The MEG experiment at Lecce

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1. Introduction

The charged Lepton Flavour Violation processes (cLFV) are a very clean channels where to look for possible new physics beyond the Standard Model (SM). Many Super Symmetric Models [1] [2] predict lepton mixing processes with achievable experimental rates, therefore every improvement to the measured LFV process branching ratio representing a possible validation to the super–symmetric theories.
In the last years, the results both from $\mu \longrightarrow e\gamma$ channel investigation and from the ATLAS experiment at CERN [3] have put a more stringent constrains to the SSM theory space parameters. In particular the MEG experiment (Figure.1) [4] at the Paul Scherrer Institute (Zurich–Switzerland) has established the present best upper limit ($\mathcal{B} < 5.7 \times 10^{-13}$ at 90 % C.L.) on the $\mu \longrightarrow e\gamma$ decay. The data collected by the MEG experiment in 2011 and 2012 years showed no excess of events compared to background expectations, improving a four times the previous decay best limit [5].

The MEG Collaboration is now working for the experiment upgrade program which aims to improve the experiment sensitivity of a further order of magnitude [6]. The main improvement is the tracker replacement in order to increase the spectrometer granularity and resolution.

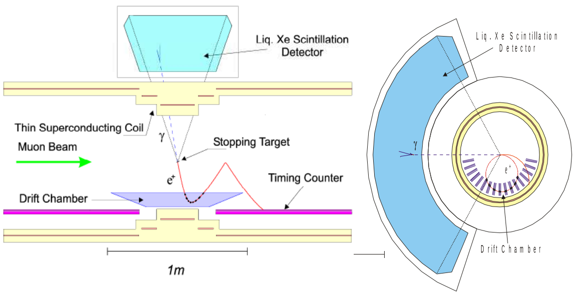

Figure 1. An overview of MEG spectrometer at Paul Sherrer Institute.

variable	old DCH	new DCH
ΔP_e in keV	306	115
$\Delta\phi_e$ in $mrad$	8.7	5.34
$\Delta\theta_e$ in $mrad$	9.4	4.81
Δt_e in ns	107	10

Table 1
The new tracker resolution values with respect the older tracker system.

The MEG–Lecce group is involved both for the new drift chamber construction and for the relative front-end electronics development.

2. The new tracker

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 [7]. The external radius of the chamber is constrained by the available room inside the magnet of the MEG spectrometer, the length is dictated by the necessity of tracking positron trajectories to reach 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 embedded in Helium – IsoButane (90 – 10) atmosphere, in order to minimize the multiple scattering contribution. The corrisponding total number of radiation lengths for the new chamber is smaller to the older MEG DCH–system. This is crucial to keep under control the multiple scattering contribution to the positron momentum, the angular resolutions and also the rate of background photons in the electromagnetic calorimeter. These improvements were confirmed by simulation studies [6]

2.1. The wiring system

The wiring system has been fully designed and assembled in the cleaning room of Physics Department of the University of Salento and INFN – Lecce. The wiring system allows automatically to stretch the wires on PCB frames keeping under control the wire tension and pitch parameters, moreover the system fix the wires on PCB by a contact less soldering.

As shown in Figure 2, the wiring system is subdivided in four sub–system:

a) The rotation system

It is an axial system composed by a cylinder, a step by step motor, a torque meter and a electromagnetic brake.
The cylinder frame is made aluminum coated with a few centimeter of fiberglass and a rubber foil, in order to reduce its inertia momentum. The cylinder radius and length are about $\sim 30\ cm$.
The rotational motion of the cylinder is done by a step by step motor, the use of a torque meter and e.m. brake allows to stop the cylinder avoiding the back–slide effect.

b) The alignment system

A group of pulleys is used in order to keep both the right pitch between adjacent wires and the correct stretch tension. The system is also provided with a high definition webcam to monitor the wire displacement on the PCB frame.

c) The soldering system

An UV laser solder [8] with tin feeder allows an accurate conctat less laser soldering on the PCB.

d) The unwind system

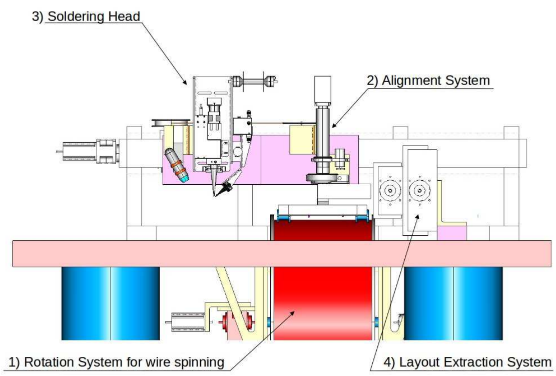

Figure 2. Schematic view of the wiring system.

A dedicated mechanical arm provided with a fork take the PCB from cylinder and move it to a special trasportation frame.

The wiring operations will be operated by a custom software developed by the MEG Lecce group. In particular, the use of cRIO controller [9] embedded in the LabView framework [10], allows to synchronize different steps as well the machine parameters settings.

