Photocathode Development in MLAPD group

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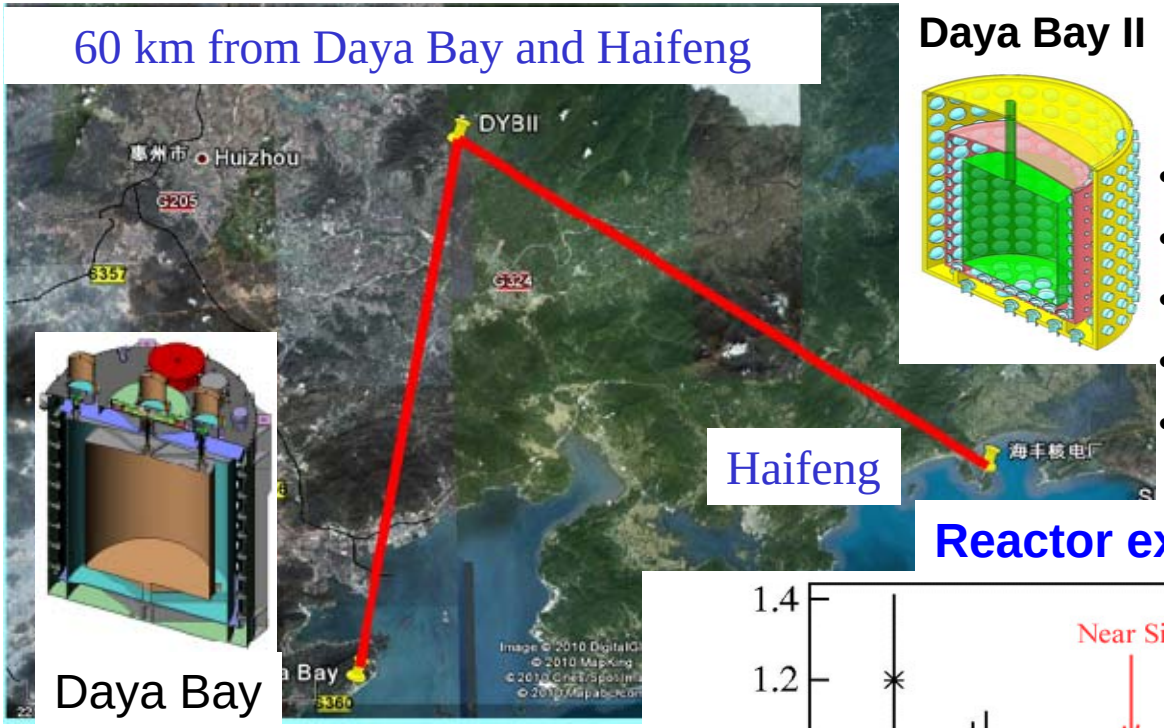
On Behalf of the Collaboration group

June 29 , 2012 Chicago

Outline

- 1. The Motivation of MLAPC;
- 2. The Research work for photocathode;
- 3. The technique for photocathode;
- 4. The prototypes;
- 5. The status of the HZC.

➢ Next generation Neutrino Experiment in China



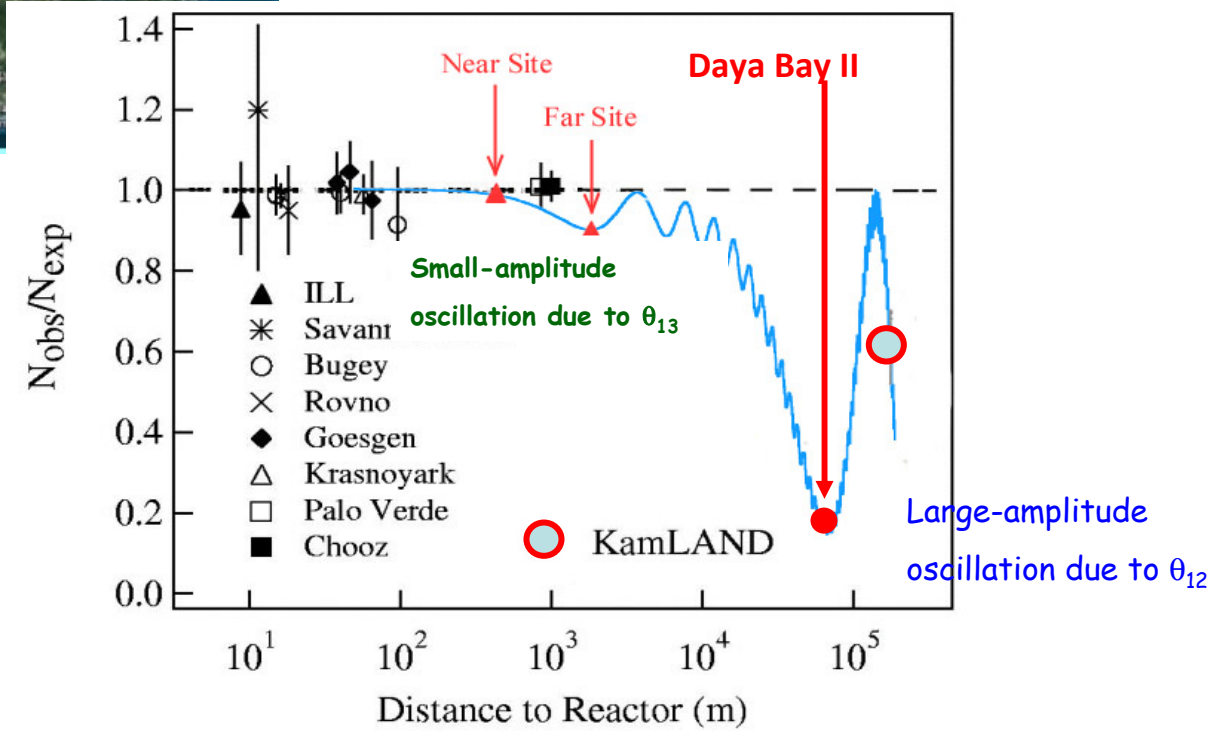
Daya Bay II

Huge Detector （LS + PMT

Energy resolution ~ 3%/√E

- Neutrino target: 30m(D)×30m(H)
- LS, LAB based : ~20kt
- Oil buffer: ~6kt
- Water buffer: ~10kt
- PMT (20”) :~20,000

Reactor experiments:



The Main Scientific goals:

⇨**Mass Hierarchy**

⇨Mixing matrix elements

⇨Supernovae

⇨geo-neutrinos

L. Zhan, et. al., Phys.Rev.D 78:111103,2008
L. Zhan, et. al., Phys.Rev.D 79:073007,2009

➢ The Quantum Efficiency of PMT

	KamLAND	Daya Bay II
Detector	~1 kt Liquid Scintillator	➢10 kt Liquid Scintillator
Energy Resolution	6%/√E	3%~4%/√E
Light yield	250 p.e./MeV	~1000 p.e./MeV
Photocathode coverage	30%	~80%

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

SBA will be available in 12" diameter format

➢**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% ?

