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The ATLAS tau trigger and planned trigger efficiency studies with early data

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The tau trigger system of the ATLAS detector has been developed to increase the sensitivity of the detector to the Higgs boson and searches for physics beyond the Standard Model. A trigger system split in three levels has been designed for hadronically decaying tau leptons optimized for efficiency and good background rejection. At the first level the trigger uses only information from the calorimeters while the other two levels include also information from the tracking. Both energy and shape variables for the hadronic tau jets are used in the trigger algorithms.

The very intense QCD background, however, makes it a challenge to develop an efficient trigger with high purity at low transverse momentum. Thus the tau trigger is best used in combination with other trigger variables such as missing transverse energy or jets. Before the tau trigger can be used in searches, it has to be commissioned with data and the efficiency and background rejection of QCD has to be studied in detail.

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PoS(CHARGED2008)027

1. Introduction

With the completion of the Large Hadron Collider (LHC) the high energy physics community has got the facility to investigate the Standard Model (SM) in a new energy regime and continue searches for new physics signatures at the TeV energy scale. The SM has for the last decades been tested in great detail and no significant deviation between theory and experiment has been observed. However, the important discovery of the Higgs boson is yet to be made. The SM, being an effective theory, is expected to fail at the TeV scale, hence the structure of the microcosm above the TeV scale is yet to be explored. Several models have been developed to supersede the SM. Supersymmetry (SUSY) is a popular model that has been studied in quite some detail and there are several other models as well. A common property of these new models is that they predict new particles and resonances. The tau lepton, being the heaviest of the leptons, may pay an important rôle in the searches for the Higgs boson and signatures of new particles not contained by the SM. As the Higgs boson couples to mass, the tau decay is favoured over other leptons making the tau decay channel important in the searches for neutral SM and SUSY Higgs bosons when the mass is lighter than 160 GeV. The tau decay channel is also very important in the charged Higgs searches over a large mass range. Other searches that would profit from a good tau lepton trigger are searches for charginos ($\chi^{\pm}$) predicted by SUSY and new Z' bosons predicted by e.g. Little Higgs and Kaluza-Klein models [1,2].

The tau lepton has a short lifetime and can only be triggered on its decay products. The leptonic decays will be triggered as electrons or muons without the possibility of knowing if these particles originated from a tau decay. A hadronically decaying tau has a unique signature of one, three or more π/K -meson final states with the single charged meson (1-prong) decays favoured. By carefully choosing variables one can construct a trigger that predominantly selects events that contain tau decays. The challenge of building a tau trigger is to achieve a high QCD-jet rejection while maintaining a high tau lepton efficiency. The QCD rate at the LHC decreases (exponentially) with increasing momentum hence tau-leptons with high momentum are more easy to trigger on than those with low momenta. This has an impact on searches for new physics signatures. Resonances decaying into tau-pairs such as the neutral Z , Higgs and Z' provide a harder tau-spectrum than resonances decaying to a single tau such as $W^{\pm}$ where a neutrino associated to the tau-lepton is produced. A soft tau spectrum does not allow for a high trigger threshold because of the low efficiency to select the signal events. By combining the tau trigger with other trigger signatures one can lower the thresholds but the drawback is that the combined trigger will be more difficult to understand.

This paper describes the ATLAS tau trigger system. The paper is organized as follows: section 2 describes the trigger system and its main variables, section 3 discusses the tau trigger menus and their use in searches for new particles, section 4 describes methods to study the tau trigger performance with first data and conclusions are drawn in section 5.

2. Description of the tau trigger system

The ATLAS detector [3] is a multi-purpose detector with tracking detectors, electro-magnetic (EM) and hadronic calorimeters and a muon detector system. The tracking detectors are surrounded by a solenoid magnet providing a 2 Tesla field. A toroidal magnet system provides a 1.2 Tesla field to the muon system. The ATLAS trigger architecture is split into three levels; L1, L2 and Event Filter (EF). The L1-trigger is hardware-based while the high-level triggers (HLT), L2 and EF, are software algorithms run on computer farms. The L1 trigger has to be robust and conservative since

PoS(CHARGED2008)027

it is less flexible to be modified than the HLT which is software based. A complete description of the trigger system is given in Ref. [4] and the references therein.

