Tau Reconstruction & Identification at ATLAS

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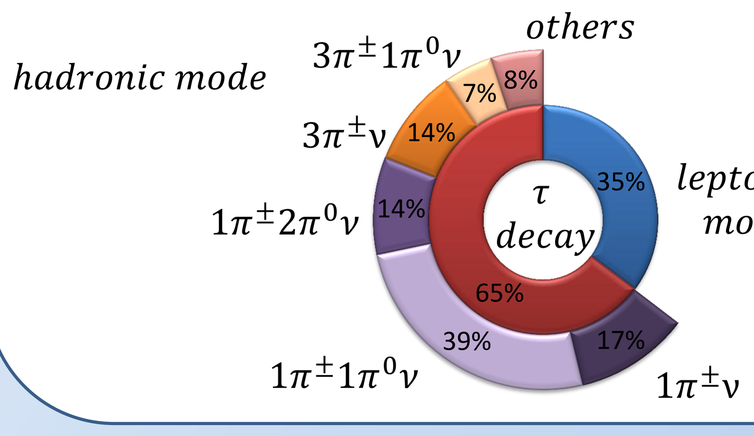
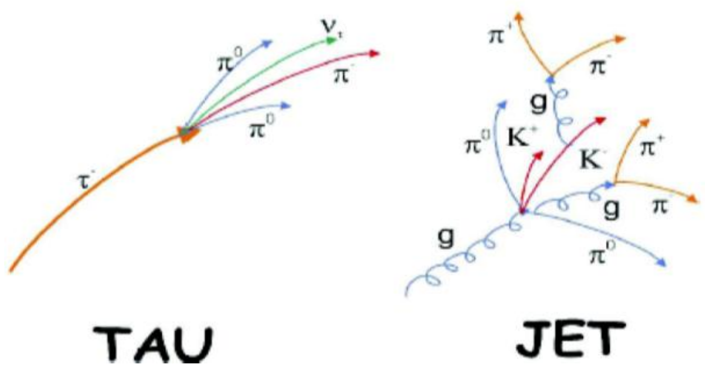
Introduction

Tau leptons are important signatures for Standard Model processes and searches for new physics. With a mass of 1.777 GeV/c^2 the tau is the heaviest lepton and due to its short lifetime of 2.9×10^{-13} seconds ($c\tau = 87\mu\text{m}$) the tau lepton decays inside the beam pipe.

In ATLAS[1] tau reconstruction and identification[2] concentrates on the hadronic decay mode of a tau lepton. Hadronic tau decays are classified according to the number of charged decay particles (prongs). These decays can be differentiated from QCD jets by their characteristics, such as low track multiplicity and collimated energy deposits.



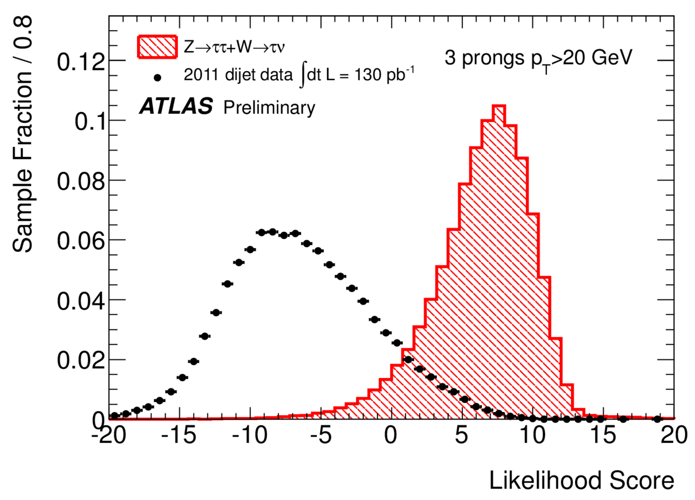


Identification

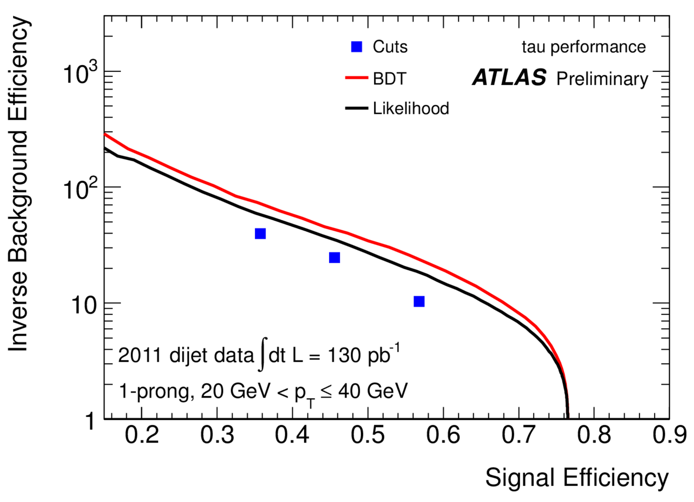
Since there is only little discrimination power between QCD jets and tau leptons in the reconstruction process a dedicated identification step is needed.