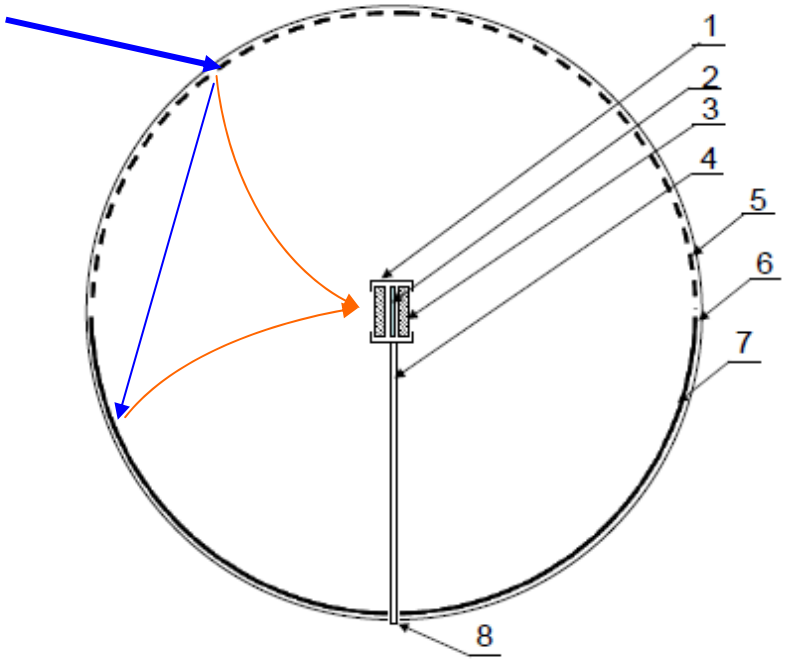
or **Photon Detection Efficiency:** 14% → 30%

➢ 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 reflective photocathode (back hemisphere) } **~ 4π viewing angle!**



1.Insulated trestle table

2.Anode

3.MCP dodule

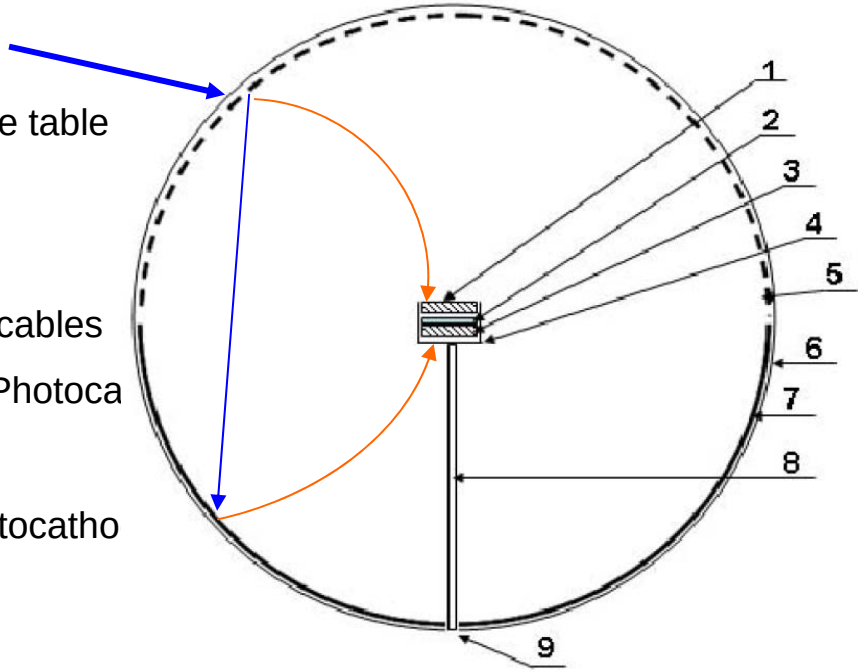
4.Bracket of the cables

5.Transmission Photoca

6.Glass shell

7.Reflection Photocatho

8.Glass joint



Photon Detection Efficiency: 14% → 30% ; ×~2 at least !

Project team and Collaborators

中国科学院高能物理研究所

Institute of High Energy Physics, CAS

R&D effort by **Yifang Wang;**

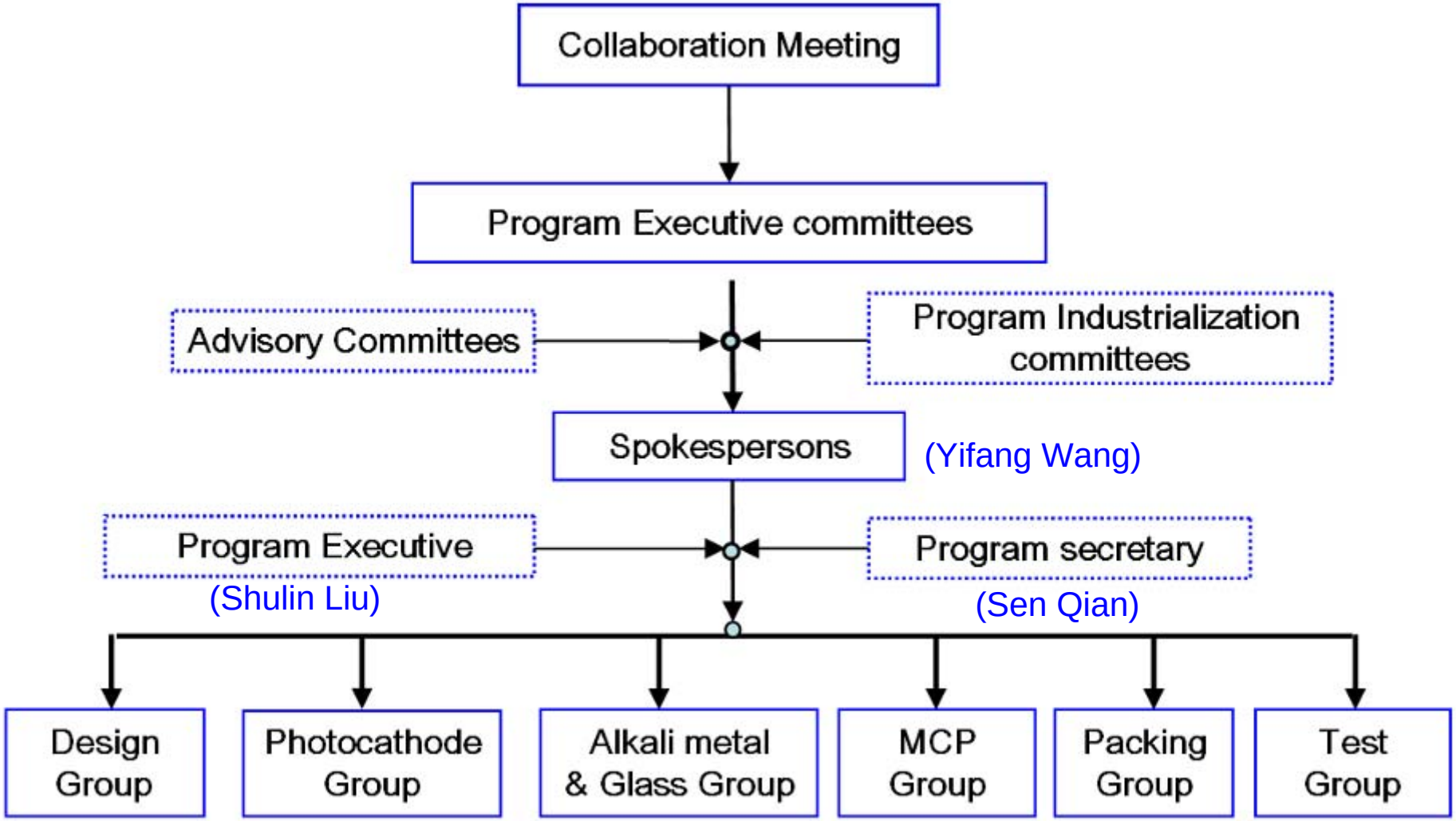
& Tianchi Zhao; Jun Cao; Yukun Heng, Shulin Liu, Sen Qian; et al

Collaborators

- **Xi'an Institute of Optics and Precision Mechanics of CAS;**
  JInshou Tian; Xiangyan Xu; Huling Liu; Xibing Cao;
- **Nanjing University;**
  Ming Qi; Shenjian Chen; Shilei Zang;
- **Companies for PMT or MCP production;**

