MEG実験 液体キセノンカロリメータにおけるエネルギー分解能の追究

東大素粒子センター 金子大輔
他MEGコラボレーション

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  - PMT Gain Stability
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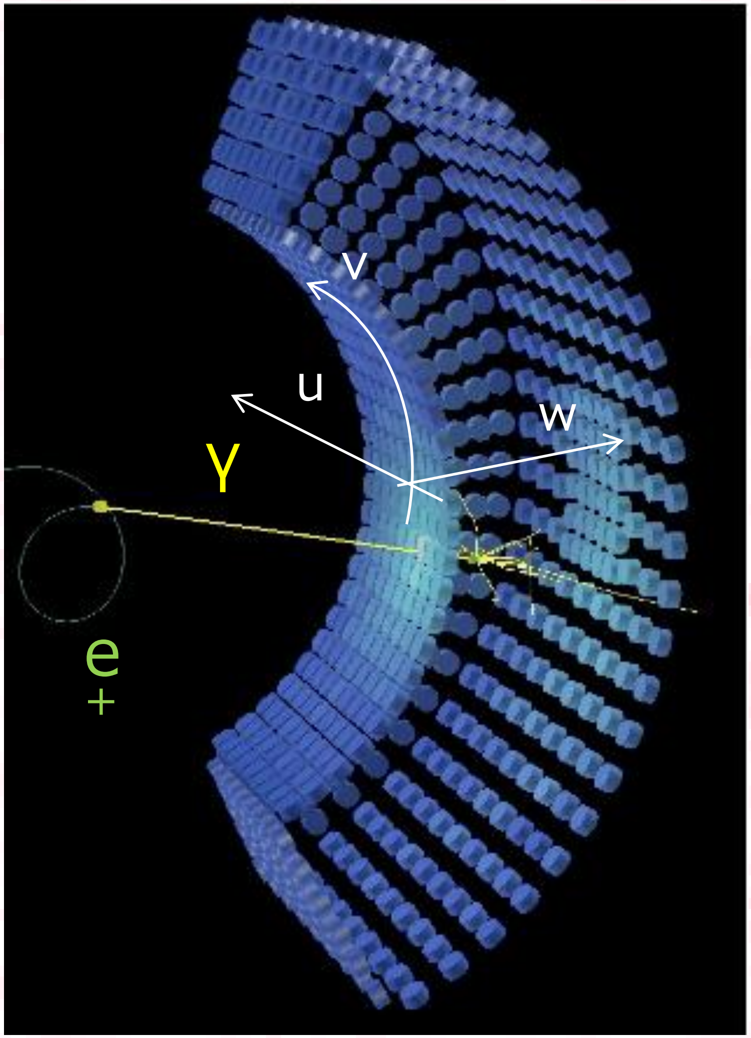
Liquid Xenon Detector



・846 2″ PMTs immersed in 165K Liquid xenon

・Reconstruct incident γ-ray from collected VUV scintillation photons.

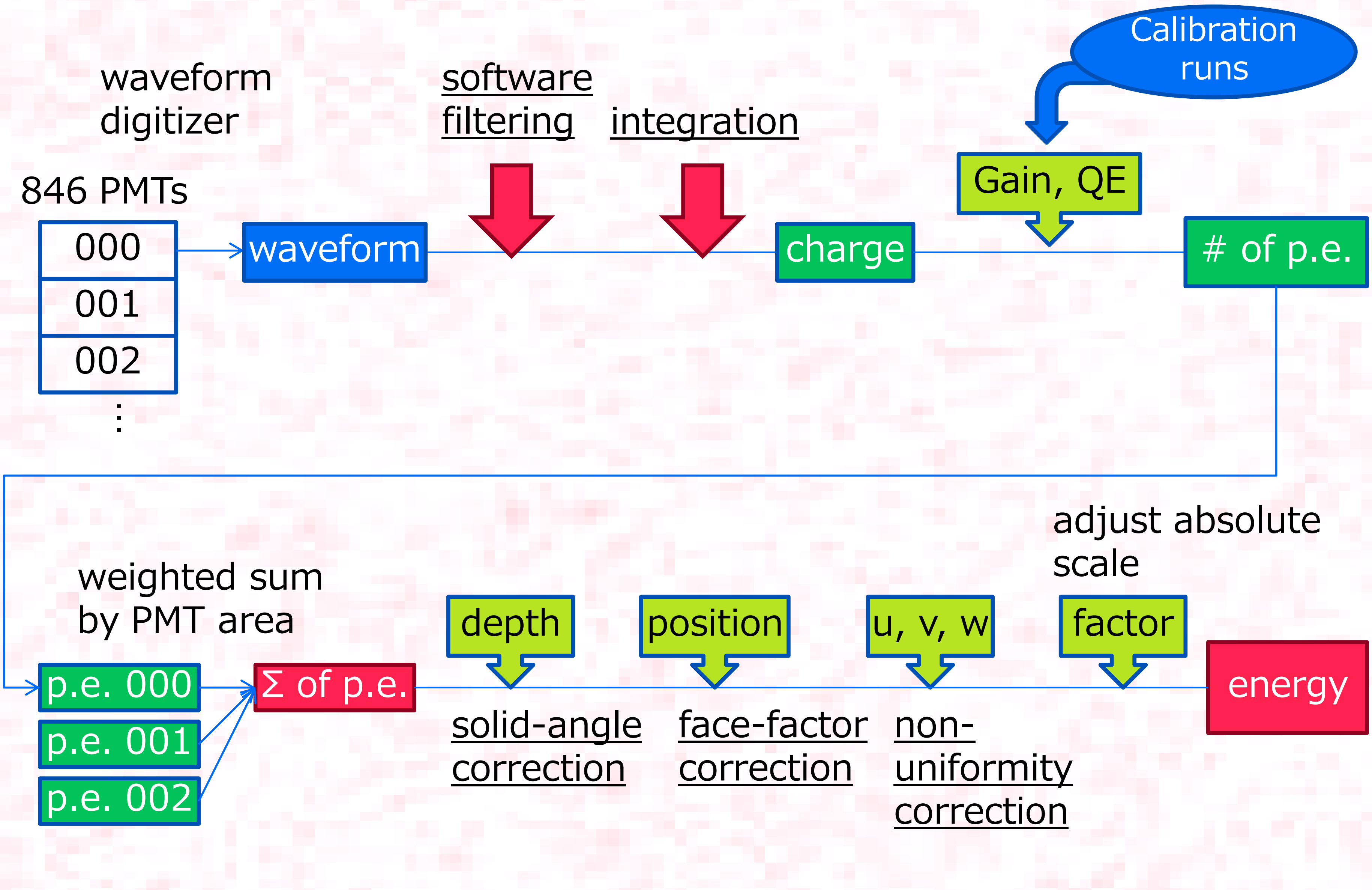
Performance (for signal γ)

Efficiency	62.8 %
Energy resolution (w>2)	1.7 %
Position resolution (uv, w)	5, 6 mm
Time resolution	67 ps

at run2011, preliminary

Energy resolution is worse than Monte-Carlo simulation.

