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Surface commissioning of the New Small Wheel upgrade project of the ATLAS Experiment

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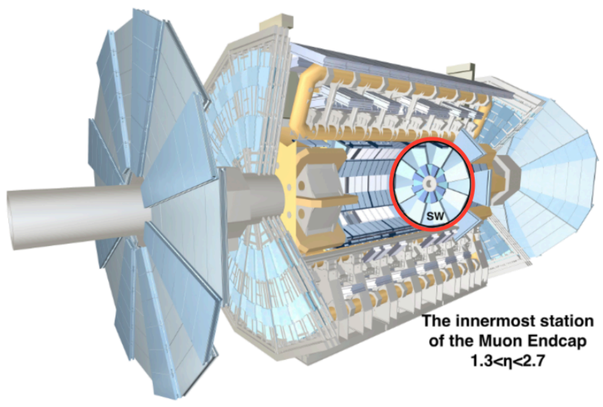
Introduction

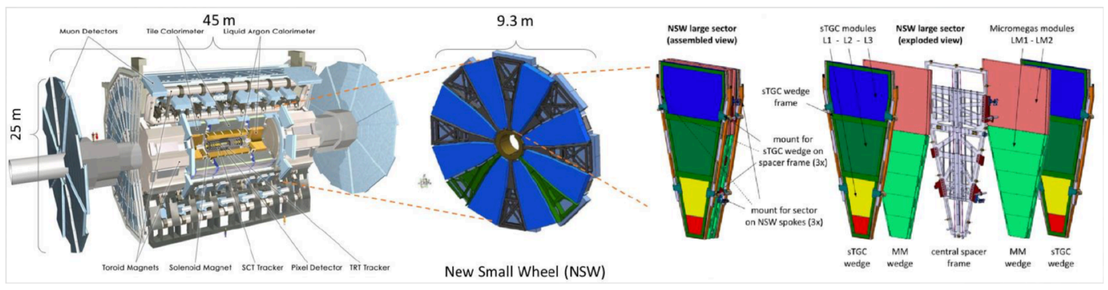
The innermost station of the muon end caps of the ATLAS experiment has recently been replaced with the New Small Wheels during the long shutdown before the Run III data taking. This upgrade aims to improve both tracking and triggering performances in the end cap region while withstanding the high pile up expected from Run III onwards resulting in rates up to 20 kHz/cm^2.



Requirements:

- Withstand high hit rate in high luminosity LHC era ($\mathcal{L}$=5-7$\times 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$)
- Fake trigger rate reduction at the Level 1 muon trigger
- Good spatial resolution and track separation

The two New Smal Wheels are made of 16 sectors each (8 large and 8 small sectors) and each sector is a sandwich of two dectors technologies, MicroMegas for the primary tracking and small-strip TGC (sTGC) for the primary triggering. Each sector contains 8 MicroMegas and 8 sTGC readout planes.

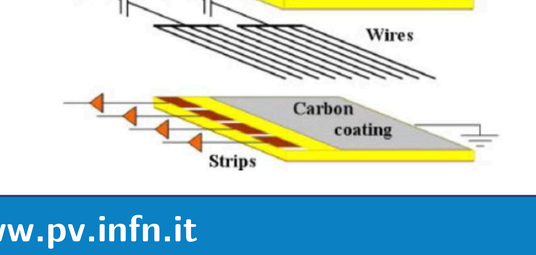


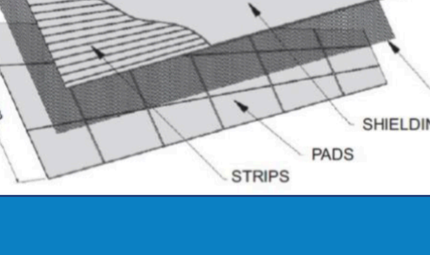
Tests are performed both during the detector construction phases and during the integration of modules into wedges, which are then combined together to make sectors.

MicroMegas and sTGC detectors

The MicroMegas detectors are resistive micro-mesh gaseous structures with the following characteristics:

- Strip resistivity ≈10 MΩ/cm for spark suppression
- Good track seraration due to readout granulatity (0.3 mm wide strips)
- Good spatial resolution (less than 100 μm)
- 93% Ar and 7% CO_2 gas mixture
- Construction sites: France, Germany, Greece, Italy and Russia





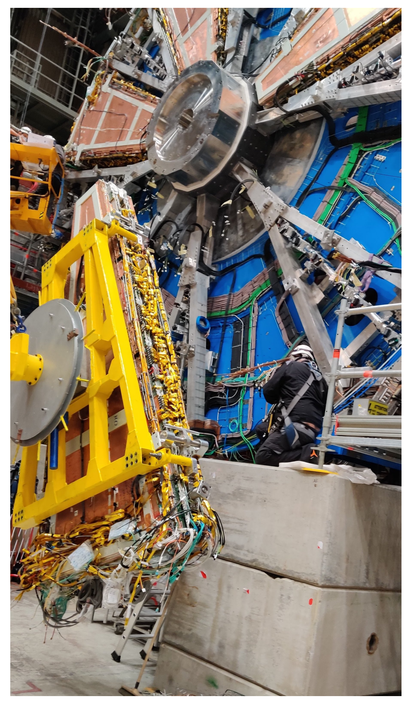
The sTGC detectors are multiwire proportional chambers where the readout is performed through pads, wires and strips,where the pads are used for muon Level 1 triggering:

- Strips for precision tracking perpendicular to wires
- Bunch ID with good timing resolution
- Hardware-based online track segment with 1 mrad angular resolution
- 55% CO_2 and 45% n-pentane gas mixture
- Construction sites: Canada, Chile, China, Israel and Russia

Sector installation on the wheel and services connections

Each sector is visually and electrically tested before being installed on the wheel. Sectors are installed following a precise procedure in order to be correctly aligned and secured on the wheel structure. When a sector is installed, the geometrical survey is performed and the services are routed and connected. This includes:

- Cu pipe connections for gas and cooling
- Fibers and twinaxial cables for detector readout
- High voltage and low voltage cables
- Temperature and B-field sensor connections



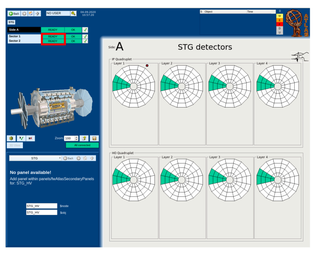
Next, each sector is throughly tested to ensure that no damage had occurred during transportation, installation and services routing and that it is within the specifications required to successfully run and record data at high performance.

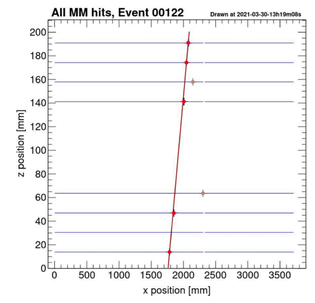
During the commissioning phase optical alignment tests of the chambers with respect to the alignment bars mounted on the support structure are performed in order to establish a grid in the ATLAS coordinate system.

Dedicated detector control systems are available to control and monitor the voltage levels, read out the temperatures while data acquisition procedures have been implemented to fulfill the tests performed during the commissioning phase.

High voltage and gas tests

- Gas and high voltage lines connections
- Connectivity and gas leak tests
- HV "conditioning" (Micromegas) to burn dust residues within gas volume or high ramp-up to check current charge up (sTGC)
- Validation after running under stable conditions for few days

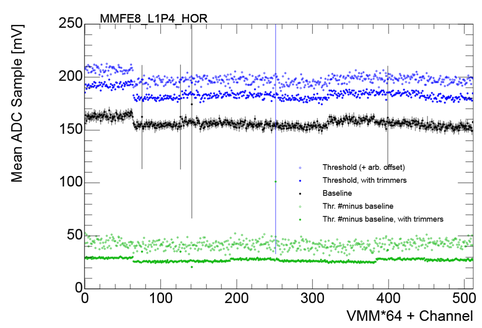


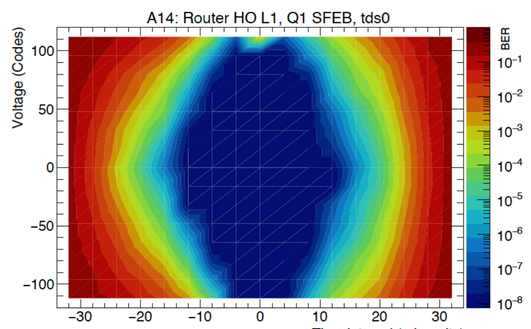


In some cases, when the schedule allowed it, cosmic muon tests were performed to verify the efficiency levels previously measured on wedges during the detector validation phase.

Cooling, low voltage and readout tests

- Connection of temperature sensors and cooling regulation, connection and connectivity tests of low voltage and readout (fibers and twinax cables)
- Readout tests (baselines and noise tests, pulser tests and emulated trigger tests to check data links)



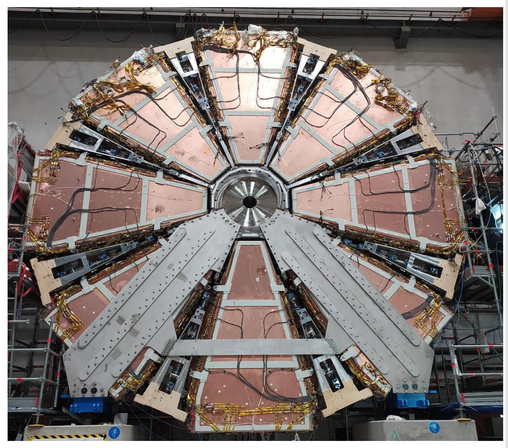


Detailed studies have been performed to mitigate the high noise by changing the grounding schemes, the improvements have been implemented and the noise levels have been greatly reduced.

Conclusions

Both wheels were fully commissioned and installed in the ATLAS experiment during 2021. The wheels were fully connected in the cavern and are now under tests. First tests (noise levels, trigger tests, HV tests) in the cavern showed very encouraging results, while preliminary tests were also performed in NSW-A with pilot beam data.

The final version of the DAQ system and the detector control systems are currently under completion and will be ready for data taking.



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