13th Pisa Meeting on Advanced Detectors – May 2015 Elba

Characterization of the ATLAS Micromegas quadruplet prototype

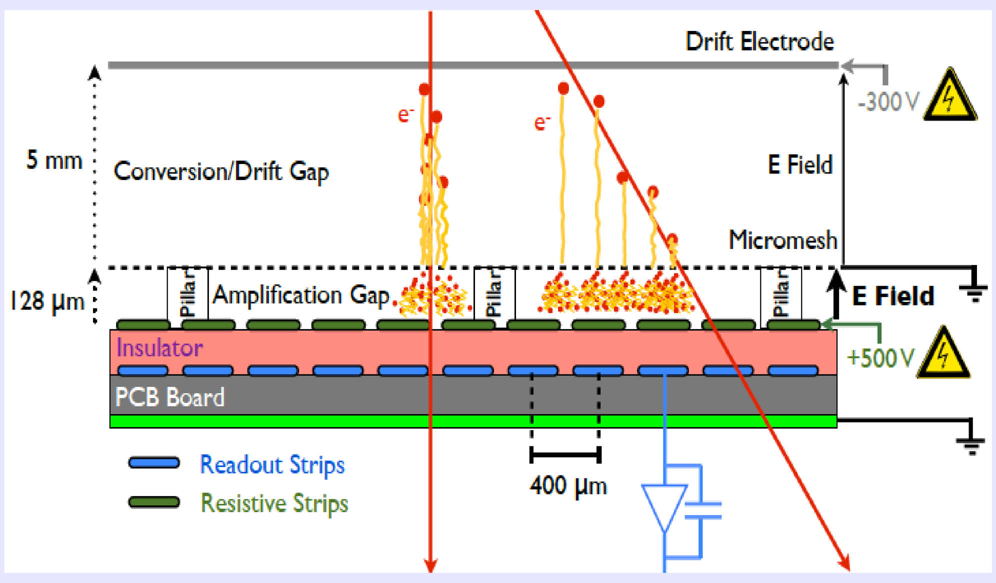
A Micromegas detector with four active layers, serving as prototype for the upgrade of the ATLAS muon spectrometer, was designed and constructed in 2014 at CERN and represents the first example of a Micromegas quadruplet ever built. The detector has been realized using the resistive-strip technology and decoupling the amplification mesh from the readout structure. The four readout layers host overall 4096 strips with a pitch of 415 μm, two layers have strips running parallel (η in the ATLAS reference system, for measuring the muon bending coordinate) and two layers have inclined strips by ±1.5° with respect to the η coordinate, in order to provide measurement of the second coordinate.

A complete detector characterization carried out with cosmic muons and a novel method based on X-Ray irradiation, used for fast detector characterization presented with the obtained results.

The Micromegas principle

Micromegas are parallel plate avalanche chambers proposed by I.Giomataris et al.(NIM A 376 - 1996). They consist of a several millimeter wide drift region and an approximately 0.1 mm wide amplification region, separated by a thin conductive micro-mesh.

Charged particles or photons traversing the drift space ionize the gas releasing electron-ion pairs depending on the type and the energy of the detected particle. Ionization electrons drift within 100 ns into the high-field amplification region while the ions drift towards the cathode. Upon reaching the amplification region, the electrons are multiplied in an avalanche like process and they are released on the anode strips where they can be detected with charge- or current-sensitive pre-amplifiers.

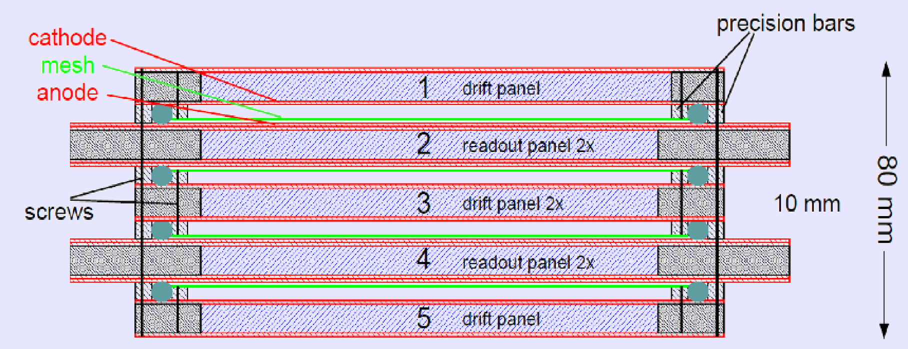


The Micromegas Small Wheel (MMSW) prototype

The 0.5 m^2 quadruplet prototype adopts the general design foreseen for the upgrade of the innermost end-cap stations of the ATLAS muon system.

