MEG II実験液体キセノンガンマ線検出器における位置分解能の評価

Evaluation of the position resolution of the MEG II liquid Xe detector

日本物理学会
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The University of Tokyo

MEG II
Mu - E - Gamma collaboration

Core-to-Core Program

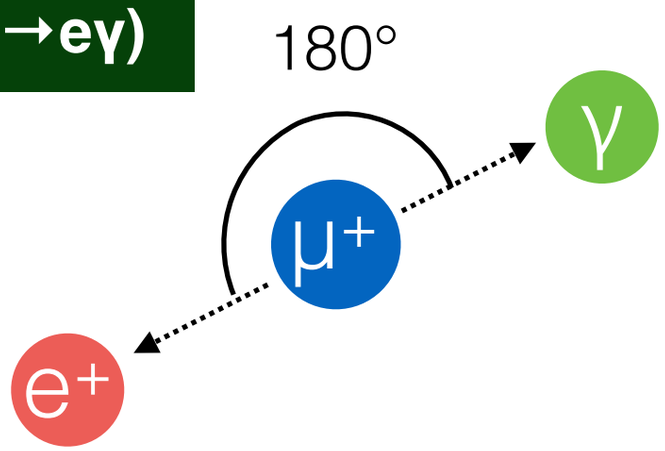
THE UNIVERSITY OF TOKYO

Outline

- Introduction
  - MEG II experiment
  - XEC upgrade
- Position Resolution measurement
  - Principle
  - First measurement in 2017
  - Improved measurement in 2018
- Summary

μ→eγ search

Signal (μ→eγ)



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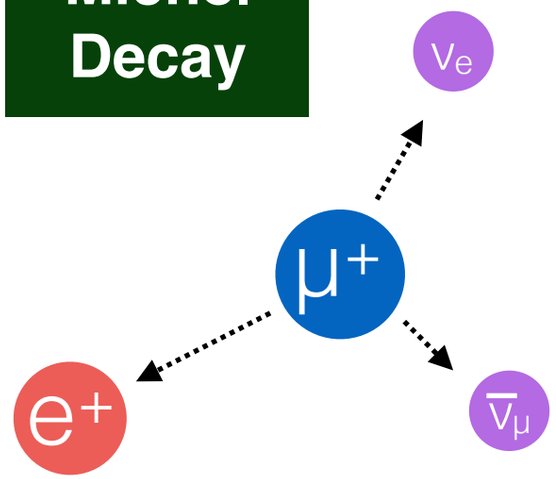
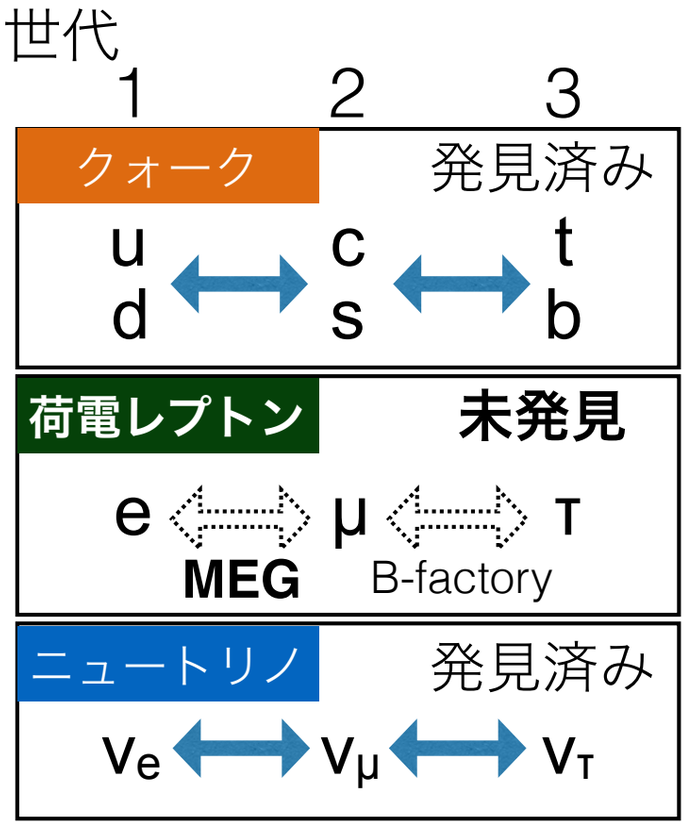
Michel Decay



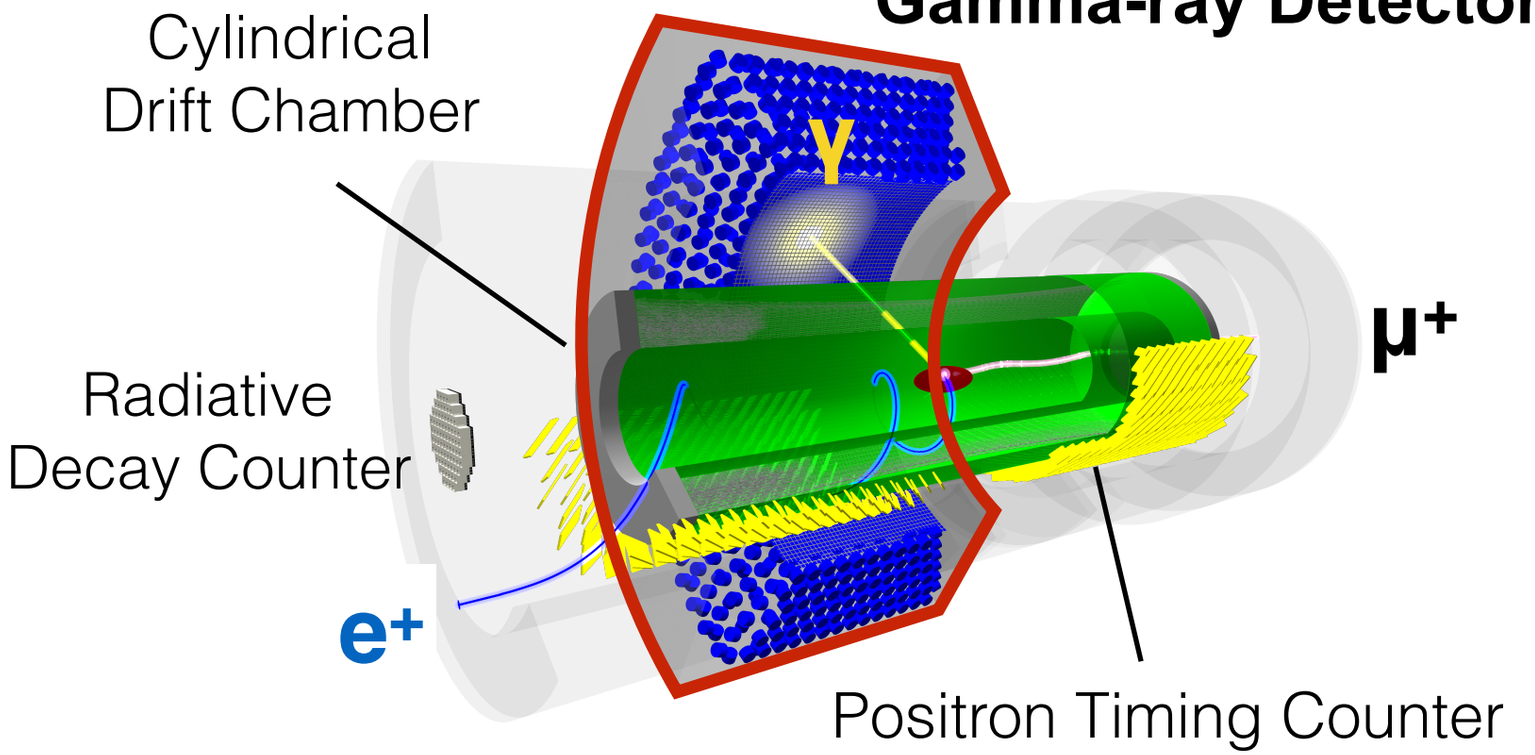
- Simultaneously emitted
- Back-to-back
- Same energy(52.8MeV)



- μ→eγ decay is a lepton flavor violating decay.
  - **almost forbidden** in SM+ν. oscillation(Br(μ→eγ)~10^{-54})
  - **predicted** in some theories(Br(μ→eγ):10^{-11}~10^{-14})
- Current upper limit of Br(μ→eγ) is given by the MEG experiment.
  - 4.2×10^{-13} (90% C.L.)

