A monitoring chamber for high precision measurements of the drift velocity in gas detectors

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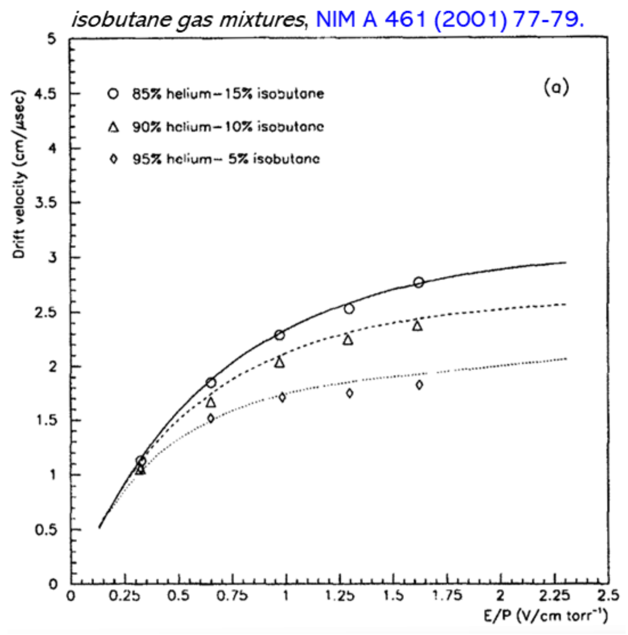
Abstract

The tracker detector of MEG II and the one under developments of FCC and CEPC experiments consists of ultralight drift chambers, operated with a mixture of Helium and Isobutane. A stable performance of the tracker detector in terms of its electron transport parameters, avalanche multiplication, composition and purity of the gas mixture is of crucial importance, so in order to have a continuous monitoring of the quality of gas, 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.

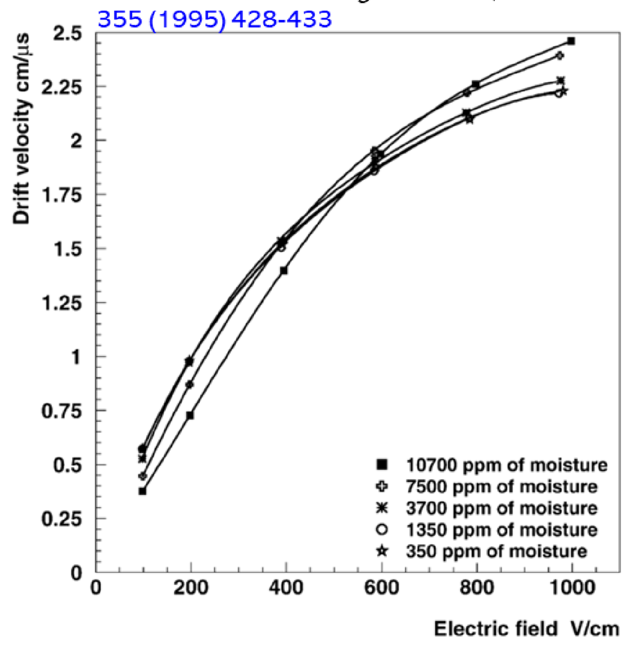
Motivations for a drift monitoring chamber

Uncontrolled fluctuations of the gas composition and contaminations by impurities would make the drift velocity unstable and could deteriorate spatial and momentum resolution of signal tracks. It is important to ensure a stable performance of the detector in terms of ***its electron transport parameters***, ***gas gain***, ***composition and purity of the gas mixture.***

V. Golovatyuk, et al, *Influence of oxygen and moisture content on electron life ime in helium-isobutane gas mixtures*, NIM A 461 (2001) 77-79.



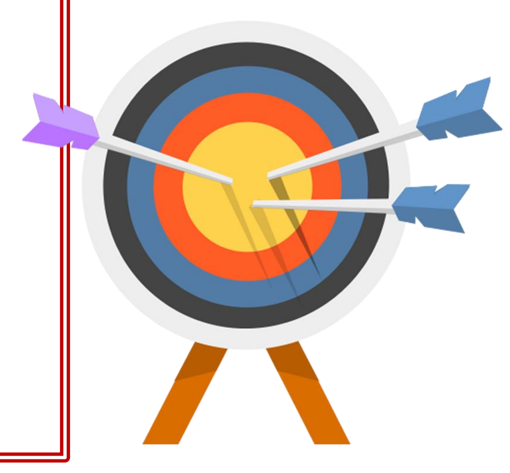
P. Bernardini et al, *Precise measurements of drift velocities in helium gas mixtures*, NIM A 355 (1995) 428-433



