PROCEEDINGS OF SCIENCE

Performance of a 1 m^2 Micromegas Detector Using Argon and Neon based Drift Gases

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Micromegas (MICRO MEsh GAseous Structures) are used in a broad field of applications due to their excellent spatial resolution and single plane track inclination reconstruction capability. They consist of three planar structures, a cathode, a micro-mesh and a strip anode with 0.45 mm modularity. The distance of the micro-mesh from the cathode is with typically 5 mm large in comparison to the tiny distance of 0.128 mm to the anode, thus creating a drift and amplification region with electric fields differing by a factor of more than 50 and thus increasing the electron transparency of the micro-mesh well above its optical transparency. Position information is obtained by the charge center on the responding anode strips. Alternatively in a TPC-like mode, the track of the incident particle can be reconstructed measuring the drift times of the ionization electrons as a function of the position of the responding anode strip.
We report on the performance of a 1 m^2 Micromegas with 2048 electronic channels using detector gases based on Ar:CO_2 or Ne:CF_4 mixtures. Central questions are hereby: homogeneity of pulse height and efficiency, mesh transparency, calibration possibility of the location of single readout strips using cosmic muons and the impact of the drift time on the angular and spatial resolution as a function of the incident angle.

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1. Introduction

Micromegas detectors (MICRO MEsh GAseous Structure) detectors are gaseous detectors consisting of three planar elements: cathode, micro-mesh and anode structure, in our case with a stainless steel mesh and a strip anode with a pitch of 450 µm. The related electron drift and amplification region are 5 mm and 128 µm high. Charge created by a traversing muon is collected on the resistive strips and readout via capacitive coupling to readout strips [1].
Position information is obtained by the charge center of the responding anode-strips, the so-called centroid: $x_{\text{cen}} = \frac{\sum_{\text{strips}} x_{\text{strip}} \cdot q_{\text{strip}}}{\sum_{\text{strips}} q_{\text{strip}}}$. Measuring the drift time of the ionization electrons versus the position of the strips enables track angle Θ reconstruction in a single plane using the so-called µTPC method. With the known strip pitch and drift velocity obtained from MAGBLOTZ [2] this leads to the track angle $\Theta = \arctan(\frac{1}{slope_{fit}} \times \frac{pitch}{v_{drift}})$. Depending on the drift velocity for different gas mixtures, position and angle reconstruction was investigated using Ar:CO_2 93:7 vol% and Ne:CF_4 80:20 vol% at atmospheric pressure. The gas mixture has to be chosen appropriate to the application. A higher drift velocity, e.g. improves the high-rate capability.

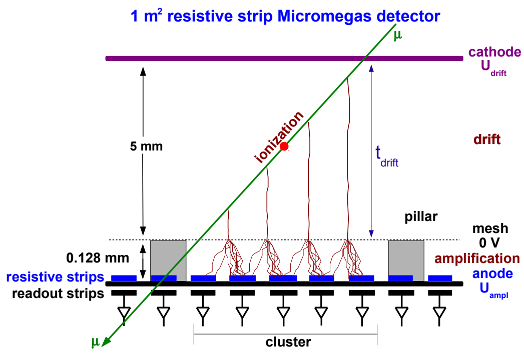


Figure 1: Schematic drawing of a muon traversing a Micromegas detector divided in drift and amplification region by a grounded micro-mesh.

