Triggering On Hadronic Tau Decays:

A Challenge Met By ATLAS

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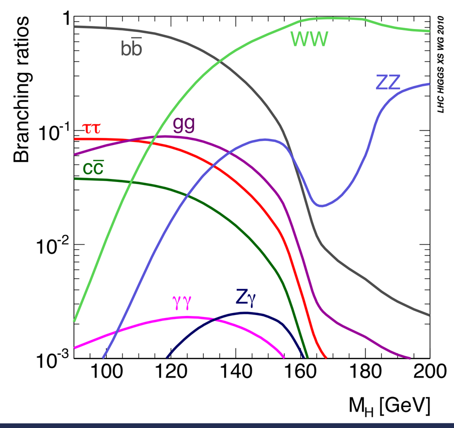
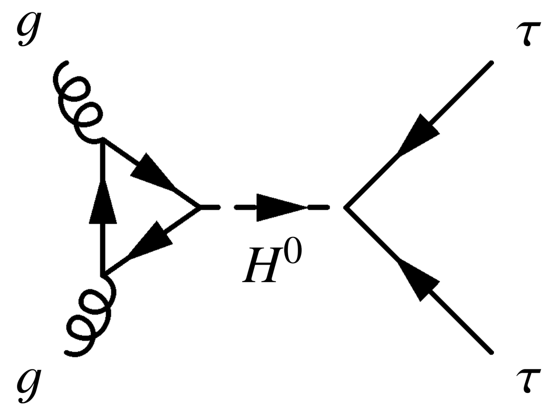
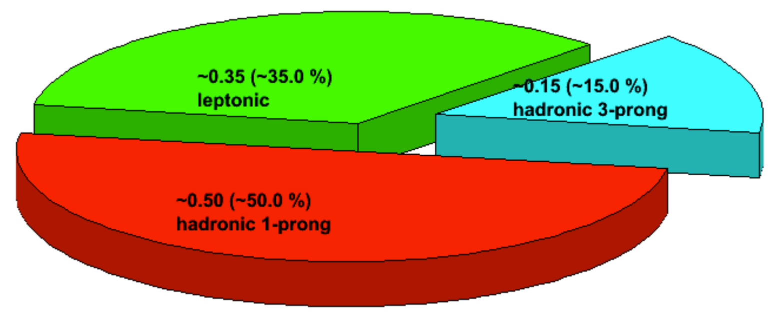
Motivation

Tau leptons play an important role in the measurement of Standard Model (SM) and Beyond the Standard Model (BSM) physics with the ATLAS detector at the Large Hadron Collider (LHC). In particular the branching fraction of Higgs decays in the SM at low Higgs mass and the minimal supersymmetric SM (MSSM) is in the order of 10% and thus contribute significantly. Triggering on hadronic tau decays is therefore an essential ingredient of these measurements.





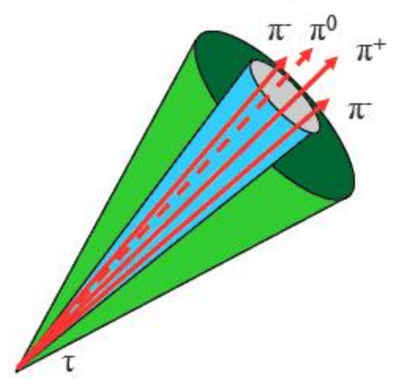


Hadronic tau decay properties

Tau leptons decay into one or three charged hadrons plus additional neutral hadrons and a tau neutrino in 65% of the time. This hadronic decay signature can be distinguished from QCD jets by the properties of the tau decays, such as:

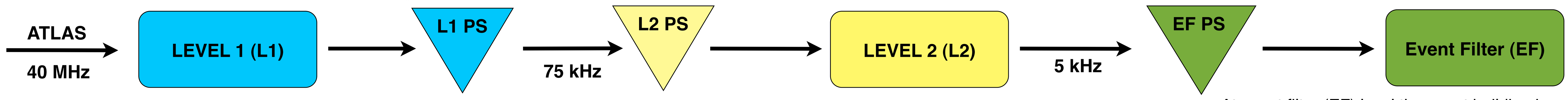
- low track multiplicity
- collimated tracks and energy deposits in calorimeter

