The Canadian Contribution to the ATLAS New Small Wheels

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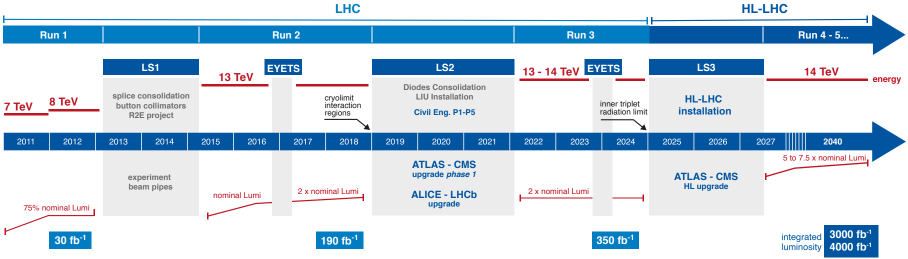
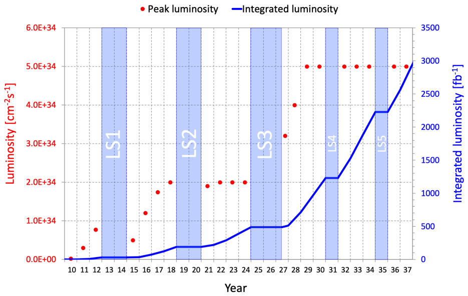
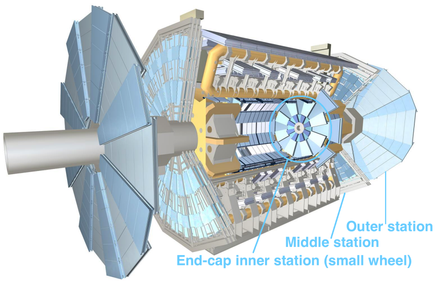
Path to the High Luminosity LHC



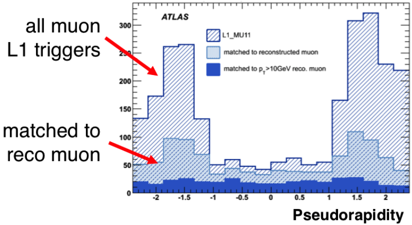
- **Long shutdown 2** (2019–2021): $\mathcal{L} = 2 \times 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ for the entirety Run-3
- **Long shutdown 3** (2025–2027): $\mathcal{L} = 2 \times 10^{34} \longrightarrow 5$ to $7.5 \times 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$
- Such an intense environment presents challenges for the experiments that use the collisions provided by the LHC.
- During long shutdown 2, improvements – called Phase-1 upgrades – to the ATLAS detector are ongoing.



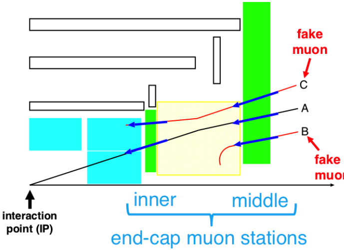
ATLAS Muon Spectrometer and High Luminosity



- At high luminosities, the trigger rate would exceed the readout bandwidth of the ATLAS data acquisition system.
- In the end-caps, most “muons” firing the trigger would in fact be background hits from particles created in the material between the inner and middle stations.
- To solve this problem, the plan is to use the inner station to distinguish muons from these fake “muons”.
- The current small wheel is unable to perform tracking efficiently.



ATLAS NSW TDR

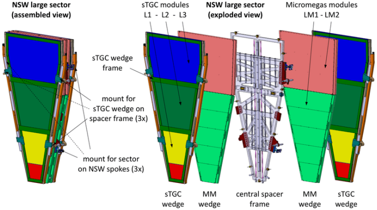


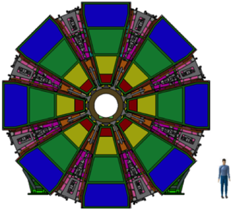
The ATLAS New Small Wheel

- The New Small Wheel (NSW) will use two different gas detector technologies: **sTGCs** primarily for triggering and **Micromegas** (MM) primarily for precision tracking.

Design/Requirements:

- Substantially reduce the fakes trigger rate at L1;
- Reconstruct online muon tracks with 95% efficiency;
- Excellent spatial and angular resolutions: $< 50\ \mu$m for offline momentum reconstruction and < 1 mrad for online matching with Big Wheel;
- Operate for the entirety of the HL-LHC.





- Canada is contributing to the construction of 54 (of 216) sTGC modules (“quadruplets”).
- Other sTGC construction site countries are Chile, China, Israel, and Russia.

sTGC Chambers:

- Multiwire ionization chambers operated with a pentane-CO_2 gas mixture;
- Operating voltage of 2.8 kV.

