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PERFORMANCE AND EVOLUTION OF THE ATLAS TAU TRIGGER DURING 2011 DATA TAKING PERIOD

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The use of the τ leptons in the Standard Model processes and in channels probing for Physics beyond the Standard Model is very important at the LHC. These processes include Higgs production, heavy mass resonances and decays of supersymmetric particles. In the selection of such rare events of interest, the hadronic τ trigger plays a fundamental role. It allows efficient collection of the desired signal events, while keeping the rate of background events within the allowed bandwidth. This contribution summarises the status and performance of the ATLAS tau trigger system during 2011 data taking period and shows the trigger efficiency curves obtained from data.

Keywords: Tau lepton; Trigger; ATLAS; LHC; TDAQ

1. Introduction

The current experimental program of the ATLAS experiment[1] contains many analyses which look for a τ lepton in the final state.[2] The decay of Higgs boson into τ leptons is one of the few decay channels which can be used to observe or exclude a Standard Model Higgs at low mass values (m_H < 130 GeV). In the search for more than one neutral Higgs boson, predicted by the Supersymmetric scenarios, Higgs decays into τ lepton pairs become highly relevant over a large range of masses. Additionally, the observation of a charged Higgs boson, which for masses below 200 GeV preferably decays into a τ lepton and a neutrino, would represent a unique clue to both the origin of mass and the deeper symmetries in Nature. Finally many Beyond Standard Model scenarios predict abundant production of τ leptons.

Being the heaviest lepton, τ can decay either to μ or electron (“leptonic τ”) or to lighter hadrons (“hadronic τ”). Most of the τ leptons decay hadronically (65 %). In hadronic decays, there is an odd number of charged hadrons possibly accompanied by neutral hadrons (due to charge conservation), forming together so-called τ jet. Finally, there is always at least one neutrino (two for leptonic modes) among the τ decay products.

The ATLAS tau trigger is designed to select hadronic τ's, characterized by the presence of 1 or 3 charged tracks ("1-prong" and "3-prong" decays), possibly accompanied by a few neutral hadrons. This distinguishes τ jets from quark or gluon jets, which typically have much larger particle multiplicities. Because the mass differences involved in a τ jet are smaller compared to τ momentum than in a classical QCD jet, the tau decay products tend to be more collimated with respect to the direction of a mother particle, thus forming very narrow jet.

The goal of the tau trigger is to cope with high luminosity conditions and high input rate of events to the trigger system, demanding a strict online selection of events to be saved for offline analysis. The tau trigger should save the interesting physics as efficiently as possible, while reducing the rate of output events down to an acceptable level.

During 2011 more than 4 fb^{-1} of pp collision data has been collected[a] and tau trigger has been actively used in many searches outlined in the previous paragraphs. It has also been used to determine cross section of $W \to \tau\nu$ processes,[3] and in the searches for light charged Higgs boson[4] and neutral MSSM Higgs boson.[5]

2. ATLAS Trigger System

The ATLAS trigger system[1] is designed to cope with an input event rate of 40 MHz and provide an output rate of 300 Hz. The current design includes hardware-based first level trigger (L1), simple and fast firmware logic, using only coarse information, and software-based High Level Trigger (HLT) split into two levels: Levels 2 (L2) and Event Filter (EF). The HLT is implemented in a large farm of processors and applies sophisticated software algorithms to select events using the full granularity of data from the detector. The processing time per event is constrained to the order of microseconds at L1, tens of milliseconds at L2 and seconds at EF.

Level 1 trigger uses information from muon spectrometer and calorimeter to establish so-called Regions of Interest (RoI) within the detector volume. The L2 trigger then inspects only the input from RoI (2-6% of total detector volume). Finally, EF has access to the full detector information and

[a]This is status in October 2011 when data taking is still ongoing

it is possible to execute almost the same algorithms that are used for object reconstruction, identification and selection during the offline analysis.

3. Tau Trigger Implementation

At L1, the tau trigger uses the electromagnetic and hadronic calorimeters to find transverse energy deposits inside the area of 2×2 trigger towers ($\Delta\phi \times \Delta\eta = 0.2 \times 0.2$[b]) that pass given programmable threshold.

Once the L1 tau trigger candidate is found, it is passed on to the HLT. At L2, full detector granularity inside the RoI of size $\Delta\phi \times \Delta\eta = 0.6 \times 0.6$ is used and tau candidate is reconstructed from calorimeter cells and inner detector tracks. Since 2011, electronic and pile-up noise suppression is applied when constructing clusters from calorimeter cells. Several selection criteria are then applied that take advantage of calorimeter cluster confinement and low track multiplicity to discriminate taus from the QCD background.

At EF, full detector information is used to reconstruct τ candidate. In particular, a topological clustering algorithm is run on cells in a region of 0.8×0.8 around the L1 RoI position, and subsequently the same tau reconstruction code as run offline is used, making the EF selection a real online analysis. During the reconstruction noise and pile-up suppression as well as hadronic and tau specific energy calibration are applied.

