Core-to-Core Program

The Development of a π Beam Position Detector for the Calibration of the MEG II Liquid Xe Detector

MEG II実験液体キセノン検出器の較正に用いる πビーム位置検出器の開発

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MEG II Mu - E - Gamma collaboration

東京大学 THE UNIVERSITY OF TOKYO

ICEPP The University of Tokyo

Outline

- Introduction
  - LXe Calorimeter of MEG II
  - $\pi^{-}p$ Charge Exchange Calibration

- Simulation Study
  - optimization of configuration
  - light yield & radiation hardness

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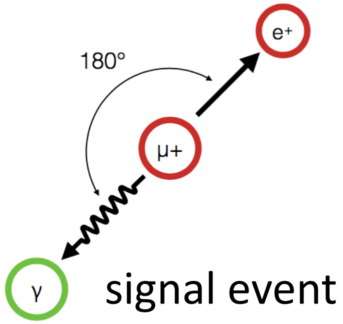
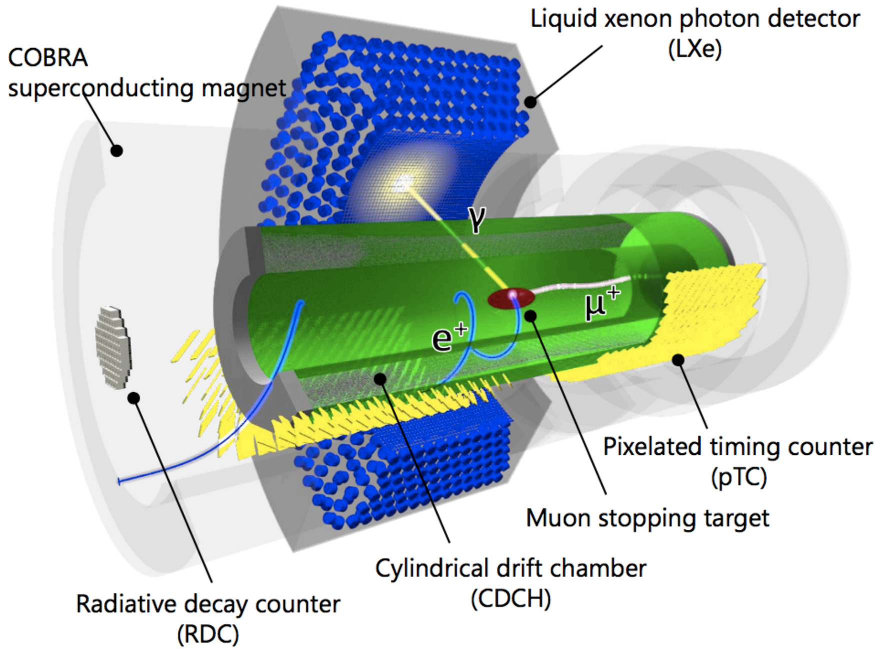
LXe Calorimeter of MEG II

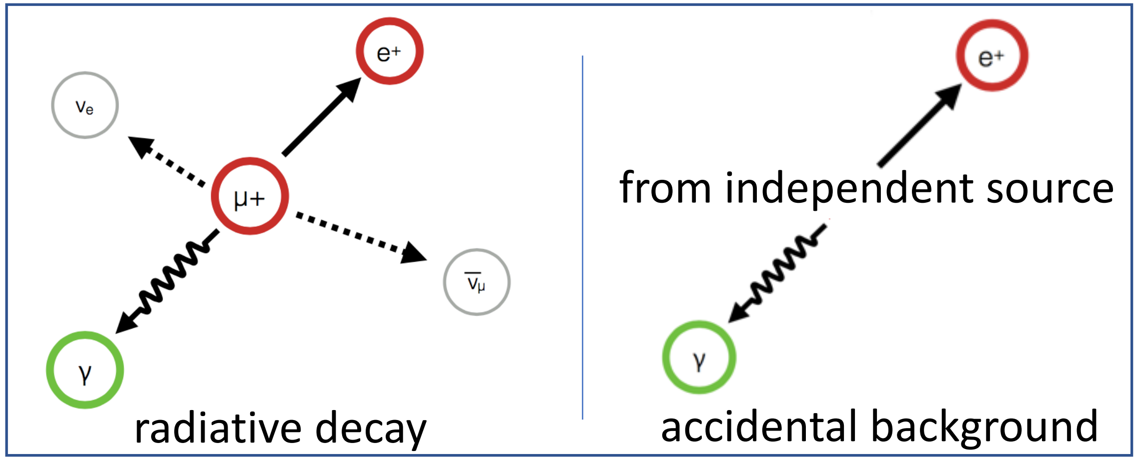
- MEG II searches for $\mu \rightarrow e\gamma$
  - 52.8 MeV/c
  - back-to-back
  - same timing





