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The new Muon-to-Central-Trigger-Processor Interface at ATLAS

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The ATLAS trigger system includes a Level-1 (L1) trigger based on custom electronics and firmware, and a high-level software trigger running on off-the-shelf hardware. The L1 trigger system uses information from the forward detectors, the calorimeters and the muon trigger detectors. The muon trigger detectors consist of Resistive Plate Chambers in the barrel, and Thin-Gap Chambers, small-strip Thin-Gap Chambers and MicroMegas in the endcaps. Once information from all muon trigger sectors has been received, trigger candidate multiplicities are calculated by the Muon-to-Central-Trigger-Processor Interface (MUCTPI). In the next stage, muon multiplicity information is sent to the Central-Trigger-Processor (CTP) and trigger objects are sent to the L1 Topological Trigger Processor (L1Topo). The CTP combines the information received from the MUCTPI with the trigger information from the forward detectors, the calorimeters and the L1Topo, and takes the L1 trigger decision. As part of the ATLAS L1 trigger system upgrade for Run-3 of the Large Hadron Collider (LHC), a new MUCTPI has been designed and commissioned. We discuss the commissioning and integration of the new MUCTPI used in ATLAS from the beginning of Run-3. In particular, we describe monitoring tools which have been developed for the commissioning and operation of the new MUCTPI.

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1. Introduction

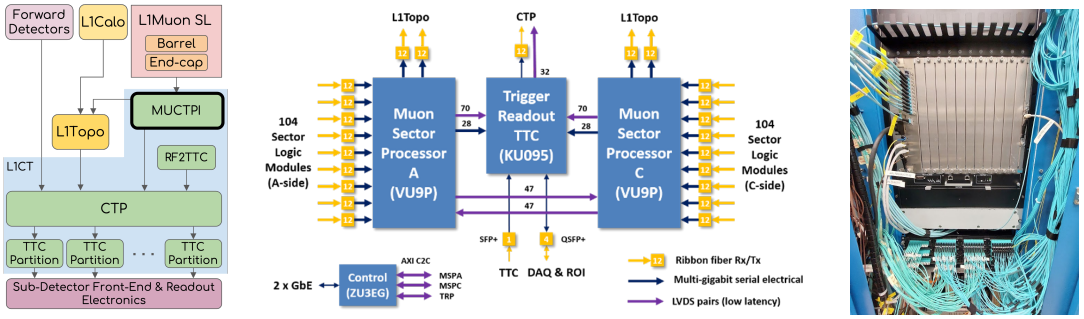
The L1 trigger system of the ATLAS experiment [1] uses information from the forward detectors, the calorimeters and the muon detectors, where the latter is handled at a first stage by the MUCTPI. A schematic description of the ATLAS L1 trigger system is found in Fig. 1(a). The MUCTPI receives muon candidate information from the 208 muon sector logic (SL) boards and handles the overlap removal in order to suppress double counting of single muons, which can occur due to geometrical overlap of muon chambers and the muon trajectory in the magnetic field. It then sends trigger object information to the L1Topo which combines it with trigger objects from the calorimeters. It also calculates the muon multiplicities and sends them to the CTP which combines all information to form the L1 acceptance decision.

The MUCTPI has been updated as a brand new system for Run-3 of the LHC [2]. There are two main motivations for the upgrade [3]: provide full-granularity muon information to L1Topo, and be compatible with the new SL modules, deployed in parallel to the New Small Wheel upgrade [4].

2. The new MUCTPI

The new MUCTPI is implemented within a single AdvancedTCA board [5]. A schematic description of the new MUCTPI is found in Fig. 1(b). The logic is implemented on three FPGAs: two Muon Sector Processors (MSPs), one for each side of the ATLAS detector, and one Trigger and Readout Processor (TRP). The MSPs receive trigger information from the 208 muon SL boards, which are Resistive Plate Chambers in the barrel, and Thin-Gap Chambers, small-strip Thin-Gap Chambers and MicroMegas in the endcaps. Next, the MSPs conduct overlap handling to remove duplicate muon candidates, calculate the transverse momentum (p_{T}) threshold multiplicities, and send trigger objects to L1Topo. The TRP combines the trigger information, and sends trigger multiplicities to the CTP and trigger data to the Data Acquisition (DAQ) system. A System-on-Chip (SoC) is used for control, configuration, and monitoring of the hardware and the operation of the MUCTPI. Run-control applications are operated directly on the SoC.

The new MUCTPI has many features that can be used for testing, diagnostics, integration, and online monitoring: counter arrays at the input, output and intermediate stages of the trigger processing; snapshot and playback memory functions, useful for interface testing; and event monitoring, which makes the MUCTPI event data available for a fraction of the L1-accepted events.



