MEG Calibration that should carry over to PIONEER

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THE UNIVERSITY OF TOKYO

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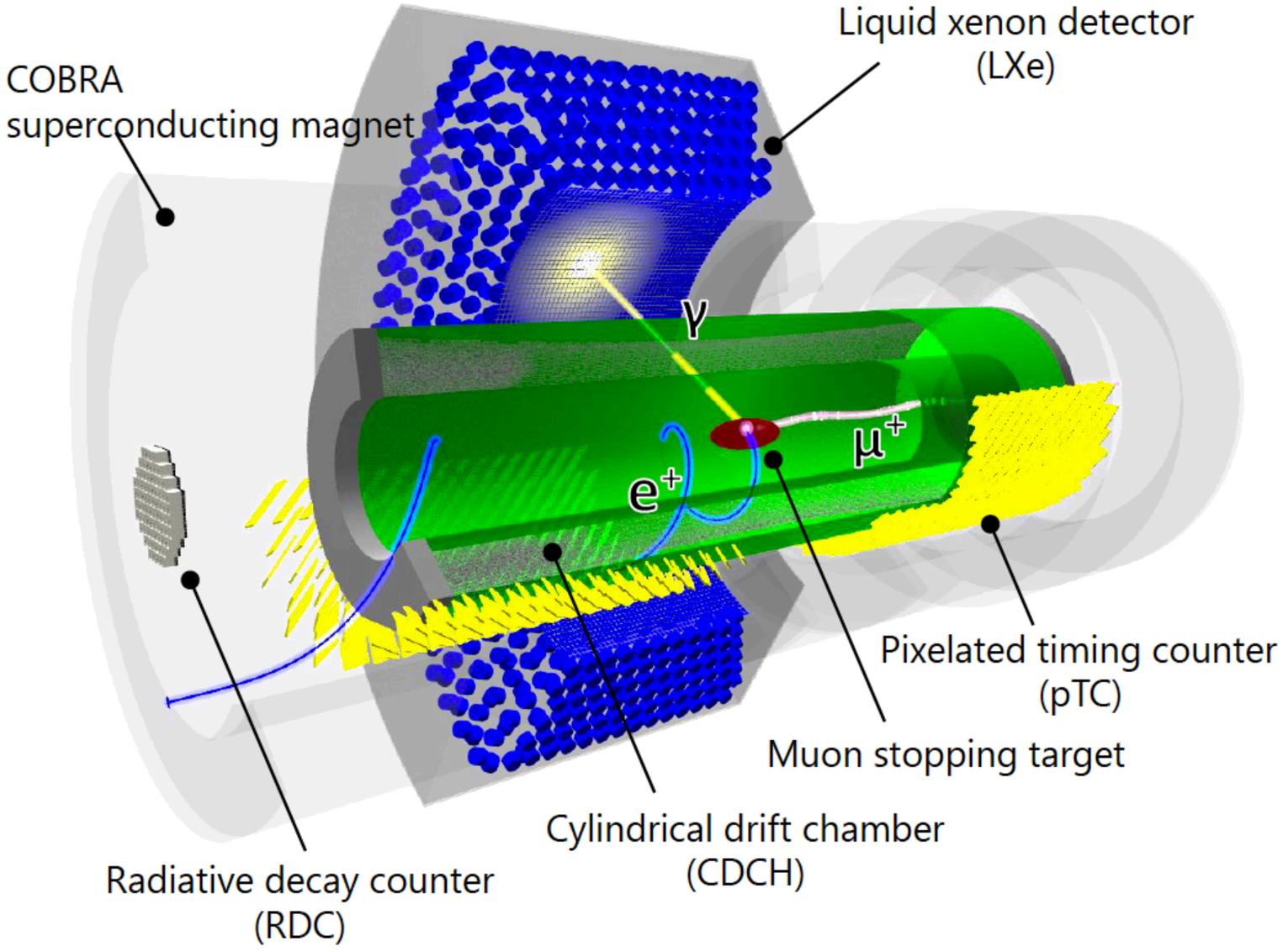
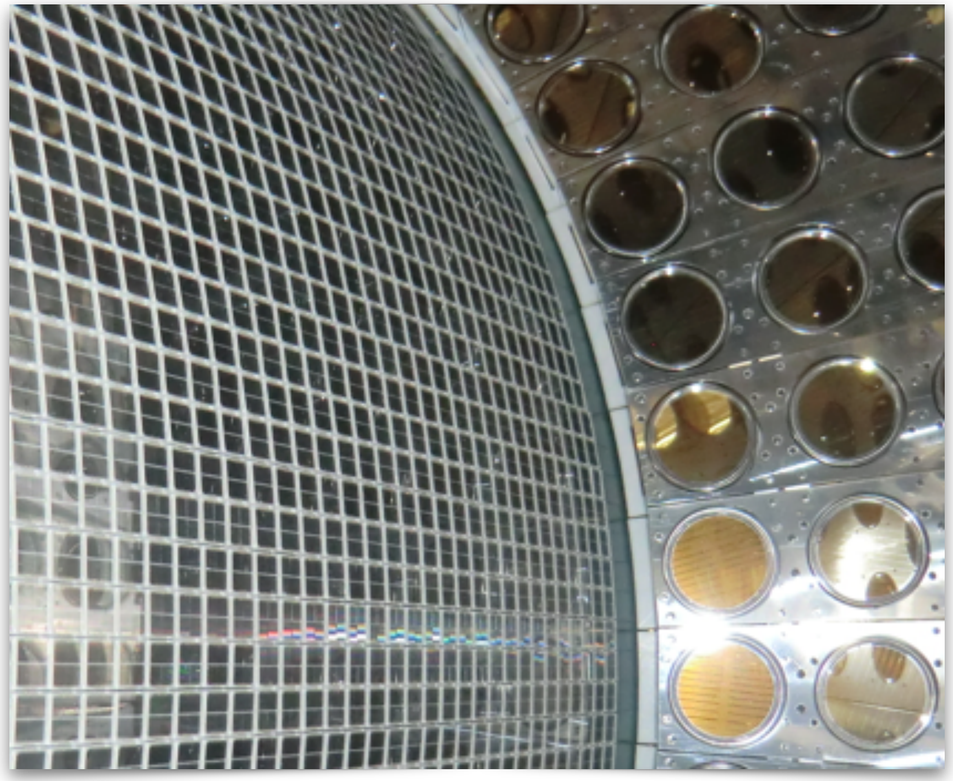
素粒子物理国際研究センター
International Center for Elementary Particle Physics
The University of Tokyo

JSPS Core-to-Core Program

MEG II Liquid Xenon Photon Detector

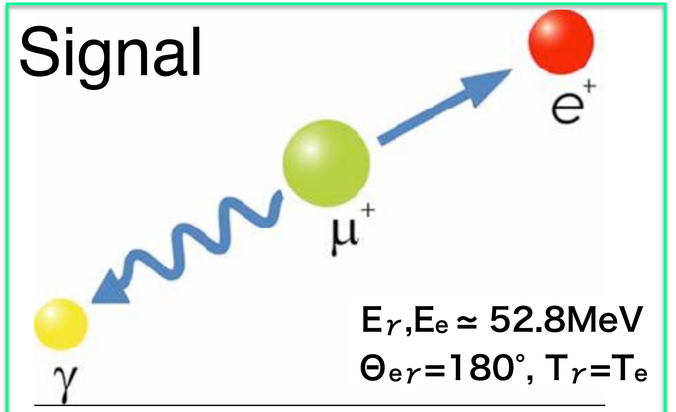




- 52.8 MeV γ detection
- energy, position, time
- 2.7 ton liquid xenon (14 X_0)
- 11% solid angle
- 165K operation, 175nm scintillation light

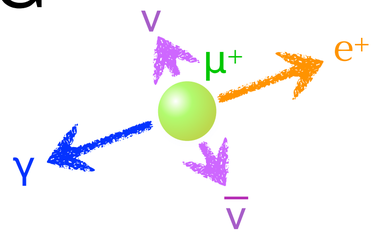
$\mu^+ \rightarrow e^+\gamma$ signal and backgrounds

