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Triggering on hadronic tau decays: ATLAS meets the challenge

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Abstract. Hadronic tau decays play a crucial role in taking Standard Model (SM) measurements as well as in the search for physics beyond the SM. However, hadronic tau decays are difficult to identify and trigger on due to their resemblance to QCD jets. Given the large production cross-section of QCD processes, designing and operating a trigger system to efficiently select hadronic tau decays, while maintaining the rate within the bandwidth limits, is a difficult challenge. This contribution will summarize the status and performance of the ATLAS tau trigger system during the 2010–2011 data taking period. Different methods that have been explored to obtain the trigger efficiency curves from data will be shown. Finally, the status of the measurements, which include hadronic tau decays in the final state, will be summarized. In light of the vast statistics collected in 2011, future prospects for triggering on hadronic tau decays in this exciting new period of increased instantaneous luminosity will be presented.

Keywords. ATLAS; tau; trigger.

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1. Introduction

The main goals of the ATLAS detector on the Large Hadron Collider (LHC) are to discover evidence of the Standard Model (SM) Higgs boson, and new physics beyond the Standard Model (BSM). Tau leptons play an important role in these searches, with both light SM Higgs bosons, and many high mass BSM particles, preferentially decaying into taus [1]. Taus decaying to e/μ can be difficult to discriminate from direct e/μ production, and so hadronic decays (with a branching ratio of 64.8%) may be the only way to detect a tau, providing motivation for a dedicated hadronic tau trigger in ATLAS.

2. ATLAS tau trigger

The ATLAS tau trigger has managed to successfully reconstruct and identify hadronic tau decays, whilst simultaneously rejecting objects with similar detector signatures. The major source of fake taus are QCD jets, due to the high dijet production cross-section.

A hadronically decaying tau usually results in one or three charged pions, any number of neutral pions, and a tau neutrino. In order to distinguish these decays from QCD jets, the tau trigger must exploit tau-specific properties, including a low track multiplicity, a narrow jet cone, and a region of isolation around the decay axis.

The architecture of the ATLAS trigger has three stages; a hardware-based level 1 (L1) trigger and software-based high level triggers (HLT). The L1 hardware trigger identifies regions of interest (RoIs) in the detector based on information from the electromagnetic (EM) and hadronic (HAD) calorimeters. Possible tau RoIs are identified using the sum of the energy in 2×1 EM towers and 2×2 HAD towers, with the EM+HAD energies passing a required threshold. The output rate of the L1 trigger may be reduced using a prescale, depending on the trigger stream (figure 1).

The HLT is split into two levels – Level 2 (L2) and the event filter (EF). The L2 trigger builds on the output from the L1 RoIs, reconstructing tracks and calorimeter showers using full detector granularity. The L2 tau trigger applies selections on variables such as the shower shape in the calorimeter and the number of tracks left in the inner detector to discriminate between taus and QCD jets. A prescale may be applied before the L2 trigger, to limit the input rate. The EF builds the full event seeded from the L2 RoIs, running the