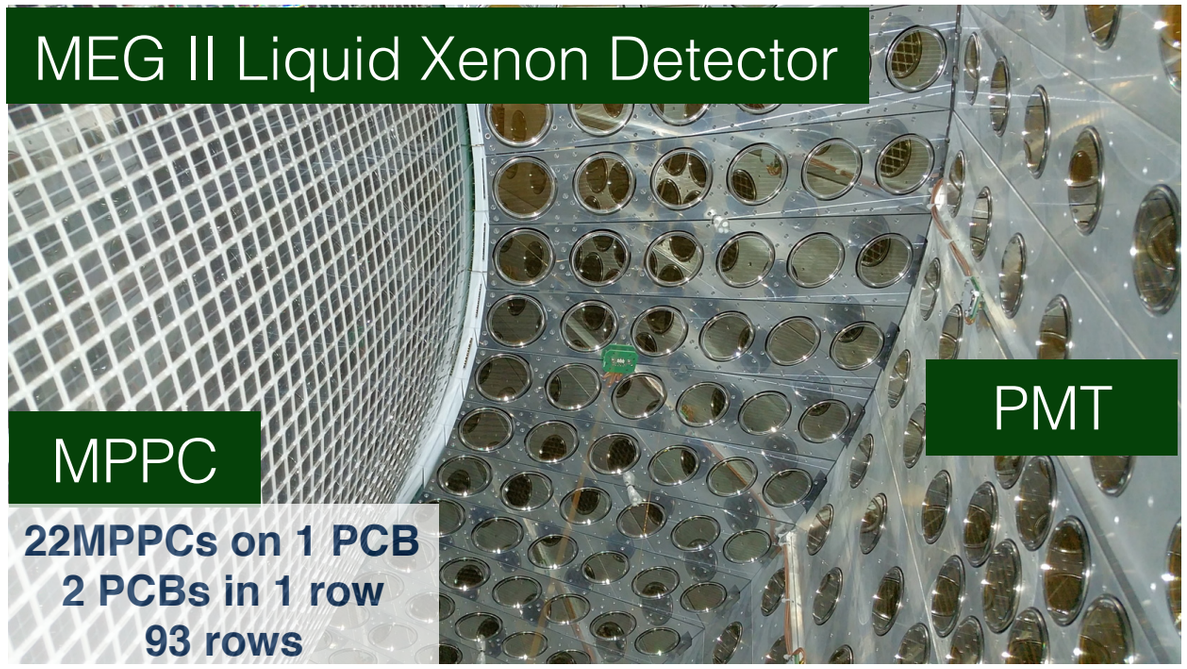
MEG II Experiment

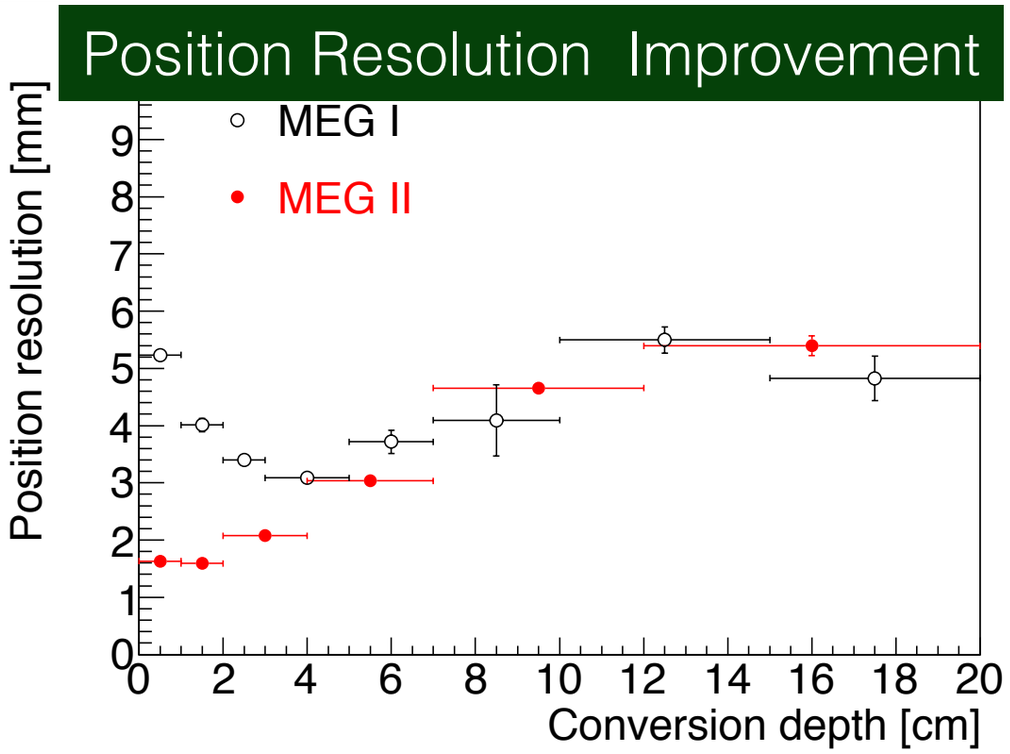
MEG II Setup



- MEG II experiment will search for the μ→eγ decay with unprecedented sensitivity.
  - Br(μ→eγ)~6×10^{-14} in 3 years
- Liquid Xenon gamma-ray detector measures position, energy and timing of the incident gamma-ray.