Signal

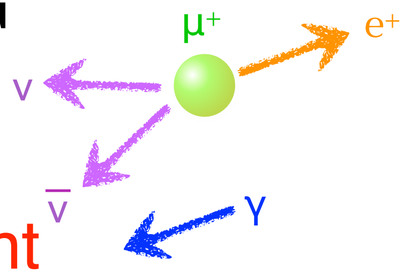


$E_\gamma, E_e \simeq 52.8\text{MeV}$
$\Theta_{e\gamma}=180°,\ T_\gamma=T_e$

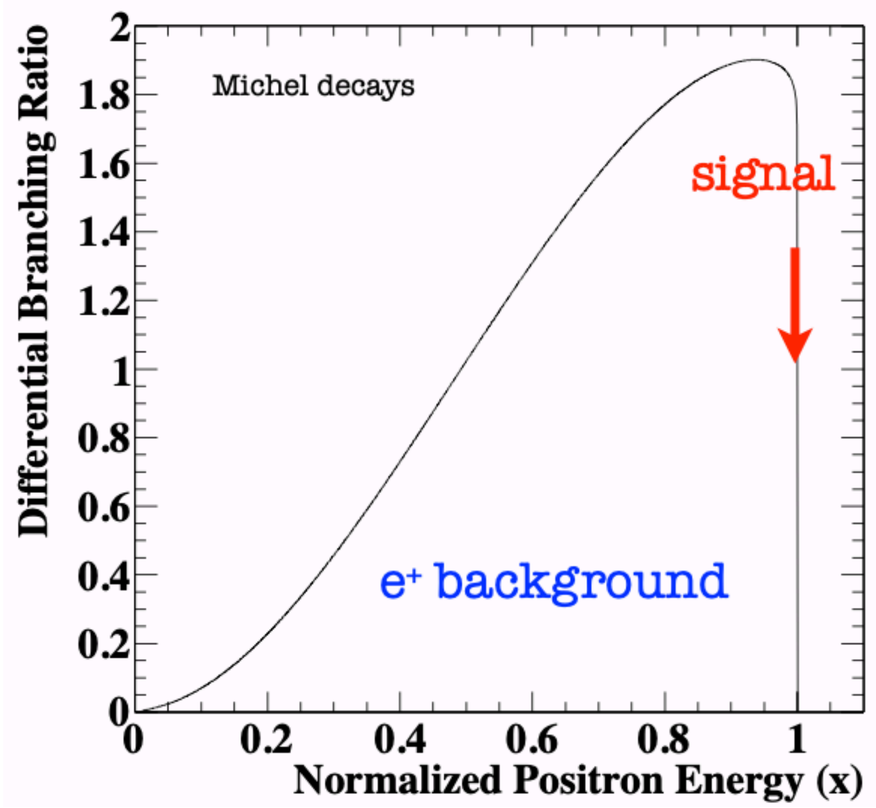
RMD BG

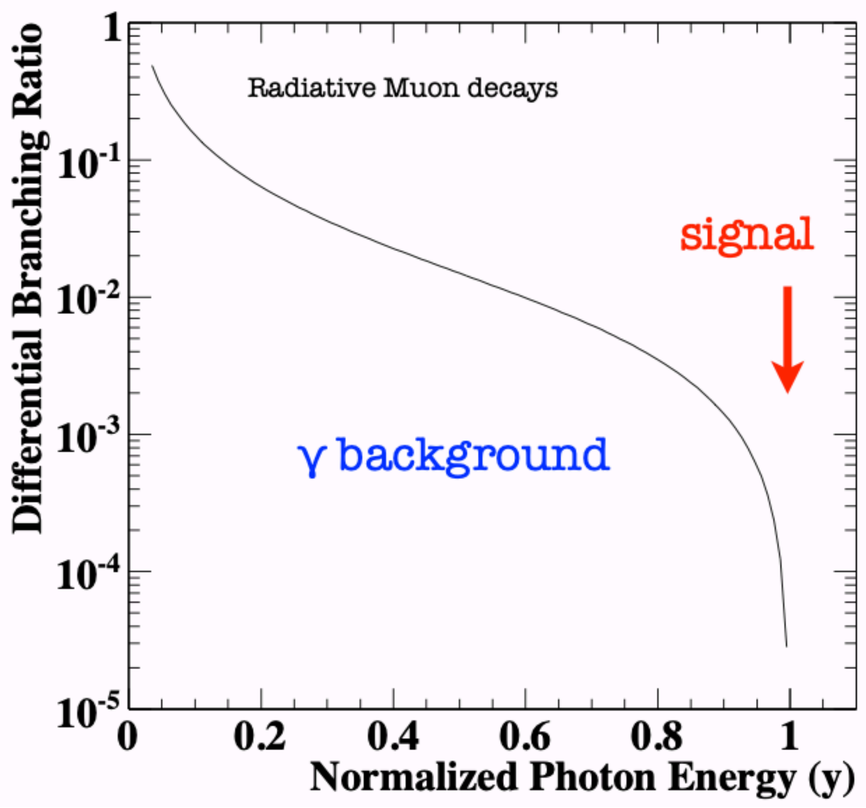


Acc BG



Dominant





$$N_{Sig} \propto R_\mu \times T \times Br(\mu \rightarrow e\gamma) \times \varepsilon$$

Efficiency crucial for statistics

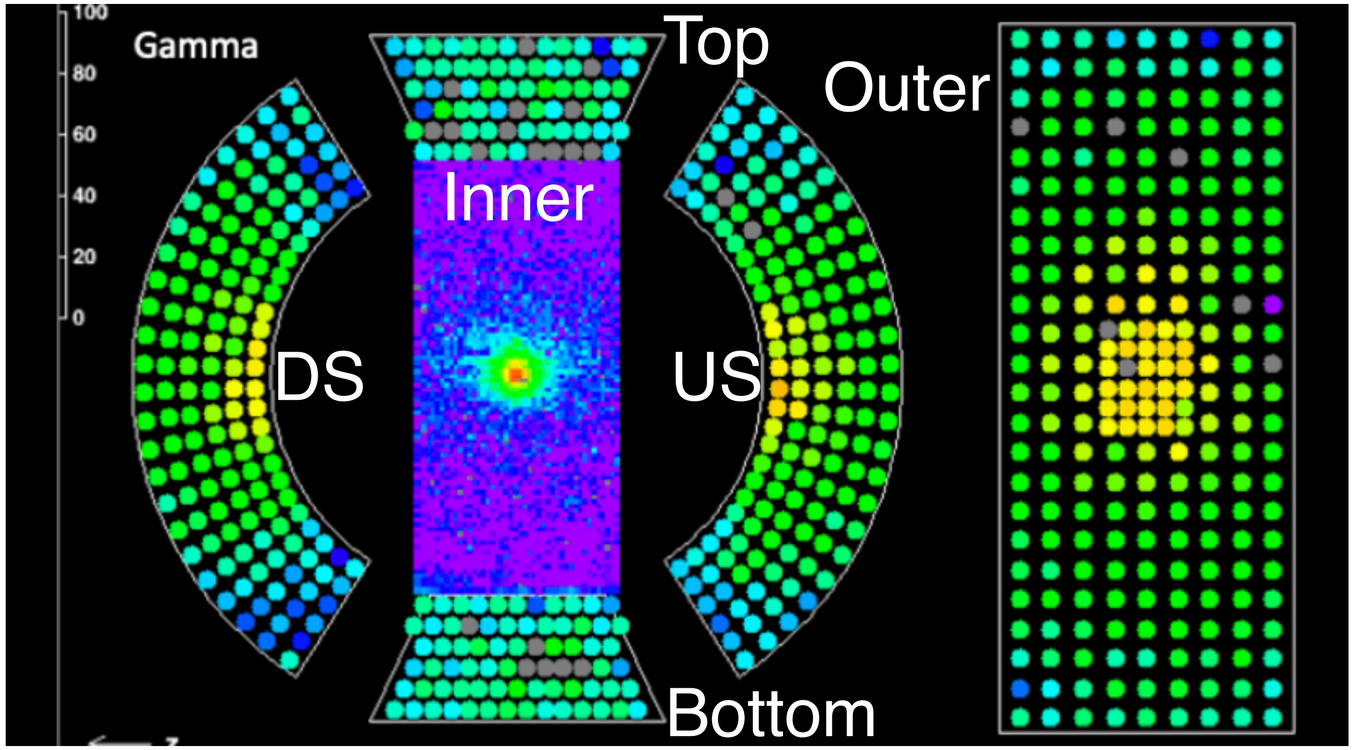
$$N_{BG} \propto R_\mu^2 \times \Delta E_\gamma^2 \times \Delta E_e \times \Delta\Theta_{e\gamma}^2 \times \Delta t_{e\gamma} \times T$$

Good resolution crucial to lower the accidental background (N_{BG})

