Performance studies of large resistive Micromegas quadruplets in Test-Beams and High Radiation Environments

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Design
Resistive Micromegas with mechanical floating mesh

- Readout strips are covered by a 50μm thick Kapton foil carrying resistive strips (0.5-1MΩ/□) to limit spark currents
- Signals are induced via capacitive coupling to the readout strips
- The mesh is fixed to the drift panel facilitating detector opening and cleaning
- When the detector is closed the mesh is attached to the pillars by electrostatic force

Results from a long R&D phase to develop Micromegas suitable for large experiments

M. Iodice (5/8/16): Resistive Micromegas for the Muon Spectrometer upgrade of the ATLAS
The first large Micromegas quadruplet prototype

- 3 drift panels
- 2 readout panels with identical micromegas structure on both sides (back-to-back)
- 4 gas gaps
- 2 HV sectors per layer
- 128 μm amplification gap
  - woven stainless steel mesh: 30 μm wires, 50 μm opening
- 5mm drift gap
- 1024 readout channels/layer
  - 315 μm wide strips, 415 μm strip pitch
- Resistive strips sputtered in the Kapton foil

Schematic illustration of strips inclination:

- Layer 1: tilt 0°
- Layer 2: tilt 0°
- Layer 3: tilt -1.5°
- Layer 4: tilt +1.5°

- precision (η) coordinate
- precision (η) and transverse (φ) coordinates
Mechanical Accuracy
Plane-to-plane alignment

- A good alignment of the strips is of prime importance.
- The goal is to know the strip positions to better than 40 μm on all detection layers.
Plane-to-plane alignment

Mechanical measurement on eta readout panel before assembly
(using laser tracker)

- Position measurement of reference strips on both sides of the $\eta$ readout panels with respect to a reference pin penetrating the panel.
- The scans of both sides are compared and overlapped at the pin position. The magnification shows the strip-to-strip alignment accuracy better than $20 \mu m$. 

![Laser scan](image)

Reference pin

Strips routed to the PCB edge

![Graph](image)
Plane-to-plane alignment

After assembly (using X-rays)

Analysis procedure:
- Fit of the strips profile with double gaussian
- Extraction of the mean value of the core
- Calculation of the mean value between angle 0° and 180°
- Calculation of the difference between the two η layers

Using an X-Ray (Ag) gun, 2 runs at each position reverting the orientation of the gun to correct for possible inclination of the gun inside the box
  - Angle 0°
  - Angle 180°

<table>
<thead>
<tr>
<th>Angle</th>
<th>L1</th>
<th>L2</th>
<th>Mean</th>
<th>L1-L2 [strips]</th>
<th>L1-L2 [μm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0°</td>
<td>461.41</td>
<td>460.29</td>
<td>463.04</td>
<td>0.0465</td>
<td>19.297</td>
</tr>
<tr>
<td>180°</td>
<td>464.67</td>
<td>465.7</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Very good agreement with the mechanical method
Basic performance parameters
Detector Efficiency

**Cosmic event**

- Minimum cluster size 2 strips
- 1 missing strip accepted
- Threshold on strip charge

**Clusterization**

- Tracking of the muon using 3 reference layers
- Extrapolation of the expected position on the layer under test
- The presence of a cluster on the layer under test around the expected position defines the efficiency

**Efficiency algorithm**

- Fermi-Dirac function:
  \[ y = \frac{A}{1 + e^{(x - B)/C}} \]
  - A = the plateau value of the efficiency
  - B = the flex point
  - C = how steep is the turn-on curve.

- Differences among the layers is due to small variations of the amplification gap
- HV sectors within the same layer show the same efficiency

**Efficiency graphs**

- Left HV sector
- Right HV sector

**Numerical results**

- L1: \( x^2/\text{ndf} = 59.84/3 \)
  - 0: 0.9972 ± 0.0005592
  - 1: 503.8 ± 0.1965
  - 2: 15.65 ± 0.1604

- L2: \( x^2/\text{ndf} = 75.75/3 \)
  - 0: 0.9972 ± 0.0007443
  - 1: 517.6 ± 0.1502
  - 2: 15.96 ± 0.1296

- L3: \( x^2/\text{ndf} = 144.7/3 \)
  - 0: 0.9999 ± 5.097e-05
  - 1: 528.5 ± 0.1531
  - 2: 17.21 ± 0.09755

- L4: \( x^2/\text{ndf} = 53.24/3 \)
  - 0: 0.9999 ± 0.0003154
  - 1: 531.3 ± 0.1525
  - 2: 18.34 ± 0.1121
Gain Uniformity after assembly

**X-Rays**

- Monitor of the amplification current
- X-Ray settings: HV=50kV, I=50μA, 2 mm collimator (cone angle 5°)
- 228 different points
- Layers under study set to 560V

**Cosmic rays**

- A window of 20 strips around each area that was irradiated with the X-rays is considered
- For each (x,y) point the cluster charge has fitted with a landau function. The MPV was extracted and plotted to the corresponding position
Gain Uniformity after assembly

**X-Rays**

L3 X-Ray current

**Cosmic rays**

MPV of cluster charge L3

Amplification current compared with the cluster charge (Layer 3)

- X-ray
- Cosmics

Very good agreement between X-Rays & cosmics
Resolution of 88 μm for the precision coordinate (η) and 2.28 mm for the transverse (φ) one has been obtained.
A dedicated irradiation facility with photon energy of ~662 KeV and flux up to $10^8$ cm$^{-2}$s$^{-1}$:

Filter system permits attenuating the photon flux in several steps to reach attenuation factors of several orders of magnitude (~1 - $10^5$)

*R.Guida* (5/8/16): GIF++ A new CERN irradiation facility to test large-area particle detectors for HL-LHC
The steps of currents at different attenuation filters are because of the voltage scans (amplification & drift).

Data with muon beam were taken with source and different attenuation filters:

- Spatial resolution for precision coordinate at muon beam (photon source off):

\[ \sigma / \sqrt{2} = 75 \mu m \]

**Poster Session on Monday:** Performance studies under high irradiation of resistive bulk-micromegas chambers at GIF++
Conclusions

- The construction of the first large four-plane resistive Micromegas detector was achieved serving as prototypes for large experiments.
- The alignment of the readout layers was measured during the construction using a laser and after the assembly using X-Rays. Both methods agree on alignment better than 20 μm.
- The gain uniformity has been studied with both X-Rays and Cosmic rays providing comparable results.
- The intrinsic spatial resolution was determined in an electron and muon beam to be better than 100 μm in the precision coordinate.
- Analysis of data with muon beam and photon background is ongoing.
- The detector is currently installed in GIF++ for long term ageing studies.
Thank you!!!
BACK-UP
Cosmic set-up

- Cosmic stand composed by two planes of 12 scintillators in the CERN GDD laboratory of the RD51 Collaboration.
- Total area $\sim 2.5 \text{ m}^2$

DAQ based on the SRS
- 32 APVS
- 2 FEC fully equipped
- dedicated DAQ software