MEG II実験液体キセノン検出器 実機MPPCのコミッショニング

Commissioning of all MPPCs for MEG II LXe detector

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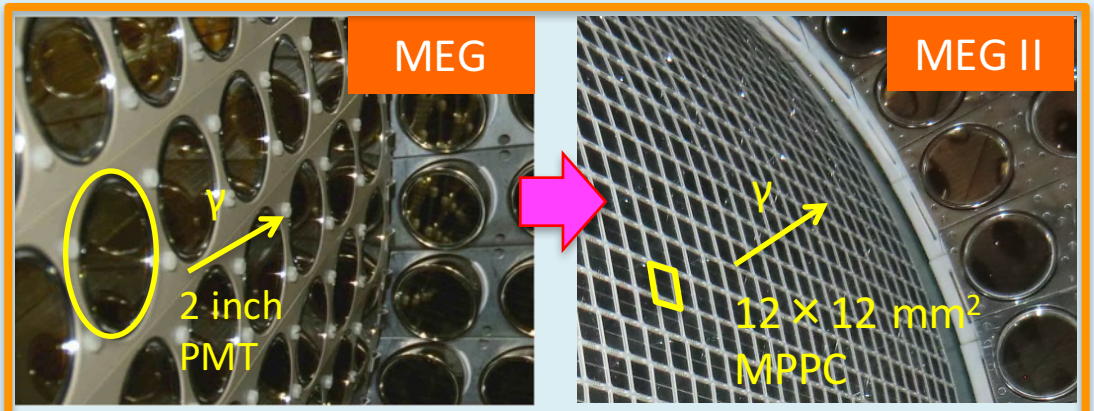
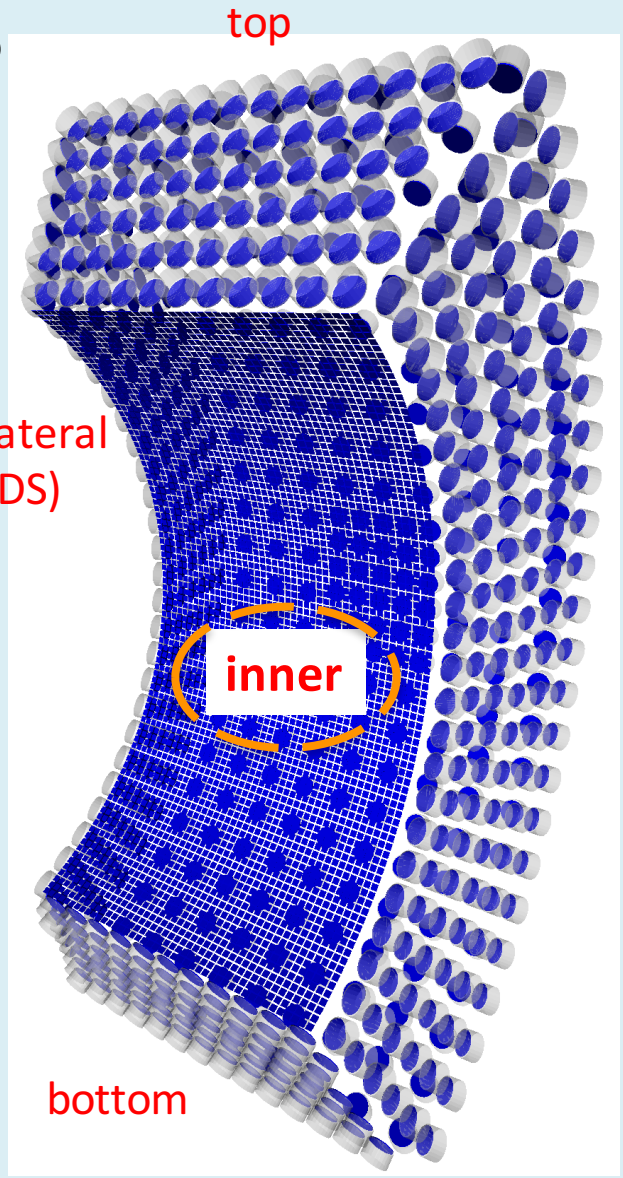
LXe detector upgrade

We have upgraded LXe detector for MEG II to significantly improve the performance.



We have replaced 216 2-inch PMTs on the γ-entrance face with 4092 12 × 12 mm² MPPCs.

- Better granularity
  - Better position resolution
- Better uniformity of scintillation readout
  - Better energy resolution
- Less material of the γ-entrance face
  - Better detection efficiency

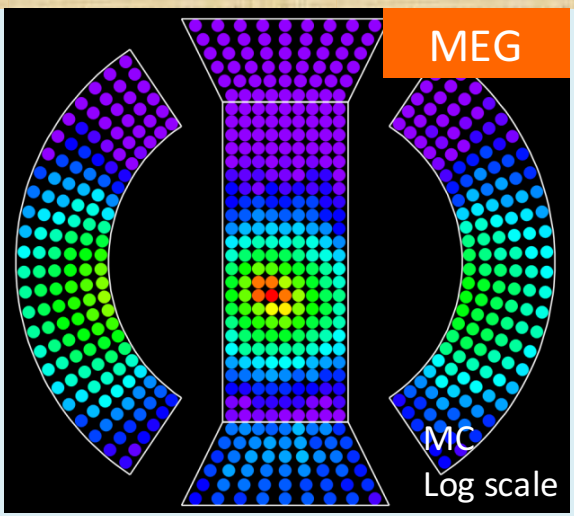


Expected performance

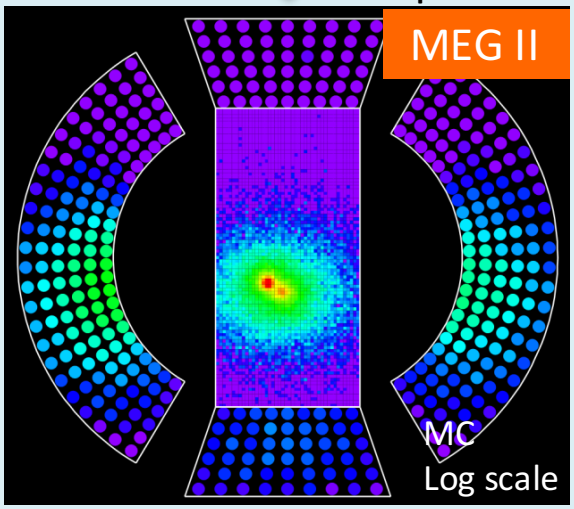
- Significant improvement of all resolutions and efficiency are expected.

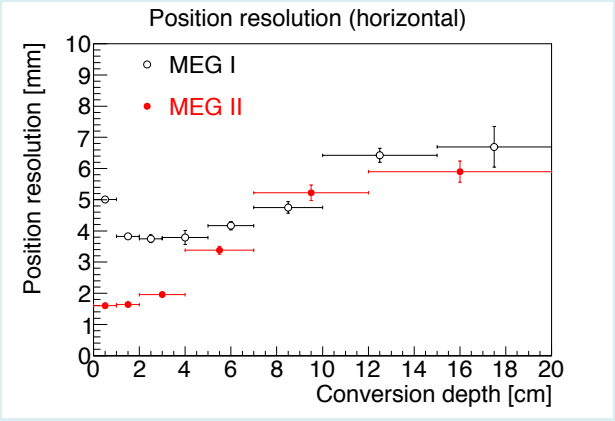
Detector performance for signal γ-ray

	MEG (measured)	MEG II (simulated)
Efficiency	65%	70%
Position	~5 mm	~2.5 mm
Energy	~2%	0.7 - 1.5%
Timing	67 ps	50 - 70 ps