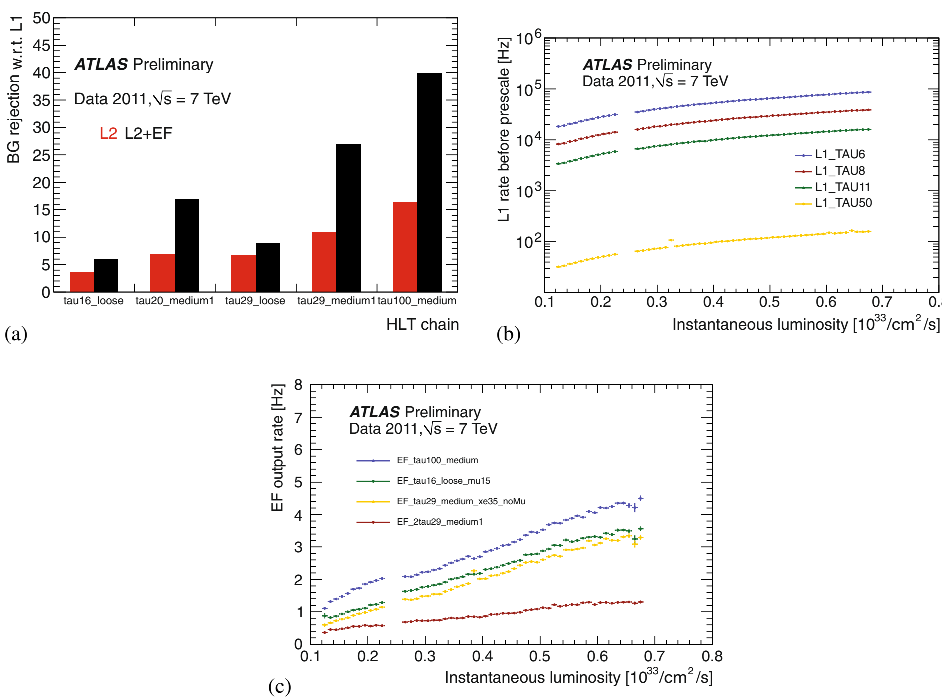

Figure 1. **(a)** QCD jet rejection factors of different tau HLT chains from 2011 collision data, with respect to the output of the associated L1 tau trigger item [5]. **(b)** and **(c)** show the L1 rates before prescale and the EF output rates, respectively, vs. the instantaneous luminosity measured by ATLAS [5]. The trigger item names show the energy requirements at L1 or EF (for example, $L1_{TAU6}$ requires a 6 GeV threshold be passed).

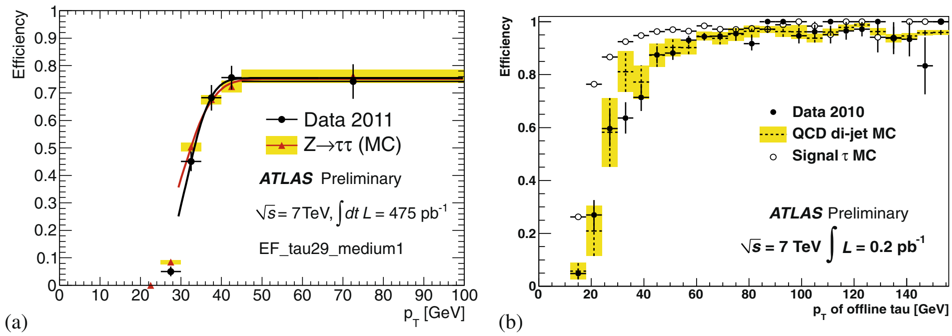

Figure 2. **(a)** Efficiency of a 29 GeV threshold tau trigger chain with respect to the offline-reconstructed tau candidates. The analysis follows the method closely from the $Z \to \tau\tau$ cross-section measurement, using $Z \to \tau\tau \to \mu h$ events in 2011 data [2] and **(b)** efficiency of a 16 GeV threshold tau trigger with respect to offline reconstructed tau candidates, using fake taus from QCD dijet events in 2010 data [5].

tau reconstruction algorithms as used by the offline reconstruction and enhancing the discrimination between taus and QCD jets compared with the L2 trigger, as shown in figure 2. As with L2, a prescale can be applied to limit the input rate to the EF.

3. Performance

The aim of the ATLAS trigger system is to reduce output event rates, while retaining a high efficiency in selecting the events of interest. Measurements of the tau trigger performance therefore include the EF output rate and the trigger efficiency (the conditional probability for an offline reconstructed tau to pass the tau trigger). Figure 1b shows the output rate for some of the L1 tau triggers used to seed HLT chains. The high rates are reduced by many orders of magnitude after the L2 and EF triggers, as seen in figure 1c.

The tau trigger efficiency was measured using collision data from 2010 to 2011, with efficiency curves being obtained using a 'tag-and-probe' method with real taus from $Z \to \tau\tau$ events (figure 2a), with one tau decaying leptonically (tag) and the other hadronically (probe), and $W \to \tau\nu$ events, where the missing energy (E_T^{miss}) was tagged. The high rate of QCD jets being misidentified as taus was exploited as an alternate method to study the tau trigger, with increased statistics. As an object identified as a tau by the offline algorithms should also pass the tau triggers, the trigger efficiency for fake taus from QCD dijet events was measured, again using a tag-and-probe method (figure 2b).

4. Outlook

Despite the ever-increasing instantaneous luminosity of the LHC, the ATLAS tau trigger has run very efficiently. As it continues to rise however, changes will need to be made to maintain the trigger efficiency as high as possible and to stay within the assigned bandwidth. While it is undesirable to raise the energy thresholds (as it limits the ability to study low-energy taus), alternatives can include increasing energy thresholds only in specific regions of the detector, or requiring an isolation ring at L1 in the EM and/or HAD calorimeters. At the HLT, improvements such as using multivariate techniques for tau identification, or the use of primary vertex information can also be implemented to increase trigger efficiency.

The ATLAS detector has run successfully during 2011, collecting over 5 fb^{-1} of data. During this time, the tau trigger has run smoothly and performed to expectations – a tau+$E_{\mathrm{T}}^{\mathrm{miss}}$ trigger was used to observe $W \rightarrow \tau\nu$ in 2010 data [3], and a measurement of its cross-section in 2011 data [4]. With the measured trigger efficiency from data agreeing well with the Monte Carlo simulations, the tau trigger will continue to be a well-understood and an important tool in future searches for new physics in the forthcoming data.

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