液体Xeカロリメータ用光電子増倍管の低温における性能評価

Cryogenic performance test of a photomultiplier for the liquid Xe calorimeter

東京大学素粒子物理国際研究センター
森研究室修士2年
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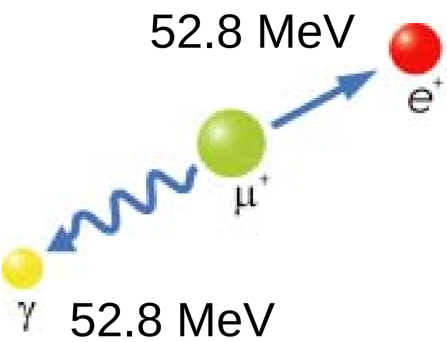
久松康子　2004年度低温工学·超伝導学会　@八戸工業大学

Abstract

- About MEG Experiment
- PMT for MEG photon detector
- Works on Final Design of PMT
- PMT test at Univ. of Tokyo
- Summary

MEG Experiment



$\mu^+ \longrightarrow e^+ \gamma$

- beyond SM
- SUSY-GUT promising

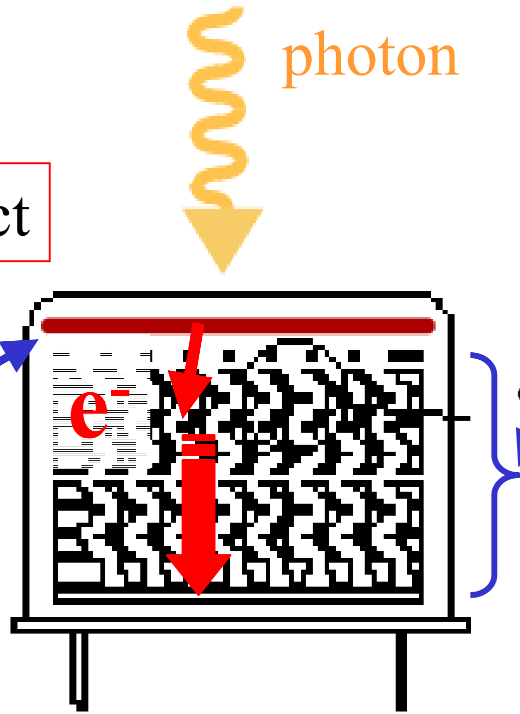
MEGA(~1999)
Br $1.2*10^{-11}$

MEG
Br 10^{-14}

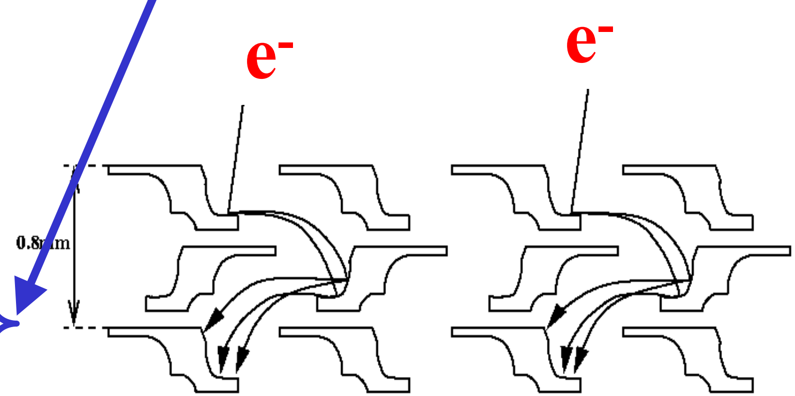
- Approved by Paul Scherrer Institut
- Using intense muon beam @PSI
  $1*10^8$/sec
- Start of Physics Run : 2006

Photomultiplier (PMT)

- Highly sensitive light sensor often used in high energy physics experiments
- Electron tube device which converts light into a measurable electric current

