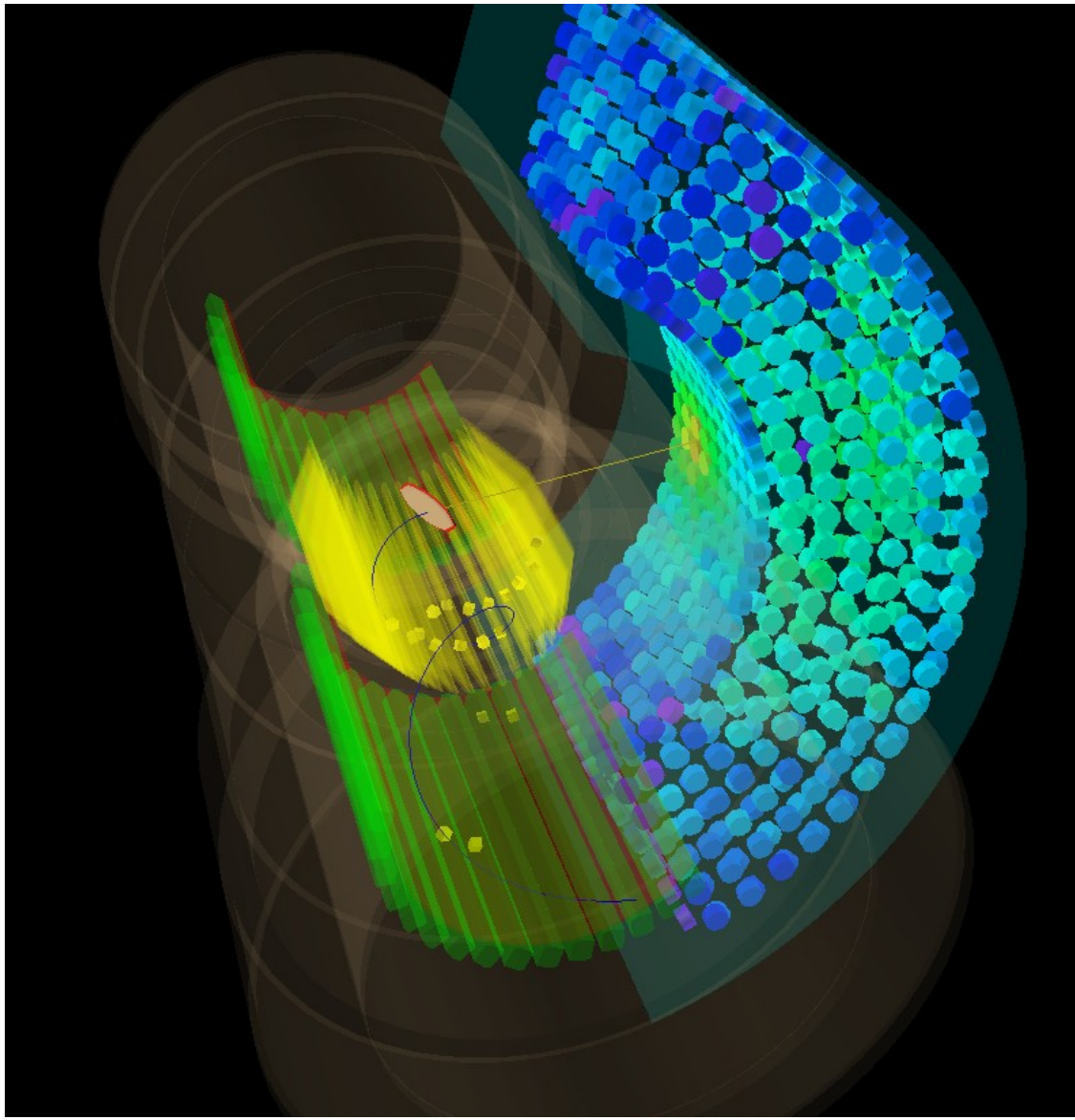
MEG
Mu-E-Gamma Collaboration

MEG Run2008

バックグラウンド



日本物理学会
20/September/2008

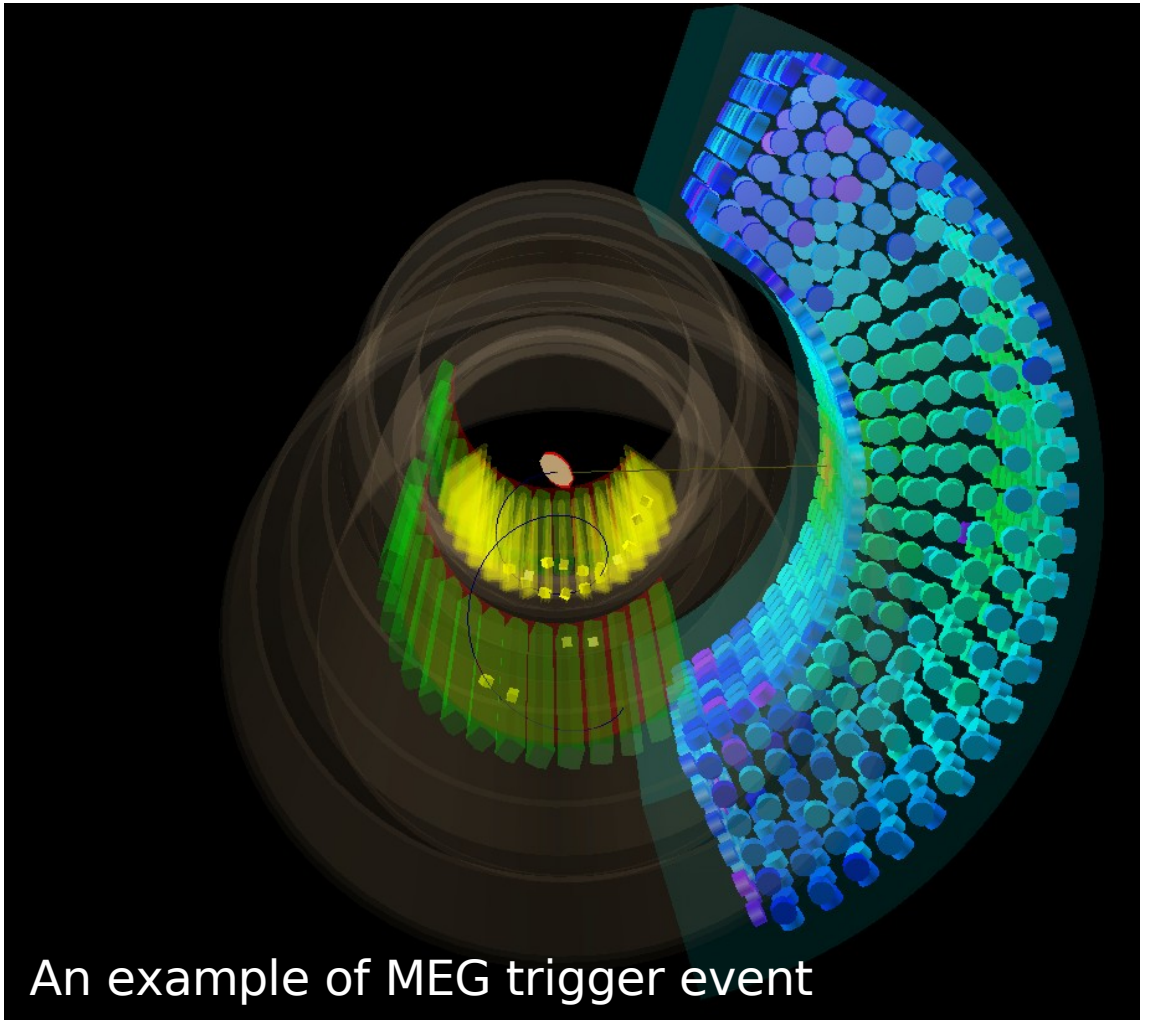
Yusuke Uchiyama
University of Tokyo

東京大学
THE UNIVERSITY OF TOKYO

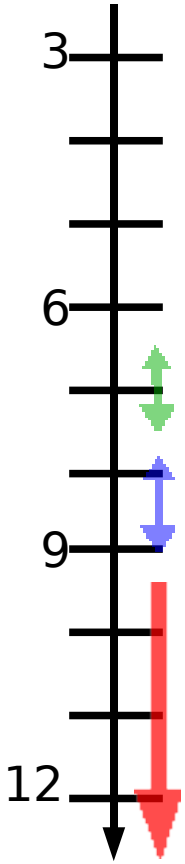
MEG Run2008

- Finally we started physics run

- What can we achieve
  - With current achieved detector performance
  - With limited period (only with this year's data)


