Performance of the ATLAS Tau Trigger in High Luminosity Scenarios

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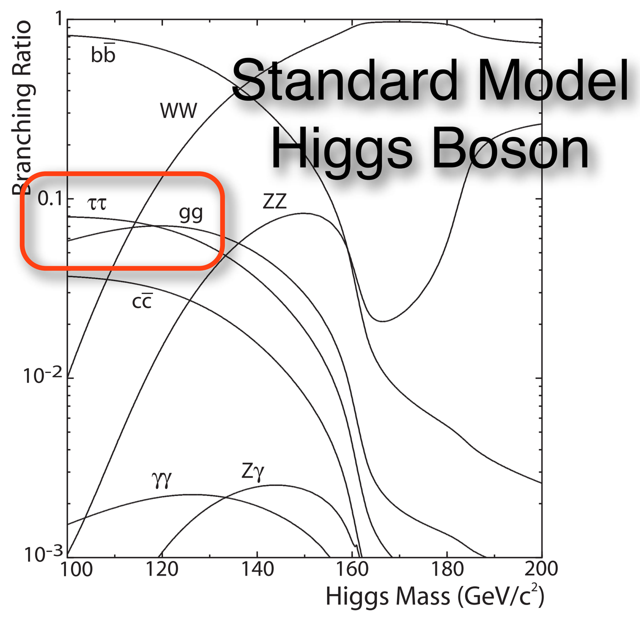
on behalf of the ATLAS collaboration

Introduction and physics motivation

The ATLAS experiment at the Large Hadron Collider (LHC) at CERN has been designed to search for the Standard Model (SM) Higgs boson and for new physics beyond the SM, such as Supersymmetry (SUSY) and exotic heavy resonances. Especially for low masses of the SM Higgs boson, the branching ratio to two tau leptons is relatively high. The sensitivity of those searches is enhanced when tau leptons decaying to hadrons are included.

A key element in the selection of these events is the hadronic *tau trigger*, which has been commissioned to achieve a good rejection against QCD jets while maintaining a high efficiency for signal events.

When the ATLAS experiment claimed the observation of $W \to \tau\nu$ decays in 2010, the tau trigger was used for selecting events [1].



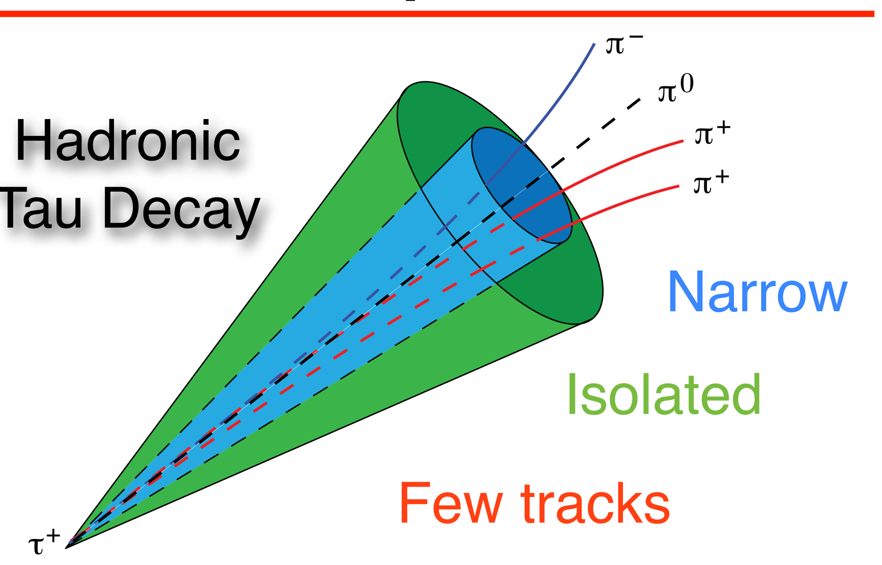
Properties of a hadronic tau decay

The decays of tau leptons to hadrons mostly involve one or three charged pions with a tau neutrino and possibly neutral pions.

