MEG2008 データ解析：陽電子スペクトロメータ

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MEG $e^+$ spectrometer
Requirements for Positron Spectrometer

- **Very high counting rate**
  - the most intense DC muon beam in the world
  - muon stopping rate: $3 \times 10^7$ muon/sec

- **Good momentum/position/timing resolution**
  - aiming excellent sensitivity
  - $\sim 1\%$ momentum resolution, 500$\mu$m position resolution for both direction ($r,z$) and 40 ps timing resolution

- **Low-mass material**
  - 52.8MeV/c positron can be affected by multiple Coulomb scattering easily
  - $\gamma$ background generation should be suppressed as much as possible
MEG Positron Spectrometer

**Solenoid**
- superconducting solenoid gradient B-field (0.5-1.7 T)
- very thin conductor and cryostat wall (0.2X₀)

**Drift Chamber**
- segmented radially (16 sectors)
- helium:ethane (50:50)
- opened-frame
- very thin cathode foil with pads

**Timing Counter**
- 2-layers of scintillators
  - scintillator bars (outer)
  - scintillator fibres (inner)
MEG Drift Chamber

- Muon stopping target
- Radial segmented DC modules
- Extremely thin cathode foil
- Opened-frame structure
- Helium based gas
- Reduced readout electronics
- Helium filled inside solenoid
Run 2008
Spectrometer in 2008

- We had the first long term experiment (*physics data taking*) in 2008.

- Rough Time-line 2008:
  - **January - May**: *Drift Chamber Maintenance*
    - Repair work for bad cable connection
    - Modification to avoid discharge problem
  - **June - July**: *Installation and Commissioning Run*
    - Michel e^+ Run was performed for Calibration/Conditioning
  - **August**: *π^0→γγ Run*
    - Spectrometer was in Summer Vacation
  - **September - December**: *MEG Physics Run*
    - Problems: Discharge on DC, Noise on Fibre Counter, *etc.*
Several DCs were inactive...

- **Discharge** on DC happened frequently during Run2008.
- Discharge problem happened 2007 originally, it was fixed at the beginning of 2008, but slowly happened again.
- Finally, 18 planes were operational, only 12 planes were working with nominal voltage...(HV is applied to each plane individually; 32 planes)
Discharges

• Inside COBRA is filled with pure helium, then DC-outside is exposed in helium atmosphere.
• HV-tracer-line is partially naked to helium in 2007, then discharged...
• We made the protection for helium in 2008 maintenance period, but...
2008 Performances
Performance Evaluation

- Positron Spectrometer Performances
  - Momentum Resolution ; $\sigma E_{e^+}$
  - Angular Resolution ; $\sigma \phi_e$, $\sigma \theta_e$
  - Vertex Resolution ; $\sigma_x$, $\sigma_y$

- Combined Performances ( LXe Calorimeter + e$^+$ Spectrometer )
  - Opening Angle Resolution ; $\sigma \theta_{e\gamma}$, $\sigma \phi_{e\gamma}$
  - Timing Resolution ; $\sigma t_{e\gamma}$

- Spectrometer Efficiency ; $\varepsilon_e$

- Probability Density Function (PDF)
  - For the Likelihood Analysis
  - $E_{e^+}$, $\theta_{e\gamma}$, $\phi_{e\gamma}$, $t_{e\gamma}$ : for Signal, Background, both
Momentum Resolution Estimation

- Momentum-Resolution function is represented by Triple-Gaussian
- Studied by mono-energetic $e^+$ in MC
- $\sigma_{\text{core}}$, $\sigma_{\text{out}}$, $\sigma_{\text{tail}}$ and their fractions are referred as resolution

- Fitting the kinematical edge of Michel spectrum to the convolution of resolution function and (theoretical) response function

**MC**
- Mono-energy: 52.8 MeV/c
  - Inactive DCs
  - Lower HV
  - Noise
  - Air Doping
Momentum Resolution (Run2008)

- Obtained Resolution
  - $\sigma_{E_{\text{core}}}$ = 374 keV
  - $\text{frac}_{\text{core}}$ = 60%
  - $\sigma_{E_{\text{out}}}$ = 1.06 MeV
  - $\text{frac}_{\text{out}}$ = 33%
  - $\sigma_{E_{\text{tail}}}$ = 2.00 MeV
  - $\text{frac}_{\text{tail}}$ = 7%
  - $\text{ave. } \sigma_E$ = 714 keV
  - $\sigma_E/E \sim 1.3\%$

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Angular Resolution (Run2008)

* Angular resolution is estimated by doubly curling track.
* Subtracted angular residual of each turn gives intrinsic angular resolution.

\[ \sigma_\theta = 1.45 \text{ deg.} / \sqrt{2} \]
\[ \approx 18 \text{ mrad.} \]

\[ \sigma_\phi = 0.81 \text{ deg.} / \sqrt{2} \]
\[ \approx 10 \text{ mrad.} \]

(*) N.B. Taking the z-axis as the beam-axis, \( \theta \) is defined as the polar angle, while \( \phi \) is the azimuthal angle.
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Vertex Resolution (Run2008)

* Vertex (muon decay position) Resolution can be evaluated by two way
  * (1) Fitting the image of hole / (2) Subtracting the double curing track
  * Both show consistent results; $\sigma_x \sim 4.5 \text{ mm}$ and $\sigma_y \sim 3.2 \text{ mm}$
* Liquid Xenon Detector knows only the incident position, not angle.