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

Goals

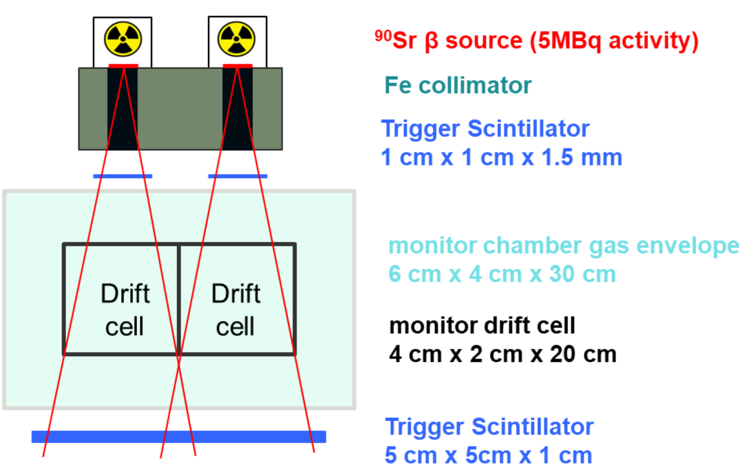
- providing a prompt response (few minutes) to drift velocity trends at 10^{-3} level as a function of:
  - Gain
  - Electric field
  - Tiny variations of the gas mixtures components
- obtaining correction factors for the drift-time relations
- performing measurements of several gas mixtures properties



Schematical setup

The monitoring chamber will be supplied with the gas mixture coming from the inlet and the outlet of the detector to determine if any gas contamination originate inside the main chamber or in the gas supply system.

The trigger is provided by two ^{90}Sr weak calibration radioactive sources placed on top of a two thin scintillator tiles telescope.

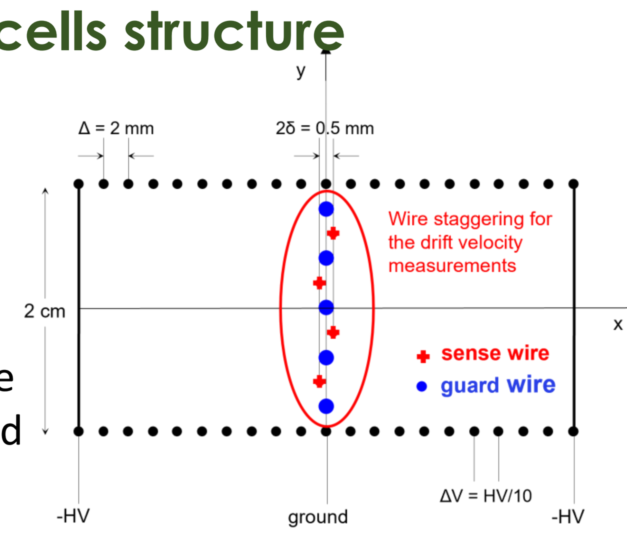


This set-up allows to measure drift velocity variation at 10^{-3} level within few minutes.

Drift cells structure

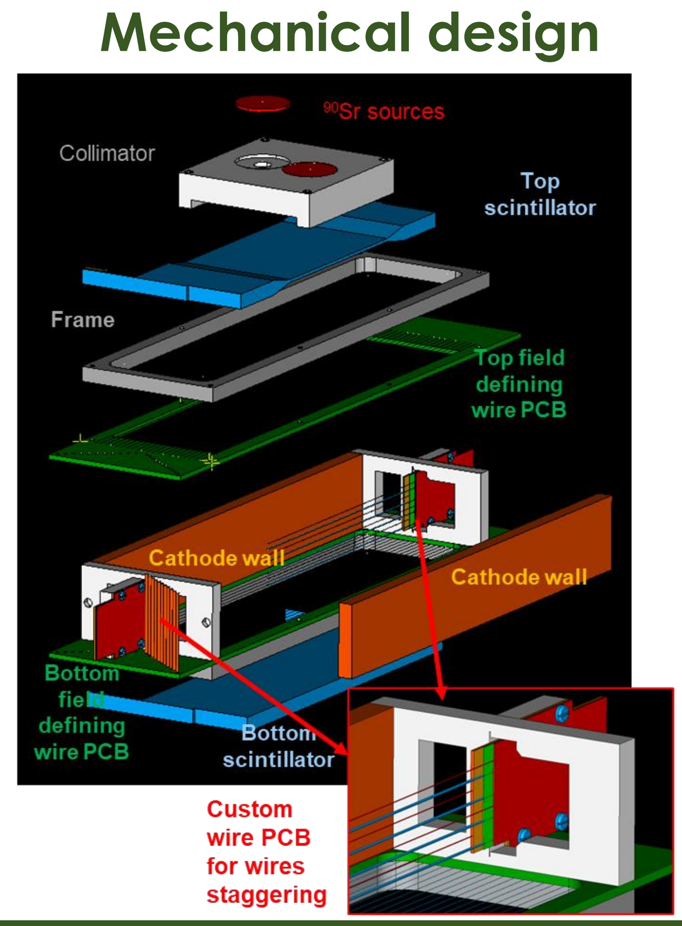
The chamber is a small box with cathode walls, that determine a highly uniform electric field inside two adjacent drift cells.

