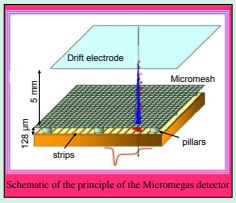

Schematic of the principle of the Micromegas detector

Development of Large Bulk-Micromegas for the Upgrade of the ATLAS Muon System for the sLHC

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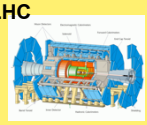
on behalf of the ATLAS-MAMMA R&D Project

Arizona, Athens (U, NTU, Demokritos), Brookhaven, CERN, Harvard, Istanbul (Bogaziçi, Doğuş), Naples, Seattle, USTC Hefei, CEA Saclay, Stony Brook, South Carolina, St. Petersburg, Shandong, Thessaloniki, Washington

ATLAS Upgrade for the sLHC

- LHC upgrade to happen in two phases
  - $L_{Phase\ I} \sim 3 \cdot L_{LHC}$ (≥2017)
  - $L_{Phase\ II} \sim 10 \cdot L_{LHC}$ (≥2020)
- Bunch crossing = 25 ns (? 50 ns in Phase II)

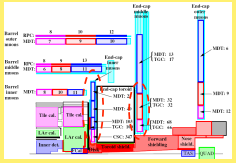


Total area of Muon System affected: ~400 m²

- End-Cap Inner (CSC,MDT,TGC)
- End-Cap Middle |η|>2 (MDT,TGC)

Muon upgrade for Phase I:

- Add a layer of new chambers with several detection planes to augment the performance of the Cathode Strip Chambers (CSC)



Average single plane counting rate (Hz/cm²) at the nominal LHC luminosity 10^{34} cm^{-2}s^{-1} (CERN-ATL-GEN-2005-001)

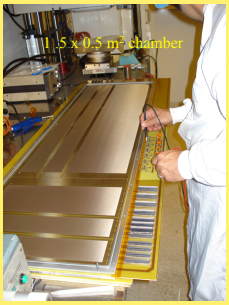
- The luminosity upgrade of the Large Hadron Collider at CERN (sLHC) foresees a luminosity increase by a factor 10 compared to the LHC. To cope with the corresponding increase in background rates, the Muon System of the ATLAS experiment at CERN will likely need major changes in, at least, the highest rapidity region.
- The MAMMA-ATLAS R&D activity is focused on the development of large-area muon detectors based on the bulk-Micromegas technology as candidates for such an upgrade.
- The detectors will combine trigger and precision tracking in a single device. Their low costs, compared to other detector technologies, and their potential for industrial production make the bulk-Micrormegas excellent candidates for mass-construction of large muon chambers.
- Beam tests of a 0.5 m² size prototype chamber have been performed in 2009, as well as several tests with different types of resistive coating of the readout electrodes, in order to reduce sparking of the chambers. A full-size prototype (1 m²) for the ATLAS upgrade Phase I is currently under construction; it includes on-chamber integration of the front-end and readout electronics.

Requirements on Micromegas for the ATLAS Muon Upgrade

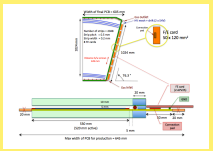
- Combine triggering and tracking functions
- Spatial resolution < 100 μm (up to 45°)
- Good double track resolution
- Time resolution ~ 5 ns
- Efficiency > 99%
- Rate capability > 15 kHz/cm² (includes 200 Hz/cm² from neutron induced hits with E_n>100 keV)

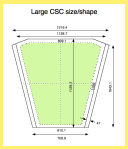
Micromegas Prototypes

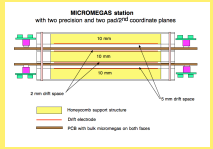
- P1: 350 x 450 mm² standard, various strip pitches (reference chamber)
- P3: 500 x 1500 mm² standard, 250 and 500 μm strip pitches, strips 400 and 1000 mm long; 6 mesh segments
- S3: Standard 100 x 100 mm²; 250 μm strip pitch
- R3: as S3 + resistive paste on strips (150-200 μm, 10 MΩ), covered with metallic pads (1 x 0.15 mm²)
- R5: as S3 + resistive paste (1 mm, 5 kΩ) and metallic pads above strips
- MM (S2) + GEM/MM for double-stage amplification



Under construction: CSC size micromegas







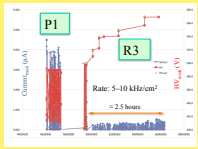
Micromegas with Resistive Coating

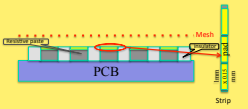
Goal:

- Make MMs insensitive to discharges induced by large energy deposits (highly ionizing particles)
- Limit discharge current to avoid HV break-down

Approach:

- Thin layers of resistive paste on readout strips, with metallic pads
- Signal through capacitive coupling to strip
- Small pad/mesh capacity
- First measurements promising (R3 in plot)
  - No HV drop up to high local rates
  - Currents in few 100 nA range
  - Much better performance compared to 'non-resistive' chamber P1
- Still some technical problems with reliable electrical contacts; work in progress

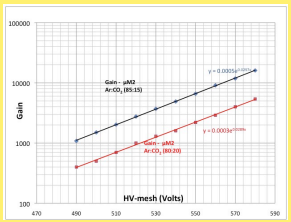




Performance Studies in H6 Beam at CERN

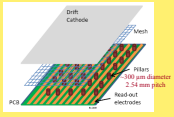
2009 Test beam set up

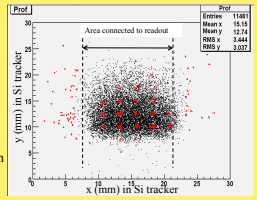
- 120 GeV pion beam
- Scintillator trigger
- External Si tracker (Bonn Univ.)
- Gas mixtures tested: Ar:CO_2:iC_4H_{10} (88:10:2), Ar:CF_4:iC_4H_{10} (88:10:2), Ar:CF_4:iC_4H_{10}(95:3:2) Ar:CO_2 (85:15)



Micromegas gain measurements for two different gases.