Imaging power improves





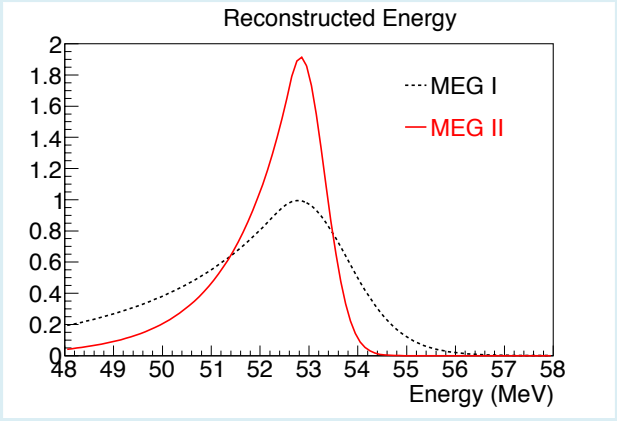


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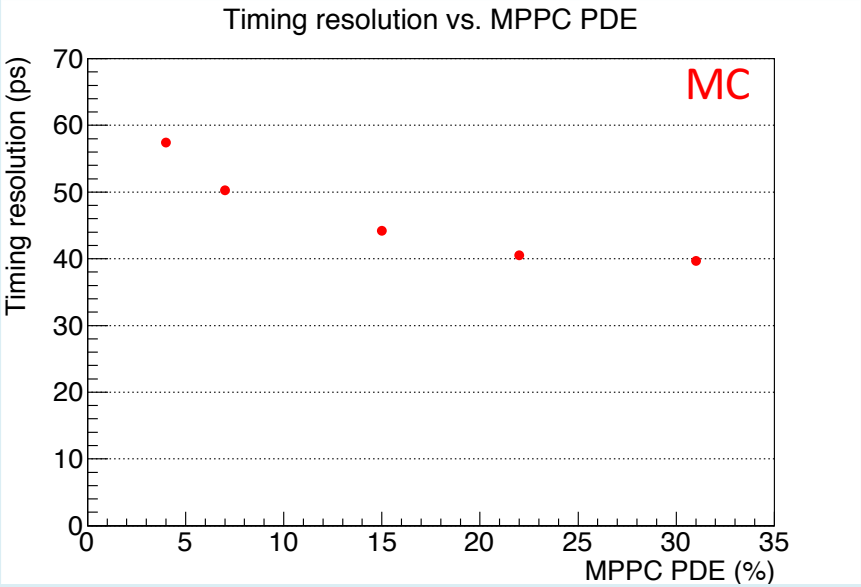
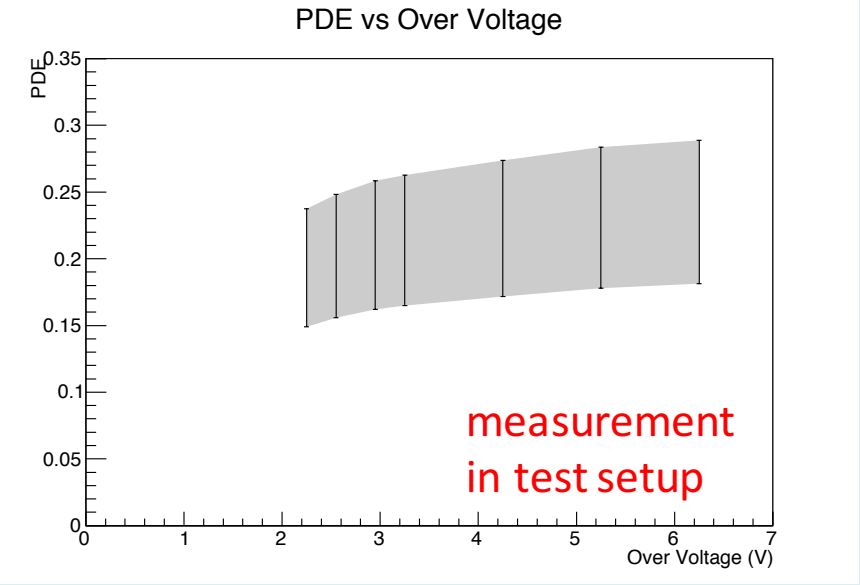
Photo sensor commissioning

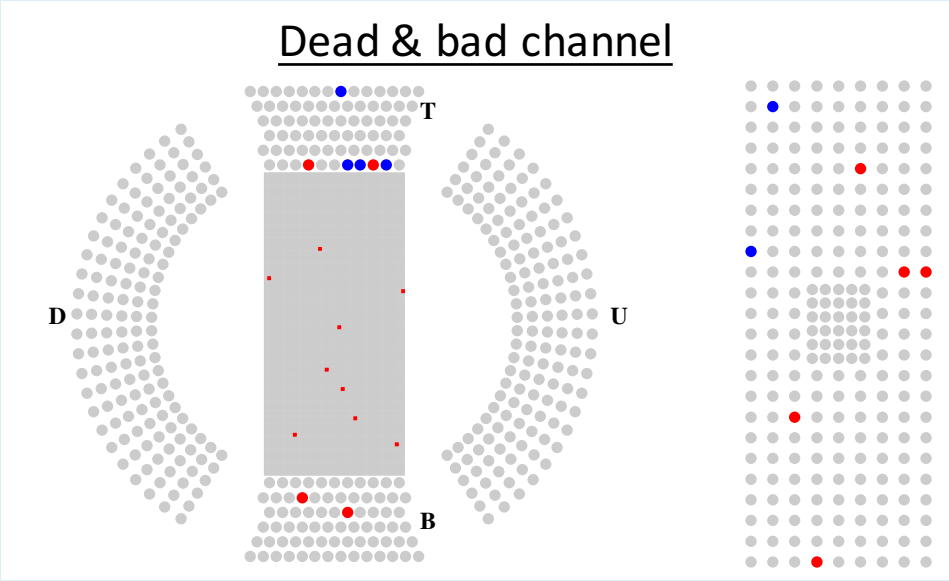
- Many photo sensors are used in LXe detector.
  - 4092 MPPCs + 668 PMTs.
- Performance of all photo sensors is being evaluated in LXe.
- Confirm reasonable MPPC PDE for LXe scintillation light in VUV.
  - PDE over 10% is needed for detector operation.
  - PDE ~20% has been measured for small number of sample MPPC.





Signal check for all photo-sensors

- Signal check has been done for all sensors in LXe.
  - With scintillation light from cosmic ray.
- Several dead and bad channels have been found.
  - Dead MPPC (9 ch) : Short circuit or bad connection of cable.
  - Dead PMT (9 ch) : Short circuit of HV cable.
  - Bad PMT (6 ch) : HV cable connection is not stable.
- Effect of dead MPPC is negligible.
- Dead PMT may affect energy resolution.
  - Under investigation.



Setup for photo-sensor calibration

- Two kinds of data have been taken for MPPC calibration.
  - LED run
    - Observe 1 p.e. peak to estimate gain.
  - Alpha run
    - Observe scintillation light from alpha source.
    - Compare measured # of p.e. with MC to estimate PDE.
- WaveDREAM (electronics developed for MEG II) has been used.
  - WaveDREAM has the functionality of waveform digitization, amplifier, trigger, HV supply for MPPC.
  - All MPPCs are grouped into 12 DAQ sets due to limited number of readout channels.

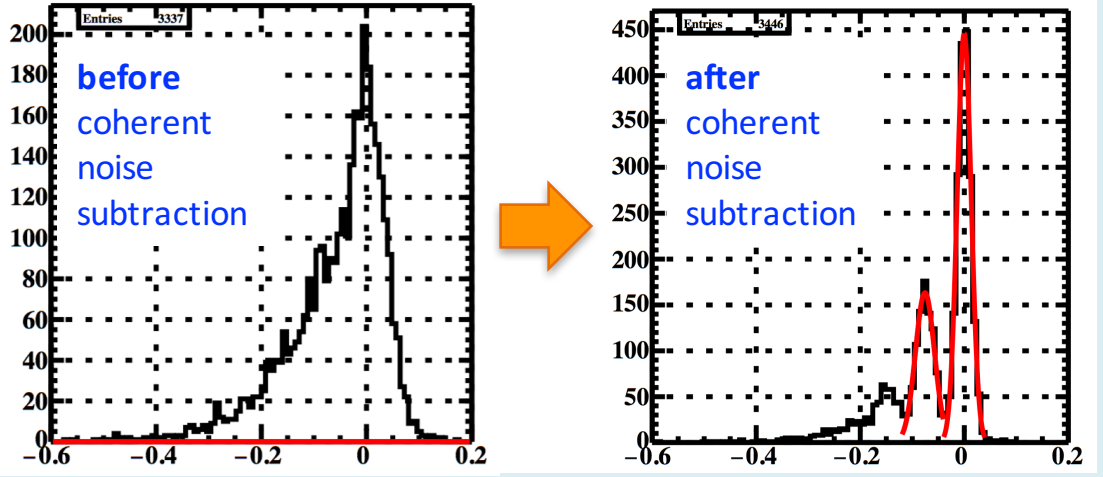
※Dark noise rate (@ LXe temp.) is too small to use it for calibration. (~5 Hz/mm^2)

Noise in LED run

- Large noise level are being observed in LED run.
  - Seems to be due to GND treatment and switching power supply of electronics.
  - Needs hardware modification to solve it.
- MPPC 1p.e. peak cannot be seen due to this noise.
- Apply following treatment as a temporally solution.
  - Subtract coherent noise by using adjacent channel waveform.
  - Operate MPPCs at relatively large voltage (over voltage 7V)
  - Use short integration range (70 ns) to improve S/N.

