MEG II実験液体キセノン検出器、背景ガンマ線エネルギー分布の測定

Measurement of background gamma-ray energy spectrum in MEG II liquid Xe detector

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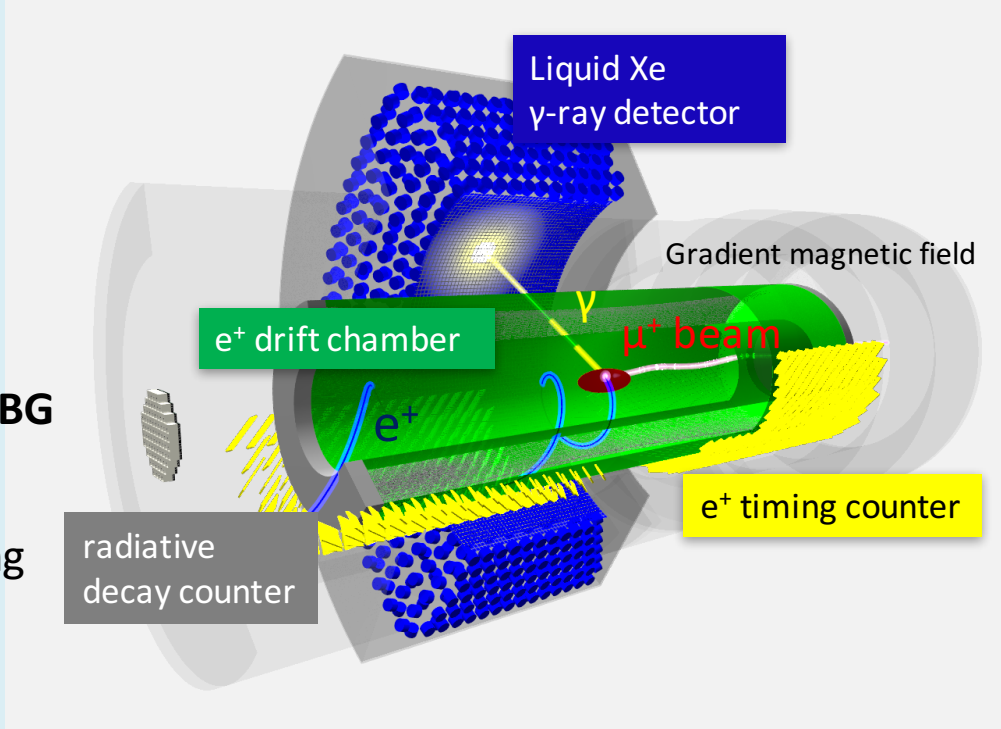
Table of contents

MEG II experiment

Upgrade of MEG experiment

- Searches for $\mu \to e\gamma$.
- Dominant BG : accidental BG
- **More statistics**
  - x2.3 muon beam rate
  - x2 positron efficiency
- **Better separation of signal event from BG**
  - x2 for all detector resolutions
  - New detector for background tagging will be introduced



Expected sensitivity: 6×10^{-14}

- One order of magnitude better than MEG

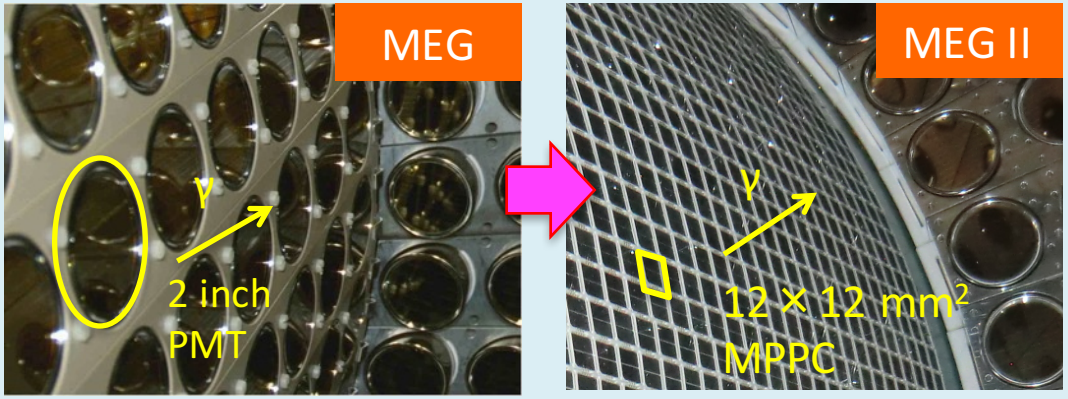
Engineering run from 2019

- Followed by physics data taking.

Reference :
"The design of the MEG II experiment",
Eur. Phys. J. C (2018) 78:38

LXe detector in MEG II

- LXe detector has been upgraded for MEG II to significantly improve the performance.

