The MEG experiment at Lecce

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1. Introduction

The Standard Model (SM) practically forbids Lepton Flavour Violation in the charged lepton sector (cLFV). In fact even introducing massive neutrinos in the model, in order to account for the experimentally measured phenomenon of neutrino oscillations, the SM foresees a branching ratio ($\mathcal{B}$) for $\mu \longrightarrow e\gamma$ below 10^{-50}, which cannot be experimentally observed. cLFV processes are therefore clean channels where to look for possible new physics beyond the SM. Although no experiment has until now observed any discrepancy from its predictions, the SM is widely considered to be a low energy approximation of a more complete satisfactory theory. Several candidates for such a theory, predict cLFV with rates close to the present $\mu \longrightarrow e\gamma$ experimental upper limit.

Predictions of the $\mu \longrightarrow e\gamma$ branching ratio depend on the particular SUSY–GUT model taken into consideration and on the several other parameters of the teory such as the masses of the suersymmetric particles. In the case where these have masses not much higher than 1 TeV, the SUSY model predict a $\mathcal{B}$ for $\mu \longrightarrow e\gamma$ larger than 10^{-13}.

The MEG experiment (Figure.1)[1] at the Paul Scherrer Institute of Zurich (Switzerland) has established the present best upper limit ($\mathcal{B} < 2.4 \times 10^{-12}$ at 90 % C.L.) on the $\mu \longrightarrow e\gamma$ decay [2] with an analysis of the data taking in the years 2009 − 2010, for a total number of 1.75×10^{14} positive muons stopped on target.

Further data acquired between 2011 and 2012 a most stringent constrain on the previous best upper limit has been set ($\mathcal{B} < 5.7 \times 10^{-13}$ at 90 % C.L.)[3].

Currently an upgrade program has been proposed to aim a sensitivity improvement of a further order of magnitude [4].

The Lecce's group has been involved either in the development of DAQ system, by implementation of the splitters for the readout electronics board, that in the R&D for new tracking detector that will be used in the experiment upgrade that will start in 2015.

2. Front–end electronics board

An experiment to search for ultra–rare events in a huge bean–related background needs high resolution detection techniques and fast front–end, digitising electronics and trigger.

The Data AcQuisition system (DAQ) records the signals from all detectors of the experiment. It must be able to measure energy with an accuracy better than a few per mil, even for small signals and the timing accuracy of the electronics must to be better than 40 ps, in order to distinguish events separated in time down to 10 ns.

In order to accomplish these goals, has been developed a system based on Field–Programmable Gate Arrays (FPGA) to process the detector signals and reconstruct the obsevables needed for the event selection [5]. The advantage of choosing an FPGA–based digital approach is manifold,

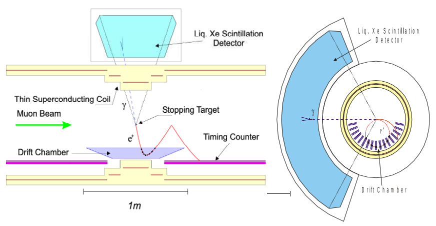

Figure 1. An overview of MEG experiment at PSI of Zurich.

in particular the versatility of the trigger scheme allows to implement different selection criteria.

Since the signals collected from the calorimeter (LXe) and the timing counter (TC), are used either for the trigger system that for the event reconstruction, a system of active splitters have been developed. Each splitter board receives 16 signals through coaxial cables and makes two copies for the DRS and trigger. The gain for each channel is one and the bandwidth is about 1 GHz for the DRS output and 100 MHz for the trigger system.

Furthermore, to improve the noise immunity due to the high number of readout channels (846), differential signals on the splitter boards are used. Afterwards the output signals are sent to digitization system characterized with a sampling speed above one Giga–Samples Per Second (GSPS). This allows into event–by–event baseline measurement to eliminate any common low frequency noise.