It consists of :

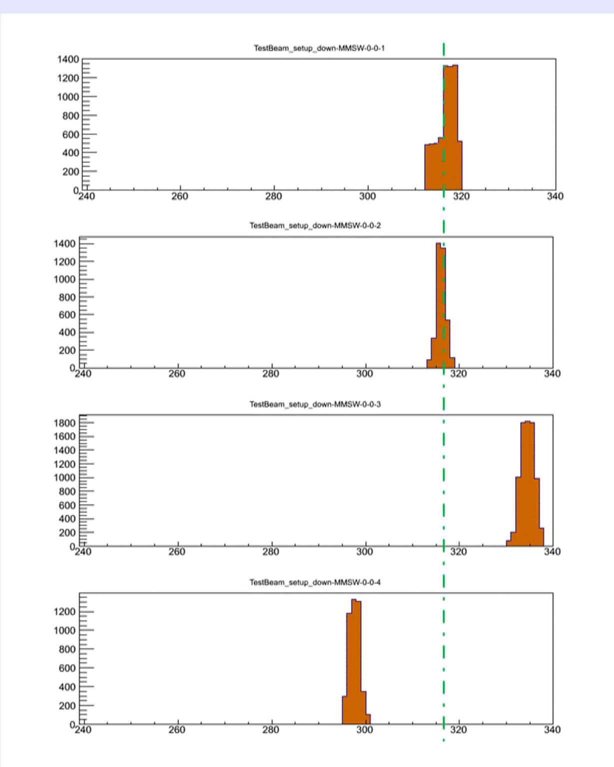
- Two double sided readout panels, one double sided and two single sided support panels equipped with the drift electrode and the micromesh.
- One readout panel has horizontal strips to measure the precision coordinate with a position resolution better than 100 μm while the other one has stereo strips inclined by an angle of ±1.5° to measure the second coordinate, providing a resolution better than 2.5 mm. Each readout layer contains 1024 strips with a strip pitch of 415 μm.
- Supporting pillars with a height of 128 μm are used to define the position of the floating mesh (non-bulk technique) and the amplification gap. The mesh is defined by wires with a diameter of 30 μm and a pitch of 80 μm.



- The readout panels are separated by a 50 μm layer of Kapton® Foil carrying high-resistivity carbon strips with a resistivity of ~10 MΩ/cm, to improve spark tolerance.

Test with cosmic rays

A dedicated cosmic stand is installed in the CERN GDD laboratory of the RD51 Collaboration. It is composed of 12 plastic scintillators each with a total active area of about 2.5 x 1.1 m^2, 2 m apart.



Front-end electronics based on APV-25 ASIC, Scalable Read-out System (SRS) and dedicated DAQ software were used to read-out the chamber.

Full track events have been observed and successfully reconstructed. For a vertical track, the clusters in the first and second layers are aligned, while in the third and fourth layers the clusters seem to be far from the ideal vertical line due to the inclination of the stereo strips.

The chamber was operated with Ar/CO_2 : 93/7 % gas mixture.