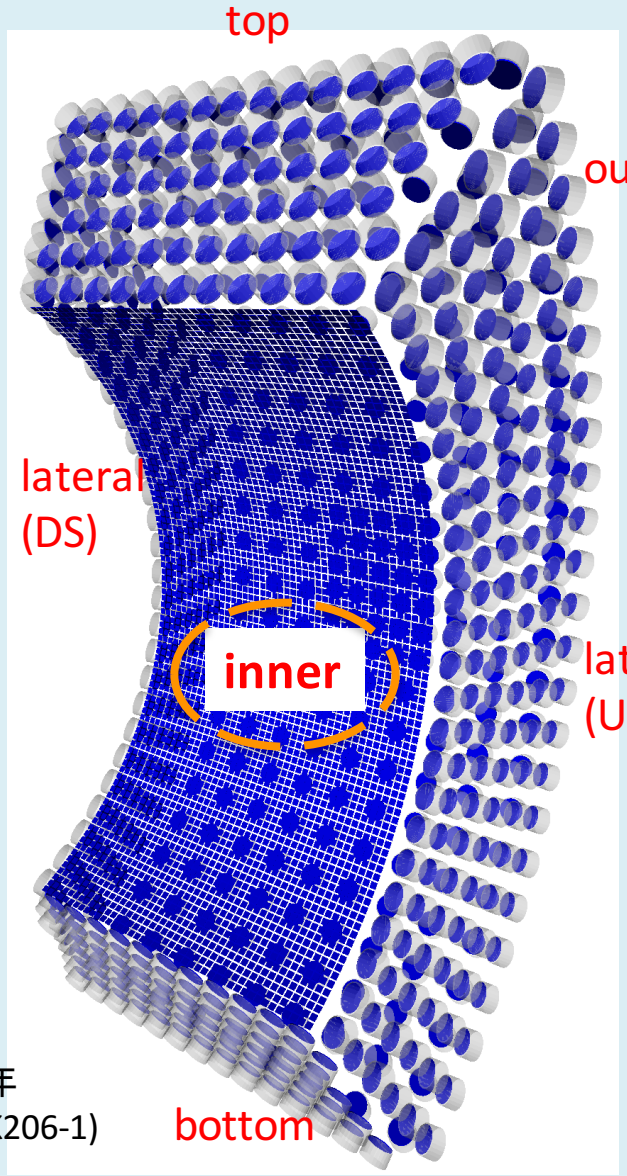


216 2-inch PMTs **4092 12 × 12 mm² MPPCs**

- Detector commissioning on going.

Performance for 52.8MeV signal γ

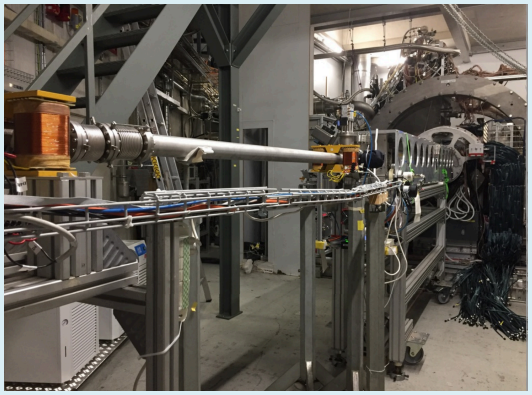
	MEG (measured)	MEG II (simulated)	
Position	~5 mm	~2.5 mm	→ Next talk
Energy	~2%	0.7 - 1.5%	→ **This talk**
Timing	62 ps	40 - 70 ps	→ Talk in 2018年年次大会 (25aK206-1)
Efficiency	65%	70%	



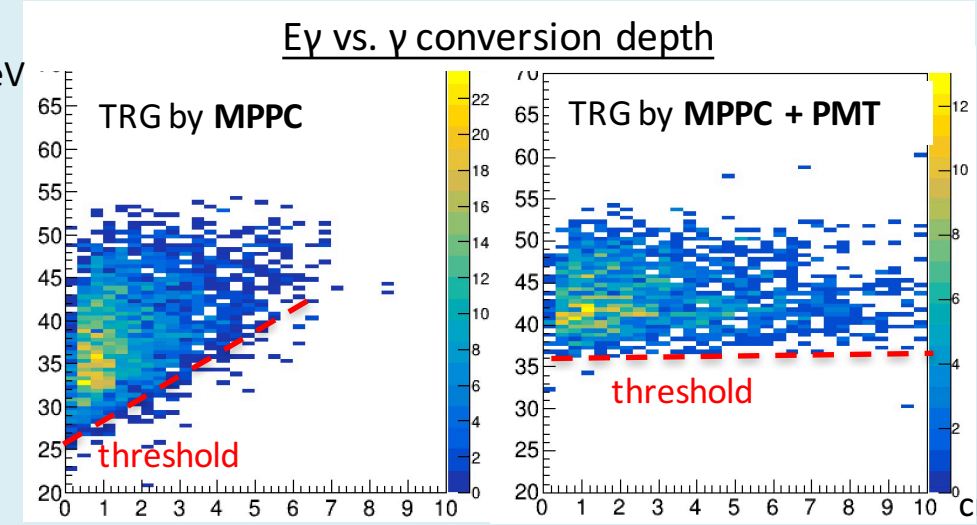
Pre-engineering run 2018

- Pilot run of LXe detector was carried out with MEG II muon beam.
- Similar beam time was also performed in 2017.
  → Several improvements in 2018.

1. Monochromatic γ from calibration source.
   - Not available in 2017.



2. Unbiased TRG thanks to better sensor calibration.
   - In 2017, trigger by sum of MPPC waveform
   - In 2018, trigger by sum of MPPC + PMT waveform



Sec. 2

Detector performance study.
Detector response calibration.