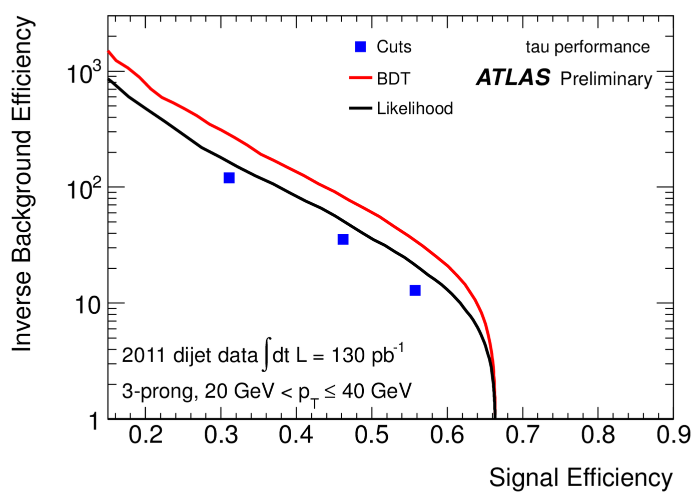
Three different methods are provided:

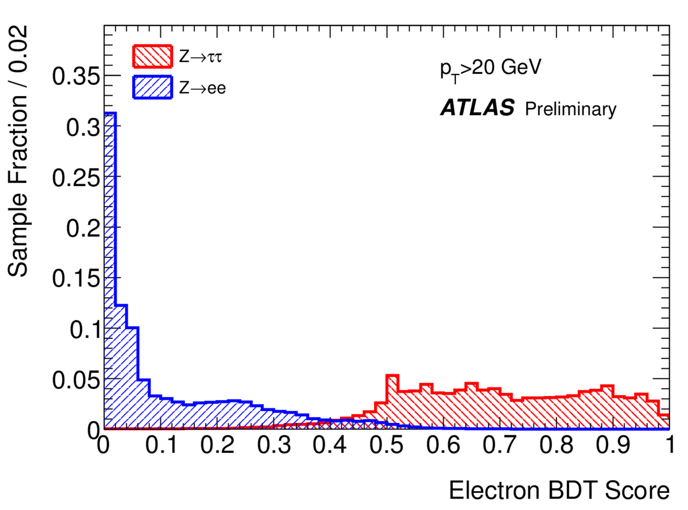
- cut-based approach
- projective likelihood (LLH)
- boosted decision trees (BDT)



They use different sets of identification variables and are separately trained for single- and multi-prong tau candidates as well as parameterized by transverse momentum of the tau candidate. In addition the likelihood and BDT is trained for different numbers of reconstructed vertices. While three dedicated working points with 60%, 45% and 30% signal efficiency are provided in the cut-based approach, the likelihood (right top) and BDT returns a continuous response. For the training of the selection algorithms the QCD background was obtained from data, while the tau decay signal is simulated in W and Z Monte Carlo samples . The inverse background efficiency versus signal efficiency for all three methods is shown for 1-prong (left) and 3-prong (right) low-p_T taus candidates.







To distinguish between electrons and tau leptons (1-prong) two vetoes – a cut-based and boosted decision tree (BDT)-based – are available. The BDT score is shown on the left. It is trained using simulated Z Monte Carlo samples.

