MEG II実験輻射崩壊同定用カウンターの実機製作及び性能評価

Construction & performance evaluation of a scintillation detector to identify BG gamma ray from radiative muon decay in MEG II experiment

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Contents

- Research Background
  - Charged Lepton Flavor Violation
  - MEG II Experiment
  - Radiative Decay Counter (RDC)
- Detector Construction
  - Timing counter part
  - Calorimeter part
- Detector test

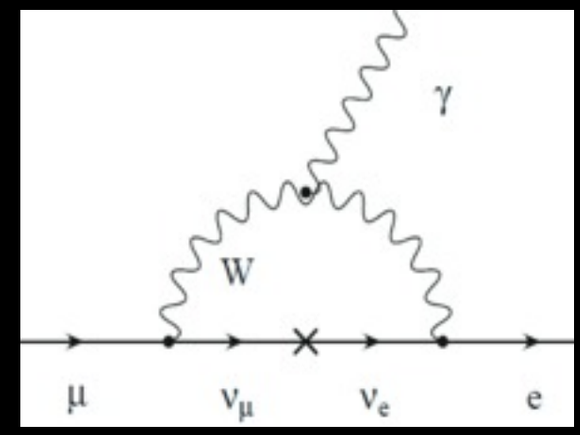
Contents

Research Background

Charged Lepton Flavor Violation

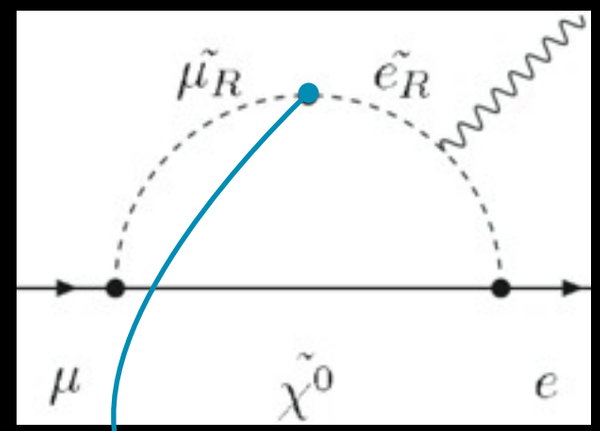
- μ→eγ decay in the SM
  - standard model + neutrino oscillation
  - B(μ→eγ) ~ **O(10^{-54})**: too small to detect

μ→eγ in the SM

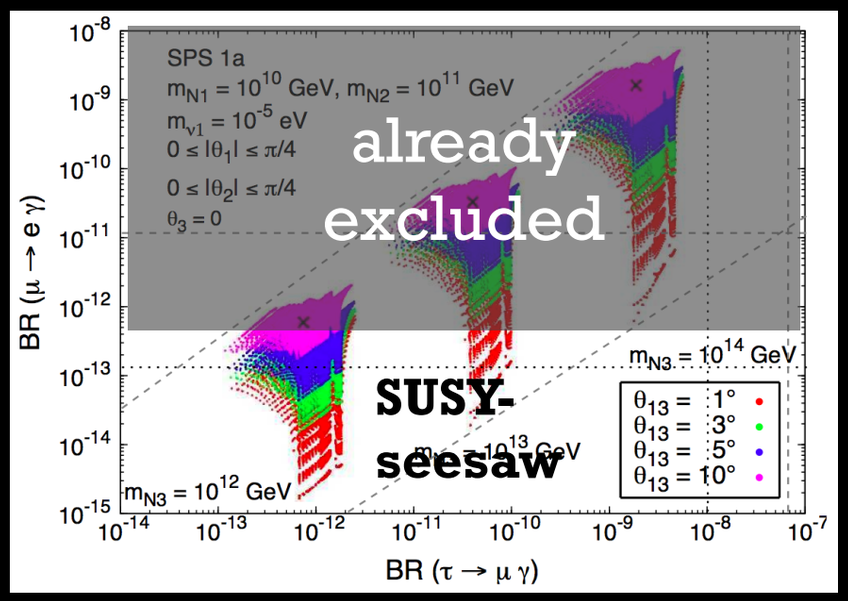


- μ→eγ decay in the new physics
  - B(μ→eγ) can be > **O(10^{-14})**: which can be reached!!

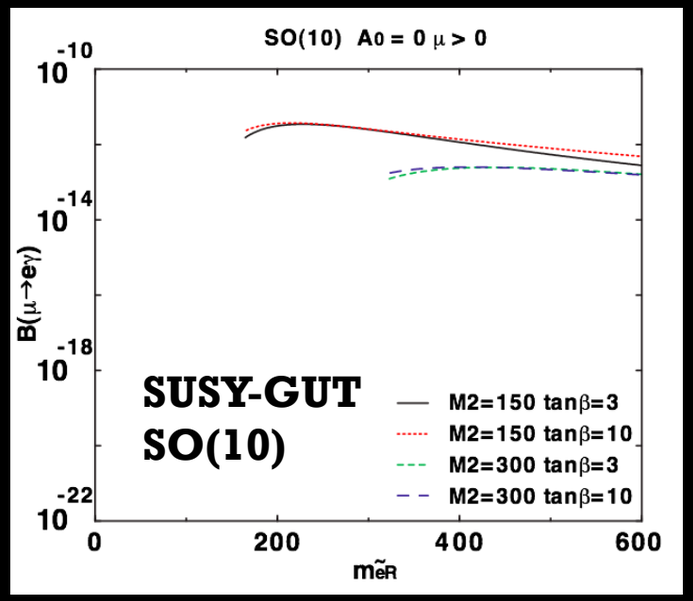
μ→eγ in the new physics



non-diagonal terms
in the slepton mass matrix



S.Antusch,E.Arganda,M.J.HerreroandA.M. Teixeira,J.HighEnergyPhys.11(2006)090

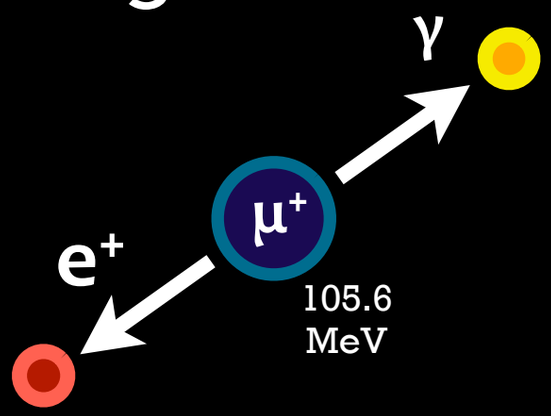


Y.KunoandY.Okada,Rev.Mod.Phys.73,151(2001)

Research Background

MEG II Experiment

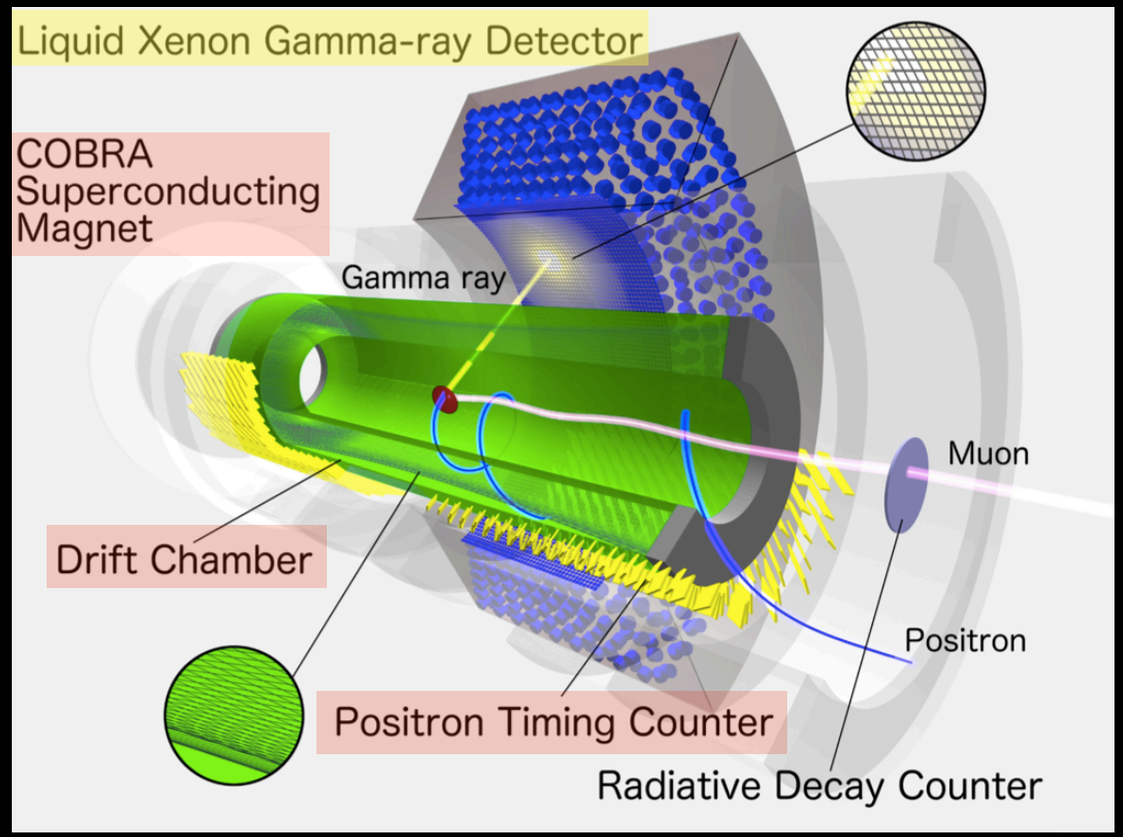
- Signal Event: 2-body decay from a muon at rest



- e^+ & γ: a **monochromatic energy**
- **time-coincidently**
- **back to back**

- High-precision measurement of E_e, E_γ, $T_{e\gamma}$, $\Theta_{e\gamma}$

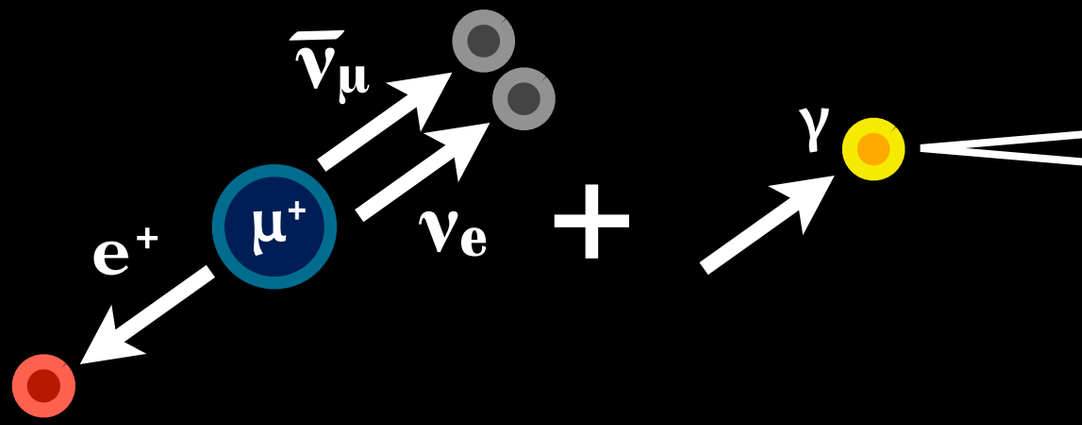
- Experimental Apparatus
  - 7×10^7 stopping muons/sec
  - 800 litter liquid xenon gamma-ray detector
  - A low mass stereo drift chamber
  - A multi-tile scintillation timing counter
  - New BG tagging detector



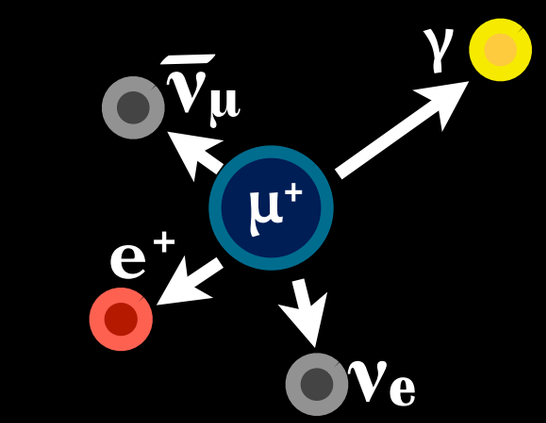
Research Background

MEG II Experiment

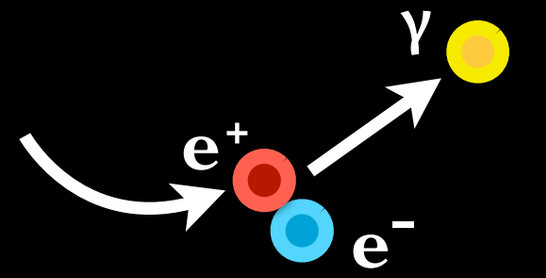
- Dominant Background:
  - Accidental background



Background gamma-ray source



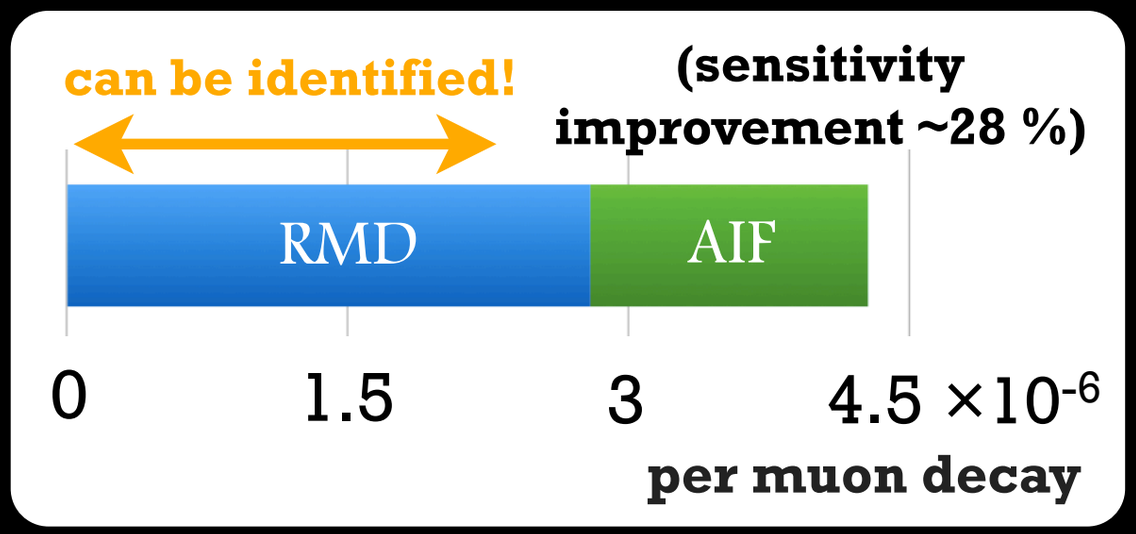
1. Radiative Muon Decay (RMD)



2. Annihilation In Flight (AIF)

  - The amount of background gamma-rays

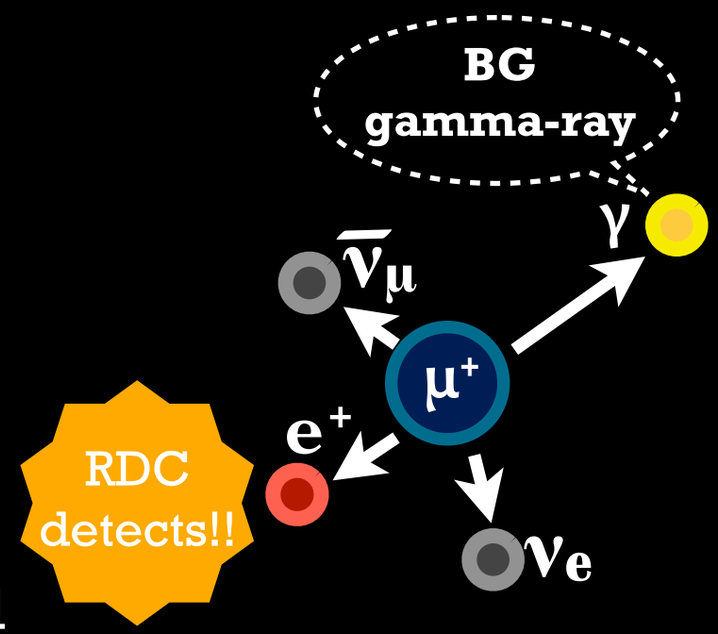
(energy deposit in gamma-ray detector > 0.9 × 52.8 MeV)

