Small-Strip Thin Gap Chambers for the Muon Spectrometer Upgrade of the ATLAS Experiment

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on behalf of the ATLAS Muon collaboration

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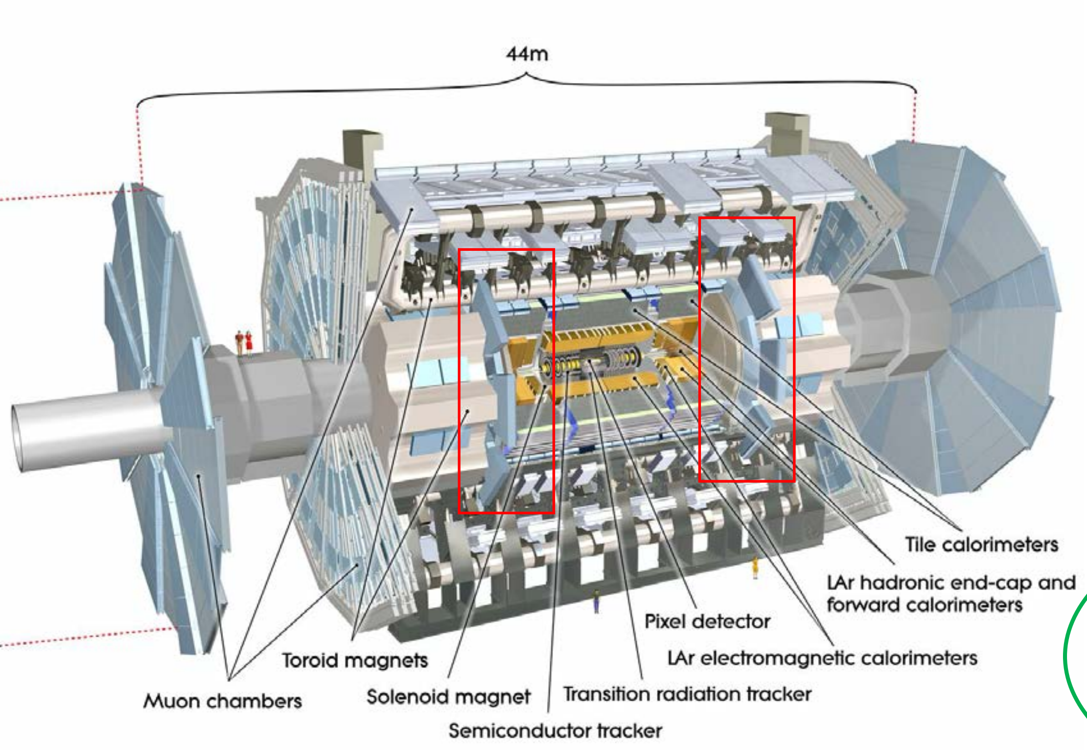
ATLAS EXPERIMENT

Introduction

- HL-LHC plan:
  - Instantaneous luminosity: $7.5 \times 10^{34}\ cm^{-2}s^{-1}$;
  - Total integrated luminosity: $3000\ fb^{-1}$ after 10 years.



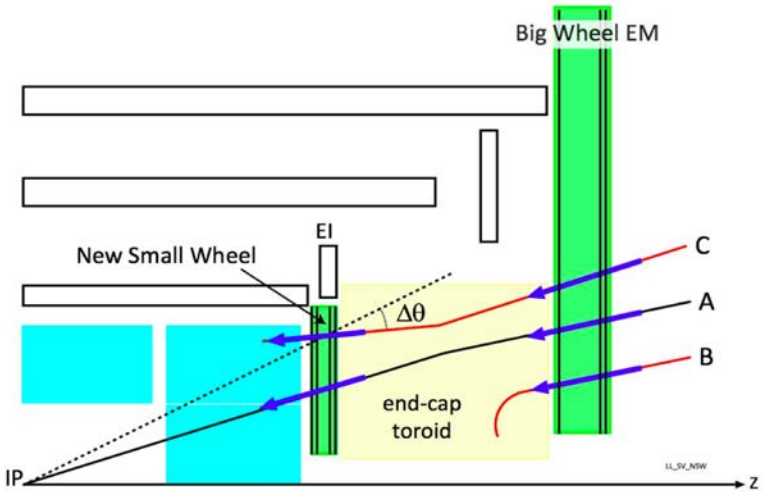
Challenges:

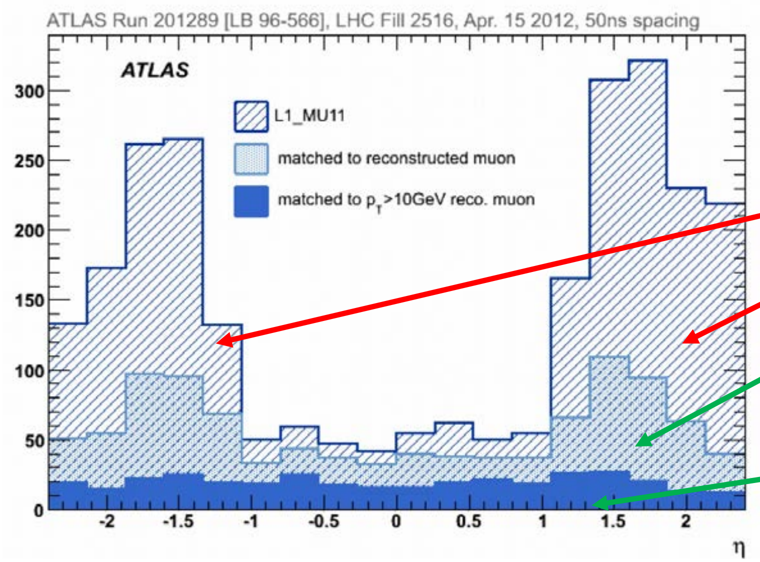
1) Intolerable endcap muon trigger rate with 90% fake muon triggers
2) Current inner end-cap stations wouldn't be able to hold such rate.

Solution

Replace the current small wheel with a new small wheel (NSW)

Trigger rate and muon ID





Current muon trigger:

- Based on coincidence between hits in the 3 BW stations
- Low p_T particles (mainly neutrons and photons) spontaneously exited from the endcap toroid fake high p_T muons (cases B&C)

Foreseen muon trigger scheme:

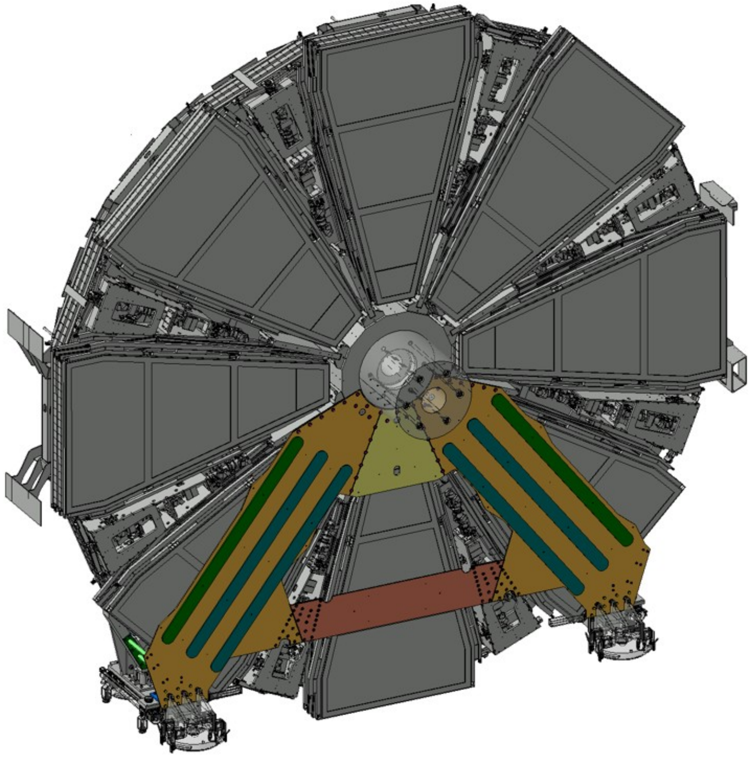
- NSW data included in the trigger
- Trigger based on coincidence between segments in the NSW and BW (case A)
- Reduce the rate of fake triggers