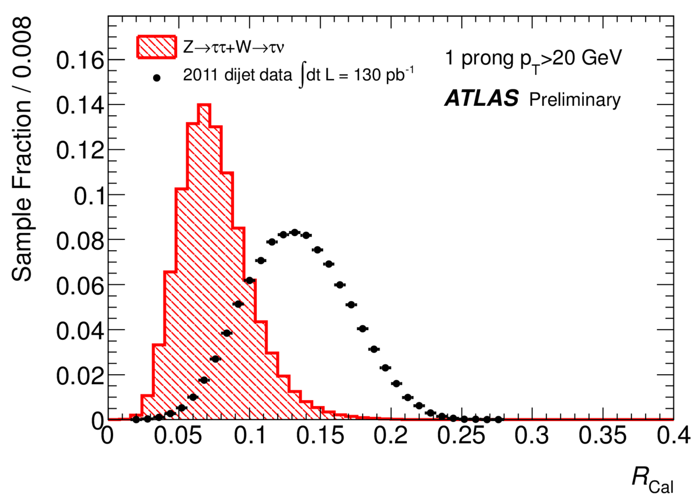
supported by: Bundesministerium für Bildung und Forschung; Physics at the Tera Scale, Helmholtz Alliance; Graduiertenkolleg Masse-Spektrum-Symmetrie

[1] The ATLAS Collaboration, The ATLAS Experiment at the CERN Large Hadron Collider, JINST 3 (2008) S08003.
[2] Atlas Collaboration, Hadronic Tau Identification Performance and Efficiency Measurement, ATLAS Note, ATLAS-CONF-2011-152

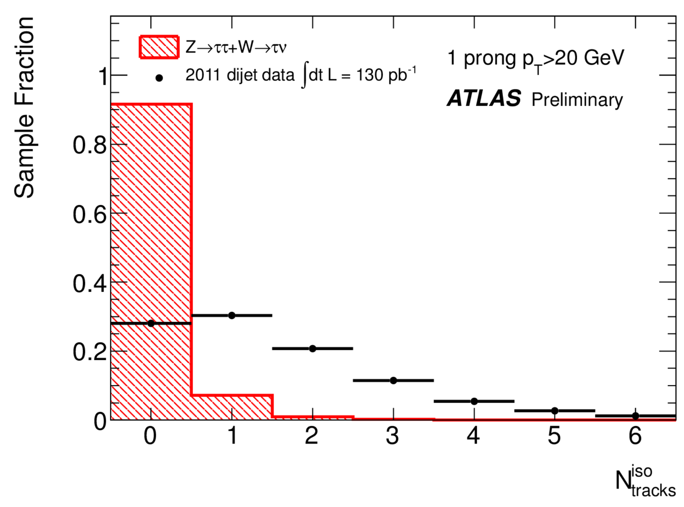
Reconstruction

Calorimeter jets with a transverse energy larger than 10 GeV and within the detector acceptance are used as a seed for tau candidates reconstruction. Tracks within a cone of $\Delta R = \sqrt{(\Delta\phi^2 + \Delta\eta^2)} < 0.4$ around the jet axis passing certain quality criteria are associated to the tau candidate and used to calculate the discriminating variables. The number of tracks within $\Delta R < 0.2$ are used to classify the tau candidate into single- or multi-prong categories.

energy weighted shower width in the calorimeter for tau signal Monte Carlo and compared to QCD di-jet data