Wires:

- Acting as our anode, wires provides a coarse measurement of the trajectory in the ϕ- or azimuthal-direction.
- Sandwiched between two cathode planes with a distance of 1.4 mm between the anode and cathode.

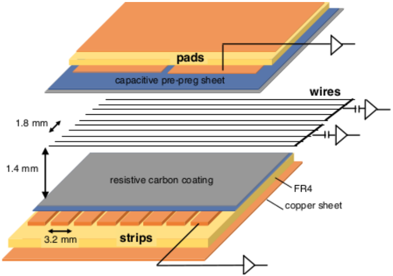
Strips:

- On one of the cathode planes, strips have a pitch of 3.2 mm;
- Used to provide precision measurements of muon trajectory in the η-direction.

Pads:

- On the other cathode plane are pads, which are used to trigger readout of the strip in a localized region of the detector.

$\longrightarrow$ Each *quadruplet* module consists of 4 pad-wire-strip planes.



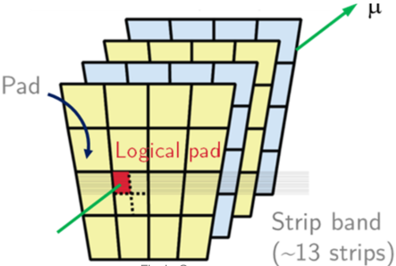


Fig: L. Guan

The Canadian sTGC Construction Project

TRIUMF

- Commercially made circuit boards etched with copper strips and pads are coated with graphite.
- Boards are then shipped to Carleton University, Ottawa.

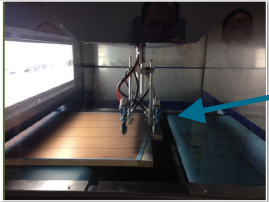
Carleton University

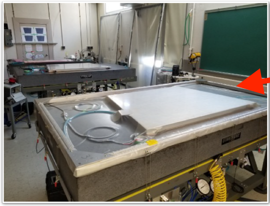
- Anode wires are strung, and gaps and quadruplets are assembled.
- Adapter boards are mounted.
- Finished modules are sent to McGill University, Montreal.

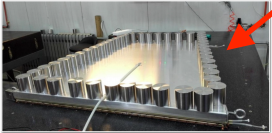
McGill University

- Detectors are characterized and tested for quality and performance using cosmic muons.
- They are then shipped to CERN, Geneva, where they are formed into wedges that will make up the NSW.

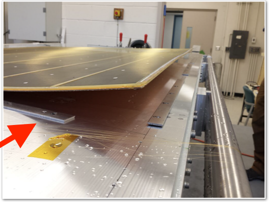
Construction







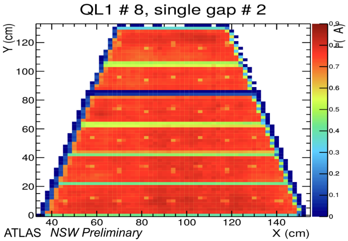
- Graphite spraying
- Half-gap production
- Wire winding
- Gap closing
- Doublet assembling
- Quadruplet assembling
- Cosmics testing

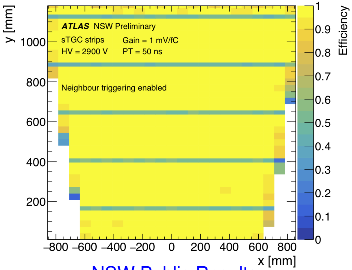


QA/QC

Quality assurance / quality control tests are performed throughout the construction process. Tests include:

- High voltage tests at the singlet, doublet, quadruplet stages to check for sparks, shorts, and leakage currents;
- X-ray scans to measure gain uniformity of single gaps and to probe internal structure;
- Electrical connectivity checks of the readout channels;
- Gas leakage checks to ensure no leaks, e.g. from a crack, are present;
- Readout noise using prototype front-end boards;
- Cosmics testing to measure efficiency and resolution of finished quadruplets, and the relative misalignment of individual gaps.

