Core-to-Core Program

Commissioning of Radiative Decay Counter for MEG II Experiment in 2018

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On behalf of MEG II collaboration

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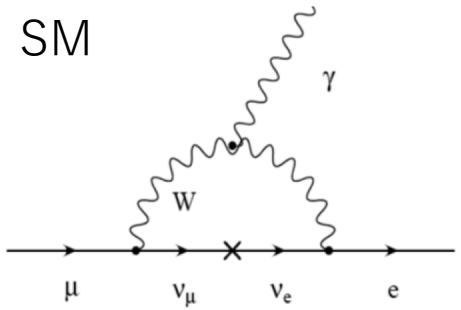
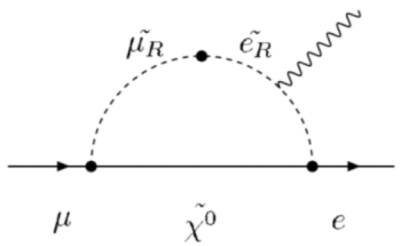
μ → e γ Search

- charged Lepton Flavor Violation (cLFV)
- **Good probe for new physics**
  - Standard Model : Br < 10^{-50}
  - New physics : Br ~ 10^{-12} - 10^{-14}

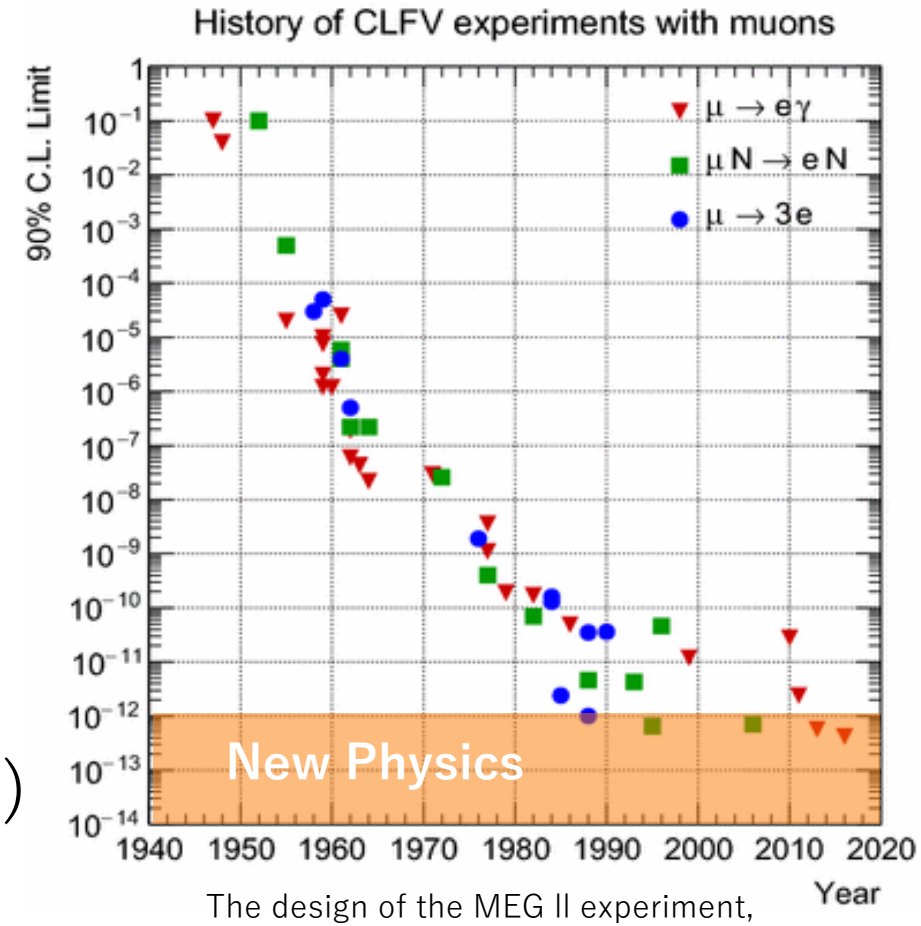
SM



New physics

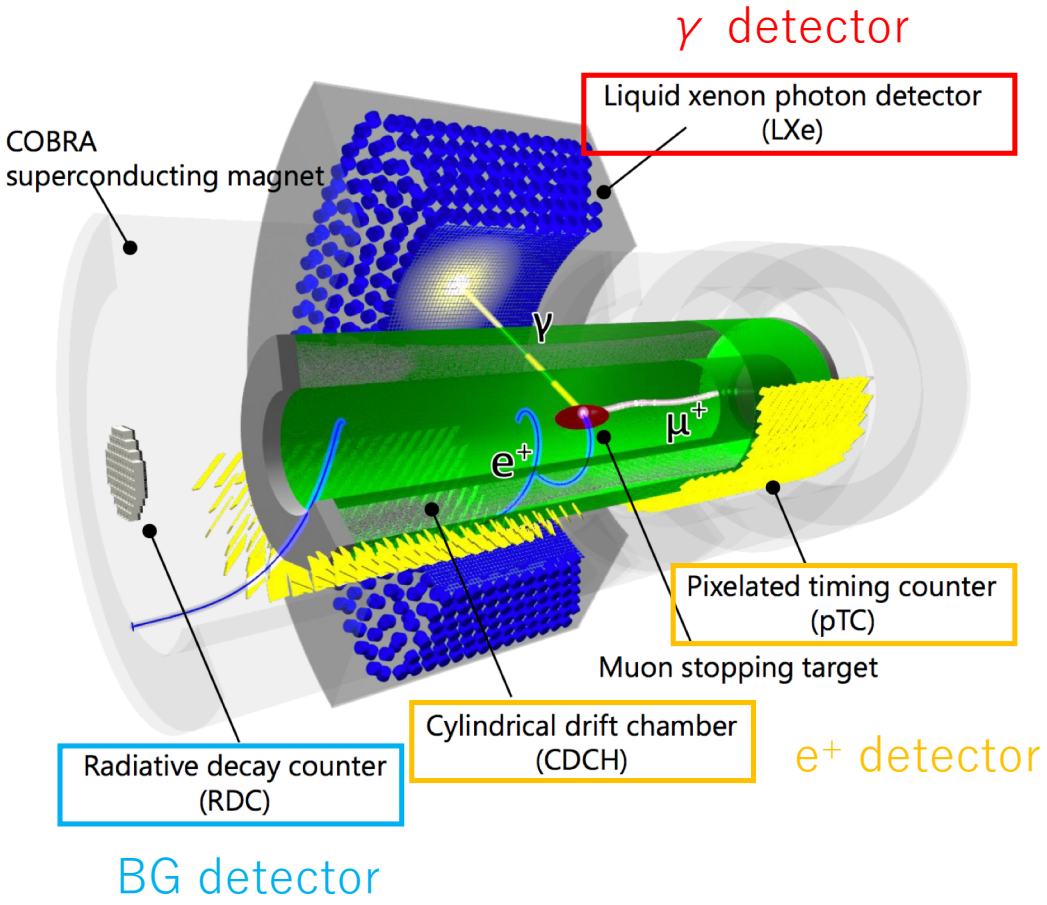


- The most stringent limit, 4.2 × 10^{-13} (90% C.L.) was given by MEG experiment



The design of the MEG II experiment, Eur. Phys. J. C (2018) 78: 380.