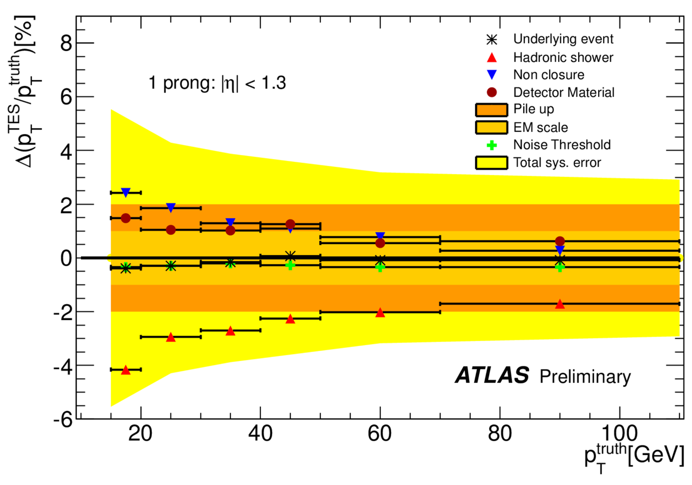


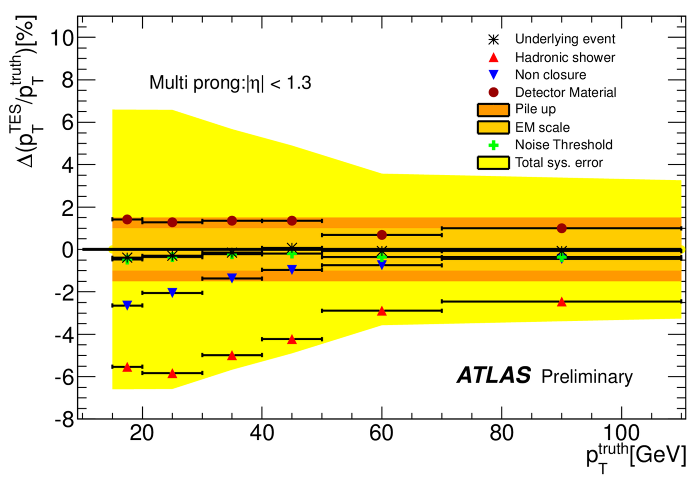
number of tracks in the isolation region of $0.2 < \Delta R < 0.4$ around the tau axis



Energy Calibration

The tau energy is calculated using all clusters within a core of $\Delta R < 0.2$ around the 4-vector sum of clusters associated with the jet seed. Calibration factors are derived from response functions using Monte Carlo simulations, where the response is defined as the ratio of reconstructed tau energy to true visible tau energy. Response functions are calculated separately for single- and multi-prong taus as well as for different detector regions as a function of p_T. The systematic uncertainties on the tau energy scale are shown for 1-prong (left) and multi-prong (right) for the barrel region and are fully derived from Monte Carlo.

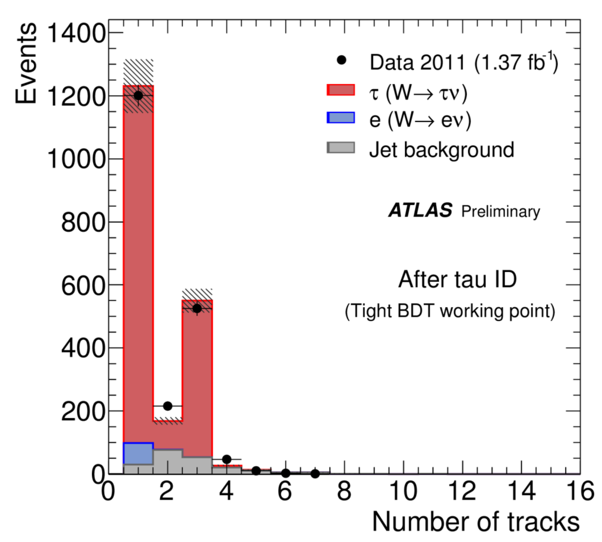


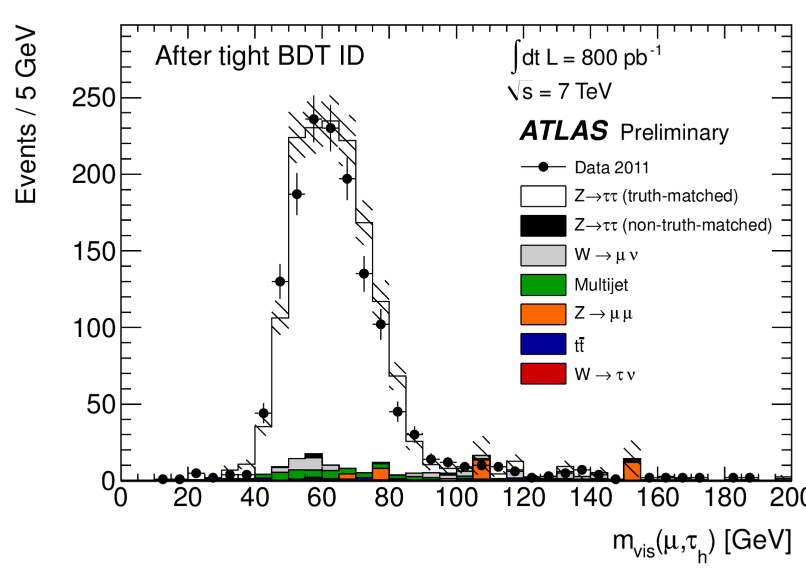


Tau Identification Efficiency Measurement

The performance and systematic uncertainties of tau identification are evaluated on data using tag-and-probe methods. To cover different spectra of possible tau p_T, two processes are used for the efficiency measurement:

$W \to \tau_h \nu$ $\quad$ $Z \to \tau_l\, \tau_h \to \mu\tau_h$





The measured efficiencies in both methods are in good agreement with Monte Carlo predictions within 5% (8 - 12%) for the $W \to \tau_h \nu$ ($Z \to \tau_l\, \tau_h$) method.