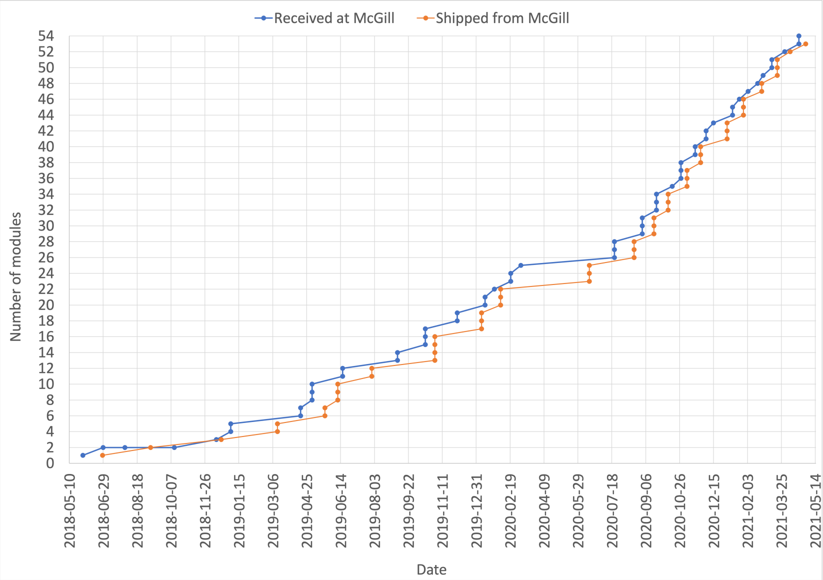




NSW Public Results

$\longrightarrow$ Detectors that pass all tests are shipped to CERN where they are assembled into wedges then sectors to be installed into the NSW.

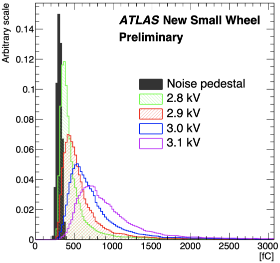
Canadian Production

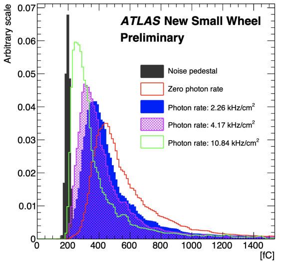


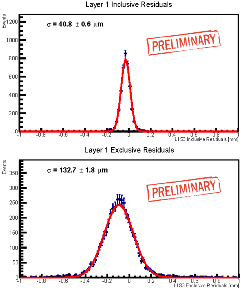
sTGC Performance

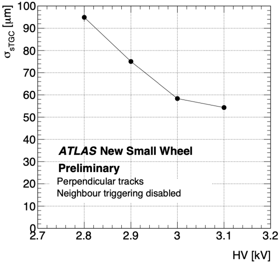
CERN Test Beam:

- Pad charge distribution studies at H8 beam-test area (top left).
- Pad charge distribution studies in GIF++ using a muon beam in the presence of high rate photon background (top right).
- Residual distributions of reconstructed perpendicular tracks (bottom left). For more details, see poster by Lia Formenti.
- In-situ measurement of the sTGC strip spatial resolution as a function of the applied high-voltage using a low-rate muon beam in the H8 beam-test area (bottom right).









NSW Public Results

Sector Installation and Commissioning

- Construction of sTGC and Micromegas modules for both NSW-A and C is nearing completion.
- Sector assembly, installation, and commissioning well underway (with major contributions from Canadians).

Sector	Type	Date of installation	Commissioning status
A14	Small	11/12/2020	Ongoing
A12	Small	16/12/2020	Complete
A16	Small	11/01/2021	Complete
A10	Small	17/12/2020	Complete
A08	Small	18/01/2021	Complete
A02	Small	25/01/2021	Complete
A06	Small	11/09/2020	Complete
A04	Small	08/02/2021	Complete
A13	Large	27/04/2021	Complete
A11	Large	19/04/2021	Complete
A15	Large	13/05/2021	Complete
A09	Large	05/05/2021	Ongoing
A01	Large	19/05/2021	Ongoing
A07	Large	25/05/2021	To be started
A03	Large	26/05/2021	To be started
A05	Large	28/05/2021	To be started

Commissioning of NSW-A expected to be completed by June 17.

Conclusions

- Inclusion of the NSW into the ATLAS detector is imperative in order to maintain high trigger efficiency and momentum resolution in the high luminosity environment of the LHC and HL-LHC for years to come.
- Production of both sTGC and Micromegas modules is nearly complete while sector assembly at CERN has kept pace.

- Canada has played a key role in the NSW project, from construction of sTGC modules to contributing to vital NSW operations at CERN.

Status of NSW-A:

- All 8 small sectors installed; all 8 large sectors installed.
- Commissioning well underway.
- Expected to be completed by 29/07/2021.
- **NEWS:** ATLAS has given the green light for installation.

Status of NSW-C:

- Three small sectors installed; large sectors yet to be assembled.
- With the experience gained from NSW-A, commissioning expected to be streamlined.
- Must be completed by 21/10/2021 to be installed during this shutdown.