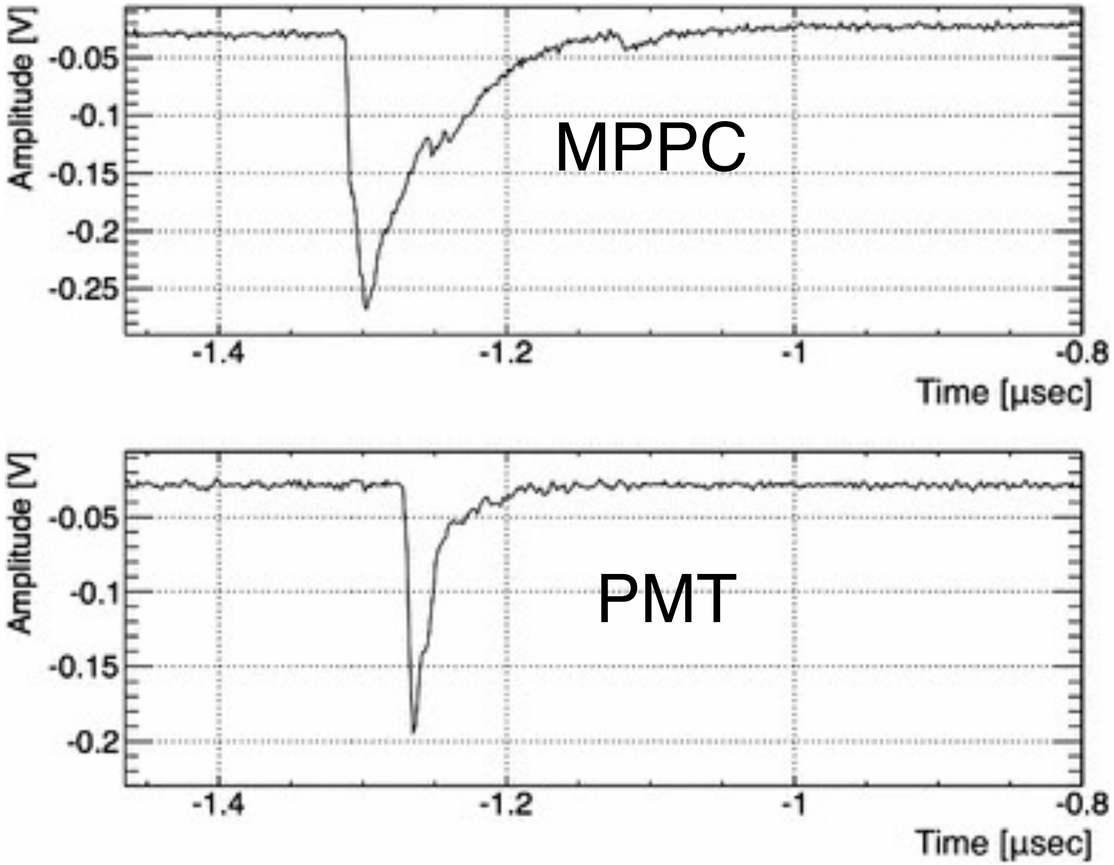
Beam rate — Resolutions — Elapsed time

LXe scintillation readout system

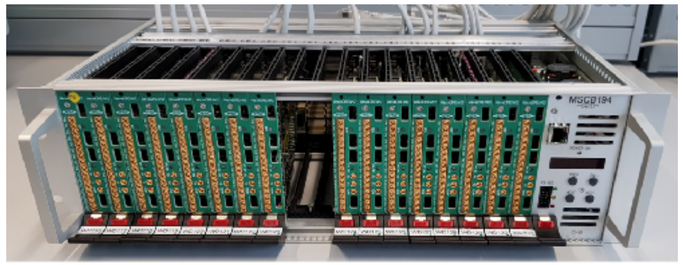
Development view of LXe detector



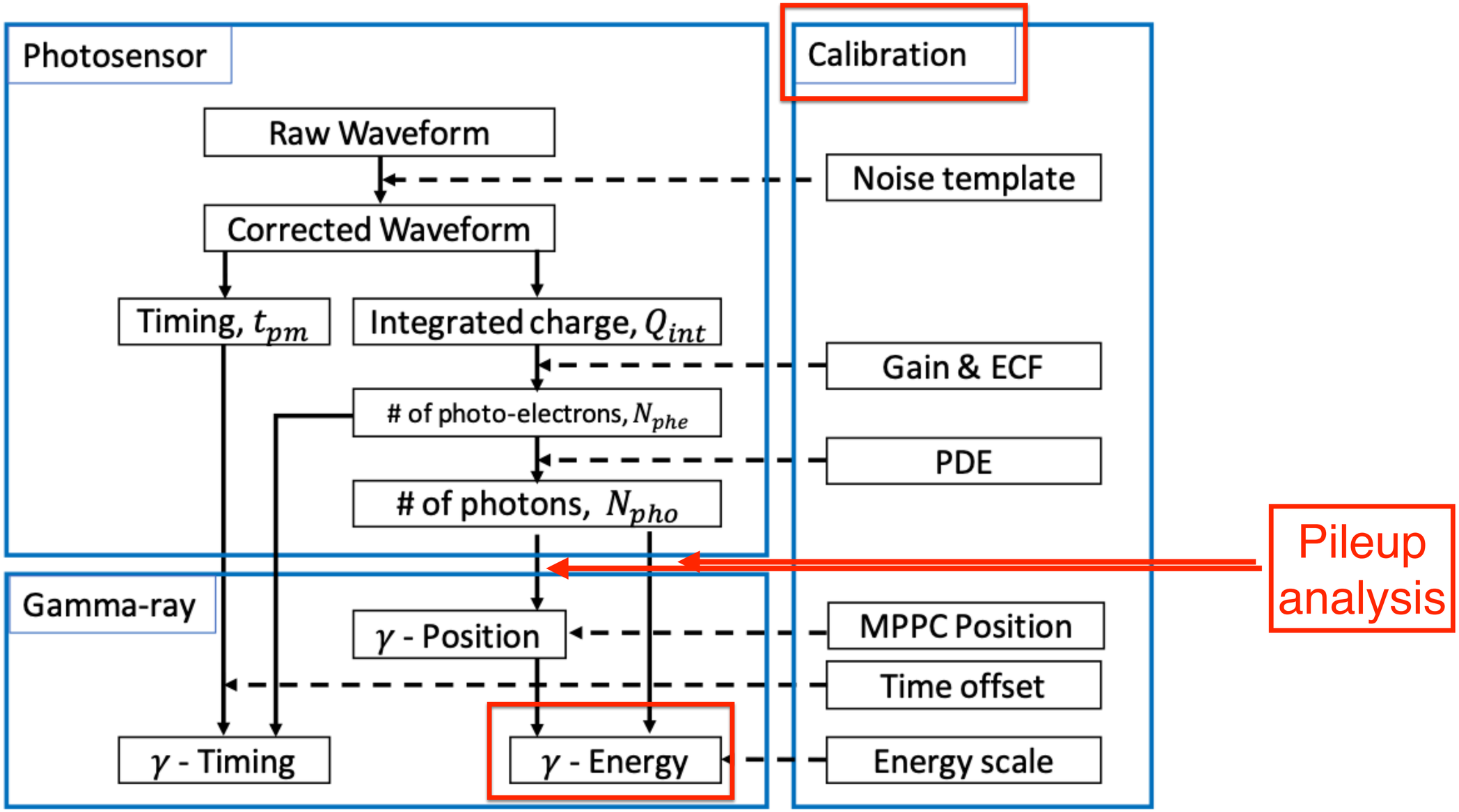
α waveform



- Inner face: 4092 MPPC ($12\times12\text{mm}^2$)
- Other faces: 668 PMTs ($51\text{mm}\phi$)
- Waveforms of all sensors readout by WaveDREAM



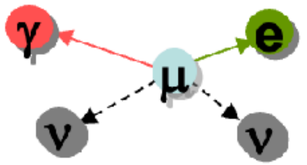
Calibration to extract energy, time, and position

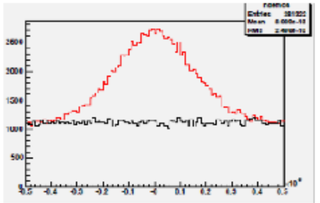


By Satoshi

Xenon Calibration

μ radiative decay

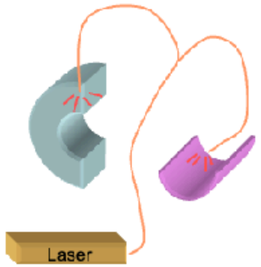




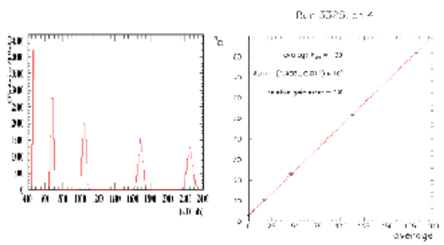
- Lower beam intensity < 10^7
- Is necessary to reduce pile-ups
- Better σ_t, makes it possible to take data with higher beam intensity
- A few days ~ 1 week to get enough statistics

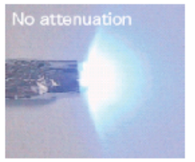
Laser

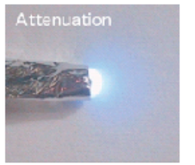
- (rough) relative timing calib.
- < 2~3 nsec



LED

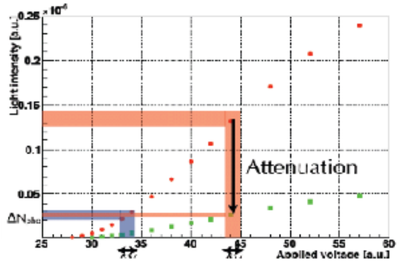




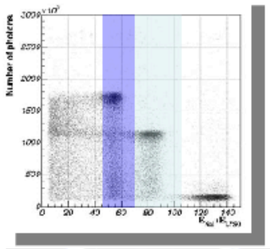


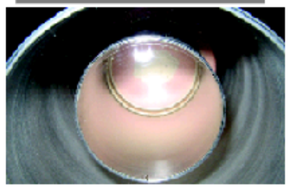
PMT Gain

- Higher V with light att.
- Can be repeated frequently

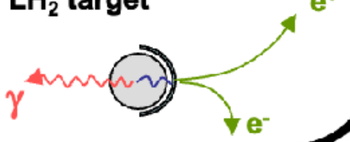


$\pi^0 \rightarrow \gamma\gamma$

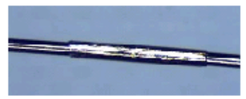


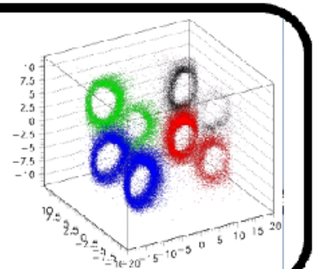


- $\pi^- + p \rightarrow \pi^0 + n$
- $\pi^0 \rightarrow \gamma\gamma$ (55MeV, 83MeV)
- $\pi^- + p \rightarrow \gamma + n$ (129MeV)
- 10 days to scan all volume precisely
- (faster scan possible with less points)
- LH_2 target



