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Status and first Results of the MEG Experiment

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The New, the Rare and the Beautiful

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Goal

- Search for the lepton flavor violating decay

$$\mu^+ \rightarrow e^+\gamma$$

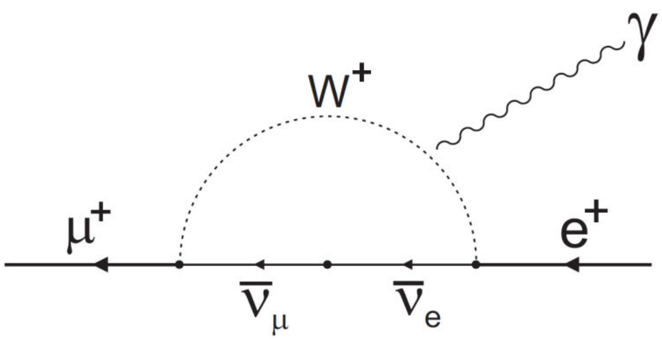
- The goal is to reach a sensitivity of $\mathrm{BR}\left(\mu^+ \rightarrow e^+\gamma\right) \sim 10^{-13}$

- Measured upper limits reached by other experiments:

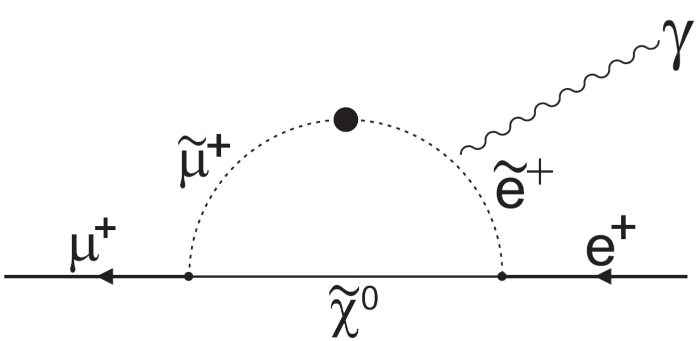
Experiment	Year	Upper Limit
TRIUMF	1977	$< 3.6 \cdot 10^{-9}$
SIN	1980	$< 1.0 \cdot 10^{-9}$
LANL	1982	$< 1.7 \cdot 10^{-10}$
Crystal Box	1988	$< 4.9 \cdot 10^{-11}$
MEGA	1999	$< 1.2 \cdot 10^{-11}$

Theory

- Standard Model (SM) and ν - Oscillation:
  - MEG decay induced by neutrino oscillations with an estimated branching ratio of < 10^{-40} (small neutrino masses)
  - ➢ Not verifiable by experimental methods!



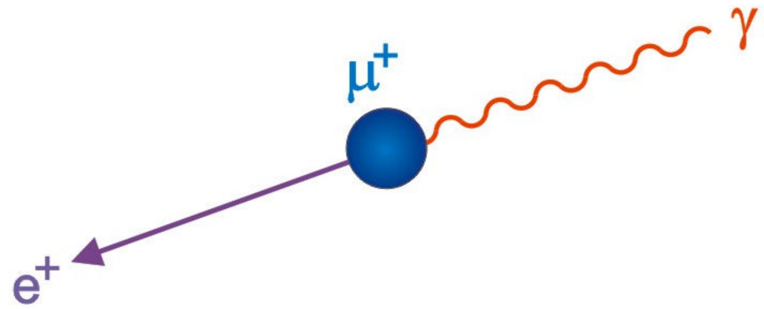
- Supersymmetry:
  - Supersymmetric theories predict branching ratios of ~10^{-14} – 10^{-12}
  - ➢ Just below the current experimental limit (1.2×10^{-11})!



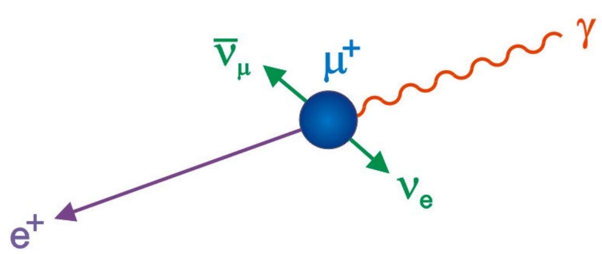
➢ An observation of $\mu^+ \rightarrow e^+\gamma$ will reveal new physics beyond the SM!