MEG II Experiment



Upgraded from MEG

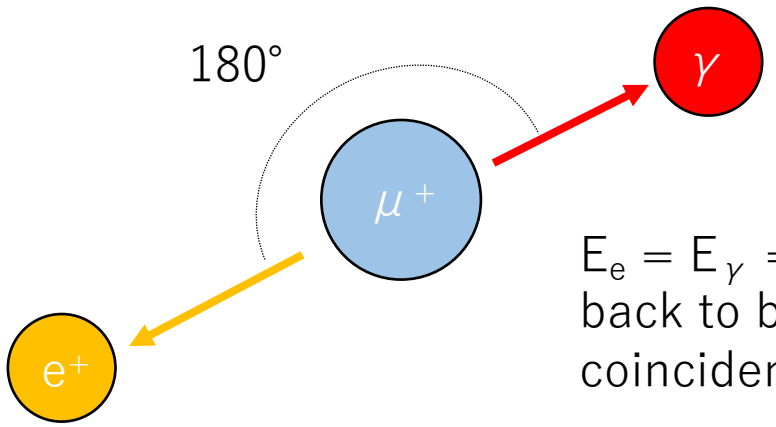
- μ^+ beam stopping rate
  3×10^7 μ^+ stops/s → 7×10^7 μ^+ stops/s
- Improved efficiency and resolution of each detector
- Installed a new detector for BG detection

Expected sensitivity :

5.3×10^{-13} → 6×10^{-14}

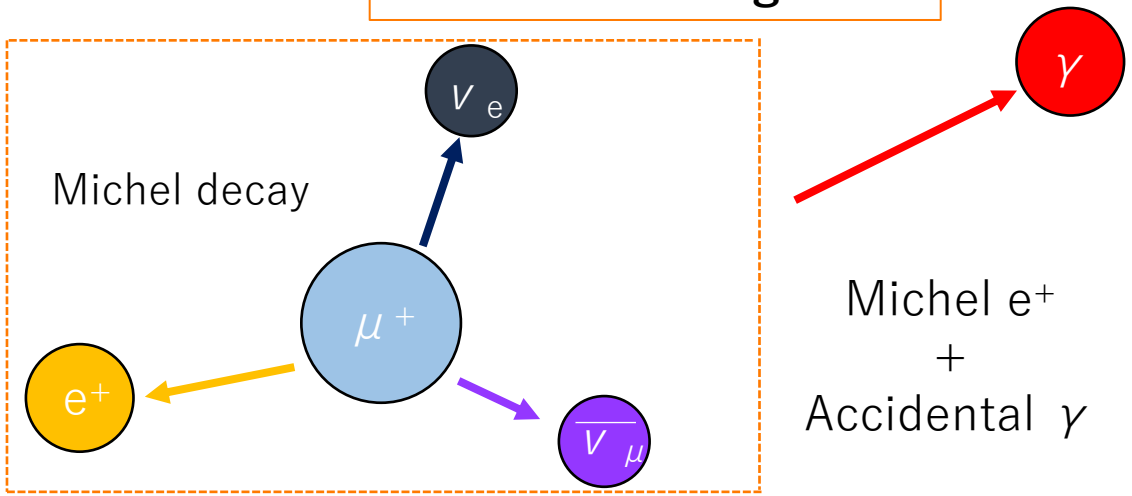
Signal & BG in MEG II

$\mu \rightarrow e\gamma$ signal



$E_e = E_\gamma = 52.8$ [MeV]
back to back
coincident in time

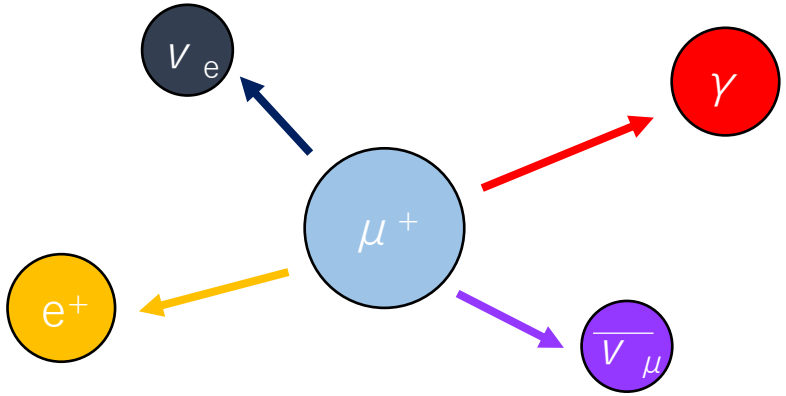
Dominant Background



Michel e^+
+
Accidental γ

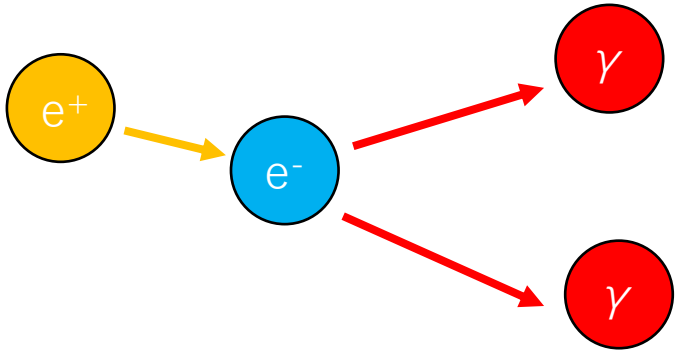
Sources of Accidental γ

Radiative Muon Decay(RMD)

