

Construction and operation of large scale Micromegas detectors for the ATLAS Muon upgrade

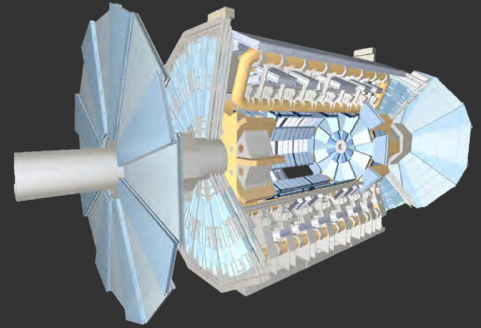
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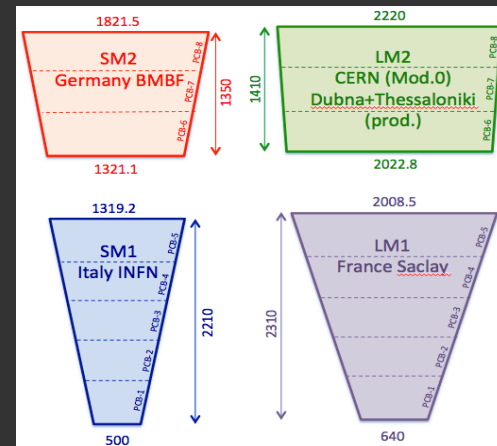
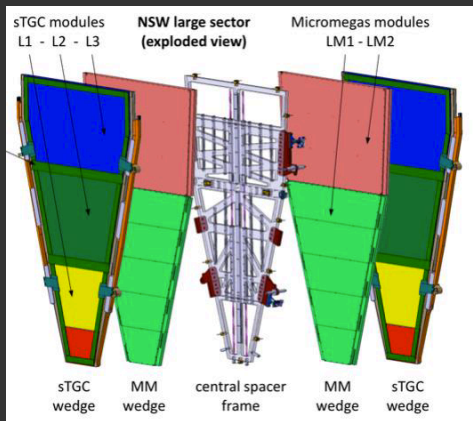
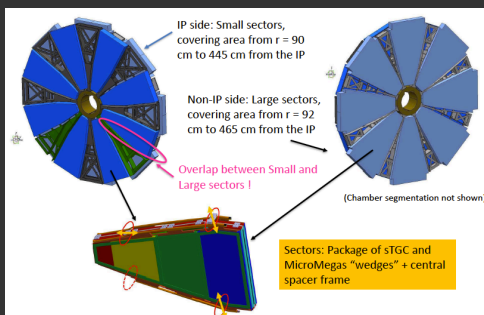
New Small Wheel

- LHC luminosity increase up to $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$
- ATLAS muon spectrometer incapable to cope with such demanding environment
- Significant fake trigger rate + increase of background \rightarrow affects spatial resolution \rightarrow overall performance
- Reinforcement by upgrading the existing SW end-caps with the New Small Wheel (NSW)
 - \rightarrow fake muon triggers at end-caps will be less than 20 kHz
 - \rightarrow online reconstruction maximum latency below 1 μsec
 - \rightarrow Resolution $\sim 100 \mu\text{m}$ in precision coordinate
- Triggering and Bunch Crossing identification \rightarrow sTGC
- Track reconstruction \rightarrow MICROME GAS



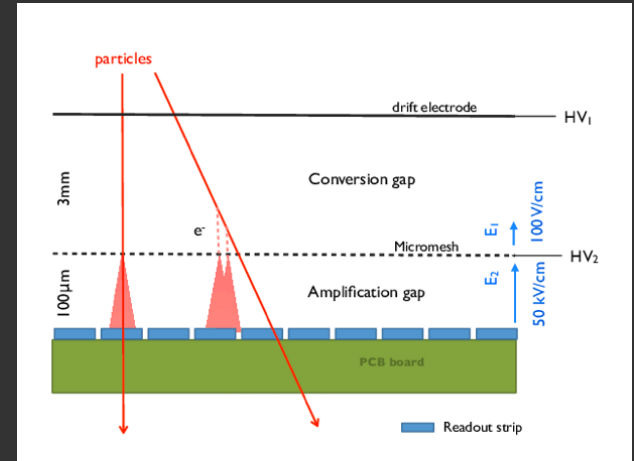
NSW layout

- Eight large and eight small sectors (wedges) partially overlapping
- Single sector consists of two MM wedges sandwiched by two sTGC wedges
- MM and sTGC chambers in the wedges have four active detector layers forming quadruplets
 - eight layers of MM and eight layers of sTGC detectors
 - each MM wedge is segmented into two modules of different size trapezoids
- Four types of MM
 - SM1 (Italy), SM2 (Germany), LM1 (France), LM2 (CERN, Greece, Russia)