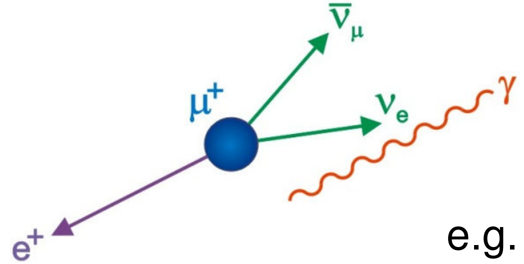
Signature and Background

- Signature of a $\mu^+ \rightarrow e^+\gamma$ event (decay at rest):
  - Emitted back-to-back
  - Each particle carries an energy equal to half of the muon mass (52.8 MeV)
  - Coincident in time



- Background
  - Radiative muon decay: $\mu \rightarrow e\ \gamma\ \nu\ \nu$
  - Accidental coincidence: $\mu \rightarrow e\ \nu\ \nu + \gamma$





e.g. from AIF

➢ Precise measurements of position, energy and timing both for photon and positron are necessary!

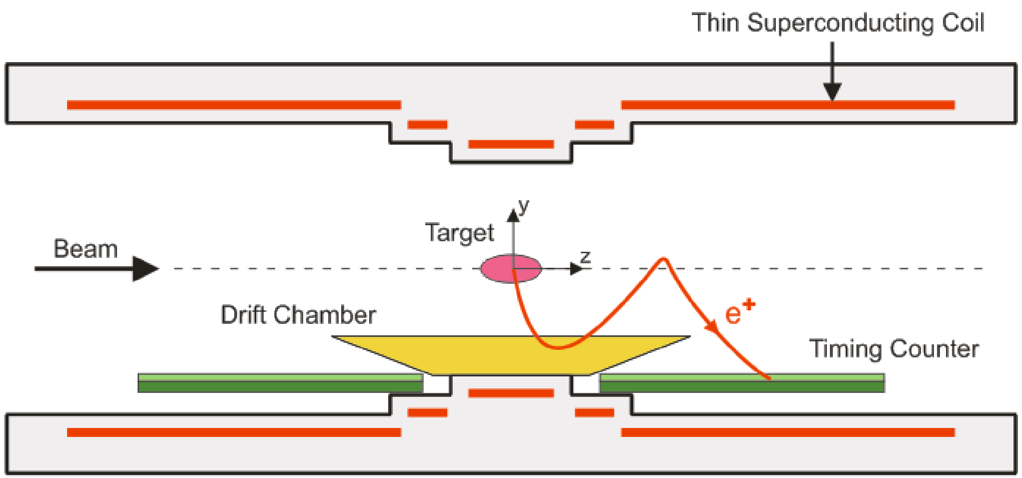
MEG Experiment

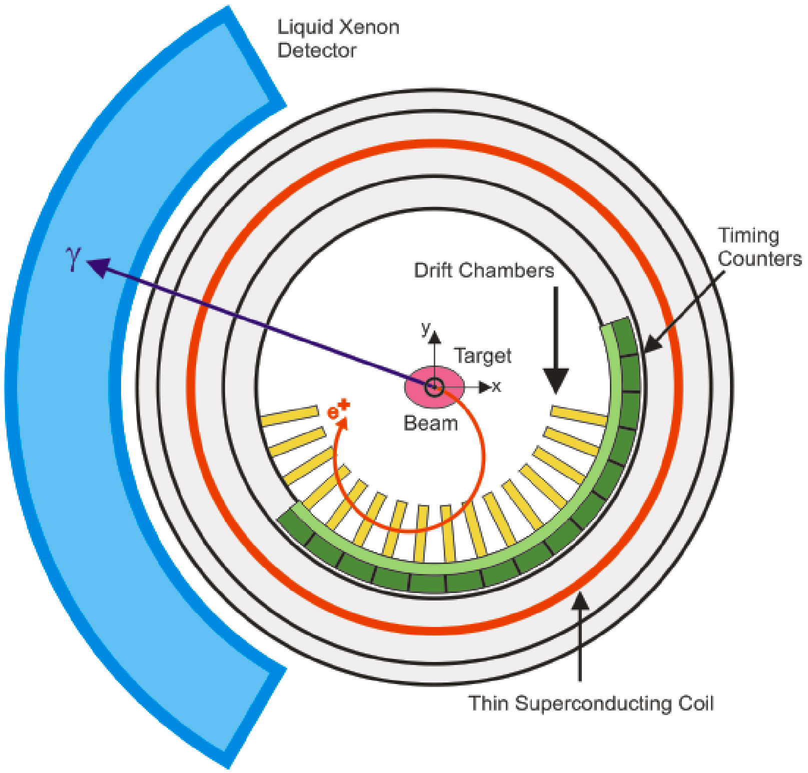
- International collaboration of ~80 physicists

