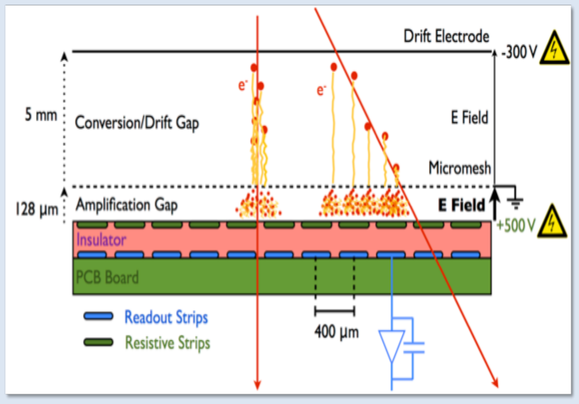
Cosmic results with the final Micromegas sectors for the ATLAS Muon upgrade

With the upgraded beam luminosity in LHC run-3, the detector technology for the innermost end-cap muon station (small wheel) of the ATLAS detector needs to be upgraded. The new technology should be able to meet the demands of keeping position resolution, high efficiency as well fast response of the present system at the expected higher background rate, up to 20 kHz/cm^2. The detectors for precision tracking and triggering at the New Small wheel (NSW) are Micromegas (MM) and small-strip Thin Gas Chamber (sTGC) respectively. The detectors are also complementary to each other. Each of the two NSWs will consist of 8 large and 8 small sectors. A sector is a combination of the sTGC wedges on either side of a double Micromegas wedge.

The Micromegas quadruplets are delivered at CERN from the different construction sites. Four Micromegas quadruplets are integrated to build a double wedge. After the electronic integration, the double wedges are tested with cosmic muons at the cosmic stand at CERN. The final high voltage configuration is verified, various parameters like the efficiency, cluster size, strip multiplicity per readout layers are measured. The double wedge of the Micromegas sector is qualified for the final integration with the sTGC wedges before mounting them on the NSW. The procedure and the cosmic test results of the final validation of micromegas double wedges is presented.

Micromegas detector operation

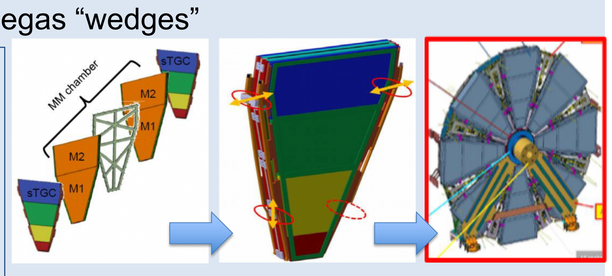
- Charged particles ionize the detector gas (100 pairs/cm in Ar:CO_2 93:7 for MIP)
- Ionization electrons produced in the conversion/drift gap drift towards the micro-mesh and pass through it due to the high field ratio. Then they are amplified in avalanches in the high field region between micro-mesh and the resistive anode strips, producing a large signal which is then collected on the anode strips
- Fast evacuation of the avalanche ions by the micromesh allows good operation in a high rate environment
- Resistive anode strips → suppress discharges



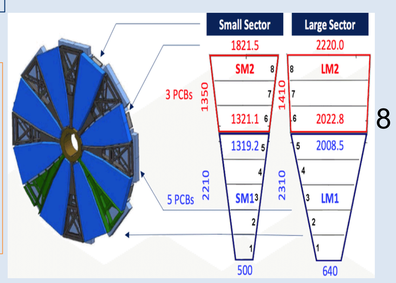
NSW Configuration

Package of sTGC (small strip TGC) and Micromegas "wedges"

sTGC primary trigger detector
- Good timing resolution for bunch ID
- Online track vector with angle resolution <1 mrad
- pads: region of interest
- strips: track info (strip pitch 3.2 mm)
- wire groups: coarse azimuthal coordinate