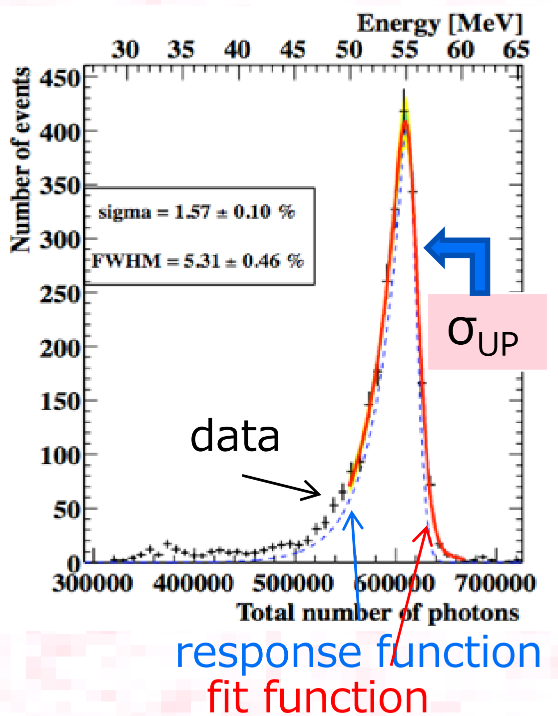
How to Get Energy

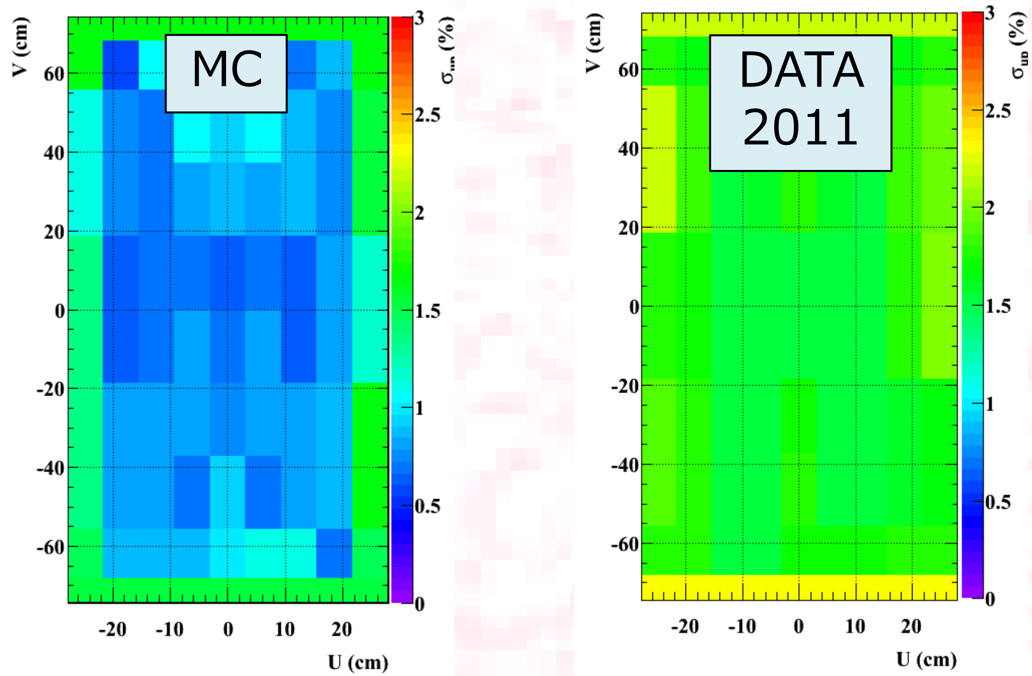


What is problem ?

Total collected photo-electron number is statistically enough.
50000 photo-electron → 0.45% in σ

Actual resolution is 1.0% for Monte-Carlo, 1.7% for data.
Result of large prototype test : 1.2%
There must be un-understood event-by-event fluctuations !





Energy resolution mapping

Studied items

- Systematic error of QE estimation
- Gain non-uniformity in a PMT

already known not to affect so much (reported in 2012 spring JPS meeting)

A: PMT Gain stability

○ gain instability effect to resolution.

B: Case of smaller PMT active area

○ if sensitive area were smaller, photon collection would fluctuate more

C: Reflection at PMT photo-cathode

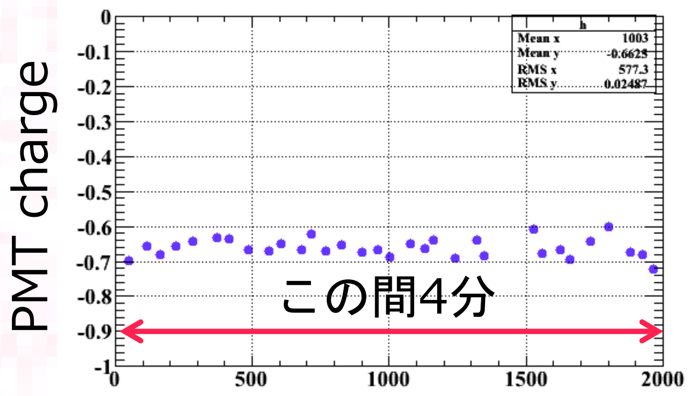
○ Dependence of light collection efficiency on the relative position between PMT & conversion point could be enhanced

A: Stability of PMT gain

We are monitoring PMT gain in MEG physics run,
by flashing PMT every a few second.

In spring JPS meeting…

Charge from one PMT in LED event fluctuate about 3% in run.

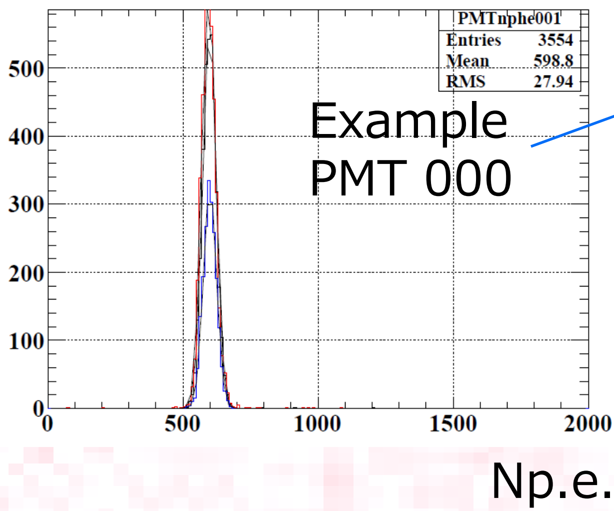


That time, I checked only about 10 min of MEG run and only some PMTs.

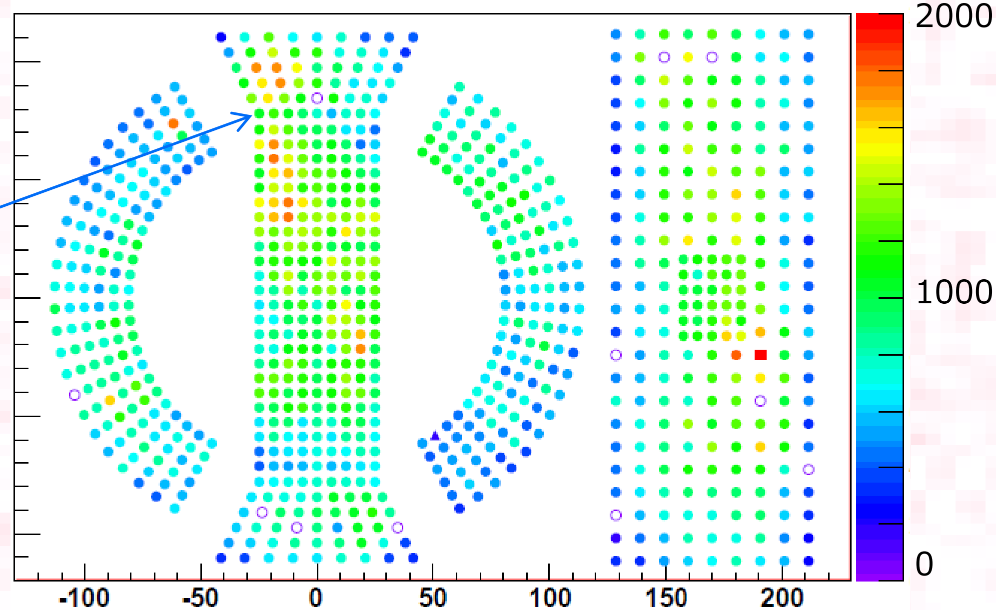
I checked more precisely.
For all PMT
Evaluate statistical fluctuation.