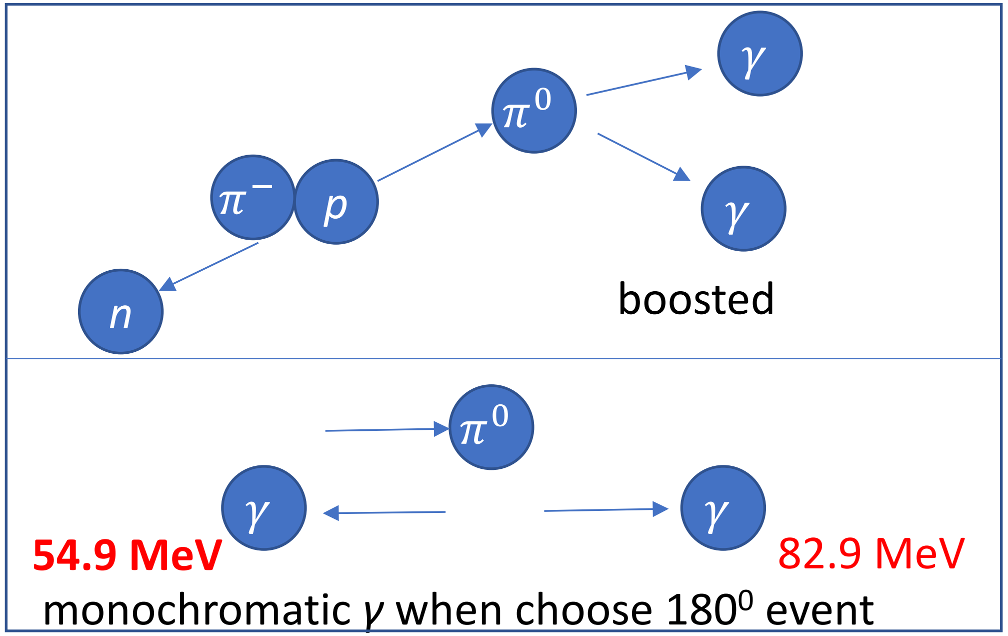
- reconstruct γ using
  - LXe (Liquid Xenon) scintillator
  - 4092 MPPC, 668 PMT