The L1 tau trigger decision is based on information from the EM and hadronic calorimeter for $\eta < 2.5$. The trigger uses concentrated energy depositions in a central cluster surrounded by an isolation ring. The two most energetic pairs of neighbouring towers in the EM calorimeter and the matching 2×2 towers (ϕ, η) in the hadronic calorimeter form a tau cluster. An isolation ring of 4×4 towers in the EM- and hadronic calorimeters surrounding the tau cluster is requested. The size of a trigger tower is approximately $\Delta\phi \times \Delta\eta = 0.1 \times 0.1$. There is a maximum of 8 tau trigger signatures available at L1 that are combinations of different energy thresholds of the tau cluster and isolation ring.

The HLT has more time to reach a trigger decision than L1 allowing a more refined analysis with much better granularity to be performed. With more time available for trigger decision, the samplings in the calorimeter towers can be calibrated and shape variables determined. The shape variables are constructed to enhance the characteristics of hadronic tau decays such as collimation and low track multiplicity. The trigger profits from tracking information that has been read out after the L1 trigger. The tau trigger signature is then a combination of shape variables and energy thresholds that gives a good separation of QCD and tau jets.

The logic of the L2 and EF triggers is very similar. The even longer latency at the EF-level gives a higher refinement and better energy calculation than at L2. The EF typically gives a rejection factor which is twice as good as at the L2 trigger with 90% efficiency. Figure 1 shows the shape variable EM Radius which is the energy weighted radius of the cluster around the seed for QCD jet background and signal samples containing either $W \rightarrow \tau\nu$ (Figure 1: a,c) or $A \rightarrow \tau\tau$(Figure 1: b,d) where the A is the pseudoscalar Higgs boson of the MSSM ($m_A = 800$ GeV)[4]. The plots on the top are for L2 and the bottom for EF. Note that because the W is lighter than the A the two studies are run with different trigger thresholds. The former is with a threshold of 20 GeV and the latter with 60 GeV. The plots show that the signal is not fully separated from background but the variable is good for discrimination and enhancement of the signal sample both at L2 and EF.

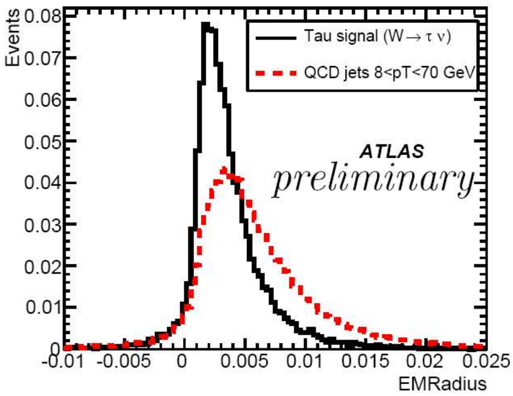
3. Tau trigger signatures and menus

The trigger menus in ATLAS will be defined for different data taking periods with different luminosities. At low luminosity in the LHC machine, one can allow lower trigger thresholds than at high luminosity without the risk of saturating the trigger bandwidth. The trigger menus contain a number of single tau trigger signatures and tau triggers combined with other triggers.

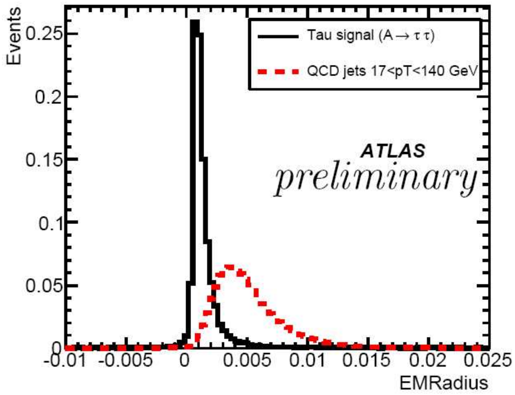
Single tau trigger signatures are applied stand alone with or without prescaling. Only very high transverse energy signatures (tau60, tau100) can be run standalone while the lower threshold triggers are run prescaled or combined with other trigger signatures. The combined trigger signatures are tailored to improve the sensitivity for dedicated physics channels. The tau plus missing transverse energy trigger will improve the selection of events containing decays of $W \rightarrow \tau\nu$ or new physics signatures such as the charged Higgs boson decaying to the same final state. The combination of tau and lepton (+jets) triggers is aimed at enriching samples containing Z bosons, neutral Higgs bosons and SUSY particles. The double tau trigger (+jets) is designed for SUSY searches and tau plus jets or tau plus bjets are designed to select $t\bar{t}$ events. On top of these triggers, there are a number of trigger signatures for commissioning.