The jet-like detector signature is characterized by:

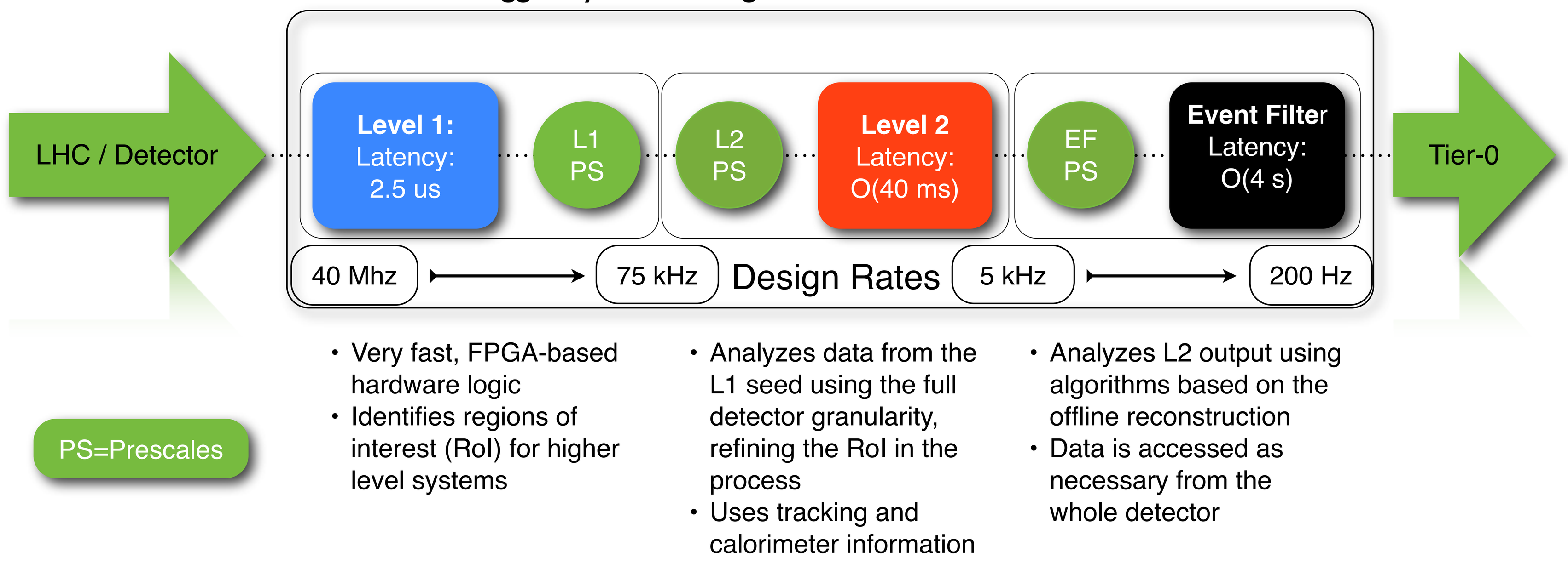
- Low track multiplicities
- Isolation in the tracker and the calorimeter
- Narrowness of the jet cone

The figure shows a typical tau decay to three charged pions and one neutral pion.



The ATLAS trigger system

The trigger system of ATLAS has been designed to reduce the initial collision event rate to a final output event rate that is feasible for disk storage at the CERN Tier-0. During this process it is crucial that the fraction of interesting physics events is kept at a maximum while events from background processes are discarded. In order to achieve this, the ATLAS trigger system is organized in three levels:



The ATLAS tau trigger

Level 1 tau trigger:

