Test Beam data analysis of Micromegas detectors operating in μTPC mode for the New Small Wheel ATLAS upgrade

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1. Introduction

The Large Hadron Collider (LHC) will be upgraded in several phases which will allow to extend significantly its physics program. After the second long shutdown (LS2) in 2018, the accelerator luminosity will be increased to $2-3\times 10^{34} cm^{-2}s^{-1}$, thus allowing the ATLAS experiment to collect few hundreds $fb^{-1}/year$. Then, a further upgrade will result in the luminosity increasing to $5\times 10^{34} cm^{-2}s^{-1}$ and will allow to reach an integrated luminosity of 3000 fb^{-1} after about 10 years of operation. In order to take advantage of the improved LHC operation the ATLAS [2] detector must be upgraded to reach a better performance at higher luminosities. The Phase-I upgrade of the ATLAS muon spectrometer focuses on the End-cap region to improve tracking and triggering systems. ATLAS will replace the present muon End-cap Small Wheels with the New Small Wheels (NSW) [3]. The NSW is a set of precision tracking and trigger detectors able to work at high rates with excellent spatial and time resolutions. These detectors can improve the muon Level-1 trigger exploiting a good angular resolution on online track segments, in order to confirm that muon tracks originate from the interaction point (IP) and thus drastically reducing fake tracks. The NSW consists of 16 detector planes arranged in two multilayers. Each multilayer consists of four small-strip Thin Gap Chambers (sTGC) and four Micromegas (MM) detector planes.

2. The Micromegas Detector

The Micromegas (Micro Mesh Gaseous Structure (MM)) technology was developed in the middle of the 1990s [4] and relies on the construction of thin wireless gaseous particle detectors. MM detectors consist of a planar (drift) electrode, a gas gap of a few millimeters thickness acting as conversion and drift region and a thin metallic mesh placed on $100-150\mu m$ height pillars whose distance from the readout electrodes creates the amplification region. A sketch of the MM operating principle is shown in Fig. 1.

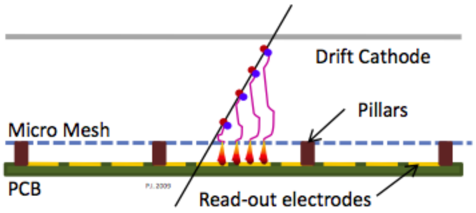


Figure 1. Sketch of the operating principle of a Micromegas detector.

3. Bulk and Floating Mesh Micromegas

The weak point of the MM original design was their vulnerability to sparking. For the MM detectors to be installed on the New Small Wheel a spark protection system has been developed, hence the name of *Bulk Micromegas*. By adding a layer of resistive strips on top of a thin insulator directly above the readout electrode the MM become spark-insensitive, as the readout electrode is no longer directly exposed to the charge created in the amplification region. Moreover, instead of applying negative HV on the amplification mesh and keeping the resistive strips at ground potential, positive HV is applied to the resistive strips and the amplification mesh is connected to ground; therefore spark-induced current can be evacuated very quickly to ground through the mesh and the mesh potential does not change. The final scheme of bulk MM detectors is shown in Fig. 2.

The limits imposed by the bulk technique of PCB manufacturing were overcome with a new scheme of large area MM [5]: the mesh is integrated in the panel containing the cathode plane. This one forms the drift gap, which is separated from the readout PCB, thus not depending of its dimension. Fig. 3 shows the sketch of the MM assembly with the *floating mesh* technique: the two subfigures are a schematic drawing of a single plane assembly with the drift and readout panels in open (Fig. 3a) and closed (Fig. 3b) position.

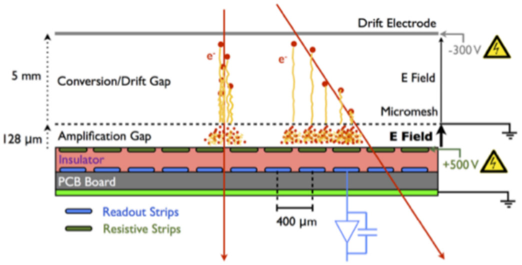
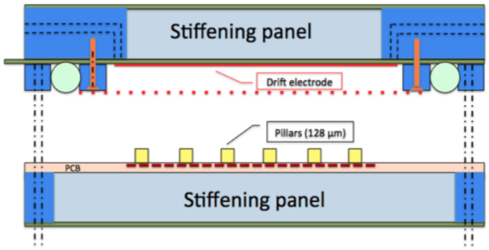
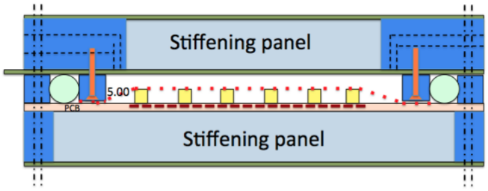


Figure 2. Bulk Micromegas with HV changes.



(a) Drift and readout panels in open position



(b) Drift panel coupled up to the readout panel

Figure 3. Floating Mesh Micromegas scheme.