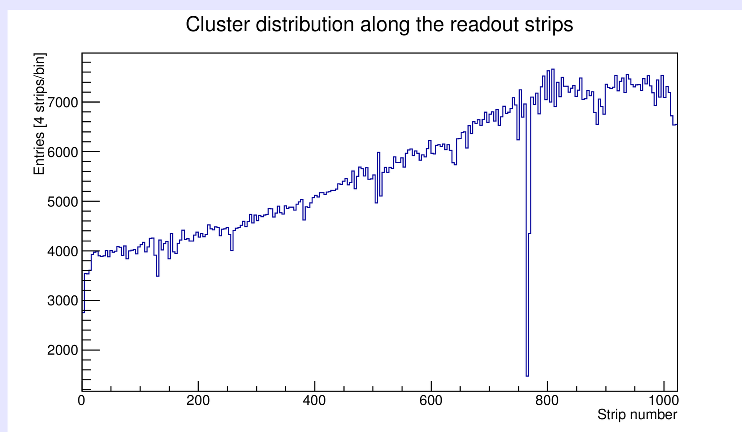


Fig.1: Typical cluster position profile for a single layer of the MMSW chamber obtained with cosmic. The particular shape (not flat) is the result of the convolution of the non uniformity of the trigger with the different strip length due to the trapezoidal chamber shape. An unconnected readout channel was present at the time of the data taking, clearly visible around strip number 760.

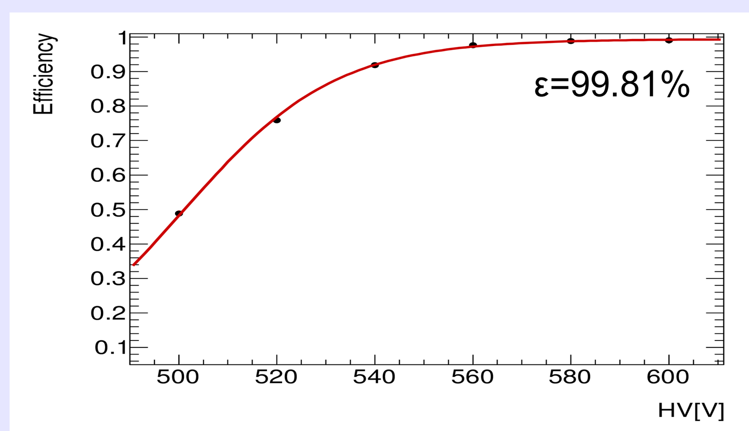
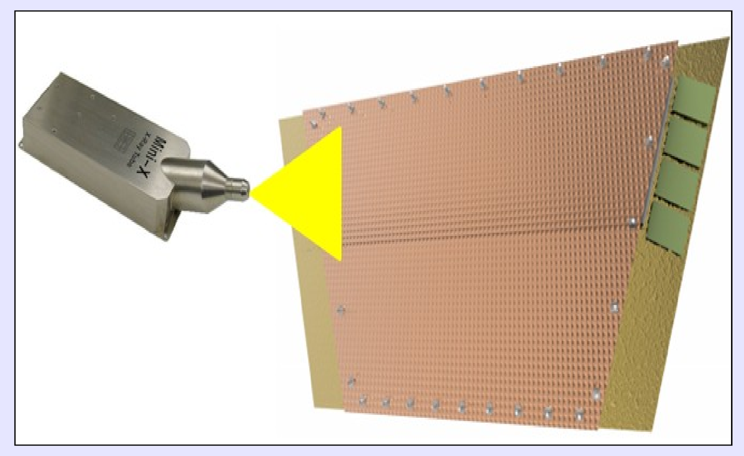


Fig.2: Efficiency curve obtained for one of the MMSW layers. To perform efficiency measurements a dedicated algorithm using all the chamber readout layers has been developed in order to reconstruct the events and perform tracking without the use of an external tracking system.

Test with X-Ray source



The chamber was irradiated using the Mini-X Silver (Ag) source. The device can provide X-rays with energy up to 50 keV and maximum flux of 50 nA. The amplification current of each readout layer was monitored to check the gain of the four active layers.