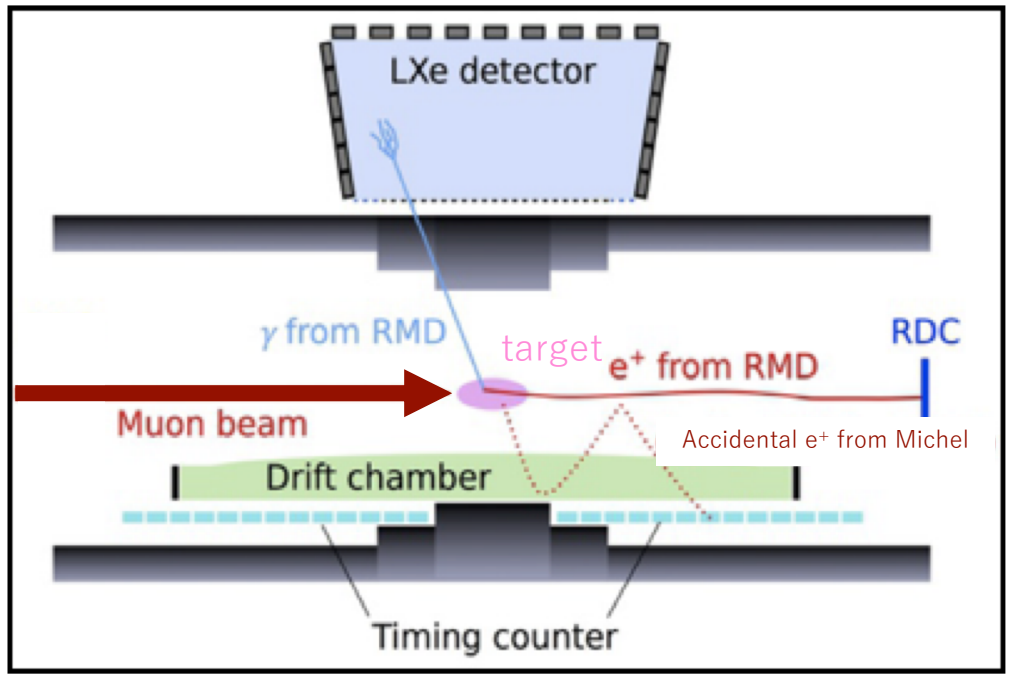


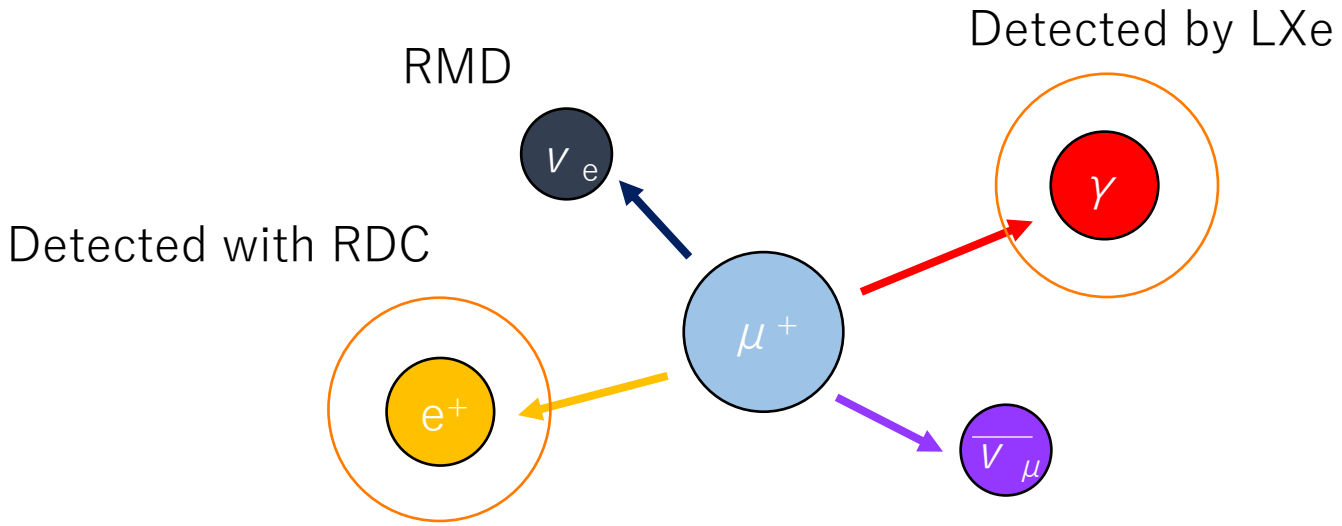
2 : 1
($E_\gamma > 48$ MeV)

Annihilation In Flight(AIF)



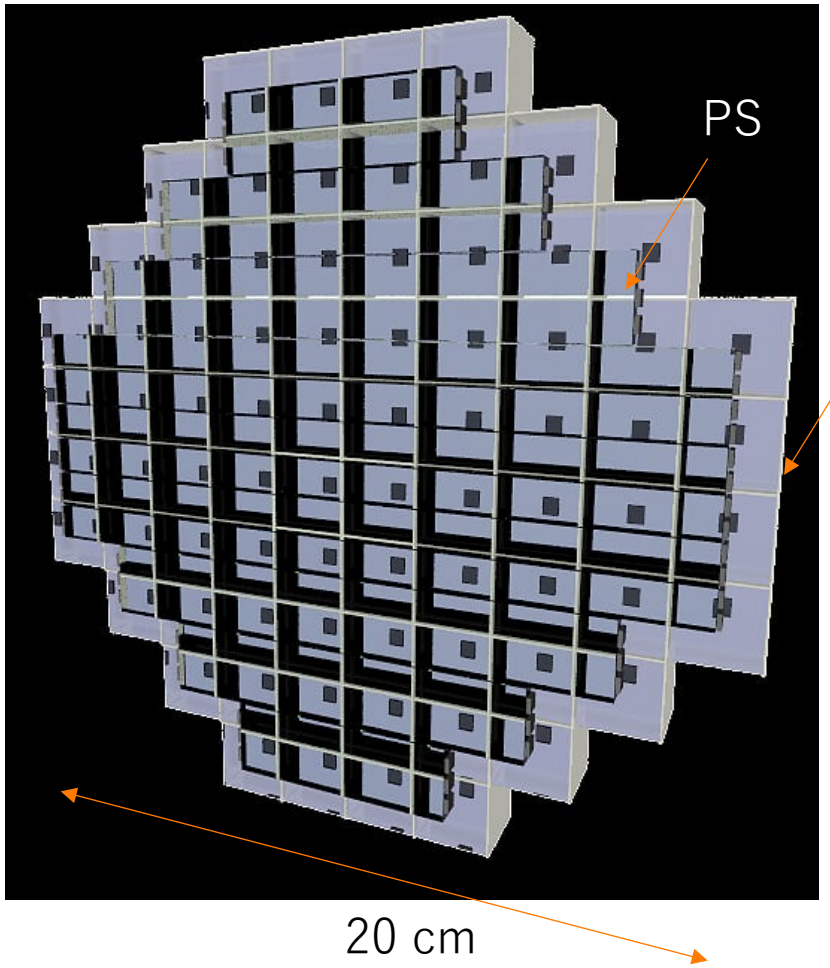
Radiative Decay Counter (RDC)



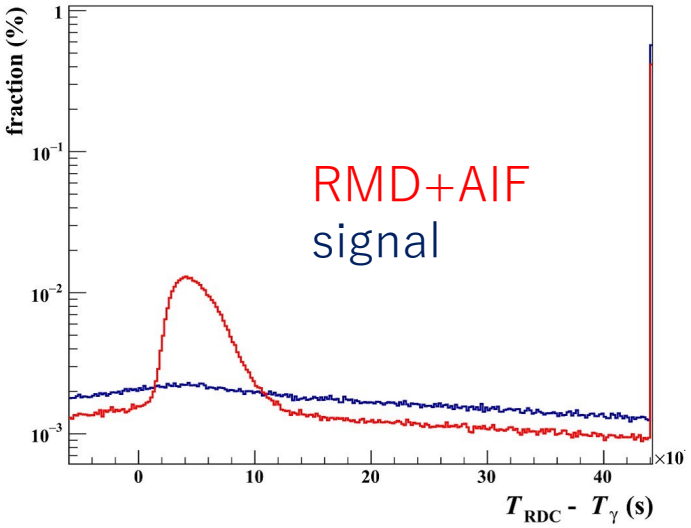


- Newly installed in MEG II
- Identify RMD events by detecting low energy e^+ deriving from RMD
  → time coincidence with γ detected by LXe

