A 10^{-3} drift velocity monitoring chamber

A.Corvaglia[a], G.Chiariello[e], F.Cuna[a,b], N. De Filippis[c,d], F.Grancagnolo[a], M.Manta[b], A.Miccoli[a], M.Panareo[a,b], G.F.Tassielli[a,b]

(a)INFN, Lecce, Italy; (b)Università del Salento; (c)INFN, Bari, Italy; (e)INFN, Roma, Italy; (d)Politecnico di Bari

ABSTRACT

The MEG-II experiment searches for the lepton flavor violating decay $\mu \to e+\gamma$. The reconstruction of the positron trajectory uses a cylindrical drift chamber operated with a mixture of He/iC_4H_{10}.

Uncontrolled fluctuations of the gas composition and contaminations by impurities would make the drift velocity unstable. Rapid variations of drift velocity (within few minutes) affects spatial and momentum resolution during the reconstruction of positron tracks.

In order to have a continuous monitoring of the quality of the gas and to provide a stable performance of the detector, we plan to install a small drift chamber with a simple geometry that allows to measure electron drift velocity variations at the 10^{-3} level, within a minute.

Motivation for monitoring chamber

Drift velocity is the most sensitive parameter for the operation of a drift chamber with respect to tiny variations of the gas mixture.

Precise measurements of drift velocities in helium gas mixtures

P. Bernardini, G. Fiore, R. Gerardi, F. Grancagnolo, U. von Hagel [1], F. Monittola, V. Nassisi, C. Pinto, L. Pastore, M. Primavera *

Università di Lecce, Dipartimento di Fisica and INFN, Sezione di Lecce, via Arnesano, 73100 Lecce, Italy

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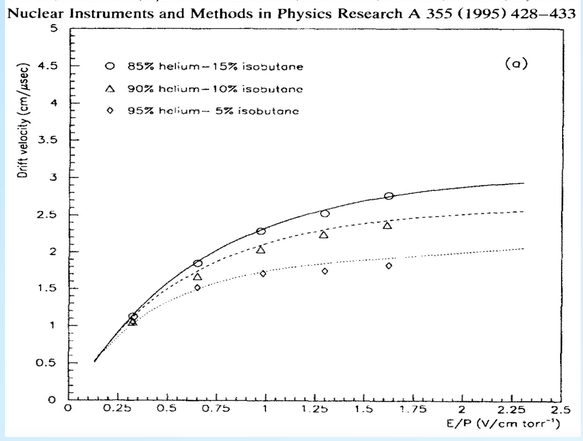

For a 90/10 mixture, at normal pressure, variations of the electric field, around the operating value of 1 V/cm/torr, of about 2 V/cm induce drift velocity variations of 1×10^{-3}.

Influence of oxygen and moisture content on electron life time in helium–isobutane gas mixtures

V. Golovatyuk*, F. Grancagnolo, R. Perrino

Dipartamento di Fisica dell'Universita, INFN Sezione di Lecce, via Arnesano, 73100 Lecce, Italy

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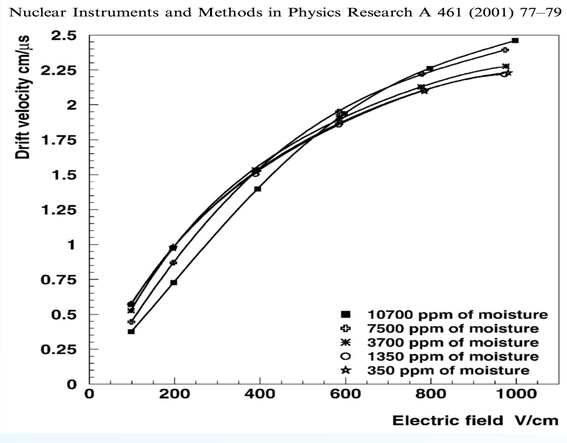
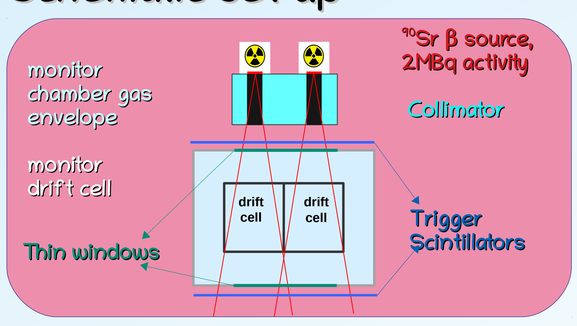


To mitigate the ageing effect, sometimes it is useful to introduce small quantities of water vapors in the gas mixtures, but it is important to control the consequent variations of drift velocity.

E.g. at the operating value of the electric field of about 1 V/cm/torr, variations of ≈ 150 ppm leads to an increase of 10^{-3} in drift velocity.