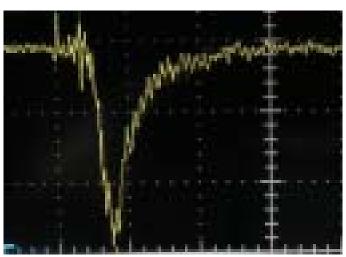


Electrode and dynode



Photoelectric effect

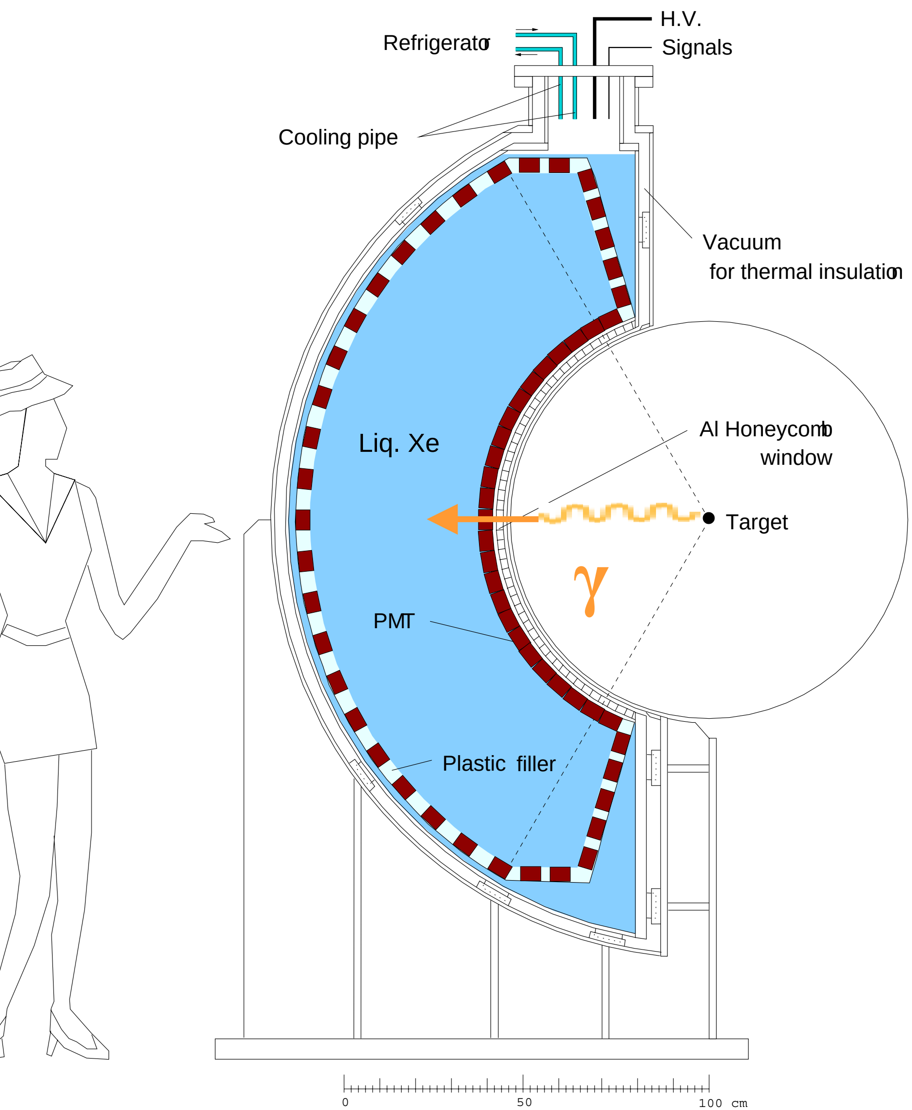
photocathode



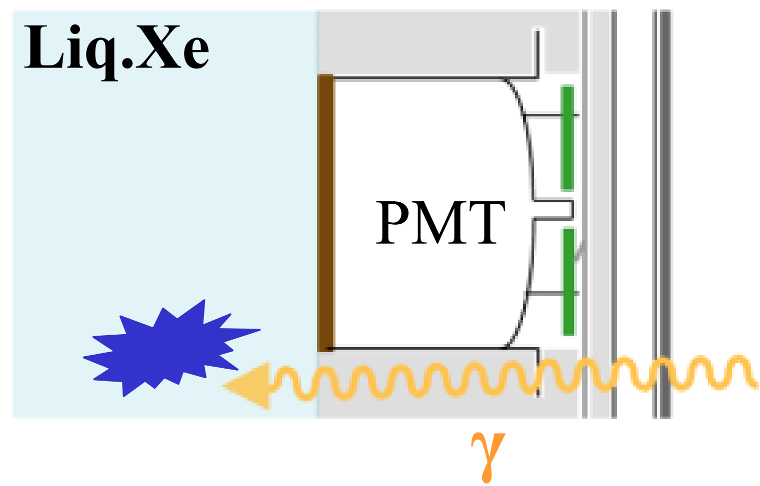
Electron collection and multiplication

Measureable electric pulse

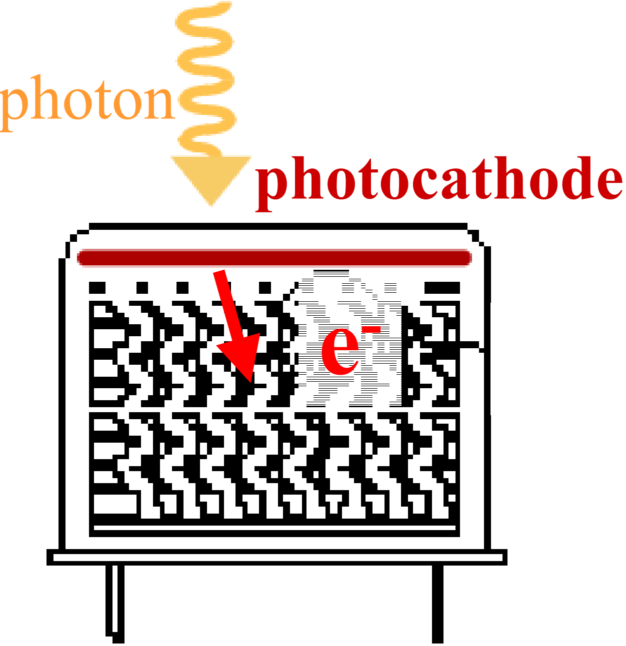
MEG Liq. Xe γ detector

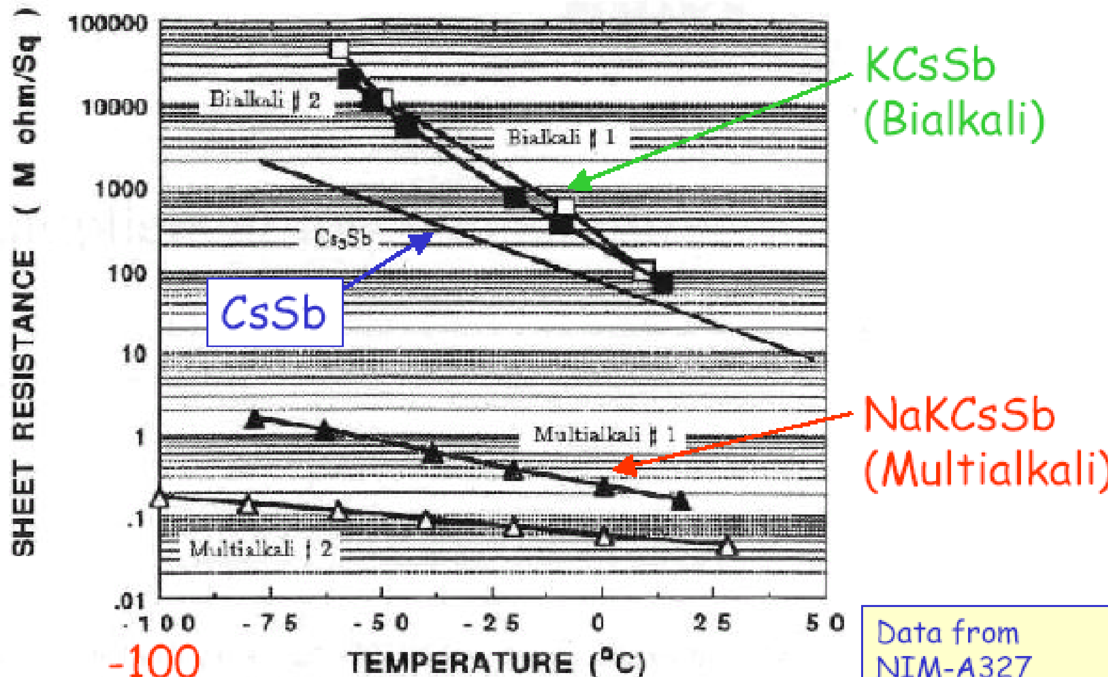


Detect **scintillation light** with 800 Liter liq.Xe and with 830 PMTs



PMT @ 165K (Liq.Xe temp.)



