ATLAS Level-1 Endcap Muon Trigger for Run 3

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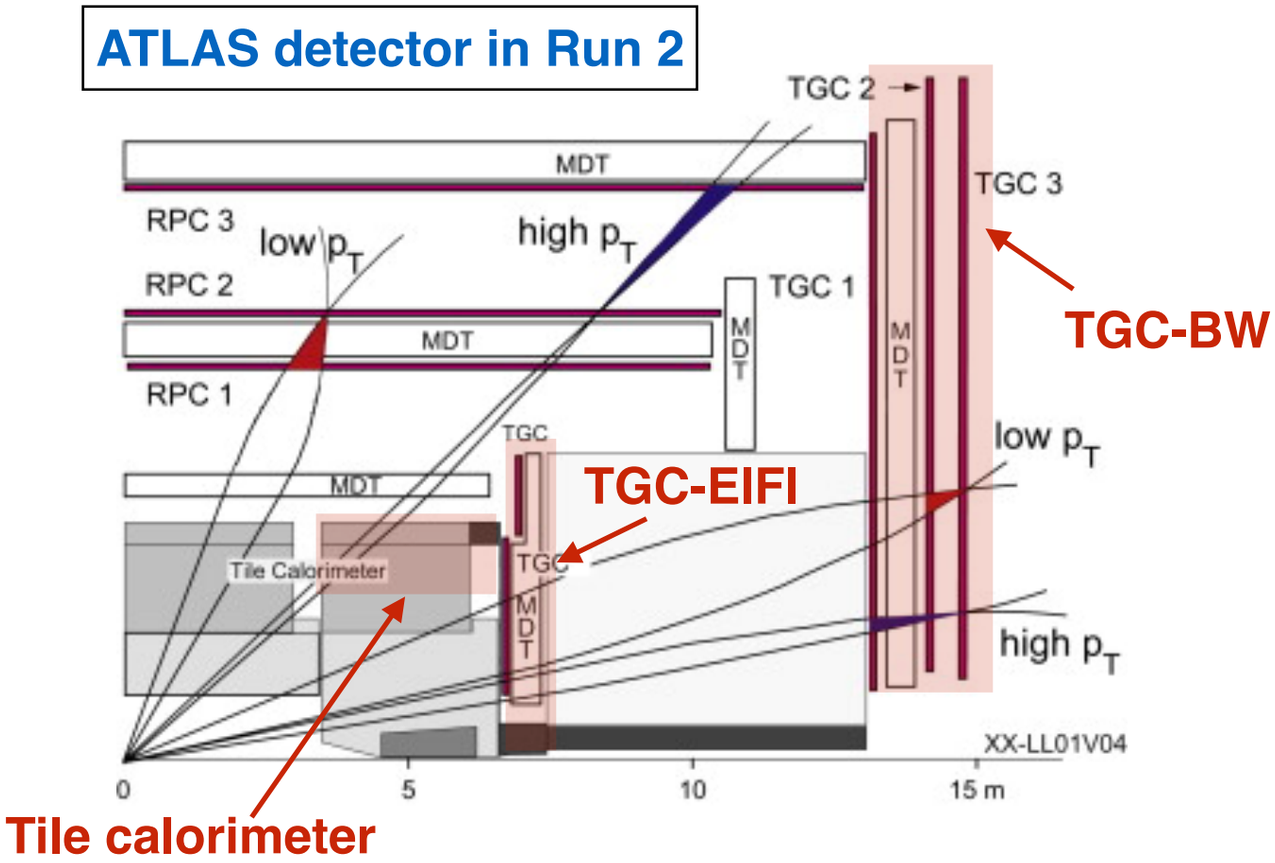
Introduction and Run 2 status

✓ Overview of the ATLAS L1 endcap muon trigger:

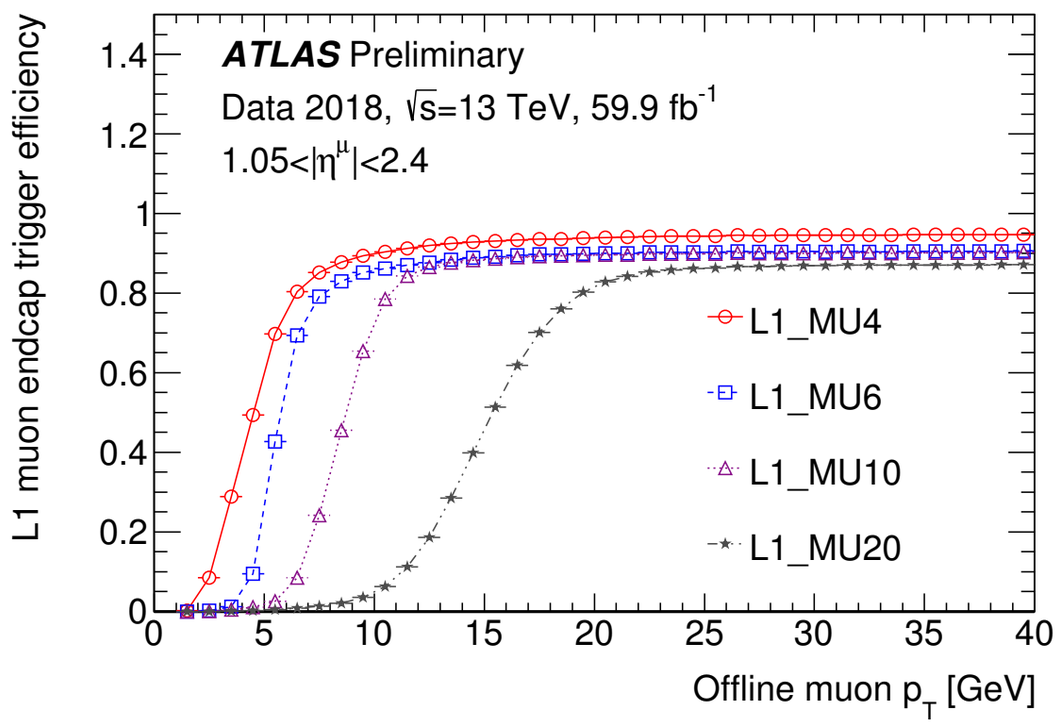


- Hardware trigger by Thin Gap Chambers (TGC) for $1.05 < |\eta| < 2.4$.
  - New coincidences using TGC inner stations (TGC-EIFI) and Tile calorimeter were introduced in Run2.
- Muon p_T measurement using pre-defined Look Up Tables (LUT).

✓ Run 2 performances:

- Primary single muon trigger with a 20 GeV p_T threshold (L1_MU20).
  - ~17kHz@L=2×10^{34}cm^{-2}s^{-1} (2018 data)
- ~90% plateau trigger efficiencies with a stable operation.

