PROCEEDINGS OF SCIENCE

The Micromegas detector for the upgrade of the Muon Spectrometer of the ATLAS Experiment

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In the next years, the LHC accelerator will be upgraded with an increase of instantaneous and integrated luminosity, so that the particle rate will drastically increase. The ATLAS goal is to cope with this large particle rate and at the same time trying to conserve the high muon detection efficiency. For this purpose the current innermost stations of the Muon Spectrometer end-caps, the Small Wheels , will be replaced in the year 2019/2020 shutdown with the New Small Wheel detector for high luminosity LHC runs. The New Small Wheel will feature two new detector technologies: resistive Micromegas will be used as a precision detector while small strip Thin Gap Chambers will provide the trigger. An overview of the design, construction and assembly procedures of the Micromegas modules will be reported with particular reference to the SM1 chambers built in Italy. Results and characterizations will also be presented.

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1. Introduction

During next years the LHC [1] accelerator will be upgraded in order to increase sensitivity to New Physics. This is possible increasing the istantaneous luminosity but it will lead to an higher particle rate, particularly in the forward region (up to 15 kHz/cm^2). The innermost stations of the ATLAS Muon Spectrometer end-cap [2], the Small Wheels (SW), will be fully upgraded during 2019-2020 Long Shutdown to stand the challenging performances requested, despite of the higher detector hit rate and trigger rate. The SW will be replaced by the so-called New Small Wheel [3] (NSW). This document is focused on the Micromegas (MM) chambers, one of the new detectors composing the NSW. After a general description of the NSW, the module layout, the construction techniques and the detector performances will be presented.

2. The New Small Wheel for the ATLAS upgrade

The NSW will be made of small Thin Gap Chamber (sTGC) and Micromegas detectors. It is designed to detect muons in the pseudorapidity region $1.3 < |\eta| < 2.7$ and face particle rates up to 15 kHz/cm^2. In Fig. 1 the NSW layout is illustrated: there will be two wheels, one for each ATLAS side, each of which is made of sixteen sectors (eight large and eight small); each sector consists of six sTGC and four MM quadruplets. Both MM and sTGC detectors, given their excellent spatial

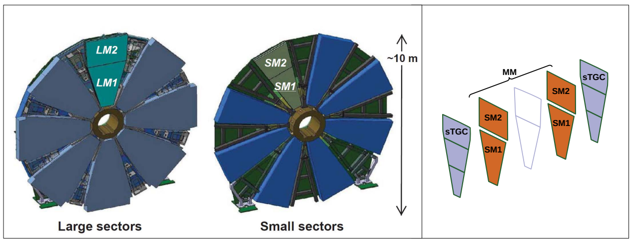


Figure 1: *Overview of the ATLAS New Small Wheel system. Left: detail of large and small sectors, each of which is segmented in two parts of different size, respectively LM1, LM2 and SM1, SM2. Right: small sector layout; four MM (orange) and six sTGC (grey) quadruplets are shown.*

($\simeq 100\ \mu m$) and time ($\simeq 10\ ns$) resolutions, will be used for precision tracking and will provide the trigger system, resulting into a fully redundant NSW measurement.

3. Micromegas working principle

A Micromegas chamber is a gaseous detector which consists of two parallel electrodes mounted on a drift (cathode) and a read-out (anode) panels. The two panels are kept at a constant distance of about 5 mm. A metallic mesh connected to ground is tensioned between the two electrodes and kept parallel to the panels. The 5 mm region between the cathode and the mesh is the conversion and drift gap with a low electric field ($\simeq$ 600 V/cm), the 128 μm region between the mesh and the anode is the amplification gap with an higher electric field ($\simeq$50 kV/cm). The last spacing is actually determined by some insulating pillars of 128 μm fixed height supporting the mesh over the read-out panel. Resistive and readout strip are mounted on the read-out panel with a pitch of $\simeq$400 μm, designed to reduce the probability of discharge and to read the capacitively-induced electric signal (Fig. 2). Micromegas are suitably operated with a two component non-flammable gas mixture: $93:7 - Ar:CO_2$.

