MEG 実験のための陽電子飛跡検出用
低物質量ドリフトチェンバーの研究開発

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Contents

- MEG experiment
- Drift chamber
- Concept
- R & D status
- Summary
MEG experiment
MEG experiment

- Search experiment for $\mu^+ \to e^+\gamma$
  - “$\mu \to e\nu\nu$” ~ 100% (Normal $\mu$ decay in SM)
  - “$\mu \to e\gamma$” violates Lepton Flavor Conservation
  - SUSY-GUT models predict higher branching ratio $\text{Br}(\mu \to e\gamma) = 10^{-11} \sim 10^{-15}$
  - Sensitive to physics beyond the SM !!

- New experiment with a sensitivity of $\text{Br}: 10^{-13} \sim 10^{-14}$ planned at Paul Scherrer Institut (PSI)
MEG Collaboration

4 countries
10 institutions

ICEPP, University of Tokyo
KEK
Waseda University

Paul Scherrer Institut
ETH-Zurich

INFN & Genova University
INFN & Lecce University
INFN & Pavia University

INFN & Pisa University

Budker Institute

PS meeting, 27–30 Sep./2004, @ Kochi University
Features

- The most intense DC muon beam
- Liquid Xenon photon detector
- Positron spectrometer with gradient magnetic field
- Thin super conducting magnet
- Thin drift chamber and timing counter for positron tracking
- Engineering run will start in 2005
- Physics run will start in early 2006

low energy, good resolution, high intensity

MEG detector

PS meeting, 27-30 Sep./2004, @ Kochi University
MEG drift chamber
Requirements for the Drift Chamber

High rate
- the most intense DC muon beam
- muon stopping rate: ~ $2.5 \times 10^7$ muon/sec

>> COBRA magnet and small chamber

High Resolution
- very excellent sensitivity
- good position resolution (300 μm) is required for both direction (r,z)

>> vernier pad system for z-position measurement
>> low material (multiple scattering suppression)
COBRA spectrometer (COnstant Bending RAdius)

- COBRA spectrometer is designed to measure constant bending radius properties.
- It utilizes a solenoid and gradient B-field for directing the beam.
- The DC region is stable for operation up to 100 MHz muon rate.
- Low energy positrons are quickly swept out.

Graph: Rate vs. Radius
- Stable operation up to 100 MHz muon rate.
Multiple Scattering in the spectrometer

<table>
<thead>
<tr>
<th></th>
<th>Rad.L (cm)</th>
<th>density (g/cm³)</th>
<th>thickness (X0)</th>
<th>MS (micron)</th>
</tr>
</thead>
<tbody>
<tr>
<td>target</td>
<td>28.7</td>
<td>1.39</td>
<td>5.23E-4</td>
<td>~280</td>
</tr>
<tr>
<td>He</td>
<td>528000</td>
<td>0.125e-3</td>
<td>4.47E-5</td>
<td>~100</td>
</tr>
<tr>
<td>Bag</td>
<td>34.3</td>
<td>1.19</td>
<td>2.92E-4</td>
<td>~200</td>
</tr>
<tr>
<td>DC wall</td>
<td>28.6</td>
<td>1.42</td>
<td>4.37E-5</td>
<td>~50</td>
</tr>
<tr>
<td>DC gas</td>
<td>65000</td>
<td>1.52e-3</td>
<td>7.69E-6</td>
<td></td>
</tr>
</tbody>
</table>
MEG drift chamber

**Z-direction measurement**
Vernier pattern is printed on cathode plane. Using the ratio of induced positive charge on each vernier pad, we can get the z-position measurement with high accuracy!!

**open-frame**
(G10/Carbon fiber)

**R-direction measurement**

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Cathode foil
Aluminized Kapton

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staggered 2-layer wires
sense ( Ni/Cr, 25um, 0.5N)
potential ( Be/Cu, 50um, 1.1N)
MEG drift chamber
Resolution & multiple scattering

- **very low material**
  - chamber gas;
  - He/C₂H₆ (50:50), long rad. length ~ 650m
  - cathode foil;
  - very thin polyimide (12.5 μm) + Al (250nm)
  - with vernier pattern

**High Resolution**

- momentum resolution is determined by multiple scattering.
- for the z-direction accuracy, ~300 μm spatial resolution(σ) is enough to achieve the required momentum resolution.
R&D with prototypes

1st prototype (1999-2000)
Fundamental schematic study
Cell config., He based gas, vernier pad, resolution check
Everything seems GOOD

2nd prototype (2000)
Same shape but small test
B-field with beam
No bad, but pre-amp.s are NG...

3rd prototype (2001)
Double cathode test
Beam test with B-field
Good z-resolution

4th prototype (2002)
Charge division test
CR & RI test with some kind of sense wire
Acceptable resolution and vernier pad

5th prototype (2003-2004)
1:1 Al-framed test chamber
Electronics check, operation and resolution check (w/o B-field)

6th prototype (2004)
1:1 final test
Mechanical test, construction study and final check
Results from prototypes

Spatial resolution (R-direction)
100~200 μm (σ)

Spatial resolution (Z-direction)
300~450 μm (σ)
making of the drift chamber (1)
~ frame and construction procedure ~
making of the drift chamber (2)
~ vernier pattern printed thin Kapton foil ~

joint development by
PSI, REPLIC, and
Hirai-seimitsu co,Ltd.
making of the drift chamber (3)
~ construction ~
Conclusion

- MEG experiment will run @ PSI, engineering run will start in next year, and physics run will start in early 2006.

- MEG drift chamber must be satisfied with some requirements, operation in high rate, resolution, low material and so on.

- Drift chamber R&D for the MEG experiment has been carried out and completed more or less.

- Our prototype reached expected performances.

- Final mass-production will start soon !!
Appendix

Additional transparencies
Signal & Background

Signal

- $E_e = E_\gamma = 52.8$ MeV
- Back to back, in time

Single event sensitivity

- $N_\mu = 2.5 \times 10^7/s$, $T \sim 4 \times 10^7$s, $\Omega/4\pi = 0.09$, $\varepsilon_e = 0.9$, $\varepsilon_\gamma = 0.6$
- Sensitivity $\sim 4.5 \times 10^{-14}$

Backgrounds

- Prompt background (Radiative muon decay)
  - background rate : $< 10^{-14}$
- Accidental : (Michel decay + random $\gamma$)
  - background rate : $2 \sim 4 \times 10^{-14}$
  - accidental events : 0.6

Good energy, timing and position resolutions are required for $\gamma$, $e^+$ detector!

Expected detector resolution (FWHM)

<table>
<thead>
<tr>
<th></th>
<th>$\Delta E_\gamma$</th>
<th>$\Delta p_e$</th>
<th>$\Delta \theta_{e\gamma}$</th>
<th>$\Delta t_{e\gamma}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma$ energy</td>
<td>4.5 %</td>
<td>0.8 %</td>
<td>10 mrad</td>
<td>141 psec</td>
</tr>
<tr>
<td>$e^+$ momentum</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>angular</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>timing</td>
<td></td>
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</tbody>
</table>
cathode pads with vernier pattern

- Rough estimation by charge division method (~ 1 cm)
- Using the ratio of induced charge on each 4 strips (~ 300 μm)
- Drop-off in readout channel and electronics

MC results
Liquid Xenon Photon detector

Features
- High light yield (75% of NaI)
- Good resolutions
- Fast signal (4.2nsec decay time)
- Reduce pileups
- Liquid (good uniformity)
- No need segmentation

Design
- Active volume of LXe ~ 800L
- 830 PMTs immersed in LXe