2. Experimental Setup

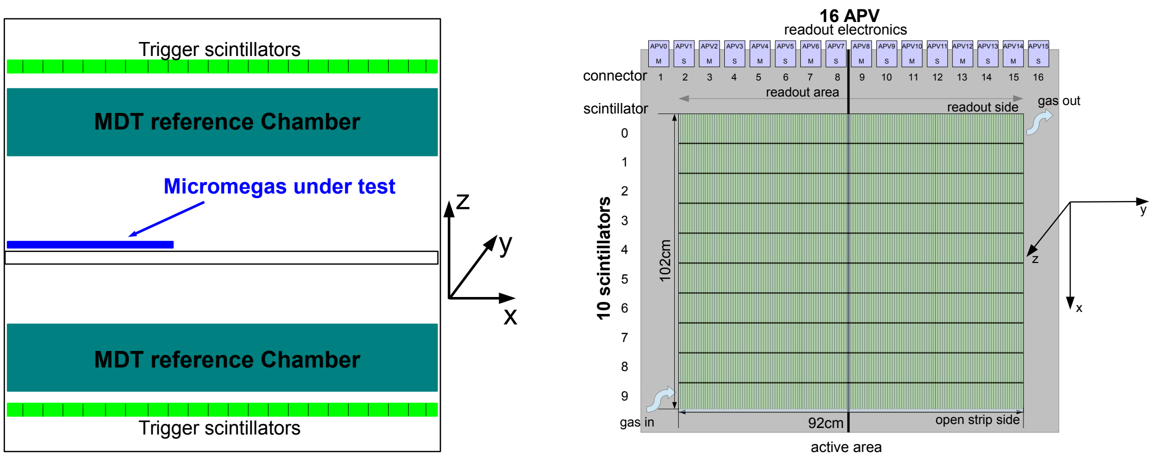


Figure 2: (left) Scheme of the Cosmic Ray Measurement Facility in Garching consisting of two trigger hodoscopes with 10 cm spatial segmentation, two MDT reference chambers and the Micromegas under test. (right) Scheme of the 1 m^2 Micromegas under test with its subdivision into 160 partitions of $5.76 \times 10\,\text{cm}^2$ (16 APV $\times$ 10 scintillators).

This measurement took place in the LMU Cosmic Ray Measurement Facility (CRMF) consisting of two Monitored Drift Tube (MDT) reference tracking chambers and two trigger scintillator

hodoscopes for the second coordinate (see fig. 2 (left)). The MDTs have an active area of about 9 m^2 and are sandwiching the Micromegas. The angular acceptance is $-30°$ to $+30°$. Therefore the investigation of the whole active area of the Micromegas is possible.
The Micromegas under test has an active area of $0.92 \times 1.02\,\text{m}^2$, strips channels with a pitch of 450 µm and was read out with 16 APV25 front-end boards [3] interlinked to Front-End Concentrator cards and a Scalable Readout Unit of the RD51 Scalable Readout System [4]. The 16 front-end boards together with the second coordinate obtained from the trigger hodoscopes along the strips allow a subdivision of the Micromegas in 160 partitions (see fig. 2 (right)).

3. Spatial Resolution - Centroid Method

The difference between the muon position predicted by the MDTs and the reconstructed position of the Micromegas is called residual. In this case the standard deviation of the Gaussian-like residual distribution is used as approximation for the spatial resolution.
Figure 3 shows the measured spatial resolution for the different gas mixtures and drift fields. For tracks perpendicular to the Micromegas the spatial resolution is almost constant at 0.45 mm limited by the multiple scattering of 2 GeV muons. In a testbeam with 120 GeV pions (CERN SPS H6) a spatial resolution of 90 µm was achieved for this Micromegas. The larger the track angle the larger gets the spatial resolution. Ar:CO_2 93:7 vol% shows a better spatial resolution for lower drift fields, almost constant for $E_{drift} = 50$ V/cm due the drift field dependence of the diffusion. For Ne:CF_4 80:20 vol% no drift field dependence can be seen, because the dependence of the diffusion on the drift field in this gas mixture is much weaker. The spatial resolution is similar to the one for Ar:CO_2 93:7 vol% at $E_{drift} = 200$ V/cm.

