# Development of large-area resistive-strip micromegas chambers for the ATLAS muon system upgrade

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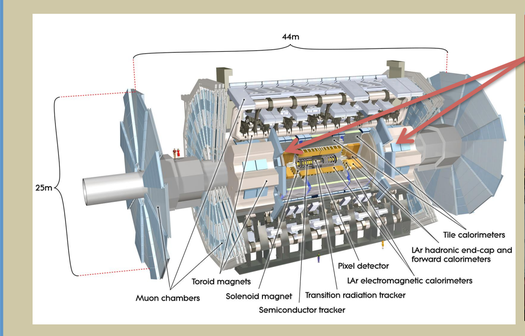
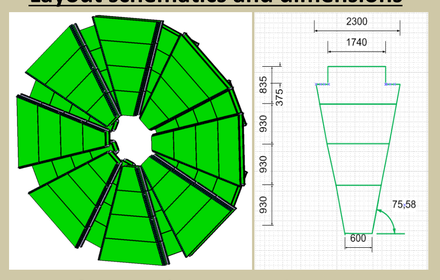
## ATLAS Small Wheel upgrade



**Requirements**

- ☑ Rate capability: ≤ 9 kHz/cm$^2$
- ☑ Spatial resolution: 60 μm/track segment
- ☑ Angular resolution: 0.3 mrad/segment
- ☑ Good double track resolution
- ☑ Trigger capability: BCID (ang. resol. ≈ 1 mrad)
- ☑ Efficiency: 98%/plane
- ☑ Radiation resistance and good ageing properties

**Layout schematics and dimensions**



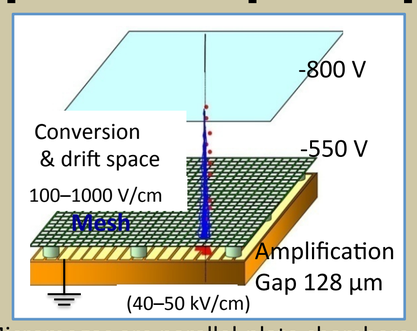

Segmentation Large sector

In the 2018 LHC long shut down it is foreseen to replace the existing small wheels to cope with the expected high luminosity. Resistive-strip micromegas have been chosen as precision chambers as the baseline for the upgrade of the Small Wheels. Micromegas' trigger functionality will be used as backup for TGC trigger chambers.

**Micromegas in the Small Wheels**

- Replace the muon chambers of the Small Wheels with 128 micromegas chambers of 0.5 m$^2$ to 2.5 m$^2$ area, each
- Micromegas provide precision, 2$^{nd}$ coordinate measurement and trigger functionality in a single device
- Each chamber comprises eight active layers, arranged in two multilayers: a total of about 1200 m$^2$ of detection layers; 2M readout channels (30k trigger channels)

## Operation principle



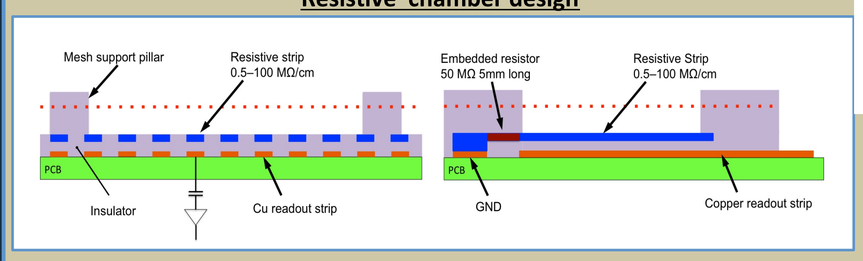

- Micromegas are parallel-plate chambers
- With amplification in a thin gap, separated from the conversion region by a metallic mesh
  *I. Giomataris et al., NIM A 376 (1996) 29*

Usual operating parameters: Ar:$CO_2$ (93:7) at atmospheric pressure, -800 V drift, -510 V mesh

