

# THE NEW MUON-TO-CENTRAL-TRIGGER-PROCESSOR INTERFACE AT ATLAS



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## OVERVIEW

The ATLAS trigger system includes a Level-1 (L1) trigger based on custom electronics and firmware, and a high-level trigger based on off-the-shelf hardware and processing software. The L1 trigger system uses information from the calorimeters and the muon trigger detectors, consisting 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 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.

## ATLAS LEVEL-1 TRIGGER

- Based on custom electronics and firmware.
- Information from calorimeters and muon detectors is used.
- The **MUCTPI** receives muon candidate information from all muon sectors and calculates multiplicities.
- Muon trigger object information is sent to the **L1Topo**, which combines it with trigger objects from the calorimeters.
- Multiplicities are sent to the **CTP**, which combines all information and issues the L1 acceptance decision.

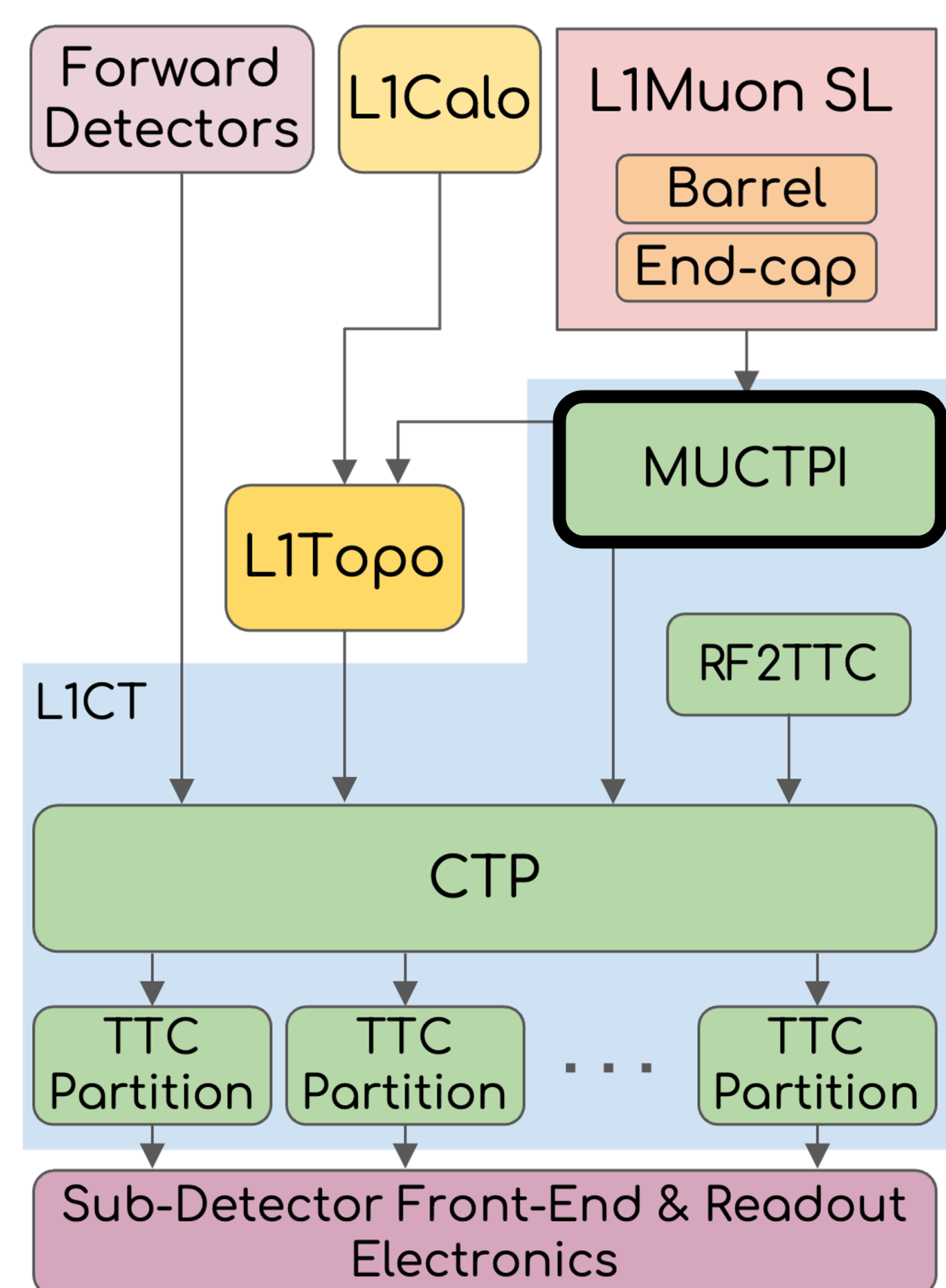


Figure 1: Schema of the ATLAS L1 trigger.

