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Construction and Performance Studies of Large Resistive Micromegas Quadruplets

E. Farina[1,2,a], P. Iengo[1], M. Bianco[1], O. Sidiropoulou[1,3], F. Kuger[1,3], G. Sekhniaidze[4], M. Vergain[1], J. Wotschack[1], H. Danielsson[1], J. Degrange[1], R. De Oliveira[1], M. Schott[5], Tai-Hua Lin[5], C. Valderanis[5], and A. Düdder[5]
on behalf of the ATLAS Muon Collaboration

[1] *CERN*
[2] *Universita e INFN, Pavia (IT)*
[3] *Bayerische Julius Max. Universitaet Wuerzburg (DE)*
[4] *Universita e INFN, Napoli (IT)*
[5] *Johannes-Gutenberg-Universitaet Mainz (DE)*

Abstract. In view of the use of Micromegas detectors for the upgrade of the ATLAS muon system, two detector quadruplets with an area of 0.3 m^2 per plane serving as prototypes for future ATLAS chambers have been constructed. They are based on the resistive-strip technology and thus spark tolerant. The detectors were built in a modular way. The quadruplets consist of two double-sided readout panels and three support (or drift) panels equipped with the micromesh and the drift electrode. The panels are bolted together such that the detector can be opened and cleaned, if required. Two of the readout planes are equipped with readout strips inclined by 1.5 degree. In this talk, we present the results of detailed performance studies based on X-Ray and cosmic ray measurements as well as measurements with 855 MeV electrons at the MAMI accelerator. In particular, results on reconstruction efficiencies, track resolution and gain homogeneity is presented.

1 Introduction

Micromegas detectors are parallel plate gaseous detectors composed by two distinct electric field regions, the drift and amplification gap, separated by a metallic mesh. The first large-area (0.3m ^{2}) Micromegas quadruplet has been realized following the design foreseen for the next ATLAS [1] Muon Upgrade, the so-called *New Small Wheel Upgrade* consisting in the replacement of the innermost muon station [2]. In the layout adopted for the construction, the readout strips are covered by a Kapton® foil carrying a pattern of carbon resistive strips[1], in order to reduce the effects of sparks. The mesh is integrated directly in the drift panel (it is not embedded in the pillars) allowing for the opening and cleaning of the readout plane. In this work the construction and the characterization of one of the two quadruplets, including efficiency, gain uniformity, alignment and resolution studies, will be presented.

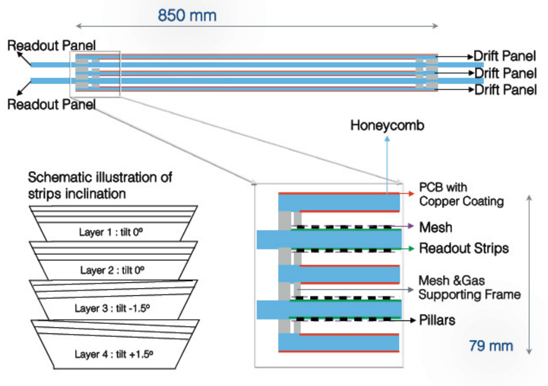

Figure 1: Internal structure of MMSW quadruplet

2 Detector design

The internal structure of the quadruplet is shown in Fig. 1. The detector is composed of three drift and two double sided readout panels. Each trapezoidal panel is formed by two FR4 printed circuit boards (PCBs) and an Al honeycomb stiffener in between, surrounded by an aluminium profile. Each readout PCB hosts 1024 readout strips with a pitch of 415 µm. On two readout panels the readout strips are parallel to the base of the trapezoid, to measure the precision coordinate (called η coordinate), while on the other two they are rotated by ±1.5° with respect to the base of the detector (stereo layers). The information provided by the stereo layers allows for the reconstruction of both coordinates (η and ϕ). A resolution of about 100 µm for the precise coordinate and 2.5 mm for the second one are expected.