## Spark protection in resistive strip micromegas

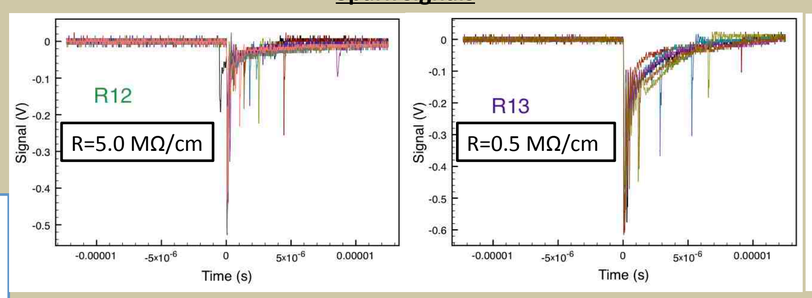
Micromegas fulfil all the requirements for the Small Wheel upgrade but there was one weak spot: the sparks. To counter this a layer of resistive strips has been introduced above the readout strips. This spark protection effectively renders the sparks harmless.

**Resistive chamber design**



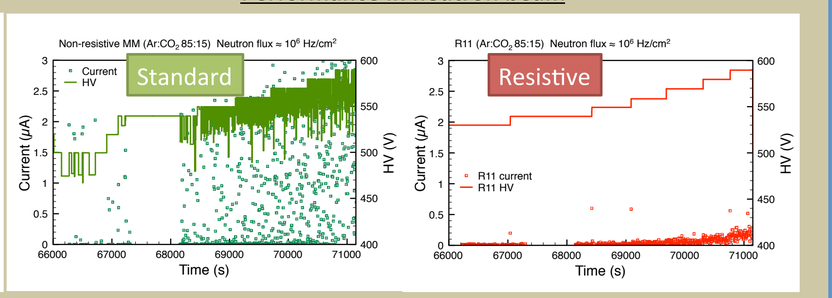

*T. Alexopoulos et al. Nucl. Instr. and Meth. A 640 (2011) 110*

**Spark signals**




- Spark signals (currents) for resistive chambers are about a factor 1000 lower than for standard micromegas (spark pulse in non-resistive MMs: few 100 V)
- Spark signals fast (<100 ns), recovery time a few μs, slightly shorter for R12 with strips with higher resistance

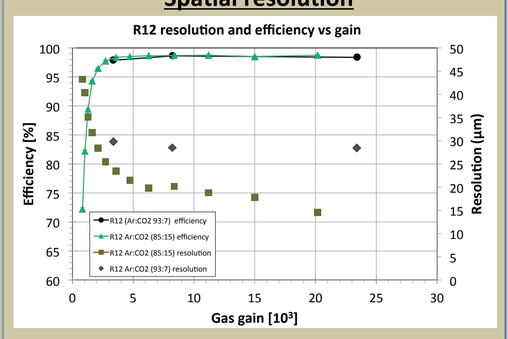
**Performance in neutron beam**




- Standard MM could not be operated in neutron beam
- HV break-down and currents exceeding several μA already for gains of order 1000–2000
- MM with resistive strips operated perfectly well,
- No HV drops, small spark currents up to gas gains of 2 x 10$^4$

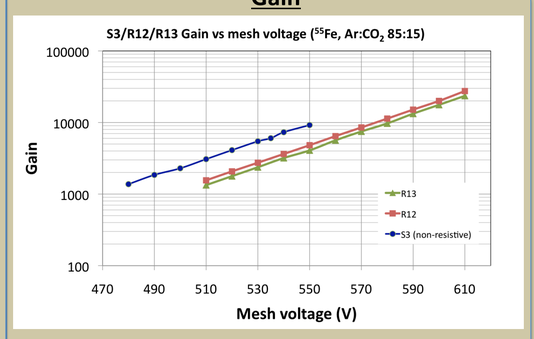
## Performance

**Spatial resolution**



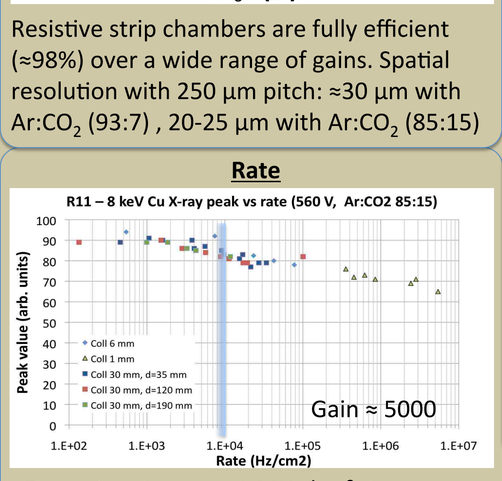

Resistive strip chambers are fully efficient (≈98%) over a wide range of gains. Spatial resolution with 250 μm pitch: ≈30 μm with Ar:$CO_2$ (93:7) , 20-25 μm with Ar:$CO_2$ (85:15)