Along the axis separating the two drift cells, four staggered sense wires alternated with five guard wires collect the drifting electrons.

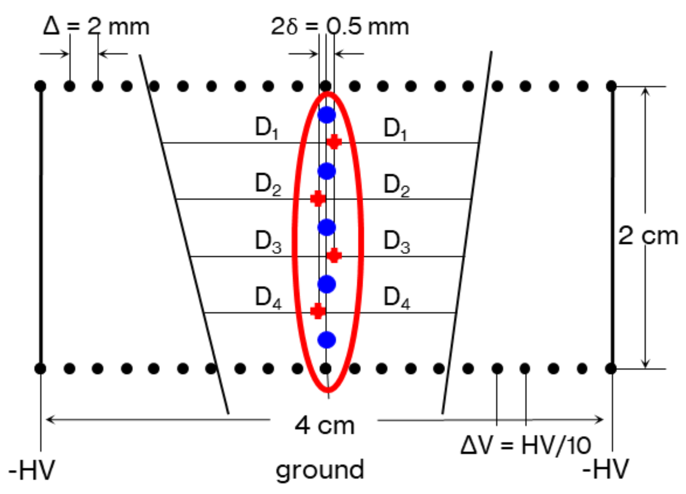


- 4 sense wires (20 μm W(Au)) staggered by δ = ±250 μm
- 5 guard wires (80 μm Al(Ag))
- 21 field wires (25 μm W(Au)) per up and down plane

Mechanical design



Applied method for of the drift velocity measurement



The drift velocity v_d can be measured thanks to the sense wire staggering.

Simple geometrical considerations lead to the following relations:

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

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

$$t_3 - t_2 \longrightarrow \quad \Theta = (t_1 + t_3 - 2t_2) - (t_2 + t_4 - 2t_3) \longrightarrow \begin{cases} \Theta_+ = +\frac{8\delta}{v_d}, & \textit{left track} \\ \Theta_- = -\frac{8\delta}{v_d}, & \textit{right track} \end{cases}$$

Θ will have a double gaussian distribution

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

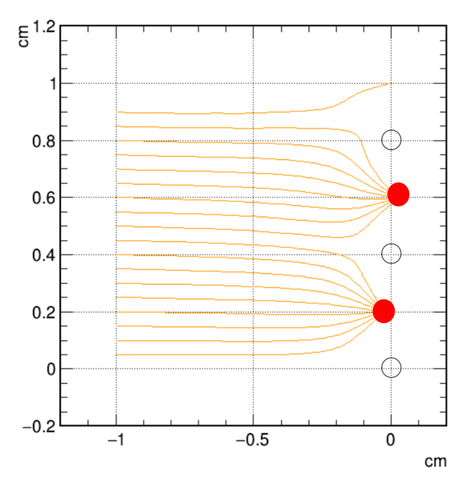
The drift velocity depends on $\Delta\Theta = \Theta_+ - \Theta_-$, which is the distance between the two gaussian peaks distribution of Θ

Simulation of the electric field configuration

The drifting electric field and the amplification field around the sense wires have been calculated with the Garfield++ software.

Considering a drifting field 1kV/cm (-2000V on cathode walls) and a gas amplification gain on sense wires $5x10^5$:

- Voltage on **sense wires**: 1000 V
- Voltage on **guard wires**: ≥ -350 V



Drift lines converging on the sense wires (red dot).

