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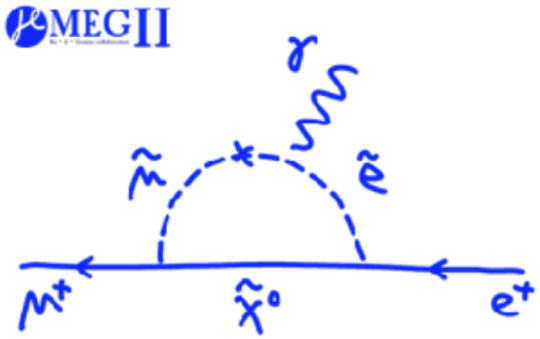



# MEG II実験：
# 2023年ランにおける液体キセノン検出器安定性およびアニーリングによる検出効率回復

Sei Ban (ICEPP), for the MEG II collaboration
18th Mar. 2024, JPS 2024年春季大会 @Online : 18pT3-6

# Outline



Introduction

LXe detector operation in 2023 run

Annealing for PDE recovery for 2024 run

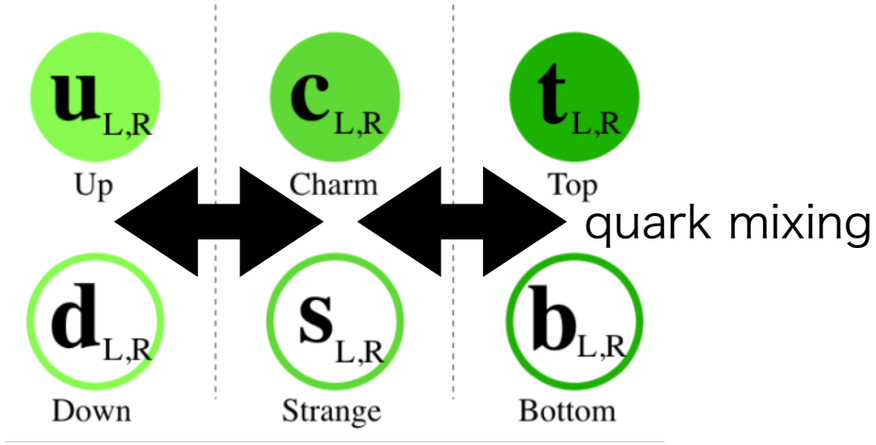
Summary and prospects

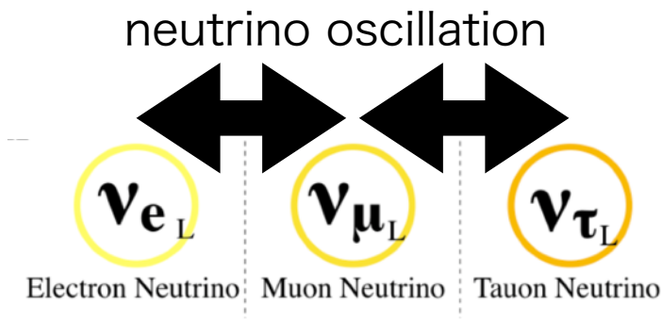
# Outline

# Charged Lepton Flavor Violation



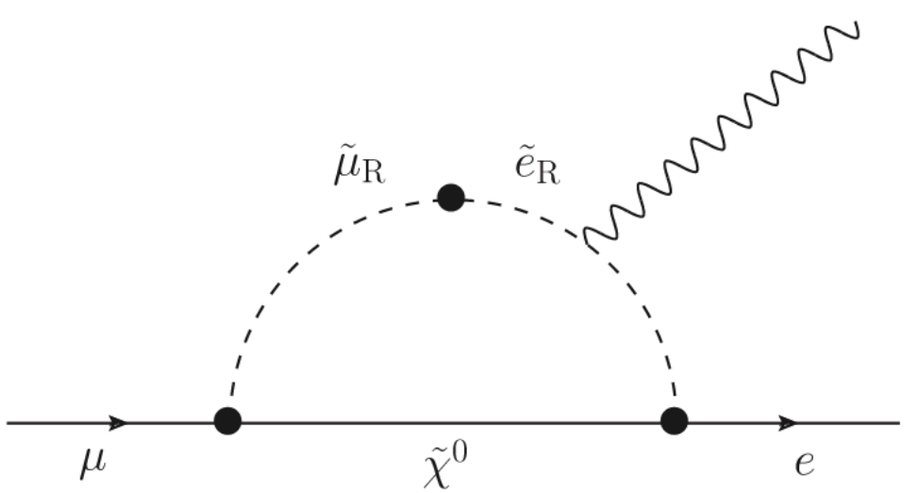
- In quark and neutrino (neutral lepton) sector, the flavor violates in SM



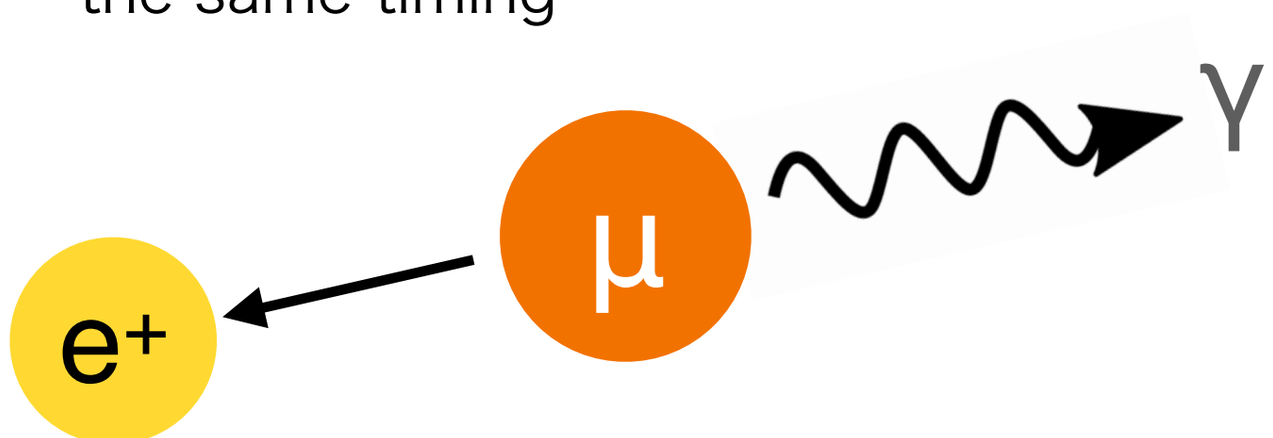




- Some theories BSM predict flavor violation in the charged lepton sector
  - In the Standard Model, it is practically prohibited : $Br(\mu \rightarrow e\gamma) = 10^{-54}$
  - In BSM, $Br(\mu \rightarrow e\gamma) \sim O(10^{-14})$ is predicted : large enough to search

- Signal : Gamma-ray and positron with 52.8 MeV ($=m_\mu/2$)
  back-to-back
  the same timing



