PROCEEDINGS OF SCIENCE

Tracker and Calorimeter Performance for the Identification of Hadronic Tau Lepton Decays in ATLAS

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Tau leptons play an important role in the physics program in ATLAS. They can be used not only in searches for new phenomena like the Higgs boson or Supersymmetry, or for electroweak measurements but also in detector related studies like the determination of the missing transverse energy scale. Identifying hadronically decaying tau leptons requires good understanding of the detector performance, combining information from calorimeter and tracking detectors. The current status of the tau reconstruction and identification with the ATLAS detector is presented. The identification efficiencies are measured with $W \to \tau\nu$ events, and found to be consistent with the prediction from Monte Carlo simulations.

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1. Introduction

The tau lepton, with a mass of 1776.82 ± 0.16 MeV [1], is the only lepton heavy enough to decay both leptonically and hadronically. It decays approximately 65% of the time to one or more hadrons and 35% of the time leptonically. The reconstruction and identification of tau leptons are important in many searches for new phenomena [2]. Standard Model processes such as $W \rightarrow \tau\nu$, $Z \rightarrow \tau\tau$ boson production can also result in signatures with tau leptons, which can be used to measure key quantities such as the tau lepton identification efficiency.

A challenge in identifying hadronic tau decays (τ_{had}) is to distinguish them from hadronic jets. However, τ_{had} leptons possess certain properties that can be used to differentiate them from jets. They usually decay into one (1-prong) or three (3-prong) charged particles and their decay products are well collimated. The tau lepton proper lifetime is 87 μm, leading to decay vertices that can be resolved in the silicon tracker from the primary interaction vertex.

2. Tau Reconstruction and Identification

In ATLAS [3], hadronically decaying tau candidates [4] are seeded by anti-k_{t} jets [5] with distance parameter $R = 0.4$ satisfying $p_{\text{T}} > 10$ GeV and $|\eta| < 2.5$ built from three dimensional clusters of calorimeter cells [6]. Tracks reconstructed with $p_T > 1$ GeV and within $\Delta R < 0.2$ of the jet seed are associated to the tau candidate if they satisfy cuts on the impact parameter and minimum silicon hit criteria.

The energy scale of tau candidates is determined using a two-step process. In the first step, local hadron calibration [7] is applied to clusters within a radius of $\Delta R < 0.2$ of the barycentre. The resultant energy from the sum of cluster four-vectors is used for the second step of the calibration. In this step, an additional correction on this energy is applied, based on Monte Carlo (MC) studies of processes involving hadronic tau decays, to obtain the fully calibrated tau candidate energy. Uncertainties on the energy scale are determined by comparing the calibrated energy in different MC simulation samples, with realistic variations of conditions such as the hadronic shower model and dead material modelling [4].

Discrimination against background candidates from jets and electrons is provided in a separate identification step. Identification variables are reconstructed from tau candidates, based on tracker and calorimeter information [4]. Examples of such identification variables include: the core energy fraction (f_{core}), the ratio of energies at the electromagnetic scale deposited within $\Delta R < 0.1$ and $\Delta R < 0.4$ of the tau candidate; and the transverse flight path significance ($S_{\text{T}}^{\text{flight}}$), the transverse decay length significance of the reconstructed vertex of multi-prong candidates. Distributions of f_{core} for 1-track candidates and $S_{\text{T}}^{\text{flight}}$ for 3-track candidates are shown in Figure 1, for both signal (in simulated $W \rightarrow \tau\nu$ and $Z \rightarrow \tau\tau$ events) and jet background (from a dijet selection) candidates.

The identification variables are combined into discriminants to suppress background candidates from jets and electrons. ATLAS has developed three such discriminants: a cut-based discriminant, a projective likelihood, and a boosted decision tree [4]. The performance of these discriminants can be evaluated by plotting the rejection (inverse efficiency) for jets in a dijet selection against the efficiency for signal tau candidates, for both 1-track and 3-track candidates. This is shown in Figure 2.

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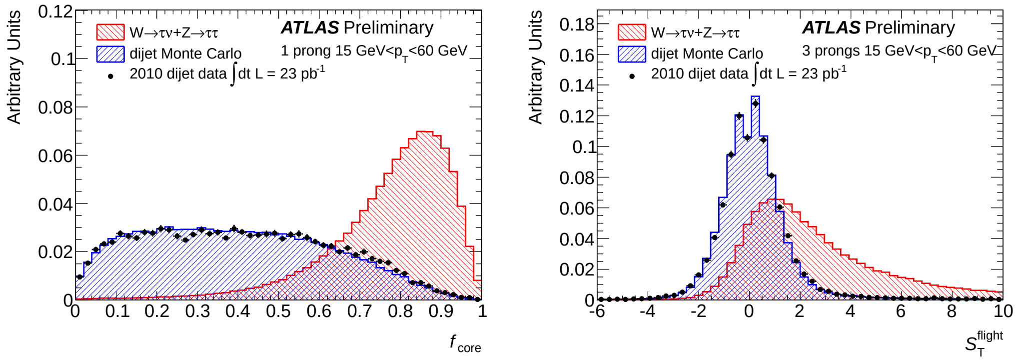

Figure 1: Two discriminating variables used for the tau identification: f_{core} and $S_{\text{T}}^{\text{flight}}$ [4]. The filled histograms are from MC simulation, the points are data with a dijet selection.

