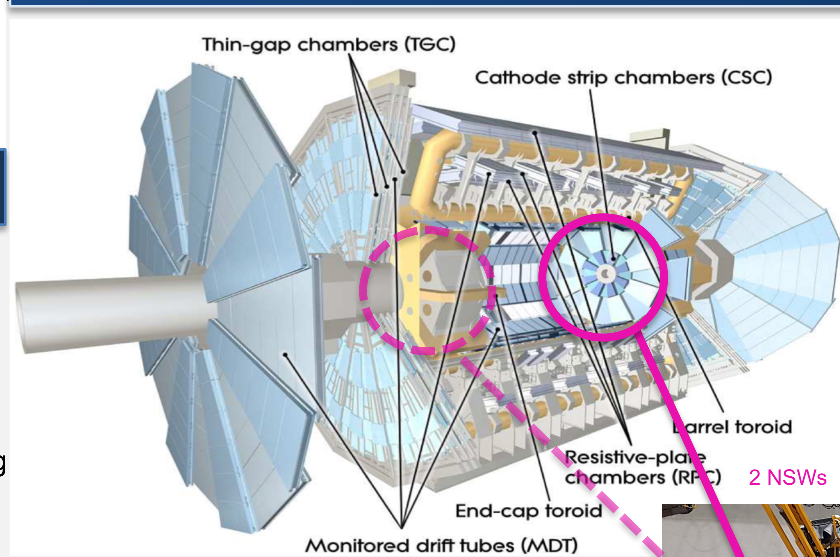
New Small Wheels for the ATLAS Muon Spectrometer

5th ICPPA, 5-9 October 2020

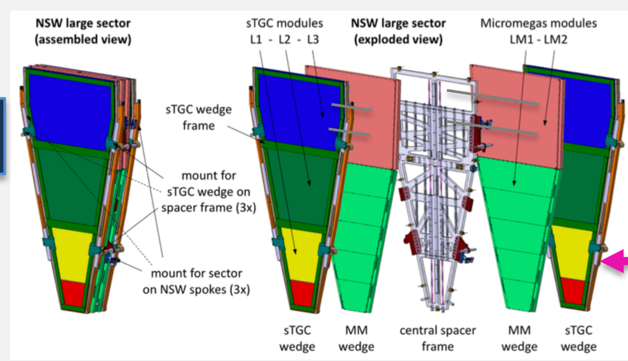
Maria Perganti[1], on behalf of the ATLAS Muon Collaboration

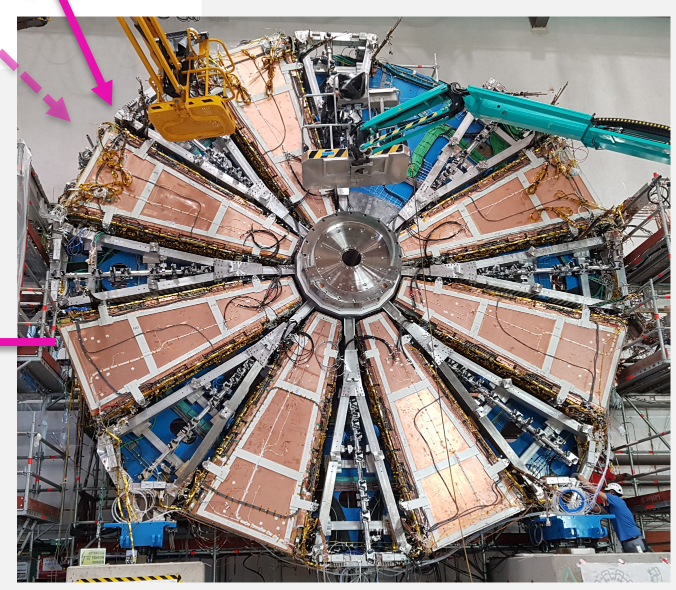
ATLAS New Small Wheel



The HL-LHC luminosity (up to 7.5 x 10^{34} $cm^{-2}s^{-1}$) requires major upgrades by the experiments to withstand the increased particle rate.
The New Small Wheel (NSW) will replace the current Small Wheel at the most forward region of its muon spectrometer 1.3 < |η| < 2.7.

The NSW consists of Micromegas detectors and small-strip Thin Gap chambers with both tracking and triggering capabilities. The integration and commissioning of the NSW is currently in a full swing at CERN and is expected to be installed in ATLAS during 2021.

