Operation of Liquid Xenon Gamma-Ray Detector for MEG II Experiment Physics Run in 2022

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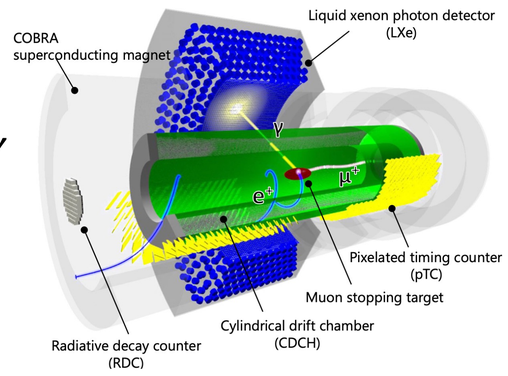
Core-to-Core Program

1. Introduction

MEG II Experiment

MEG II experiment searches for $\mu \to e\gamma$ using the most intense μ^+ beam at Paul Scherrer Institute.

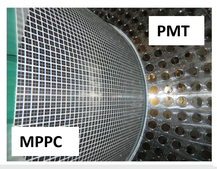
This is a charged lepton flavor violation decay. If $\mu \to e\gamma$ decay is observed, it would be an evidence of new physics. In MEG experiment, $\mathcal{B}(\mu \to e\gamma) < 4.2\times10^{-13}$ (90%C.L.) was obtained. The goal of MEG II experiment is to search for the decay with 10 times better sensitivity by detector upgrade.



Liquid Xenon Gamma-ray Detector (LXe Detector)

LXe detector measures the position, energy and timing of γ-ray.

900 L liquid xenon
4092 VUV-sensitive MPPCs
668 PMTs



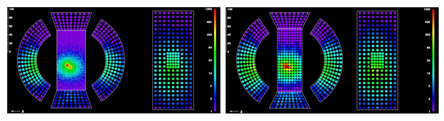
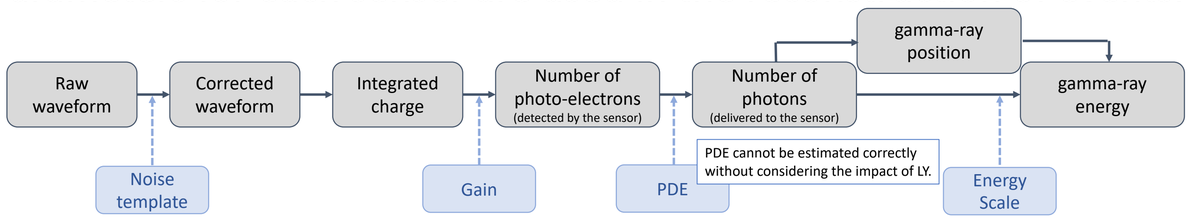


Fig. 58 Example of scintillating light distributions detected by photo-sensors in case of (left) PMTs and (right) smaller photo-sensors (12 × 12 mm²) on the inner face for the same MC event

2. Gamma Reconstruction in LXe Detector

Parameters for each senser are used in the reconstruction of events.



3. Calibrations of LXe Detector

Calibration is necessary to take physics data stably with sufficient energy resolution because the parameters of sensers fluctuate over beam time.