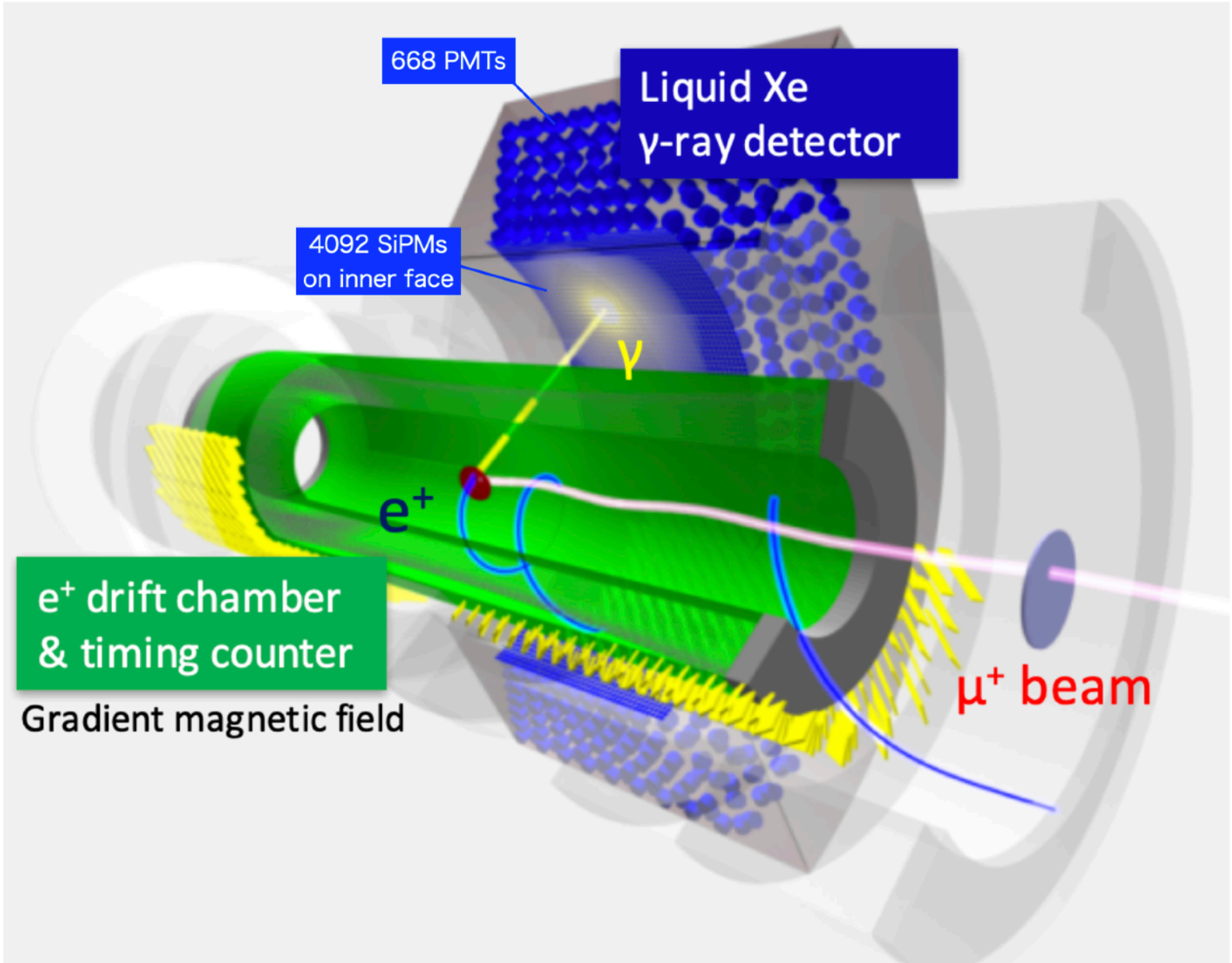

Possible diagram in SUSY-GUT senario

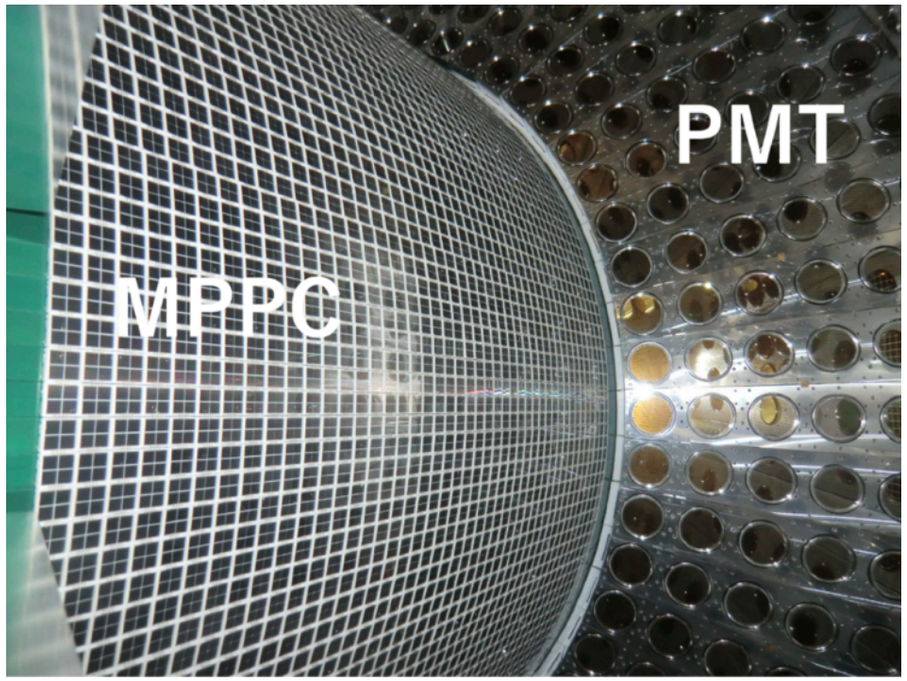


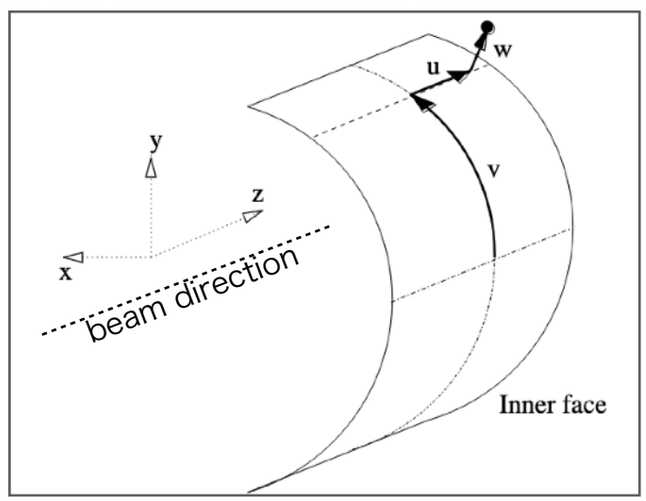
# MEG II experiment, LXe detector



- MEG II experiment aims to search for charged lepton flavor violation : $\mu^+ \rightarrow e^+\gamma$
  - with higher sensitivity by one order of magnitude compared to the MEG
- Consists of LXe detector for γ-ray, drift chamber & timing counter for $e^+$
  - LXe detector consists of 4092 MPPCs and 668 PMTs (both VUV-sensitive)
- Physics run started in 2021 (pilot run) -> full physics run in 2022, 2023



# MEG II experiment (and related talks)



**2021**

- Engineering run + First physics run (3, 4, 5e+7 μ/s beam)
  - The first MEG II result : arXiv.2310.12614 (will be published in Eur. Phys. J. C.)
  - Upper Limit : $B(\mu^+ \to e^+\gamma) < 3.1\times10^{-13}$ (90% C.L.)
  - see talk : 18aT2-6 (A. Oya)

**2022**

- Physics run with 3e+7 μ/s beam -> 4e+7 μ/s
  - Achieved long term physics run successfully
  - Analysis is ongoing : see talk : 18aT2-7 (K. Yamamoto)

**2023**

- Physics run with 4e+7 μ/s beam
  - **Main topic of this talk**
  - Analysis will be started soon

**2024**

- Preparation for physics run in 2024 is ongoing
  - PDE recovery by annealing, LXe detector maintenance
  - Refreshment of SiPMs in pTC is ongoing
    - see talk : 21aT1-1 (T. Yonemoto)
      - Cause of MPPC PDE decrease in the LXe detector is under investigation by Labo. exp. : see talk : 18pT3-7 (R. Umakoshi)