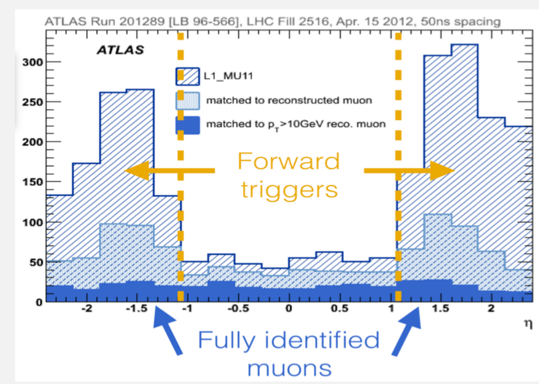




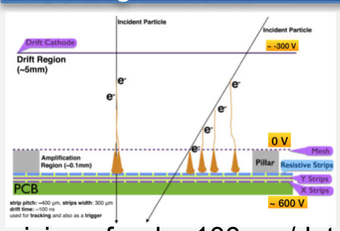
- 2 gaseous detector technologies: MM & sTGC.
- 8 Small sectors / 8 Large sectors (4 wedges/sector, 4 layers/wedge).
- 8 layers of sTGC surround 8 layers of MM.

Muon system upgrade goals:

- Improve the tracking efficiency in the high rate environment.
- Reduce fake triggers from back-ground hits. Currently, intolerable end-cap muon trigger rate with 90% fake muon triggers.



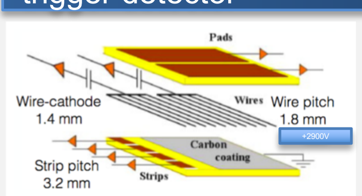
MICRO MEsh GAseous Structure (MM) - tracking detector



The MM is a type of parallel plate gaseous detector. Thanks to the metal mesh separating drift and amplification regions, MM is able to track particles with a precision of order 100 μm/detection gap while withstanding a particle rate around 20 kHz/cm^2. Free drift electrons arisen from gas ionization, move in the electric field inducing signal on the readout strips by activating avalanche mechanism.

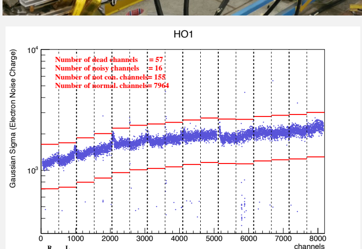
The MMs will be primarily used for the NSW tracking.

Small Strip Thin Gap Chamber (sTGC) - trigger detector

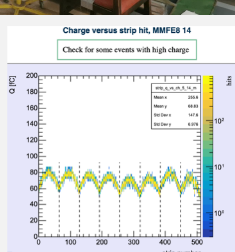


A gaseous detector with an anode plane, sandwiched between two parallel cathode planes. One cathode plane has readout strips and the other one has the pads for triggering. Signal pick-up copper pads and strips are on the back side of the two isolation layers, respectively. The sTGC will be primarily used for the NSW trigger (resolution ~1 mrad).

Electronics Integration & Validation



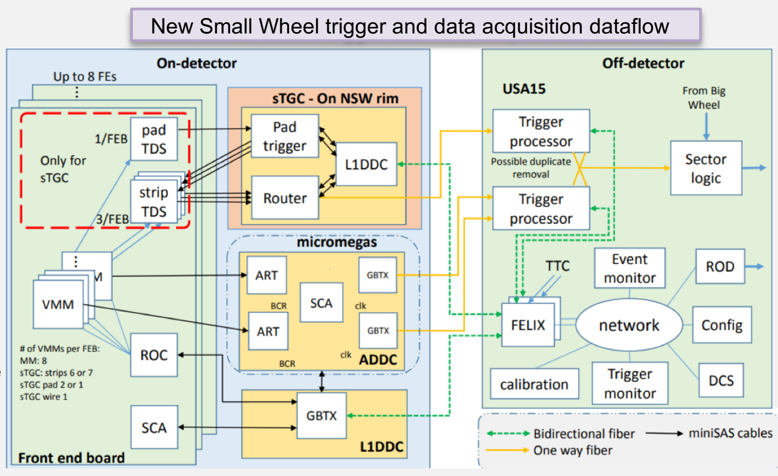
Baselines taken to check the noise of front-end electronics. Noise rms increasing with strip length.



Pulser run to cross check the number of dead channels with those from baselines and perform an overview of the electronics.