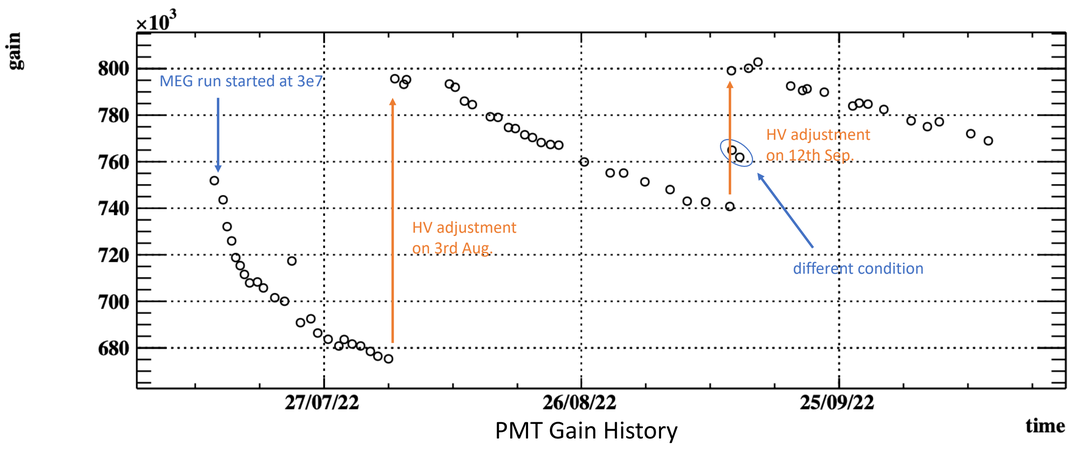
Purpose	Calibration source	Frequency	
Noise	Pedestal	Once a day	
Gain	LED	Once a day (PMT) / 3 times a week (MPPC)	→ Sec.4
PDE	Alpha	Once a day	→ Sec.5
Energy scale	Cosmic-ray	3 times a week	
Energy scale	17.6 MeV gamma-ray from $^{7}\mathrm{Li}(p,\gamma)\,^{8}\mathrm{Be}$	3 times a week	→ Sec.6
Energy scale	9 MeV gamma-ray from $^{58}\mathrm{Ni}(n,\gamma)^{59}\mathrm{Ni}$	3 times a week	

4. PMT Gain Calibration

LEDs are installed inside LXe detector for gain calibration. Gain can be calculated using the following equation. Calibration data is taken at different LED intensities and gain is estimated.

$$\sigma_q^2 = Ge\bar{q} + \sigma_0^2$$

(σ_q: spread of charge distribution, G: gain, e: elementary charge, $\bar{q}$: average charge)



Gain degreases over beam time. Therefore, gain is aligned by adjusting PMT HV once a month. Gain is kept between 0.65×10^{6} and 0.8×10^{6} during the beam time.

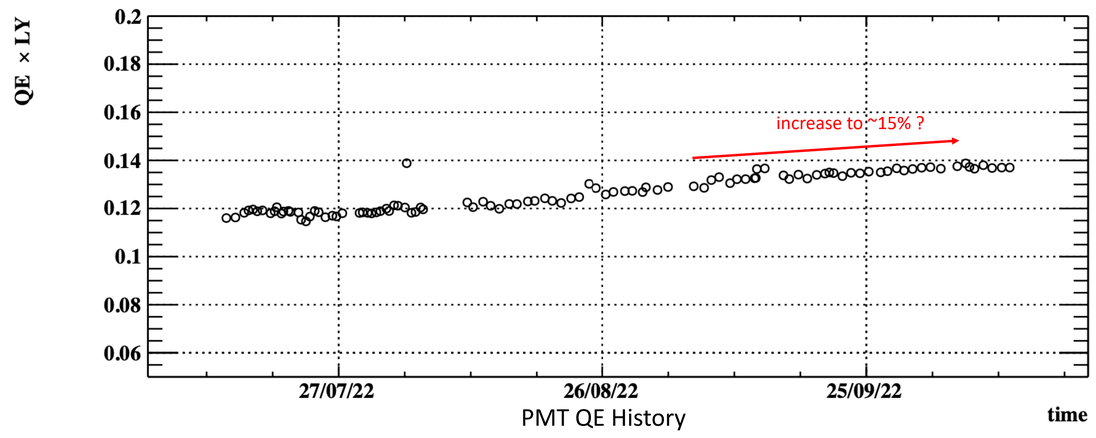
5. MPPC PDE Calibration

The PDE/QE values of the photosensors are evaluated by measuring the alpha-rays from $^{241}\mathrm{Am}$ installed inside LXe detector.

$$PDE_{data} = PDE_{MC} \times \frac{N_{\mathrm{data}}^{\mathrm{meas}}}{N_{\mathrm{MC}}^{\mathrm{expected}}} \times R_{LY}$$