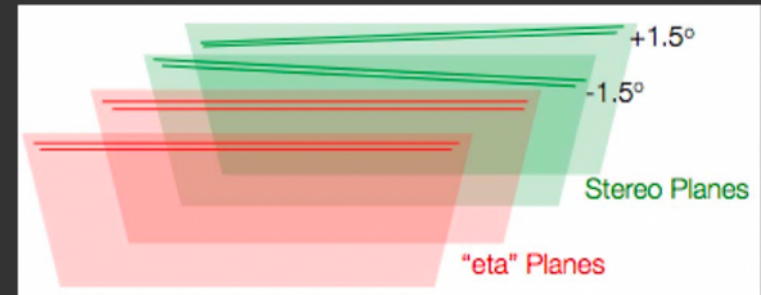
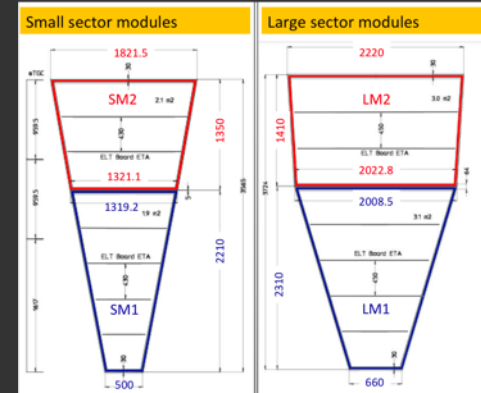
MICROME GAS – Structure & operation

- Consists of two parallel planes which are used as electrodes
 - Thin metallic mesh placed between them
- Thicker volume - Drift region → Weak electric field (hundreds of V/cm) → Charged traversing particle interacts with gas molecules → Cathode - planar
- Thinner volume - Amplification region → Strong electric field (~kV/cm) → Multiplication process → Anode - strips
- Mesh sits on pillars → Grounded
- Difference electric fields → Transparency ~95%
- Resistive anode strips
 - Suppress discharge influence on efficiency



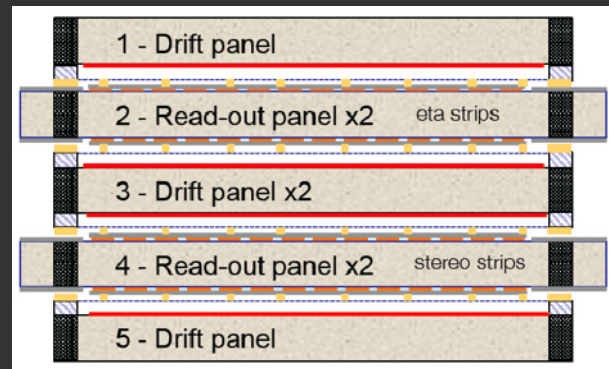
Large scale MICROMEAS

- Due to production constraints of the PCBs' width, it was selected to be divided each wedge layer into eight PCBs.
 - LM1 – SM1: 5 PCBs
 - LM2 – SM2: 3 PCBs
 - Photolithographic printed copper strips: 300 μ m width, 12 μ m height, 425-450 pitch
 - Resistive strips parallel to the readout strips (10 M Ω /cm)
 - Insulating pillars determines amplification region: 128 μ m height, 350 μ m diameter, 0.4 mm pitch
 - Three types of readout PCBs
 - 1) Strips perpendicular to wheel's radial direction (precision direction η)
 - 2) Strips tilted by a small angle $\pm 1.5^\circ$ w.r.t η
- strips (non precision direction φ)

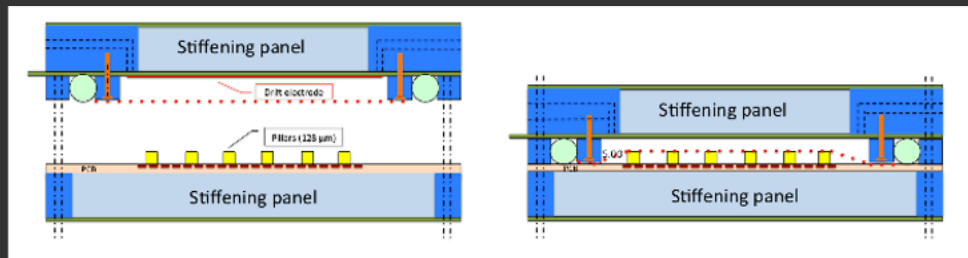


MICROMEGAS Quadruplet

- Four gas gaps forming a quadruplet of MM detectors
- Five panels bound the four active MM gaps.
- Two drift panels with one side copper covering
- One drift panel both sides covered (central)
- Mesh is glued on the drift panels
- Attached to the pillars when the quadruplet is assembled due to electrostatic forces
- Readout panels features readout strips on both sides

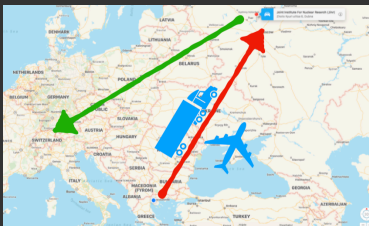


- Placed between drift panels
- Novel technique on mesh placement
 - Floating mesh
 - Removable → easy to clean detector from remnants