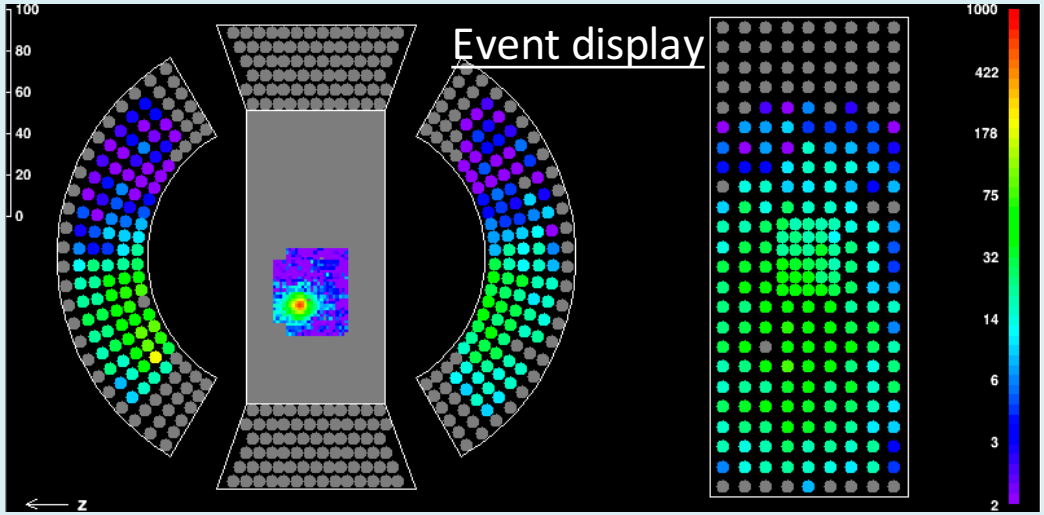
Sec. 3

Beam background γ spectrum study with calibrated detector.

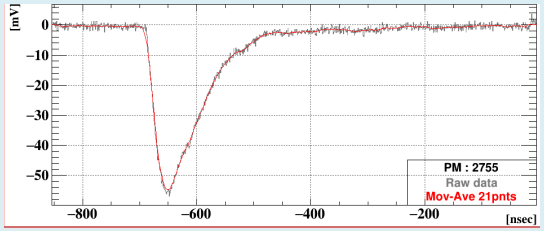
Table of contents

CW-Li

- 17.6MeV γ-ray from $^{7}_{3}\mathrm{Li}(\mathrm{p},\gamma)^{8}_{4}\mathrm{Be}$. (called as CW-Li)
  - Proton from Cockcroft-Walton accelerator is injected to Lithium target.
- Use WaveDREAM (electronics for MEG II) for waveform readout.
  - Read out 25% of detector.