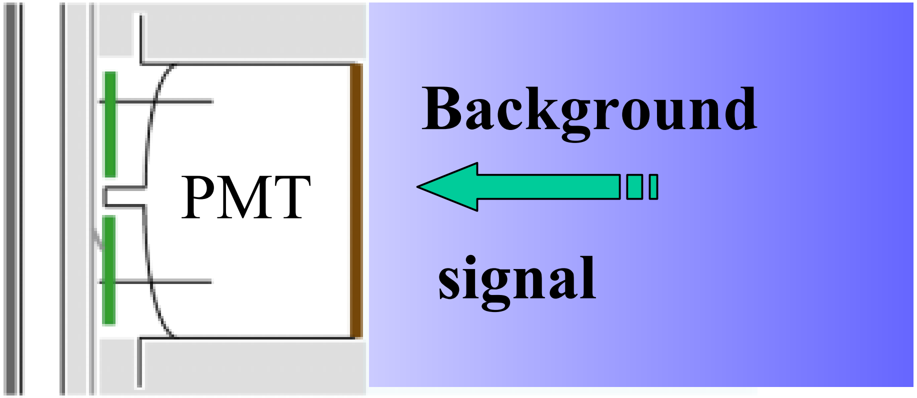


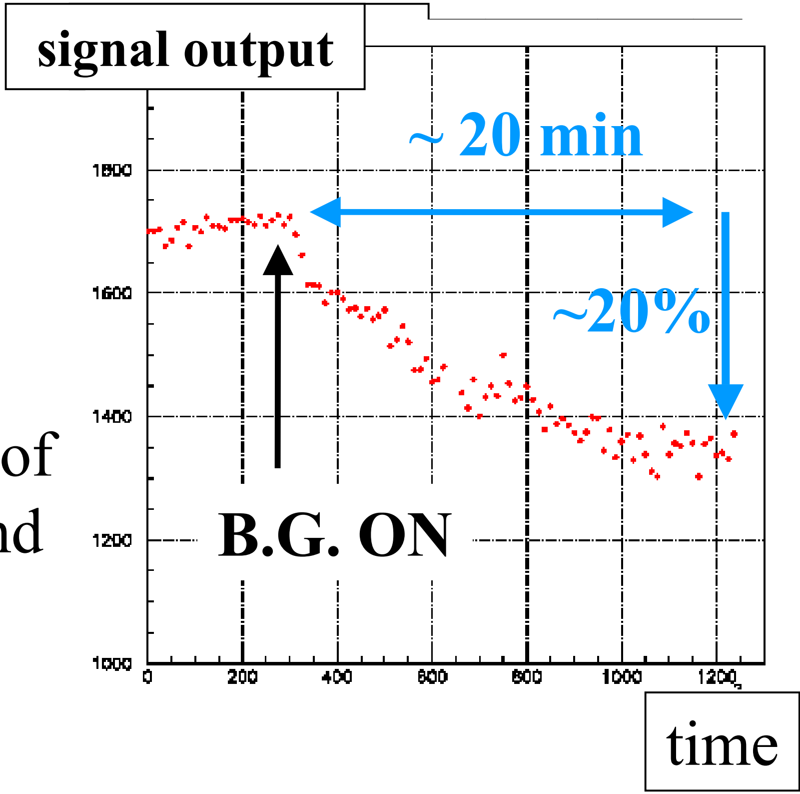
Data from NIM-A327 (1993) 144-147 Dr.Doke et al.

Temperature ↓
surface resistance ↑
Quantum Efficiency ↓
Signal Output ↓

} Need to reduce surface resistance of photocathode

PMT @165K under high rate B.G.





PMT will be exposed to large amount of light produced by high rate background radiation

➡ PMT output needs to be stable under high rate B.G.

First version PMTs output deteriorates under high rate B.G.
Related to the characteristics of photocathode at the low temperature

Development of PMT for MEG Experiment

- Efficient Q.E. @ 165K (reduction of surface resistance)
- Stable output under high rate background

First Ver.

Second Ver.

Final Ver.

	First Ver.	Second Ver.	Final Ver.
Photocathode	Rb-Cs-Sb	K-Cs-Sb	K-Cs-Sb
Material to reduce surface R	Mn layer	Al Strip	Al Strip (doubled)
Q.E. @ 165K	~5%	?	??

Development of PMT for MEG Experiment

- Efficient Q.E. @ 165K (reduction of surface resistance)
- Stable output under high rate background


First Ver.


Second Ver.


Final Ver.

Photocathode	Rb-Cs-Sb	K-Cs-Sb	K-Cs-Sb
Material to reduce surface R	Mn layer	**How much has Q.E. improved? Will PMT survive the high rate background environment @165K ?**	
Q.E. @ 165K	~5%		

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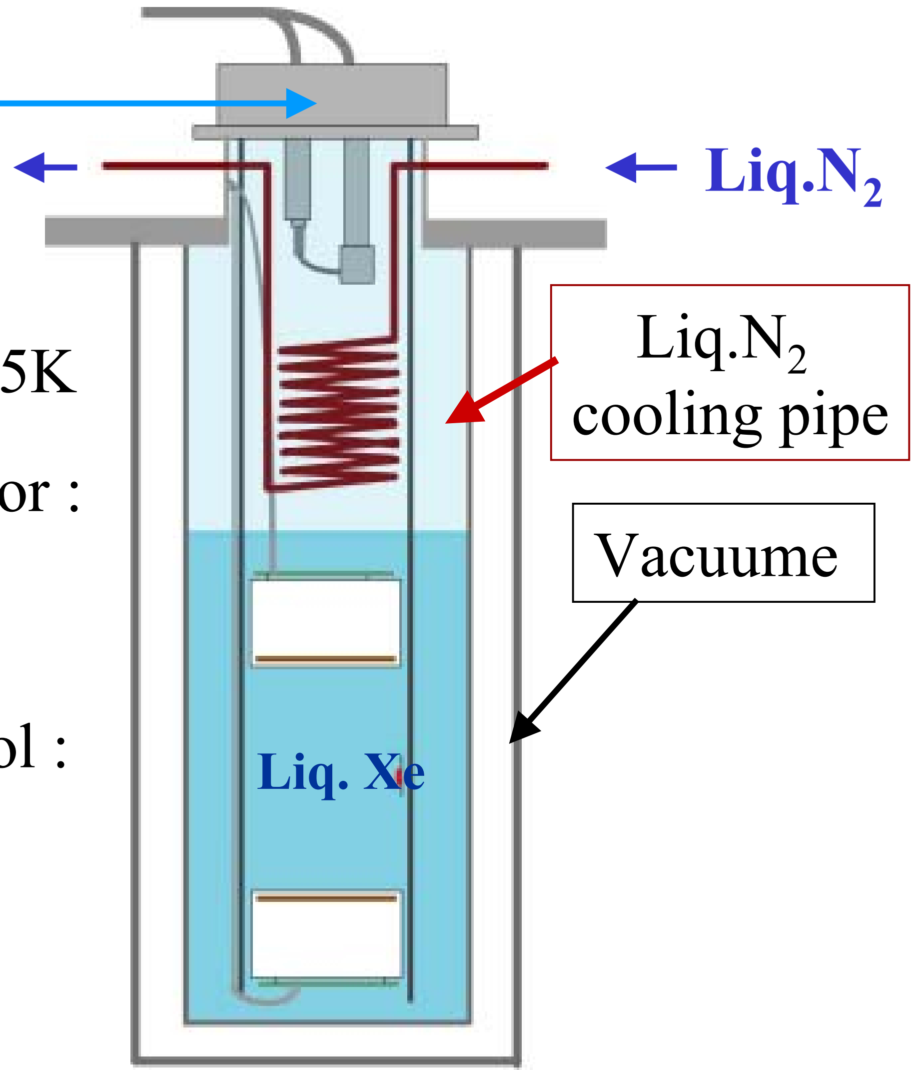
PMT Test @ Univ. of Tokyo *Liq.Xe chamber*

