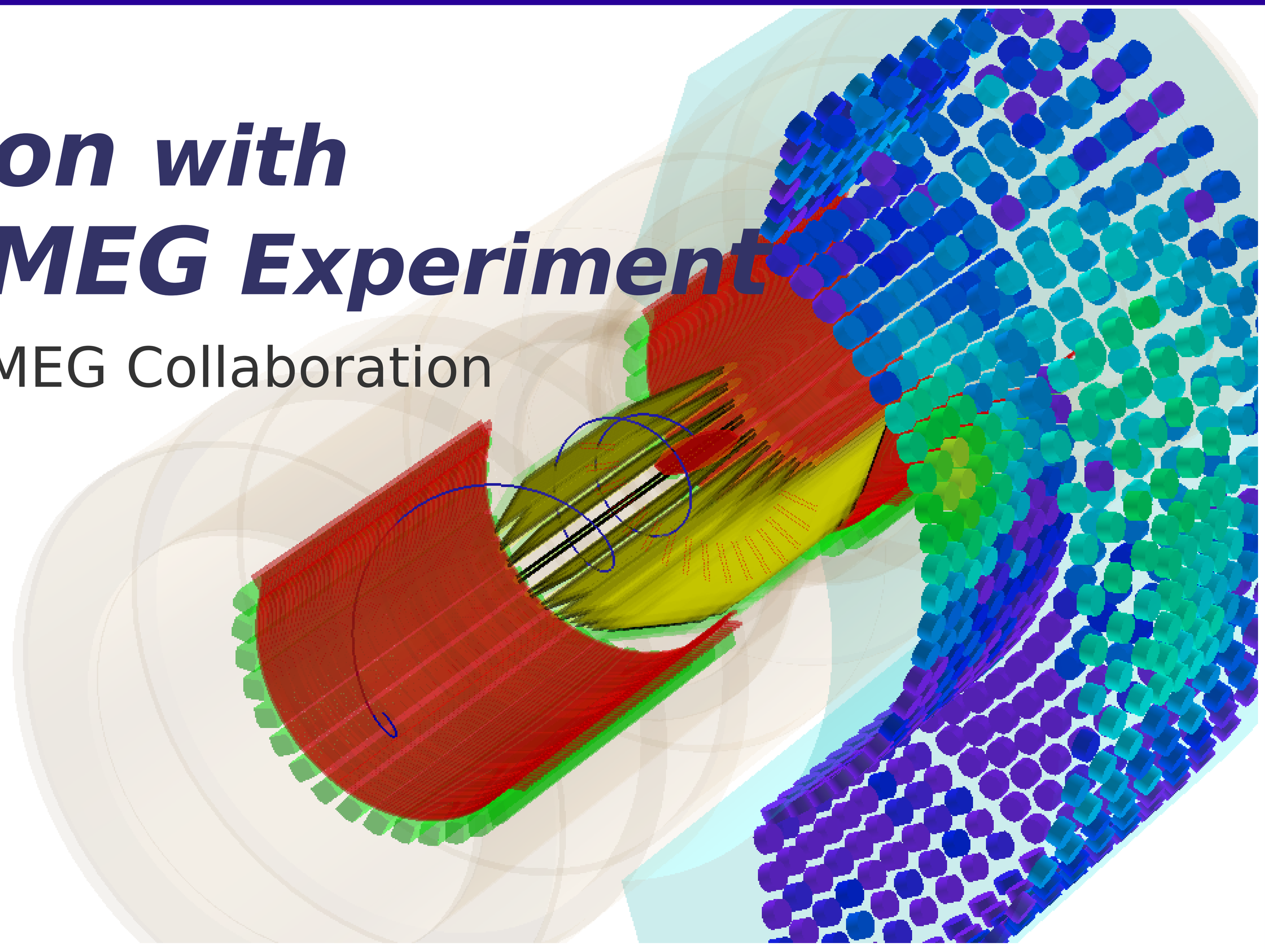
Gamma Ray Reconstruction with *Liquid Xenon Calorimeter for the MEG Experiment*

Yusuke UCHIYAMA, Univ. of Tokyo/ICEPP (Japan), MEG Collaboration



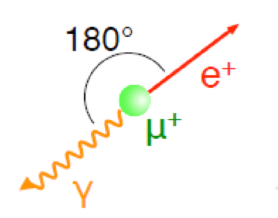
The MEG experiment[1] searches for the ***lepton-flavor violating*** muon decay ($\mu^+ \to e^+\gamma$) at PSI in Switzerland. Physics data taking started in 2008 aiming at the sensitivity **~10^{-13}**.

