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# The readiness of the ATLAS Trigger-DAQ system for the second LHC run

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**Abstract**

After its first shutdown, the Large Hadron Collider (LHC) will provide proton-proton collisions with increased luminosity and energy. In the ATLAS experiment, the Trigger and Data Acquisition (Trigger-DAQ) system has been upgraded to deal with the increased event rates. The updated system is radically different from the previous implementation, both in terms of architecture and expected performance. The main architecture has been reshaped in order to profit from technological progress and to maximize the capacity and efficiency of the data selection process. Design choices and the strategies employed to minimize the data-collection and the selection latency will be discussed. First results of tests done using beam splashes in the commissioning phase will be presented.

*Keywords:* LHC, ATLAS, Trigger, DAQ

## 1. Introduction

ATLAS [1] data taking was very successful with very high efficiency in Run-1 of the LHC program. In Run-2 the requirements to the ATLAS Trigger-DAQ system are to reduce the rate by rejecting non-interesting collision events while keeping high efficiency for events of physics interest, however with changed conditions [3]. The center of mass energy of proton-proton collisions will increase from 8 to 13 TeV, the bunch spacing of subsequent colliding bunches will shrink from 50 to 25 ns, the instantaneous luminosity will increase from $8 \times 10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ to $\sim [1-2] \times 10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ and the average interactions per bunch crossing from 40 up to 50.

## 2. Upgrades to the Trigger-DAQ system for Run-2

An overview of the ATLAS Trigger-DAQ system for Run-2 is shown in Fig. 1. The trigger system in ATLAS consists of a hardware Level-1 (L1) and a software based high-level trigger (HLT) that reduces the event rate from the design bunch-crossing rate of 40 MHz to an average recording rate of a few hundred Hz. Many upgrades have been implemented in the trigger components during the two-year shutdown in order to cope with the increased trigger rates while maintaining or even improving the selection efficiency on relevant physics processes. A huge number of separate trigger selections was defined, i.e. $\sim 500$ at L1 and $\sim 1000$ at HLT in preparation of Run-2. The components of the L1 trigger are depicted in Fig.2. It consists of custom hardware with latency of less than 2.5 $\mu s$ and reduces the rate of 40 MHz to 100 kHz. The maximal output rate increased from 70 kHz to 100 kHz from Run-1 to Run-2. Furthermore Region of Interests (RoIs) from calorimeter- and

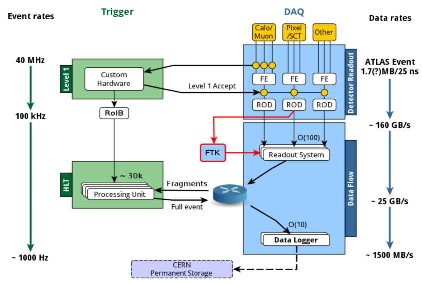


Figure 1: Scheme of the upgraded ATLAS Trigger-DAQ system for Run-2 of the LHC [2].

muon detector information is defined and provided to the HLT. The L1 system in Run-2 consists of the L1 calorimeter trigger system (L1Calo), the L1 muon trigger system (L1Muon), new L1 topological trigger modules (L1Topo) and the Central Trigger Processors (CTP).
The L1Calo system processes signals from the electromagnetic and hadronic calorimeters and provides trigger signals to the CTP. During Run-1 missing compensation of the pile-up in the first bunch crossings in the bunch trains in the L1Calo electronics resulted in unmanageable rates of triggers involving global signatures like missing transverse momentum ($E_{\mathrm{T}}^{\mathrm{miss}}$). New Multi-Chip Modules (nMCM) have been installed for the use of auto-correlation filters to improve the energy resolution and dynamical pedestal subtraction to reduce the pile-up dependency. The improved handling of pile-up will lead to a significant reduction of the $E_{\mathrm{T}}^{\mathrm{miss}}$ trigger rates.
New coincidences have been put in place in the L1Muon trigger. At pseudorapidity $1.3 < |\eta| < 1.9$ additional hits are required with the inner muon chambers placed just before the end cap toroid and at $1.0 < |\eta| < 1.3$ with the extended barrel region of the tile calorimeter. At 25 ns bunch spacing and with these new coincidence requirements, roughly 50 % rate

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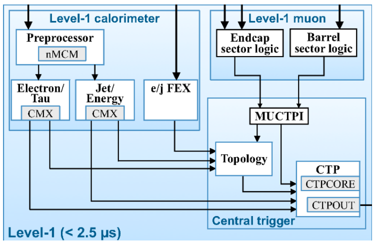


Figure 2: Scheme of the components of the ATLAS L1 trigger for Run-2 of the LHC [3].

