Commissioning the new Muon-to-Central-Trigger-Processor Interface at ATLAS

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ATLAS EXPERIMENT

OVERVIEW

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 calorimeters, the forward detectors 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. The Muon-to-Central-Trigger-Processor Interface (MUCTPI) processes the muon candidate information which is passed on. The Central-Trigger-Processor (CTP) combines the information received from the MUCTPI with the trigger information from the calorimeters, L1 Topological Trigger Processor (L1Topo) and forward detectors, and takes the L1 trigger decision, which is transmitted via the Timing Trigger and Control (TTC) system. 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.

ATLAS LEVEL-1 TRIGGER

- Based on custom electronics and firmware.
- Input from calorimeters, forward and muon detectors.
- 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.
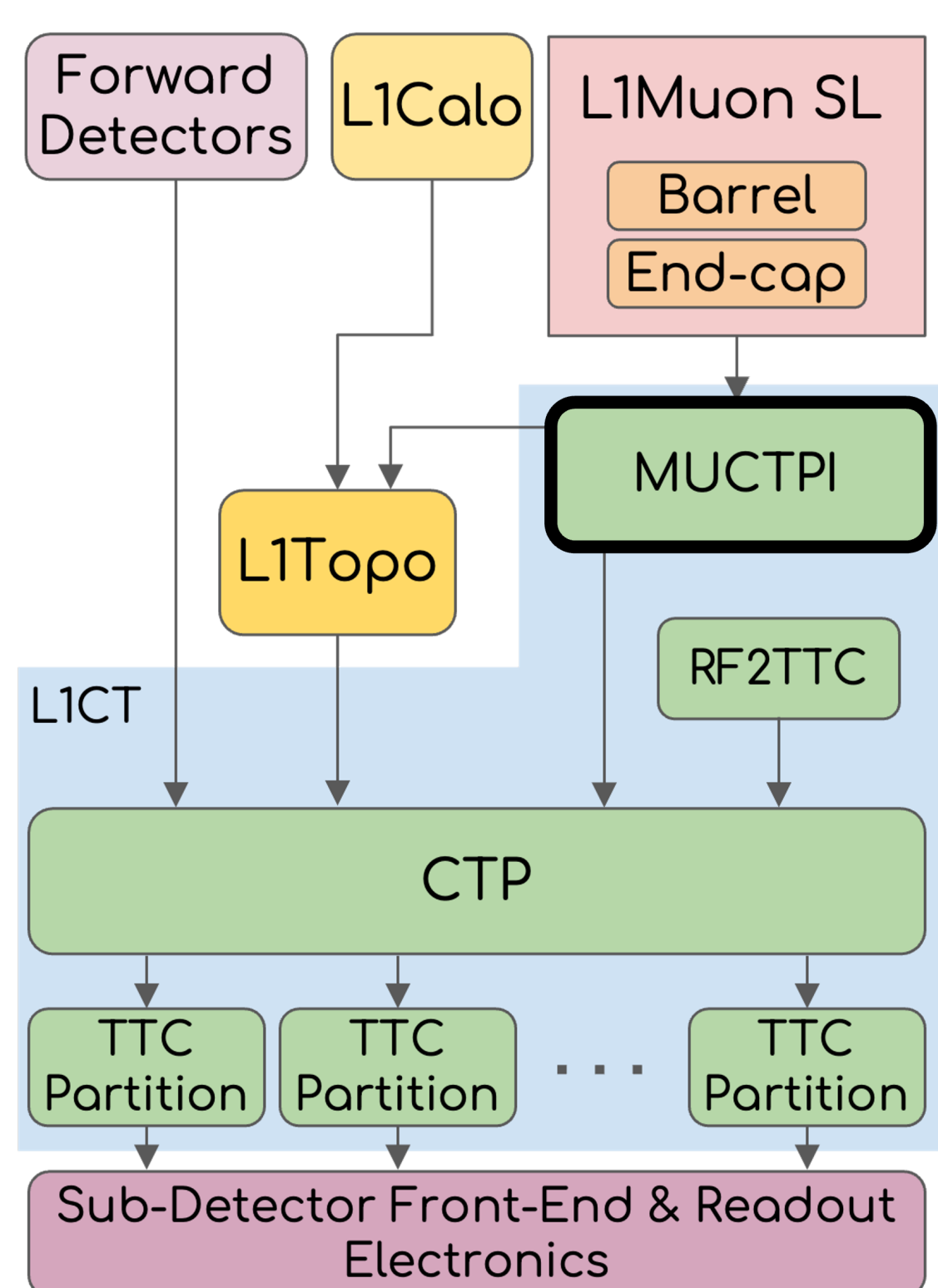

Figure 1: Schema of the ATLAS L1 trigger.

