MEG Run2008

バックグラウンド

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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
- Michel run
- MEG run
- Beam shut down

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

- Gamma energy 5.64% (in FWHM)
- 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

\[
\text{S.E.S} = \frac{1}{N_\mu \cdot T \cdot \Omega/4\pi \cdot \epsilon_e \cdot \epsilon_\gamma} = \frac{1}{N_\mu (10^7) \cdot 4.8\times10^6 \cdot 0.09 \cdot (0.65 \cdot 0.5) \cdot (0.4 \cdot 0.7)} = 2.54 \times 10^{-12} / N_\mu (10^7/\text{sec})
\]

- \( N_\mu = 3 \times 10^7 : 8.46 \times 10^{-13} \)
- \( N_\mu = 6 \times 10^7 : 4.23 \times 10^{-13} \)

\( N_\mu \): average muon intensity

1 week = 4e5 sec
Accelerator status
DAQ dead time
Signal & Background

- signal
  - Back to back
  - Mono energetic: E_e = 52.8 MeV, E_g = 52.8 MeV
  - 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

\[ B_{\text{acc}} = R \cdot f_\mu^0 \cdot f_e^0 \cdot \left( \delta \omega / 4\pi \right) \cdot (2\delta t) \]

= \( N_\mu \) (DC beam)

Back to back

Time overlap

Accidental background is dominant background source
  - \( \gamma \) ray measurement is most important
Accidental Background

• Background
  - Can estimate with

\[ B_{acc} = R \cdot f^0_\mu \cdot f^0_\gamma \cdot \left( \frac{\delta \omega}{4\pi} \right) \cdot (2\delta t) \]

  - 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 $10^7$)
• 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

\[ \text{Integral region} \]

\[ \text{c.f. With normal ADC, we used} \]
\[ \text{~500ns gate width} \]
Pileup Rejection

• Inefficiency is estimated using MC (preliminary)

Beam intensity 3x10^7

# of events

3 x10^7 : 4.8%
6 x10^7 : 9.6%

Pileup prob
1 x10^7 : 1.6%
3 x10^7 : 4.8%
6 x10^7 : 9.6%

Miss ID prob
10%

↓
efficiency
1 x10^7 : 88.6%
3 x10^7 : 85.7%
6 x10^7 : 81.4%

 Identified as pileup by
Light distribution
Time distribution
Waveform peak search

Identified as cosmic ray

All
After pileup+CR rejection

Pileup prob
1 x10^7 : 1.6%
3 x10^7 : 4.8%
6 x10^7 : 9.6%

+  
Miss ID prob
10%

down

efficiency
1 x10^7 : 88.6%
3 x10^7 : 85.7%
6 x10^7 : 81.4%
Background Rate Estimation

- Rate in signal region
  - $1 \times 10^7$: 2.47 Hz
  - $3 \times 10^7$: 6.68 Hz
  - $6 \times 10^7$: 14.9 Hz

- Expected number of accidental BG
  - $1 \times 10^7$: 0.04
  - $3 \times 10^7$: 0.30
  - $6 \times 10^7$: 1.32
Prospect Sensitivity

- Sensitivity (90% C.L.)
  - $1 \times 10^7 : 6.5 \times 10^{-12}$
  - $3 \times 10^7 : 2.6 \times 10^{-12}$
  - $6 \times 10^7 : 1.8 \times 10^{-12}$

- BG are there in $6 \times 10^7$ intensity

- $3 \times 10^7$ intensity is suitable for this year
Prospect Sensitivity

- If we run with current condition for 2 years (100 weeks)
  - Expected number of accidental BG
    - $1 \times 10^7 : 0.30$
    - $3 \times 10^7 : 2.46$
    - $6 \times 10^7 : 10.9$
  - Sensitivity (90% C.L.)
    - $1 \times 10^7 : 9.4 \times 10^{-13}$
    - $3 \times 10^7 : 4.9 \times 10^{-13}$
    - $6 \times 10^7 : 4.3 \times 10^{-13}$
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: \( \pm 3\sigma \)
  - 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
  - \( P(x_i) = \frac{(N_{sig}S(x_i) + N_{RD}'(x_i) + N_{BG}(x_i))}{N} \)
  - \( N = N_{sig} + N_{RD} + N_{BG} \)
  - \( L(N_{sig}, N_{RD}) = \prod(P(x_i)) \)
  - Describe detector non-uniformity (position, angle dependence)
    - PDFs for different region
  - Analysis region: \( \pm 5\sigma \)
Summary

• Background estimation
  - Estimated background form g-ray single spectrum
  - Looked at the dependency on the beam intensity
    • Optimization of beam intensity (3 x 10^7)
  - Prospect sensitivity with Run2008 data
    • 2.6 x 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 $1-2 \times 10^{-13}$ (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

- 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
Analysis: Likelihood Fit

- Maximum likelihood analysis
  - \( P(x_i) = \frac{(N_{\text{sig}}S(x_i) + N_{\text{RD}}S'(x_i) + N_{\text{BG}}B(x_i))}{N} \)
  - \( N = N_{\text{sig}} + N_{\text{RD}} + N_{\text{BG}} \)
  - \( L(N_{\text{sig}}, N_{\text{RD}}) = P(P(x_i)) \)

- Describe detector non-uniformity (position, angle dependence)
  - PDFs for different region

- Analysis region: +5s
Analysis : Likelihood Fit

• Maximum likelihood analysis
  – $P(x_i) = \frac{(N\text{sig}S(x_i) + N\text{RD}S'(x_i) + NB\text{GB}(x_i))}{N}$
  – $N = N\text{sig} + N\text{RD} + NB\text{G}$
  – $L(N\text{sig}, N\text{RD}) = P(P(x_i))$

• Describe detector non-uniformity (position, angle dependence)
  – PDFs for different region

• Analysis region : $\pm 5s$
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

RD distribution 3 @ $\cos^2\theta_w = -0.998643$
MEG : $\mu \rightarrow e \gamma$ Search Experiment

- Search for Lepton-flavor violating muon decay : $\mu \rightarrow e + \gamma$
  - Clear evidence of new physics beyond the SM
- Expected sensitivity : B.R. $\sim 10^{-13}$
  - Can improve the present limit two orders of magnitude