alpha

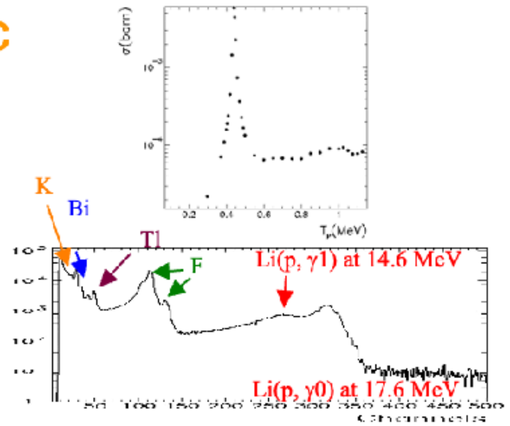




PMT QE & Att. L

- Cold GXe
- LXe

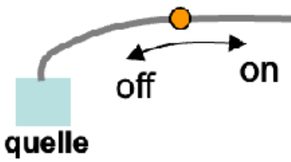
Proton Acc

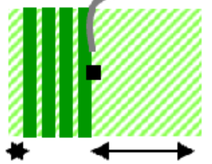


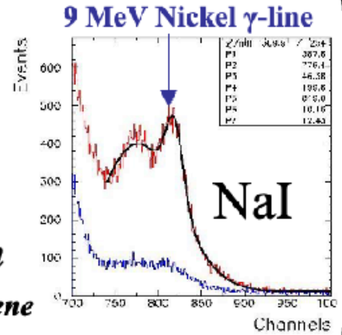
Li(p,γ)Be

- LiF target at COBRA center
- 17.6MeV γ
- ~daily calib.
- Can be used also for initial setup

