IL NUOVO CIMENTO Vol. 37 C, N. 3 Maggio-Giugno 2014
DOI 10.1393/ncc/i2014-11776-4

Colloquia: Pontecorvo100

# The MEG experiment upgrade

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**Summary.** — The MEG experiment at the Paul Scherrer Institut (PSI) searches for the Lepton-Flavour Violating (LFV) decay $\mu \rightarrow e\gamma$ . The analysis of the data collected in the years 2009-2011 set the most stringent upper limit to date on charged LFV $\mathcal{B}$ ($\mu^+ \rightarrow e^+\gamma$ ) $< 5.7 \times 10^{-13}$ at 90% confidence level. The MEG collaboration is working on a detector upgrade, whose new design and associated research and development projects will be illustrated here.

## 1. – Introduction

The $\mu \rightarrow e\gamma$ decay is forbidden in the Standard Model (SM) of particle physics since it violates the conservation of the lepton flavour. Even with the introduction of the 3 generation neutrino masses and mixing, the SM would predict an immeasurably small branching ratio for this decay ($\mathcal{B} < 10^{-50}$). Several beyond the SM scenarios [1] with new heavy particles entering into virtual loops, predict $\mathcal{B}$ in the range $10^{-12} - 10^{-14}$, close to the current experimental sensitivities. Observation of such process would hence be an unambiguous sign of New Physics (NP) beyond the SM, while improvements on the current limit would strictly constraint many NP scenarios.

The experimental signature of a $\mu^+ \rightarrow e^+\gamma$ decay is a two-body final state, with photon and positron emitted coincident in time and back to back in the muon rest frame, each with an energy equal to half the muon mass. The two major backgrounds to this process are the radiative muon decay (RDM) $\mu^+ \rightarrow e^+\nu_e\bar{\nu}_\mu\gamma$ and the accidental coincidence between a high energy positron from the Michel muon decay $\mu^+ \rightarrow e^+\nu_e\bar{\nu}_\mu$ and a high energy photon from either RMD events, positrons annihilating in flight or bremsstrahlung.

## 2. – The current MEG experiment

A very high rate continuous beam ($\sim 3 \times 10^7$ $\mu$/s) of surface muons at 28 MeV/c momentum from one of the world's most intense sources (the $\pi$E5 line at PSI) is stopped in a 205 $\mu m$ polyethylene target surrounded by the MEG detector [2]. The MEG detector is schematically composed of a quasi-solenoid spectrometer with low-mass drift chambers (DC) for the measurement of $e^+$ kinematic, scintillators bars and fibers (TC) for the measurement of $e^+$ time and a liquid Xenon calorimeter (XEC) for the photon detection. We adopt a blind analysis technique and we determine simultaneously the number of RDM, accidentals and signal events by an extended maximum likelihood fit to five kinematic distributions: positron and photon energies, relative time between the photon and the positron and opening angle between the two. A frequentist approach with a profile likelihood-ratio ordering is used to compute the confidence intervals on $N_{\text{sig}}$. The result based on data collected in 2009-2011, for a total of $3.6 \times 10^{14}$ muons stopped on target, provides a 90% C.L. upper limit on the $\mu^+ \to e^+\gamma$ branching ratio of $\mathcal{B}\ (\mu^+ \to e^+\gamma\ ) < 5.7 \times 10^{-13}$ [3]. The data collected in 2012-2013 doubled the number of muons stopped on target with respect to this result and the final expected sensitivity is $4 \div 5 \times 10^{-13}$.

## 3. – The MEG upgrade

The MEG upgrade project [4] relies on exploiting as much as possible the already existing apparatus and a well established collaboration team for low cost and early realization time (3 years of R&D plus 3 years of data taking). The increase of beam intensity and improvement in efficiency and resolution will allow to reach the sensitivity goal of $\sim 5 \times 10^{-14}$. The upgrade key elements are:

1. the beam intensity will be increased of a factor 2-3.
2. the target thickness will be reduced to 140 $\mu m$ in order to minimize positrons multiple scattering and reduce $\gamma$s from annihilation in flight and bremsstrahlung.
3. in order to improve tracker stability and resolutions, the DC system will be replaced by a single volume stereo-wire drift chamber, with high rate tolerability, high granularity ($\sim$ 1300 cells), 130 $\mu m$ single hit resolution and cluster counting capability. This will allow to improve all the resolutions on positron kinematic variables by a factor 2. Several small and full length prototypes have already been build in order to test ageing (up to nearly twice the expected charge collected in 3 years of running with no problems), single hit resolution ($\sim 120\mu m$ resolution confirmed), electronics, mounting procedure and charge division (all on going).
4. the new tracker and TC geometry will double the matching efficiency between the two detectors and, allowing tracking to the TC entrance, highly reduce the uncertainty on track length and thus positron-photon time difference resolution.
5. TC bars and fibers will be replaced by an array of many ultra-fast plastic scintillators counters with SiPM readout, increasing granularity and time resolution, which is expected to reach 30-35 ps (now is 65 ps). Single counters and small prototypes have been developed, confirming the expected time resolution of 34 ps on PSI beam test. Additional beam tests on more complex prototypes are on going.
6. XEC acceptance will be extended modifying the lateral PMTs orientation, improving also light collection uniformity.
7. XEC energy, position and time resolution for shallow events will be highly improved by replacing the 46 mm diameter round-shaped PMTs of the entrance face with 12x12 mm square Multi Pixel Photon Counters (MPPC), which will also greatly help the pile-up rejection capability thanks to the much better position resolution.

Development and test of large area UV-enhanced MPPCs in collaboration with Hamamatsu Electronic is on going. It has already produced the world largest UV-sensitive SiPM with 1 p.e. counting capability and a photon detection efficiency larger than 15%.

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