MEG実験
陽電子スペクトロメータの性能と今後の展望

Yuki Fujii
On behalf of the MEG collaboration
JPS meeting @ Hirosaki University
17th Sep. 2011
Outline

- Introduction
- Run 2009 & 2010
- Status of run 2011
- Noise reduction
- Summary and prospects
Introduction

- The decay of $\mu \rightarrow e \gamma$ is strictly forbidden in the standard model because of lepton flavor conservation.

- BUT... some of beyond the SM (e.g. SUSY) predict this decay can happen in the range of $10^{-11}$-$10^{-15}$.
  - Previous upper limit is $1.2 \times 10^{-11}$ (MEGA experiment).
  - $\mu \rightarrow e \gamma$ is a good probe to search for new physics!

- Background
  - Radiative decay (prompt)
  - Michel decay + $\gamma$ (accidental).

- Experimental requirement
  - High resolution detector $\rightarrow$ reduce background.
  - Operation under high luminosity $\rightarrow$ high statistics.
The MEG experiment started to search for $\mu \rightarrow e \gamma$ in 2008.
- World’s most intense DC $\mu^+$ beam @ PSI
- 900 litter large Xenon calorimeter $\rightarrow$ (白:17pSE2, 金子:17pSE3)
- The COBRA (COntant Bending RAdius) spectrometer $\rightarrow$ main topic

Result 2009 & 2010: $\text{Br}(\mu \rightarrow e \gamma) < 2.4 \times 10^{-12}$ (90 % C.L.)
- 5 times lower than previous one
  $\rightarrow$ (大谷:18aSJ4, 岩本:19aSD7, 澤田:19aSD8)

Our sensitivity goal is a few $\times 10^{-13}$
- Performance improvement is essential!
Introduction

- The COBRA spectrometer
  - **COBRA magnet**: fast sweeping low momentum e+ and get uniform angular response for signal e+
  - **Drift chamber**: e+ tracking, low mass materials to reduce the production of background gamma ray
    - Vernier pattern method
    - Waveform data acquisition
  - **Timing counter**: e+ timing, bar counters (φ measuring) + fiber counters (z measuring)
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Introduction

- **Positron measurement**
  - Coordinate system
  - Hit reconstruction
    - $R \rightarrow$ time reading edge
    - $Z \rightarrow$ charge division w/ Vernier pad
  - Track reconstruction
    - Kalman filter
Run 2009 & 2010

- Run and analysis summary of 2009 and 2010
- Drift chamber alignment
  - Millipede using cosmic rays
- COBRA Magnetic field
  - reconstructed field
- $B_\phi$ and $B_r$ are corrected a possible misalignment of hole probe to conserve the Maxwell’s equations from measured $B_z$
- All APDs off because of noise problem
- Drift chamber waveform in 2010 was a little noisier than in 2009 ($\sigma$ of pedestal: $\sim 1.8$ mV $\rightarrow \sim 2.0$ mV)
Run 2009 & 2010

- Performance estimation
- **Momentum resolution**: Michel edge fitting and double turn events
- **Angular & vertex resolutions**: Double turn events
- **Efficiency**: count # of MD
- **Correlations**: sideband data
Run 2009 & 2010

- All performance of the e+ spectrometer are estimated by data itself (radiative decay events, Michel decay events, and so on)

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<th>2009</th>
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<td>$E_e$</td>
<td>330 keV (core 82 %)</td>
<td>330 keV (core 79 %)</td>
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<td>$\phi$ (at $\phi=0$)</td>
<td>6.7 mrad</td>
<td>7.2 mrad</td>
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<tr>
<td>$\theta$</td>
<td>9.4 mrad</td>
<td>11.0 mrad</td>
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<td>$Z$</td>
<td>0.15 cm</td>
<td>0.20 cm</td>
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<td>$Y$</td>
<td>0.11 cm (core 87 %)</td>
<td>0.11 cm (core 85 %)</td>
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<tr>
<td>$T_{e\gamma}$ (RMD)</td>
<td>150 psec</td>
<td>130 psec</td>
</tr>
<tr>
<td>$\varepsilon_{\text{Michel}}$</td>
<td>40 %</td>
<td>34 %</td>
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Status of 2011

- 7 drift chamber modules were replaced because of increased remaining current or frequent trip
- Physics data taking started at the end of June
- In 2009 and 2010, only 14 MHz noise is dominant
  - reduced by adjusting charge integration time
  - other noise components appeared (>30 MHz from APD fiber counters)
- Working of hardware noise reduction was done in the middle of July
  - Change HV module for drift chambers and turn off noisy APD channels
Status of 2011

- At the beginning of 2011 run, noise situation was the worst...

- But
Status of 2011

- At the beginning of 2011 run, noise situation was the worst...

- After hardware modifications, the lowest noise condition realized!

