ATLAS L1 Muon Trigger Upgrade with sTGC: Design and Performance

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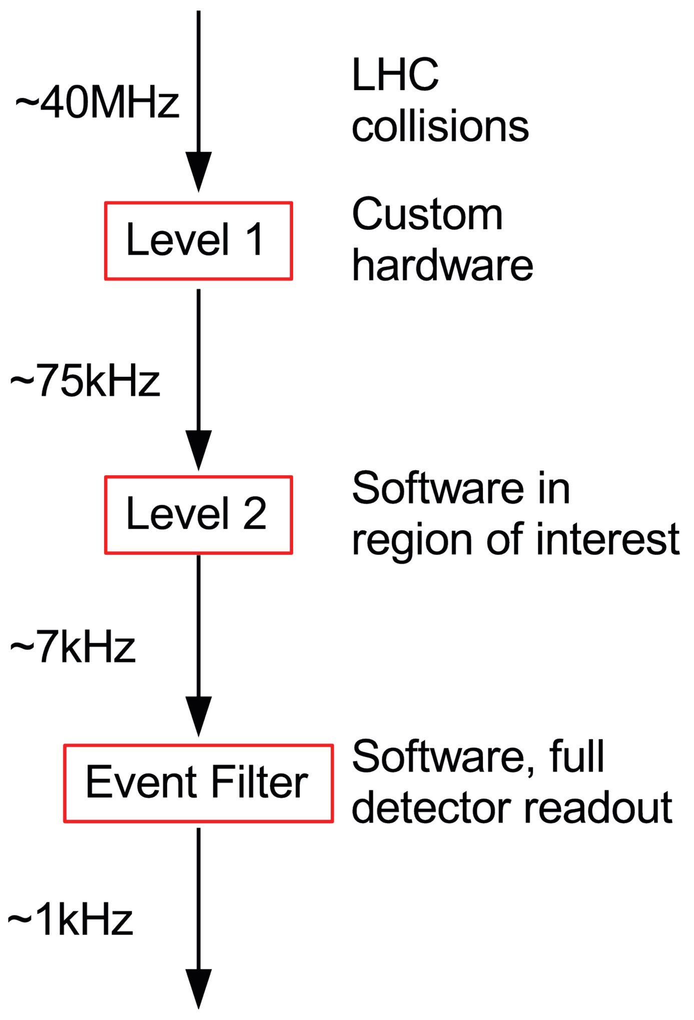
The ATLAS trigger system

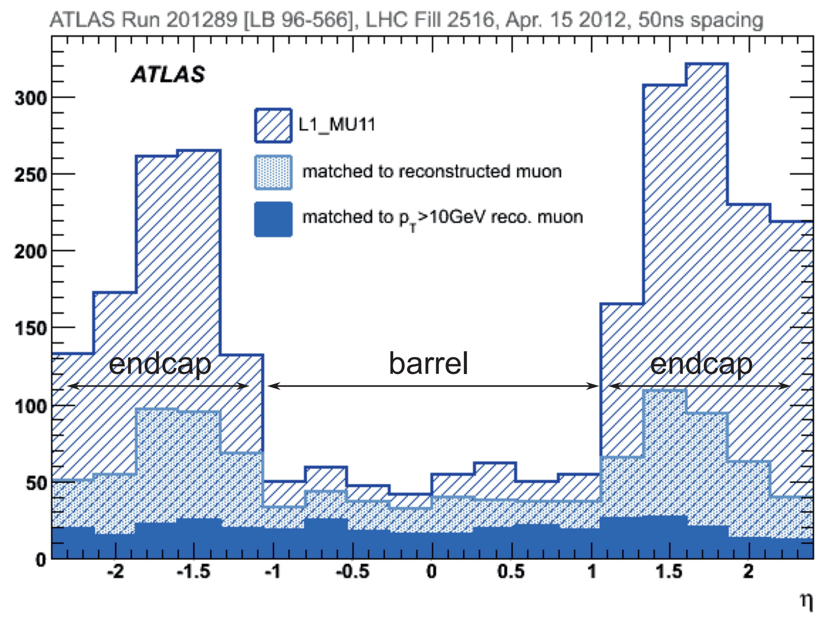
It is organized in three levels, with increasing degree of detail and accuracy.

