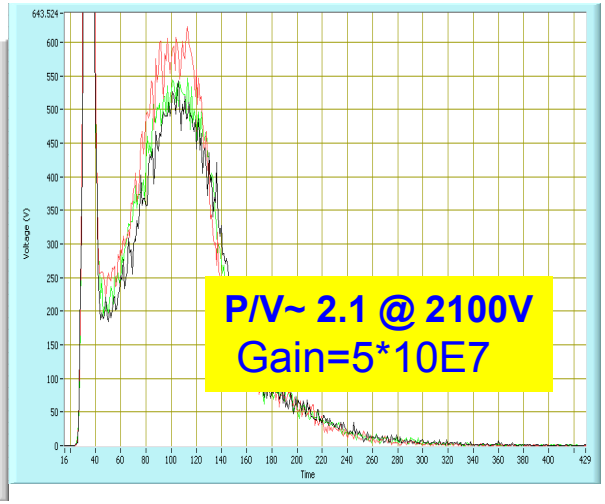
MCP-PMT 信号波形



样管光阴极 I-V 坪曲线



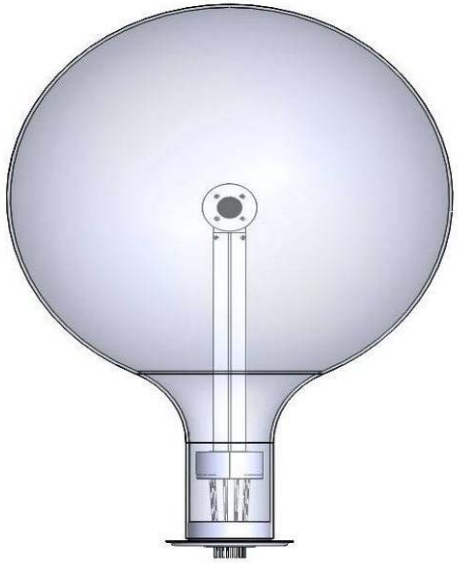
样管MCP的体电阻率



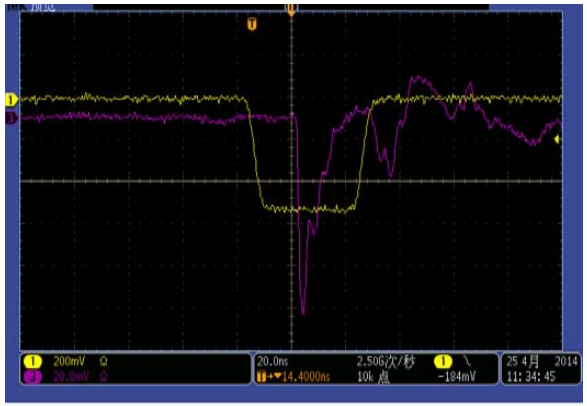
样管单光电子谱SPE

2.4 20吋样管（竖直MCP组件）

MCP-PMT设计



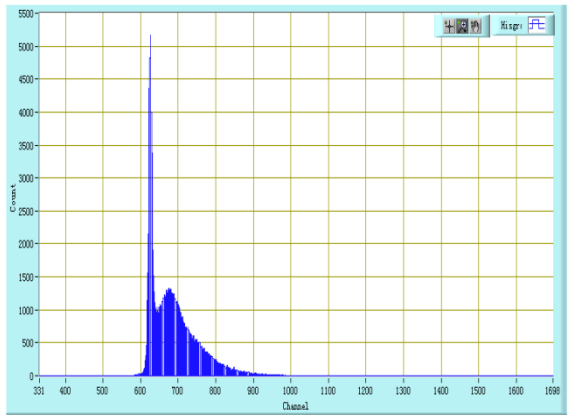
MCP-PMT 样管



MCP-PMT 信号波形

QE= **10.3% @410nm**;