- The APD fiber counters are partially operational now (not all)
  - Data quality to be checked
Noise reduction

- Performance of noisy runs and low noise runs
  - compare 2 condition by checking single hit resolutions (residuals between reconstructed wire hit and reconstructed track)
  - Single hit resolutions are estimated from double Gaussian fitting

- Give up noisy data to improve? → **OF COURSE NO!**

- Filtering
  - Low pass filter → small contribution
  - High pass filter → distort the shape of signal pulse
  - FFT

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<th>2011 (noisy)</th>
<th>2011 (low noise)</th>
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<td>Intrinsic Z (um)</td>
<td>668 (core 56 %)</td>
<td>758 (core 52 %)</td>
<td>710 (core 56 %)</td>
</tr>
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<td>Intrinsic R (um)</td>
<td>209 (core 66 %)</td>
<td>233 (core 66 %)</td>
<td>197 (core 67 %)</td>
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~ 1 month data taking
Noise reduction

- Large periodical noises are eliminated in FFT power spectrum from DCH waveform
- After that, filtered spectrum is transformed inverse to the waveform
  - Charge integration done for filtered waveform
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- Single hit Z resolution improved!!
  - 758 $\rightarrow$ 664 um, #of hits increased
Noise reduction

- Thanks to offline noise filtering, twice better of pedestal realized (2.4 mV → 1.2 mV)
- Single hit Z resolution improved!!
  - 758 → 664 um, #of hits increased
- Efficiency & resolutions
  - Very good!

432 keV (80 %) → 380 keV (79 %)

11.7 mrad (68 %) → 12.4 mrad (78 %)

13.1 mrad → 11.6 mrad
Noise reduction

- Filtering for waveform in low noise condition
  - What happen if FFT filtering used in low noise condition?
  - Single hit Z resolution
    - Only a few % better (710 → 697 um)
    - # of hits increased
  - Efficiency and resolutions improved, too

- 390 keV (82 %) → 321 keV (75 %)
- 14.4 mrad (84 %) → 11.4 mrad (76 %)
- 12.0 mrad → 11.7 mrad
Performance summary

- 2011 performance summary (Preliminary)
  - Only parts of data were analyzed
  - Correction for resolutions in 2011 not yet done
  - Calibrations still ongoing

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<td>7.2 (core, $\phi=0$)</td>
<td>12.4 (core 78 %)</td>
<td>11.4 (core 76 %)</td>
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<tr>
<td>$\theta$ (mrad)</td>
<td>11.0</td>
<td>11.6</td>
<td>11.7</td>
</tr>
<tr>
<td>#of 2 turn e+</td>
<td>-</td>
<td>2499 $\rightarrow$ 4019</td>
<td>3184 $\rightarrow$ 3833</td>
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Summary and prospects

• Summary
  • **Thanks to FFT noise filtering, data quality of noisy runs achieved to the level of low noise situation!**
    - Further check needed
      - Transformation accuracy
      - Check with more data
      - Single hit R resolution

• Prospects
  • **Calibrations for the spectrometer in preparation now**
    - Better resolutions and efficiency expected
  • Monochromatic calibration source for the spectrometer
    - Mott scattering with e+ beam (energy tunable)
  • Hardware improvement for $\varepsilon_e$ ($\equiv$ reduce materials between DC and TC)
    - **Readout cable exchange to thinner one (40 % $\rightarrow$ 50 + x %)**
    - According to changing cables, the support structure system for drift chambers will be updated
backup
Vernier method

Vernier angle $\alpha$ is defined as

$$\alpha = \tan^{-1} \left( \frac{\epsilon_1}{\epsilon_2} \right)$$

where

$$\epsilon_a = \frac{Q_U - Q_D}{Q_U + Q_D}.$$  

- Compare $\alpha$ to reconstructed $z$ position, we can decide $z$ more precisely.
Positron correlations

- Correlations

Case: \( E_{\text{meas}} < E_{\text{true}} \)
\( \gamma_{\text{meas}} < \gamma_{\text{true}} \)
\( \phi_{\text{meas}} > \phi_{\text{true}} \)

...
Efficiency

- Material between drift chambers and timing counters make lower efficiency because of multiple scattering.

Breakdown of Inefficiency caused by DC components:

- Frame: 49%
- Cable: 28%
- Preamp: 19%
- Duct: 4%
Check for APD data

- Quality check for APD outputs

- **First step**
  - Matching between hit $z$ at fiber and $e^+$ track at timing counter bars
  - Only downstream of APDs are working now
Check for APD data

- Quality check for APD outputs

- First step
  - Matching between hit z at fiber and e+ track at timing counter bars → peak position is same, but large tail found
  - Only downstream of APDs are working now

Data and MC comparisons for hit z at fiber and track z at bar counters.