[a] e-mail: edoardo.maria.farina@cern.ch
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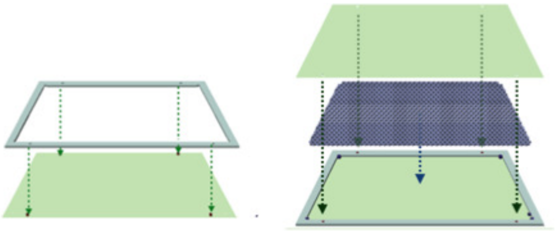

(a) Step 1 (b) Step 2

Figure 2: Schematic of the drift panel construction

3 Detector Construction

In order to reach the required panel planarity, two dedicated stiff-backs, composed of an aluminium honeycomb core between two skins of carbon fibre and coated by a 0.5 mm thick gel-coat layer, have been realized. The panel construction is almost identical for drift and readout panels. In a first step a PCB is sucked face down on one stiff-back, in order to transfer the planarity of the stiff-back to the PCB, then the aluminium frame is glued on the PCB. In a second step the honeycomb is put on the PCB and glued. Finally the second PCB, previously prepared and sucked face down on the second stiff-back, is glued on the honeycomb in order to close the panel. After the glue curing, an aluminium frame, called *mesh frame*, is then assembled on the drift panels, in order to host the pre-stretched metallic mesh. More details about the construction and assembly of the quadruplet can be found in [3], [4].

4 Characterization of the detector

The characterization of the quadruplet has been realized in the RD51 laboratory at CERN by using both X-rays and cosmic rays. A dedicated test stand has been built to host large area detectors up to 2.5 m^2. The characterization of the detector includes efficiency, gain uniformity and alignment studies. Resolution studies have been moreover performed at the MAMI accelerator in Mainz.

4.1 Efficiency studies

The efficiency of each layer has been evaluated as a function of the amplification voltage (drift voltage set at 300 V) by using cosmic rays. A specific tracking algorithm has been developed in order to track muons without requiring any external tracking system, but only using the information provided by the four layers of the detector. In Fig. 3 the efficiency curves for the four layers as a function of the HV are shown. All layers reach the same efficiency, higher than 98%, at 580 V.

The difference in the efficiencies are related to the different gains for the four planes. These in turn are coming

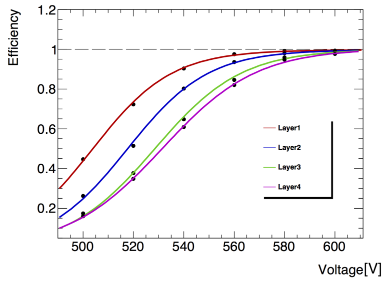

Figure 3: Efficiency curves for the four layers as a function of the voltage

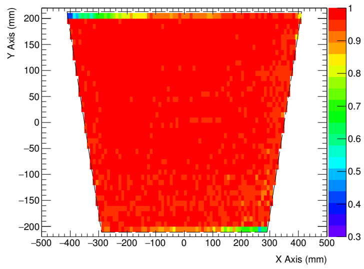

Figure 4: 2D distribution of the efficiency for a stereo layer. Note the inefficient corners due to the absence of the readout strips

from variations of the pillar height and the mesh tension and are consistent with the measured values. It should be noted that most of the observed variations can and will be avoided in the future. However, even variations as large as observed in the MMSW gains are acceptable for the NSW detectors. Bi-dimensional distributions of the efficiency have been realized in order to spot local inefficiencies of the panels and to study the efficiency homogeneity within a layer at lower voltage with respect to the nominal value. As an example in Fig. 4 the 2D map of the efficiency at 580 V for a stereo layer is shown. In particular it is possible to notice two small low efficient areas at the corners: in these areas there are no readout strips due to the rotation of the strips in the stereo layers. For all the layers an excellent homogeneity of the efficiency is reached at 580 V (differences within 5% with respect to the average value).