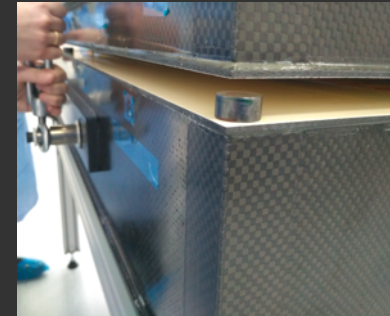
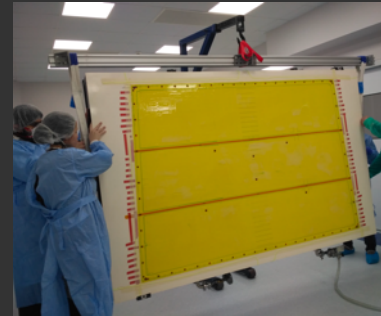
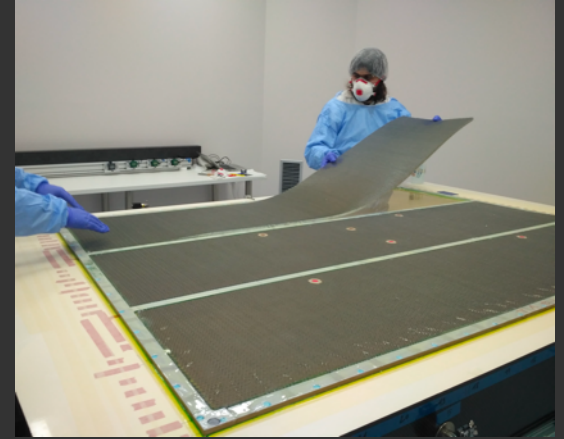
LM2 Drift panels @ Thessaloniki

- The production and test of 96+9 Drift panels equipped with mesh sent to Dubna for the chamber assembly (quadruplet)
- New Laboratory for detector construction established (360 m²)
- New Clean Room (145 m², *Grade D*)
- Production started July 2017 – ended January 2020



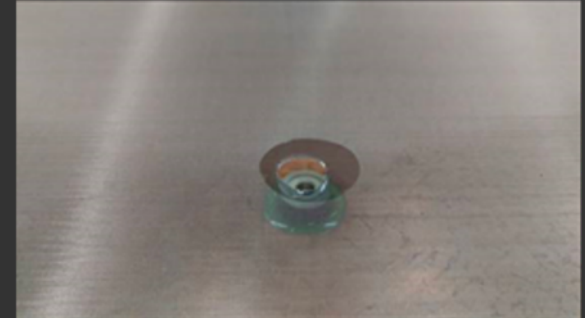
MICROME GAS drift panels construction

- Pair of ultra flat tables are used for placing PCBs during gluing
- High precision holes are drilled on these tables → relative alignment of PCBs
- Steps of construction:
 1. Assembly and gluing of the aluminum frame → Trapezoidal frame with three sub-areas
 2. Panel gluing is a one step process using the vacuum table method
 3. Under-pressure of about 100 mbar on vacuum tables → PCBs mimicking table's planarity
 4. Kapton tape attached along PCB junctions to reassure sealing
 5. 3 kg of glue is distributed on aluminum frame and PCBs
 6. Honeycomb is placed inside frame's sub-areas
 7. Second table (movable) is rotated and placed on top of the first one standing on ten high precision spacers
 8. 20 hours glue curing with under-pressure



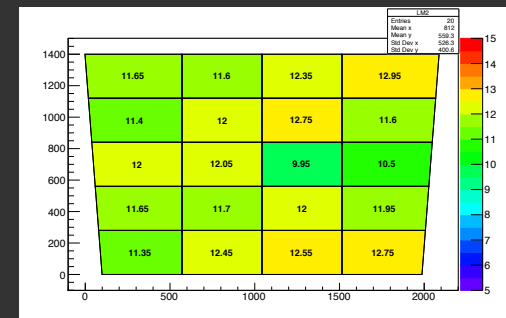
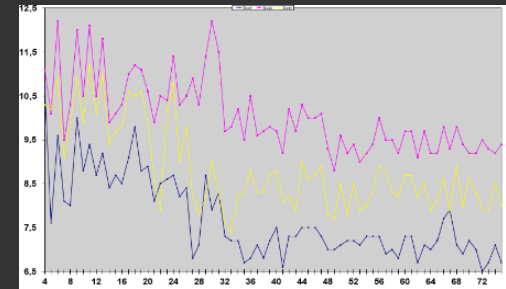
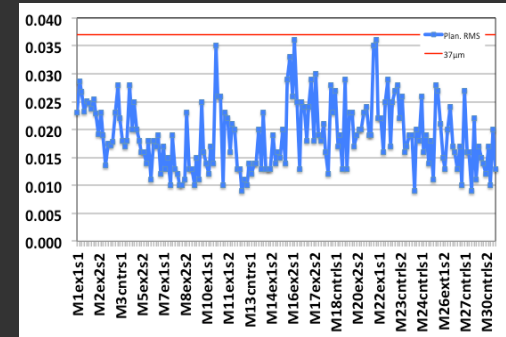
MICROME GAS drift panels construction

- Steps after gluing:
 1. PCB excesses remove
 2. Sealing PCB junction to prevent gas leaks
 3. Mesh frame gluing
 4. Interconnection drift spacers gluing
 5. Gas pipes gluing
 6. HV connectors gluing
 7. Mesh stretch to a certain mechanical tension
 8. Mesh gluing on a transfer frame (mandatory for movement from stretching machine to bare panel)
 9. Perforation of mesh around the interconnection area
 10. Mesh gluing on bare panel
 11. Mesh excesses remove