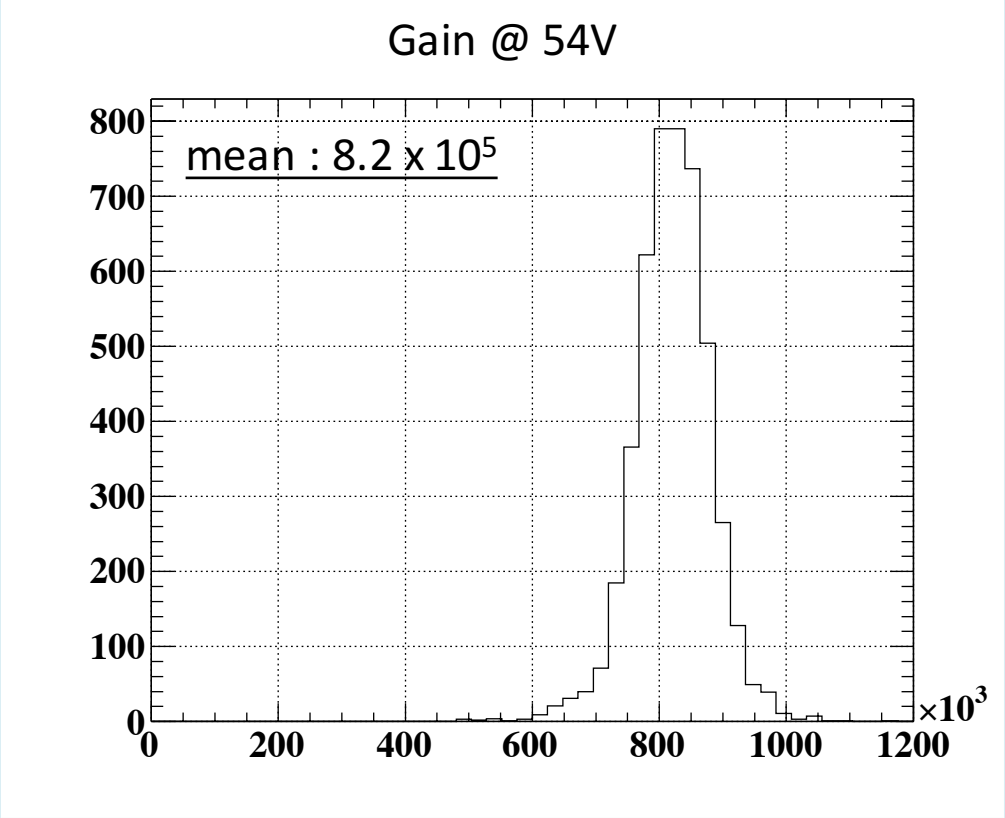
→1 p.e. can be seen except for noisy channel of electronics (6% of total).

Charge distribution from LED light



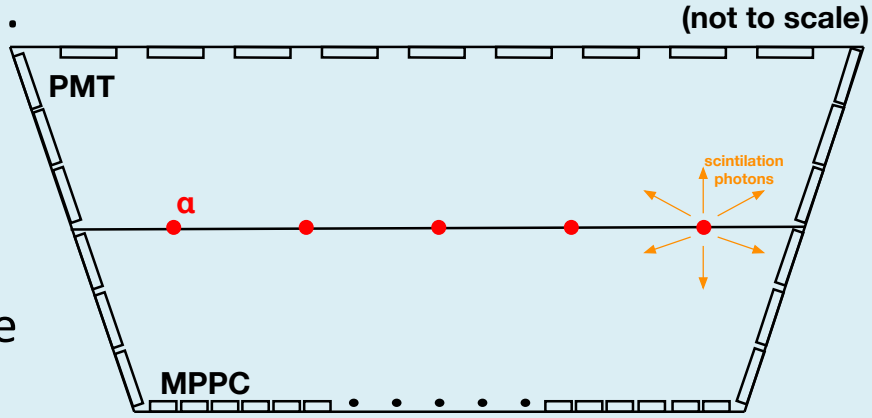
MPPC Gain

- MPPC gain has been estimated from 1p.e. peak.
- Reasonable gain has been confirmed.
  - 8 x 10^5 @ over voltage ~7V
- Gain spread is 5% at same over voltage.

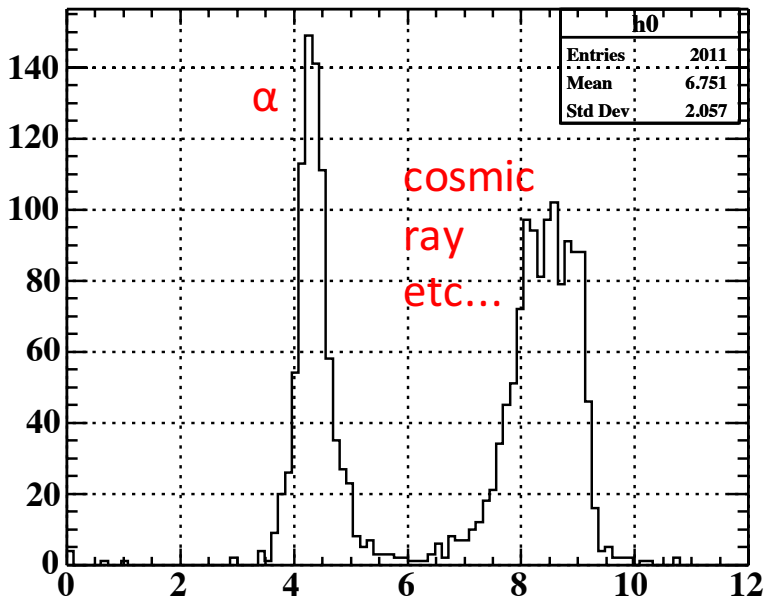


Alpha run

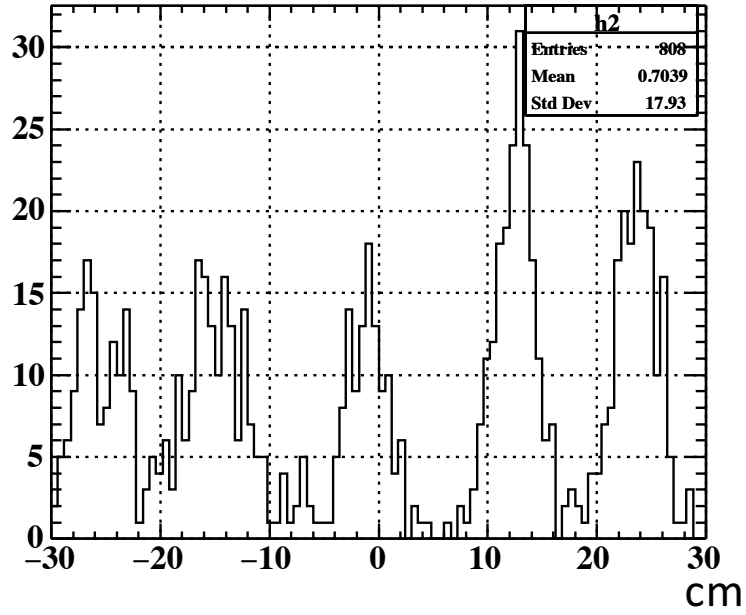
- Alpha event trigger by lateral PMT.
- Event selection
  - Separate alpha and others by pulse shape discrimination
  - Select events from each alpha source by position reconstruction.



charge / height



Reconstructed position (α event)