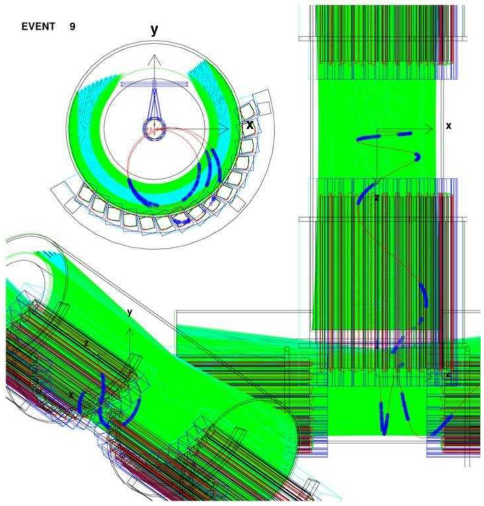

Figure 2. Simulation of a 52.8 MeV/c positron track in the new drift chamber.

3. The new tracker

The new program foresees to build a new tracking chamber, designed to improve efficiency, momentum and angular resolutions and able of steady operation at high rates.

The new tracking detector is a unique volume, cylindrical wire drift chamber, with the axis parallel to the muon beam, inspired to the one used in the KLOE experiment [6]. The external radius of the chamber is constrained by the available room inside the magnet of the MEG experiment, while the length is instead dictated by the necessity of tracking positron trajectories until they hit the timing counter. This minimizes the contribution of the track length measurement to the positron timing resolution and increases the positron reconstruction efficiency avoiding any material along the positrons path to the timing counter. The drift chamber is composed of 10 criss–crossing sense wire planes with wires extending along the beam axis with alternanting stereo angles in order to reconstruct the coordinate along the axis of the chamber by combining the information of adjacent layers.

Drift cells have an almost square shape (eight field wires surrounding the central anodic wire) with 7 mm of side, in order to guarantee a tolerable occupancy of the innermost wires, which are placed ta roughly 18 cm from the beam axis where the rate is $\sim 1\ MHz$ for a stopping rate of $7 \times 10^7 \mu/s$. The distribution of cells inside the magnet volume is dictated by the angular coverage of the calorimeter: the number of anodic wires is ~ 1200, while the cathode wires are ~ 6400.

To minimize multiple scattering a helium–isobutane (90:10) gas mixture is presently foreseen, with the possibility to increase the isobutane fraction to meet the best compromise between track resolution and multiple scattering. Further, this gas mixture to keep under control also the rate of background photons in the e.m. calorimeter generated by positron annihilation in the chamber.

The response of the new chamber to 52.8 MeV/c positrons from $\mu \longrightarrow e\gamma$ decay was studied by means of a full Monte Carlo simulation program (Figure.2). The most probable number of wires hits is ~ 60, a factor of 3 larger than the present MEG DC–system.

This represent a big improvement for the reconstruction efficiency and for the momentum and angular resolutions, as well as a formidable help for pattern recognition in a high occupancy environment.

4. Track reconstruction

The usage of the gas mixture as He/Isobutane produces an average number of ionization clusters, by the passage of a minimum ionizing particle, quite low (about 12.5 per cm of track), which in turn introduces a bias in the measurement the distance of closest approach (impact parameter) of a particle from the anode wire.

Aiming to eliminate this bias has been proposed an alternative track reconstruction strategy: the cluster timing/counter technique [7]. This technique, as opposed to the traditional determinanion of the impact parameter, which uses only the arrival time of the first cluster, consists in measuring the timing of all the individual clusters.

The cluster counting/timing technique needs a very fast front–end electornics for signal acquisition, being the temporal separation between signals produced by the different ionizations cluster a few naonseconds.

Therefore, to acquire signal temporally separated it is necessary to have front–end electronics characterized by a large bandwidth on the order of 1 GHz.

To study the resolution performances of the new chamber, a larger prototype has been developed by the Lecce group. Its body is $24 \times 28 \times 67\ cm^3$, made of aluminum and hosts 20 layers of sense wires alternating to the field wires with stereo angle value about $11°$. Each layer is subdivided in three sectors: in the up and down sectors are positioned the guard wires, while in the middle there are ten anodic wires of 40 μm tungsten size.

The signals are read with a TDC module by an acquisition software just developed in MIDAS framework [8].

The test is starting in March 2014 at BTF of Frascati's laboratory.

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