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# Research and Development activities at INFN Pisa on a new drift chamber for the MEG experiment upgrade

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## Abstract

We present the research and development activities performed at the Istituto Nazione di Fisica Nucleare (INFN) sezione di Pisa about the new drift chamber for the MEG experiment upgrade.

*Keywords:* Muon physics, Lepton Flavor Violation, drift chamber, chamber aging

## 1. Introduction

The MEG experiment [1] at the Paul Scherrer Institut is searching for evidence of new physics beyond the Standard Model through the Lepton Flavor Violating decay $\mu^+ \rightarrow e^+\gamma$. The experiment recently improved the upper limit on this decay down to BR($\mu^+ \rightarrow e^+\gamma$) $\leq 5.7 \times 10^{-13}$ at 90% confidence level. [2]. Data taking finished at the end of August 2013 thus leading to an expected sensitivity $\approx 4-5\times10^{-13}$. A second phase of the experiment will follow in the next 6 years with an upgraded detector in order to further improve the sensitivity by one order of magnitude [3]. A new tracking device, conceived as a single volume drift chamber to be operated at higher muon rate ($7 \times 10^7$ $\mu/s$), is essential to improve the sensitivity.

The $\mu^+ \rightarrow e^+\gamma$ event signature is the coincidence of mono-energetic 52.8 MeV photon and positron simultaneously emitted at 180°.

In addition to the new tracker the detector will be equipped with a segmented Timing Counter (TC) detector, consisting in scintillator tiles read by silicon photomultipliers (SiPM), to measure the positron timing. The $\gamma$-detector will be an improvement over the LXe detector used during the first phase of the experiment, the most relevant difference being related to the inner face read out: 2" PMTs will be replaced by SiPM to improve detector uniformity (notably for shallow $\gamma$-rays), single photo electron response and imaging capability as well.

A sketch of the MEG experiment and its upgrade is shown in Fig. 1

## 2. The drift chamber for the MEG experiment upgrade

The positron tracker is a unique volume, cylindrical wire drift chamber (DC), with the axis parallel to the muon beam ($z$ axis in MEG coordinates), inspired by the one used in the KLOE experiment [4]. The external chamber radius ($\approx$ 29 cm) is constrained by the available room inside the spectrometer magnet COBRA, while its length is dictated by the necessity of tracking positron trajectories until they hit the TC, to be at least 180 cm.

The DC is composed by 10 criss-crossing sense wire planes with wires extending along the beam with alternating stereo angles to reconstruct the coordinate along the beam axis by combining the information of adjacent layers. The stereo average angle is 8° and the cells have a transversal dimension of 7 mm in order to guarantee a

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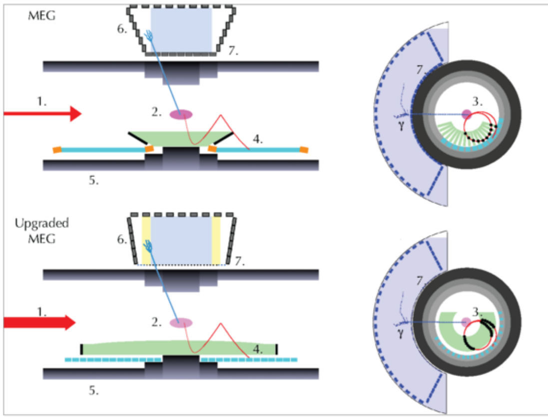


Figure 1: An overview of the MEG upgraded experiment versus the present one. The MEG upgrade will rely on a higher intensity beam rate (1.) stopped in a thinner target to reduce the multiple scattering (MS) (2.), a new unique volume drift chamber with higher granularity and transparency (3. and 4.) to the the new pixelated timing counter (TC) (5.); the LXe detector will have a larger acceptance and the inner face PMTs will be replaced with SiPM (6.,7.).

tolerable occupancy of the innermost wires. These are placed at roughly 18 cm from the beam axis where the rate is $\approx$ 30 KHz/cm$^2$ for a stopping rate of $7 \times 10^7$ $\mu$/s. With a maximum drift time of $\approx$ 150 ns this corresponds to a 15% occupancy of the innermost wires.

To minimize multiple scattering the DC runs with a low $Z$ gas mixture: a (85:15) He/Isobutane ($He : iC_4H_{10}$) is presently foreseen; the corresponding total number of radiation lengths for the new chamber is smaller by $\approx$ 10% than the current MEG drift chamber.

The number of anodic wires is $\approx$ 1300 while the cathode wires are $\approx$ 7000.

A design of the final drift chamber is presented in Fig. 2 and the required performances ($\sigma$) are listed in Table 1.

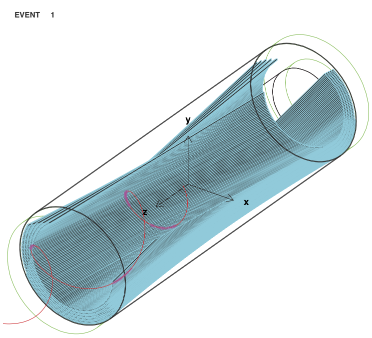


Figure 2: Sketch of the current design of the new cylindrical drift chamber, the hits of a signal positron emitted from the target in the detector are shown in magenta.

| | |
|---|---|
| Momentum resolution | 130 keV |
| Angular resolutions ($\theta$ and $\phi$) | 5 mrad |
| Transparency to TC | $\geq$ 85% |

Table 1: New DC minimum requirements for the MEG experiment upgrade.

## 3. Hit resolution

The use of low $Z$ gas mixture such as He/Isobutane (85:15) is essential for minimizing the effects of multiple scattering on the positron trajectory. The average number of ionization clusters produced by the passage of a 52.8 MeV positron in this gas mixture is about 12.5 per cm, leaving a bias in the measurement of the distance of closest approach of a particle from the anode wire (impact parameter). This can be eliminated by using a cluster timing technique [5] on the DC digitized waveforms at 2 GHz with a bandwidth of about 1 GHz which will be guaranteed by the new electronics.

A cosmic ray tracker made of four modules from the silicon vertex tracker of the BaBar experiment [6] is used to determine the track impact parameter of the cosmic ray track on DC prototype cells with a resolution of 20 $\mu$m.

A special prototype, consisting of three, 7×7 mm$^2$, cells vertically aligned, the central one being slightly displaced (500 $\mu$m) on one side, is used for hit resolution measurements. In this configuration, for vertical cosmic rays, it is possible to show that a combination of the drift distances in the three cells

$$\Delta = \pm \left[ \frac{(d_1 + d_3)}{2} - d_2 \right] \tag{1}$$

gives the displacement of the central cell up to a sign ambiguity. By plotting the quantity in Eq (1) for all events one obtains a doubly-peaked distribution, and the width of the two peaks is related to the single hit resolution by the formula

$$\sigma_\Delta = \sqrt{3/2}\sigma_{\text{singlehit}}. \tag{2}$$

A preliminary result in terms of time difference between the three cells is shown in Fig. 3, where the correlation between drift time and space is not applied yet.

## 4. Aging measurement

During the entire acquisition time of the MEG upgraded experiment the total charge collected by the innermost cell was evaluated to be $\approx$ 0.4 C/cm for a gain