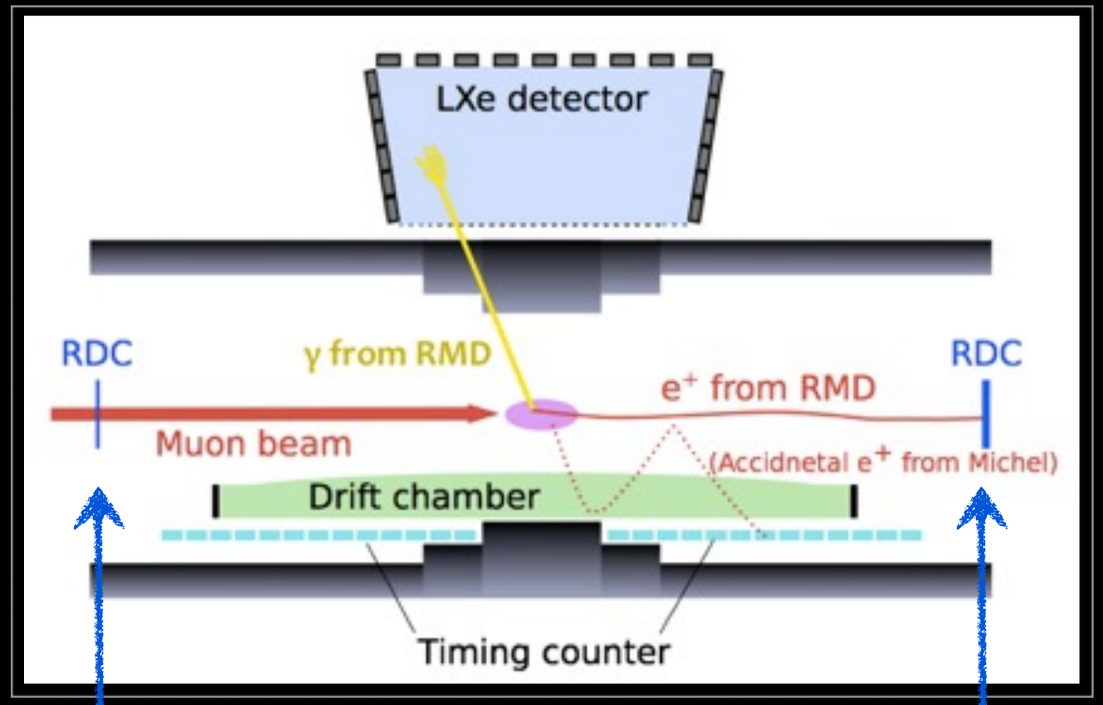


Research Background

Radiative Decay Counter (RDC)

- Radiative Decay Counter (RDC)
  - New detector
  - Identify background gamma-rays actively
- Mechanism
  - High energy gamma-ray from the RMD
  - Low momentum positron is coincidentally emitted





Effect on muon beam?

Approved

- Small detector
  - Upstream & Downstream
- Hit time:

  Time coincidence with γ
- Energy deposit:

  Distinguish RMD from Michel decay

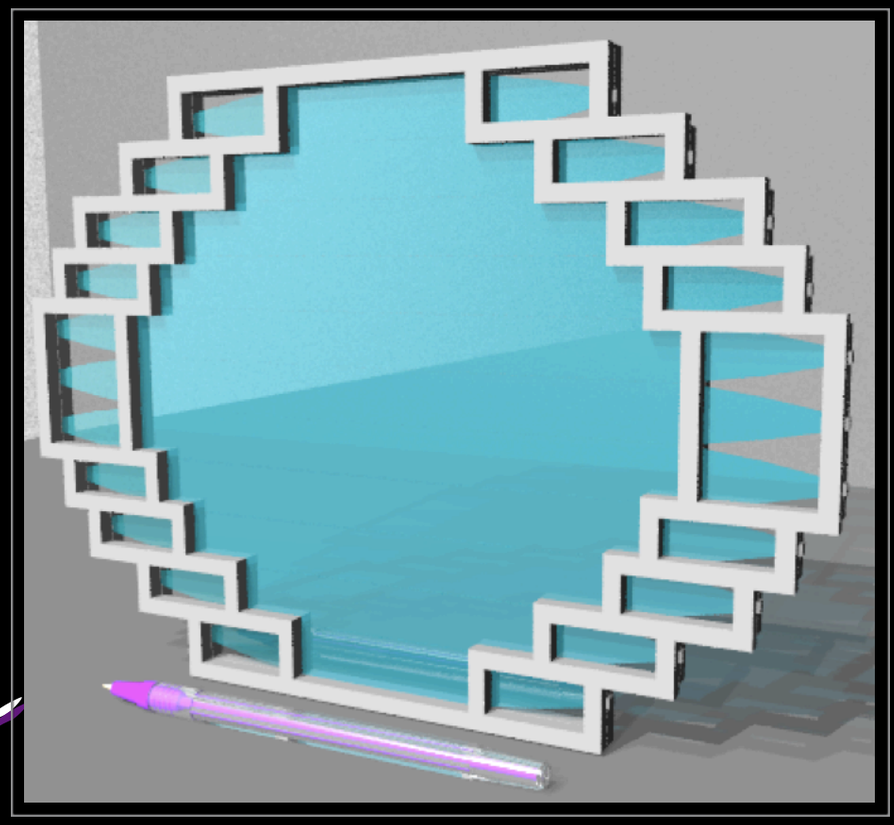
  (only downstream)

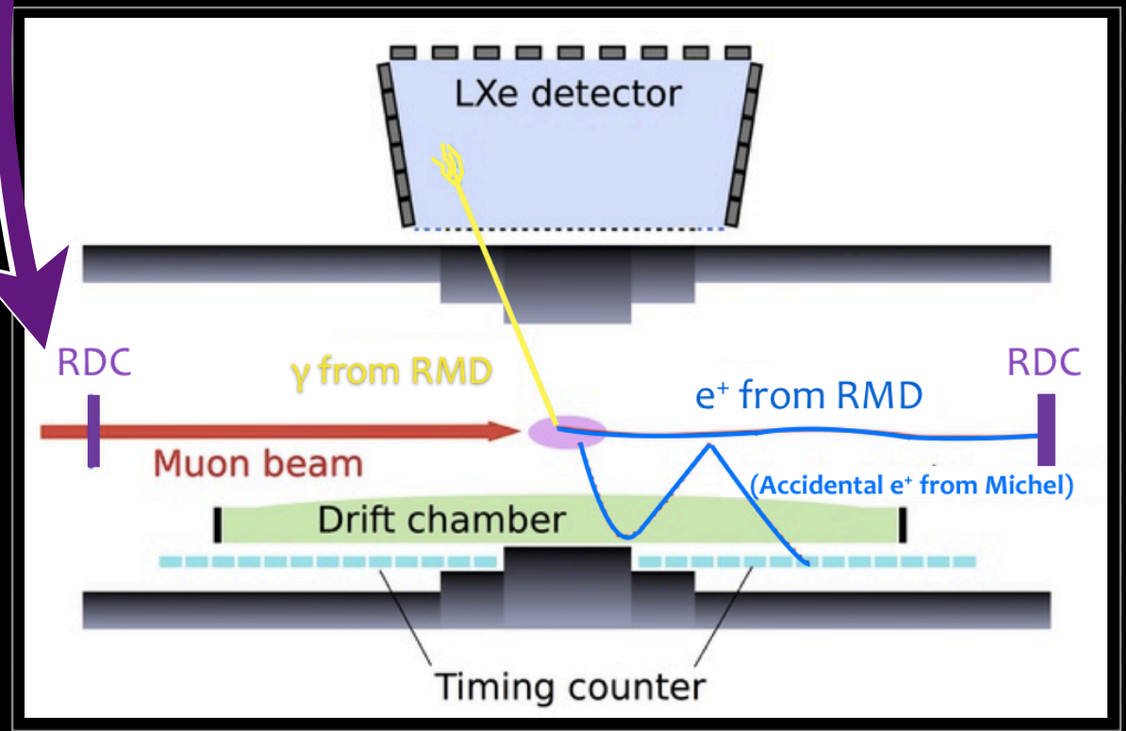
Research Background

Radiative Decay Counter (RDC)

Upstream RDC

- Made of 784 plastic scintillation fibers
  - thickness = 265 - 270 μm
  - small effect on μ^+ beam transportation
- Separate μ^+ from e^+
  using difference of energy deposit
- check the time coincidence
  between e^+ (RDC) - γ (LXe)





The effect on the μ^+ beam properties ?

- Beam test with the mockup detector
  - A small influence on the beam spread

    $\sigma_x \cdot \sigma_y \sim 16\ \%$
- Simulation
  - Stopping efficiency loss: 3 %
  - Positron efficiency loss: 4 %

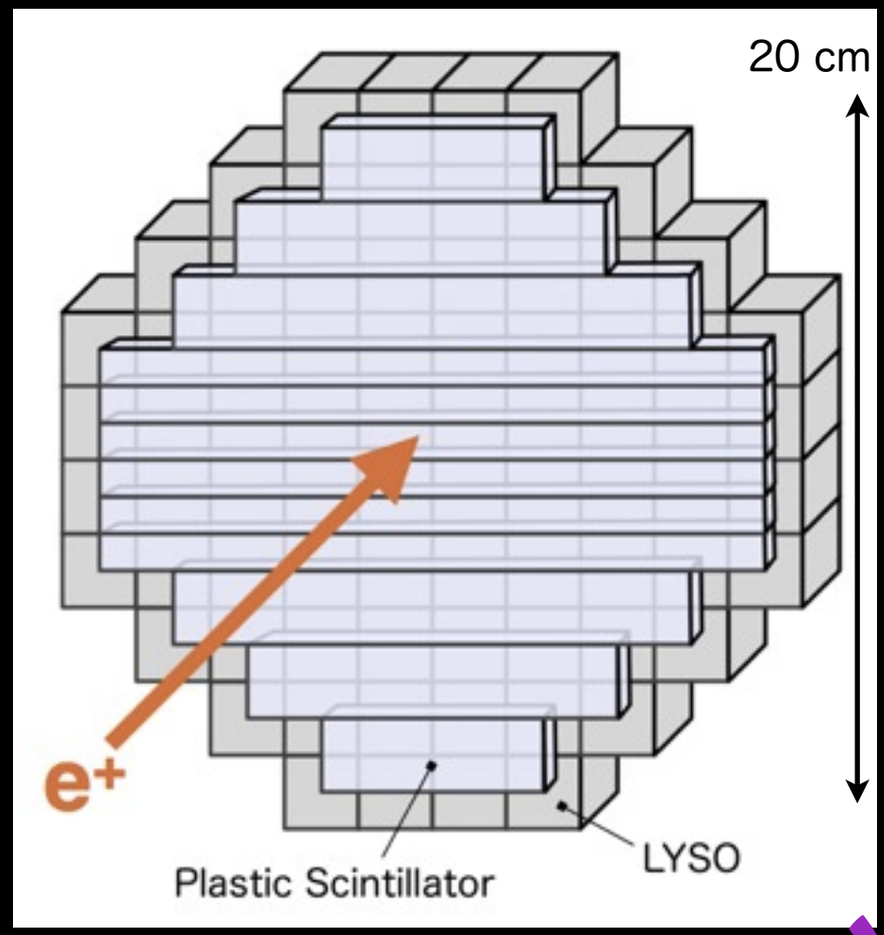
Research Background

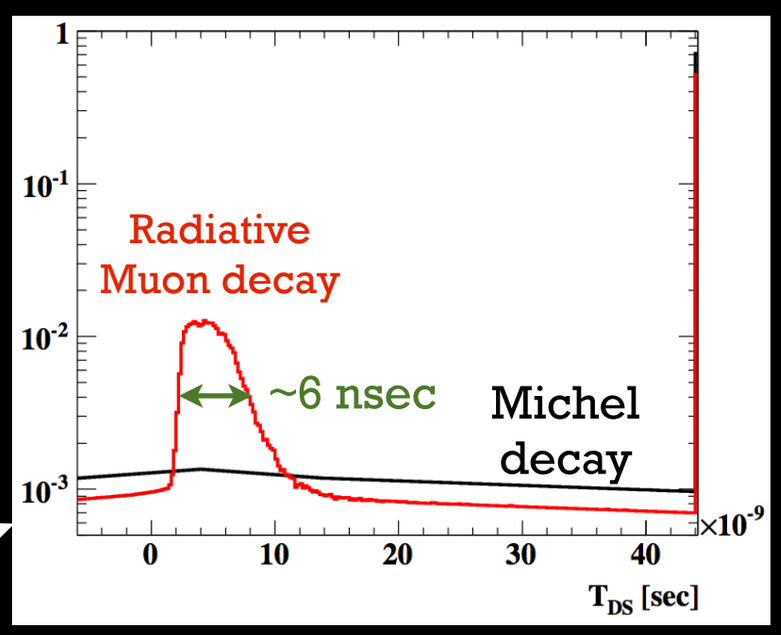
Radiative Decay Counter (RDC)

Downstream RDC

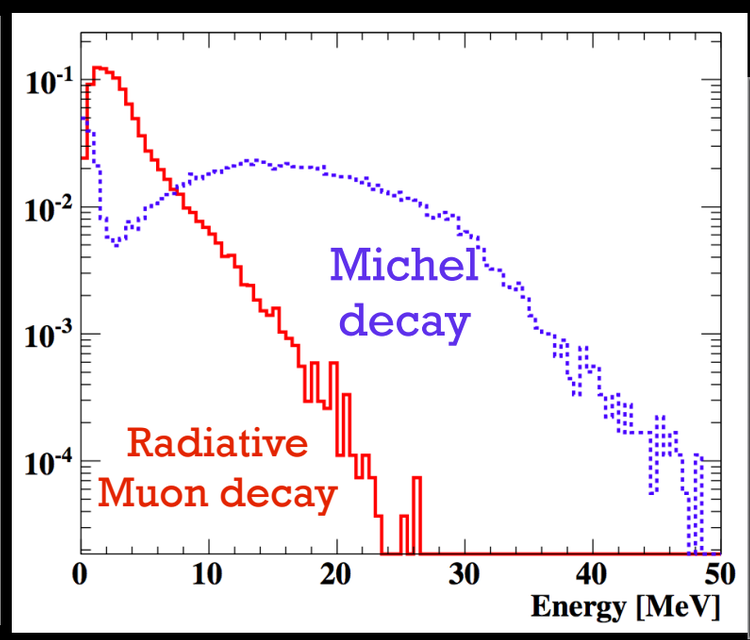
- Timing counter part
  - 12 plastic scintillator bars
  - check the time coincidence between

    e^+ (RDC) - γ (LXe)
- Calorimeter part
  - 76 LYSO crystals
  - distinguish Radiative Decay from Michel decay

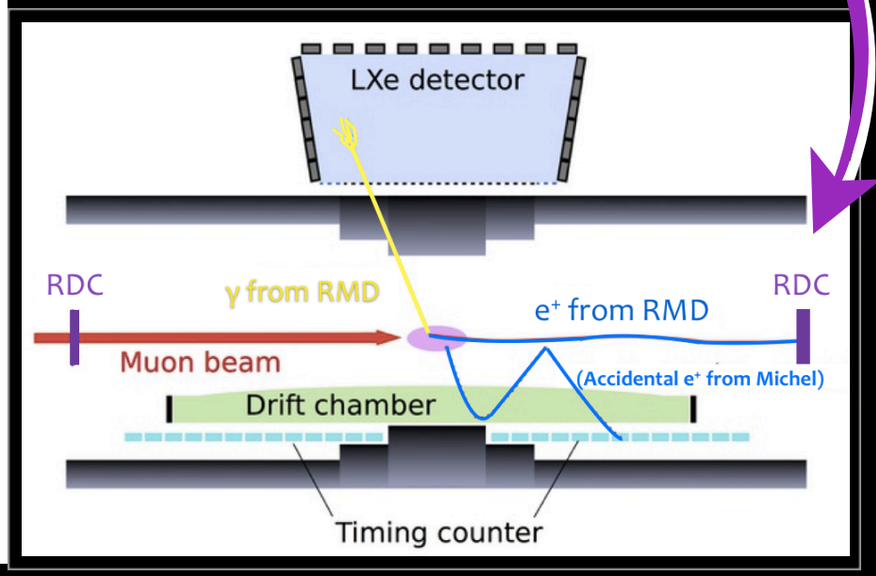




T(e^+ in RDC) - T(γ in LXe)



Energy deposit



Research Background

Radiative Decay Counter (RDC)