An example of MEG trigger event

Schedule



- Maintenance work
- Detector installation
- Evacuation, cooling, LXe transportation
- Purification
- Stability check
- Pi0 run
- Trigger setting, Background data
- MEG run ← now
- Beam shut down

- Michel run

We've just started physics run !
Continue until end of this year
(12 weeks)

Summary of Detector performances

(in FWHM)

- Gamma energy 5.64%
- Gamma timing 300ps
- Gamma position 12.2mm

- Positron energy 2.2%
- Positron timing 127ps
- Positron angle 14.5mrad

- $T_{e\gamma}$ 325ps
- $\Theta_{e\gamma}$ 23.3mrad

- 1.4 x FWHM for signal region for this study

Single Event Sensitivity

- Single event sensitivity of this year

$$S.E.S = \frac{1}{N_\mu \cdot T \cdot \Omega/4\pi \cdot \varepsilon_e \cdot \varepsilon_\gamma}$$

$$= \frac{1}{N_\mu(10^7) \cdot 4.8e6 \cdot 0.09 \cdot (0.65 \cdot 0.5) \cdot (0.4 \cdot 0.7)}$$

$$= 2.54 \times 10^{-12} / N_\mu(10^7/\mathrm{sec})$$

$N\mu=3x10^7$: 8.46 x 10-13

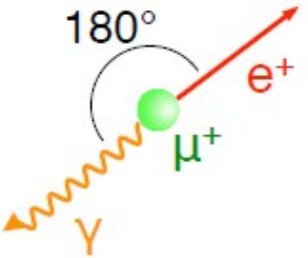
$N\mu=6x10^7$: 4.23 x 10-13

N_μ : average muon intensity

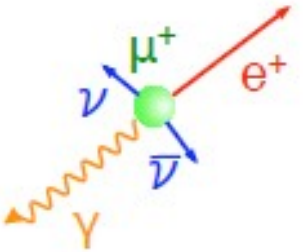
1 week = 4e5 sec
Accelerator status
DAQ dead time

Signal & Background

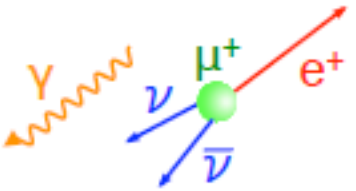
- signal
  - Back to back
  - Mono energetic : Ee=52.8MeV, Eg=52.8MeV
  - Coincidence in time



- Background
  - Prompt background

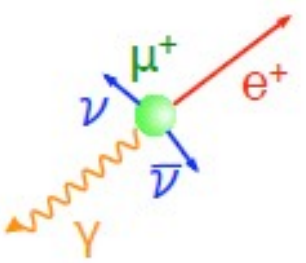


  - Accidental overlap

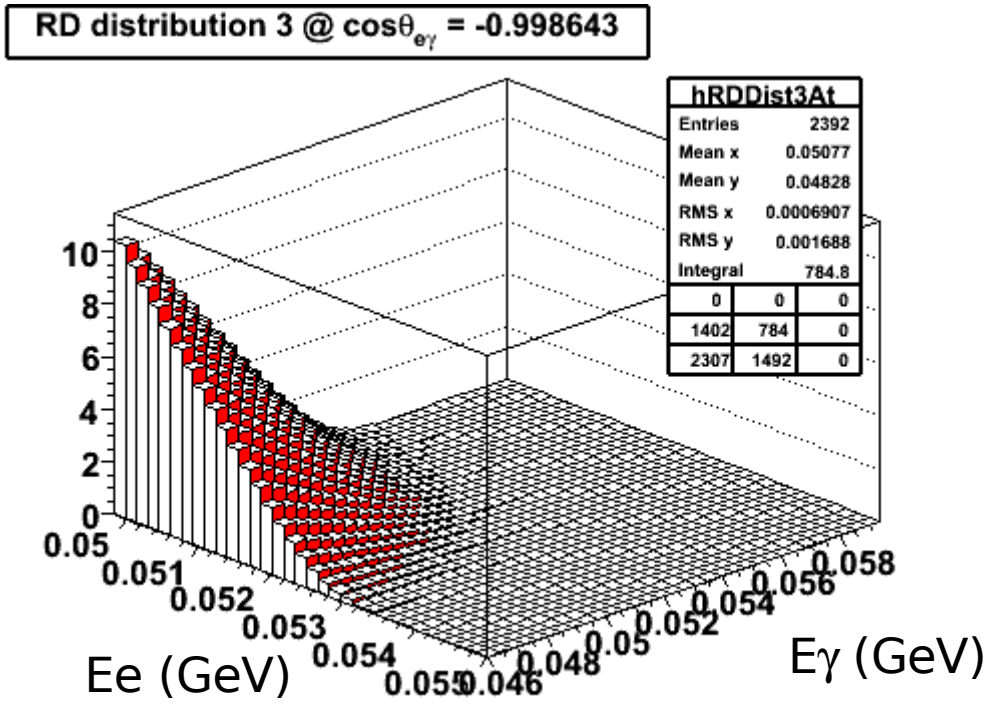


Prompt Background Estimation

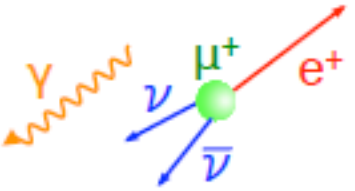
- Prompt background (radiative muon decay)
- Branching ratio (B_{RD}) can be calculated from theoretical formula
- Rough estimation of B_{RD} with current resolutions
  - $B_{RD} \sim 5.8 \times 10^{-4} (\delta x)^2 (\delta y)[\delta x/3 + \delta y](\delta z)^2$
    $= 2.4 \times 10^{-14}$