To better distinguish these decays from background isolation criteria are applied



The ATLAS tau trigger

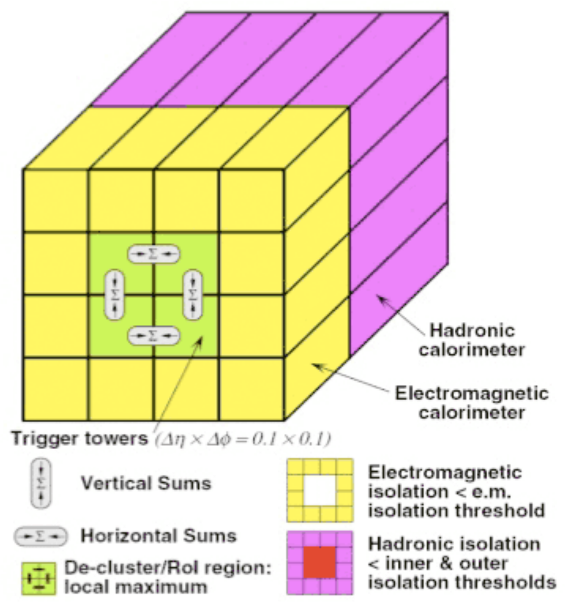
The ATLAS trigger system is designed to reduce the initial collision data rate to a feasible rate for disk storage by filtering the maximum of interesting physics events. This is achieved by a three-level trigger system. In addition a prescale factor (PS) can be applied to suppress the trigger rate at each processing level.



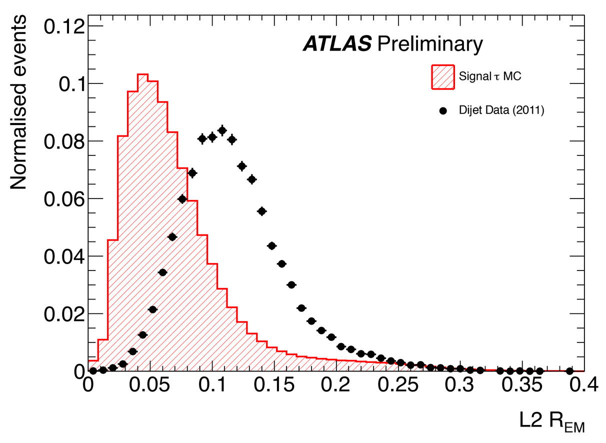
The level 1 (L1) trigger is a hardware based system using electromagnetic (EM) and hadronic calorimeter information, provided as trigger towers of size $\Delta\eta \times \Delta\phi = 0.1 \times 0.1$. A L1 tau is identified by

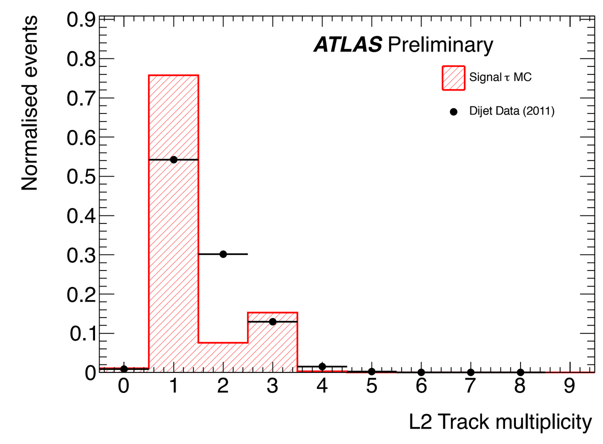
- sum of energy in 2×1 pairs of EM towers
- sum of energy in 2 × 2 hadronic towers behind the EM layers
- sum of energy in isolation region in a 4 × 4 ring around the core region of 2 × 2 towers

For a given L1 item a specific threshold is applied on the transverse energy, E_T, determined in the region-of-interest (RoI), e.g. for the L1_tau11 item $E_T > 11$ GeV is required. To cope with the high input rate an isolation criteria has to be applied in addition. A hardware prescale (PS) can be applied to further decrease the rate.