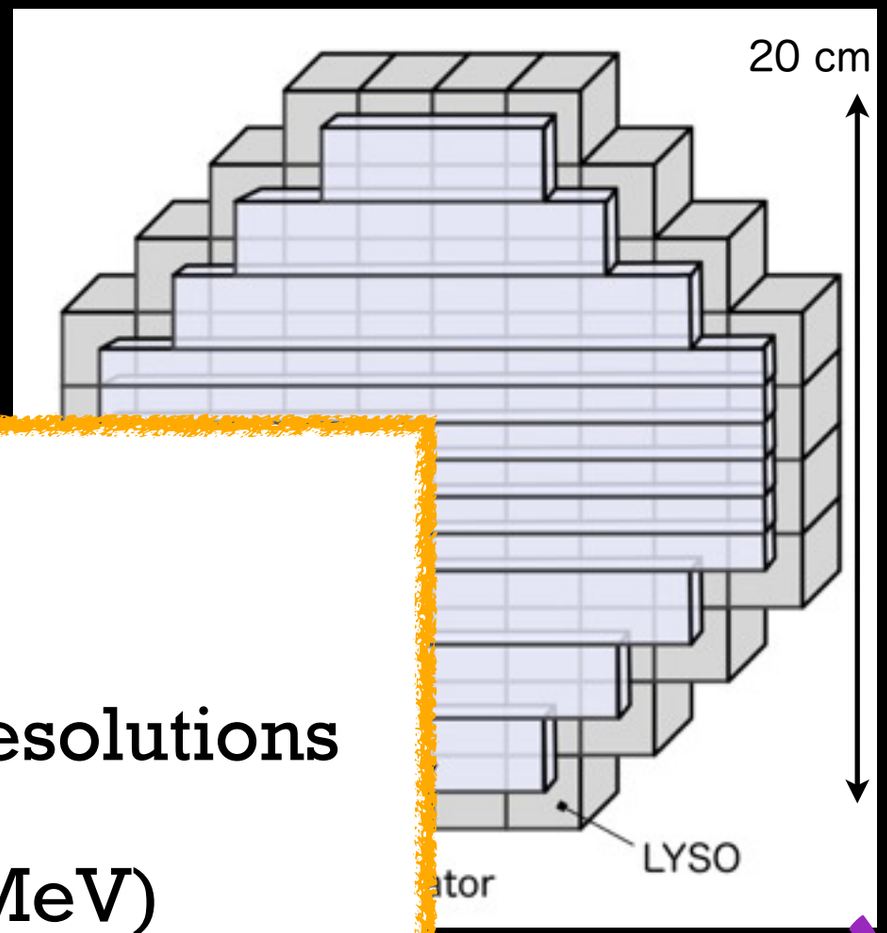
Downstream RDC

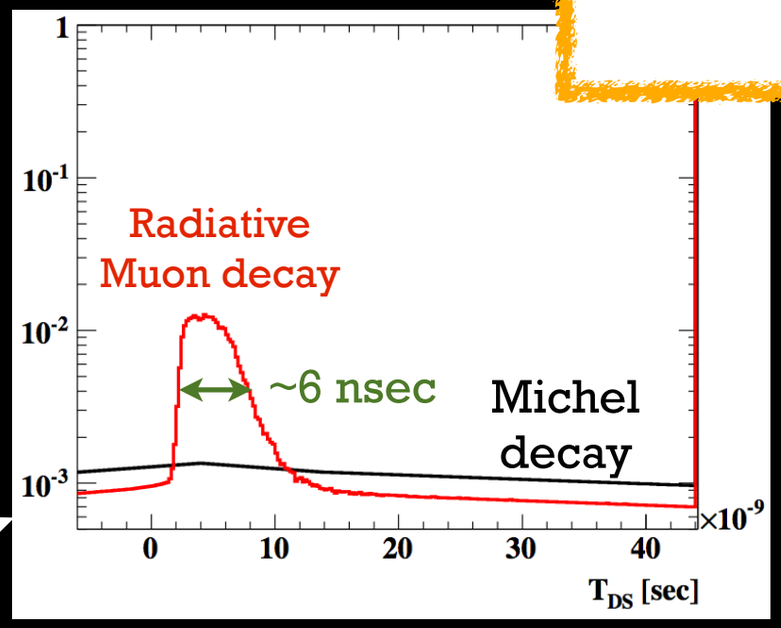
- Timing counter part
  - 12 plastic scintillator bars
  - check the time coincidence between
    e^+ (RDC) -
- Calorim
  - 76 LYSO
  - distinguis
    from Mic

Requirement:

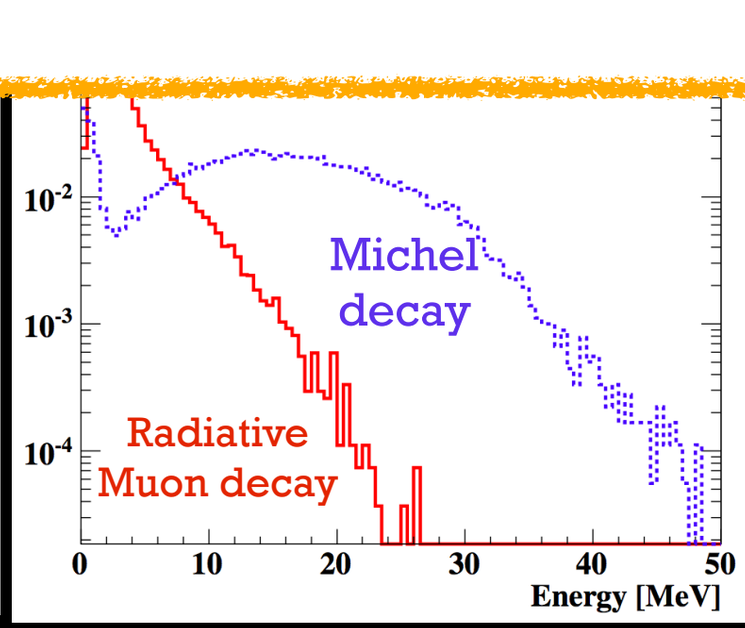
- Good time & energy resolutions

(100 psec & 8 % at 1MeV)

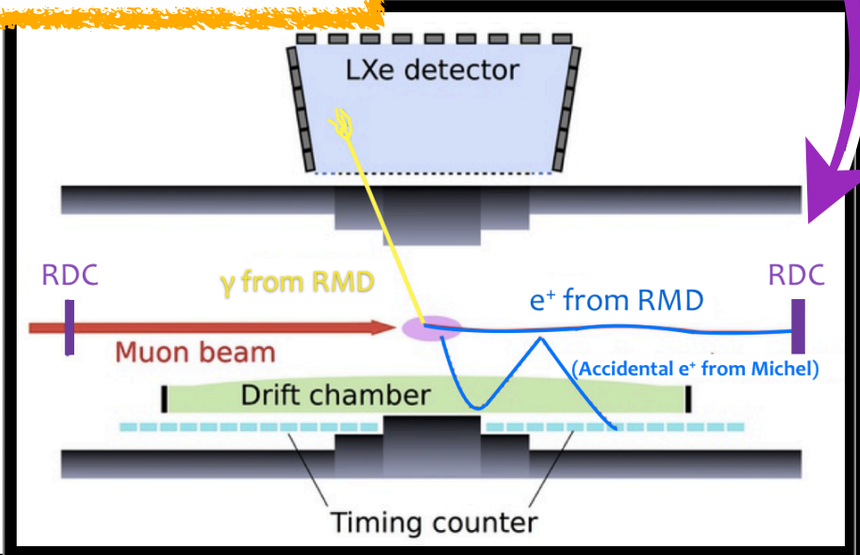




T(e^+ in RDC) - T(γ in LXe)



Energy deposit



Research Background

Radiative Decay Counter (RDC)

downstream RDC

R&D	RMD detection with prototype	✓
	scintillator selection	✓
	MPPC selection	✓
	crystal shape optimization	✓
	optical coupling optimization	✓
	afterglow study	
Construction	MPPC test	✓
	scintillator test	✓
	PCB production	✓
	counter assembling	
	individual counter test	
	combined counter test	

Today's Topic

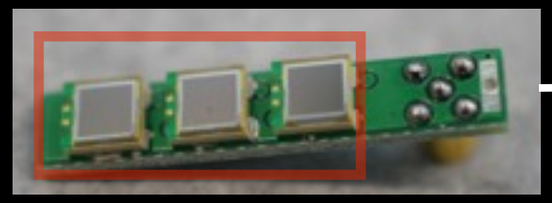
Contents

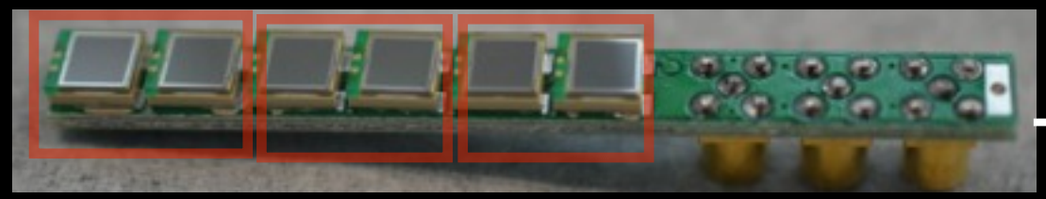
- Research Background
  - Charged Lepton Flavor Violation
  - MEG II Experiment
  - Radiative Decay Counter (RDC)
- Detector Construction
  - Timing counter part
  - Calorimeter part
- Detector test

Construction

Timing Counter Part

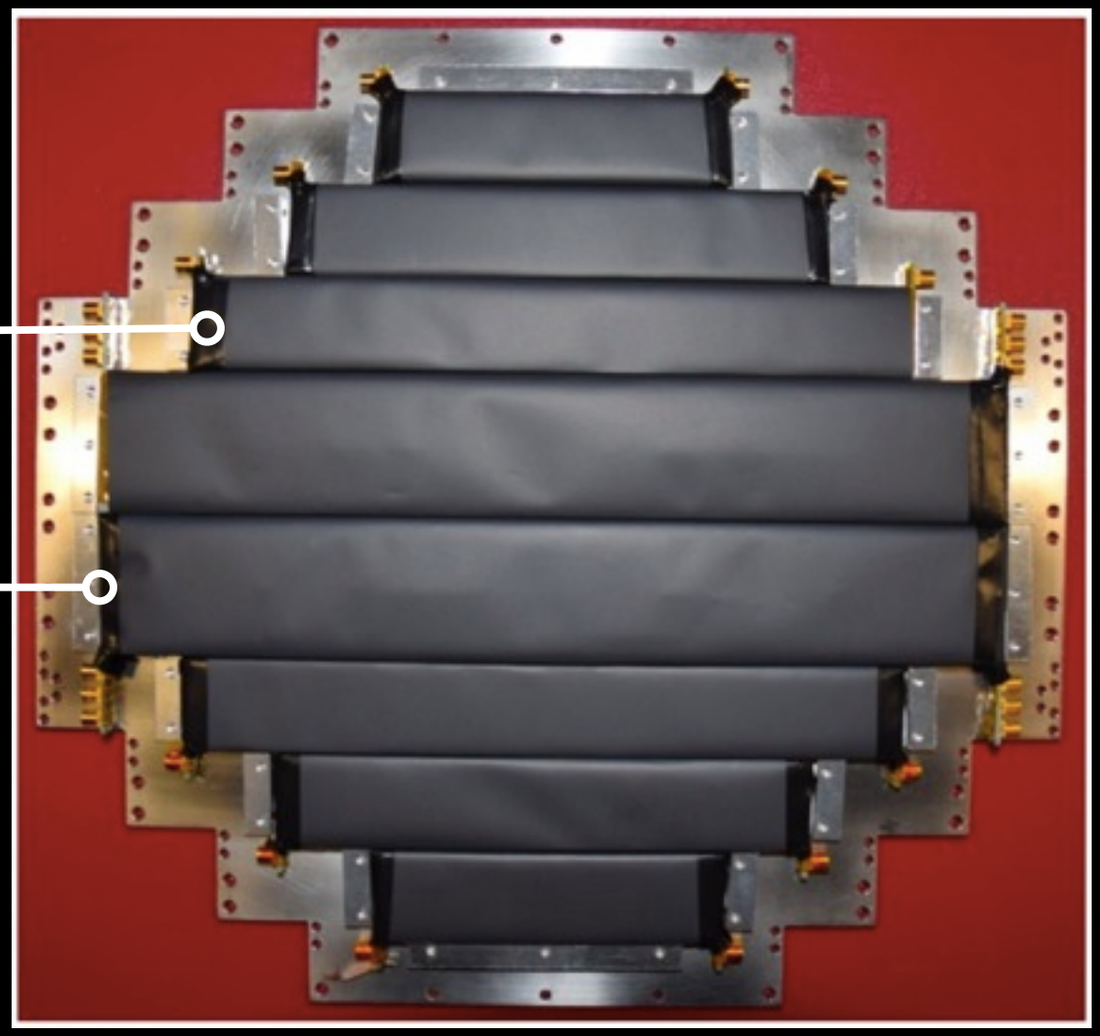
- 12 scintillator bars
  - PCBs: compact readout circuits





MPPC in series

- Glued with conductive epoxy (CW2400)



- Optical cement

- Aluminized mylar

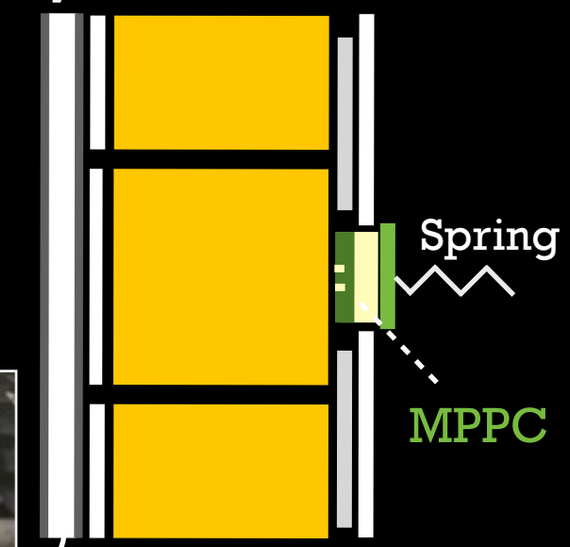
- Light- shielding film (@ Tedlar)

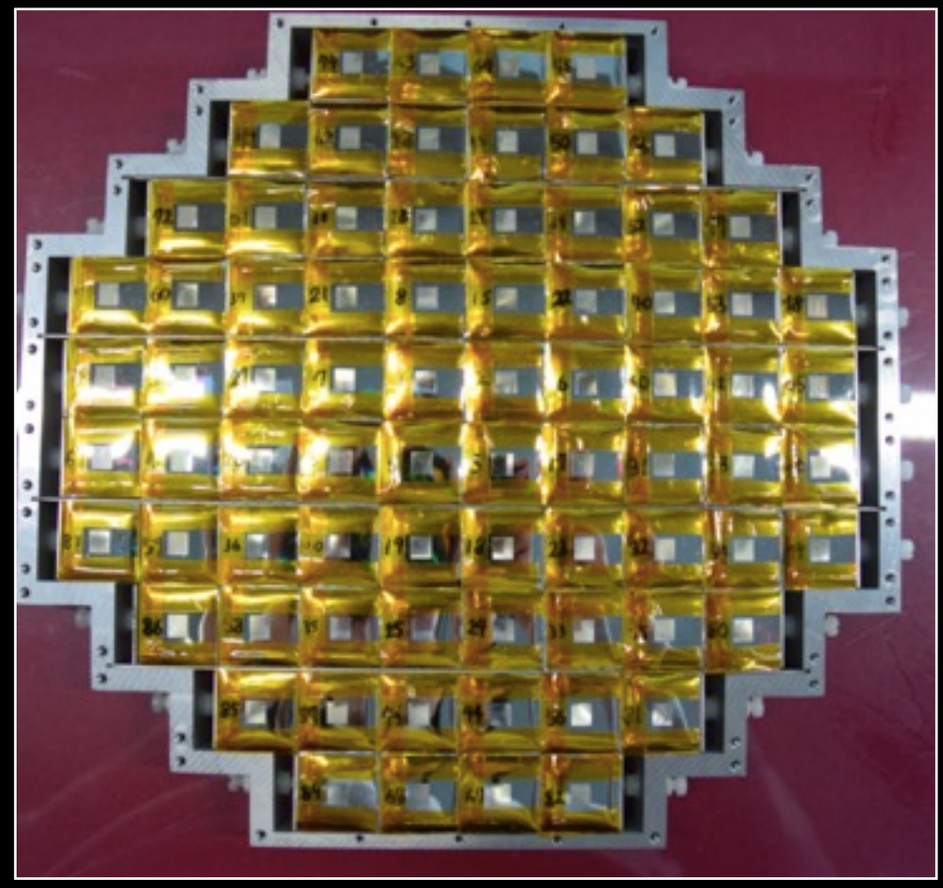
- Good timing resolution (< 90 psec) for all counters