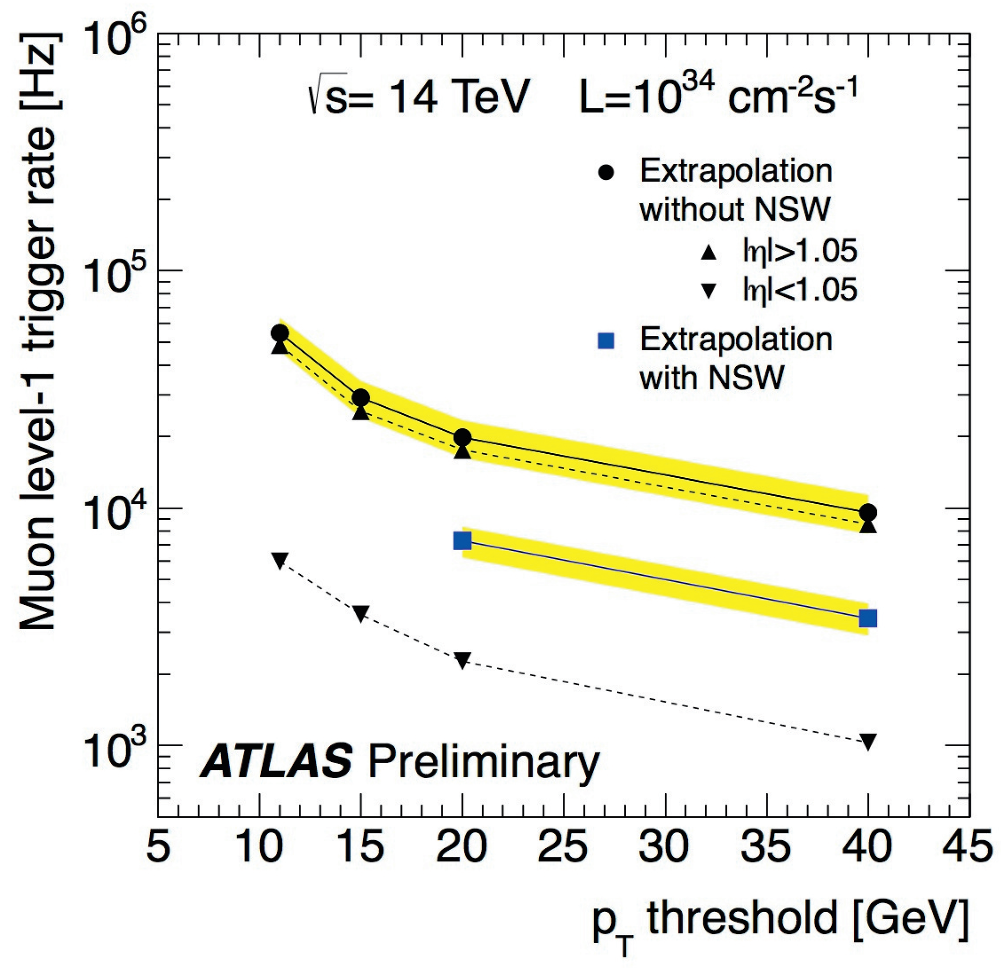


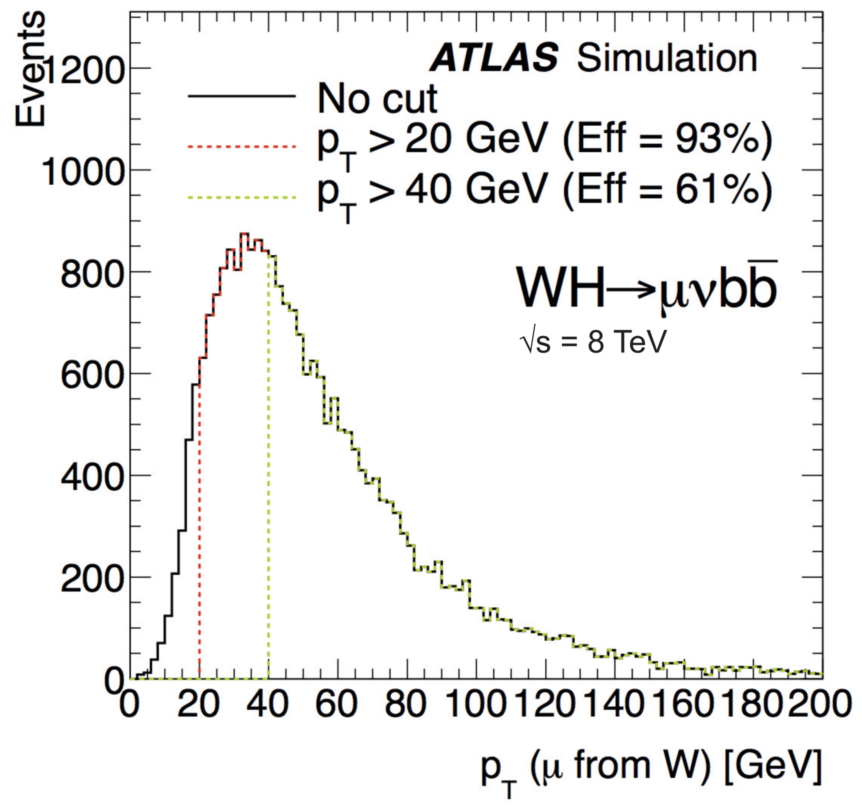
Motivation

Current limitation

The current level 1 (L1) forward muon trigger is based on the track p_T measured in the big-wheel detectors. At L1, the endcap region has a large false positive (fake) rate due to production of secondary particles in the endcap material. The current fake rate becomes unsustainable when extrapolated to the LHC running conditions for 2018. The introduction of the New Small Wheel (NSW), and its inclusion in the L1 trigger, aims at reducing this fake rate without increasing the minimum transverse momentum required to trigger muons at L1.