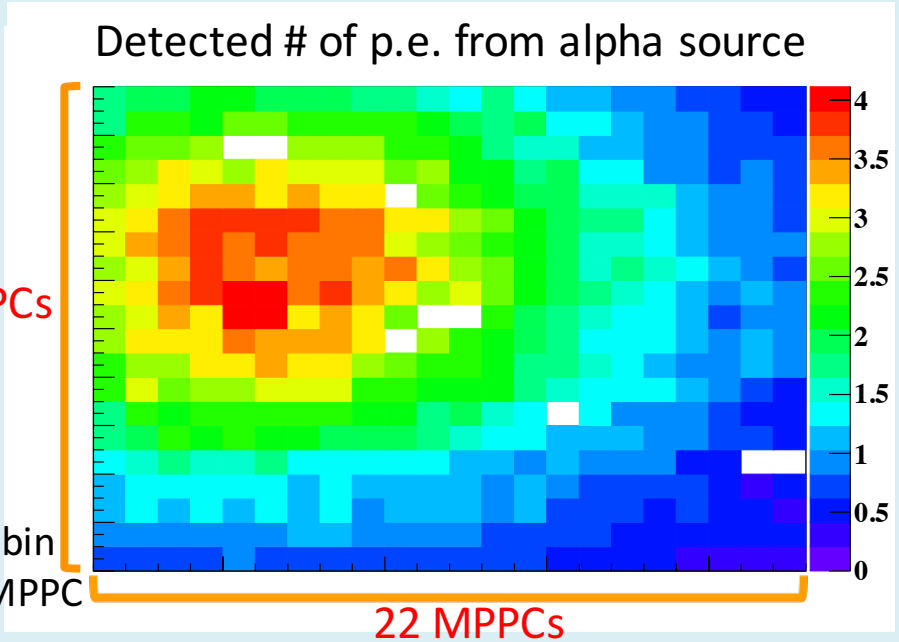
MPPC PDE

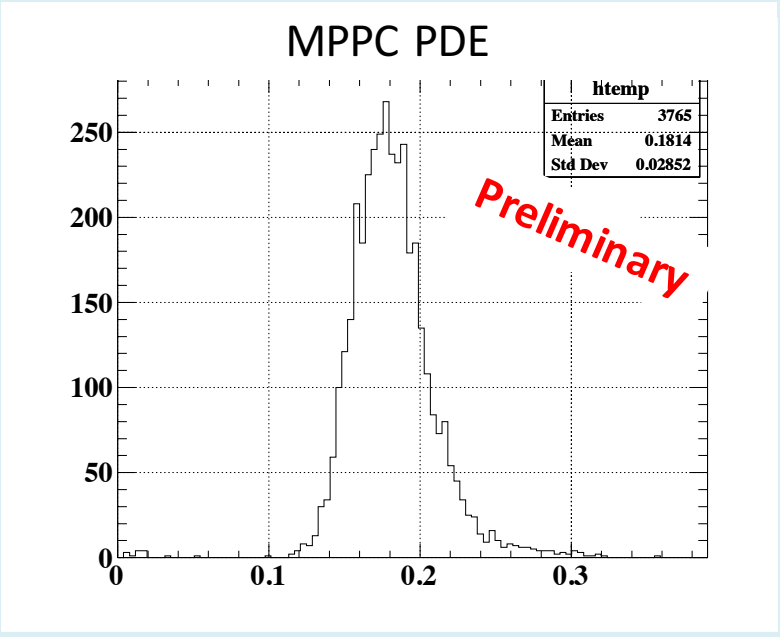
- MPPC PDE has been estimated.
  - PDE = (measured # of p.e.) / (expected # of photon in MC)
- Mean of PDE : 18%
  - Sufficiently large PDE (> 10%) has been confirmed.
  - Roughly consistent with previous measurement result (~20%).

※Several effects which affect the measured PDE.

- crosstalk & afterpulse
- short charge integration range
- LXe light yield still improving

} should be ~10-30%





Summary of MPPC commissioning

- We have upgraded LXe detector for MEG II to significantly improve the performance.
- Commissioning of the detector is ongoing.

- Performance of all VUV-MPPCs is being evaluated.
  - Reasonable gain (~ 8 x 10^5 at over voltage 7V) and sufficiently large PDE (~18%) have been confirmed for most MPPCs.

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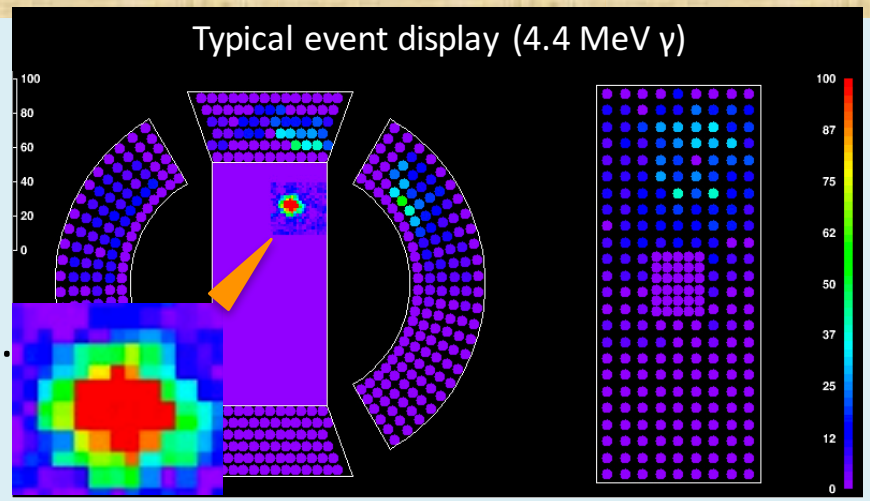
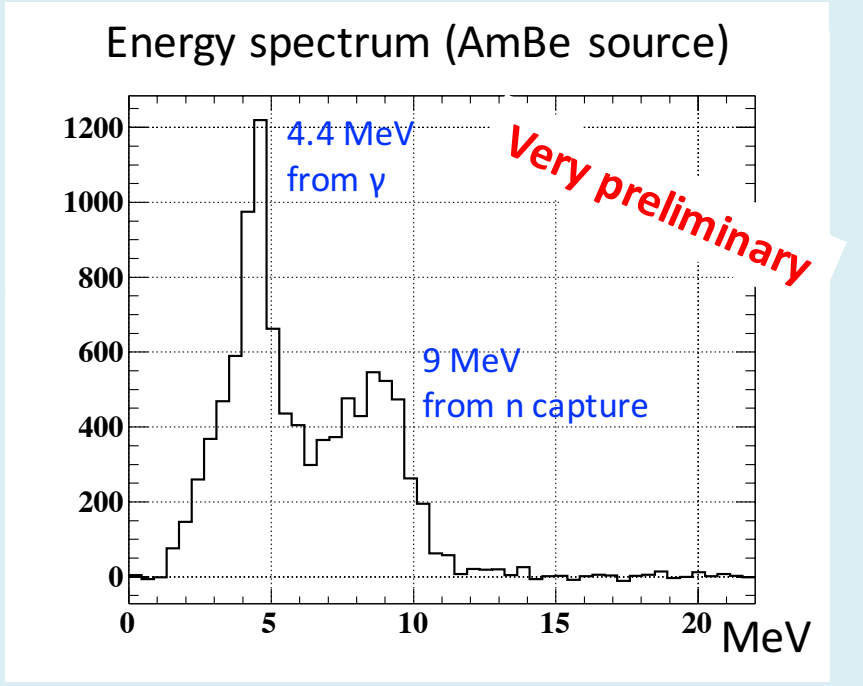
Detector commissioning by γ-ray

- We have started to see γ signal.
- 4.4MeV γ from AmBe source has been successfully observed.
  - From excited $^{12}_{6}\mathrm{C}^{*}$ from $^{9}_{4}\mathrm{Be}(\alpha,\mathrm{n})^{12}_{6}\mathrm{C}^{*}$.
  - Hit the detector from inner face.
  - Detector performance is under investigation.
- Detector response will be checked by several γ-ray sources.
  - ~9MeV from thermal neutron capture
  - 4 & 12 MeV from $^{11}_{5}\mathrm{B}(\mathrm{p},\gamma)^{12}_{6}\mathrm{C}$.
  - 18 MeV from $^{7}_{3}\mathrm{Li}(\mathrm{p},\gamma)^{8}_{4}\mathrm{Be}$.
- Pilot run of the detector will be performed with μ beam.

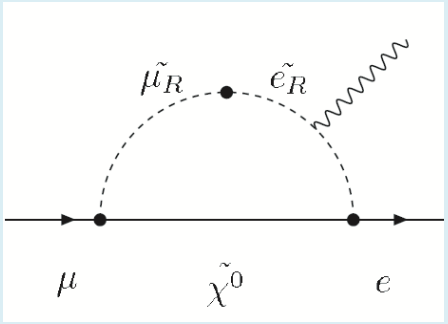




BACKUP

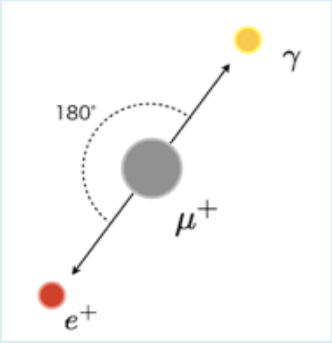
μ→eγ search

- We search for charged **lepton flavor violating decay of muon, μ->eγ.**
- Prohibited in SM, detectable branching ratio in some BSM model
- Main background is the **accidental background**.
- Detector resolutions, **especially energy resolution of γ-ray**, are important to effectively distinguish the signal event from the accidental background.



