Performance of the ATLAS Tau Trigger with 7 TeV Collision Data at the LHC

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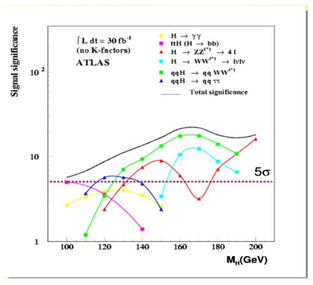
Tau leptons are a fundamental ingredient in the discovery of New Physics at the LHC. Many models for physics beyond the Standard Model predict an increase in the production of tau leptons. The reconstruction of hadronic tau decays at the trigger level, although a very challenging task in proton-proton collision environments, allows us to double the sample of tau decays collected, and provides additional discovery power to final states which include tau leptons.

In this contribution we show the understanding of the tau trigger system using data collected with the ATLAS detector at the LHC in proton-proton collisions at a center-of-mass energy of 7 TeV. We present the most relevant quantities used in the different stages of the trigger selection, and the trigger efficiencies as a function of E_T using tau-like QCD events passing the offline reconstruction and identification selection. We also present the prospects for tau trigger measurements with real taus from W and Z decays involving taus.

Motivation

Triggering on hadronically decaying taus will help in understanding the Standard Model in early running. Discovery potential with the ATLAS detector through searches for the Higgs boson and supersymmetric particles at high luminosities will also be substantially increased.

SM Higgs boson discovery potential is shown on the right. For a Higgs mass between 115 and 125 GeV, the **significance is highest** for the tau decay channel.

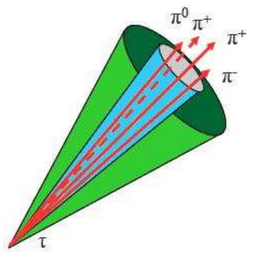


Tau Properties

The hadronic decays of taus mainly consist of one or three charged pions with a neutrino and possibly neutral pions. This leads to the following signature in the detector:

- Low track multiplicity
- Isolation
- Narrowness

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



The Atlas Trigger is designed as a 3-level system:

Level 1: latency 2.5 μs

Level 2: latency O(40 ms)

Event Filter: latency O (4 s)

LHC bunch crossing rate: 40 MHz → *L1 output rate: 75 kHz* → *HLT output rate: 200 Hz*

Level 1: Hardware, identifies geometrical Regions of Interest (RoI) for higher level systems

Level 2: Analyzes data seeded by the RoI at L1 using the full granularity of the detector with regional detector readout, without noise suppression.

Event Filter: Events accepted by L2 are analyzed at Event Filter (EF) using algorithms based on the offline reconstruction. Data is accessed as necessary from the whole detector.

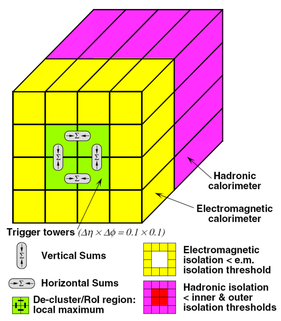
Level 1 Tau Trigger:

A hardware trigger using the electromagnetic 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 x 1 pairs of EM Towers
- Energy in 2 x 2 Hadronic towers behind EM clusters
- EM energy in isolation region (4 x 4 ring around the 2 x 2 core)

Current settings apply a relatively low threshold at L1 and use the identification power and better energy determination at High Level Trigger (HLT).

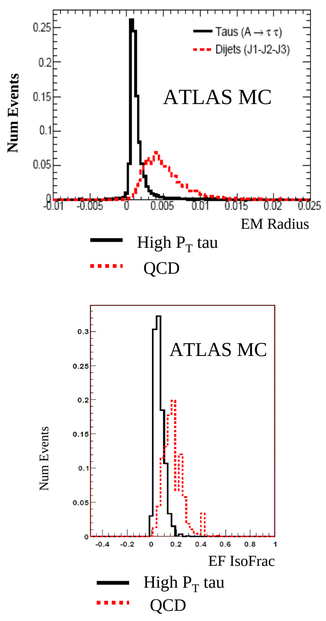


High Level Trigger

Level 2:

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

The plot shows the electromagnetic radius, which is the squared EM energy weighted cluster radius, for high p_T signal (black) and background (red).



