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

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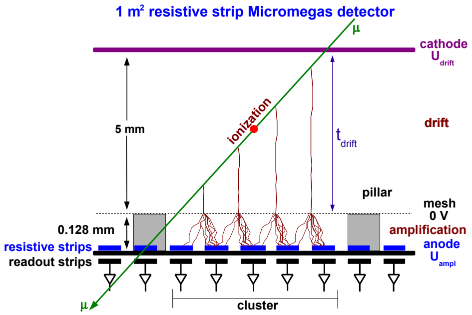
Working Principle of Micromegas



- MICROMEsh GAS detectors (Micromegas)

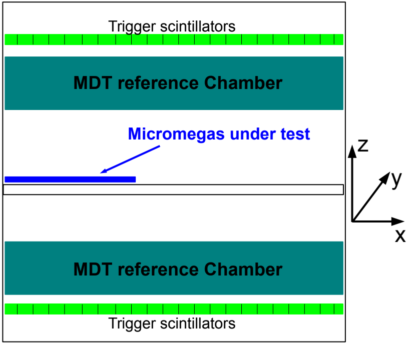
- electron drift region
- amplification region

- charge collection on resistive strips
- charge detection on readout strips by capacitive coupling

- centroid method: $x_{\text{cen}} = \frac{\sum_{\text{strips}} x_{\text{strip}} \cdot q_{\text{strip}}}{\sum_{\text{strips}} q_{\text{strip}}}$
- μTPC method: angle reconstruction

$$\Rightarrow \Theta = \arctan\left(\frac{1}{slope_{fit}} \times \frac{pitch}{v_{drift}}\right)$$

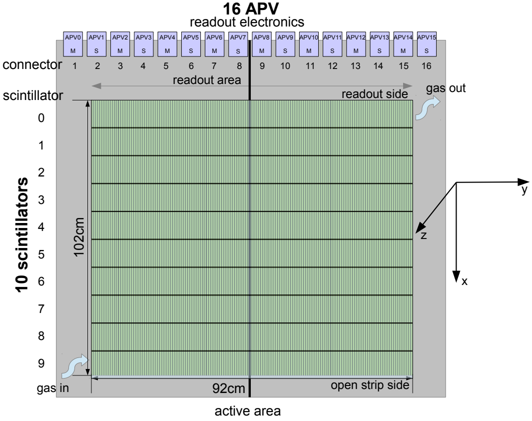
Experimental Setup - Cosmic Ray Facility, LMU



- two Monitored Drift Tube (MDT) reference chambers
  $\Longrightarrow$ two reference tracks
- two trigger scintillator hodoscopes
  $\Longrightarrow$ second coordinate
  $\Longrightarrow$ segmentation of test Micromegas in 10 cm wide segments
- active area $9\,\mathrm{m}^2$, $\Theta \in [-30^\circ, 30^\circ]$

$\Longrightarrow$ investigation of the whole active area of the Micromegas

1 m^2 Micromegas Chamber



- **active area**: $0.92 \times 1.02\,\mathrm{m}^2$
- **2048 electronic channels**
- **pitch**: 0.45 mm
- amplification gap: 128 µm
- drift gap: 5 mm
- **gas** @ atmospheric pressure
  - Ar:CO_2 93:7 vol%
  - Ne:CF_4 80:20 vol%
- gas flux: $\Phi = 8\ {}^{ln}/_{h}$
- **16 APV25 front-end** boards à 57.6 mm (y - coordinate)
- **10 scintillators** à 100 mm (x - coordinate)

$\Longrightarrow$ subdivision of detector in 16 APV $\times$ 10 scintillators $=$ 160 partitions

The detector (L1) was provided by the MAMMA collaboration (CERN)