Signal

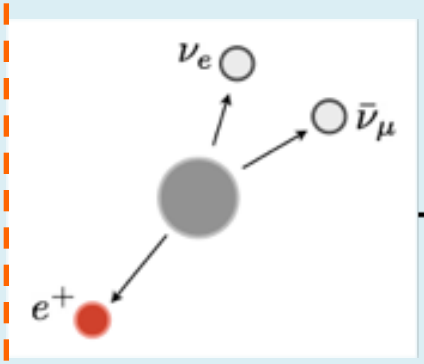
Signal decay



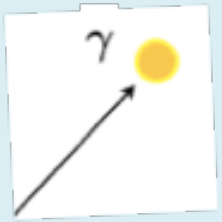
- E=52.8MeV
- back-to-back
- coincident

Background

Accidental background

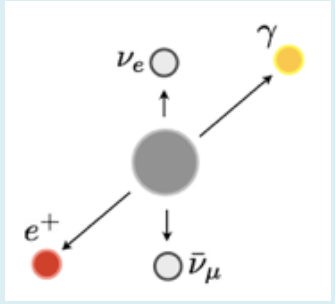


+



- **Dominant background**
- E < 52.8MeV
- not back-to-back

Radiative muon decay



- E<52.8MeV
- not back-to-back
- coincident

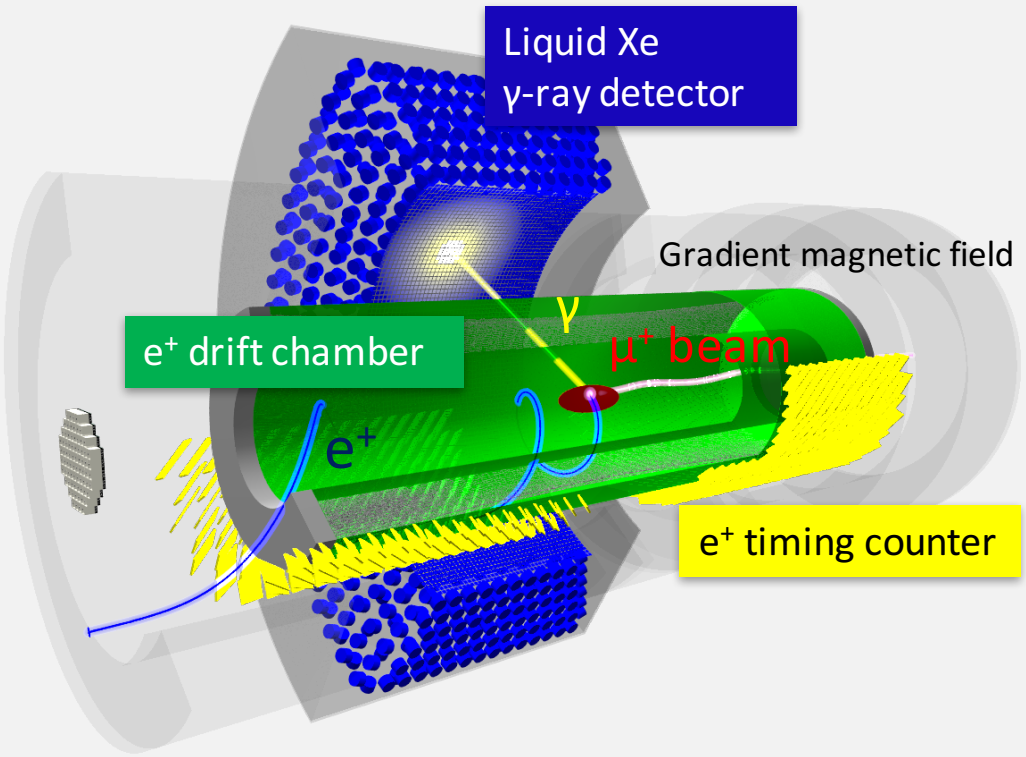
MEG II experiment

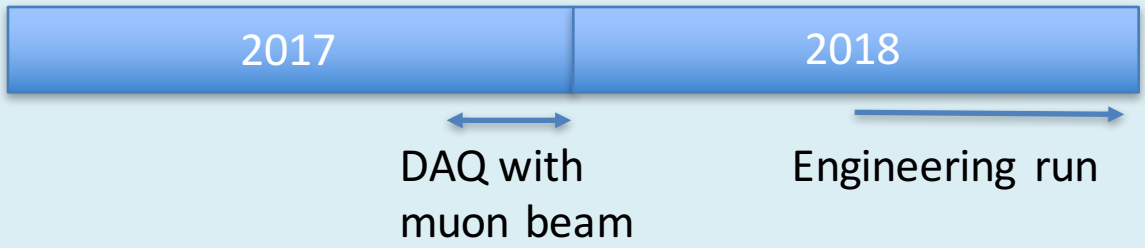
Upgrade of MEG experiment

- μ^+ stopping rate will be doubled
  - 3×10^7 μ/s → 7×10^7 μ/s
- Detection efficiency will improve.
- Resolutions of all detectors will become half.
- New detector for background tagging will be introduced

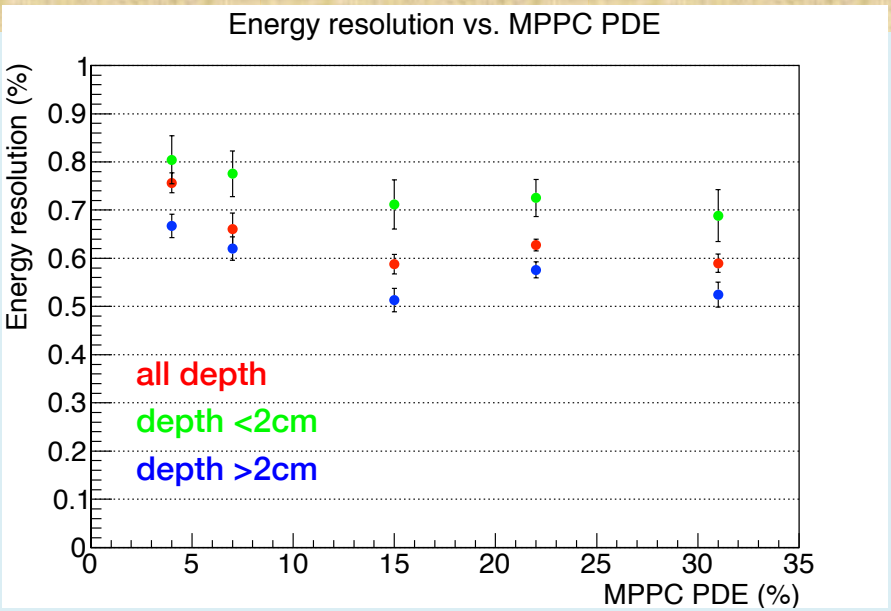
Expected sensitivity: 4×10^{-14}

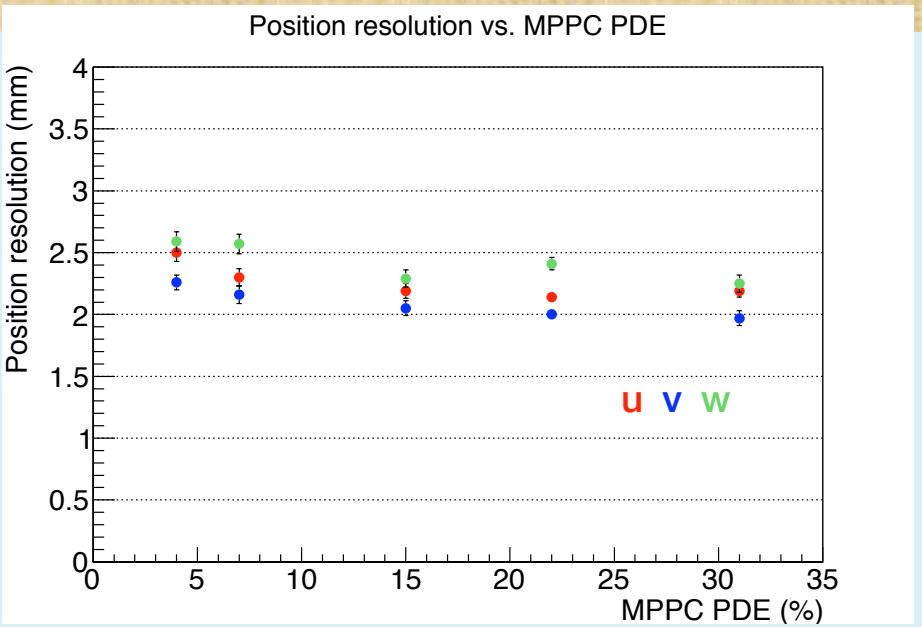
- One order of magnitude better than MEG