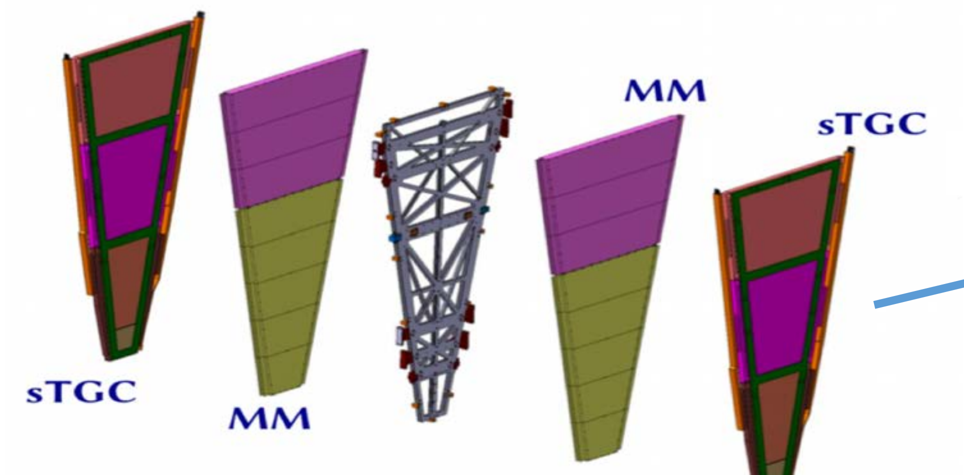
Strict requirements:

- Fast response – to act as trigger system
- Excellent angular resolution (1 mrad) at trigger level for efficient rejection of fake triggers

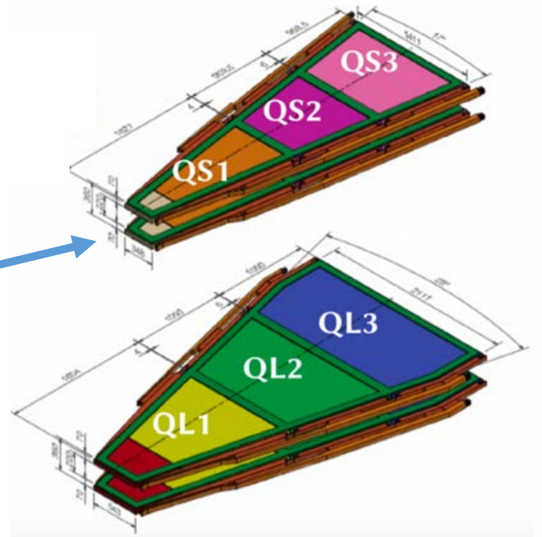
New Small Wheel

- Two detector technologies are used:
  - small-strip Thin Gap Chambers (sTGC)
  - Micromegas (MM)
- NSW will provide:
  - Excellent angular resolution (MM)
  - High-precision trigger (sTGC)





Layout of a small sector



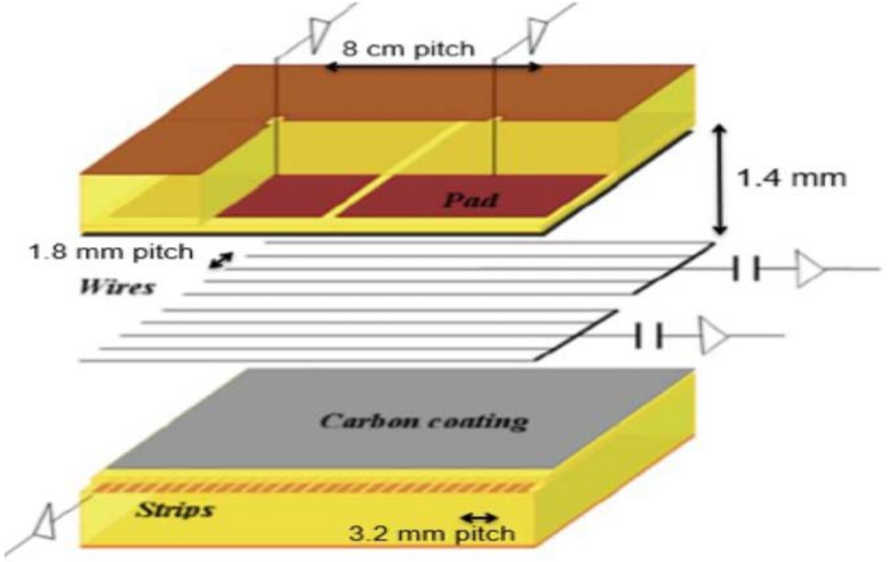
sTGC construction sites	
Russia	QL3
Israel	½ QS3 и QL1
China	QS2
Canada	½ QS3 и QL2
Chile	QS1

sTGC detector

Multiwire chamber operating at 2.8 kV with a gas mixture 55% of CO2 and 45% of n-pentane.

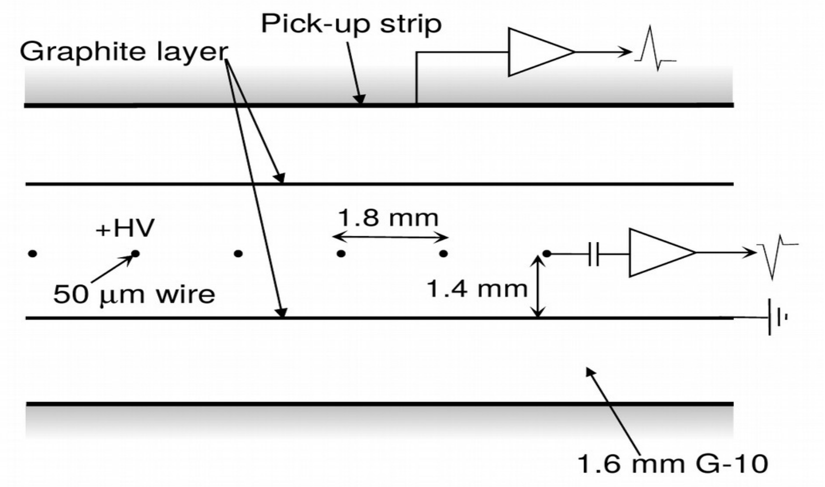
Wire to wire pitch - 1.8 mm
Wire to graphite layer – 1.4 mm
Wire diameter – 50 μm