Pulse tube refrigerator

AISIN PR121
Compressor : TAC 101J
Cooling Power : ~25W @165K

Cold head temperature monitor :
Pt100
Platinum Thin Film Resistance

Cold head temperature control :
MINCO Thermofoil Heater



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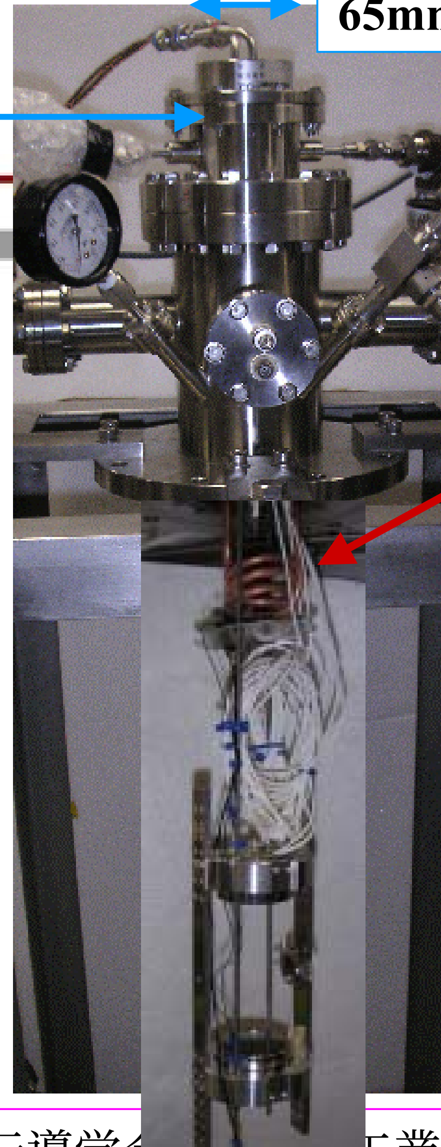
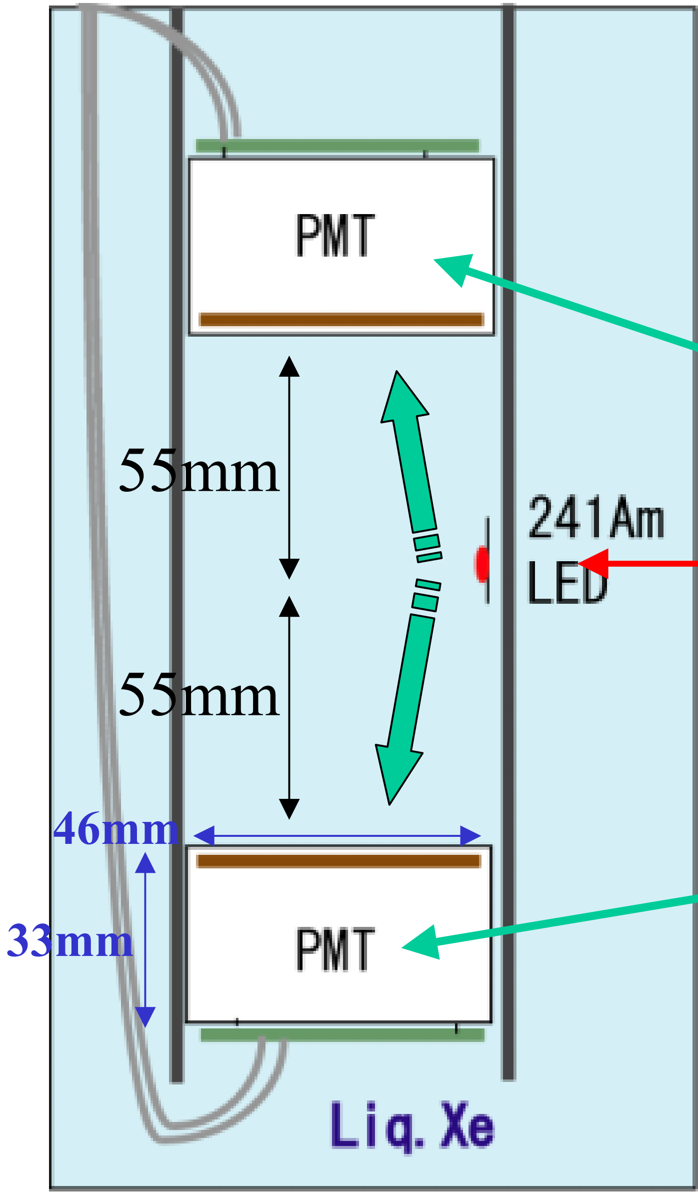


PMT Test Set up



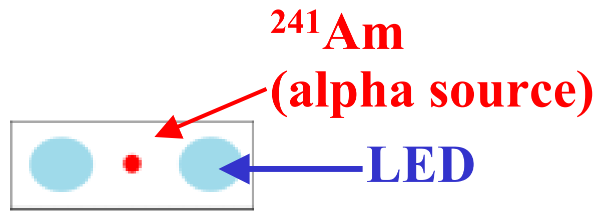
Q.E. measurement

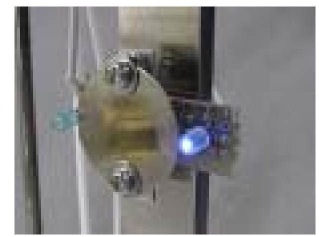
- How much has Q.E. improved?

