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Performance of the low-mass Drift Chamber System of the MEG Experiment

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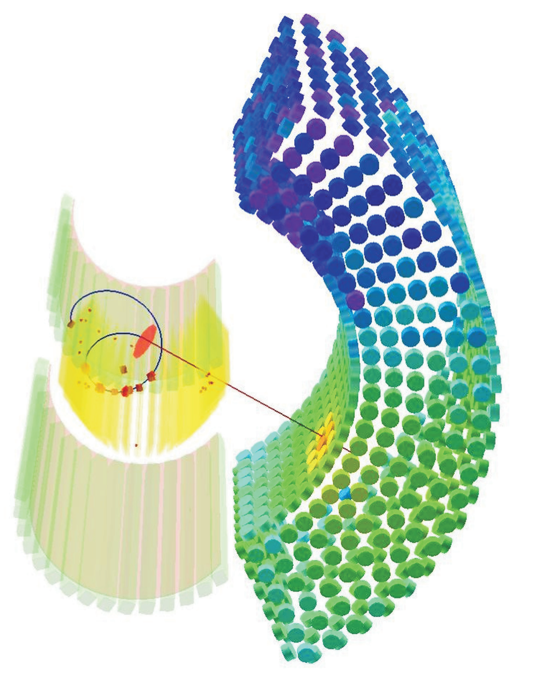
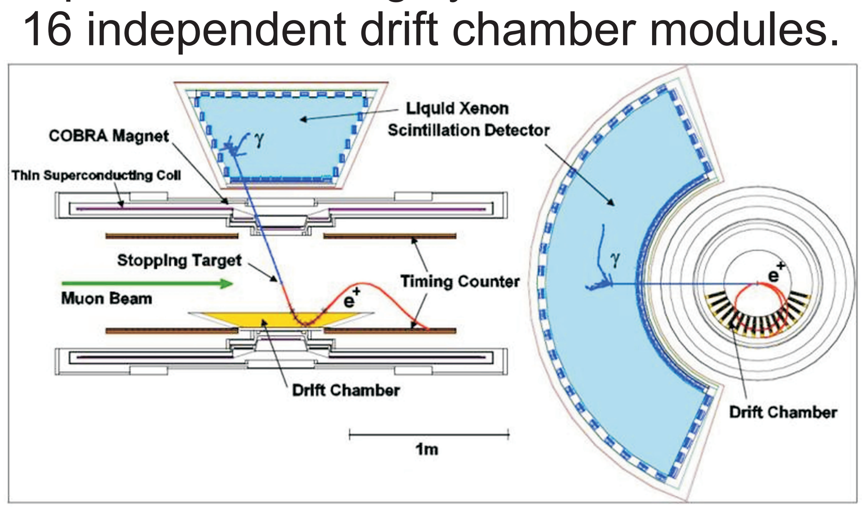
1. Introduction

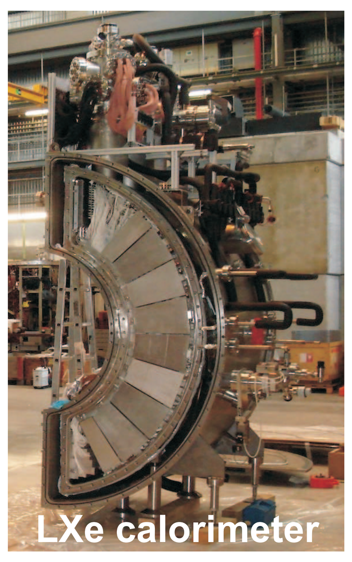
- The goal of the MEG experiment at PSI (Switzerland) is the search for the LFV decay $\mu^+ \rightarrow e^+ + \gamma$ with a sensitivity of 10^{-13} in the branching ratio.
- This decay channel offers the real chance to discover an evidence of new physics beyond the standard model.
- The MEG experiment is a complementary approach to LHC in the search for new physics, approaching the “high precision frontier”, instead of the “high energy frontier”.

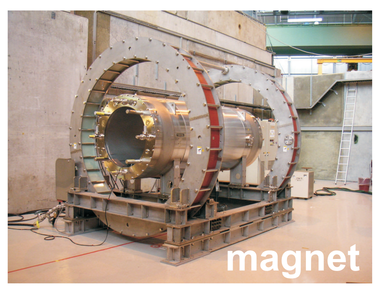
2. Event Signature and MEG Detector

- The $\mu^+ \rightarrow e^+ + \gamma$ decay for a muon at rest, has a clear two-body final state in which the decay positron and the γ-ray are emitted
  - coincident in time,
  - back to back and
  - each with an energy 52.8 MeV, corresponding to half of the muon mass.
- The γ-ray is detected in the world’s largest liquid Xenon scintillation detector.
- The decay positron is detected with a specially designed positron spectrometer containing:
  - a gradient magnetic field,
  - a scintillation timing-counter array for fast timing and triggering and
  - a positron tracking system with 16 independent drift chamber modules.