Spatial Resolution - Centroid Method

residual $\Delta y = y_{\text{measured}} - y_{\text{predicted}}$

fit distribution with Gaussian function $\Rightarrow \sigma_{\text{res}}$

variation of E_{drift}

Ar:CO_2 93:7 vol%

- better spatial resolution for low E_{drift}
- due to smaller diffusion

Ne:CF_4 80:20 vol%

- equal spatial resolution for all E_{drift}
- similar to Ar:CO_2 93:7 vol% @ $E_{\text{drift}} = 200\,\text{V/cm}$

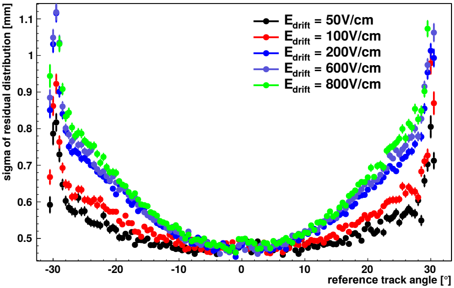
multiple scattering

2 GeV: $\Delta y(z_{\text{MDT2}} = 0.5\,\text{m}) = 0.67\,\text{mm}$

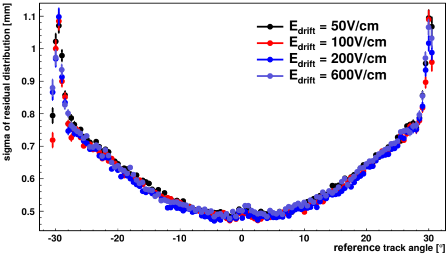
$\Longrightarrow \sigma_{\text{res}} > 0.45\,\text{mm}$

120 GeV pions: $\sigma_{\text{res}} \sim 90\ \mu\text{m}$ (CERN SPS H6)

Ar:CO_2 93:7 @ $E_{\text{ampl}} = 44.5\text{kV/cm}$



Ne:CF_4 80:20 @ $E_{\text{ampl}} = 42.2\text{kV/cm}$

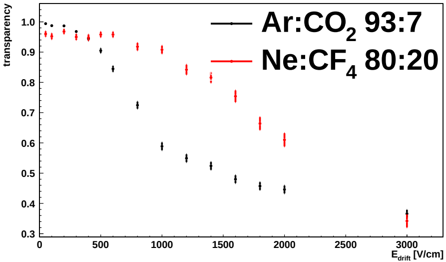


Electron Transparency of the Mesh

simulation of transparency using Garfield++, ELMER and Gmsh:

- electron transparency $\neq$ optical transparency due to ratio between drift and amplification field
- transparency $> 95\,\%$ at low E_{drift} for meshes with optical transparency $\approx 50\,\%$

mesh transparency



MPV of pulse height distribution:

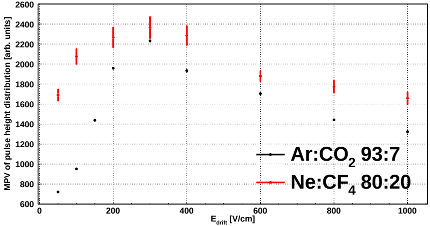
Ar:CO_2 93:7 vol%

- low E_{drift}: slow electron drift
  $\Longrightarrow$ integration time of readout not long enough
- high E_{drift}: low transparency

Ne:CF_4 80:20 vol%

- similar as for Ar:CO_2 93:7 vol%
- but higher transparency for high E_{drift}

pulse height distribution



Efficiency

3σ efficiency ($\Delta y < 3\sigma_{\text{res}}$):

