MEG II実験2021データを用いた $\mu \to e\gamma$崩壊探索の状況 - ガンマ線再構成のまとめ -

日本物理学会
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23pT1-1

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The University of Tokyo

ICEPP The University of Tokyo

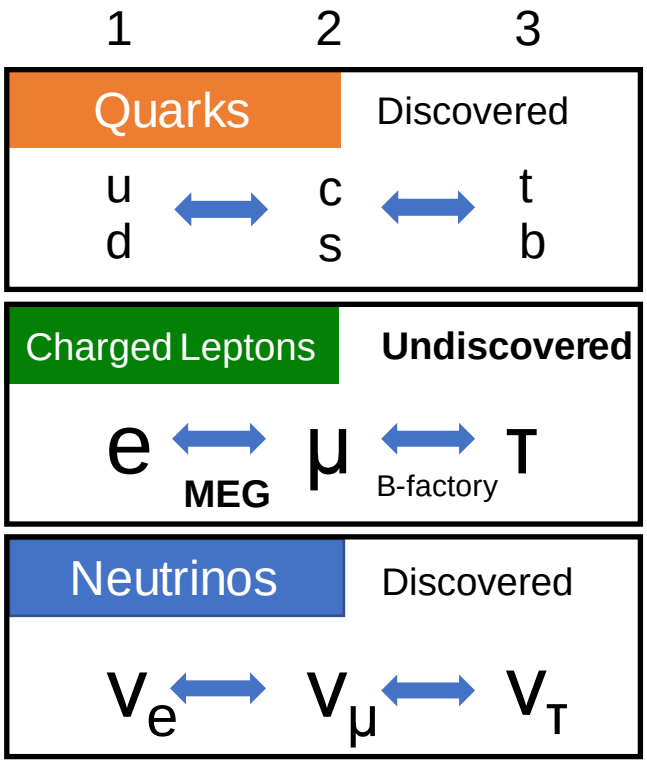
THE UNIVERSITY OF TOKYO

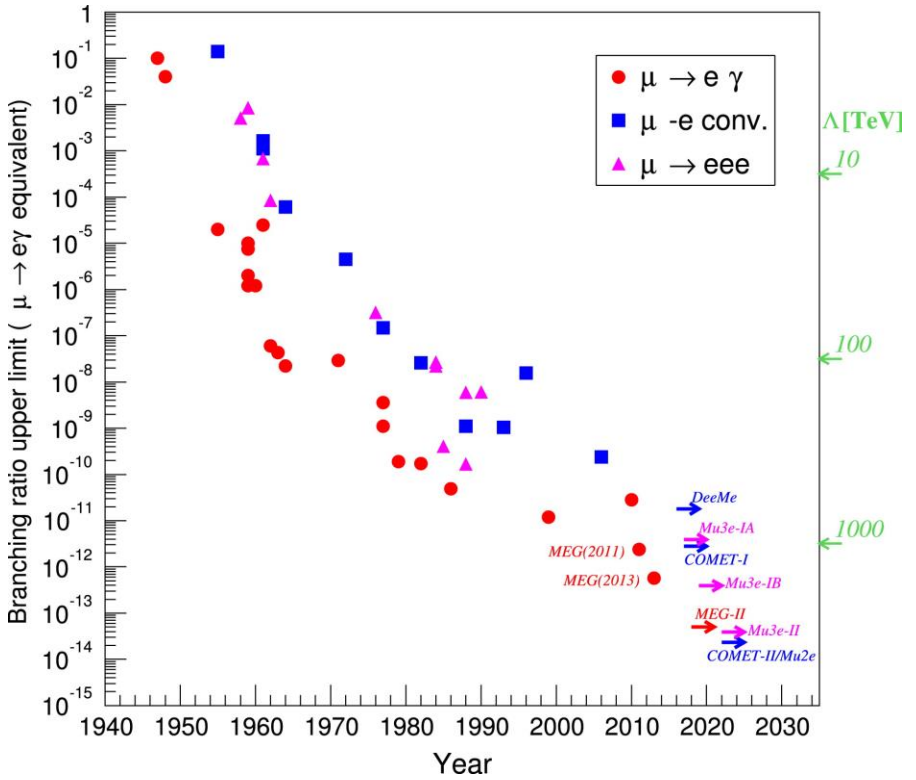
Core-to-Core Program

Outline

- Introduction
  - MEG II experiment
  - Liquid Xenon gamma-ray detector
  - RUN 2021
  - Gamma-ray analysis
- Analysis of physics dataset
  - Pileup analysis
  - Event categorization
  - Analysis efficiency
  - Uniformity
- Summary & Prospects

Charged Lepton Flavor Violation (cLFV)