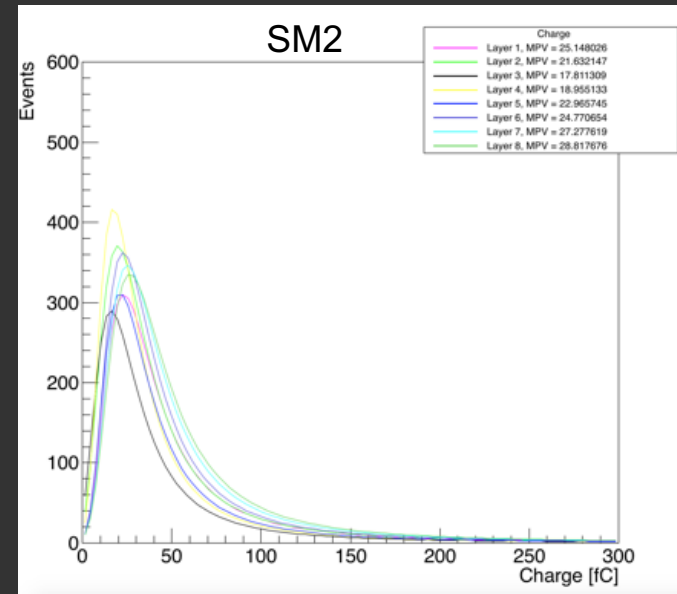
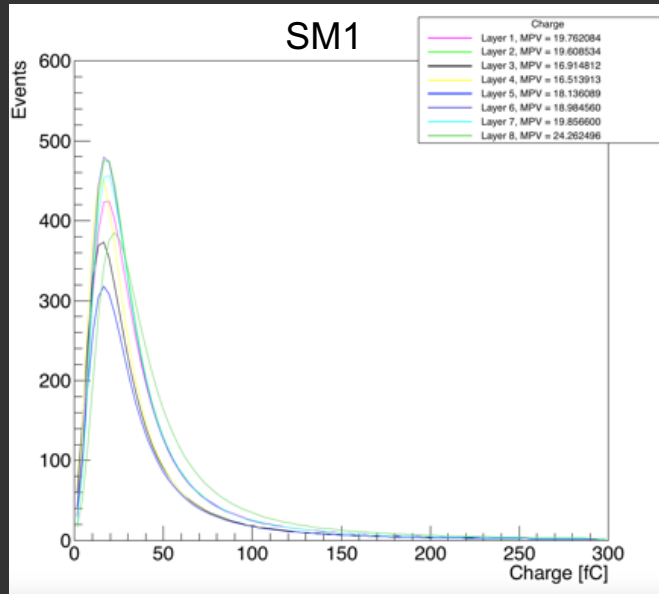
MICROMEAS drift panels QC

- All panels are checked in terms of planarity and thickness
 - Planarity is affected by deformations of vacuum tables
 - Planarity measured by 19x8grid with vacuum off
 - Average RMS 19 μm
- All additional glued parts on top of bare panel were measured (periphery, interconnection, mesh frame etc)
- Gas leakage measurement
 - Pressure Drop Rate (DPR) method used \rightarrow Gas leak estimation by using inlet and outlet gas pressure
 - Leakage is given by $Q = V \frac{dp}{dt}$, by assuming a fixed volume
 - Gas deformats detector \rightarrow Parametrization
- Mesh tension
 - Spatial map of the mechanical tension (35 measurements on transfer frame – 24 measurements on drift panel)
 - Uniformity better than 10%



MICROMEAS validation @BB5

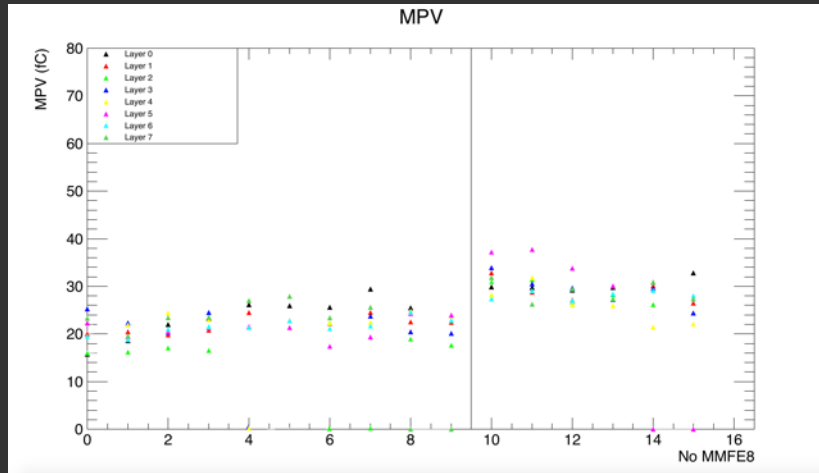
- Investigation of systematic difference on gas gain between module types (SM1 – SM2)
- MPV for charge systematically was higher on SM2