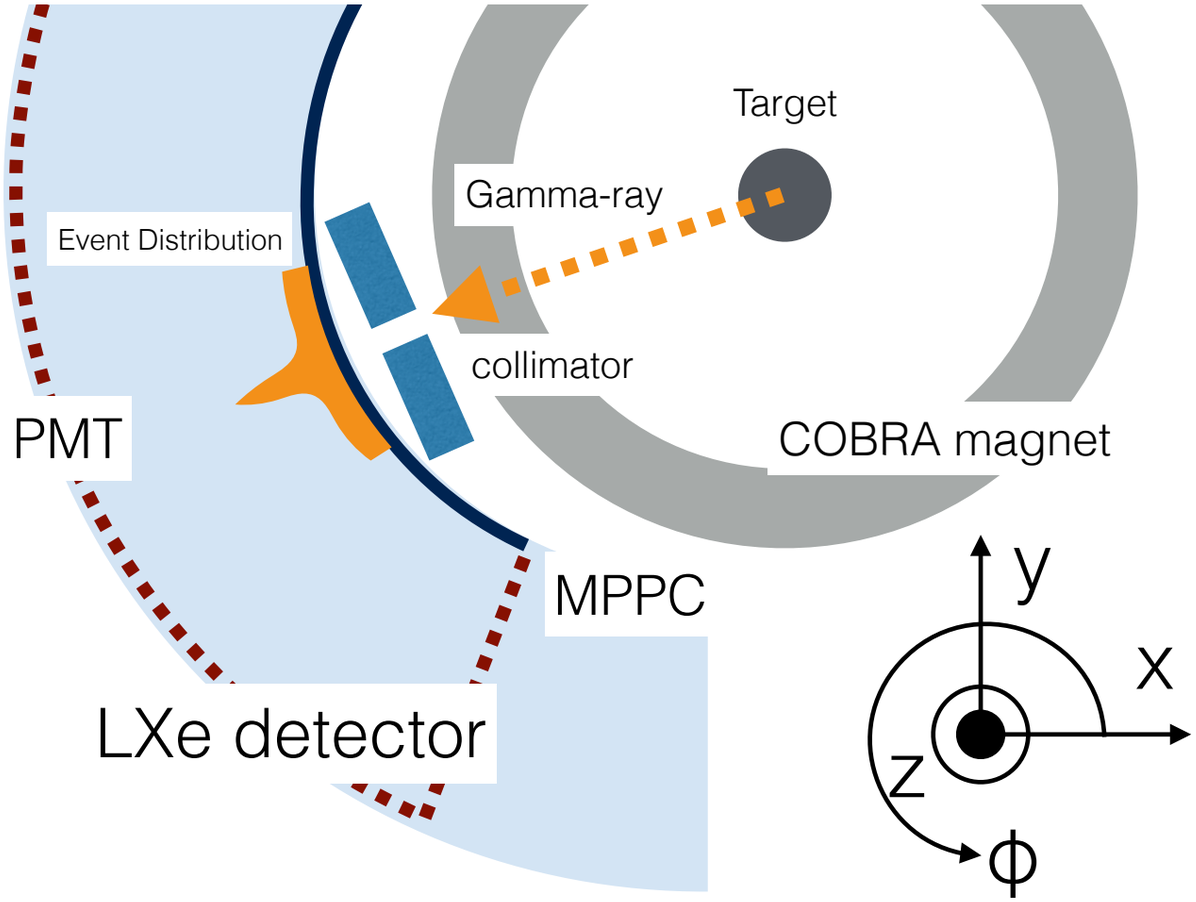
Liquid Xenon Detector Upgrade

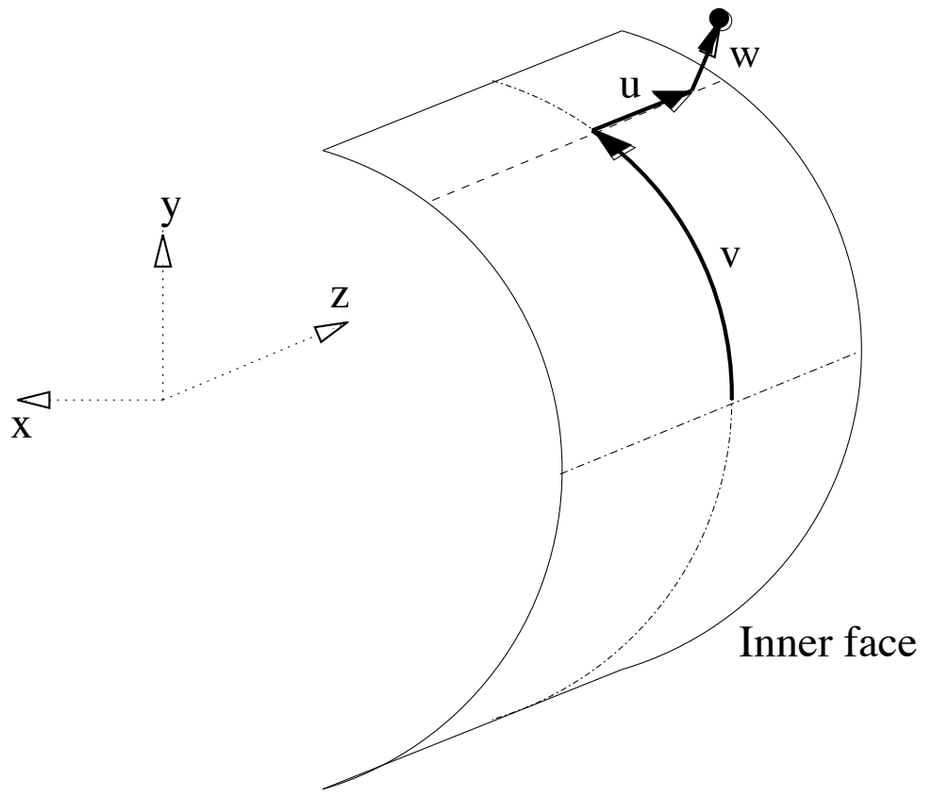




- We have replaced 216 2-inch PMTs on the γ-entrance face with 4092 12×12 mm^2 VUV-MPPCs.
  - High granularity & uniform readout
    - **Position resolution: 5 mm → 2.5 mm**
    - Energy resolution: 2% → 1%
  - Less material of the entrance face
    - Better detection efficiency

Principle of Evaluation





XEC Coordinate

$$\underline{\sigma^2} \sim \underline{\sigma_{hit}^2} + \underline{\sigma_{rec}^2}$$

Peak width — width of hit distribution — resolution

- Goal: evaluate the position resolution.
- The position resolution can be estimated using peaks of the reconstructed position distribution of collimated gamma-ray.

First Measurement in 2017 - Set up

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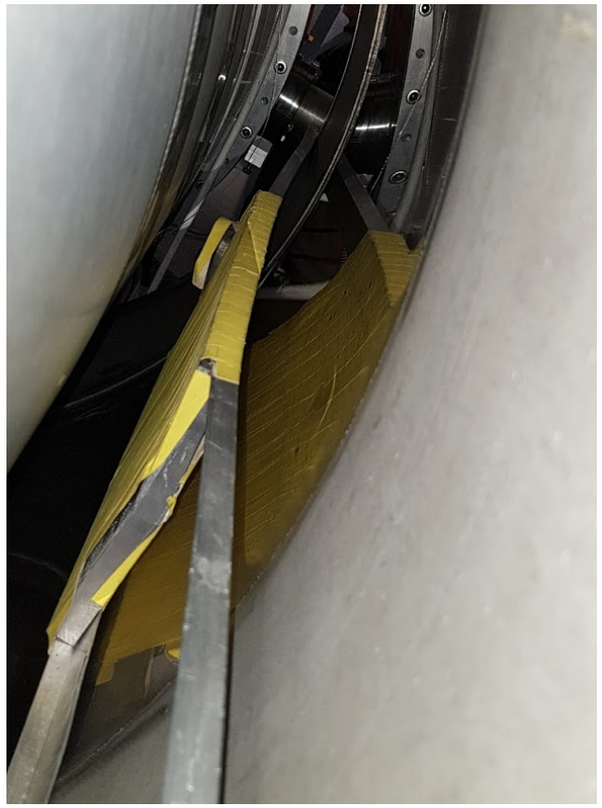
Installed collimator (v direction)

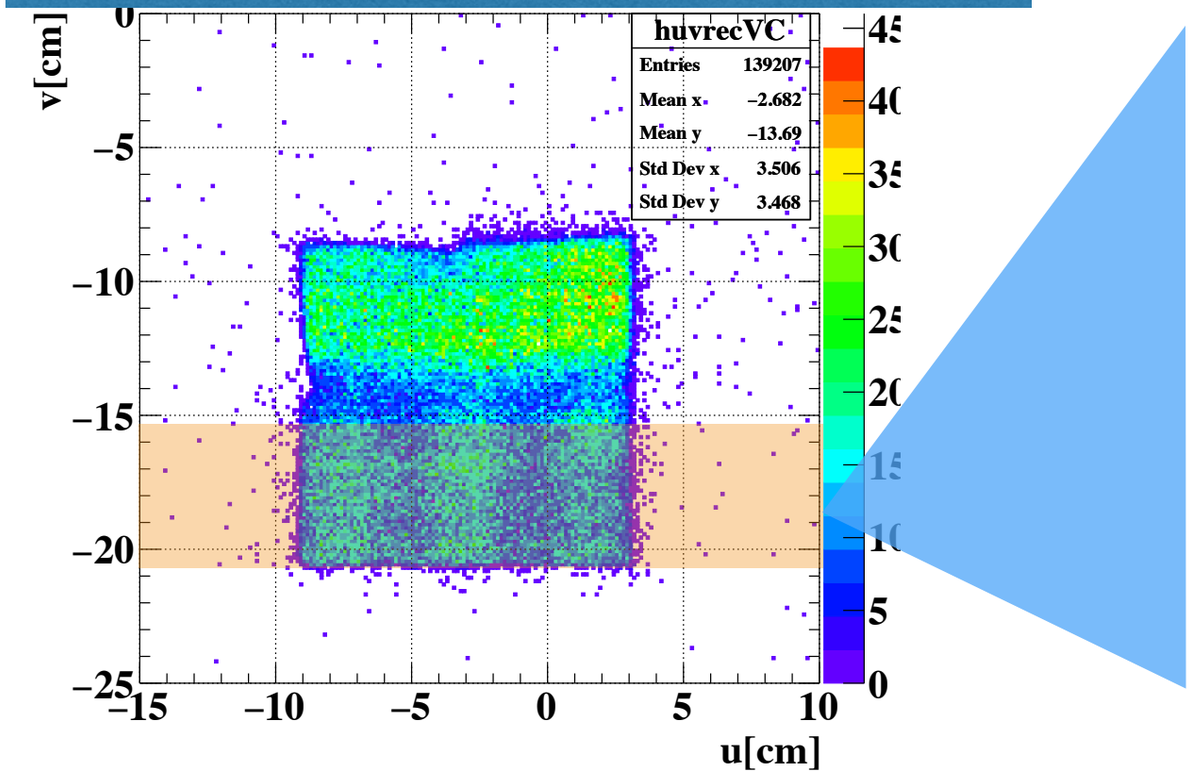


Collimator (u direction)