Gain=**7.8E6 @2000V;**



样管单光电子谱SPE

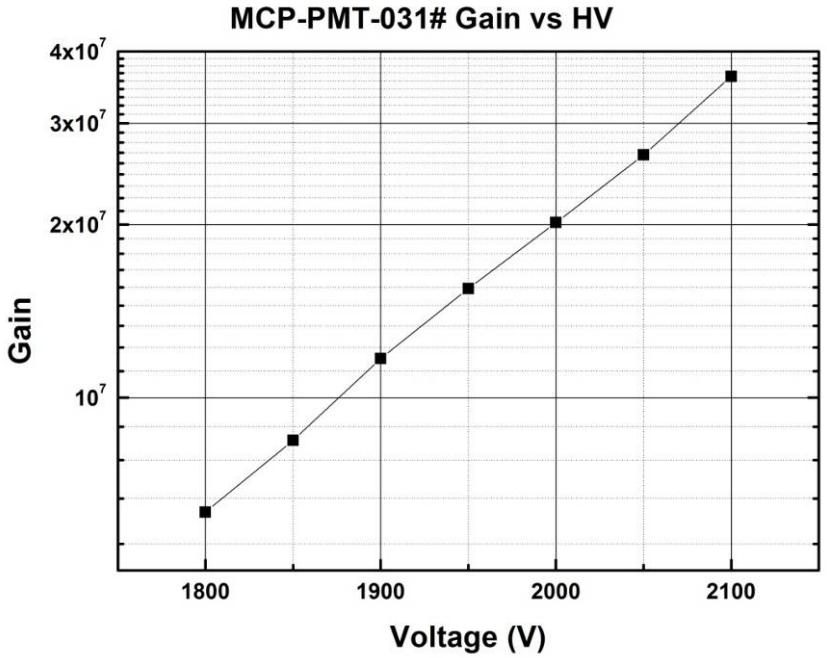
Outline

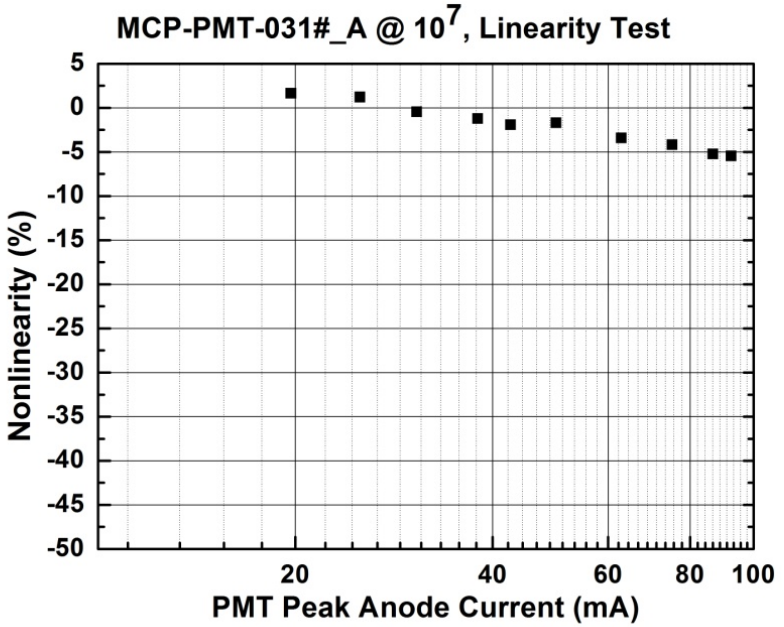
- 1. 研制目的;
- 2. 新型大面积MCP-PMT样管研制;
- 3. 新型8吋MCP-PMT性能测试;
- 3.1 光阴极量子效率测试;
- 3.2 波形和单光电子谱测试;
- 3.3 增益和线性测试;
- 3.4 暗噪声、暗计数率测试;
- 4. 总计及计划

