Performance of Canadian-made muon chambers for the ATLAS experiment Phase-1 upgrade

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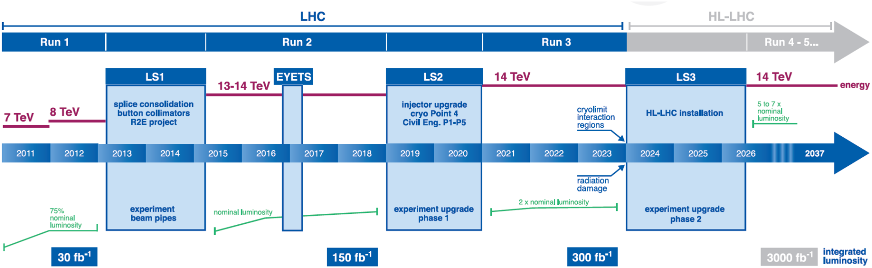
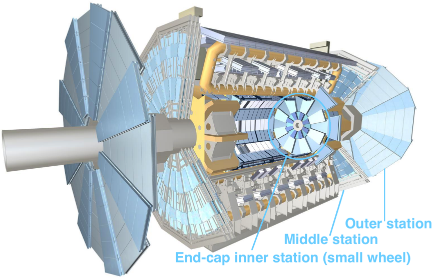
Luminosity Increases to the LHC

- The long shutdown 2 (LS2) of the LHC is planned for 2019–2020 after which the LHC will collide protons at a rate twice that of its design luminosity $\mathcal{L}_{nom} = 10^{34}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$.
- Following LS3, 2024–2026, this rate will be further increased up to $\sim 7\mathcal{L}_{nom}$.

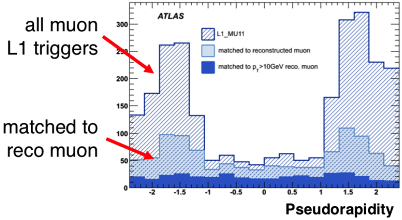


- Such an intense environment presents challenges for the experiments that use the collisions provided by the LHC.
- During LS2, improvements – called Phase-1 upgrades – to the ATLAS detector are planned.

ATLAS Muon Spectrometer and High Luminosity



- At high luminosities, the trigger rate will exceed the readout bandwidth of the ATLAS data acquisition system.
- In the end-caps, most "muons" firing the trigger will 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 small wheel is unable to take track measurements; we need a new small wheel.



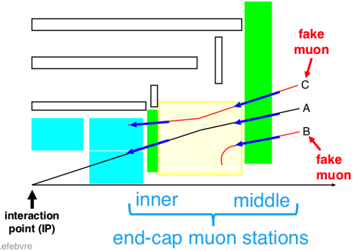
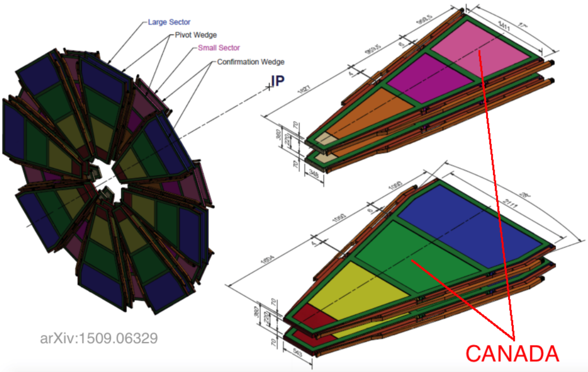


Fig: B. Lefebvre

The ATLAS New Small Wheel

- One of the Phase-1 upgrades to the ATLAS detector is the construction of a new small wheel (NSW) to replace the old.
- The NSW will use two different gas detector technologies: small-strip thin gap chambers (sTGC) primarily for triggering and “Micromegas” for precision tracking.
- There will be two small wheels, one at each end-cap of the detector.
- Each wheel is comprised of individual wedges and each wedge is built from individual modules.
- Canada is contributing to the construction of 64 sTGC modules (“quadruplets” or “quads”) that make up a wedge.