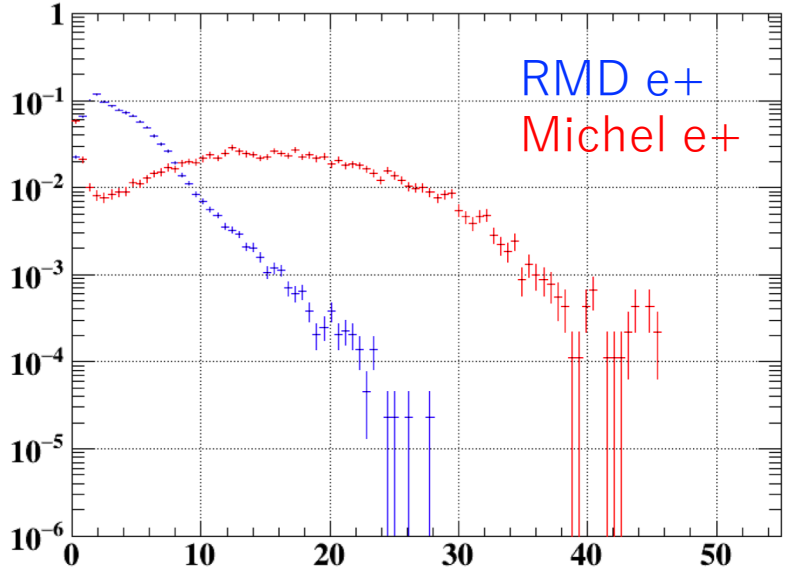
Downstream RDC



Timing difference of RDC e⁺ and LXe γ

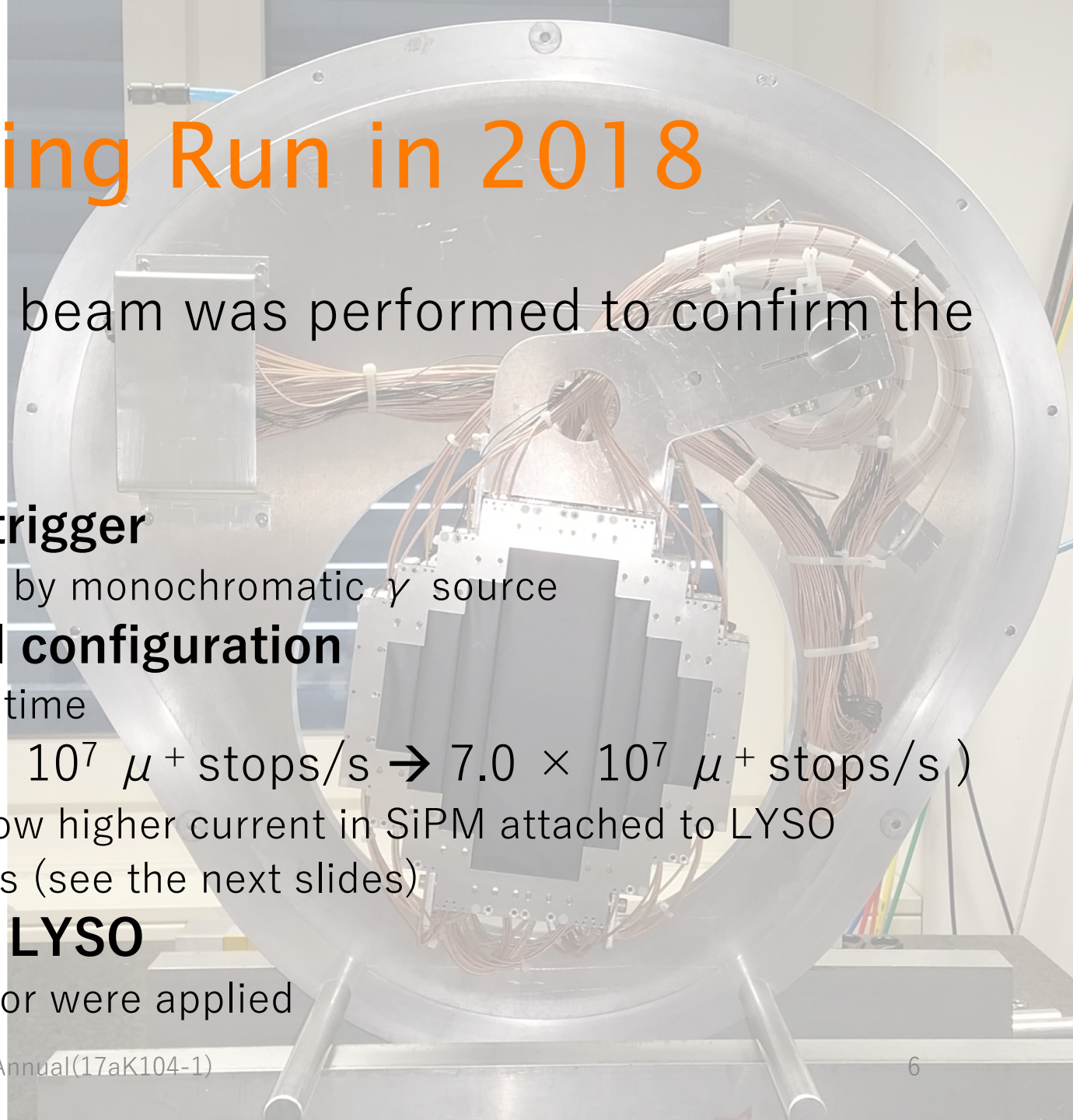


RDC e⁺ Energy



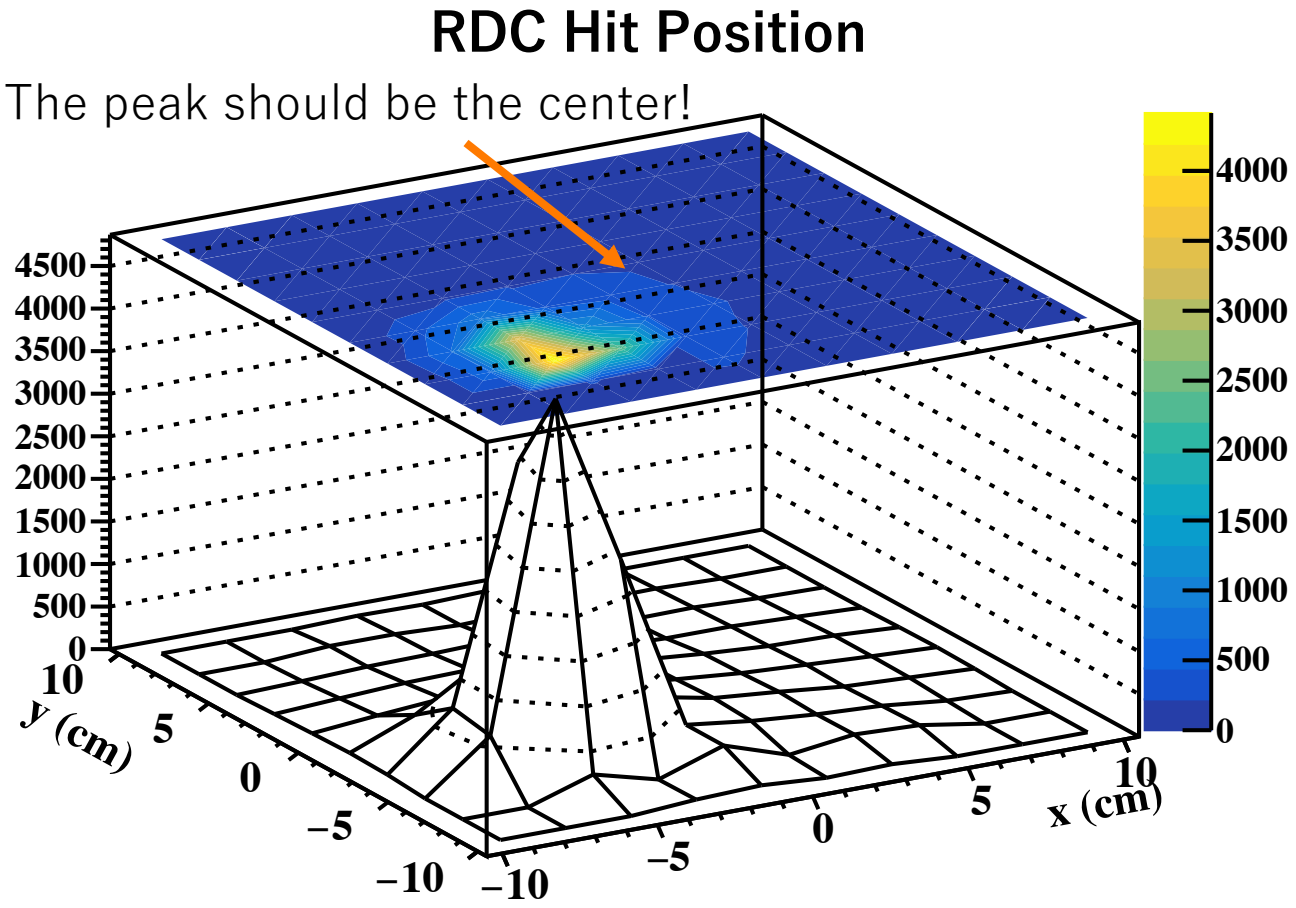
- Timing measurement
  - 12 plastic scintillators (PS)
  - 2, 3 SiPMs on each side in series connection
- Energy measurement
  - 76 LYSO crystals
  - 1 SiPM on the back of one crystal

Commissioning Run in 2018



- Commissioning run using μ^+ beam was performed to confirm the performance
- Improvement from 2017
  - ○ **Better understanding for γ trigger**
    - LXe energy scale was measured by monochromatic γ source
  - △ **BG measurement in the final configuration**
    - CDCH was installed for the first time
  - ✕ **Higher beam intensity** (3.2×10^7 μ^+ stops/s → 7.0×10^7 μ^+ stops/s)
    - Electronics was exchanged to flow higher current in SiPM attached to LYSO