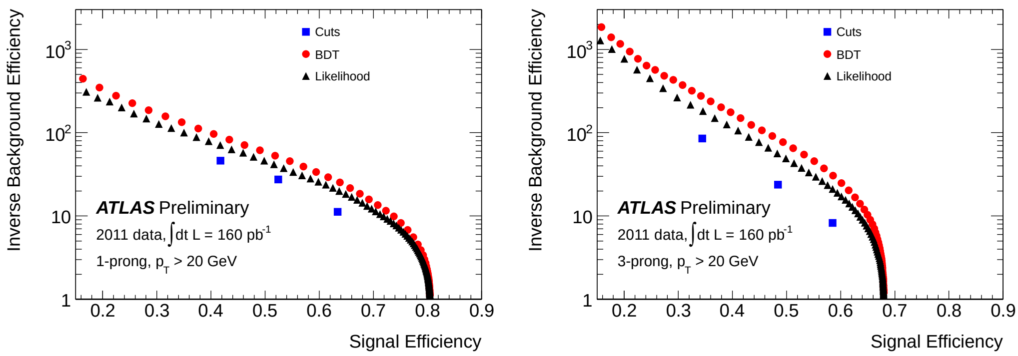

Figure 2: Inverse background efficiency in dijet data as a function of signal efficiency in $W \to \tau\nu$ and $Z \to \tau\tau$ MC events for all discriminants on 1-track and 3-track candidates [8].

3. Tau Identification Efficiency Measurements

The identification efficiency for hadronic tau decays is measured with $W \to \tau\nu$ events [9]. In the tag & probe method, events are selected with $S_{E_{\text{T}}^{\text{miss}}} = E_{\text{T}}^{\text{miss}}/(0.5\text{GeV}^{1/2}\sqrt{\Sigma E_{\text{T}}}) > 6$, where $E_{\text{T}}^{\text{miss}}$ is the missing transverse energy and ΣE_{T} is the scalar sum of cluster transverse energy. A tau candidate that is well separated from the direction of the $E_{\text{T}}^{\text{miss}}$ is required, and the tau track multiplicity is fitted before and after applying tau identification to extract the fraction of $W \to \tau\nu$ events in the sample. The track multiplicity templates for true τ_{had} leptons are taken from $W \to \tau\nu$ MC events, while for jet candidates, a template from a jet-enriched control region $2 < S_{E_{\text{T}}^{\text{miss}}} < 4.5$ is used. The tau track multiplicity before and after tau identification is shown in Figure 3.

This measurement is cross-checked with a second method that compares the observed $W \to \tau\nu$ event yield with the predicted $W \to \tau\nu$ event yield based on the measured $W \to e\nu$ and $W \to \mu\nu$ cross-sections. Both methods measure a tau identification efficiency in $W \to \tau\nu$ events that are consistent with the predicted efficiency from MC simulation [9].

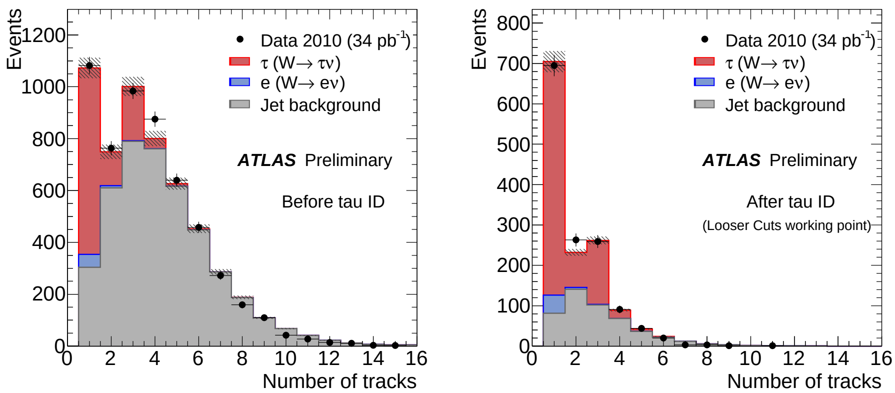

Figure 3: Track multiplicity before and after tau identification [9]. The hatching represents the systematic uncertainty. The normalisation of the different processes is determined through a fit to the track multiplicity spectrum.

4. Summary

ATLAS has developed a well-performing reconstruction algorithm to identify hadronic tau decays, enabling various measurements and searches of physics processes with tau leptons in the final state. MC predictions of the identification efficiency are shown to be consistent with measurements of the efficiency in $W \to \tau\nu$ data events.

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