$x : 2E_e / M_\mu$
$y : 2E_\gamma / M_\mu$
$Z : \pi - \theta_{e\gamma}$



Accidental Background



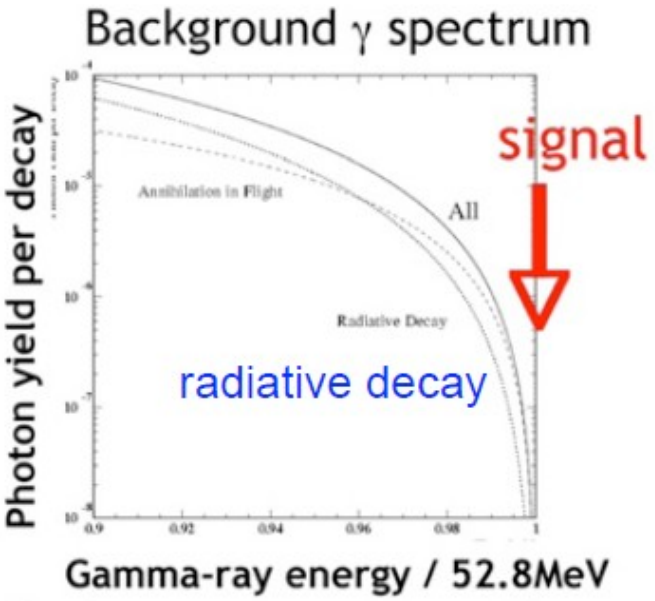
- Background
  - Can estimate with

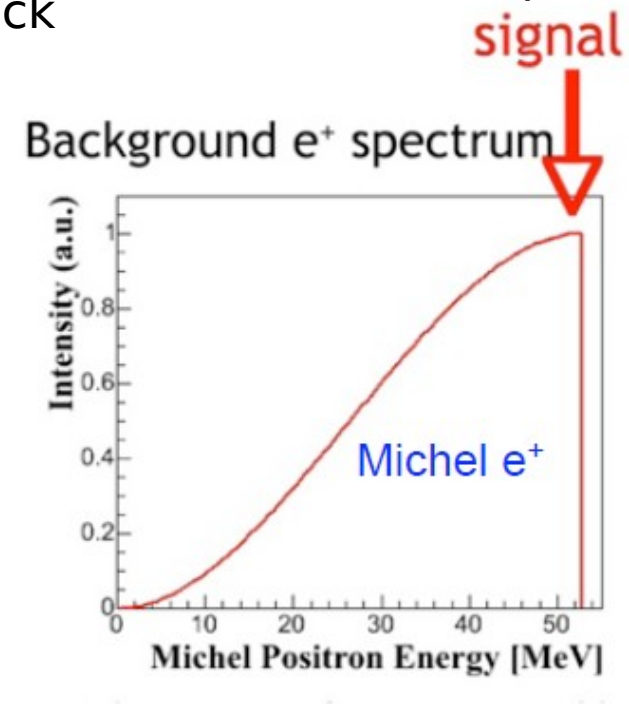
$$B_{acc} = R_{\mu} \cdot f_e^{0} \cdot f_{\gamma}^{0} \cdot (\delta\omega/4\pi) \cdot (2\delta t)$$

$=N_{\mu}$ (DC beam)

Back to back

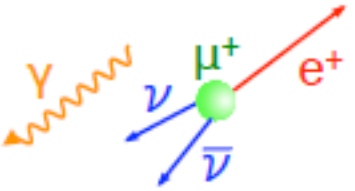
Time overlap





- Accidental background is dominant background source
  - γ ray measurement is most important

Accidental Background



- Background
  - Can estimate with

$$B_{acc} = R_{\mu} \cdot f_e^{0} \cdot f_{\gamma}^{0} \cdot (\delta\omega/4\pi) \cdot (2\delta t)$$

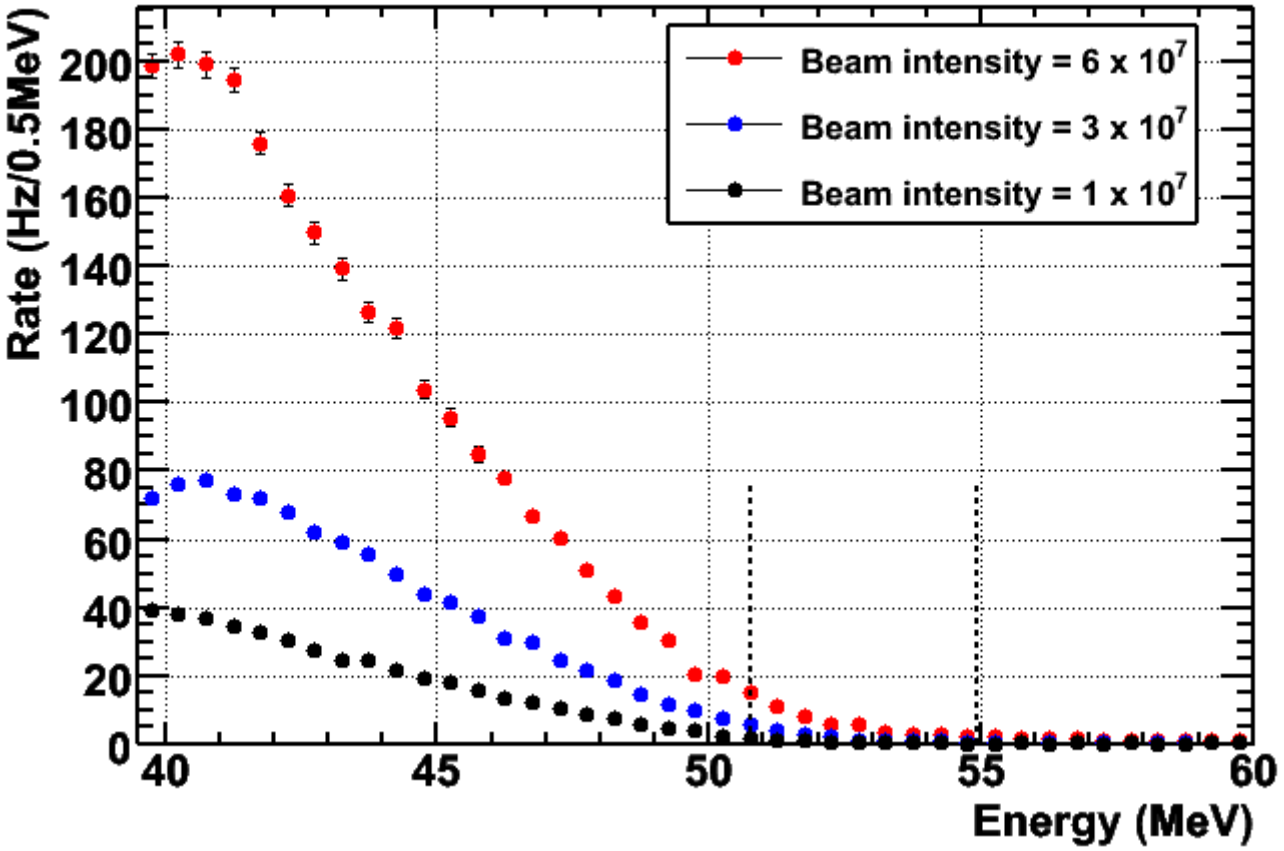
  - Now we can measure photon yield with our detector

Main topic of this talk

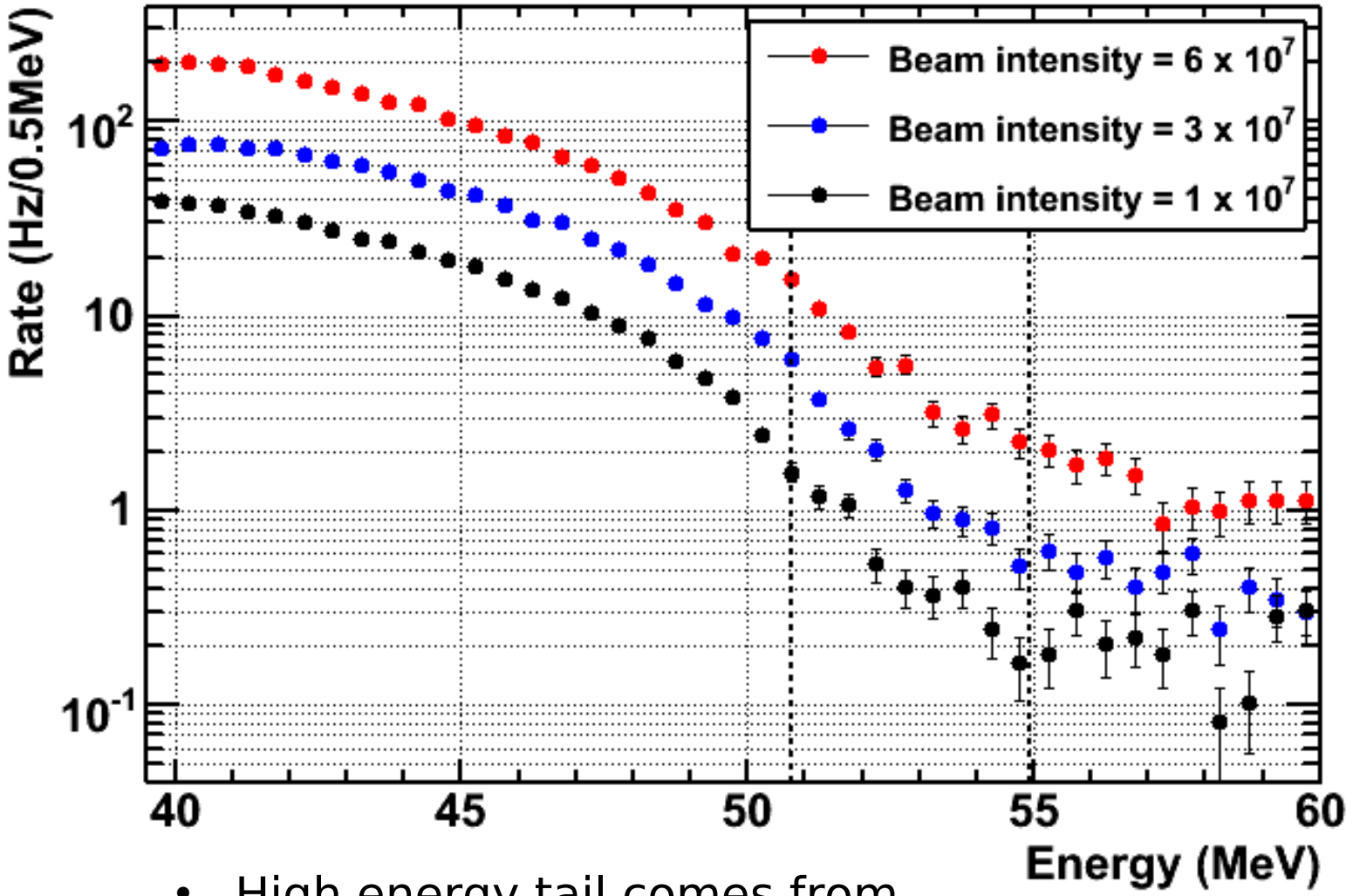
- Measure the actual photon yield
- Estimate accidental BG with it
  - Total time
  - Detector resolution
  - BG rejection power
  - Beam intensity