    - Not achieved due to beam issues (see the next slides)
  - ○ **Better energy calibration for LYSO**
    - Corrections of Energy Scale factor were applied

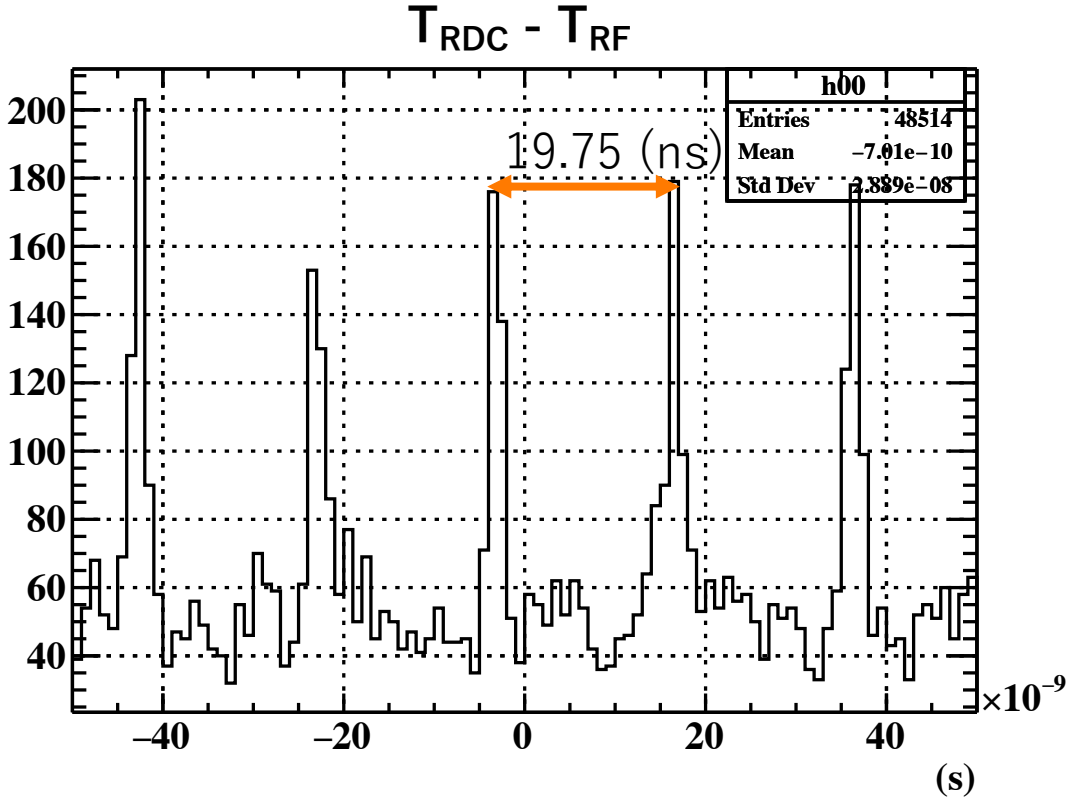
Beam Issues

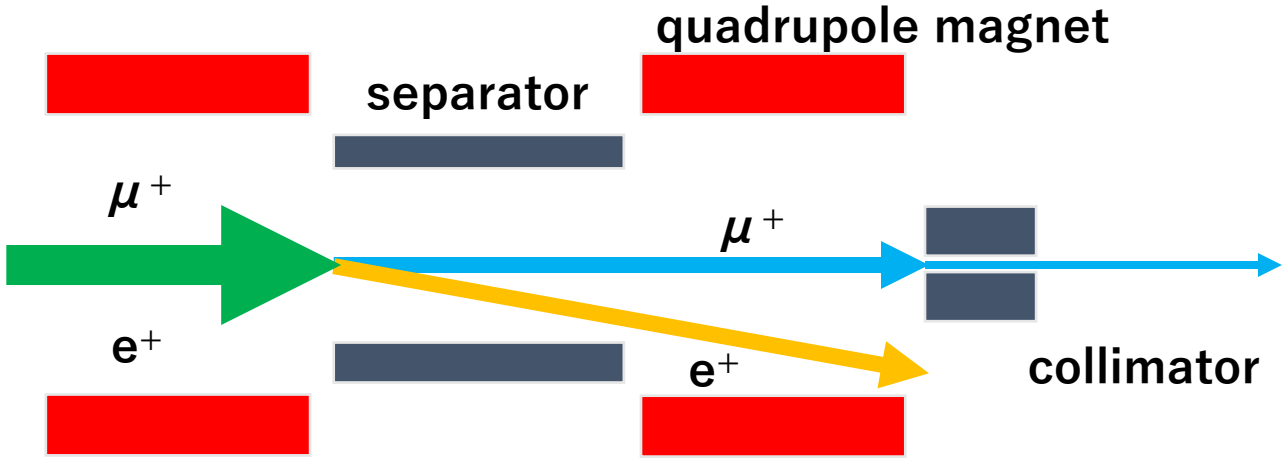


Some strange behaviors were observed by RDC, which never happened before

- The center of hit positions was off the center of RDC
- Total hit rate was ten times higher than expectation
- The highest hit rate per channel was 40 times while the lowest was consistent with MC
- Too high current flowed in some channels (40 times larger than expected)

Timing Correlation w/ RF





- There is a correlation b/w RDC hit timing and accelerator Radio Frequency (RF) timing
- The peak interval, 19.75 ns, was consistent with RF
  → contamination in beam?
- Eight times e^+ are contained in beam, but basically they must be excluded by a separator
  → Not excluded for some reasons?