4.2 Gain uniformity

The uniformity of the gain has been measured both with X-rays and cosmic rays. In the first case an Ag X-rays gun equipped with a 2 mm collimator (5 degrees of opening angle) has been used. The X-rays gun has been operated at 50 kV and a current of 50 μA. The X-ray spectrum can be found on the Amptek website (http://amptek.com/product/mini-x-ray-tube/#5). It extends up to 50 keV, with peaks at 22.5 and 25 keV. However it should be noted that almost all of the lower-energy photons are absorbed in the first detector panel such that the average photon energy detected lies somewhere between 30 keV and 50 keV. A scan of the

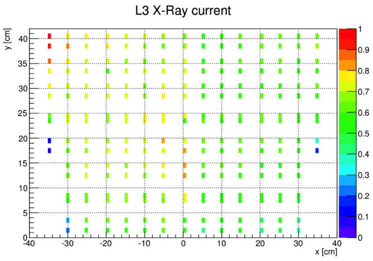

Figure 5: 2D map of the current for 228 points irradiated with the X-ray gun normalized to the maximum value

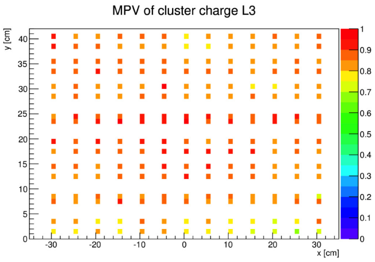

Figure 6: 2D distribution of the mean cluster charge normalized to the maximum value

whole surface of the detector has been realized by moving the gun in 228 different points on the detector. The relative gain, as a function of the position of the gun, has been measured by recording the current on the resistive strips for each point. A 2D map of the current, normalized to the maximum value, is reported in Fig. 5. Despite the large area of the layers (about 0.3 m^2) this study shows an excellent homogeneity of the amplification within the layers.

An equivalent study has been realized by using cosmic rays. This time the detector has been equipped with the readout electronics (APV 25) and the data obtained from the DAQ system have been analysed. In order to study the relative gain, the cluster charge distribution as a function of the position on the chamber has been studied. In more details, the cluster charge distribution of hits reconstructed around each of the same 228 points already used for the X-rays analysis has been fitted with a Landau distribution. The most-probable-value (MVP) of the fit has been then plotted in the corresponding position in a 2D map of the layer. An example of a 2D map of the cluster charge related to a stereo layer and normalized to the maximum value is reported in Fig. 6. Also in this case a very good gain homogeneity has been found. The results from the two methods, X-rays and cosmic rays, have been compared showing a good agreement for all the four layers.

4.3 Alignment studies

The alignment of the PCB skins on the two sides of the readout panel has been measured with a laser interferometer. Some of the strips have been routed up to the edge of the PCBs. The relative position of these strips with respect to a reference pin has been evaluated on both sides of the readout panel and compared. In Fig. 7 the measurements obtained on one layer (blue) and on the other (yellow) are reported. An upper limit on the misalignment of the two PCBs of 20 μm has been extracted.

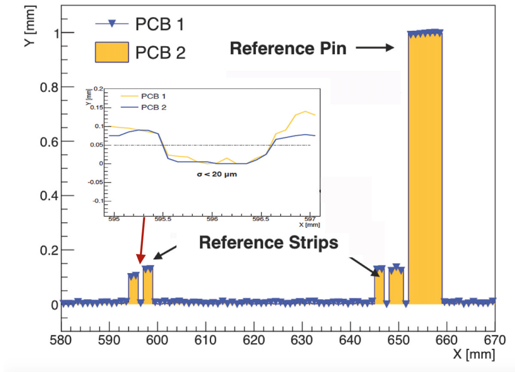

Figure 7: Results of the measurement of the distance between strips and the reference pin on both sides of the R.O. panel. In the insert a zoom of a group of strips

The alignment of the two PCBs has been studied also after the assembly of the quadruplet by using the X-rays gun. The detector has been equipped with readout electronics. In order to give an estimation of the alignment of the planes, the profiles of the strips irradiated by the X-rays on the two sides of the panel have been compared. For each point, two different measurements have been taken, rotating the position of the box containing the gun by 180 degrees, in order to get rid of a possible effect due to the inclination of the gun inside the box. For each measurement the strip profile has been fitted with a Gaussian. The mean value between the two measurements (same position, different orientation of the gun) for each point has been calculated and compared with the other layer. A misalignment between the two layers of about 19 μm has been found, compatible with the result obtained using the laser interferometer.

