Triggering on hadronic Tau Decays in *ATLAS*

Algorithms and Performance

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ATLAS Analyses based on Tau Trigger

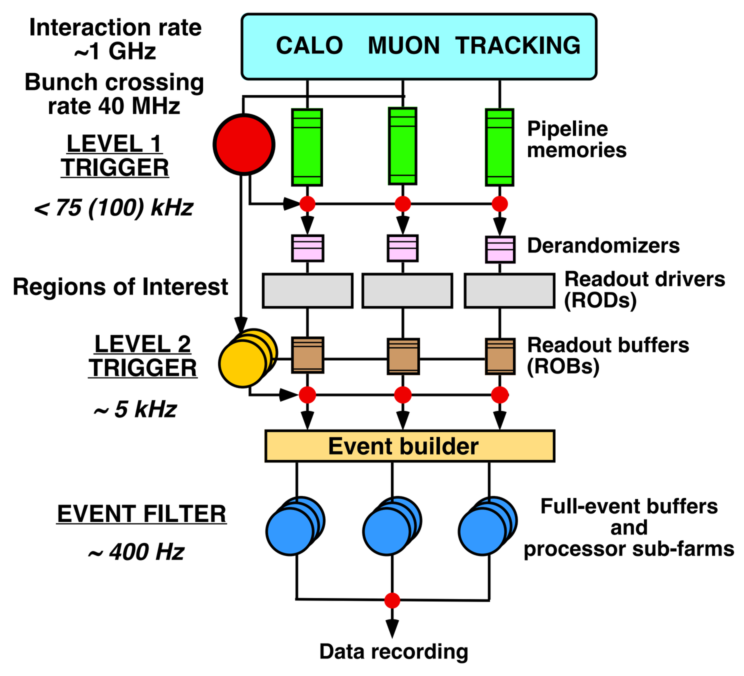
Various ***ATLAS*** analyses rely on the tau trigger. Hadronic taus (τ_h) are not only important for (MS)SM Higgs searches, but also for *W* and *Z*-Boson cross section measurements and the tau polarization measurement in $W\rightarrow\tau_h\upsilon$ decays. Following table gives an overview of analyses using the data taken with hadronic tau triggers combined with electron, muon and missing E_T (transverse energy) triggers.

Trigger	Channel	Documentation
di-tau trigger	$H\rightarrow\tau_h\tau_h$ (Higgs search)	ATLAS-CONF-2012-014
tau + electron/μ trigger	$H\rightarrow\tau_{e/\mu}\tau_h$ (Higgs search)	ATLAS-CONF-2012-014
tau + missing E_T trigger	$H^+\rightarrow\tau_h\upsilon$ (charged Higgs search)	CERN-PH-EP-2012-083
tau + missing E_T trigger	$W^+\rightarrow\tau_h\upsilon$ (cross section and τ polarization measurement)	CERN-PH-EP-2011-122 CERN-PH-EP-2012-075
tau + electron/μ trigger	$Z\rightarrow\tau_{e/\mu}\tau_h$ (cross section measurement)	ATLAS-CONF-2012-006

ATLAS Trigger System- Step by Step

40 000 000 Hz

The ***ATLAS*** three level trigger system, described in detail in [Eur. Phys. J C72 (2012) 1849], is a crucial part of data acquisition, taking on the challenge to reduce the collision rate of 40 MHz to a storage-able rate of 400 Hz without losing interesting physics events. Another challenge for the trigger system is the continuously increasing instantaneous luminosity delivered by the Large Hadron Collider (LHC).



Level 1 Trigger (L1)

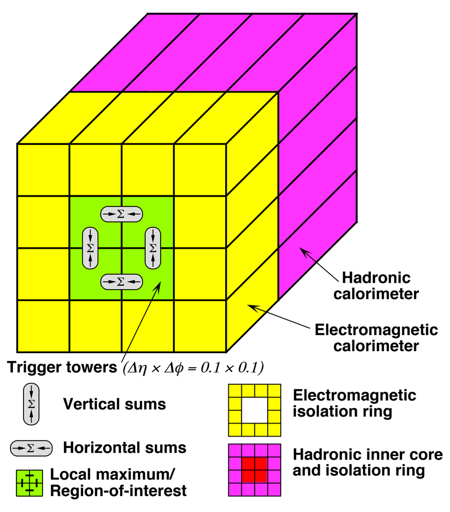
< 75 000 Hz (t < 2.5 μs)

The level 1 (L1) calorimeter trigger is a hardware-based system using coarse electromagnetic (EM) and hadronic (HAD) calorimeter information, provided as trigger towers of size $\Delta\eta\times\Delta\phi = 0.1\times0.1$.