Nickel γ Generator

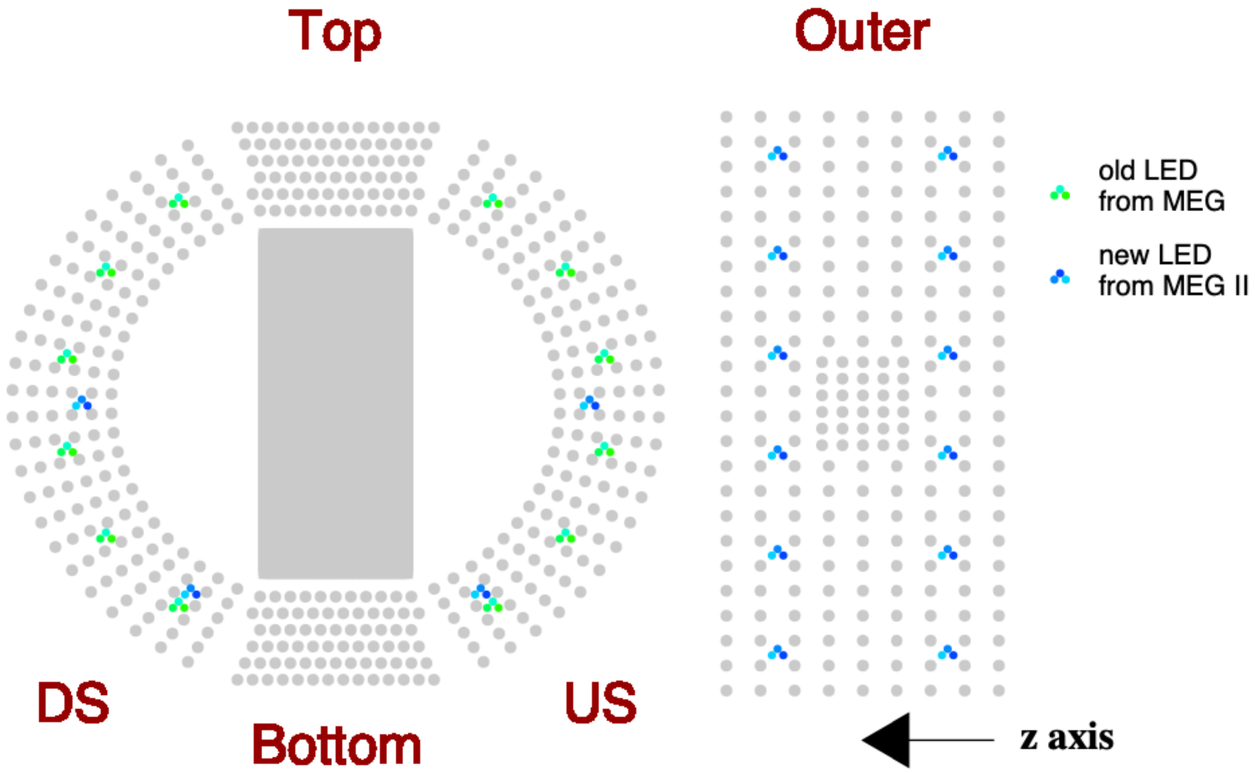




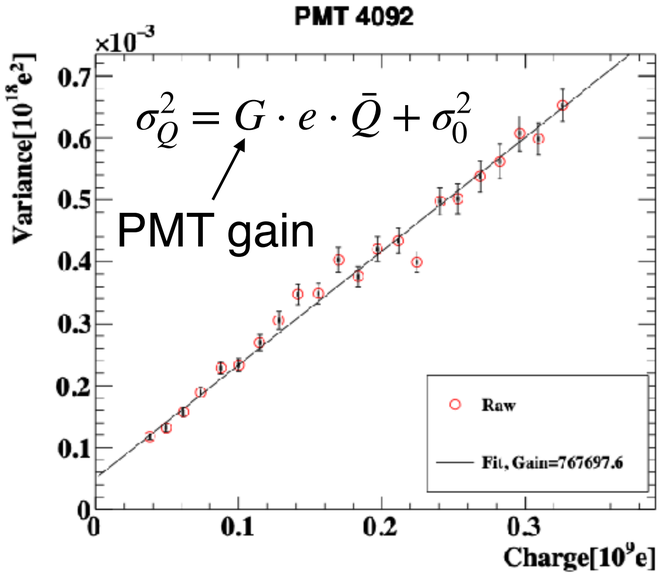


- Illuminate Xe from the back
- Source (Cf) transferred by comp air → on/off

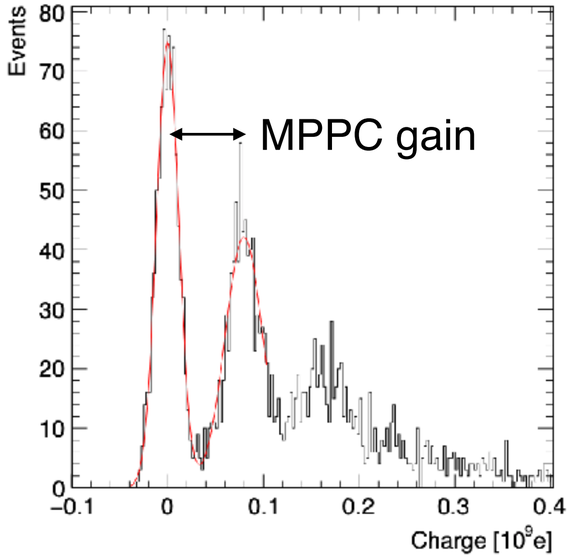
LED

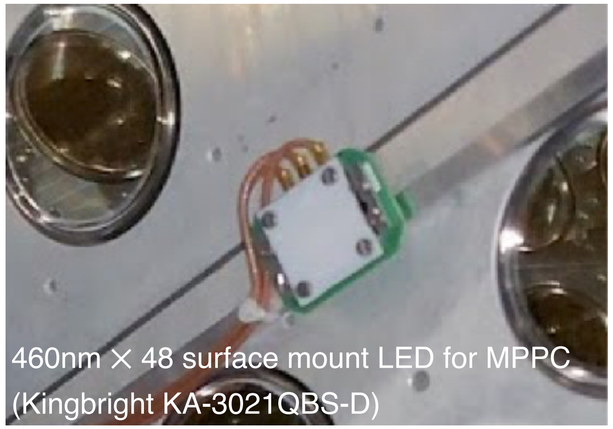


Variance vs Charge mean
w/ different LED intensities



Charge spectrum
w/ low intensity LED

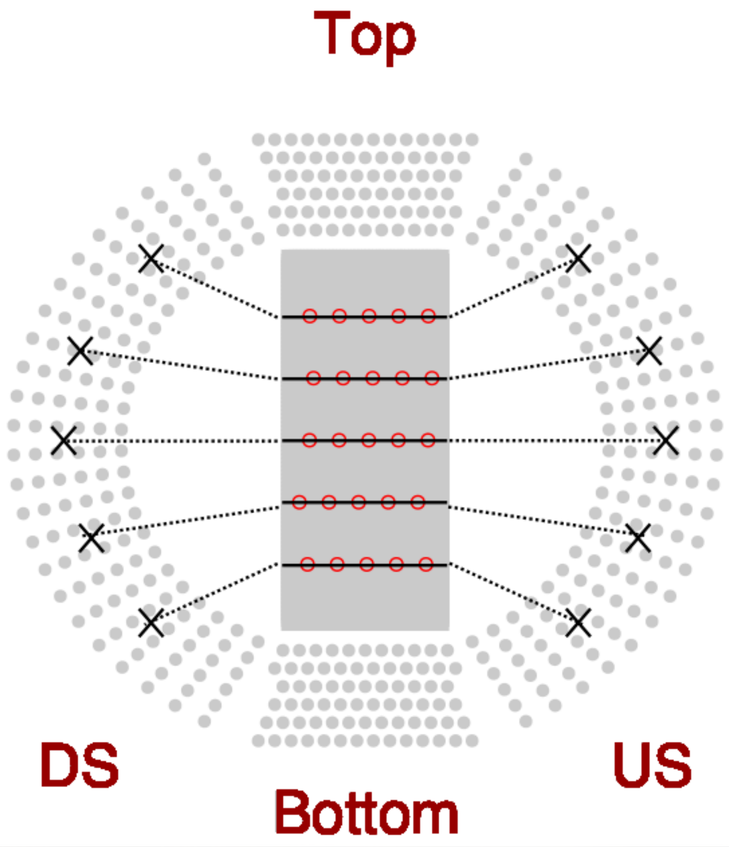


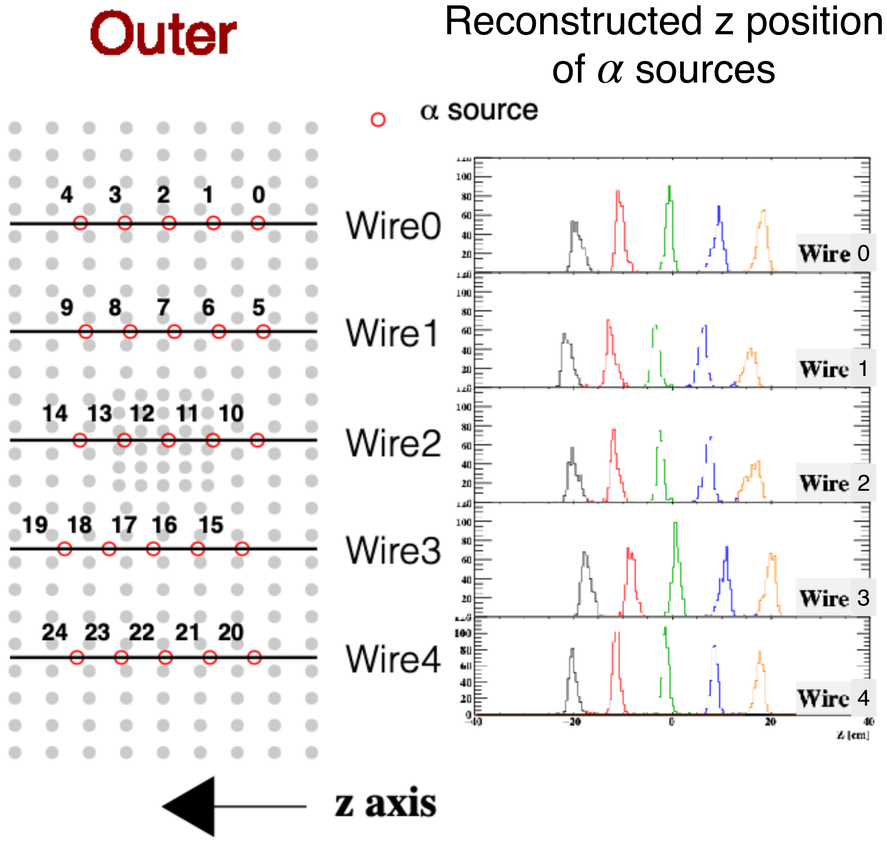


- PMT/MPPC gain, MPPC cross talk/after pulse measurements
- PMT gain decreases under muon beam