## THE NEW MUCTPI

- A brand new system for Run-3.
- Implemented as a single AdvancedTCA board.
- Main motivation for the upgrade:
  - Provide full-granularity muon region-of-interest information to L1Topo.
  - Be compatible with the new sector logic modules, deployed as part of the New Small Wheel upgrade.
- Logic implemented on three **FPGAs**: two Muon Sector Processors (**MSPs**) and one Trigger and Readout Processor (**TRP**).
- The **MSPs**:
  - Receive trigger information from the 208 muon trigger sectors.
  - Conduct overlap handling to remove duplicate muon candidates.
  - Calculate the transverse momentum ( $p_T$ ) threshold multiplicities.
  - Send trigger objects to L1Topo.
- The **TRP**:
  - Combines the trigger information.
  - 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.

- Many features that can be used for testing diagnostics, integration, and online monitoring:

- Counter arrays at the input, outputs and intermediate stages of trigger processing.
- Snapshot and playback memory functions, useful for interface testing.
- Event monitoring, making the information of a fraction of events available.

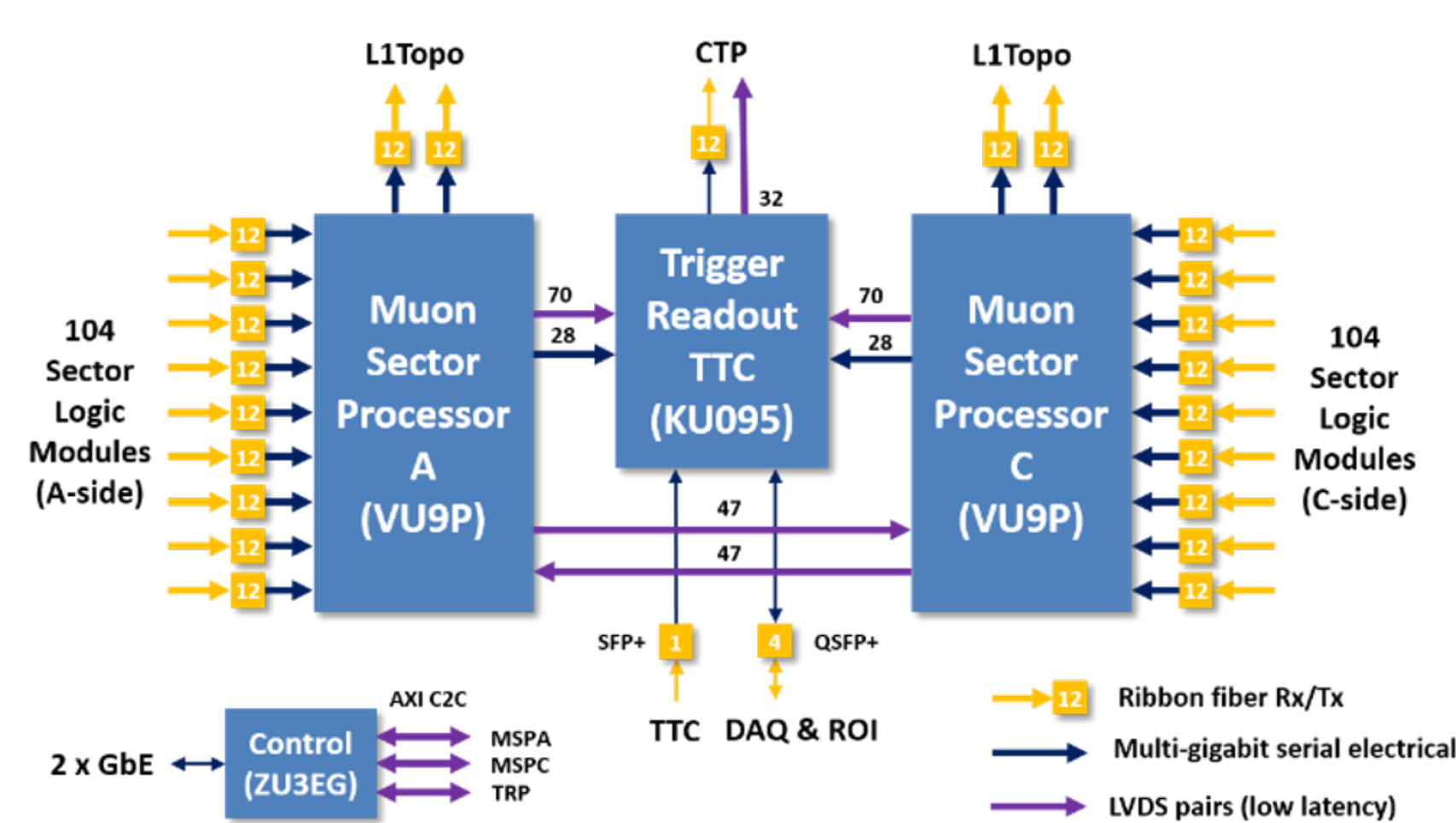


Figure 2: Schema of the MUCTPI board.

## SOFTWARE

- Low-level hardware access software is generated off a higher-level description of the firmware.
- Run-Control applications run directly on the SoC.

