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The MEG experiment result and the MEG II status

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Summary. — The MEG experiment at the Paul Scherrer Institut is searching for the lepton-flavour violating decay $\mu^+ \rightarrow e^+\gamma$ with unprecedented sensitivity. MEG set the most stringent experimental bound to date, based on the analysis of 2009, 2010 and 2011 data, to be $\leq 5.7 \times 10^{-13}$ with an associated sensitivity of about 7.7×10^{-13}. Here we present the MEG final result which has an associated sensitivity of about 5.3×10^{-13}. An experiment upgrade is conceived in order to further improve the sensitivity by one order of magnitude in three years of data taking. The MEG II experiment is currently under construction.

1. – Introduction

An indication of the existence of the $\mu^+ \rightarrow e^+\gamma$ decay would be a clear evidence of physics beyond the Standard Model (SM). In fact the SM prediction, taking into account the neutrino oscillation and masses square differences [1], for the decay probability is about 10^{-50}, which is not experimentally accessible.

However, many theories beyond SM, as for example grand unification supersymmetric theories, naturally accommodate finite neutrino masses and predict relatively large (and probably measurable) branching ratios (BR) for cLFV processes (see for example [2-7]).

2. – Signal and background

Positive muons coming from decays of π^+ produced by proton interactions on a fixed target, are brought to stop and decay at rest, emitting simultaneously a γ and a e^+ in opposite directions. Neglecting the e^+ mass, both particles carry away the same kinetic energy: $E_{e}^{+} = E_\gamma = m_\mu/2 = 52.83$ MeV. The signature is very simple, but, because of the finite experimental resolutions, it can be mimicked by two types of background: the physical background from the radiative muon decay and the accidental one due to random coincidences of photons and positrons in the detector. The accidental background is the dominant one.

(*) On behalf of the MEG Collaboration.

3. – Detector and calibration systems

A 3×10^7 μ^+/s beam is stopped in a 205 μm slanted polyethylene target. The e^+ momentum is measured by a magnetic spectrometer, composed by an almost solenoidal magnet (COBRA) with an axial gradient field and by a system of sixteen ultra-thin drift chambers (DC). The e^+ timing is measured by two arrays of plastic scintillators (Timing Counter, TC): it is equipped with two sections of 15 scintillating bars each. The γ energy, direction and timing are measured in a ≈ 800 l volume liquid xenon (LXe) scintillation detector by means of 846 PMTs. Please refer to [8] for a detailed detector description.

4. – Data analysis and result

The data are analysed with a combination of blind and likelihood strategy. Events are pre-selected on the basis of loose cuts, requiring the presence of a track and the relative time $|\Delta T_{e\gamma}| < 4$ ns between the two daughter particles. When the optimisation procedure is completed, the event sample in the signal region is opened and a maximum likelihood fit is performed on the distributions of five kinematical variables (positron and gamma energies, relative time and angles: E_e^+, E_γ, $\Delta T_{e\gamma}$, $\theta_{e\gamma}$ and $\phi_{e\gamma}$). The branching ratio sensitivity at 90% C.L. is found to be 5.3×10^{-13} consistent with the upper limits obtained in several comparable analysis regions of the $T_{e\gamma}$ sidebands.

The analysis of the combined data sample gives a 90% C.L. upper limit of 4.2×10^{-13} [9], which constitutes the most stringent limit on the existence of the $\mu^+ \to e^+\gamma$ decay, superseding the previous limit by a factor of 30, the profile likelihood is shown in fig. 1(a).

5. – MEG II status

The MEG Collaboration has proposed a significant detector upgrade [10], which has been approved by the scientific committee of PSI and the national funding agencies. As

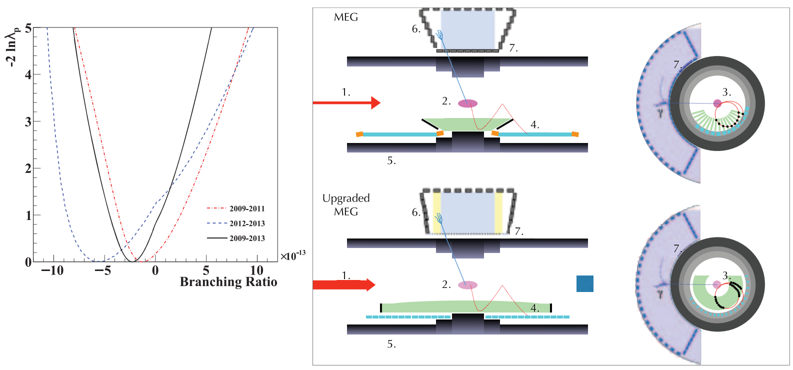

Fig. 1. – (a) Profile likelihood ratios as a function of the $\mu^+ \to e^+\gamma$ branching ratio for 2009, 2010, 2011 and the combined 2009–2011 data sample; (b) an overview of the MEG upgraded experiment *vs.* the present one. The MEG upgrade will rely on a higher intensity beam rate (1) stopped in a thinner target to reduce the multiple scattering (2), a new unique volume drift chamber with higher granularity and transparency (3 and 4) to the new pixelated TC (5); the LXe detector will have a larger acceptance and the inner face PMTs will be replaced with SiPM (6, 7); the RDC counter (blue box) is placed downstream along the beam axis.

Table I. – *Comparison between MEG design and the obtained resolution with the upgrade expected ones.*

Variable	Foreseen	Obtained	Upgrade Scenario
ΔE_γ (%)	1.2	1.7	1.0
Δt_γ (ps)	43	67	≤ 67
γ position (mm)	4-6	4-6	~ 2
γ efficiency (%)	> 40	63	70
ΔP_e (keV)	200	306	≤ 130
e^+ angle (mrad)	$5(\varphi), 5(\theta)$	$8.7(\varphi), 9.4(\theta)$	$\leq 4(\varphi), \leq 5(\theta)$
Δt_{e^+} (ps)	50	107	30
e^+ efficiency (%)	90	40	≥ 85
$\Delta t_{e\gamma}$ (ps)	65	122	80

reported in table I the resolution and efficiencies of the MEG experiment are not at the level of the proposal; the new experiment will solve most of the problems in particular on the positron side. The new detector is shown in fig. 1(b).

The MEGII experiment is currently under construction. A medium size prototype of the new Timing Counter and the RDC detector were tested at PSI with the μ-beam at the MEG II intensity together with the first module of the new TDAQ in 2016 summer. The results, being in agreement with the design values, are very promising for both devices. The detector will be assembled within June 2017 to be ready for a first engineering run next year. The physics data taking will start in 2018 and will last 3 years.

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