Small-Strip Thin Gap Chamber Technology

sTGC Chambers:

- Multiwire ionization chambers operated with a pentane-CO_2 gas mixture;
- Operating voltage of 2.9 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.

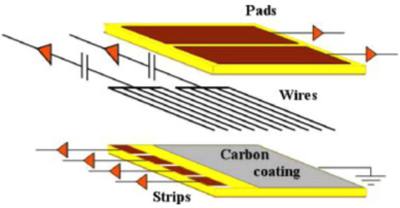
Strips:

- 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.



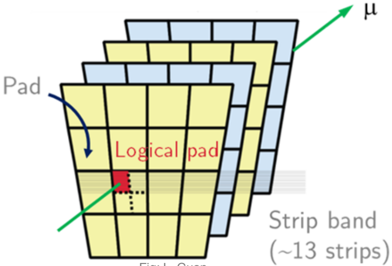


Fig: L. Guan

The Canadian sTGC Construction Project

TRIUMF

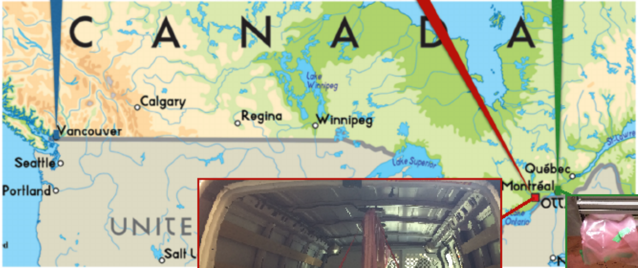
- Commercially made circuit boards etched with copper strips and pads are coated with graphite.
- These boards are then shipped to Carleton University.

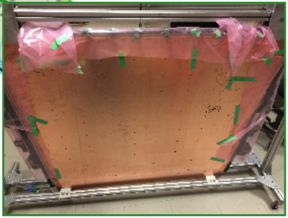
Carleton University

- Anode wires are strung, and the assembly of the gaps and quadruplets are performed.
- Finished quadruplets are sent to McGill University.

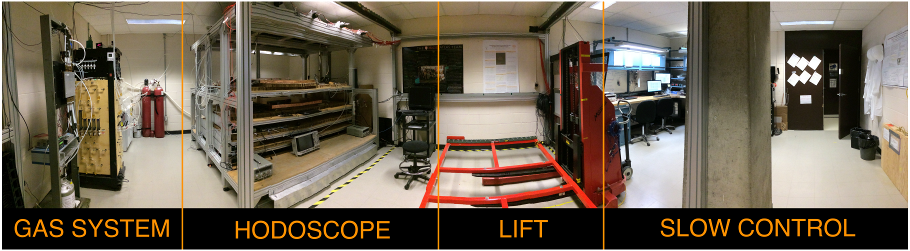
McGill University

- Using cosmic muons, the quadruplets are characterized and tested for quality.
- Quadruplets that pass these tests are sent to CERN where they are formed into wedges that will make up the NSW.