Link to L1 Muon Trigger Public Results

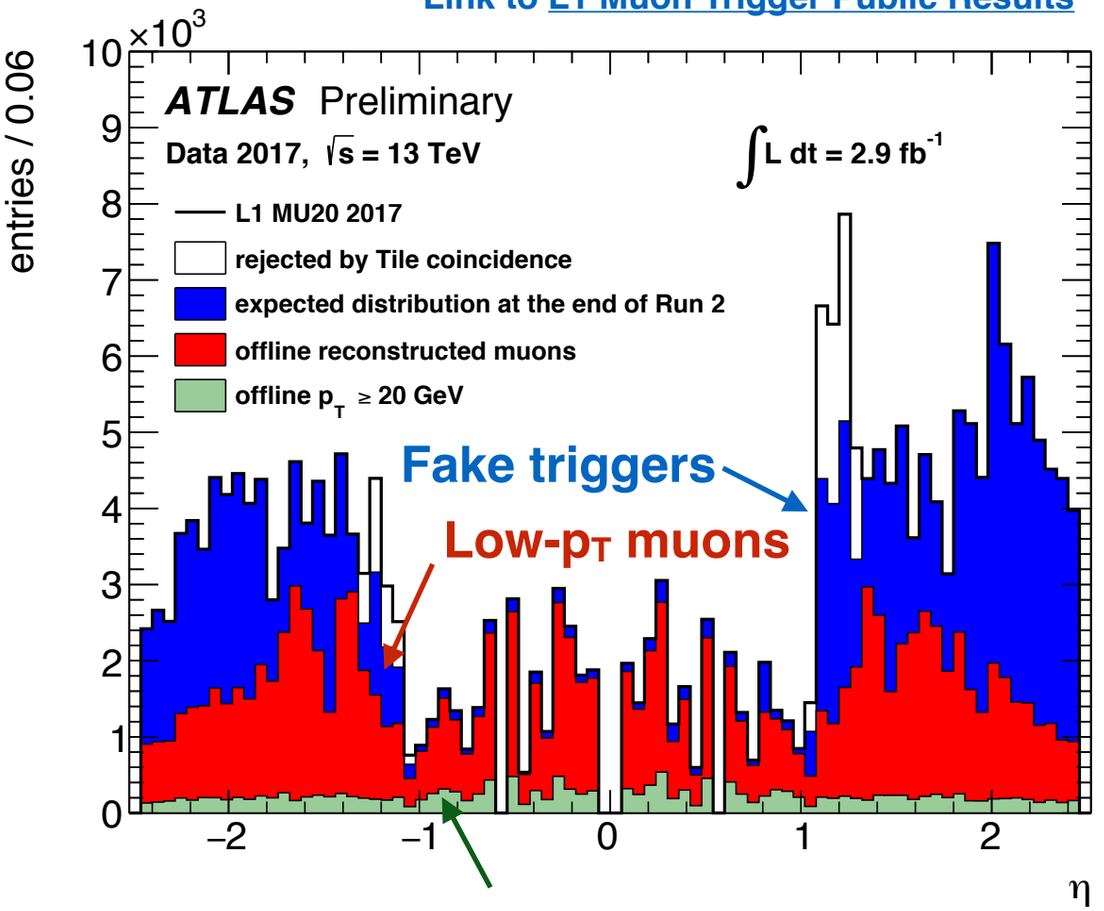


Upgrade motivation for Run 3

- ✓ Main motivation of upgrade program for Run 3:
  - Reject “fake” triggers, ~50% of the trigger candidates is fake due to slow particles emanating from the endcap toroid or shielding.
  - Reduce low-p_T muon contamination below the threshold.

→ **Improvements of the L1 muon trigger are important for various physics analyses. (the total budget of L1 rate is 100 kHz)**

Link to L1 Muon Trigger Public Results



Offline reconstructed muons with $p_T > 20$ GeV

- ✓ This presentation focuses on:
  - Development of the new trigger processor board (Sector Logic) and its trigger algorithms.
  - Trigger rate estimation.

Upgrade overview for Run 3

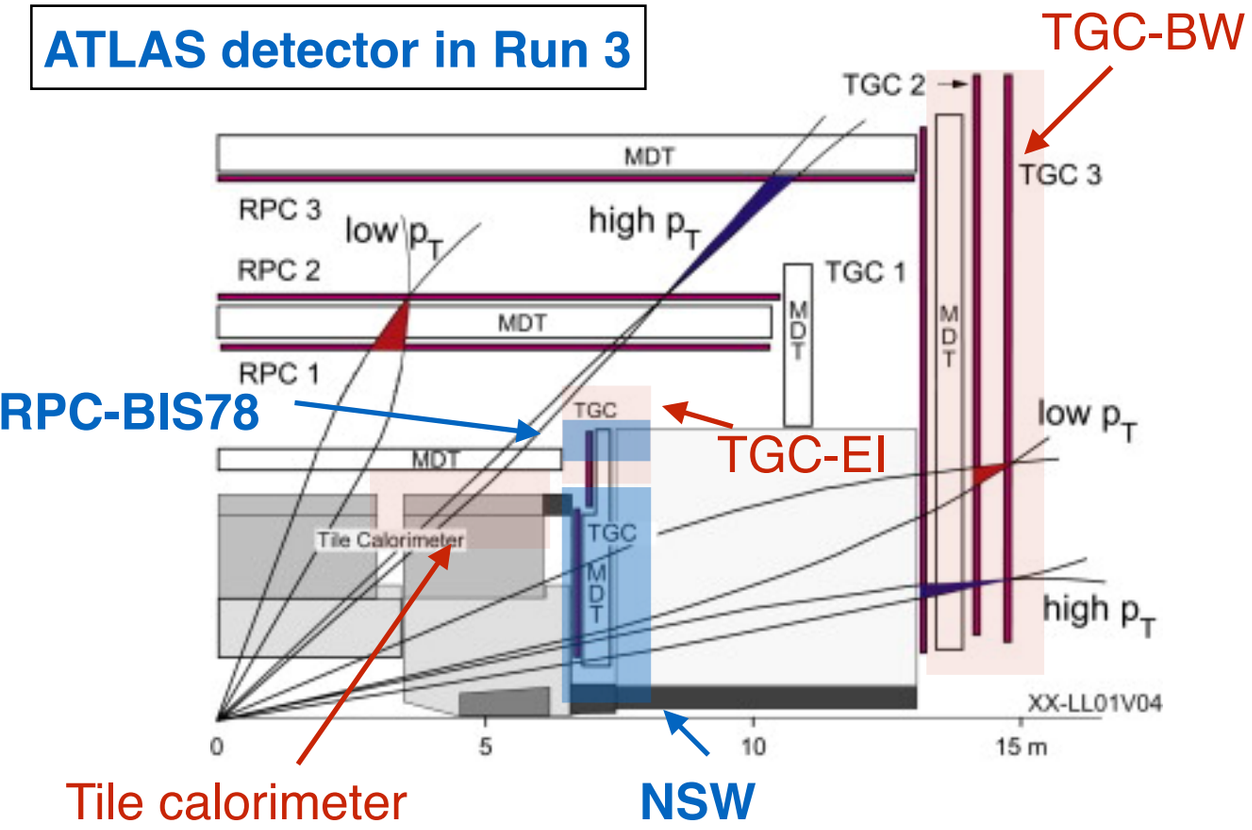
✓ New muon detectors will be installed into the inner regions:

- Small Wheel (TGC, MDT, CSC) will be replaced with New Small Wheel (sTGC, MM)
  - sTGC: small-strip TGC detector, MM: Micromegas detector

→ better coverage for the TGC-BW and Small Wheel coincidence ($|\eta| < 2.0 \rightarrow |\eta| < 2.4$)

→ precision measurement of muon track segments

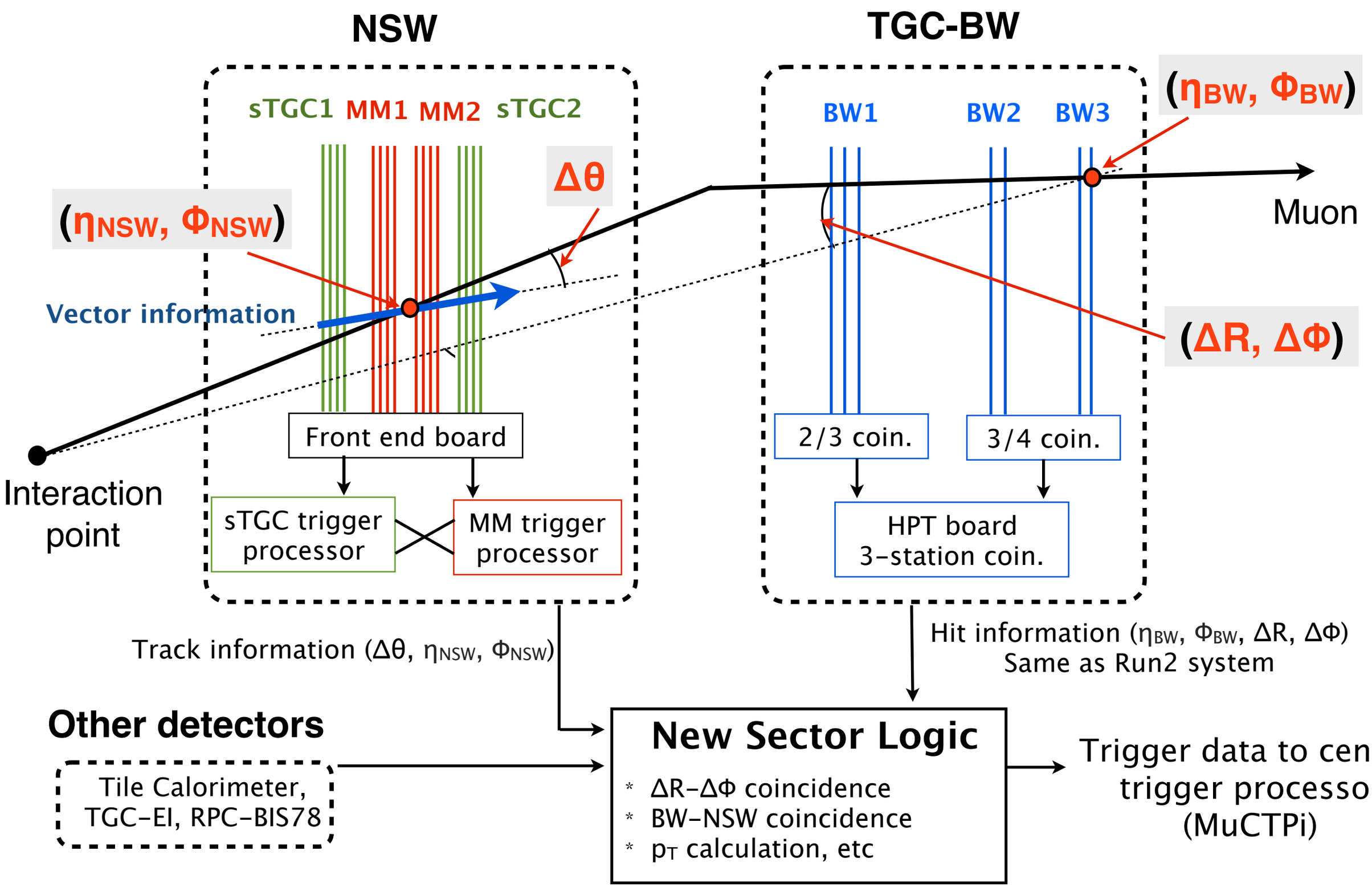
- New RPC detectors (RPC-BIS78) will be added to the edge of the barrel muon trigger system



