# ATLAS TDAQ Integration and Commissioning

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#### Abstract

The ATLAS detector will be exposed to proton proton collision at the center of mass energy of 14 TeV with the bunch crossing rate of 40 MHz. In order to reduce this rate down to the level at which only interesting events will be fully reconstructed, a three-level trigger system has been designed. The level 1 trigger reduces the rate down to 75 kHz via the custom-built electronics. The Region of Interest Builder delivers the Region of Interest records to the level 2 trigger which runs the selection algorithms with the commodity processors and brings the rate further down to  $\sim$ 3 KHz. Finally the Event Filter reduces the rate down to  $\sim 200$  Hz for permanent storage. The subsystems will be reviewed. The commissioning in situ using detectors, the full trigger system and the DAQ system will be discussed. Results on system functionality and performance based on the cosmic data will be presented. Some studies on system scalability and reliability will be shown with preselected simulated events running through the trigger and dataflow system.

# I. ATLAS TDAQ SYSTEM

The ATLAS detector [1] is designed to study the proton proton collision at the Large Hadron Collider (LHC), at the center of mass energy of 14 TeV with the bunch crossing rate of 40 MHz. In order to fulfill the physics goals, the ATLAS detector is instrumented with the magnet system, the inner detector system, the calorimetry system, the muon system and several forward detectors. The magnet configuration consists a superconducting solenoid and three large superconducting toroids. The inner detector system combines the high resolution semiconductor pixel detector, strip detector and the straw tube tracking detector. The calorimetry system has the high granularity liquid argon electromagnetic sampling calorimeter and the scintillator tile hadronic calorimeter. The muon spectrometer includes high precision tracking chambers and trigger chambers. Forward detectors are mainly used to determine the luminosity.

The trigger/data acquisition (TDAQ) system will have to handle the extremely high data rates (Figure 1). The level 1 (LVL1) trigger reduces the rate down to 75 kHz via the custombuilt electronics. The Region of Interest Builder (RoIB) delivers the Region of Interest (RoI) records to the level 2 (LVL2) trigger which brings the rate further down to  $\sim$ 3 KHz, at which events will be fully built. Finally the Event Filter (EF) reduces the rate down to 200 Hz for permanent storage. Both LVL2 and EF, together High Level Trigger (HLT), run selection algorithms with the commodity processors.



Figure 1: Schematic diagram of the TDAQ system.

#### II. LVL1

The ATLAS LVL1 system [2] consists of three components, the Calorimeter Trigger (L1Calo), the Muon Trigger (L1Mu) and the Central Trigger (Figure 2). The Central Trigger includes the Central Trigger Processor (CTP) and the Muonto-CTP-Interface (MUCTPI). The L1Calo system forms electron/photon, tau/hadron, and jet multiplicities as well as global event energy information. The MUCTPI obtains muon candidate information from the L1Mu system which includes the barrel (RPC) and endcap (TGC) muon trigger chambers, then produces muon multiplicities for six configurable transverse momentum thresholds. Based on these local trigger objects the CTP makes the trigger decision with a configurable trigger menu. The trigger decision, together with the clock and other signals, is distributed to the detector front end and readout systems via the Timing, Trigger and Control (TTC) system. Some LVL1 components are shown in Figure 3.



Figure 2: Schematic diagram of the LVL1 system.



Figure 4: Some results from combined runs.

# III. HLT

HLT algorithms are executed based on trigger chains and chains are activated based on result of previous level. Each chain is divided in steps and each step executes an algorithm sequence (one or more algorithms). A step failed to produce an expected result ends the chain and any chain can pass the event. The LVL2 algorithms are seeded by the RoI information identified at LVL1 while the EF ones access the full event [3].

The LHC startup luminosity is expected to be  $\sim 10^{31} cm^{-2} s^{-1}$  with less bunches. The initial ATLAS data taking under this condition will focus on commissioning the trigger and detector systems, and studying the basic Standard Model physics signatures. A trigger menu ( $10^{31}$  menu) is being deployed for this running phase, by applying low thresholds, loose selections and pass-through mode wherever possible. The  $10^{31}$  menu has been continuously exercised in the final TDAQ infrastructure with the simulated data. Figure 5 shows the LVL2 processing time and EF processing time for accepted events.



