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The Tau Trigger at the ATLAS Experiment

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The selection of events with tau leptons is motivated by the prospects of new physics discoveries at the energy scales accessible at the LHC. A dedicated tau trigger will increase the discovery potential of ATLAS in many physics searches including the search for the Higgs boson (Standard Model and Supersymmetry). Using the advanced tracking and calorimeter capabilities of the ATLAS detector, the tau trigger is designed to efficiently select events with hadronically decaying taus while keeping the multi-jet backround under control.

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1. Tau Properties

With a lifetime of 2.9×10^{-13}s, taus decay before reaching the inner part of the ATLAS detector. About 65% of them decay hadronically generally resulting in one ("1-Prong") or three ("3-Prong") charged pions, a tau neutrino and possibly neutral pions as shown in Fig. 1. This leads to the following characteristics: low track multiplicity, isolation and narrowness.

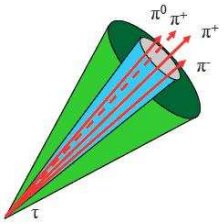

Figure 1: Hadronic tau decay.

2. The ATLAS Tau Trigger

The tau trigger is a part of the ATLAS trigger system which is designed to select events in three steps. The 40 MHz bunch crossing rate is reduced to 75 kHz by the hardware based Level 1 (L1) trigger. With a decision time of $\sim 2.5\mu$s, it identifies Region of Interests (RoIs) for the higher level trigger systems. Using the full granularity of the detector, the Level 2 (L2) trigger further analyzes the RoIs with a latency of $\sim$ 40ms to reduce the rate to 1 kHz. The third level trigger (Event Filter or EF) takes the final decision, using the full detector information, and reduces the event rate to 200 Hz. The latency of the EF is 4s.

At L1, the tau trigger [2] uses the electromagnetic (EM) and hadronic calorimeter trigger towers of size $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$ to calculate the energy in a core and an isolation region. At L2, selection criteria are applied using tracking and calorimeter based information. This takes advantage of narrowness and low track multiplicity to discriminate taus from the multi-jet background. Exploiting the same characteristics, the EF uses different selection criteria for 1-prong and multi-prong decays in more refined algorithms which are similar to the reconstruction algorithms.

3. Tau Trigger Menu for Early Running

In order to control rates at higher luminosities, different levels of tightness are designed for each signature (loose, medium and tight), corresponding to different selection criteria and efficiencies. Loose will be used for early running, while medium and tight are planned for higher luminosities. Due to their high rates, single tau triggers will be run either with a high threshold of the energy transverse to the beamline (E_T) or in conjunction with other triggers. Tables 1 and 2 show an overview of tau signatures for a luminosity of 10^{31}cm^{-2}s^{-1} and 10^{33}cm^{-2}s^{-1}, respectively [3]. The name of the trigger reflects the E_T threshold at EF and the EM isolation requirement at L1. The symbol "xe" refers to a trigger based on missing transverse energy (MET), while the rate is calculated using MC simulation.

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

Menu	Goal	Trigger	Unprescaled Rate [Hz]
Single Tau	Searches at high P_T	tau50	1.5
tau+lepton	$Z \to \tau\tau$	tau12+e10/tau16+mu10	1.8/0.5
tau+MET	$W \to \tau\nu$, $t\bar{t}$, $Z \to \tau\tau$	tau16i+xe30	0.7
tau+(b)jets	$t\bar{t}$	tau16i+3j23	0.2

Table 2: Tau trigger menu for $L = 10^{33}\text{cm}^{-2}\text{s}^{-1}$.

Menu	Goal	Trigger	Unprescaled Rate [Hz]
Single Tau	Searches at high P_T	tau84	3.1
tau+lepton (+jets)	$H \to \tau\nu$, $H \to \tau\tau$, SUSY	tau16(i)+e15(i)/mu15i	3.2/2.9
tau+MET	$H \to \tau\nu$, SUSY	tau38i+xe40	3.0
tau+tau	$H \to \tau\tau$	2tau29i	5.3

4. Measurement of Tau Trigger Efficiency

All single tau triggers are optimized, using Monte Carlo (MC) simulation, to select truth matched reconstructed taus above certain E_T thresholds. Figure 2 shows the fraction of these taus in a $Z \to \tau\tau$ MC sample passing different triggers, as a function of their true visible E_T.

Tau trigger efficiency can be measured with first collision data using the tag-and-probe method. For a single tau trigger in the medium E_T range, $Z \to \tau(\to e/\mu)\tau(\to had)$ events passing a single electron or muon trigger are selected. This yields $\sim$ 500 events in 100 pb^{-1}. The fraction of hadronically decaying taus that passes the tau trigger gives the efficiency. Another method to measure the tau trigger efficiency is to select semi-leptonically decaying $t\bar{t}$ events containing hadronic taus from events collected by a 4-jet trigger. The tau-leptonic decay products are used as a probe for the efficiency measurement.

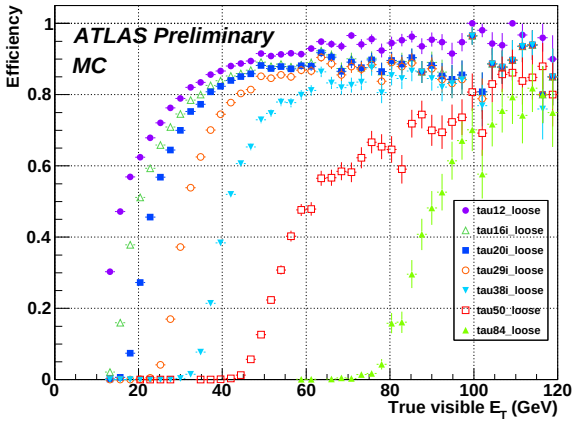

Figure 2: Efficiency for different tau triggers.

In order to measure the efficiency of a higher E_T trigger ε_A, a Bootstrap method can be used. Given the efficiency of one trigger ε_B, the efficiency ε_A can be calculated using $\varepsilon_A = \varepsilon_{A|B} \cdot \varepsilon_B$. The term $\varepsilon_{A|B}$ can be obtained by requiring the events, which already passed trigger B, to pass trigger A. Given the abundance of multi-jet events in the tau trigger output ("fake taus") and the difficulty in selecting a pure sample of real taus, fake taus are used to estimate the relative efficiency of real taus between various E_T and η ranges. Tight offline selection criteria need to be applied to select fake taus with similar properties as real taus.

References

[1] ATLAS Collaboration, *The ATLAS Trigger/DAQ Authorlist*, ATL-DAQ-PUB-2009-004, Geneva, 2009

[2] ATLAS Collaboration, *Expected Performance of the ATLAS Experiment:Detector, Trigger and Physics*, ATLAS Report, CERN-OPEN-2008-020, Geneva, 2008[arXiv:0901.0512]

[3] ATLAS Collaboration, *Tau Trigger: Performance and Menus for Early Running*, ATL-PHYS-PUB-2009-028, Geneva, 2009