Status of the art of the Italian micromegas for the upgrade of the ATLAS detector

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Summary. — Large-size multilayer resistive micromegas detectors will be employed for the muon spectrometer upgrade of the ATLAS experiment at CERN, the new small wheel project. The status of the art of the micromegas construction in Italy will be reviewed, along with the performance studied on the first full size module.

1. – ATLAS new small wheels

Large-area micromegas (MM) detectors will be part of the upgraded innermost station of the muon end caps, New Small Wheels (NSW), of the ATLAS experiment [1]. The new detector will be mounted during the long shutdown in 2019/20. NSW specifications are: good spatial resolution (less than $100\,\mu$m for single hit, independent of the track incident angle); good track separation (0.4 mm track granularity); good angular resolution (1 mrad); 15% momentum resolution at 1 TeV. In each of the two NSW, four detector modules will be sandwiched together along the beam direction: two small-strip Thin Gas Chambers (sTGC) and two MM detectors, for a total of 16 active planes. Each trapezoidal MM module will contain two eta (read-out strips parallel to the basis) and two stereo (strips slanted by $1.5°$) layers.

The MM detectors will provide primarily tracking and secondly triggering information, while being able to withstand the high pile-up expected from Run III onward, resulting in rates up to $15\,\text{kHz/cm}^2$. Four types of MM modules will be integrated in the two NSW (fig. 1), divided into 128 modules covering an active area of $1280\,\text{m}^2$: 32 SM1 and 32 SM2 modules (4 small wedges); 32 LM1 and 32 LM2 modules (4 large wedges), constructed in Italy, Germany, France and Russia/Greece, respectively.

2. – Micromegas detectors for the New Small Wheels

The MM detectors for the NSW (fig. 2) are characterized by 93% Ar and 7% CO_2 gas mixture; strip pitch 425–450 μm; strip resistivity $\sim$10 MΩ/cm; drift voltage -300 V, readout strip voltage 600 V, drift gap 5 mm, amplification gap 128 μm.
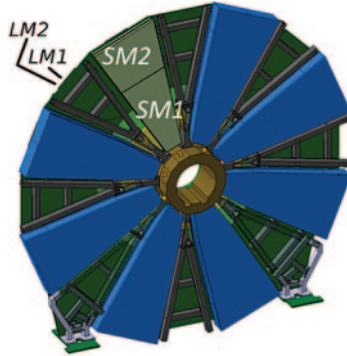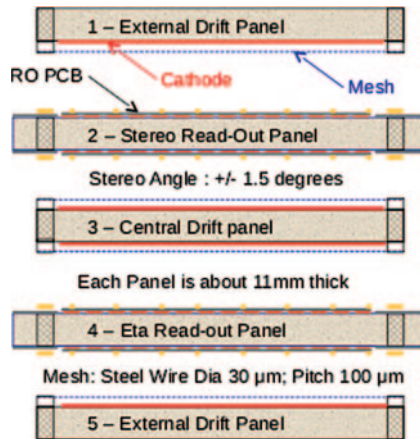
Fig. 1. – MM detectors in a NSW.

Fig. 2. – MM module exploded view.

3. – SM1 modules

The INFN groups responsible for the construction of the SM1 modules are: Pavia for the readout panels, Roma 1 for the drift panels, Roma Tre for the mesh stretching, Frascati for the module assembly while Cosenza, Lecce and Napoli provide support. The mechanical precision represents a challenge in MM construction: alignments of the readout strips on each detection layer within $30\,\mu$m RMS in η and $80\,\mu$m RMS in Z, the direction perpendicular to the RO plane, are required.