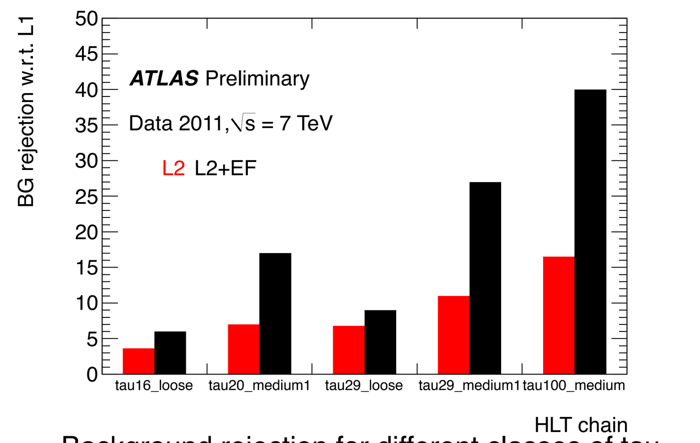


At level 2 (L2) track reconstruction starts and is used together with calorimeter information to identify taus. The full detector granularity within the RoI is taken into account. The discrimination power of the L2 is based on several identification variables measuring e.g. the narrowness of the tau decay products or the number of charged particles. In the plots the electromagnetic radius (left) and track multiplicity (right) measured at L2 are shown. MC predictions for tau signal are compared to data dominated QCD di-jet. Depending on the L2 trigger chain a PS is applied.





At event filter (EF) level the event building is performed and reconstruction as well as identification algorithms (similar to the ones used for offline analyses) are applied. For this, variables used for offline identification need to be computed. Depending on the trigger chain a PS needs to be applied to match the constraint on the output rate.



Background rejection for different classes of tau identification and different trigger thresholds.

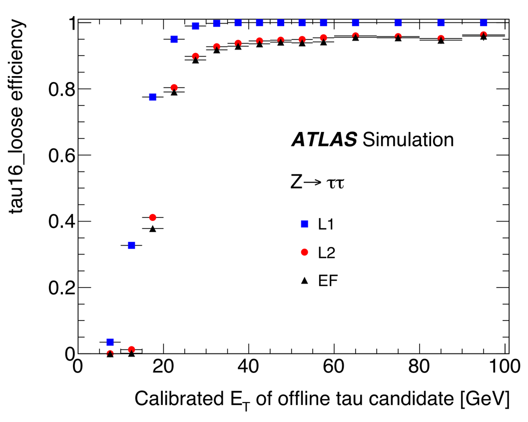
Tau trigger efficiency

For physics analyses it is mandatory to know the trigger efficiency. This is the probability for a reconstructed and identified offline tau to pass the trigger. For this purpose several methods have been used to determine the trigger efficiency, considering both Monte Carlo (MC) and data.

$Z \to \tau\tau$ Monte Carlo

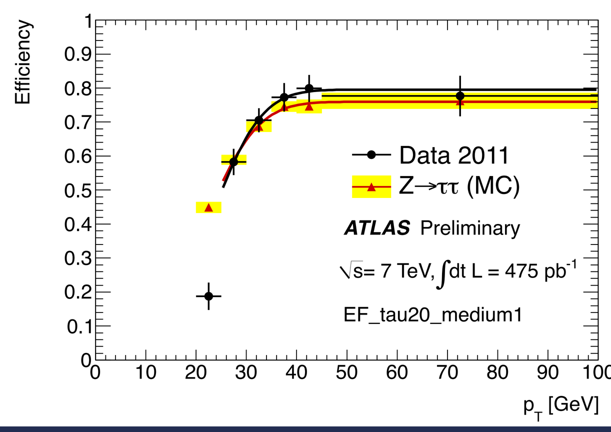
In order to measure the tau trigger efficiency, MC simulated $Z \to \tau\tau$ events have been used. The Figure below shows the trigger efficiency as a function of E_T for the EF tau trigger for a threshold of $E_T > 16$GeV and loose identification. This item is seeded by a L1 item with a threshold of $E_T > 6$ GeV.