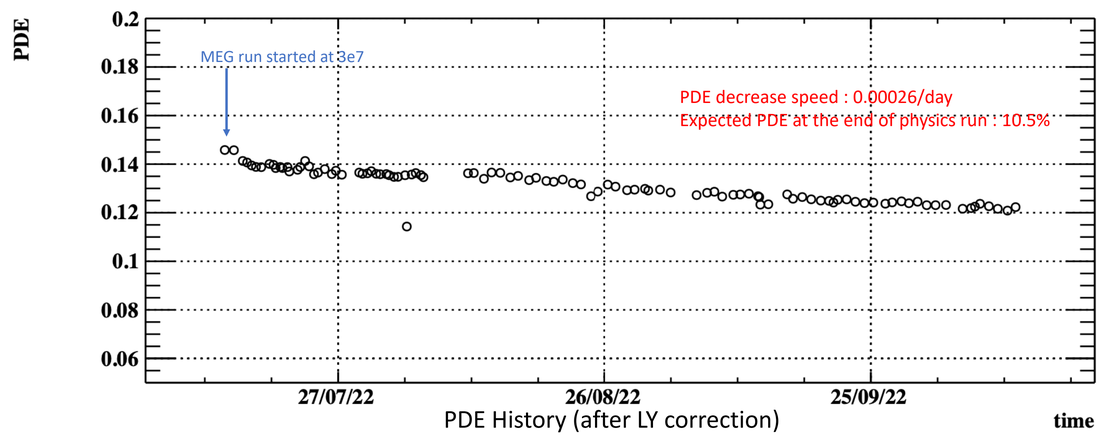
$N_{\mathrm{data}}^{\mathrm{meas}}, N_{\mathrm{MC}}^{\mathrm{expected}}$: the number of photoelectrons in data and MC

R_{LY}:Light yield correction factor



Since the PMT QE values should be constant, the above graph really indicates the history of the LXe light yield (LY). LY at the beginning of this year is lower than that of the last year(~15%). Purification of gaseous xenon continues during physics data taking and LY is increasing and may reach the same level as last year.

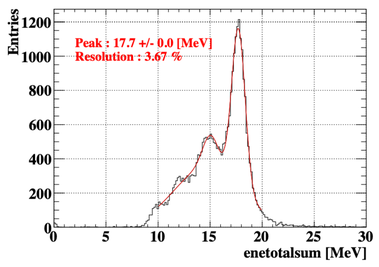
PDE at the beginning of this year's beam time is 16 ± 2%, and the estimated PDE value at the end of this year's beam time is higher than 2%, which satisfies the requirements. MPPC PDE after LY correction is monotonically decreasing after the start of physics data taking due to the radiation damage.



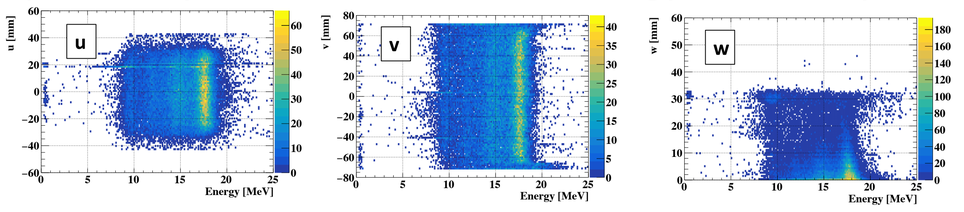
More detailed information can be found in the poster "Recovery of Photon Detection Efficiency of SiPMs in the liquid xenon detector by annealing" by Sei Ban.

6. Energy Scale

Protons are accelerated onto a $\mathrm{Li_2B_4O_7}$ target and 17.6 MeV gamma-rays are emitted from $^{7}_{3}\mathrm{Li}(p,\gamma)^{8}_{4}\mathrm{Be}$. This gamma-ray is used for energy scale monitoring.



Energy resolution is 3.67 % in 2022 offline data, and it will be improved by iterated calibration. Energy uniformity is also confirmed.



7. Summary

- It is necessary to calibrate parameters of each sensor to take physics data with sufficient energy resolution.
- PMT gains are kept under well control due to monthly HV adjustments.
- LY is increasing due to purification.
- PDE is sufficient to do this year's DAQ.
- Energy scale and uniformity is being monitored in the beam time.