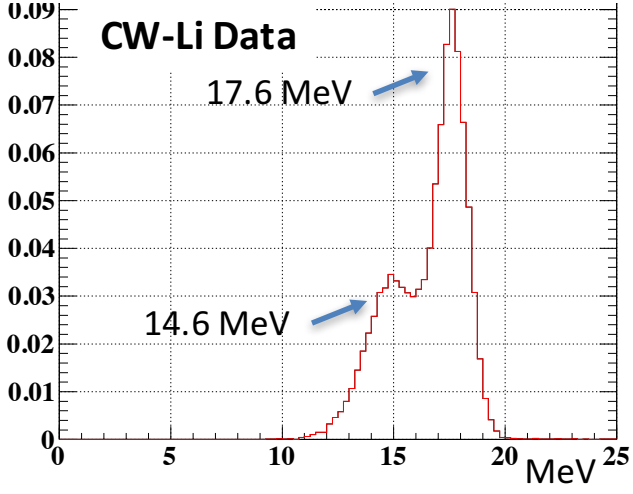


MPPC waveform



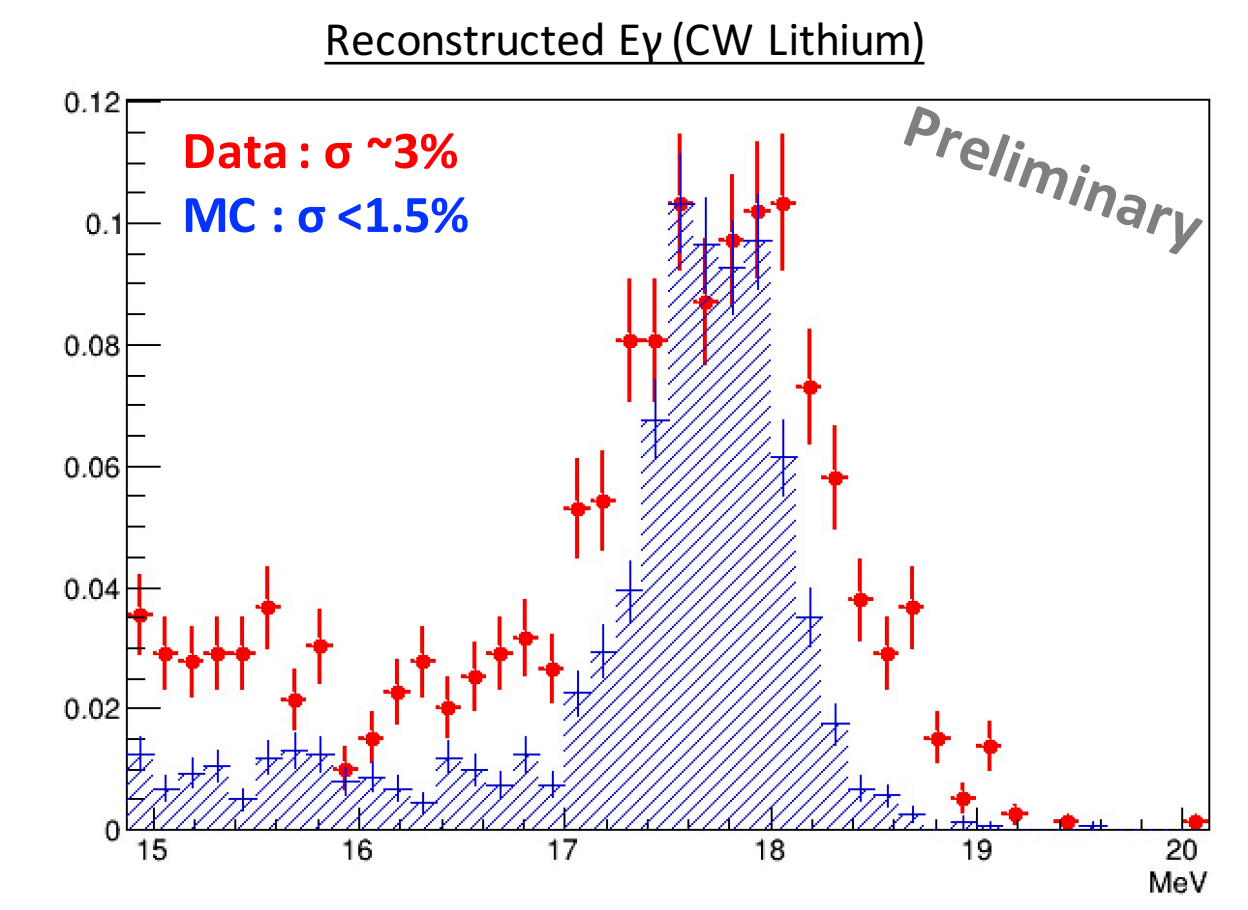
- Energy is reconstructed based on sum of detected # of photon.
  - $E_\gamma = Const. \times \sum_{sensor} \frac{charge}{gain \times EQF \times PDE}$

Reconstructed Eγ (CW Lithium)

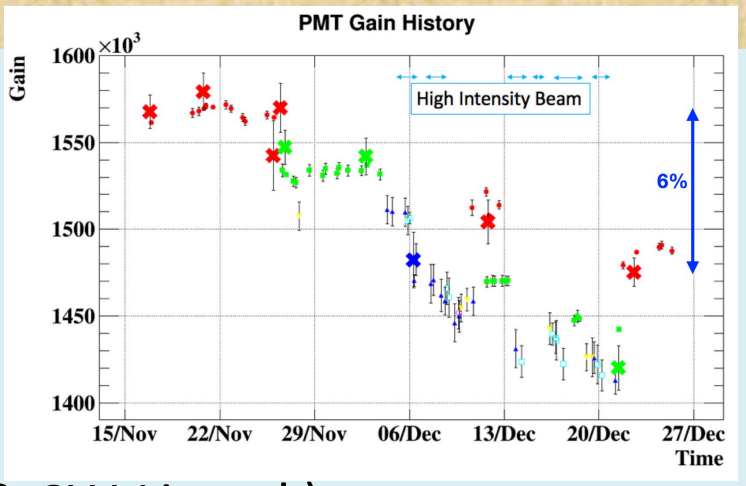


Energy resolution @ CW-Li line

- Energy resolution can be estimated from CW-Li line.
- Estimated to be ~3%.
  - Twice worse than MC. Under investigation.



Energy scale stability



- Photo sensor response changes.
  - PMT gain shift by
    Magnetic field, beam charge-up.
  - PMT gain aging by beam.

→ Needs to be monitored.

- Monitor by 2 independent methods (LED & CW-Li peak).
  → Gain shift by ~10% observed. Still ~2% inconsistency left.