4. The μTPC method

When a particle impacts on the detector with an angle greater than 10° with respect to the orthogonal direction, the reconstruction of the precision coordinate inside the MM chamber with the cluster charge centroid method becomes inaccurate and another method must be used in order to achieve the same spatial resolution obtained with the centroid method at small impact angles. The *μTPC method* is used for a local track segment reconstruction in the few-millimiter wide drift gap. It exploits the measurement of the hits time and the highly segmented readout electrodes: 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 linear relation $z = tv_{drift}$; the hit time is measured for each strip by applying a fit to the output of the charge integrating pre-amplifier. Therefore for each event (x_i, z_i) coordinates are assigned to each hit and a linear fit is performed, from which the best position measurement "x_{half}" is obtained, corresponding to the track fit at half-gap. Fig. 4 summarizes the global procedure.

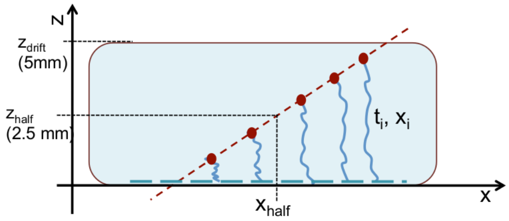


Figure 4. Principle of the Micromegas μTPC operating mode.

5. Spatial resolution

The performace of MM detectors have been extensively studied during several test beams campaigns with high particle beams at CERN. The following results are based on tests performed at the H6 beam line at the Super Proton Synchrotron (SPS) at CERN in September 2015. The H6 line provides a 120 GeV pion beam with an intensity ranging between 5 and 30 kHz over an area of approximately $2cm^2$. Four floating mesh chambers (J12-J15) were studied, aligned along the beam line. The detectors were operated with an Ar:CO_2 (93:7) mixture. The main purpose of the test beam analysis was the spatial resolution estimate, especially the one obtained with the μTPC method. The analysis focused on runs with all four chambers oriented at 35° with respect to the beam direction. The first analysis step is to look at the reconstructed angle in the μTPC operating mode: Fig. 5 shows this angle for all J-chambers: the peak value is always in the range between 30° and 40°; however the μTPC method is known to reconstruct an angle which is sometimes bigger than expected, hence the long right tail. This issue is currently under study.

The μTPC spatial resolution has been measured by the difference of x_{half} in two chambers with the same orientation, the difference being divided by $\sqrt{2}$, assuming the same resolution for the two chambers.

The time jitter introduced by the front-end electronics APV25 is equal in the two chambers and cancels out in the difference. The distributions can be fit with a double-gaussian function, accounting for a core distribution plus tails. In Fig. 6 results are reported, showing MM core posi-

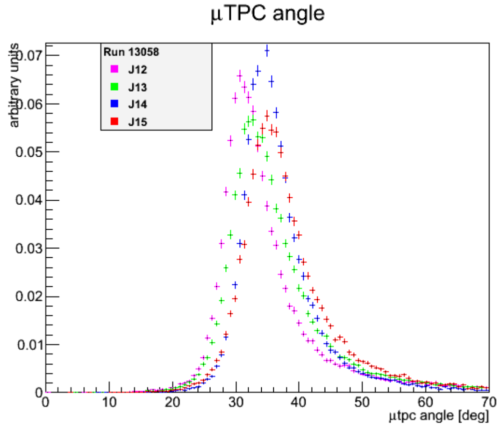
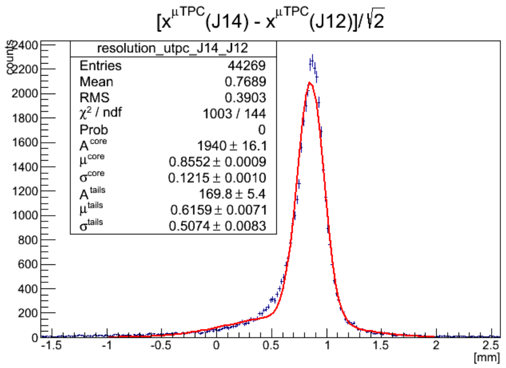
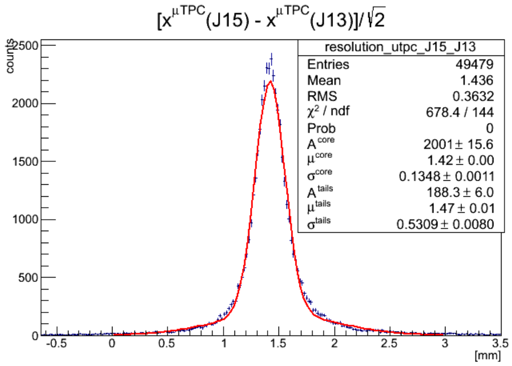


Figure 5. Reconstructed angle in the μTPC operating mode.



(a) Chambers J12 and J14



(b) Chambers J13 and J15

Figure 6. Spatial resolution plots for the four J-chambers under study.

tion resolutions of about 120-130 μm in μTPC method.

REFERENCES

1. ATLAS Collaboration is made of about 3000 Physicists coming from 173 Institutions of the following countries: Argentina, Armenia, Australia, Austria, Azerbaijan, Belarus, Brazil, Canada, Chile, China, Colombia, Czech Republic, Denmark, France, Georgia, Germany, Greece, Israel, Italy, Japan, Morocco, Netherlands, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Taiwan, Turkey, UK, USA, CERN, JINR.
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