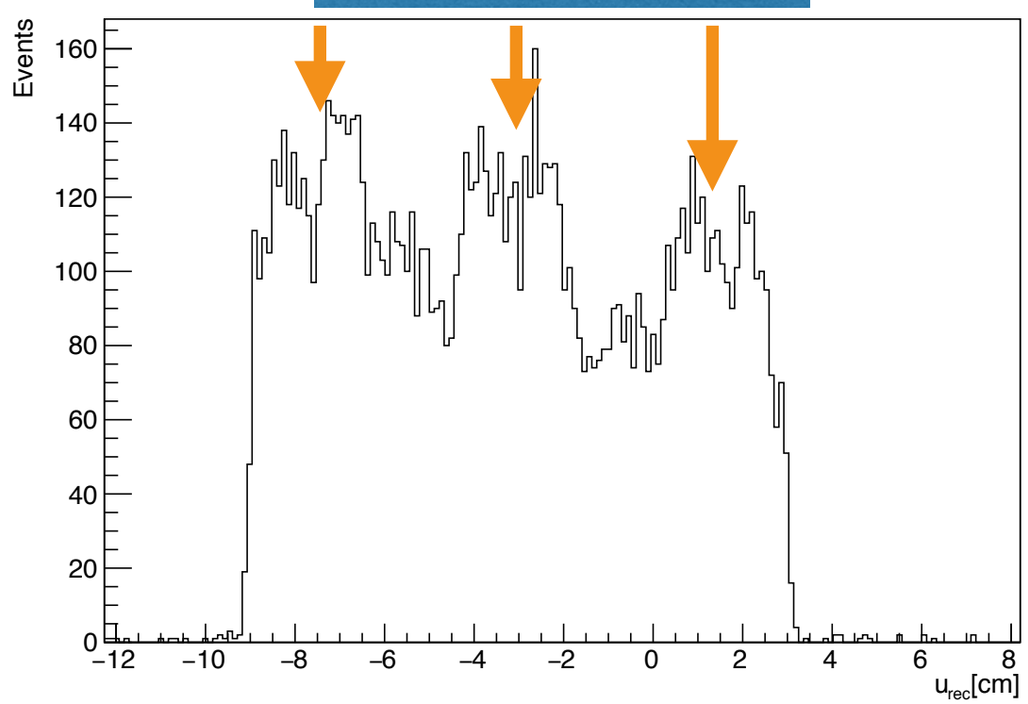
- We tried to estimate the resolution using BG gamma-ray from muon decay.
- We reused MEG lead collimators.
  - Along with their support structure.

First Measurement in 2017 - Result

Reconstructed position in uv plane



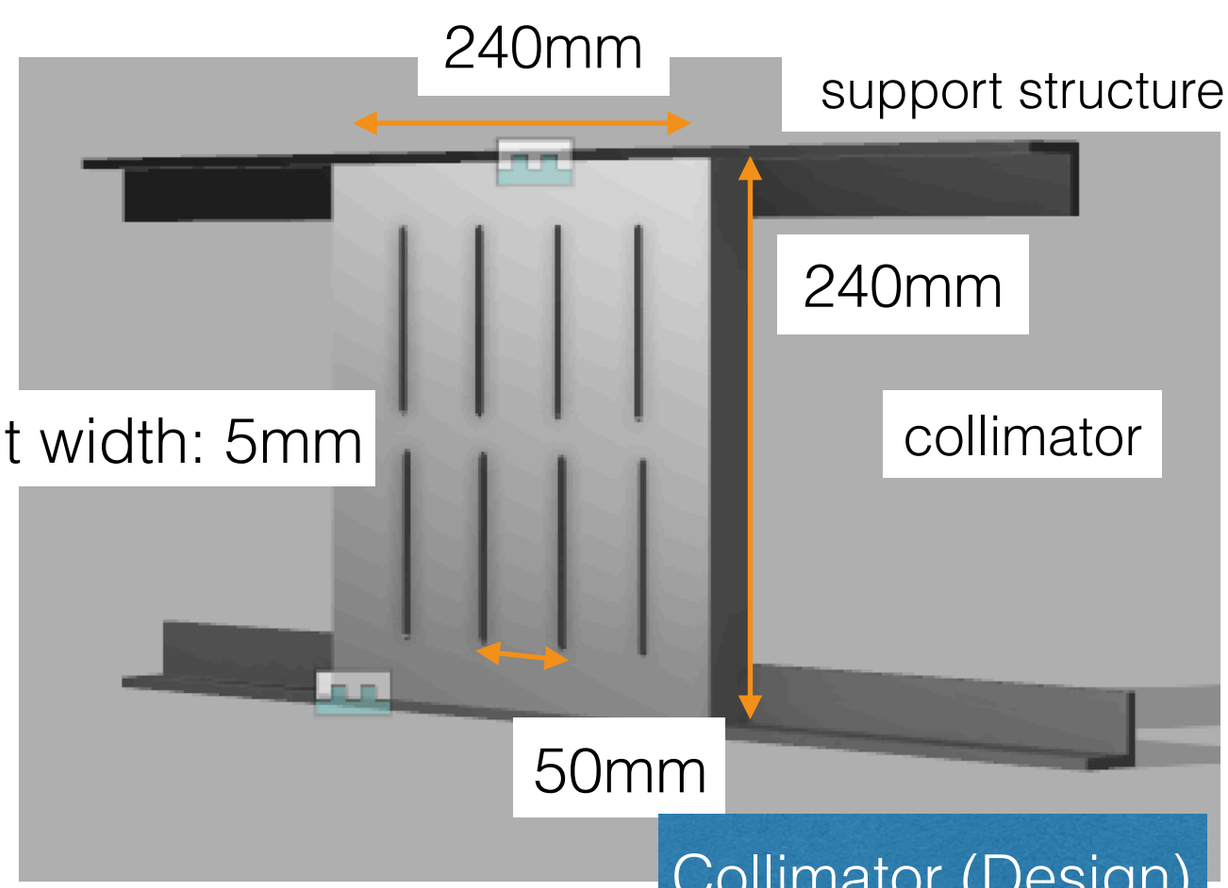
Reconstructed u



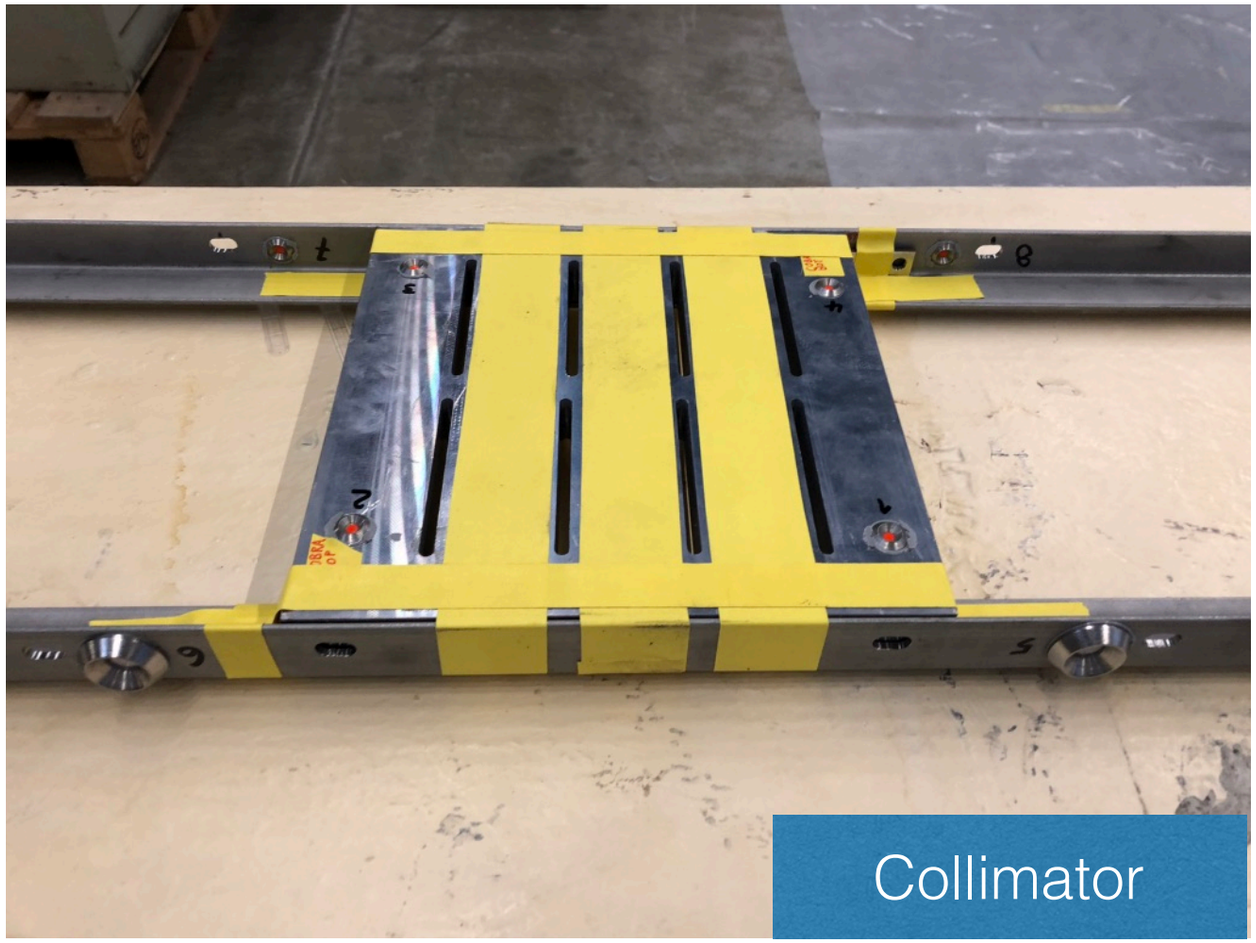
- Vague position distribution.
  - **The slit of the collimator was too wide.**
  - The spread of the vertex of gamma-ray was too wide(a few cm).
- Furthermore, following issues make it difficult to compare data with MC.
  - **Neither detector nor collimator were aligned.**
  - Support structure for the collimator was not robust enough.

