Simulation of Micro Mesh Gas Chambers (Micromegas): μTPC method

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1. Introduction

The Large Hadron Collider (LHC) will be upgraded in several phases which will allow the reach of the physics program to be significantly extended. After the second long shutdown (LS2) in 2018, the accelerator luminosity will be increased to $2-3\times10^{34}cm^{-2}s^{-1}$, allowing ATLAS to collect approximately $100fb^{-1}/year$. A subsequent upgrade step is planned and will result in the luminosity increasing to $4\times10^{34}cm^{-2}s^{-1}$. The integrated luminosity with this ultimate upgrade will be $3000fb^{-1}$ after about 10 years of operation.

In order to take advantage of the improved LHC operation the ATLAS detector must be upgraded to have better performance at higher luminosity. The Phase-I upgrade of the ATLAS muon spectrometer focuses on the end-cap region to let the trigger work to the desired efficiency. ATLAS proposes to replace the present muon Endcap Small Wheels with the New Small Wheels (NSW). The NSW is a set of precision tracking and trigger detectors able to work at high rates with excellent real-time spatial and time resolution. These detectors can provide the muon Level-1 trigger system with online track segments of good angular resolution to confirm that muon tracks originate from the IP. The NSW consists of 16 detector planes in two multilayers. Each multilayer comprises four small-strip Thin Gap Chambers (sTGC) and four Micromegas (MM) detector planes.

2. The Micromegas Detector

The micromegas (an abbreviation for micro mesh gaseous structure (MM)) technology was developed in the middle of the 1990s [21]. It permits 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 at typically $100-150\mu m$ distance from the readout electrode, creating the amplification region.

The detectors are often operated with an Ar:CO2 gas mixture (93:7). The reference operating settings were 600 V/cm electric drift field and an amplification voltage HV_{mesh}=500 V. The spatial resolution of MM with sub-mm strip pitch and analog readout can easily go below 100?m for perpendicular tracks by using the cluster charge centroid method. A spatial resolution of about 73 μm has been easily obtained for many chambers under test, with an average cluster size of approximately 2.4 strips. For impact angles greater than 10° the μTPC method is used for a local track segment reconstruction in the few-millimeter 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 z-t relation ($z = t \times v_{drift}$), see Fig. 1.

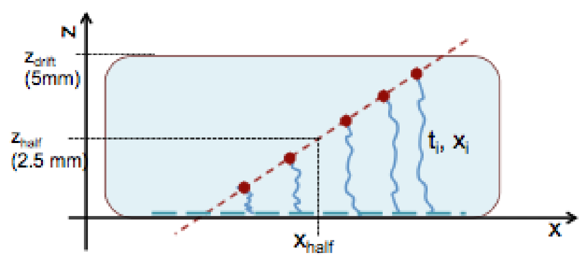

Figure 1. principle of the Micromegas μTPC operating mode

3. Micromegas μTPC toy simulation

A toy simulation of the Micromegas physical behaviour has been performed using simple hypotheses. Using the known gas mixture characteristics (as the mean free path) one can generate the primary (and secondary) ionizations along the track path and transport the produced electron clusters in the drift region (5 mm size) of the chamber taking into account physical processes as the diffusion. Assuming an average gain (about 5000) the cluster are then multiplied and the charge is gathered on the corresponding strip (400μm size). Timing of the electronics is actually simulated only by including a gaussian spread on arrival time fixed at about 10ns. For each strip the time of the first cluster is recorded and stored for that strip together with the collected charge. From all the recorded time and the strip position a straight fit is built Fig. 2 and the angle of the track is extracted and compared with the simulated track.

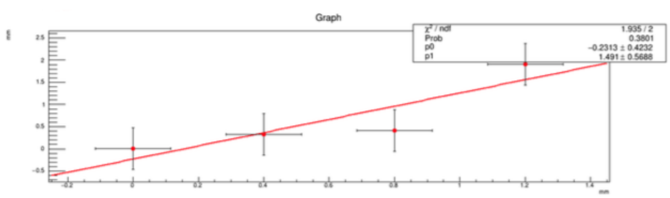

Figure 2. example of a reconstructed track in microTPC mode

in 3, 4 and 5 are shown the distribution of the reconstructed angles for angles ranging from 10° to 40° for this simple simulation. As can be seen the reconstructed angle is always larger than the real one, this because the use of the first hit arrived in time, and this reproduces the real effect even being this a simple simulation.

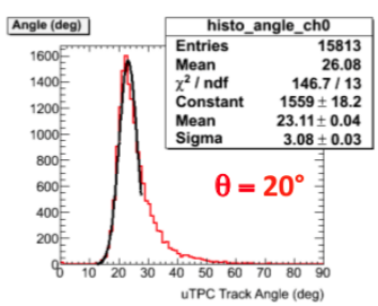

Figure 3. reconstracted microTPC angles

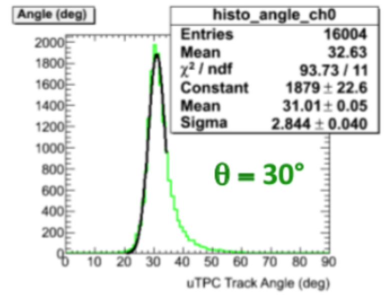

Figure 4. reconstracted microTPC angles

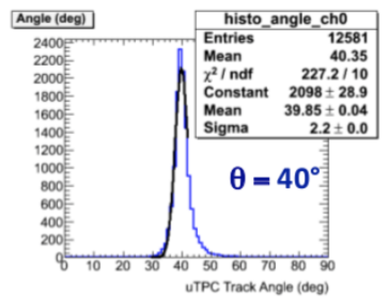

Figure 5. reconstracted microTPC angles

REFERENCES

1. ATLAS Collaboration, JINST 3 S08003 (2008) 1-407.
2. ATLAS Collaboration, CERN-LHCC-2013-006, ATLAS-TDR-20-2013, June 2013.