For the $\mu^+ \to e^+\gamma$ search, precise measurement of γ-ray is essential to achieve such a good sensitivity. A new type of γ-ray detector using ***liquid xenon (LXe)*** is built up.

For this new detector, we developed dedicated reconstruction algorithms which can extract the performance of the LXe as much as possible.

Signal & backgrounds

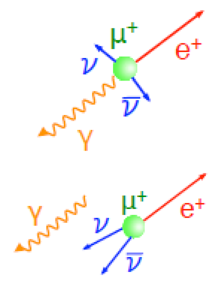
Signal

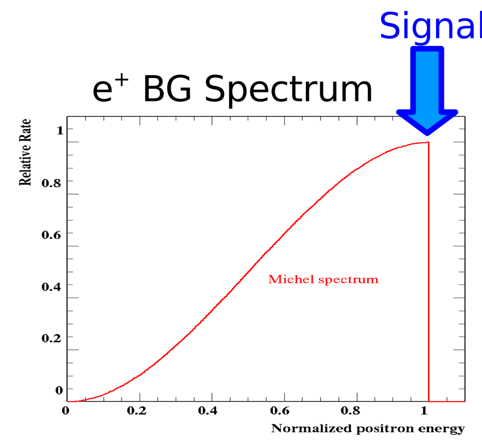


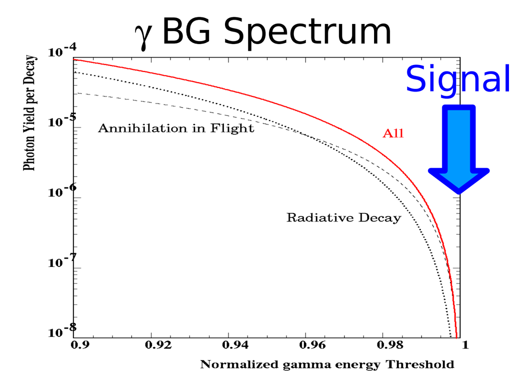
Clear 2-body decay
- 52.8 MeV
- Back-to-back
- Time coincidence

Radiative muon decay

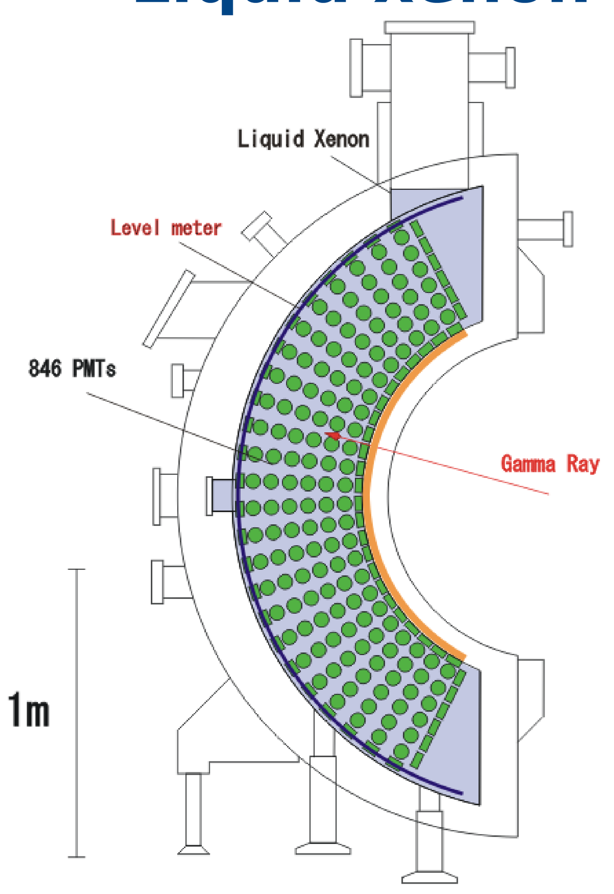
Accidental overlap







Liquid xenon γ-ray detector



We use 850*l* liquid xenon as a scintillator. The scintillation light is detected by 846 PMTs surrounding the active volume of LXe. LXe properties enable us to measure the energy, timing and position of incident γ-ray at the same time with required resolution