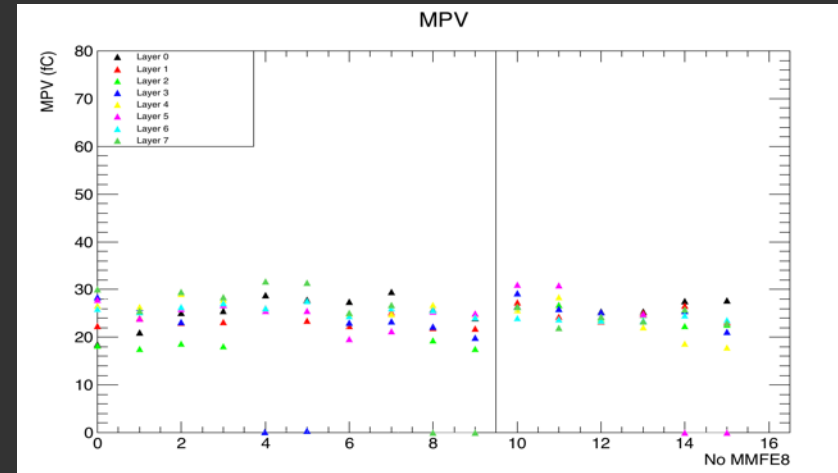
MICROME GAS validation @BB5

- Studies with reversed gas flow

Normal flow



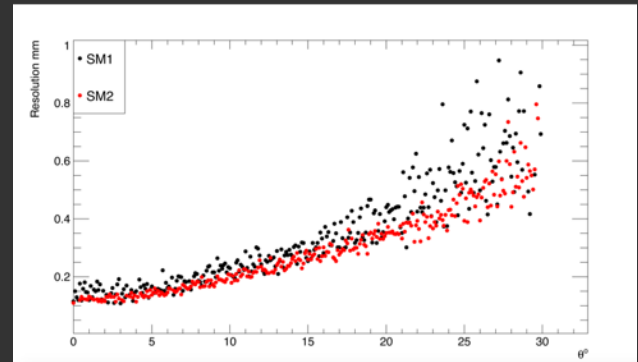
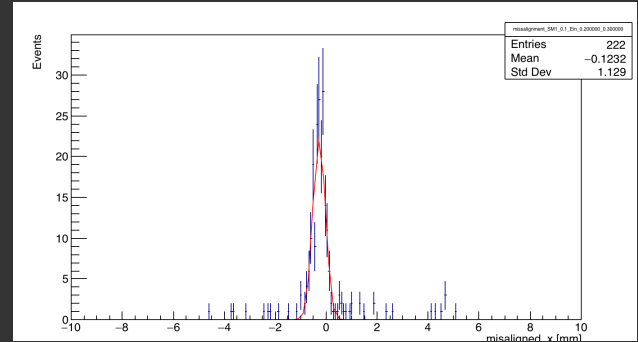
Reversed flow



- No evidence that gas flow impacts the observed gain

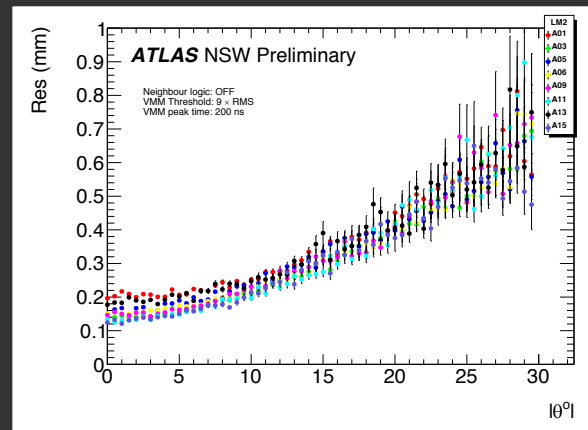
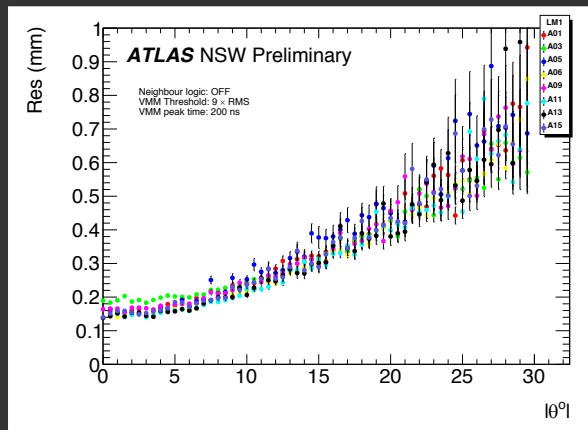
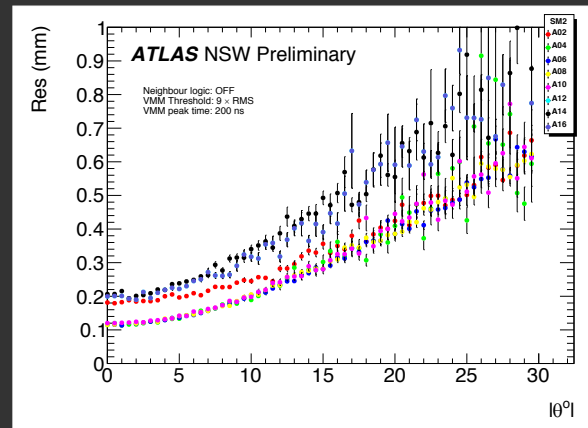
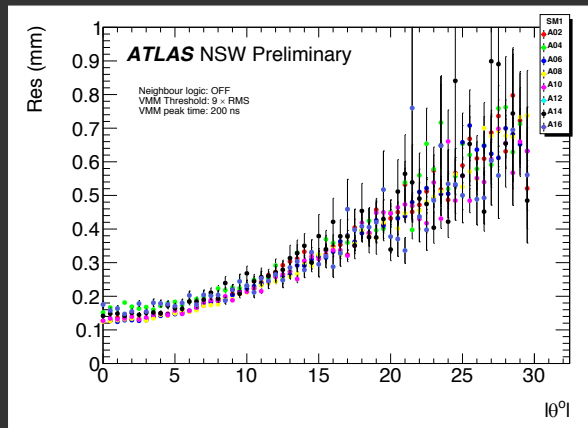
MICROMEAS validation @BB5