- LEDs can be installed to PIONEER easily

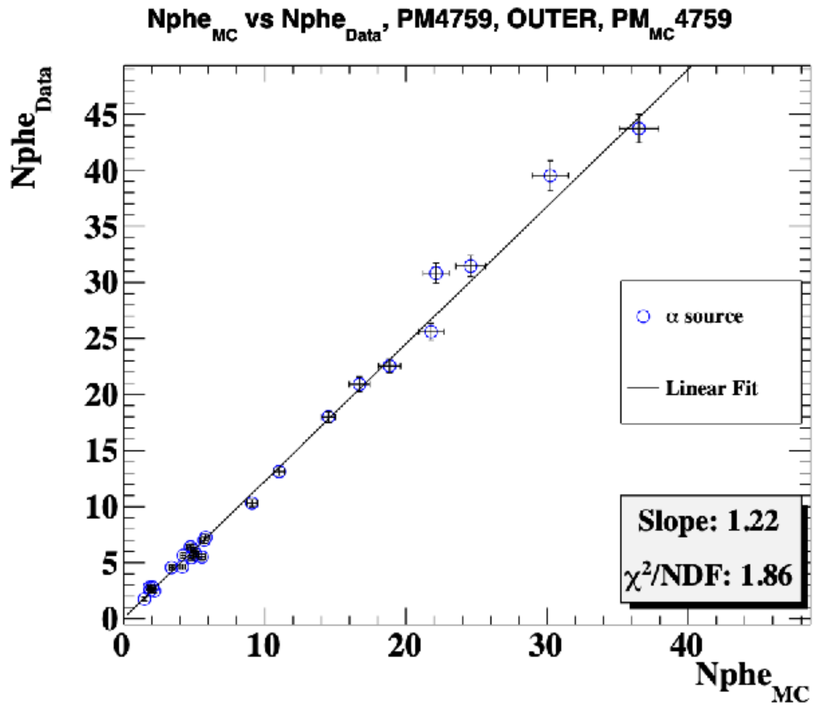
α sources

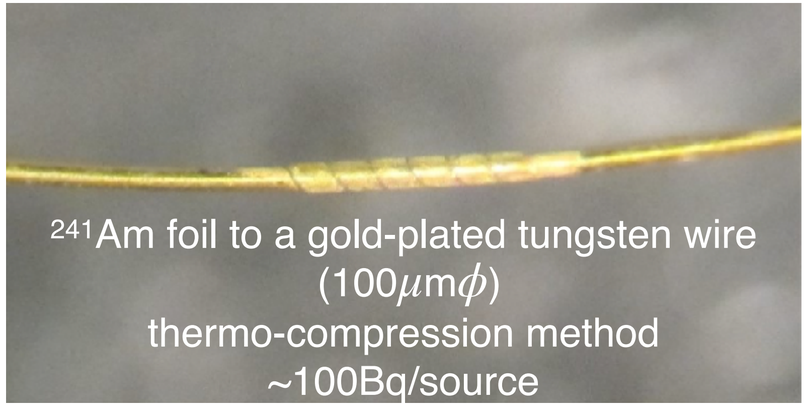




Reconstructed z position of α sources

Ratio of data/MC for a PMT

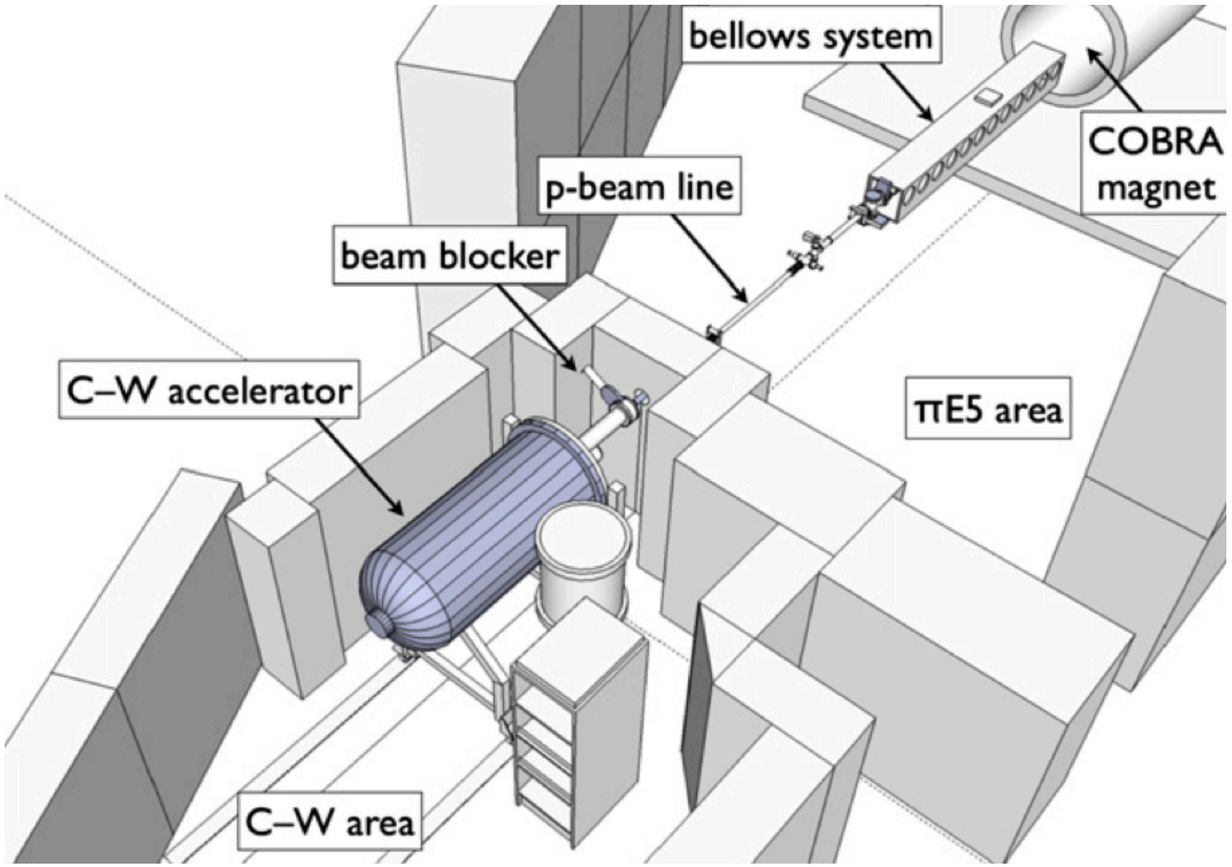


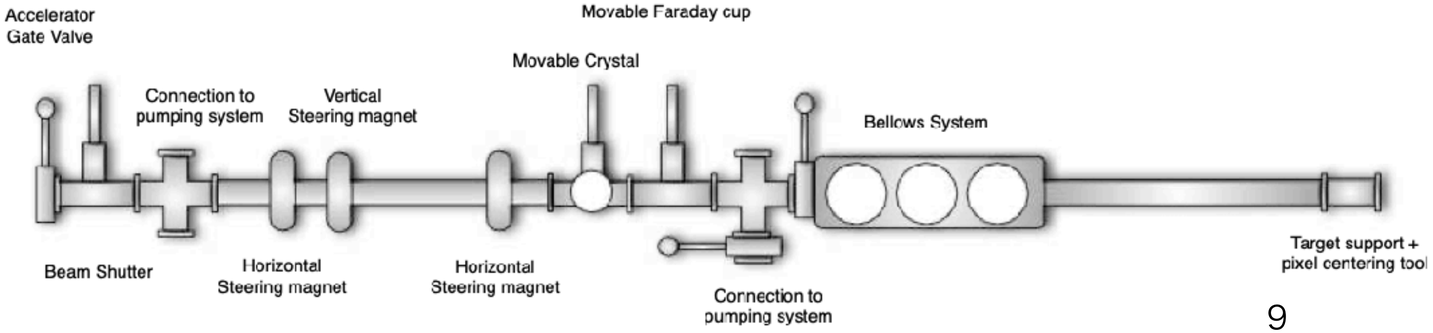


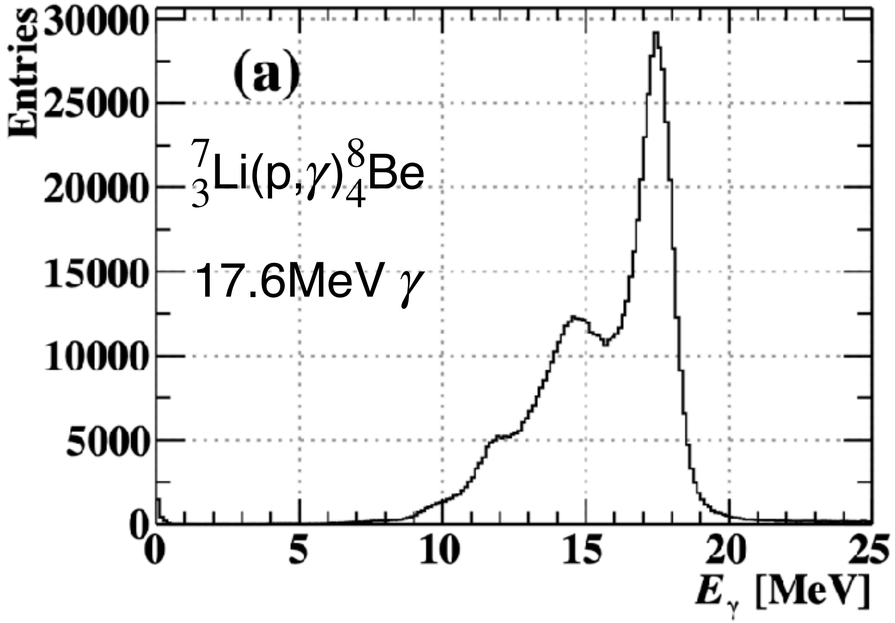
- PMT QE/MPPC PDE including LXe light yield extracted from ^{241}Am α sources
- MPPC PDE decreases under muon beam

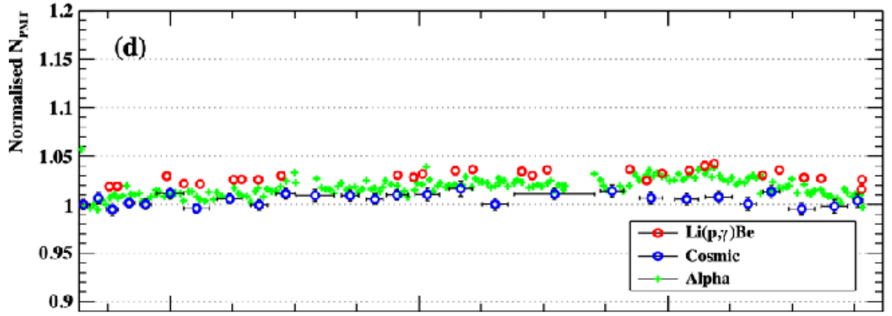
- Better to install α sources in the PIONEER. The problem might be the source production (Sorad Ltd. which produced the MEG α sources does not exist anymore)

Cockcroft Walton proton accelerator + Li target





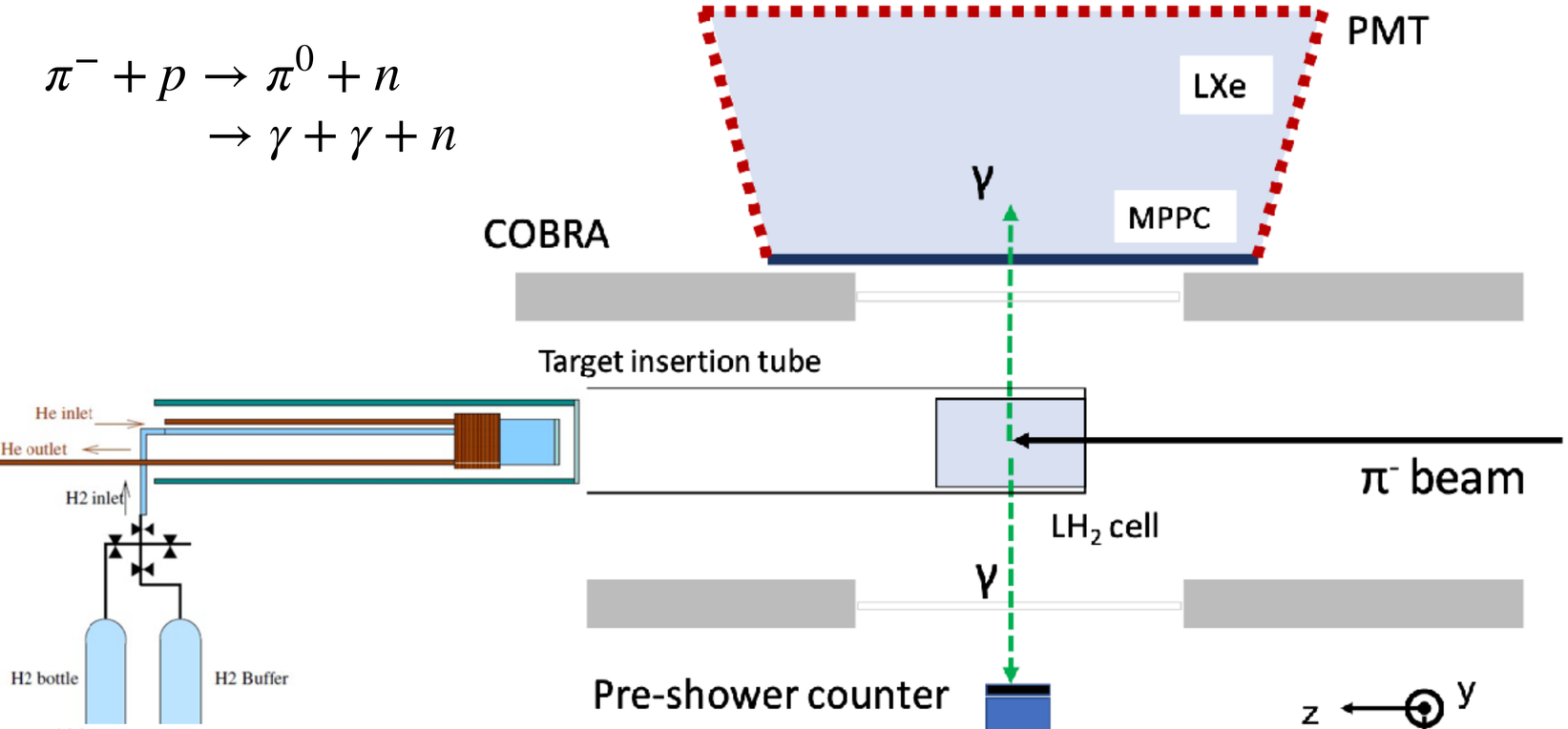


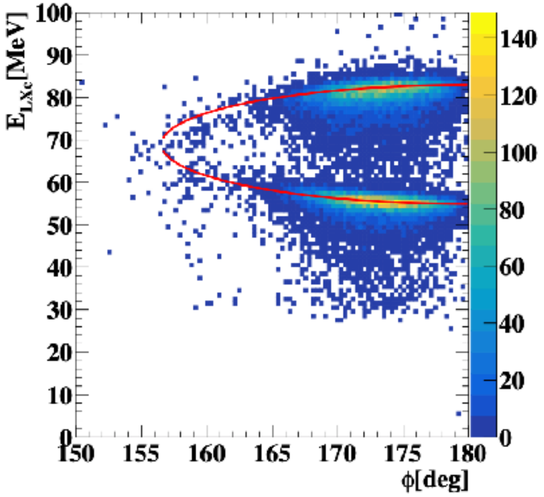


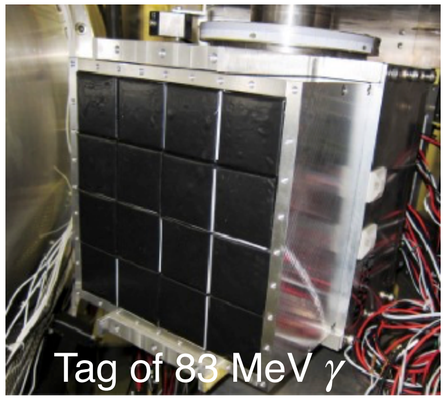
- γ energy scale and resolution monitoring at 17.6MeV three times per week