We needed to optimize the collimator and align it.

Redesign of collimator



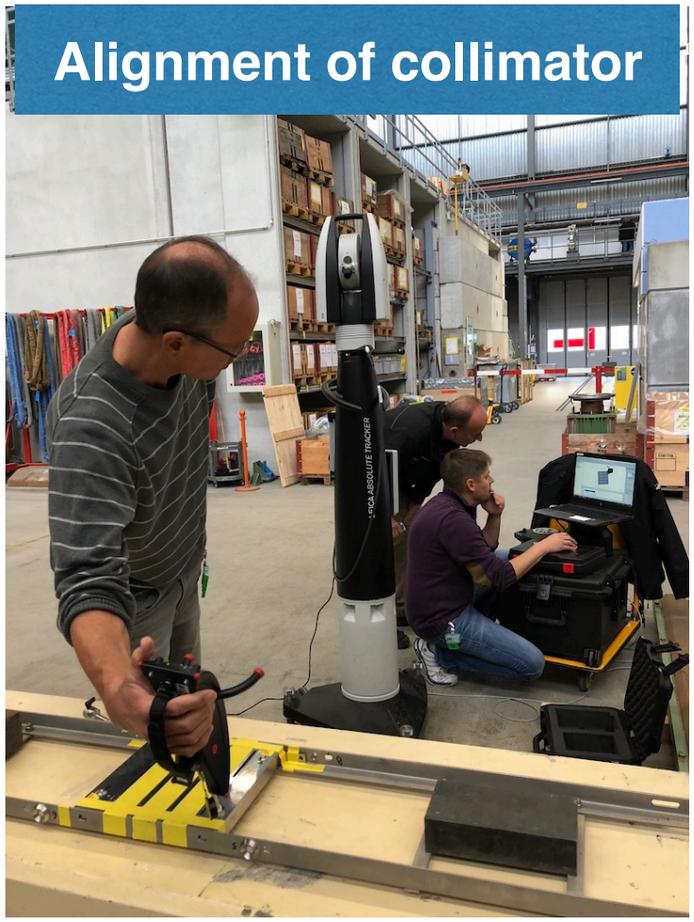
Collimator (Design)


Collimator

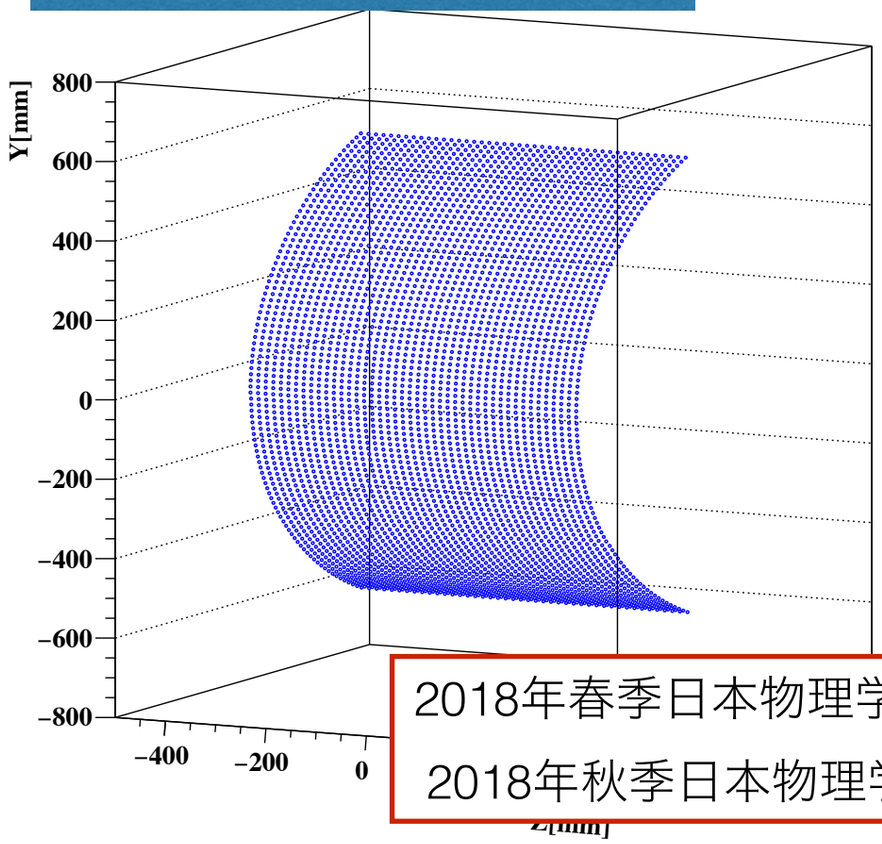
- A new collimator with narrow slits was produced.
  - Slit width: 10mm→5mm: narrow peak
  - Thickness: 18mm→25mm: better S/N
- Rigid support structure was produced.
  - Supports 15kg lead collimator with little deformation.