Calculation of number of photoelectron

Calculate mean & σ of *N* p.e.
by fitting with Gaussian.



Average *N*p.e. for all PMT

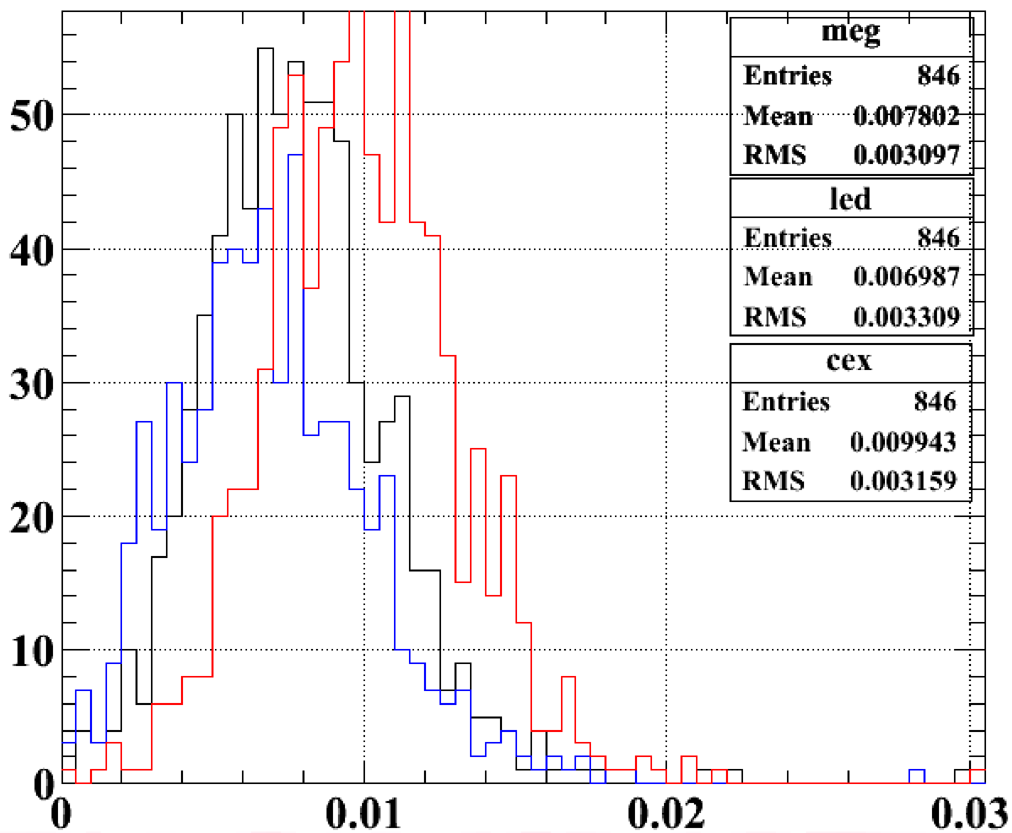


Average for all PMTs : 757.2

Subtract normal statistical fluctuation assuming *Np.e.* is distributed in poisson distribution

$$\sigma_{\mathrm{add}} = \sqrt{\sigma_{\mathrm{p.e.}}^{2} - \mu_{\mathrm{p.e.}}}$$

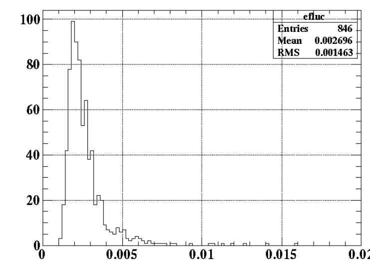
Result : A



remainder gain fluctuation σ_{add}

Average gain fluctuation is 0.78% in MEG run

Statistical error is about 0.2-3 % →

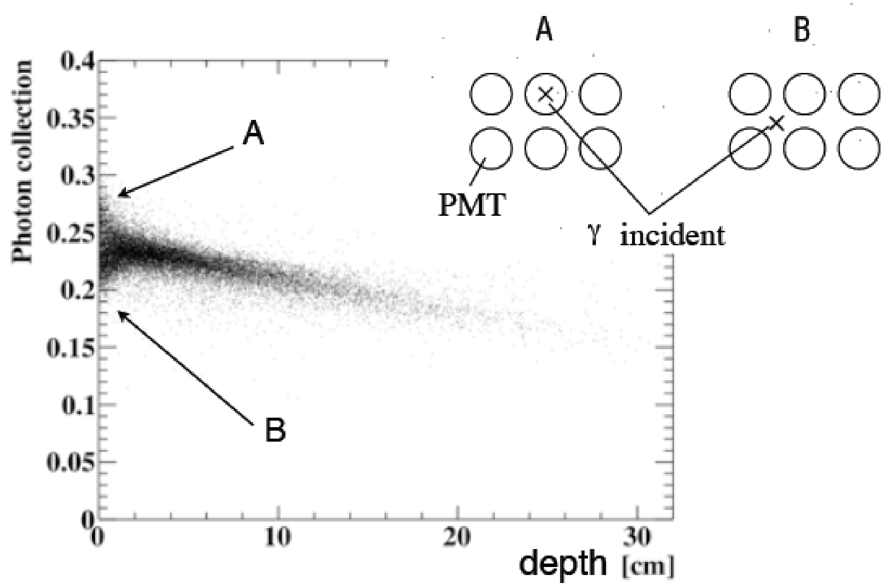


In other data
0.70% in LED run (beam off),
0.99% in CEX run (pion beam).

This fluctuation hardly worsen total energy resolution, because gain fluctuation is random for each PMT in a event.

B: How PMT area affect ?

It is already known that difference of relative position to PMT causes additional fluctuation in photon collection.



If PMT's cathode were smaller than designed size, this fluctuation would become larger.

for example from

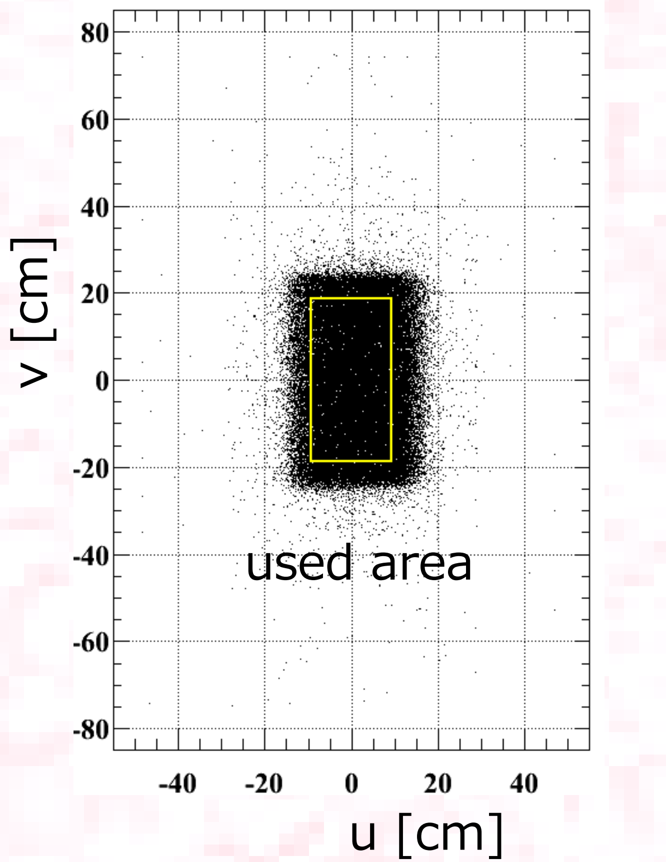
- cathode deterioration
- effect of B field
- etc.