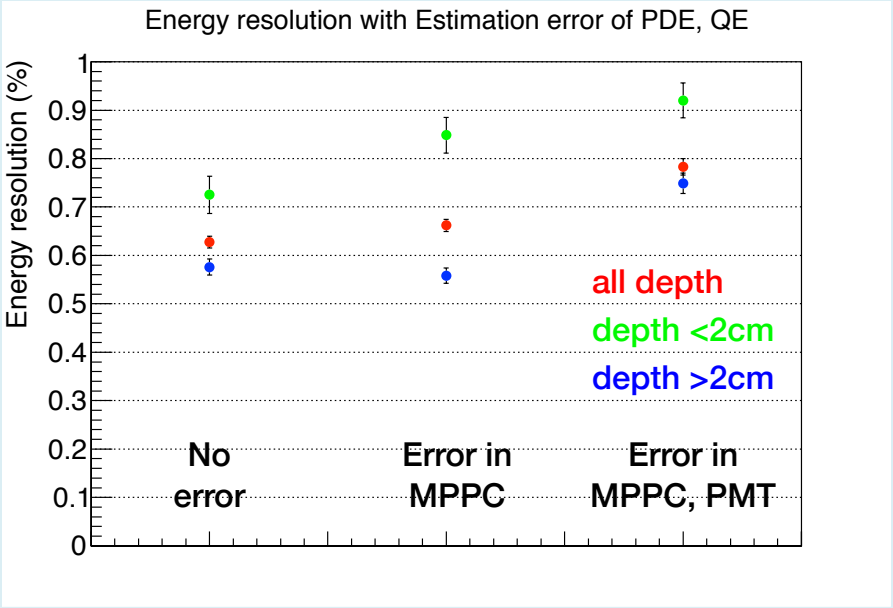




Expected

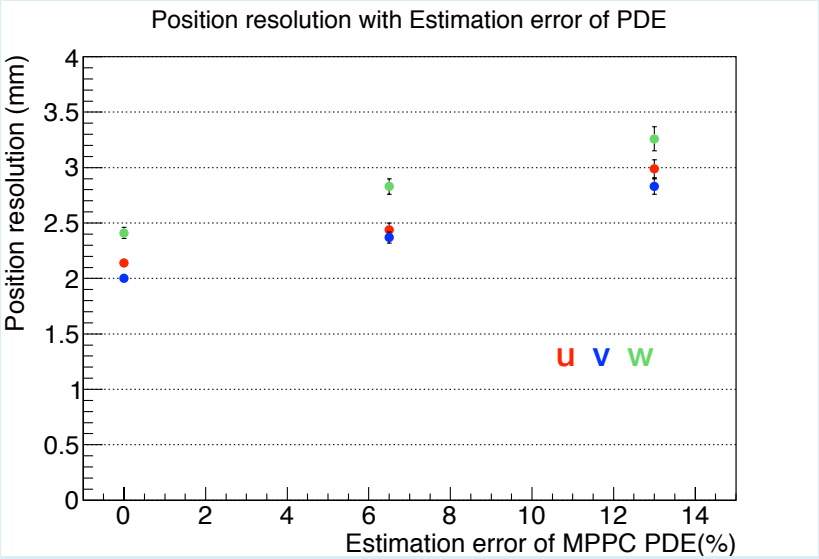

Energy resolution vs. MPPC PDE
Energy resolution (%)
MPPC PDE (%)
all depth
depth <2cm
depth >2cm

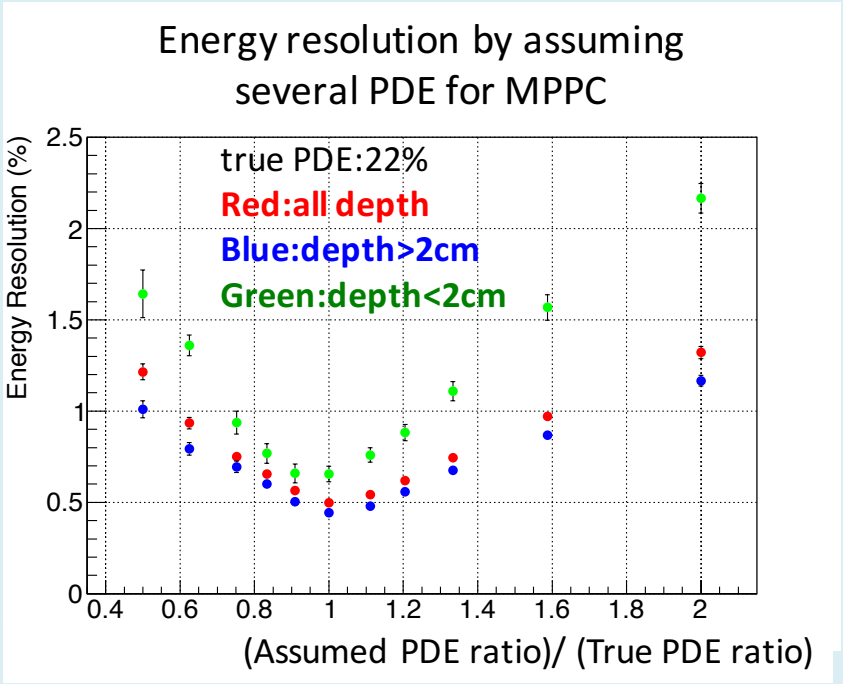

Position resolution vs. MPPC PDE
Position resolution (mm)
MPPC PDE (%)
u v w


Energy resolution with Estimation error of PDE, QE
Energy resolution (%)
all depth
depth <2cm
depth >2cm
No error
Error in MPPC
Error in MPPC, PMT

Motivation

- 検出器コミッショニングの1stepとして、光センサーの較正を実施。
- 検出器較正手法の確認、問題の洗い出しをする。
  - 検出器性能には光センサーの性能の正しい理解が必要。
    - 光センサー特性(Gain, PDE)の個体差
    - 二種類の光センサーのPDEの比

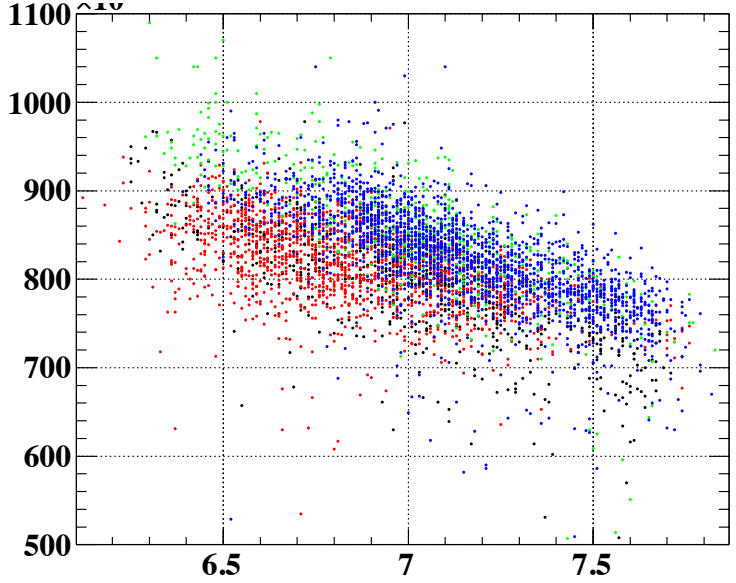




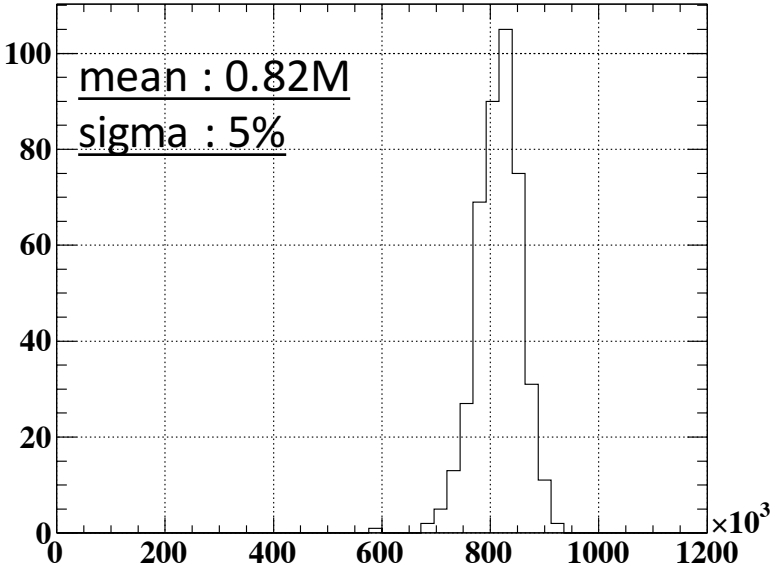
MPPC Gain

- MPPC gain has been estimated from 1p.e.peak.
- Reasonable gain has been confirmed.
  - 0.8M @ over voltage 7V