Without reducing the fake rate, the L1 p_T threshold would need to be raised, reducing the reconstruction efficiency of many critical physics analyses: Higgs boson, B-physics, SUSY and exotic searches.

For example, this table shows the L1MU efficiency for events where the Higgs boson is produced with a W boson.

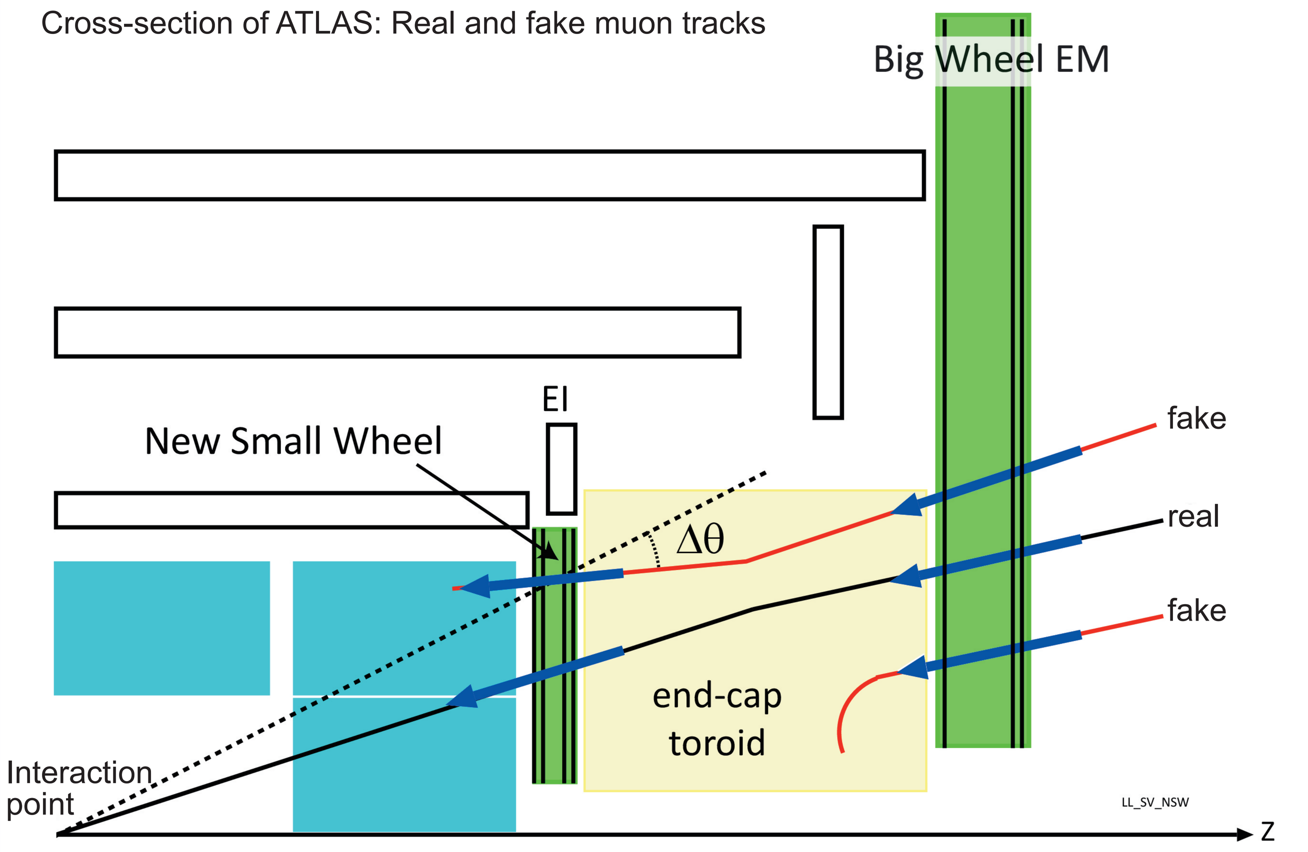
p_T threshold [GeV]	L1MU efficiency for WH [%] $H \to bb$	$H \to WW$
> 20	93.0	94.0
> 40	61.0	75.0
> 20 barrel only	43.0	72.0
> 20 with NSW	90.0	92.0