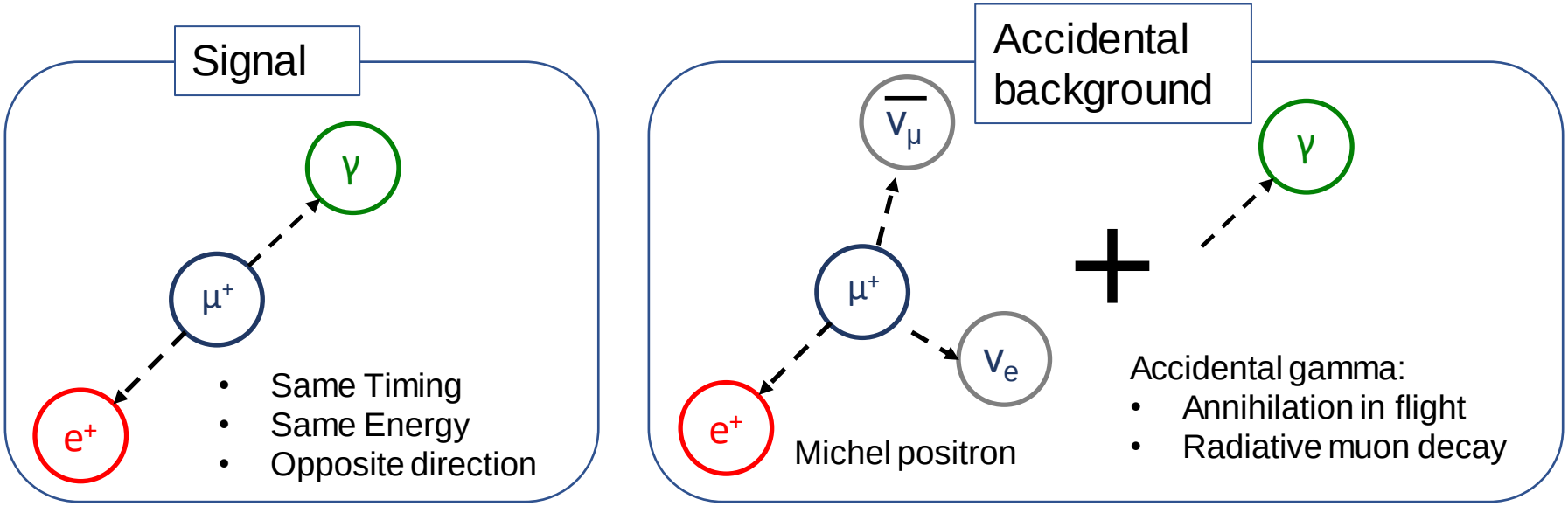




"An Experimental Review of Charged Lepton Flavor Violation in Muon Channel ", W. Ootani

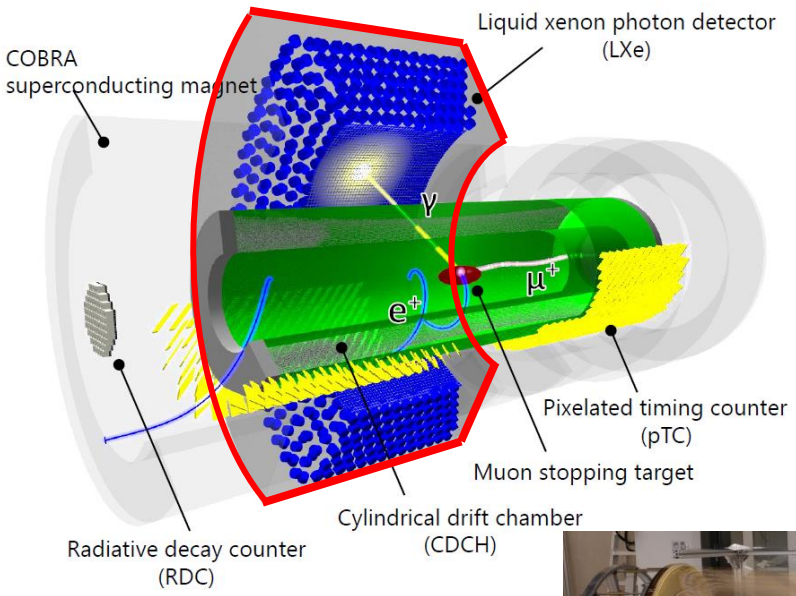
- Flavor mixing is not observed only for charged leptons.
- cLFV is strongly suppressed in SM + ν oscillation ($Br(\mu \to e\gamma) \sim 10^{-54}$).
- Large enhancement is predicted by new physics.
- High energy scale beyond LHC is indirectly accessible.