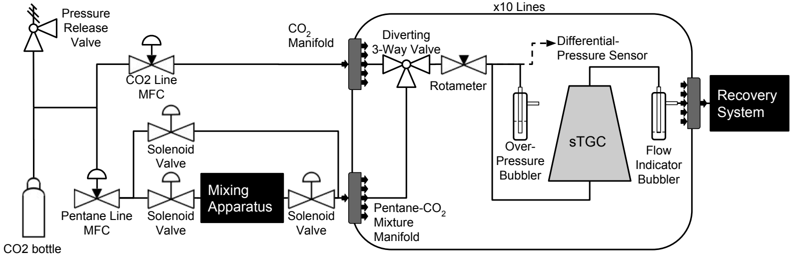


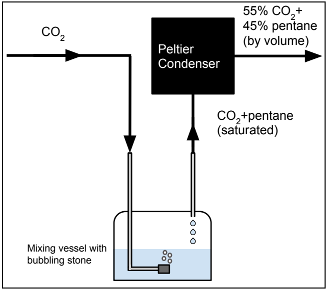
McGill sTGC Testing Facility



- **Gas System:** Designed and constructed by McGill, it flows a gaseous mixture of pentane-CO_2 in the gaps of the quads.
- **Cosmic Muon Hodoscope:** Consists of scintillators on the top and bottom of the testbench and the quad placed in one of the shelves.
- **Lift:** Used to place quads onto testbench.
- **Power Supply:** High and low voltage for sTGC module, readout electronics, and scintillator detectors.
- **Slow Control:** Monitors conditions in the lab to ensure safety and used to control gas flow and the power supply.
- **Data Acquisition System:** Used to configure electronic readout boards and to collect cosmics data from the quad.

McGill sTGC Testing Facility: Gas System

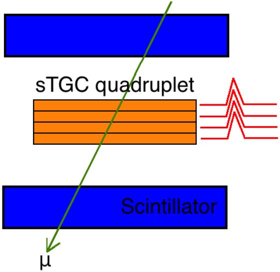




- The gas system flows a pentane-CO_2 (45:55%) gas mixture in the sTGC quad.
- CO_2 gas is flowed into a mixing vessel containing liquid pentane producing a pentane-CO_2 saturated with pentane (57:43%).
- The mixture flows through a Peltier Condenser which cools the gas mixture to 14.5°C causing some of the pentane to condense.
- The result is a 45:55% pentane-CO_2 gas.

McGill sTGC Testing Facility: Hodoscope

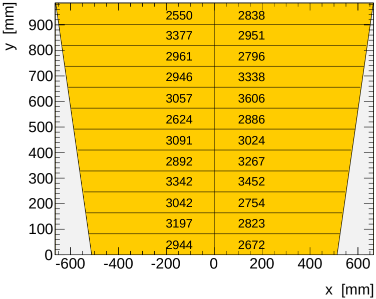
- Scintillators, read out by photomultiplier tubes, are positioned at the top and bottom of the testbench structure.
- An sTGC quad is placed on one of the shelves with 4 front-end boards reading out the 4 pad layers and similarly for the strip layers.
- If there is coincidence between the top and bottom scintillators, the signals from the quad are outputted.
- The outputted signals are used to calculate the hit efficiency and spatial resolution.
- Quads must have high efficiency in order to be sent on to CERN: 95% efficiency over 95% of the active area on the quadruplet.

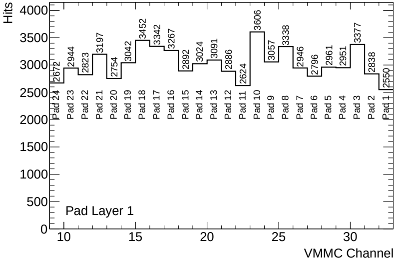


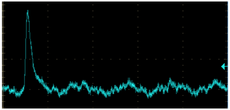
Preliminary Measurements

We recently received a production quadruplet from TRIUMF/Carleton. We've been able to record hits data from all four pad layers of the quad.

Layer 1 hit map:







= 1 Cosmic Muon Hit

Note: Readout threshold has not yet been optimized and equalized.

Summary

- With the looming upgrade to the LHC, the ATLAS detector must also be upgraded in order to cope with the increased luminosity.
- Canada is taking part in the Phase-1 upgrade to the muon spectrometer, specifically the production and testing of the sTGC detectors in the new small wheel.
- Production of these detectors occurs at TRIUMF and Carleton while testing using cosmic muons is performed at McGill.
- Significant efforts have been made at McGill in preparing a lab that can be used to perform these tests.
- We received our first production quad on May 30, 2018 and have begun to study its performance and finalize our infrastructure.
- Numerous important tasks will be performed in the coming days.
- Quads showing good test results will be sent to CERN where they will be assembled into the NSW and used to collect data for many years to come.