Requirements and Challenges

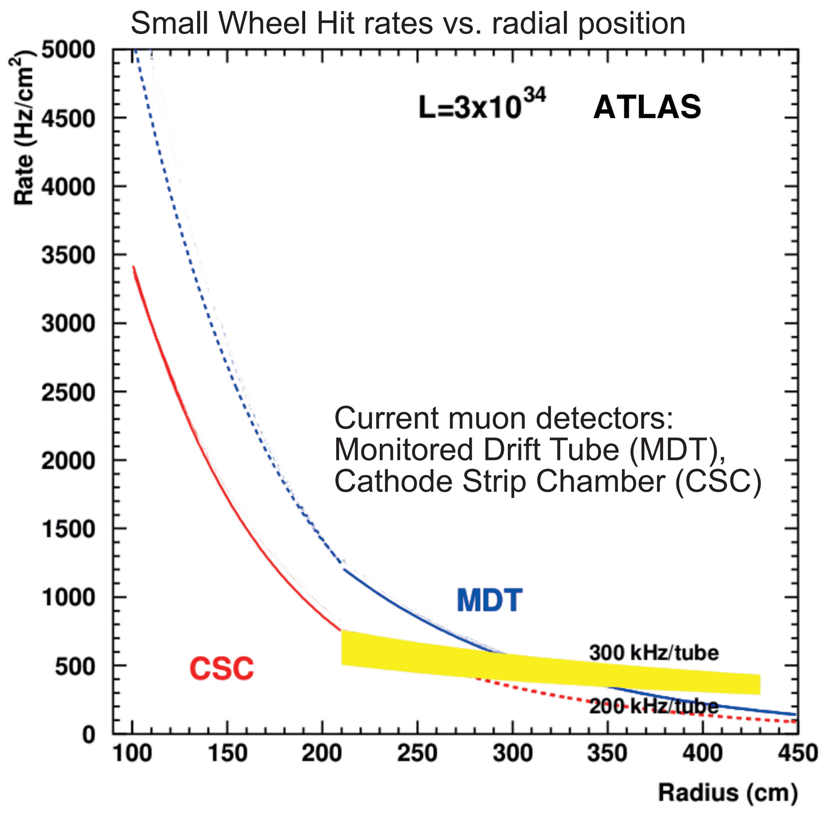
This angle is 10 mrad.
Can you measure it? Can you measure 1 mrad?
Can you measure it 40,000,000 times per second?

Fake triggers correspond to tracks of charged particles not from the interaction point, but from the toroid region. The NSW will require at L1 a track match between the small wheel and the big wheel. The NSW track segment must be reconstructed within 1μs after the collision with ~1 mrad angular resolution. In this region, close to the beampipe, the detector must tolerate hit rates up to 15 kHz/cm^2, as well as the consequent radiation damage.