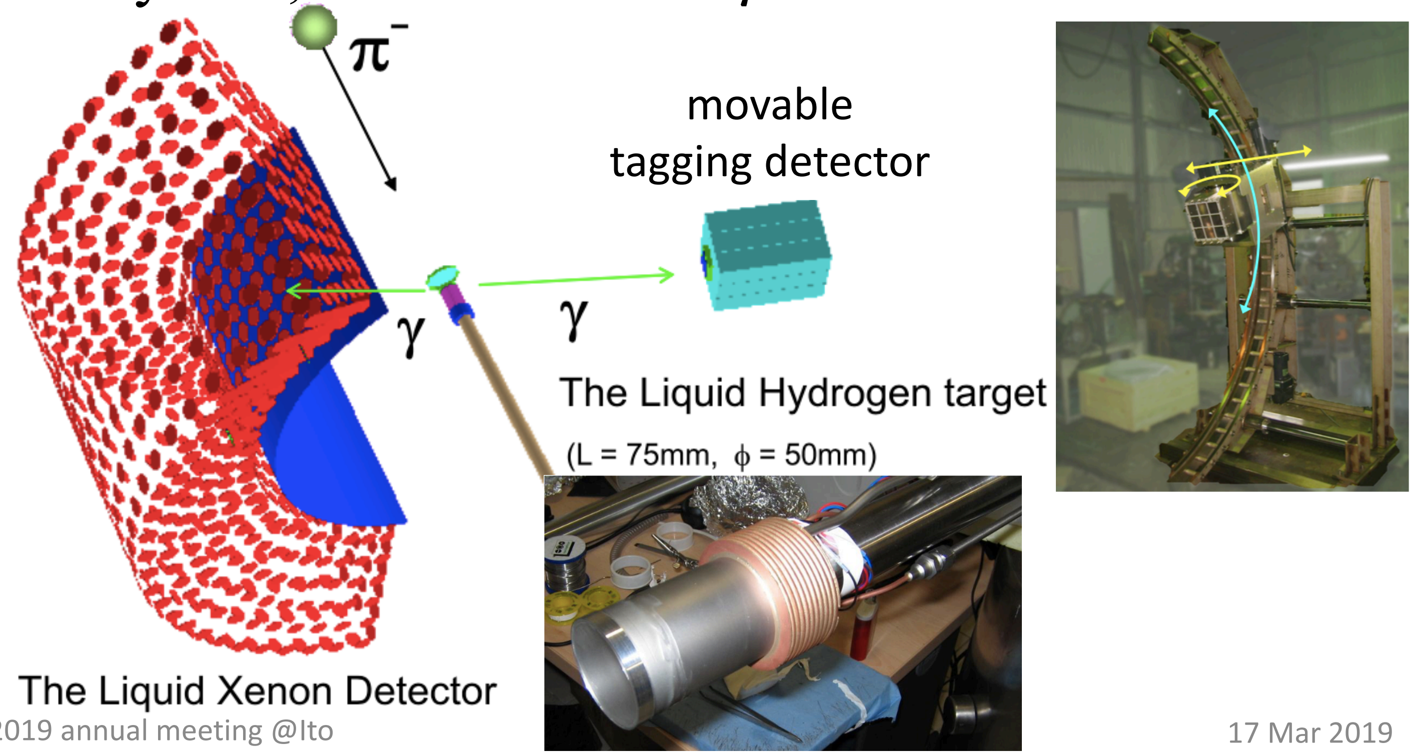
- background events
  - radiative muon decay
  - accidental background
  - → resolution is important



$\pi^- p$ Charge Exchange Calibration

- $\pi^- p$ charge exchange reaction: $\pi^- + p \rightarrow \pi^0 + n,\ \pi^0 \rightarrow \gamma + \gamma$
  - stop π^- beam on hydrogen target at rest
  - π^0: momentum is 28 MeV/c
  - E_γ depends on angle b/w two γ in Lab. system (54.9 MeV – 82.9 MeV)
  - when choose back-to-back event in Lab. system, monochromatic γ can be obtained.





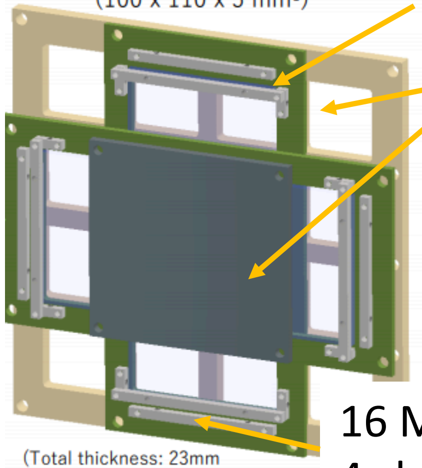
Estimation of Conversion Time & Energy

- timing is calculated from Time of Flight
- energy is determined from $\theta_{\gamma\gamma}$

timing

Pb for conversion

$\gamma \rightarrow e^{+}e^{-}$



Plastic Scintillator

16 MPPC

4 channel readout

pre-shower counter

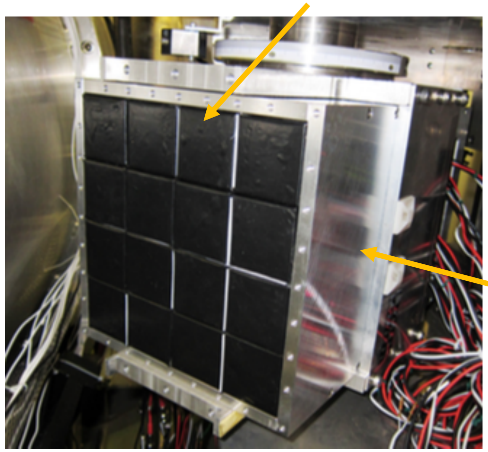
position resolution: ～ 7 mm

timing resolution : ～ 40 ps

energy

4 × 4 BGO crystal

46 × 46 × 200 mm each



PMT behind each crystal

BGO calorimeter

position resolution: ～ 10 mm

energy resolution : ～ 2.4 %

XEC

position resolution: O(mm)