- Resolution studies
 - Subtract cluster coordinate of two eta layers
 - Centroid method for cluster position
 - Distribute them w.r.t track's angle
 - Gaus fit
 - $Res = \frac{\sigma}{\sqrt{2}}$
 - Dependence on data size



MICROMEAS validation @BB5

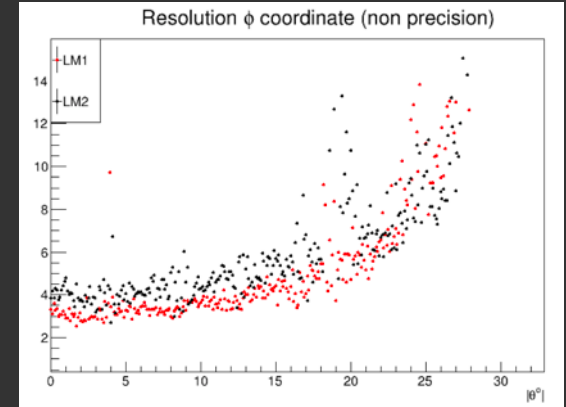
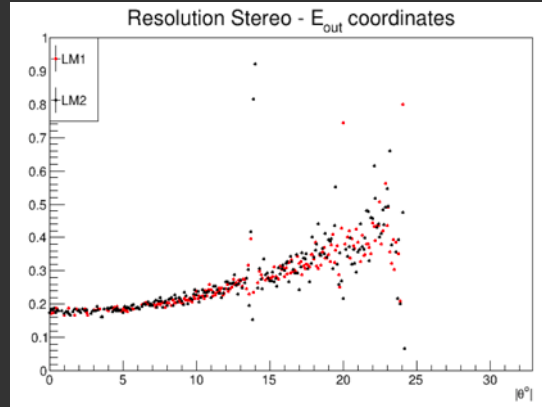
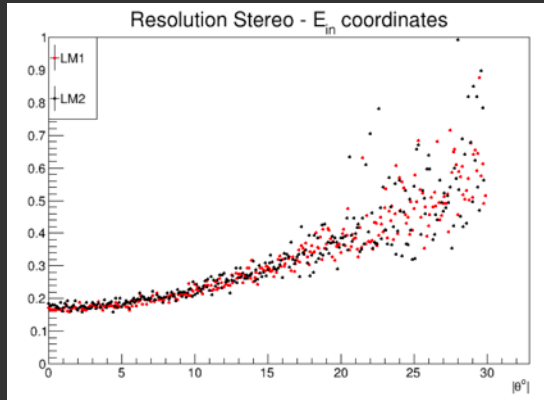
- Great performance for perpendicular tracks on most DWs
- Expected $\sim 100 \mu\text{m}$
- Centroid \rightarrow good results for tracks up to $\sim 10^\circ$
- Same performance on most Sectors



MICROMEAS validation @BB5

- Resolution also from stereo layers
- Calculation of a virtual coordinate from stereo layers data
 - $\eta_v = \frac{\eta_s + \eta'_s}{2 \cos 1.5^\circ}$
- Subtraction $\eta_6 - \eta_v \rightarrow E_{in}$
- Subtraction $\eta_7 - \eta_v \rightarrow E_{out}$
- Same procedure $\rightarrow Res = \frac{\sigma}{\sqrt{1.5}}$
- Non - precision coordinate also
 - $\phi = \frac{\eta_s - \eta'_s}{2 \sin 1.5^\circ}$

