Development of Large-Size Micromegas Detector for the Upgrade of the ATLAS Muon System

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on behalf of

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https://twiki.cern.ch/twiki/bin/view/Atlas/MuonMicromegas

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The Upgrade of ATLAS

- LHC upgrade
  - \( L_{SLHC} \approx 10 L_{LHC} \) (phase 2)
  - BC time = 50 ns (25 ns)

- Highest rate regions in the ATLAS Muon Spectrometer:
  - EI layer (CSC, MDT, TGC)
  - EM layer \( \eta \geq 2 \) (MDT, TGC)
  - Total area \( \approx 400 \text{ m}^2 \)

- Real rates after first collisions
Micromegas as candidate technology

- Combine triggering and tracking functions
- Matches required performances:
  - Spatial resolution \( \sim 100 \, \mu m \) \((\Theta_{\text{track}} < 45^\circ)\)
  - Good double track resolution
  - Time resolution \( \sim 5 \, \text{ns} \)
  - Efficiency > 98%
  - Rate capability > 5 kHz/cm²
- Potential for going to large areas \( \sim 1m \times 2m \) with industrial processes (bulk-Micromegas)
  - Cost effective
  - Robustness
- Never used in large muon systems
R&D Activity: the first prototype

- Standard bulk micromegas fabricated at CERN in 2007
- Homogeneous stainless steel mesh
- 325 line/inch = 78 μm pitch
- Wire diameter ~25 μm
- Amplification gap = 128 μm
- 450mm x 350mm active area
- Different strip patterns (250, 500, 1000, 2000 μm pitch; 450 mm and 225 mm long)
- Drift gap: 2-7 mm
- Characterized in lab and tested on beam
**Laboratory test**

- **Test with $^{55}$Fe source**
  - Energy resolution $\sigma \approx 22\%$
  - Gas amplification $10^3$-$10^4$
  - Electron transparency $> 90\%$ for $E_{\text{amp}}/E_{\text{drift}} > 100$

Lines are from GARFIELD simulation
Test beam set up

- Detector tested @ CERN H6 beam line in 2008
- 120 GeV pion beam
- Scintillator trigger
- External tracking with three Si detector modules (Bonn Univ.); independent DAQ
- Three non-flammable gas mixtures with small isobutane percentage:
  - Ar:CO$_2$:iC$_4$H$_{10}$ (88:10:2), Ar:CF$_4$:iC$_4$H$_{10}$ (88:10:2), Ar:CF$_4$:iC$_4$H$_{10}$ (95:3:2)
- Data acquired for 4 different strip patterns and 5 impact angles (90° to 50°)
Readout

DAQ based on ALTRO CHIP

FEC

32 channels

Two inverted diodes for spark protection

Zero channels died

32 channels
200 ns integration time
65 charge samples/ch
100 ns/sample
15 pre-samples
1 ADC count ~ 1000 e-
No trigger time info recorded

Typical ADC spectra

- Noise subtraction (from 12 pre-samples)
- Cluster position from center of gravity
Simple event display

Micromegas

Si module 1

Si module 3

Si module 6

8mm (32x250 µm)

16mm (32x500 µm)
Gain measurement on beam

- Gas mixture: Ar:CF$_4$;iC$_4$H$_{10}$ (88:10:2)
- Drift gap 5 mm; drift field = 200 V/cm
- Strip pitch = 250 µm
- 1 ADC count = 1000 electrons

- Good agreement with measurement with $^{55}$Fe source
- Stable working point @ gain $\sim 3 \cdot 10^3$
Efficiency

- Gas: Ar:CF₄:iC₄H₁₀ (88:10:2)
- Strips: 500 µm pitch 400 µm width
- $V_{\text{mesh}} = 450$ V
- Drift field = 200 V/cm

- Black: beam profile
- Red: event with micromegas not efficient

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Efficiency vs $V_{\text{mesh}}$

- $\text{Eff} > 98\% @ V_{\text{mesh}} > 430 \text{ V} (\text{Gas Ampl.} > 10^3)$
- Working point: $V_{\text{mesh}} = 440-450 \text{ V}$