Alignment of collimator & detector

Alignment of collimator



Alignment of MPPCs



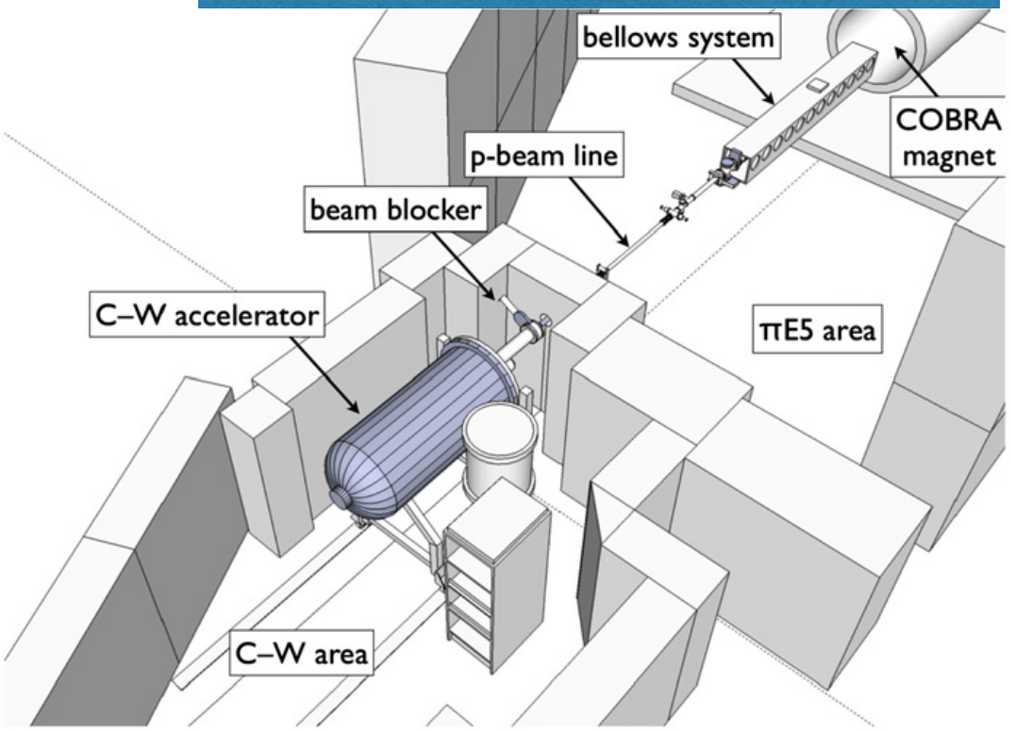
2018年春季日本物理学会 25aK206-03

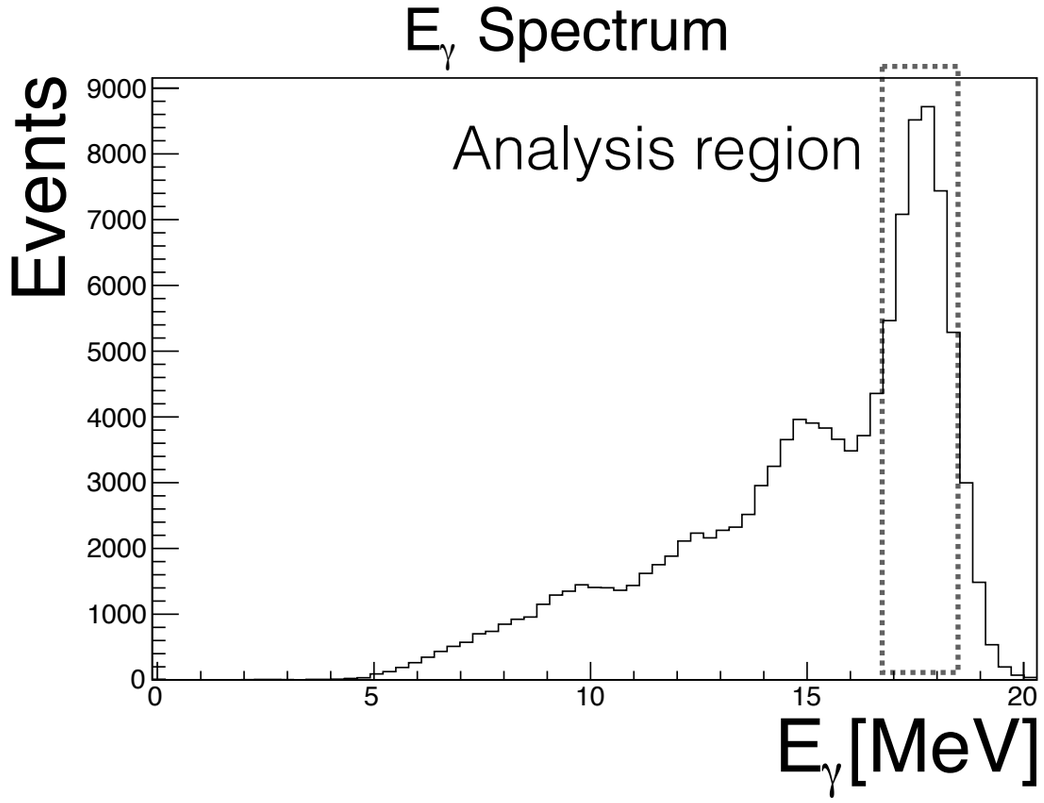
2018年秋季日本物理学会 16aS41-07

- Collimator is precisely surveyed after the installation by laser tracker.
  - Precision: ~a few 10um.
- The position of MPPCs was measured and transformed considering the position of the detector.
  - Precision: <500um.
- The measured geometry is taken into account in MC simulation.

Measurement in 2018

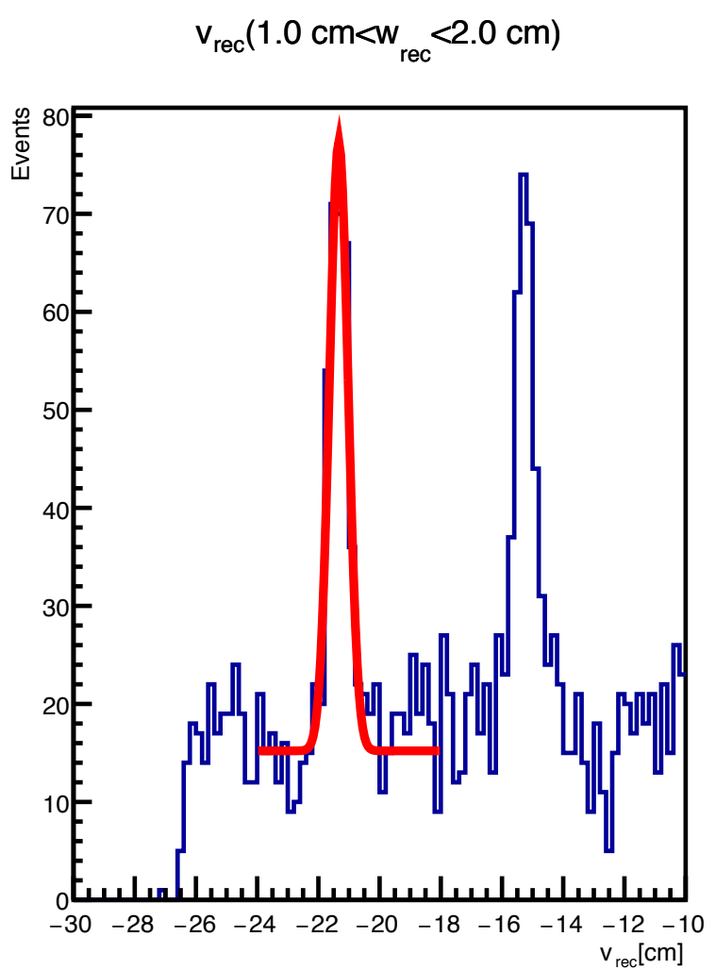
Cockcroft-Walton beamline

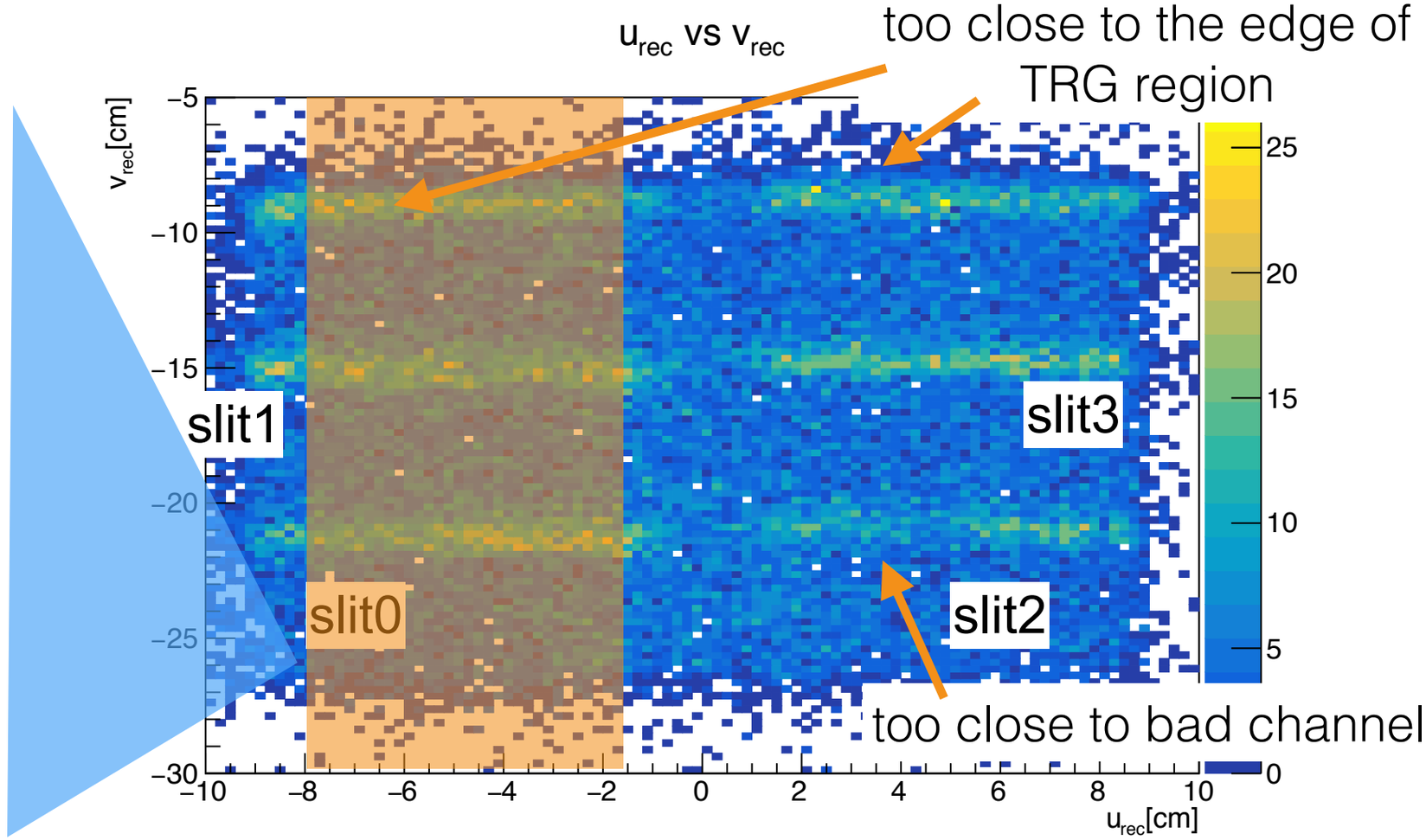




- Gamma-ray source: 17.6 MeV from $^{7}_{3}\mathrm{Li}(\mathrm{p},\gamma)^{8}_{4}\mathrm{Be}$
  - Proton beam from Cockcroft-Walton accelerator.
  - Target: $\mathrm{Li_2B_4O_7}$
  - Beam vertex spread <1mm (2017: a few cm)
- Data taking : ~3 days in pre-engineering run.