Generated MC

I studied the simple case
PMT cathode is concentrically smaller.

d < (PMTsize) ?

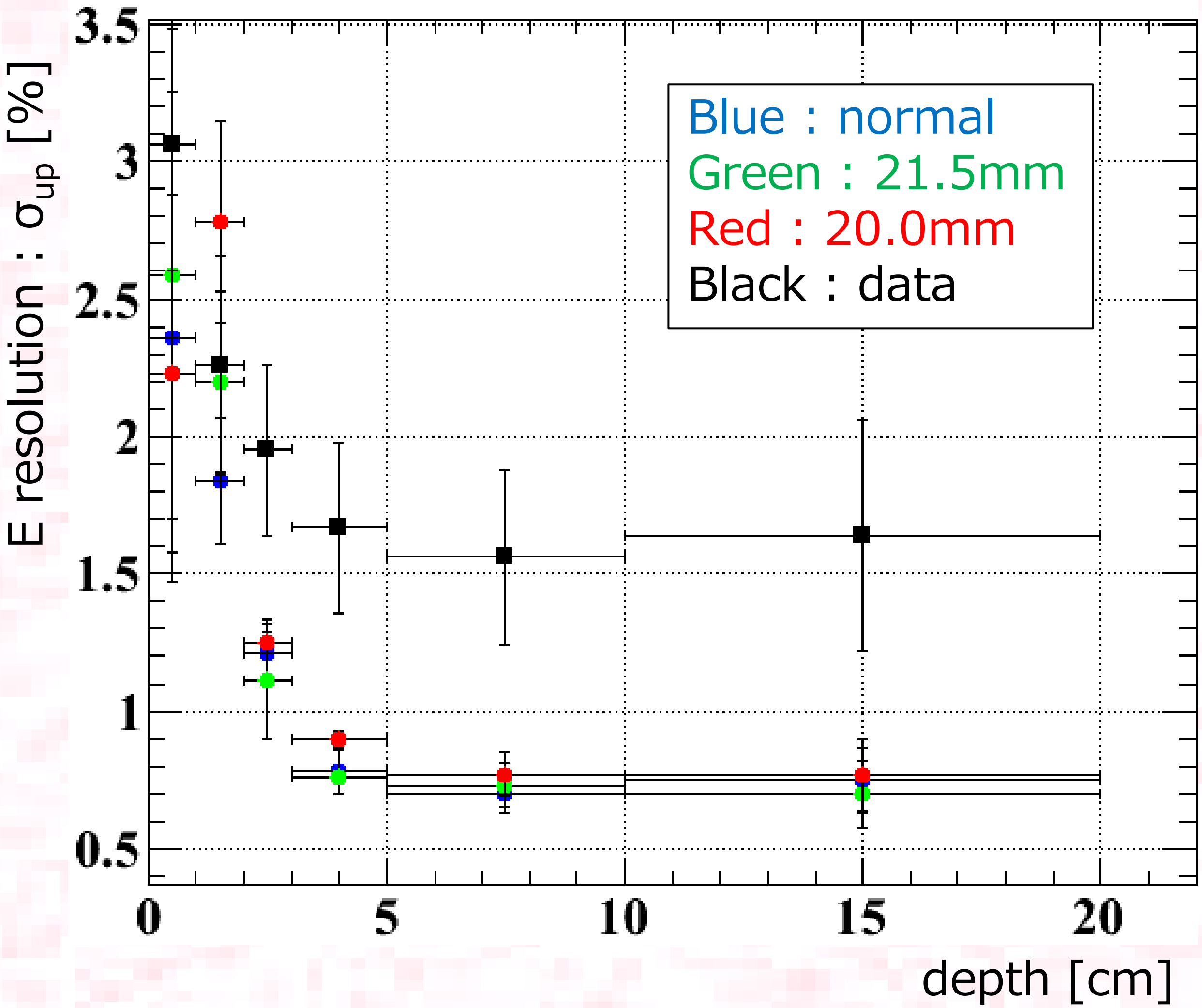
Range : center 18PMT
not to see non-uniformity
↓



Event generation : signal γ (52.8MeV)

	Radius[cm]	Area (ratio)
Case 0	2.25	100%
Case 1	2.15	91%
Case 2	2.00	79%
Data	2011 charge-exchange calibration (55MeV γ)	

Result : B



Resolution of real data is worse than MC, in all depth region.
(0.6 ~ 0.8 % in σ_{up})

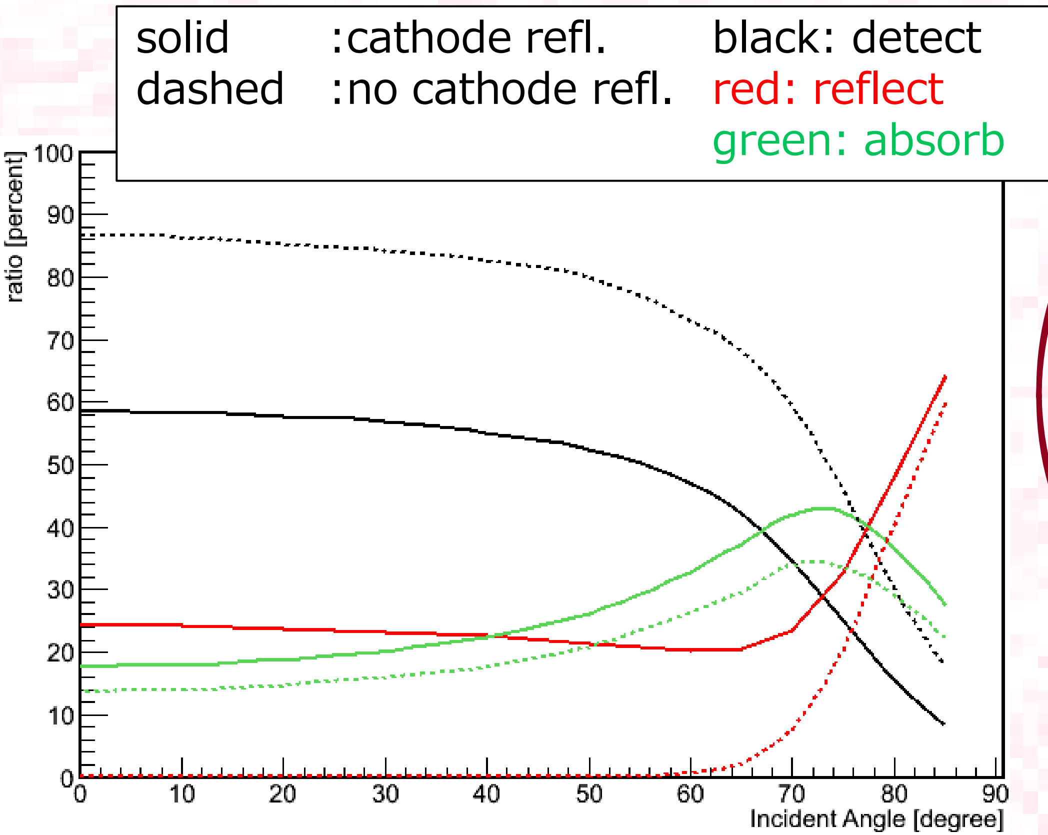
It is hard to explain discrepancy between MC & data with PMT's smaller cathode size, because no visible effect is seen.