4. Tau Trigger Performance in 2011

The tau trigger has been active during the whole 2011 run. The instantaneous luminosity has been rising steadily to eventually reach $3.3 \times 10^{33} \mathrm{cm}^{-2}\mathrm{s}^{-1}$, more than 25 times the value at the start of the year. The development of the tau trigger output rates as a function of inst. luminosity is shown on Fig. 1. The rejection ($\frac{1}{\varepsilon_b}$, where ε_b is the background efficiency) for several tau trigger items with different thresholds and different shape cuts is shown on Fig. 2.

The physics analyses using tau trigger to select events needs to know its response to the τ leptons in data. Because Monte Carlo models of signals like W or Z bosons production might not well reproduce data on the new energy frontier of LHC and detector simulation might be incomplete, it is necessary to determine trigger efficiency from real data. The large amount of data collected in 2011, containing also sizable amount of events with τ leptons coming from the decays of Z bosons, makes it possible.

[b]Pseudorapidity η is defined as $\eta = -\ln \tan \frac{\theta}{2}$ where θ is angle measured from the beam axis.

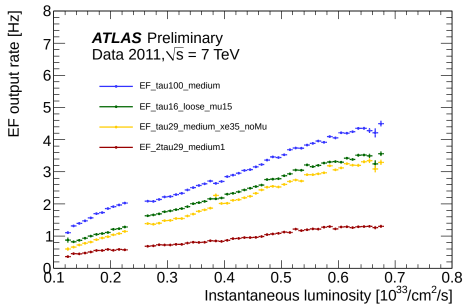

Fig. 1. The EF output rates versus the instantaneous luminosity for 4 selected tau triggers. The numbers in item names correspond to E_T requirements and "medium" identifies the tighthess of identification criteria. One of the triggers is combined with muon trigger and other is combined with missing E_T ("xe") trigger.

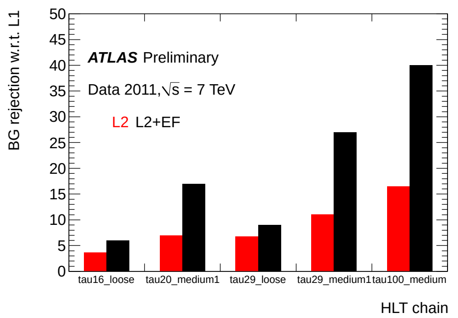

Fig. 2. Rejection of QCD jets for various tau triggers. The numbers are given w.r.t. L1 output of associated tau trigger item. The red and black bars show rejection after L2 and EF, respectively.

The classic method for efficiency measurement is called "tag and probe" and relies on a trigger different from the tau trigger, to tag or save the event to disk, allowing to probe the performance of the tau trigger on the rest of the event where a τ lepton is expected and its presence is unbiased by tau trigger itself. Example is the production of a Z boson decaying into τ leptons, where one τ lepton tags the event via decay to electron or muon. The result of tau trigger efficiency measurement in such events is shown on Fig. 3. The results in general showed good agreement between data and Monte Carlo simulation and high tau trigger efficiency w.r.t. offline tau candidates passing medium identification criteria.

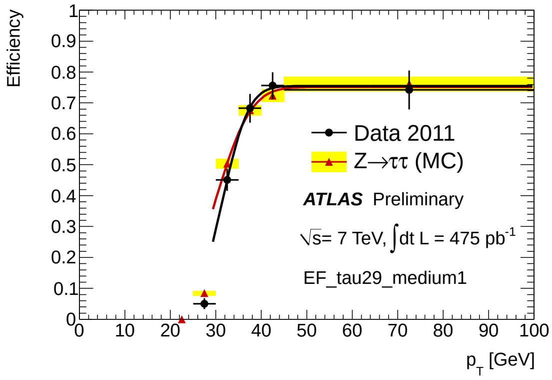

Fig. 3. Efficiency of tau trigger with E_T threshold of 29 GeV w.r.t. reconstructed offline tau candidates passing medium identification criteria as a function of offline p_T.

5. Summary and Outlook

The year 2011 has been another successful year for LHC and ATLAS and the tau trigger has been running smoothly over the whole period. The tau trigger is essential in various Standard Model measurements as well as in the searches for the Higgs boson and the new physics. The performance of the trigger is well described by the Monte Carlo simulation and efficiency has been measured in data using $Z \to \tau\tau$ events. The tau trigger successfully coped with the increasing instantaneous luminosity by rising momentum thresholds and/or tightening the selection on the candidate's shape. The most advanced offline tau identifications algorithms, like Boosted Decision Trees based ID deployed in 2011, are being considered to possibly replace a simple EF cut-based identification in the future. Overall the tau trigger at ATLAS is in very good shape and will continue to select events that might help us to understand more the nature of spontaneous electroweak symmetry breaking or bring some hints about the physics beyond Standard Model.

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