Cross-section of ATLAS: Real and fake muon tracks



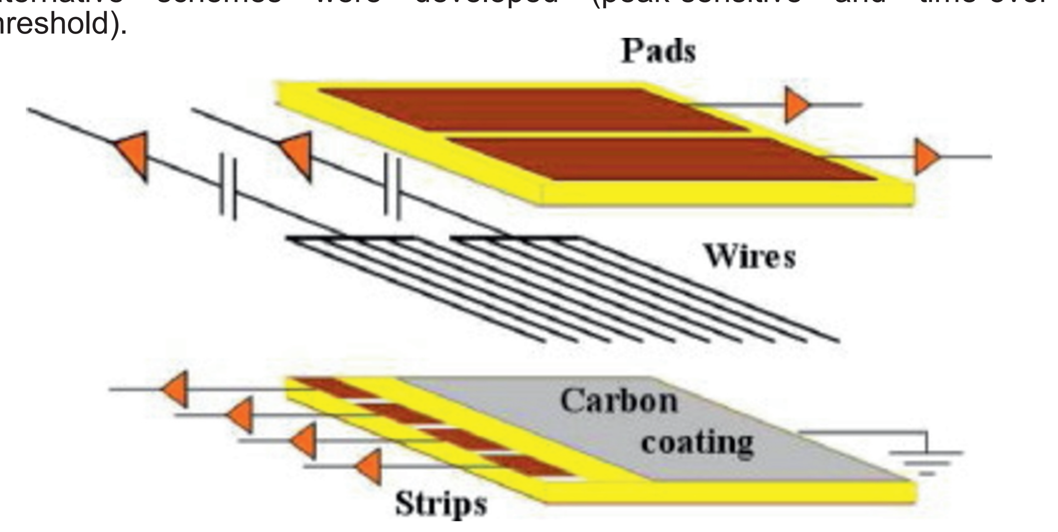
Small Wheel Hit rates vs. radial position



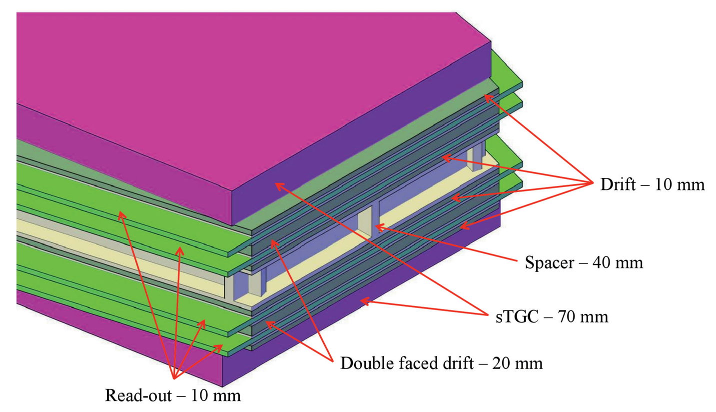
Small-strip Thin Gas Chamber (sTGC)

The NSW will use sTGC detectors. The sTGC detector is a gas ionization chamber (CO_2+n-pentane gas volume ~2.8 mm thick) operated at high voltage (2.85 kV) with multiple readouts. Large (~10 cm x 80 cm) pads provide a very fast signal that can be used to identify the bunch crossing as well as a region of interest within each sector. The signal from readout strips (3.2 mm pitch) can then be processed to provide a more accurate position measurement. Wires (1.8 mm pitch) can be used to improve the offline precision.

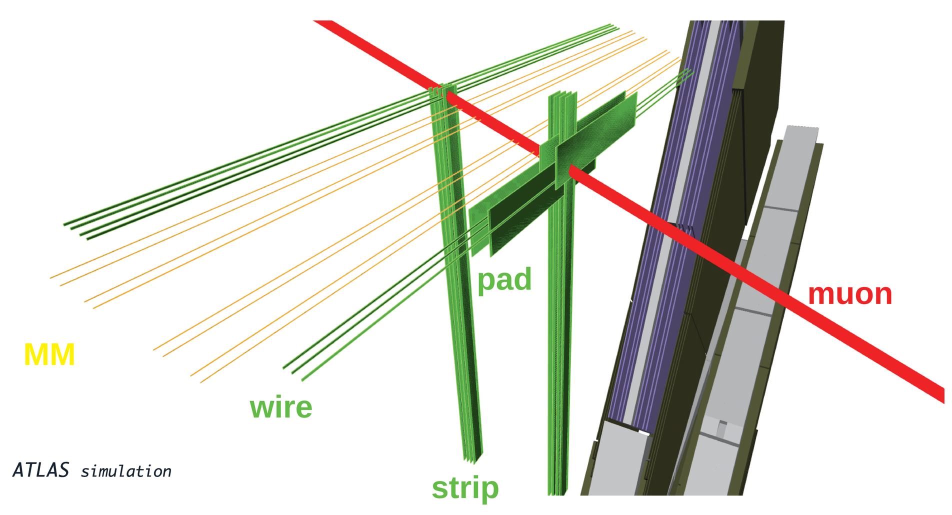
The precision required at L1 is achieved by computing the charge centroid from the strip readouts; however, conventional ADCs are too slow so alternative schemes were developed (peak-sensitive and time-over-threshold).