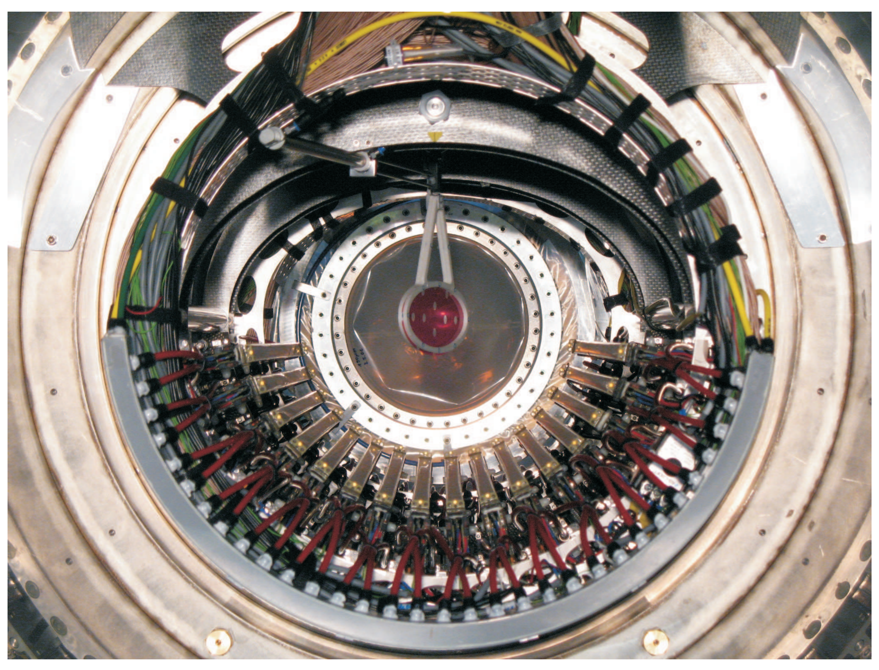


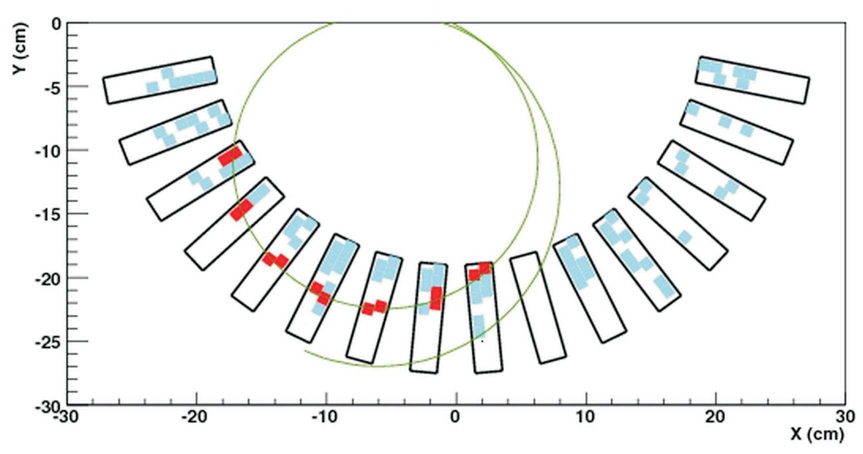




3. Drift Chamber System

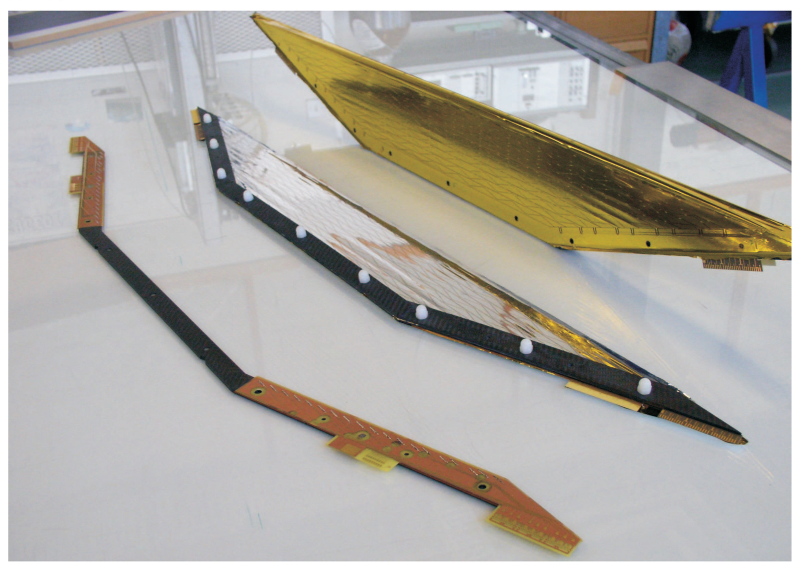
- The drift chamber system is designed to ensure precision measurement of 52.8 MeV/c positrons.
- The system consists of 16 independent drift chamber modules
- The modules are aligned radially in a half circle with 10.5° intervals.
- The complete drift chamber system is placed inside the bore of a magnet.
- The magnet provides a high gradient magnetic field:
  $\rightarrow$ positrons with same absolute momenta follow trajectories with a constant bending radius, independent of the emission angle.
- The geometrical acceptance of the drift chamber system is optimized for selecting high-momentum signal positrons.





