LHCC Poster Session - CERN, 13 March 2013

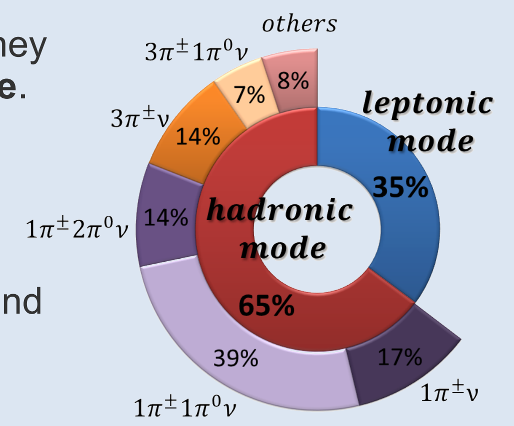
Performance of Tau Reconstruction and Identification with ATLAS

Introduction to Tau Leptons at ATLAS

Tau leptons are the third generation of charged leptons. Their mass is approximately 1.78 GeV, and they have a mean lifetime of 0.3 picoseconds. This means they typically **decay inside the LHC beam pipe**.

Tau leptons decay to hadrons (often **1 or 3 charged pions** and **neutral pions**) and a neutrino in 65% of decays and to light leptons (muons, electrons) and two neutrinos in remaining 35% of decays.

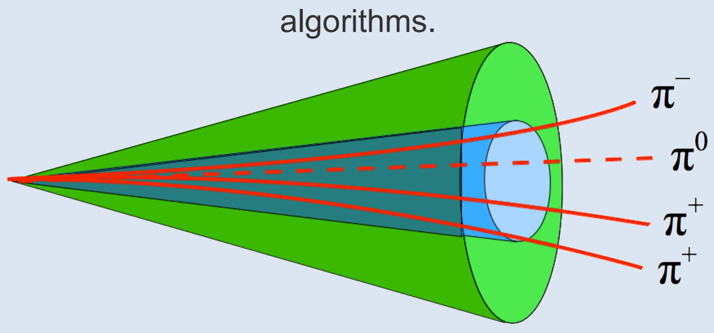
At ATLAS, algorithms exist to discriminate hadronic jets from tau lepton decays ("**taus**") from quark- and gluon-initiated jets ("**QCD jets**"). Light leptons from tau lepton decays are identified with the same algorithms as for identifying prompt light leptons.



Tau Reconstruction

Tau candidates are seeded by **anti-k_t** (R=0.4) jets with p_T > 10 GeV and |η| < 2.5.

Tracks in the **core cone** (ΔR < 0.2) of the tau axis are associated to the tau candidate. Tracks in the **isolation annulus** (0.2 < ΔR < 0.4) of the tau axis are used for isolation variables in identification algorithms.



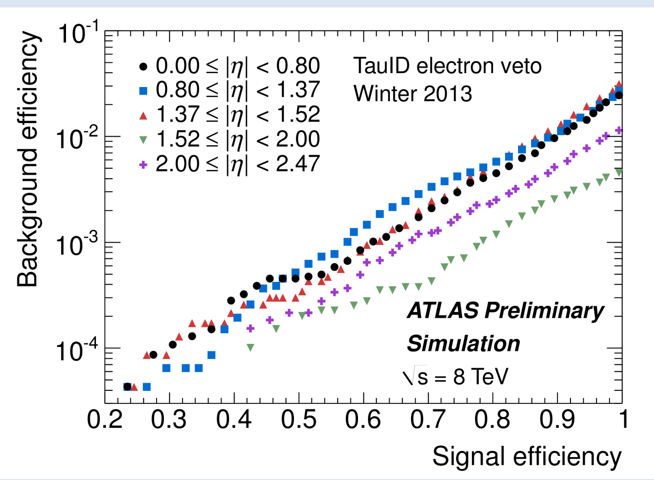
Topological clusters are made from calorimeter cells using a local hadron calibration.

The Tau-Jet Vertex Association (TJVA) algorithm is used to identify the primary vertex for each tau candidate. This ensures track association is **robust against pile-up conditions**.