- MEG is located at the Paul Scherrer Institute (PSI):
  - 590 MeV proton ring cyclotron facility
  - 2.2 mA proton current
  - πE5 beam channel: Surface μ^+ of 28 MeV/c
  - Continuous μ^+ beam

MEG Detector

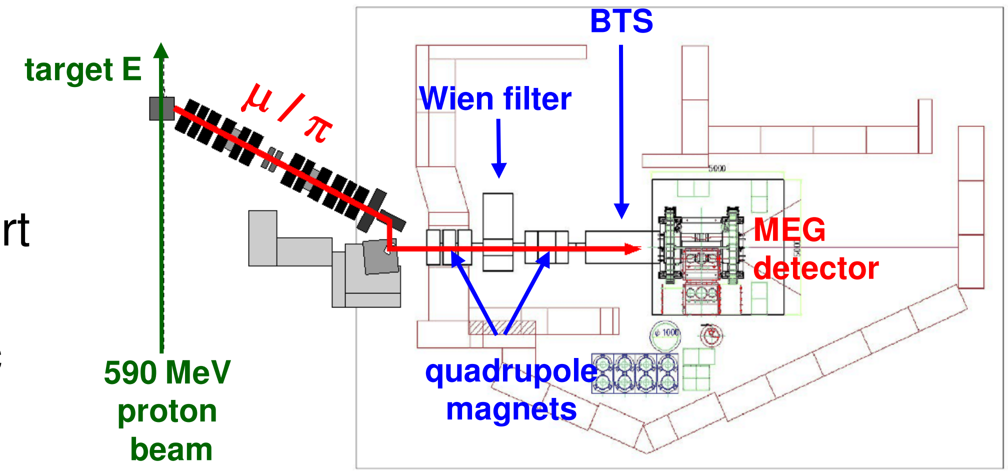
- **Photon:** Liquid xenon scintillation detector (position, timing, energy)
- **Positron:** COBRA positron spectrometer (position, timing, energy)



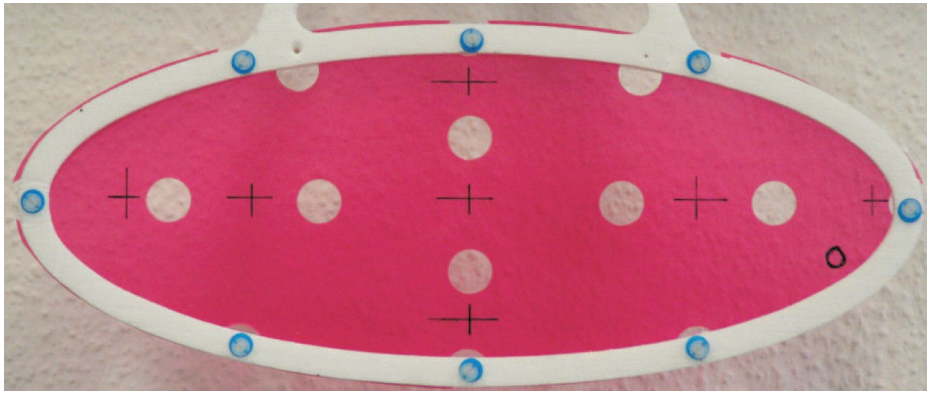


Beam and Target

- Beam
  - πE5 beam channel
  - Wien filter (μ^+/ e^+separation)
  - Superconducting beam transport solenoid (BTS) with degrader
  - Stopping rate of 3 × 10 ^{7} μ^+/sec