MPPC gain (@54V) vs. Over voltage

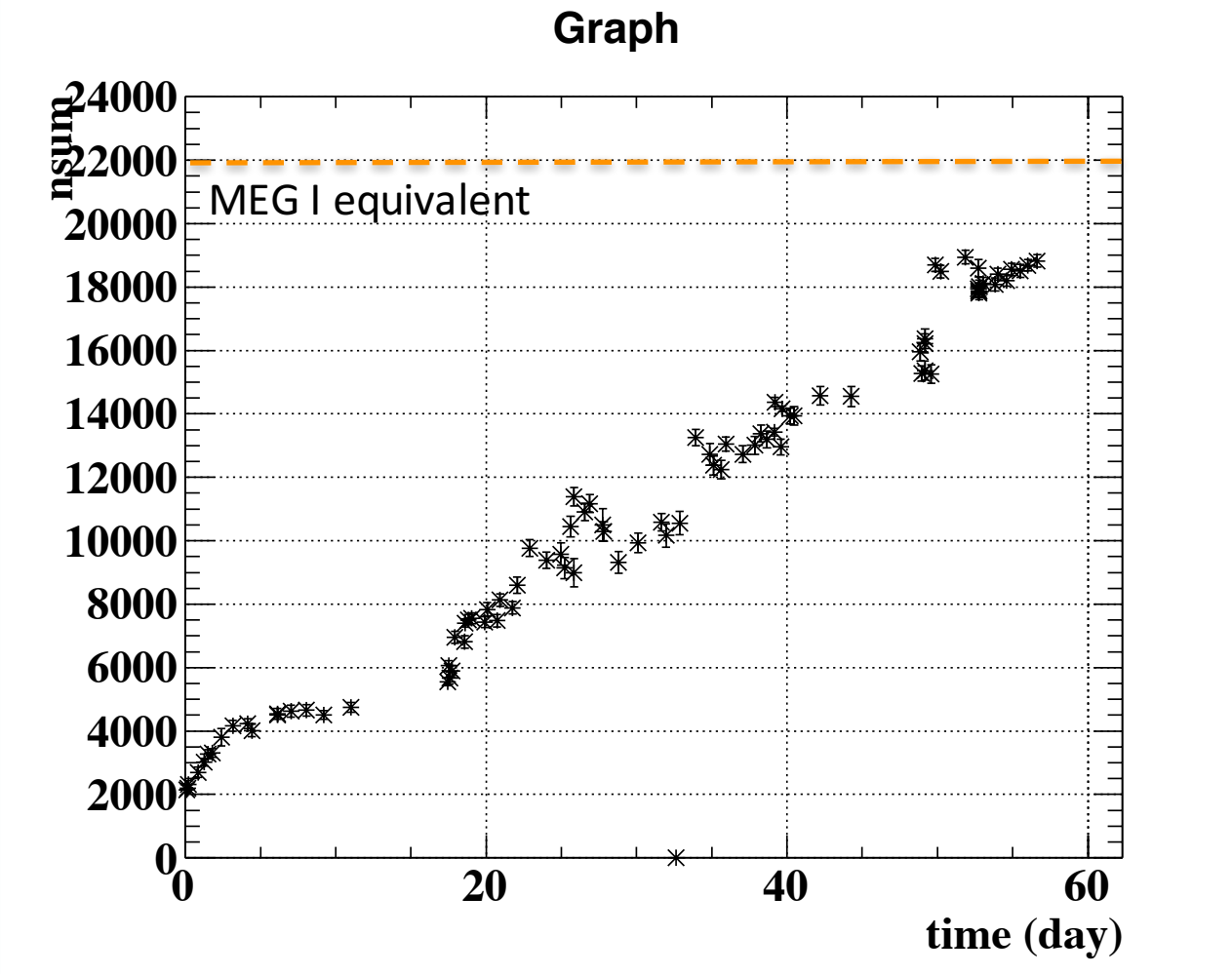


Gain @OV 7V



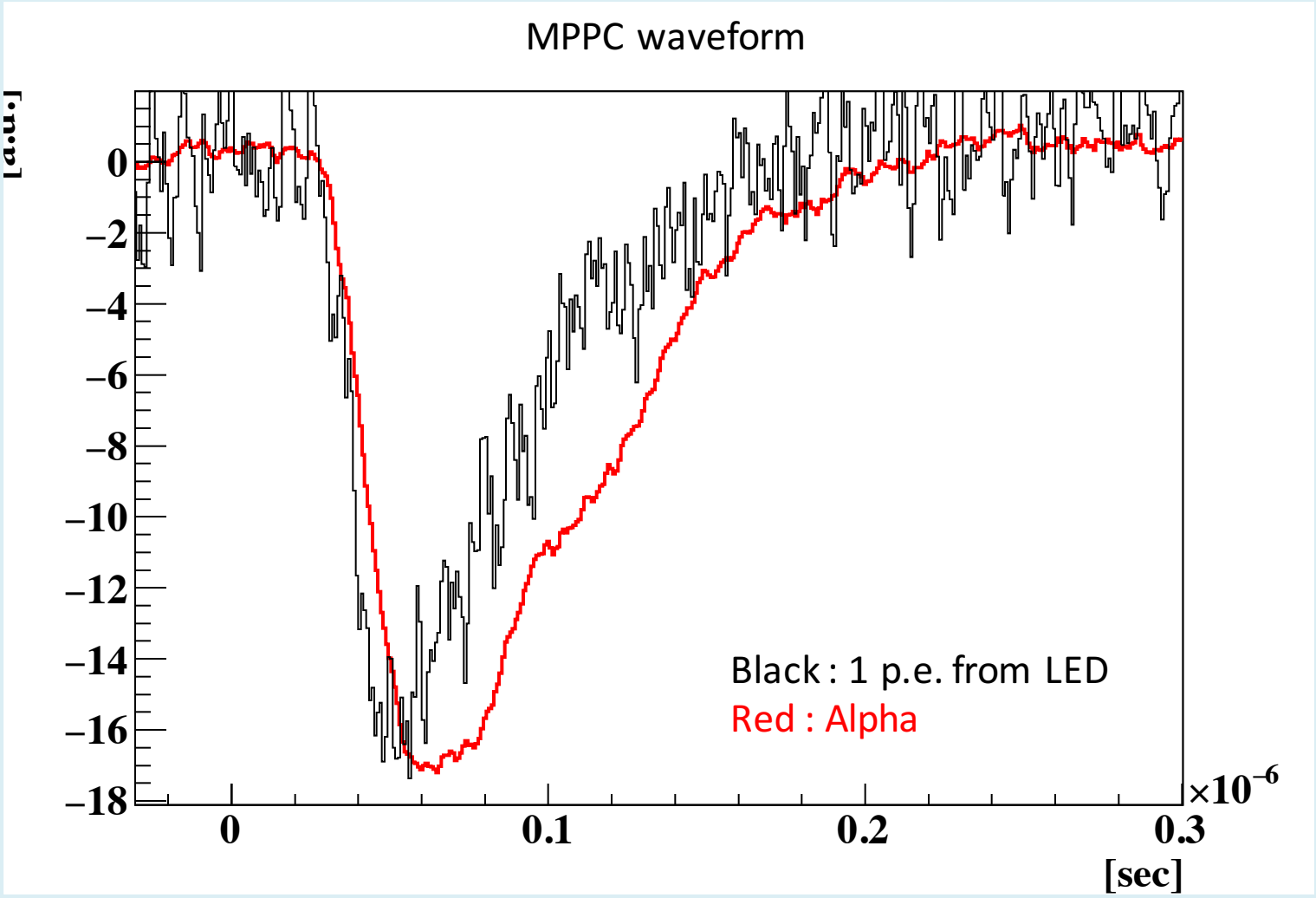
LXe light yield

- aa

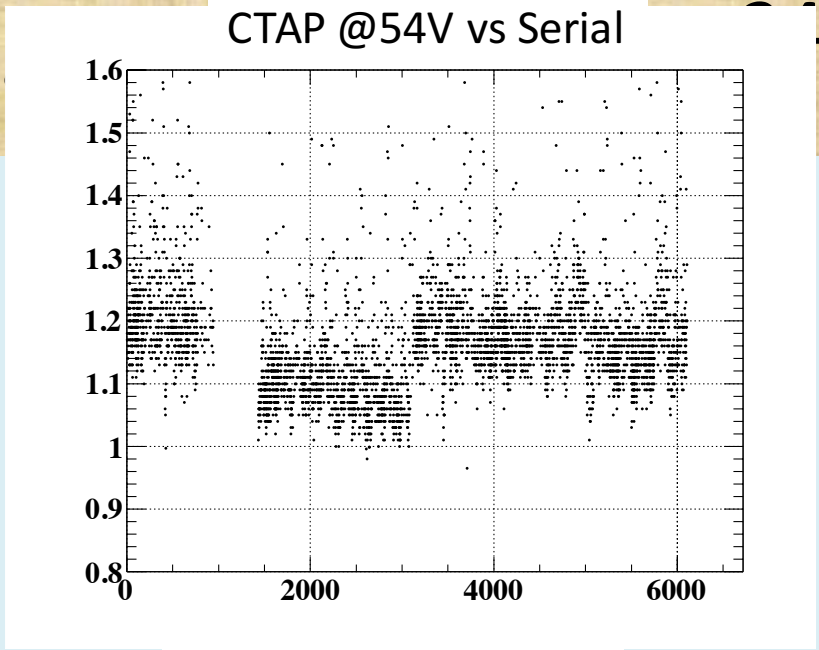


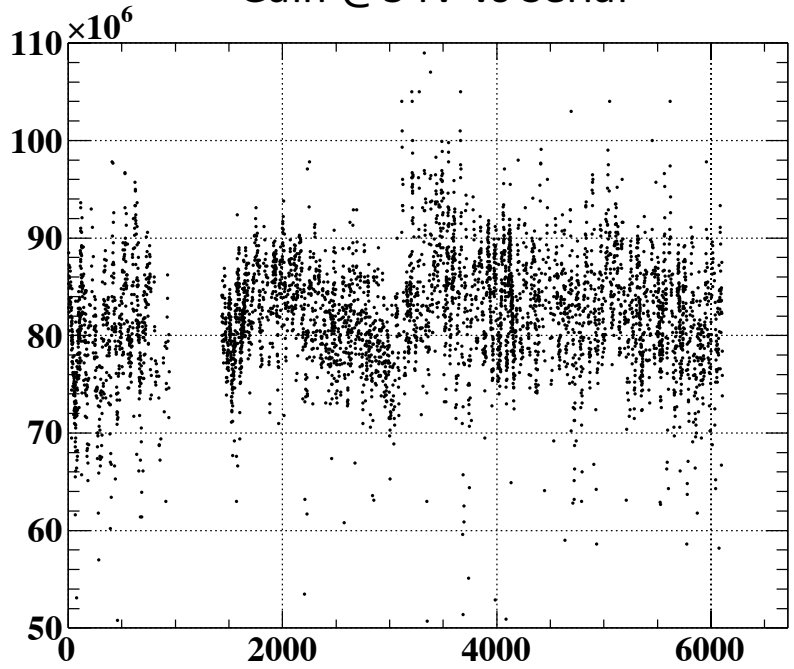
Average MPPC waveform

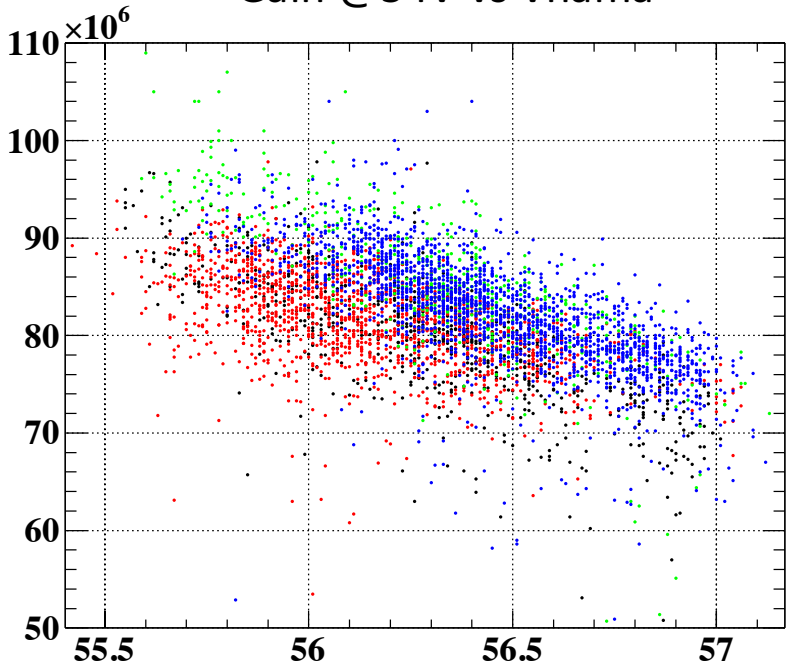
- aa



MPPC G

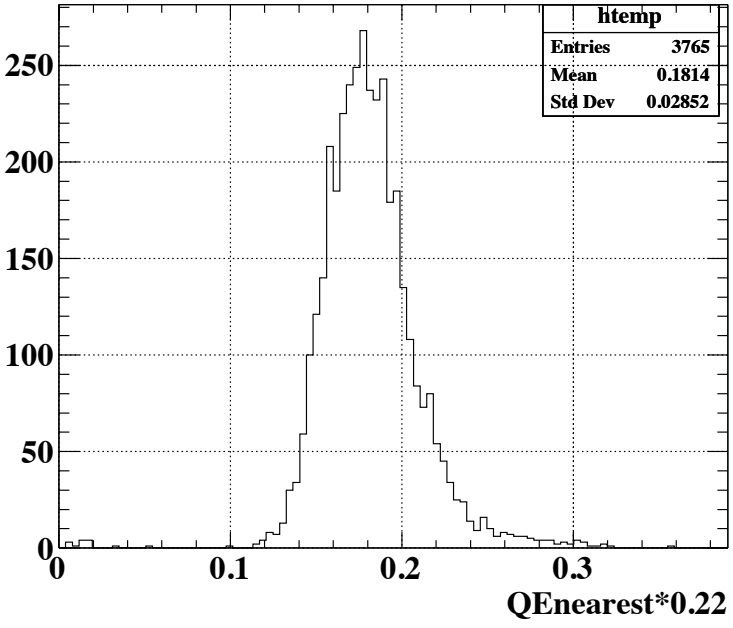

CTAP @54V vs Serial