- New coincidences between TGC-BW and NSW/RPC-BIS78 will be introduced to reject the fake triggers and improve the p_T resolution.

→ **New electronics have been developed to handle the new information and make coincidences.**

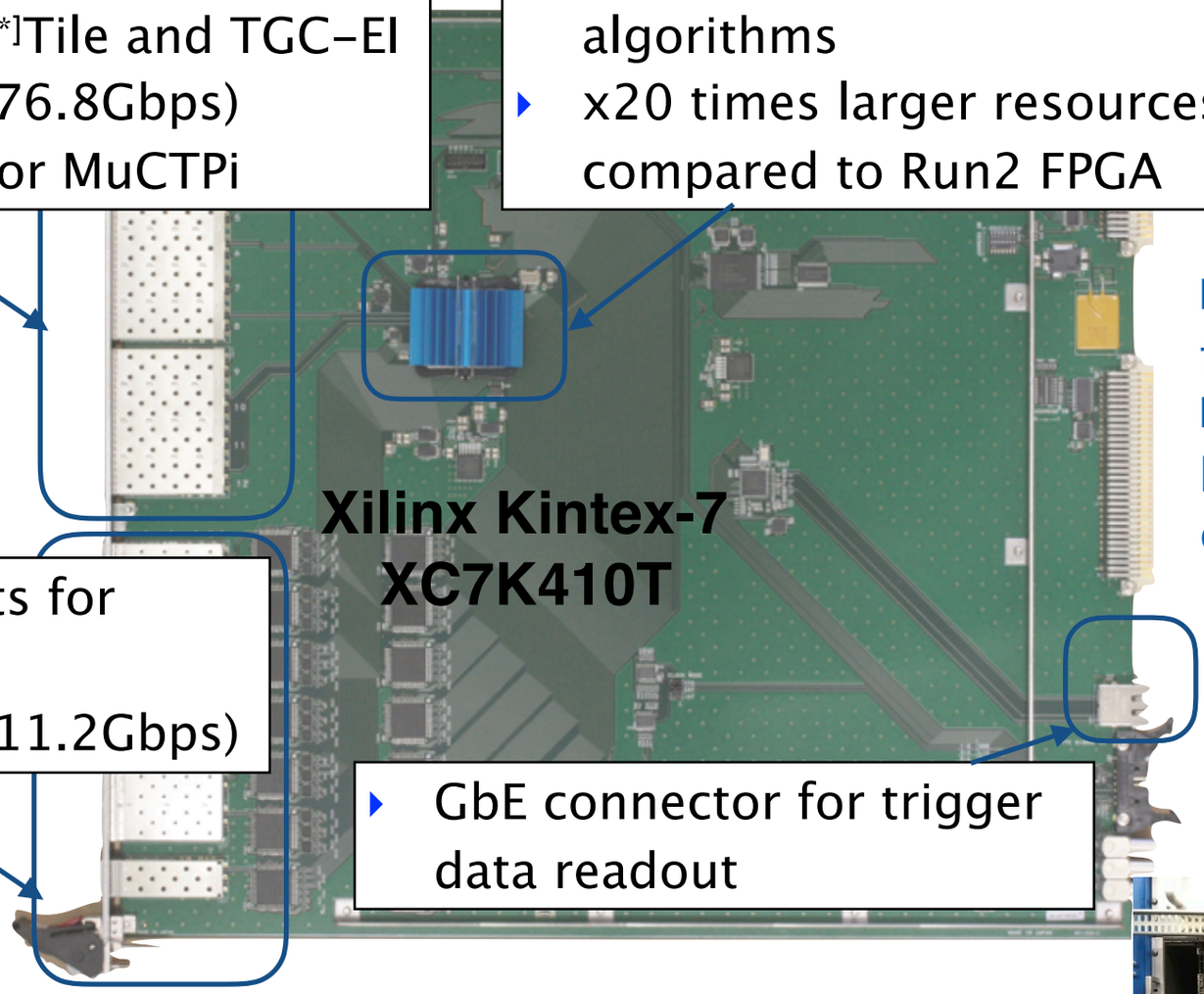
L1 endcap muon trigger schema for Run 3



New Sector Logic board design

- 12x [*]**GTX** inputs for NSW,RPC-BIS78,[**]Tile and TGC-EI (12 x 6.4Gbps = 76.8Gbps)
- 2x **GTX** outputs for MuCTPi

- Main FPGA for trigger algorithms
- x20 times larger resources compared to Run2 FPGA

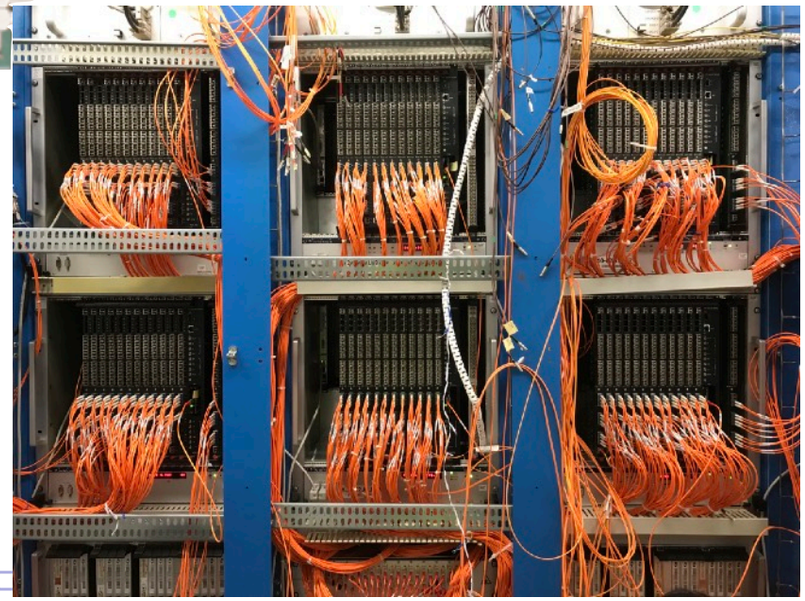


- 14x **G-Link** inputs for legacy TGC-BW (14 x 0.8Gbps = 11.2Gbps)