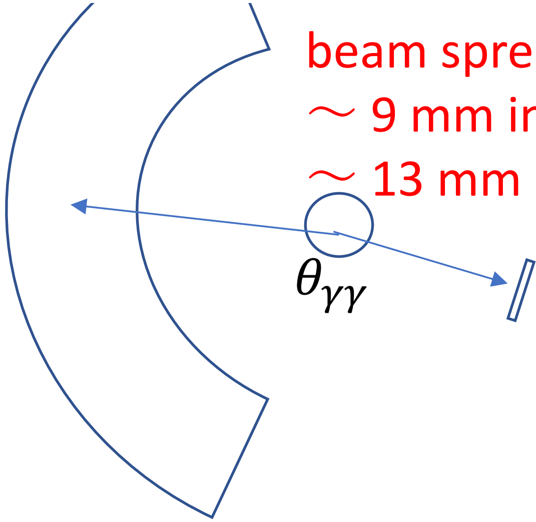
(expected energy resolution: ～ 50 ps)

(expected energy resolution: ～ 500 keV)

beam spread

～ 9 mm in transverse

～ 13 mm in depth



uncertainty of vertex position leads to uncertainty in estimation

→ introduce beam position detector

- small material
- radiation hardness

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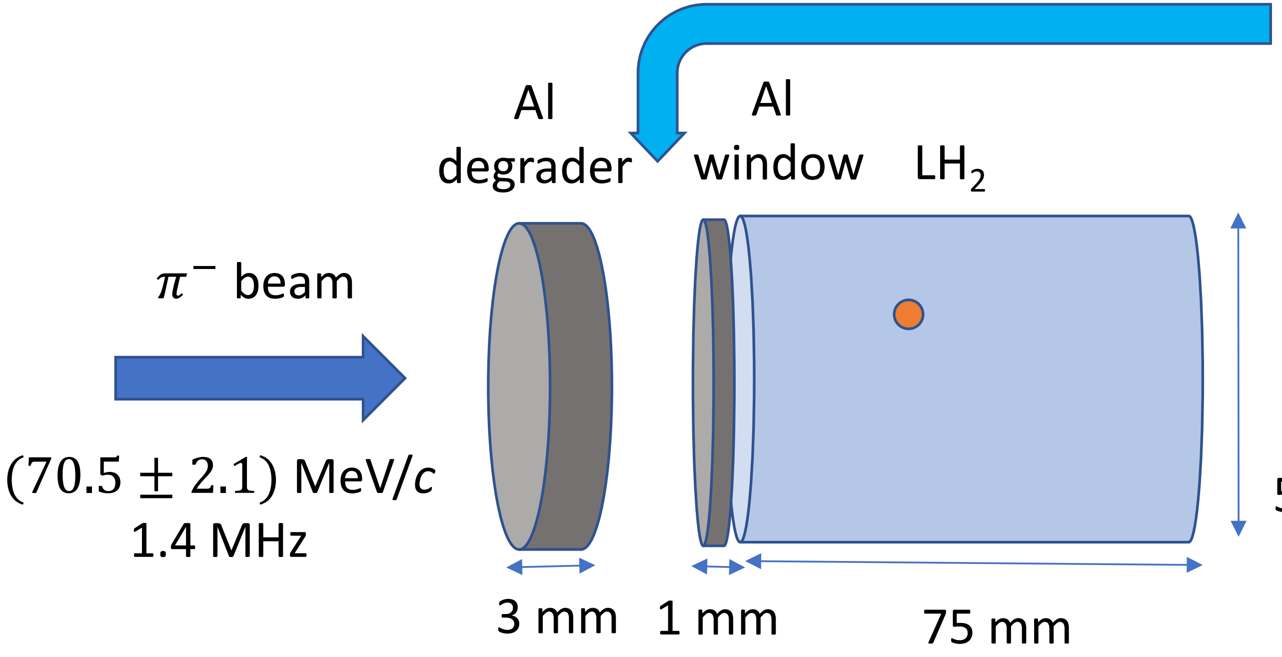
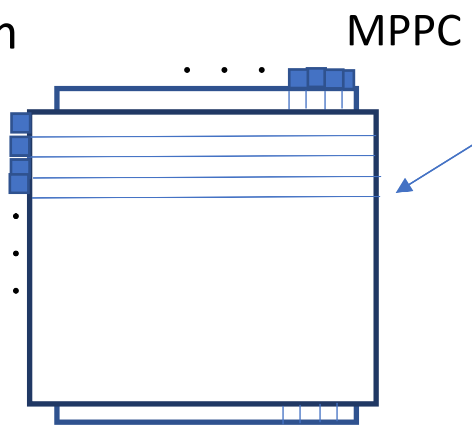
Idea of π^- Beam Position Detector