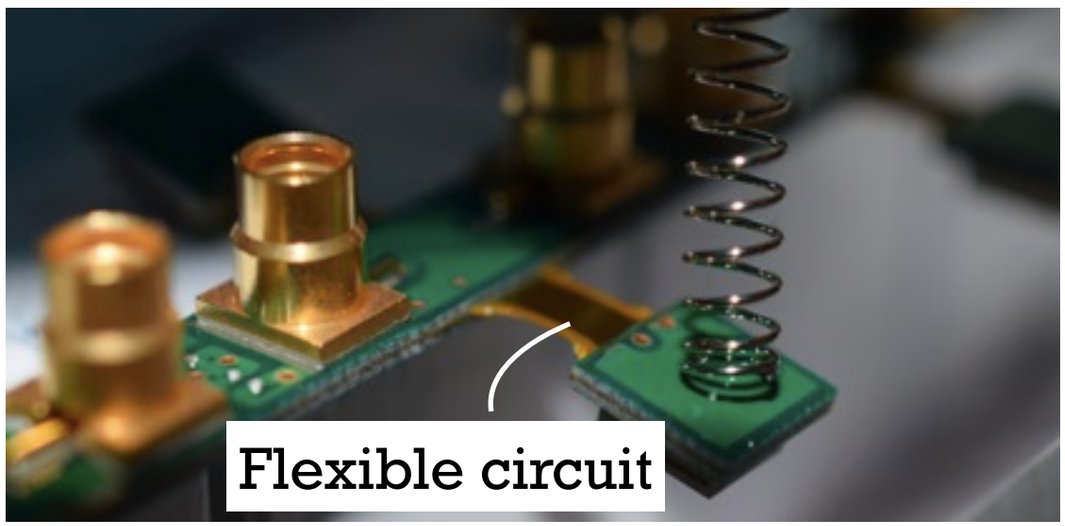
Construction

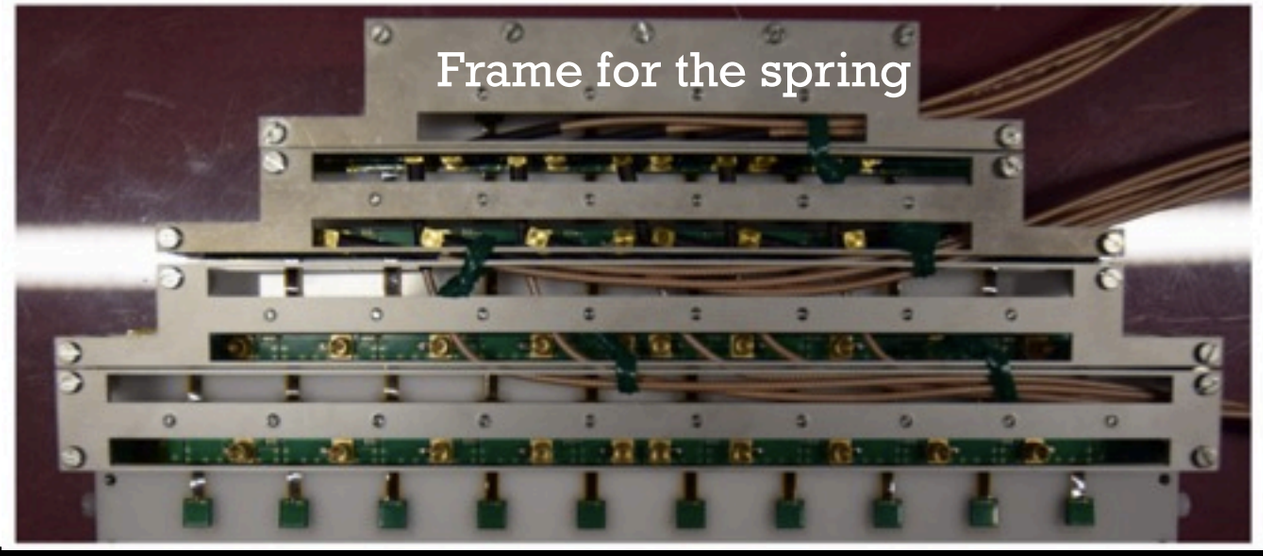
Calorimeter Part

- 76 LYSO crystals
  - Covered with reflectors
  - MPPCs are pushed onto LYSO crystals





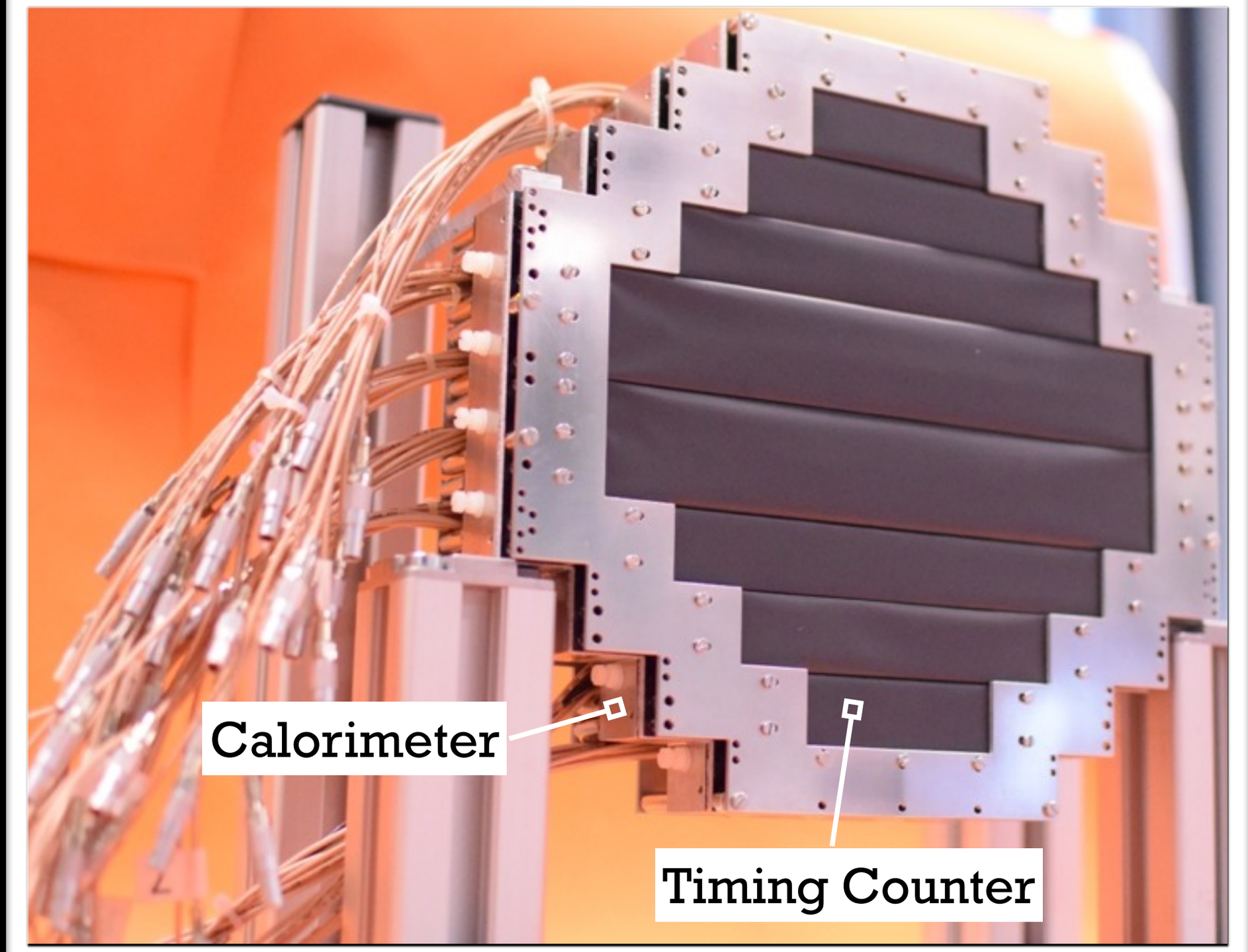




- Good energy resolution (< 6 % at 1 MeV) for all crystals

Construction

- The two parts were combined



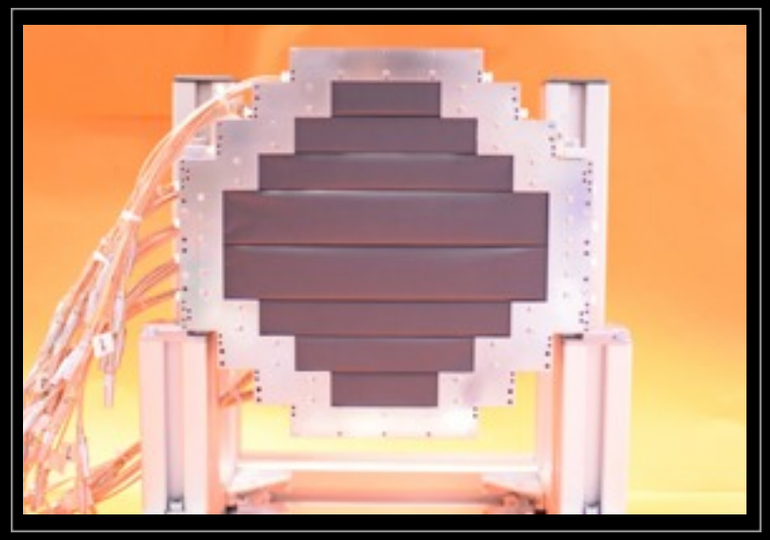
- Downstream RDC was constructed!!

Contents

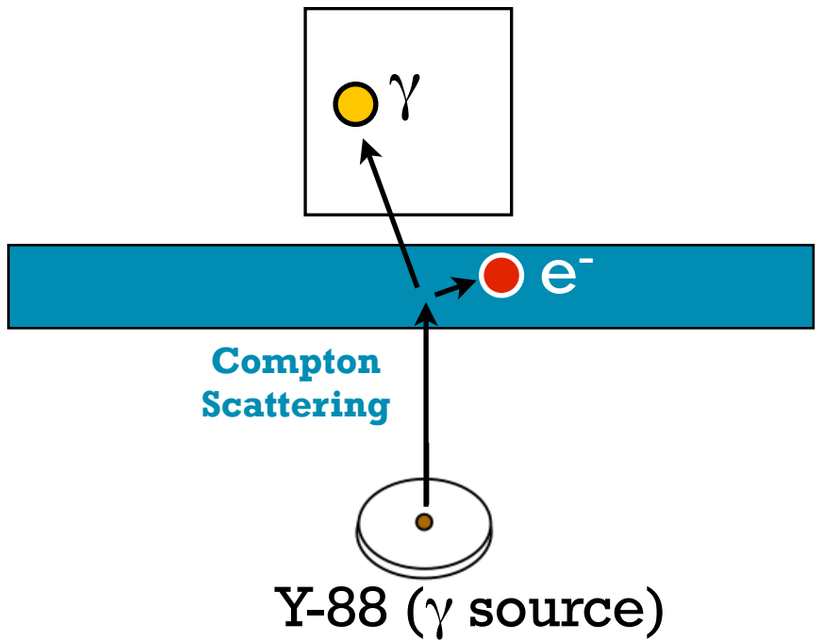
Detector test

Goals of the test

- Lab test of the constructed detector
  - All components in the constructed detector work ?
  - Calibration method of the each counter



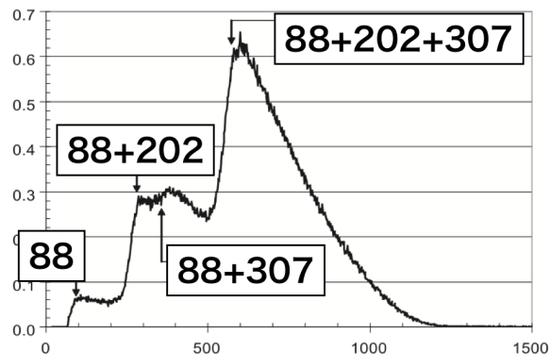
- Total energy absorption process



Y-88 (γ source)

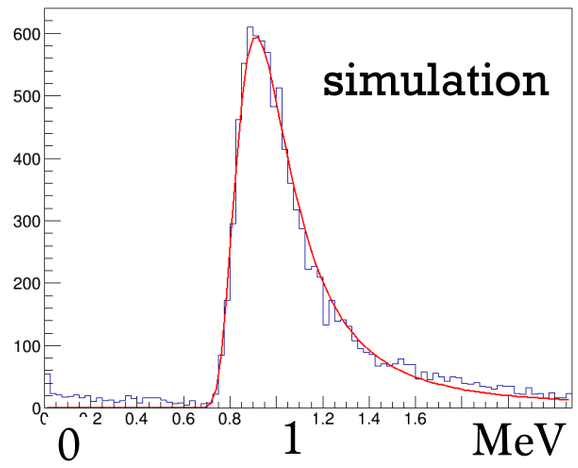
- Peak at the incident energy

- Energy calibration
  - LYSO
    : Self-Radiation
    (0.6 MeV)