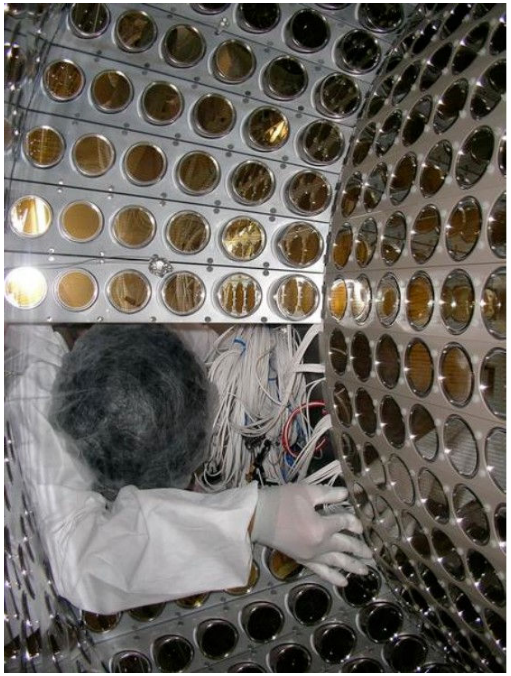


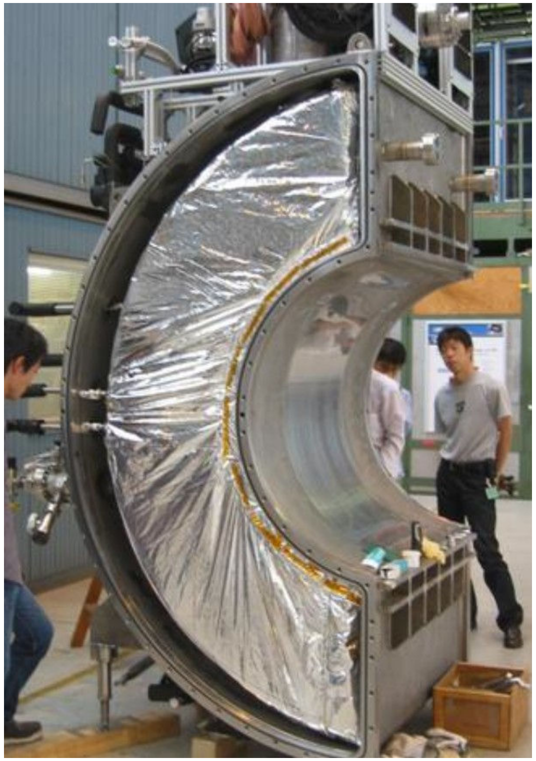
- Target
  - 205 μm thick polyethylene foil clamped between a ROHACELL frame
  - Slanted angle of 20.5°
  - Holes (r=5mm) to check vertex reconstruction