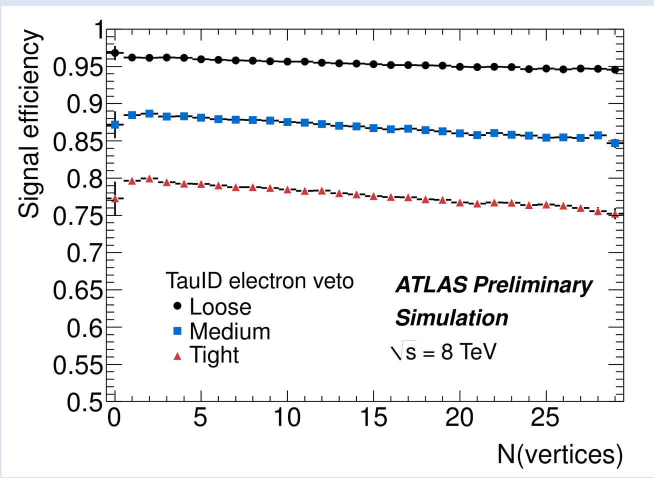
Tau Identification: Discrimination against electrons

The characteristic 1-prong signature of taus can be mimicked by electons, even those which fail dedicated electron identification algorithms. A BDT algorithm is trained with MC to discriminate taus against electrons. Its efficiency has been measured in data and MC.

Electrons tend to emit **more transition radiation**, have **narrower calorimeter showers**, and have **shallower calorimeter showers** than taus.



Performance of the Winter 2013 electron veto. Tau candidates do not overlap with any reconstructed electrons passing tight identification.



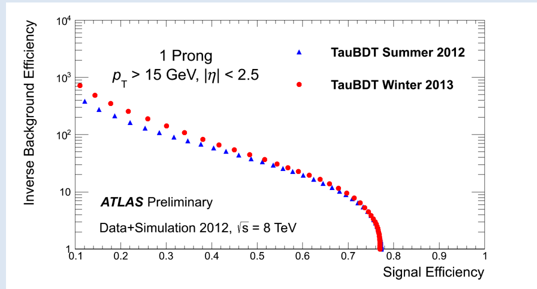
Signal efficiency of the Winter 2013 electron veto as a function of the number of reconstructed vertices.

Tau Identification: Discrimination against jets

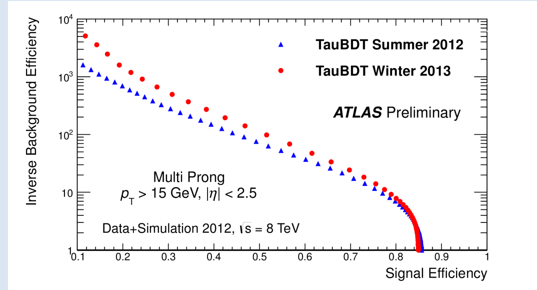
Discriminating taus from QCD jets at a hadron collider is challenging because they have similar signatures and QCD jets are produced at a much higher rate. A Boosted Decision Tree (BDT) algorithm is trained on MC for taus and data for QCD jets to discriminate these objects.

- QCD jets tend to have **more associated tracks** than taus
- QCD jets tend to have **more broadly spaced tracks** than taus
- QCD jets tend to have **wider calorimeter showers**, in both the ECAL and HCAL, than taus
- QCD jets tend to have **no displaced secondary vertex**, whereas taus (especially multi-prong) sometimes do

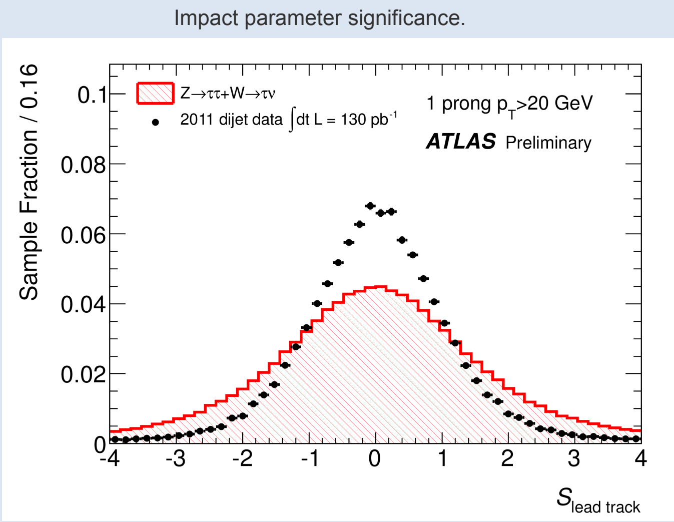
In the Winter 2013 tau ID, neutral pion information is used to enhance performance. This information is obtained from a dedicated BDT algorithm trained to determine the presence and kinematics of neutral pions in a tau candidate.