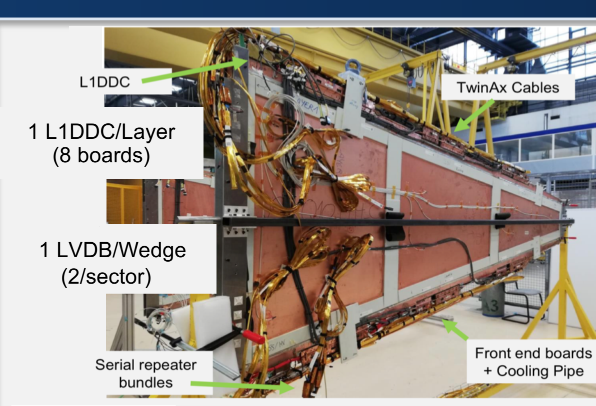
- 4 L1DDC/Layer 1 & 4 (16 Level-1 data driver cards)
- 16 MMFE8/Layer (128 Micro-Megas Front-End Boards)
- 4 LVDB/Layer 1 & 4 (16 Low Voltage Distribution Boards)
- 4 ADDC/Layer 1 & 4 (16 Address in Real Time Data Driver Cards)

New Small Wheel trigger and data acquisition dataflow

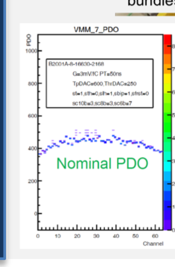


Micromegas

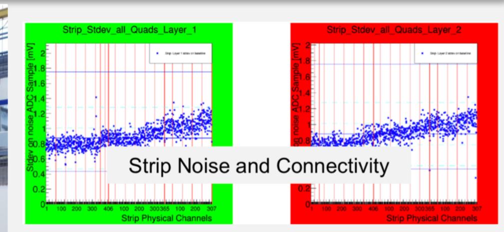
sTGC

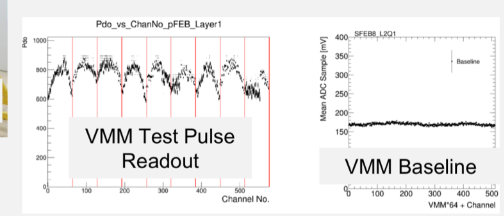


6 FEBs/Layer (24 boards)



Pulser run to check electronics operation, i.e. pdo (charge), tdo (time).



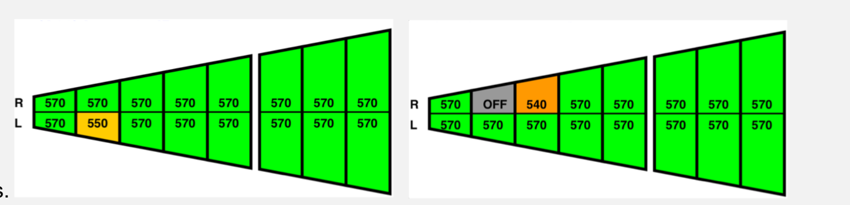


VMM channel aliveness is validated with test pulse readout.

High Voltage Validation

The MM HV values of all the 128 HV-sections of a MM DW are tested and decided:

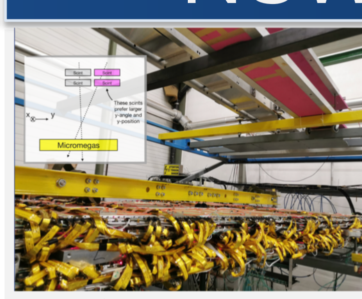
- Operating gas mixture: Ar + 7%CO_2. However, studies on alternate gas mixture is ongoing.
- Operating voltages: Drift cathode at -300 V, Micro-mesh at grounded, Readout at +570 V.
- 16x8 = 128 HV-sections in a full Micromegas double wedge.
- A moderately unstable HV-section still can be operated at a lower value on a separate HV line (which is referred to as the hospital line). A very unstable HV section is turned off during HV-validation.



A possible HV-map of two layers.

sTGC HV validation: keeping the nominal voltage for 1 Month with proper gas mixture (nPentane/CO2 (45% / 55%)) ⟶ No sparks should be detected, no trip.

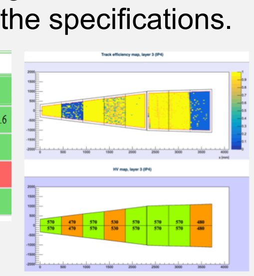
NSW performance validation



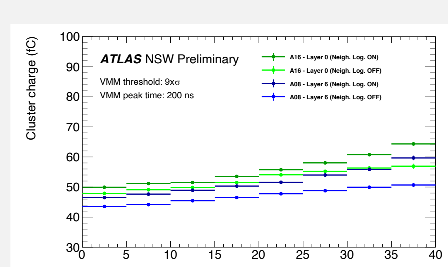
2 pairs of scintillators trigger with frequency at 120Hz, covering partially the detectors along φ coordinate.

Look at the basic detector parameters, i.e. charge, cluster size, efficiency. Meant to validate that the system works within the specifications.