A L1 tau is identified by:

- sum of energy in 2 × 1 pairs of EM towers and sum of energy in 2 × 2 HAD towers behind the EM layers
- sum of energy in isolation region in a 4 × 4 ring around the core region of 2 × 2 towers

For a given L1 item a specific threshold is applied on the E_T, e.g. for the *L1_TAU11* item E_T > 11 GeV is required. The position of this L1 deposit gives the region of interest (RoI) to HLT. To cope with the high input rate an isolation criteria has to be applied in addition.

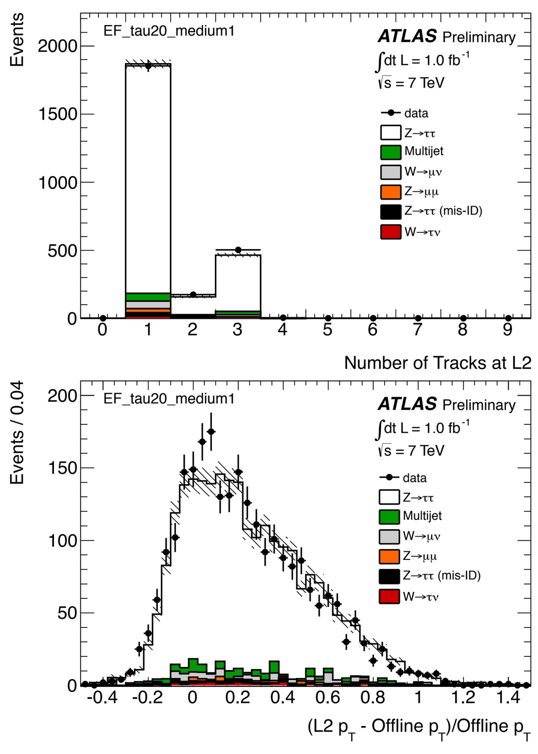


High Level Trigger (HLT)

Level 2 Trigger (L2)

~ 5000 Hz (t ~ 40 ms)

In the second level of the tau trigger, the full granularity, as well as the tracking information, within the RoIs, is processed with fast algorithms (around 40 ms). These calculate discriminating variables, which are used to discard tau candidates potentially stemming from QCD jets. Major discriminating variables are track multiplicity, the difference of the tau candidate's p_T with respect to offline reconstruction are shown in the Figures on the **right**. Here the events are selected by applying a tag and probe selection in $Z\rightarrow\tau\tau\rightarrow\mu\tau_h$ final state, described on the right side of the poster, it closely followed the tau identification (ID) efficiency measurement described in [ATLAS-CONF-2011-152].

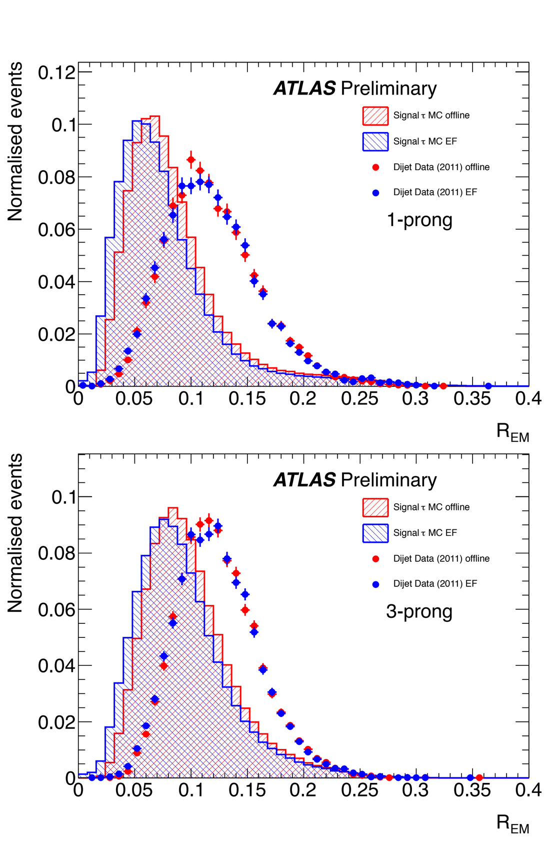


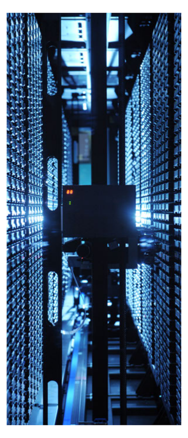
Event Filter Trigger (EF)