Position Distribution

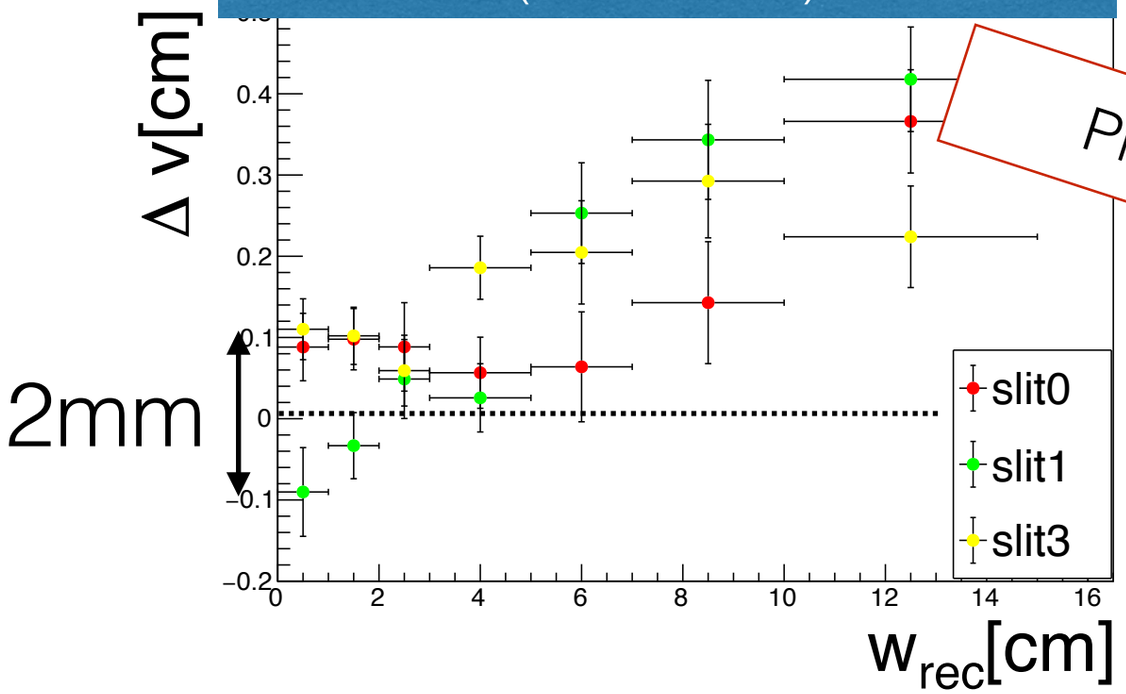


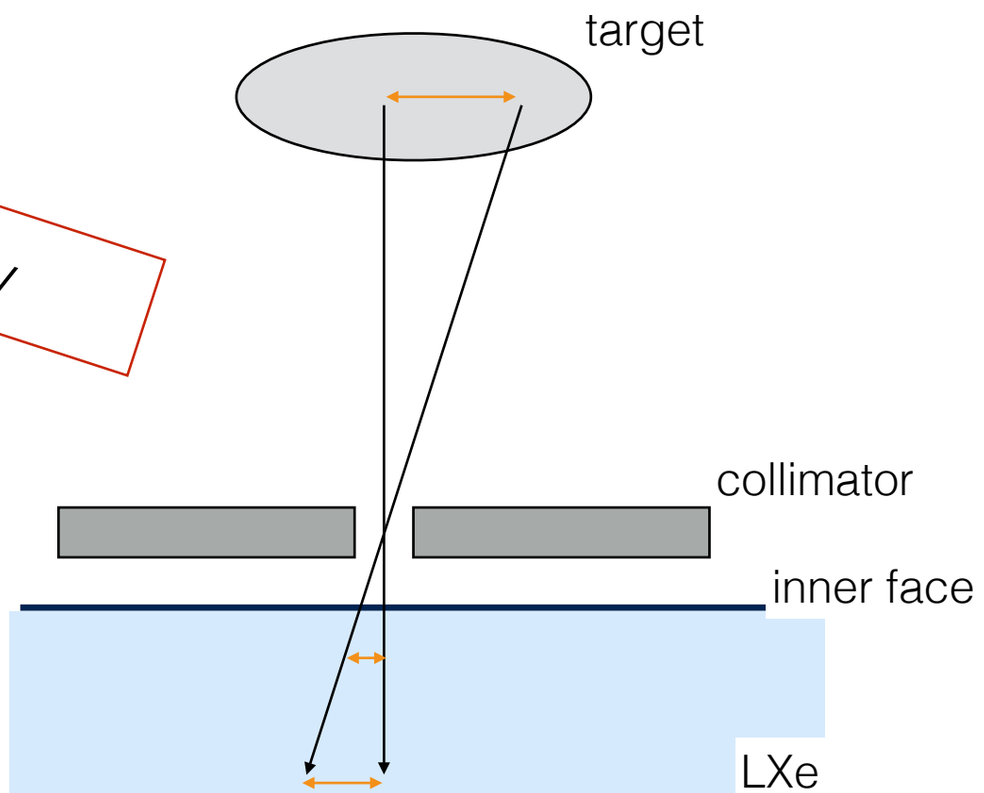


- Sharp position distribution was successfully observed.
  - **Narrow peak width & Higher S/N**
- Peaks are fitted with constant + Gaussian.
  - **Position & width** are compared with MC values.

Peak Position

Deviation between data and MC
(v direction)