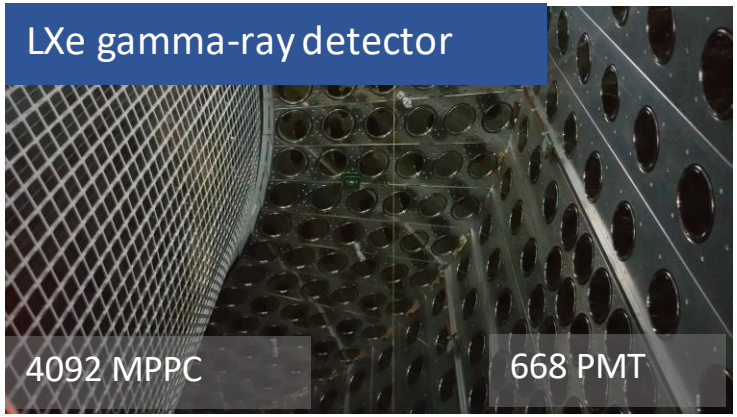
μ→eγ Search

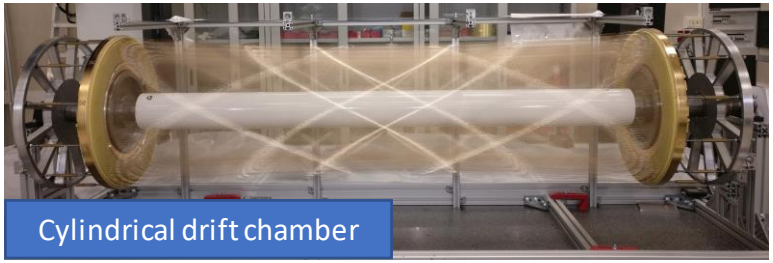


- $\mu^+ \to e^+\gamma$ decay: two-body decay
  - Signal: Coincidence & back-to-back & 52.8 MeV e^+ and γ
  - Main background: accidental
    - Positron from Michel decay + accidental gamma-ray.
  - Key: Precise measurement of e^+ and γ to discriminate signal and BG.
- Current limit: Br($\mu^+ \to e^+\gamma$) < 4.2×10^{-13}(90% C.L., MEG)

MEG II experiment



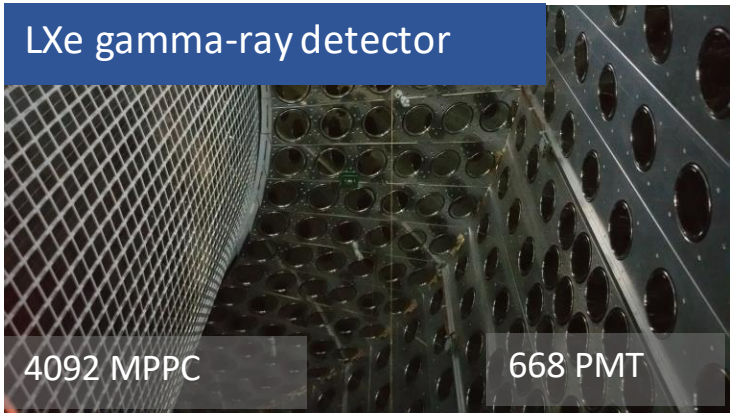




- MEG II started searching for $\mu^+ \to e^+\gamma$ decay in 2021.
  - Goal: Br(μ→eγ) ~ 6×10^{-14} (2021-202x).
  - Continuous high intensity muon beam ($\geq 3 \times 10^7 \mu/s$) @PSI, Switzerland
  - Detector upgrade (Resolution improvement for each detector)
- In 2021, the first physics dataset was collected for 1.5 months.
  - Beam rate: $3 - 5 \times 10^7$ /s.

Liquid Xenon detector upgrade

Performance	MEG	MEG II (measured)
Position resolution[mm]	5 – 6	2.5
Energy resolution[%]	2.4 / 1.7	**2.0 / 1.7**
Time resolution[ps]	62	**61**
Efficiency[%]	65	**67**



- The entrance face is covered with 4092 VUV-sensitive Multi-Pixel Photon Counters (MPPC).
  - Uniform light collection efficiency → Improve energy & position resolution.
  - Reduced material budget → Higher detection efficiency
- The performance is estimated with 55 MeV gamma rays from $\pi^0 \to \gamma\gamma$.
- In this talk, the status of the analysis for the physics dataset is presented.