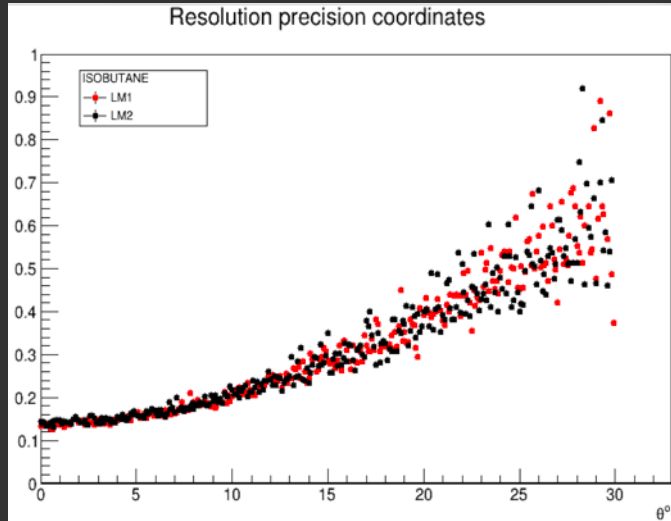
MICROMEAS validation @BB5



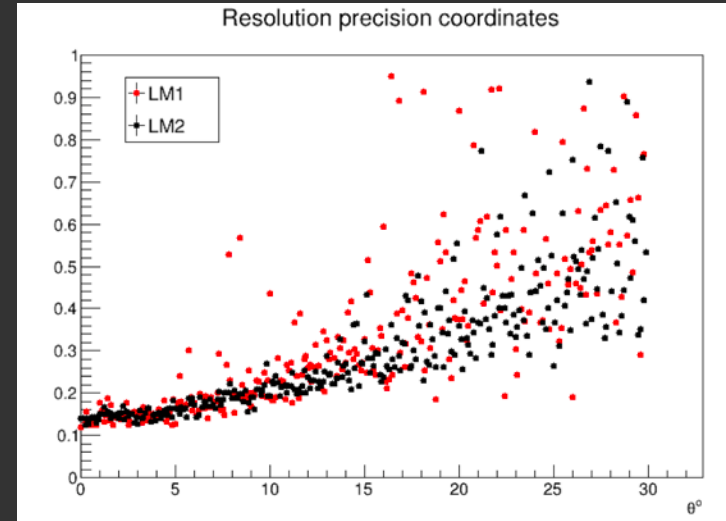
- Resolution deterioration was expected
 - Multiple scattering
- ϕ coordinate just for estimation

MICROME GAS validation @BB5

ArCO₂ + C₄H₁₀



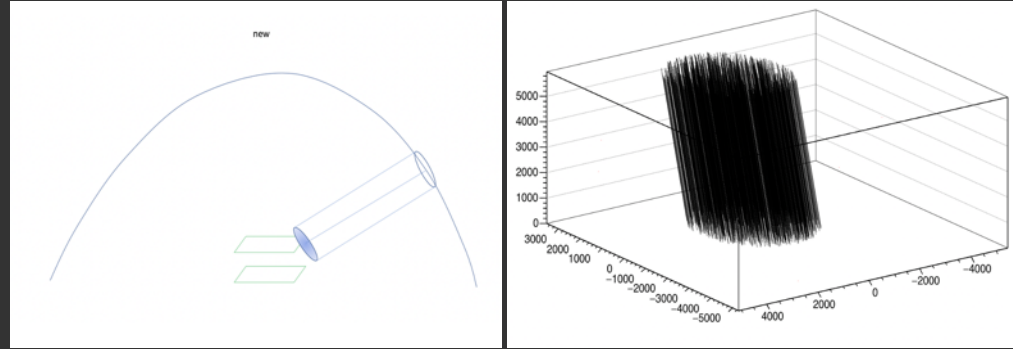
ArCO₂



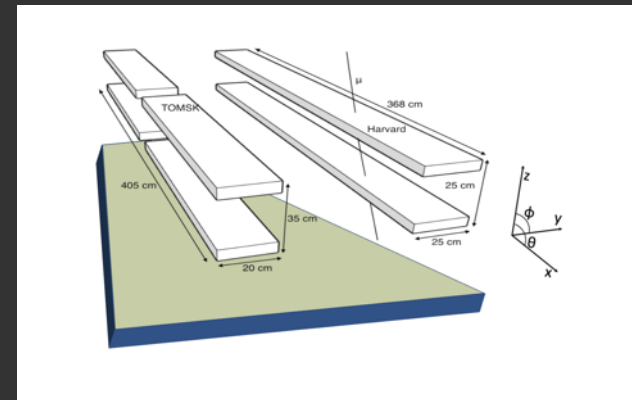
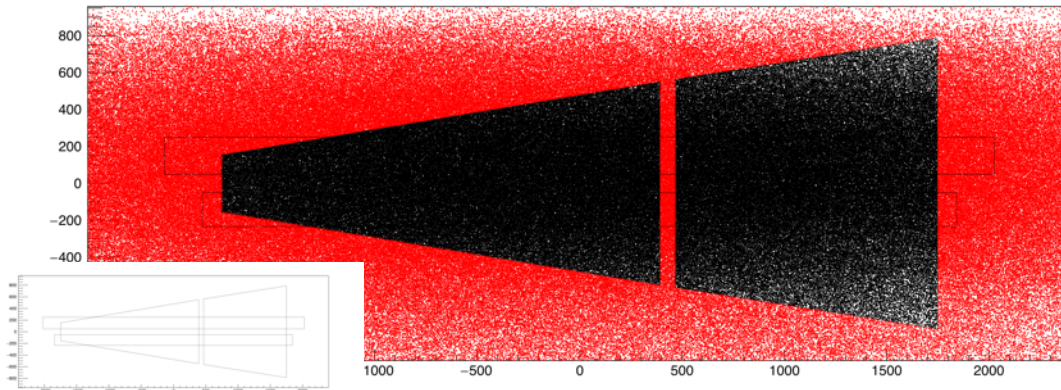
- Different gas mixtures don't affect resolution

BB5 Cosmic Ray stand MC

- Uniform coordinates on sphere's surface
- Bunch of parallel tracks for every random coordinate
- Simulate detector upper layer and pairs of scintillators