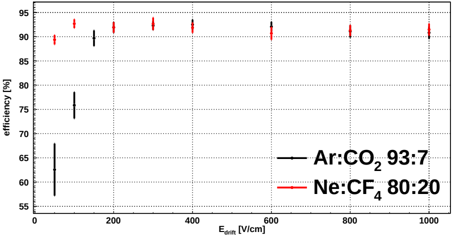
Ar:CO_2 93:7 vol%

- low E_{drift}: low efficiency due to integration time effect

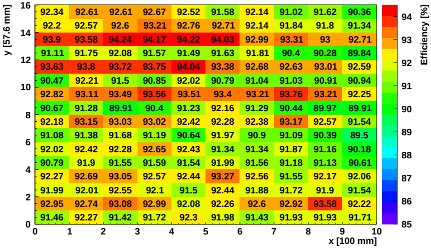
Ne:CF_4 80:20 vol%

- electron drift much faster for all E_{drift}
- no integration time effect

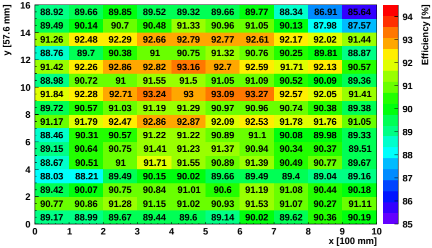
3σ efficiency



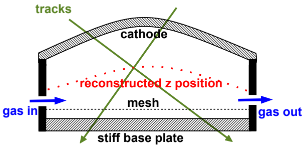
Ar:CO_2 93:7 @ $E_{\text{drift}} = 400\text{V/cm}$



Ne:CF_4 80:20 @ $E_{\text{drift}} = 400\text{V/cm}$



Inhomogeneity of Drift Velocity



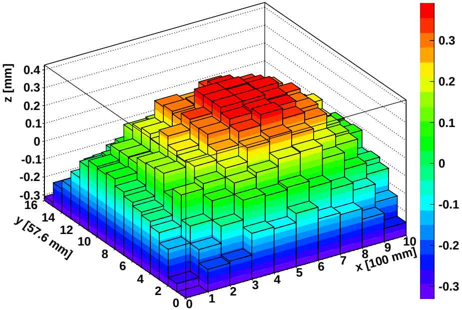
inclined muon tracks:

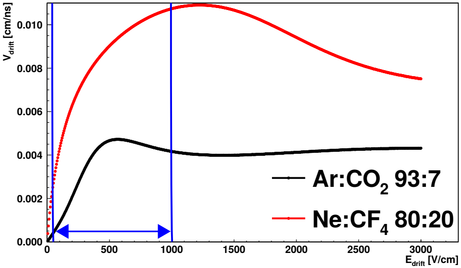
- drift gap deformation due to small overpressure (10 mbar)
- maximum deviation 0.8 mm from plane

⟹ 1.6 mm at drift cathode (stiff base plate support)

⟹ determination of drift velocity for each partition

measurement in CRF



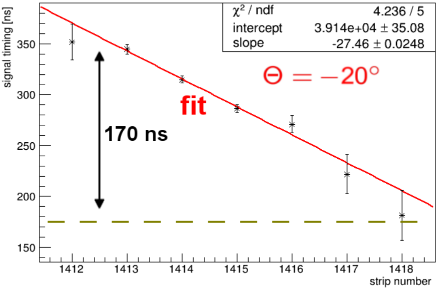


µTPC Method - Angle Reconstruction

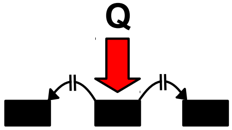
reconstruction of track angle

- drift velocity simulated with Magboltz
- strip pitch $= 0.45\,\mathrm{mm}$
- linear fit on (strip,t_{drift}) data points

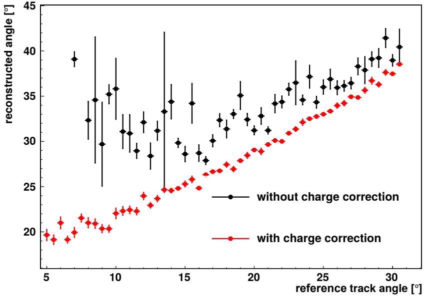
$$\Rightarrow \Theta = \arctan\left(\frac{1}{slope_{fit}} \times \frac{pitch}{v_{drift}}\right)$$