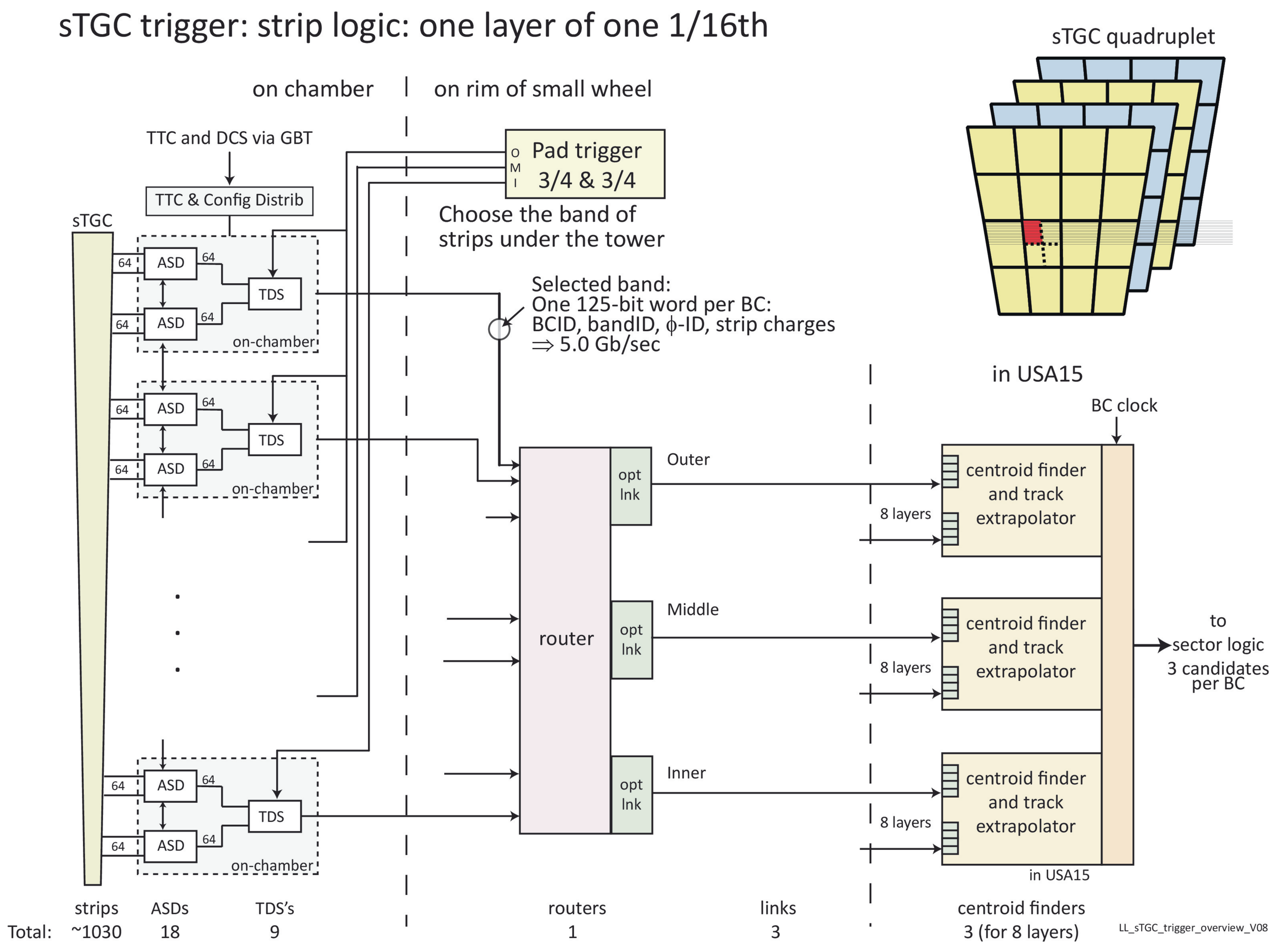
Design and Implementation



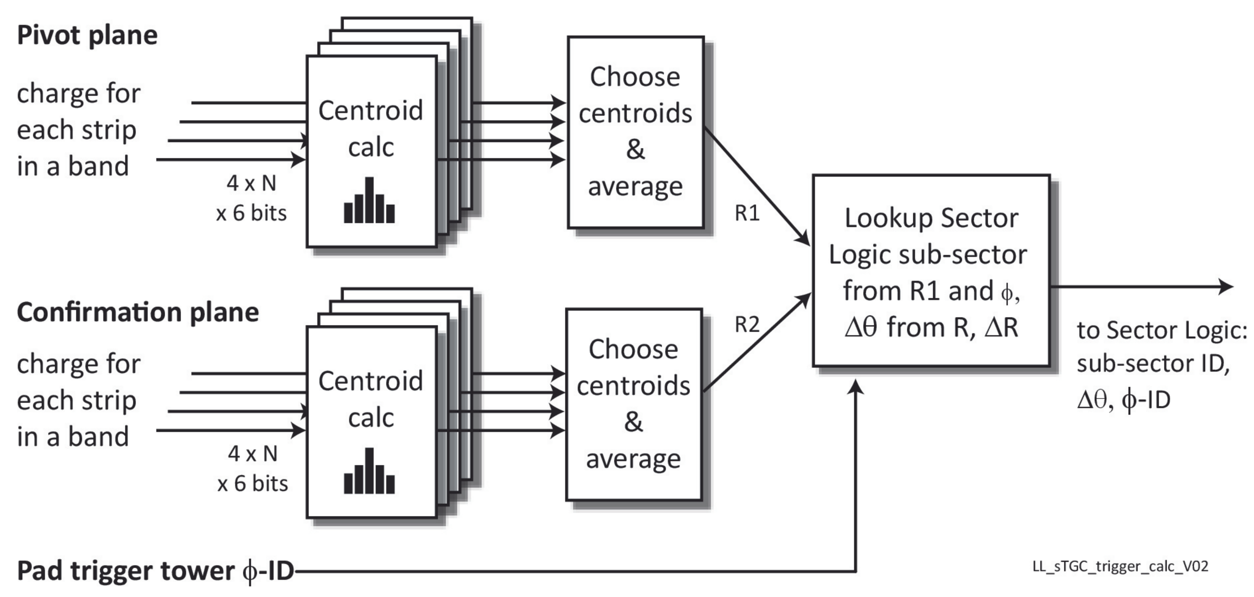
Eight sTGC layers, grouped in two 4-layer multiplets with one micromegas (MM) detector in between, will provide a redundant, fast, and accurate track measurement. The MM detector will improve the offline muon p_T measurement.



sTGC trigger: strip logic: one layer of one 1/16th

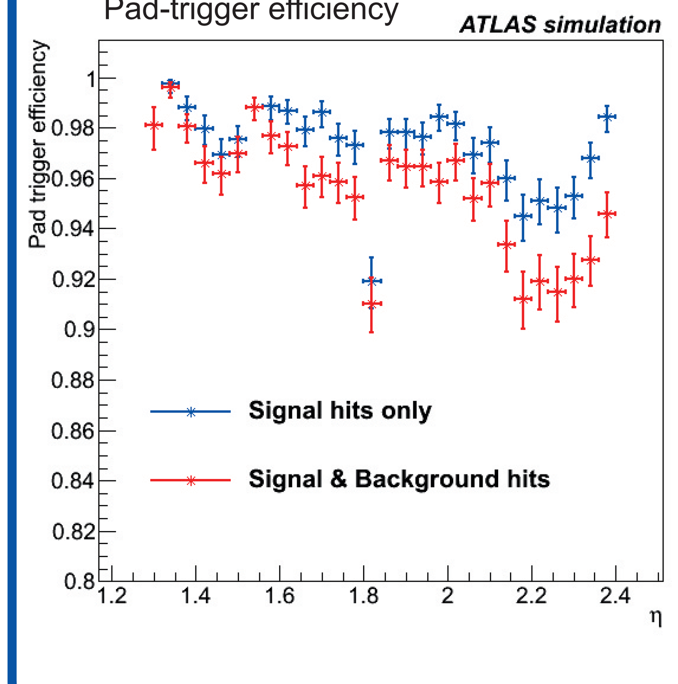


A pad trigger is generated when 3/4 or 4/4 coincident pads have signals on a 4-layer multiplet. Pads are staggered to reduce the solid angle. The matching algorithm relies on the pad indices and can be implemented on an FPGA (with a lookup table) located on the detector. Within each sector (1/16th of the wheel), two pad triggers are required, one for each multiplet. When they are in matching locations, a 20-strip band is read out by the trigger data serializer (TDS). These data are sent from the detector to the cavern, where the charge centroid is computed. From charge centroids with ~100μm spatial precision, a linear fit is performed, and a segment is reconstructed with 1mrad angular resolution. The segment is required to point in the direction of the detector center. The sector-trigger candidate is then sent to the sector logic, where the matching between small wheel and big wheel is performed.