~ 400 Hz (t ~ 4 s)

The third level of the trigger accesses the complete event information and a full reconstruction of tau candidates is performed. At this stage the same algorithms as in offline reconstruction are run, to achieve maximal background rejection. The Figures on the **left** show an EF to offline comparison of the EM energy weighted radius, R_{EM}, for EF and offline reconstructed tau candidates with exactly 1 (**upper** Figure, 1-prong) and 2 or 3 (**lower** Figure, 3-prong) associated tracks were required.

From several input variables as the one shown the BDT and LLH scores are calculated, which are then the final discriminating variable being cut on by this last trigger stage.



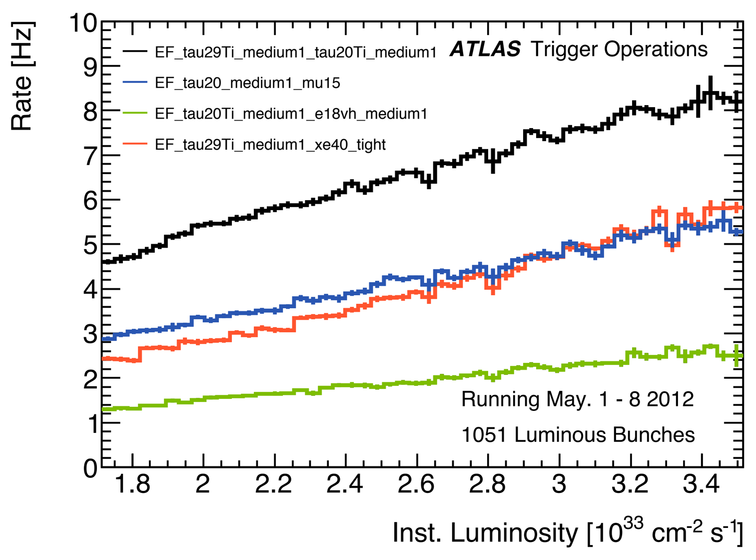


The hatched area represents the combined contributions from $Z'\tau\tau$, $W\rightarrow\tau\upsilon$ and $Z'\rightarrow\tau\tau$ signal Monte Carlo samples, while the points represent the data. A dijet selection has been applied to select the events in data. A less precise energy calibration applied at EF causes a shift of this distribution with respect to offline.

