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 415µm.

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 0.5m 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.
- Each readout plane comprises 1024 strips per plane with a pitch of 415µm. The strips are rotated by ±1.5° 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 25 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 128µm high support pillars to define the position of the floating mesh.

Chamber preparation and end 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.

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 × 1.2 m² apart, providing large and uniform cosmic muon trigger.

The chamber was operated with Ar/CO₂ 90:10% gas mixture with a flow of few litre/hour, the drift plane was set to 300 Volt while the high voltage on the resistive strips was charged according to the studies of interest. Using APV25 front-end ASIC, an SRS based readout system and the dedicated DAQ software MMAO (Micromegasampling) 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.

Test with X-Ray source

Using a Micromegas X-Ray gun the MMSW chamber has been irradiated. Current monitoring (first right plot) has been used to monitor and check the amplification pattern of the four active layers. A local inefficiency can be easily detected as step in current absorption.

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

Test beam results

MMSW chamber has been extensively studied during the Micromegas test beam campaign. The chamber has been placed between an hodoscope, housing several MMs small chambers (4 double view chambers (7mm) and a similar chamber (7mm) placed behind the MMSW chamber to reconstruct the incoming particles, (pions and protons).

Due to the 1.5° rotation used to build the stereo strip a resolution on the second coordinate is expected to be: σ≈0.27° ± 0.05° (right upper plot).

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

MMSW Installation into the ATLAS cavern

The DAQ system for the MMSW into the ATLAS framework

The 4x1024 strips will be read out by newly developed VMDM hybrid chips. Their HDMI output will be converted to optical fibers through optical connector boxes (OCB).

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 STGC links from the ATCA-SRS. The STGC 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 data stream.

Online software will provide fast detector monitoring.