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Performance studies on MicroMegas detector

M. Trovatelli
Università di Roma Tre e INFN, Sezione di Roma Tre - Roma, Italia

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Summary. — MicroMegas detector is one of the technologies chosen for the upgrade of the forward muon detectors of the ATLAS experiment, in view of LHC luminosity increase. Performance studies on MicroMegas detector, such as time and spatial resolution, based on data collected at the CERN SPS beam line, are here reported and discussed.

PACS 29.40.Cs – Gas-filled counters: Ionization chambers, proportional and avalanche counters.

1. – Introduction

After the long shutdown planned for 2018, the Large Hadron Collider at CERN laboratory will reach the nominal luminosity of $2.5 \times 10^{34}\,\mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ and the ATLAS experiment will enter in the Phase-1 upgrade [1].

In order to benefit from the high luminosity operation of the collider the Small Wheels (SWs), which are placed in the endcap part of the ATLAS muon spectrometer and cover approximately 50% of the whole acceptance of the muon system, will be replaced. In this region of the detector there is the highest cavern background flux, which will become higher with the LHC luminosity increase expected for 2018, eventually causing detectors performance deterioration. For this reason ATLAS has decided to partially substitute the muons detectors in the New Small Wheels (NSWs) with MicroMegas detectors (MM), which have a higher rate capability than MDTs detectors.

In developing MicroMegas detectors for the upgrade several test beams were performed at CERN in 2012 by the MAMMA Collaboration (Muon ATLAS MicroMegas Activity), using a $120\,\mathrm{GeV}/c$ pion beam coming from the Super Proton Synchrotron (SPS).

2. – Detector technology

MicroMegas is a high gain gaseous detector which consists of a planar drift electrode, a gas gap of few mm thickness acting as ionization and drift region, and a thin metallic mesh at typically 100÷150 μm from the readout electrode, creating the gas amplification region [2].

Charged particles traversing the drift region ionize the gas; the electrons produced in the ionization process drift towards the mesh which is transparent to more than 95% of the electrons as long as the the ratio between the electric field in the amplification region and the drift field is high ($\sim$ 50÷100).

Electrons traversing the mesh multiplicate and are then collected on the highly segmented readout electrode.

Due to their high mobility in the gas mixture electrons drifting results in a fast pulse on the readout strip (elctrons drift time $\sim$ few ns). The ions produced in the last avalanche step move back to the amplification mesh and given their relatively low drift velocity, it takes them about 100 ns to reach the mesh. It is the fast evacuation of the positive ions which allows MM operation at very high particle fluxes.

3. – Performance studies

The performance of MM have been studied during several test beam campaigns with high energy particle beams at CERN.

Eight MM chambers (T1-T8), with an active area of 10 $\times$ 10 cm^2, a strip pitch of 0.4 mm and a drift gap of 5 mm have been aligned along the beam line. The chambers were oriented in back-to-back configuration forming four doublets and they were operated with Ar:CO2 gas mixture (93:7). The voltages applied were 600 V/cm for the drift field and 500 V to the amplification region.

3·1. *Time resolution.* – Time resolution of MM detector was determined by taking the time difference between two chamber in back-to-back configuration, in order to remove the trigger-jitter. The time resolution of a single chamber is then computed by dividing the sigma of the distribution by square root of two.

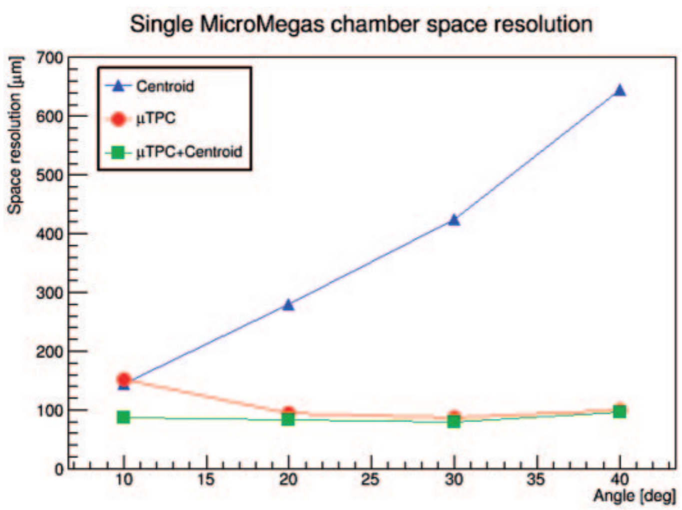

Fig. 1. – MicroMegas space resolution for incident beam angles of 10÷40 degrees. Results of different methods used to extract the MM resolution are shown.

Each chamber was equipped with several APV25 chips [3] which integrate the single strip's charge with a sampling time of 25 ns. The pulse shape is then fitted using the Fermi-Dirac function and the time of the strip extracted. The measured time resolution is of the order of 11÷12 ns.

3˙2. *Spatial resolution.* – MM chambers will enter in the NSWs project as the new tracking detectors of the endcaps muon spectrometer. Muons from IP enter the MM with angles ranging from 8 to 30 degrees with respect to the normal incidence; a spatial resolution of the order of 100 μm is required to obtain precise track reconstruction.

Many data have been taken and analysed with beam perpendicular to MM chambers and under various angles (10÷40 degrees). The spatial resolution is measured by using the charge centroid method for particle incident angle near zero degrees.

For particles entering the MM with a non-zero angle respect to the normal axis the charge centroid method is not suited and should be substituted by the μTPC method. A local track is reconstructed inside the small drift gap by taking the time and the position of each strip forming the cluster. The position of each strip gives an x coordinate, while the z coordinate (perpendicular to the strip plane) can be reconstructed from the time measurement of the hit after calibrating the z-t relation ($z = t \times v_{\mathrm{drift}}$, $v_{\mathrm{drift}} = 47\,\mu\mathrm{m/ns}$). The best position measurement, x_{half}, corresponds to the track fit at half-gap. For both methods, charge centroid and μTPC, MM resolution has been measured by the difference of the cluster centroid position, in the first case, or the difference of the x_{half}, in the second case, in two chambers in the same doublet. The distribution of x_{half} difference is fitted with a double-Gaussian function and the resolution is extracted as $\sigma = \sigma(x_{\mathrm{half1}} - x_{\mathrm{half2}})\sqrt{2}$.

Results of the MM spatial resolution are summarized in fig. 1 where it is evident that the cluster centroid behaves better at small angles while the μTPC reaches best performance for larger angles, as expected. Furthermore a weigthed average of the two methods can significately improve the resolution, as shown with the squares. A spatial resolution of 100 μm is obtained for all impact angles.

4. – Conclusions

In 2012 the MAMMA Collaboration has performed several tests on particle beams at the Super Proton Synchrotron (SPS) beam line at CERN, using MM detectors of dimensions $10 \times 10\,\mathrm{cm}^2$. The aim of these tests was to evaluate the performance of the detectors under operational conditions as in the ATLAS SWs.

Data analysis has shown that a time resolution of 12 ns and a spatial resolution of 100 μm can easily be obtained with such detectors, in agreement with the requirements for the Phase-I Upgrade of the ATLAS Muon Spectrometer.

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