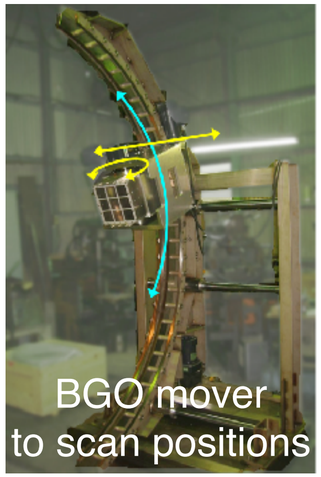
Back-to-back photons from π^0 decay

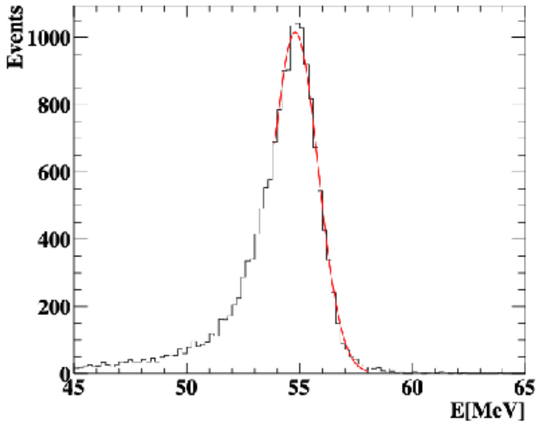
$$\pi^- + p \rightarrow \pi^0 + n$$
$$\rightarrow \gamma + \gamma + n$$