3. Front–end electronics board

Waveforms in MEG experiment have a typical time separation between consecutive ionization acts, in helium–based gas mixture that goes from a few ns to a few tens of ns. The read–out interface, therefore, has to be able to process signals with bandwidths of the order of 1 GHz. In order to reach this goal it is necessary a high performance acquisition chain.

The Front–end electronics board consist of a two–stages eight channels amplifier. The input section provides decoupling, protection and matching. The amplification is realized by means of two high performances commercial devices:

- ADA4927 [11] a low noise and low distortion Op–Amp used as preamplifier;

- THS4509 [12] a wide–band and Fully Differential Op–Amp used as second stage gain and output driver.

In order to compensate the attenuation of the output cable, a pre-emphasis circuit on both the gain stages has been implemented. In this way we achieve a bandwidth of a about 1 GHz with a voltage gain of 10. An accurate PCB design preserve the signal integrity and minimize the cross–talk between channels.

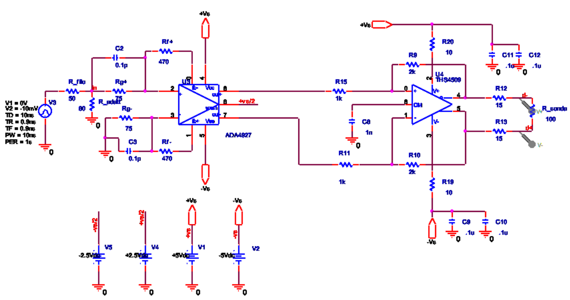

Figure 3. The schematics Front–End electronics board.

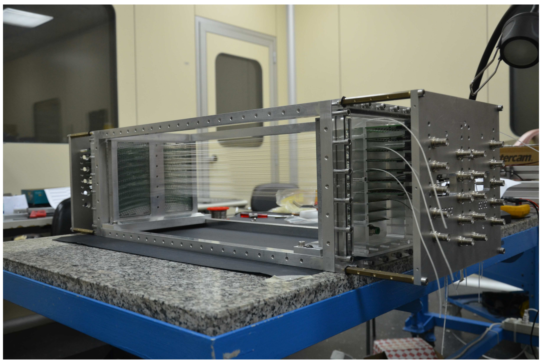

Figure 4. The picture of large prototype built in Lecce.

The schematics front–end is shown in Figure 3. The front–end board is designed, realized and tested in the INFN–Lecce laboratories.

4. The prototype test

The new chamber performances was studied in a test beam at Beam Test Facility of Frascati's Laboratory [13] on March 2014. A larger prototype ($24 \times 28 \times 67$ cm^3) has been built in Lecce (Figure 4); it hosts 15 criss–crossing sensitive layers with stereo angle (about $\sim 11°$), each one subdivided in three sub–layers: the field wire (aluminum of 0.040 mm diameter) at the top and bottom ones, while the sense wires (gold–tungusten of 0.020 mm diameter) in the middle.

The front–end electronics for signal acquisition was similar to the one that will be used in the final experiment [14], a standard VME based DAQ system (ADC/TDC) was used. The time measurements is the traditional tecnique to estimate the distance of closest approach (impact parameter) of a particle from the anode wire giving the arrival time of the first cluster, while the waveforms recording allow to use the timing technique [15], based on the measuring the timing of all the different ionizations clusters, to define the impact parameter. Both the typical time distribution from the TDC and signals waveforms are shown in Figure 5.

The test results allowed to define the gas mixture working point versus the high voltage bias, and to perform a study of the amount of anodic charge collected (cell gain). The data analysis is yet under development and the final results are foreseen to published in the next months.

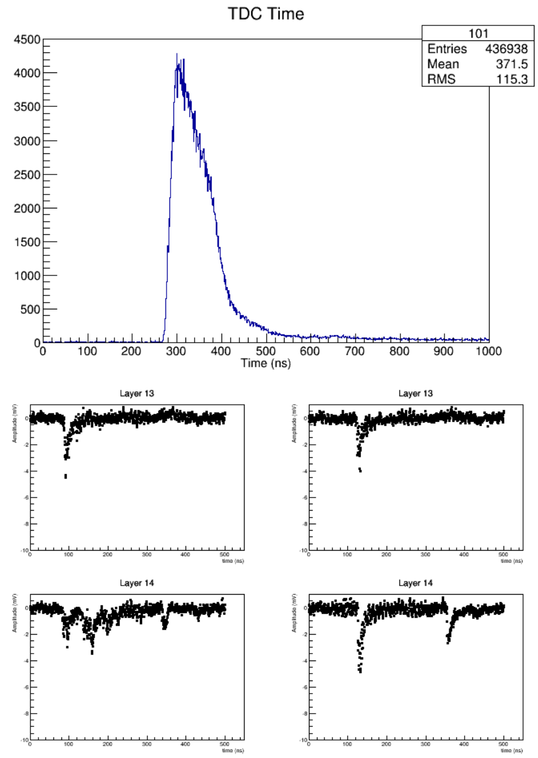

Figure 5. The time distribution (top); typical waveforms (bottom).

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