The MEG experiment at PSI: status and prospects

Giovanni Signorelli

on behalf of the MEG collaboration

INFN Sezione di Pisa, Largo B. Pontecorvo 3, 56127 Pisa (Italy)

Abstract. The present status of the MEG experiment at PSI is reviewed. This experiment aims at measuring the branching ratio of the lepton flavor violating process $\mu^+ \to e^+\gamma$ with a sensitivity two orders of magnitude below the present experimental limit, set to 1.2×10^{-11} by the MEGA experiment. The positron momentum will be measured by a set of drift chambers inside a non-homogeneous magnetic field while the photon four-momentum will be measured by an innovative homogeneous liquid xenon scintillation calorimeter. The experiment is now in an advanced construction stage and it is scheduled to start engineering runs during the year 2006.

Keywords: Lepton Flavor Violation, MEG experiment, Liquid Xenon

INTRODUCTION

The Standard Model of the Electro-Weak and Strong Interactions (SM) is presently the theory which successfully explains the particle physics phenomenology. It is nonetheless believed to be a low energy approximation of a more fundamental theory whose effects must be searched for in the possible observation of rare events, forbidden by SM symmetries. In this framework the $\mu \to e\gamma$ decay search provides a sensitive tool to test both the SM and some of its proposed extensions. The present limit on this decay branching ratio (BR) is set to BR($\mu \to e\gamma$)$< 1.2 \times 10^{-11}$ by the MEGA experiment [1]. Super-symmetric theories of Grand-Unification generally predict a BR in the range $10^{-12} \div 10^{-14}$ [2]. It is for this reason that a new experiment, called MEG from the abbreviation of MuEGamma, has been designed in order to reach such a sensitivity [3], by an Italian-Japanese-Russian-Swiss collaboration.

THE MEG DETECTOR

The signature of a $\mu \to e\gamma$ event is given by a coincidence of a 52.8 MeV photon with a 52.8 MeV positron in space, time and direction. The MEG experiment [3] will be conducted at the Paul Scherrer Institut (PSI), using the πE5 beam line. A schematic view of the detector is shown in Fig. 1. The positive muon beam, with intensity up to 10^8 μ/s in a ~ 0.5 cm radius spot, is brought to stop in a thin target after passing a stage in which most of the contaminating positrons are eliminated. The momentum and the emission direction of the e^+ are measured precisely by a magnetic spectrometer, composed of a quasi-solenoidal magnetic field and a set of ultra-thin drift chambers. The field is shaped so that monochromatic e^+s from the target follow

CP842, *Particles and Nuclei,*
Seventeenth International Conference on Particles and Nuclei
edited by P. D. Barnes, M. D. Cooper, R. A. Eisenstein, H. van Hecke, and G. J. Stephenson

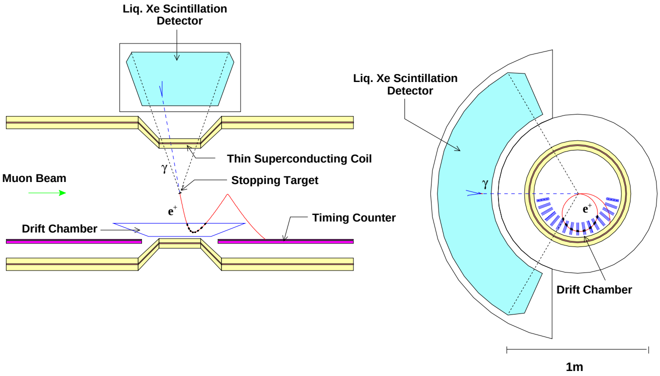

FIGURE 1. Schematic drawing of the MEG detector

trajectories with constant projected bending radius, independent of the emission angle over a wide angular range. Furthermore the sweeping capability of the non uniform magnetic field reduces the persistence of low longitudinal momentum e^+s in the tracking volume. Both features greatly reduce the accidental pile-up of the Michel positrons, decrease the pattern recognition complexity and enhance the system efficiency. The expected FWHM resolutions range between 0.7% and 0.9% for the positron momentum and from 9 to 12 mrad for the angle. An array of plastic scintillators is placed on each side of the spectrometer to measure the e^+ emission time with resolutions 0.1 ns FWHM. While all e^+ are confined inside the magnet, the γ-rays penetrate through the thin superconducting coil of the spectrometer ($\simeq$ 80% transmission probability) and are detected by a liquid Xenon scintillation detector. It consists of a single volume of liquid Xenon viewed from all sides by about 800 photomultipliers (PMTs). The liquid Xenon light yield is comparable to that of NaI ($\sim$ 37500 photo-electrons/MeV) and emission time of the scintillation light is short ($\simeq$ 40 ns) so that all the kinematical variables of the impinging photons can be reconstructed from the PMT signals only. Tests on a large scale prototype as well as a full simulation show that one can expect FWHM resolutions of $<$ 5% for the energy, 10.5 mm for the position and 0.1 ns for the timing measurements for 52.8 MeV γ-rays.