Large signals produced within 25 ns → serve as a trigger system

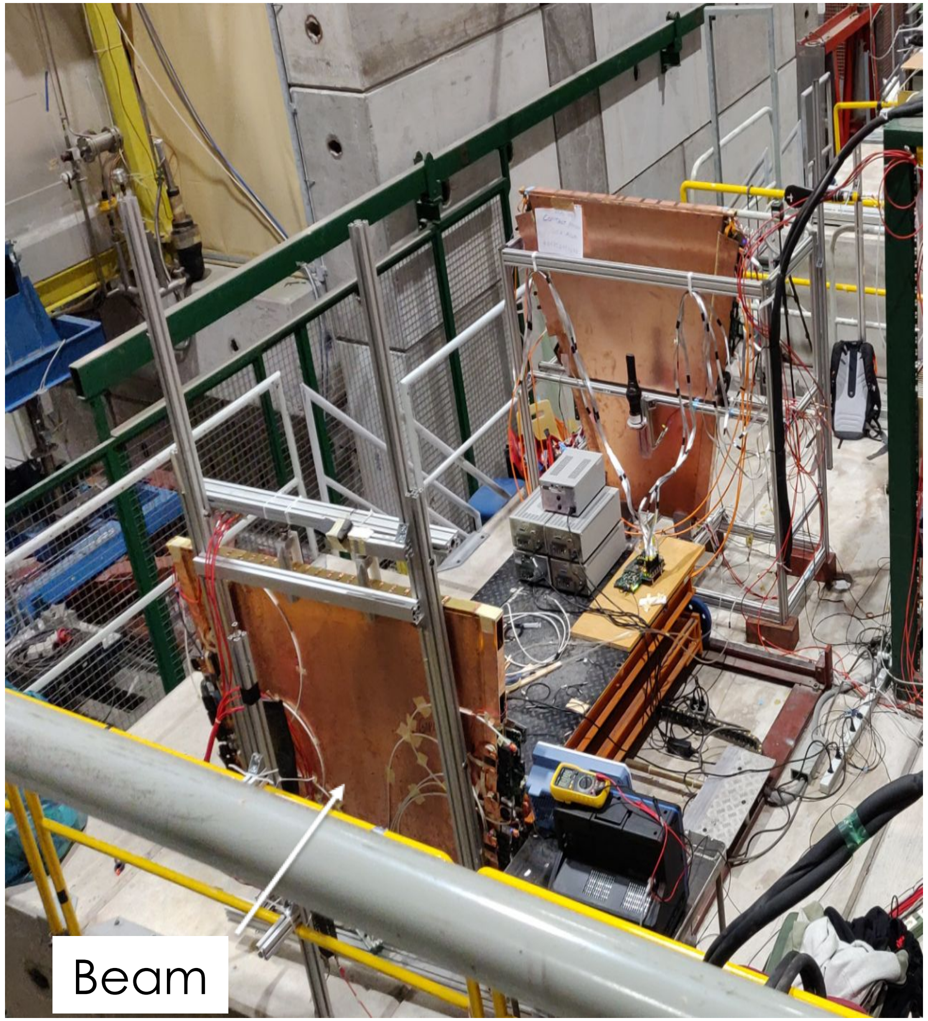


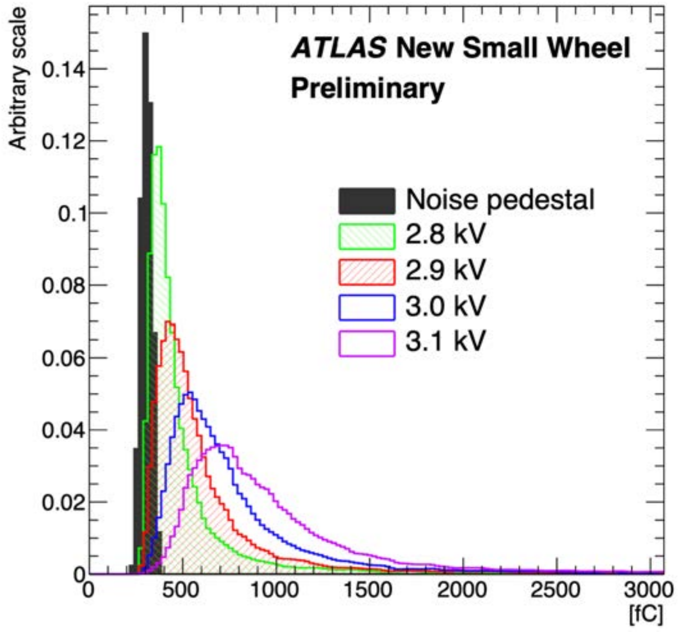
Three readout channels:

1) Pad patterned on one cathode board
   - Corse trigger to define RoI in the NSW
   - Fully digital
2) Strip patterned on the 2nd cathode board
   - Precise eta coordinate at trigger level and offline
   - Analog (10 bit ADC readout)
3) Wire groups
   - 2nd coordinate for offline reconstruction