5 Performance study at MAMI accelerator

The spatial resolution of the detector has been studied in a test beam campaign at the MAMI accelerator in Mainz. The accelerator delivers an almost continuous electron beam at 855 MeV. The setup was composed of the MMSW detector followed at 30 cm distance by a 10 × 10 cm^2 Micromegas chamber with 70 μm spatial resolution. The distribution of the residuals, consisting of the difference between the cluster position on the two η layers of the MMSW has been fitted as reported in Fig. 8. The contribution of the multiple scattering and the beam divergence has been accounted for and a comprehensive resolution of 90 μm for the coordinate perpendicular to the base of the trapezoid has been found. The contribution of multiple scattering and beam divergence has been determined by comparing the position measurement in the η coordinate between MMSW and the reference chamber. The second coordinate has been measured combining the information

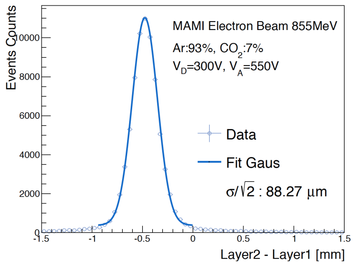

Figure 8: Difference between cluster position measured on the two sides of a readout panel

of the two MMSW stereo layers and comparing it with the coordinate measurement provided by the small tracking chamber. The residuals and the fit are shown in Fig. 9. Different from the η case, given the large distance between MMSW and the reference detector, multiple scattering and beam divergence contribute for about 1.8 mm, leading to a second coordinate resolution of MMSW of 2.3 mm. These

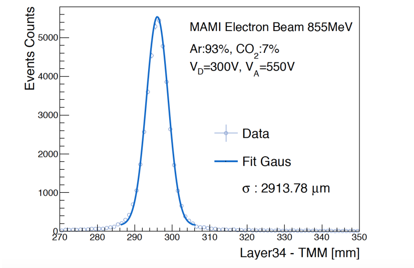

Figure 9: Difference between the cluster position calculated combining the stereo layer information and the measurement provided by the tracking chamber

results are in line with the expectations [5] and meet the ATLAS requirement for the NSW upgrade.

6 Conclusion

The construction of the first Micromegas quadruplet, realized according to the general design foreseen for the ATLAS Muon upgrade has been described. A detailed characterization of the prototype has been performed by using cosmic rays and X-rays. All the layers show efficiency higher than 98% at 580 V. The 2D efficiency maps has not shown any local inefficiency of the panels. The alignment of the readout layers has been measured during the construction using the laser interferometer and after with X-rays showing an alignment better than 20 µm.

The spatial resolution of the chamber has been studied at the MAMI accelerator in Mainz providing a resolution of 90 µm for the most accurate coordinate (η) and 2.3 mm for the second coordinate (ϕ). These results meet the ATLAS requirements.

References

[1] ATLAS Collaboration, *The ATLAS Experiment at the CERN Large Hadron Collider*, JINST 3 S08003 (2008)

[2] ATLAS Collaboration, *New Small Wheel Technical Design Report*, ATLAS-TDR-020, June 2013, http://cdsweb.cern.ch/record/1552862

[3] P. Iengo, et al., *Construction of two large-size four plane micromegas detectors* [arXiv:1511.03884]

[4] P. Iengo, et al., *Construction of a large-size four plane micromegas detector* PoS 058 TIPP2014 2014

[5] Ntekas, Konstantinos, *Study of the performance of the Micromegas chambers for the ATLAS muon spectrometer upgrade.* ATL-MUON-PROC-2014-011, http://cdsweb.cern.ch/record/1971986