➢ 3.3 增益和线性测试；

The data statistics by the QDC with SPE signals

MCP-PMT-031#-A



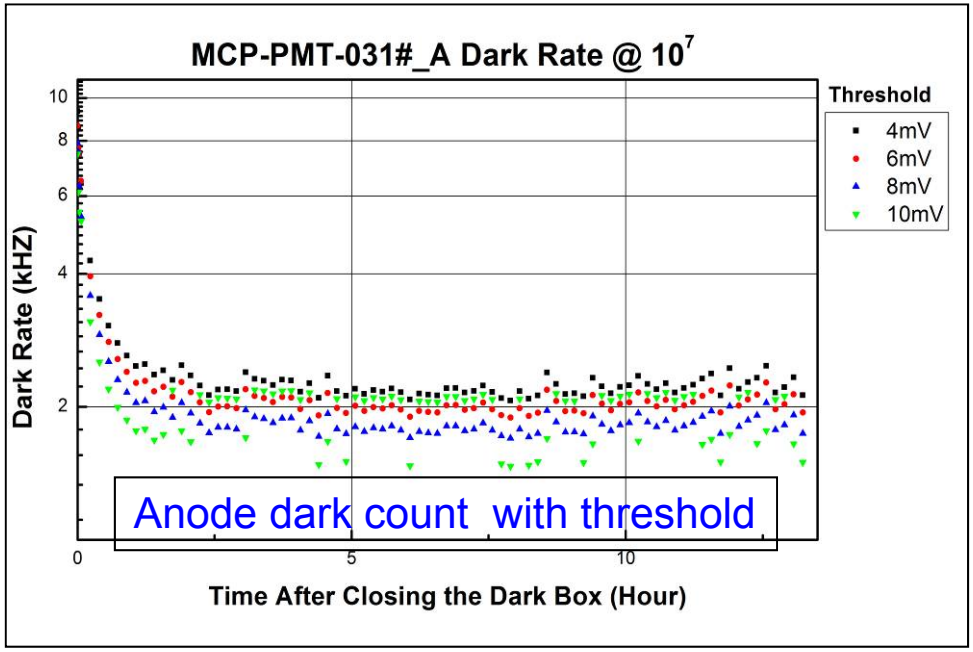


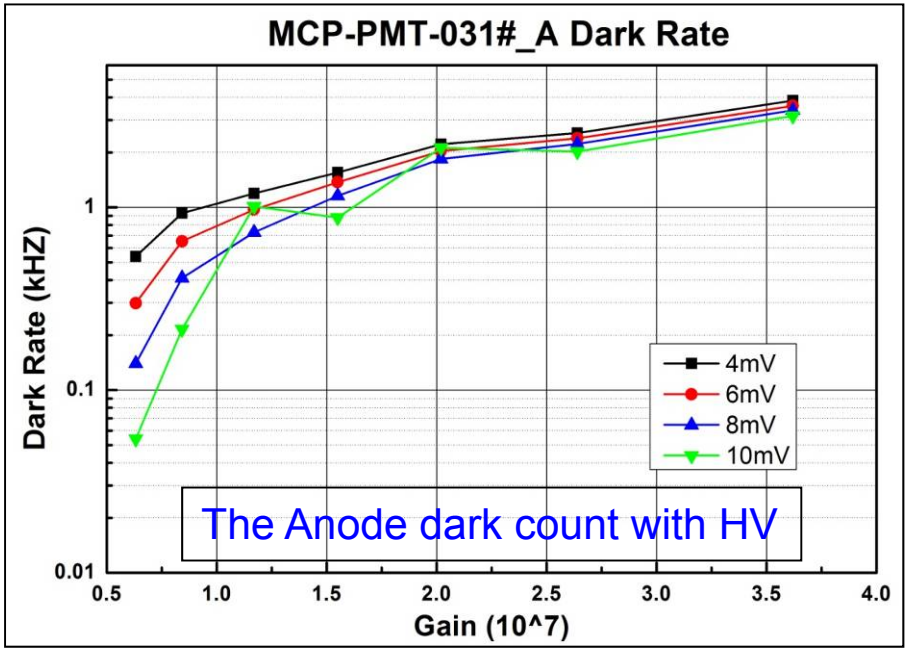
	HV@2 *10^7
R5912	1600V
R5912-100	1550V
MCP-PMT	2000V