THE NEW MUCTPI

- 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 (SL) 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. Each MSP handles one hemisphere.
  - Conduct overlap handling to remove duplicate muon candidates, which come as a result of detector geometry and magnetic field.
  - Calculate the transverse momentum (p_T) threshold multiplicities.
  - Send trigger objects to L1Topo.
- The **TRP**:
  - Combines the trigger information from the MSPs.
  - Sends trigger multiplicities to the CTP and trigger data to the Data Acquisition (DAQ) system.
- A Zynq-7000 System-on-Chip (**SoC**) is used for control, configuration, and monitoring of the hardware and the operation of the MUCTPI. Newer versions employ a Zynq Ultrascale+ SoC.

- 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; makes the full MUCTPI event data available for a fraction of the L1-accepted events.
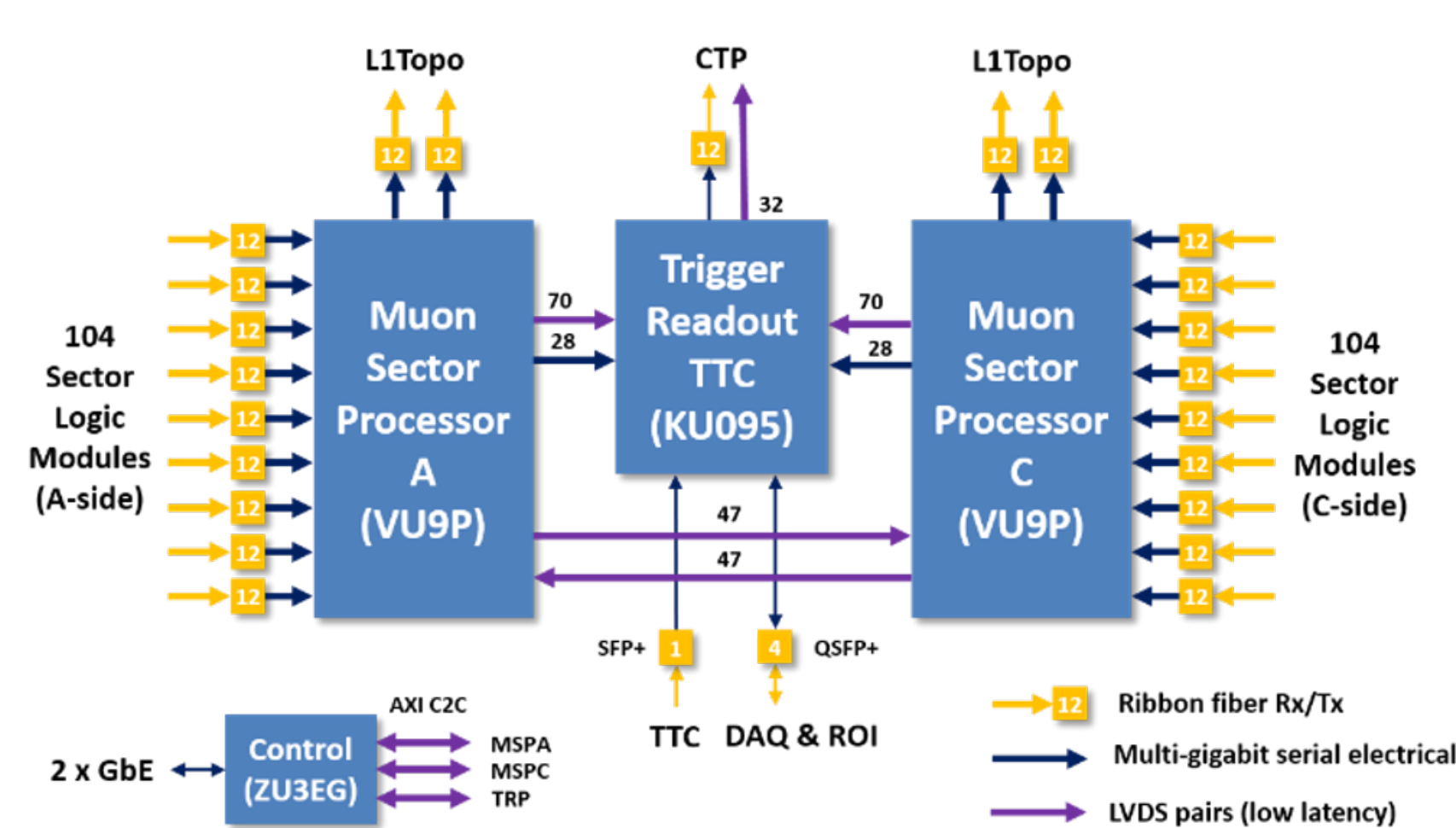