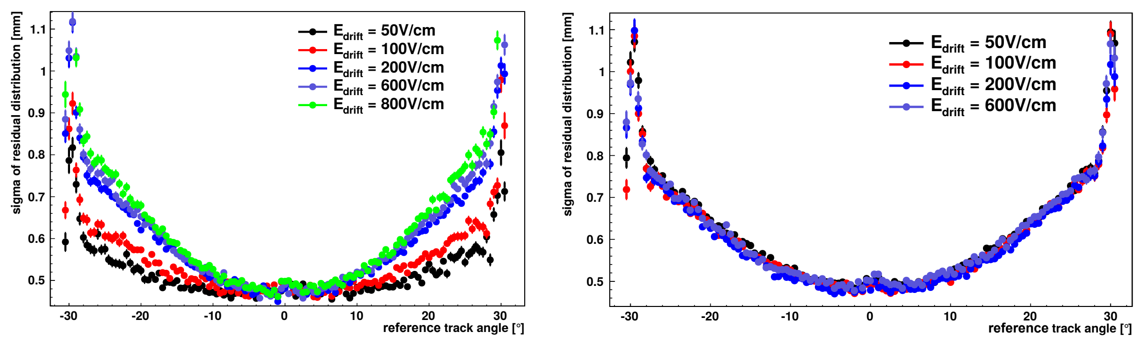


Figure 3: Measured spatial resolution as a function of the reference track angle for different drift fields for Ar:CO_2 93:7 at $E_{ampl} = 44.5$kV/cm (left) and Ne:CF_4 80:20 at $E_{ampl} = 42.2$kV/cm (right).

4. Electron Transparency of the Mesh

The micro-mesh of a Micromegas has typically an optical transparency around 50 %. Due to the large ratio between amplification and drift field the electron transparency can be increased to almost 100 %. The electron transparency of a woven stainless steel mesh with 63.5 µm pitch and 18 µm wire diameter was simulated as a function of the drift field for different gas mixtures using Garfield++ [5]. In Figure 4 (left) the decrease of the electron transparency with the drift field is shown. For Ne:CF_4 80:20 vol% the decrease is less rapid than for Ar:CO_2 93:7 vol%. This can also be seen in the behavior of the most probable value of the pulse height distribution (see fig. 4 (right)). The rise of the pulse height with increasing field is due to decreasing attachment and increasing drift velocity, leading to a better matching between electronics integration time and signal duration.

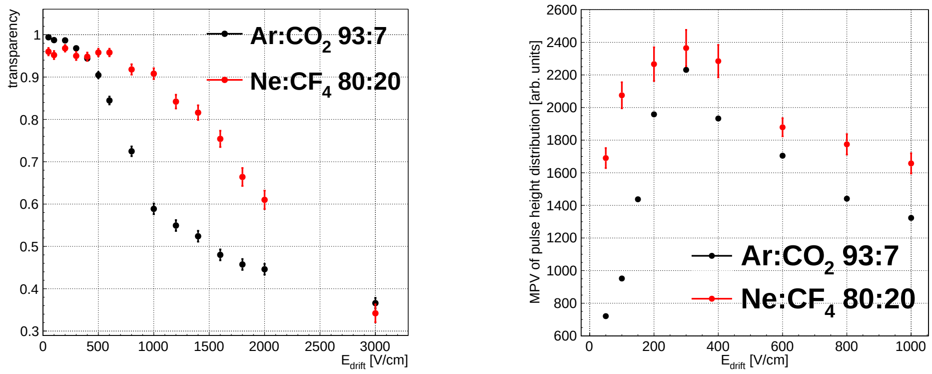


Figure 4: Simulated electron transparency (left) and measured most probable pulse height (right) as a function of the drift field for different gas mixtures.

5. Efficiency

The efficiency of a Micromegas depends, among others, on the electron transparency of the micro-mesh. A traversing muon is considered as efficiently detected if the residual is smaller than $3\sigma_{\text{spatial resolution}}$. Figure 5 shows $\epsilon_{3\sigma}$ as a function of the drift field for both drift gas mixtures. Ar:CO_2 93:7 vol% at low drift fields shows lower efficiency due to the before mentioned integration time effect. For higher drift fields both gas mixtures have good efficiency above 90 %. The maximum of 93 % results from multiple scattering of muons exceeding the $3\sigma_{\text{spatial resolution}}$ range.