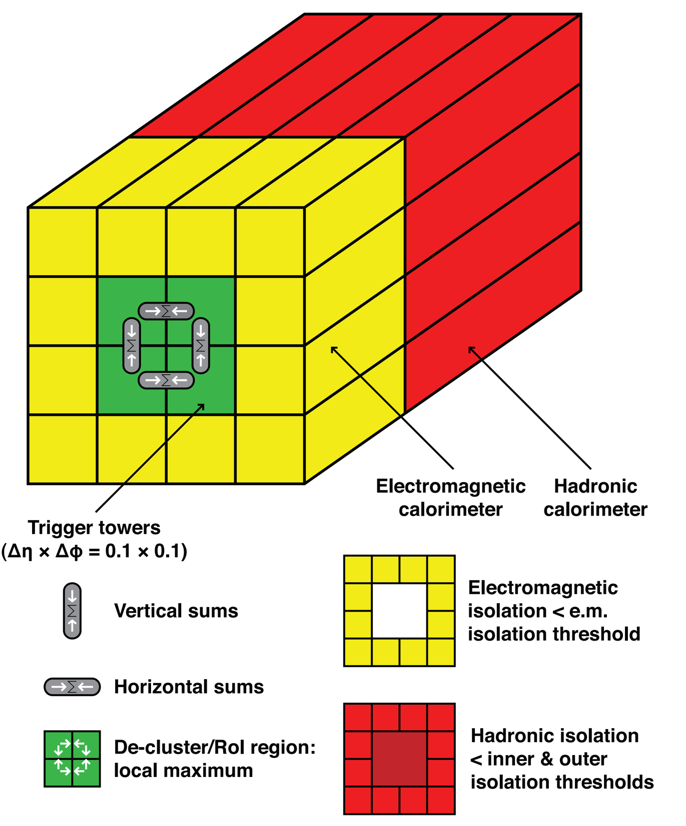
- Hardware-based trigger using the electromagnetic (EM) and hadronic calorimetry.
- Trigger towers: $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$

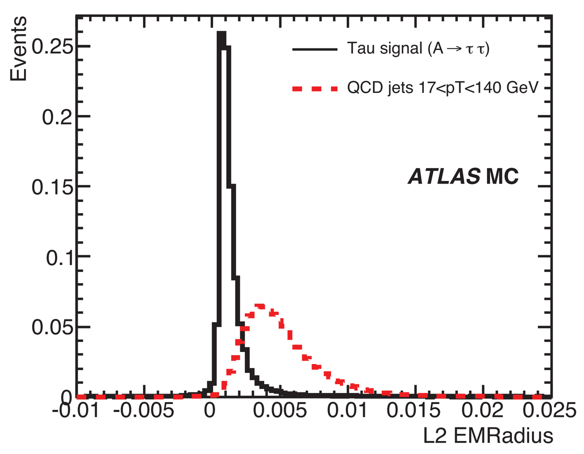
At L1, taus are identified based on the following features:

- Energy in 2×1 pairs of EM towers
- Energy in 2×2 hadronic towers behind EM clusters
- EM energy in isolation region (4×4 ring around the 2×2 core)

In order to pass the energy requirements, the sum of the RoI energies in the EM and hadronic towers must exceed the threshold energy of a given L1 item, e.g. greater than 6 GeV for the L1_TAU6 item. All energies are measured at the EM scale.

Current settings apply a relatively low threshold at L1 and use the identification power and better energy determination at the High Level Trigger (HLT). So far, no isolation requirements have been used at this level.





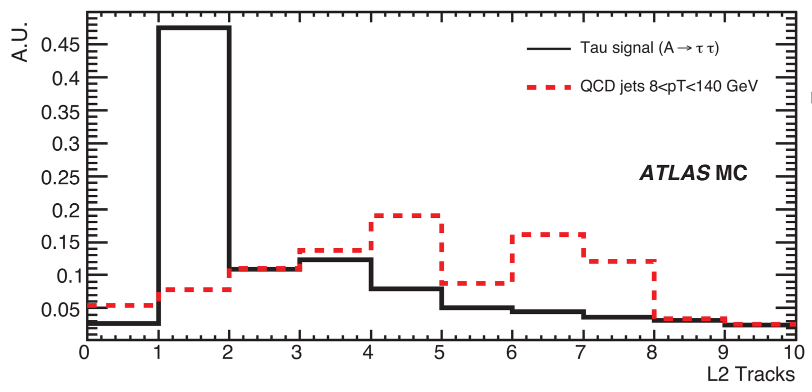
HLT tau trigger:

Level 2 (tracks and cluster):

Tracks are reconstructed starting at L2. The characteristic narrowness and low track multiplicity of the tau jet is used to discriminate against background.

