The New Small Wheel Trigger for the ATLAS experiment

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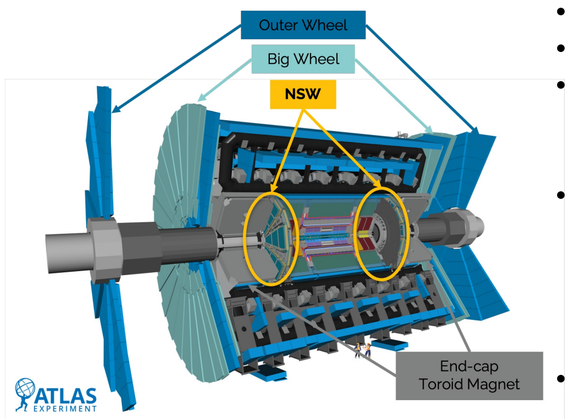
Abstract

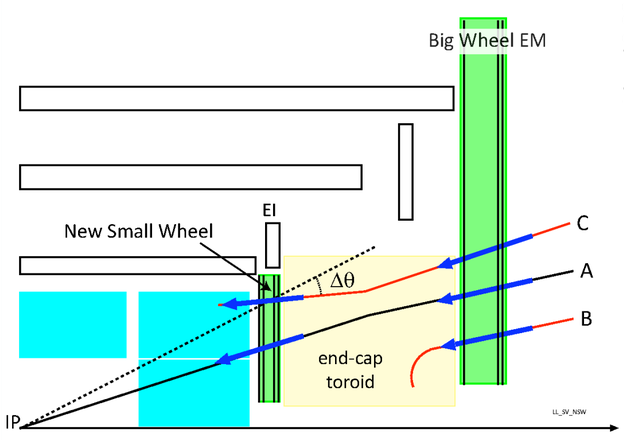
The ATLAS New Small Wheel (NSW) Muon spectrometer upgrade was completed in 2022 and constituted the largest detector upgrade in Phase I among the LHC experiments. The main purpose of NSW is to provide triggering capabilities in the endcap region $1.3 < |\eta| < 2.4$ for confirming muons coming from the interaction point and reject the large fake contribution from the endcap region. It provides also improved muon tracking capability in the endcap, as it is equipped with 2.5 million channels with high spatial resolution of about 100 μm for every one of the 16 layers. The NSW Trigger is based on both the sTGC and the Micromegas technologies that form the basis of the detector operation. It is a Level_1 trigger capable to provide trigger in every Bunch Crossing (BC) at Mixed low latency (44 BC). In 2023 the NSW Trigger was integrated in ATLAS offering critical fake rate rejection, reducing thus the overall readout deadtime of the experiment. We will present the architecture of the NSW Trigger system that is based on custom made electronics, capable to collect the trigger information, process it and efficiently trigger on IP muons. We will concentrate in the sTGC Pad trigger that was fully operational as well as the Micromegas part that was included in the last runs. Performance studies of the NSW Trigger, using pp collisions at 13.6 TeV, will be presented. NSW can operate in the HL-LHC era. The perspectives of the Phase II NSW Trigger upgrade will be given.

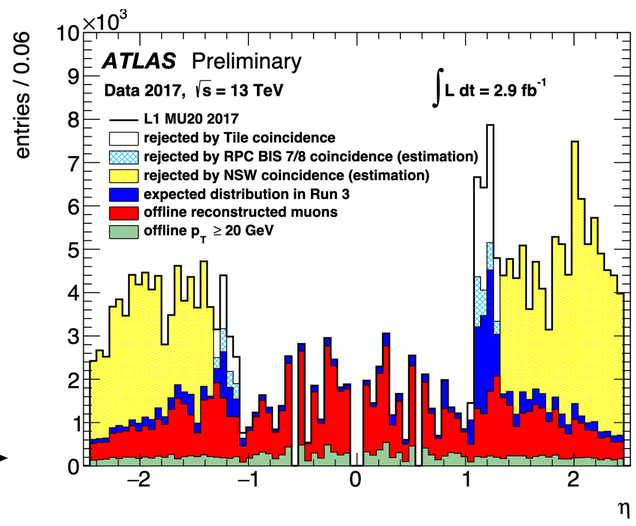
Introduction

New Small Wheel



- Biggest ATLAS Phase I upgrade
- Innermost Muon station - endcap region
- 2 new detector technologies
  - Micromegas (MM)
  - Small-strip Thin Gap Chambers (sTGC)
- Improve trigger and maintain tracking performance for forward muons.
  - high pile-up from Run-3
  - high background rates of HL-LHC from Run-4 (up to 20 kHz/cm²)
- Reduce fake muons in the endcap region