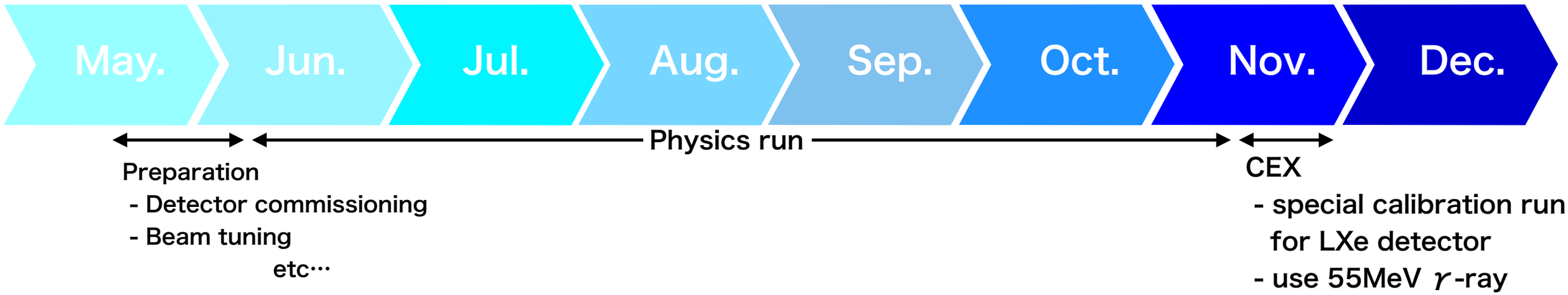
# Outline

# 2023 run

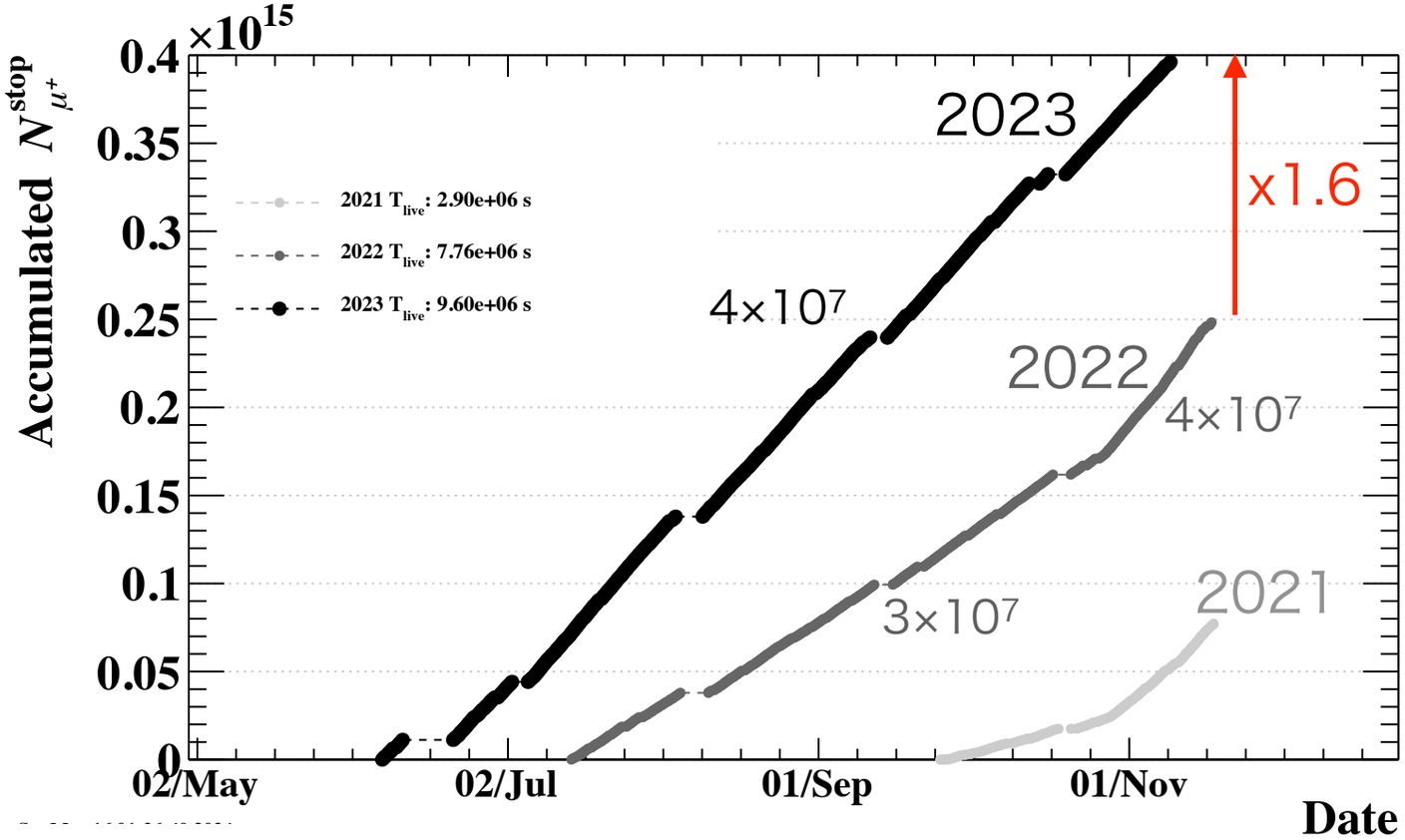


**MEG II beam time in 2023**

Assigned beam time : Middle of May. - End of Nov.




- Physics run : 7th Jun. to 9th Nov. with intensity of ~4×10$^7$ μ/s in 2023
- In total, 4e+14 stopped muon in 2023 run : **x1.6 statistics** compared with 2022