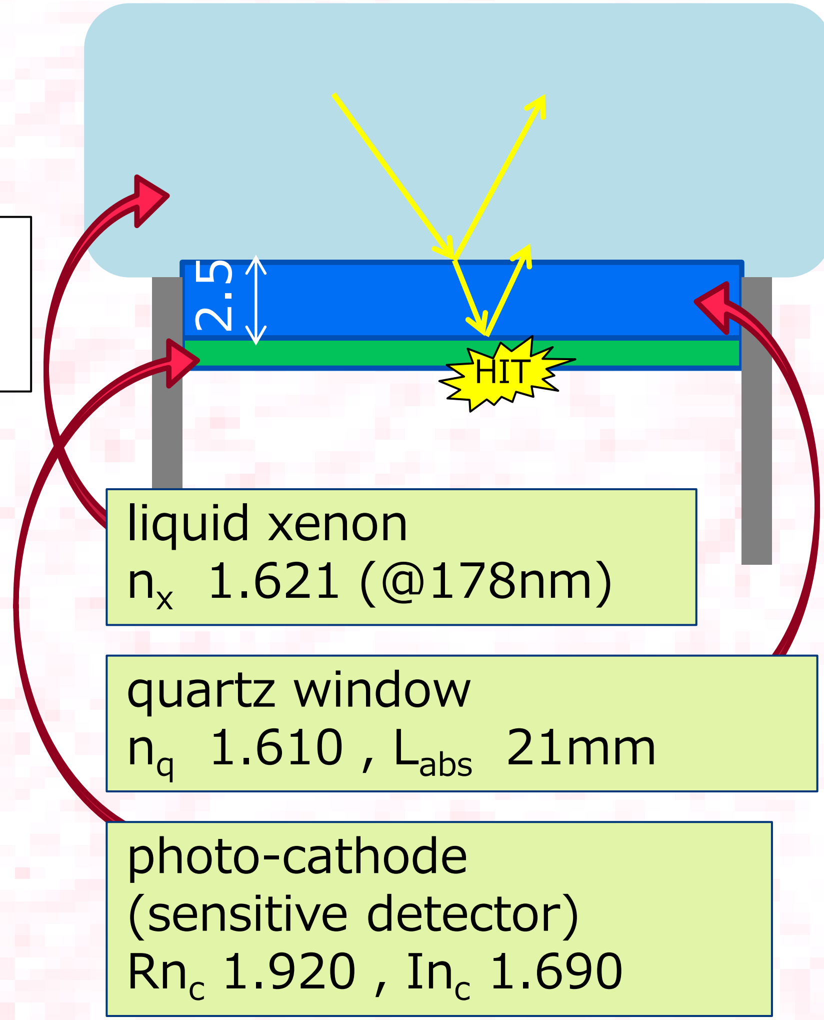
C: Reflection on PMT cathode surface

Current MEG Monte-Carlo simulation only consider reflection on quartz window.

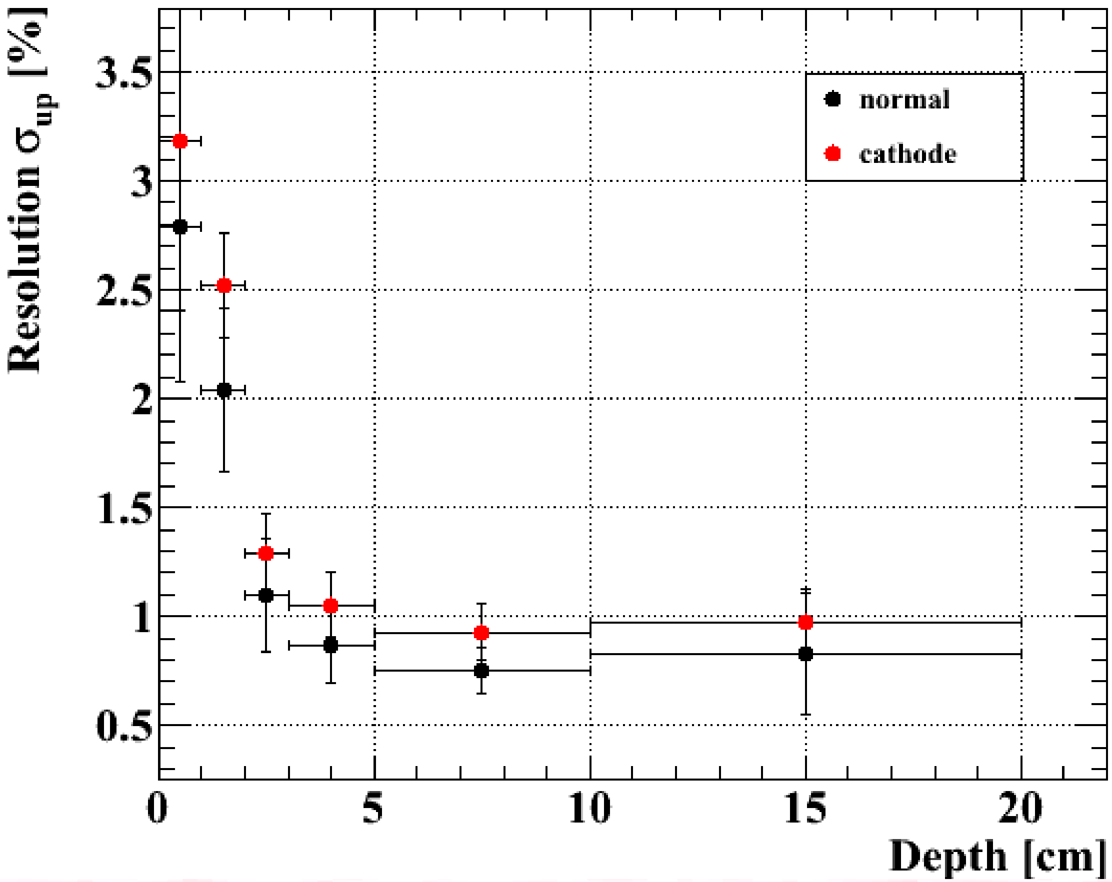
↓

introduce reflection on cathode surface

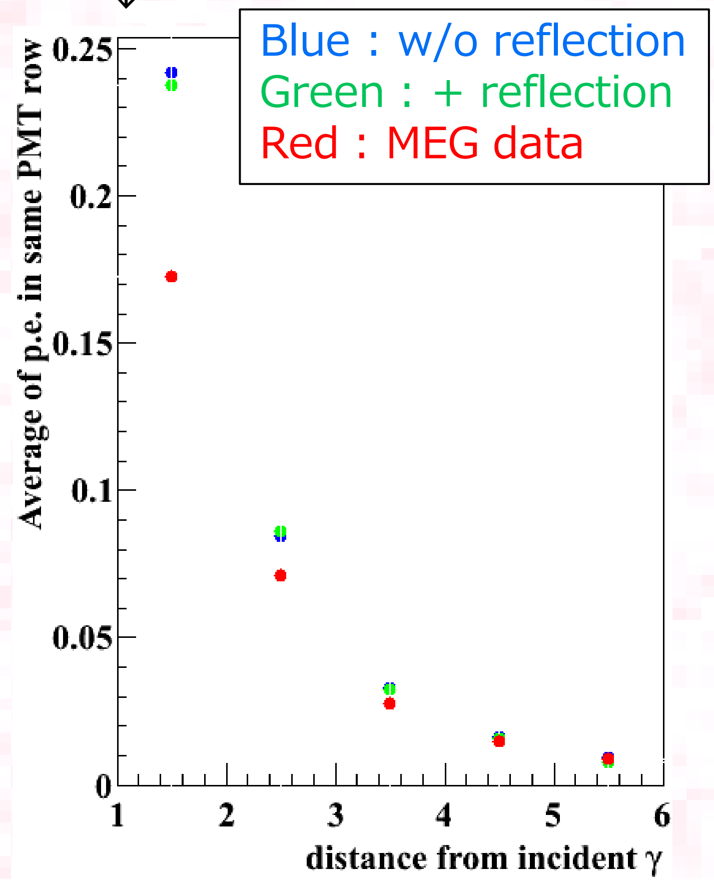




Result : C



Photon distribution got little closer to data.
Parameters were not good ?
↓



Energy resolution become worse in all depth by 0.2 ~ 0.5%.
This can't explain all discrepancy between MC & data, but is not ignorable part if this is true.