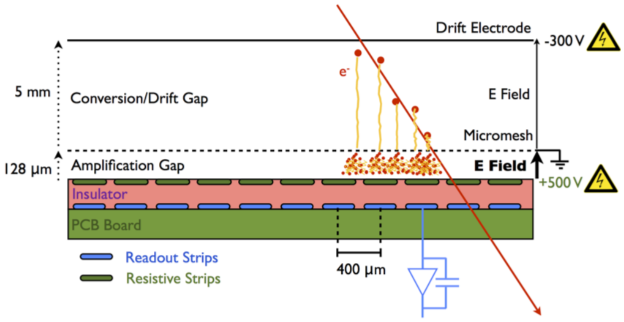


Figure 2: *Layout of a single Micromegas layer and sketch of signal production and read-out.*

4. The ATLAS micromegas quadruplets structure

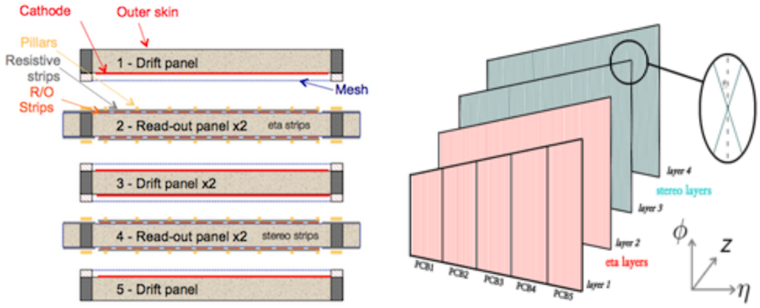
Each Micromegas module (quadruplet) is made of three drift panels (panels 1, 3 and 5 in Fig. 3a), which include cathode and mesh, and of two read-out panels (2 and 4 in Fig. 3a), which include pillars and four (two per side) strips layers. In the quadruplet layout (Fig. 3b), the first and second layer (called η layers) have strips in the η direction, while in the third and fourth layer (called stereo layers) strips are inclined of an angle $\theta = \pm 1.5°$. The η coordinate is obtained using the first two layers, while from the third and fourth ones is possible to measure η and ϕ in the following way:

$$\eta = \frac{x_{layer3} + x_{layer4}}{2 \cdot \cos\theta} \qquad \phi = \frac{x_{layer3} - x_{layer4}}{2 \cdot \sin\theta} \tag{4.1}$$

where x_{layer3} and x_{layer4} are respectively the local positions on layer3 and on layer4. The panels have a trapezoidal shape and the size is $\simeq 2\ m^2$ for the small sector and $\simeq 3\ m^2$ for the large one. In order to guarantee the uniformity of the electric field and a good quality in the precision measurements, panel surfaces are required to be planar (RMS $\leq 37\ \mu m$ or equivalently $\pm 110\ \mu m$ mechanical tolerance) and strips should be aligned between layers to better than 60 μm .

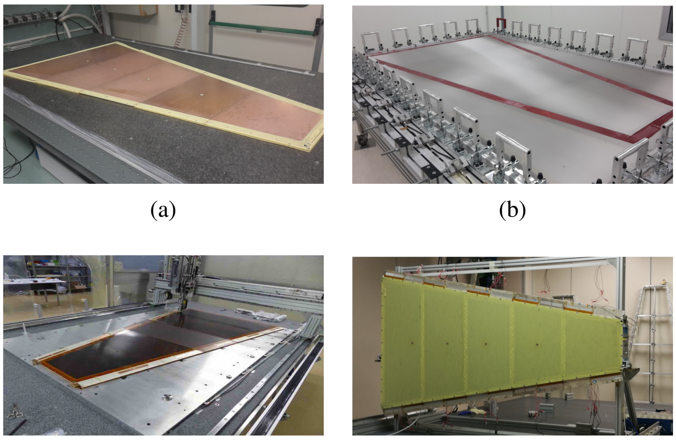
5. Micromegas construction and assembly: SM1