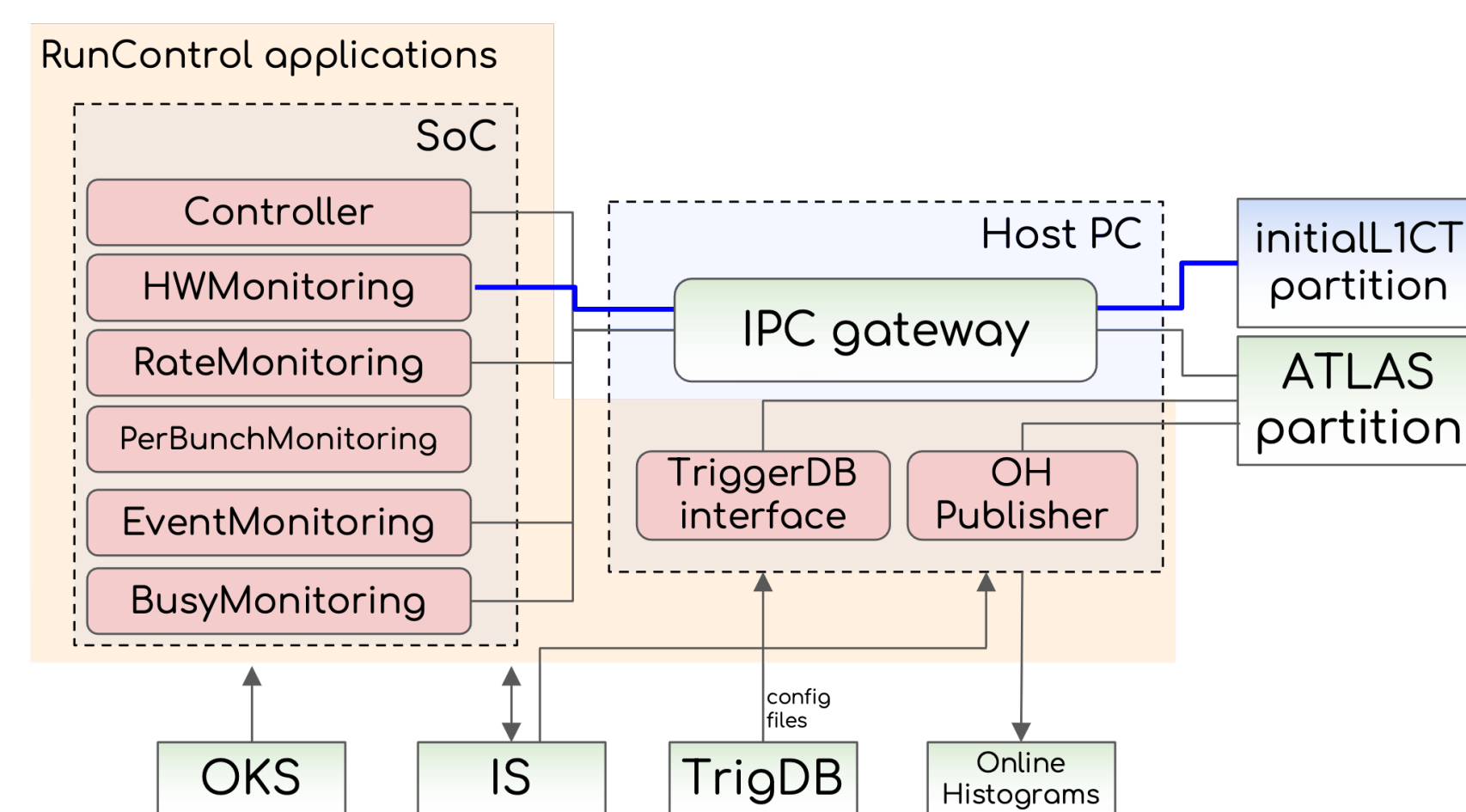


Figure 3: Schema of the MUCTPI software.

## INTEGRATION AND COMMISSIONING

- The new MUCTPI was installed in the ATLAS service cavern (USA15).
- Connections to the interfacing systems were completed:
  - Input fibers from the muon sector logic boards.
  - 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 trigger and data taking.