Summary

I studied energy resolution of MEG γ-ray detector.

Following results were obtained,

- PMT gain is stable enough in MEG data taking.
- PMT cathode size does not affect resolution.
- Reflection on cathode surface can cause a part of discrepancy between MC & data.

Prospects

- Understand mechanism how reflection affects resolution.
- Optimize optical parameters of PMT material.
- Seek another cause of E-resolution discrepancy.

- Improve current energy analysis method.
- Use for upgraded detector.

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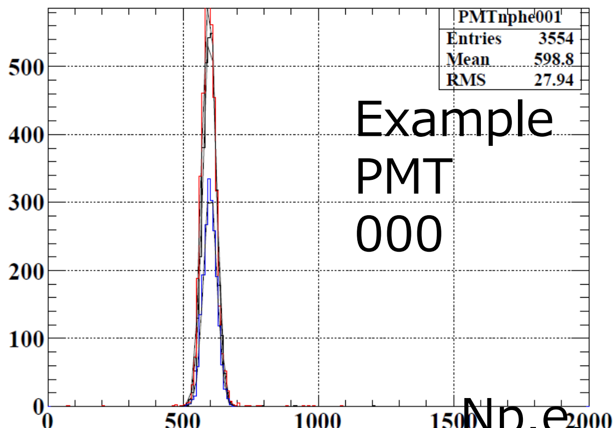
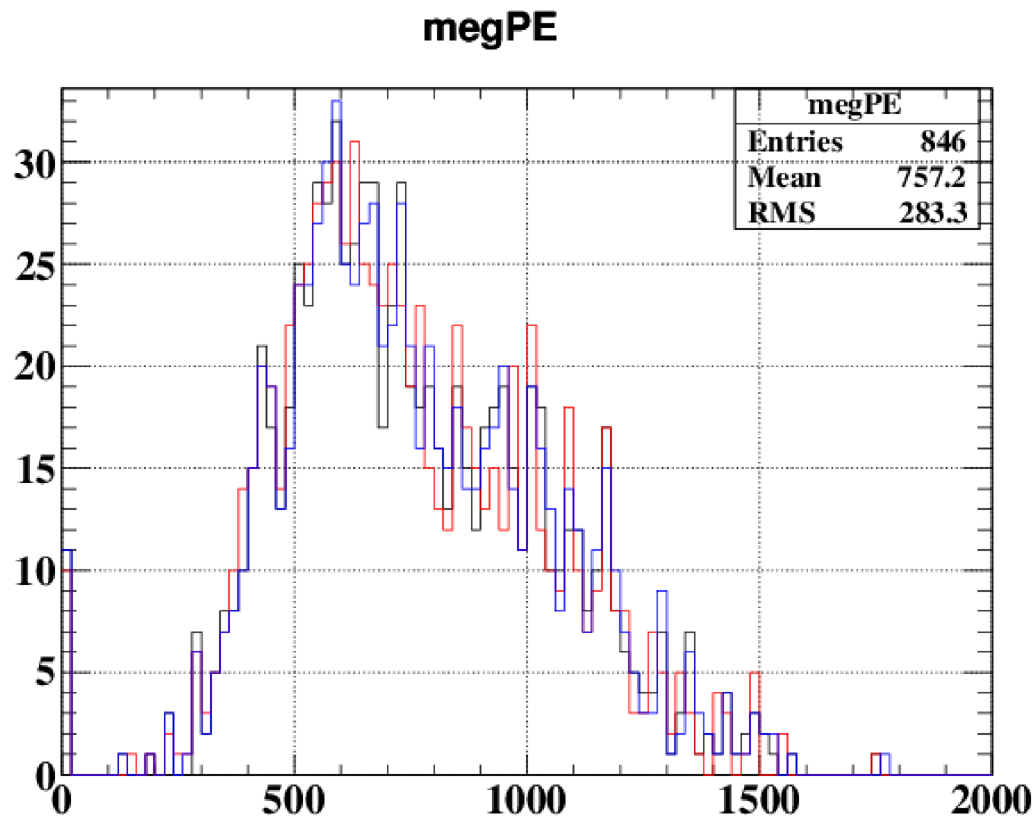
Calculate mean & σ of Np.e.
by fitting histogram.





Analyzed data

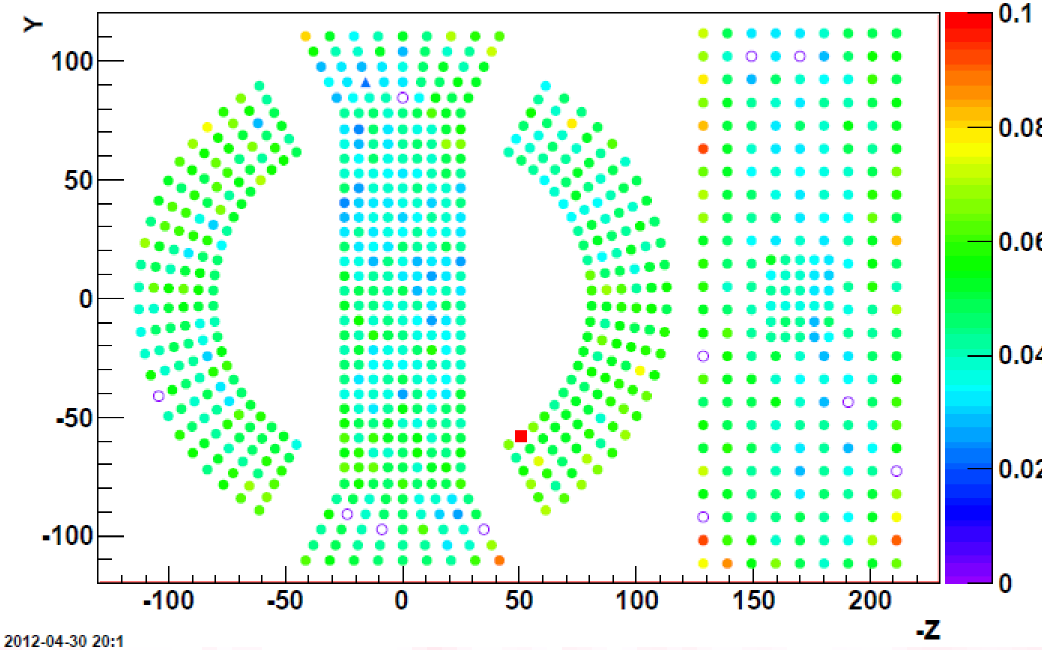
Black : MEG physics data
Red : Charge exchange calibration run
Blue : LED gain calibration run