➢ The Organization Chart

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



➢ The Technical Workshop & Collaboration Meeting

Technical Workshop

Kunming 20110911

Xian 20120227

Nanjing 20120620

Collaboration Meeting

Beijing 20111118

Xian 20120301

Nanjing 20120621

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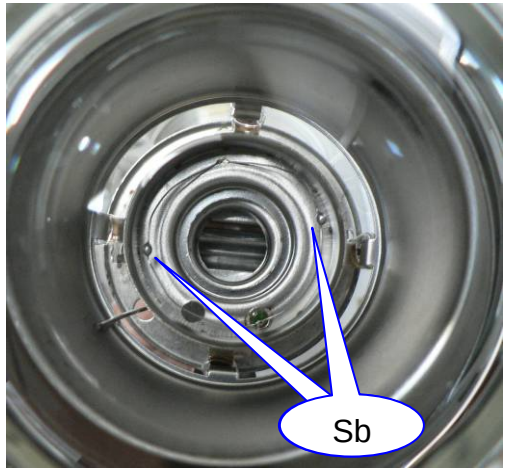
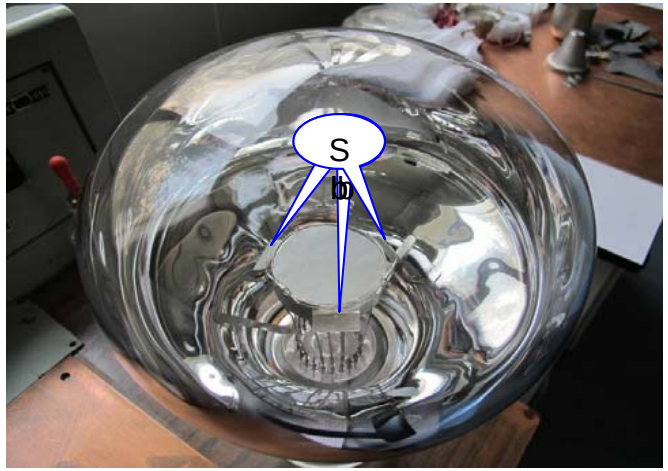
➢ The Research work for photocathode

Technique	We have !	We need !
Mn Manganese deposition	**Mn, but Ni-Wire Technique**	
Sb Antimony deposition	**Mn, but Ni-wire Technique**	
Oxygen Plasma	**The technique, and better using**	The **transfer equipment** to do the Oxygen Plasma in glass with MCP
Hydrogen Plasma	**We know the benefit and try to understand this.**	The **transfer equipment** to do the Oxygen Plasma in glass with MCP
Alkali Metal Source	**The Source activated by current;** **The source activated by high frequency**	The high QE photocathode

Antimony deposition





How to generate the antimony layer more uniform?

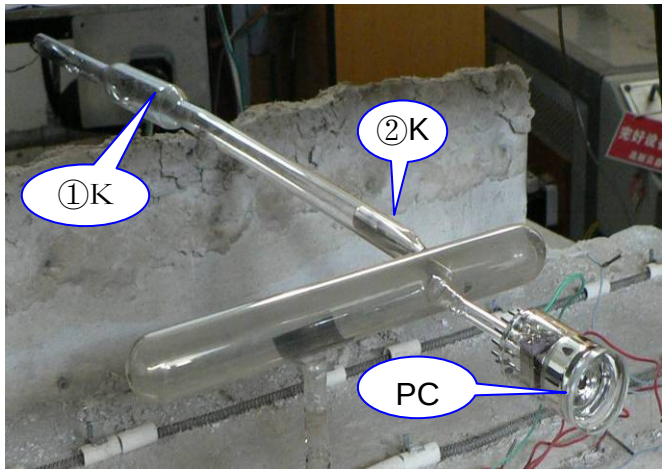
How to protect the **MCPs** not to be effected by the antimony without the **transfer equipment**?

Oxygen Plasma

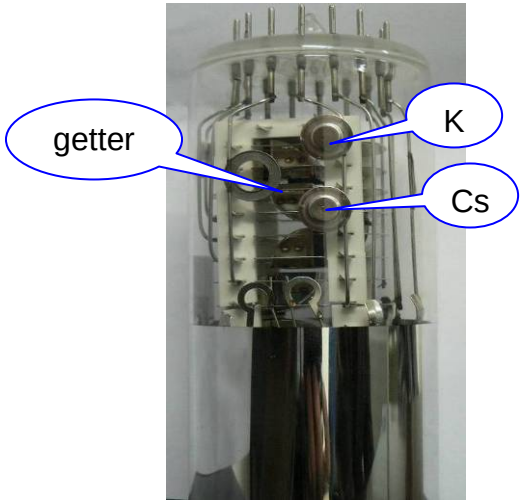
How to protect the **MCPs** not to be effected by the **Oxygen** without the **transfer equipment**?

Alkali Metal Source

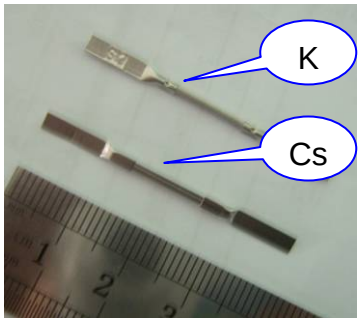
external generators



internal generators

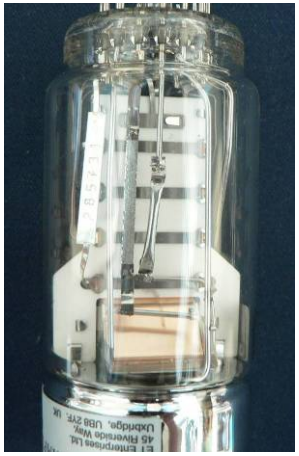


Evaporation by HFR

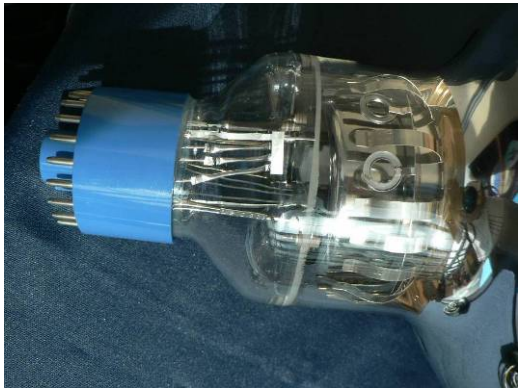


Evaporation by current

We need to produce the standard alkali metal generator to control the quality during the mass production process in the future.



ET company



Hamamatsu company

➢ The Research work for photocathode

Technique	We have !	We need !
Mn Manganese deposition	Mn, but Ni-Wire Technique	**To uniform the layer,** **Generate it in transfer equipment**
Sb Antimony deposition	Mn, but Ni-wire Technique	**To uniform the layer** **Generate it in transfer equipment**
Oxygen Plasma	The technique, and better using	**The transfer equipment to do the Oxygen Plasma in glass with MCP**
Hydrogen Plasma	We know the benefit and try to understand this.	**The transfer equipment to do the Oxygen Plasma in glass with MCP**
Alkali Metal Source	The Source activated by current; The source activated by high frequency	**The high QE photocathode**

Transfer Equipment = The photocathode + The MCP (friendly!!!)