Event Filter:

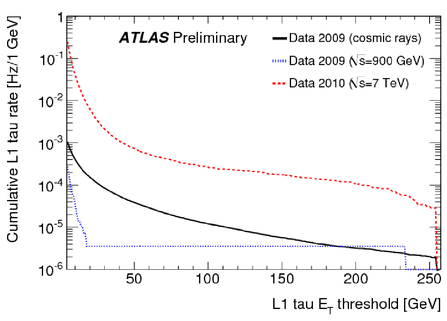
Using the L2 tau objects as seeds, the EF tau candidates are reconstructed using algorithms derived from the offline reconstruction.

Two reconstruction algorithms are available:

- calorimeter seeded
- track seeded

The EF tau candidates provide a wide range of identification variables, refined with respect to L2. **Rejection of jets at High Level Trigger is of the order 10 or more, depending on the P_T range and tightness of selection**.

L1 Tau Trigger Rates in 7 TeV Data



The plot on the left shows the cumulative L1 tau trigger rate as a function of the L1 tau object E_T threshold. It corresponds to an average instantaneous luminosity of $3.7 \times 10^{26}\ cm^{-2}\ s^{-1}$.

This plot shows that while in 900 GeV data the rate for tau triggers was much lower than in cosmic rays, in 7 TeV data the rate has greatly increased.

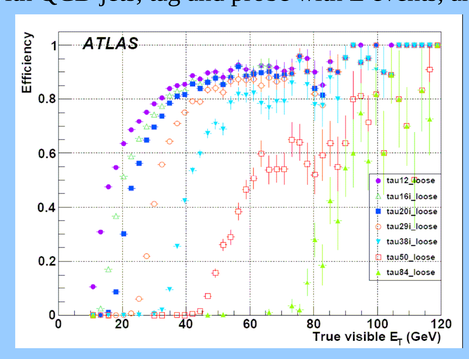
In 900 GeV data almost all triggers occurred below 20 GeV. In 7 TeV data statistics have improved significantly for higher energetic clusters.

Measurement of Tau Trigger Efficiency

Tau trigger efficiency with respect to offline reconstruction is the probability that the trigger accepts an event when a tau candidate was reconstructed by the offline algorithms. There are many methods of determining tau trigger efficiency, including fake rates with QCD jets, tag and probe with Z events, and top events for tau +MET trigger.

Tag and Probe with Real Taus:

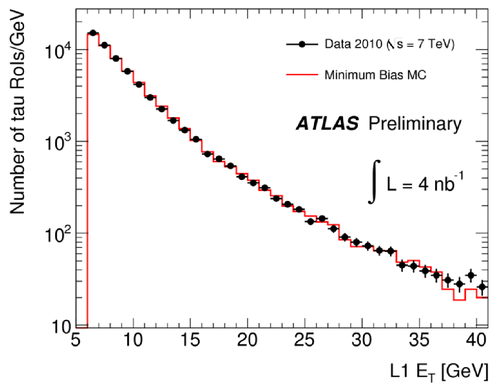
Z bosons can be used for tau trigger efficiency determination in the medium p_T range (30-60 GeV). Events are selected with single object electron or muon triggers (tag side). The tau trigger efficiency is then determined on the other side (probe side) for tau leptons reconstructed and identified offline. This selection method is expected to minimally bias the probability of a single particle tau trigger, once the overlap between offline electrons, muons, and taus has been removed.



The above plot shows the trigger efficiency for taus which are also reconstructed offline for various trigger items (produced from Z→ττ Monte Carlo Simulation).