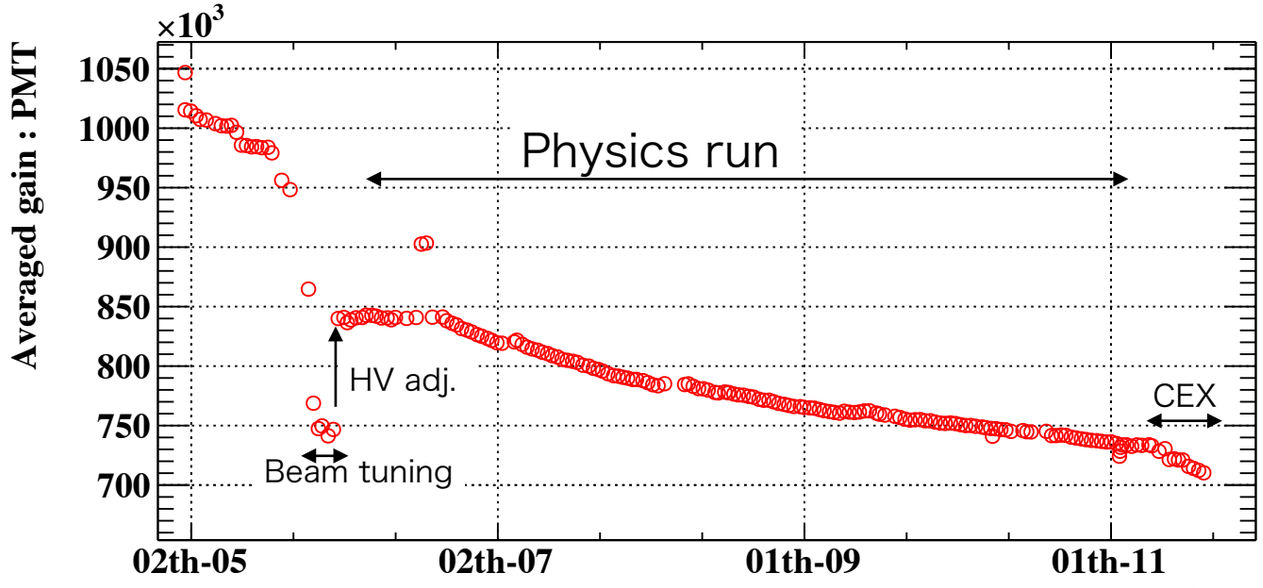


# LXe detector status in 2023 run : sensor calibration

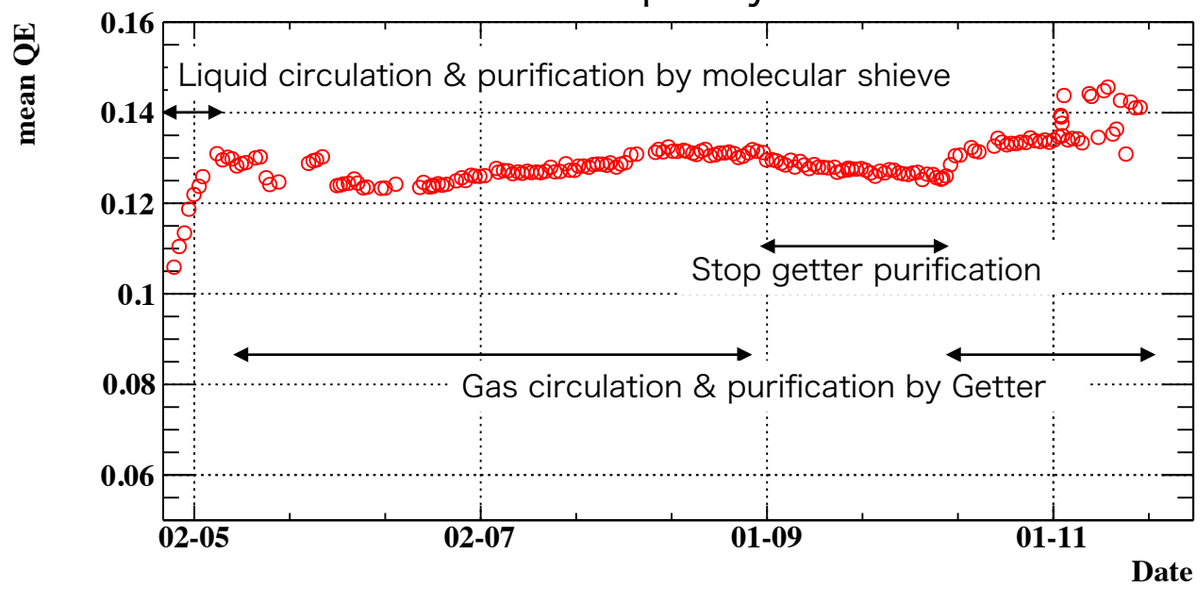


- Sensor calibration (Gain, QE, PDE) for monitoring the LXe detector during run

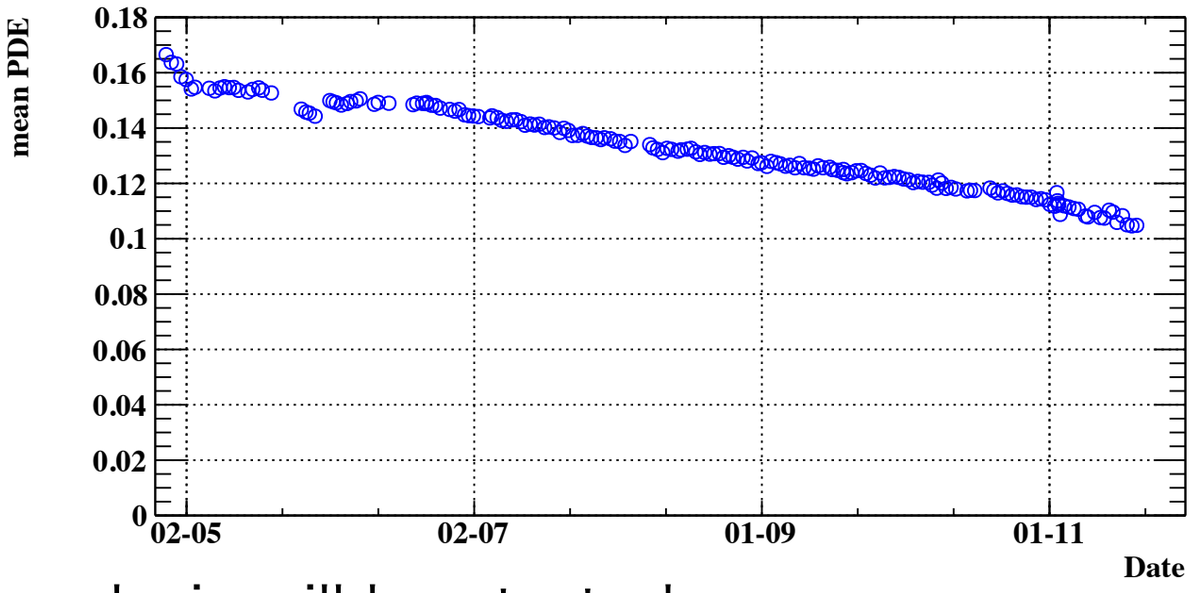
- For PMT gain
  - It decreases by irradiating beam
  - During whole beam time in 2023, it kept gain>0.5M without any HV adjustment
    - If gain<0.5M, timing resolution will get worse
    - In 2022, HV adjustments were done twice




- For PMT Quantum Efficiency (QE)
  - The calculation of QE is largely affected by purity of the LXe
    - PMT QE itself is expected to be constant
    - -> can be used as purity monitor of the LXe




- For MPPC PDE
  - It decreases by radiation damage (known problem)
    - sensitivity gets worse when PDE < 4%
  - Cause is under investigated : see talk : 18pT3-7

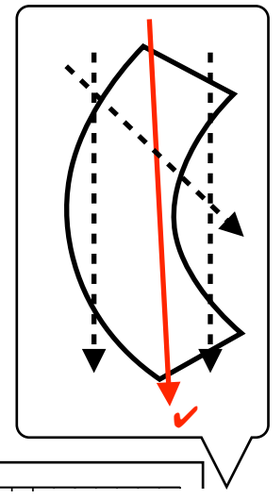



- Precise sensor calibration for physics analysis will be started soon

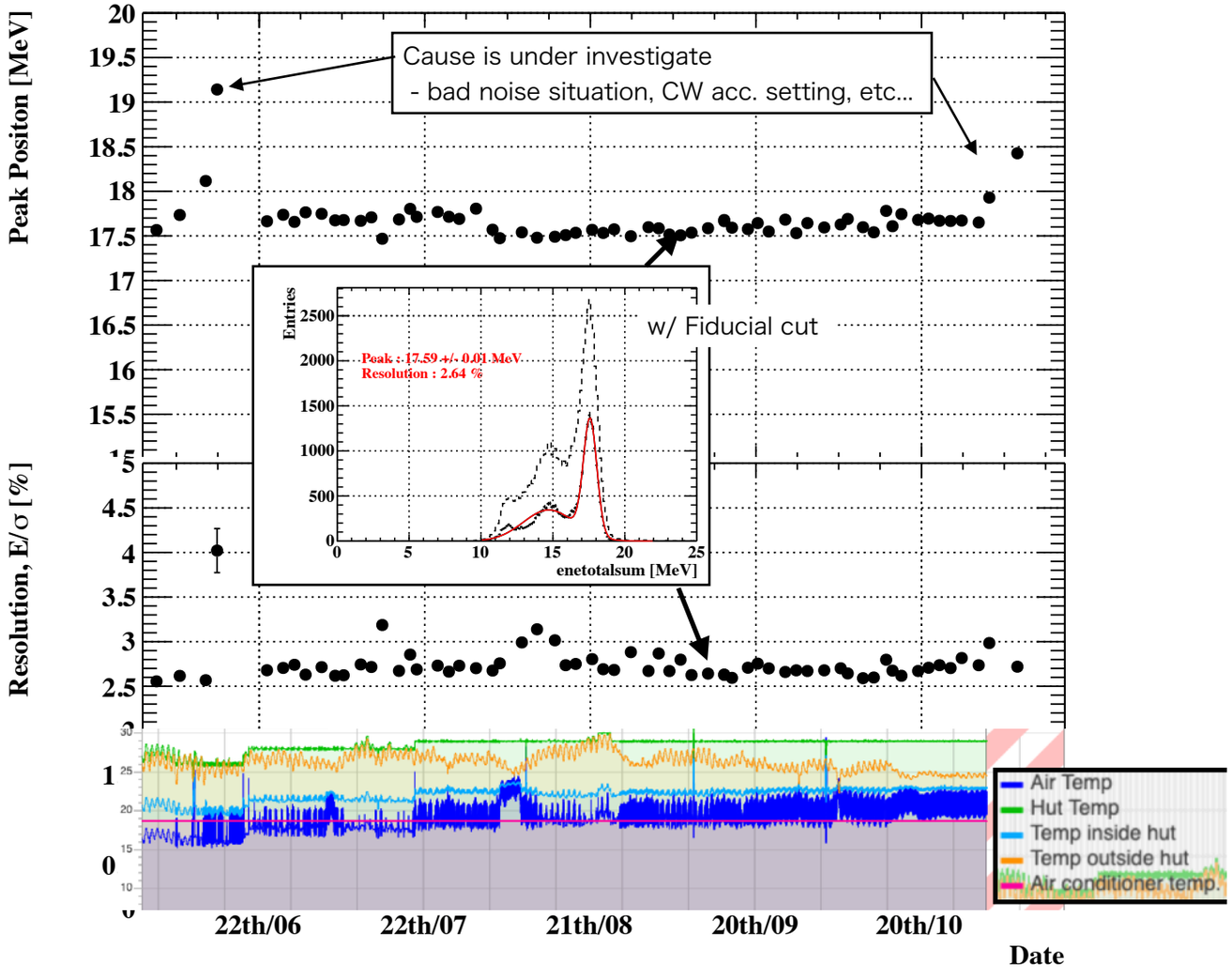
# LXe detector status in 2023 run : Energy scale stability