**Gain**




Difference between standard and resistive micromegas gains vs. mesh voltage with $ArCO_2$ (85:15)

**Rate**




Clean signals up to >1 MHz/cm$^2$, but some loss of gain. Blue band marks expected highest rates in ATLAS Small Wheel

**Long term X-ray exposure**

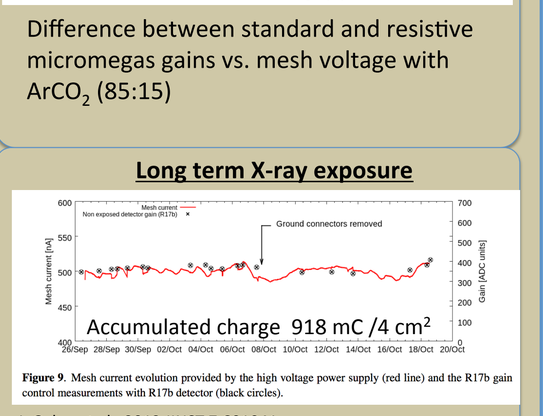
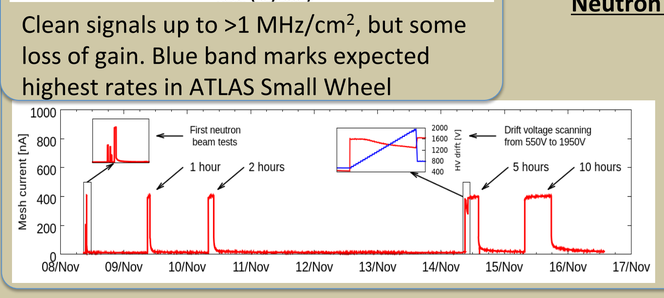



**Figure 9**. Mesh current evolution provided by the high voltage power supply (red line) and the R17b gain control measurements with R17b detector (black circles).

J. Galan et al., 2012 JINST 7 C01041

**Neutron irradiation at the Orphee reactor**

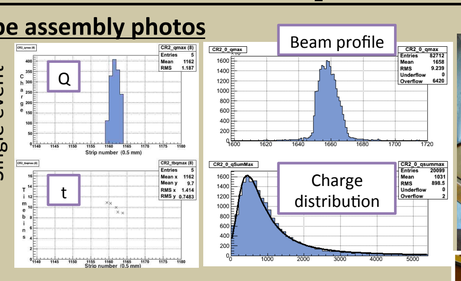


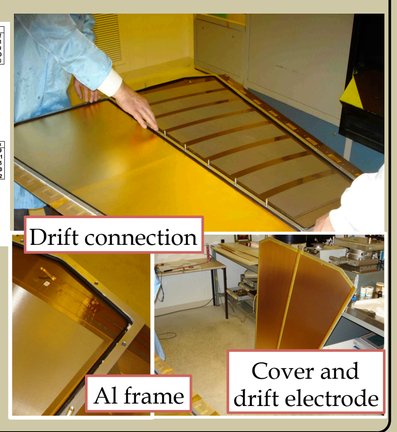

- $n_{flux}$ ≈ 0.8 x 10$^9$ n/cm$^2$/s,
- energy 5-10 x 10$^{-3}$ eV
- Total exposure time 40 h (equivalent 20 years of LHC at 5x10$^{34}$ cm$^{-2}$s$^{-1}$)
- Detector response perfectly stable over full duration of irradiation

## Detector Development

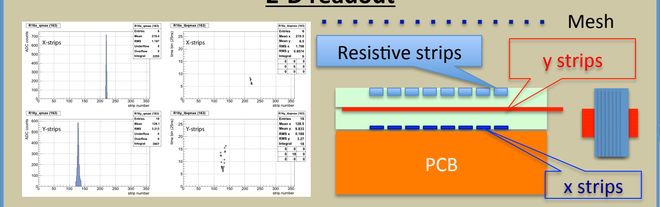
**Large area chambers: 2011 prototype assembly photos**

