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A 10^{-3} drift velocity monitoring chamber for the MEG II experiment

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ABSTRACT

The MEG-II experiment searches for the lepton-flavor-violating decay: $\mu \longrightarrow e + \gamma$. The reconstruction of the positron trajectory uses a drift chamber operated with a mixture of He and iC_4H_{10} gas. It is crucial to provide a stable performance of the detector in terms of its electron transport parameters, avalanche multiplication, composition and purity of the gas mixture. In order to have a continuous monitoring of the quality of the gas injected, we plan to install a small drift chamber, with a simple geometry that allows to measure very precisely the electron drift velocity in a prompt way. The chamber is a small box with cathode walls, that determine a highly uniform electric field inside two adjacent drift cells. Along the axis separating the two drift cells, four staggered sense wires alternated with five guard wires collect the drifting electrons. The trigger is provided by two ^{90}Sr radioactive sources placed on top of a two thin scintillator tiles telescope. The whole system is designed to give a response in few minutes about drift velocity variations at the 10^{-3} level. In this paper the development of the drift chamber is presented, with a particular focus on the details of its construction.

1. Introduction: the importance of a constant monitoring of the gas mixture

The choice of a gas mixture in a drift chamber is of utmost importance, in particular for the experiments, like MEG-II, in which the trajectories of low momentum particles need to be reconstructed with high accuracy. It is crucial to control the purity of the gas injected in the drift chamber because uncontrolled fluctuations of the gas composition and contamination by impurities would make the drift velocity unstable and could deteriorate spatial and momentum resolution of candidate signal tracks.

Several studies about the behavior of drift velocity as a function of the reduced electric field in a mixture of He/iC_4H_{10} have been published [1–3], proving that drift velocity is the most sensitive parameter for the operation of a drift chamber with respect to tiny variations of the gas mixture.

2. The monitoring drift chamber set-up

The main goal of the monitoring chamber is to provide a fast response about drift velocity variations at 10^{-3} level.

This purpose can be obtained with a conceptually very simple structure, illustrated in Fig. 1. We will use two ^{90}Sr radioactive sources placed on top of two thin scintillator tiles telescope. The sources will be collimated to select the tracks crossing the drift cells. The chamber is placed inside a box and it will be supply with the gas coming from the inlet and the outlet of the MEG II drift chamber.

Fig. 2 shows the transverse view of the chamber. Along the plane separating the two drift cells, four sense wires (20 μm diameter gold plated tungsten) alternated to five guard wires (80 μm diameter silver plated aluminum) collect the drifting electrons. The drift electric field is defined by two high voltage cathode walls and graded by two wires planes down to 0 V on the symmetry plane, containing the sense and guard wires.

The mechanical design is presented in Fig. 3, with a focus on the central part of the chamber which hosts the custom PCB for the wires staggering (details in Section 3).

3. The construction of the monitoring drift chamber

After a campaign of simulations aimed at studying the electric field configuration and the measurement procedure of the chamber [4], the construction of its components has been started and despite being conceptually simple, the constraint on the 10^{-3} precision has made its construction quite challenging.

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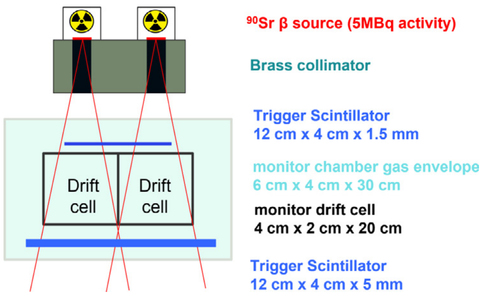

Fig. 1. Schematic of the experimental set up of the monitoring drift chamber.

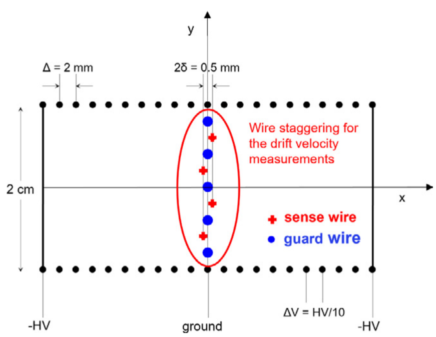

Fig. 2. The transverse view of the monitoring drift chamber.

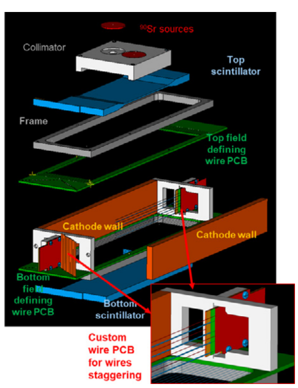

Fig. 3. Mechanical design of the monitoring drift chamber.

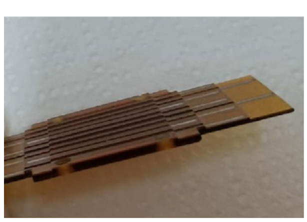

Fig. 4. Custom PCB for wires staggering.

The accomplishment of the central wire staggering has been implemented, by using a custom PCB, shown in Fig. 4, consisting of subsequent layers of resin and silver pad for wires soldering, performed with a 3D printing device. Fig. 5 shows the drift velocity monitoring chamber complete in all its parts. The cathode walls are made of gold plated brass. Two peek supports define the position of the upper and

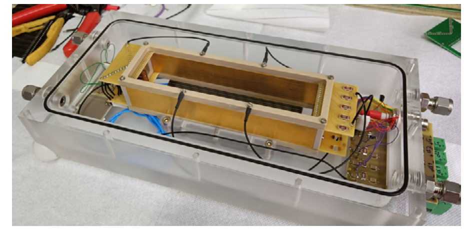

Fig. 5. The monitoring drift chamber inside the gas box containment.

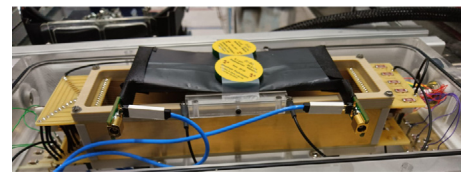

Fig. 6. The two ^{90}Sr sources placed on top of the tapered scintillator.

lower potential grading wire planes. The bottom trigger scintillator is kept in place by plastic supports anchored to the external gas container. The top scintillator, thinned down to 1.5 mm to minimize the β rays absorption, lays on top of the upper voltage grading plane, as shown in Fig. 6. Two feed-through PCBs connect the drift chamber to the HV supply and to the data acquisition system.

4. Conclusion

The monitoring drift chamber, equipped with two radioactive sources and triggered by a telescope of thin scintillator tiles, allows the monitoring of the drift velocity of the MEG II central tracker, in short time and with a high precision. It enables to evaluate variations of the operating conditions affecting the spatial resolution, being sensitive to variations of:

- $+0.4\%$ in iC_4H_{10} content (from 10.0% to 10.4%)
- -0.3% in iC_4H_{10} content (from 10.0% to 9.8%)
- $\pm 0.4\%$ in E/p ($\approx 6\%$ in gas gain) at gain $\approx 5 \times 10^5$
- ∓ 6 V at $p \approx 1$ bar, $T \approx 25\,°C$
- ∓ 4 mbar at $V \approx 1500$ V, $T \approx 25\,°C$
- $-0.3\,°C$ at $p \approx 1$ bar, $V \approx 1500$ V

The chamber construction has been completed and now it is under test.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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