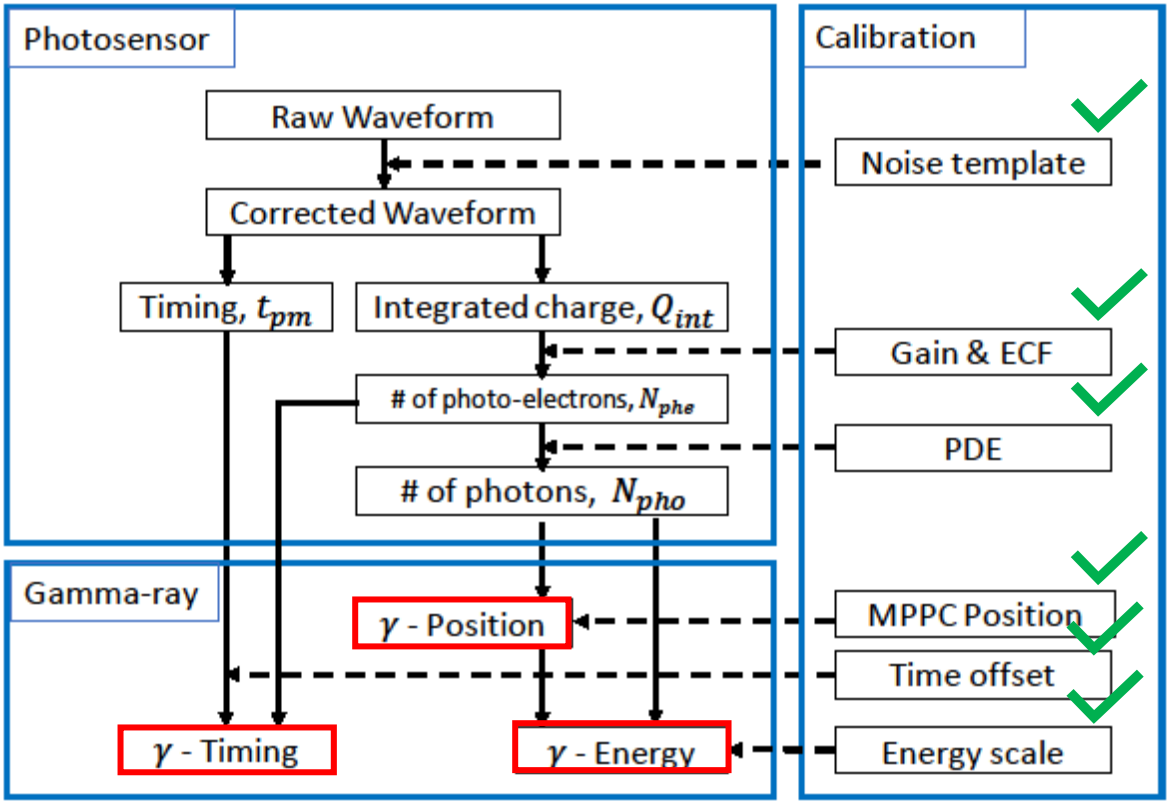
MEG II talks

- Analysis, summary
  - 23pT1-2 Oya
  - 23pT1-3 Uchiyama
- LXe detector
  - 23aT3-6 Matsushita
  - 23aT3-7 Ban
- Timing counter
  - 23aT3-2 Yonemoto
- RPC

- Beyond MEG II
  - 22aT3-4 Ikeda

Gamma-ray analysis

Reconstruction chain



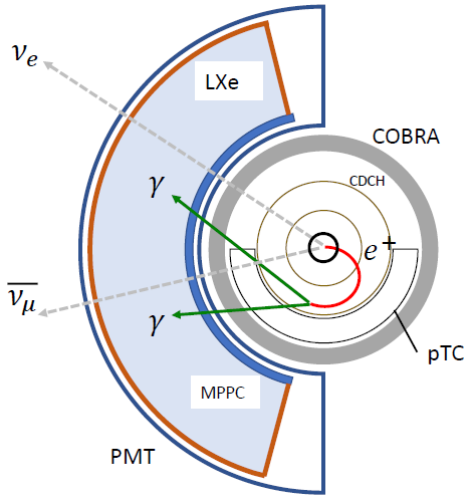
- The calibrations for the gamma-ray reconstruction are almost ready.
- One missing part: **pileup analysis**.
  - Reduce the background gamma-ray event rate.
  - Precise energy reconstruction under a high-intensity environment.

Calibration is ready. Pileup analysis is essential to analyze the physics data.