Monitoring chamber structure

Schematic set up

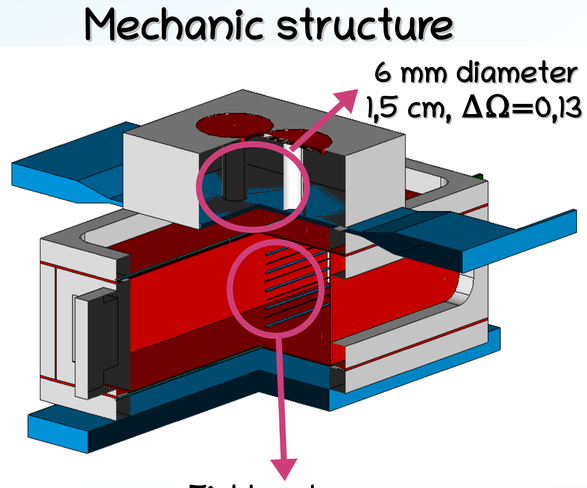


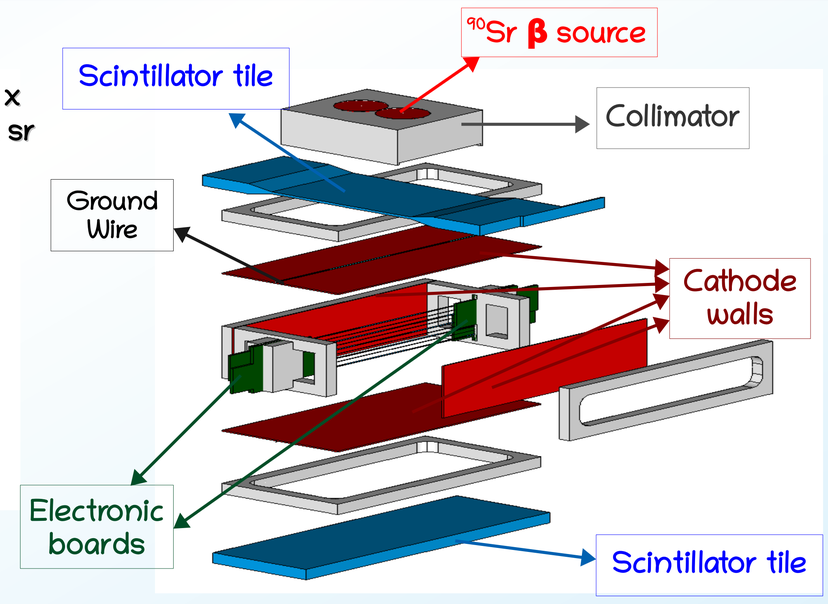
The chamber can be supplied with gas coming from the inlet and the outlet of the detector.

We will determine if gas contaminations originate inside the main chamber or in gas supply system.

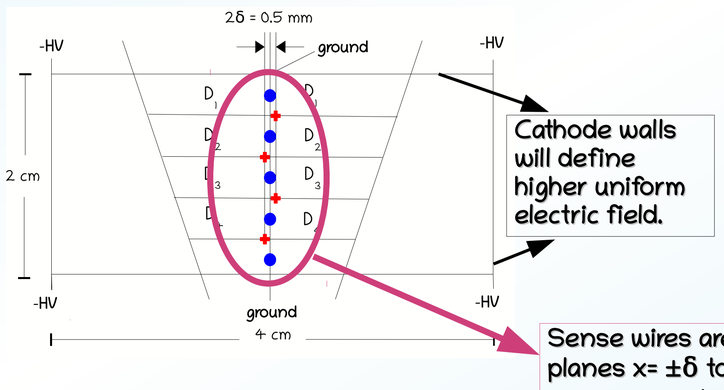
We will use two ^{90}Sr weak calibration radioactive source placed on top of two thin scintillator tiles telescope.
To select electrons that pass through the chamber, the two sources will be collimated, so that the number of decays that can be used will be around 4×10^3 per second.
This set-up allows to measure variations of drift velocity at 10^{-3} level within a minute.

Mechanic structure





Sensitivity of drift velocity measurement



Drift velocity can be measured using the shift on wire positions, starting by time relations:

$$t_2 = \frac{t_1+t_3}{2} \mp \frac{2\delta}{v_d} \qquad t_3 = \frac{t_2+t_4}{2} \pm \frac{2\delta}{v_d}$$

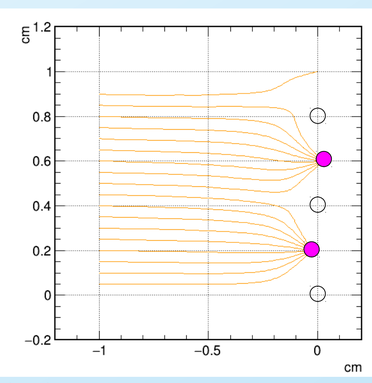
Subtracting t_3-t_2

$$\Theta = (t_1+t_3-2t_2)-(t_2+t_4-2t_3)$$

For tracks on left side $\Theta_+ = +8\delta/v_d$
For tracks on right side $\Theta_- = -8\delta/v_d$

