Tau Reconstruction, Energy Calibration and Identification at ATLAS^[1]

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Tau decay modes

All tau decays also involve a tau neutrino.
The leptonic modes involve two neutrinos.

Tau leptons are massive ($1.777 \text{ GeV}/c^2$) short-lived ($2.9 \times 10^{-13} \text{ s}$) particles playing a significant role in the search for the Standard Model Higgs boson and supersymmetry. They are recognized in the ATLAS detector via their hadronic decays.

The main challenge in recognizing these decays lie in differentiating them from QCD jets. Distinguishing features such as the number of final state particles, the width of the energy depositions in the calorimeter, the displacement of the secondary vertex and the small invariant mass are used to overcome this challenge.

Reconstruction

Tau candidates are found by scanning the ATLAS calorimeter for jets with a transverse energy (E_T) higher than 10 GeV. Tracks in the angular vicinity of the jet barycenter ($\Delta R = 0.2$) are associated with the tau candidate. The collected tracks and calorimeter clusters from the jet are then used to calculate a number of identification variables. Tau candidates are treated differently whether they have one or multiple tracks.

Energy Calibration

For each tau candidate, an energy scale correction is applied to the sum of the calibrated energy clusters with noise suppression found within $\Delta R = 0.2$ of the candidate's barycenter. The tau energy scale is obtained from the measured transverse momentum by scaling it to its expected value from Monte Carlo simulation of tau decays in the detector. Different response functions are derived whether the tau candidate is found to have one or many tracks, be in the barrel, the endcaps or intermediate regions of the detector.

Identification

Three separate identification methods are maintained. Each of them is based on the identification variables calculated during reconstruction. The simplest method is a cut-based approach for which the cuts have been parametrized by the transverse momentum of tau candidates. The second method (likelihood) consists of taking the logarithm of the ratio of the joint probability of the identification variables for signal over the joint probability for background. The third method consists of boosted decision trees which define regions in the multi-dimensional space defined by the identification variables. These regions are each assigned a score which tells how likely it is that they contain signal.

Identification efficiency in data^[2]

The tau identification efficiency has been measured in data using $W \rightarrow \tau \nu$ events. A first method used was to find events with large missing E , and probing for a tau candidate. The track multiplicity spectrum was monitored while applying tau identification. A second method was to assume the $W \rightarrow \tau \nu$ cross-section and compare the expected yield to the one found in data. Both methods are consistent with Monte Carlo prediction within 7-15% uncertainty.

[1] Atlas Collaboration, *Reconstruction, energy calibration, and identification of hadronically decaying tau leptons in the ATLAS experiment*, ATLAS Note ATLAS-CONF-2011-077

[2] Atlas Collaboration, *Measurement of hadronic tau decay identification efficiency using $W \rightarrow \tau \nu$ events*, ATLAS Note ATLAS-CONF-2011-093

[3] Atlas Collaboration, *Measurement of the $Z \rightarrow \tau \tau$ cross-section with the ATLAS detector*, CERN publication CERN-PH-EP-2011-097

$$\text{tau decay} \\ 3\pi^\pm + 1\pi^0 + 1\nu^\tau$$

ATLAS coordinate system

Electromagnetic radius

E_T -weighted sum of ΔR to the jet barycenter of energy depositions in the first 3 layers of the electromagnetic calorimeter. It quantifies the width of the tau candidate.

Track spectrum after tau identification^[3]

Even after applying a loose tau identification cut, the track spectrum exhibits the features of tau decays, that is prominent peaks at 1 and 3 tracks.

Z → ττ invariant visible mass

By selecting for events with a muon and a hadronic tau decay and applying various background suppression cuts, the $Z \rightarrow \tau \tau$ invariant mass peak clearly stands out in the ATLAS data.

Thanks to

$$\text{QCD jet} \\ 6\pi^\pm + 2\pi^0$$