Single Spectrum

- We took LXe self trigger data
  - Trigger requirement is only energy deposit in LXe
  - 3 sets of beam intensity (1x, 3x, 6x 10^7)



Single Spectrum

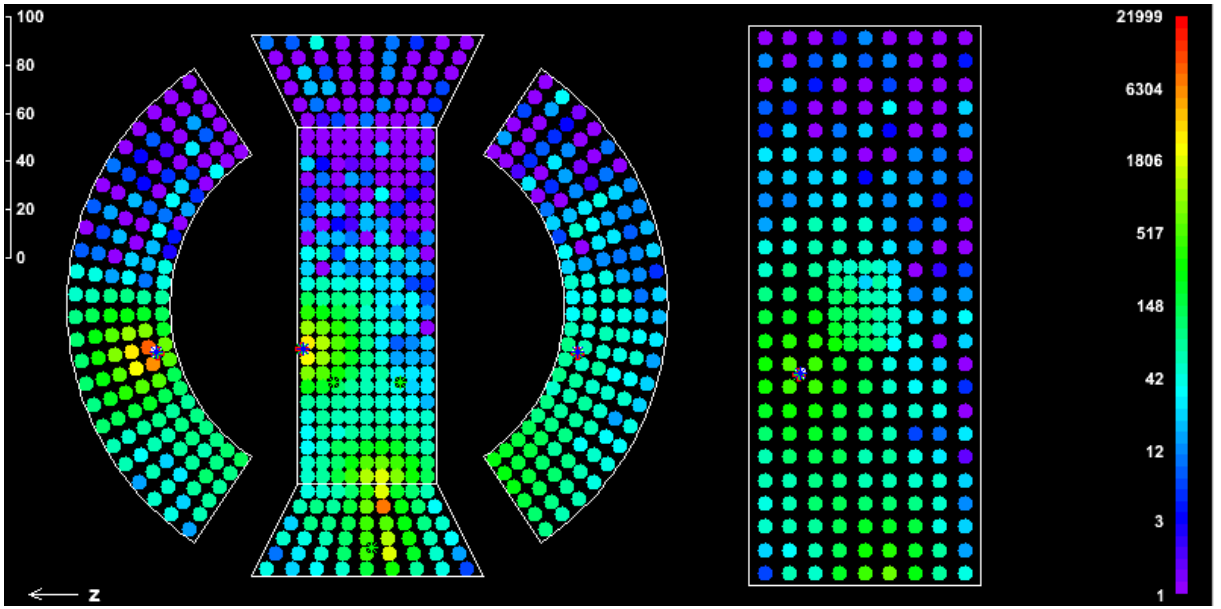


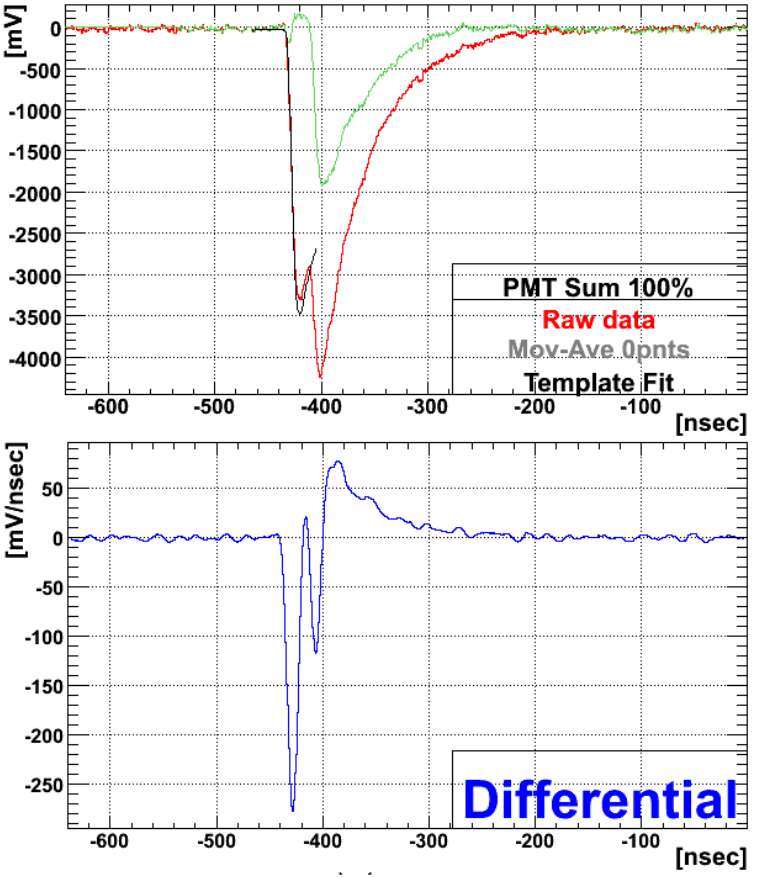
- High energy tail comes from
  - Incursion of RD photons due to resolution
  - High energy photon from AIF, Cosmic ray
  - Pile-up events

Pileup Identification

- Pileup events become dominant background source as increasing beam intensity

- The detector can identify pileup events by
  - Pattern of the light distribution
  - Time difference of every PMT
  - Waveform