ATLAS Tau Trigger for 2012

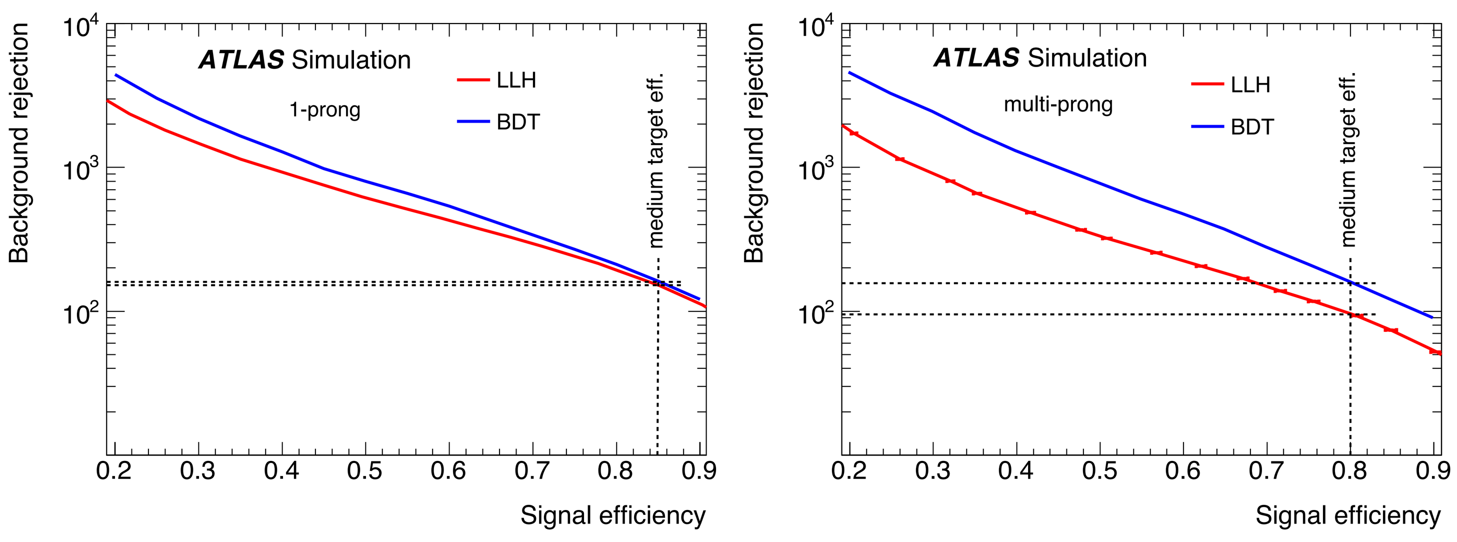
Tau Trigger Rates

A trigger has to balance between the rate constraints and maintaining high signal selection efficiencies for analyses. Keeping the rates under control is a crucial part of efficient and stable data acquisition. The Figure to the **right** shows the trigger rates as a function of instantaneous luminosity for combined tau triggers. The numerical figures in the name of each trigger chain correspond to the E_T or p_T threshold applied at EF.



Performance of multivariate-based Tau Triggers

Since 2012 the Event Filter trigger utilizes the multivariate tau identification algorithms, boosted decision tree (BDT)- and Log Likelihood (LLH)-based, as applied in the offline tau ID. The following Figures show the signal efficiency, defined with respect to the offline tau candidates and background rejection with respect to jet candidates, of the two ID algorithms. **Left** the 1-prong and **right** the multi-prong tau trigger candidates for BDT- and LLH-based triggers are shown. The trigger decision is optimized to 85% and 80% with respect to the offline candidates for 1-prong and multi-prong, respectively.

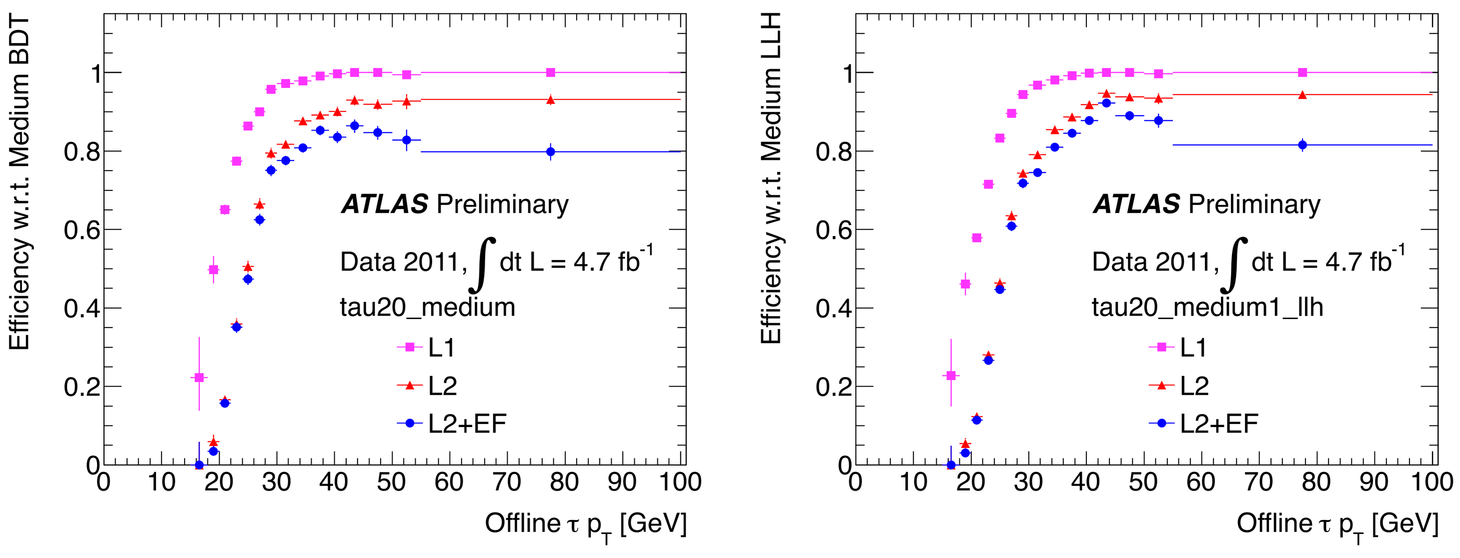


Trigger Efficiency

In order to be able to determine the efficiency of the tau trigger a tag and probe selection, following the $Z\rightarrow\tau\tau$ cross section measurement, [ATLAS-CONF-2012-006], was utilized. The isolated muon in the $Z\rightarrow\tau\tau\rightarrow\mu\tau_h$ decay channel is used as a tag for the process. A reduction of the *W*+jets and QCD backgrounds is achieved by imposing further restrictions on the event, as for example a requirement on transverse mass[1], m_T, cuts on the angles between the selected objects and the missing E_T, opposite charge of the selected muon and tau candidate pair, as well as the constraint on its invariant mass to lie within an optimized mass window.