For each of the 160 partitions of the detector $\epsilon_{3\sigma}$ was individually determined. Two examples at $E_{\text{drift}} =$ 400V/cm are plotted in figure 6. Both show a good homogeneity with an RMS of about 1 %.

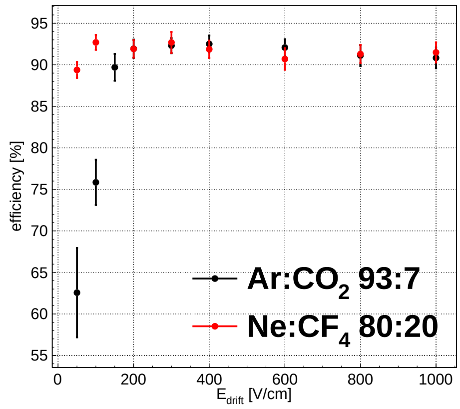


Figure 5: 3σ efficiency as a function of the drift field for different gas mixtures.

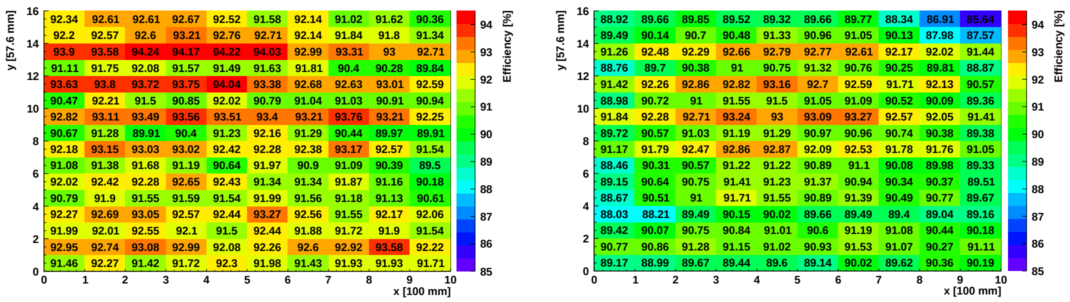


Figure 6: Measured homogeneity of $\epsilon_{3\sigma}$ for Ar:CO_2 93:7 (left) and Ne:CF_4 80:20 (right).

6. Variation of Drift Velocity due to Deformed Drift Region

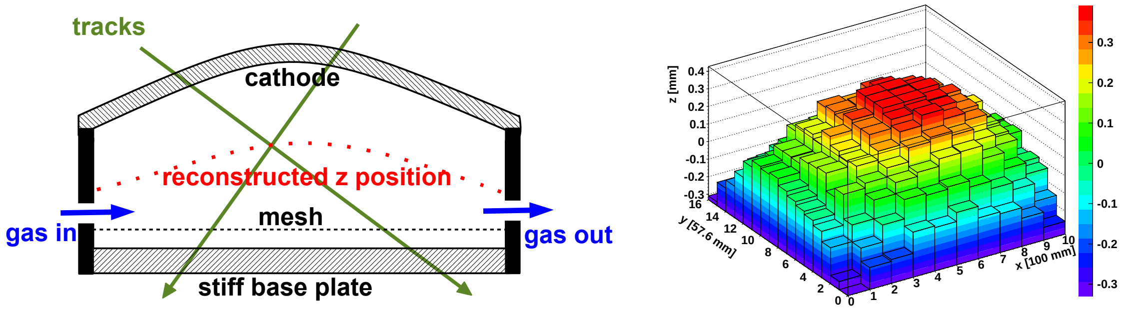


Figure 7: Schematic drawing of the deformation of the drift region with reconstructed z position (left) and measured z position for all 160 partitions of the Micromegas (right).