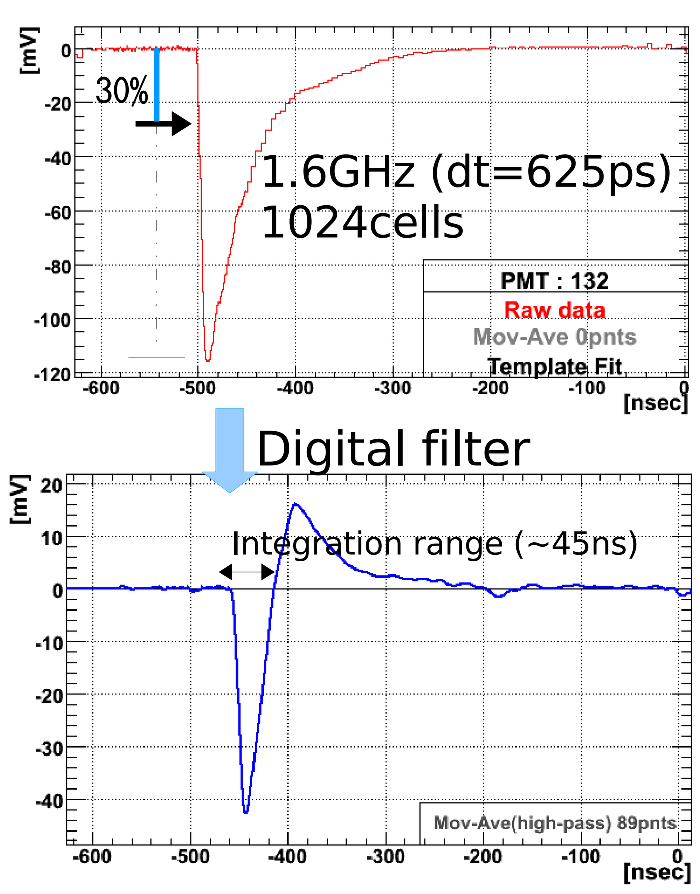
Properties of LXe as scintillator

	NaI	BGO	GSO	LSO	LXe
Eff. Atomic number	50	73	58	65	**54**
Density (g/cm^3)	3.7	7.1	6.7	7.4	**3.0**
Rel. light output (%)	100	15	20-40	45-70	**80**
Decay time (nsec)	230	300	60	40	**4.2,22,45**

T.Iwamoto's talk on 26/May (Calorimetry I)

Waveform analysis

All PMT outputs are digitized with fast waveform digitizer[2] at 1.6 GHz. We can extract not only charge and timing but also information on pile-up events.

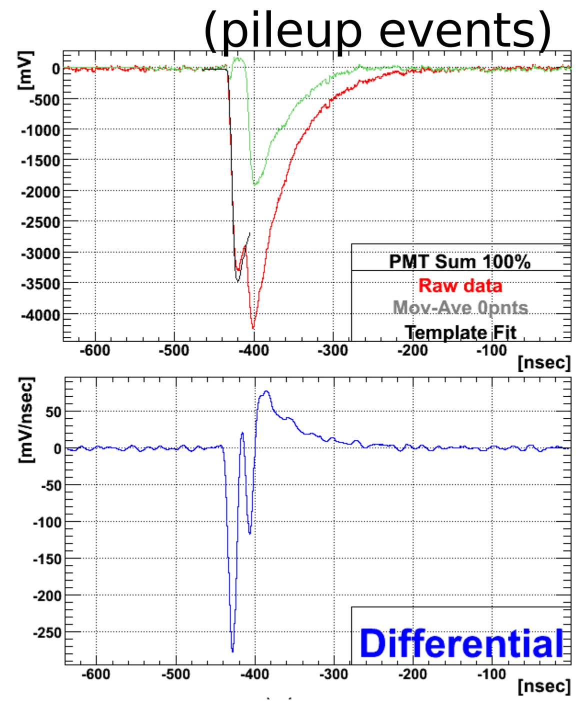


Best algorithm of time pick-off
- Digital constant-fraction method
  - Time-walk free
  - Optimal threshold

Optimize charge integration
- Event-by-event baseline
- Optimal integration range
- Digital filtering

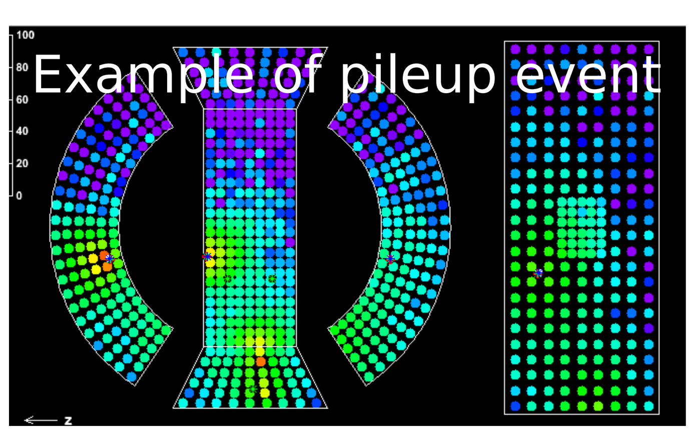
Pile-up identification
- Differential peak search
- Fitting waveform