The plot to the left shows the EM radius at L2 for a high p_T signal (black, solid) and QCD jet background (red, dashed).

The number of tracks in the vicinity of the L1 seed is a powerful rejection variable already at L2, in particular for one-prong tau decays (middle plot).

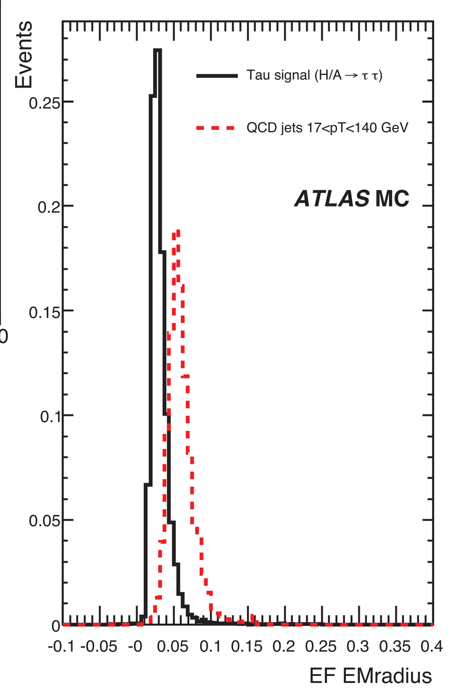


Event Filter (tracks and cluster):

If a tau candidate has been accepted by L2, the EF variables are computed using algorithms similar to the offline tau reconstruction.

The EF tau candidates provide a wide range of identification variables, refined with respect to L2, such as the EF EM radius which is shown to the right.

Rejection of QCD jets by the HLT is of the order of 10 or more, depending on the p_T range and tightness of selection.



Tau trigger configuration for high luminosities

Various tau trigger signatures have been used in the past for early running and also for increasing instantaneous luminosities. In general, the p_T thresholds applied at EF will be tightened as luminosity increases.

In addition, different quality requirements (i.e. *loose*, *medium* and *tight*) are available for each HLT chain. Chains with the *loose* requirements were used for single tau triggers at low luminosities and currently only appear in combined chains.

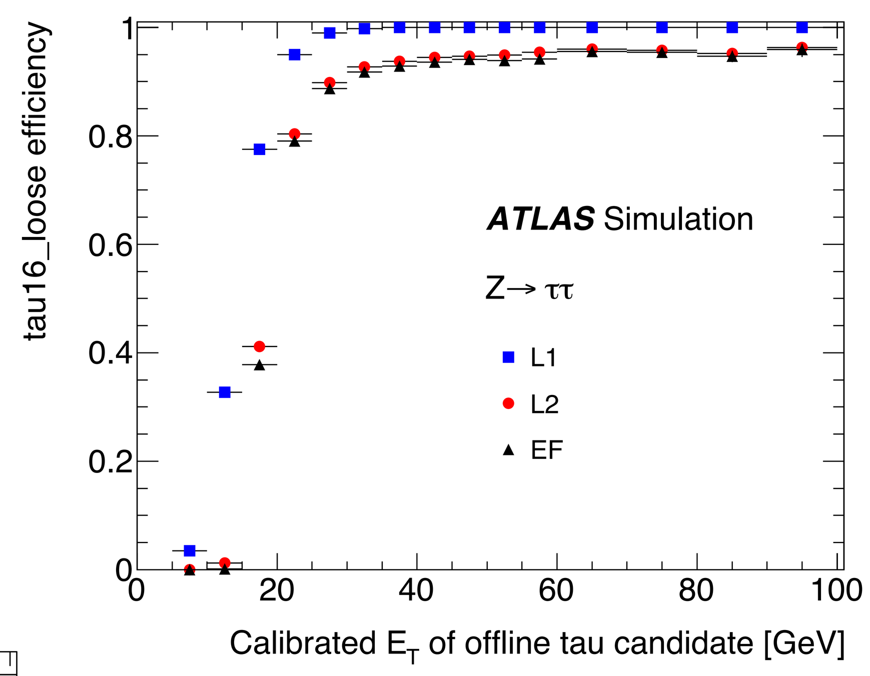
Menu	Purpose	Trigger
Single Tau	H+, SUSY	tau100_medium
Di-Tau	H, Z	2tau29_medium1
Tau + Lepton	H, t, Z	tau16_loose_mu15
		tau16_loose_e15_medium
Tau + MET (significance)	H+, W→τν	tau29_medium_xe35_noMu
		tau29_loose_xs70_loose_noMu
	H+	tau29_loose1_xs45_noMu_3L1J10