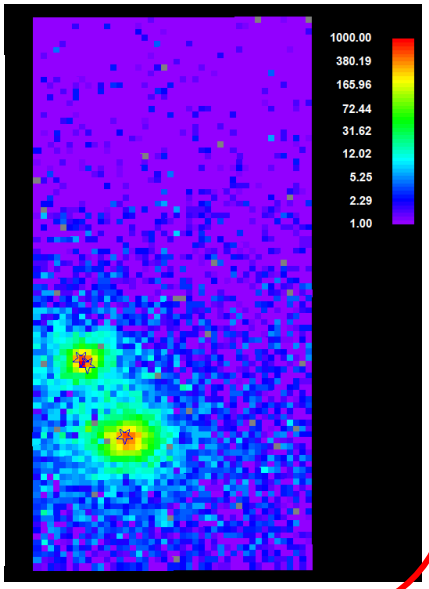
Pileup analysis

On-time pileup

AIF2γ event

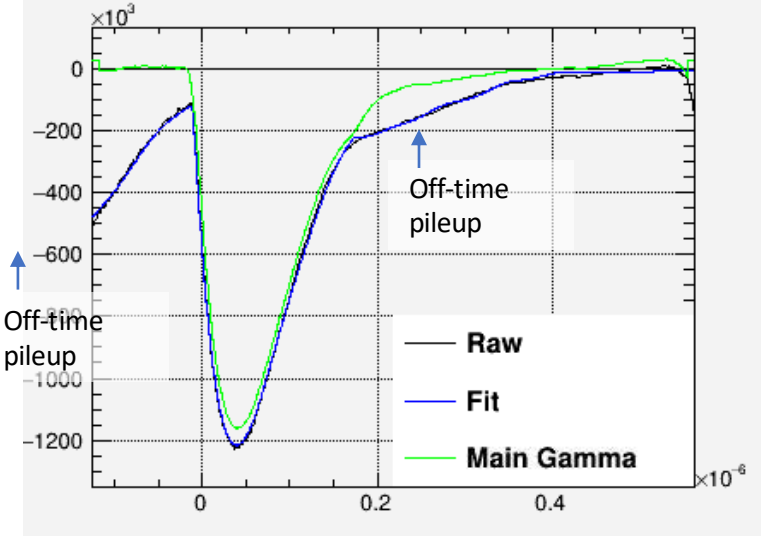


Light distribution (inner)



Off-time pileup

Summed waveform of MPPC in a pileup event



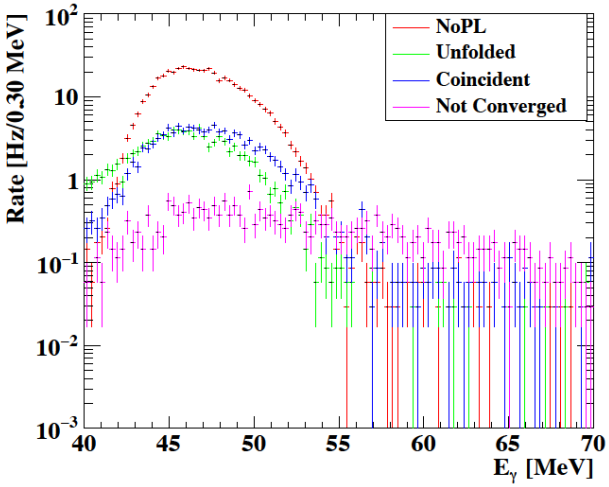
- Two types of pileup gamma-rays worsen the sensitivity.
  - On-time pileup gamma-ray: AIF2γ.
  - Off-time pileup gamma-ray: mainly RMD.
- Pileup analysis is a combination of
  - Peak search in the light distribution.
  - Template fit of MPPC and PMT summed waveform.
- The pileup analysis was tested with the data for the first time.

Event categorization

Category	Definition
NoPileup	No pileup found
Unfolded	Off-time pileup found + unfolded
Coincidence	On-time pileup found
NotConverged	Template fit not converged

Not used for the physics analysis

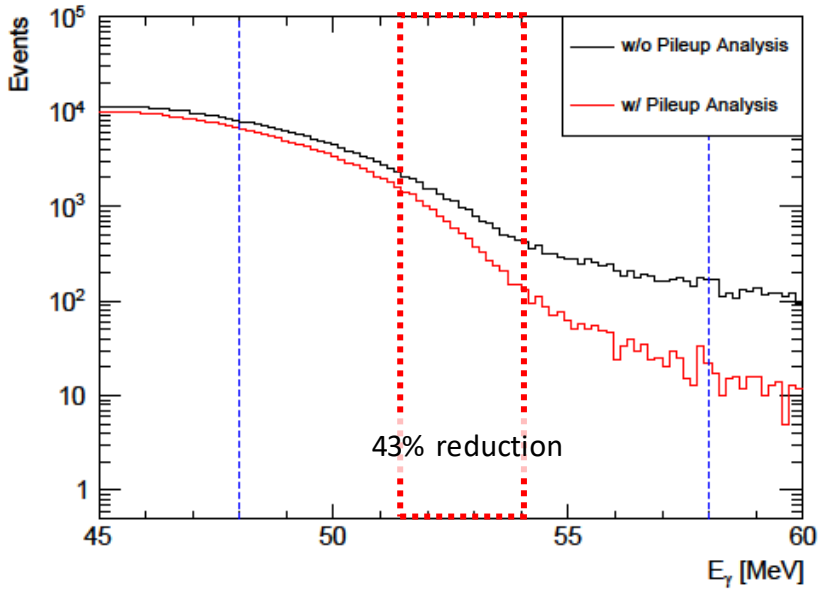
Energy spectrum of each category



- A gamma-ray event is categorized into four based on the analysis result.
- "Coincidence" and "NotConverged" events are **not** used for the physics analysis.
  - Coincidence: likely to be AIF2gamma events.
  - NotConverged: Off-time pileup in the analysis window.
- Event categorization is consistent with MC with 0.5% accuracy.

