Precision Calibration of Large Area Micromegas Detectors Using Cosmic Muons

Philipp Lösel

LS Schaile
Ludwig-Maximilians-Universität München

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Outline

1. Motivation

2. Calibration of Large Area (1-3 m$^2$) Micromegas using Cosmic Muons

3. Micromegas Telescope in the Cosmic Ray Facility

4. Summary
Motivation: Excellent Spatial Resolution

small Micromegas:
- simple construction
- accurate realization
- well understood

large Micromegas (request):
- accuracy conservation at large scale
- more than one PCB:
  - precise assembly needed
  $\implies$ calibration needed
Working Principle of Micromegas

- MICROMEsh GASEous Structure (Micromegas)
- electron drift region
- amplification region
- charge collection on resistive strips
- charge detection on readout strips by capacitive coupling

centroïd method:

$$x_{cen} = \frac{\sum_{\text{strips}} x_{\text{strip}} \cdot q_{\text{strip}}}{\sum_{\text{strips}} q_{\text{strip}}}$$

μTPC method: angle reconstruction

$$\Theta = \arctan\left(\frac{1}{\text{slope}_{\text{fit}}} \times \frac{\text{pitch}}{v_{\text{drift}}}\right)$$

$$\text{slope}_{\text{fit}} = \frac{t_{\text{drift}}}{\Delta\text{strip}}$$
two Monitored Drift Tube (MDT) reference chambers
   ⇒ two reference tracks
two trigger scintillator hodoscopes
   ⇒ second coordinate
   ⇒ segmentation of test Micromegas in 10 cm wide segments
34 cm iron absorber ⇒ \( E_\mu > 600 \text{ MeV} \)
active area \( 9 \text{ m}^2 \), \( \Theta \in [-30^\circ, 30^\circ] \)

⇒ investigation of the whole active area of 2-3 m\(^2\) large Micromegas
- resistive strip technology
- **active area**: $0.92 \times 1.02 \, \text{m}^2$
- two readout boards with in total **2048 strips**
- **pitch**: 0.45 mm
- Ar:CO$_2$ 93:7 vol% @ atmospheric pressure

- **16 APV25 front-end** boards
  57.6 mm wide (y - coordinate)

- **10 scintillator segments**
  100 mm wide (x - coordinate)

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

$\Rightarrow$ **calibration and alignment for each of the 160 partitions**
**measurement of y position (perpendicular tracks):**
residual via centroid method:
\[ \text{res} = y_{\text{measured}} - y_{\text{predicted}} \]
\[ \Delta y = \text{res} \]

**measurement of z position (inclined tracks):**
\[ \Delta z = \frac{\text{res}}{\tan \alpha} \]
\[ \text{res} = m_y \cdot \Delta z \]
with \( m_y = \tan \alpha \)

**fit with a straight line**
\[ \Rightarrow \Delta z = \text{slope} \]
\[ \Delta y = \text{intercept} \]
Deformation of Drift Region

inclined muon tracks:

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

⇒ 1.6 mm at cathode (stiff base plate support)

- resolution < 0.1 mm

finite element simulation (ANSYS)
2 readout boards
no alignment tool used

perpendicular muon tracks:

- variation of gap size between PCB plates due to gluing
- **shift:** 100 µm
- **rotation:** 350 µm/m
- determination of strip position within 15 µm
Spatial Resolution – CRF

determination of spatial resolution:
- residual with centroid method
- fitted with double Gaussian function
- sigmas weighted by integral

spatial resolution limited by:
- multiple scattering
- extrapolated tracks from MDTs
- cut on slope of reference detectors

Ph. Lösel (LMU)
Precision Calibration Using Cosmic Muons
06/08/2016
120 GeV pions testbeam (H6 @ SPS/CERN):

- centroid method
- spatial resolution at $0^\circ$: $\approx 100 \mu m$
- angular dependent
Micromegas Telescope in the CRF

- comparison of large and small Micromegas
- investigation of spatial resolution

Telescope consisting of:

- $2 \times (9 \times 9) \text{ cm}^2 \ (Tmm1 + Tmm2)$
  - 2D readout
  - $250 \ \mu\text{m} \ \text{pitch}$
  - $\sigma < 60 \ \mu\text{m}$

- $1 \times (10 \times 10) \text{ cm}^2 \ (T1)$
  - 1D readout
  - $400 \ \mu\text{m} \ \text{pitch}$
  - $\sigma < 80 \ \mu\text{m}$

- $1 \times (102 \times 92) \text{ cm}^2 \ (L1)$
  - 1D readout
  - $450 \ \mu\text{m} \ \text{pitch}$
  - $\sigma < 100 \ \mu\text{m}$
Analysis of Telescope Data

spatial resolution (centroid method):
- same reconstruction method as before, MDTs as reference, no cuts applied
- L1 restricted to size of T1
- large error bars due to low statistics for the broad Gaussian

angle reconstruction:
- same quality
3σ tracking efficiency:
- homogeneous 3σ tracking efficiency over whole active area within 1%
- limited by multiple scattering
- regions with lower efficiency due to edge effects

reduced efficiency due to increased multiple scattering in telescope detectors
Summary

- calibration of the whole active area of large Micromegas in Cosmic Ray Facility with accuracy < 30 µm

- measurement includes:
  - homogeneity of efficiency and charge distribution
  - determination of z position with resolution < 0.1 mm
  - calibration of readout strip position every 10 cm with an accuracy of 15 µm

- L1 Micromegas (1 m²):
  - shift and rotation between readout boards calibrated
  - 1.6 mm deformation of the drift gap due to 10 mbar overpressure
  - spatial resolution limited by multiple scattering, also in MDTs

- measurements with a Micromegas telescope in CRF:
  - spatial resolution better for part of L1 covered by telescope
  - angle reconstruction similar for L1 and small detector
  - no drift gap deformation for small Micromegas

- uniformity of efficiency and pulse height at 1 m²
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THANK YOU
Backup
128 preamplifier channels $\rightarrow$ Analogue pipeline buffer $\rightarrow$ Selected columns output

- 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
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\times Max, 0.5\times Max and 0.9\times Max of inv. Fermi function (Max \(\hat{=}\) maximum of pulse height)
- extrapolate to \( t_s = t(q = \text{pedestal}) \)

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