Due to the small overpressure of about 10 mbar in the Micromegas the drift region is slightly deformed (see fig. 7 (left)). The effective z position of its sensitive layer can be determined using inclined tracks for each of the 160 partitions of the detector and is shown in figure 7 (right). Since the stiff base plate support does not deform like the cathode, the deviation in height is inhomogeneous. The maximum deviation of 0.8 mm from the plane leads to a deviation of 1.6 mm at the drift cathode. Therefore the drift field has to be determined for each partition separately and thus the drift velocity. Figure 8 shows the drift velocity as a function of the drift field for different gas mixtures simulated with MAGBLOTZ.

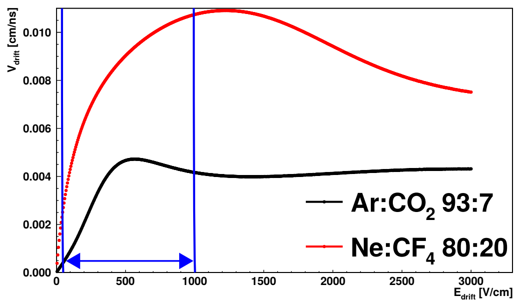
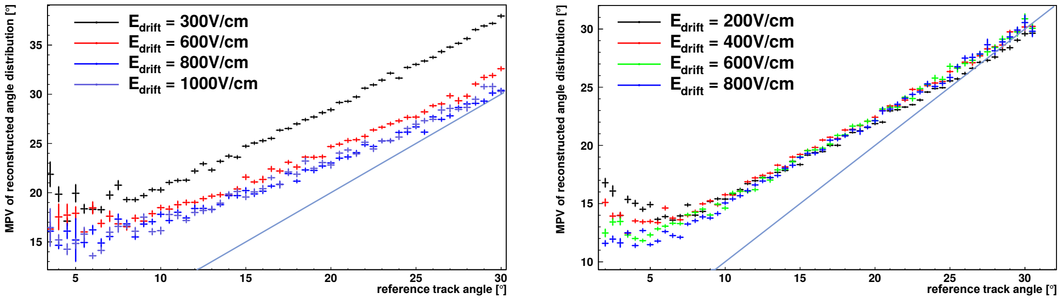


Figure 8: Simulated electron drift velocity as a function of the drift field for different gas mixtures.

7. Angle Reconstruction using the µTPC Method

The track angle can be reconstructed within a single detector plane by measuring the arrival time of the ionization electrons reaching the strips. This leads together with the strip pitch and the drift velocity, calculated for each detector partition, directly to the track angle. A simulation of the readout circuit has shown a signal crosstalk of 29 % to the neighboring strips. After correcting for this effect the angle reconstruction for Ne:CF_4 80:20 vol% improves, especially with higher drift fields for the smaller angles (see fig. 9b). For Ar:CO_2 93:7 vol% (see fig. 9a) and drift fields above 300 V/cm the reconstruction works as well. But for data points at 300 V/cm the variation of the drift velocity is probably too large within the partitions such that the drift velocity was estimated too small.

The presented measurement can be used to correct the systematic deviation from the bisecting line in figure 9 for specific applications.



(a) Ar:CO_2 93:7 @ $E_{ampl} = 44.5$kV/cm (b) Ne:CF_4 80:20 @ $E_{ampl} = 42.2$kV/cm

Figure 9: Reconstructed track angle as a function of the reference track angle for different drift fields and gas mixtures. The blue line is the angle bisector.

8. Summary

The investigation of a 1 m^2 Micromegas in the LMU Cosmic Ray Measurement Facility with Ar:CO_2 93:7 vol% and Ne:CF_4 80:20 vol%, under variation of the drift field was shown. Ne:CF_4 80:20 vol% has shown an almost equal spatial resolution for all drift fields. Both gas mixture show a homogeneous efficiency above 90 % for drift fields larger than 200 V/cm. Ar:CO_2 93:7 vol% has a larger pulse height variation due to an imperfect matching between electronics integration time and signal duration at low fields and lower transparency. After correction of capacitive coupling between strips the angle reconstruction works well for Ne:CF_4 80:20 vol% at all drift fields.

Acknowledgments

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