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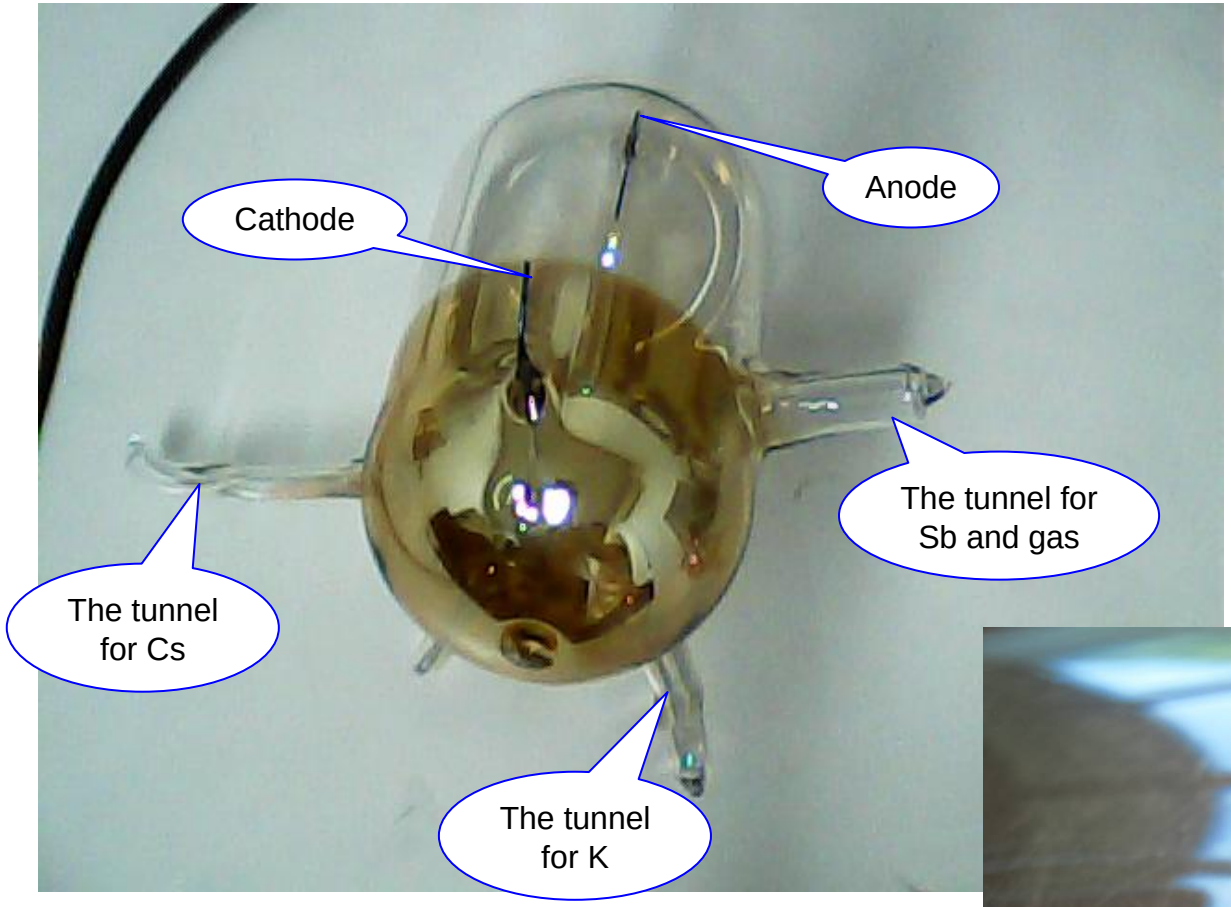
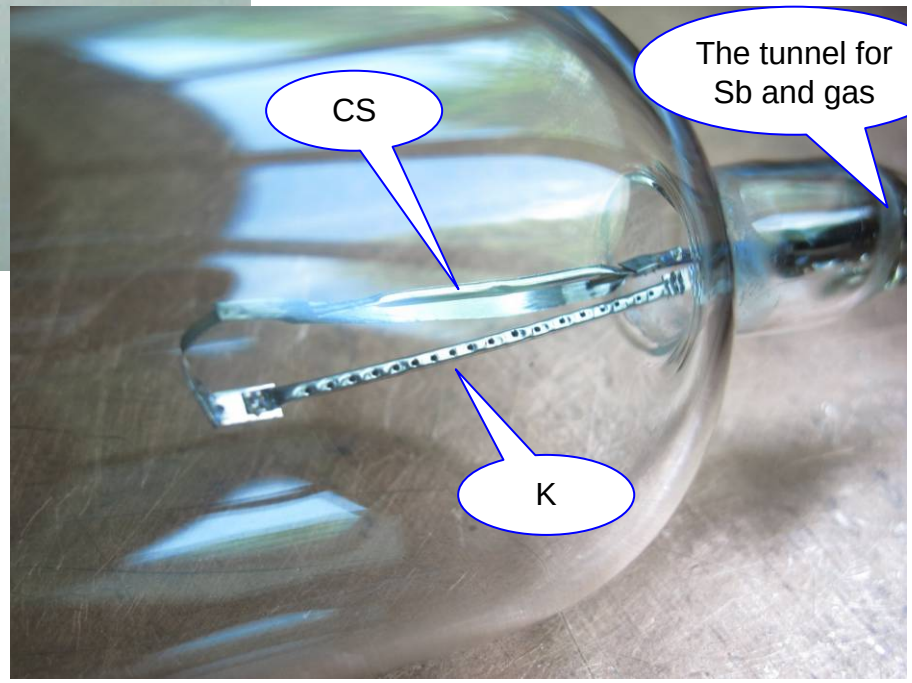
➢ The small prototype for producing the PC





➢ The contrast of different Alkali materials

Potassium (Cesium) **chromate** VS Potassium (Cesium) **Chloride**

The Chromate ones are better than the chloride ones! Just as the choice of the SAES

Sodium chromate (Na_2CrO_4) Sodium dichromate ($Na_2Cr_2O_7$)

element	Na	Cr	O	Al	Zr	
Mass %	7.82	8.00	37.42	6.94	39.83	100%

Potassium chromate (K_2CrO_4) Potassium dichromate ($K_2Cr_2O_7$)

element	K	Cr	O	Al	Zr	C	
Mass %	14.72	8.53	22.56	6.19	37.47	10.53	100%

Cesium chromate (Cs_2CrO_4) Cesium dichromate ($K_2Cr_2O_7$)

element	Cs	Cr	O	Al	Zr	C	B	
Mass %	24.68	4.46	16.29	5.53	31.29	10.75	6.99	100%

Nickel pocket

element	Ni	Cr	Si	Fe	Zr	Mn	
Mass %	69	28.4	0.6	0.3	0.41	0.07	100%

ICP: Inductively Coupled Plasma ; XRF: X-ray fluorescence

➢ The relative QE of the photocathode

The Photocathode comes from ANL（QE~27%）

53--current

Voltage of LAMP 100V

The Photocathode comes from CAS（QE~16%）

32--current

Voltage of LAMP 100V

- **Source:** SAES? Hamamastus? Others?
- **Setup position:** inside? Outside?
- **Evaporation method:** Current? HRF?
- **Purity?** Material ? Impurity?
- **The Know-How! ……**

Composition

- **Oxygen Plasma:** When? How Long?
- **Baking:** Temperature? Time?
- **Growth method:** fast? Slow?
- **Thickness of Sb:** monitor and control?
- **Anti-reflective layer:** Material ? Thickness?
- **Thickness of K/Cs:** Monitor and control?
- **The Know-How! ……**