➢ put Scintillating Fiber in front of target



insert new detector

- ∼100 mm length, 500 or 250 μm thickness
- some fibers (BCF-12) make a bundle
- 1 MPPC for 1 bundle
- 2 layers for x & y

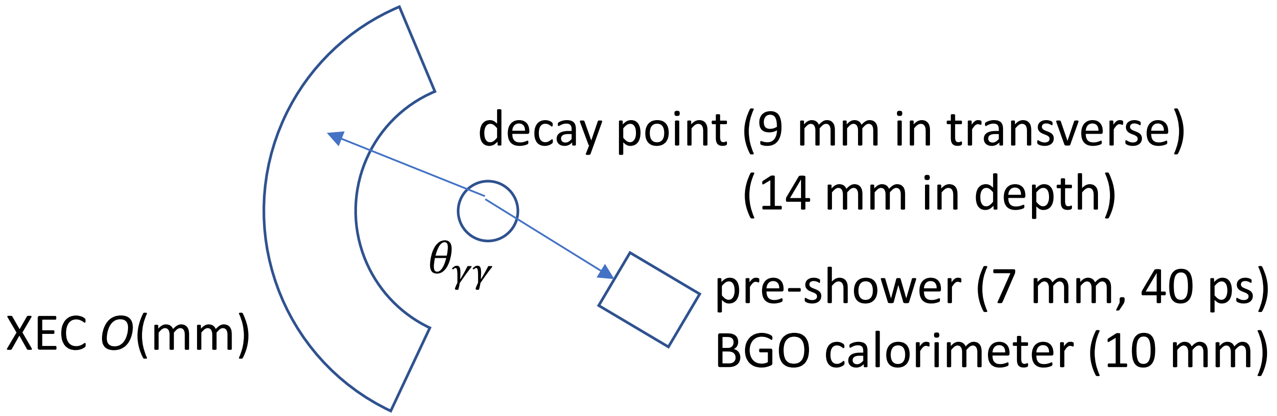


each bundle is made of some fibers

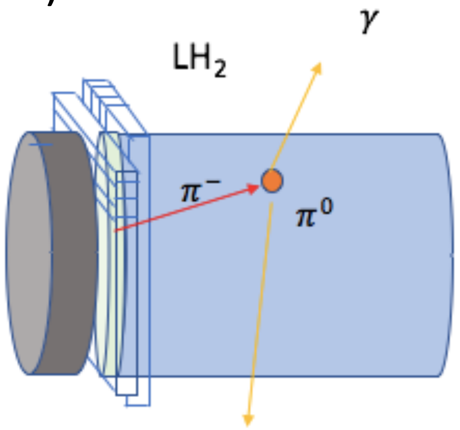
- how finely should it be segmented?
- large enough signal?
- radiation hardness? → simulation study

Simulation Setup

- use geant4 (ver. 10.3.1)
- inject (70.5 ± 2.1) MeV/c π^- (100,000 events)
- uncertainty of each detector is considered
  - π^- position detector
  - tagging detectors
    - pre-shower counter
    - BGO calorimeter
  - XEC