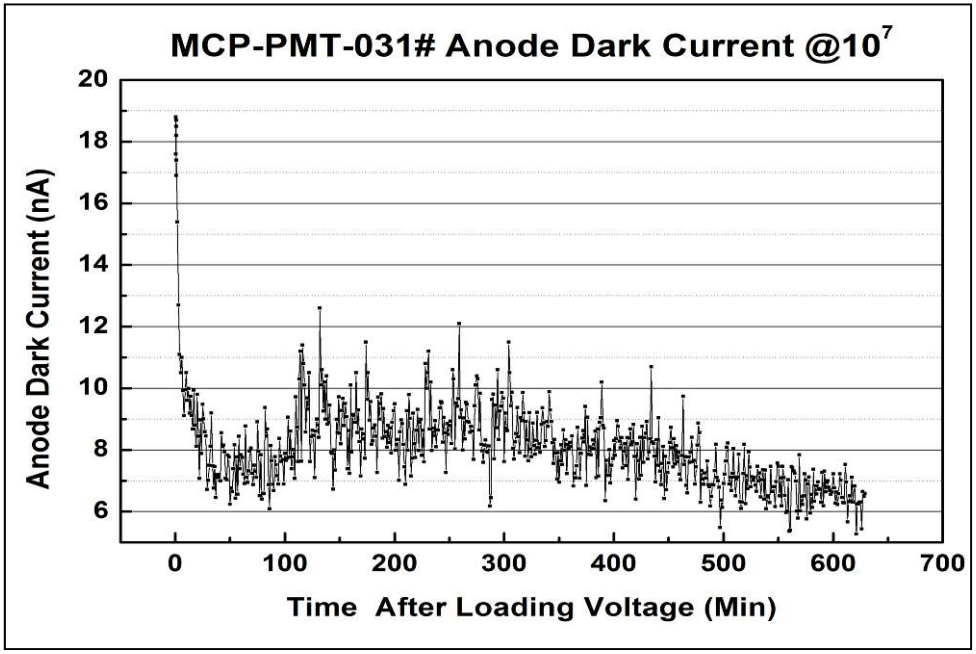
	Up to 40 mA	< 60mA
R5912	±2%	±5%
R5912-100	±2%	±4%
MCP-PMT	±2%	±4%