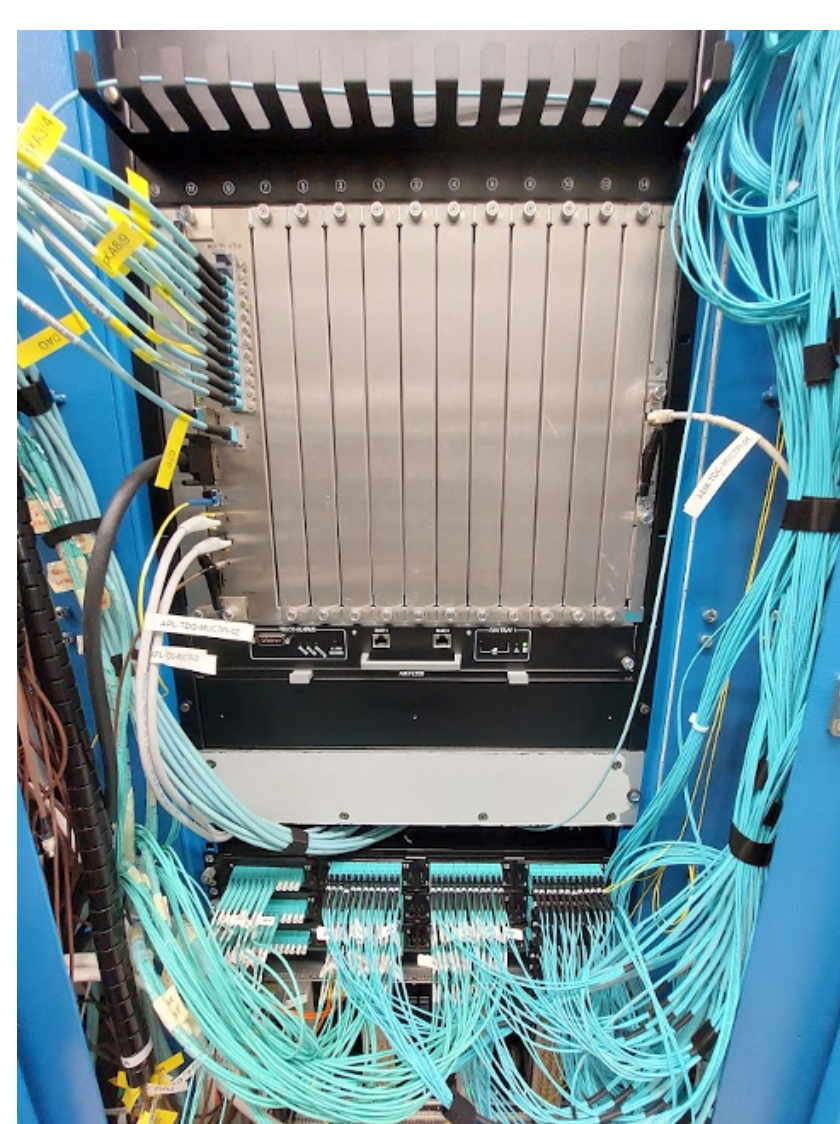


Figure 4: The new MUCTPI installed in the ATLAS service cavern. All of the input fibers from the muon sector logic boards (L1Muon SL) and the output fibers to L1Topo, CTP and the DAQ system are installed and shown in the picture. The MUCTPI board is found on the left side.