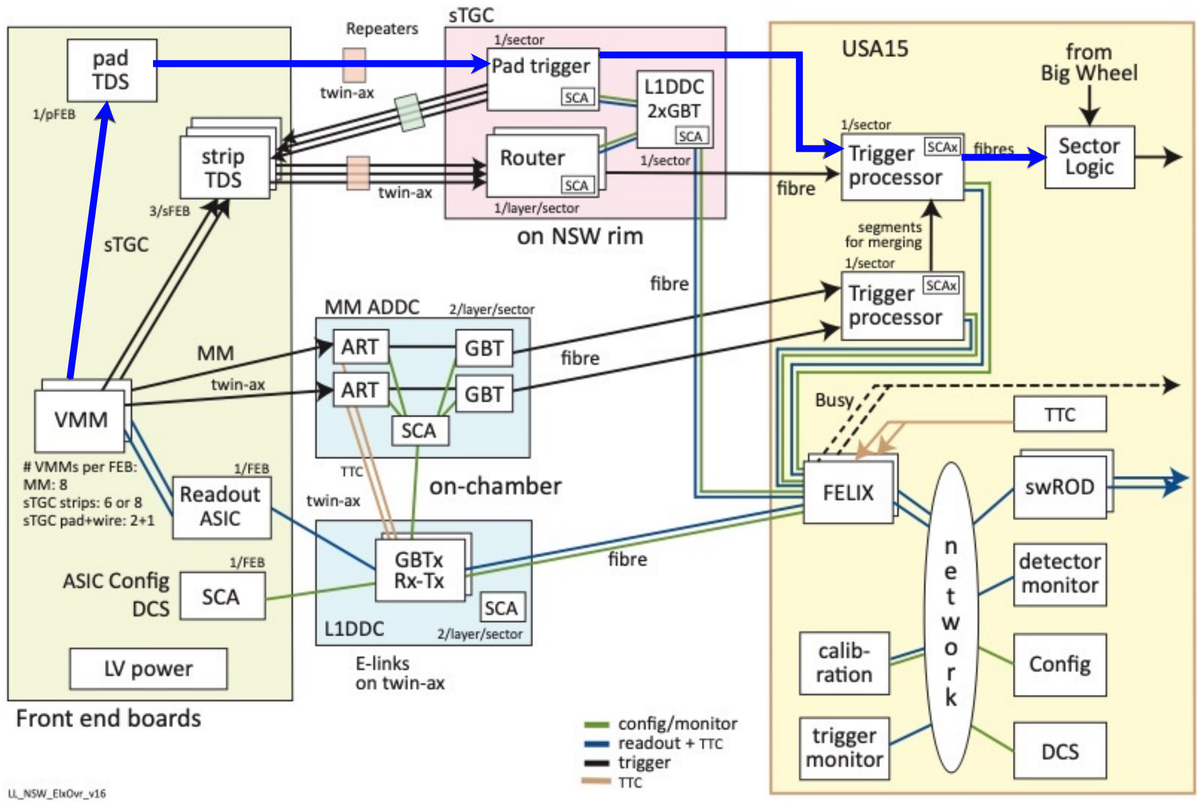




New Small Wheel Trigger System

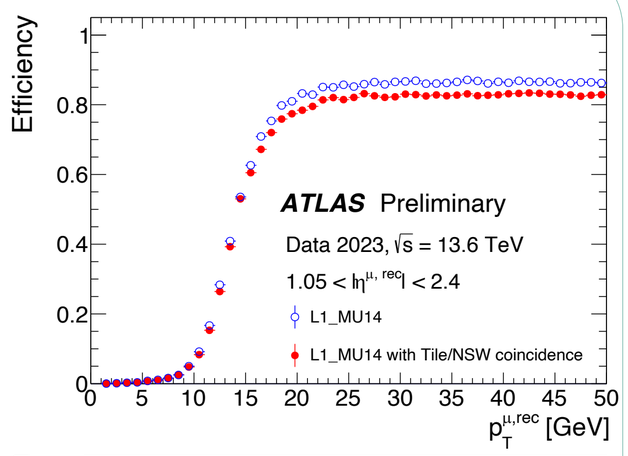
During 2023-2024 Run-3 pad-only path was used in ATLAS Trigger decision.
Pad-only path: pFEB → Pad Trigger (PT) → Trigger Processor (TP) → Sector Logic (SL)