Figure 2: Architecture of the MUCTPI board.

SOFTWARE

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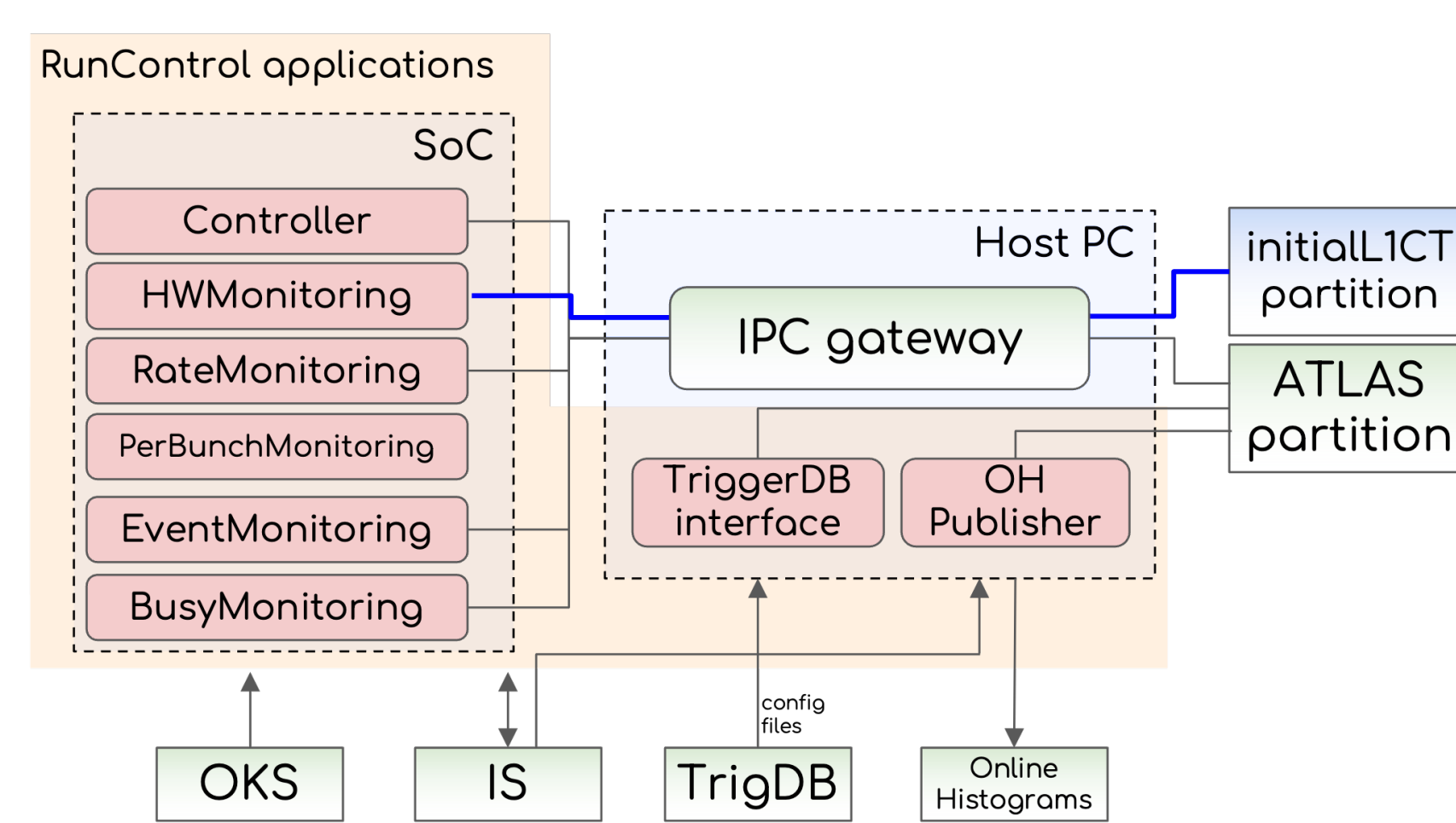- Run-Control applications run directly on the network-isolated SoC.