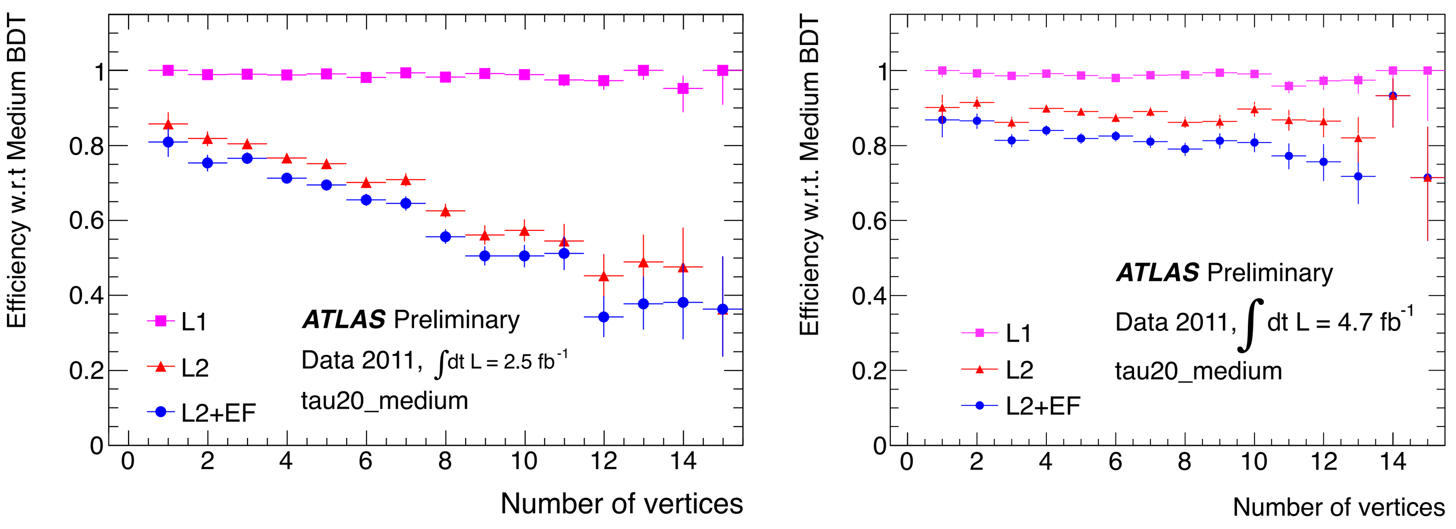
[1] Definition: $m_T = \sqrt{2p_T^\ell \cdot E_T^{miss}(1-\cos\Delta\phi(\ell, E_T^{miss}))}$

The efficiency of the *EF_tau20_medium* trigger (Event Filter tau candidate with at least 20 GeV, passing medium quality selection on the shower shape variables) as a function of the offline tau p_T is measured with data collected in 2011. Selections applied at EF are based on multivariate techniques. The **left** Figure is based on BDT and **right** is the LLH ID method. The shown efficiency is defined with respect to the offline reconstructed tau identified by the corresponding multivariate algorithm. In 2012, the BDT-based tau triggers will be used as the baseline.



Tau Trigger Pileup-Recovery

Studies of the tau trigger used in 2011 with respect to pileup robustness showed a degradation of the efficiency with increasing pileup conditions. This effect is demonstrated in the **left** Figure below, showing the *tau20_medium* trigger efficiency as a function of numbers of vertices, measured using the described tag and probe analysis with events collected in 2011.



In 2012 a smaller calorimeter cone size of 0.2 compared to 0.4 in 2011 and the implementation of a selection of tracks originating from the same interaction point as the highest p_T track (all tracks were considered before) provide robustness against pileup. The impact on the efficiency is shown by applying the modified selections to the tau candidates selected by the tag and probe, in the **right** Figure above, thereby providing a prospect for 2012.

With the recently implemented improvements we expect to see improved performance of tau trigger in 2012.