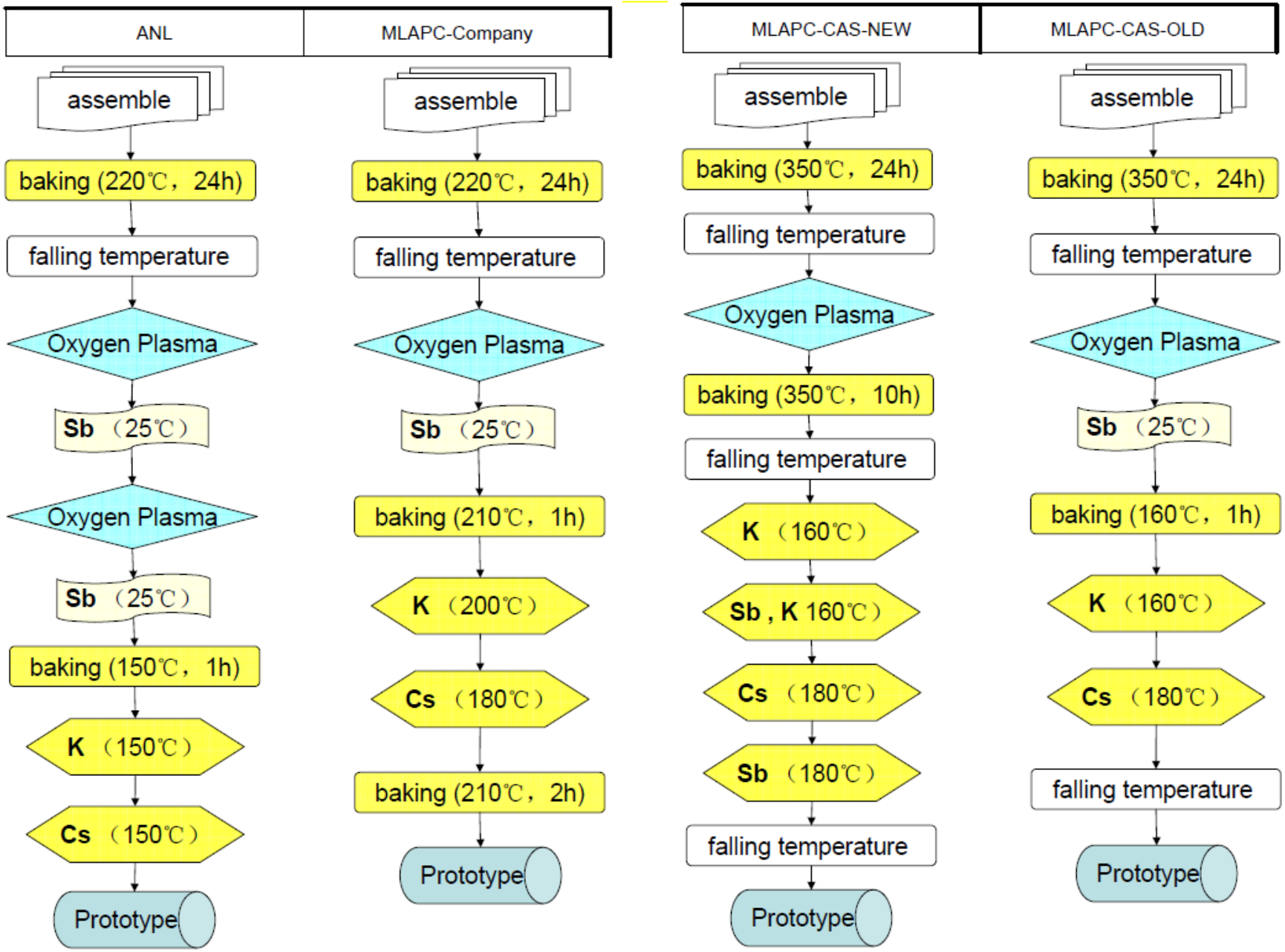
The growth technology

Alkali Metal

High QE photocathode

The AMD for Industry

➢ The contrast of different technique process



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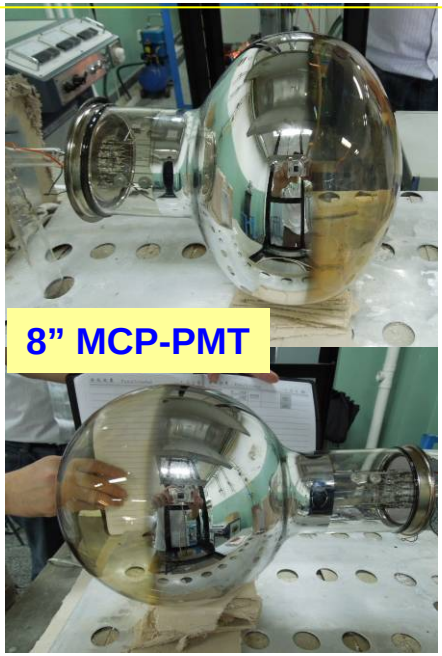
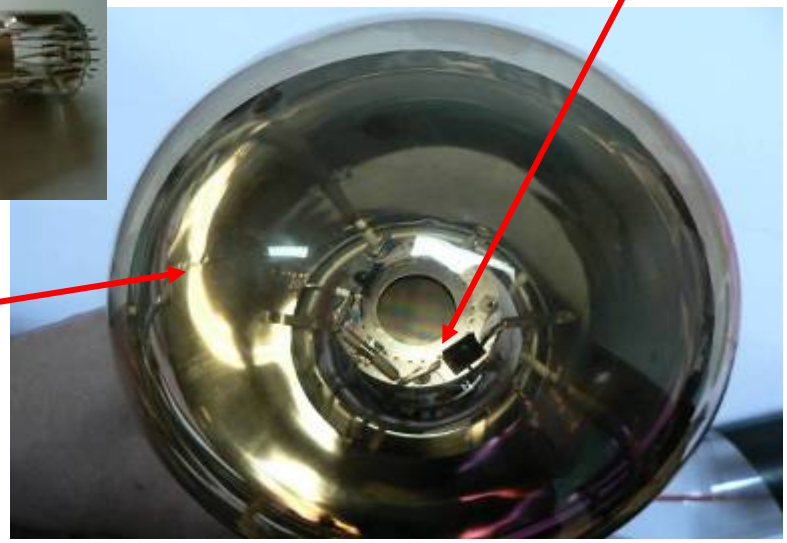
➢ The Prototypes

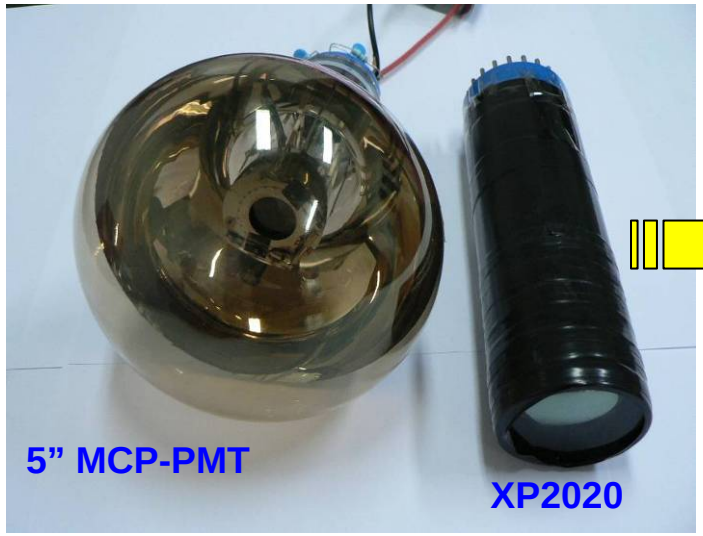


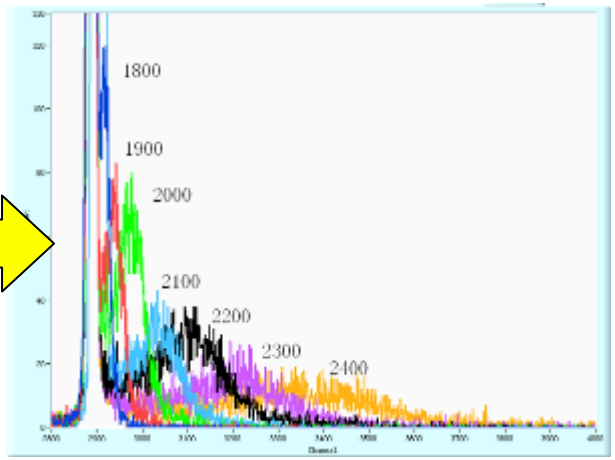


transmission photocathode

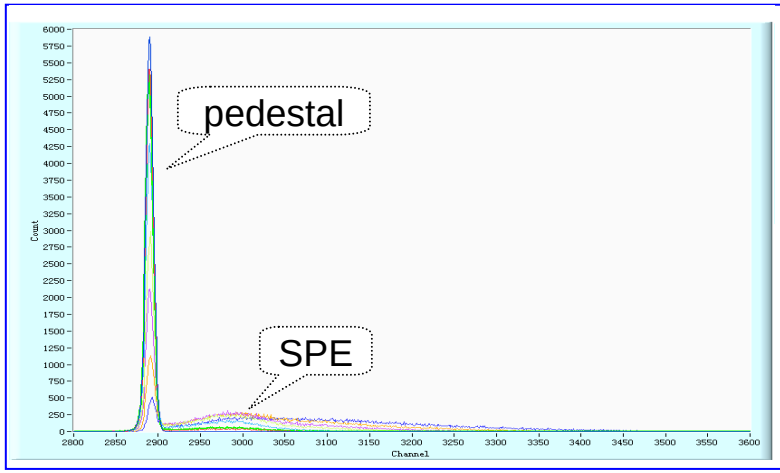
The single photoelectron spectrum and the multi-photoelectron spectrum of the PMT