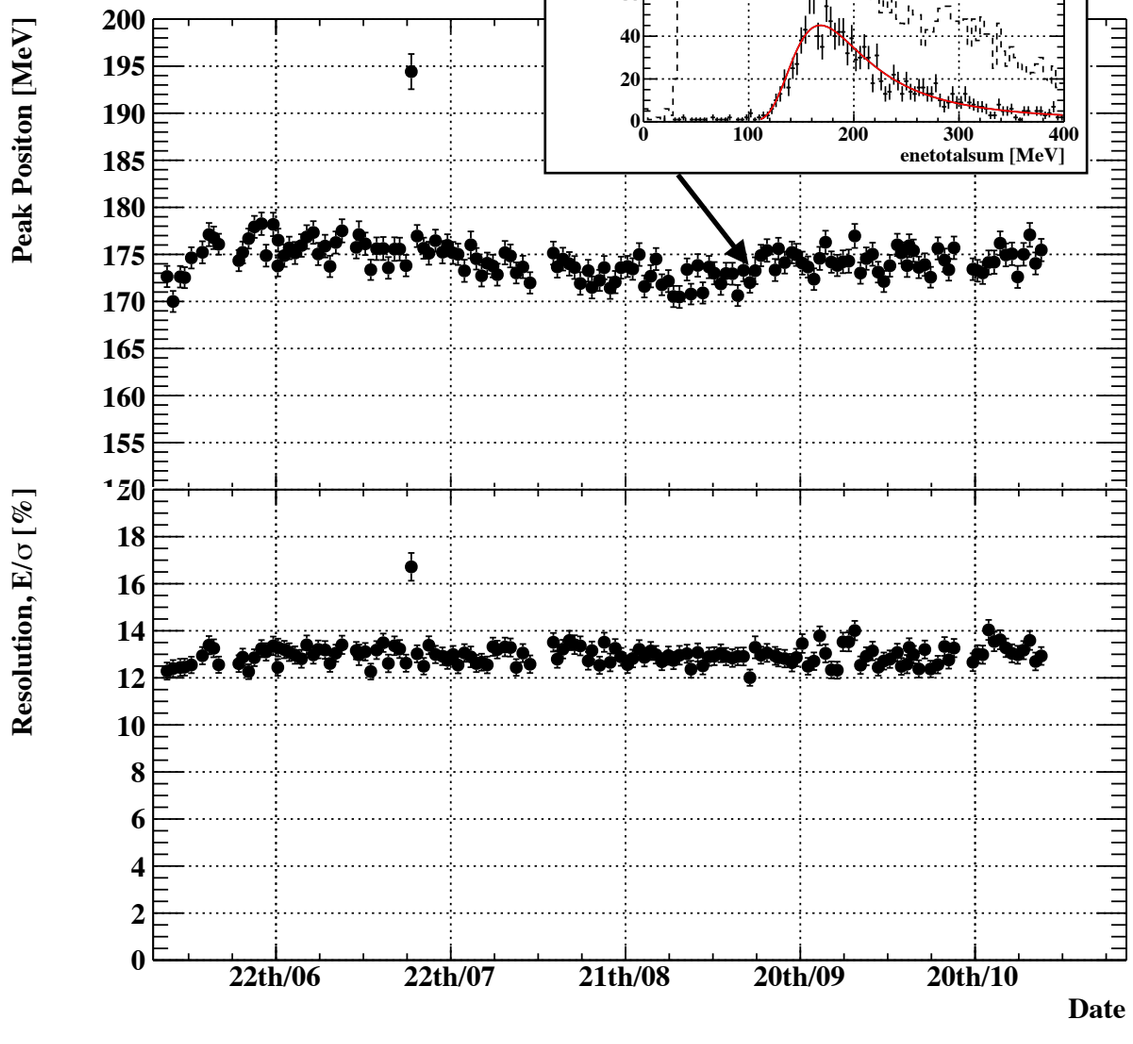
- Energy scale stability is monitored by some calibration source
  - Mono-energy gamma-ray (17.6 MeV, 9 MeV) : 3 times/week
  - Cosmic-ray : everyday
- Energy scale stability :
  - <2% for 17.6 MeV (except for the beginning and end of beam time)
  - <3% for cosmic



- Li(p,γ)Be reaction : 17.6 MeV gamma-ray

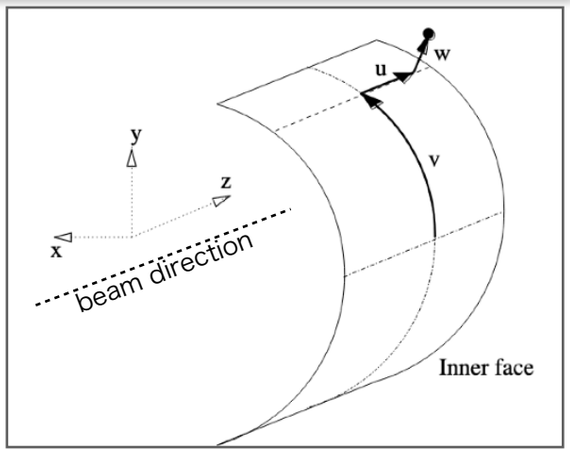



- Cosmic-ray

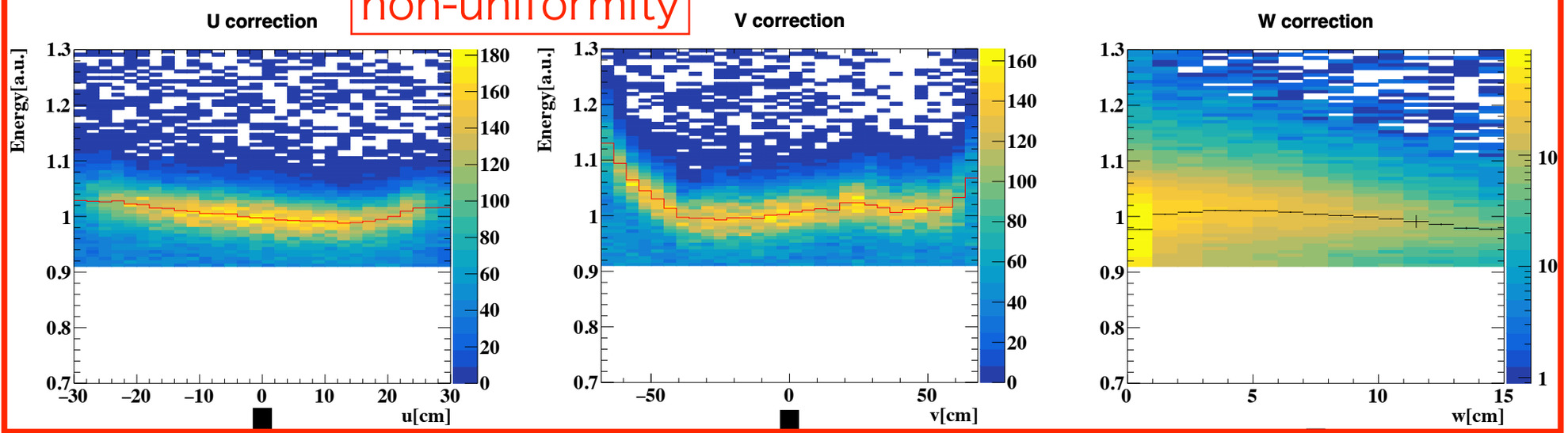


# Non-uniformity correction using 17.6 MeV Gamma

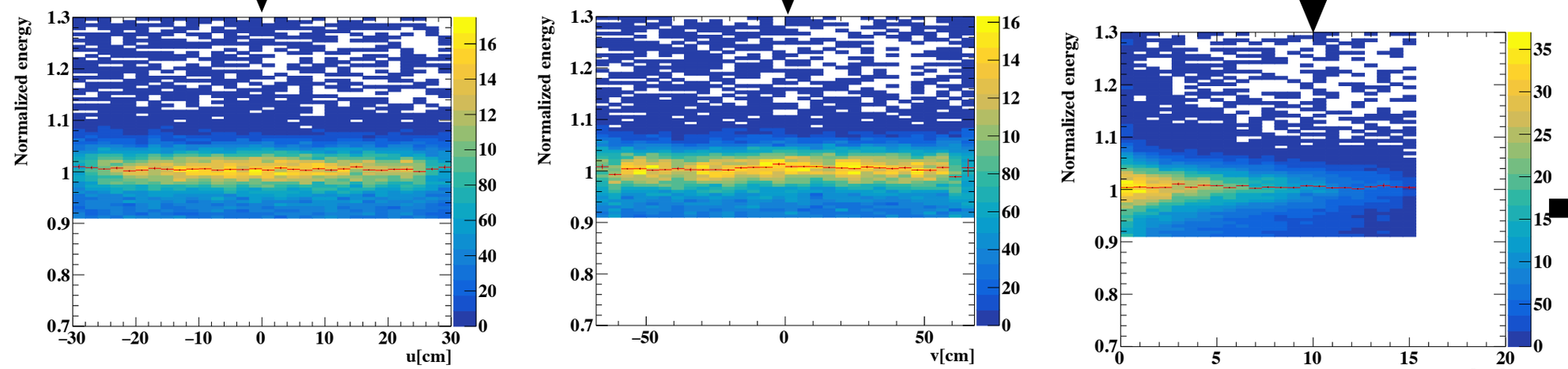
- Non-uniformity is observed and corrected
  - using 17.6 MeV gamma-ray events to obtain correction table for non-uniformity during run time
  - First, the correction factor for 1-D (for u, v, w each) is calculated
  - Then, 2-D correction table (u,v plane) is calculated
  - Finally further correction for depth is applied with 3x8 uv sections
- Degree of non-uniformity didn't change much during 2023 beam time