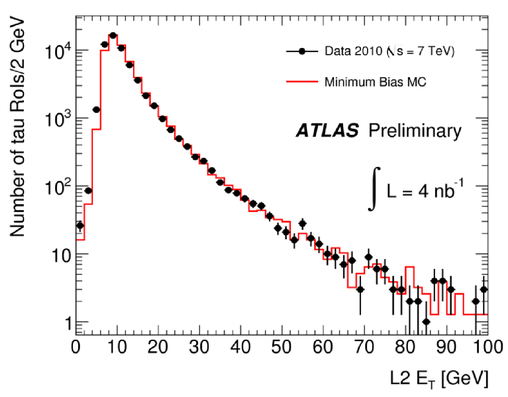
Evaluation of Tau Trigger Performance in Early Data:

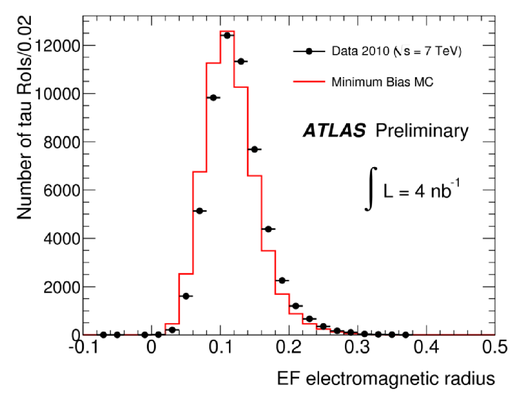
A clean sample of real hadronic tau decays will not be available in early data, therefore all possible useful information must be extracted from fake taus which are copiously produced in multijet events.



These plots show a comparison between 7 TeV data and Minimum Bias MC for important quantities at each level of the tau trigger.

- The top left plot shows the E_T distribution of the tau candidates at L1.
- The bottom left plot shows the E_T distribution of the tau candidates at L2.
- The bottom right plot shows the EM radius distribution of the tau candidates at EF.



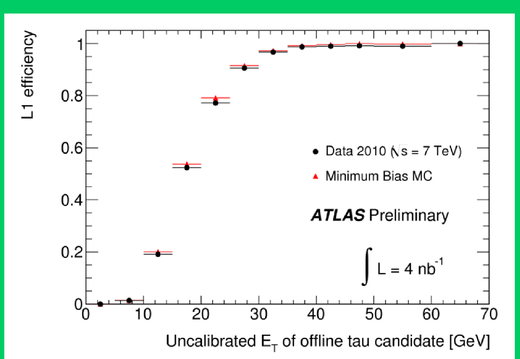


Tau Trigger Efficiency Measurements in Early 7 TeV Data:

QCD Fake Rate:

An estimate of tau trigger efficiency can be made by counting tau triggers on fake taus from QCD jets that pass offline reconstruction. The basic premise is that an object that resembled a tau sufficiently to pass the offline reconstruction algorithms should resemble a tau sufficiently to pass the hadronic tau trigger.

The plot on the right shows the fraction of the offline tau candidates matched to a L1 trigger object with ET > 5 GeV as a function of the ET of the offline tau candidate.



Menu Evolution:

Various tau trigger signatures are planned for early running and for higher luminosities. In general the p_T threshold applied at EF will be increased as luminosity increases.

In addition, different options (e.g. loose, medium, and tight) for HLT chains are foreseen for every signature. Loose is used for early running, while medium and tight are planned for higher luminosities.

For $10^{31}\ cm^{-2}\ s^{-1}$

Menu	Goal	Trigger
Single Tau	Heavy H, exotics	tau38
Tau+Lepton	Z → ττ, Higgs, SUSY	tau12+e10/ tau12+mu10
Tau + Tau	Higgs, Z	2tau12
Tau + jets	ttbar, SUSY, Higgs	tau12+3j40

For $10^{32}\ cm^{-2}\ s^{-1}$

Menu	Goal	Trigger
Single Tau	Heavy H, exotics	tau84
Tau+Lepton	Z → ττ, Higgs, SUSY	tau16+e10/ tau16+mu10
Tau + Tau	Higgs, Z	2tau29
Tau + jets	ttbar, SUSY, Higgs	tau16+3j40