Observe 5.5MeV alpha event
Gain calibration using LED

Reference PMT

Gain :10^6





PMT

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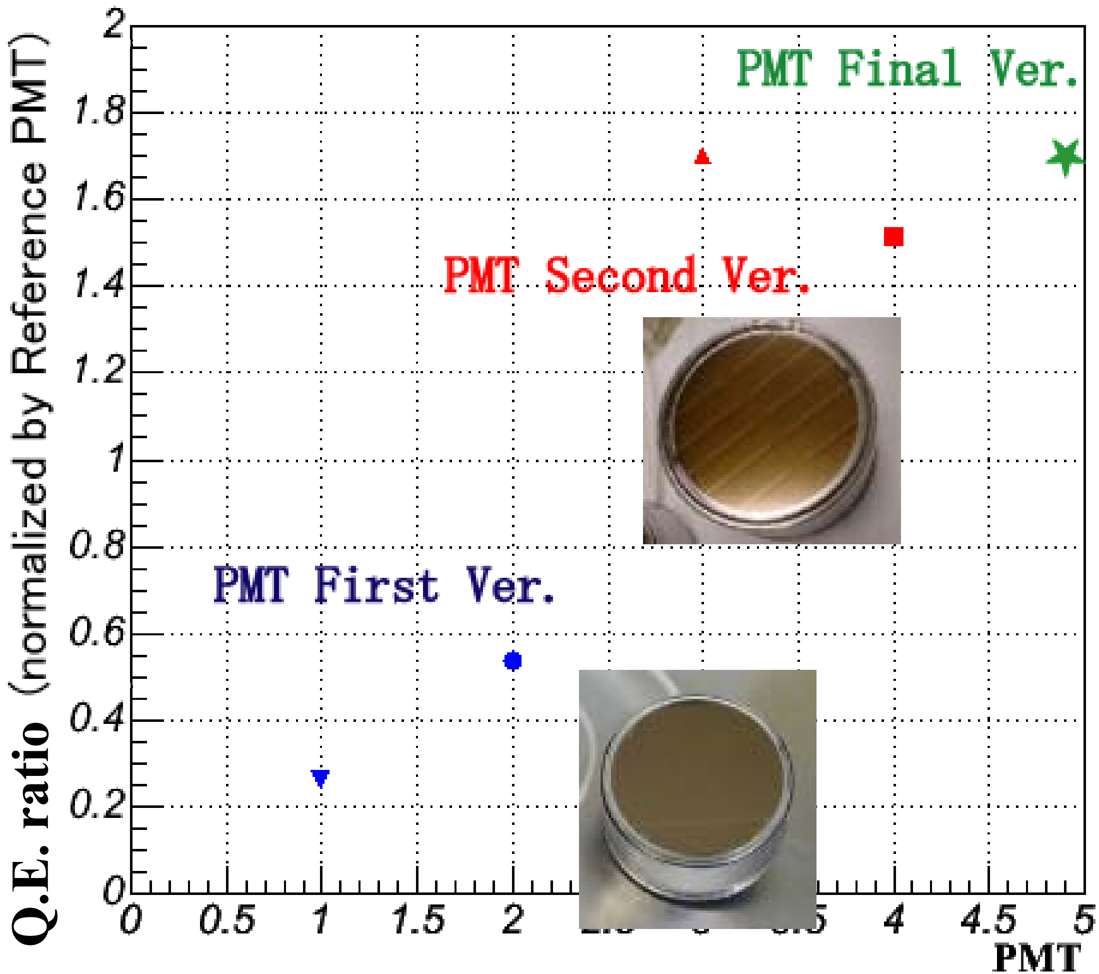
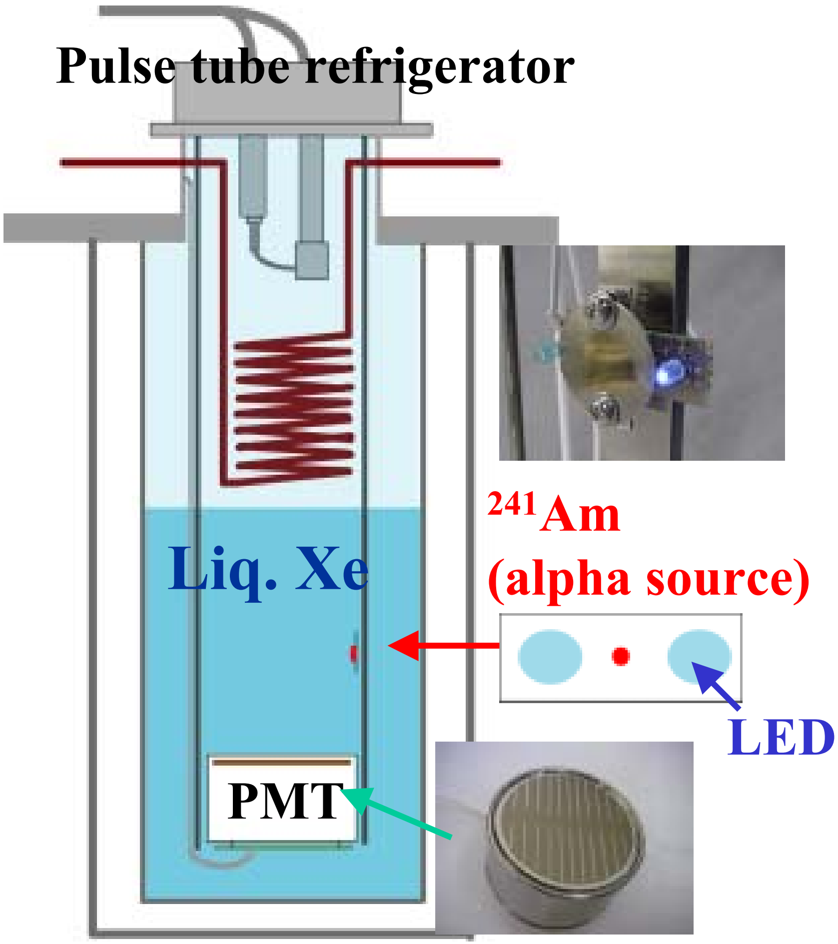
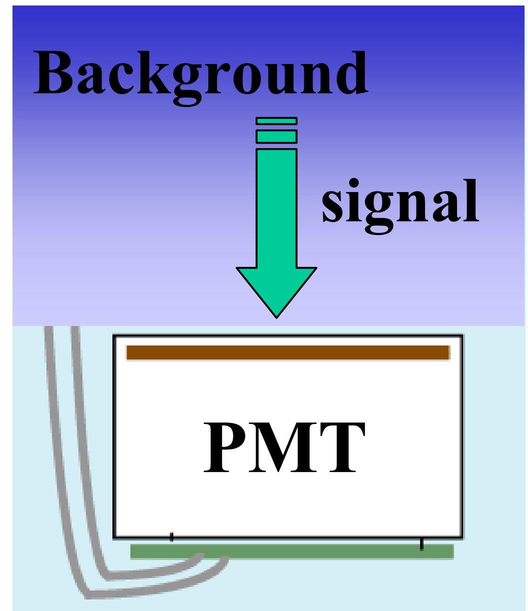
Q.E. measurement



PMT Test Set up *Rate dependence test*

➤ Will PMT survive the high B.G. environment at 165K?

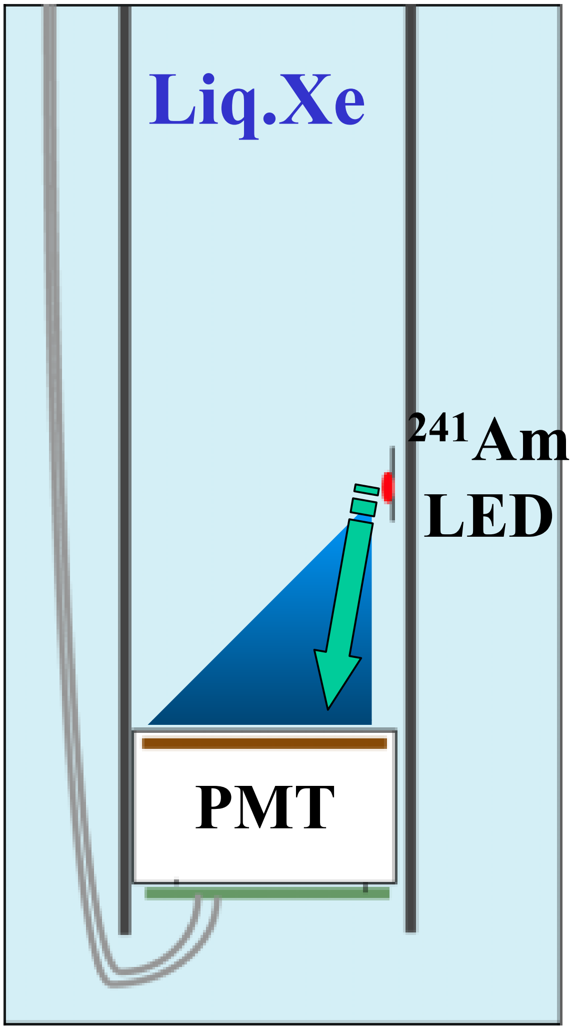




How to simulate High rate B.G. ?