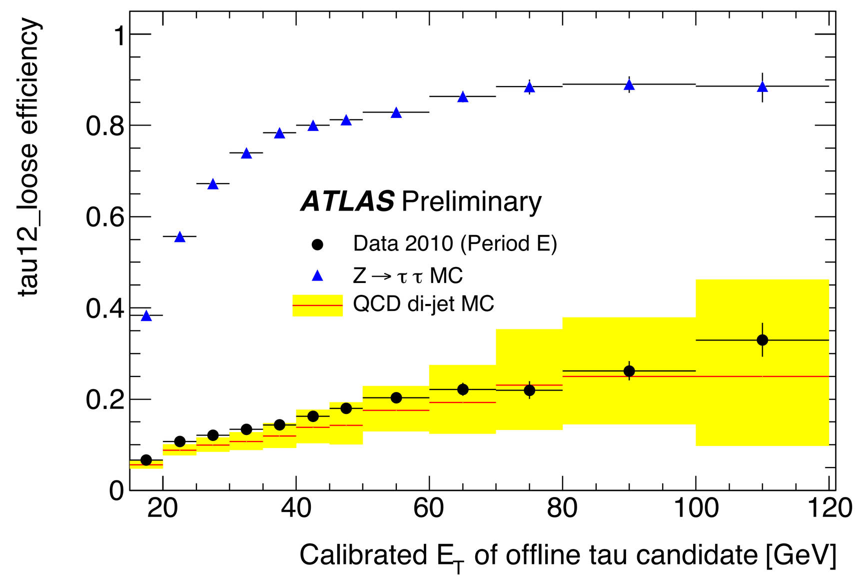
Tau trigger signal and background efficiencies

In order to demonstrate the performance of the ATLAS tau trigger, signal efficiencies for $Z \to \tau\tau$ are shown in the following.

The plot to the right shows trigger efficiencies for Monte Carlo (MC) simulated $Z \to \tau\tau$ decays. The tau16_loose HLT tau chain is seeded by the L1_TAU6 item. It is used as the tau trigger in combined lepton chains.

At L1, an efficiency of 100% is reached in the plateau region, while at L2 and EF, the efficiency is above 90% starting from a calibrated tau energy of 30 GeV.





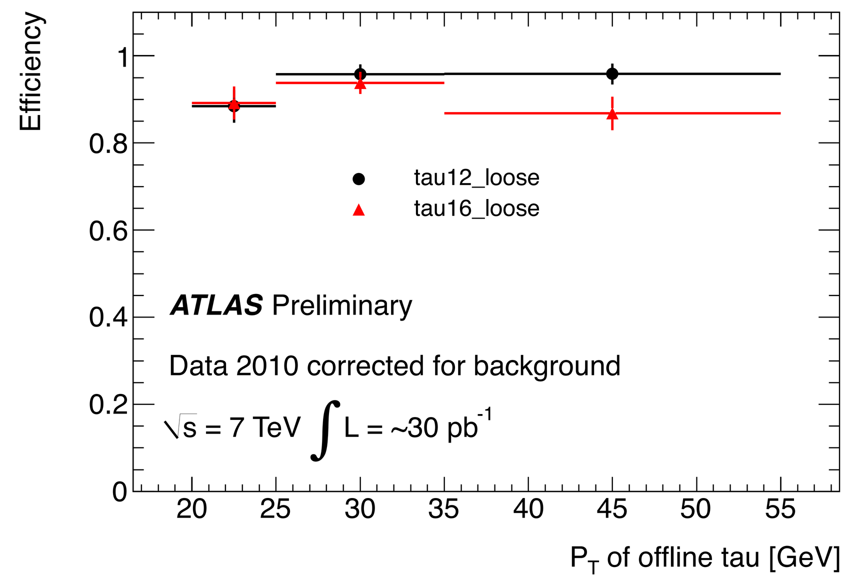
The histogram to the left shows a comparison of $Z \to \tau\tau$ signal MC to QCD di-jet background for the tau12_loose HLT chain. After the application of a loose di-jet event selection, the trigger efficiency for data taken in 2010 agrees very well with the QCD background sample after applying a tight offline tau selection. The uncertainties shown include statistics only.