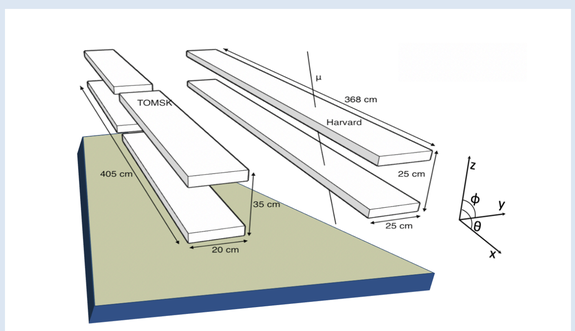
Micromegas primary precision tracker
- Good Spatial resolution < 100 μm
- Good track separation (0.4 mm readout granularity)
- Provide online segments for trigger



16 Sectors:
8 Small + 8 Large

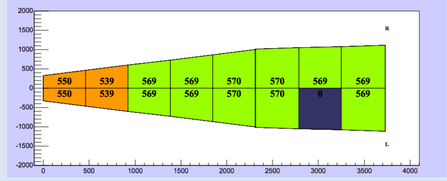
Cosmic Ray stand @ CERN

- Two pairs of scintillators
- Coincidence on each set triggers data acquisition system
- Angular acceptance:
  - $-45^o < \theta < 45^o$
  - $-30^o < \varphi < 30^o$
- 65536 strips connected to 128 MMFE8 boards (acquisition rate120 Hz)



High Voltage validation

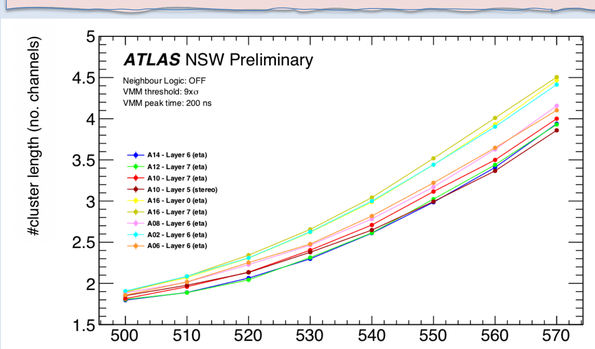
- Optimum read-out high voltage (HV) depends on the gas mixture used
  → $ArCO_2$ 93:7: cathode -300 V, read-out +570 V, grounded mesh
  → ArC_4H_{10} 93:5:2: cathode -300 V, read-out +510 V, grounded mesh
- 128 HV-sections on read-out PCB (16 sections x 8 layers)
- Induced sparks affect detector's operation
  → Moderate discharging sections are supplied by a different HV line (lower)
  → Intensively discharging sections are turned off



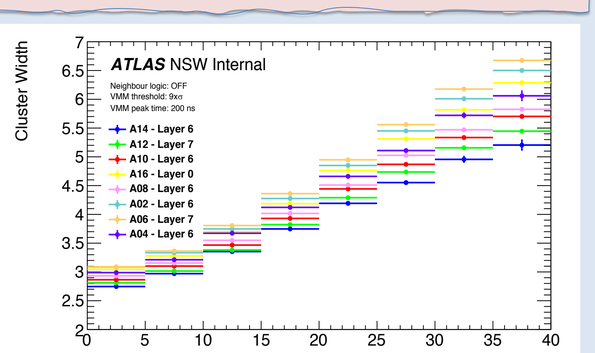
Micromegas validation

Cluster reconstruction

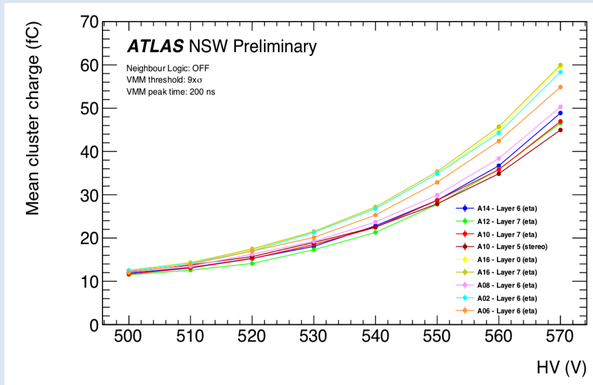
- Position calculation: centroid method
- Cluster with at most two consecutive not firing strip
- Eta layers used only (orthogonal to the longitudinal axis)