➢**8吋MCP-PMT**样管的高压增益曲线和线性测试结果，与滨松**8**吋样管的性能具有可比性！

➢ 3.4 暗噪声、暗计数率测试；



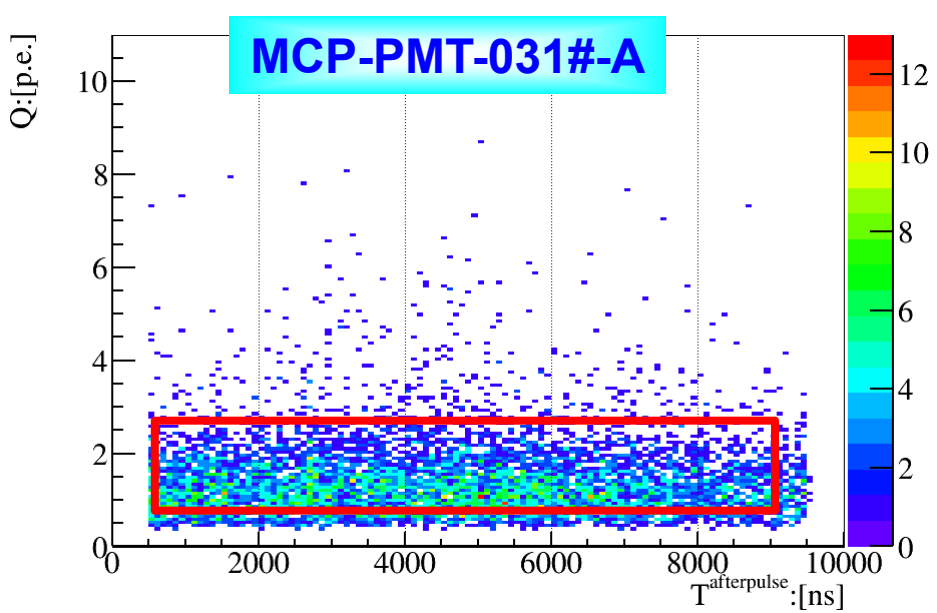


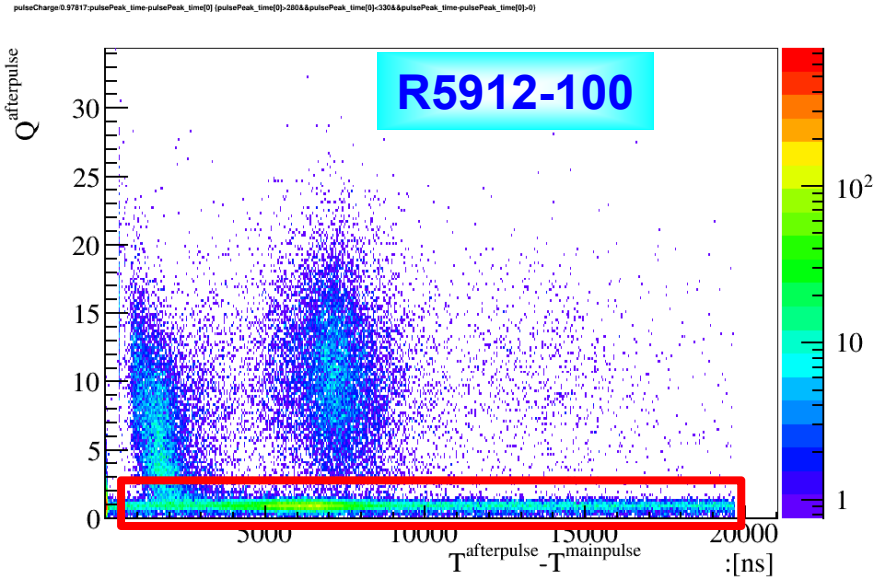


	Dark rate (0.25PE)	Dark current
R5912	< 1kHz	~1nA
R5912-100	~3.5kHz	~2nA
MCP-PMT	~2.2kHz	~6nA

The data statistics after 10 hours later

The dark noise distribution





	Dark rate (0.25PE)	Dark current	The charge of the dark noise
R5912	< 1kHz	~1nA	1pe
R5912-100	~3.5kHz	~2nA	1pe
MCP-PMT	~2.2kHz	~6nA	1.4pe

MCP-PMT 样管具有低的暗计数率（ **Dark Rate**）,但高的暗电流（ **Dark Current**）；

1. **MCP_PMT**样管是使用非转移阴极系统制备，光阴极材料对**MCP**表面有污染.
2. 如果采用真空转移设备制备样管，暗电流和暗计数率会明显降低；

Outline

- 1. 研制目的;
- 2. 新型大面积MCP-PMT样管研制;
- 3.新型8吋MCP-PMT性能测试;
- 4. 总计及计划

Parameters \ PMT Type	R5912-100	MCP-PMT
量子效率QE of the Photocathode@ 410nm	35%	20% (25%)
量子效率均匀性QE uniformity	±3%	±3%
时间信息Rise / Fall time of the SPE signal	3.4ns / 4.6ns	5ns / 6.3ns
渡越时间涨落Transit Time Spread (TTS)	1.5ns	3.5ns
峰谷比P/V of the SPE signal	> 2.5	1.5~2.5
暗计数率Anode dark count @ Tro.=0.25pe	~3.5kHz	~2.2kHz
暗电流Anode dark current	~2nA	~6nA
暗噪声电荷分布 Charge of the dark noise distribution	1 pe	1.4 pe
线性linearity of the PMT upto 40mA / < 60mA	±2% / ±4%	±2% / ±4%

以上测试条件： Gain=2*10^7

➢MCP-PMT 研发近况:

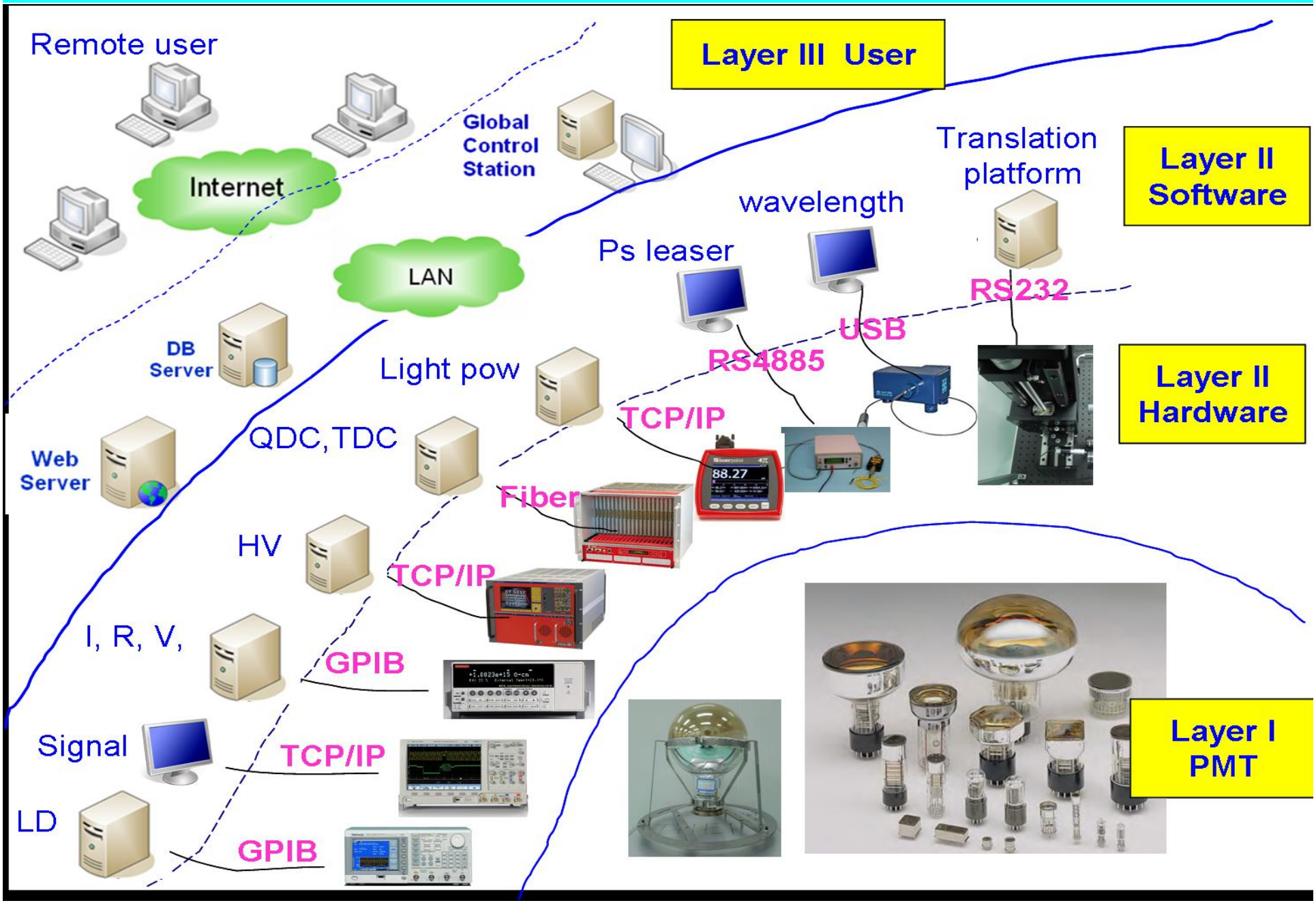
- **1. 许多关键技术及方案得到突破和解决;**
- **2. 成功研制出多个8吋样管;**
  - 量子效率QE ~ 25%@410nm;
  - 峰谷比P/V 0f SPE > 2.0;
  - 暗计数率和暗噪声可以通过真空转移设备得到改善;
  - 光阴极量子效率均匀性可以通过真空转移设备得到改善;
  - 后脉冲信号（After Pulse ）非常少;
  - 收集效率均匀性需要进一步得到改善;
- **3. 研制出少量 20”样管;**
  - 使用真空转移设备制备，量子效率均匀性和单光电子谱性能优于8吋样管;
  - 收集效率均匀性需要进一步得到改善;
  - 大面积量子效率需要进一步改善;

There are lots of work to do!

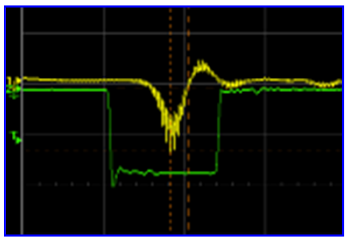
Thank！谢谢！

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

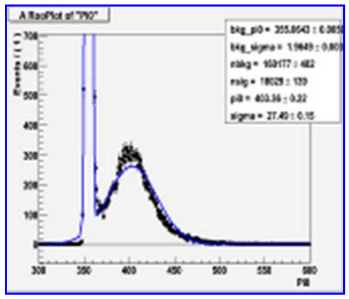
➢ The Large PMT evaluation system for MCP-PMT of JUNO



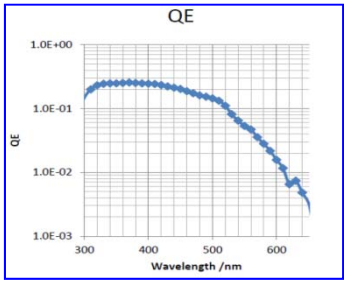
➢ The parameters of the MCP-PMT (testing)



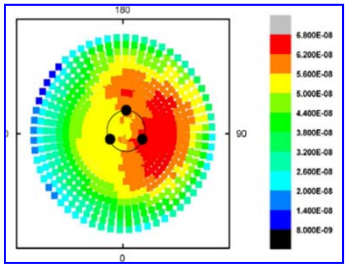
- ➢ Anode Pulse Rise Time;
- ➢ Pre/Late/After Pulse;
- ➢ Dark Count