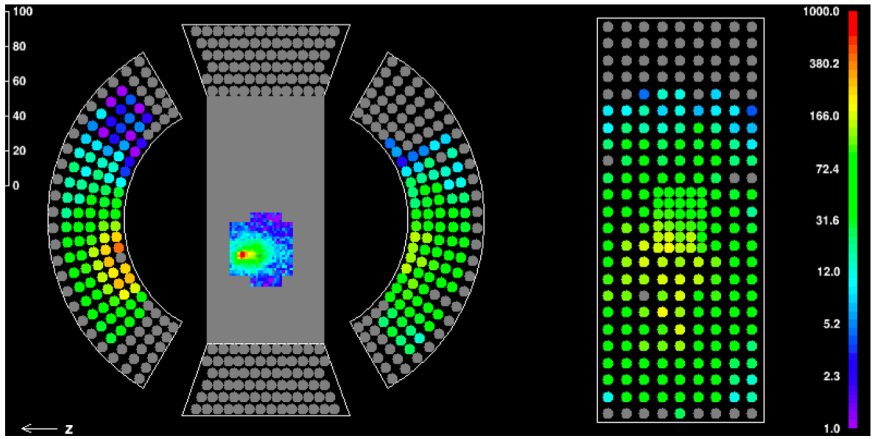
DAQ Configuration

- Could not fix the problem, and so decided to take data with lower intensity, 8×10^6 μ^+ stops/s
  - to avoid too high current
  - to avoid radiation damage

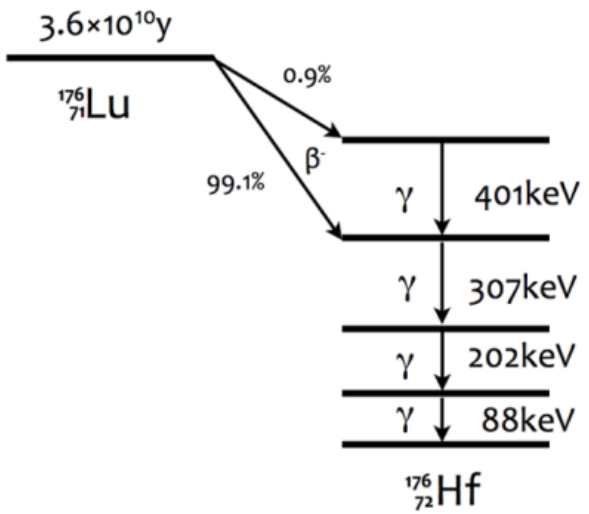
  ※ Not affect RMD detection performance though BG rate is higher than expected

- γ trigger by LXe ($E_\gamma > 45$MeV)
  (limited readout channels due to electronics)