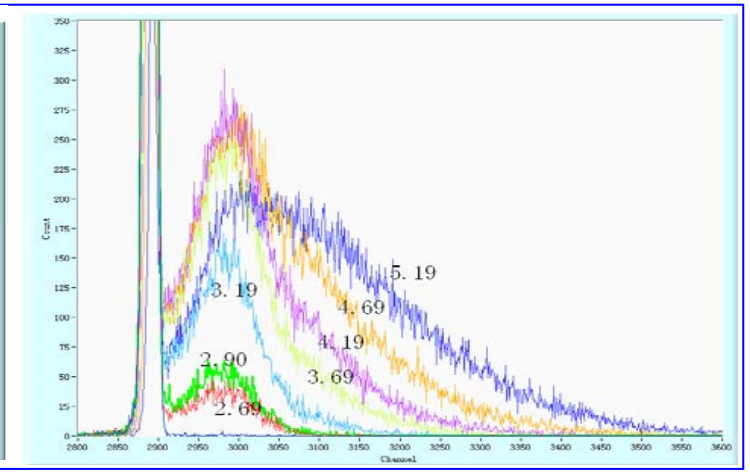
➢**The photoelectron spectrum of the XP2020 PMT**





➢**SPE vs the Voltage of the PMT**

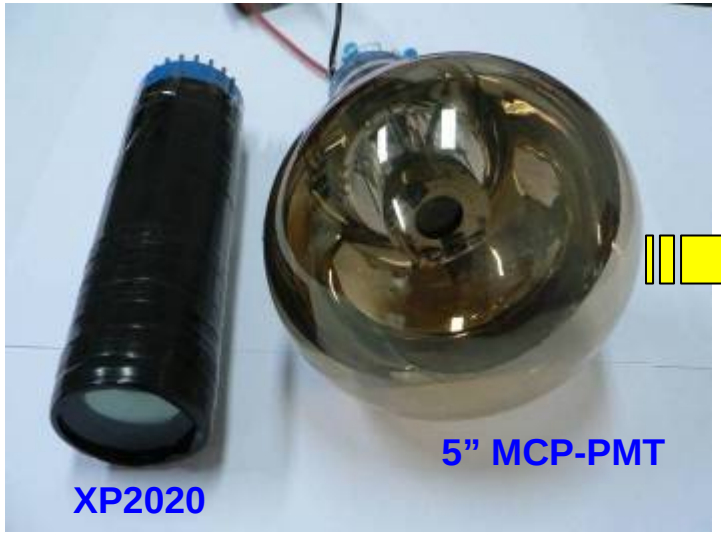


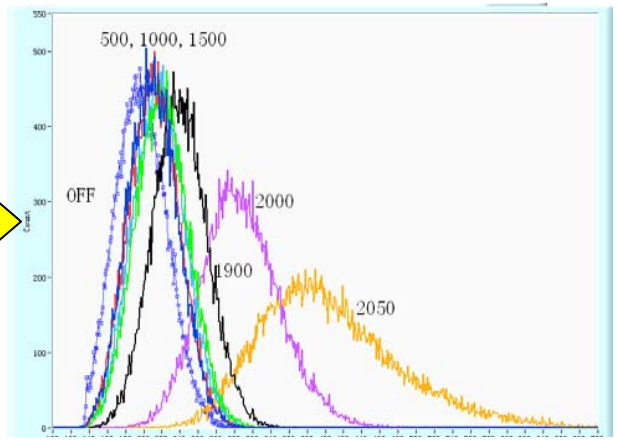


➢**SPE vs the luminance of the LED light**

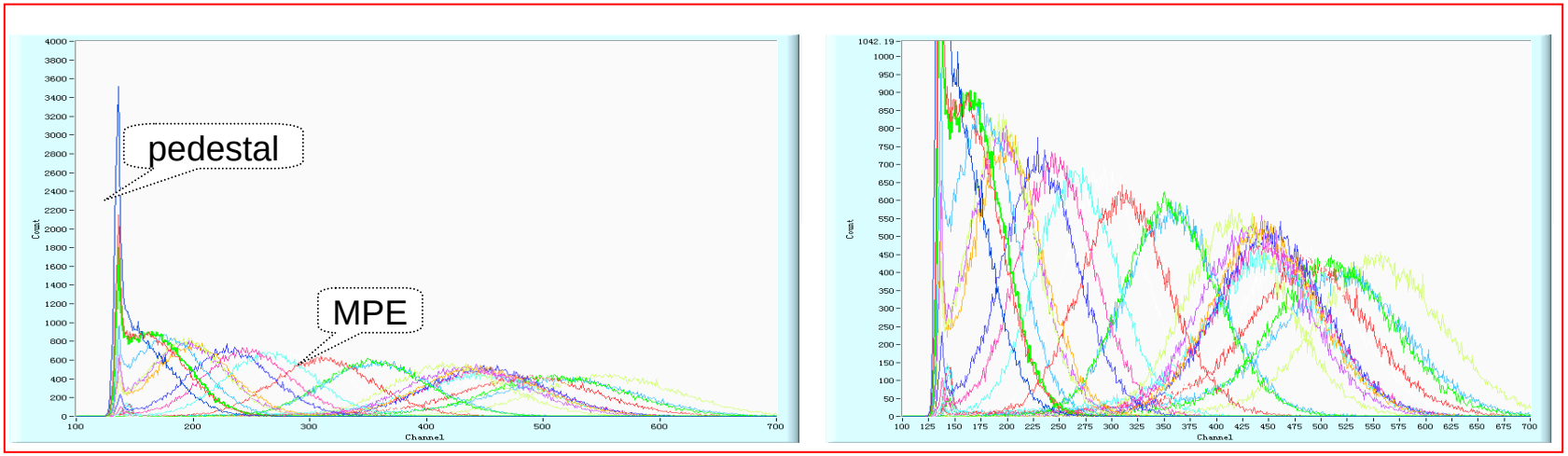
**--adjust the working voltage of the LED to adjust the luminance of the LED light.

