Muon Trigger Menus for the ATLAS Experiment at LHC

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ATLAS (A Toroidal LHC ApparatuS) [2] is a general purpose experiment which will start to collect data at CERNs Large Hadron Collider (LHC) in fall 2009. It has been designed and built for new discoveries in High Energy Physics as well as for precision measurements of Standard Model parameters. The ATLAS trigger system requires high efficiency and selectivity in order to exploit the full physics potential of the experiment keeping a small rate of interesting events (∼200 Hz) among about ∼1 GHz of events, which is the event production rate at LHC at the project luminosity, and fitting the limits imposed by the data acquisition capability. These requests are accomplished with a trigger system composed of three sequential levels of increasing accuracy. In the case of events containing muons, the first hardware-based level (LVL1) starts from measurements of the Muon Spectrometer trigger chambers to select Regions of Interest (RoI) where muons produce significant activity. Such RoIs are used as seeds for the two subsequent trigger levels (LVL2 and Event Filter), software implemented in specialized algorithms (heavily using the offline reconstruction in case of Event Filter) and running on dedicated online farms, which constitute the High Level Trigger (HLT)[3]. This seeding strategy is crucial to drastically reduce the total processing time. For each trigger level, a given trigger object is classified accordingly to a set of specific signatures, thus allowing the event to be registered on the basis of them and finally recorded in data streams for physics analyses. Tables containing the lists of such signatures are referred to as Trigger menus. Trigger menus defines the physics content of the events finally retained by the experiment, given the above constraint of a final rate of ∼200 Hz to be acquired, in the different luminosity scenarios foreseen for LHC operations (starting from 10^{31}cm^{-2}s^{-1} up to 10^{34}cm^{-2}s^{-1}. Menu definition requires that each signature in the table is justified on the basis of physics or detector performance/calibration/commissioning requirements, keeping into account expected rates and efficiencies. A rank of priority between trigger signatures is established by setting prescale (PS) factors at each trigger level, i.e. reducing of suitable factors the rate to be retained for that level.

While, for example, in the low LHC luminosity operation regime low transverse momentum muon signatures as $mu6$ or $mu10$ (i.e. muon p_T $\geq$ 6 or 10 GeV) will be selected, only high p_T signatures like $mu20$ for single muons ($\geq$ 20 GeV) or, in case of exclusive signatures involving muon pairs, $2mu6$ or $2mu10$ will contribute to the final rate in the intermediate-high luminosity regime.

However, even before to foresee how to evolve menu definition with luminosity, it must be clearly stated in order to fit the different detector and trigger commissioning/debugging phases. At LHC startup HLT will work in unstable beam (0.9 TeV, 10 TeV, 14 TeV) and detector conditions, physics process rates will be poorly known and menus should change often in order to keep rates under control. As soon as beam and detector will be more stable and the initial debugging of HLT will have been performed, main purpose will become to maximize the trigger processing and recording of relevant signatures for physics and detector/HLT algorithm performance evaluation. At this stage menus will be more stable. When detector, LHC beams and HLT will be finally stable and understood, menus will be optimized to study relevant physics channels in the intermediate luminosity regime and the evolution to the project high luminosity.

Presently, in Atlas menus have been developed and operated for Monte Carlo simulation, for single beam and cosmic rays data, widely tested during the single beam LHC commissioning phase in september 2008 and the following cosmic run until the end of the year, and for different luminosities. However, the most studied menu, used as benchmark to optimize HLT algorithms and rate estimates is the 10^{31} physics menu [4]: the 10^{32} menu has been, for the moment, directly derived from it, just adjusting PS factors, but needs to be reviewed after the initial phase of low luminosity run. A reasonable 10^{33} menu has been not yet defined, while menus for early collision phase are under development.

A useful classification of trigger items in a menu can be introduced in order to justify and to prioritize them. A "primary trigger" is a trigger used to acquire the data sample for a physics or performance study as well for detector commissioning and it is "unprescaled", i.e. no PS factors are applied to it in the menu. A "supporting trigger" is a signature used to measure some property of a primary trigger, like efficiency, or to study specific algorithms or background. A "backup trigger" is a signature which may be used in case the rate of the primary trigger is higher or lower than expected, due, e.g., to detector malfunctioning or background and physics rates different from expectations. A "calibration trigger" is a signature which is used explicitly to collect data for detector calibrations.

The muon 10^{31} physics menu, to be used in initial physics run at 10 TeV, contains a reasonable number of simple muon signatures, backup items and HLT commissioning items, uses pass-through (PT factors), i.e. the possibility to retain a trigger item even if it didn't pass the trigger selection at a given level (L2 or EF), in order to collect unbiased events for HLT debugging and monitoring, it's fairly manageable in case of increasing/decreasing rates with respect to what expected. Primary muon signatures in this menu are: mu10 ($\sim$20 Hz expected for $10^{3}1$ running at 14 TeV of center of mass energy) for single muon trigger, mainly aimed to B physics and Drell-Yan processes and to W, Z and top production, and $2mu4$ ($\sim$7 Hz expected for 10^{31} running at 14 TeV of center of mass energy) for di-muon trigger, for B physics, Drell-Yan, J/Ψ, Y and Z production. Lower threshold signatures like $mu4$ and $mu6$, prescaled of relevant factors, are used as supporting triggers to measure efficiency. Other signatures are triggers supporting $mu10$ in order to study the performance of specific algorithms: e.g. $mu10i\_loose$, which requires an isolated muon and allows to monitor the isolation algorithm [5] and $mu10\_MG$, which applies at EF stage a muon tagging technique [6] starting from an Inner Detector track seed instead of the standard muon reconstruction and identification algorithm, performing the muon pattern recognition in the muon spectrometer [7]. Backup triggers to be used if the rates of the primary triggers will be found too high are $mu15$ ($\sim$7 Hz for 10^{31} running at 14 TeV of center of mass energy) and $2mu6$ ($\sim$3 Hz for 10^{31} running at 14 TeV of center of mass energy) while there are no signatures with lower thresholds allowed to run unprescaled if the rates will be found only a factor 2 or 3 lower than expected.

All rate estimates obtained at 14 TeV with the present definition of 10^{31} muon menu are quite reasonable [8] and a complete review of the requirements of the different analyses in all physics Atlas groups has shown that it basically satisfies the requests made for Standard Model, B, Top, Higgs, Susy and Exotics physics. Specialized triggers for initial detector commissioning are instead still under definition and will enter in a single beam/early collisions menu which will be deployed in may 2008.

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1. ATLAS Collaboration is made of about 2500 Physicists coming from 167 Institutions of the following countries: Argentina, Armenia, Australia, Austria, Azerbaijan, Belarus, Brazil, Canada, Chile, China, Colombia, Czech Republic, Denmark, France, Georgia, Germany, Greece, Israel, Italy, Japan, Morocco, Netherlands, Norway, Poland, Portugal, Romania, Russia, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Taiwan, Turkey, UK, USA, CERN, JINR.
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