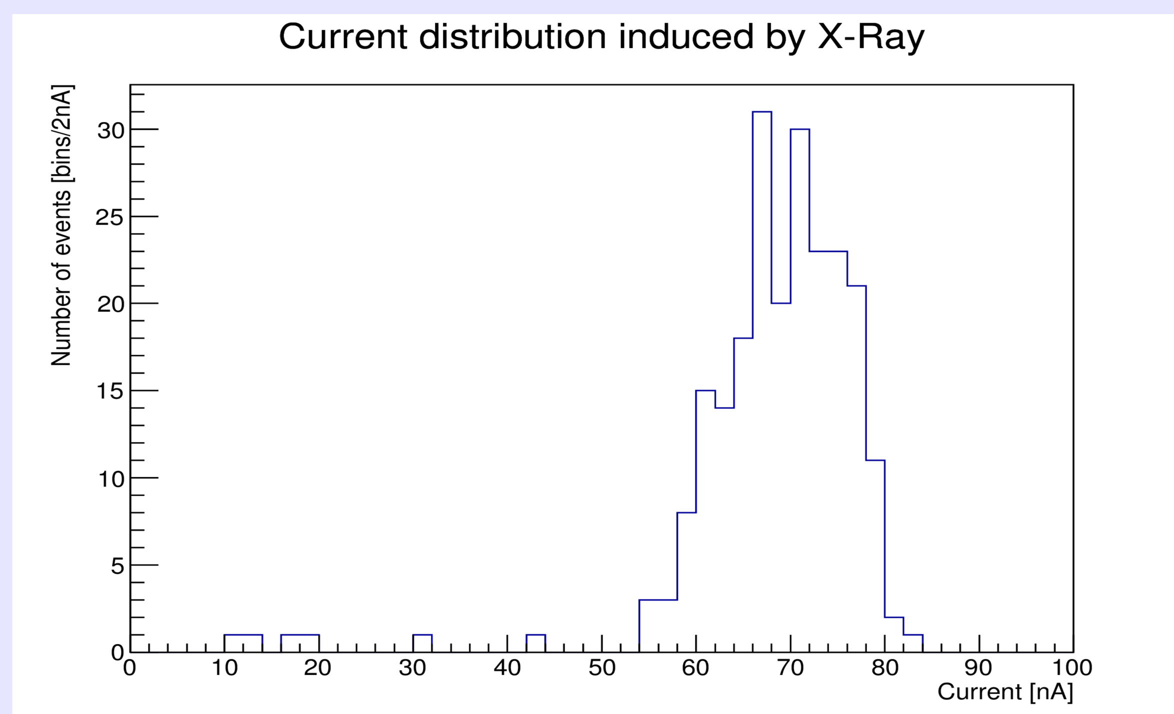


Fig.3: Distribution for the induced amplification current obtained from a single MMSW layer operated at 560 V on the readout planes and 300 V on the drift planes. The outliers correspond to the edges of the active area.

Comparison of Cosmic rays and X-Rays

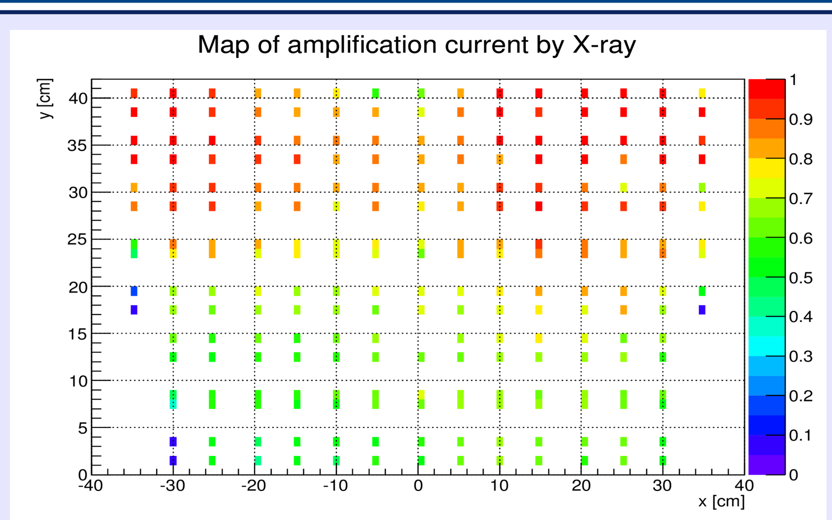


Fig.4: Amplification current (normalized) induced by X-Ray gun in one of the layers using a small collimator. Readout panels operated at 560 V and drift panels at 300 V.