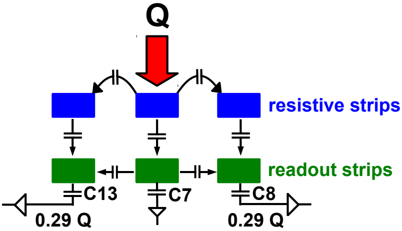
capacitive coupling between strips

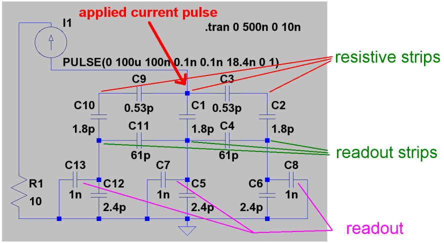


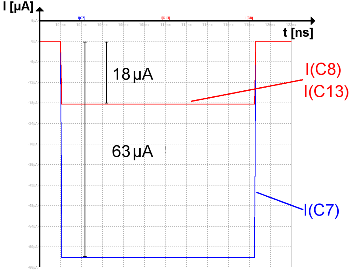
$\Longrightarrow$ needs correction
for each strip and timebin



Capacitive Coupling between Strips - LTspice Simulation







- simplified Micromegas,
  3 resistive strips, network
- current pulse applied on middle resistive strip

$$R_{xt} = 29\,\%$$

consequence:

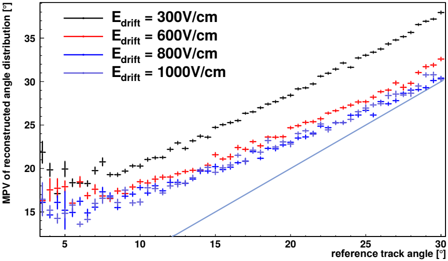
reconstructed angle > real angle

Angle Reconstruction with Charge Correction

$Ar:CO_2$ 93:7 vol%

- calculation of v_{drift} for each partition
- $E_{drift} \leq 300\,V/cm$: inhomogeneity of v_{drift} too large within partitions
- $E_{drift} > 300\,V/cm$: good result

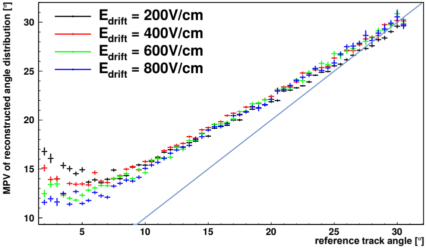
$Ar:CO_2$ 93:7 @ $E_{ampl} = 44.5kV/cm$



$Ne:CF_4$ 80:20 vol%

- good results for all E_{drift}
- better reconstruction of small angles for higher E_{drift}

$Ne:CF_4$ 80:20 @ $E_{ampl} = 42.2kV/cm$



Summary

- investigation of Micromegas in the Cosmic Ray Facility with different drift gas mixtures
  - Ar:CO_2 93:7 vol%
  - Ne:CF_4 80:20 vol%
- variation of E_{drift}
- equal spatial resolution with Ne:CF_4 80:20 vol% for all E_{drift}
- homogeneous efficiency $> 90\,\%$ for $E_{\mathrm{drift}} \geq 200\,\mathrm{V/cm}$
- larger pulse height variation for Ar:CO_2 93:7 vol% due to integration time effect and lower transparency
- simulation of capacitive coupling between strips of 29 %
- good angle reconstruction with charge correction for Ne:CF_4 80:20 vol% @ all E_{drift}
- improved algorithm for angular reconstruction and charge correction

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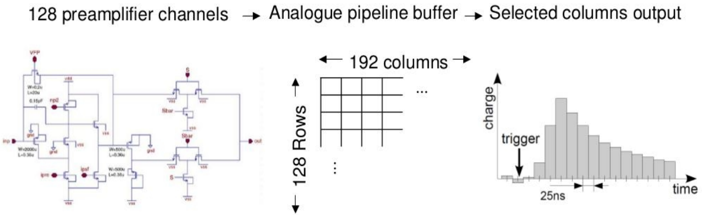
THANK YOU