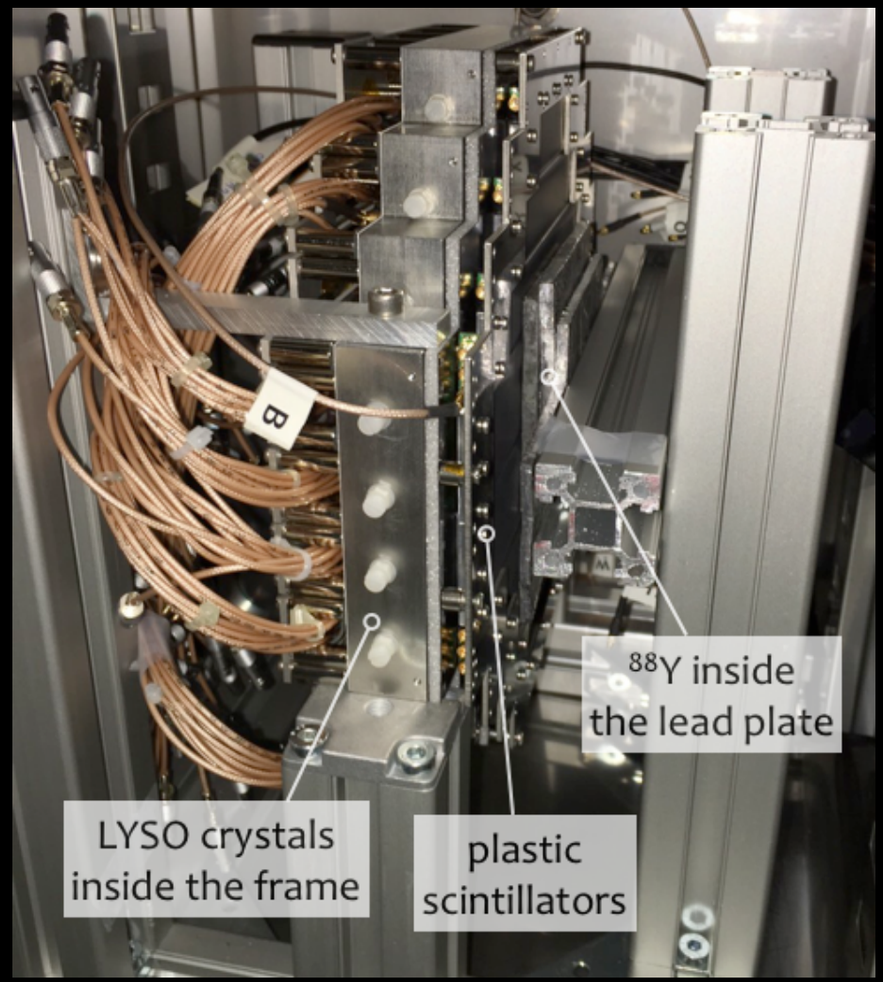
Saint-Gobain PreLude™ 420 data sheet

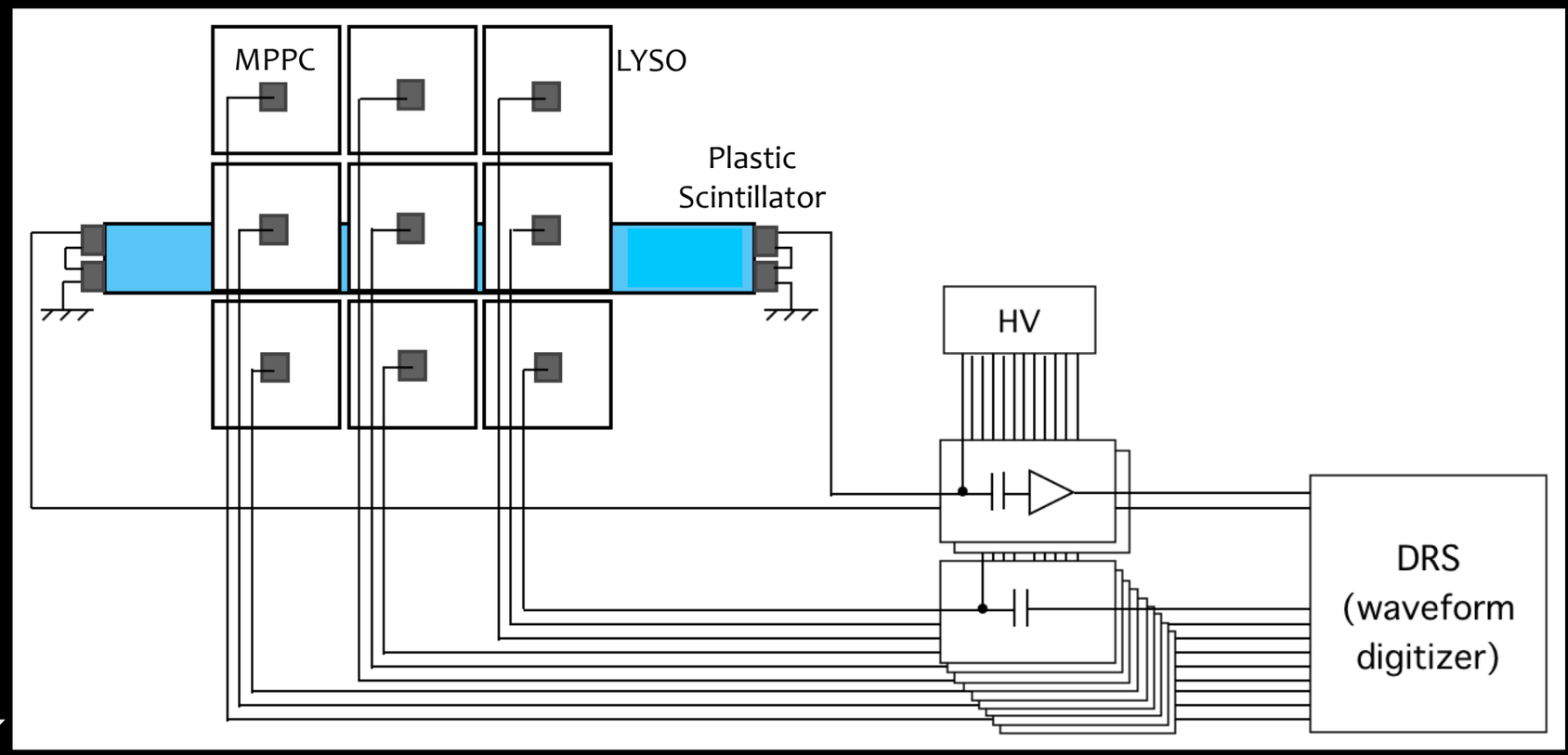
  - Plastic scinti.
    : Landau-Peak
    (0.9 MeV)

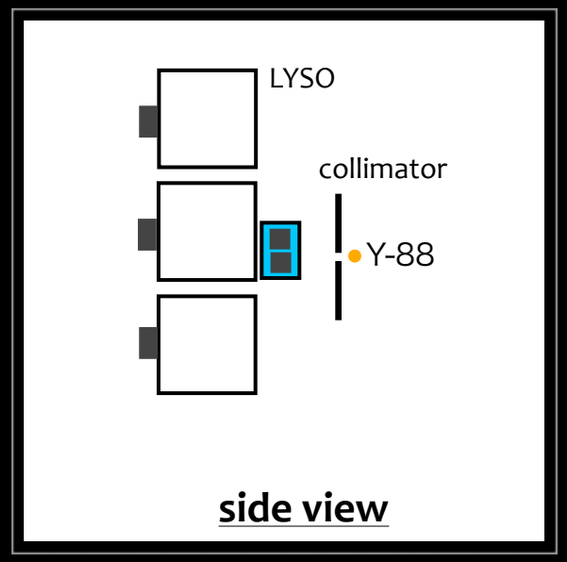


Setup

- **Setup**
  - Detector in the thermostat chamber
  - 9 LYSO crystals & 1 plastic scintillator
  - Trigger = Plastic scintillator & LYSO crystal







Detector test

Setup

- Setup
  - Detector in the thermostat chamber
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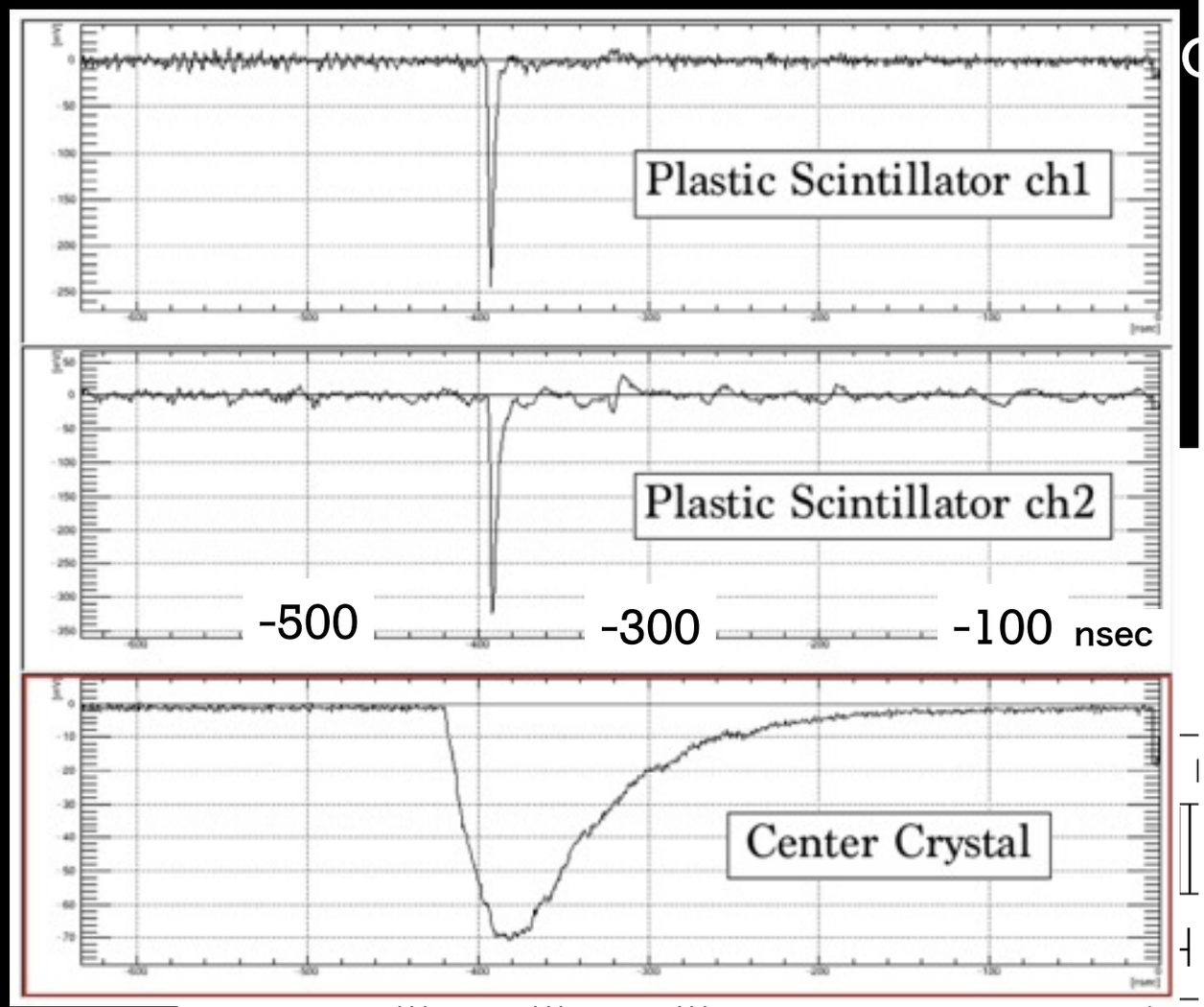
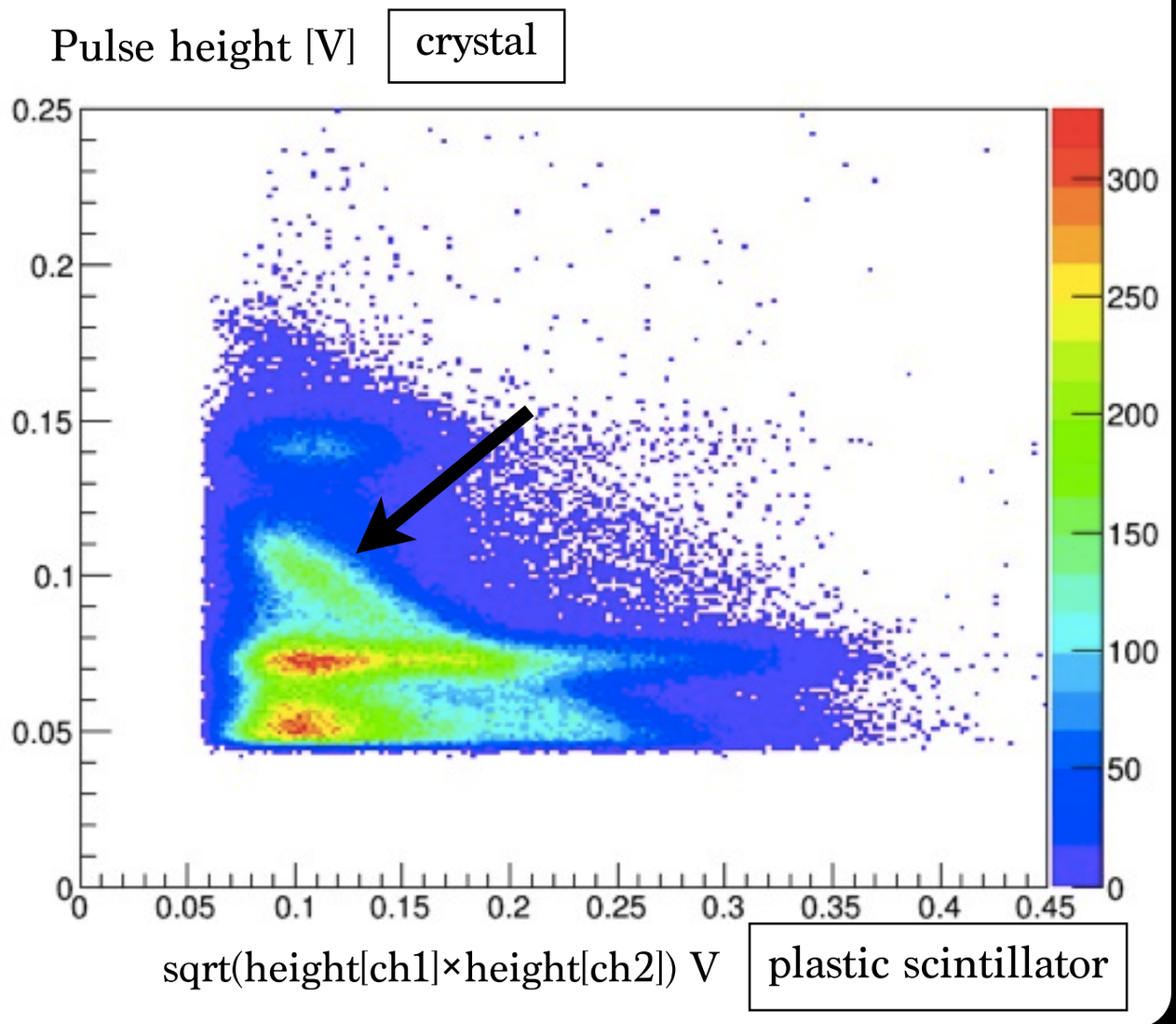


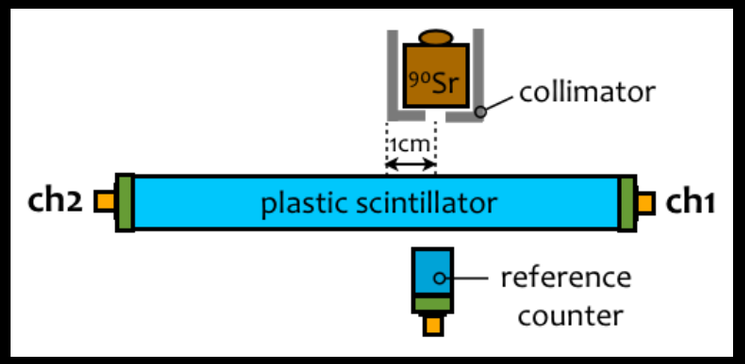


(waveform digitizer)