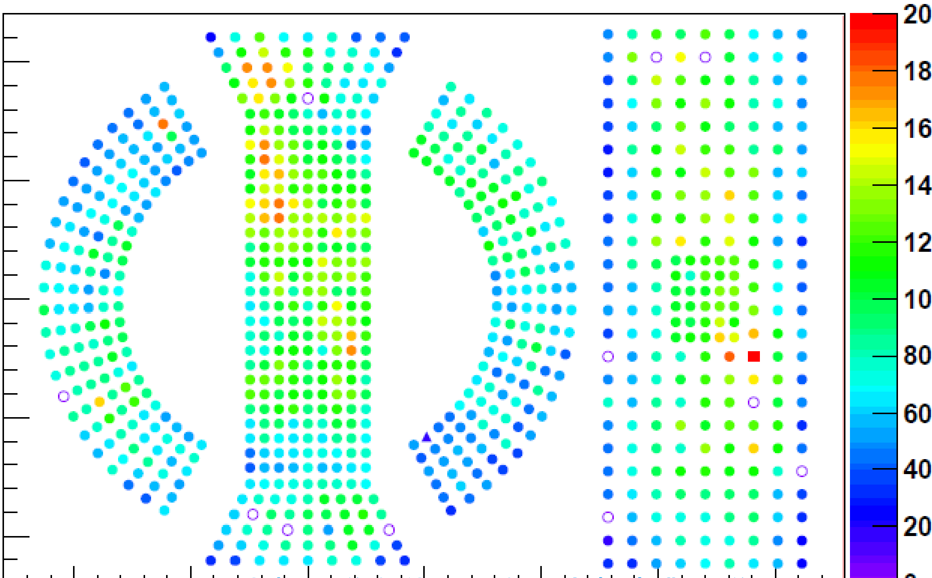
Average photo electrons
MEG : 757.2
CEX : 749.1
LED : 759.5

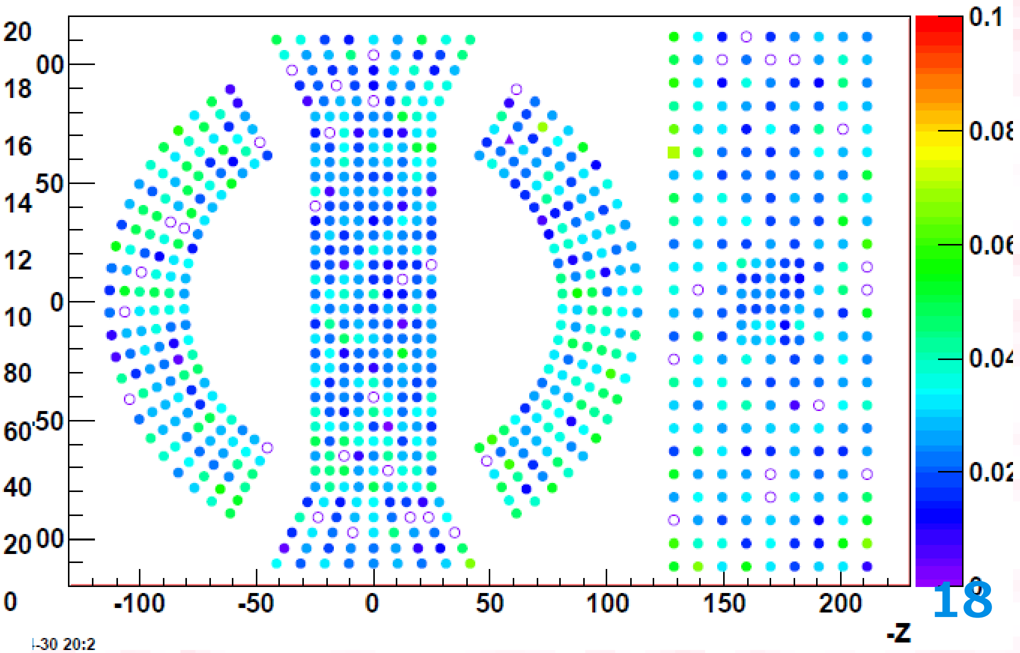
Fluctuation by Position

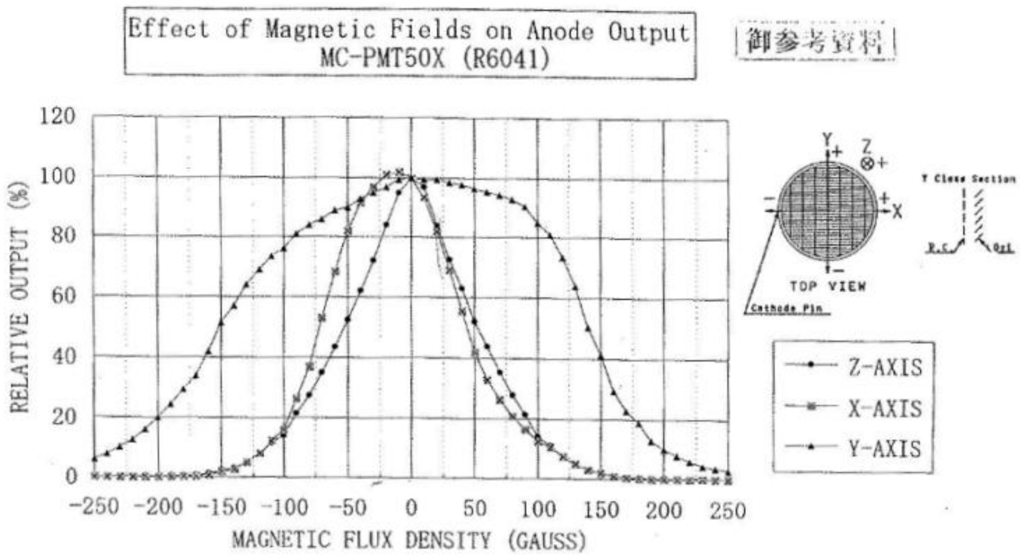
Left : LED nphe mean

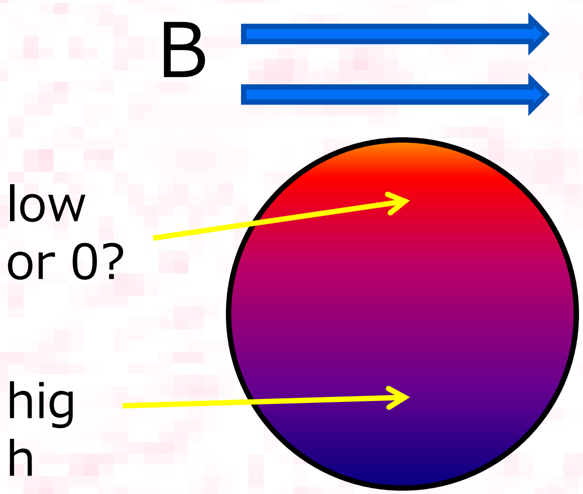
Right Top : RMS (relative)
Right Bottom : Subtracted Statistic