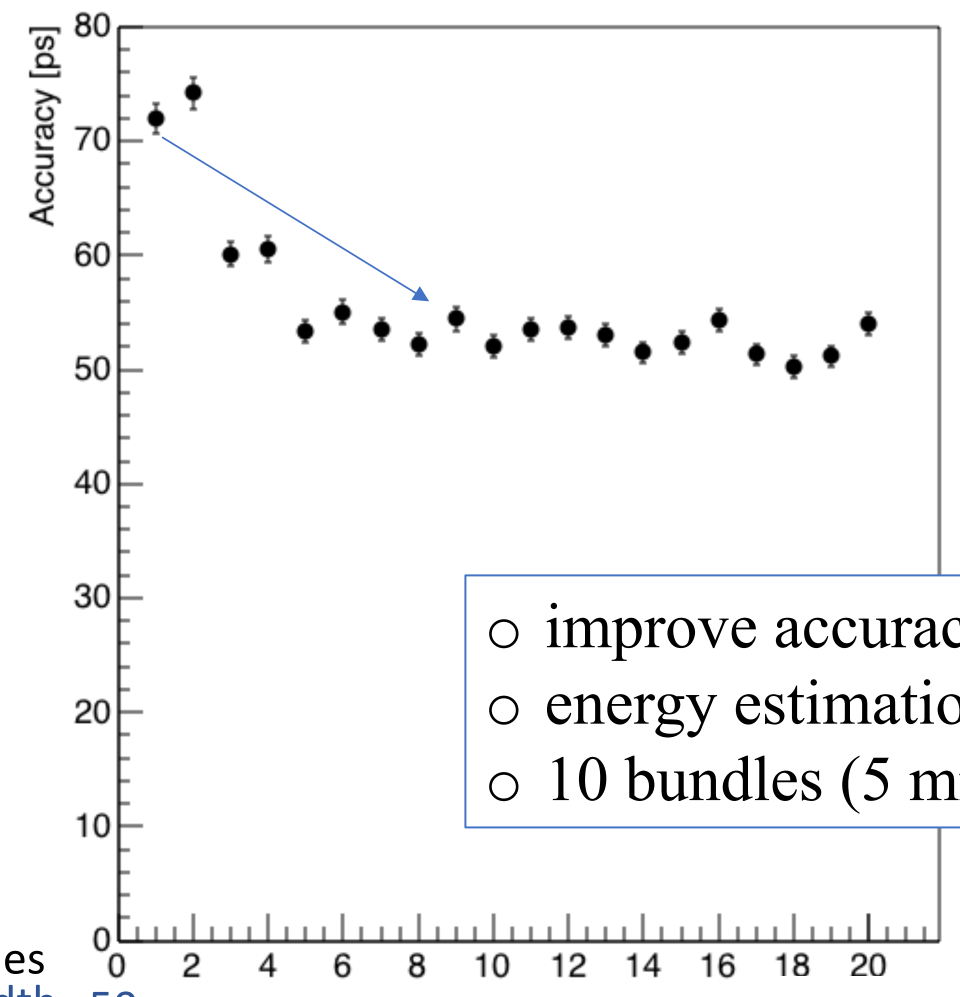


- scintillation photon is not simulated
- calculate "accuracy" :
  standard deviation of
  "estimated conversion time or energy" – "truth"