- GbE connector for trigger data readout

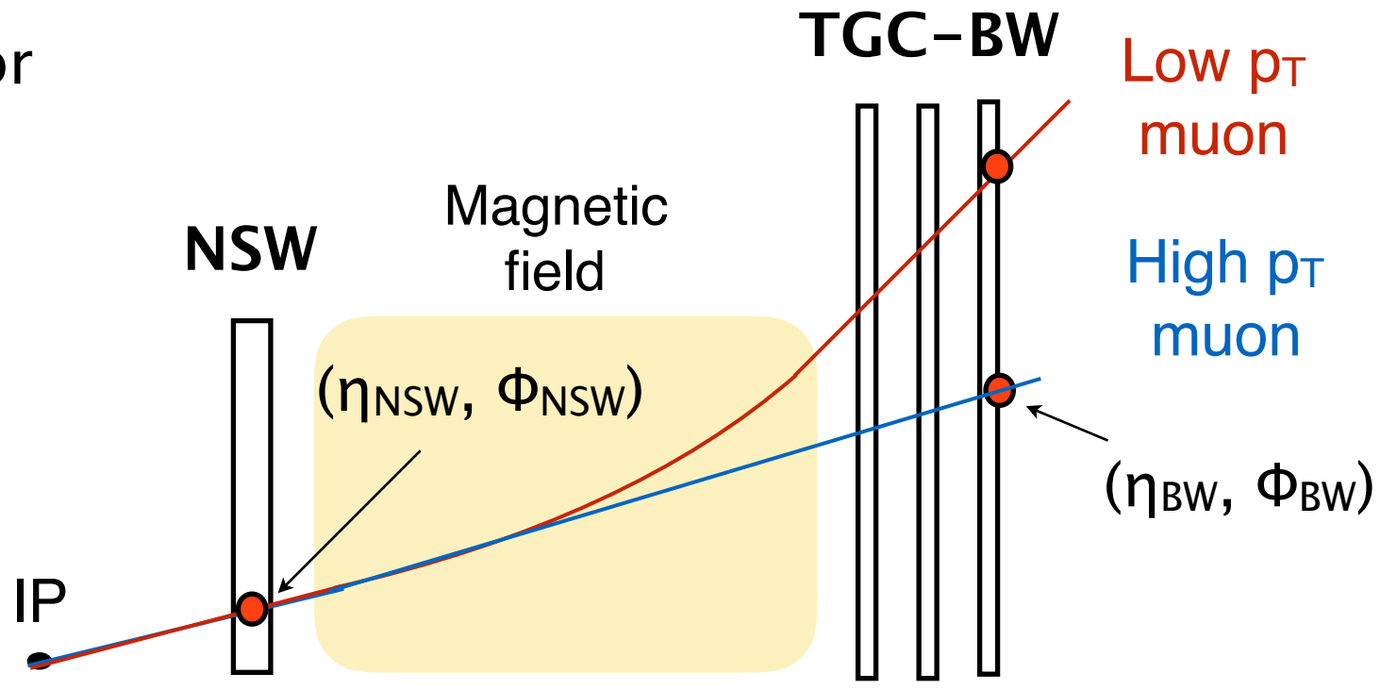
[*] GTX: multi-gigabit transceivers for Xlinx Kintex-7 FPGAs
[**] Tile and TGC-EI(FI) signals will be converted to GTX by dedicated electronics

- x72 Sector Logic boards for the whole L1 endcap muon trigger system
- The new Sector Logic boards have been produced and installed to the ATLAS counting room, commissioning is ongoing.

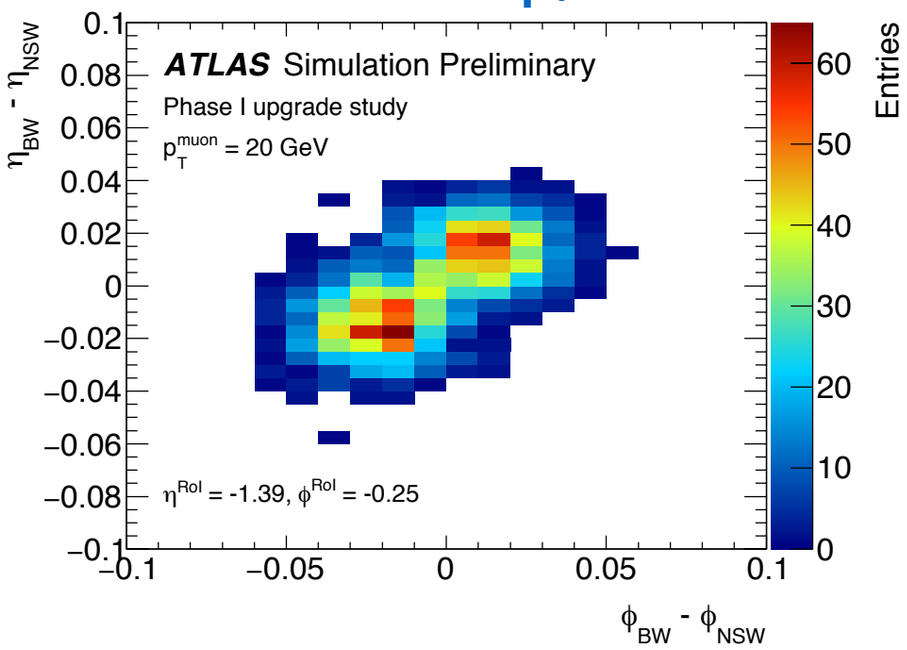


Idea of BW and NSW coincidence

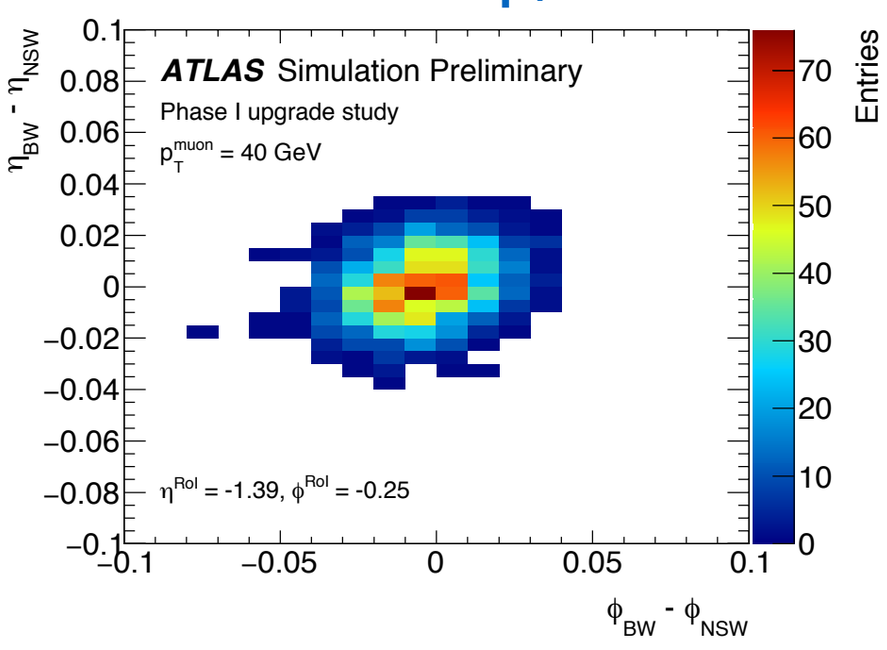
- ✓ There are several baseline ideas for TGC-BW and NSW coincidence.
  - Use the position and angle correlations between TGC-BW and NSW.
    - (η_{BW}, Φ_{BW}) and (η_{NSW}, Φ_{NSW})
    - $\Delta\theta$ and (η_{BW} -η_{NSW})
  - LUT is defined based on hit and angle patterns of simulations.