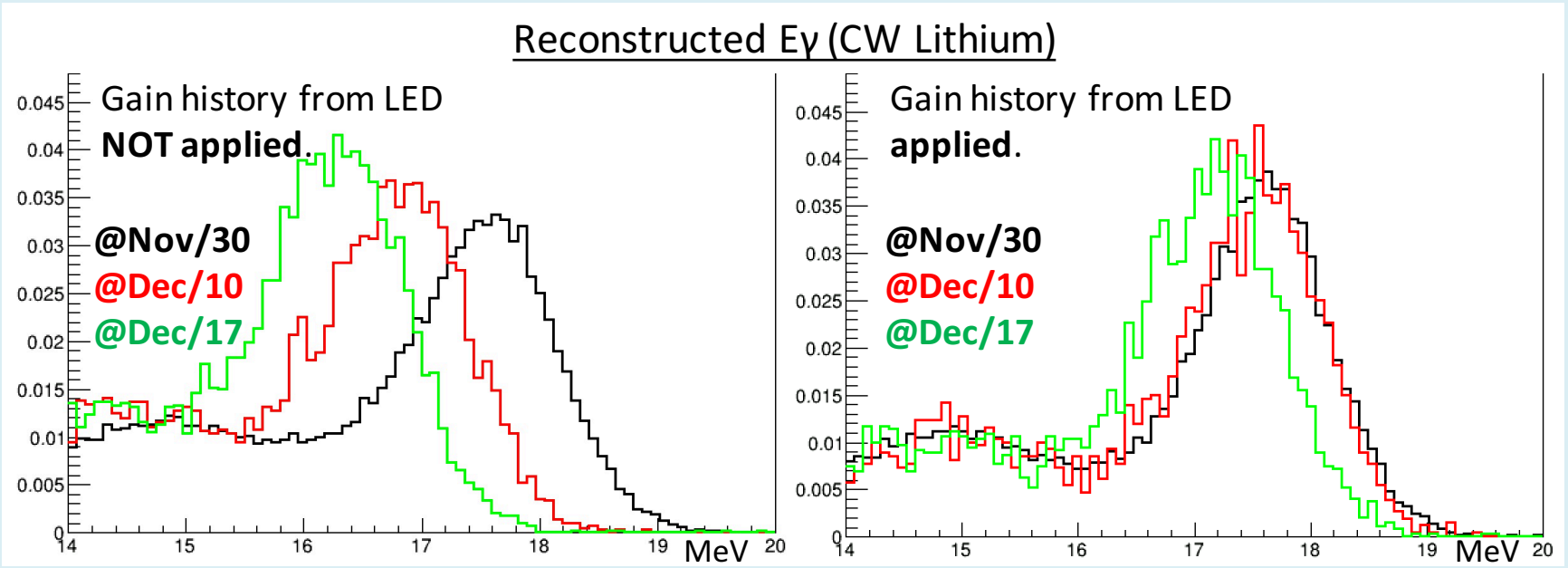
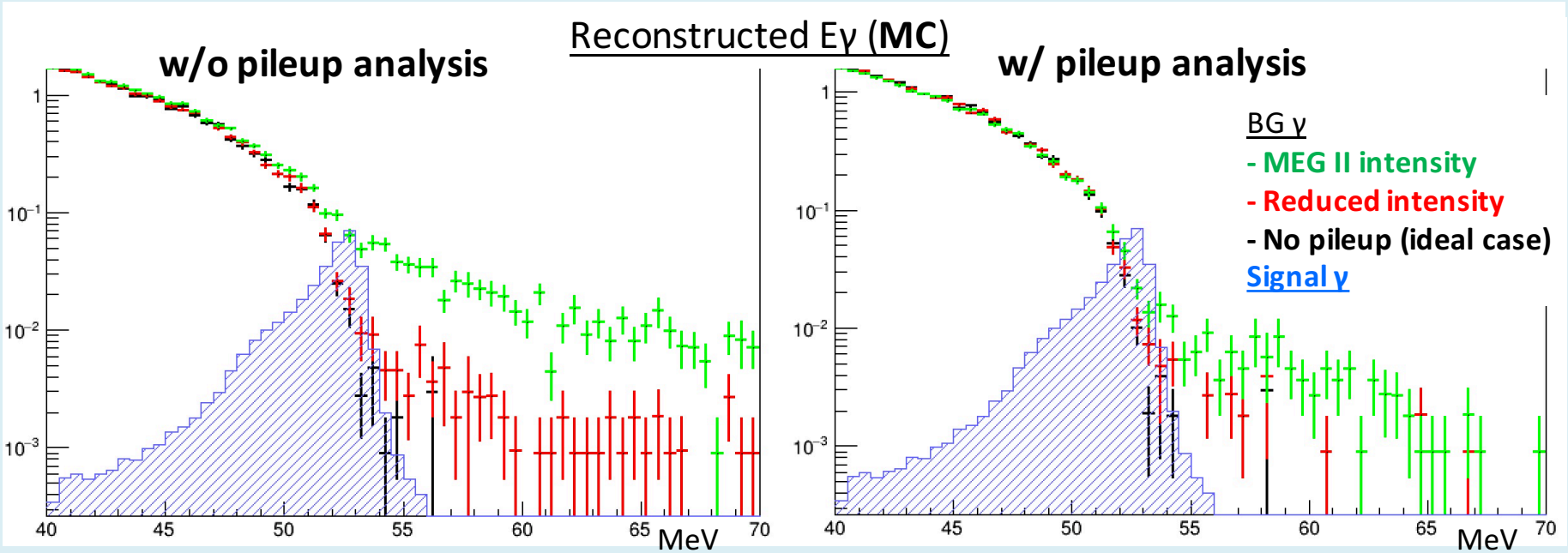