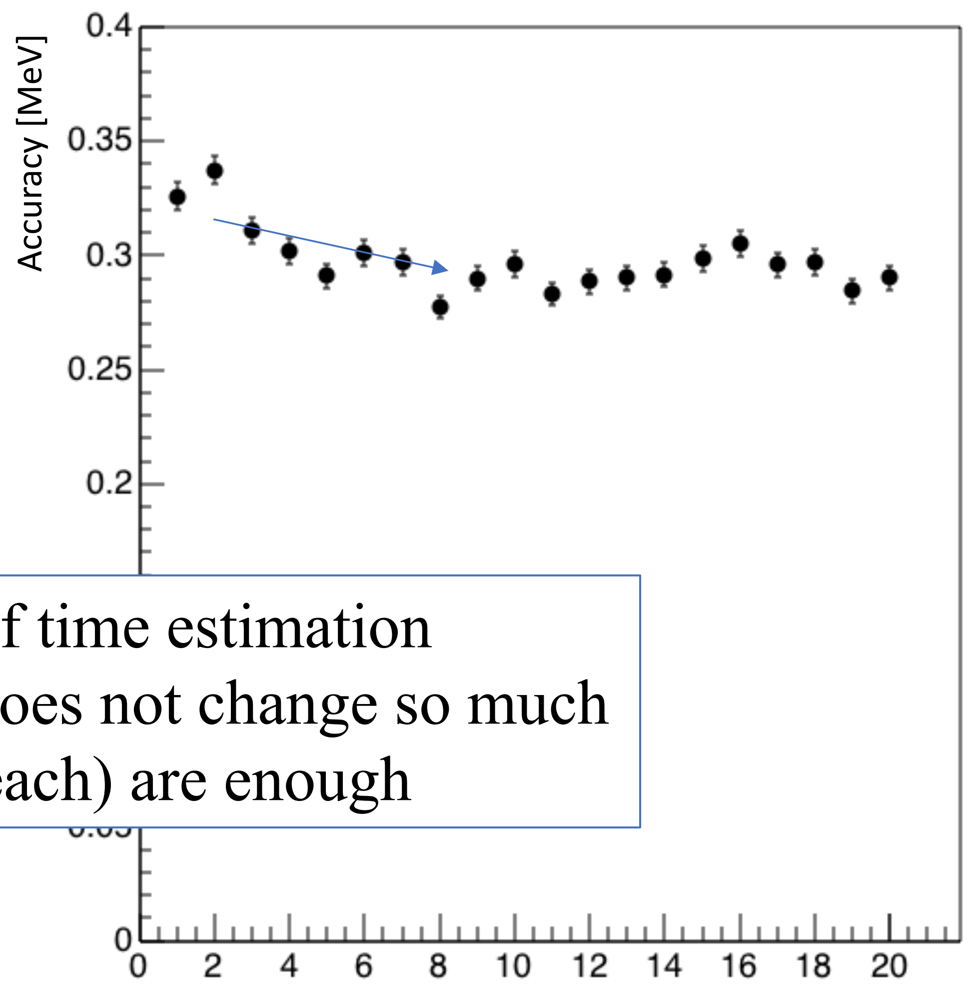


Segmentation Optimization

Accuracy of Time Estimation



Accuracy of Energy Estimation



- improve accuracy of time estimation
- energy estimation does not change so much
- 10 bundles (5 mm each) are enough

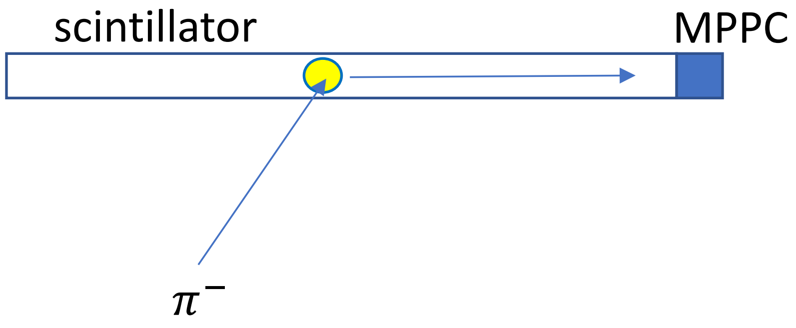
Light Yield

- $N_{pe} = N_{gen} \cdot T \cdot PDE$
  - N_{pe} : # of photons counted by MPPC
  - N_{gen}: # of generated scintillation photons