In May 2016 the first full size SM1 prototype (M0) was constructed by the INFN consortium, and studied on a dedicated beam test at CERN in June. Further tests included mechanical studies for the detector assembly in the wheel and performance under deformation, as well as tests on high-voltage stability and ongoing checks using cosmic rays. To address issues that arised during M0 construction as well as to test new tooling, a second SM1 prototype (M0.5) was completed by the end of April 2017. Tests and studies of the performance of the new module took place in summer 2017.
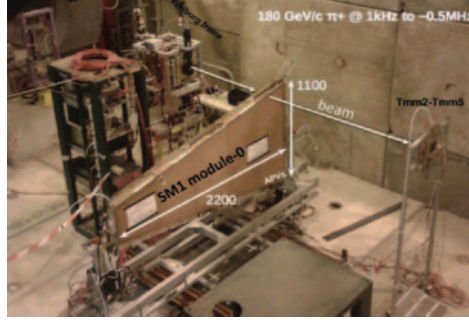
Fig. 3. – SM1 M0 in the SPS H8 beam-test hall.

4. – SM1 M0 beam test

Test beam measurements were performed at CERN in June 2016 at SPS H8 experimental hall. A $180\,\mathrm{GeV}/c\,\pi^+$ beam with a rate between $1\,\mathrm{kHz}$ and $\sim 0.5\,\mathrm{MHz}$ (beam spot of $\sim 1\,\mathrm{cm}^2$) was used. The experimental setup included a detector array composed by the SM1 M0 and five small dimension MM chambers, with X and Y coordinate readout, used as reference (fig. 3).

The purpose of the beam test was to certify the M0 prototype with respect to the project requirements. Both the quality of the single RO layer and the quality of RO layer assembly have been tested. Each RO panel is composed by two RO layers (eta, eta or stereo, stereo). Each trapezoidal layer is composed by 5 trapezoidal PCBs, whose dimensions increase from PCB1 to PCB5 (fig. 4). The beam was centered on PCB3 (the middle one) and PCB5 (the largest) of M0, performing X and Y scanning on both PCBs. Data have been collected at different HV amplification values (from 550 to 590 V). The HV drift baseline was set at 300 V but data have been collected also at 200 V and 400 V.

The spatial resolutions have been evaluated using data collected on PCB5. The residuals between the two eta layers of the SM1 M0 have been used to estimate the spatial resolution of the precision coordinate η. The position is reconstructed in each eta layer by exploiting the charge-centroid method. A fit with a bi-Gaussian function estimates a width of the core Gaussian of $81\,\mu\mathrm{m}$ (required resolution: less than $100\,\mu\mathrm{m}$), while the weighted average of the widths of the two Gaussians is $160\,\mu\mathrm{m}$, well within requirements.

Similarly, to evaluate the spatial resolution of the second coordinate ϕ, the difference between the second coordinate position in the two stereo layers of SM1 M0 has been
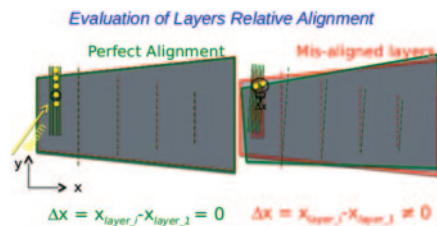

Fig. 4. – SM1 M0 layer alignment.

used. The position is reconstructed in each stereo layer using the centroid method. A fit with a bi-Gaussian function estimates a width of the core Gaussian of 2.3 mm, in good agreement with the expectations.

A measurement of the displacement of strips in the precision coordinate as a function of the second coordinate for the different layers of PCB3 and PCB5 has been performed. This kind of measurement is an indication of layer-to-layer rotation or strip pattern global deformation. Measurements are taken at different vertical positions along the strips (yellow spots in fig. 4). For each y-position, Δx are measured between layer i and layer $(i-1)$ using reference tracks (fig. 4). The displacements, less than $\pm\,80\,\mu$m, indicate the presence of both shift and rotation within tolerance ($\pm\,90\,\mu$m).

These effects are under investigation at the construction site in Pavia using compact Charge-Coupled Devices (cCCDs). Twenty cCCDs are used to read twenty Rasnik masks located on the ten RO PCBs used for a RO panel, to establish the precise PCB coordinates and to control strip alignment and rotation.

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REFERENCES

[1] The ATLAS Collaboration, *New Small Wheel Technical Design Report*, CERN-LHCC-2013-006.