p_T = 20 GeV



p_T = 40 GeV



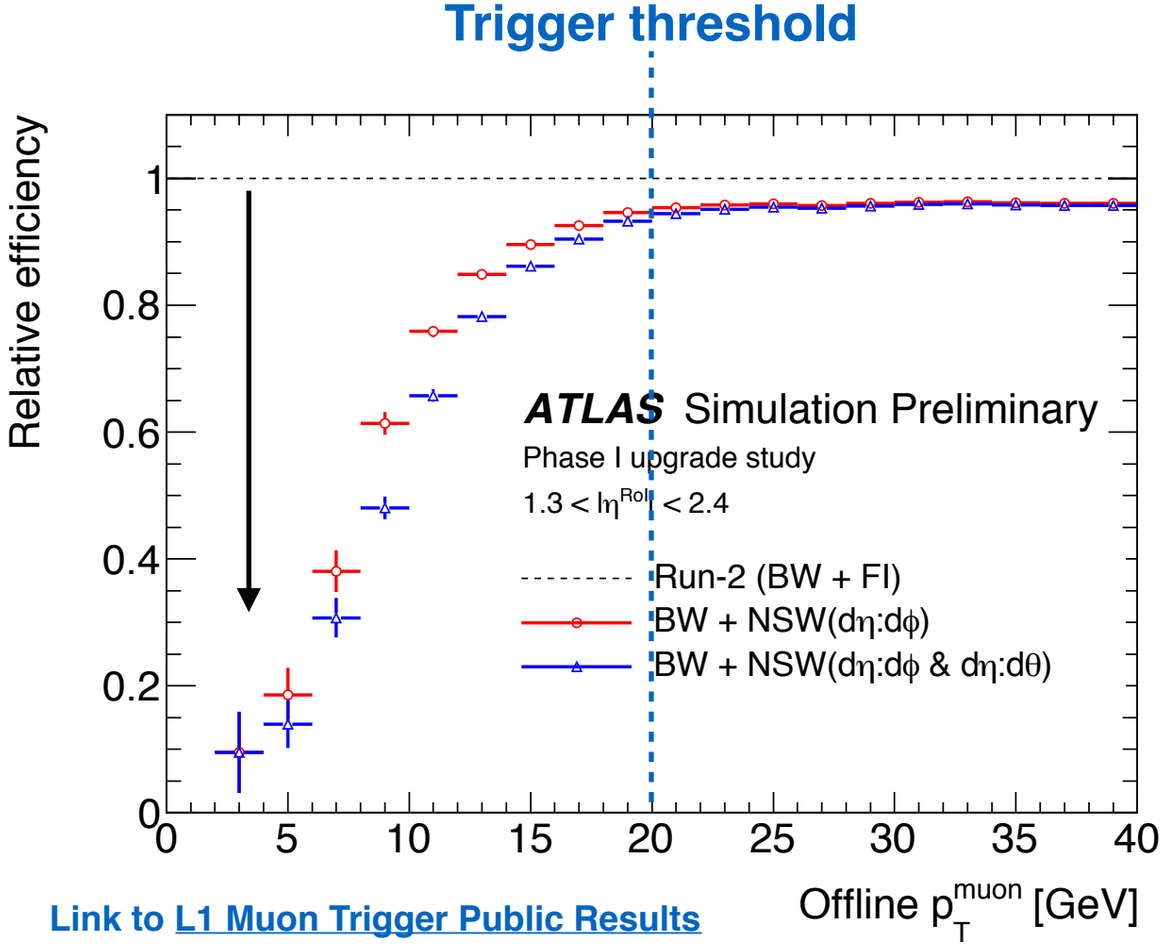
Link to L1 Muon Trigger Public Results

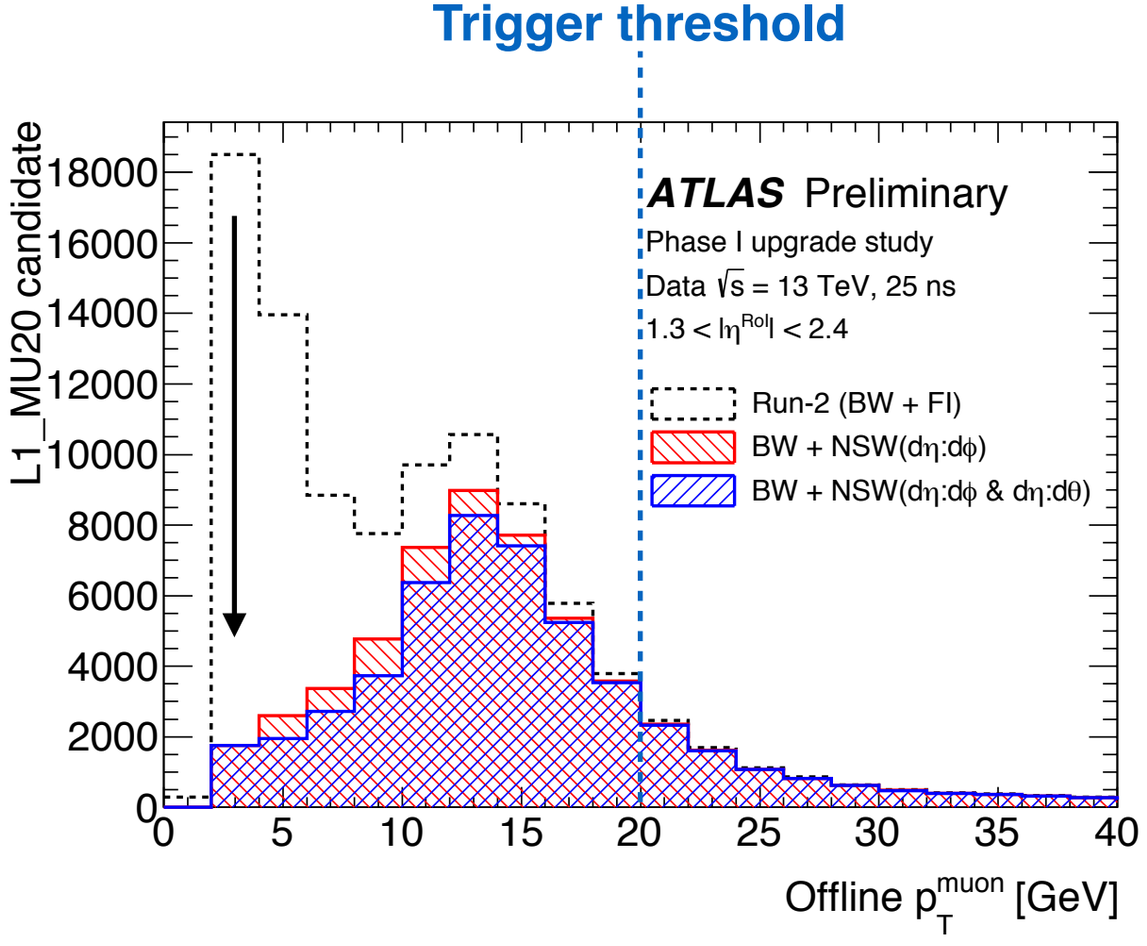
p_T resolution will improve thanks to the fine NSW granularity.

Position resolution:
η_{NSW}=0.005, Φ_{NSW}=0.01
Angle resolution:
$\Delta\theta$=0.001 rad
are assumed in this study

Performance of BW and NSW coincidence

- ✓ Low p_T candidates are rejected effectively by the coincidence.
  - Only a few percent efficiency loss is expected because of the NSW track reconstruction efficiency.
  - For L1_MU20, 50% reduction at 10 GeV and 85% reduction at 5GeV.