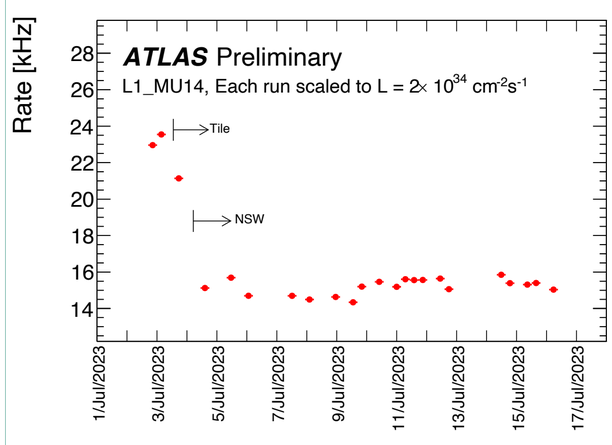
sTGC Strip and MM path to be merged when ready.

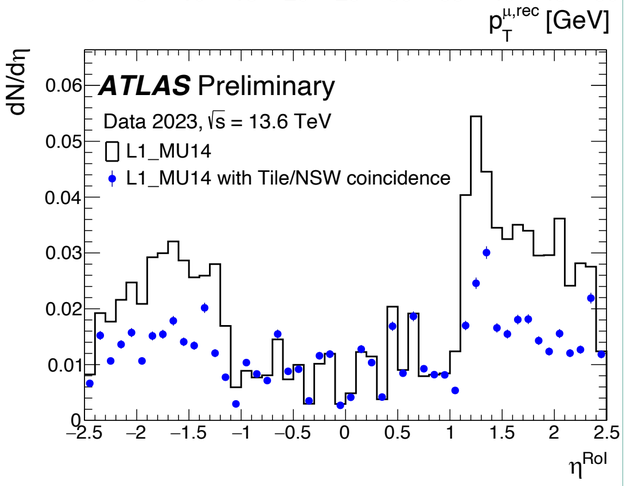


NSW @ ATLAS Run-3

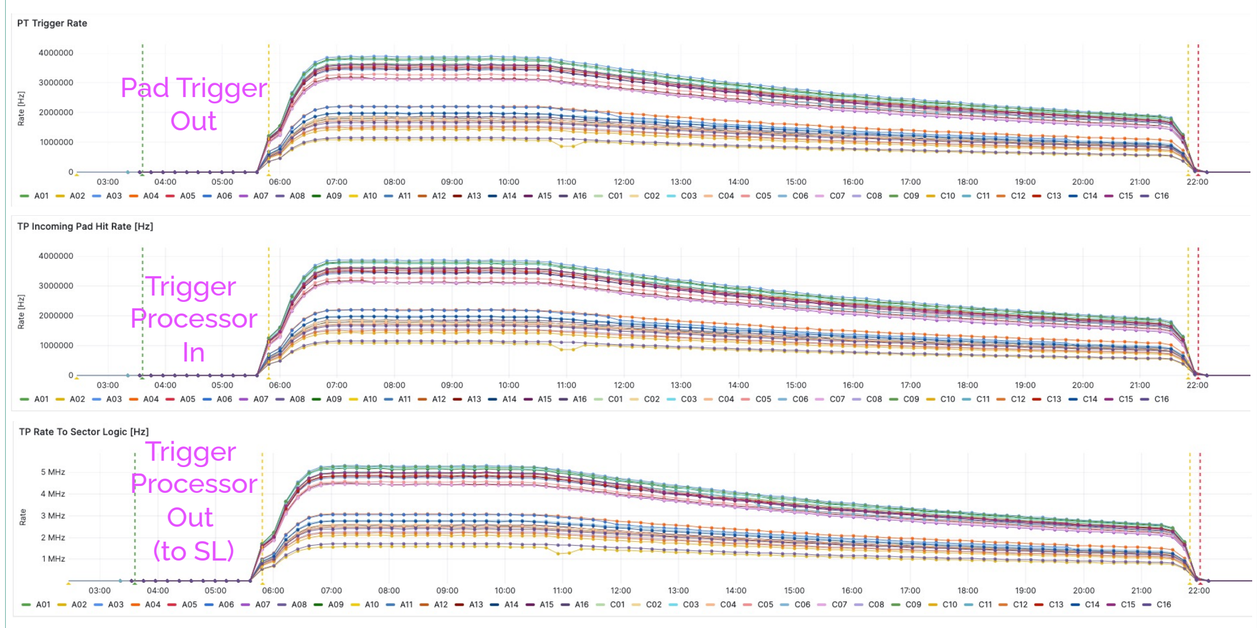
- During 2023, NSW was included in ATLAS trigger decision with 108/144 SL sectors
- Sector Logic checks for coincidences between NSW + Big Wheel
- Reduced L1A rate by ~6 kHz
- NSW+TGC matching efficiency >95%
- 2023 plots below
  (*thanks to the SL group*)





