Characterization and commissioning of the ATLAS micromegas quadruplet prototype

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Micromegas (Micro Mesh Gaseous Detector) chambers have been chosen for the New Small Wheel (NSW) project, the upgrade of the forward muon spectrometer of the ATLAS experiment both to provide precision tracking and contribute to the trigger.

A quadruplet (1m X 0.5m) has been built at the CERN laboratories, it will serve as prototype for the future ATLAS chambers. This detector is realized using resistive-strip technology and decoupling the amplification mesh from the readout structure. The four readout planes host overall 4096 strips with a pitch of 415 μm .

A complete detector characterization carried out with cosmic rays, X-Ray source and dedicated test beam is discussed. Characterization is done using analog front-end chip (APV25).

The efforts that lead to the chamber construction and the preparation for the installation in the ATLAS experimental cavern are presented. Finally, an overview of the readout system developed for this prototype, and integration in to the ATLAS Data Acquisition System is provided.

The Micromegas Small Wheel (MMSW) prototype

The 0.5m² prototype adopts the general design foreseen for the Micromegas detectors in the NSW project:

- A quadruplet structure with two double sided readout boards, one double sided and two single sided support (drift) panels equipped with the drift electrode and the micromesh.
- Readout comprises 1024 strips per plane with a pitch of 415 μm . The strips are rotated by $\pm 1.5^\circ$ on two planes to measure the second coordinate. Position resolution are expected to be better than 100 microns in the precision coordinate (along the direction of the track bending), and better than 2.5 mm in the second coordinate orthogonal to the precision one.
- The readout strips are covered by Kapton® foil with sputtered resistive strips to improve spark tolerance and a pattern of 128 μm high support pillars to define the position of the floating mesh.

Chamber preparation and equipment:

- HV distributors for the resistive strips and drift panels are installed on the sides of the chamber
- Two gas manifolds allow to flush independently the four layers
- The APV25 boards are plugged on mezzanine cards, inserted on the readout panels, connecting through Zebra connectors, the readout strips to the Panasonic connectors used by the APV25 boards.

MMSW: Tools & procedures for construction

Two vacuum Stiff-backs are used to accurately position and fix the readout / drift boards during the gluing process.

A Gel coat + glass fiber surface is meant to inherit the flatness of the marble table the Stiff-back is produced on. The honeycomb structure ensures stiffness and low weight.

Panel Construction procedure steps:

- PCBs placed face down on the upper and lower halves of the assembly table and sucked
- Glue distributed on the inner face of PCB1 and Al frame and honeycomb positioned together with reference pins for alignment
- Glue distributed on PCB2
- PCB2 glued on the top side of the Al honeycomb to get the full panel
- Glue curing

Test with cosmic rays

A preliminary chamber characterization has been carried out with cosmic rays with a dedicated cosmic-rays test-stand that was installed in the CERN laboratory of the RD51 Collaboration.

The cosmic-stand is composed of two planes of 12 plastic scintillators each, for a total active area of about 2.5 × 1.1 m² 2m apart, providing large and uniform cosmic muon trigger.

The chamber was operated with Ar/CO₂ 93/7% gas mixture with a flow of few l/hour, the drift plane was set to 300 Volt while the high voltage on the resistive strips was changed according to the studies of interest

Using APV25 front-end ASIC, an SRS based readout system and the dedicated DAQ software MMDAQ3 cosmic rays could be detected in all detector layers.

Full track-events have been observed and successfully reconstructed.

For a vertical track, while the clusters on the first and second layers look aligned, due to the presence of stereo strips on the third and fourth layers, the clusters can look to be far from the ideal vertical line. This is an effect of the stereo strips. The distance of the cluster from such a vertical line is a function of the distance of the incoming particle to the center of the chamber.

Hits charge distribution, with the typical APV saturation peak

MMSW cluster charge as a function of the HV

Chamber response to cosmic events, the empty spaces at the corner of the chambers are due to the missing overlap between stereo and eta strips

Test with X-Ray source

Using a MiniX-Ray gun the MMSW chamber has been radiated.

Current monitoring (first right plot) has been used to monitor and check the amplification gain of the four active layers. A local inefficiency can be easily detected as drop in current absorption.

Collecting data, using front end electronics (second right plot) the relative alignment between panels can be checked.

Amplification current, as well as the number of converted photons detected as function of the position of the layer from the X-Ray gun, closer in the lower plot, farther in the upper plot.

Test beam results

MMSW chamber has been extensively studied during the MMs test beam campaign.

The chamber has been placed between an hodoscope, hosting several MMs small chambers including 4 double view chambers (Tmm) and a similar chamber (Tmm) placed behind the MMSW chamber to reconstruct the incoming particles (pions & protons).

Due to the 1.5° rotation used to built the stereo strip, a resolution on the second coordinate is expected to be: $\sigma_y = 27 \cdot \sigma_x$ (right upper plot).

Resolutions for the precision and second coordinate, extracted by the test beam data (right lower plots)

MMSW Installation into the ATLAS cavern

Who?

- ATLAS Micromegas community

What?

- Micromegas quadruplet prototype

Why?

- To test a MMs prototype in the ATLAS cavern environment
- To record and verify the trigger information provided by the new trigger electronics (VMM2) and compare it with the MM readout data and a "offline" trigger calculation.
- To record beam/background data which will be used for simulation of the trigger, crucial for the designing the trigger algorithms.

When?

- In the autumn of 2014, before the closure of the ATLAS experimental cavern.

Where?

- On the HO structure, Side A level 7, behind the MDT wheel. Level 7 allows to collect particles at 20° w.r.t. the chambers surface, an optimal angle for the microTPC studies.
- MMSW should be relocated in the Small Wheel during next Xmas stop, depending on access condition.

The DAQ system for the MMSW into the ATLAS framework

The 4x1024 strips will be read out by newly developed VMM2 hybrid chips. Their HDMI output will be converted to optical fibers through optical converter boxes (OC),

Optical fibers will send the data to an ATCA-SRS board in USA15.

A standard Scalable Readout Unit (SRU) will be used in order to get the DTCC link from the ATCA-SRS. The SRU will act as a ReadOut Driver (ROD) to generate valid event fragments that can be transmitted to the ReadOut System (ROS) via the standard ATLAS readout link (S-Link).

A Micromegas segment has been implemented using the ATLAS Online TDAQ Software in order to be attached to the main ATLAS DAQ partition

MMSW data will be automatically inserted into the ATLAS byte stream

Online software will provide fast detector monitoring