Figure 3: Schema of the MUCTPI software.

INTEGRATION AND COMMISSIONING

- The new MUCTPI was installed in the ATLAS service cavern.
- Connections to the interfacing systems done:
  - Input fibers from the muon sector logic boards.
  - Output fibers to L1Topo, CTP and 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 shown.

ONLINE MONITORING

- **HW Monitoring**: voltages, temperatures, power supply currents, optical receiver power.
- **Rate Monitoring**: sector logic inputs and output multiplicities rate.
- **Per Bunch Monitoring**: sector logic inputs and output multiplicities rate per-bunch.
- **Busy Monitoring**: busy fraction of different sources.
- **Event Monitoring**: samples events for online data validation.
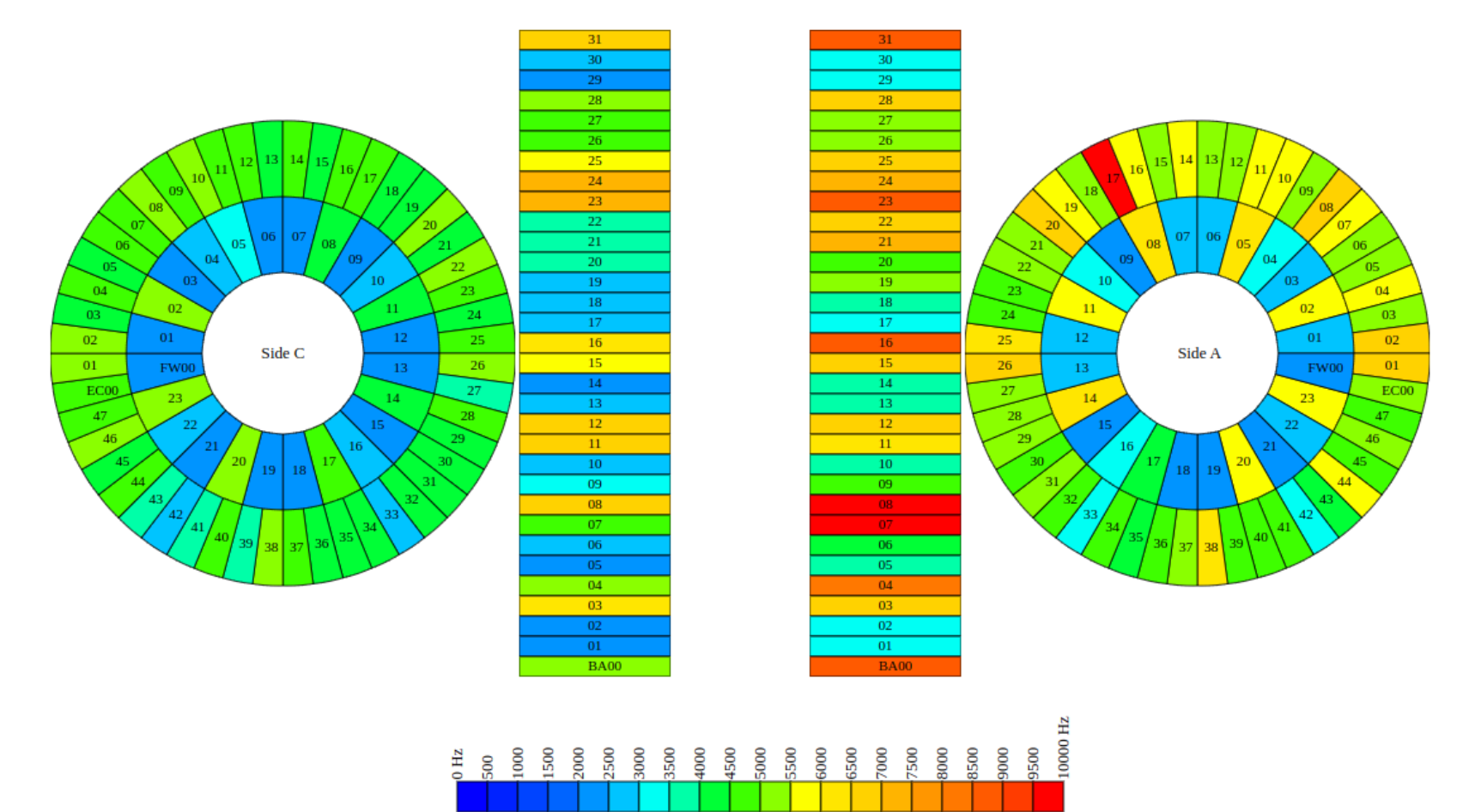