Photon Detector

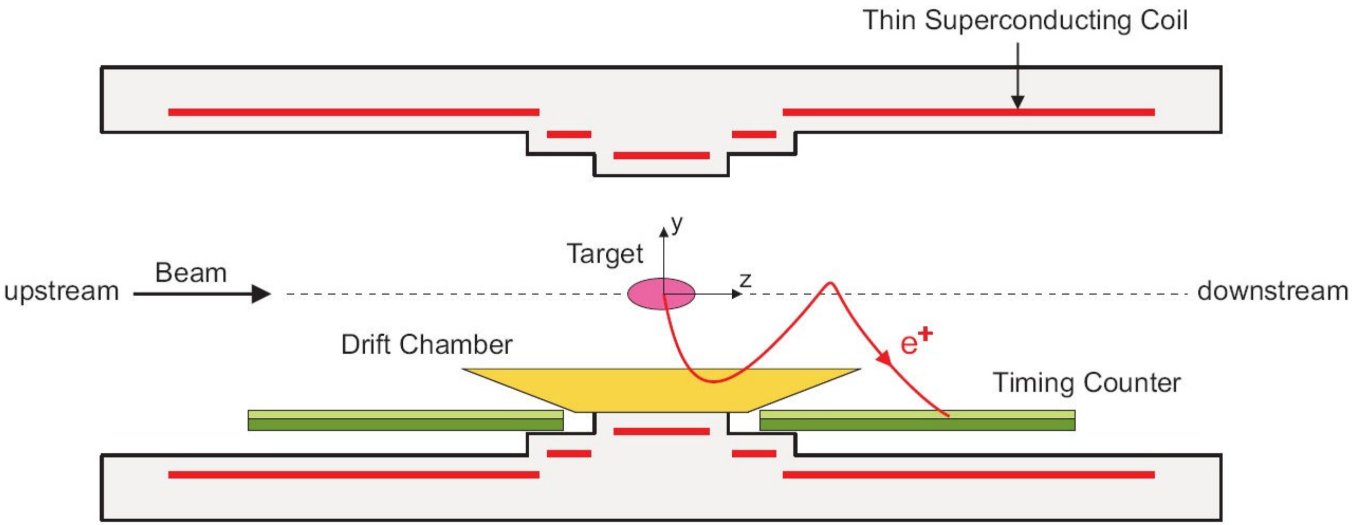
- Photons are detected with the world's largest liquid xenon detector
- Filled with 900 liter of LXe (T=161-165 K)
- Scintillation light is picked up by 846 PMTs surrounding the detector
- High purity at sub-ppm level to avoid scintillation light absorption due to impurities (water, oxygen)





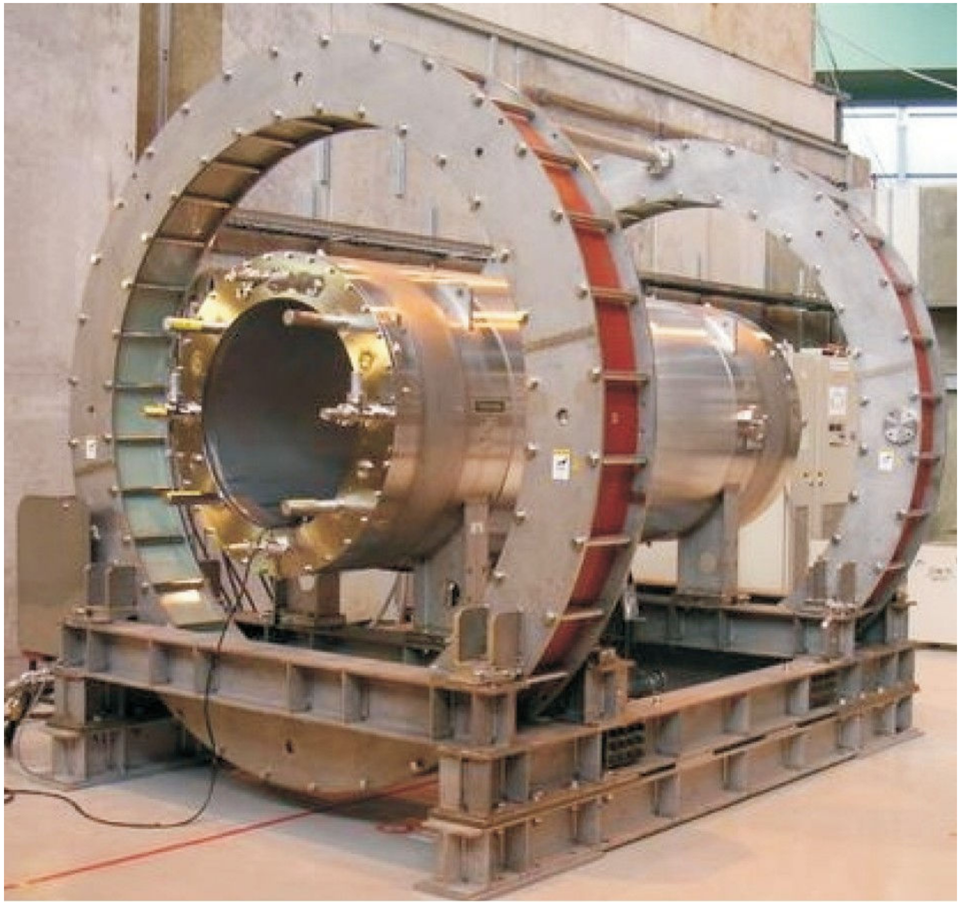
Positron Spectrometer

- The MEG positron spectrometer consists of a specially designed superconducting magnet COBRA, a drift chamber system and timing counters
- The spectrometer provide momentum, track and timing information about the positron