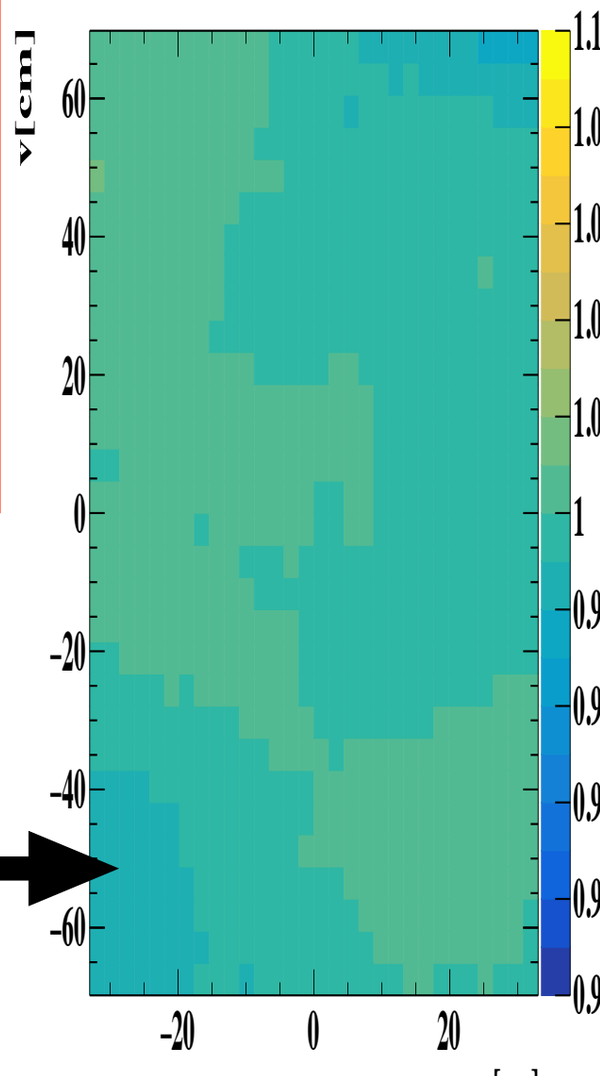



non-uniformity




correction

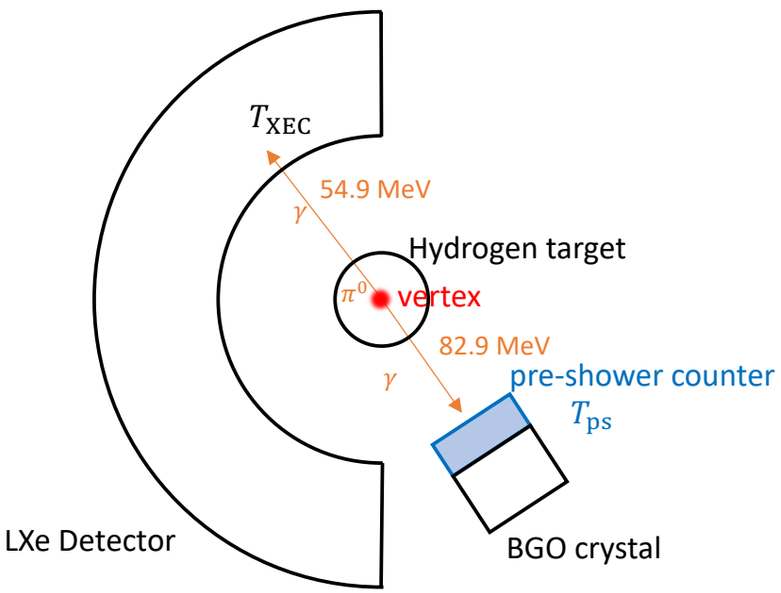


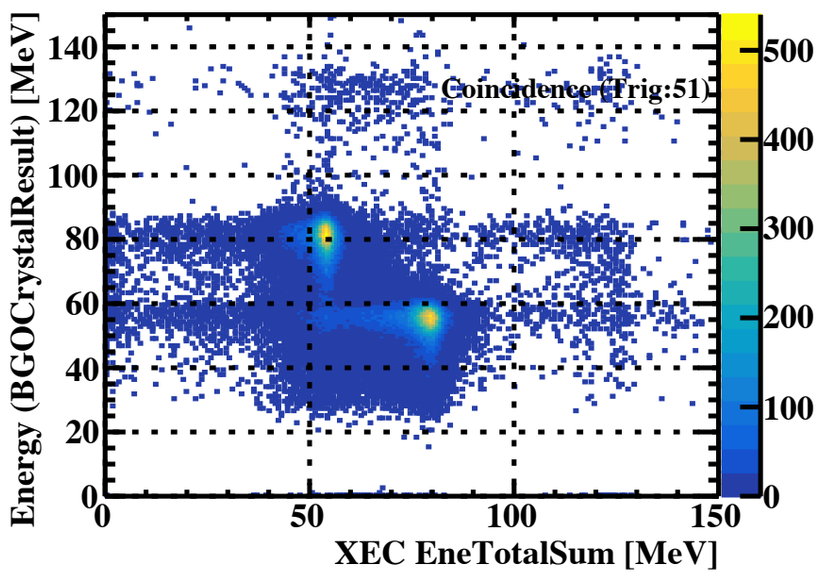



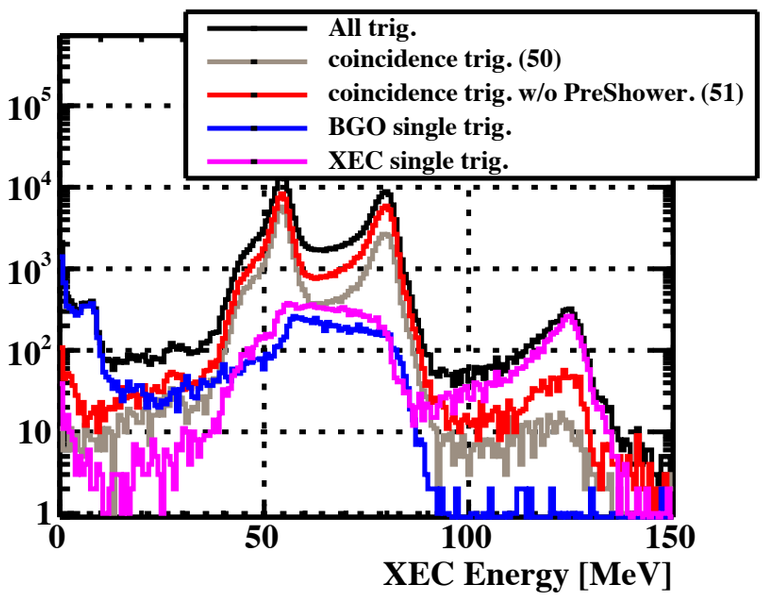
# Calibration by charge exchange reaction



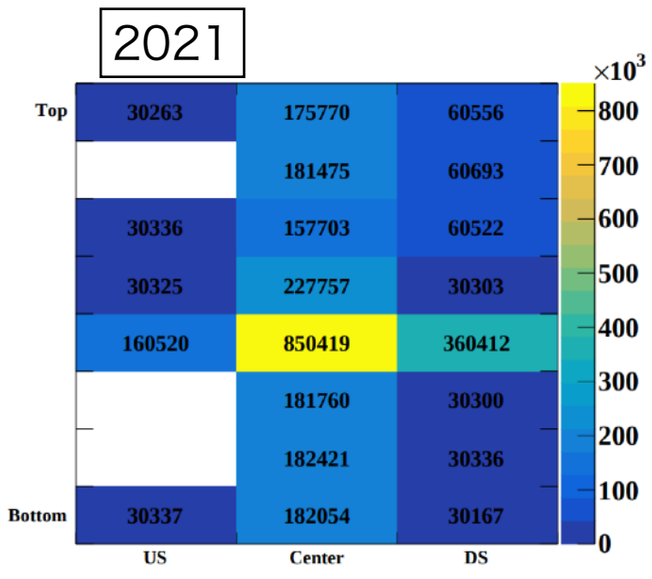
- Calibration using 55, 80 MeV gamma-ray by Charge EXchange (CEX) reaction
  - $\pi^- \rightarrow \pi^0$ (in Hydrogen) $\rightarrow \gamma + \gamma$ (55 MeV, 80 MeV)