BACKGROUND ESTIMATES AND SENSITIVITY

There are two major backgrounds to the $\mu \to e\gamma$ search: the physics background from radiative muon decays, $\mu \to e\nu\overline{\nu}\gamma$, and the accidental background, given by the accidental selection of a Michel positron and a photon from a different process. The background crucially depends on the detector performances. The physical background (B_{phys}) calculated by numerical integration, was found to contribute 3.1×10^{-15} events per muon decay. The accidental background poses more threat than the physical one. The positron rate can be computed from the Michel positron spectrum and the response function of the tracking system. The single photon yield per muon decay was evaluated by taking into account: radiative muon decays, annihilation-in-flight of positron in the target, positron interactions with surrounding materials and neutron induced background. The accidental background B_{acc} scales with the detector resolutions as follows:

$$B_{\mathrm{acc}} \propto R_{\mu} \cdot \Delta E_{e} \cdot \Delta t_{e\gamma} \cdot (\Delta E_{\gamma})^{2} \cdot (\Delta \theta_{e\gamma})^{2}, \tag{1}$$

and it was found to contribute with $\approx 3 \times 10^{-14}$ events per muon decay, for the running muon stop rate of $R_{\mu} = 0.3 \times 10^{8}$ μ /s. With this R_{μ} stop rate, the expected detector resolutions and a total running time of 2.6×10^{7}s, the single event sensitivity (SES) of MEG results 3.8×10^{-14}. The sensitivity can be converted into 90% confidence level upper limit of 1.2×10^{-13}, in case of no signal observed, by using these background rate estimates.

PRESENT STATUS AND PERSPECTIVES

The existing πE5 beam line has been coupled to the spectrometer magnet, maintaining an intensity up to 10^{8} μ^{+}/s. An electrostatic separator has been integrated in the beam line and the positron contamination of 10^{9} e^{+}/s has been suppressed by more than 6 orders of magnitude. The preliminary field mapping of the magnet confirmed the design field structure. A tracking chamber prototype, with the 15 μm thin cathode foils, has been built and tested. The measured hit position resolution were near the design goals and resulted in $\sigma_{R} \approx 90$ μm and $\sigma_{Z} \approx 400$ μm. A full scale prototype of one module of the timing counter system has been produced and tested in magnetic field environment with electrons. The measured timing resolution was < 100 ps FWHM.The most critical and innovative device is the liquid Xenon calorimeter whose energy resolution is required to be $\approx$ 4% FWHM at 52.8 MeV. The major uncertainty on the calorimeter is the liquid Xenon transparency to scintillation light. A large calorimeter prototype was produced and operated. It has $40 \times 40 \times 50$ cm^{3} Xenon active volume read by 228 PMTs; it is equipped with ^{241}Am α-sources and blue LEDs for calibration. A Xenon absorption length > 100 cm was measured with α-sources. The prototype performances were measured by means of γ's coming from π^{0} decay, produced in the charged exchange reaction of π^{-} on protons. The achieved energy resolution is 4.8% FWHM at 55 MeV, not far from the design goal. The final detector, presently under construction, will use PMTs of improved quantum efficiency, therefore we are confident that the design resolution will be obtained. The detector is presently in the construction phase and the data taking is foreseen starting in 2006.

REFERENCES

1. M. Ahmed *et al.*, [MEGA collaboration] *Phys. Rev.* **D65** (2002) 112002
2. R. Barbieri *et al.*, *Nucl. Phys.* **B445** (1995) 215.
   J. Hisano *et al.*, *Phys. Rev.* **B391** (1997) 341.
   R. Ciafaloni *et al.*, *Nucl. Phys.* **B458** (1996)
3. A. Baldini, T. Mori *et al.*, “The MEG experiment: search for the $\mu \to e\gamma$ decay at PSI”, available at `http://meg.psi.ch/docs`