→ **LED**

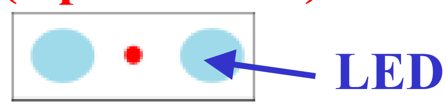
Rate Dependence Test Procedure



LED

- simulate the high rate background
- pulse height:4000~7200 p.e./event
- pulse shape: ~10nsec
- rate: 500Hz ~ 10KHz

^{241}Am
(alpha source)

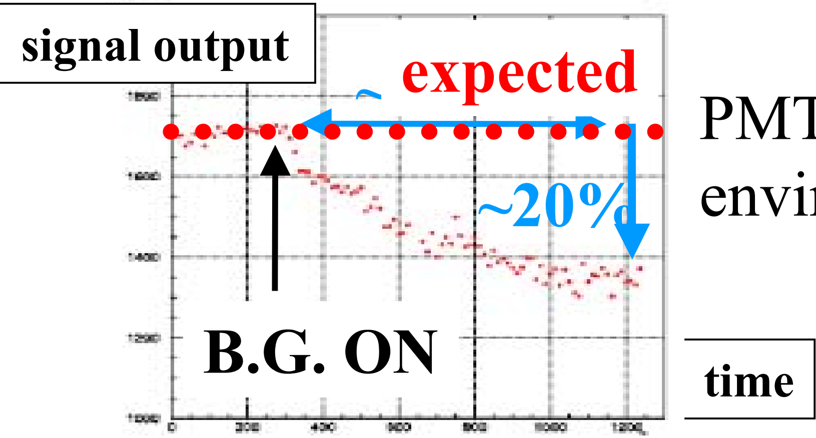


alpha

Observe 5.5MeV alpha event,
~200Hz

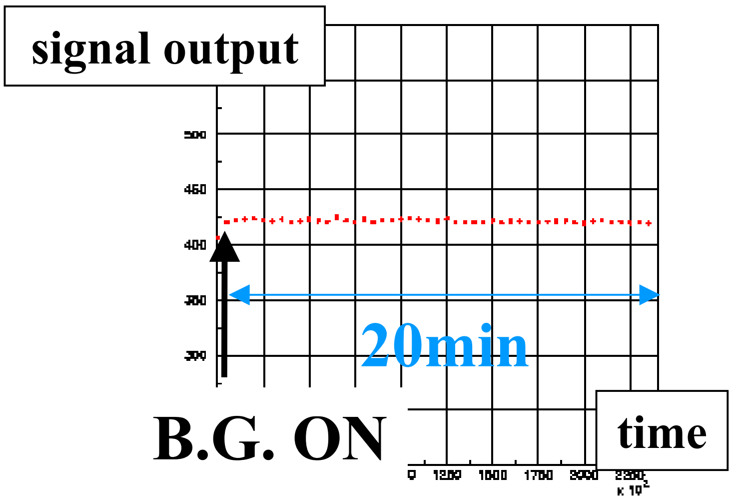
PMT for MEG final version

Rate Dependence @ Liq. Xe



PMT was tested under various background environment by changing the rate of LED

c.f. First Version PMT



The output from final version PMT is stable under the high rate background environment

Max. B.G. Level in MEG experiment

$1.3*10^7$p.e./sec

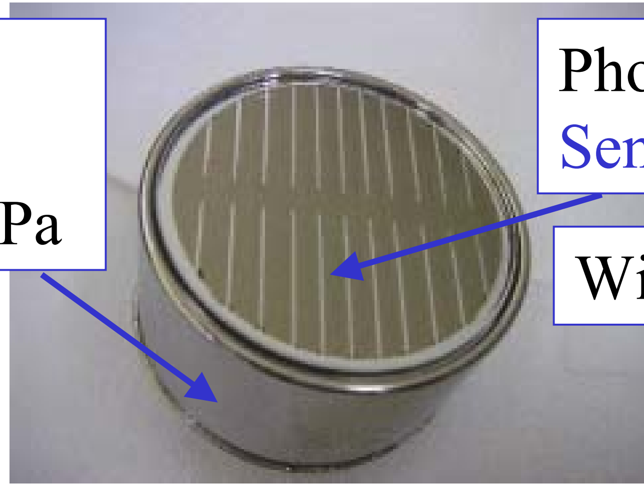
Summary

- PMT for MEG experiment has been developed.
  - Able to operate under 165K, Liq.Xe temp.
- Cryogenic performance of Final Version PMT is tested @ liq.Xe.
- PMT has efficient Q.E. even at 165K
- PMT output at 165K is stable under the high rate background environment.

以下予備トラペ

PMT for MEG Experiment

Metal Cover SUS
Able to withstand pressure up to 0.3MPa



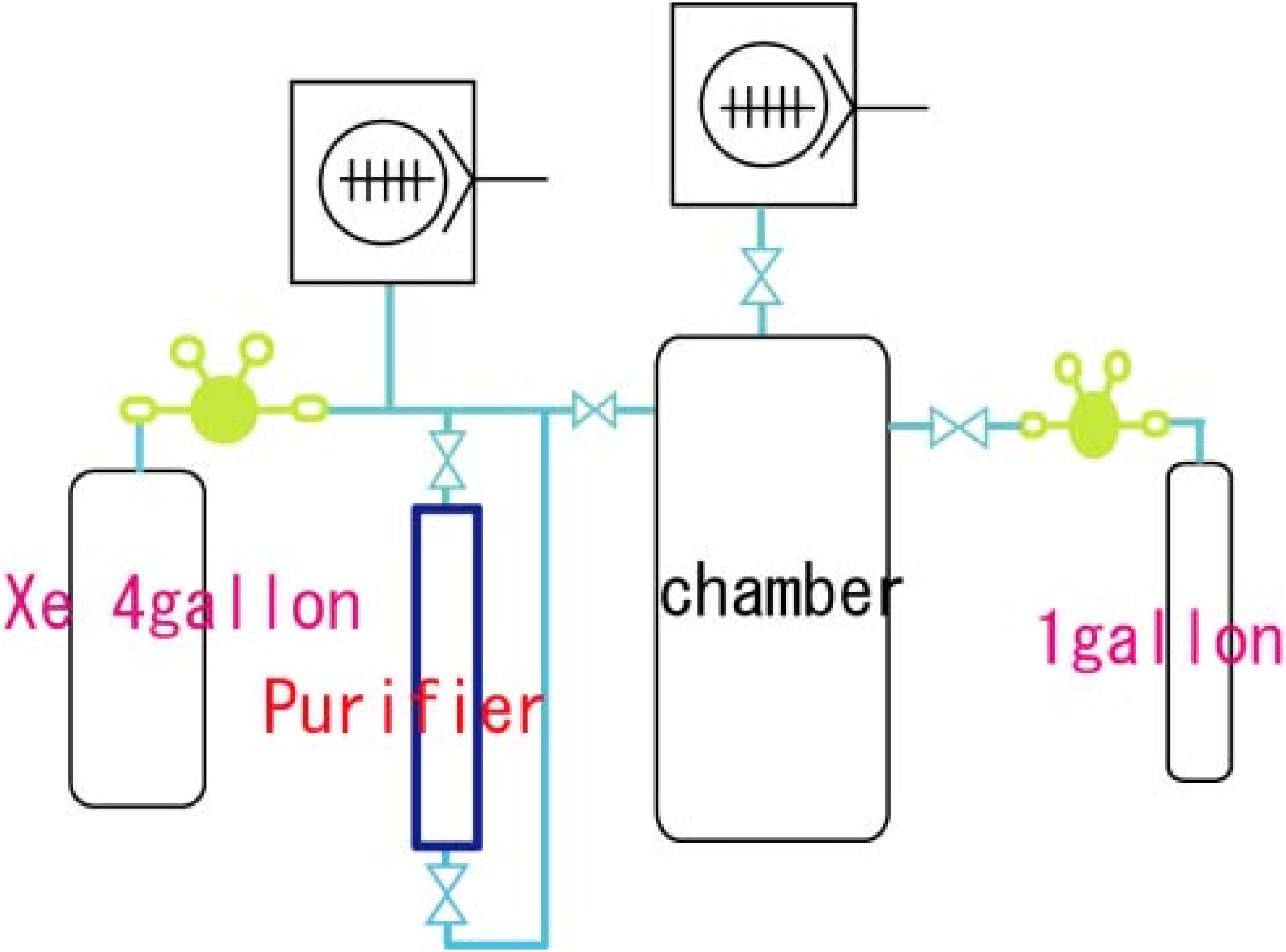
Photocathode : Bialkali
Sensitive to VUV