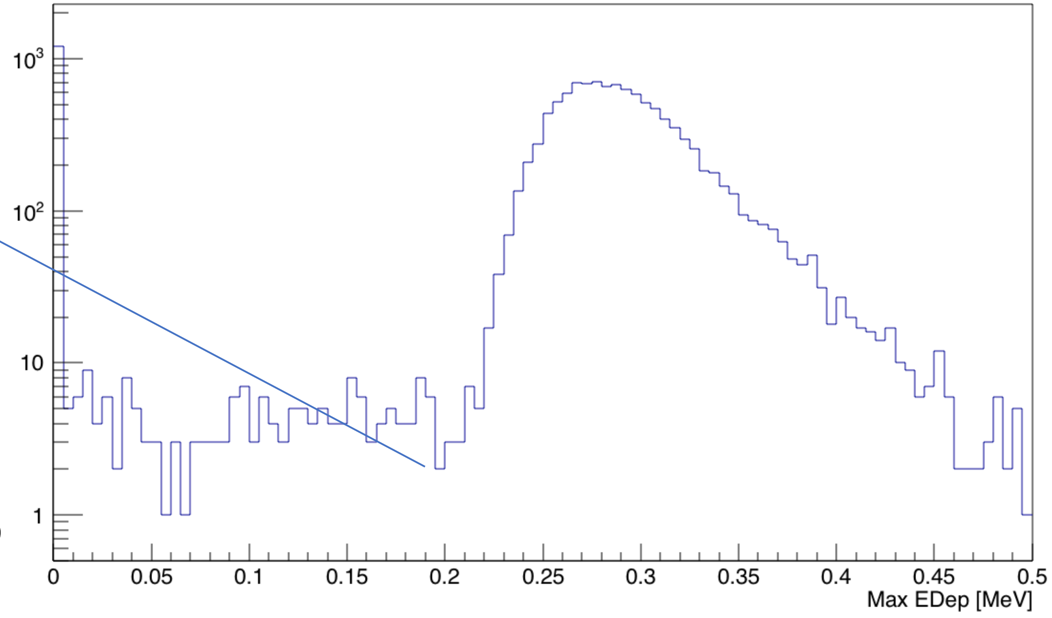
$$N_{gen} = \frac{\Delta N_\gamma}{\Delta E} \Delta E$$

> 0.2 MeV (efficiency: 89 %)

8,000 photon/MeV (BCF-12)



Energy Deposit (for 250 um width fiber)



  - T: probability of reaching MPPC

$$T = \frac{\delta\Omega}{4\pi} e^{-\frac{L}{L_{att}}}$$

∼15 cm

∼ 7 %

  - PDE: photon detection efficiency ∼40 %

→ N_{pe} ∼ 23 pe (large enough!)

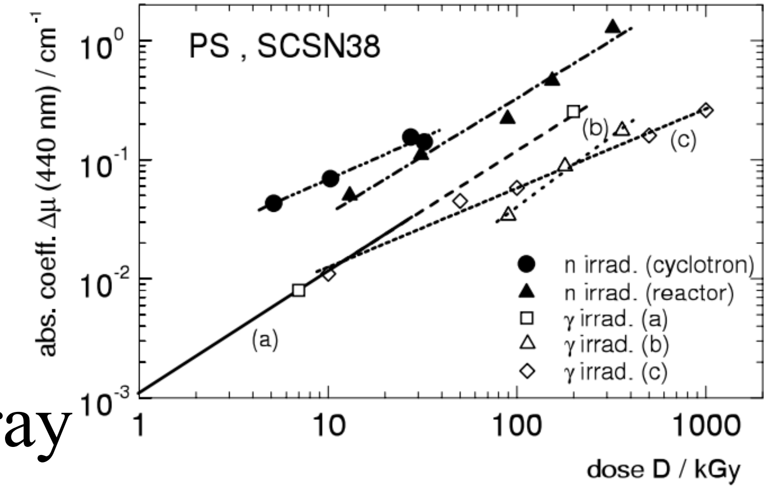
Radiation Damage on Fiber

- Calculation of Dose (Gy = J/kg)
  - beam rate: 1.4 MHz
  - e^- contamination: 26 times of π^- (can distinguish by ToF and signal size)
  - DAQ days = 10 days/year × 3-5 years

  → 15,000 Gy at center of beam spot

- effect to property
  - light yield: 50-65 % at 34,000 Gy of γ ray
  - transmittance: ~ 40 % at 10 cm at 15,000 Gy of γ ray

  → still detect ~ 10 pe after 5 years DAQ



Y.M. Protopopov, V.G. Vasil'chenko
Nucl. Instr. and Meth. in Phys. Res. B 95 (1995) 496-500

B. Bodmann, U. Holm
Nucl. Instr. and Meth. in Phys. Res. B 185 (2001) 299-304

Summary & Prospect

- $\pi^{-}p$ charge exchange calibration is important calibration method of LXe Calorimeter
- by placing Sci-Fi in front of target, estimation of timing & energy improves;
  σ_t: 70 ps → 50 ps, σ_E: 320 keV → 300 keV
- signal will be large enough even after 50 days radiation

- still need investigation on background from reaction on scintillating fiber
- possibility of make target active