Detector test

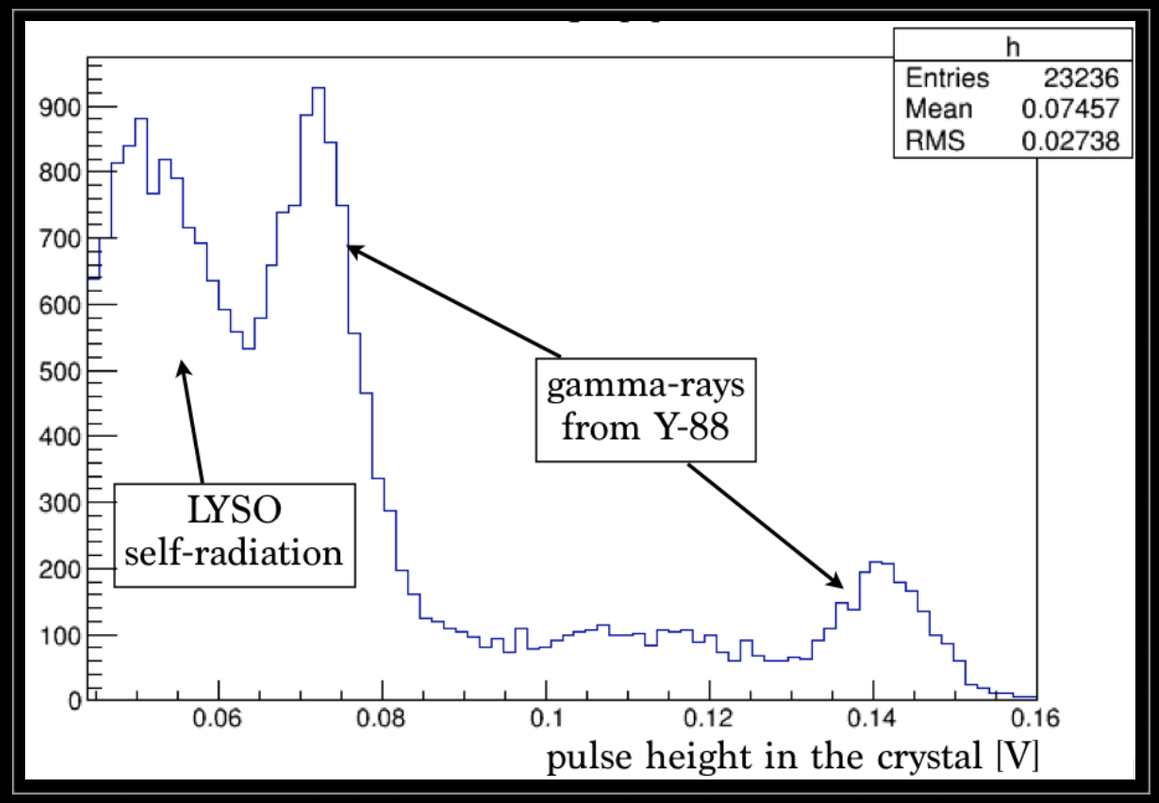
Calibration

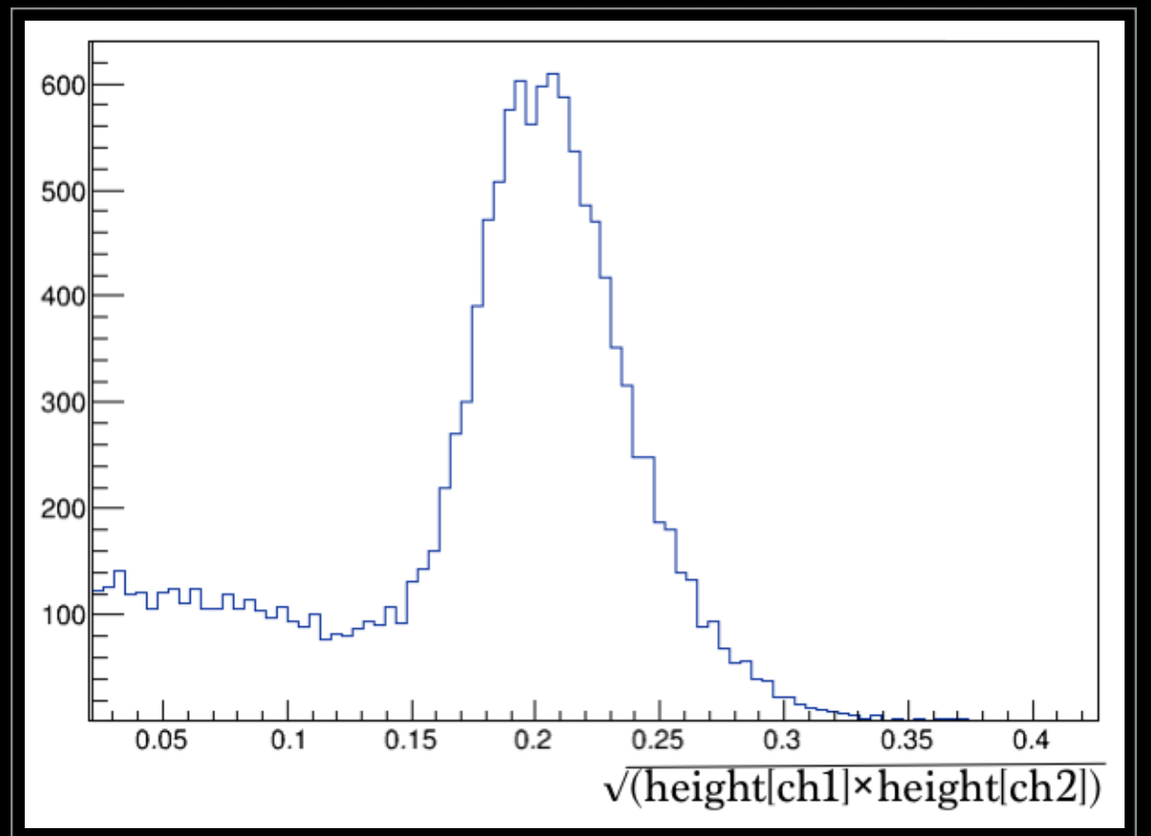
- LYSO
  - Self-radiation
  - Photo-Peak at 0.9 & 1.8 MeV
- Plastic scintillator
  - DAQ with ^{90}Sr
  - Landau Peak ~ 0.9 MeV



- Sum energy
  - Peak at 1.8 MeV

Expected energy





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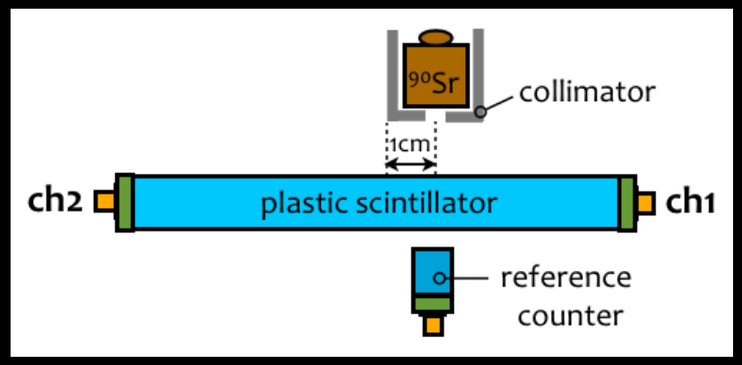

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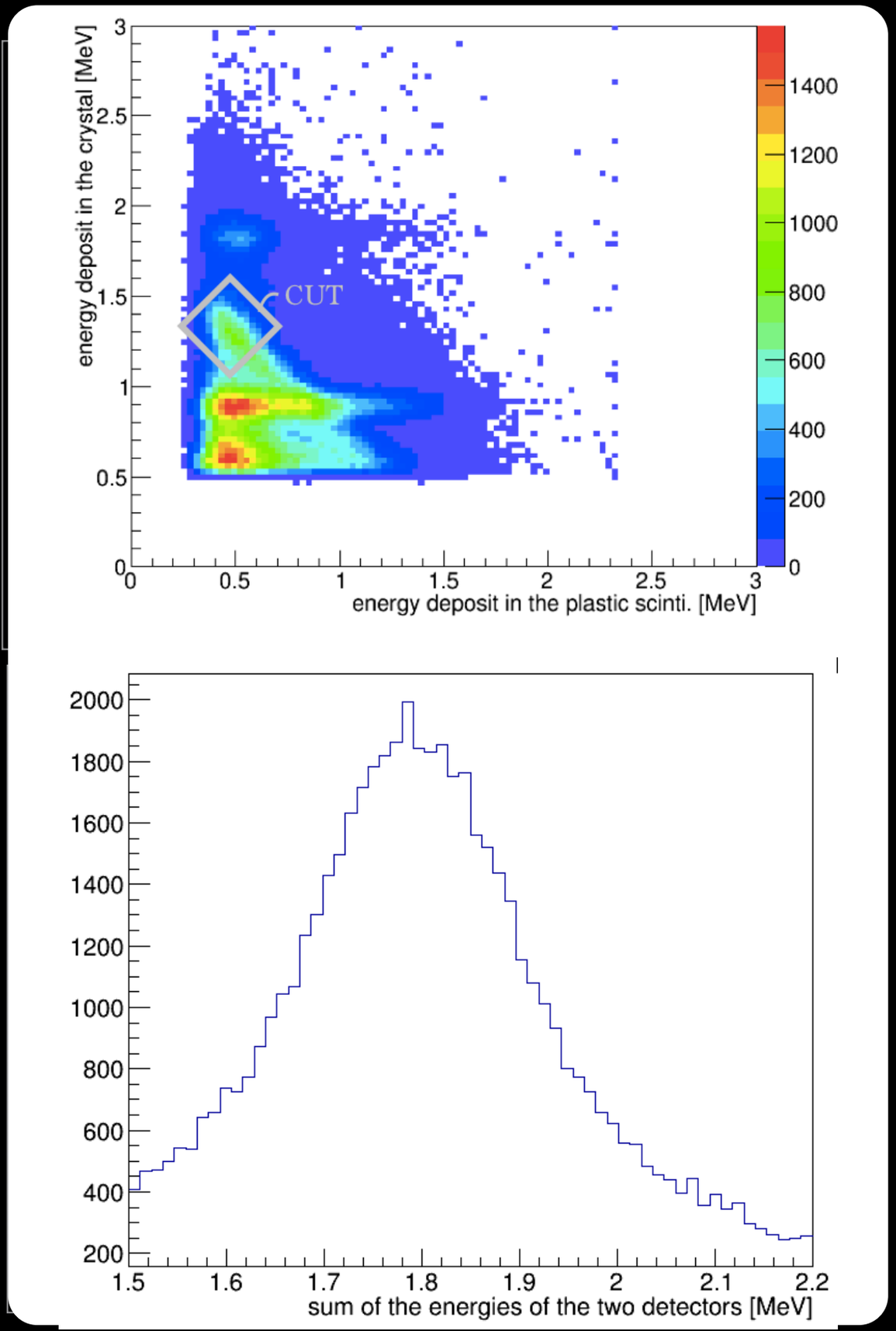

Calibration

Detector test

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- Plastic scintillator
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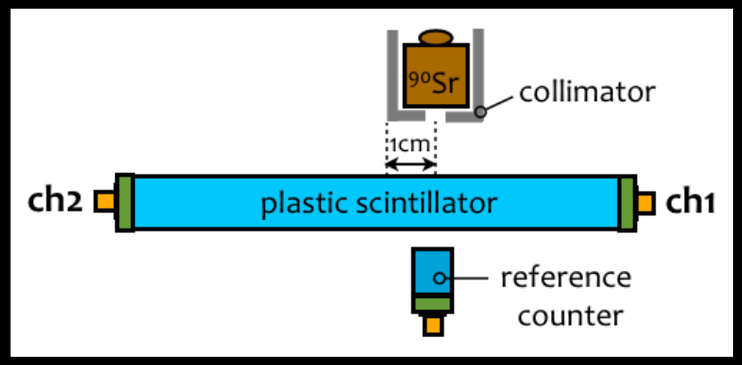

- Sum energy
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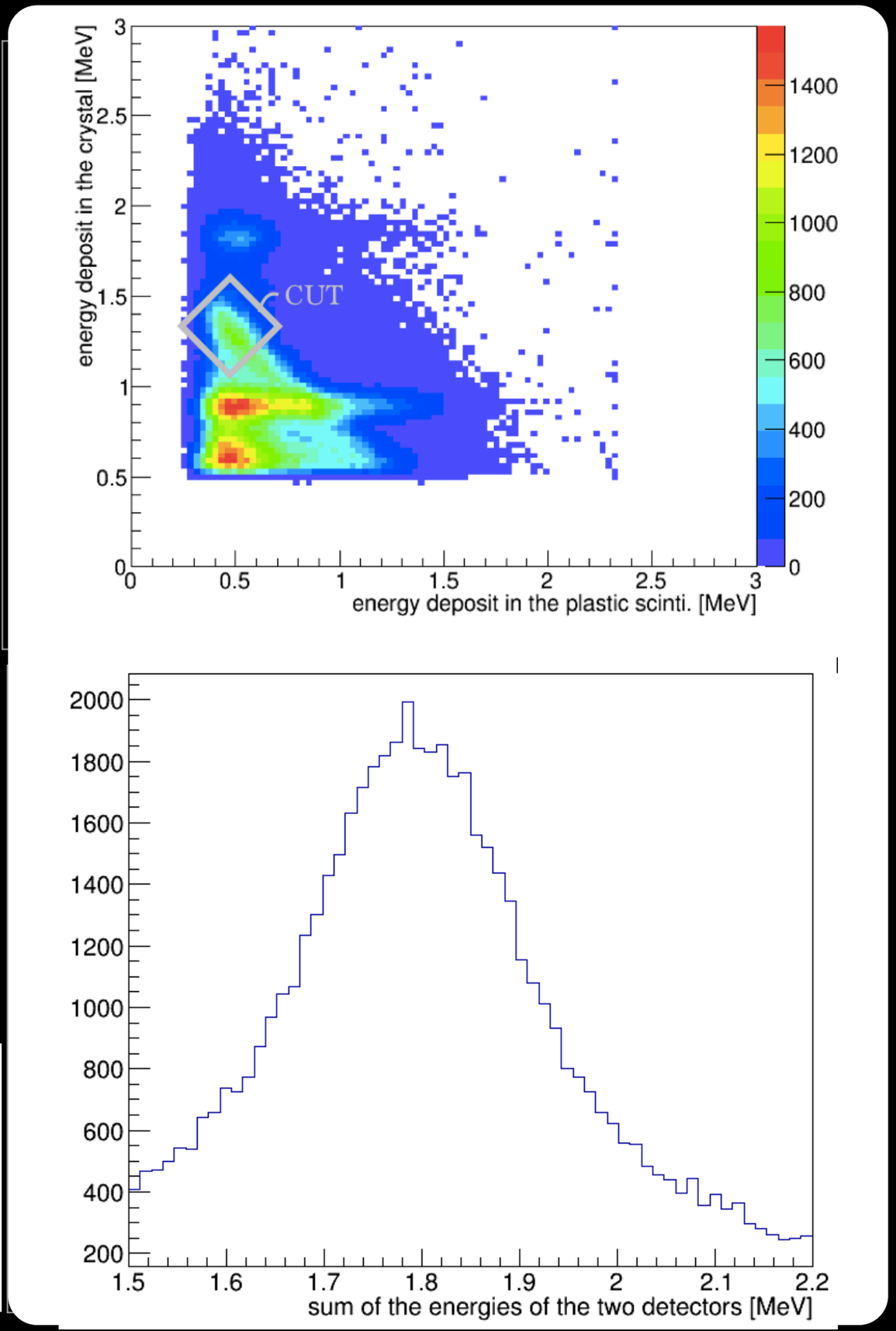
Expected energy



Conclusion

- DAQ with the two parts
- Energy calibration

) OK !

Summary

- **$\mu^+ \rightarrow e^+\gamma$ search**
  - Important probe to test the new physics
  - MEG II experiment aims at starting taking data in 2017
  - To further improve the sensitivity, the RDC will be newly introduced

- **Construction of the downstream RDC**
  - Timing counter & Calorimeter Parts were constructed
  - Their performances were separately checked

    and they showed good resolutions

- **Downstream Detector test**
  - The two parts were combined and tested in the lab
  - The data with the two parts was successfully taken
  - The calibration method for each counter worked properly

Summary & Prospect

Prospect

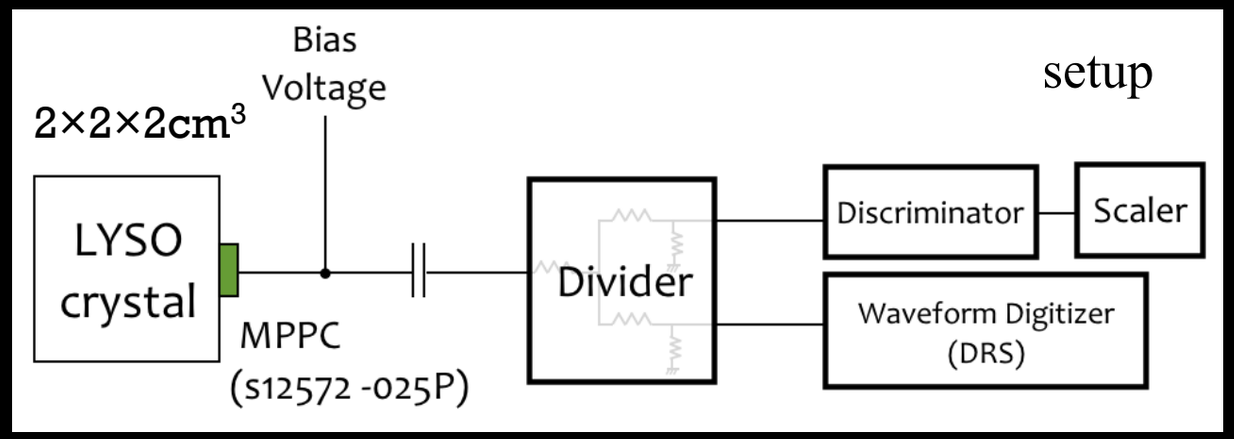
- Beam Test in June
  - RMD detection with the constructed detector
- Upstream RDC
  - Pileup study, engineering design, and so on…
- We will improve the sensitivity of MEG II using the RDC and try to discover the cLFV, $\mu^+ \to e^+ \gamma$.