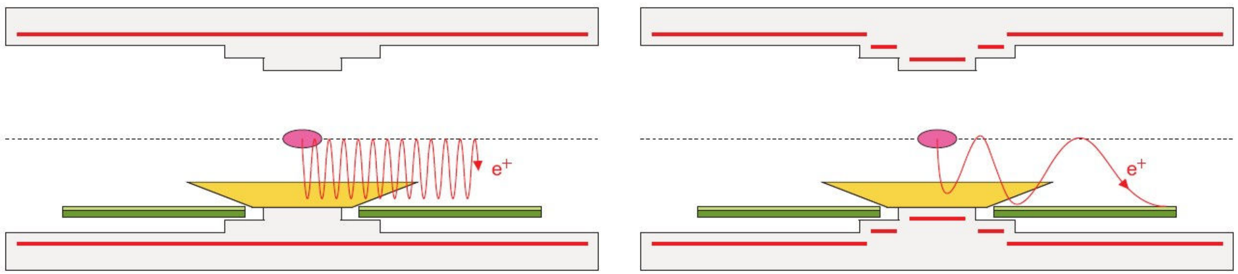
Positron Spectrometer: COBRA

- COBRA is composed of a superconducting main magnet and two normal conducting compensation coils:
  - Main magnet:
    Composed of 5 superconducting coils with different radii
    → gradient magnetic field
    (B = 0.49 – 1.27 Tesla)
  - Compensation Coils:
    Reduce magnetic field around the photon detector