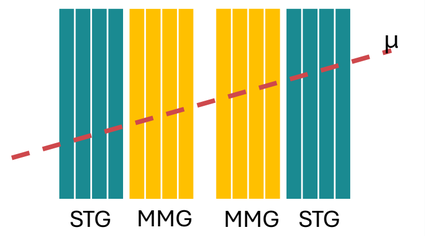


Trigger Rates – Grafana page (online register monitoring)



NSW Trigger Configuration

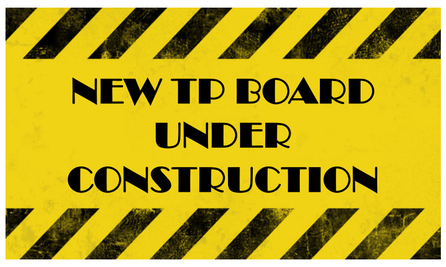
- Pad Trigger coincidence logic is 2/4 AND 3/4.
  Other logics are also available
  - Coincidence patterns → PT FPGA logic revisited
- Stretching logic
  (*to ensure that timing issues won't affect trigger*)
  - Pad Trigger stretches the hits by 2 BCs
  - Trigger Processor streches the trigger by 1 BC
    - Duplicate removal mechanism is applied
- Option to mask-to-1 individual pads/full layers in case of HV/other issues
- NSW guarantees fixed latency to the Sector Logic



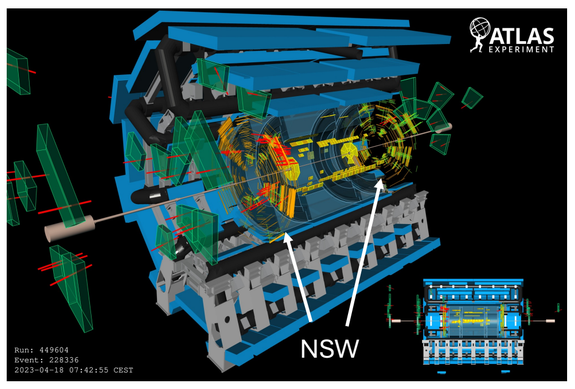
Phase II Upgrade

New NSW Trigger Processor

- 1 common FPGA for MM + sTGC
- Readout rate: 1 MHz instead of 100 kHz



Summary



- 2023 was a very intense year with amazing results for NSW trigger
- During 2023-2024 YETS, improvements (VTRx replacements) took place
- For 2024 Run-3 NSW is again included in ATLAS trigger decision
  - 90% of NSW sectors
  - Reduced L1A rate by 9 kHz!
- More exciting results to come!

References
NSW Technical Design Report: https://cds.cern.ch/record/1552862/files/ATLAS-TDR-020.pdf
The NSW Electronics Paper: https://arxiv.org/pdf/2303.12571.pdf
ATLAS Run-3 paper: https://arxiv.org/abs/2305.16623
ATLAS Run-3 luminosity: https://twikiai.cern.ch/twiki/bin/view/AtlasPublic/LuminosityPublicResultsRun3

Huge thanks to the NSW Trigger group for the material and support!