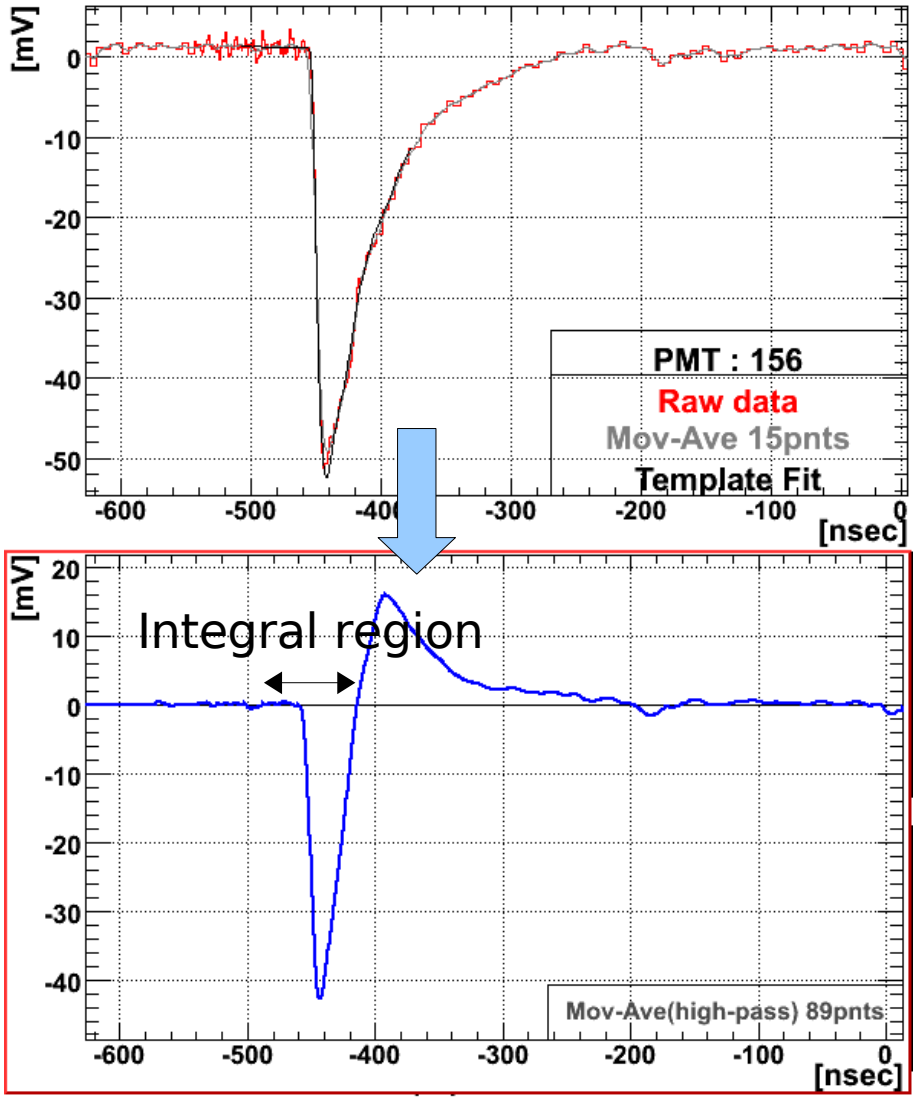




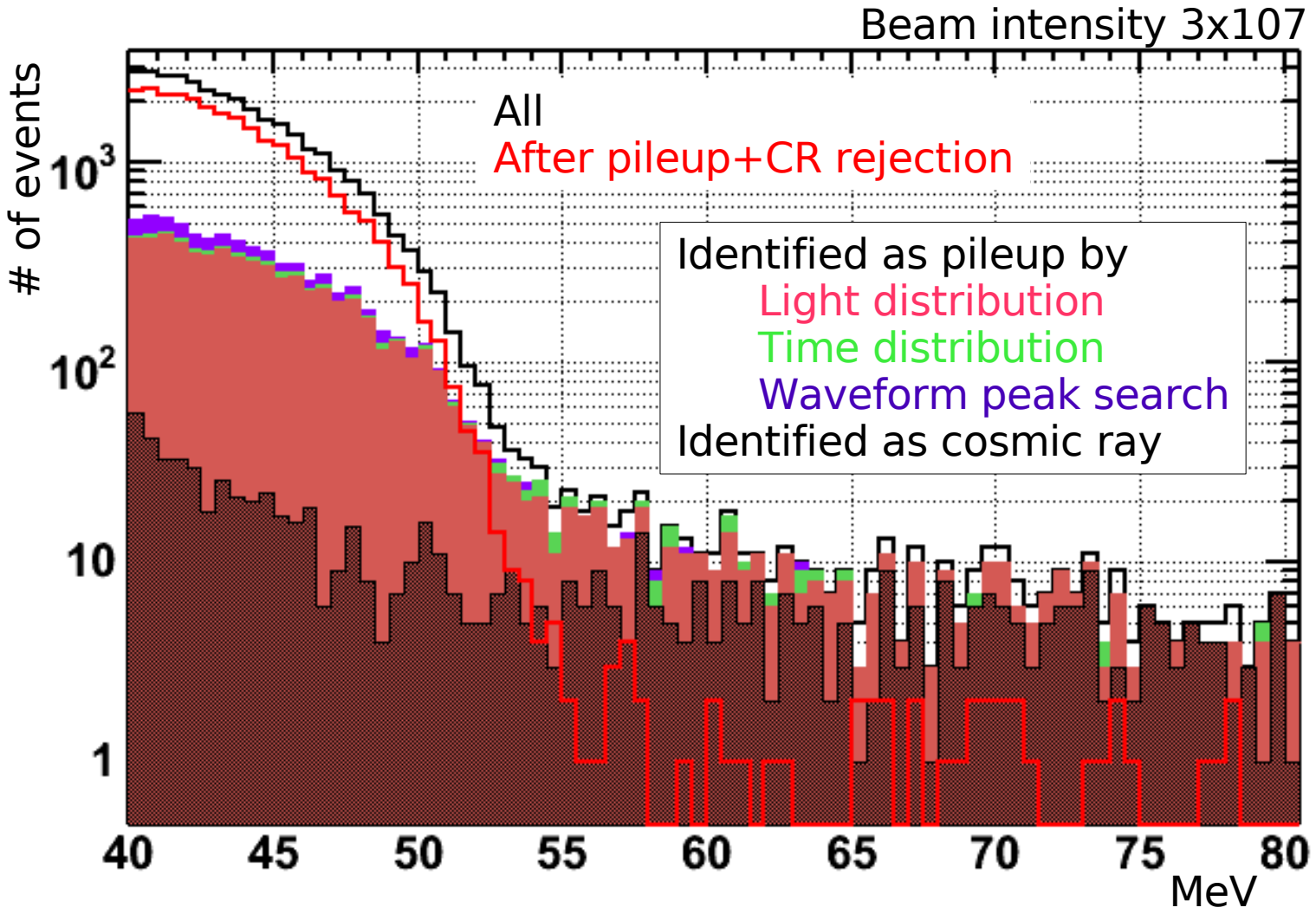
Waveform Analysis

- Acquiring full waveform of all PMTs
  - Sampling at 1.6 GHz
- Apply high-pass digital filter
  - Originally to reduce slow component noise
  - It improves also the ability for high rate environment
  - Only 50ns integration range