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





➢**SPE vs the Voltage of the PMT**



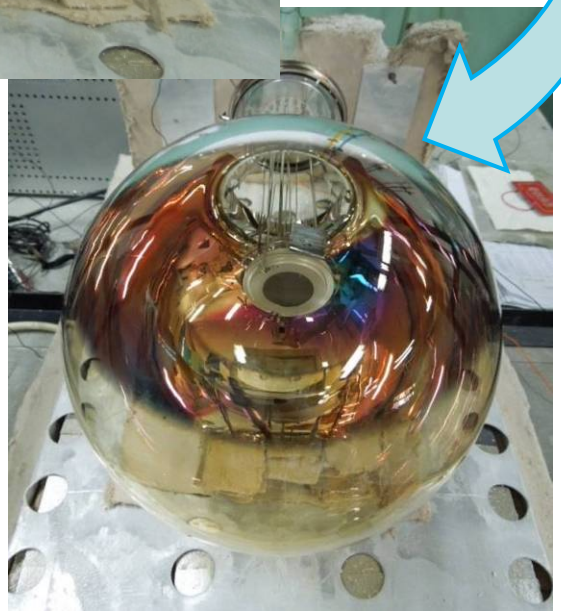
➢**MPE vs the luminance of the LED light**

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

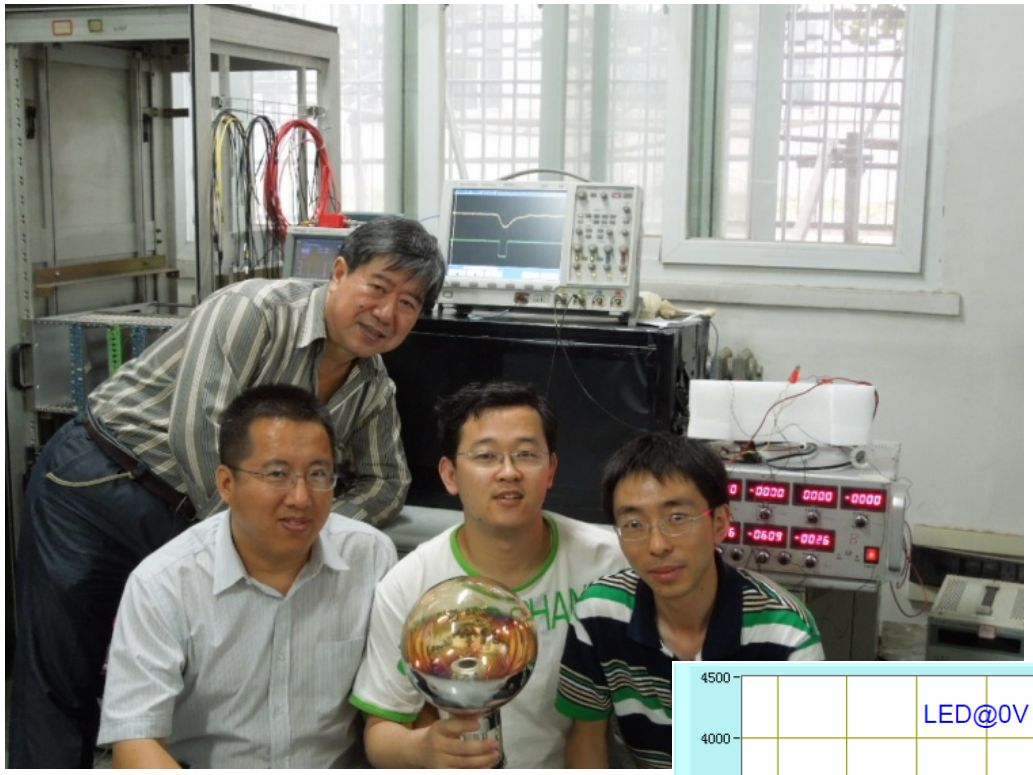
➢ The Prototypes in factory

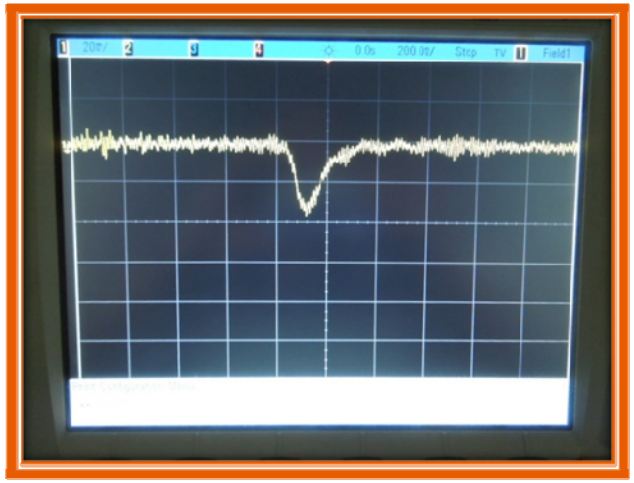
8” ellipse

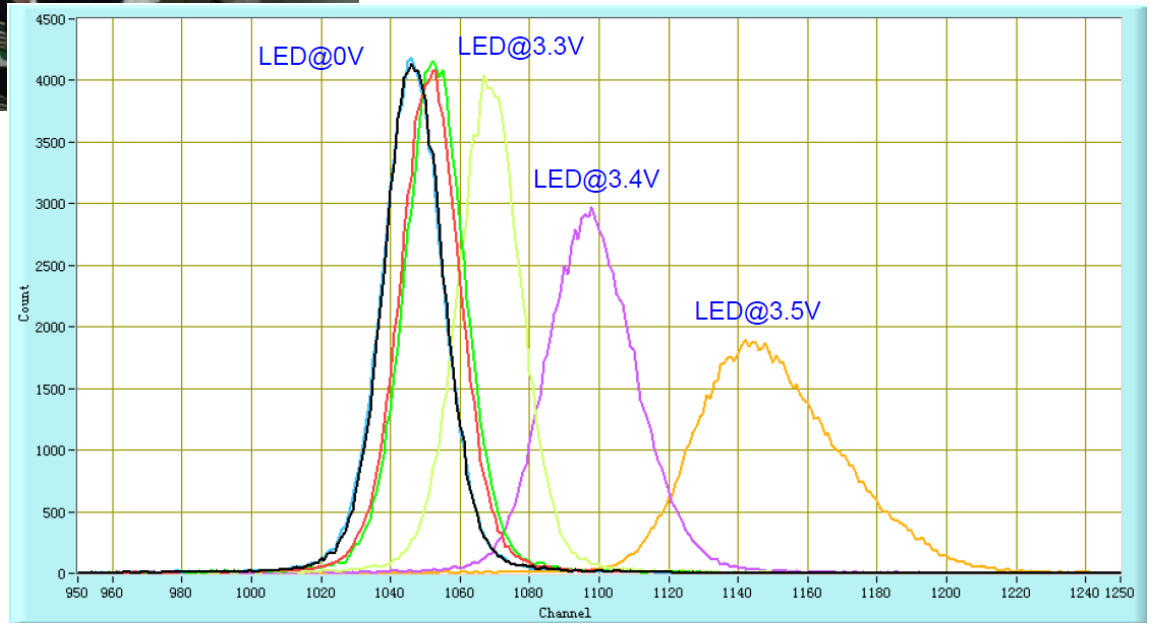
8” spherical



➢ The Prototypes in Lab for measurement







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➢ The Status of the HZC

The schedule：

2012-03 Equipment Arriving
Before 2012-06 Built workshop
2012-07 Equipment assemblage
2012-08 preproduction