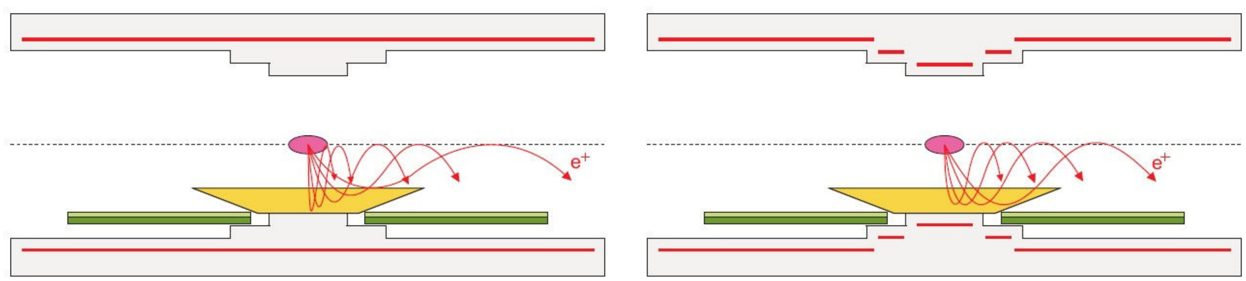
Positron Spectrometer: COBRA Advantages

- Positrons emitted close to 90°



(a) Normal Uniform Solenoid (b) COBRA Magnet

- COnstant Bending RAdius

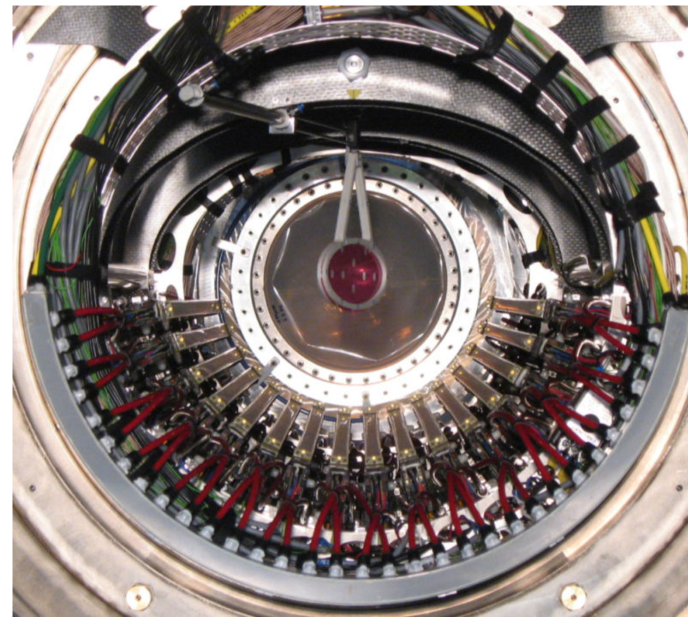


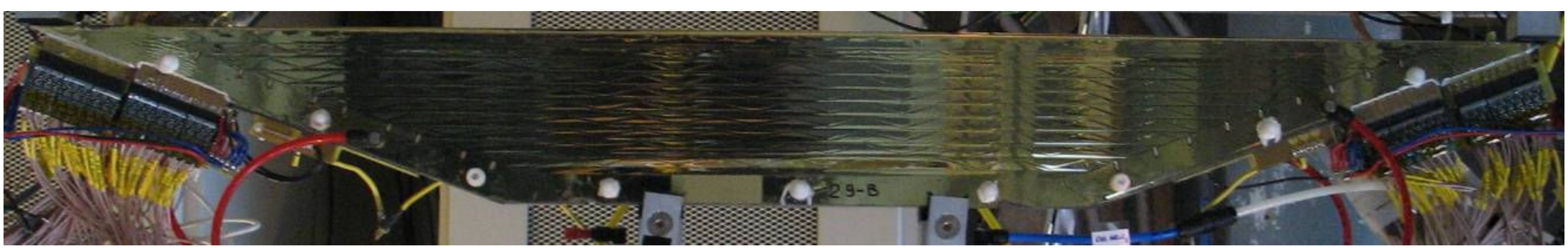
(a) Normal Uniform Solenoid (b) COBRA Magnet

Positron Spectrometer: Drift Chamber System

- MEG drift chamber system:
  - 16 modules aligned radially to the beam axis
  - Each module consists of two wire planes shifted against each other

- Low-material construction:
  - Cathodes consist of 12.5 μm thick Kapton foils with 250 nm aluminium deposition
  - Open frame construction
  - Operated with a He:C_2H_6 (50:50) gas mixture





Positron Spectrometer: Timing Counter

- The MEG timing counter consists of two scintillator timing counter arrays placed at each end of the spectrometer each with a 2-layer construction:

- Phi-Counter:
  - Plastic scintillator bars along beam axis
  - Read out by PMTs at both sides
  - Positron timing measurement

- Z-Counter:
  - Scintillation fibers
  - Read out by APDs
  - Additional trigger information

scintillating fibers with APDs

scintillation bars with PMTs

Data Taking

- Commissioning run 2007:
  - All detector components assembled
  - Calibrations, trigger tuning
  - **Test physics run (1 – 2 days)**

- Run 2008:
  - Shutdown period: Solve problems appeared during 2007
  - May – Aug 2008: Calibrations
  - Sep – Dec 2008: **Physics data taking (~ 3 months)**