- Size: 1.2 x 0.6 m$^2$
- 2048 circular strips, pitch: 0.5 mm
- Mesh: 400 lines/inch
- 5 mm high frame defines drift space
- O-ring for gas seal
- Closed by a 10 mm foam sandwich
- Panel serving at the same time as drift electrode




**2-D readout**




X strips: 250/150 μm r/o and resistive strips
Y strips: 250/80 μm: only r/o strips

R16 chamber resistivity
$R_G$ ≈ 55 MΩ
$R_{strip}$ ≈ 35 MΩ/cm

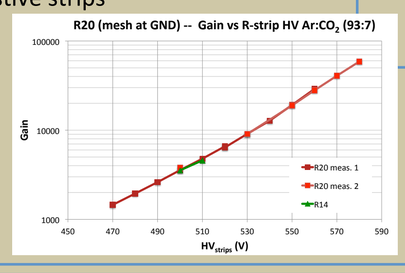
**Readout electronics: readout and trigger through VMM01 chip**

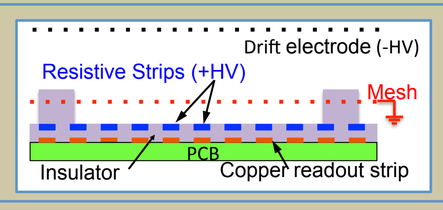
- A new chip is being developed in BNL for reading out micromegas chambers
- Prototypes to be tested during test beam in July 2012
- Features:
  - Zero suppression, Peak finding, Time measurement, 64 channels, Trigger output (16)

*G. De Geronimo et al. TWEPP and IEEE/NSS 2012 meetings*

**Inverted HV scheme**

- Positive voltage on resistive strips
- Mesh to GND potential
- Simplifies construction
- MM achieve higher gain



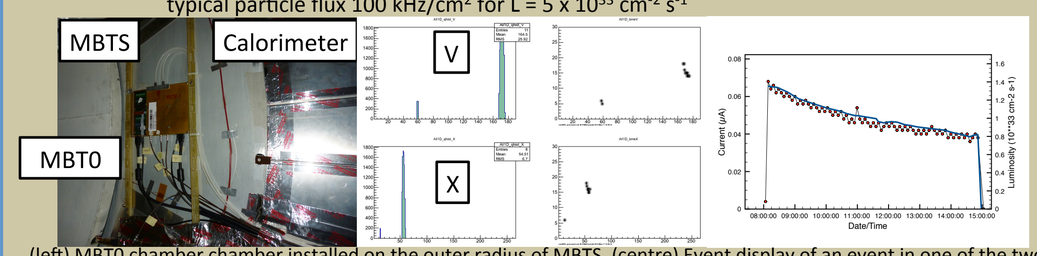

## Prototypes installed in ATLAS in 2012

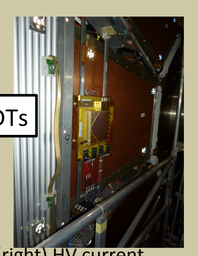
**MBTS-A Location at z = 3.5 m**

Small 9x4.5 cm$^2$ detector at r = 1m (on front face of end-cap calorimeter)
typical particle flux 100 kHz/cm$^2$ for L = 5 x 10$^{33}$ cm$^{-2}$ s$^{-1}$

**Small Wheel - A Sec 9**

Four 9x9 cm$^2$ chambers at CSC Sector 9




(left) MBT0 chamber chamber installed on the outer radius of MBTS. (centre) Event display of an event in one of the two gas gaps. (right) HV current superimposed on ATLAS luminosity (LHC fill 2580). Readout of these chambers now runs in the random trigger mode. Integration into ATLAS readout in progress *(see A. Zibell, Development of a Read Out Driver for Micromegas at ATLAS )*

## Near-future development plans

- 1 x 1 m$^2$ prototype by summer 2012
- 1 x 2 m$^2$ prototype by the end of 2012
- Readout integration of the SRS-based readout electronics with ATLAS DAQ