Thanks！ 谢谢！

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

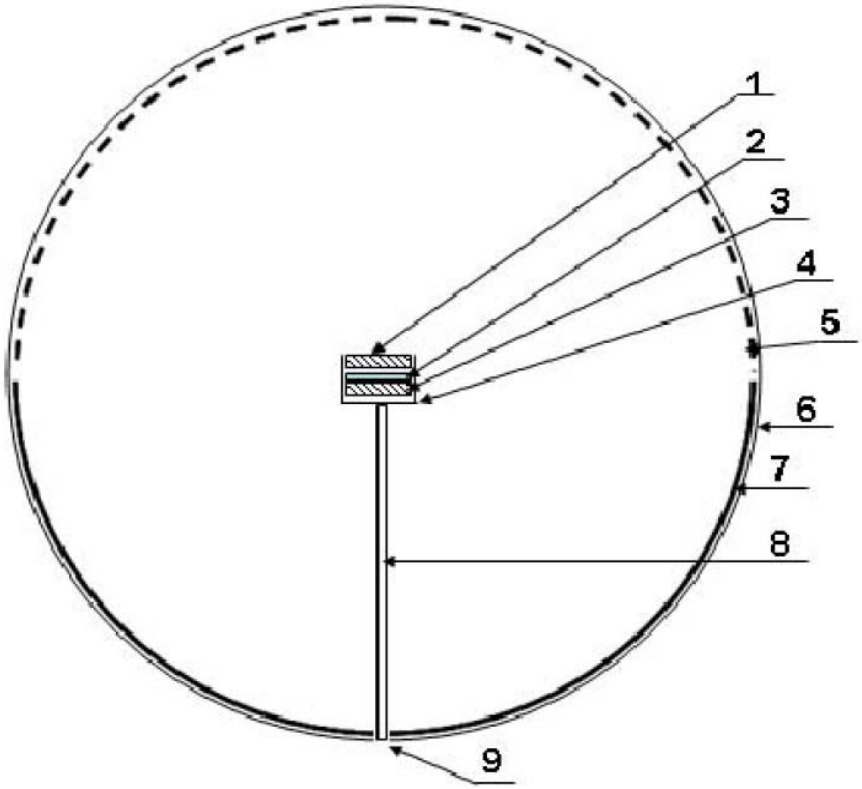
Back up

➢ 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 reflective photocathode (back hemisphere) } ~ 4π viewing angle!!



1. up MCP
2. anode
3. down MCP
4. insulated trestle table
5. transmission photocathode
6. glass shell
7. reflection photocathode
8. bracket of the cables
9. glass joint

➢ **Quantum Efficiency:**

Transmission photocathode: 20%

Reflection photocathode: 40%

➢ **MCP Collection Efficiency: 60%**

Photon detection efficiency:

→ 20% * 60% = 12%

→ 70% * 40% * 60% = 17%

➢ **Total Photon Detection Efficiency: ~30%**

Photon Detection Efficiency: 14% → 30% ; ×~2 at least !

The new design of a large area PMT

High photon detection efficiency + Single photoelectron Detection + Low cost

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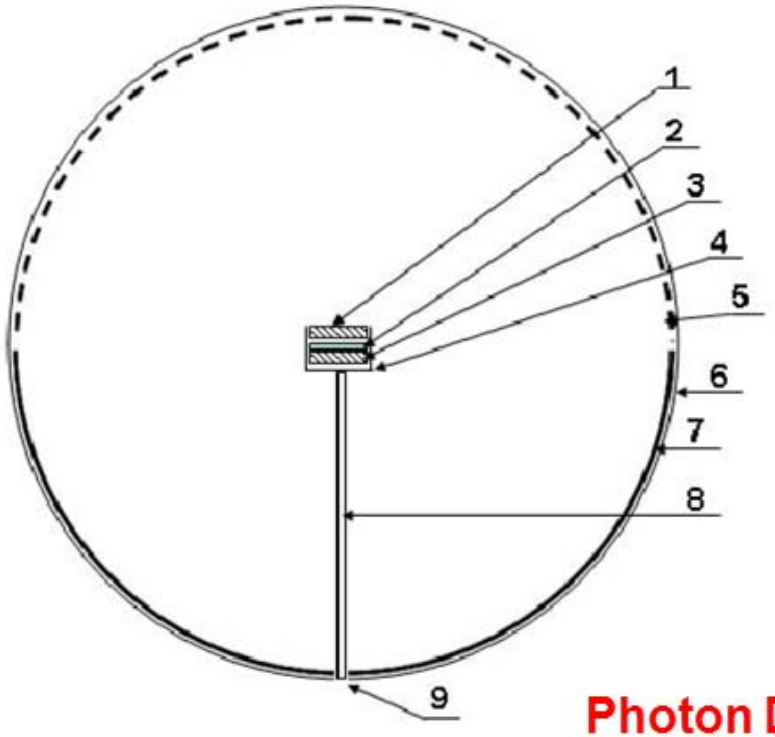

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8. bracket of the cables
9. glass joint

➢**Quantum Efficiency:**

Transmission photocathode: 30%

Reflection photocathode: 35%

➢**MCP Collection Efficiency:** 70%

Photon detection efficiency:

30% * 70% = 21%

40% * 35% * 70% = 9. 8%

➢**Total Photon Detection Efficiency:** ~ 30. 8%

Photon Detection Efficiency: 15. 4% → 30. 8% × ~2 **at least**

➢ The new design of a large area PMT

High photon detection efficiency + Single photoelectron Detection + Low cost

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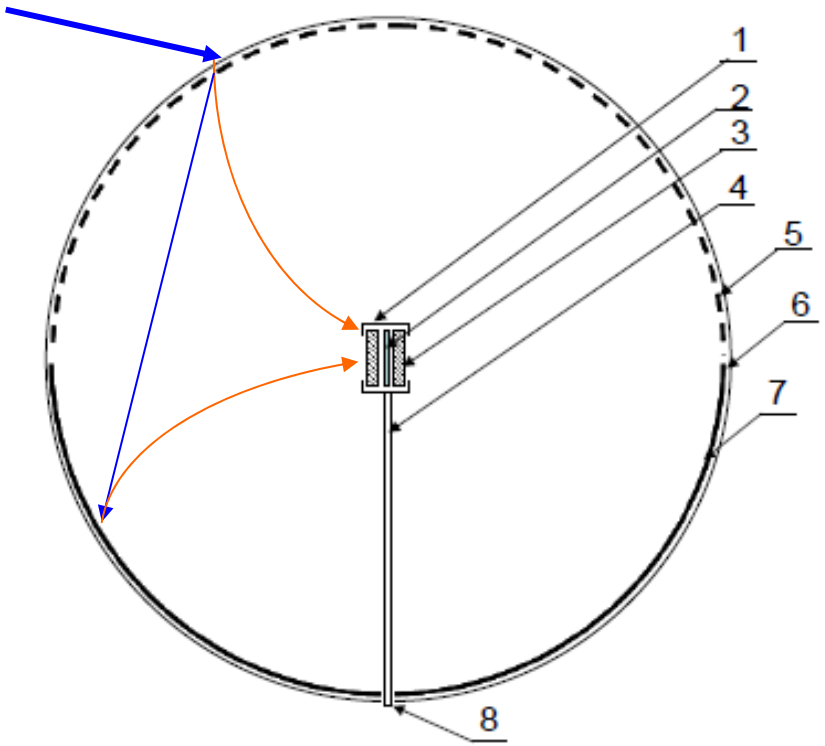

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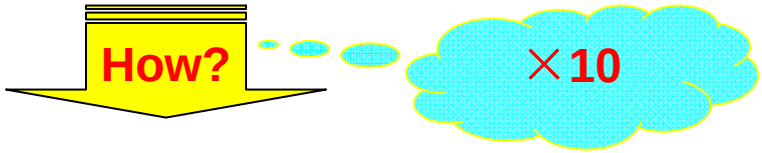
Photon Detection Efficiency: 14% → 30% ; ×~2 at least !

	KamLAND	Daya Bay II	Daya Bay II
Detector	~1 kt Liquid Scintillator	➢10 kt Liquid Scintillator	➢10 kt Liquid Scintillator
Energy Resolution	6%/√E	2%/√E	3%/√E
Light yield	250 p.e./MeV	2500 p.e./MeV	1100 p.e./MeV



- **Ongoing R&D:**

– **Highly transparent LS: Attenuation length ;**

Attenuation length: 15m → 25m; the Light Yield (% standard): ×**1.5**

Attenuation length: 15m → 30m; the Light Yield (% standard): ×**2**;

– **High light yield LS: increasing PPO% ;**

KamLAND: 1.5g/l → Daya Bay II : 5g/l;

Light Yield (% standard): **30%→ 45%;** × **1.5**

– **Photocathode coverage :**

KamLAND: 34% → Daya Bay II : ~ 80% × **2 ~ 2.5**

– **High QE "PMT": Quantum Efficiency (**or **Photon Detection Efficiency)**×**2;**