Background reduction

Energy spectrum of background gamma rays

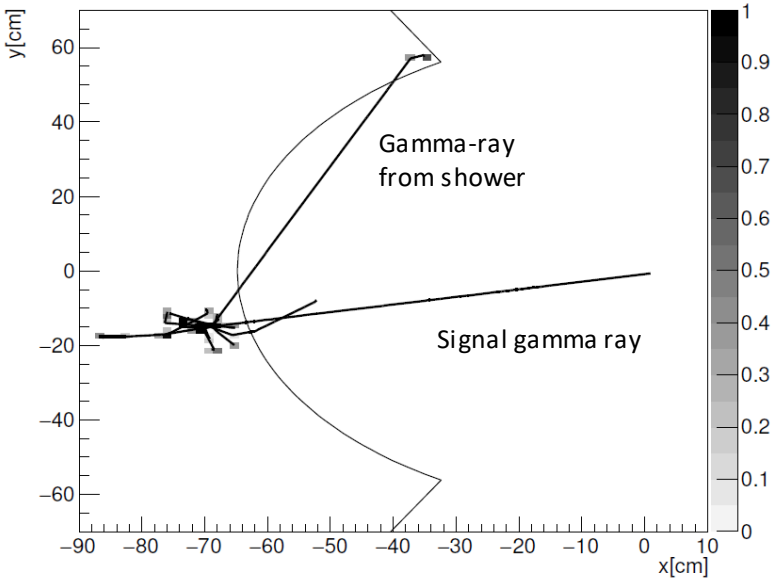


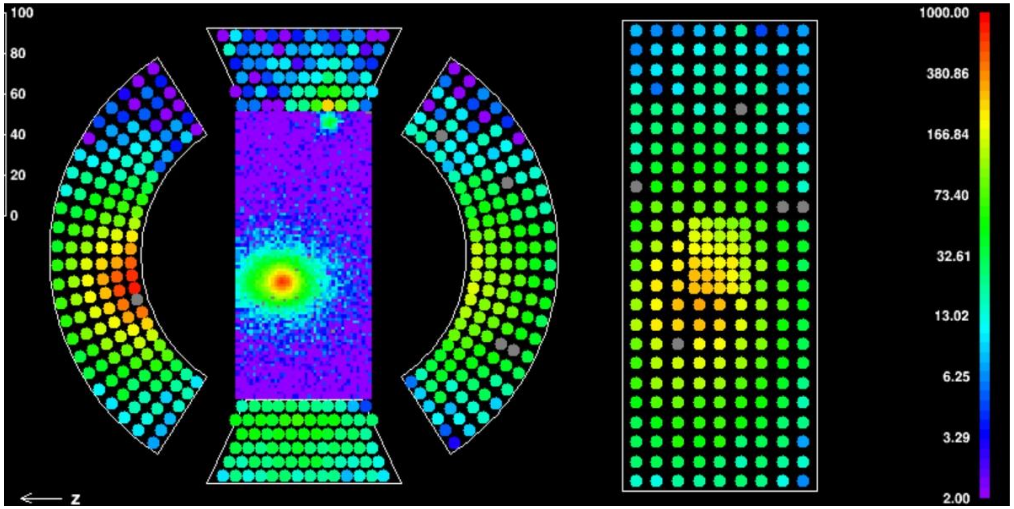
- The rate of the background gamma-ray events close to the signal energy is reduced by **43%**.
  - Energy range: [51.5 MeV, 54 MeV]
  - 51% in MC with low analysis threshold.

Significant reduction of background gamma-ray event rate is achieved.

Analysis efficiency

Energy deposit of a signal gamma ray with two inner peaks (side view)





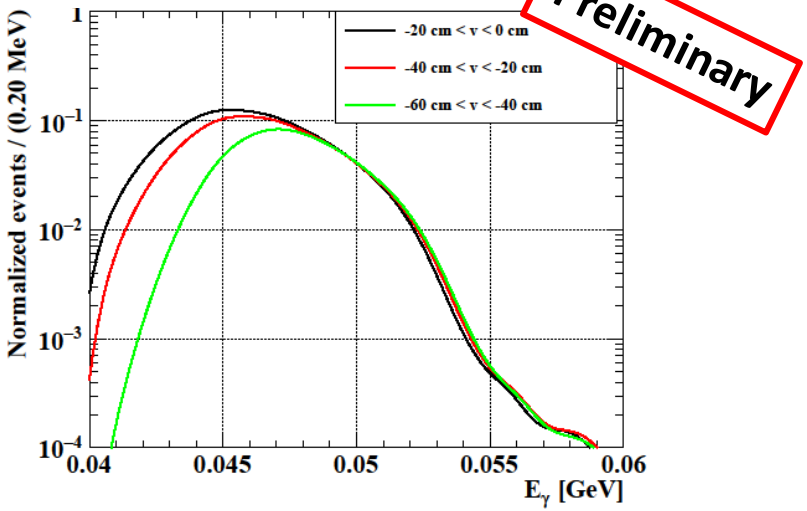
- Analysis efficiency is estimated by using signal gamma rays with pileup background gamma rays in MC.
- The analysis inefficiency is 6.5%.
  - 4.7% Coincidence : Signal gamma ray can have multiple peaks.
  - 1.4% NotConverged
  - 0.4% cosmic-ray rejection : Light distribution of deep gamma ray is similar to that of a cosmic ray.
- A study to improve the efficiency is in progress.