Efficiency & pillar localization

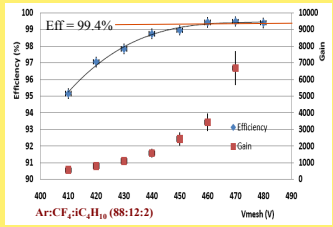




Measured in 120 GeV pion beam

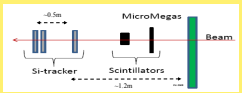
- Ar:CF_4:iC_4H_{10} (88:10:2)
- Strips: 500 μm pitch
- V_{mesh} = 450 V (35.2 kV/cm)
- Drift field = 200 V/cm

Black: beam profile
Red: tracks w/o micromegas hit



Pillars contribute to the geometrical inefficiency of the chamber at the ~1% level.

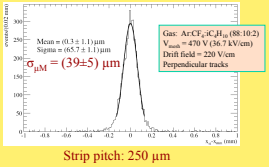
Spatial Resolution



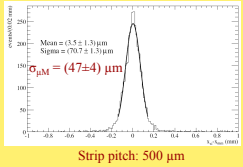
Residuals of MM cluster position and extrapolated track from Si tracker. Contributions to width of distribution:

- Si telescope extrapolation to μM
- Multiple scattering
- Intrinsic μM resolution

} ~53 μm

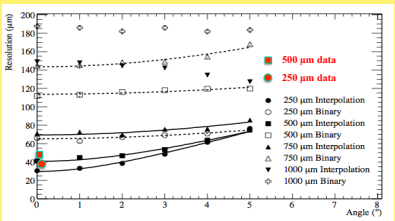


Strip pitch: 250 μm



Strip pitch: 500 μm

Comparison: Data with Simulation

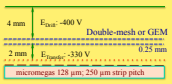


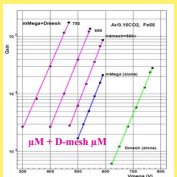
Spatial resolution for charge interpolation and binary read-out as a function of the incidence angle and strip pitch (simulation); also shown is the measured spatial resolution for 250 and 500 μm strip pitch.

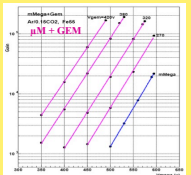
μM with two-stage amplification

Test of 100 x 100 mm² μM with pre-amplification stage made of

- double-mesh μM
- standard GEM



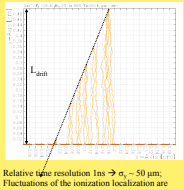




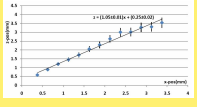
Micromegas as μ-TPC

For non-perpendicular incidence position resolution is degraded due to fluctuation of charge deposition along the track

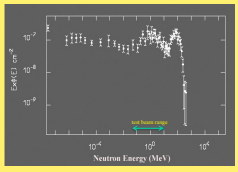
Use the Micromegas as a μ-TPC: Measure arrival time of signals on strips and reconstruct space points in the drift gap



Relative time resolution 1ns → $\sigma_x \sim 50$ μm; Fluctuations of the ionization localization are of the same order of magnitude



- Gas: Ar:CF_4:iC_4H_{10} (95:3:2)
- Drift field = 360 V/cm
- Drift velocity = 7.8 cm/μs (Magboltz)
- Chamber rotation = (40±3)°
- Reconstructed track inclination = (44±4)°

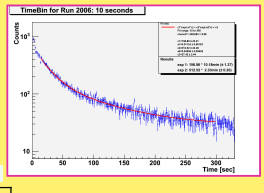


The energy spectrum of the neutron background ration in the ATLAS Hall (ATLAS muon TDR, 1997)

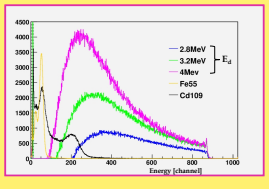
The "N.C.S.R. Demokritos" neutron facility serves as a micromegas beam test lab

Nuclear Reaction	Proton/Deuteron Energy Range (MeV)	Neutron Energy Range (MeV)
^{7}Li(p,n)^{7}Be	1.9 to 8.4	0.1 to 6.7
^{2}H(d,n)^{3}He	0.8 to 8.4	3.9 to 11.5
^{3}H(d,n)^{4}He	0.8 to 8.4	16.4 to 25.7

Activation of a micromegas in a neutron beam



- Lifetimes of :
  - ^{28}Al (2.24 min)
  - ^{27}Al(n,p)^{27}Mg (9.46 min)



Energy spectra corresponding to the net neutron contribution and to the superimposed calibration with ^{55}Fe & ^{109}Cd sources.

References:

T. Alexopoulos et al., *The ATLAS muon Micromegas R&D project: towards large-scale chambers for the s-LHC*, JINST, 4:P12015,2009
T. Alexopoulos et al., *Development of large size Micromegas detector for the upgrade of the ATLAS Muon System*, NIM A.2009.06.113
T. Alexopoulos et al., *Study of a micromegas chamber in a neutron beam*, accepted for publication in JINST