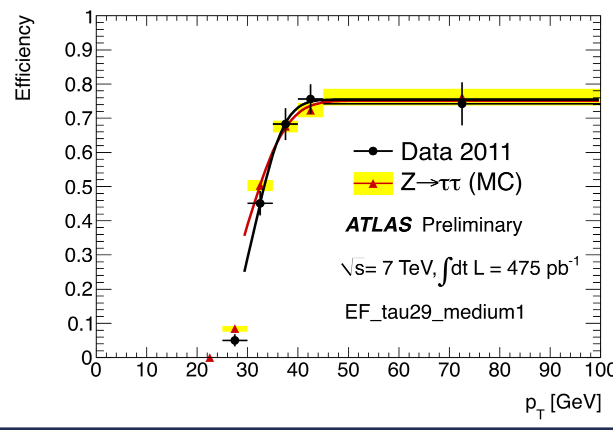
The latter does not apply any isolation criteria and thus reach 100% efficiency in the plateau.



$Z \to \tau\tau$ data

The tau trigger efficiency has been measured in data using Z boson decays into two tau leptons. For this purpose a tag-and-probe method has been applied. An event is tagged by an electron or muon from a leptonically decaying tau using an unbiased lepton trigger. On the probe side, taus reconstructed and identified by the offline algorithms are used to determine the trigger efficiency. The measured trigger efficiency of the EF for 20 GeV (right) and 29 GeV (left) E_T threshold and medium tau identification is shown.

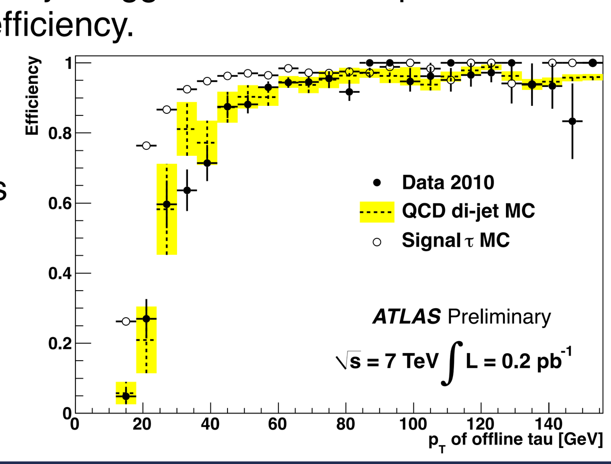




Efficiency using QCD jets in data

QCD di-jet events can be used to measure the tau trigger efficiency, in particular at large transverse momentum. The idea is that a jet faking a reconstructed tau should also fire the trigger. For this purpose a di-jet sample is selected by applying a tag-and-probe method, in which the two jets are back-to-back and balanced in p_T. The tagging jet has to fire a jet trigger whereas the probe is used to measure the tau trigger efficiency.

The efficiency of the EF tau trigger with $E_T > 16$ GeV and loose identification w.r.t. to taus identified imposing tight offline identification criteria is shown in the figure on the right.



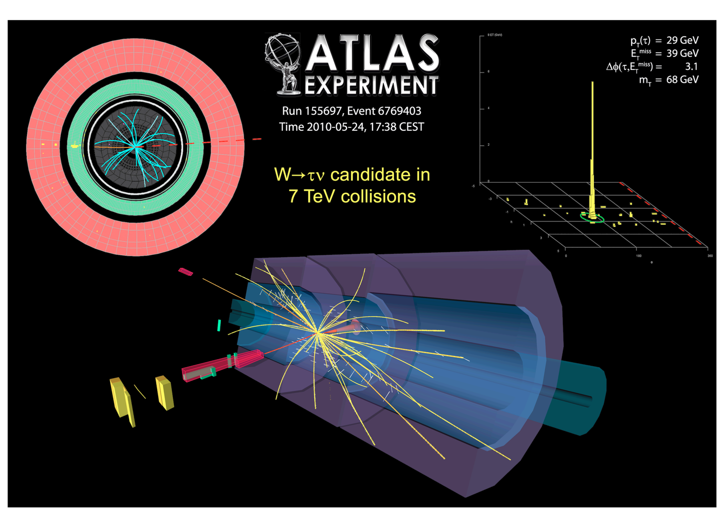
Physics with tau triggers

Due to the high rates of single tau triggers several combined items are provided and used by different physics analysis, for example:

- tau + lepton (e, μ) trigger
- tau + E_T^{miss} trigger
- di-tau trigger

Example: $W \to \tau\nu$ measurement

W decays have been measured in 2010 data with an observed signal of 55.1±10.5(stat.)±5.2(syst.) events. In this analysis a combined tau + E_T^{miss} trigger was used. One $W \to \tau\nu$ candidate is displayed on the right.



Example: $H \to \tau\tau$ search

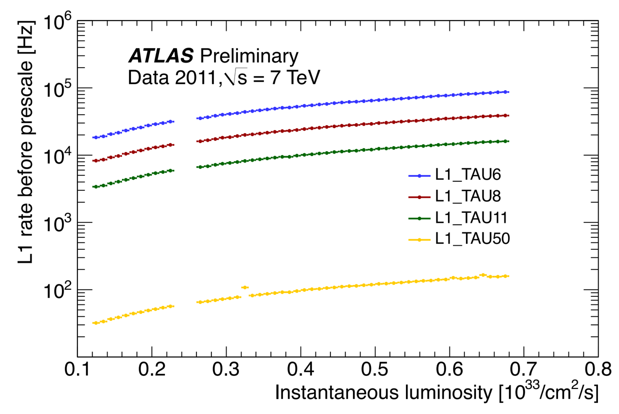
An analysis searching for SM and MSSM neutral Higgs bosons decaying into two hadronically decaying taus [2] has been performed using a ditau trigger with asymmetric thresholds of $E_T > 29$ GeV and $E_T > 20$ GeV. It could be shown that the total di-tau trigger efficiency can be factorized into the product of single tau trigger efficiencies, as displayed above.

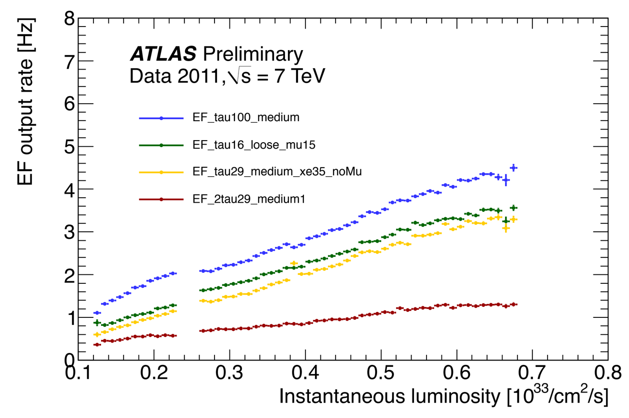
[1] Observation of W -> tau nu Decays with the ATLAS Experiment, *The ATLAS collaboration*, ATLAS-CONF-2010-97, Nov 2010
[2] Search for neutral MSSM Higgs bosons decaying to tau+tau- pairs in proton-proton collisions at sqrt(s) = 7 TeV with the ATLAS detector, *The ATLAS collaboration*, ATLAS-CONF-2011-132, Sep 2011

Tau trigger for data taking in 2012

To deal with the increase in instantaneous luminosity, associated with an increasing trigger rate, several methods can be used:

- increase of the p_T threshold
- application of isolation criteria
- increase background rejection and trigger efficiency by more advanced algorithms





The plots show the rate evolution as a function of the instantaneous luminosity for several L1 (left) and EF (right) trigger signatures and trigger thresholds.

Increasing the E_T thresholds will be insufficient to meet the requirements of the given trigger bandwidth. Therefore new algorithms based on multivariate techniques are currently developed in ATLAS.

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