Positron timing and detection in the MEG experiment

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Outline

- Brief review on the $\mu^+ \rightarrow e^+ \gamma$ decay
- The MEG experiment: concept
- Positron detector: *Timing Counter*
- Preliminary results
History of the experimental $\mu^+ \rightarrow e^+ \gamma$ decay research

BR improves as the $\mu$ rate increases
Also Background events increase

1. Physics or prompt background
   Radiative muon decay $\rightarrow$ linear dependence on muon Rate

2. Accidental background
   Coincidence of positrons in normal muon decay and high energy photon $\rightarrow$ quadratic dependence on muon Rate
   
   dominant contribution: $R_{acc} = R^2_\mu \frac{\alpha}{2\pi} \frac{2}{2} dE_\gamma^2 dE_p d\theta(e\gamma)^2 dt(e\gamma)$

The background rejection depends on the detector performance
Efforts devoted to the improvement of the detection resolution
The MEG experiment: concept

Aim: optimize the detection of the back-to-back positron-photon pairs

The positron momentum is measured by a set of drift chambers placed in inhomogeneous magnetic field (COBRA) and its timing is given by a timing counter, whereas the photon energy and timing are measured by a liquid Xe calorimeter. (Performance of the LXe Calorimeter for the mu-> e gamma experiment D. Nicolò S6)
The MEG experiment: concept

Drift chambers  COBRA magnet  LXe calorimeter
Positron detector

Magnetic field + Tracking detector

**COBRA magnet:** the COBRA spectrometer was designed to provide a graded magnetic field whose flux lines have a large divergence also in the center (1.27 T at the center and 0.49 T at both ends). Positrons with the same absolute momentum follow trajectories with a constant projected bending radius, independent on the emission angles over a wide angular range.

**Drift-Chambers:** especially designed with low mass to minimize multiple scattering, high spatial resolution for measuring positron momentum and trajectory:

\[ \sigma_p = 0.9\% \]

Vertex reconstruction 1mm
Timing counter in the COBRA magnet

It is designed to detect positrons emitted by decaying muons.

**first level trigger:**
- Smart timing resolution (~ns for triggering purposes);
- Preliminary direction of emission;
- High efficiency (>90%).

**Allow for precise determination of positron kinematics during event analysis:**
- Impact point for track reconstruction
- Very high timing resolution (100 ps FWHM) for e⁺-γ coincidence

**Dimensions:**
- \( R = 31.9 \text{ cm} \)
- \( \Phi = 157^\circ \)
- \( 27.6 < |z| < 108.0 \text{ cm} \)
Timing counter layout

Two-fold detector:
1. Scintillator bars readout with PMTs for high timing accuracy (Longitudinal Detector).
2. Highly segmented APD + scintillating fibers for longitudinal coordinate measurement (Transverse Detector).
Progress on the timing counter performance

Main parameters to be evaluated:
Longitudinal detector:

1. PMT TTS, gain as a function of magnetic field and orientation angles
2. Scintillation time, attenuation length, PMT-bar coupling

1. Fine-mesh PMTs show good timing properties even in magnetic field up to 1 Tesla
   Gain behaviour is related to the orientation angle - best for $q = 20-30^\circ$
   A high number of photoelectrons is necessary to be in a 100 ps resolution range
**Progress on the timing counter performance**

Main parameters to be evaluated:

**Longitudinal detector:**

1. PMT TTS, gain as a function of magnetic field and orientation angles
2. Scintillation time, attenuation length, PMT-bar coupling

2. Results of BC 404 and BC 408 types vs positions and impact angles in accordance with the MC simulation
Progress on the timing counter performance

Main parameters to be evaluated:

Transversal detector:

New solution with APD and scintillating fibers:

1. High QE of APD
2. Good performances, not influenced by magnetic field
3. Optimum matching APD-fiber
4. Better spatial resolution
5. Low background due to single photons matching (ENC = 1500e)
6. Custom made signals
7. Digital output with hitmap encoding
8. Good mechanical shaping of scintillating fibers

8 Channels analog sum

Signal of 8+8 Interleaved fibers
Progress on the timing counter performance

Transversal detector:

Electronic FE Boards

Water system for APD cooling

Fibers APDs gluing
Preliminary results run 2007
Timing Counter

Time resolution ~ 104 ps FWHM
After jitter correction (run 2007)

Reconstructed impact point vs longitudinal module
Preliminary results and run 2008

- Preliminary result from ’07 Engineering Run
- Just few days of true MUEGAMMA trigger
- Several improvements already implemented
- Obtained:
  - \( N_\nu = 1.89 \times 10^{12} \)
  - \( R_\nu = 3.7 \times 10^7 \) /sec
  - Total live time = \( 5.1 \times 10^4 \) sec
  - \( \Omega / 4 \Pi = 0.1 \)
  - \( \varepsilon_\gamma = 0.28 \)
    - \( \varepsilon_\gamma \) (detection) = 0.6
    - \( \varepsilon_\gamma \) (analysis) = 0.46
  - \( \varepsilon_\theta = 0.18 \)
    - \( \varepsilon_\theta \) (detection) = 0.65
    - \( \varepsilon_\theta \) (track rec.) = 0.65
    - \( \varepsilon_\theta \) (TC-DC match) = 0.5

Ready for full run  July 2008......
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