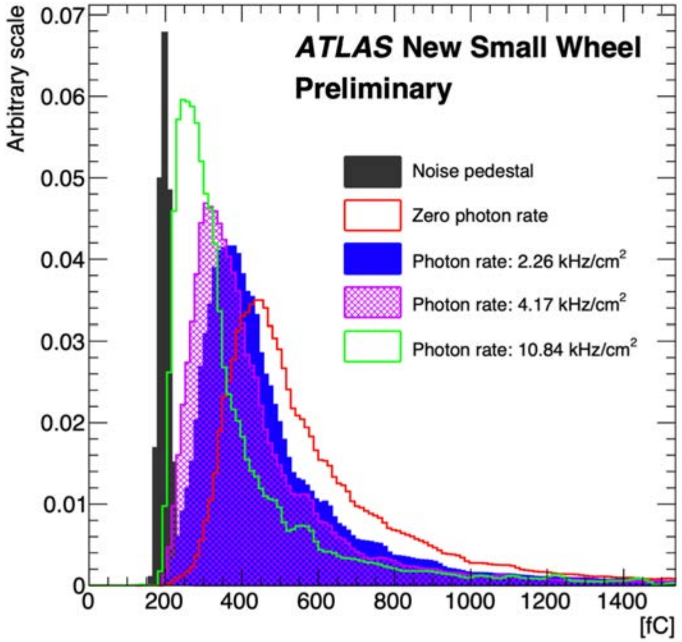


Test beam at CERN





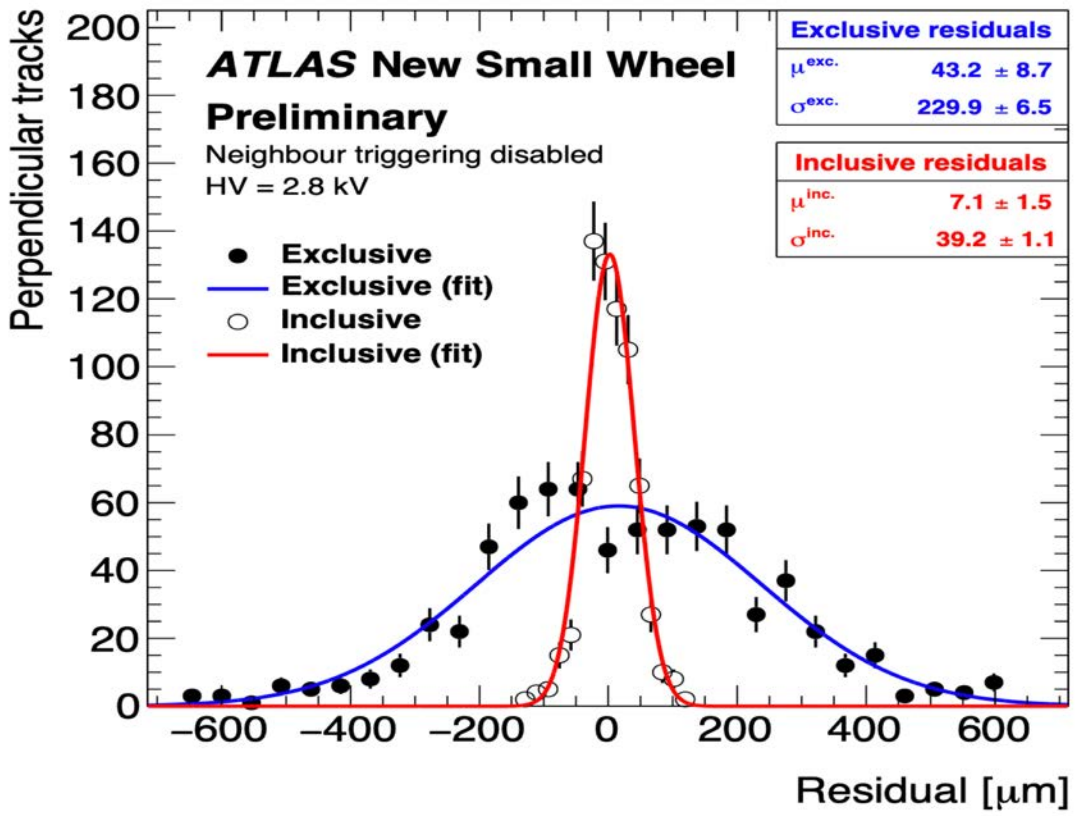
Muon beam, different voltages

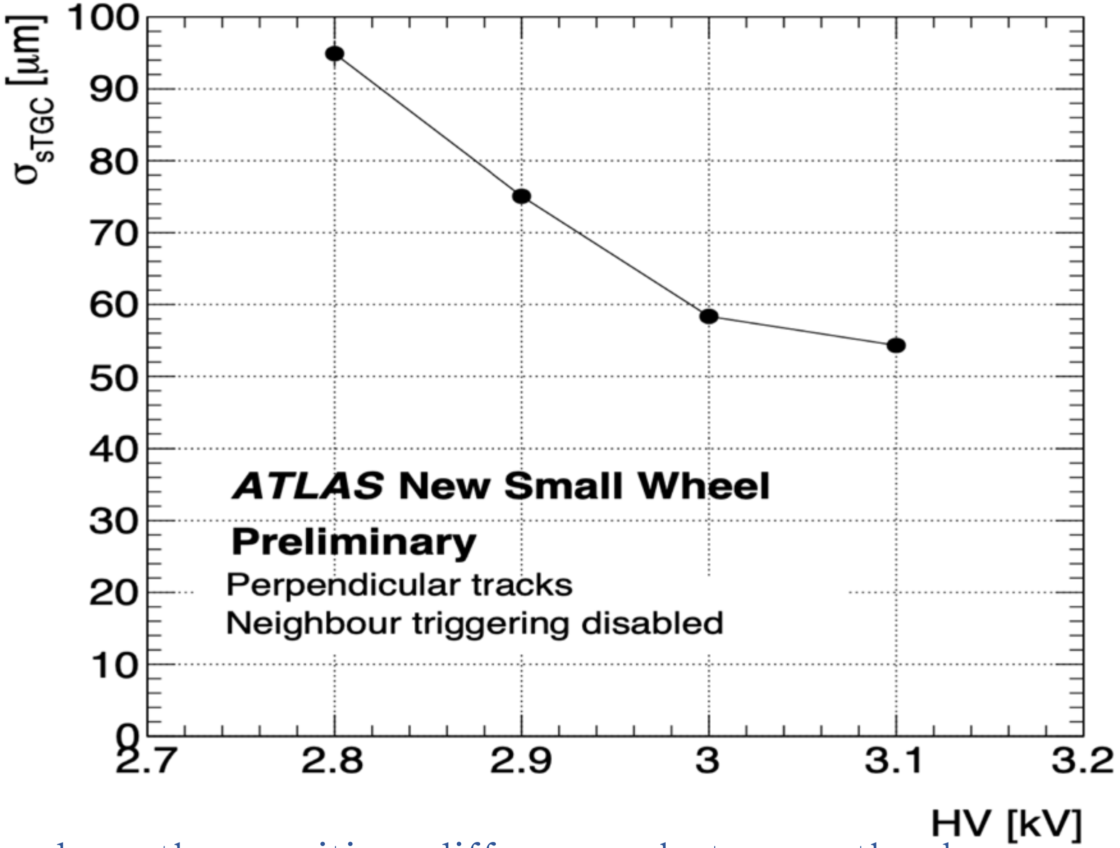


Muon beam + source, different rates

sTGCs show good signal to noise separation with/without high background rate.

Spatial resolution (Test beam)