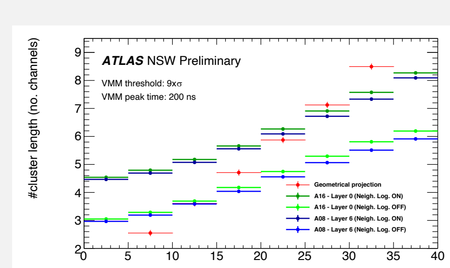
Micromegas Layer		0		1		2		3		4		5		6		7	
Efficiency [%] (sm)		89.2		93.5		91.1		89.5		94		93.6		93		95.2	
Eff. LM1 [%](sm)	Eff. LM2 [%](sm)	91.4	87	92.3	94.8	92.1	90.1	94	84.9	94.7	93.3	93.7	93.5	93.4	92.6	95.7	94.6
Percent zero occ. (no. channels)		0.88 (70)		1.1 (90)		0.93 (74)		1.3 (104)		0.5 (40)		0.59 (47)		1.1 (90)		1.2 (92)	
Percent low occ. (no. channels)		2.2 (173)		2.4 (189)		3.4 (270)		2.6 (209)		2.4 (193)		2.4 (191)		2.4 (189)		2.6 (204)	
Percent high occ. (no. channels)		1.2 (100)		1.3 (107)		2.2 (184)		1.9 (155)		1.6 (131)		2.6 (212)		1.2 (97)		0.99 (81)	



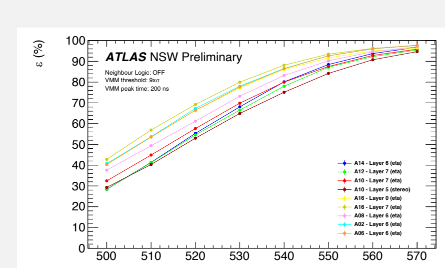
Example of a track reconstructed with MM layers. Correlation between Efficiency map (up) and HV map (low).



Mean MM cluster charge vs the incident angle θ taken from the track reconstruction using the other layers of the double-wedge.

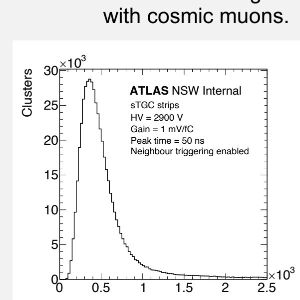


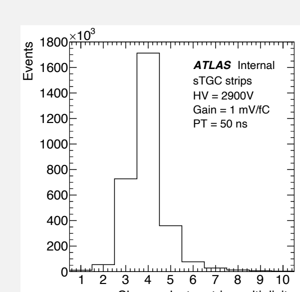
MM cluster width (number of hits+holes per cluster) vs the incident angle θ taken from the track reconstruction using the other layers of the double-wedge for Small chambers tested with cosmic muons.

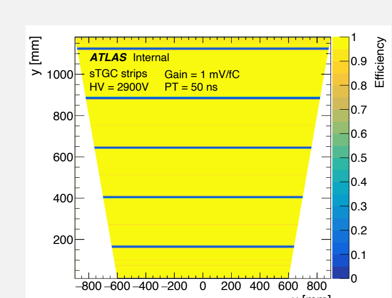


Micromegas efficiency vs amplification voltage (HV) for chambers tested with cosmic muons.

Cosmic studies at the construction sites of the sTGCs.







Studies related to the track efficiency, cluster strip charge, strip multiplicity.

Challenges of the project

- ➢ New electronics system: Separate sTGC & MM new readout architecture, several different frontend/backend electronics that have to provide precise segments in the trigger and precision hits for muon reconstruction. The reduction of noise levels (noise rate, spark rate) is a main electronic challenge.
- ➢ New TDAQ: Up-to-date using Felix[2] and Swrod[3]. System is still in developing mode. Focusing on data format and running functionalities. It needs initialization, recovery, integration with ATLAS/TTC system.
- ➢ MM HV Configuration: Achievement of stability of 16 HV section/layer is a challenge for every sector.

2. New data-routing device that distributes trigger signals and configuration data to the MMFE8s.
3. Software Read-Out Driver interface with FELIX, process the incoming data before sending them to the High Level Trigger.

1.National Technical University of Athens

Επιχειρησιακό Πρόγραμμα
Ανάπτυξη Ανθρώπινου Δυναμικού, Εκπαίδευση και Διά Βίου Μάθηση
Ειδική Υπηρεσία Διαχείρισης
Με τη συγχρηματοδότηση της Ελλάδας και της Ευρωπαϊκής Ένωσης
Ευρωπαϊκή Ένωση
ΕΣΠΑ 2014-2020

ATLAS EXPERIMENT