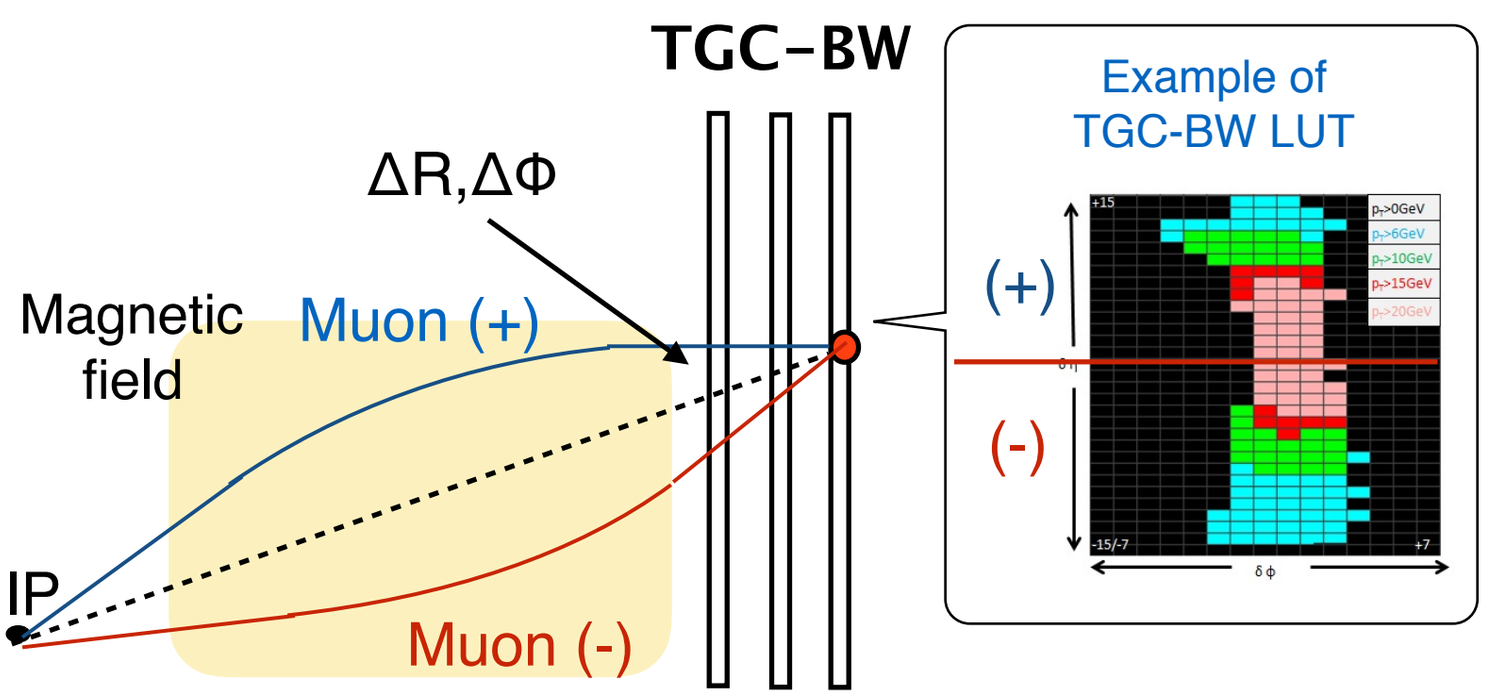


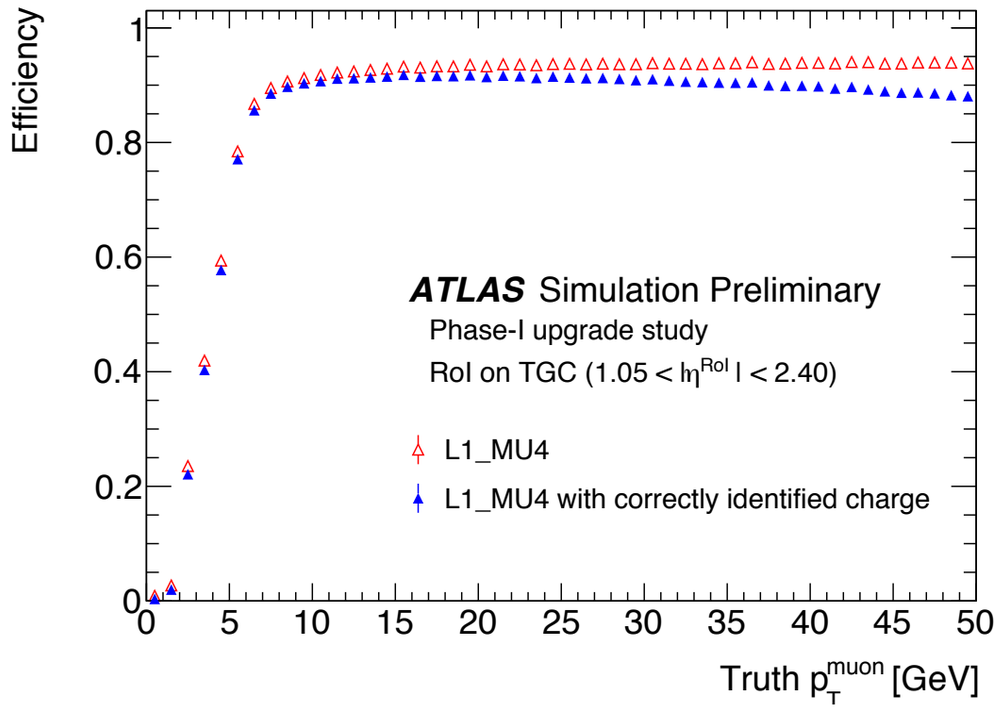
Link to L1 Muon Trigger Public Results

Muon charge identification at L1 trigger

- ✓ L1 muon endcap trigger has a capability of identifying muon charges.
  - Several applications in the L1 trigger benefit by the charge information.
    - E.g. Topological triggers for low p_T muons, such as di-muons with opposite charges for Y(nS) decays.
    - Crucial use case for the flavor physics.
  - Dedicated LUTs can be implemented thanks to new FPGA resources.
- ✓ Accuracy of the muon charge identification at the L1 muon endcap trigger is estimated using simulations.
  - The accuracy is very high for low p_T muons, >98% accuracy up to p_T=30GeV

(The charge information is not important for high p_T single muon triggers)



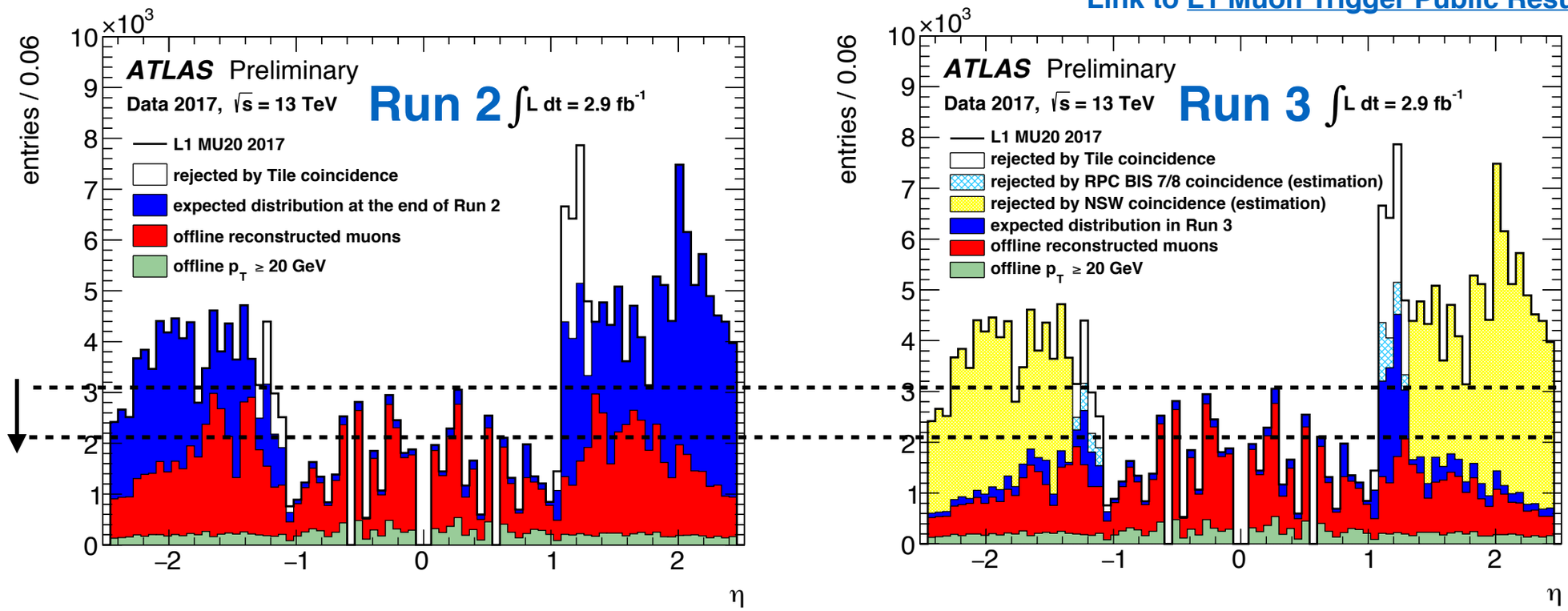


Link to L1 Muon Trigger Public Results

Trigger rate estimation

- ✓ Expected reductions of the trigger rate by introducing the new coincidences are estimated using Run 2 real data.
  - MDT track segments in the current system are used as NSW and RPC-BIS78 tracks.
  - >90% of fake triggers are rejected by the new coincidences !!
  - Low p_T candidates are reduced thanks to the fine granularity of NSW.

Link to L1 Muon Trigger Public Results



Reduction of low p_T candidates

→ ~45% rate reduction is expected for the L1_MU20 trigger.