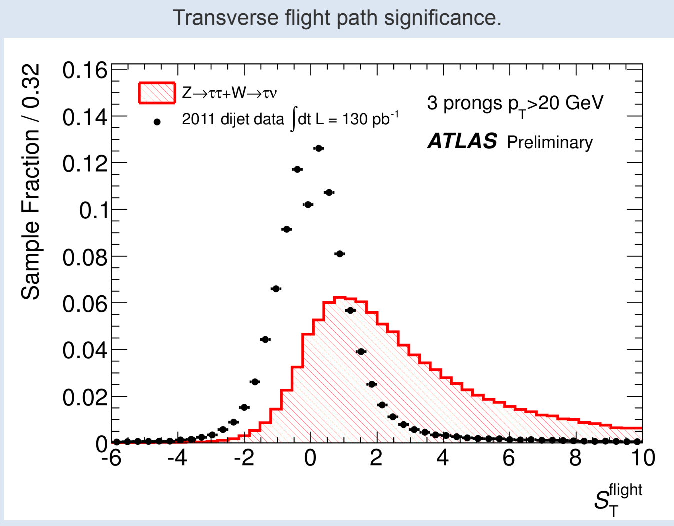
Performance of the Summer 2012 and Winter 2013 tau ID for 1-prong (above) and multi-prong (below) tau candidates.



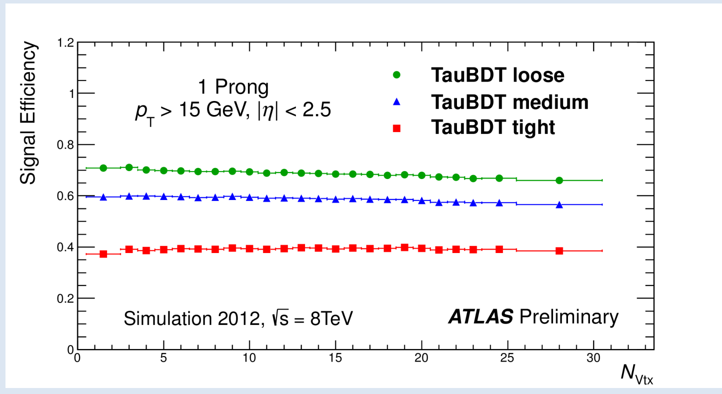
Impact parameter significance.



Transverse flight path significance.



Efficiency of the Winter 2013 tau ID for 1-prong tau candidates for signal tau candidates as a function of the number of reconstructed vertices.



Tau Identification: Efficiency in data

It is important to check how well tau identification is modeled in MC. This is done by measuring the tau identification efficiency in data via a "**tag-and-probe**" approach in three processes:

h = hadrons

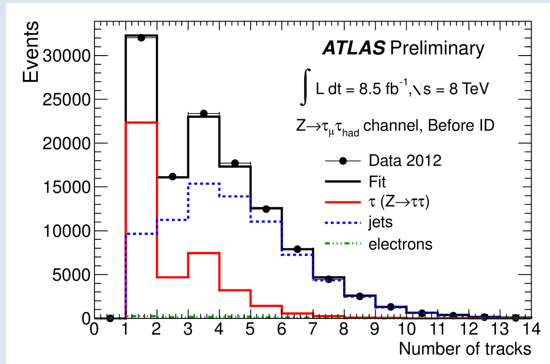
$Z \to \tau\tau \to h\nu\mu\nu\nu$ $Z \to \tau\tau \to h\nu e\nu\nu$

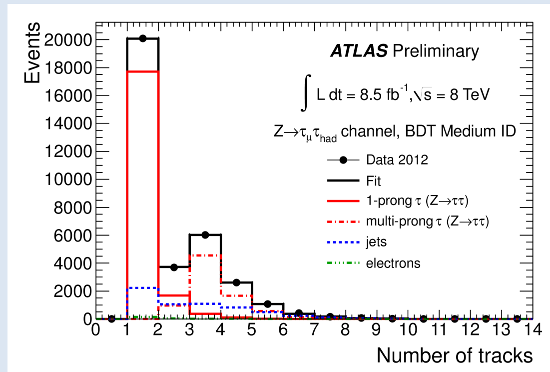
$W \to \tau\nu \to h\nu\nu$

The **number of tracks is fit** for each process, before and after tau identification, to measure the efficiency in data and in MC. Templates for the number of tracks are taken from data for QCD jets and MC for tau and electrons.