- ➢ The Single Photoelectron Spectrum;
- ➢ The voltage distribution (BASE) ;
- ➢ The Supply voltage;
- ➢ Typical Gain Caracteristic;
- ➢ Anode Dark Current



- ➢ Spectral Response；
- ➢ Wavelength of Maximum Response；
- ➢ Cathode Sensitivity: Luminous(2856K);
- ➢ Quantum efficiency with λ



- ➢ Photocathode efficiency Area;
- ➢ Photocathode efficiency Uniform;
- ➢ The position of the Sb, K, Cs;

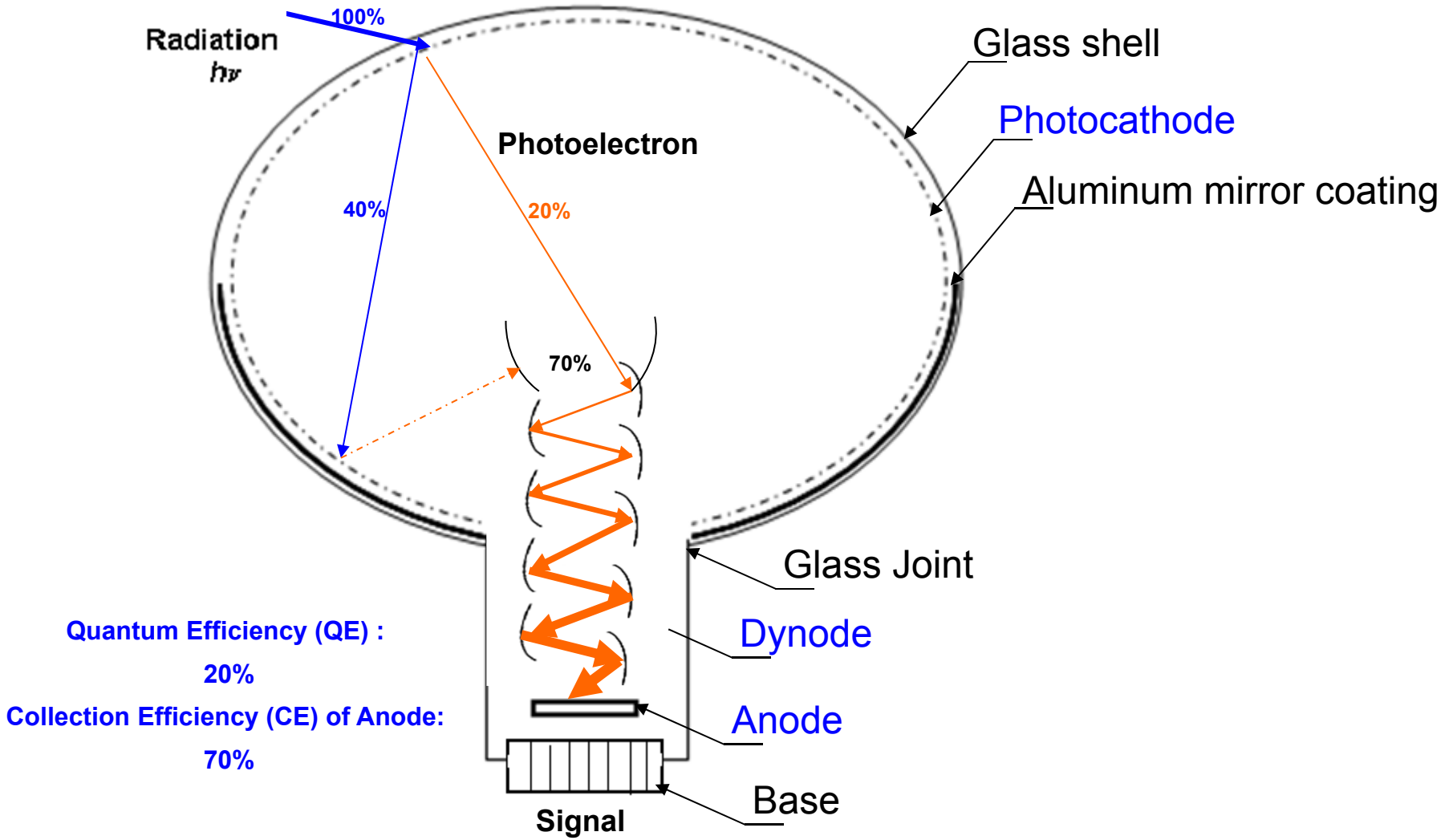
Others

……

- ➢ The linearity of the PMT
- ➢ Magnetic characteristics;
- ➢ Transit Time Spread (FWHM)