Window : Quartz glass

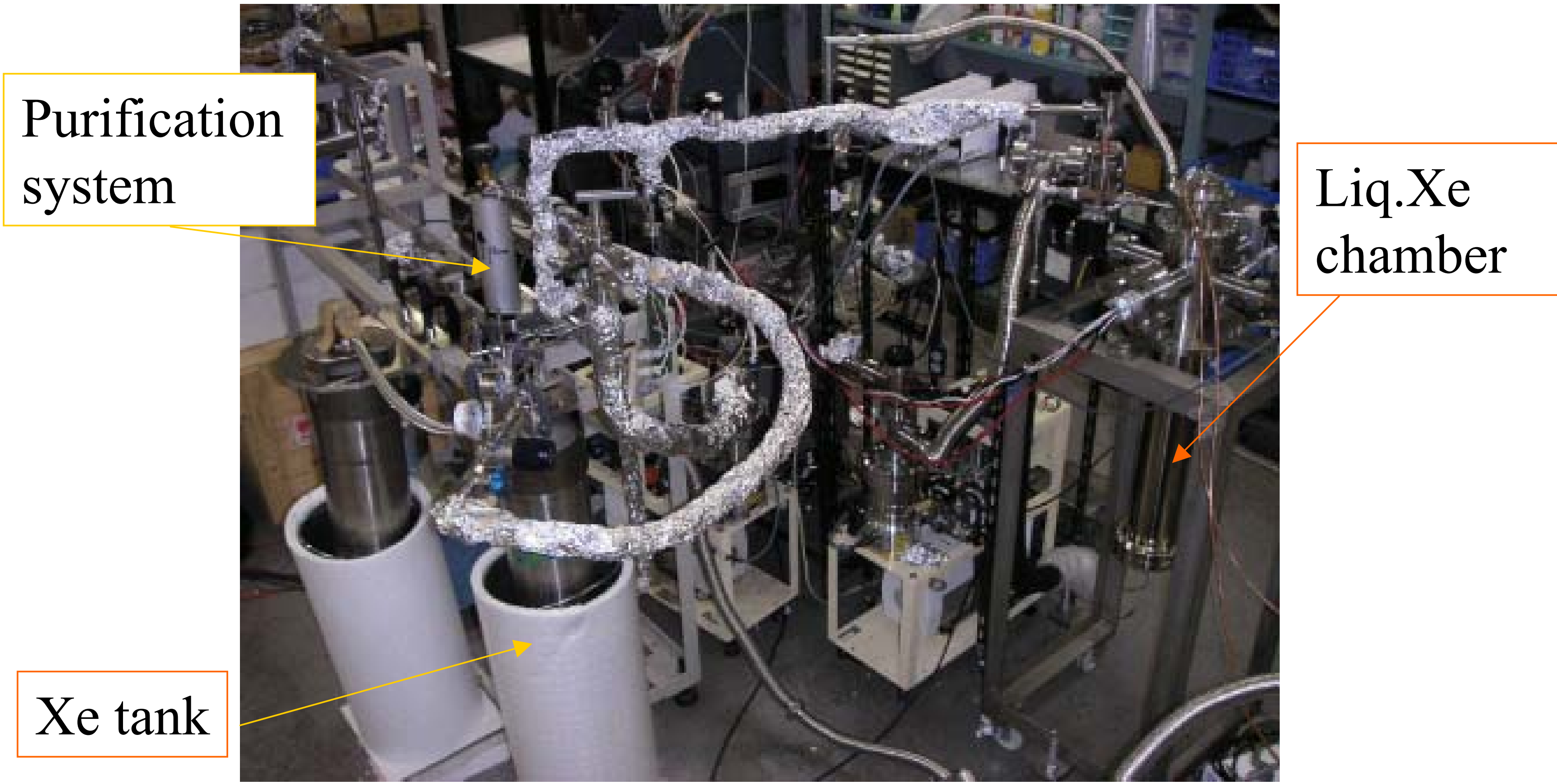
Kovar Metal

Kovar Glass

Flow sheet @ PMT Test Facility

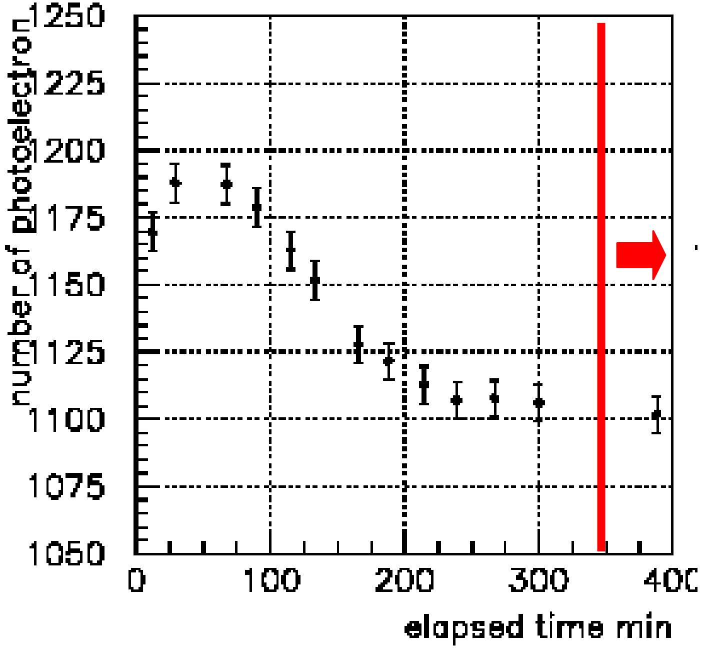


PMT Test facility @ Univ. of Tokyo



PMT stability, DAQ Procedure

DAQ started after all chamber
components become low temperature



Trigger : alpha self trigger

DAQ Procedure :