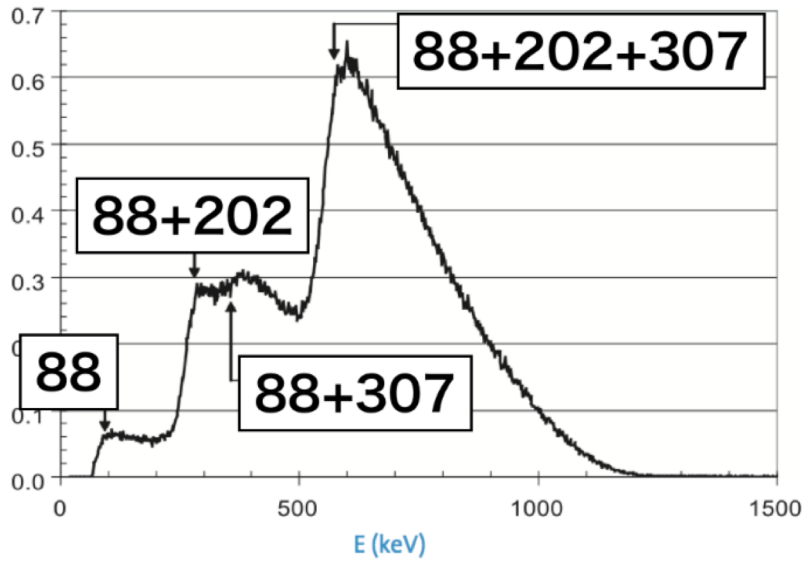
LXe Event Display



LYSO Energy Calibration

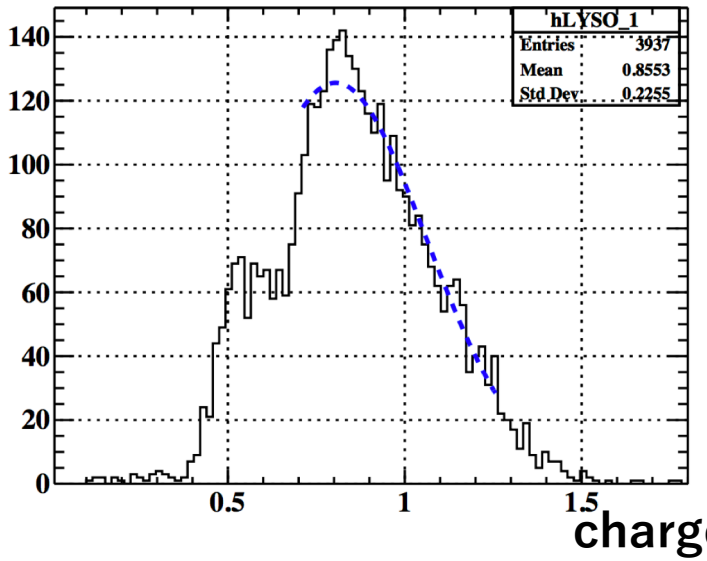


Energy Spectrum of LYSO self-radiation



Saint-Gobain, PreLudeTM 420 data sheet

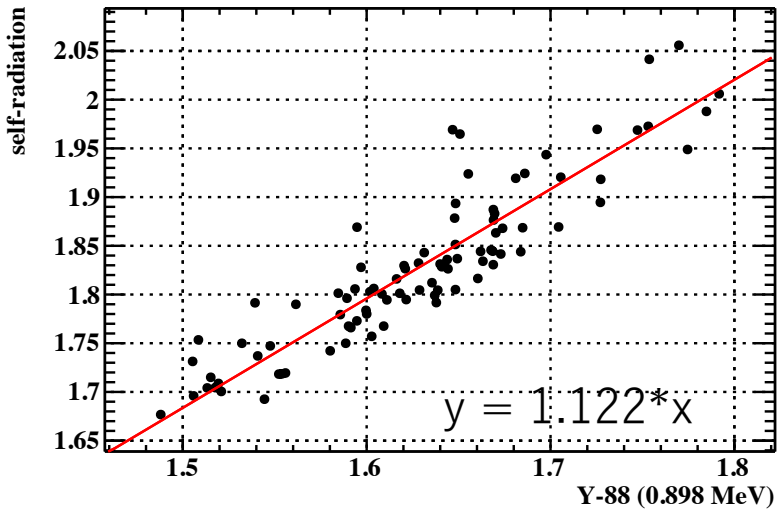
Example of Fitting



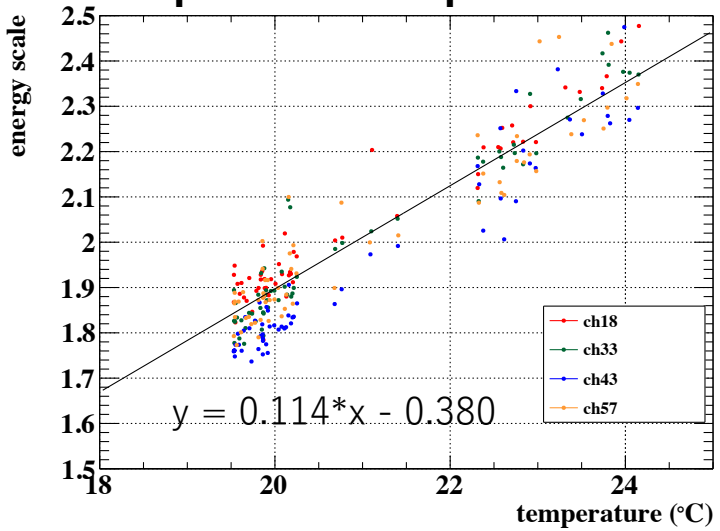
- ^{176}Lu in LYSO decays emitting γ and β
- LYSO was calibrated using the 597 keV peak in self-radiation spectrum
  Fit function : γ peaks + β decay spectrum
- Energy is reconstructed by $E = charge \times ES$ ← calculate ES by the calibration

Correction of ES Factor

correlation b/w energy scale factors



temperature dependence



- ES factor calculated using self-radiation spectrum needs corrections
  - **Bias correction** : Larger comparing to ES factors calculated by fitting γ peak from ^{88}Y (0.898 MeV)
  - **Temperature correction** : Linear correlation b/w energy scale and temperature

- Energy is reconstructed by

$$ES = (ES_{\mathrm{self}} + f_{\mathrm{temp}} \times \delta T)/f_{\mathrm{bias}}$$

$$E = charge \times ES$$

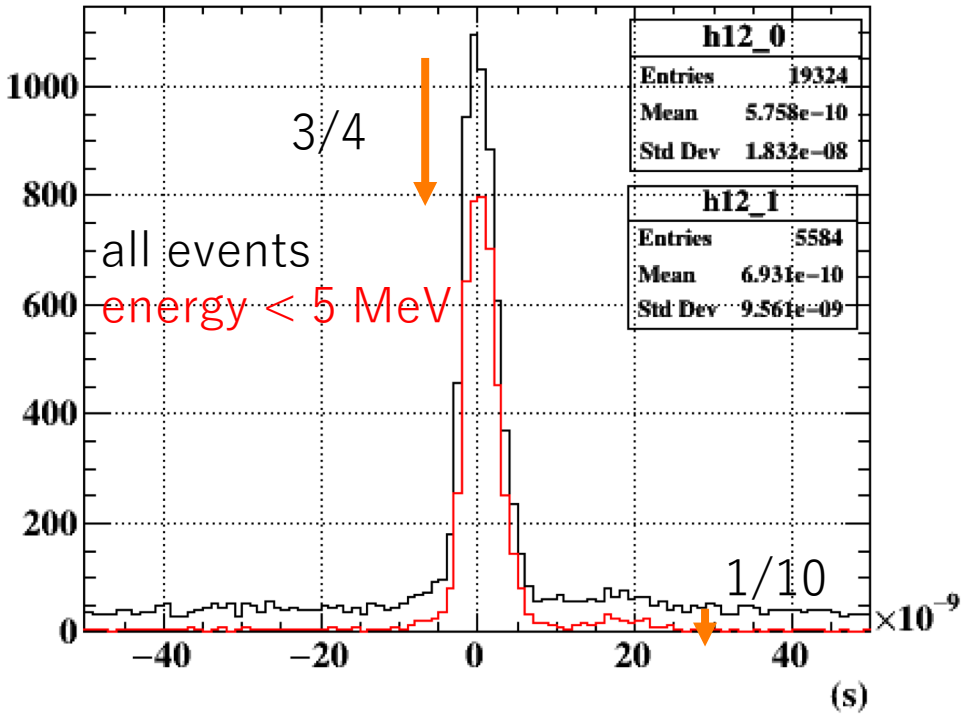
- The correction parameters were decided by measurements:

$$f_{\mathrm{bias}} = 1.122$$

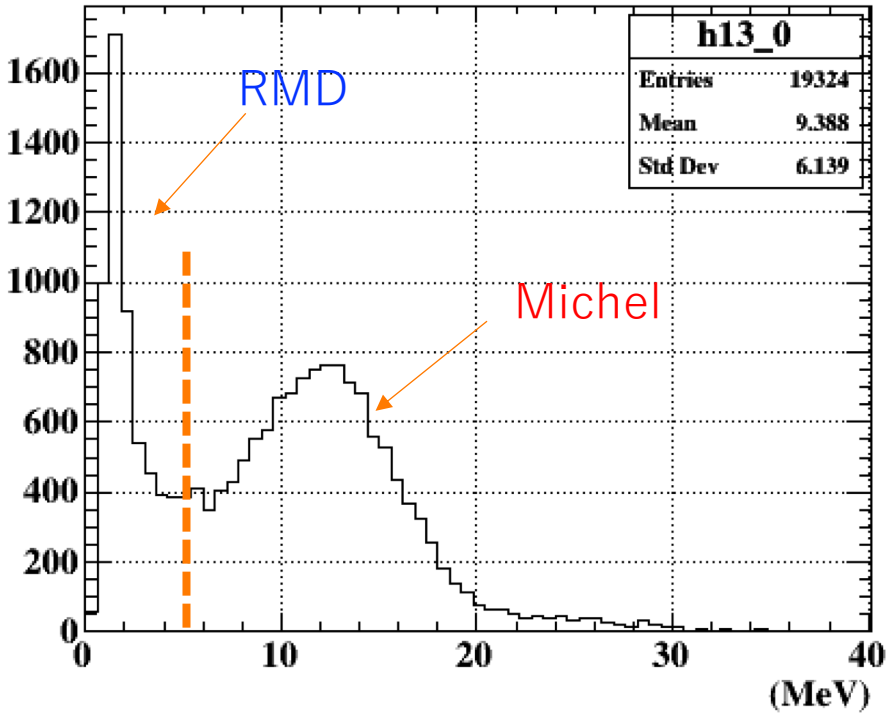
$$f_{\mathrm{temp}} = 0.114$$

Analysis Result

$T_{RDC} - T_{LXe}$

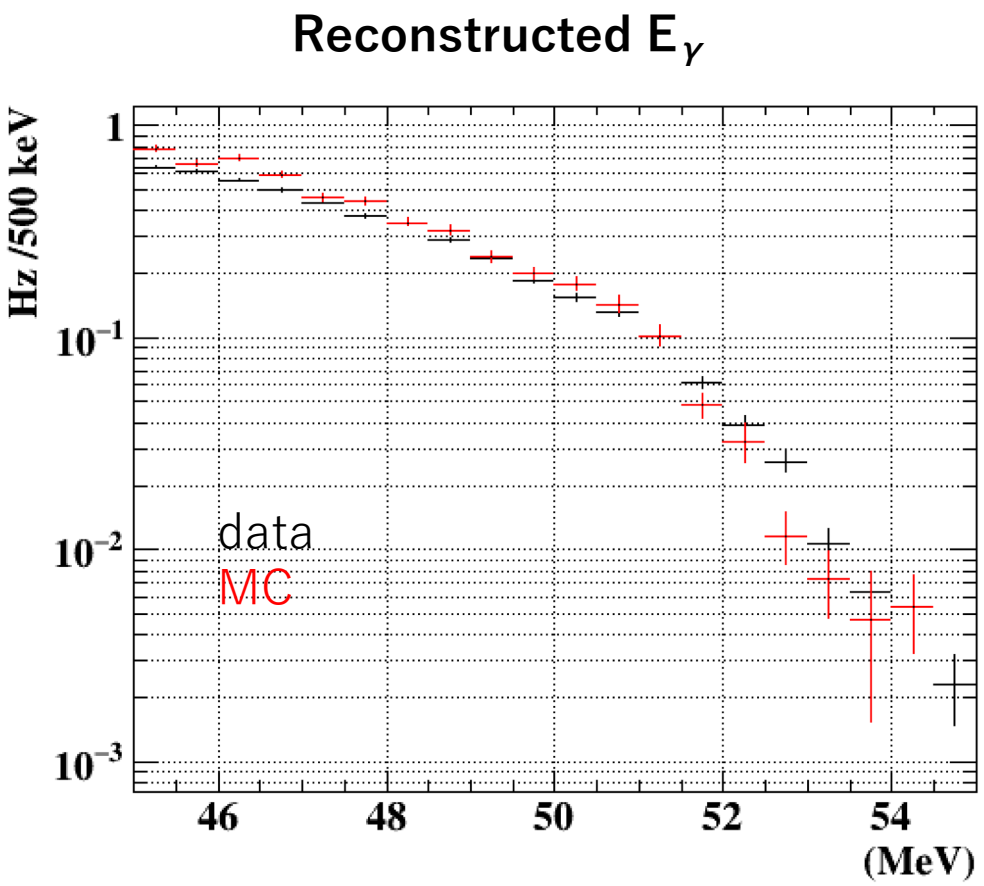


Reconstructed Energy



- A clear RMD peak can be seen in the time difference b/w RDC and LXe
- There are RMD and Michel energy peaks like MC
- Energy cut reduces background to 1/10, but the RMD events to 3/4
  → Energy can be used for RMD identification

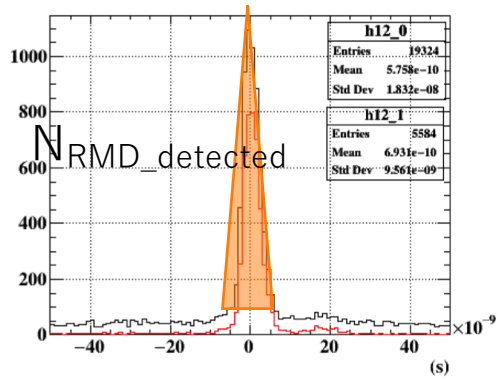
Comparison with MC



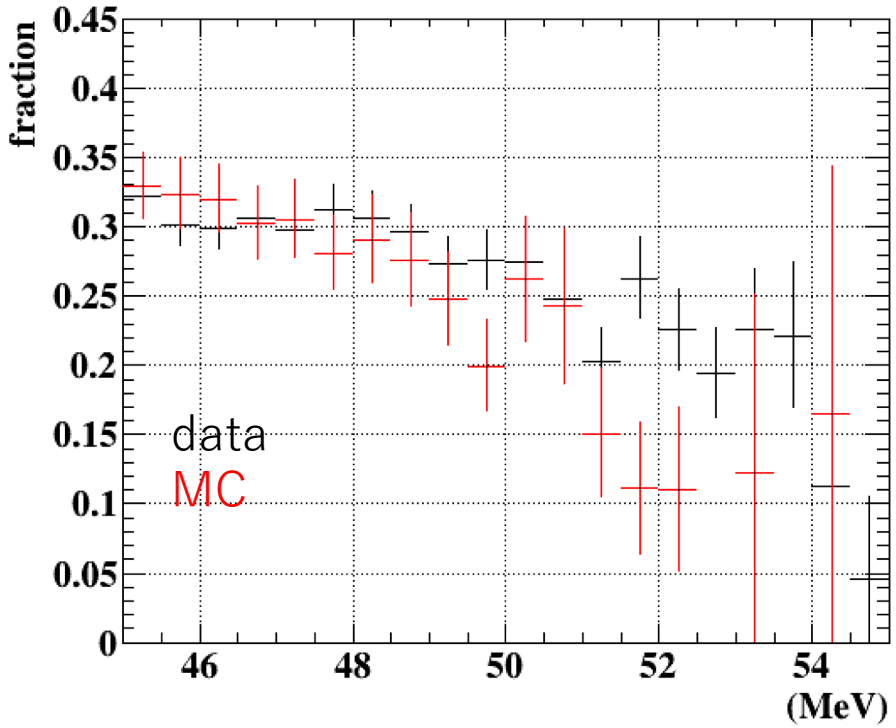
- Mixed events of three types for MC
  - RMD events from μ decay on the target
  - AIF events from μ decay on the target
  - μ decay in flight
- Reconstructed E_γ spectrum is almost consistent, but the number of events of data exceeds that of MC in high energy region due to pile-up events

Comparison with MC

$T_{RDC} - T_{LXe}$ (data)



(the number of events detected by RDC) /
(the number of all events)



Energy detected by LXe

data

$N_{RMD\_detected}$ = 5684 ± 154 events

MC expectation

$N_{RMD\_expected}$
= N_{events} * (RMD trigger fraction)
* (RMD hit probability to RDC)
* (RDC hit in time window)
= 19324 (events) * 0.78 * 0.39 * 0.94

= 5552 ± 267 events

The number of RMD events was consistent,
but there is excess of data in the high energy region
← E_γ spectrum is not perfect in the region due to pile-up

Summary

- Commissioning run for RDC with LXe was performed.
- Took data w/ low intensity (8×10^6 μ^+ stops/s) because of beam contamination
  ← separator is going to be exchanged
- RMD events can be seen clearly in the plot of RDC and LXe time difference.
- RMD detection efficiency was almost consistent with MC except for pile-up events.
- Performance with higher beam rate will be checked in 2019.