The proposed trigger menu for data-taking at a luminosity of 10^{-31} cm^{-2}s^{-1} is shown in Table 1. This trigger menu aims to have a high sensitivity for SM events that are crucial for the commissioning of the ATLAS detector at early running. Already at this low luminosity one cannot

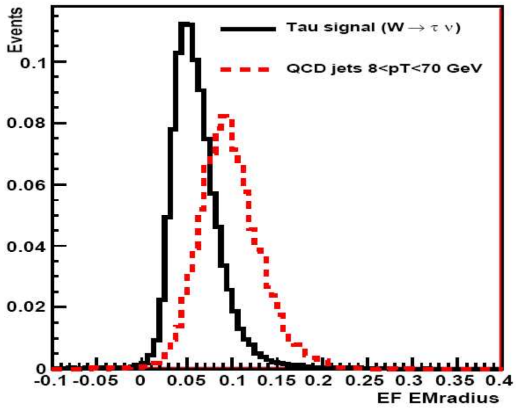
PoS(CHARGED2008)027



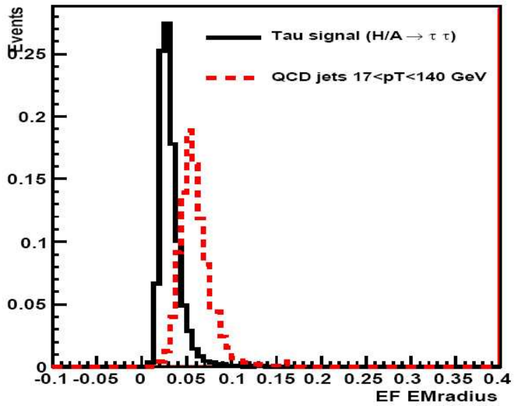
(a) EM Radius L2:TAU20i



(b) EM Radius L2:TAU60



(c) EM Radius EF:TAU20i



(d) EM Radius EF:TAU60

Figure 1: Distributions of EM Radius shape variable for W and A ($m_A = 800$ GeV/c^2) signals with respect to QCD background for EF and L2 triggers.

afford unprescaled single tau triggers below 60 GeV. The total bandwidth expected for this menu is 28.6 Hz which can be compared to the total trigger rate of 200 Hz for the ATLAS experiment. The trigger menus for higher luminosity periods have not yet been designed because of the lack of large enough samples of fully simulated background events, however, these triggers clearly need to have higher thresholds in order not to saturate the maximal bandwidth.

4. Trigger performance studies with first data

The commissioning of the tau trigger has already started with cosmics data while preparing for collisions in the LHC. The cosmics will probe the functionality of the trigger but not allow for a performance study of the trigger. Once the LHC starts to collide protons, precise performance studies of the tau trigger can be done rapidly. The early data is important since only at a very low luminosity can one study a large number of unprescaled triggers. Also the study of the triggers'

PoS(CHARGED2008)027

Trigger	Prescale	Rate (Hz)	Cumulative Rate (Hz)	Events in $100pb^{-1}$ $W_{\tau\rightarrow hX}$	Events in $100pb^{-1}$ $A_{\tau\tau}(800)$
TAU100	1	2.4±0.5	2.4±0.5	699	406
TAU60	1	10.7±1.0	10.7±1.0	4399	484
TAU45i	10	2.5±0.2	12.6±1.1	1406	47.5
TAU45	20	4.1±0.1	16.0±1.4	816	26.2
TAU20i_XE30	1	4.9±0.7	20.1±1.4	29005	429
TAU20i_E10	1	1.2±0.4	21.2±1.5	0	83
TAU20i_MU6	1	2.8±0.5	23.7±1.6	0	96
2TAU25i	1	2.6±0.5	25.3±1.6	0	37
TAU20i_4J23	1	0.1±0.1	25.4±1.6	957	1.31
TAU20i_3J23	1	0.9±0.3	25.8±1.6	3852	2.31
TAU20i_J70	1	7.1±0.9	28.6±1.7	8672	2.96

Table 1: Tau trigger menu for $L = 10^{31}\, cm^{-2}\, s^{-1}$.

background rejection power is better performed with data than with MC because of the limited number of fully simulated QCD background events. Signal events for tau trigger studies are known SM processes including W, Z and top. An integrated luminosity of $100pb^{-1}$ is sufficient for performance studies with a tag-and-probe method. The events are selected with a trigger signature different than the tau trigger using a part of the decay that is not used by the tau trigger. For the $t\bar{t}$ study the events are triggered by four jets, where two b-jets arise from the decaying top quarks and two light jets are from a decaying W-boson from one of the top quarks. The tau trigger probe is the second W-boson in the event decaying to a tau lepton.