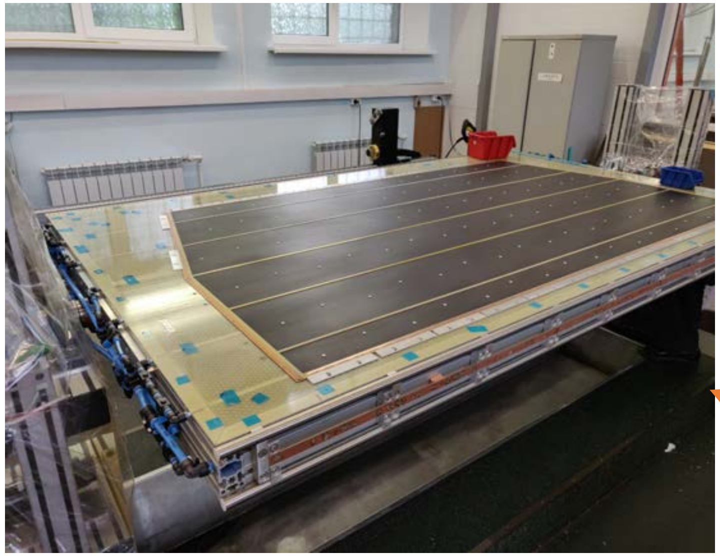


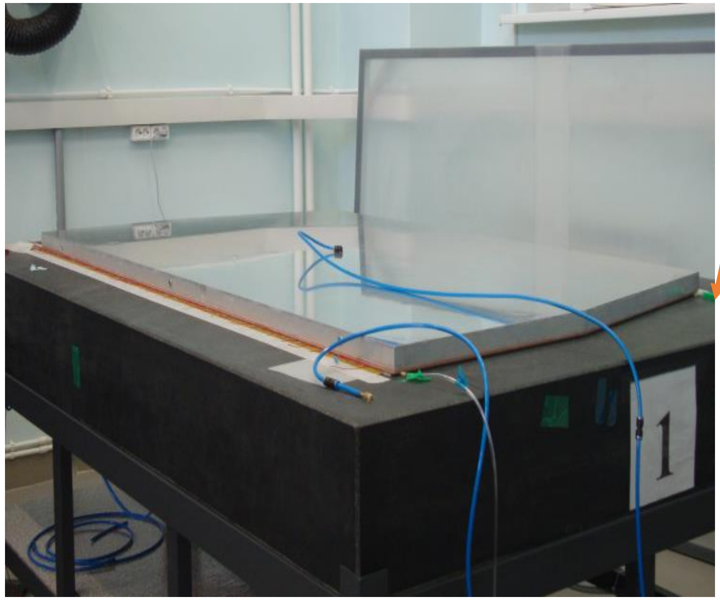


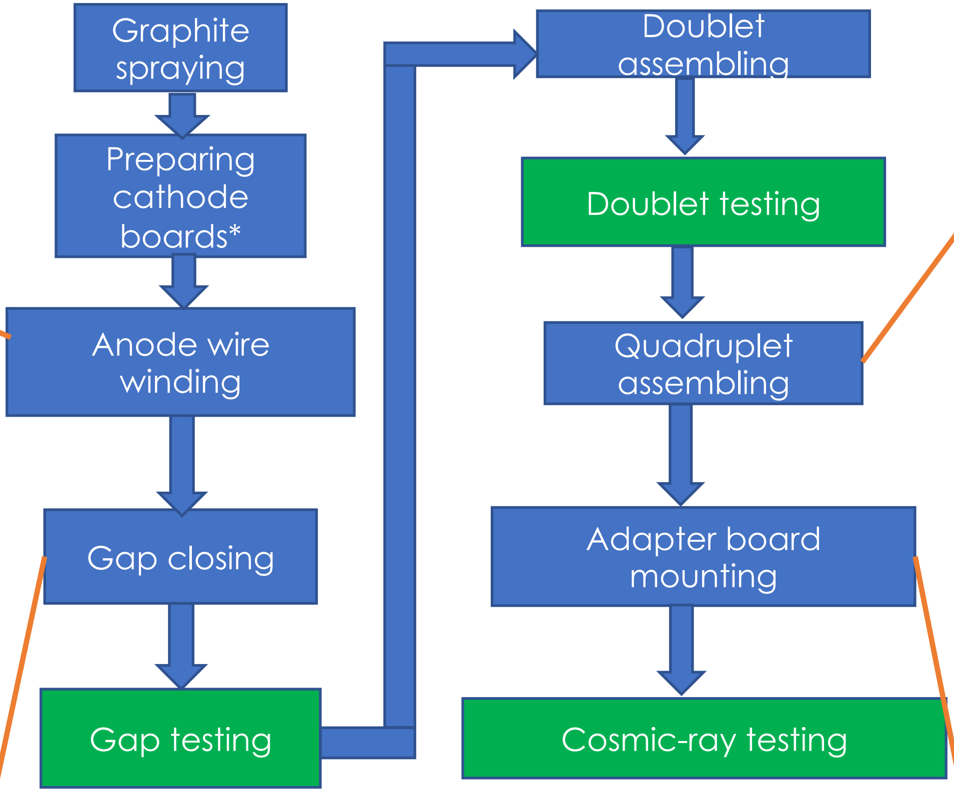
Inclusive residuals for a layer of interest are defined as the position difference between the layer space point and the position of a track reconstructed using the space points of all 3 layers. The exclusive residuals are obtained the same way but reconstructing the track without the space point of the layer of interest.

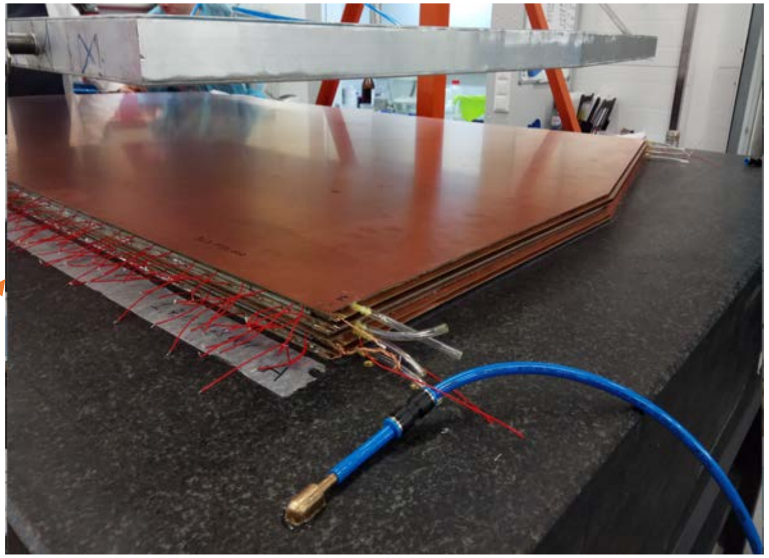
The spatial resolution is obtained using $\sigma_{sTGC} = \sqrt{\sigma_{inc}\sigma_{exc}}$