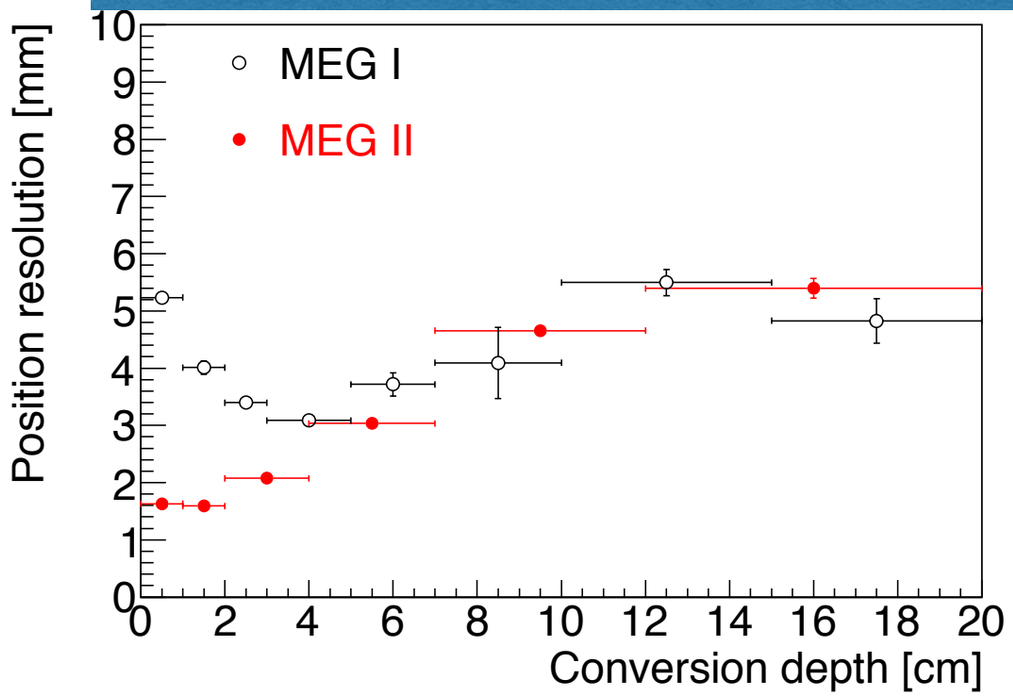




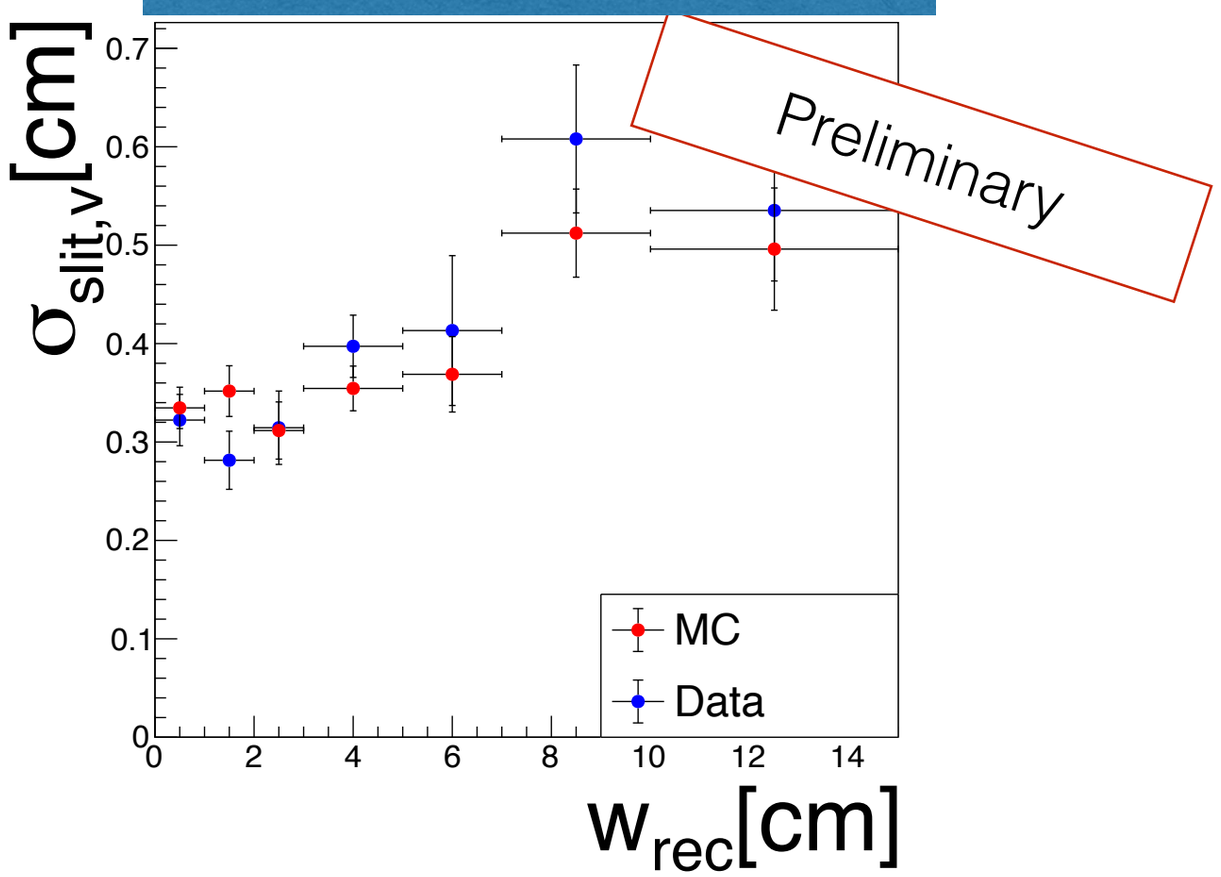
- Depth-dependent deviation between data and MC
  - Mis-alignment of gamma-ray vertex position @ target?
    - The collimator and the detector are aligned to an accuracy of <500um.
  - Bias of position reconstruction
- Further investigation is planned.

Peak Width

Position Resolution(Simulation)



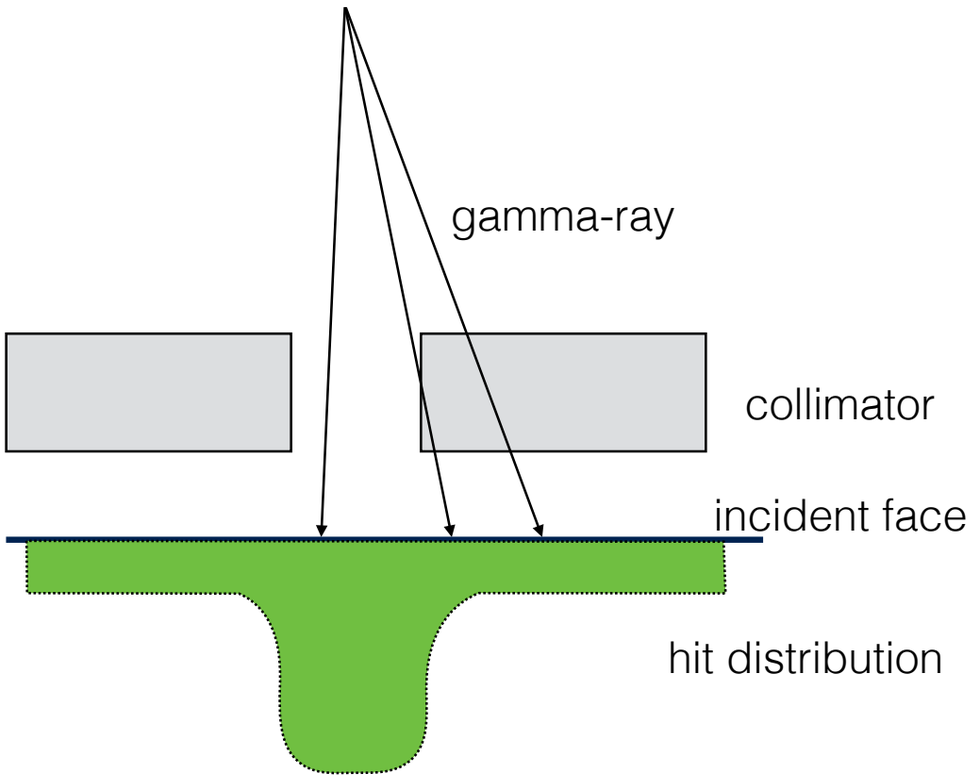
Peak width in v vs depth



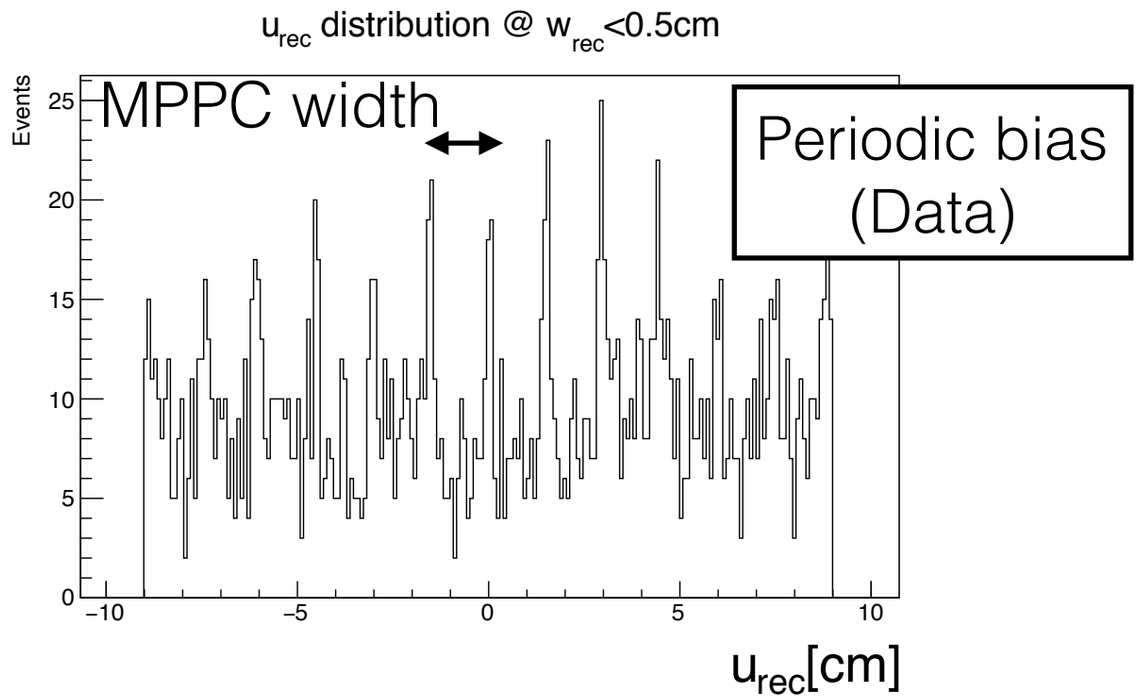
- The position resolution should be improved especially at shallow region(depth<4cm).
- Peak width in data has similar depth dependence to that in MC as expected.
  - However, we have several sources of systematic uncertainty.

Systematics to be considered

Hit distribution of collimated gamma-ray



Reconstructed u at shallow region(w<5mm)



- There are several sources of systematic uncertainty.
  - Hit distribution may not be Gaussian-shaped.
  - Bias of reconstructed position.
  - Uncertainty of beam vertex position & spread.

Summary

- MEG II experiment will search for **μ→eγ** down to Br(μ→eγ)~6×10^{-14}.
- Expected gamma-ray position resolution is 2.5 mm.
- We improved the set up of the position resolution measurement.
- At the first measurement in 2017, several issues were found.
  - Vague position distribution.
  - Alignment of collimator and detector.
- In 2018, these issues were solved.
  - High contrast position distribution was successfully observed.
- The evaluation of position resolution is in progress.
  - The estimation of systematic errors.