With the $Z \rightarrow \tau\tau$ one can tag the leptonic decay of one of the τ and probe the hadronic decay of the second τ . There will be approximately 150 000 events with $Z \rightarrow \tau\tau$ produced for 100 pb^{-1} data at the LHC. With a 10 GeV muon trigger and including acceptance and off-line cuts around 1200 Z will be reconstructed. These can then be used to study the tau trigger efficiency with respect to off-line reconstruction. Figure 2 shows the turn-on curve for three different tau trigger signatures for 30 pb^{-1} of data (TAU25i, TAU45 and TAU60). Figure 3 shows a trigger slice of L1,L2 and EF for TAU45. These plots do not include background due to the insufficient number of fully simulated background events. The uncertainty on the number of background events passing the reconstruction is large. Extrapolation from smaller background samples indicates that the background will be less than 30%.

5. Conclusions

A three-level hadronic tau trigger has been developed for ATLAS. The challenge in the design of the trigger is to find features in the tau decay that are sufficiently different from the overwhelming QCD background to obtain a good signal efficiency and background rejection factor. The tau trigger uses all available information from the subdetectors for shape and energy variables that are built into tau trigger signatures. The tau trigger rates for low transverse energy thresholds are, however, too large to be run standalone but in combination with non-tau triggers they can be run unprescaled. Single tau triggers with a transverse energy threshold larger than 60 GeV can be run unprescaled in the initial low luminosity period.

The tau trigger will be commissioned with first data. Already at the integrated luminosity of 100 pb^{-1} one has enough data for detailed performance studies. These are essential to commission

PoS(CHARGED2008)027

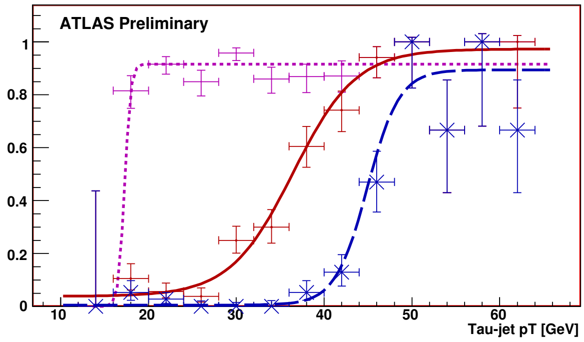


Figure 2: Turn-on curve for L2 trigger for trigger signatures TAU25i (dotted), TAU 45 (solid) and TAU60 (dashed).

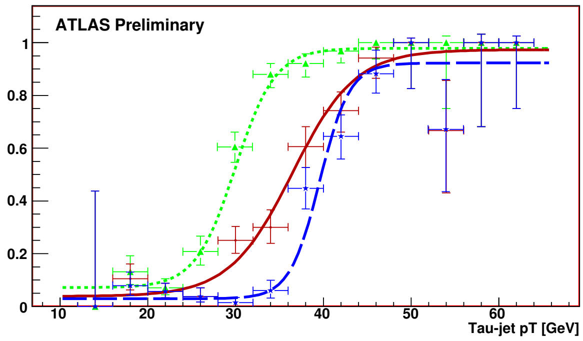


Figure 3: Turn-on curve for a trigger slice of TAU45: L1 (dotted), L2 (solid) and EF (dashed).

the single tau trigger signatures that will later be built into more complex signatures for use in searches of new physics.

References

[1] L. Randall and R. Sundrum, Phys. Rev. Lett. 83 (1999)

[2] N. Arkani-Hamed, A.G. Cohen and H. Georgi, Phys Lett. B 513 (2001)

[3] The ATLAS Collaboration, G Aad et al, JINST 3, S08003, (2008)

[4] ATLAS Collaboration, Expected Performance of the ATLAS Experiment, Detector, Trigger and Physics, CERN-OPEN-2008-020

PoS(CHARGED2008)027