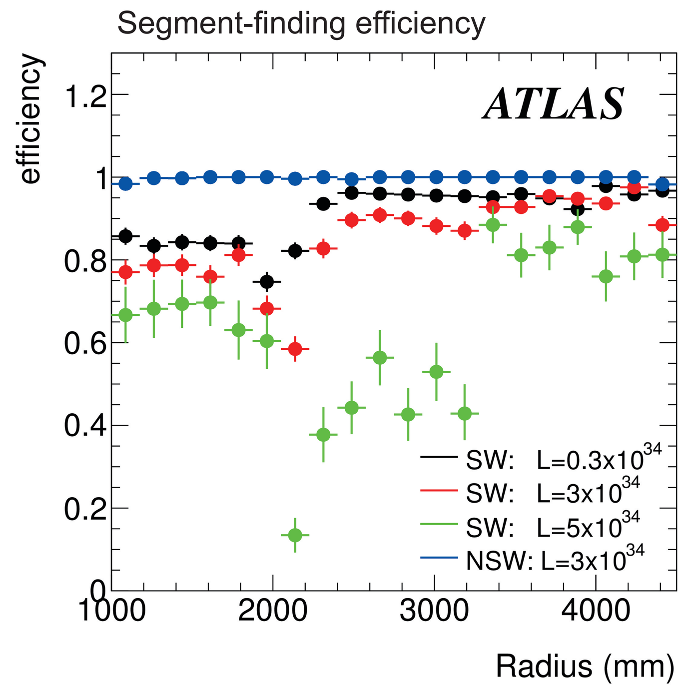


Outlook

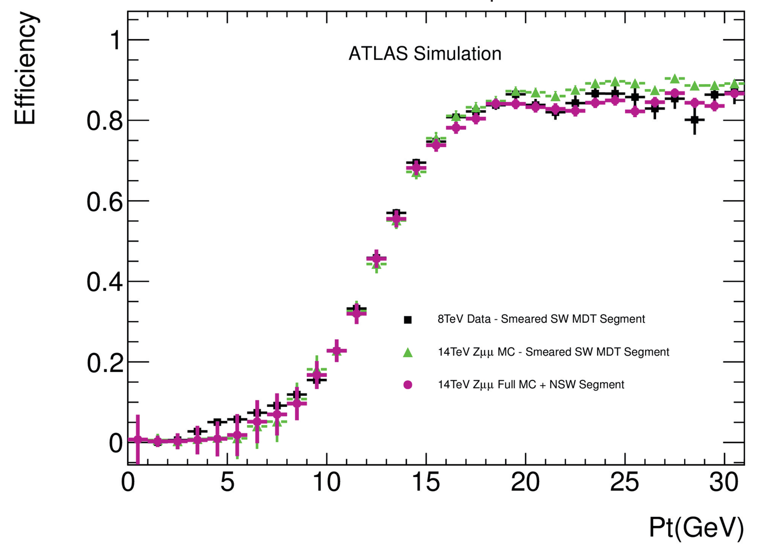
Pad-trigger efficiency



Segment-finding efficiency



Muon trigger efficiency (p_T > 20 GeV)



The expected perfomance of the sTGC-based L1 ATLAS muon trigger upgrade is determined from testbeam studies, from extrapolation of data recorded with the existing detector @8 TeV, and from simulation. The NSW can actually provide a L1 muon trigger that is effective at maintaining a low-p_T threshold in the forward region when the LHC will operate at its design luminosity L = 2x10^{34} cm^{-2} s^{-1}. The required performance can be achieved with an 8-layer NSW producing the trigger decision from the pad and strip readouts. The NSW trigger decision will allow a track match with the big wheel at L1, significantly reducing the fake rate. Very good efficiency (93%) can be achieved, with small dependence on rapidity and on p_T.

The sTGC measurement, combined with the one from the micromegas, will also improve the offline muon spectrometer precision.

The ATLAS collaboration has recently approved the NSW project, and its construction will begin shortly, on time for its installation in 2018.

Further reading

[1] Letter of Intent for the Phase-I Upgrade of the ATLAS Experiment, ATLAS collaboration, CERN-LHCC-2011-012, 2011
[2] The New Small Wheel Technical Design Report, ATLAS Collaboration, CERN-LHCC-2013-006, 2013

Acknowledgements

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This poster was prepared with the Scribus Open Source software.