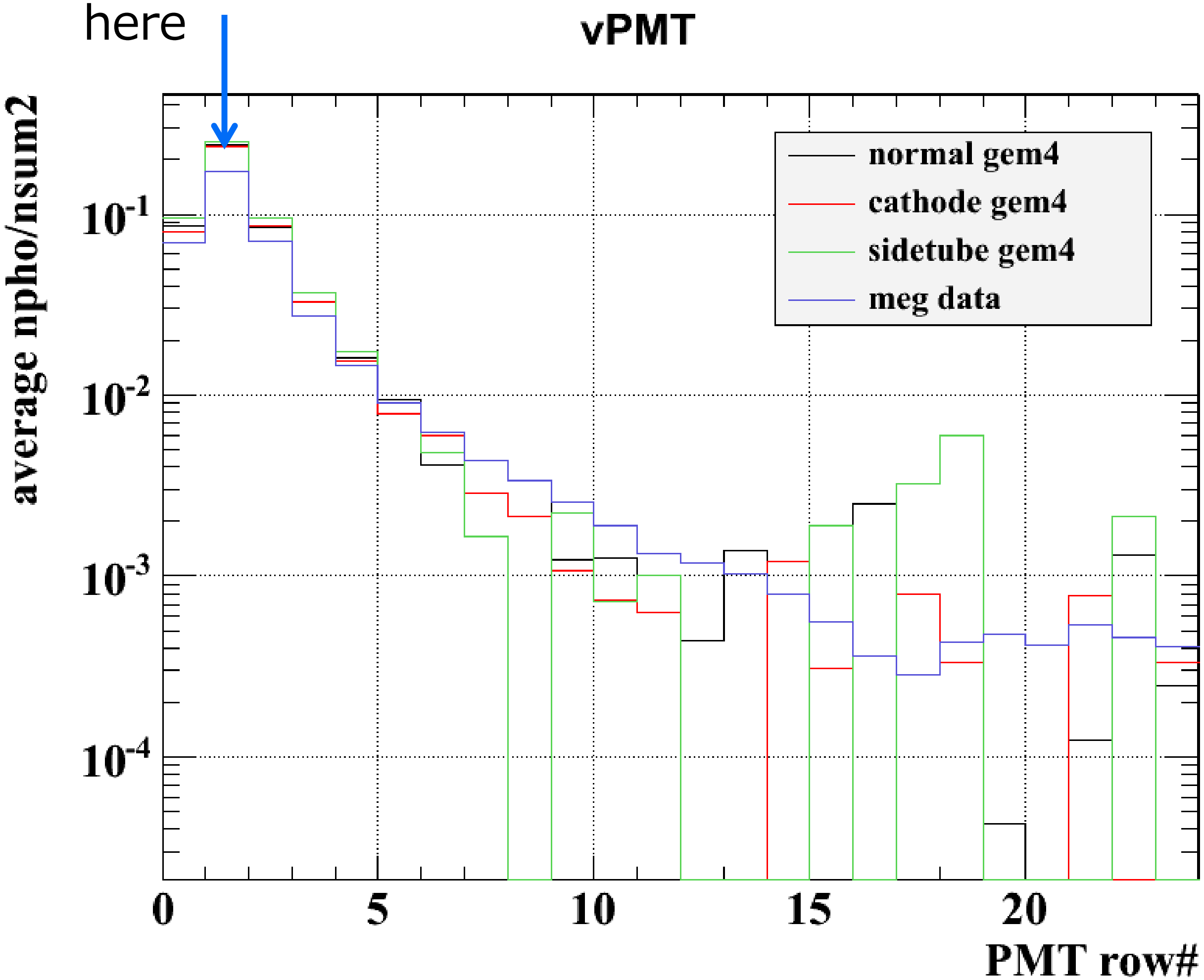


※ **this is imaginary picture**

B dependence of total gain come from position dependence of gain (collection efficiency) ?

Photon collection (project to U direction)

select
event
here



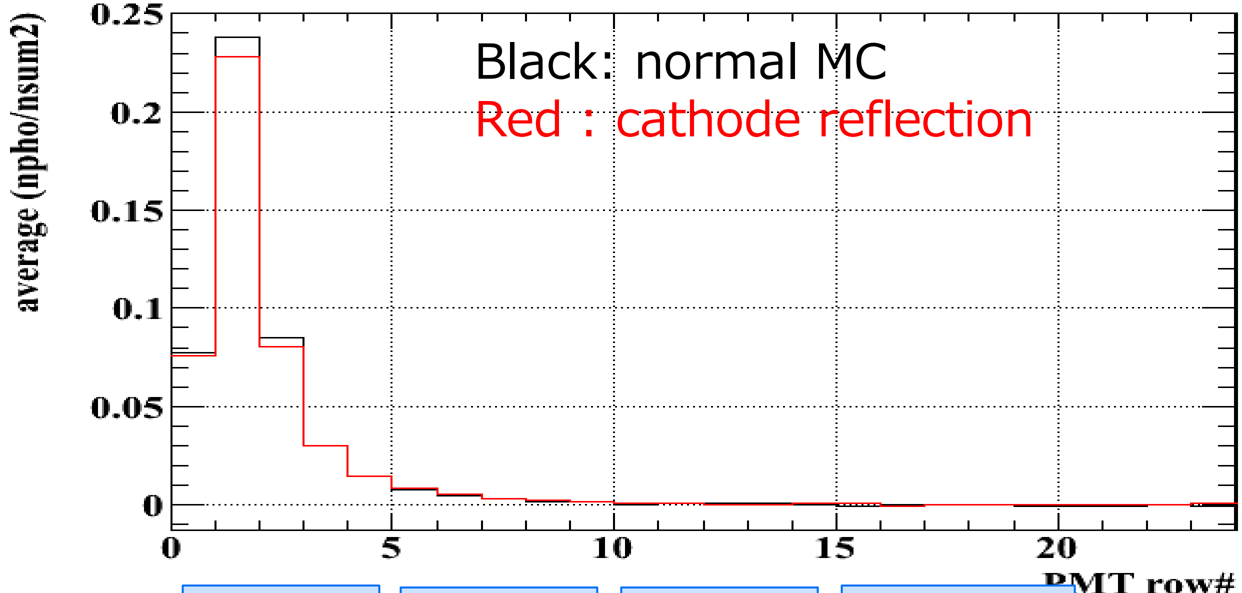
Notice

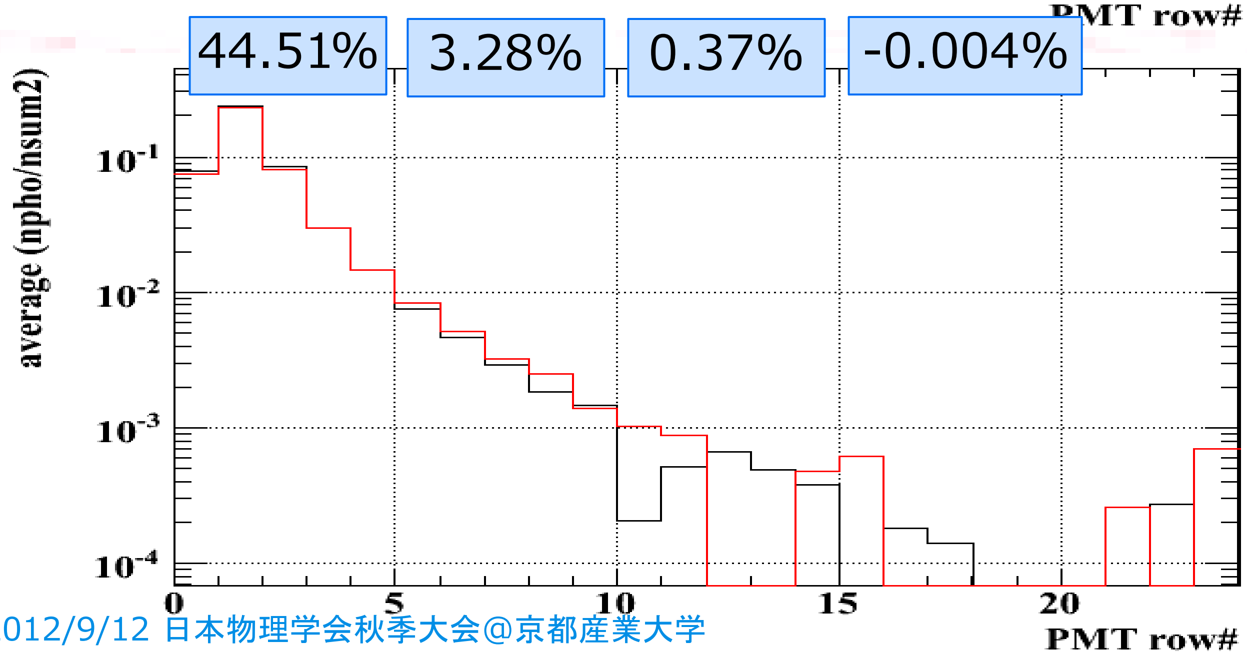
Data have lower peak & longer tail.

Cathode reflection is hidden due to small statistics?

From where can I cut summation for energy calculation?

Introduction of photo-cathode reflection





Average Nsum2
normal : 3.365e5
reflection : 2.387e5

No obvious difference except nearest 3 rows.

Is this affect to energy resolution?

↑checking…

Difference in photon distribution between data & MC can be explained from this? →