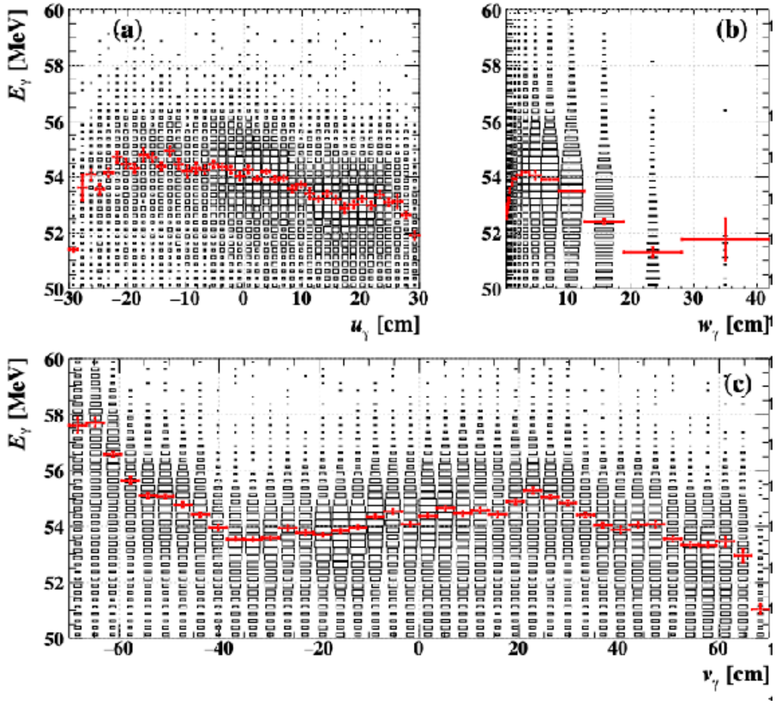






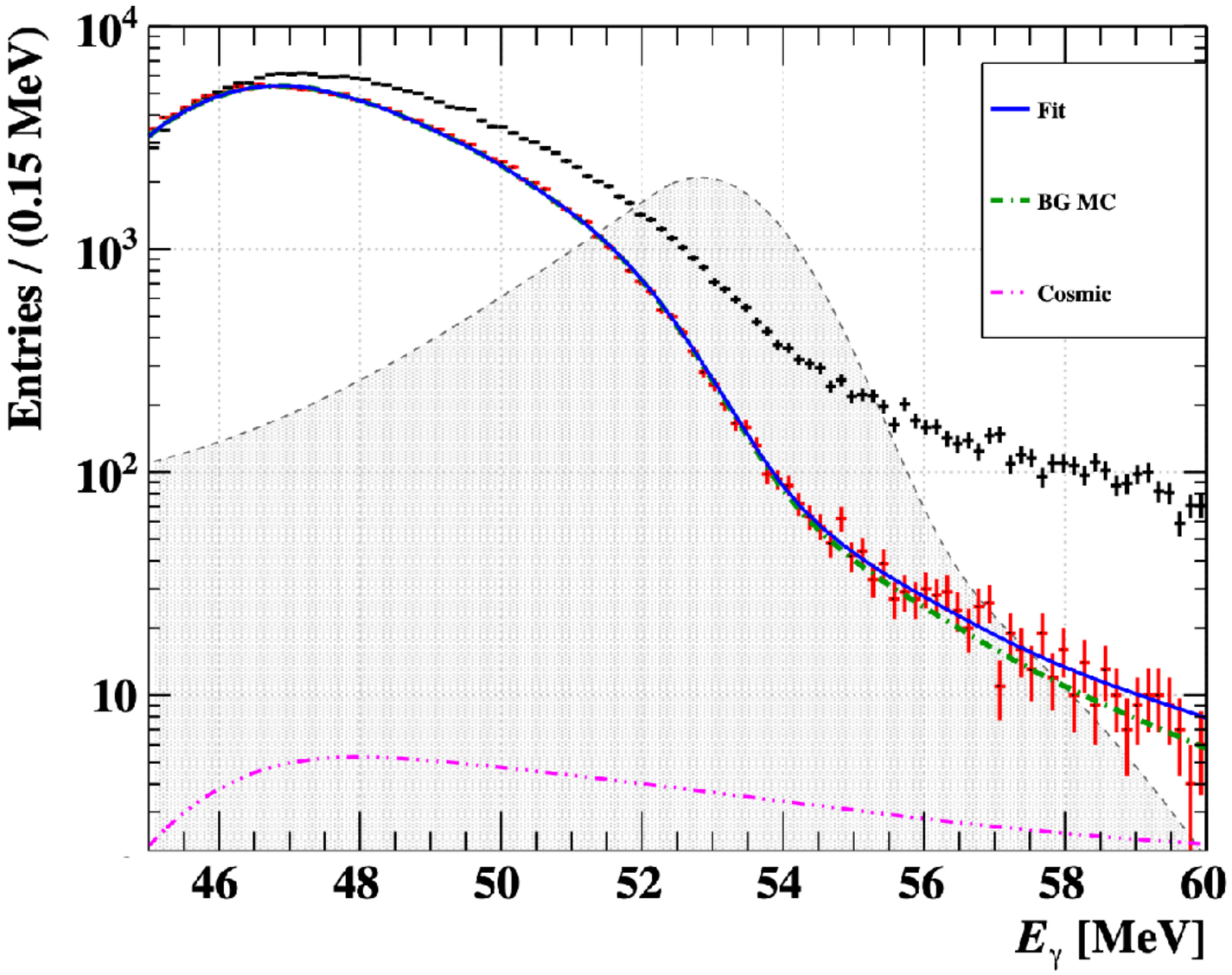


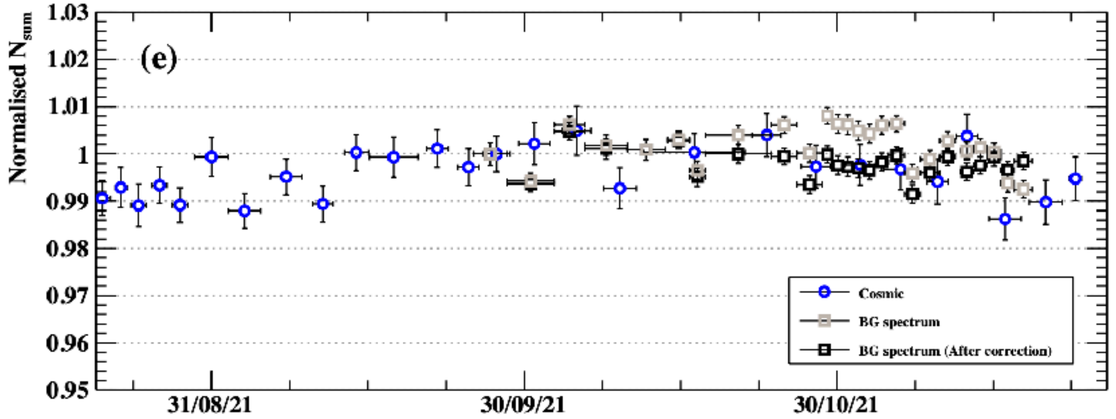




- γ energy scale, uniformity and resolution measurements at 55MeV once per year

Background spectra from μ decay

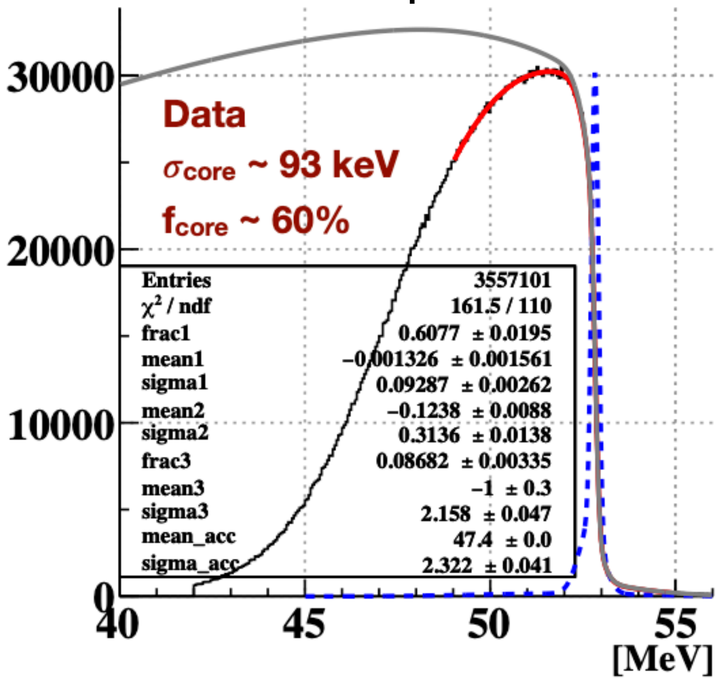


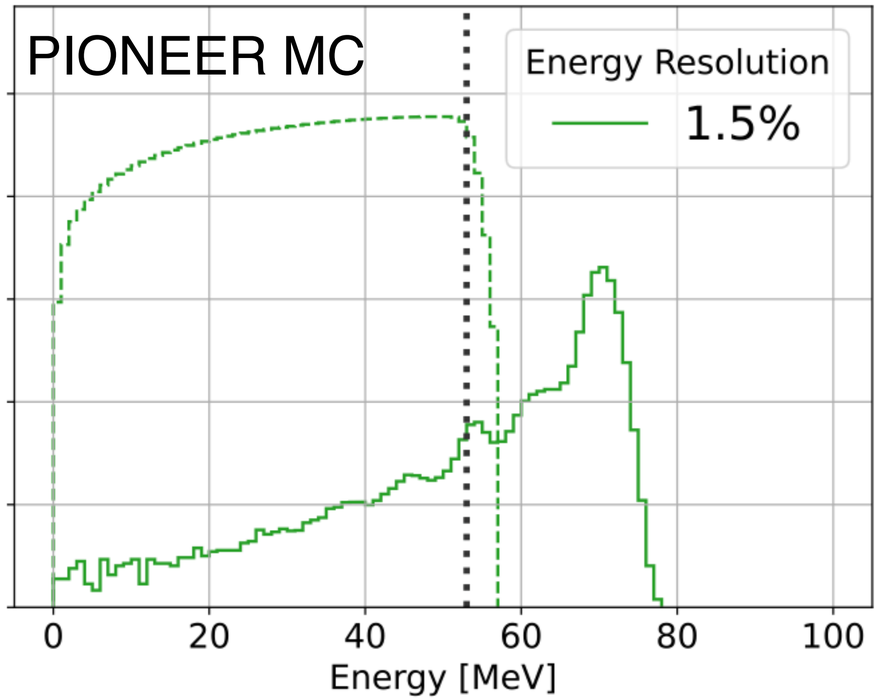


- Extract energy scale, resolution from BG spectra from μ decay at signal energy
- Stability during muon beam time can be checked

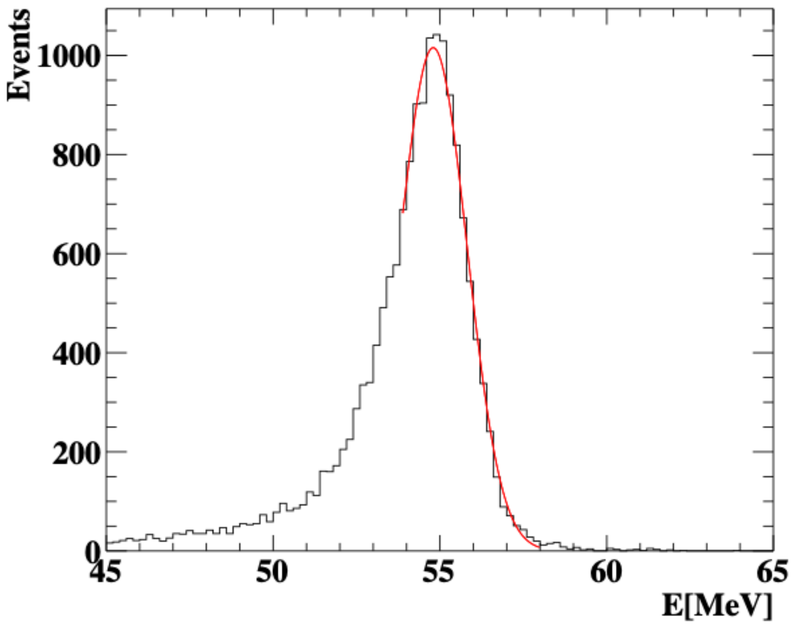
PIONEER case

MEG e^+ spectrum





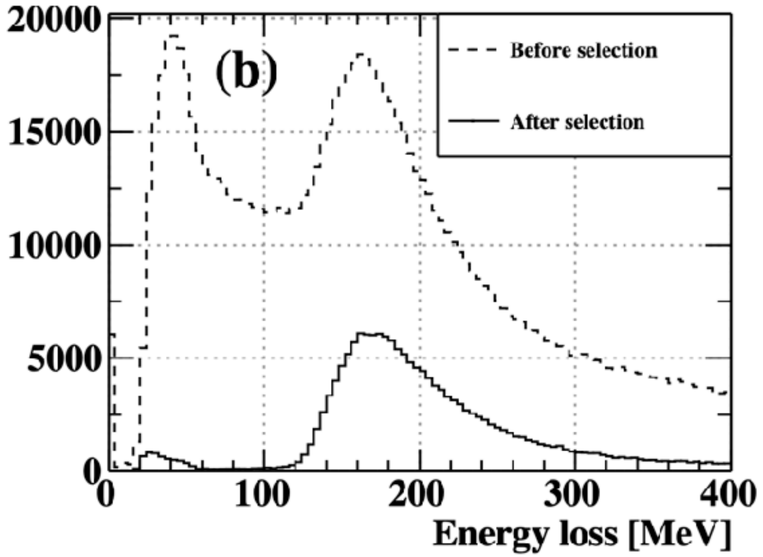
MEG γ spectrum

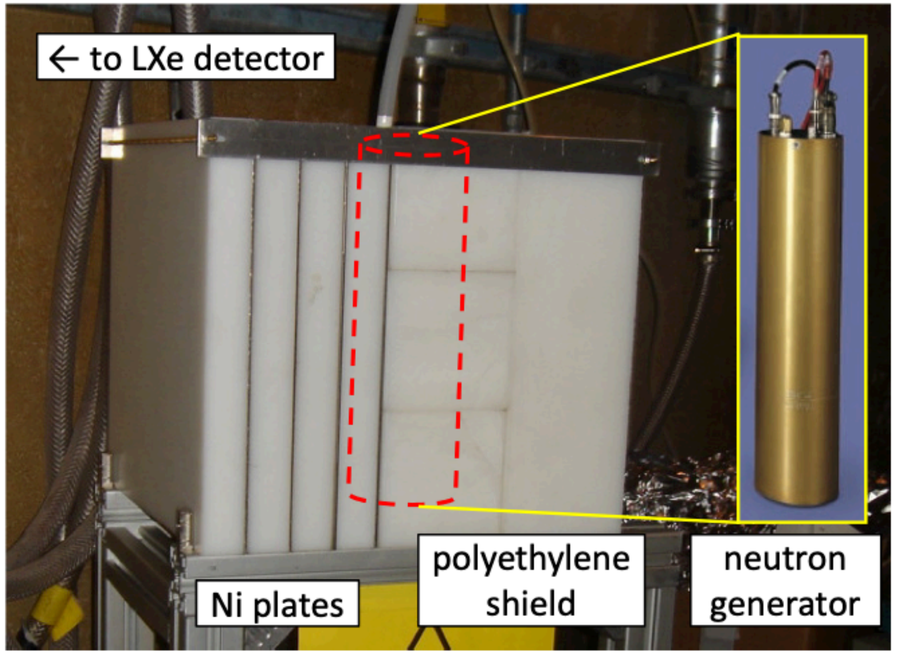


- Energy scale, resolution can be directly extracted from 70 MeV peak and from 53MeV Michel edge in PIONEER (robust calibration possible)
- Sensor calibration, LXe light yield monitoring by LED, α crucial
- Other γ calibration sources (AmBe 4.4MeV, Ni 9MeV, Li 17.6MeV, π^0 55MeV, Cosmics) are optional
- Positron incident position can be measured by trackers
- Each photo sensor time offset might be available from the LGAD time as a reference

Summary

Other devices





$^{58}_{28}\mathrm{Ni}(\mathrm{n},\gamma)^{59}_{28}\mathrm{Ni}$