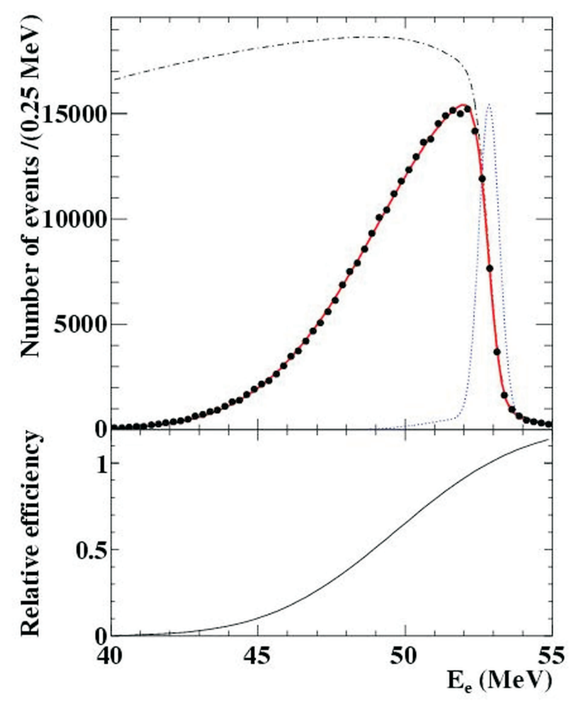
4. Drift Chamber Module

- Each module has an open frame geometry with trapezoid shape.
- The chamber module consists of two detector planes which are staggered in radial direction by half a drift cell to resolve left-right ambiguities.
- The wire frames contain alternating anode and potential wires, stretched in axial direction and mounted with a pitch of 4.5 mm.
  The anode-cathode distance is 3.5 mm.
- The anode wires are resistive wires made of nickel chromium (2.2 kΩ/m).
- All cathodes are made out of 12.5 μm thick polyimide foil with an aluminum deposition of 2500 Å.
- A so-called “double-wedge” or “vernier pattern” structure is etched on the cathode planes.
- The drift chambers are operated with He/C_2H_6 (50/50) and the bore of the magnet is filled with helium.
- The amount of material sums to an average value of only
  - $2.6\cdot10^{-4}$ X_0 per module and
  - $2.0\cdot10^{-3}$ X_0 along the e^+ track.



5. Performance of the Drift Chamber

- chamber detection efficiency: ~95%
- The determination of the hit *z*-coordinate is based on charge division using the charge asymmetry on anode wires and cathode vernier pattern.
  $\rightarrow$ single hit position resolution: σ_z = 800 μm in axial direction
  σ_r = 210 μm in radial direction
- The angular resolutions are measured using events where the positron undergoes two turns in the drift chamber system (”double-turn method”).
  $\rightarrow$ angular resolutions: $\sigma_\theta = (9.4\pm0.5)$ mrad
  $\sigma_\varphi = (8.4\pm1.4)$ mrad
  $\rightarrow$ decay vertex resolutions on the target:
  $\sigma_{z,e^+} = (2.5\pm1.0)$ mm
  $\sigma_{y,e^+} = (1.1\pm0.1)$ mm
- The e^+ energy resolution is determined with a fit of the measured energy distribution (red) to the theoretical Michel spectrum (dashed black) multiplied by an acceptance function (bottom plot) and convoluted with a detector resolution function (dashed blue).
  $\rightarrow$ energy resolution: $\sigma_{E,e+} = (330\pm16)$ keV



6. New MEG result and outlook

- Combining the physics data taken in 2009 and 2010 the MEG experiment achieved a new upper limit on the braching ratio of the $\mu^+ \rightarrow e^+ + \gamma$ decay:
  $$BR\,(\mu^+ \rightarrow e^+ + \gamma) \leq 2.4\cdot10^{-12}\ (90\%\text{C.L.})$$
  This is the most stringent limit on the existence of this decay to date.
- Physics data taken in 2011 will double the statistics of the previous years and data analysis based on a blind analysis technique will be finished soon.
- Physics data taking of MEG (phase 1) will continue until August 2013. An upgrade program with substancial technical improvements has started.

7. References

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