* Combined Angle Resolution: $\sigma_{\theta e\gamma} = 20.6 \text{ mrad.} / \sigma_{\phi e\gamma} = 13.9 \text{ mrad.}$
Timing Resolution (Run2008)

- Relative Timing \( (e^+ / \gamma) \) in physics data shows Radiative Decay Peak on the accidentals.
- Positron timing is measured by TC and corrected by track length.
- Gamma-ray timing is corrected by ToF to the conversion point in LXe.
- Peak width is corrected by small energy dependence
  - \( \sigma t_{e\gamma} = 148 \text{ psec} \)

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Spectrometer Efficiency (Run2008)

- Spectrometer Efficiency $\varepsilon_{e^+}$ consists of two efficiencies
  - Track Reconstruction $\varepsilon_{DC}$
    - affected by lack of hit
  - DC-TC matching $\varepsilon_{DC-TC}$
    - affected by material between DC-TC
  
  $\varepsilon_{e^+} = \varepsilon_{DC} \times \varepsilon_{DC-TC}$

- $\varepsilon_{e^+}$ was degrading over physics-run period

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Background PDFs: $Ee^+, \theta_{e\gamma}, \phi_{e\gamma}$

- Background PDF (radiative muon decay and accidentals) are obtained by unbiased-trigger data. (Michel Trig. and RMD Trig.)
- Used by Physics Analysis

Next Talk
Even though we had worse performances than the design value, the performance of Run2008 was evaluated to perform physics analysis.

<table>
<thead>
<tr>
<th>Items</th>
<th>2008</th>
<th>2009 expectation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Momentum Resolution; $\sigma E_{e^+}$</td>
<td>$\sim 1.3%$</td>
<td>$\sim 0.9 %$</td>
</tr>
<tr>
<td>Angular Resolution; $\sigma \theta_e$, $\sigma \phi_e$</td>
<td>10-18 mrad</td>
<td>10-13 mrad</td>
</tr>
<tr>
<td>Timing Resolution; $\sigma t_{e\gamma}$</td>
<td>148 psec</td>
<td>$\sim 100$ psec</td>
</tr>
<tr>
<td>Spectrometer Efficiency; $\varepsilon_{e^+}$</td>
<td>7-24 %</td>
<td>$\sim 40%$</td>
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(80% $\times$ 50%)
Conclusions

- **MEG e⁺ Spectrometer** have run the first long-term experiment 2008.
- Unfortunately, several problems happened during the physics run, in particular, **HV discharge problem**.
- Due to discharge, **DC system was operational partially**, and thus the spectrometer performance was limited. **Inefficiency was particularly severe, i.e. statistics was limited.**
- Performance is estimated even it is limited, PDF’s for Signal and Background are obtained.

- Now, ready to discuss “**Physics Analysis**”. 
- Spectrometer should be improved. 
  Next Talk. 
  Next to Next Talk.
backups
Signature and Backgrounds

• Signal
  - $E_e = E_\gamma = m_\mu/2 = 52.8\text{MeV}$
  - $\theta = 180\text{deg.}$
  - time coincidence

  ![Signal Diagram]

  Clear 2-body kinematics
  use $\mu^+$ to avoid capture inside stopping target
  Background dominated by Accidental overlap
  - lower muon beam rate is better
  - DC muon beam is the best

• Background
  - radiative muon decay
  - accidental overlap

  ![Background Diagram]
COBRA Solenoid

uniform B

graded B

low energy $e^+$ quickly swept out

uniform B

graded B

constant bending radius independent of emission angles
Hit Rate in COBRA

![Graph showing hit rate in COBRA with different B-fields.](image-url)
MEG Drift Chamber
2008 Summary of MEG-DC

- **April**: maitainance
- **May**: install
- **June**: conditioning & Michel Run
- **July**: $\pi^0$ run
- **August**: discharge start
- **September**: Physics Run
- **October**: shutdown
- **November**: $\pi^0$ run
- **December**: discharge start

# of operational plane:

- April: 32
- May: 28
- June: 27
- July: 24
- August: 21
- September: 18

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Discharge Studies

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