For the signal, a plateau efficiency of about 90% is obtained while the efficiency for background from fake tau candidates does not exceed 30%.

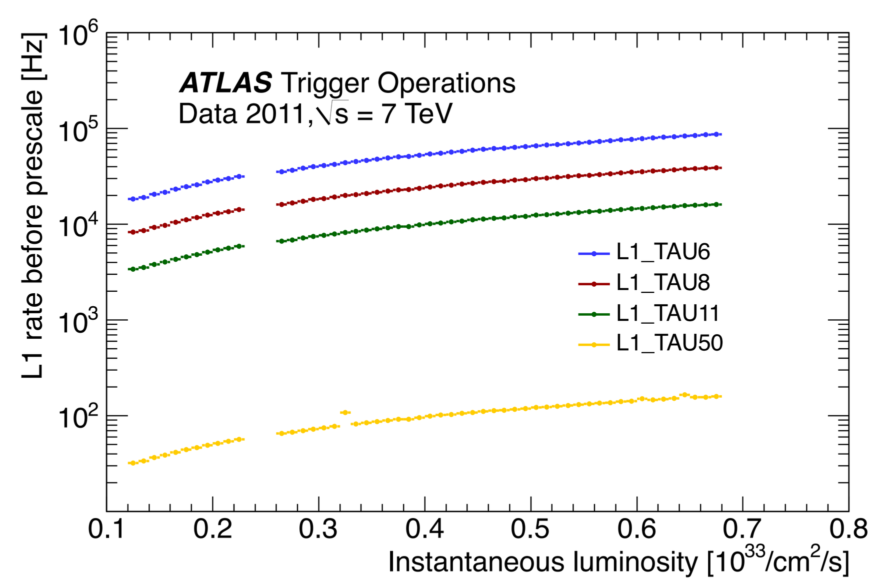
$Z \to \tau\tau$ events are commonly selected by requiring one of the taus decaying leptonically and probing for a hadronic tau decay in the event. The reconstructed invariant mass of the jet+lepton system is correlated with the true Z mass and a signal can be extracted.

Tau trigger efficiencies from combining the electron and muon channel are shown to the right for tau12_loose and tau16_loose vs. the offline tau candidate p_T. The numbers are derived from real data after correcting for background contamination.

An efficiency above 90% is obtained for the whole range of the tau candidate p_T presented here.



QCD jet rejection



In order to enrich the collected data with interesting signal signatures, it is necessary to reject as many background events as possible. Only then the rate budget for the trigger can be optimally exploited.