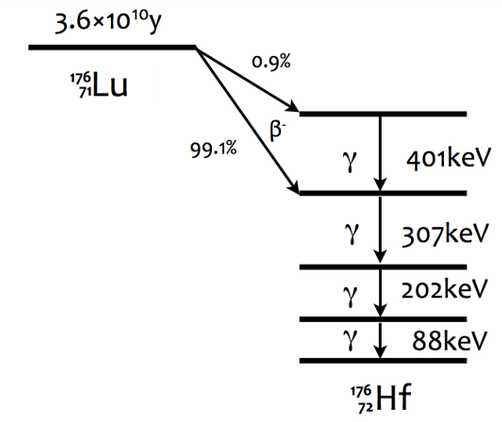
BACKUP SLIDES

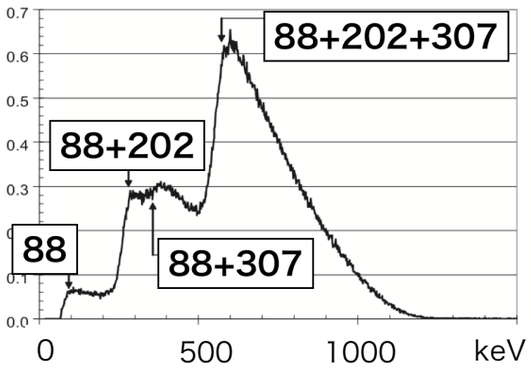
R&D

Calorimeter Part

- Self-radiation as calibration source
  - Radioactive isotope ^{176}Lu
  - The rate of the self-radiation was measured with a prototype detector

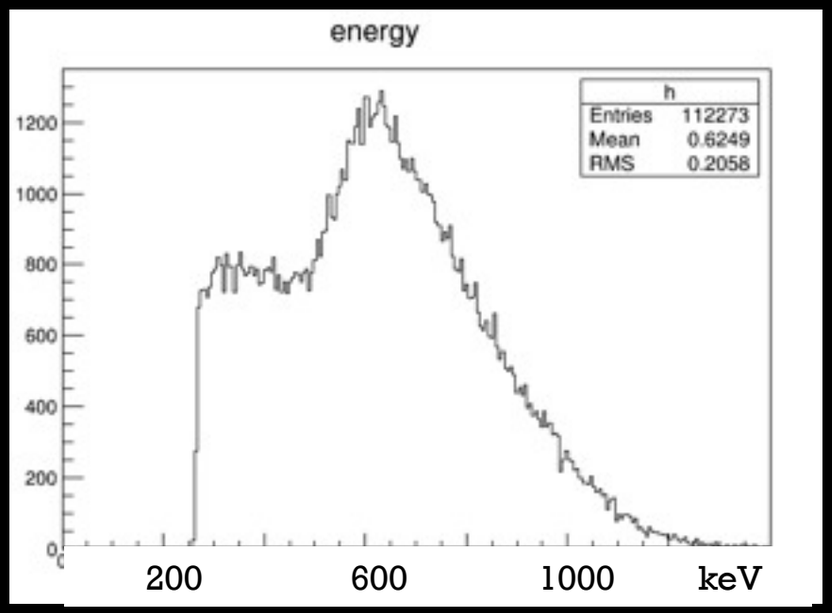






Saint-Gobain PreLude™ 420 data sheet

- Result: 2.1 kHz (energy > 250keV)



- High enough as calibration source
- Pile up events

  2.1kHz × (pulse width~0.5 μsec) ~ 1%
- LYSO was selected

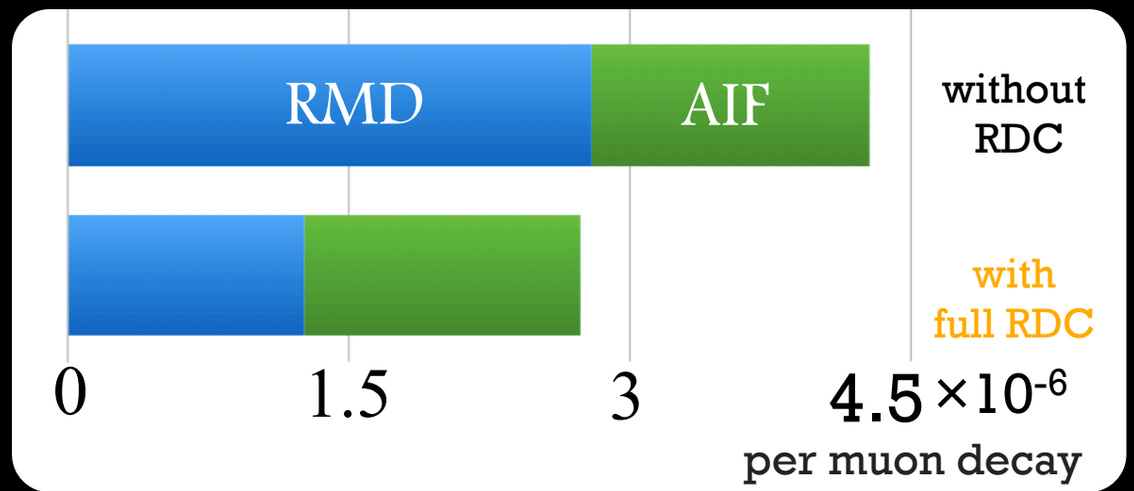
Research Background

Radiative Decay Counter (RDC)

■ Sensitivity

・54 % of the total background gamma-rays will be identified

and the sensitivity will be improved by 28 %



	sensitivity (in 3 years)
Without RDC	5.0×10^{-14}
RDC Downstream	4.3×10^{-14}
RDC Downstream+Upstream	*$3.9\sim4.1\times10^{-14}$

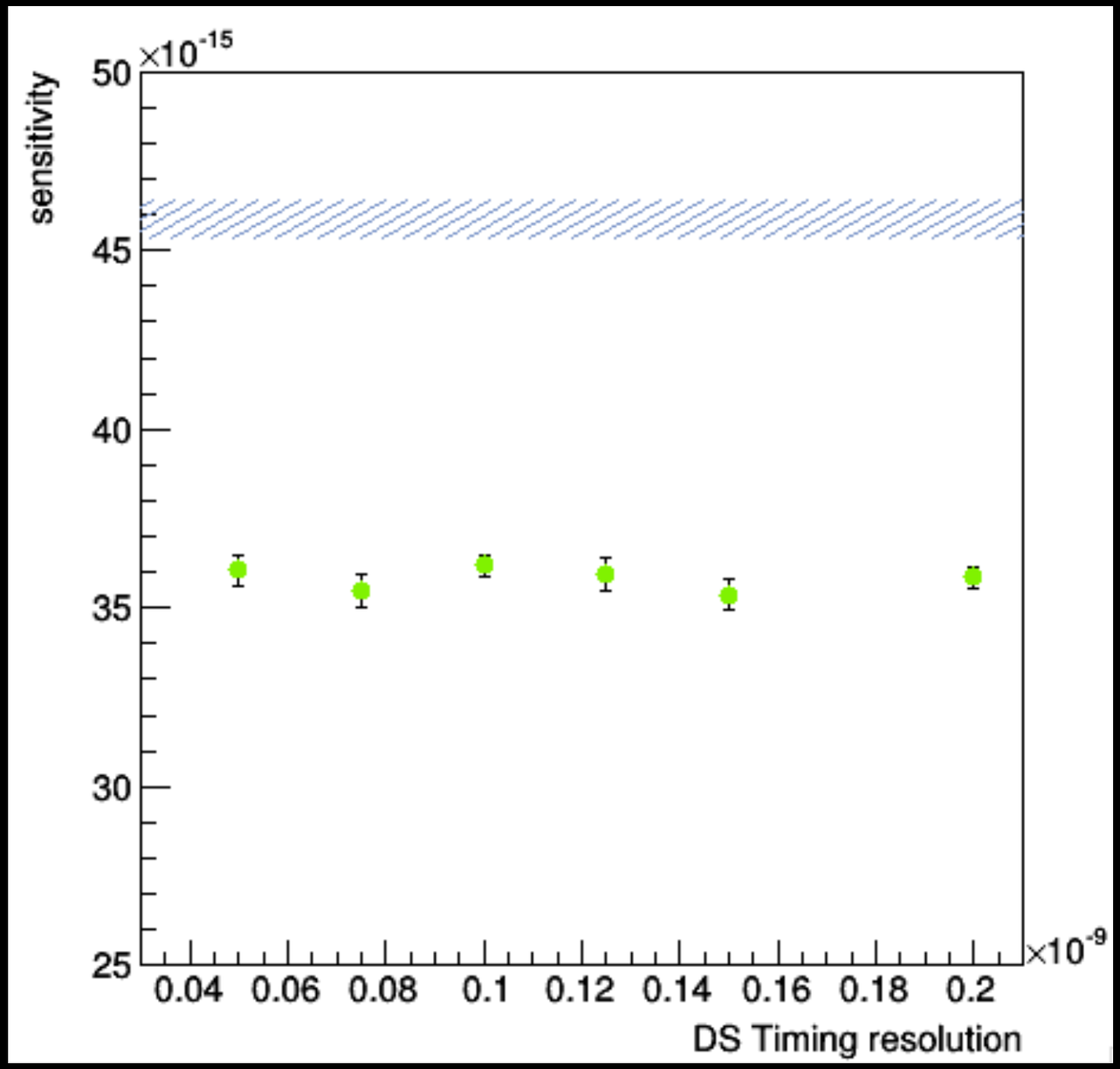
~16 %

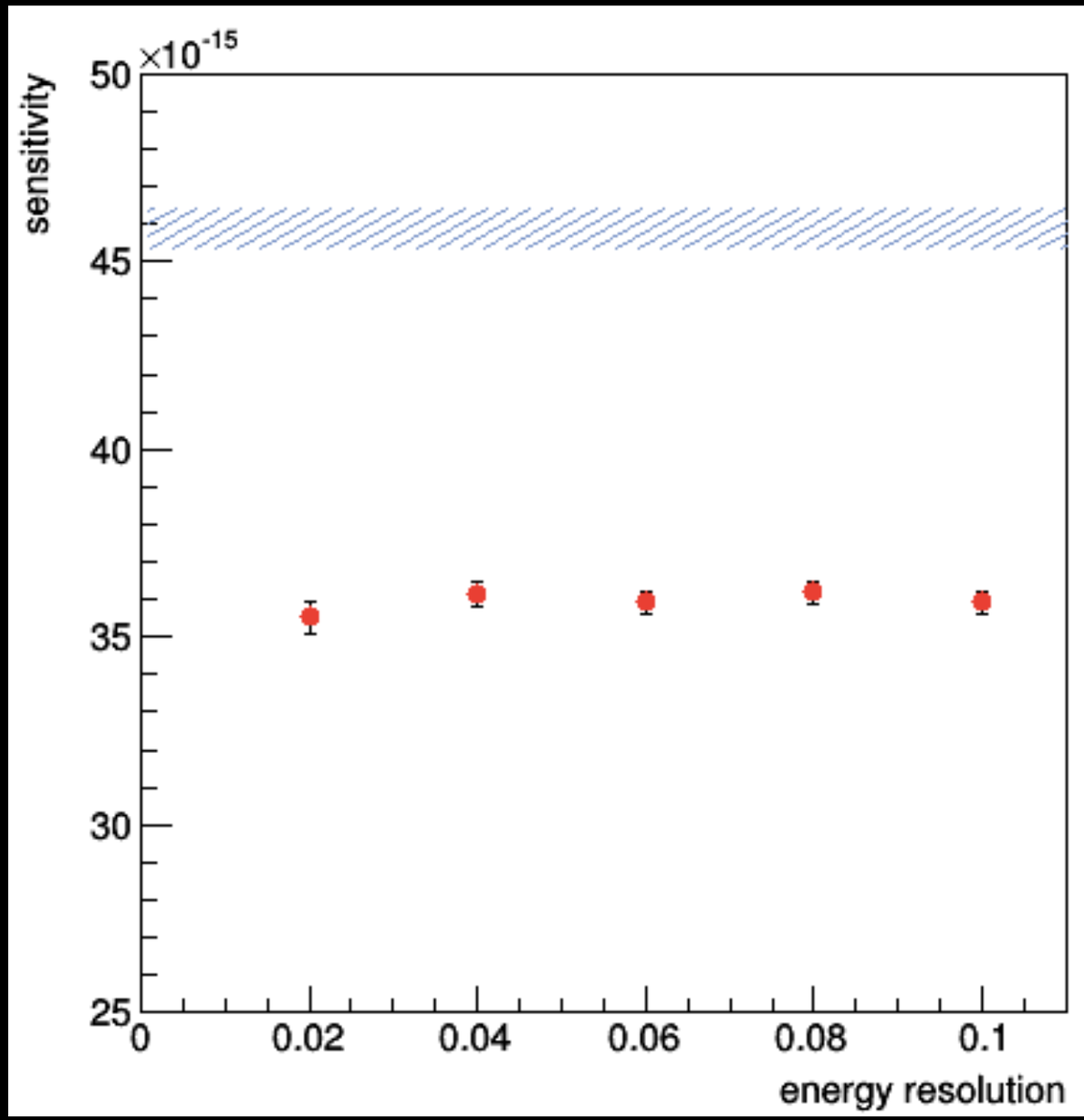
~28 %

* depending on detection efficiency (50%~80%)

Research Background

Radiative Decay Counter (RDC)

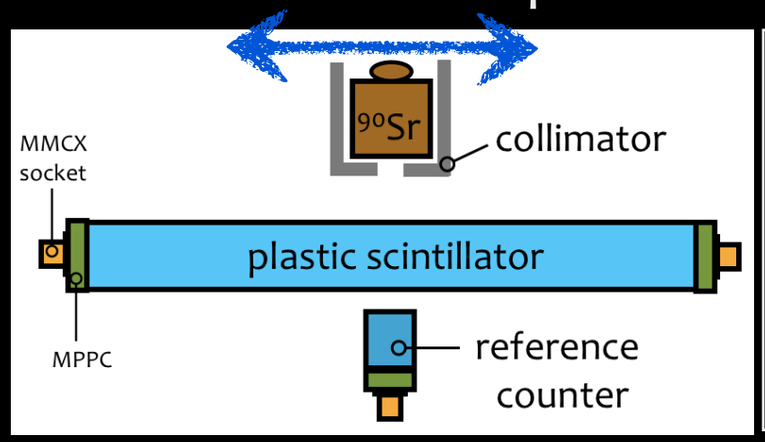




Timing Counter Part

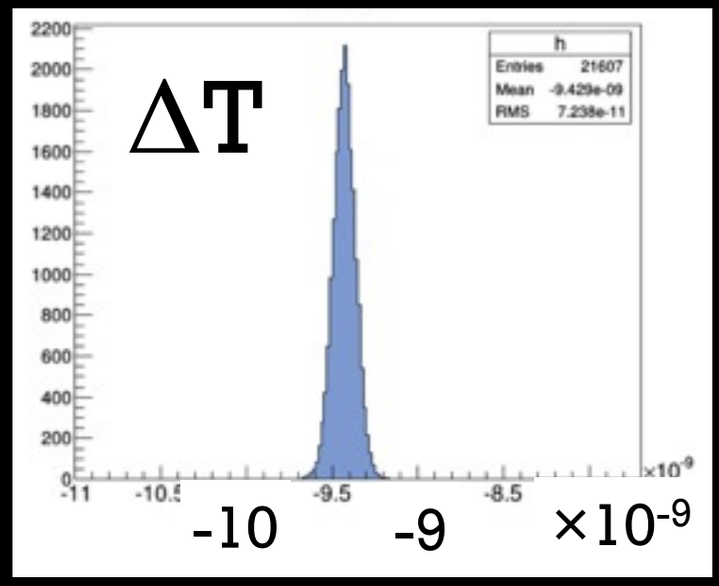
Construction

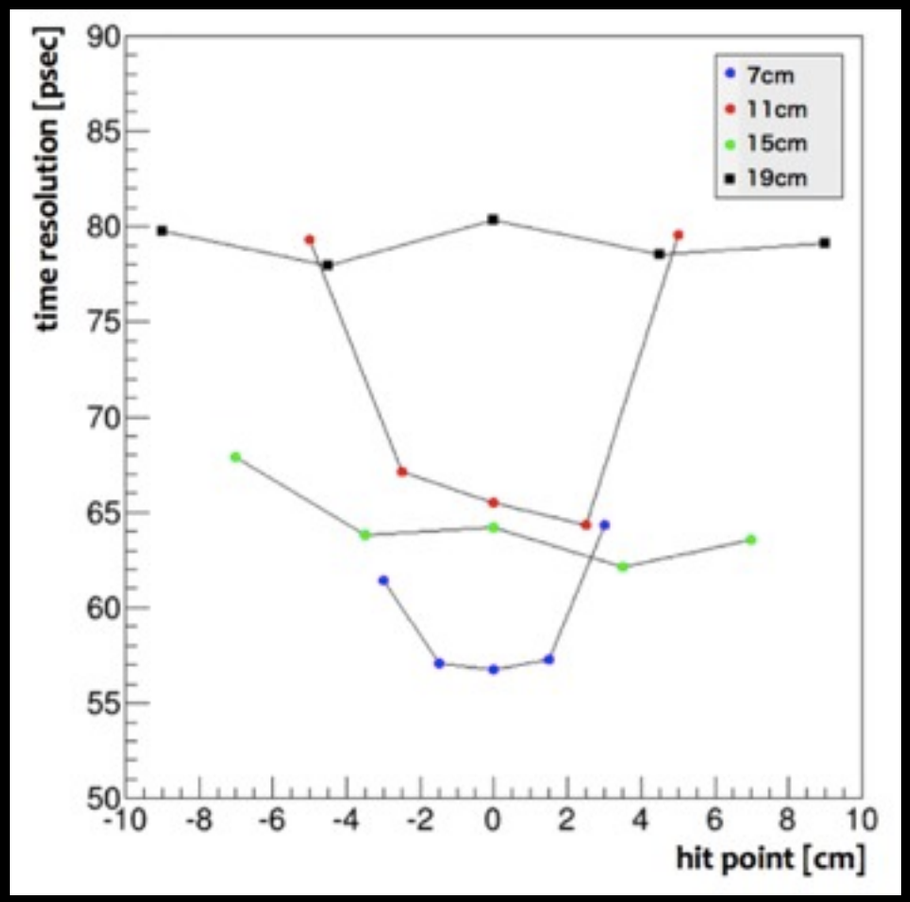
- Time resolution
  - Position dependence