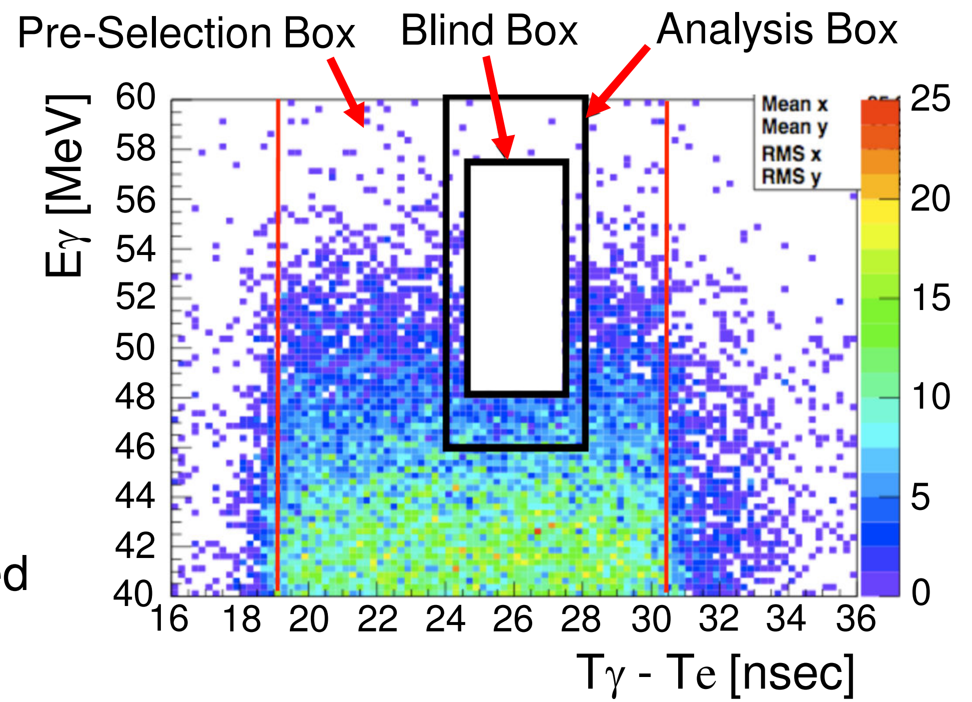
- Remark:
  - PSI accelerator shutdown from Christmas to mid of April → no beam!
  - Another experiment is located in the πE5 area → beam time is split

MEG Detector Resolutions in 2008

- Positron Energy:
  - Resolution function: triple Gaussian (core + 2 tail components)
  - Core: 374 keV (60%)
    Tails: 1.06 MeV (33%) / 2.00 MeV (7%)
- Photon Energy:
  - Asymmetric with low-energy tail
  - $\Delta E/E$ = (5.8 ± 0.35) % FWHM with a right tail of σ_R = (2.0 ± 0.15) %
- Positron – Photon Timing:
  - $\sigma_{te\gamma}$ = (152 ± 16) ps
- Positron – Photon Angles:
  - $\sigma_{\theta e\gamma}$ ~ 21 mrad
  - $\sigma_{\phi e\gamma}$ ~ 14 mrad

Blind Box & Likelihood Analysis

- Pre-Selection Box:
  - Data reduction for analysis
- Blind Box:
  - Written to separate data-stream
  - Not used to study background and optimize analysis
- Analysis Box:
  - Maximum likelihood analysis based on Feldmann – Cousins approach



➤ The preliminary result from the first 3 months startup period of MEG 2008:

$$\mathrm{BR}\left(\mu^+ \to e^+\gamma\right) \leq 3.0 \times 10^{-11} \quad (90\%\ \mathrm{C.L.})$$

Source: arXiv:0908.2594v1 [hep-ex] "A limit for the $\mu \to e\gamma$ decay from the MEG experiment"

Run 2009

- Jan – Aug 2009: Hardware improvements
  - New printed circuit board (PCB) for the drift chambers
    → DC high voltage problem solved
  - Improvement of the LXe purification system
    → higher light yield
  - Installation of DRS4 chip
    → ghost pulse problem solved, no/reduced temp. dep.
- September 2009: Detector assembling
- October 2009: Calibrations
- Nov – Dec 2009: **Physics data taking (~ 2 months)**

➢ Run 2009 stopped at 22 December 2009

Results 2009

- The preliminary result from MEG run 2009:

coming soon...

Summary and Prospects

- The MEG experiment is searching for the LFV decay $\mu^+ \to e^+\gamma$ aiming a sensitivity of ~10 $^{-13}$
- Physics data production started in Sep 2008 (physics runs in 2008/2009)
- Data taken during the first startup period (3 months) of the MEG experiment in 2008 yielded an upper limit on the branching ratio of

$$\mathrm{BR}\left(\mu^+ \to e^+\gamma\right) \leq 3.0 \times 10^{-11} \quad (90\%\ \mathrm{C.L.})$$

- MEG time schedule:
  - Hardware improvements (Jan – April 2010)
  - Assembling of all detector components / calibrations (May 2010)
  - Take physics data (June – Dec 2010, 2011)

➢ MEG is expected to reach a sensitivity of ~10 $^{-13}$ in a few years