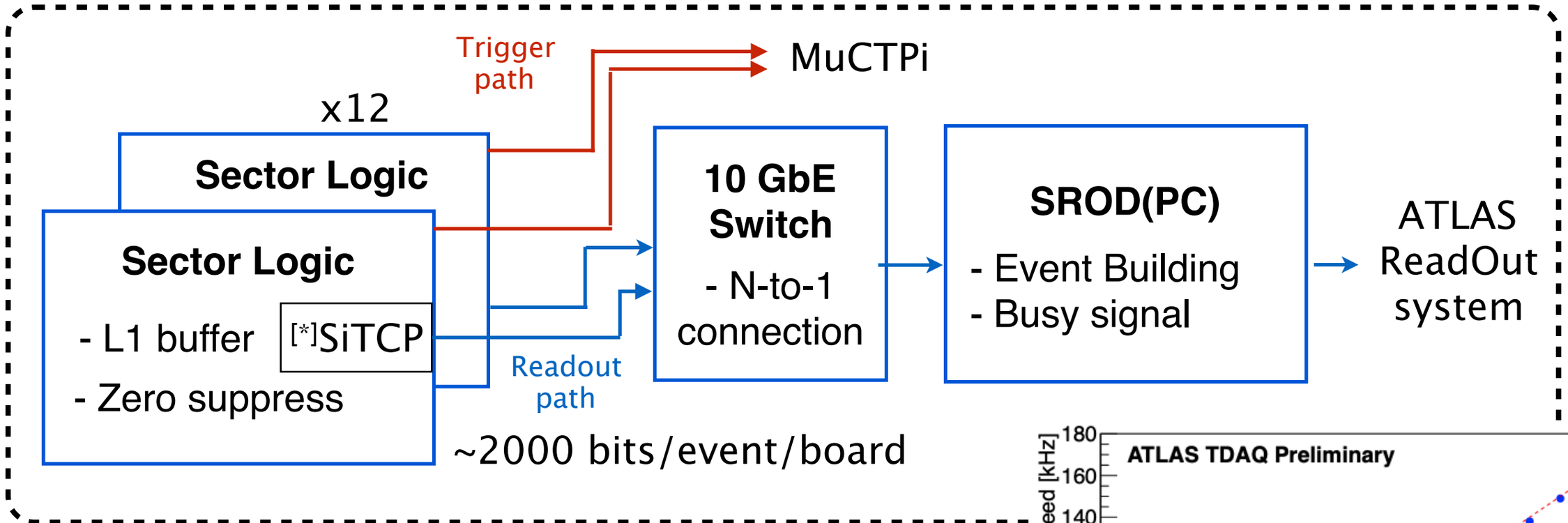
Summary

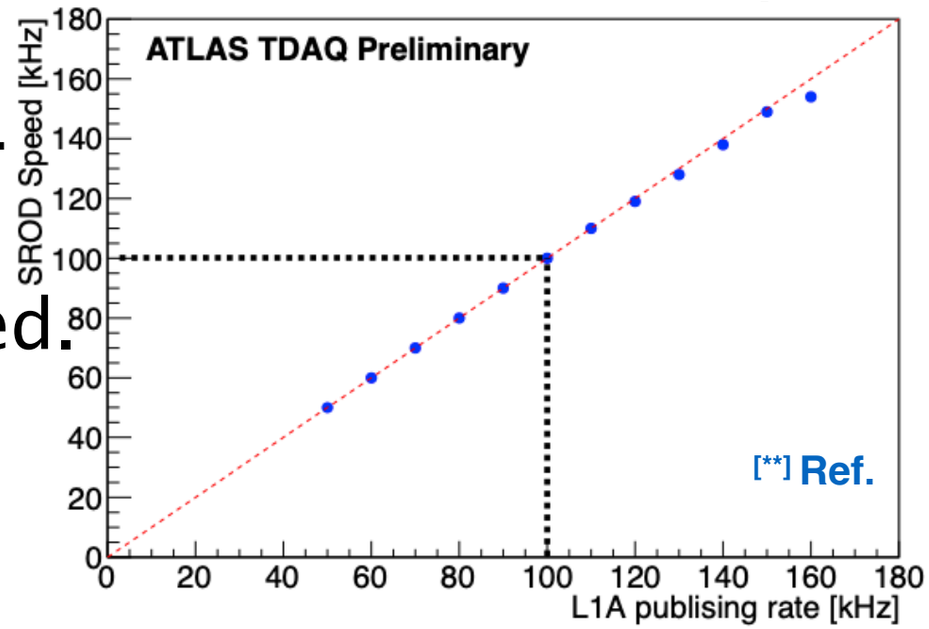
- ✓ The upgrade of the ATLAS L1 endcap muon trigger is required to cope with the high event rate in Run 3.
  - New muon detectors (NSW and RPC-BIS78) will be installed to improve the detector coverage and resolutions.
    → New electronics need to be developed to handle the data.
- ✓ The new Sector Logic boards have been produced.
  - Installation completed, and commissioning is underway.
  - Baseline ideas of trigger algorithms, such as TGC-BW and NSW coincidence, are tested using simulations, and show good performances.
    - e.g: >90% of fake triggers will be rejected by the TGC-BW and NSW coincidence.
- ✓ L1_MU20 trigger rate for Run 3 is estimated using real data.
  - ~45% rate reduction is expected compared to Run 2.

Backup

New readout system for trigger data

- ✓ The readout system for trigger data is re-designed.
  - Custom electronics → commercial PCs and network switches.
  - Software-based data acquisition system (SROD).



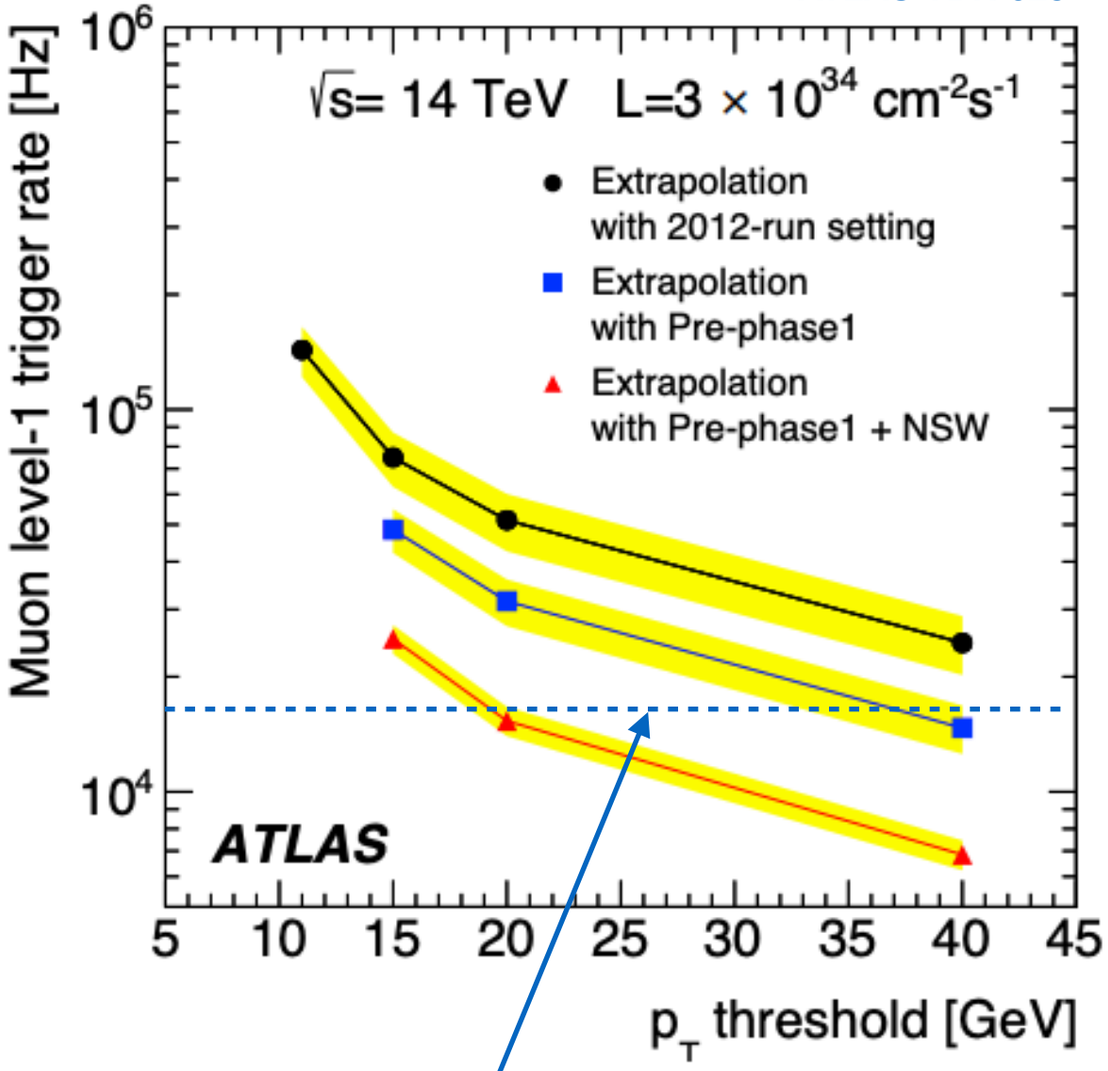


- ✓ The SROD shows a good processing speed.
  - Maximum L1 trigger rate is 100kHz.