Gas: Ar:CF$_4$:iC$_4$H$_{10}$ (88:10:2)
- Strips: 500 µm pitch 400 µm width
- $V_{\text{mesh}} = 450 \text{ V}$
- Drift field = 200 V/cm
Spatial resolution

- Residuals of MM cluster position and extrapolated track from Si
- Convolution of:
  - Intrinsic MM resolution
  - Tracker resolution (extrapolation)
  - Multiple scattering

\[ \sigma_{\text{MM}} = (24 \pm 7) \mu m \]

\[ \sigma_{\text{MM}} = (36 \pm 5) \mu m \]

Gas: Ar:CF$_4$ iC$_4$H$_{10}$ (88:10:2)

Drift field = 220 V/cm

\[ V_{\text{mesh}} = 470 \text{ V} \]

Perpendicular tracks

Strip pitch: 250 µm
Strip width: 150 µm

Strip pitch: 500 µm
Strip width: 400 µm

\[ \text{Mean} = (0.3 \pm 1.1) \mu m \]
\[ \text{Sigma} = (65.7 \pm 1.1) \mu m \]

\[ \text{Mean} = (3.5 \pm 1.3) \mu m \]
\[ \text{Sigma} = (70.7 \pm 1.3) \mu m \]
Micromegas as μ-TPC

- Measure arrival time of signals on strips and reconstruct space points in the drift gap
- Solves the problem of spatial resolution for large track inclination
- A time resolution of 1ns results in a space point resolution of 5-10 μm along the drift direction

Example on a real event:

- Gas: Ar:CF₄:iC₄H₁₀ (95:3:2)
- Drift field = 360 V/cm
- Drift velocity = 7.8 cm/μs (Magboltz)
- Chamber rotation = (50±3)°
- Reconstructed track inclination = (46±4)°
Micromegas as $\mu$-TPC

- With a good time resolution a good local track reconstruction is possible
- A (slightly) larger drift gap will help in getting a better time resolution
- Requirement to operate MM in $\mu$-TPC mode:
  - Small strip pitches (250 $\mu$m)
  - Time resolution with $O$(few ns) resolution
  - moderate charge measurement (TOT)

- Gas: Ar:CF$_4$:iC$_4$H$_{10}$ (88:10:2)
- Drift field = 220 V/cm
- Drift velocity = 6.8 cm/$\mu$s (Magboltz)
- Chamber rotation = (50±3)$^\circ$
- Reconstructed track inclination = (57±6)$^\circ$
- Resolution = 11%
Future plans

- New test beam measurement on the first prototype
- A 50% prototype now under construction
  - 400 x 1300 mm² active area
  - Segmented mesh
  - One group of strips with resistive coating
  - Strip pitches: 250 µm and 500 µm
  - Long (~100 cm) and short (~40 cm) strips
- Irradiation test in neutron facility on small chamber
- Finalization of construction and working parameters
- Read-out
- Ageing test
- Implementation in ATLAS (?)
Summary & conclusions

- With SLHC an upgrade of some ATLAS Muon chambers is needed
- Micromegas technology is a good candidate
- 350 x 450 mm\(^2\) prototype built and tested
- Test with encouraging results
  - Good working performance (gas amplification, efficiency)
  - Measured spatial resolution of 24 µm (36 µm) with 250 µm (500 µm) strips
  - For inclined tracks, local track reconstruction is possible: MM in µ-TPC mode
- New test beam campaign now with improved DAQ
- 50% prototype chamber (400 x 1300 mm\(^2\)) under construction
- Decision about which detector technology will be chosen to be taken “soon” by the ATLAS Muon community (probably this year)
Back-up slides
Tracks with different impact angle

Impact angle: 90°

Cross-talk

Impact angle: 50°
Drift velocity from simulation

Drift velocity

\[ \sigma = 20-30 \text{ ns} \]
\[ \sigma_m \approx 1.2 \text{ ns} \]

Peak time distribution
Strip response uniformity

Ratio (strip response/average) of MPV of Landau distribution

Similar behavior for different strips

Small variation mainly related to electronics (not to strips)