Figure 5: Sector logic rates during a 13.6 TeV physics run of the LHC. Endcap SL shown as wheels; Barrel SL shown as columns.
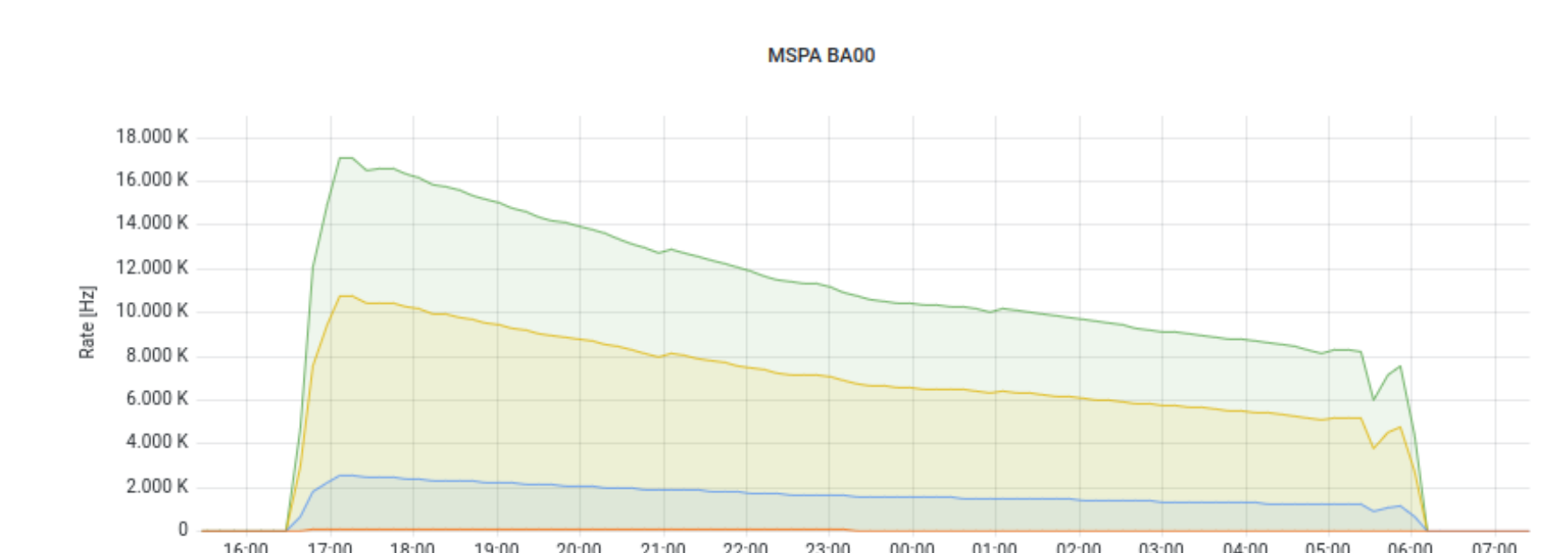

Figure 6: Input rate monitoring from a Barrel SL during a 13.6 TeV physics run. The drop in rate follows the provided luminosity from the LHC.