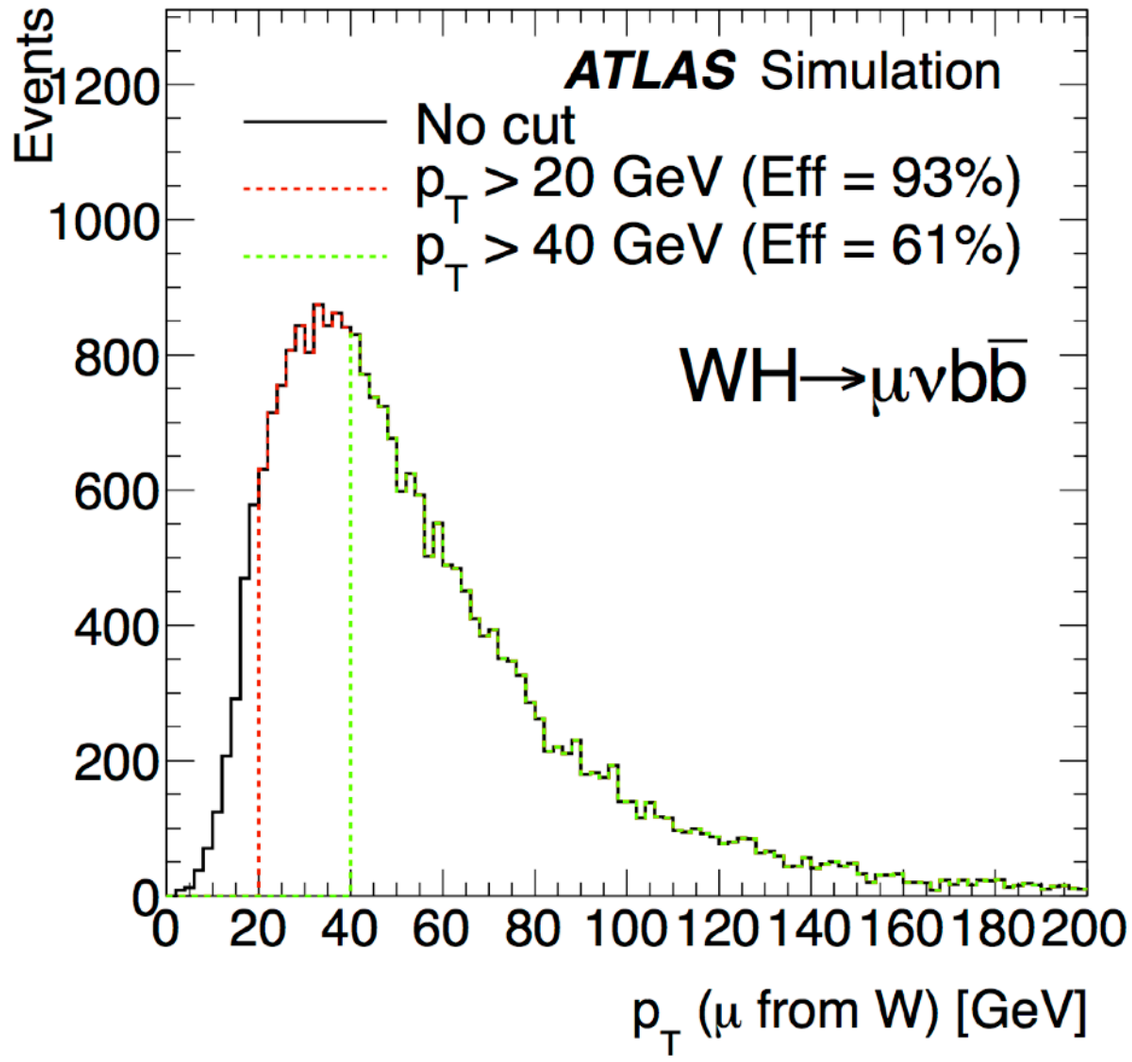
[*] T. Uchida, Hardware-Based TCP Processor for Gigabit Ethernet, Nuclear Science, IEEE Transactions on 55 (2008) no. 3, 1631–1637.
[**] L1 Muon Hardware Public Results

Trigger rate and physics impact

ATLAS-TDR-023

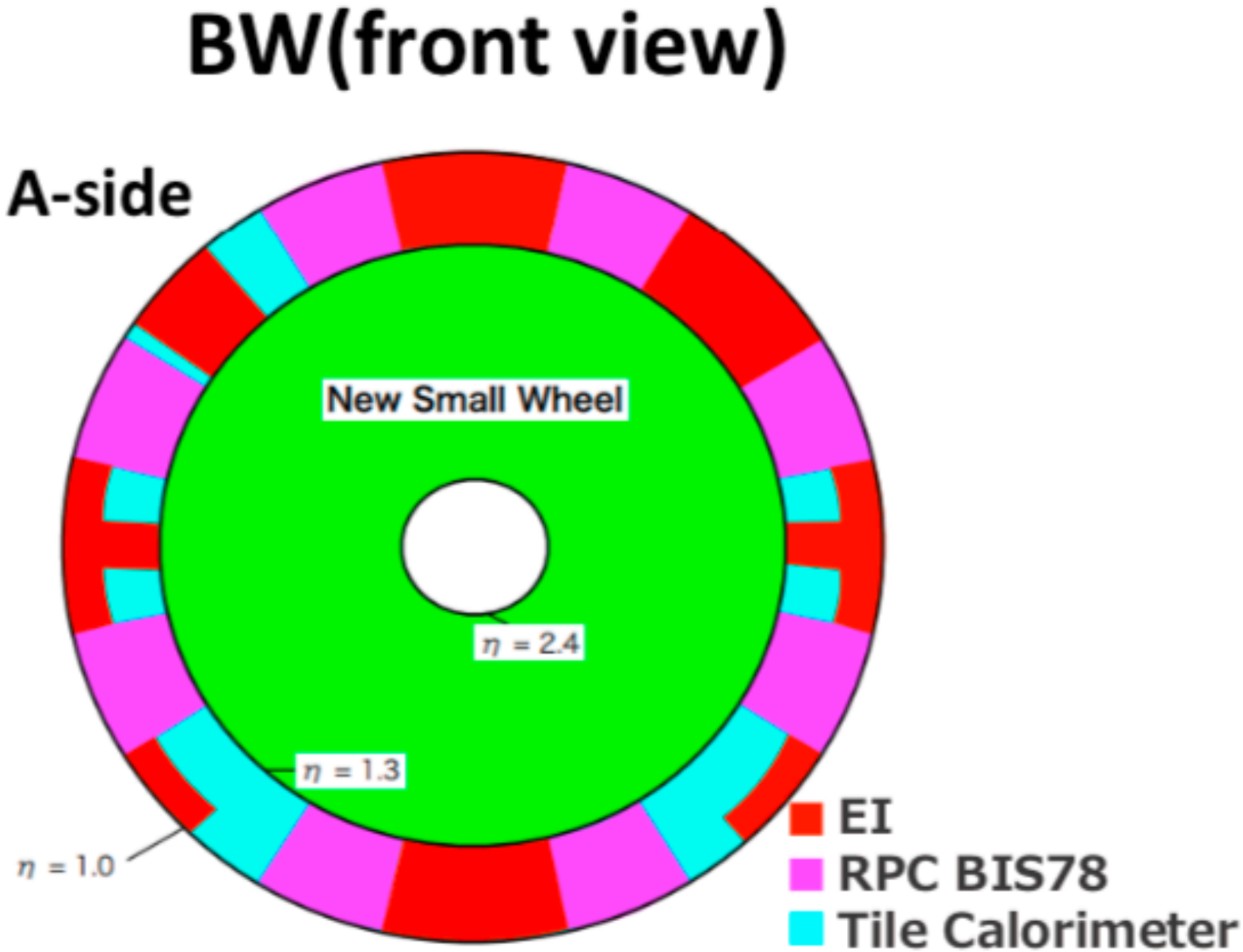


ATLAS-TDR-020



Requirement for Run3 (~15kHz)

Coverage of inner detectors



Map of covered region by each detector