In this section the assembly procedure of the SM1 quadruplet used by INFN ATLAS-NSW team is presented. Roma1, Roma3, Pavia, Frascati Cosenza, Lecce and Napoli INFN teams are the ones involved in the SM1 construction. Before assembling the quadruplet in Frascati site, the components are separately built and validated in other sites. Roma1 takes care of drift panels construction, Roma3 deals with the mesh stretching and finally the read-out panels are built in Pavia (Fig .4). After the construction, planarity and high voltage tests are performed to validate both drift and read-out panels. INFN is committed to build 1/4 of the chambers. The other construction sites are Germany (SM2), Saclay (LM1) and Dubna-Thessaloniki (LM2). All construction sites use very similar construction and assembly procedures.



(a) (b)

Figure 3: *Left: a schematic view of the five panels of a MM quadruplet. Right: a layout of the four strips layers[4].*



(a) (b) (c) (d)

Figure 4: *Top left: drift panel construction in Roma1. Top right: mesh stretching in Roma3. Bottom left: read-out panel construction in Pavia. Bottom right: final assembly of the module in Frascati.*

6. SM1 module-0 test beam

The spatial resolution for both precision coordinate η and second coordinate ϕ of SM1 module-0 has been evaluated with the H8 beam line of the Super Proton Synchrotron (SPS) at CERN providing the following:

- pion beam of 180 GeV/c at a rate ranging from 1 kHz to 0.5 MHz
- beam spot of $\sim 1\ cm^2$

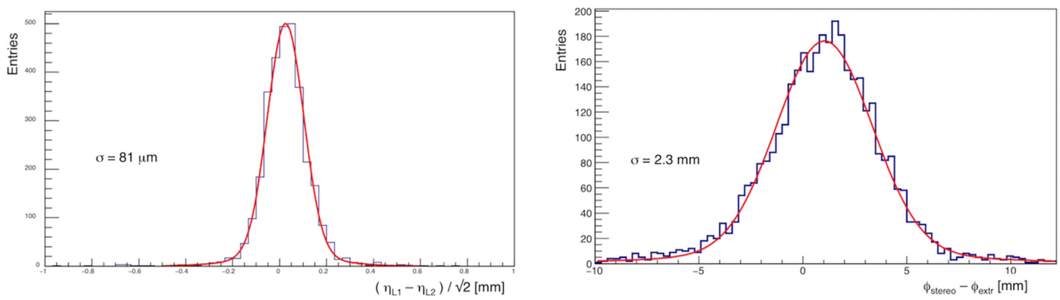
The test of the SM1 module-0 has been done using a trigger based on scintillators and 5 Micromegas small size chambers (10x10cm^2) used as a telescope reference. These chambers provide a two-dimensional track reconstruction. The resolution has been determined for tracks perpendicular to the chamber under test. Resolution for the η coordinate is obtained evaluating the η coordinate in each layer using the charge centroid, and taking the difference:

$$\sigma_\eta = \frac{\eta_{Layer1} - \eta_{Layer2}}{\sqrt{2}} \quad (6.1)$$

assuming that the first and second layer have the same resolution, while the resolution for ϕ is calculated as:

$$\sigma_{\phi} = \phi_{stereo} - \phi_{extr} \tag{6.2}$$

where ϕ_{stereo} is the position reconstructed using the stereo strips, and ϕ_{extr} is the position extrapolated using the 5 small Micromegas chambers. The uncertainty on ϕ_{extr} is negligible with respect to the expected ϕ_{stereo} resolution. Data are fitted with a gaussian distribution, as shown in Fig. 5. The intrinsic resolution is measured to be 81 μm for the η coordinate (Fig. 5a) and 2.3 mm for the ϕ coordinate (Fig. 5b).



(a) (b)

Figure 5: *Left: spatial resolution of the η precision coordinate. Right: spatial resolution of the second coordinate ϕ.[5]*

7. Conclusion

The first phase needed to define the construction and assembly procedures is complete. A full size prototype SM1 of a Micromegas chamber (module-0) for the ATLAS NWS has been built, tested and validated by the INFN Micromegas collaboration. The production and assembly phase of SM1 has begun, and its program is in agreement with the schedule provided by ATLAS.

References

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