Table of contents

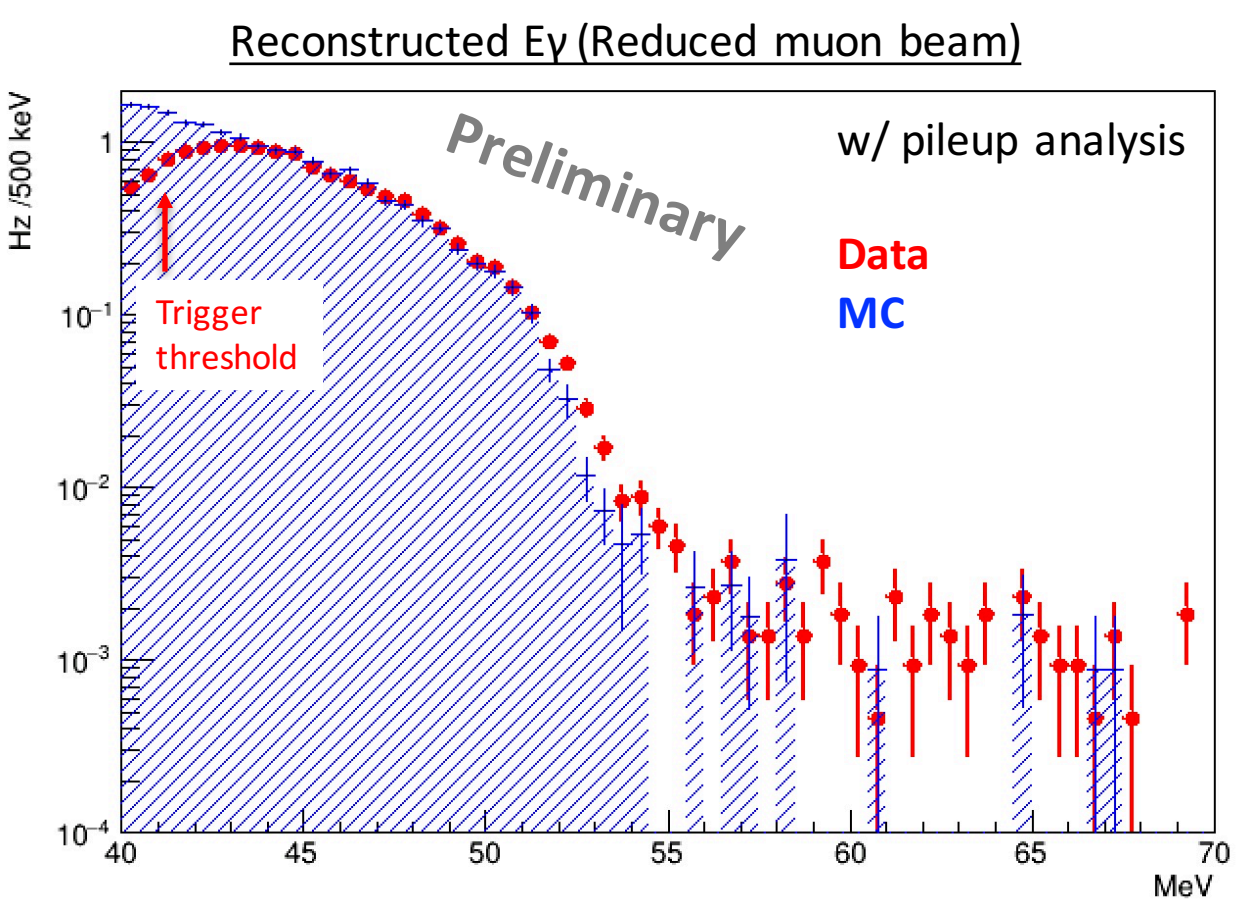
γ-ray DAQ with muon beam

- γ-ray DAQ with muon beam.
  (i.e. background γ spectrum in $\mu \to e\gamma$ search)
  - γ-ray from radiative muon decay + converted γ from Michel muon decay.
- DAQ performed at 2 types of beam rate.
  - MEG II intensity rate (7×10^7 μ/s) → To check pileup effect.
  - Reduced beam rate (8×10^6 μ/s) → To check detector response w/o pileup.
- Pileup identification and unfold is applied in offline analysis.



Eγ spectrum (@ reduced muon beam rate)

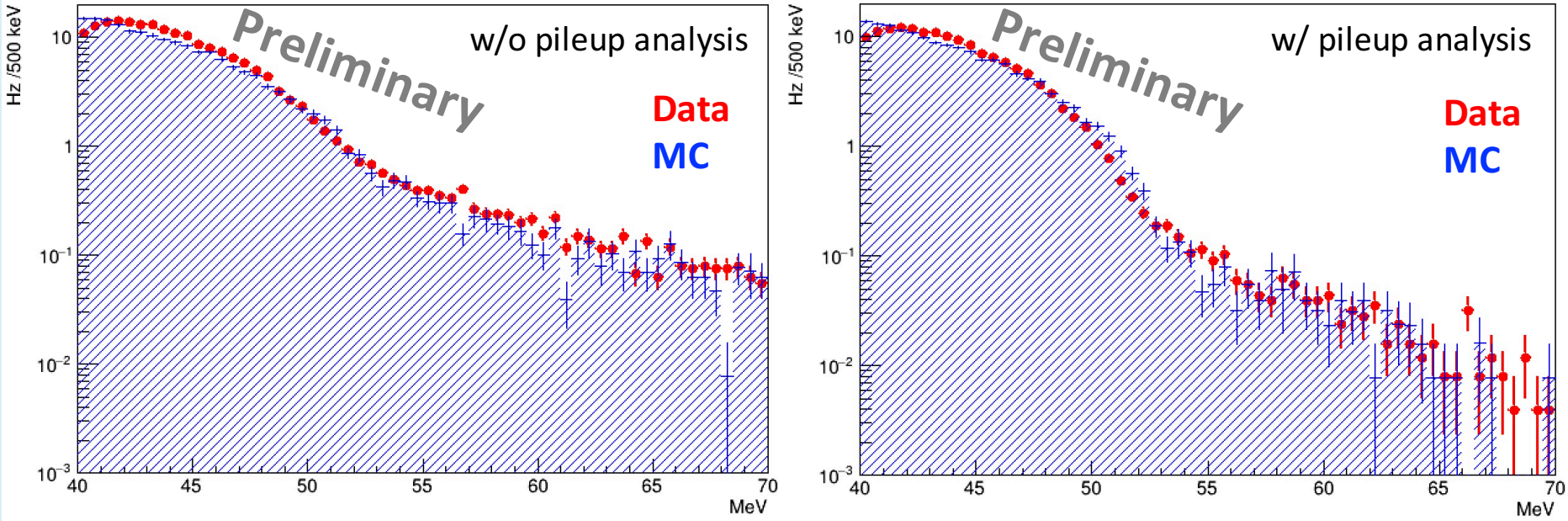
- Energy spectrum is well consistent up to ~51 MeV.
- Inconsistency observed in high energy region.
  - maybe due to BG events not coming from muon beam.