Simulation of the procedure

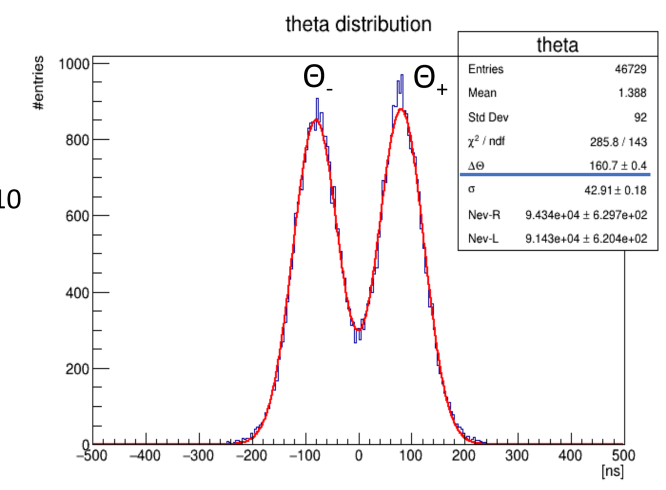
For the measurement of the drift velocity, $2x10^5$ tracks have been simulated with Garfield++ software , generated with a uniform angular distribution within 12°.

Simulations parameters

Gas mixtures: 90%He-10%iC_4H_{10}

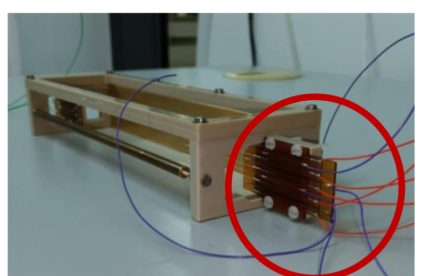
P=760 Torr

T=300K

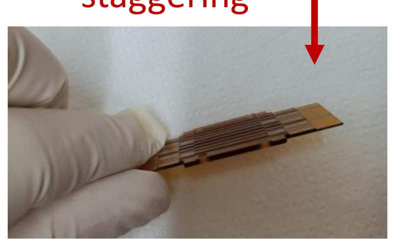


$$v_D = 2.488 \pm 0.006\ cm/\mu s$$

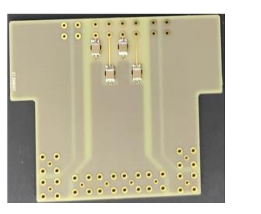
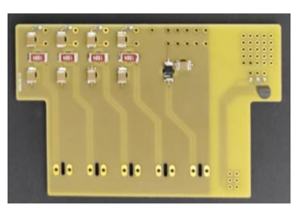
The construction of the drift chamber



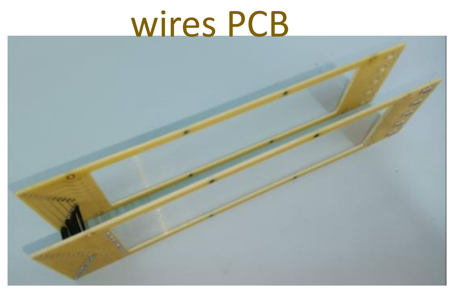
PCB for the wires staggering

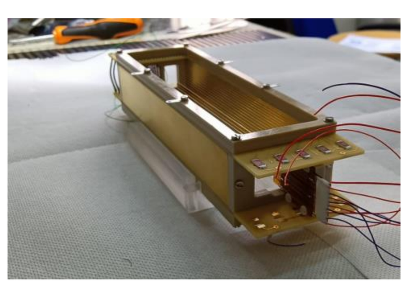


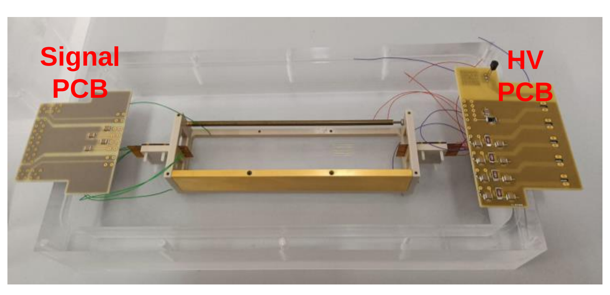
Feedthrough PCB for electronic connections

Up and down field defining wires PCB







Conclusion

The continuous monitoring of drift velocity variations of ±1 x 10^{-3} at 1 KV/cm/bar is sensitive to variations of (considering the other parameters as constant):

- +0.4% in iC_4H_{10} content (from 10.0% to 10.4%)
- -0.3% in iC_4H_{10} content (from 10.0% to 9.7%)
- 0.4% in E/p (≈6% in gas gain) at gain ≈ 5 x 10^5
- ∓ 6V at p ≈ 1 bar, T ≈ 25°
- ∓ 4 mbar at V ≈ 1500V, T ≈ 25°
- 1.2 °C at p ≈ 1 bar, V ≈ 1500V