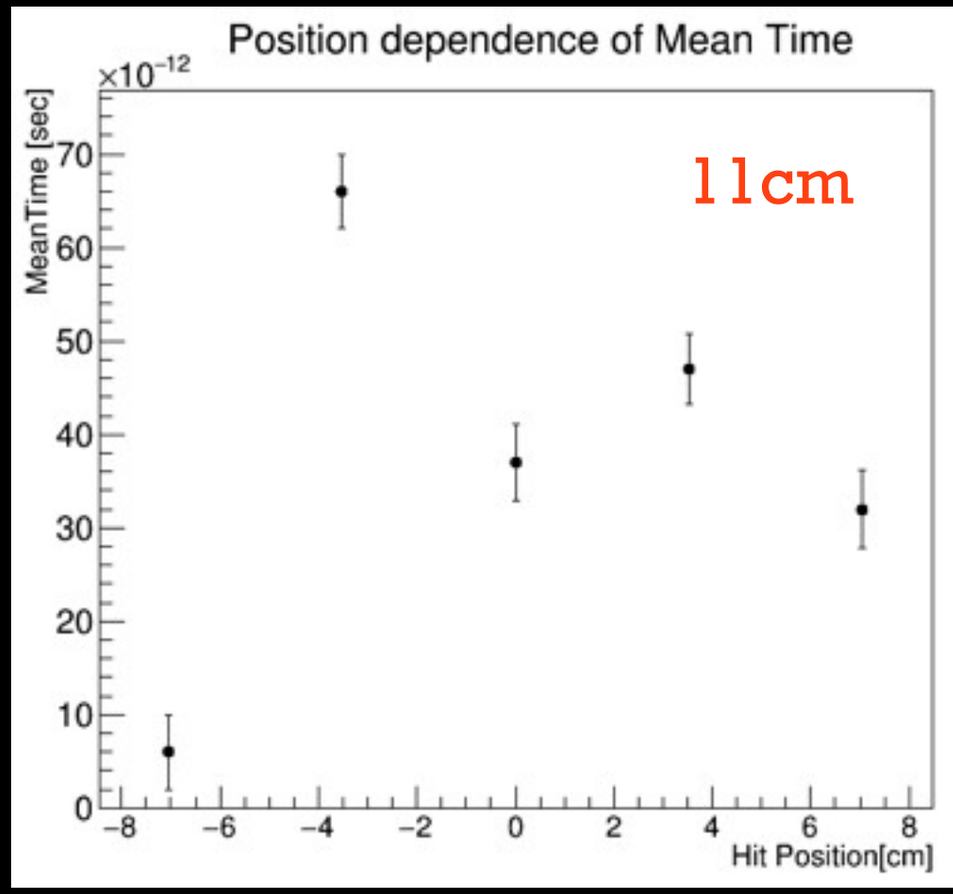


- Constant fraction time (15 %)
- [T(ch1) + T(ch2)] / 2 =: T_{mean}

  $\Delta T = T_{mean} - T_{ref}$
- Time Resolution = sigma





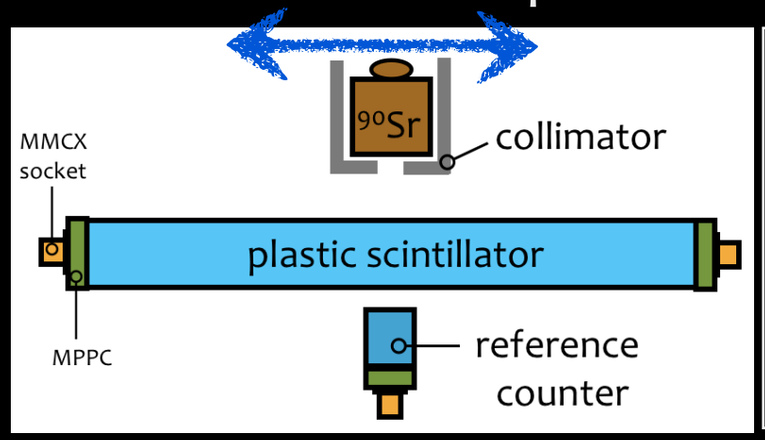


- Good resolutions (better than 90 psec) measured for all counters !
- Acceptable position dependence of mean time

Timing Counter Part

Construction

- Time resolution
  - Position dependence



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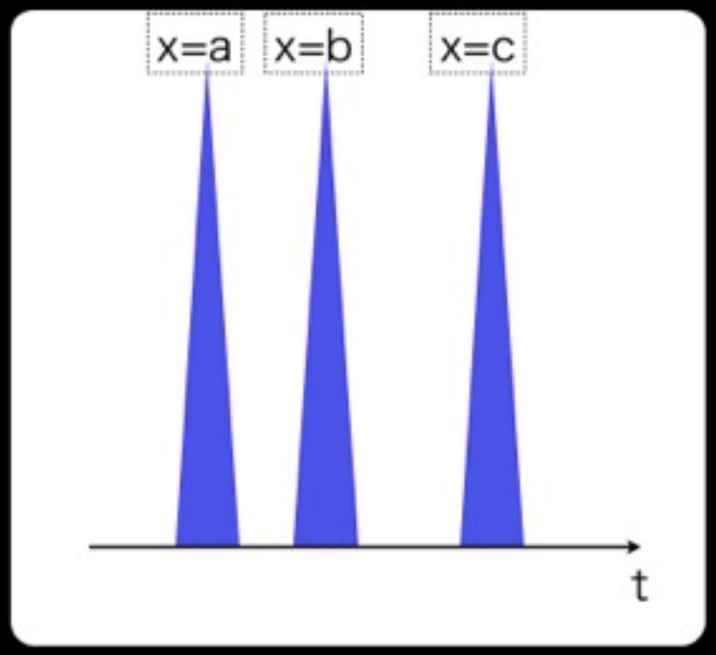
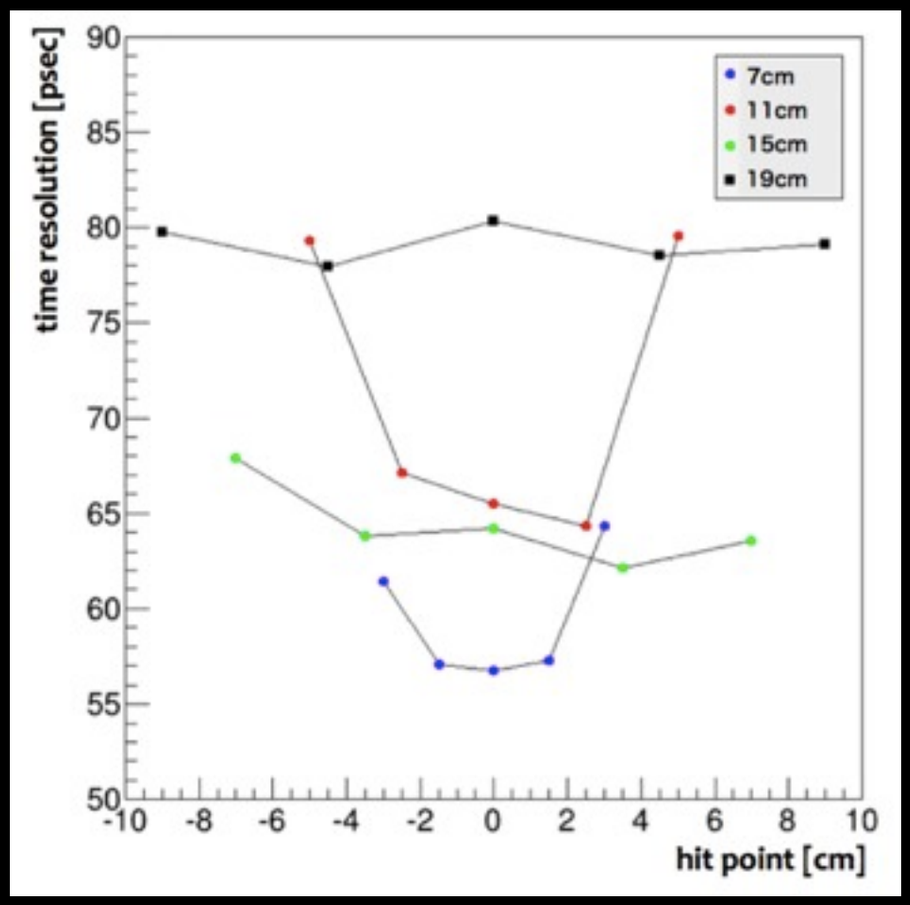
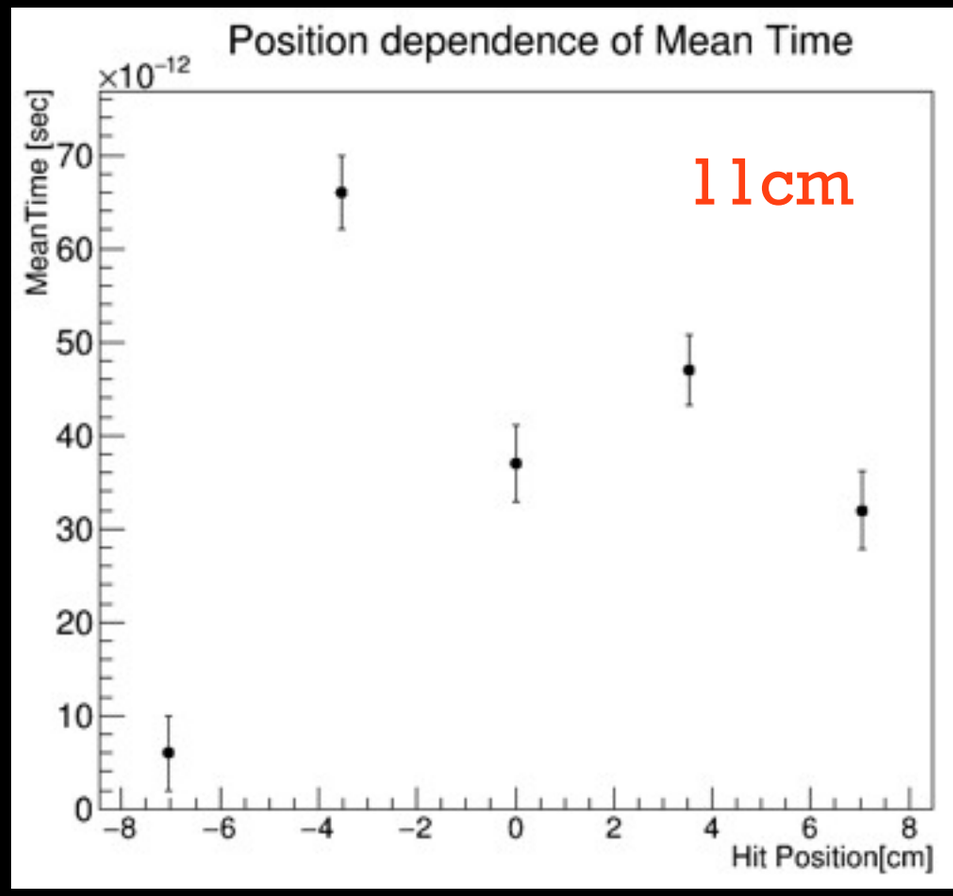






- Good resolutions (better than 90 psec) measured for all counters !
- Acceptable position dependence of mean time

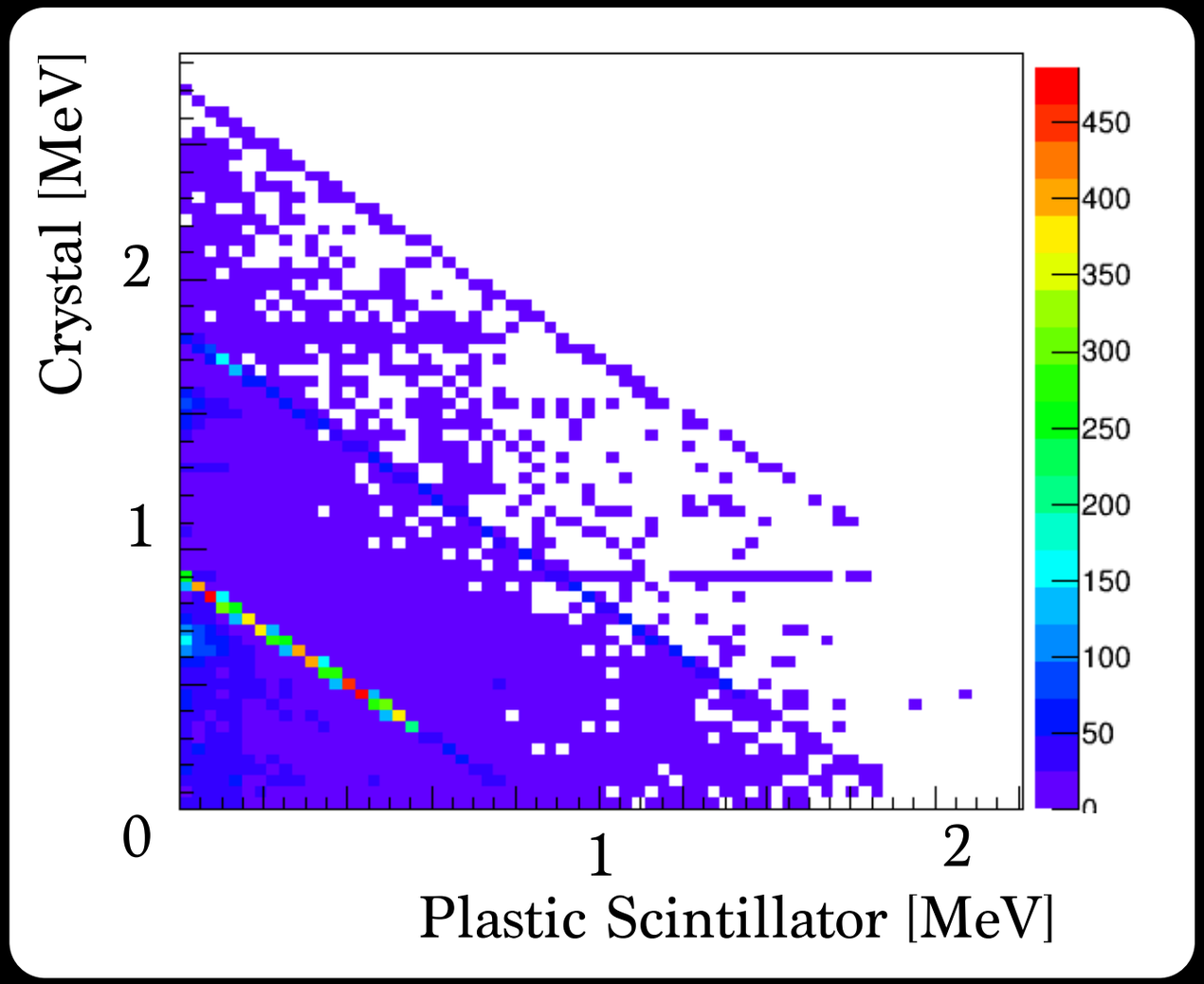
Detector test

Simulation

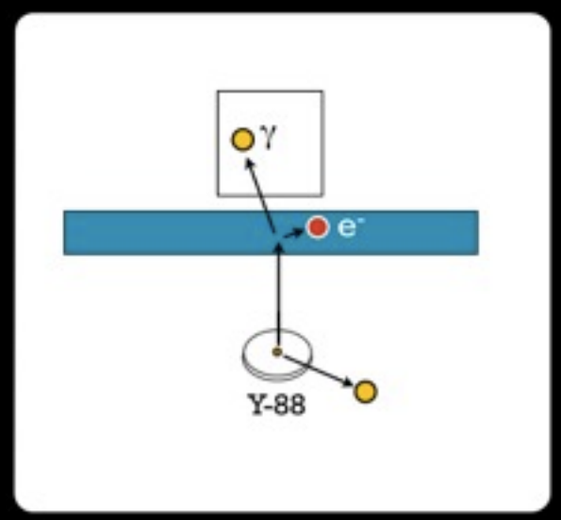
- Y-88
  - Dominant decay mode

    Two gamma-rays of 0.9 & 1.8 MeV

- Energy deposit



Correlation



Horizontal lines