MEG実験2009：陽電子スペクトロメータの改良

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JPS Meeting, 20-23/Mar./2010, Okayama University
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MEG Experiment
MEG Experiment

* Search Experiment for \( \mu \rightarrow e \gamma \)
  * \( \mu \rightarrow e \nu \nu \sim 100\% \) (normal muon decay in SM)
  * \( \mu \rightarrow e \gamma \) violates Lepton Flavour Conservation
  * Even assuming "SM" + "Neutrino-Oscillation", \( B(\mu \rightarrow e \gamma) \) is predicted to be \( < 10^{-50} \)
  * However many models of beyond SM predicts large \( B \sim 10^{-15} \sim 10^{-11} \) (present limit = \( 1.2 \times 10^{-11} \))

* New experiment with a Sensitivity of \( B \sim 10^{-13} \) was proposed at PSI
  * Two orders of magnitude better than current best limit
  * Cover the most of theoretically predicted region
  * Physics data-taking started 2008 and is currently running.
Hunting for $\mu \rightarrow e\gamma$

- Signal and Backgrounds

- Clear 2-body kinematics ($E_e = E_\gamma = 52.8\text{MeV}$, $\theta_{e\gamma} = 180^\circ$, Time Coincidence)

- Sensitivity is Limited by “Accidental Overlap”

- **DC muon is the Best Solution**

- **Good Resolution (Energy, Spacial and Timing) under Very High Rate**
Hunting for $\mu \rightarrow e\gamma$

- Signal and Backgrounds

World Most Intense DC Muon Beam at PSI
10$^8$ muon/sec

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Sensitivity is Limited by “Accidental Overlap”

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- **Signal and Backgrounds**
  - Clear 2-body kinematics ($E_e = E_\gamma = 52.8\text{MeV}$, $\theta_{e\gamma} = 180^\circ$, Time Coincidence)
  - Sensitivity is Limited by “Accidental Overlap”
  - **DC muon is the Best Solution**
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World Most Intense DC Muon Beam at PSI $10^8$ muon/sec

Liquid Xenon Scintillation Detector (gamma)

Accidental BG.
Hunting for $\mu \to e\gamma$

* Signal and Backgrounds

- Clear 2-body kinematics ($E_e = E_\gamma = 52.8\text{MeV}$, $\theta_{e\gamma} = 180^\circ$, Time Coincidence)

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- World Most Intense DC Muon Beam at PSI $10^8\text{ muon/sec}$

- DC muon is the Best Solution

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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
  - $<1\%$ momentum resolution, 500$\mu$m position resolution for both direction (r,z) and 50 ps timing resolution

- **Low-mass material**
  - 52.8 MeV/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)

**COBRA SPECTROMETER**

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MEG Drift Chamber

- muon stopping target
- radial segmented DC modules
- helium filled inside solenoid
- opened-frame structure
- helium based gas
- extremely thin cathode foil
- reduced readout electronics
- e⁺

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Run 2008;
Discharge Crisis
Run 2008 \textit{(inter.alia. spectrometer)}

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- Detector maintenance
- Test & installation
- Commissioning
- Physics Run
- No discharge happened !!!!

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Many DCs were not operational

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

$\varepsilon_{(e^+)}^{2008} \sim 14\%$ ...
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...
Run 2009; Getting Over
What is still Weak for Discharge?

Suspicious Weak Point (1)
“Potting for HV-cable contact”

Suspicious Weak Point (2)
“HV-via on anode PCB”

Suspicious Weak Point (3)
“HV-tracer print circuit”

Suspicious Weak Point (4)
“Land for decoupling-C”
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2009 Result

\[ \mathcal{E}(e^+) \sim 14\% \rightarrow \mathcal{E}(e^+) = ?? \% \]

congratulations !!!
Run 2010;
Next Step
Damaged Cathode Foil

* Several “Damage” of cathode foil were observed during disassembly.

* aging ?

* Special Vernier pattern by “\(t250\text{nm Al with 100 \(\mu\text{m accuracy pattern over 1m length}\)}\)”

* Peeling off, Micro-holes(?), Isolating layer.

* “Source” is still unclear, but this must be solved ASAP.

* Just a quick solution; New Vernier foil with Better Adhesion by adding \(t0.5\text{nm Ni-Cr sub-layer}\).

* 3 modules with new foil are getting ready, and will replace the current module.
Improve Efficiencies

* Spectrometer Efficiency is recovered by fixing discharge.
* However, overall spectrometer efficiency is still lower than 50%.
* This is due to materials “after DC” but “before TC”.
* New Studies to improve the Spectromter Efficiency is just started.
  * Change Cable?
  * Big modification is needed...
Improve Resolutions

- Efficiency is largely recovered, and resolution is improved (See Next Talk)
- But the resolution improvement is not so much...

Next Crucial Issue is Noise

- Precision of the Z-coordinate (along wire) measurement is dominated by S/N → Leading Bad Angular Resolution.
- Noise level is ~1.8mV (cf. signal-pulse height is ~several ten mV)
  - unfortunately, noise situation was worse than 2008...
  - present $\sigma_z = 800\sim900 \mu m... (300\sim400 \mu m is expected)$

- Several Studies are ongoing;
  - better grounding, noise subtraction, increasing HV, wire-configuration modification
Improve Resolutions, contd.

- New Calibration Source will be implemented.
- Using Mott-Scatt. (coherent elastic) on light nuclei.
- “Variable / Monochromatic” e\+ is available.
- Momentum Calibration and Resolution Understanding will be improved.
Conclusions

- MEG is searching for $\mu^+ \rightarrow e^+ \gamma$, and currently running at PSI from 2008.
- In the first physics-run period (2008), severe discharge problem was occurred on DC system, and hence Spectrometer Performances (efficiency and resolution) were much worse than expected.
- Intense Investigations/Modifications/Repair Works/Tests were done.
- After this "counter-discharge campaign", Positron Spectrometer has been fully running !! without discharge, very stable !!
- Efficiency/Resolutions were improved and closing to expectations.
- Next Issues, & Next Steps;
  - Noise is limiting the position measurement (See Next Talk)
  - Low Efficiency due to materials outside DC, Studies are starting
  - Damaged Cathode Foil, New foil R&D is ongoing.
  - New $e^+$ source for Better Calibration and Resolution Studies.