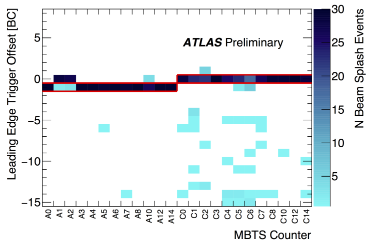


Figure 3: Relative timing of the trigger signal from Minimum Bias Trigger Scintillator (MBTS) counters in beam splash events [4].

reduction is expected for background from low-$p_{\mathrm{T}}$ charged particles (i.e. protons) for muon trigger selections with $p_{\mathrm{T}}$ above 20 GeV. Additional muon chambers have been installed in the feet of the barrel region, which will give 4 % larger acceptance for L1 muons for $|\eta| < 1.05$.

The conceptually new L1Topo trigger modules receive input trigger objects from L1Calo and L1Muon and are able to calculate derived quantities, which are used in the selection. These topological selections are used to deal with increased rates in final states with $E_{\mathrm{T}}^{\mathrm{miss}}$, b-jets, B-mesons and $\tau$ leptons.

The CTP was upgraded for Run-2 to increase flexibility. The number of L1 items increased from 256 in Run-1 to 512 in Run-2, and the input bits from 160 in Run-1 to 512 in Run-2. The software framework was redesigned and includes several improvements.

In Run-2, the Level-2, Event Builder and Event Filter farms have been merged into a unique HLT farm for simplification and dynamic resource sharing. The HLT software, re-adapted to a new architecture, allows the increase to 100 kHz throughput and provides higher rejection power (100 kHz $\rightarrow$ 1kHz) operating with an average processing time per event of 0.2 s. The maximum total output rate has been increased from 600 Hz to 1.5 kHz at peak luminosity. HLT algorithms have been redesigned to take full advantage of the new single HLT system. A major effort has been undertaken to bring the trigger performance closer to the offline reconstruction performance. In particular this includes improvements in data preparation, tracking and clustering algorithms, selection cuts, access to averaged pile-up information and the possibility to use full event scan algorithms in addition to those based on RoIs.

The adoption of more offline algorithms and the increase of trigger selections has led to higher operational memory demand by the HLT processes. Therefore the HLT infrastructure has been upgraded to a smart multiprocessing workflow. Only one HLT processing Unit (HLTPU) is started and configured per server. After processing of the first event(s) additional processes are cloned and take over the event processing requests. This approach allows most of the memory containing configuration data to be shared and memory consumption significantly reduced, when many processes are running per server node. The merged HLT system makes better use of the readout infrastructure by eliminating duplicate data requests as in Run-1 in high rate triggering and event building; however the overall data request rate is increased compared to Run-1. In Run-2 the events are built on HLT farm nodes.

The ROS (Read Out System) buffers front-end data from the detectors. New ROS hardware was installed in order to increase data bandwidth to the HLT. A complementary increase of the network bandwidth has been implemented. Improved load balancing and link redundancy backup solutions for all components have been put in place for Run-2. Finally the data logger, which saves the events for permanent storage, has been upgraded allowing for multiple storage front-ends and its fault tolerance was improved by implementation of redundant data paths.

## 3. Commissioning and first data taking

The upgraded TDAQ system was tested continuously with cosmic-ray data between Run-1 and Run-2. It was used to commission and allow initial timing of the sub-detectors. First beams and beam splashes in spring 2015 have been used to further commission the trigger signal paths. In beam splashes the detectors are illuminated from single beams impacting on upstream collimators. In Fig.3 an example of timing measurements in minimum bias trigger scintillators is shown. Ultimately the first collisions have been used for timing in the detectors and to start offline studies of detector performance as well as exercise the full chain of event readout and triggering.

## 4. Conclusion

The ATLAS Trigger-DAQ system has undergone a major upgrade between Run-1 and Run-2 to cope with new conditions at the LHC. It has been continuously tested during the long shutdown with calibration, cosmic-ray, first beams and first collisions runs. No bottleneck has been found and the ATLAS Trigger-DAQ system is ready to record collision data in Run-2 of the LHC program.

## References

[1] ATLAS Collaboration, The ATLAS Experiment at the CERN Large Hadron Collider, JINST 3, S08003 (2008) 1-437.

[2] R.Hauser for the ATLAS Collaboration, The ATLAS Data Flow system for the Second LHC Run, 21st Conference in High Energy and Nuclear Physics 2015, Okinawa, Japan

[3] ATLAS Collaboration, Technical Design Report for the Phase-I Upgrade of the ATLAS TDAQ System, CERN-LHCC-2013-018, ATLAS-TDR-023 (2013).

[4] https://twiki.cern.ch/twiki/bin/view/AtlasPublic/MinBiasTriggerPublicResults