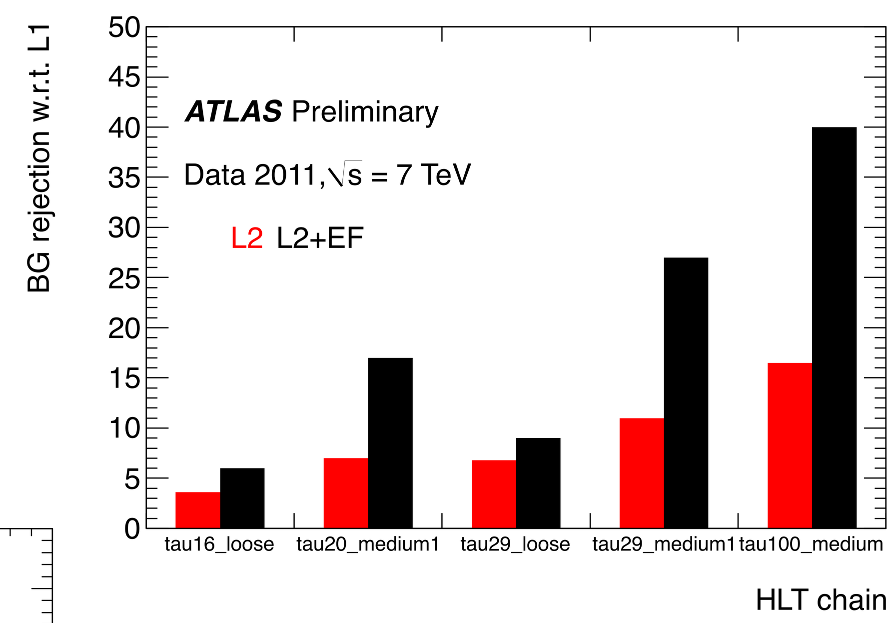
The L1 rates (before prescaling) are shown for the L1 items seeding the current primary tau trigger HLT chains as a function of instantaneous luminosity. The rates scale linearly over a large luminosity range for data taken from several ATLAS runs in 2011.

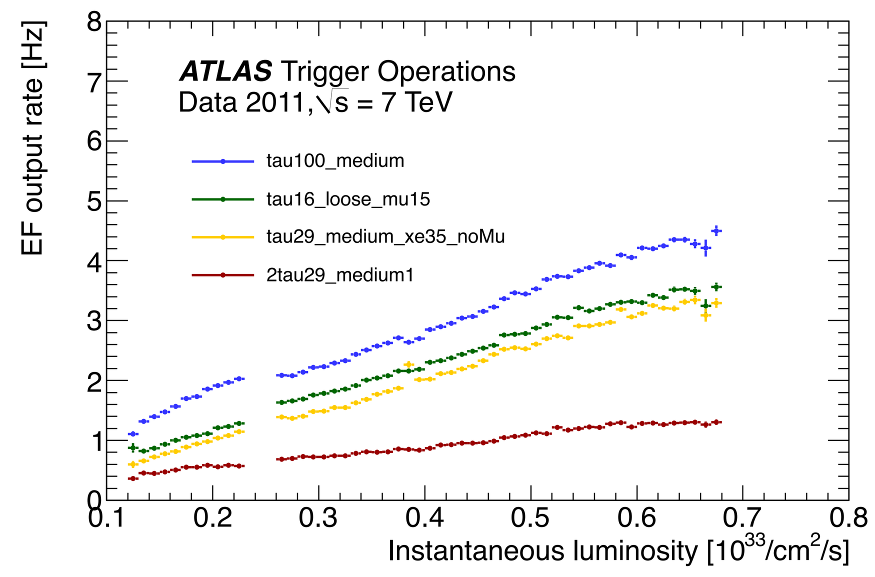
Each entry represents the rate for a given luminosity averaged over all selected data.

After the first trigger level, L2 and EF help rejecting background events which is shown in the plot to the right after L2 and after L2+EF in red and black, respectively.

The HLT chains on display are *tau16_loose*, *tau20_medium1*, *tau29_loose*, *tau29_medium1* and *tau100_medium*.

For the medium quality chains, the EF algorithms double the rejection achieved at L2 (w.r.t. L1).





As a result, the HLT output rate is significantly lower than at L1. For the same selection, four *primary* HLT chains are shown to the right.

A linear scaling of the rate as a function of instantaneous luminosity can be observed, also for combined HLT chains of tau with missing E_T and lepton triggers.

[1] *Observation of* $W \to \tau\nu$ *Decays with the ATLAS Experiment*, ATLAS-CONF-2010-097, Nov 2010