- Θ will have double gaussian distribution.
- The distance between the two peaks is related to drift velocity

$$v_d = \frac{16\,\delta}{\Delta\Theta} \qquad \sigma_{v_d} = \sqrt{\left(\frac{16}{\Delta\Theta}\right)^2 \sigma_\delta^2 + \left(\frac{-16\,\delta}{\Delta\Theta^2}\right)^2 \sigma_{\Delta\Theta}^2}$$



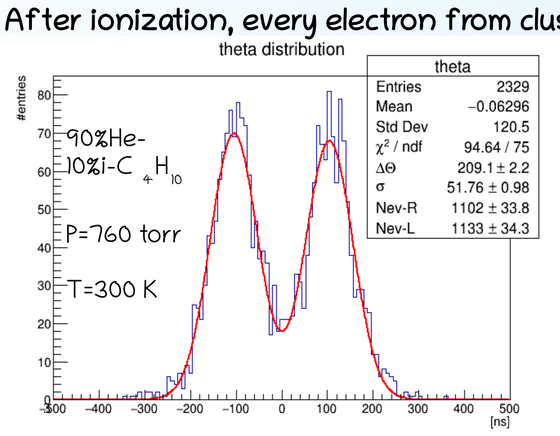
Simulation results for electric field

We made simulations using Garfield++. First step was the optimization of electric field inside the two drift cells.
We fixed the voltage on cathode plane at -2000V and varied the voltage on field wires from 0V to -800 V and on the sense wires from 0 V to 1200 V.

The optimized values are:
- 925 V for sense wires
- -350 V for field wires

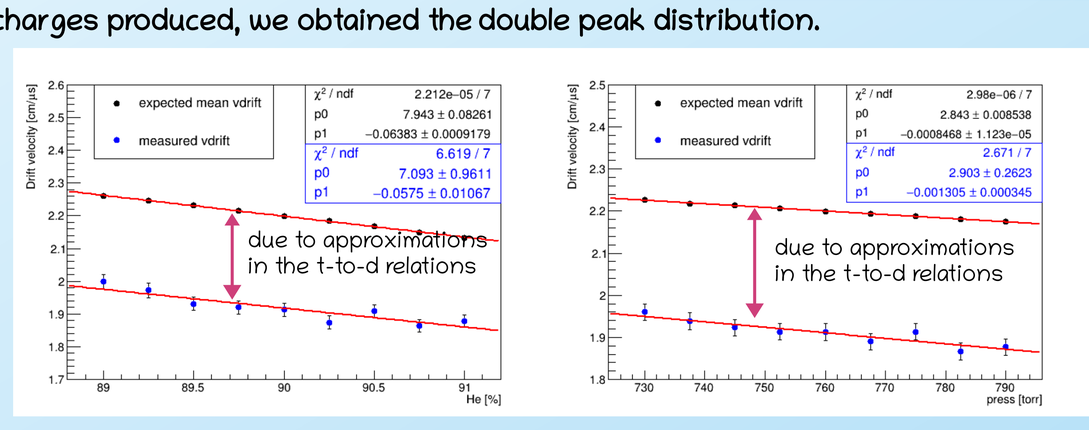
Simulation results for electron tracks

We simulated 2000 tracks on left side and 2000 on the right side.
After ionization, every electron from cluster drifted to the sense wire. Saving drift times and total charges produced, we obtained the double peak distribution.



$$\Delta\Theta = (209.1 \pm 2.2)\,ns \qquad v_d = (1.91 \pm 0.02)\,cm/\mu s$$

An increment in the number of event of a factor of 100 increases the sensibility at 10^{-3} level.
The number of tracks necessary to obtain this sensibility is 4×10^5 and it will be obtained with the radioactive source and the experimental set-up chosen.



Conclusion

The continuous monitoring of drift velocity variations at 1 ‰ level is sensitive to variations of:
- +0.4% in i-C_4H_{10} content (from 10.0% to 10.4%)
- -0.2% ini-C_4H_{10} content (from 10.0% to 9.8%)
- ±0.4% in E/p (≈6% in gas gain) at gain≈ 5×10^5
- ∓ 4 V at p≈1 bar, T≈25 °C
- ∓ 4 mbar at V≈1500V, T≈25 °C
- -0.3 °C at p≈1 bar, V≈1500 V
- ≈ 150 ppm variations in water vapor content .

A simple small drift chamber, equipped with low activity radioactive ^{90}Sr β-sources and triggered by a telescope of thin scintillator tiles, allows to monitor the drift velocity of the MEG-II central tracker, in short time and with a high precision that asses to evaluate variations of the operating conditions, which would affect tracking reconstructions.
We are now assembling the hardware of the monitoring chamber.