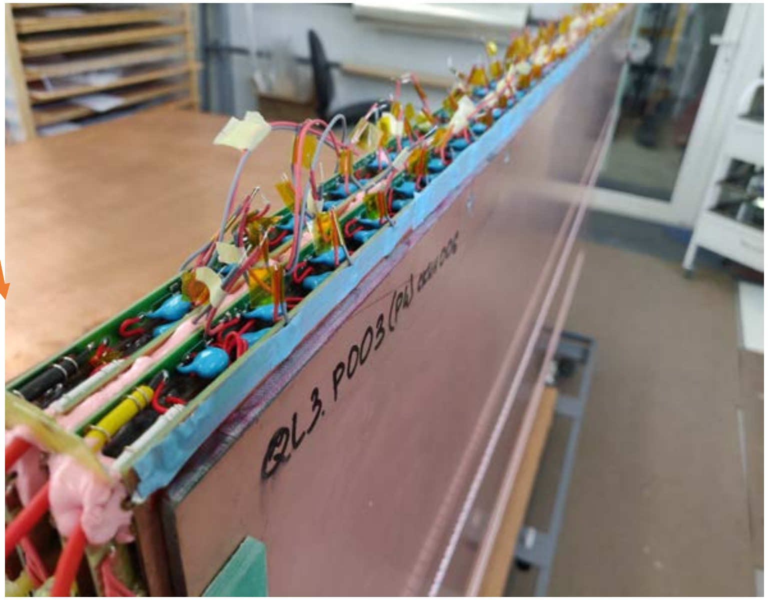
sTGC construction







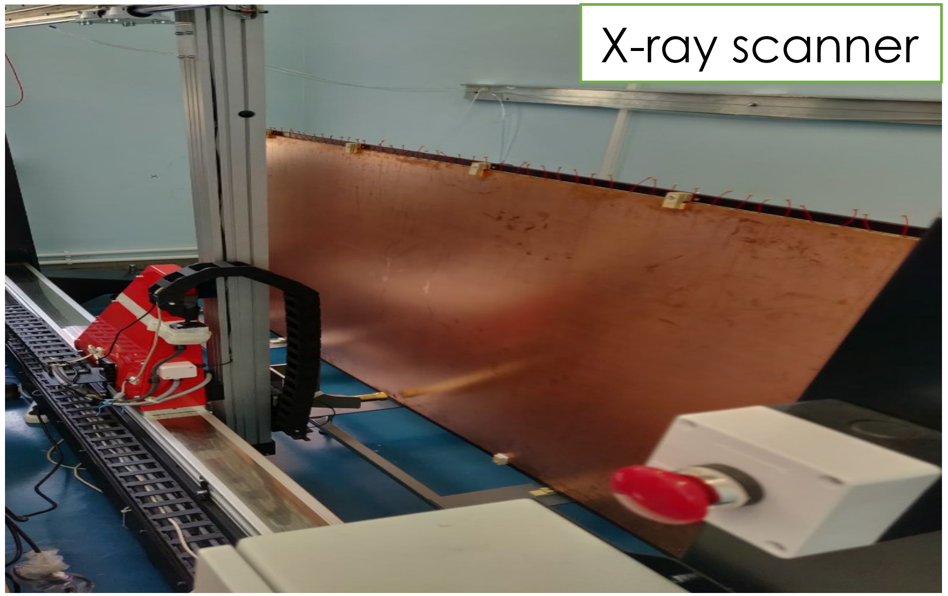




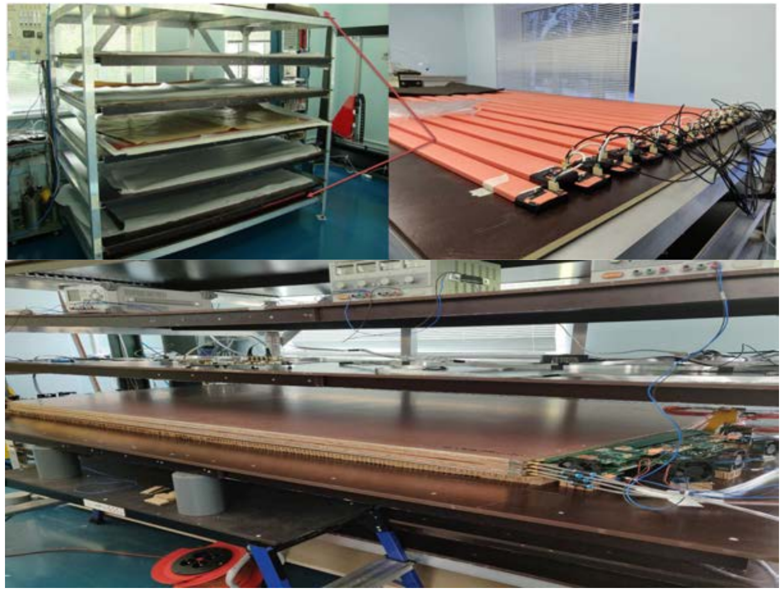
*The sTGC cathode boards are large area multilayer PCBs consisting, from the outer side to the inner one (facing the gas) of the following layers:
15 um thick copper serving as a ground layer, 1.3 mm thick FR4 plate,
15 um thick patterned (pads or strips) copper readout electrode,
100–150 um FR4 plate separating the readout electrode from the graphite ground layer.

QC@construction sites

- QC tests conducted at each construction site:
  - HV tests at each stage (single gaps, doublets, quads) to identify shorts, sparks, leakage currents;
  - X-Ray scan of single gaps to ensure gain uniformity and locate hot spots;
  - Pulser test after AB assembly to ensure solid electrical connectivity of readout channels;
  - Cosmic ray test with fully equipped quad – final test at nominal operation mode with signal-like particles – check for noise level, hit rate, efficiency.

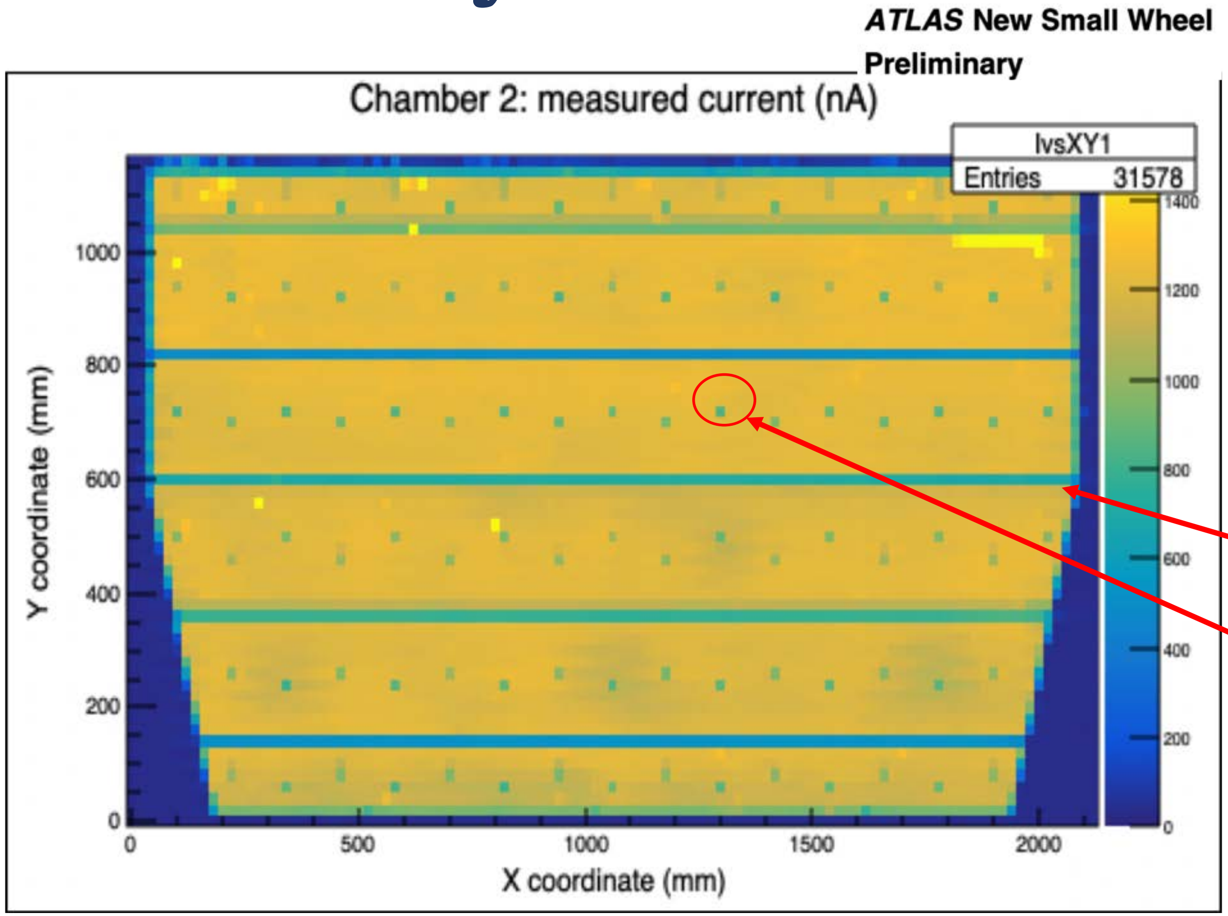


X-ray scanner



Cosmic-ray test bench

X-ray scan

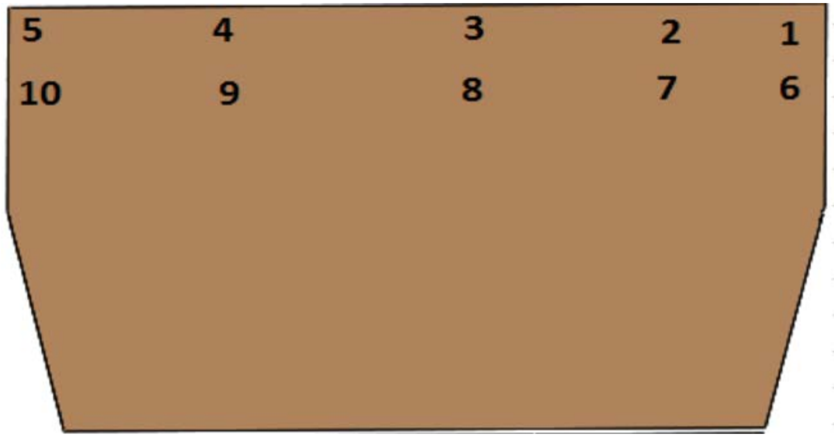


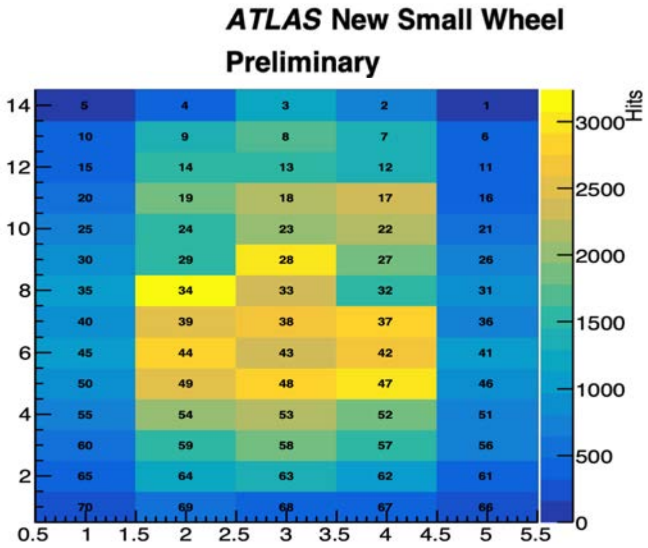
- Internal structure of gaps is visible on the plot (buttons and wire supports).
- Gain uniformity is within 20% of 1.2 μA.