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0
2000
4000
6000


Gain @54V vs Serial
×10^6
110
100
90
80
70
60
50
0
2000
4000
6000

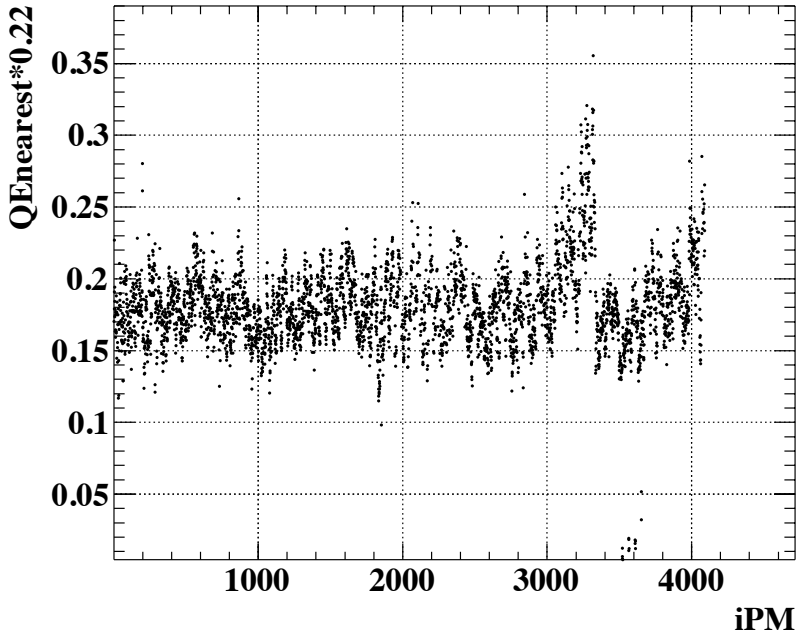

Gain @54V vs Vhama
×10^6
110
100
90
80
70
60
50
55.5
56
56.5
57

MPPC PDE

MPPC PDE

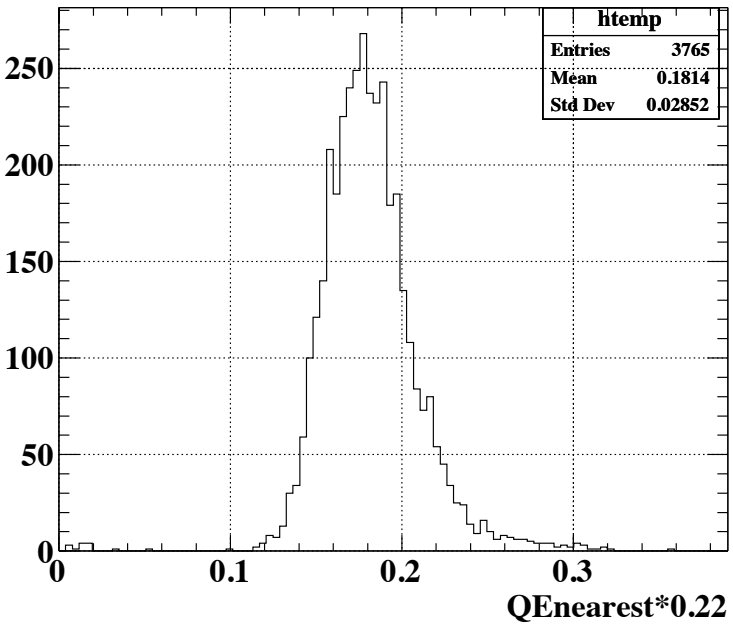


MPPC PDE vs index



Absolute PDE / QE

MPPC PDE



PMT QE