Welcome to Kaiping

The Conventional PMT



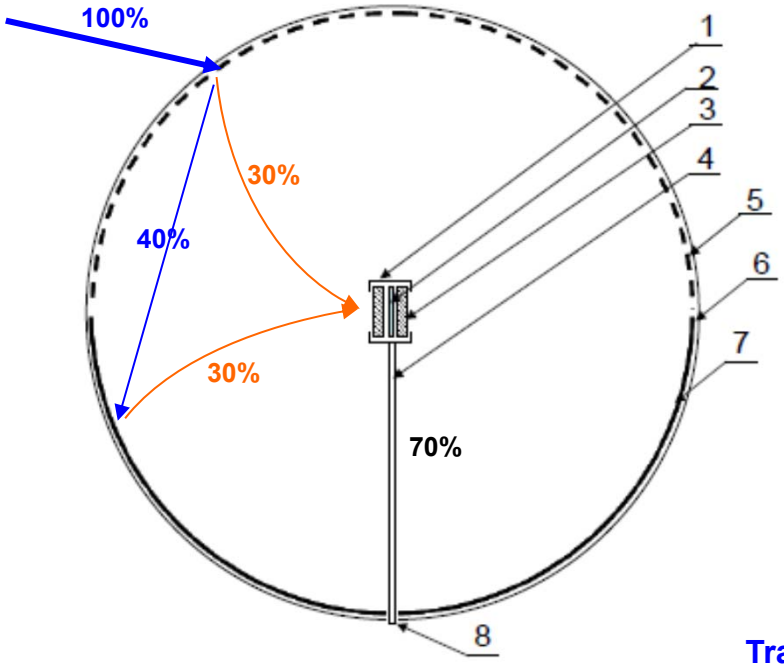
Photon Detection Efficiency (PE)= QE_{Trans} * CE = 20% * 70% = 14%

➢ The new design of a large area PMT

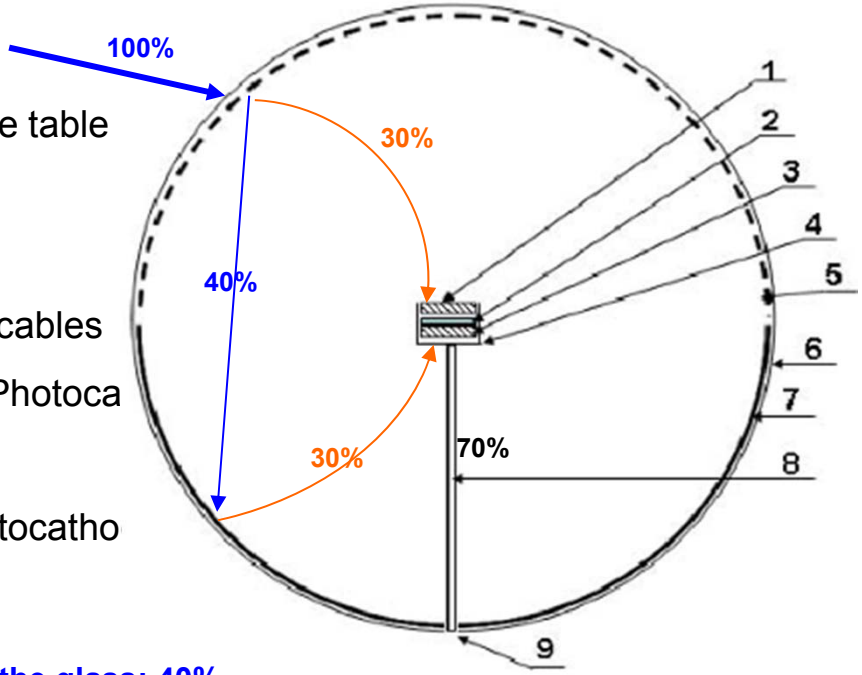
High photon detection efficiency + Single photoelectron Detection + Low cost

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

2) Using transmission photocathode (front hemisphere) and reflection photocathode (back hemisphere) } **~ 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 !