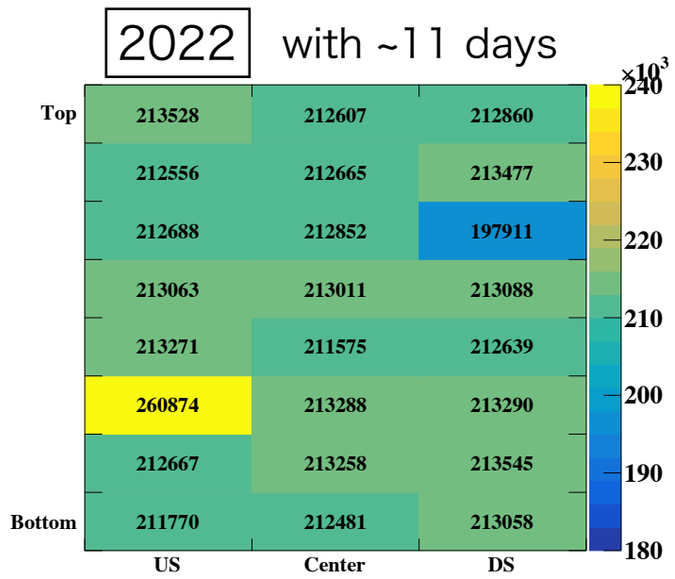


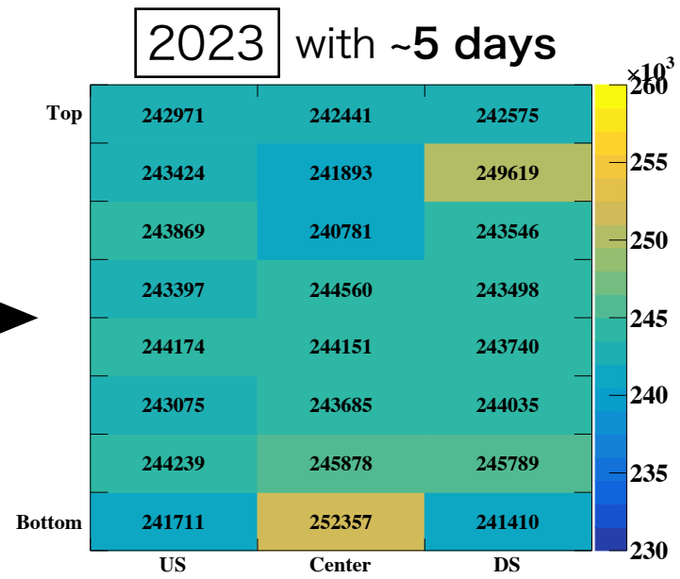




- Thanks to improvement of LH2 target stability, dead time for DAQ was less than 20%
  - Scan for all the region of XEC inner face was completed
  - Sufficient statistics was achieved with much shorter time than 2022 CEX