A good analysis efficiency of 93.5% is achieved.

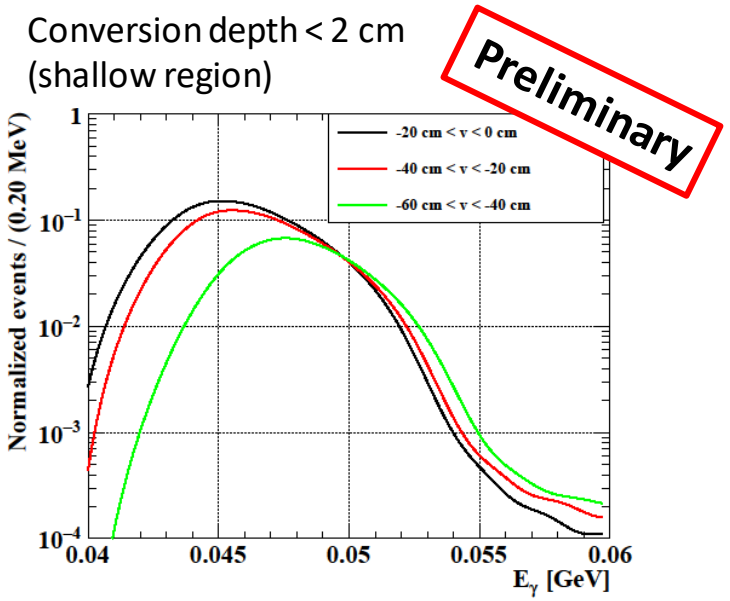
Uniformity

Energy spectrum of background gamma rays

Conversion depth > 2 cm
(deep region)



Conversion depth < 2 cm
(shallow region)