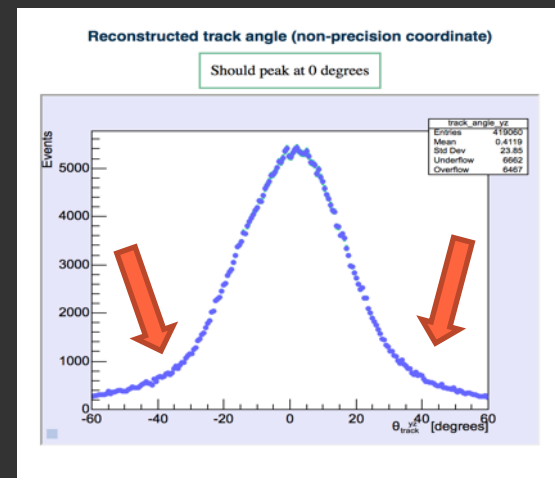
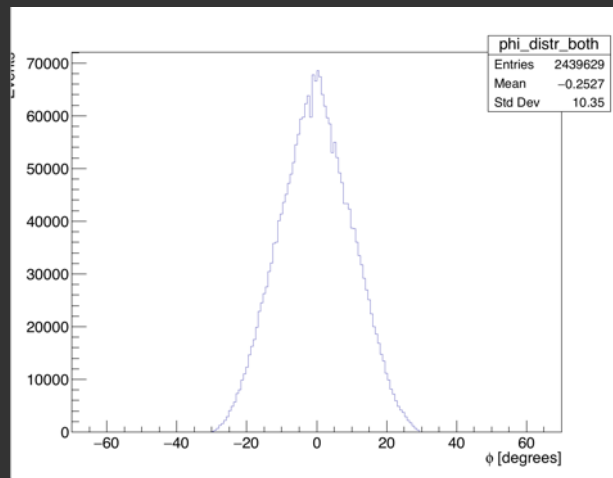
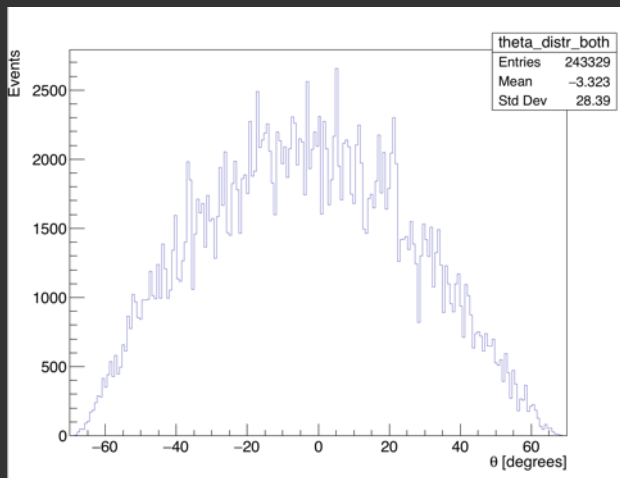


Tracks = 2504900, Triggers = 904232, Hits = 409332



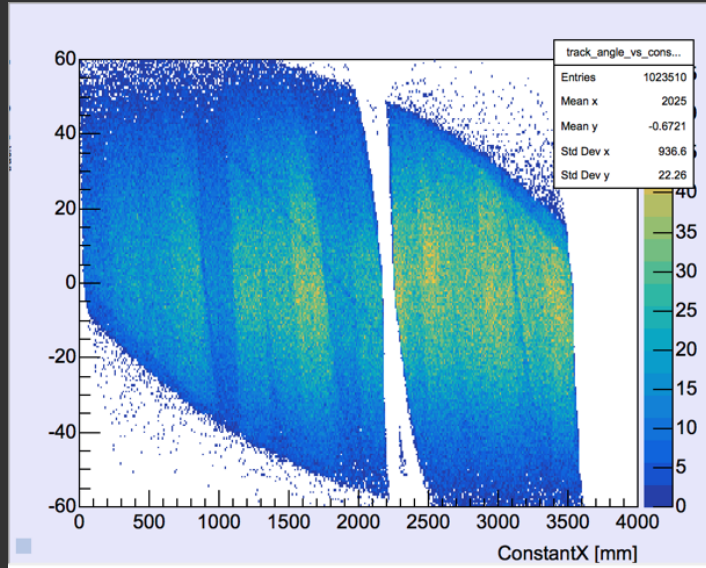
BB5 Cosmic Ray stand MC

- CRS angle coverage → Study revealed limits of coverage

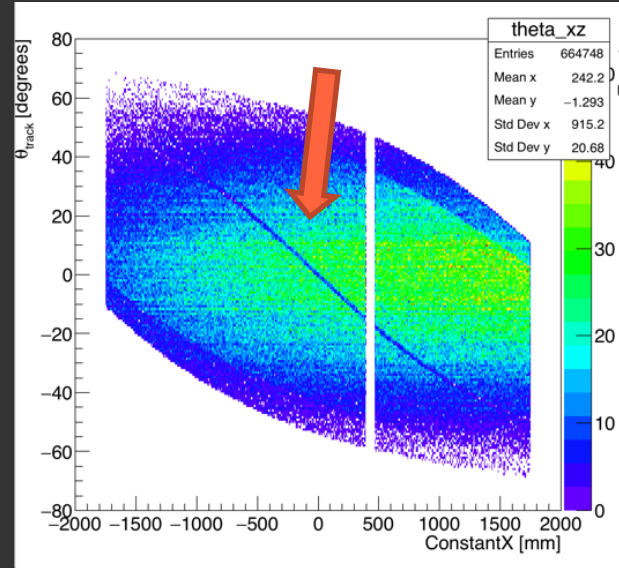


CRS MC studies

Cosmic data



Monte Carlo



Conclusions

- Successful completion of drift panels production
- Fruitful involvement on Micromegas sectors validation
- Ongoing studies for different gain on different module types
- Promising resolution performance for most of validated Micromegas Sectors on Wheel-A
- MC studies confirmed numerical predictions

Thank you!



ACKNOWLEDGEMENTS

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Also