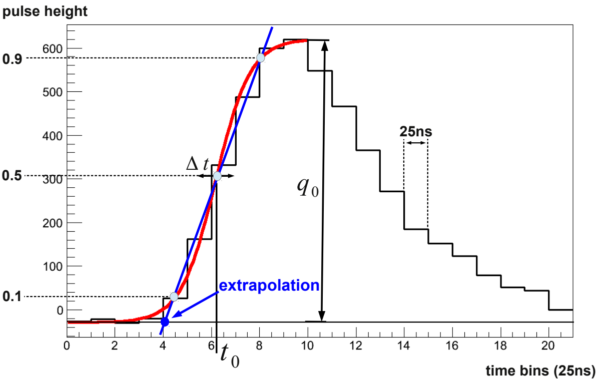
Backup

Readout with APV25



- 128 charge sensitive amplifier channels
- pipeline buffer of 192 cells depth for each input channel
- filled consecutively with every clock cycle
- blocks of one or more pipeline columns can be read out for each trigger

Start of Signal: Fit Using Inverse Fermi Function

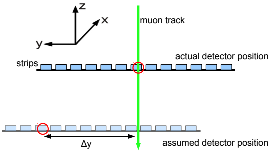


- signal-rise fitted with $q(t) = \frac{q_0}{1+\exp\left(\frac{t_0 - t}{\Delta t}\right)} \implies t_0$
- extrapolate starting point:
  - straight line through: **0.1**×Max, **0.5**×Max and **0.9**×Max of inv. Fermi function (Max $\hat{=}$ maximum of pulse height)
  - extrapolate to t_s = t(q = pedestal)

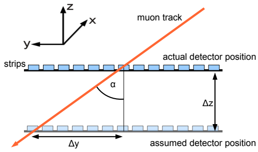
$\implies$ starting point: $t_s = t_0 - \frac{\ln(81)}{1.6} \Delta t$

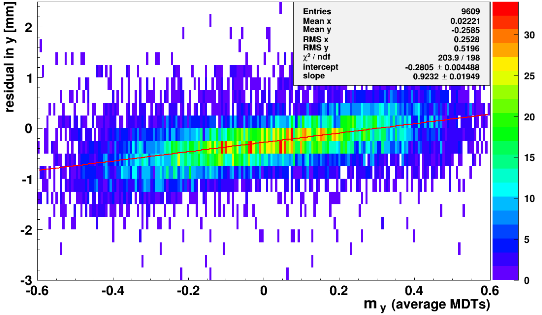
- correction in y (**perpendicular tracks**):
  residual via centroid method:
  $\text{res} = y_{\text{measured}} - y_{\text{predicted}}$
  $\Delta y = \text{res}$
- correction in z (**inclined tracks**):
  $\Delta z = \frac{\text{res}}{\tan \alpha}$
  $\text{res} = m_{\text{y}} \cdot \Delta z$
  with $m_{\text{y}} = \tan \alpha$
- fill a histogram
- fit with a straight line
  $\Rightarrow \Delta z = \text{slope}$
  $\Delta y = \text{intercept}$
- for each of the 160 segments

correction in y



correction in z

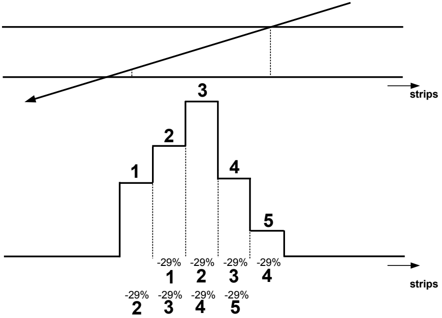




Charge Correction

due to capacitive coupling between strips

$$charge(i) = charge(i) - 0.29 \cdot charge(i+1) - 0.29 \cdot charge(i-1)$$



- cluster charge distribution for one timebin
- correct neighboring strips by coupling-effect-charge
- for each timebin
- neglect outer most strips if their charge is smaller than 29 % charge of neighboring strip