## ONLINE MONITORING

- **HW Monitoring**: numerous voltages, temperatures, power supply currents, optical receive powers, and other hardware values.
- **Rate Monitoring**: sector logic inputs and output multiplicities rate.
- **Per Bunch Monitoring**: sector logic inputs and output multiplicities rate per-bunch.
- **Event Monitoring**: sampling events from data for validation of event recording.
- **Busy Monitoring**: busy fraction of different sources.

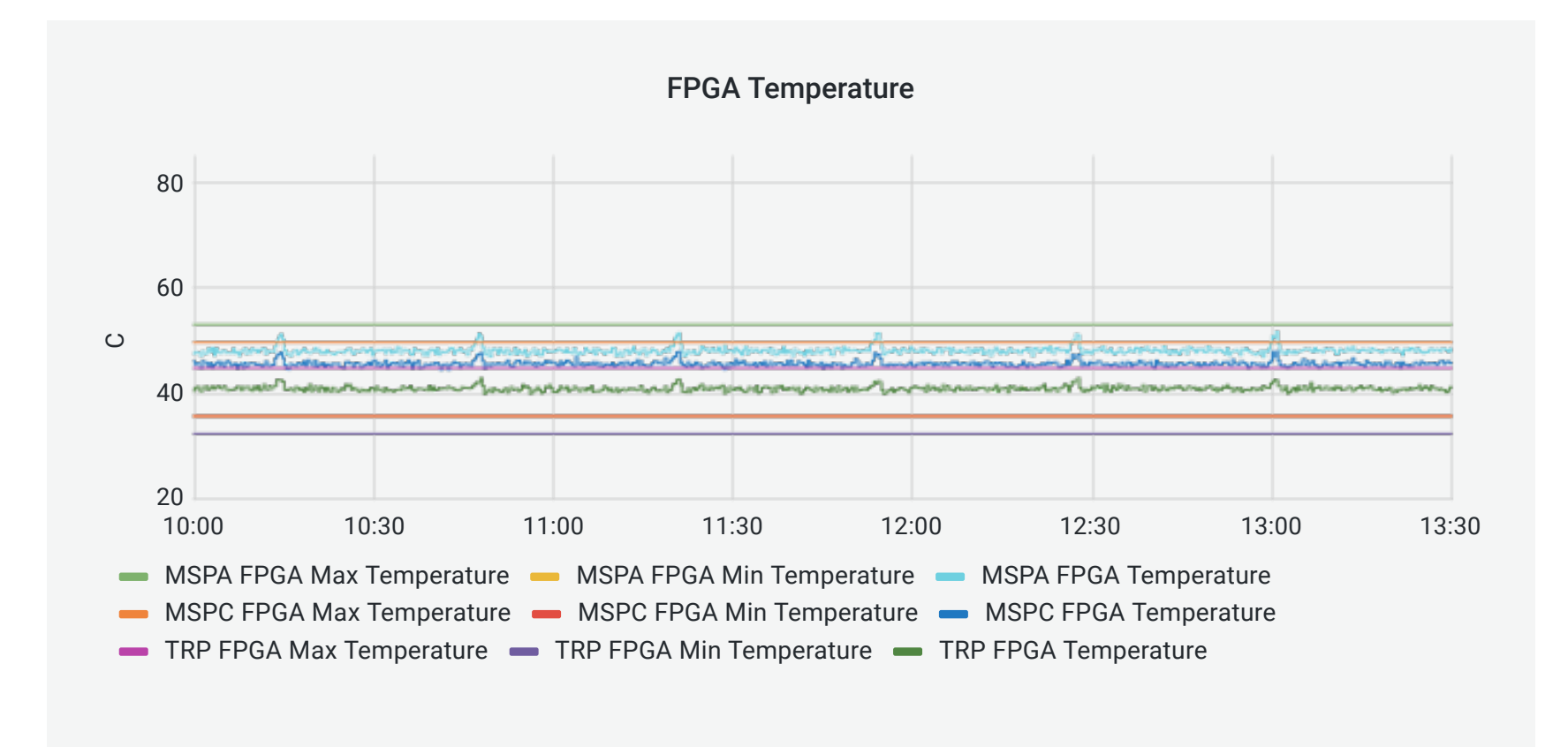


Figure 5: Temperature of the FPGAs in the MUCTPI: both of the MSPs and the TRP.