TIMING

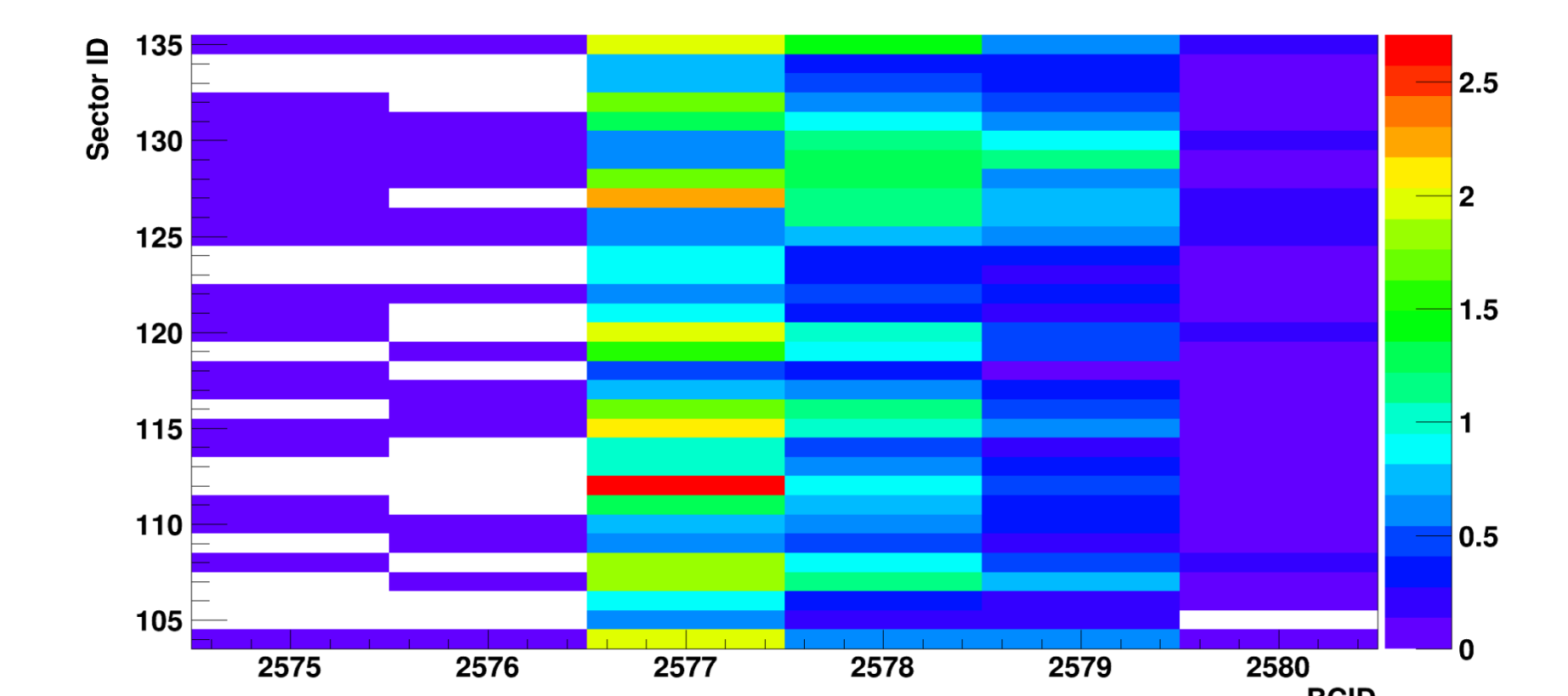Input timing is checked per bunch crossing and must follow the bunch group pattern of LHC.

Figure 7: SL timing plot, zoomed for one side of Barrel SL (y-axis) on isolated colliding BCID 2577 (x-axis).

CONCLUSION

As part of the upgrades of the ATLAS experiment for Run-3, a new MUCTPI has been integrated. It plays a key role in the ATLAS L1 system in that it provides the muon trigger information from the muon detectors. The new MUCTPI was installed in the experiment. It has been commissioned and is operational since the beginning of Run-3 of the LHC.