c.f. With normal ADC, we used ~500ns gate width



Pileup Rejection



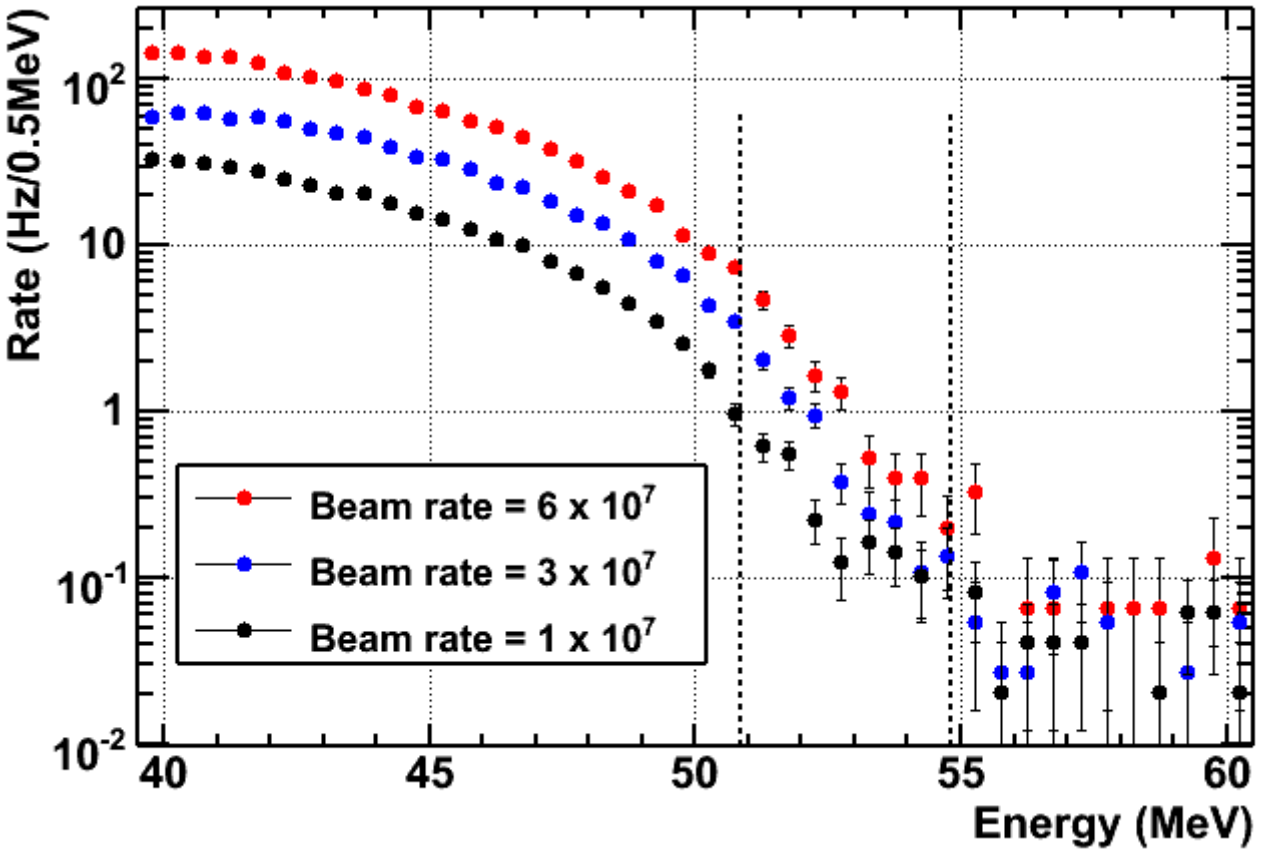
Pileup prob
1x107 : 1.6%
3x107 : 4.8%
6x107 : 9.6%
+
Miss ID prob
10%
⇩
efficiency
1x107 : 88.6%
3x107 : 85.7%
6x107 : 81.4%

- Inefficiency is estimated using MC (preliminary)

Background Rate Estimation

- Rate in signal region
  - $1x10^7$: 2.47Hz
  - $3x10^7$: 6.68Hz
  - $6x10^7$: 14.9Hz

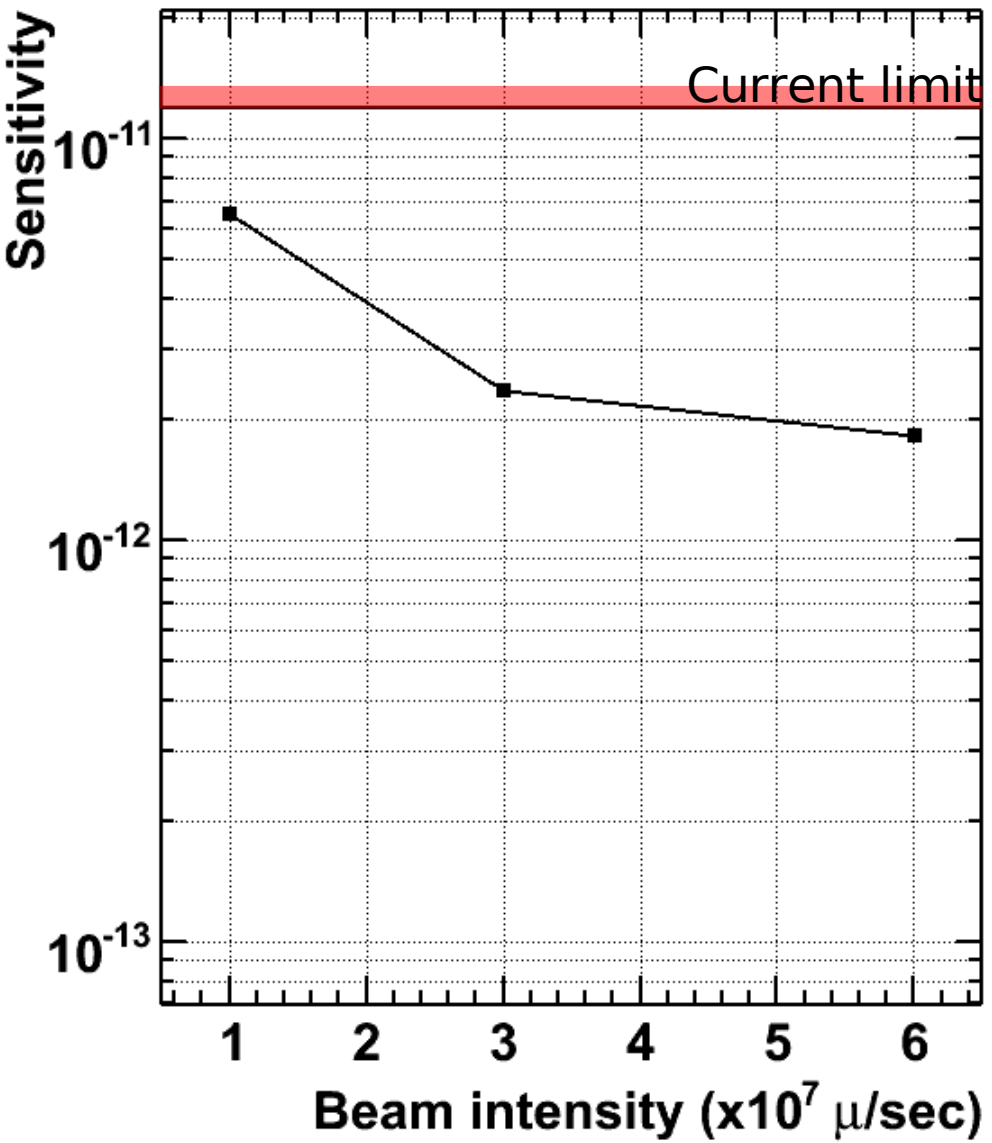
- Expected number of accidental BG
  - $1x10^7$: 0.04
  - $3x10^7$: 0.30
  - $6x10^7$: 1.32



Prospect Sensitivity

- Sensitivity (90% C.L.)
  - $1x10^{7}$: $6.5x10^{-12}$
  - $3x10^{7}$: $2.6x10^{-12}$
  - $6x10^{7}$: $1.8x10^{-12}$

- BG are there in $6x10^{7}$ intensity
- $3x10^{7}$ intensity is suitable for this year