Sum of all PMTs (pileup events)



Pile-up identification

- Time distribution (O(1ns))
- Light distribution (>15cm)
- Waveform analysis

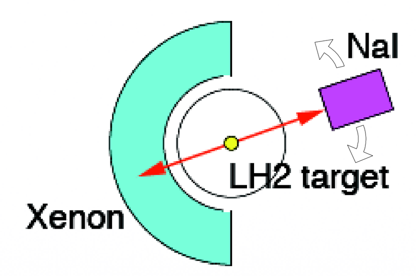


π^0 calibration run 2008

- We took calibration run with π^- beam
  - **55 MeV** and 83 MeV monochromatic γ from π^0 decay by selecting opening angle~180°
  - Tag back-to-back γs with NaI detector
  - Full scan over the acceptance
  - August (full) and December (short)
  - Calibration, check performance, obtain response

$\pi^- + p \to \pi^0 + n$

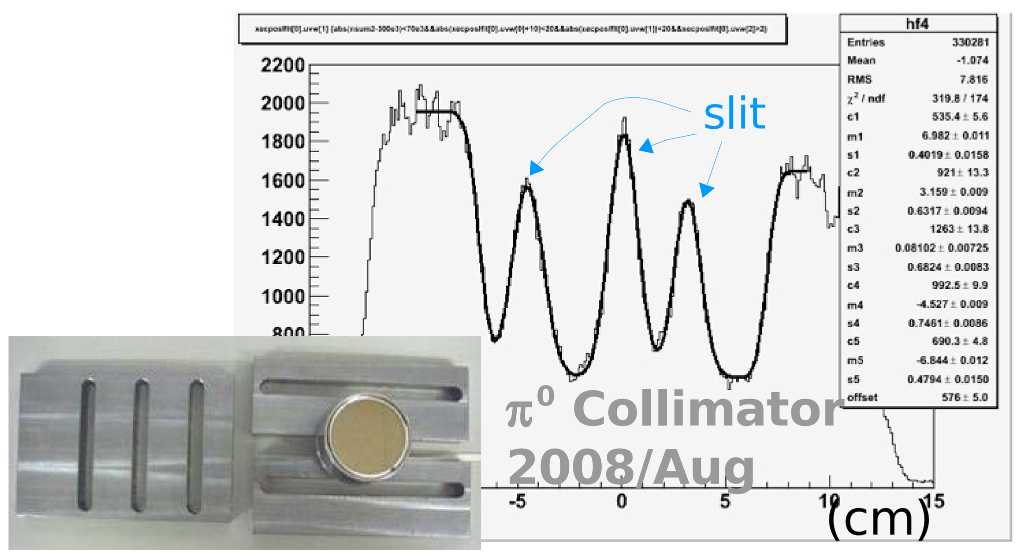
$\pi^0 \to \gamma\gamma$

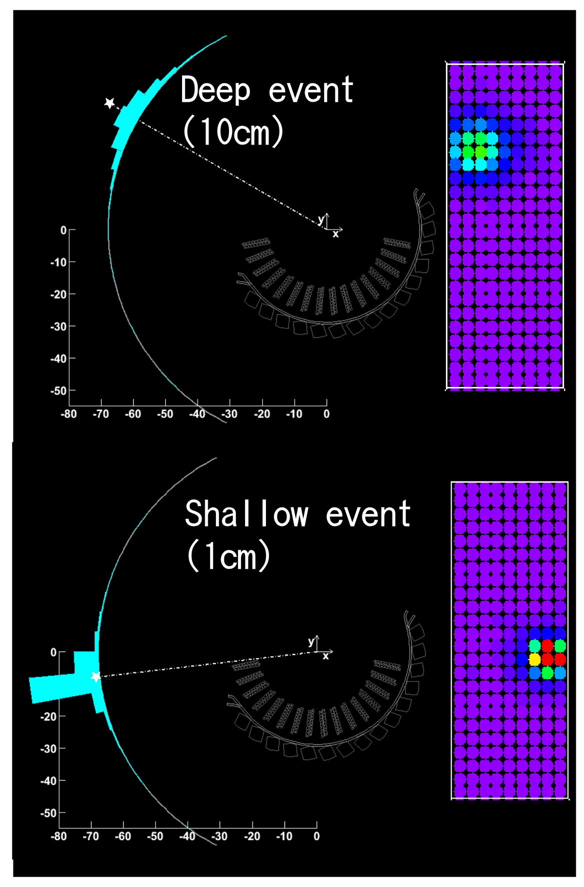


Able to use same beam line

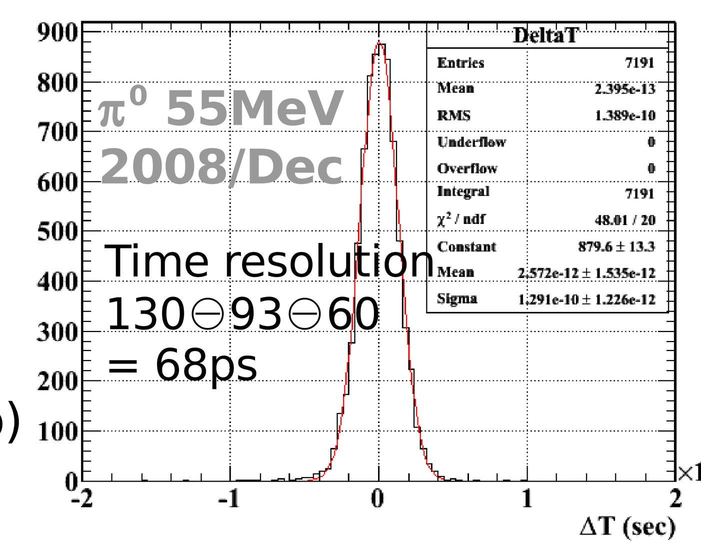
Reconstruction & performance

- Position
  - Fit light distribution by solid angle
    - Only use PMTs in limited region to minimize shower fluctuation
  - Solid angle of each PMT is calculated numerically
  - Performance check with collimator run

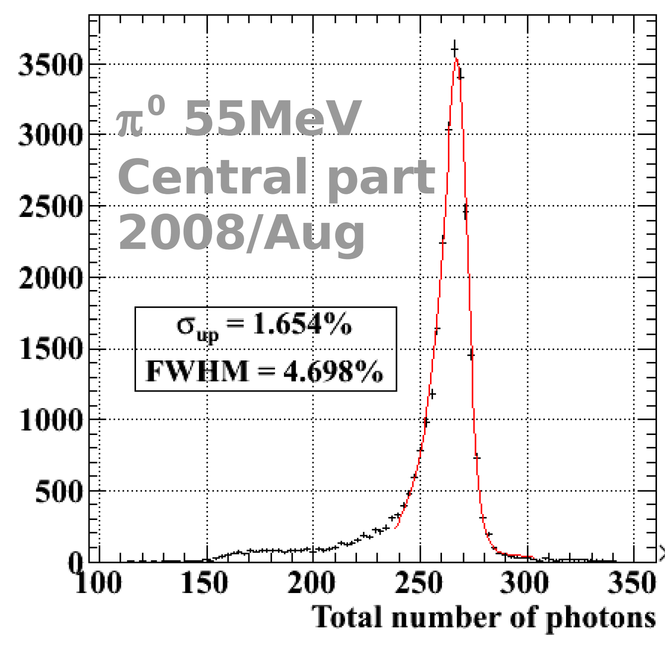




- Timing
  - Reconstruct hit time with each PMT
    - $T_i = T_{pmt,i} - t_{offset,i} - d/v_{eff} - t_{delay}(\eta)$
      - d : distance b/w hit point and the PMT
      - η : incident angle to the PMT
  - Minimize variance of PMT times
    - Typically ~150 PMTs are used
  - Filtering bad χ^2 channel (reject pileup)
  - Performance check by the difference b/w tagging counter
    - Subtract spread by tagging counter and beam size



- Energy
  - Sum up all PMT outputs
    - Precise PMT calibration (gain, QE)
    - Photocathode coverage factor
  - Correct position dependence
  - Alternative algorithms
    - Optimize weights
    - Fit PMT charges



Summary of performances with new algorithms (preliminary)

	Goal (σ)	Resolution (σ)
Energy	1.2-1.5% (4.5-5%)	1.75% (5.5% FWHM)*
Timing	65 ps	78 – 68 ps**
Position	2-4 mm	5 mm

* Mean value. Depending on position
** Improving with LXe purity

[1] MEG Collaboration, T.Mori *et al.* Research Proposal to PSI R-99-05 (1999), http://meg.psi.ch
[2] DRS chip, See Roberto Dinapoli's poster in Frontend Electronics session, http://drs.web.psi.ch