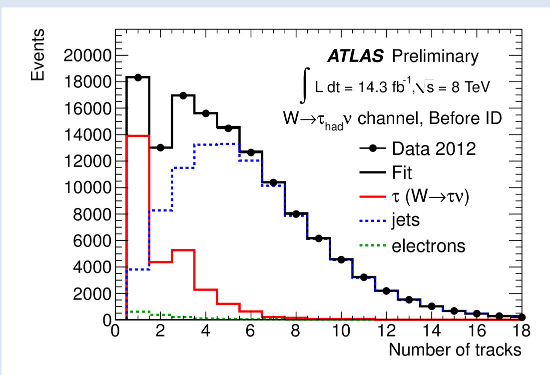
Ratio of efficiency measured in data divided by efficiency measured in MC and associated error for Summer 2012.

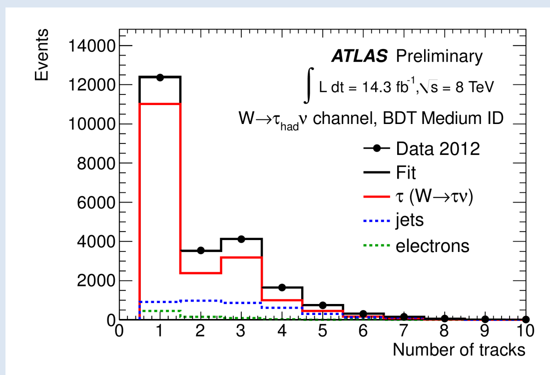
BDT Medium ID	|η| ≤ 1.5	|η| > 1.5
1-prong	0.978 (0.030)	0.957 (0.024)
Multi-prong	1.039 (0.052)	0.992 (0.059)





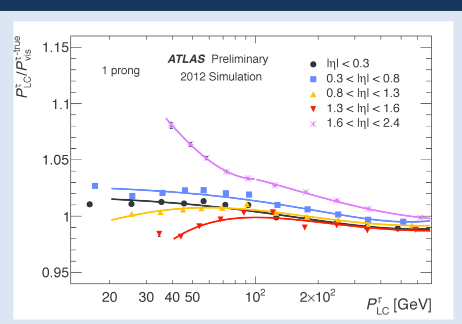
Fitted number of tracks before (left) tau ID and after (right) for Z (above) and W (below) processes.

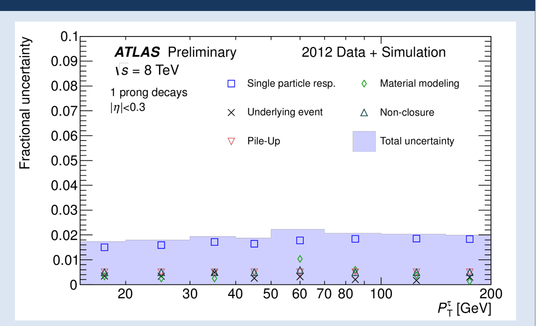




Tau Energy Scale

The reconstructed tau energy is **calibrated to the true visible tau energy** starting from calorimeter clusters in the core cone of the tau candidate. This calibration is needed to account for effects from pile-up interactions, the underlying event, energy lost before the calorimeters, out-of-cone information, and the non-compensating nature of the calorimeters. The response curves are derived from MC.



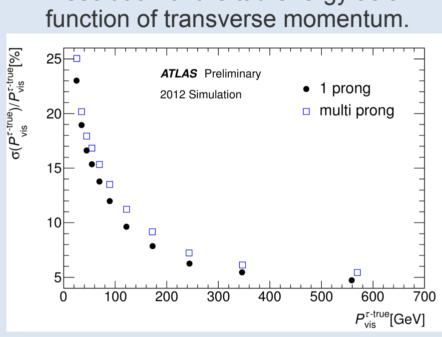


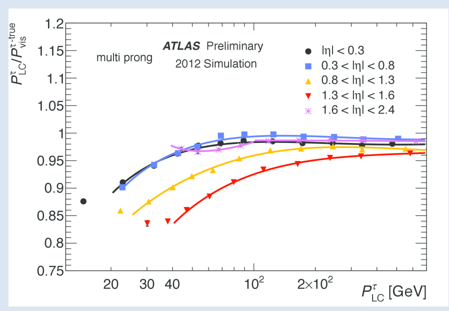
Response curves for 1-prong (above) and multi-prong (below) tau candidates.