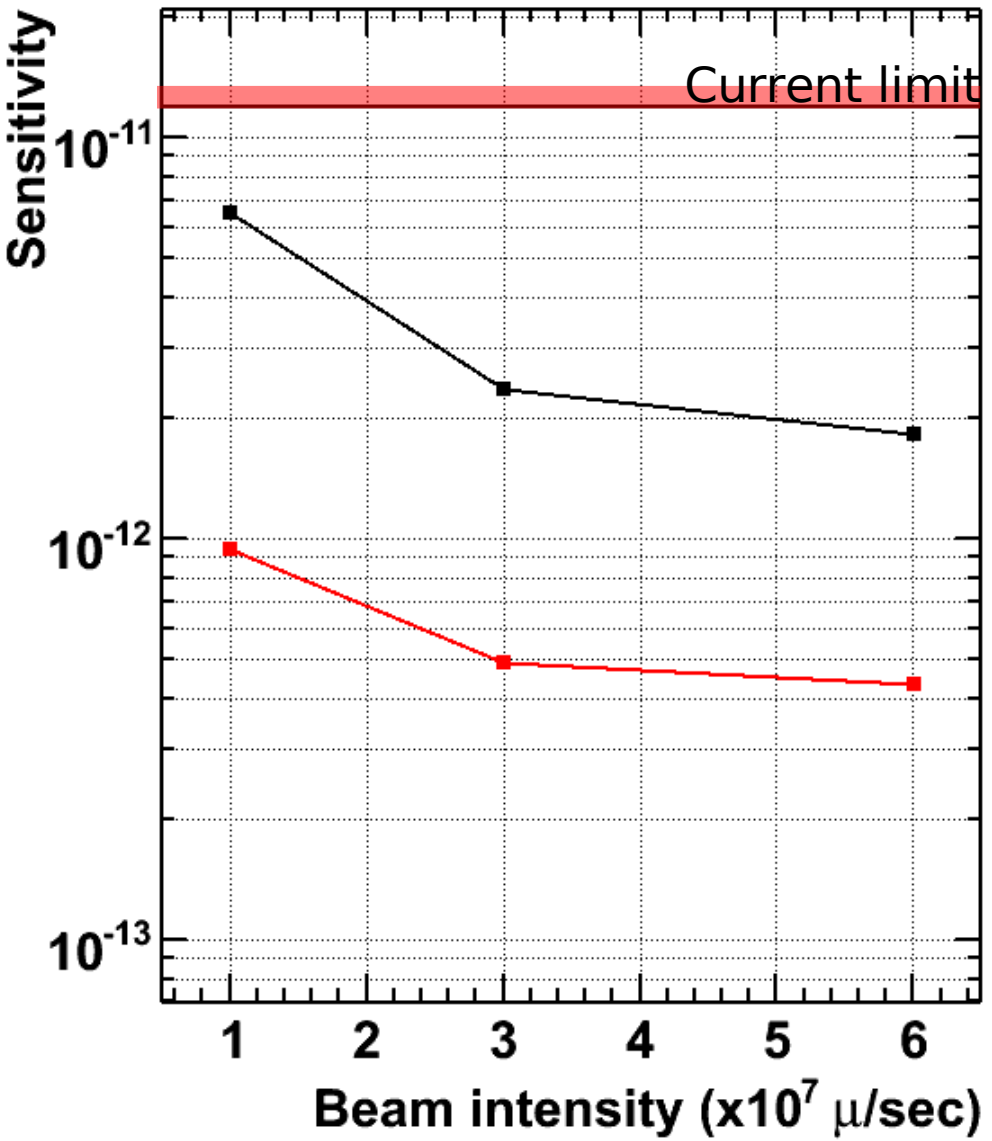


Prospect Sensitivity

- If we run with current condition for 2 years (100 weeks)

- Expected number of accidental BG
  - 1×10^7 : 0.30
  - 3×10^7 : 2.46
  - 6×10^7 : 10.9

- Sensitivity (90% C.L.)
  - 1×10^7 : 9.4×10^{-13}
  - 3×10^7 : 4.9×10^{-13}
  - 6×10^7 : 4.3×10^{-13}



Analysis

- We are thinking of analysis with combination of blind analysis & likelihood analysis
- Blind analysis (Hidden signal box)
  - Hidden parameter set
    - (Ee, Eg, Teg, qeg) or (Eg, Teg) (under discussion)
    - Boundary : +-3σ
  - Able to estimate BG rate in signal region without data in the box
    - Projection on each parameter
    - Single spectrum
    - Maximum likelihood fit
      - Compare PDF with BG data
- Maximum likelihood analysis
  - P(xi) = (NsigS(xi) + NRDS'(xi) + NBGB(xi)) / N
  - N = Nsig + NRD + NBG
  - L(Nsig, NRD) = Π(P(xi))
  - Describe detector non-uniformity (position, angle dependence)
    - PDFs for different region
  - Analysis region : +-5σ

Summary

- Background estimation
  - Estimated background form g-ray single spectrum
  - Looked at the dependency on the beam intensity
    - Optimization of beam intensity (3×10^{7})
  - Prospect sensitivity with Run2008 data
    - 2.6×10^{-12}

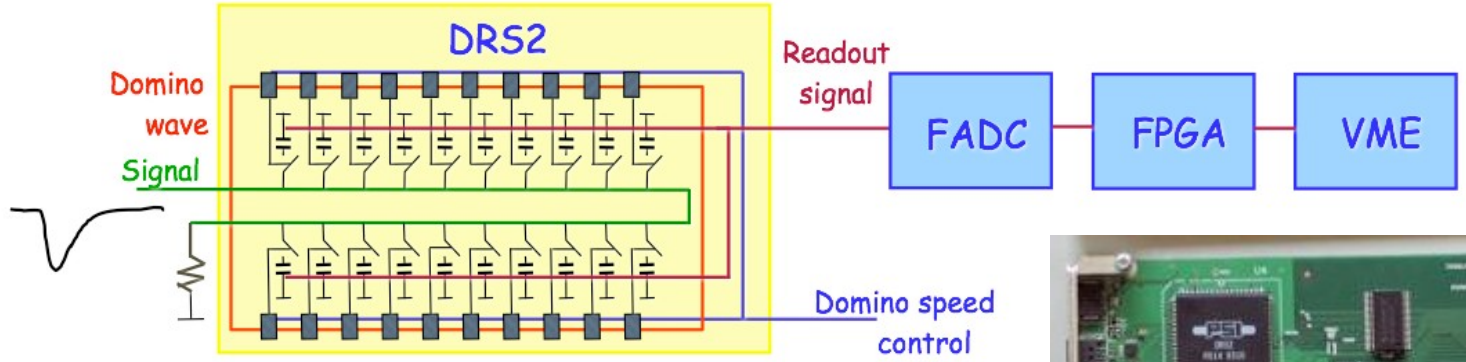
- Started physics data taking (Run2008)
  - We performed complete calibration runs
    - We are intensively working on analyzing these data
    - Our understanding of detector is growing
    - Detector performance is progressively improving
  - 12 weeks physics run this year
  - Good chance of discovery even with this years data

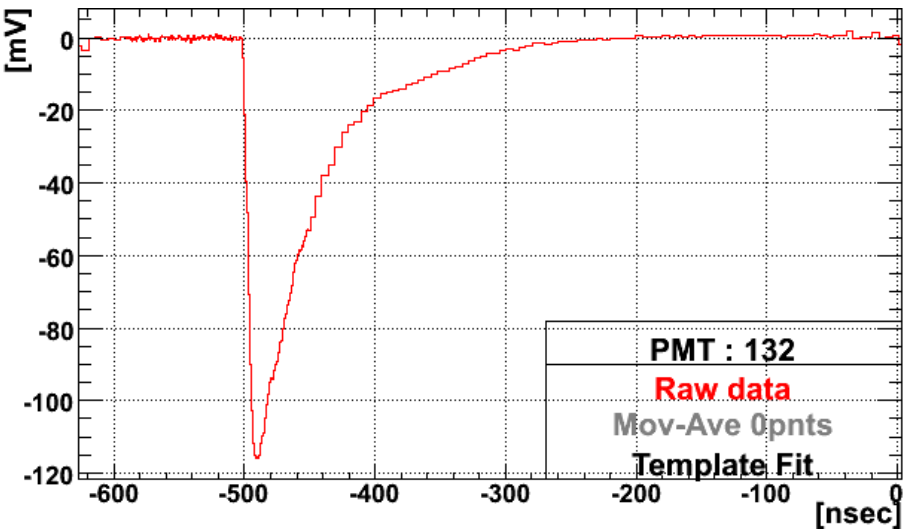
Summary

- Future prospect
  - Run2009 will start from June (long shutdown period)
    - Hardware modification
      - Upgrade of electronics (New version of waveform digitizer)
        - Better linearity, S/N, timing
      - Purity of LXe will be improved further
      - Maintenance work for full performance
    - Analysis
      - Complete calibration and reconstruction algorithm
      - Physics analysis of Run2008 data
  - Will take another 2 years to reach 1-2x10^{-13} (MEG goal)

DAQ Electronics

- Waveform of all PMTs are recorded
  - DRS : waveform digitizer with switched capacitor array
  - 1.6 GHz sampling for LXe PMT
  - 1024 cells : 600ns window
- No ADC, TDC