Eγ spectrum (@ MEG II nominal muon beam)

- Energy spectrum has similar shape, but not consistent with MC.
  - Large number of events in high energy region.
    This is due to larger number of pileup γ than expected.
  - Some inconsistency also in low energy region.
- Pileup subtraction in offline analysis works.

Reconstructed Eγ (MEG II muon beam)



※ Energy scale of Data is shifted by -3% to match MC.

Summary

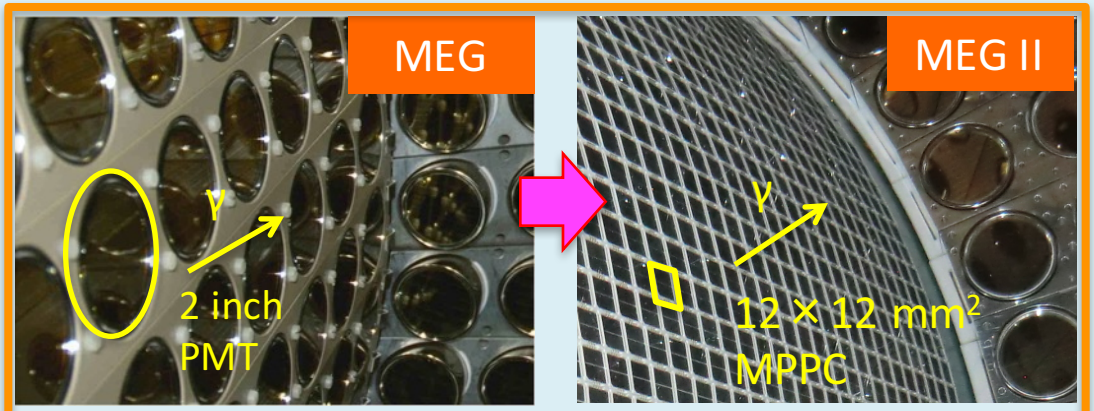
- Pilot run of LXe detector was carried out with MEG II muon beam.
  - 17.6MeV monochromatic γ from excited $^{7}_{3}\mathrm{Li}(\mathrm{p},\gamma)^{8}_{4}\mathrm{Be}$.
  - 40-53 MeV background γ-ray from muon beam.

- Preliminary results are reported.
  Further investigation is going on.
  - 17.6MeV peak from CW-Li is successfully observed.
    - Measured energy resolution is worse than expected.
  - Energy scale is monitored by sensor gain calibration & CW Li line.
    - Inconsistency of 2% is left.
  - BG spectrum is roughly consistent with MC.
    - Some inconsistency with MC is still left.