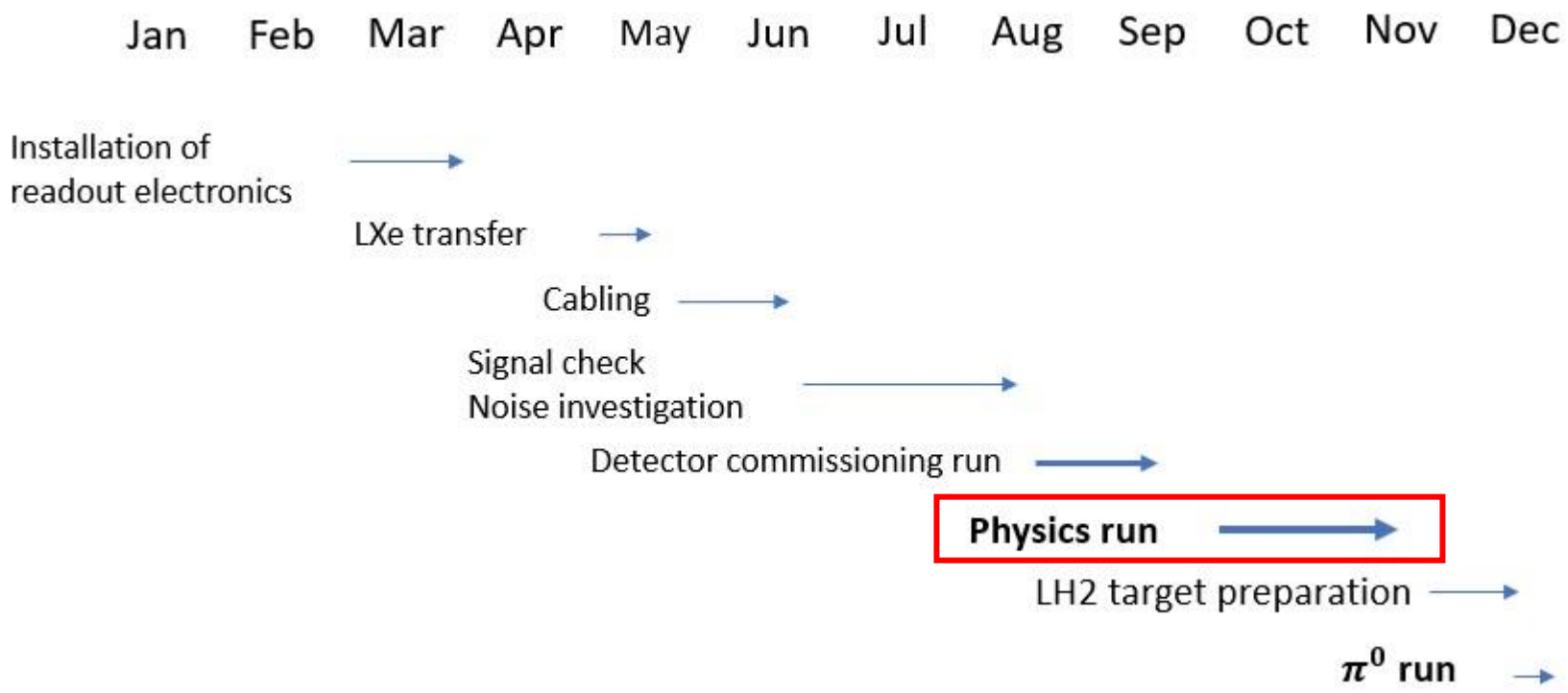


- Non-uniformity of the energy scale is corrected based on the energy peak of 55 MeV gamma ray.
- A large non-uniformity for shallow gamma-ray energy spectrum is found.
- We are checking the non-uniformity carefully.

Conclusion

- Pileup analysis for gamma-ray events under a high-intensity environment is developed.
- 43% reduction of background gamma ray event rate is achieved.
  - Comparable to MC (51%)
- The analysis efficiency is 93.5%
  - evaluated using signal gamma ray in MC.
  - Study to improve the efficiency is in progress.
- The non-uniformity of the energy spectrum is under investigation.

2021 Physics run



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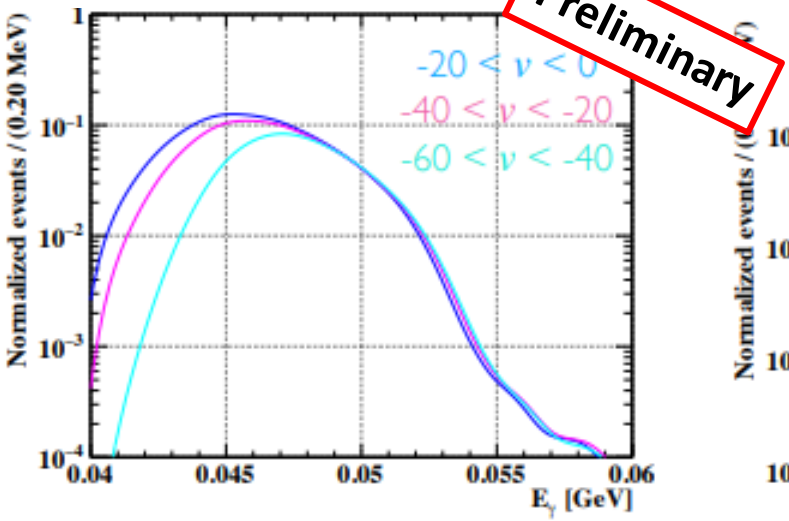

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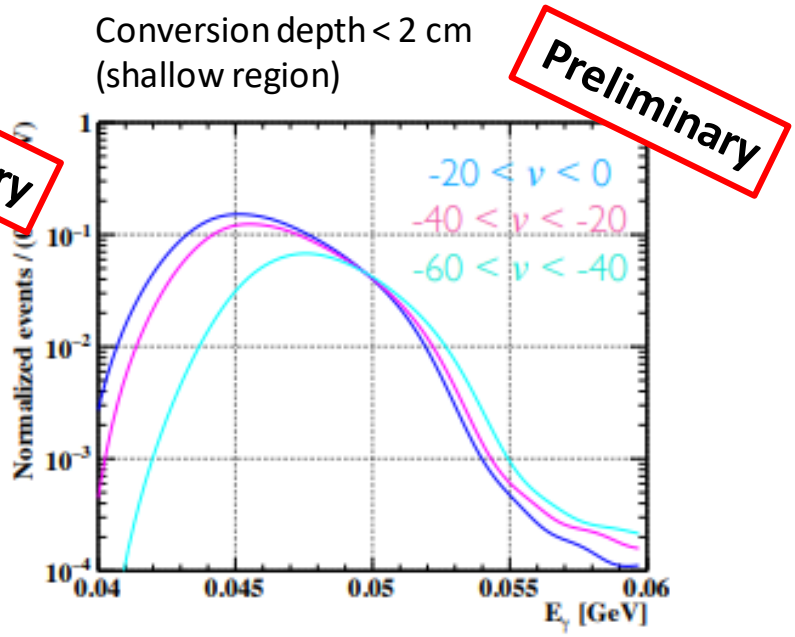

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