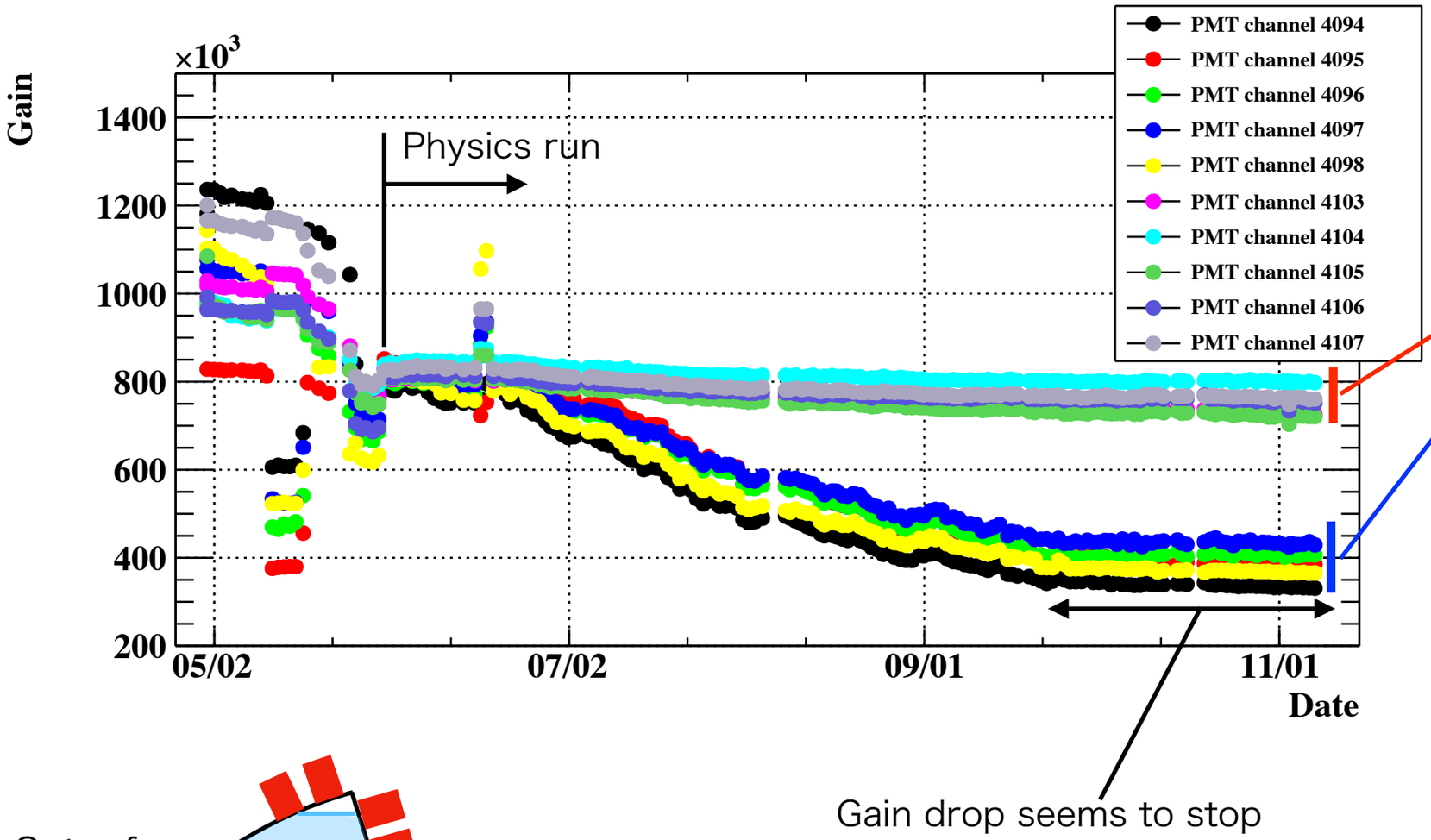



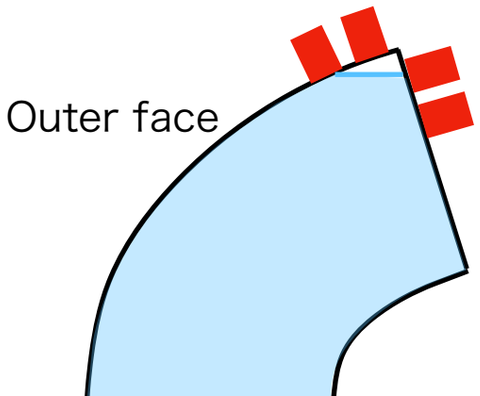



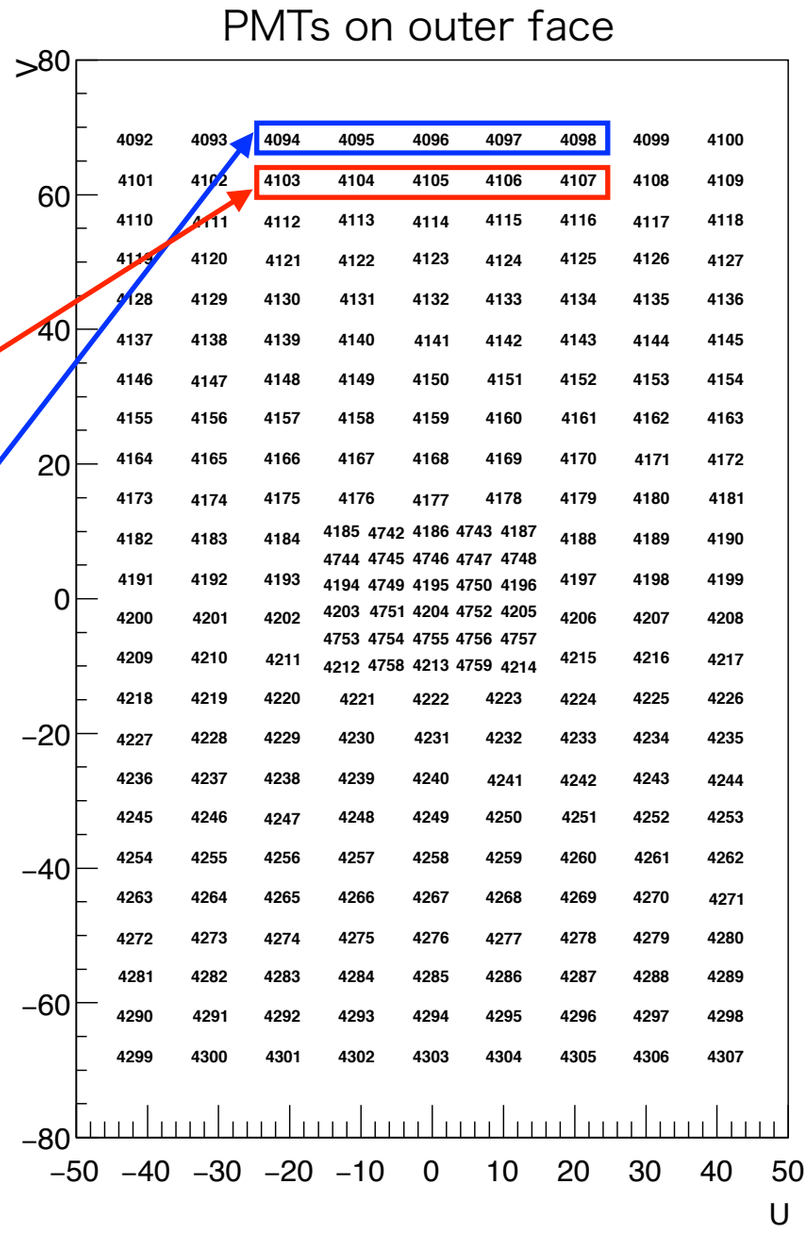
# Liquid xenon



- Charge for LED decreased gradually for PMTs at the top line
  - This indicates that the liquid level decreased gradually
  - -> PMTs at the top most line exposed above the liquid level
- **Leak may exist and leak point will be investigated during shutdown period 2024**
  - Currently we know leak may exist at the detector side (not in gas circ. part)



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Annealing for PDE recovery for 2024 run

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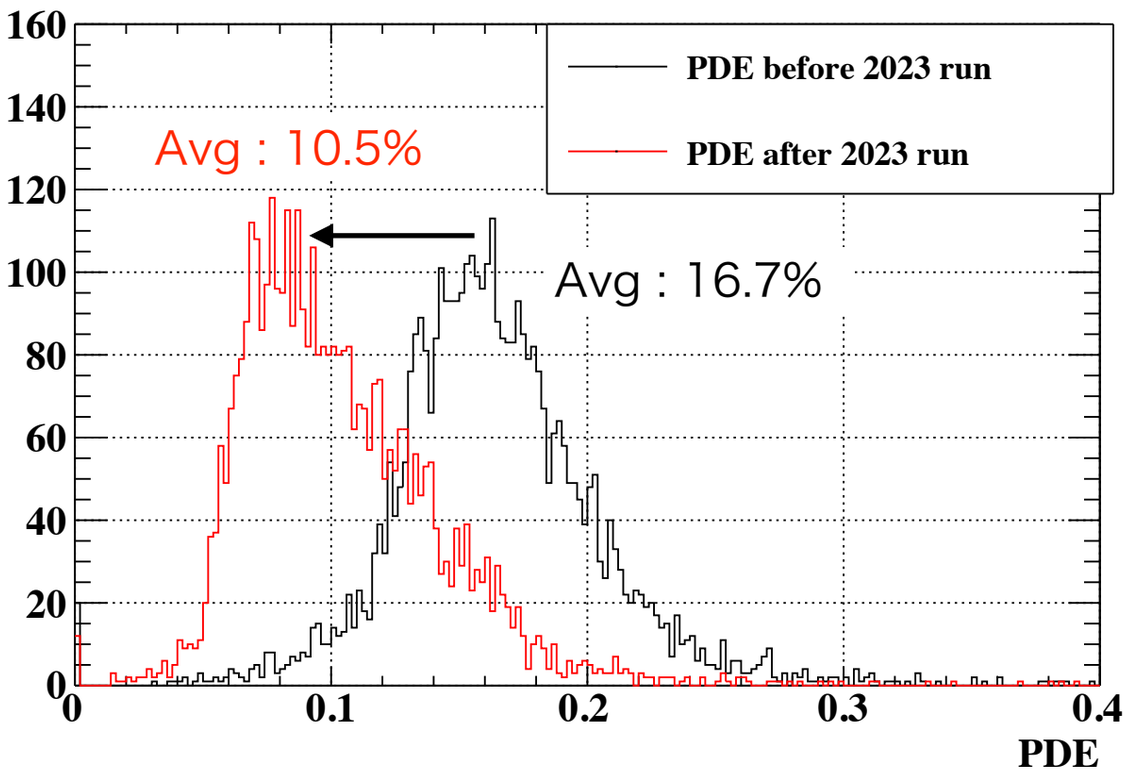
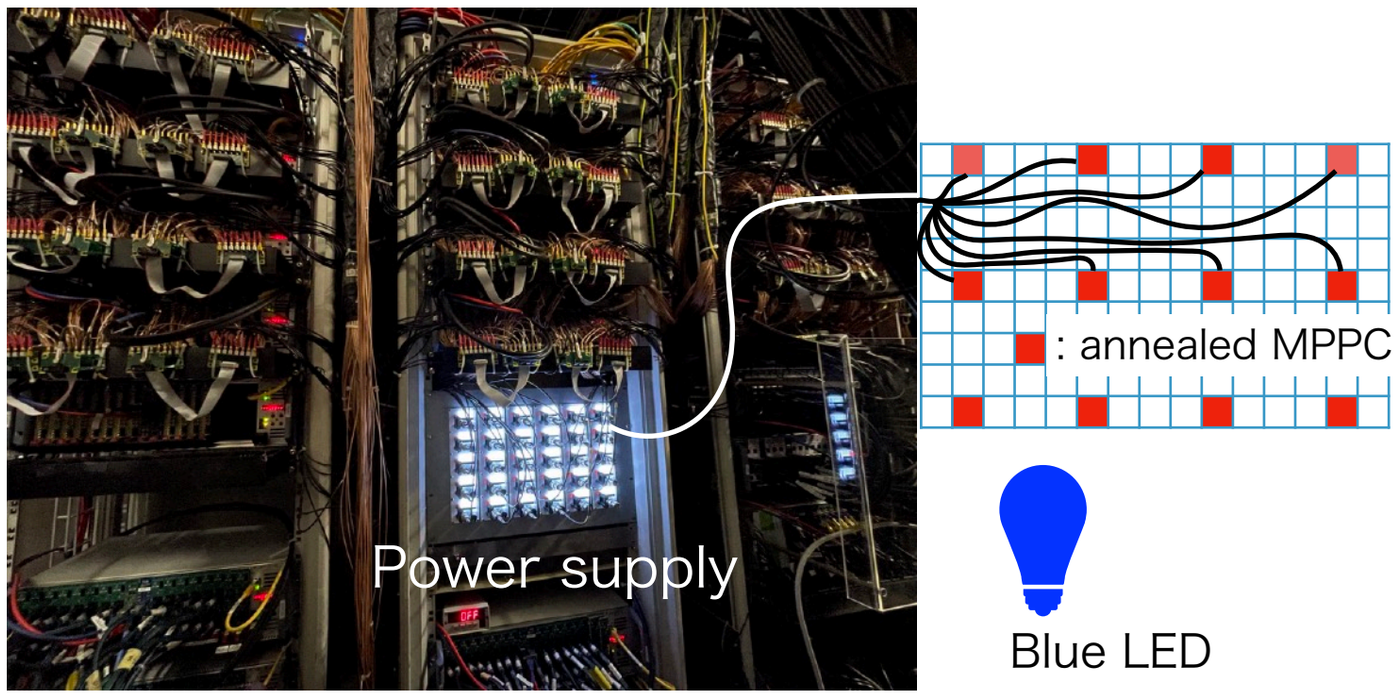
# Recovery of MPPC PDE by annealing for 2024 run



- In 2023 run, the MPPC PDE decreased from 16.7% to 10.5% in average
- **Annealing procedure was conducted** : 24th Jan. - 15th Mar. 2024
  - Using blue LED light and applying 71V, ~20mA (~1.42W) to each MPPC
  - ~30 hours annealing for each MPPC
- Monitoring data using visible LED were also taken during the annealing
  - empirical correlation b/w charge increase for visible light and PDE light is known
- PDE value will be measured soon after the LXe is re-filled for 2024 operation
  - to evaluate the effect of annealing



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# Summary



- MEG II experiment searches for charged lepton flavor violation : $\mu^+ \to e^+ \gamma$
  - Physics run started since 2021 and continued to 2022, 2023
  - In 2023, ~**5 months physics run with $4\times10^7$ μ/s beam was successfully** conducted
  - Approximately 1.6 times more statistics than 2022 are accumulated

- Stability of sensor gain, QE/PDE were monitored during the run 2023
  - gain and PDE with sufficient level were kept
- Energy scale/resolution stability were also monitored by gamma-ray and cosmic-ray
  - energy scale stability less than 3% fluctuation is achieved
- Special calibration data using CEX reaction was conducted
  - Thanks to improvement of LH2 target stability, highly efficient calibration data taking was achieved

- PDE recovery by annealing was done during beam off period in the beginning of 2024