Cosmic test

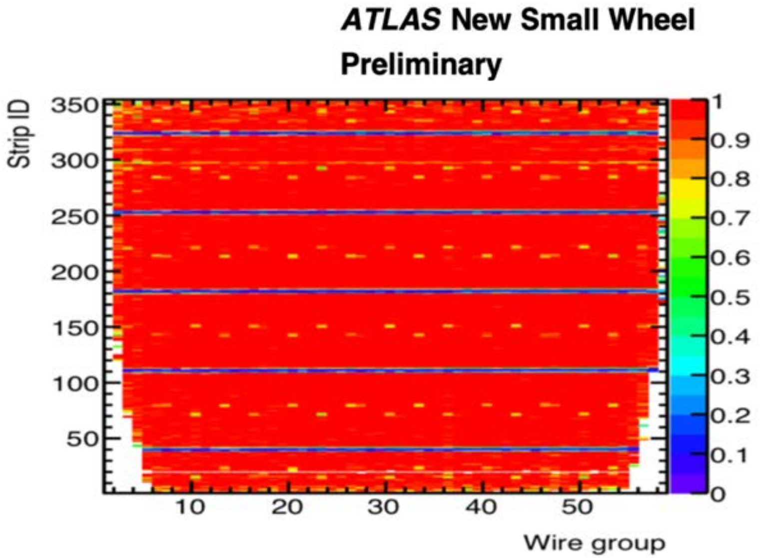
Tests are conducted in operation mode as close as possible to the one foreseen and allow to produce:

- Hit maps
- 2D efficiency maps
- Noise measurement





Number of cosmic muons counted in a QL3 gap during a period of approximately 13 hours
Low hit count on the edges due to limited coverage of the scintillators



Preliminary 2D efficiency of strip channels of a QL3 gap

Wedge assembly

Assembly divided into 4 sub procedures:

1) Quad acceptance – ensure no damage during shipment and stability under high irradiation;

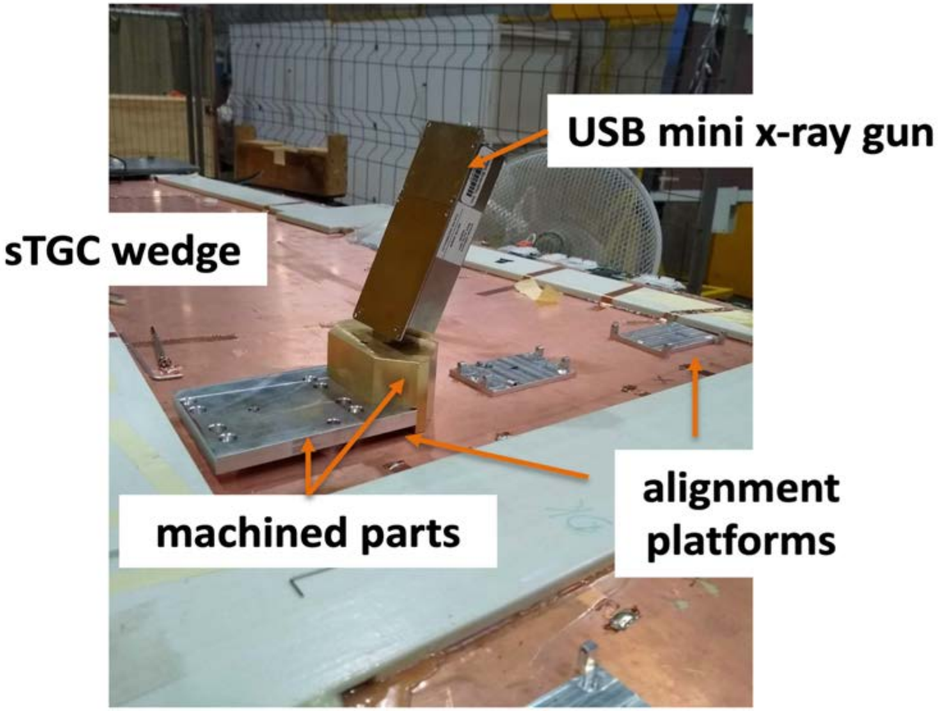
2) Gluing – 3 quads are assembled into a single wedge;

3) Faraday cage assembly

4) Electronics mounting

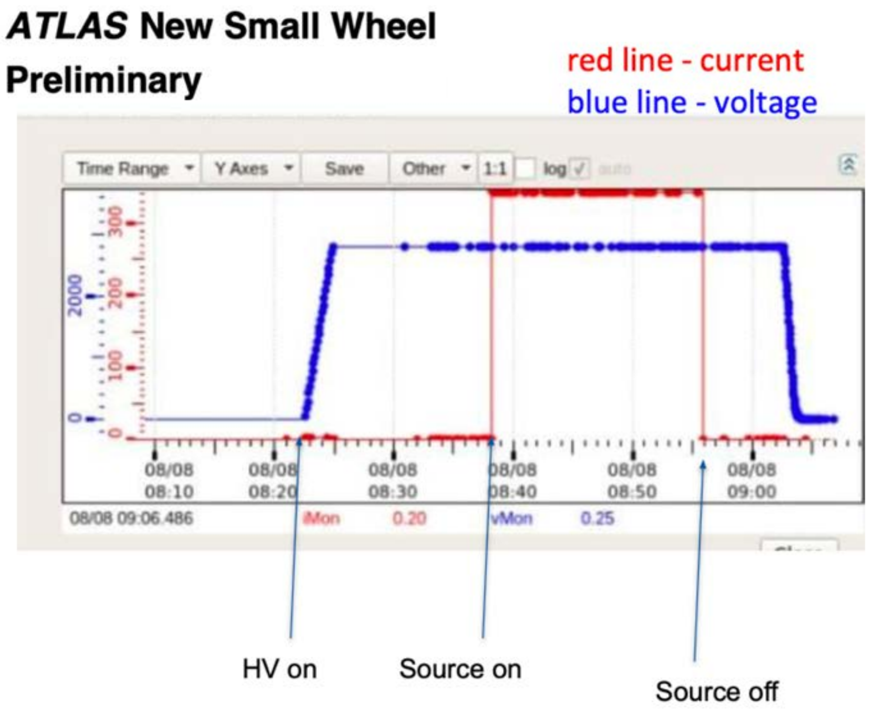
QC@CERN

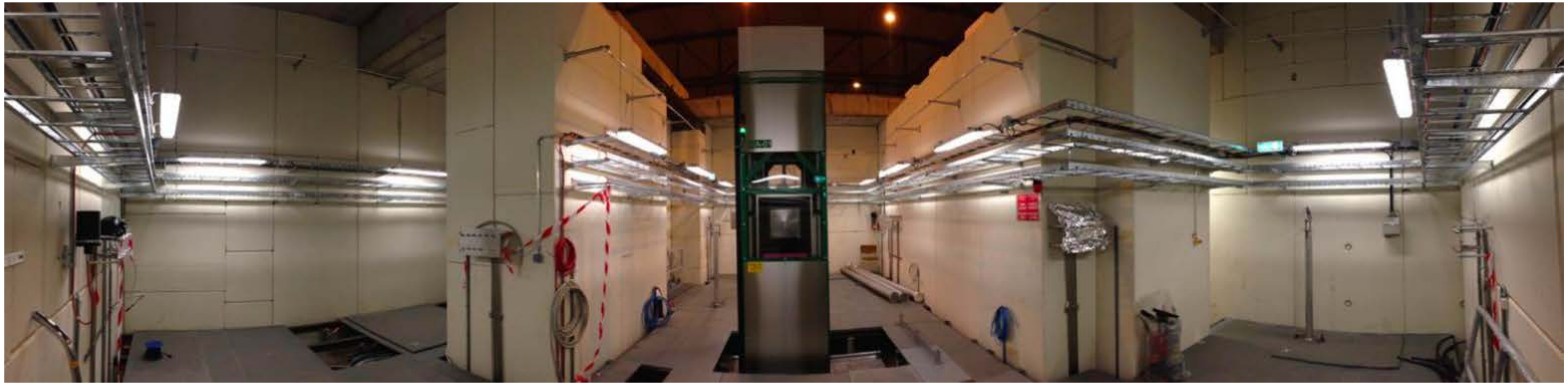
- High radiation testing (at GIF++) → test of sTGCs quadruplets under high radiation
- Noise measurements with final electronics (wedges)
- Long-term HV test (wedges)
- Measurement of misalignment using x-rays (wedges)