BACKUP

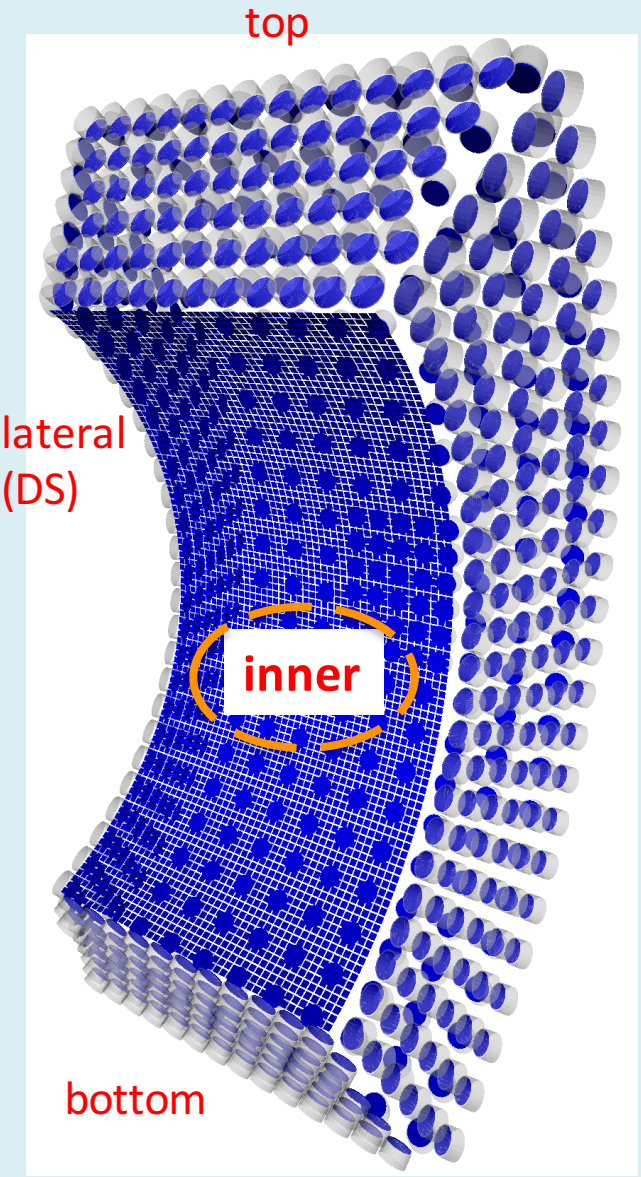
LXe detector upgrade

LXe detector has been upgraded 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

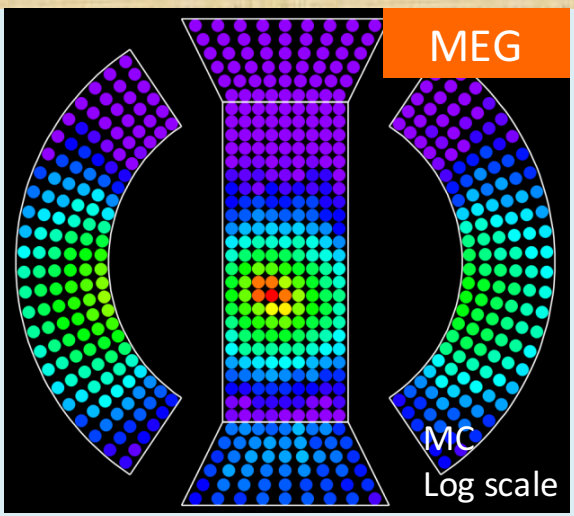


Expected performance

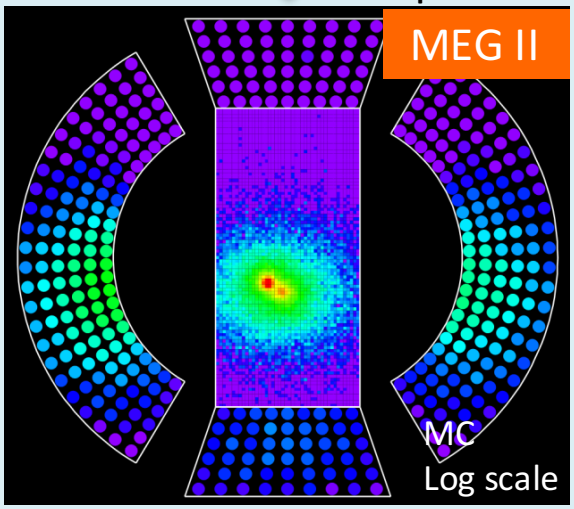
- Significant improvement of all resolutions and efficiency are expected.

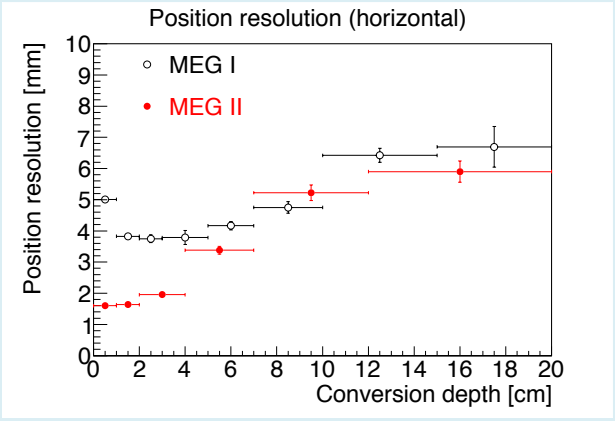
Detector performance for signal γ-ray

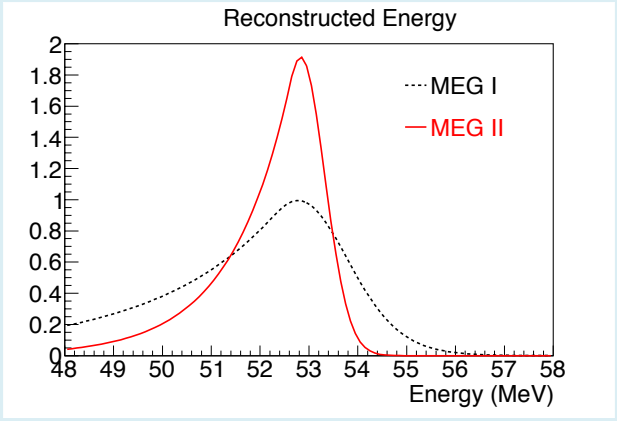
	MEG (measured)	MEG II (simulated)
Position	~5 mm	~2.5 mm
Energy	~2%	0.7 - 1.5%
Timing	62 ps	40 - 70 ps
Efficiency	65%	70%



Imaging power improves







Multiple γ identification

- Granularity of γ incident face has been largely improved.
  - 1 PMT replaced with 4 x 4 MPPC. (i.e. factor 16 improvement)
  - Main purpose: Improvement of position/ energy resolution.
- Can we utilize higher granularity for other purpose?
  → ***Identification of multiple γ event.***