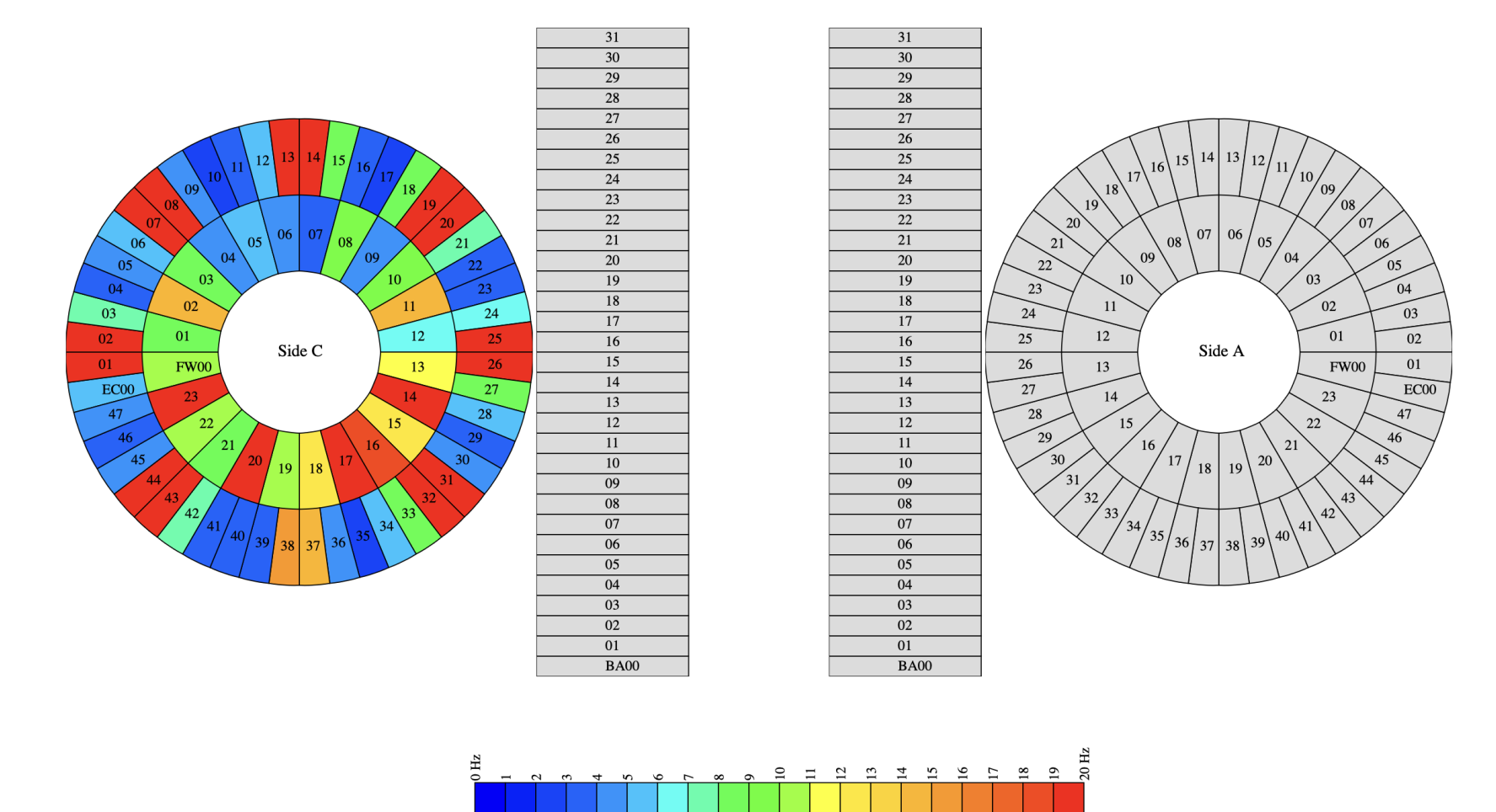


Figure 6: Sector logic rates during a special setup of the LHC: the collimators on one side of ATLAS are slightly closed, which translates to hits of horizontal muons on the other side. Only forward and end-cap muon sectors are operated.