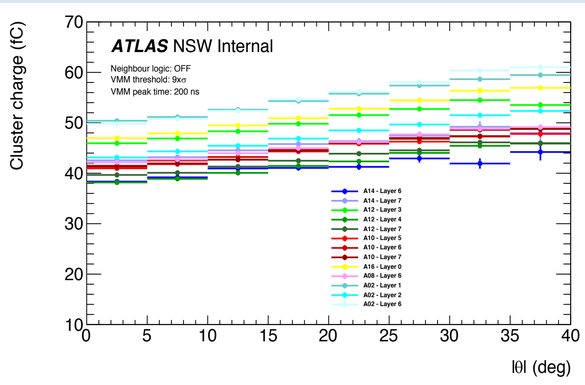
- Cluster length (number of hit strips per cluster) vs amplification voltage (HV)
- About 4 strips per cluster is the mean cluster width for nominal applied High Voltage



- Cluster length vs incident angle θ (from track reconstruction)
- Only eta Layers used for the analysis



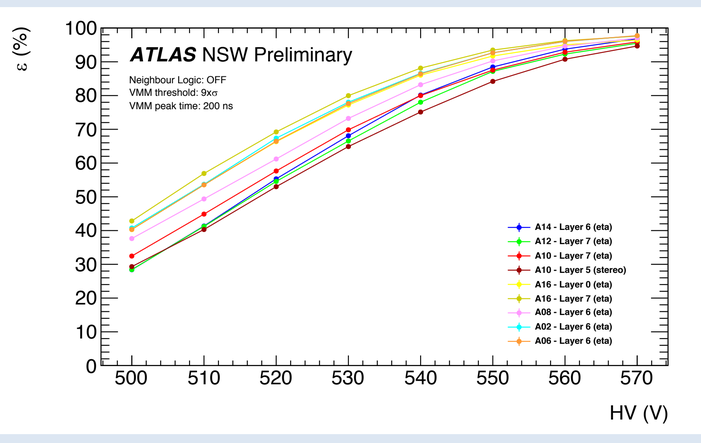
- Mean cluster charge vs amplification voltage



- Mean cluster charge vs incident angle θ (from track reconstruction)

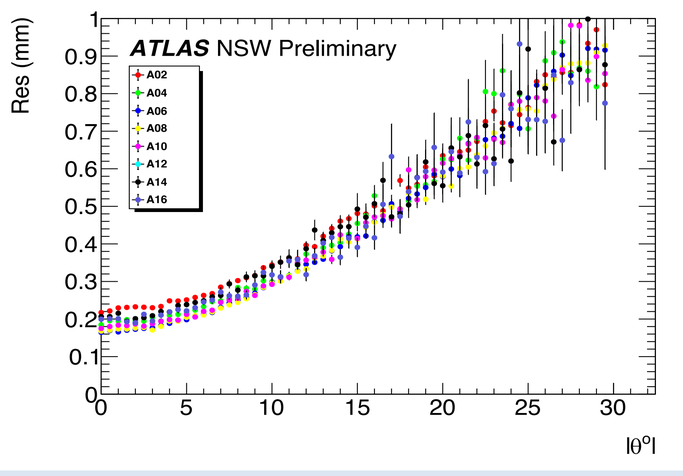
Efficiency / Resolution results

Efficiency vs amplification voltage



Calculation with Tag and Probe method
➤Probe: Track reconstructed by at least 5 layers other than the one under study layer
➤Tag: Clusters whose position is within ± 5 mm distance (for eta layers) from the extrapolated track position

Resolution with centroid method vs incident angle θ



Resolution calculation:
1. Subtract cluster position of Eta layers
2. Fill distributions for the angle intervals
3. Calculate σ of distribution
4. Res = $\frac{\sigma}{\sqrt{2}}$

✓ Same performance for most of modules

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