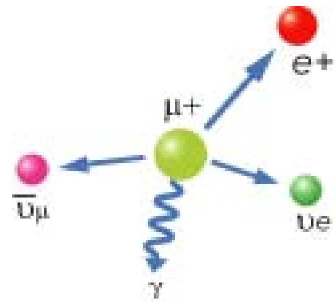
Pedestal Run

→ Gain Calibration

→ alpha run

Major Background for PMT

- muon radiative decay
- Gamma from positron annihilation
- Neutrons from proton beam

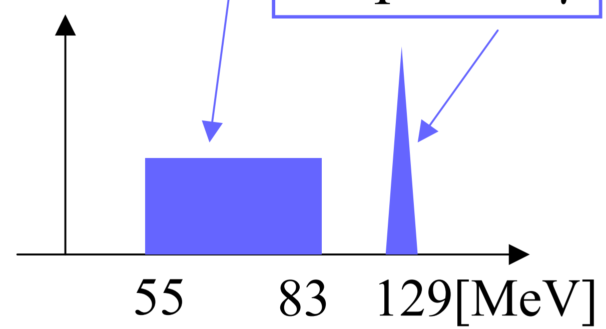


- neutrons from pion's CEX reaction (@calibration run)

$\pi^- p \rightarrow \pi^0 n$

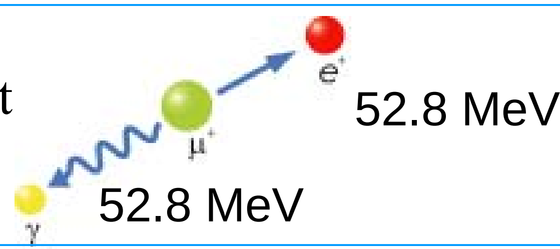
$\pi^0 \rightarrow \gamma\gamma$

$\pi^- p \rightarrow n\gamma$



γ energy spectrum

c.f. muegamma event



⇒ BG level ~ 2μA @10^6gain (~10^7p.e./sec)

Condition and Procedure

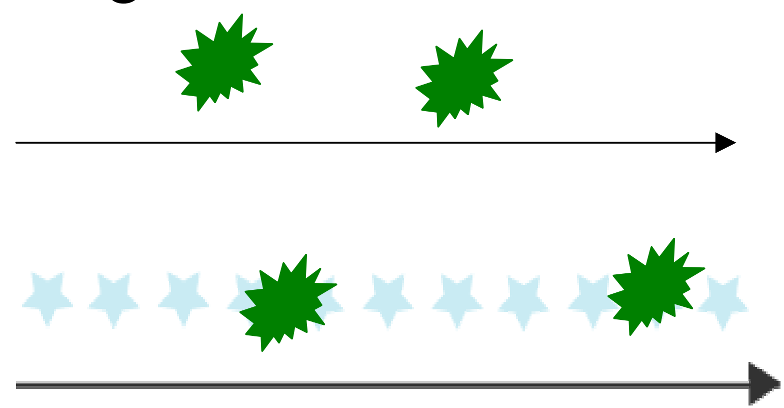
- Gain 1*10^6
- Trigger: alpha self trigger (veto by LED driver pulse)
- Procedure

Pedestal Run & Gain calibration using LED

Alpha Run @ LED OFF 20 min

Alpha Run @ LED ON 20 min

-Change LED Pulse height, rate



(R9288) 感度測定

PMT gain calibration 1

How to gain calibration?

PMTに入射した光子が光電面で光電子をたたき出す過程をPoisson分布であるとすると

$$\sigma_{Npe} = \sqrt{Npe} \quad (Npe: 光電子数)$$

増幅率GのPMTと1ch当りの電荷量CのADCで見ると

$$G = \frac{C \times M}{e \times Npe} \quad (e: 電気素量、M: ADCスペクトルの平均値)$$

$$\therefore Npe = \frac{C \times M}{e \times G}$$

また、

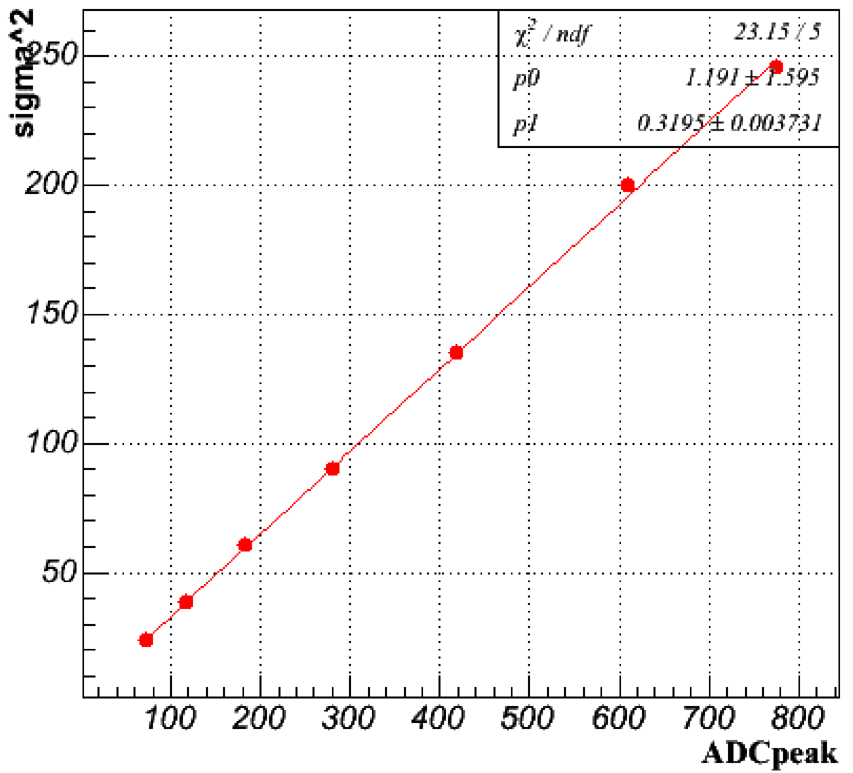
$$\sigma_{Npe} = \frac{C \times \sigma_{ADC}}{e \times G}$$

以上より

$$\sigma_{ADC}{}^2 = \frac{C \times M}{e \times G} = \left(\frac{C \times \sigma_{ADC}}{e \times G}\right)^2$$

$$\therefore \sigma_{ADC}{}^2 = \frac{e \times G}{C} \times M$$

M v.s sigma^{2}のplotの傾きからgainを算出



gain calibration(sample)