(a) (b) (c)

Figure 1: (a) Schema of the ATLAS L1 trigger. (b) Architecture of the MUCTPI board. (c) The new MUCTPI installed in the ATLAS service cavern. All of the input fibers from the muon SL boards (L1Muon SL) and the output fibers to L1Topo, CTP and the DAQ system were installed and are shown in the picture. The MUCTPI board is found on the left side.

3. Integration and Commissioning

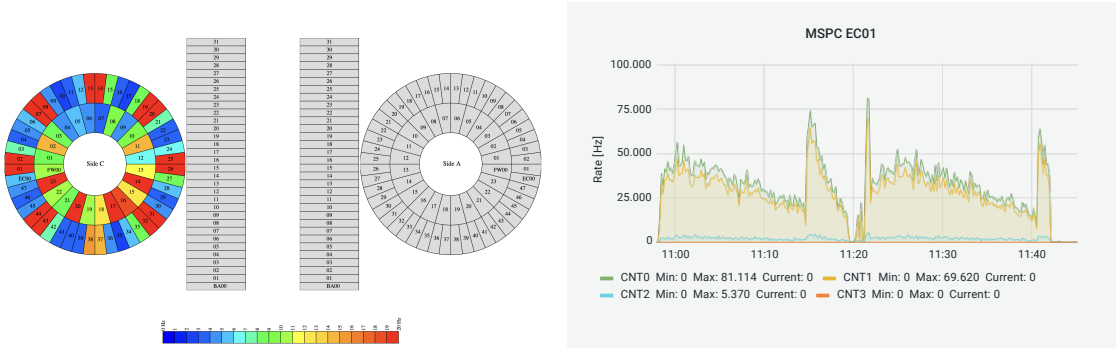
The new MUCTPI was installed in the ATLAS service cavern [6], as shown in Fig. 1(c). Connections to the interfacing systems were completed: input fibers from the muon SL boards and output fibers to L1Topo, CTP and the DAQ system. Tests were conducted together with the interfacing systems to validate communication and data flow. The new MUCTPI is fully working and included in the ATLAS trigger and data taking since the start of Run-3 of the LHC.

4. Online Monitoring

A few applications are used in order to monitor the operation of the MUCTPI:

- Hardware monitoring - presents numerous voltages, temperatures, power supply currents, optical receiver powers, and other hardware values.
- Rate monitoring - follows SL input and output multiplicity rates.
- Per-bunch monitoring - shows SL input and output multiplicity rates per-bunch.
- Event monitoring - samples events for online data validation.
- Busy monitoring - shows the busy fraction of different sources.

The DAQ software is cross-compiled in order to run all applications directly on the SoC. Examples for rate monitoring display are shown in Figs. 2(a)-2(b).



(a) (b)

Figure 2: Figures from the online monitoring: (a) SL rates during a special setup of the LHC: the collimators on one side of ATLAS are slightly closed, which translates to hits of horizontal muons on the other side. Only forward and end-cap muon sectors were operated. (b) Input rates monitored from one of the end-cap Thin-Gap Chamber sectors during the same run.

5. Conclusion

As part of the upgrade of the ATLAS experiment for Run-3, a new MUCTPI has been integrated. Since it provides the muon trigger information from the muon detectors, it plays a key role in the ATLAS L1 system. The new MUCTPI was installed in the experiment and has been commissioned to be ready for Run-3 of the LHC. Various applications have been developed and are used in order to monitor the MUCTPI operation, as part of the ATLAS operation of Run-3. With Run-3 of the LHC having already started, the new MUCTPI is already part of the DAQ system in ATLAS.

References

[1] G. Aad et al. The ATLAS Experiment at the CERN Large Hadron Collider. *JINST*, 3:S08003, 2008.

[2] A. Armbruster et al. The ATLAS Muon to Central Trigger Processor Interface Upgrade for the Run 3 of the LHC. In *2017 IEEE Nuclear Science Symposium and Medical Imaging Conference*, pages 1–5, 2017.

[3] G. Aad et al. Technical Design Report for the Phase-I Upgrade of the ATLAS TDAQ System. 9 2013.

[4] T. Kawamoto et al. New Small Wheel Technical Design Report. 6 2013.

[5] G. Anders et al. Hardware and firmware developments for the upgrade of the ATLAS Level-1 Central Trigger Processor. *JINST*, 9:C01035, 2014.

[6] S. Perrella et al. Integration and commissioning of the ATLAS Muon-to-Central-Trigger-Processor Interface for Run-3. *JINST*, 17(04):C04006, 2022.