Analysis

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- Blind analysis (Hidden signal box)
  - Hidden parameter set
    - (Ee, Eg, Teg, qeg) or (Eg, Teg) (under discussion)
    - Boundary : +-3s
  - Able to estimate BG rate in signa[illegible]o[illegible] data in the box
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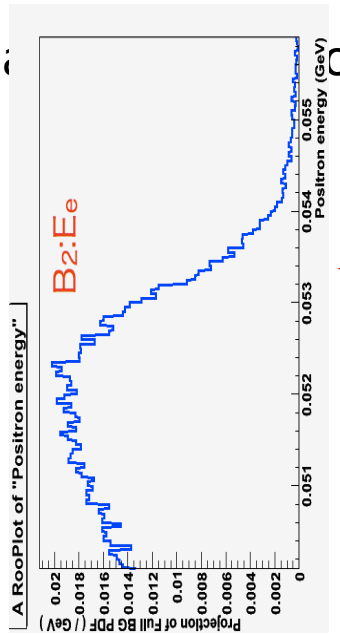

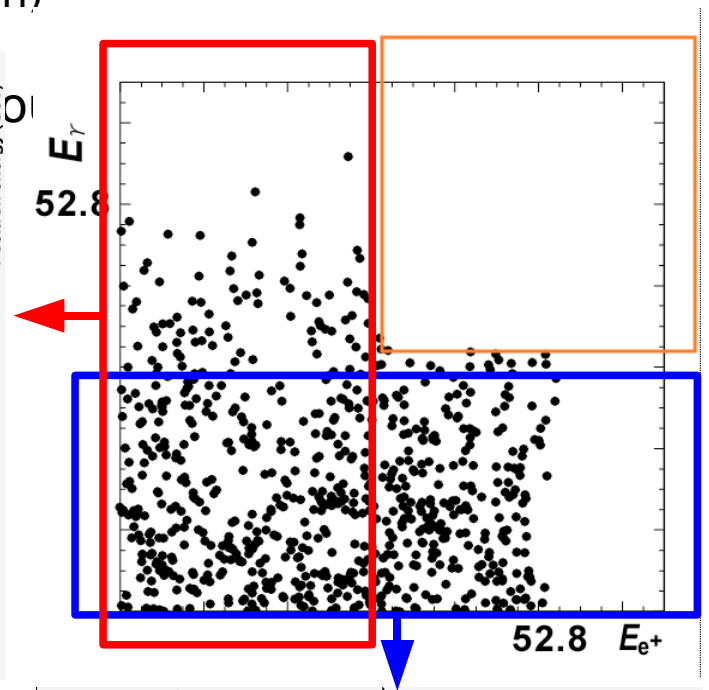

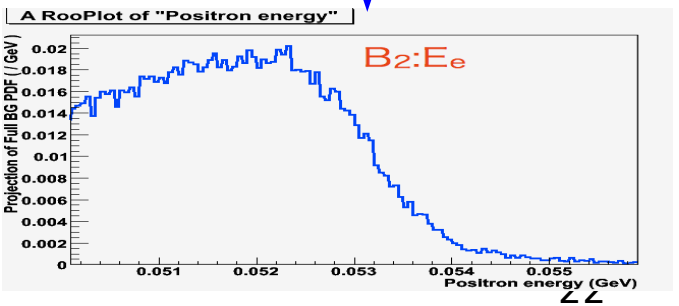

Analysis : Likelihood Fit

- Maximum likelihood analysis
  - P(xi) = (NsigS(xi) + NRDS'(xi) + NBGB(xi)) / N
  - N = Nsig + NRD + NBG
  - L(Nsig, NRD) = P(P(xi))
  -
- Describe detector non-uniformity (position, angle dependence)
  - PDFs for different region
- Analysis region : +-5s

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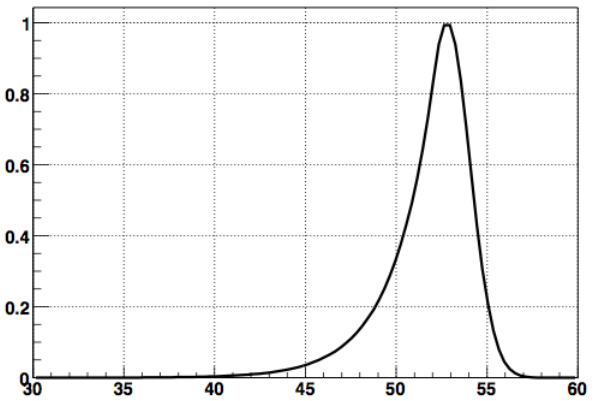
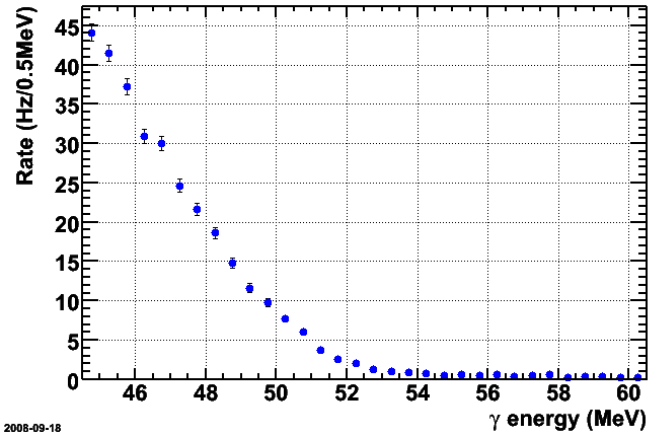
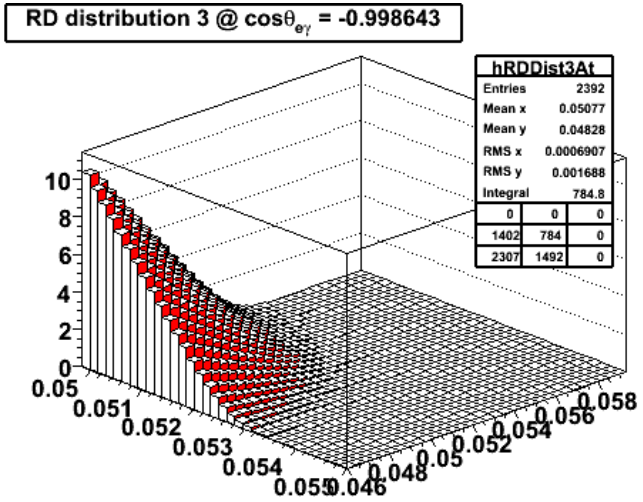
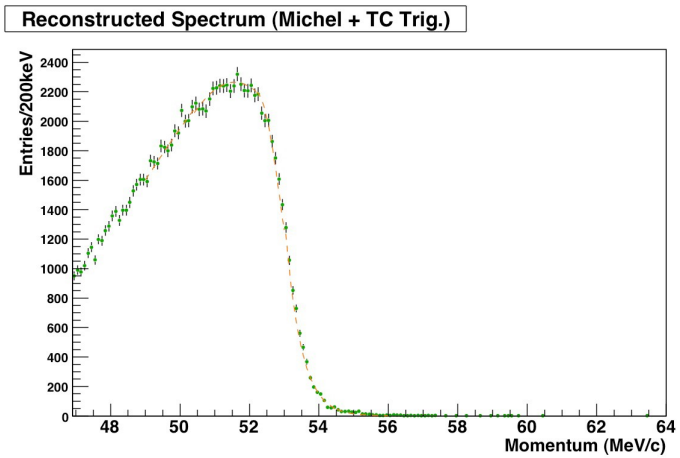
Analysis : PDF

- Signal PDFs
  - Gamma : pi0 data
  - Positron : Michel data
- Background PDFs
  - Single spectrum
  - Flat for timing
- RD PDFs
  - Theoretical distribution
  - Convolved with known detector response









MEG : μ → e γ Search Experiment

- Search for Lepton-flavor violating muon decay : μ → e + γ
  - Clear evidence of new physics beyond the SM
- Expected sensitivity : B.R. ~ 10^{-13}
  - Can improve the present limit two orders of magnitude