GIF++

- Purpose: testing sTGC stability under high radiation with 20 kHz/cm^2 (estimated photon background at ATLAS during runs)
- 14 TBq 137Cesium source

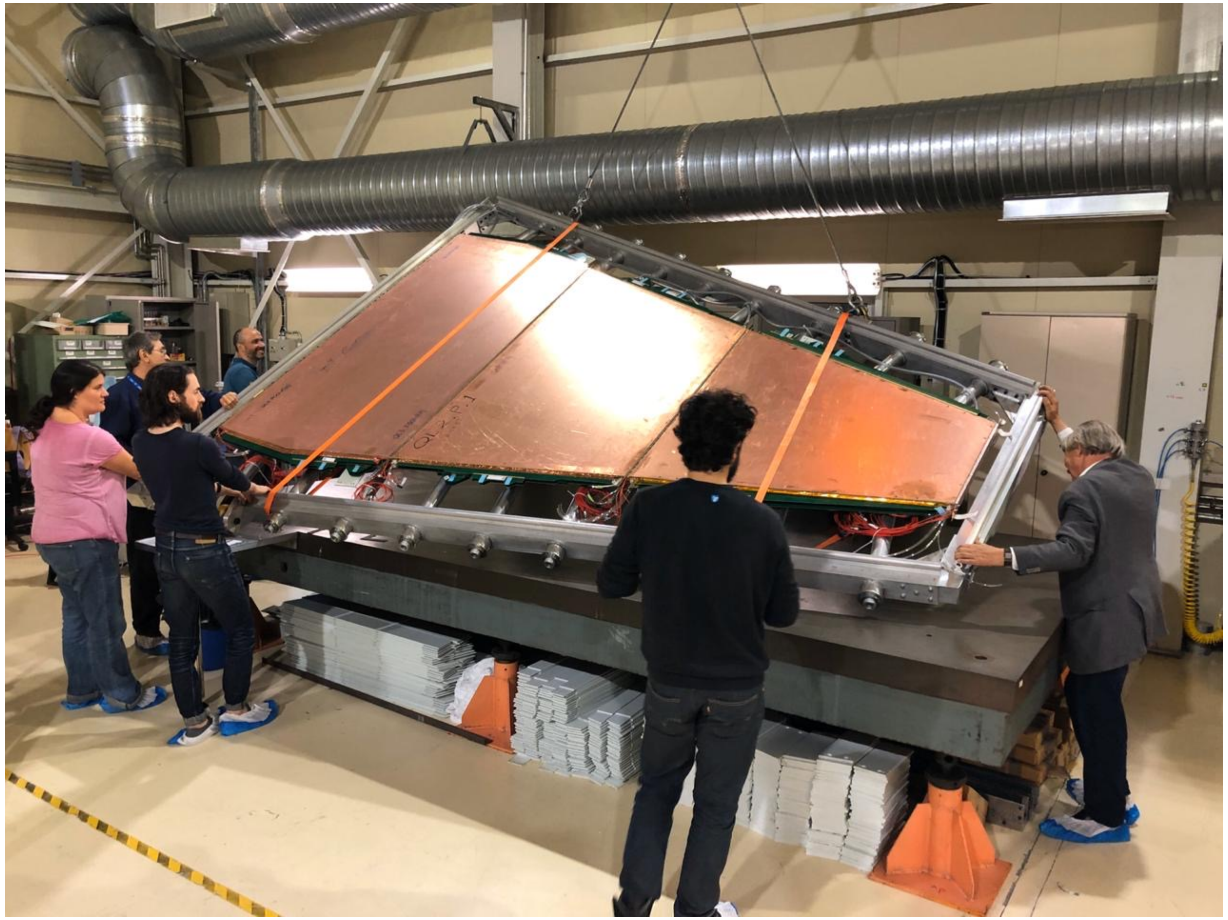




Inside the GIF++ bunker

Gluing into wedges

1. Quads cleaned and fitted on alignment table (alignment pins ensure <50μm precision)
2. Mounting frame is glued
3. Wedge is rotated on the table
4. Fiber alignment platforms are mounted
5. Frame is completed

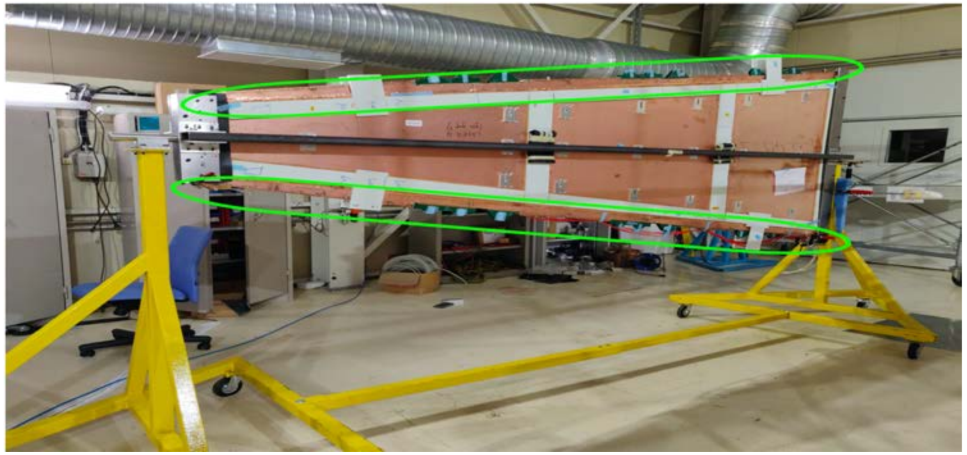


Faraday cage assembly and services

Faraday cage assembly (with services) is done in several steps:

- Ground interconnection
- Noise test
- Connectivity fixes
- Gas interconnection
- HV Filter & Faraday cage installation

Before



Completed Faraday cage

Integration at CERN

- Final electronics produced: enough boards at CERN for the assembly of 2 sectors. Others are on the way from China.
- First sector (2 sTGC and 2 MM wedges) installed on the wheel in December
- Next sector installation is on the way.

Summary

- The NSW is essential for achieving high trigger efficiency at low fake trigger rate as well as high momentum resolution at the high radiation environment expected for high luminosity running.
- Required precision for the NSW forced optimizing the entire alignment procedure at each step of assembly of quads and wedges.
- sTGC quadruplet production is on track at every production site.
- Expect to finish small wedges for NSW-A by mid-March. Large wedges – late June.
- Integration at CERN is progressing. Next sector installation is due by the end of February.
- Installation of a first NSW in ATLAS scheduled for autumn 2020.

Thank you for listening!