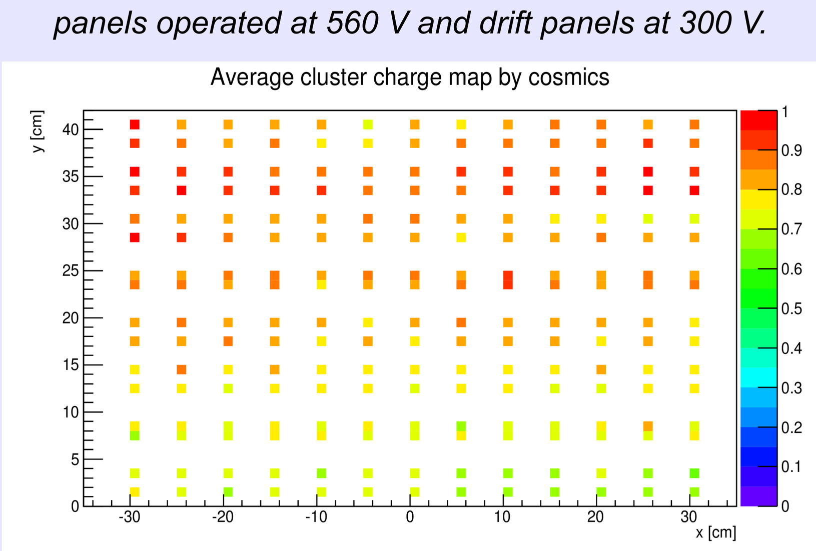


Fig.5: Average cluster charge distribution for cosmic events. Readout panels operated at 560 V and drift panels at 300 V.

Pros/Cons of the two methods

To check the uniformity of the chambers two methods can be compared, one using an X-Ray source and the other using cosmic rays.

X-Ray

Pros

- ✔ No front-end electronics
- ✔ No DAQ system
- ✔ Only HV monitoring

Cons

- ✗ No info of the readout channels (dead/missing channels)
- ✗ Dedicated instrument and setup

Cosmic

Pros

- ✔ Fully chamber characterization
- ✔ Complete channel map

Cons

- ✗ DAQ system with large amount of readout channels
- ✗ Time consuming

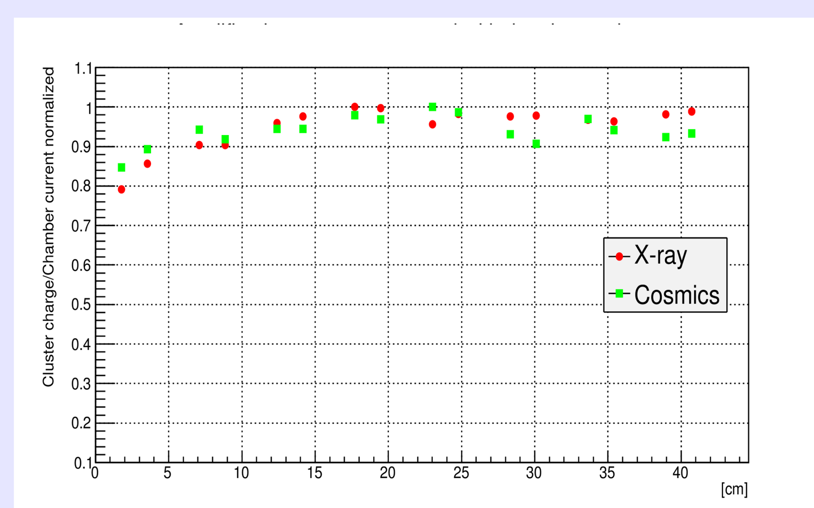


Fig. 6: Comparison between the amplification current, as result a of the X-Ray irradiation, and the average cluster charge obtained with cosmic events, for a single readout layer. The chamber was operated at 560/300 V readout/drift planes respectively, in both cases.

Summary

The performance of a quadruplet Micromegas detector built at CERN has been measured. The chamber resulted to be fully working in all layers with efficiency > 95%. The gain homogeneity has been measured both with cosmic and X-Rays. The two methods give comparable results showing a good homogeneity of the detector gain on the full surface.

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