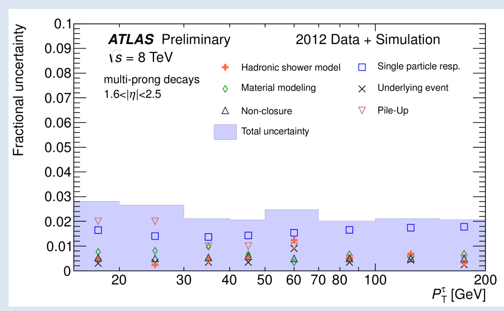
Fractional energy uncertainty for 1-prong (above) and multi-prong (below) tau candidates.

The systematic uncertainty for the tau energy scale is a combination of uncertainties from propagating **single particle response measurements** ($\pi^{\pm}$, π^0) from data to the tau candidate and additional uncertainties (e.g., shower shape uncertainty).

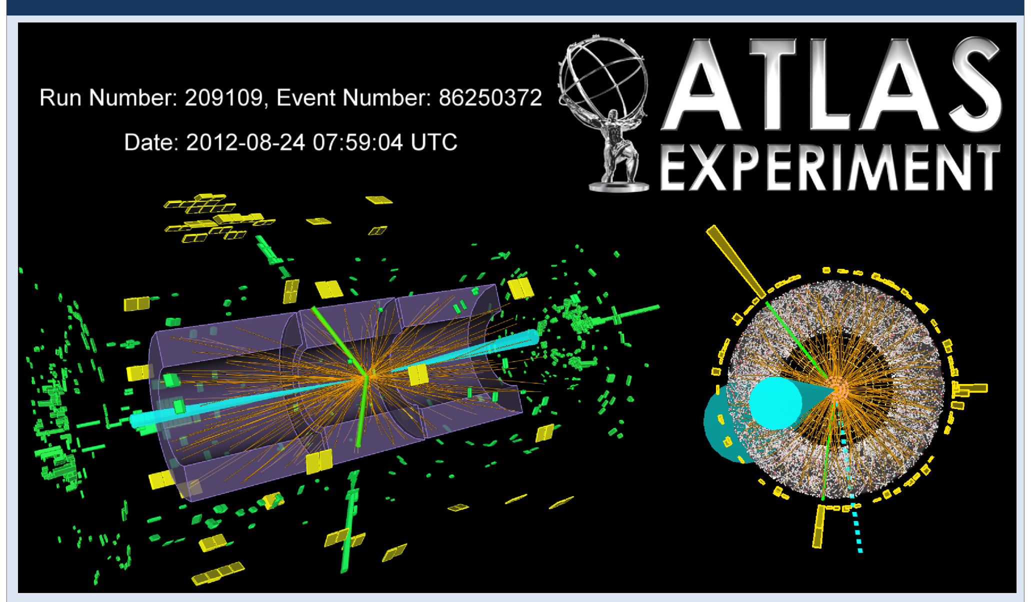
Resolution of the tau energy as a function of transverse momentum.







Taus in the ATLAS detector



Display of an event selected by the $H \to \tau\tau \to h\nu h\nu$ analysis in the VBF category. The tau candidates are indicated by green tracks.

Reference material: The ATLAS collaboration, Performance of the Reconstruction and Identification of Hadronic Tau Decays in ATLAS with 2011 Data, ATLAS-CONF-2012-142.
The ATLAS collaboration, Performance of the Reconstruction and Identification of Hadronic Tau Decays with ATLAS, ATLAS-CONF-2011-152.
The ATLAS collaboration, Determination of the tau energy scale and the associated systematic uncertainty in proton-proton collisions at sqrt(s) = 7 TeV with the ATLAS detector at the LHC in 2011, ATLAS-CONF-2012-054.
The ATLAS collaboration. Tau Public Collision Plots. https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TauPublicCollisionPlots

Alexander Tuna (University of Pennsylvania), for the ATLAS Collaboration