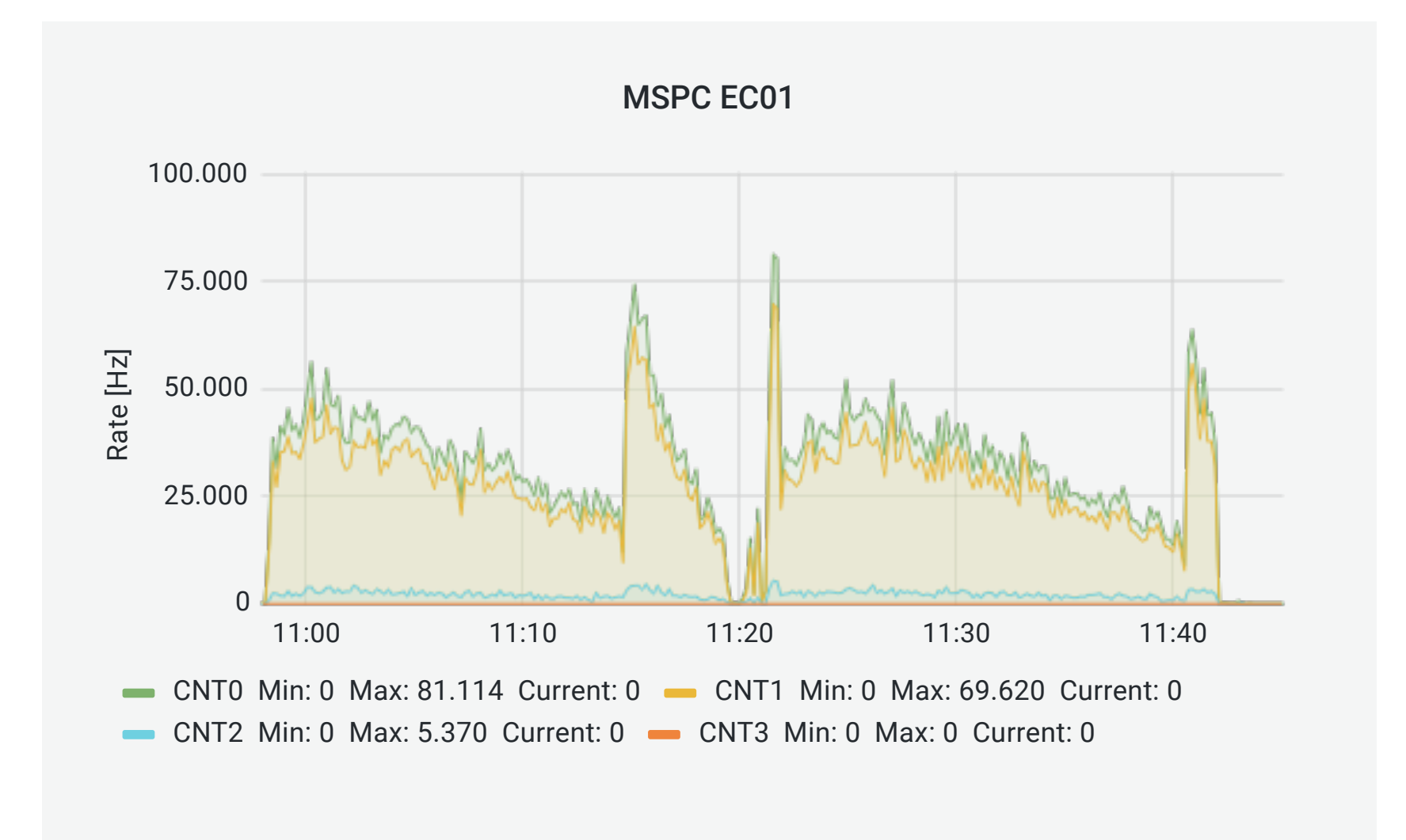


Figure 7: Input rates monitored from one of the end-cap Thin-Gap Chamber sectors during the same run described in the caption of Figure 6.

## CONCLUSION

As part of the upgrades of the ATLAS experiment for Run-3, a new MUCTPI has been integrated. As 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.