Figure 5: HLT performance for  $10^{31}$  menu.



Figure 3: LVL1 Hardware.

While deploying functionalities and improving performance with standalone tests, the LVL1 system joins combined runs with detectors for integration and cosmic data taking, more frequently L1Mu with RPC, TGC and monitored drift tube (MDT) chambers, L1Calo with the liquid argon calorimeter (LAr) and the tile calorimeter (TIL), sometimes all possible systems together. The focus of the combined runs has been turning from problem finding to combined studies. Figure 4 shows some results from the combined runs.

### **IV. DATAFLOW SYSTEM**

Figure 6 illustrates the baseline of the dataflow architecture [3]. Data fragments of LVL1 accepted events from the detector front readout are transfered to the Read Out Systems (ROSes), each contains several Read Out Buffers (ROBs). Based on RoI records assembled by LVL2 supervisors (L2SVs) from RoIB, L2PU request data fragments from selected ROBs and send output to the LVL2 result handler (pROS). Data fragments for LVL2 accepted events are then built, on the initiation of the Data Flow Manager (DFM), from the ROSes, across a switched Ethernet network, into a complete event by one of the event building nodes (SFIs). The SFIs then send the complete events to the Event Filter nodes (EFD/PT). Events passed the EF are sent to the local data storage (SFO) before transfered to permanent storage for offline reconstruction. Most of the element interconnection in the Dataflow system is performed with the standard Gigabit Ethernet network and switching technology.



Figure 7: Dataflow system hardware.



Figure 6: Principal components of the dataflow system.



Figure 8: Dataflow subsystem performance for the  $10^{31}$  menu.

A large fraction of the dataflow system has been installed and commissioned. Some components are shown in Figure 7. The system is kept operational 24/7 for performance study and detector commissioning. Stability and scalability have been improved significantly. A typical test of  $10^{31}$  menu with the simulated data in a system including 136 ROSes, 4 L2SVs, 94 SFIs and 600 HLT nodes shows that the installed system is adequate for data taking in the early phase (Figure 8).

#### V. COSMIC RUN

The full trigger chain, including MUCTPI, CTP, RoIB and LVL2, was tested at the first time in Feb 2007. A trigger rate of 30 Hz at LVL1 for cosmic rays was achieved with partial RPC detector. Downward muons were selected with LVL2 algorithms and accepted events were built then stored with a Small event building system. Figure 9 shows the  $\eta$  and  $\phi$  distribution of the cosmic tracks.



Figure 9:  $\eta$  and  $\phi$  distribution of the cosmic tracks.

Since then the TDAQ system has been continuously running to take cosmic data, with the detector coverage gradually increasing (Figure 10).



Figure 10: Event display of cosmic run.

# VI. TRIGGER STRATEGY FOR STARTUP

The TDAQ system, together with almost full detector, is ready for the LHC beam. With the beam condition changing from cosmic, to single beam, to proton proton collision, different date samples will be used for LVL1 to perform timing calibration, energy calibration, logic verification and efficiency study. A few iterations will be needed before the stable triggering can be achieved. HLT will be studied under condition with colliding beams and stable detector operating.

Beam pickups (BPTX) are installed on both sides of ATLAS. Minimum bias trigger scintillators (MBTS) are installed on the LAr cryostat, with 16 modules each side. Loose coincidence logic with BPTX, MBTS (and beam position monitor) will be used for early data taking to trigger any activity in the detector. MBTS provide the triggers while BPTX sets the precise timing. HLT will run in pass-through mode as much as possible. On September 10, 2008, the first beam was seen by the ATLAS detector (Figure 11).



Figure 11: Beam 1 seen by ATLAS.

#### REFERENCES

- [1] ATLAS Collaboration, The ATLAS Experiment at the CERN Large Hadron Collider, JINST 3 (2008) S08003.
- [2] ATLAS Collaboration, ATLAS Level-1 Trigger Technical Design Report, CERN/LHCC/98-014 (1998).
- [3] ATLAS Collaboration, ATLAS High-Level Trigger Data Acquisition and Controls Technical Design Report, CERN/LHCC/2003-022 (2003).