Tau Identification in ATLAS

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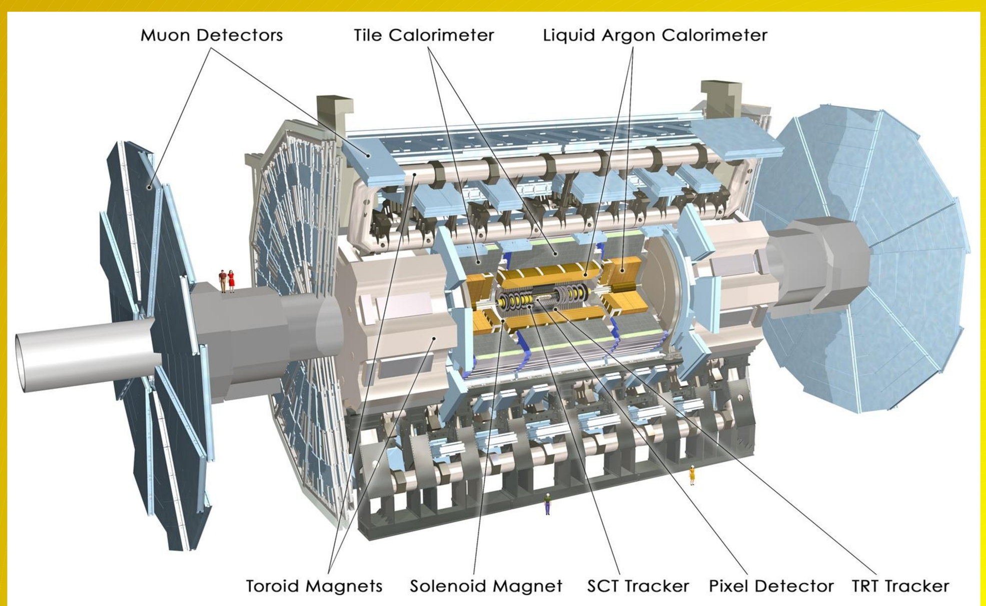
The tau lepton, with a mean lifetime of $2.9 \cdot 10^{-13}$ s, decays inside the ATLAS beam pipe, so that its decay products can be measured.

The ATLAS Detector

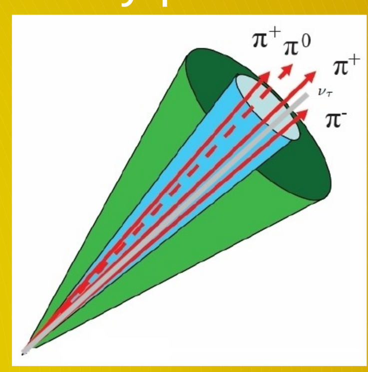


It can decay leptonically into $e\nu_e\nu_\tau$ or $\mu\nu_\mu\nu_\tau$ with 35% probability or into hadrons with 65% probability.

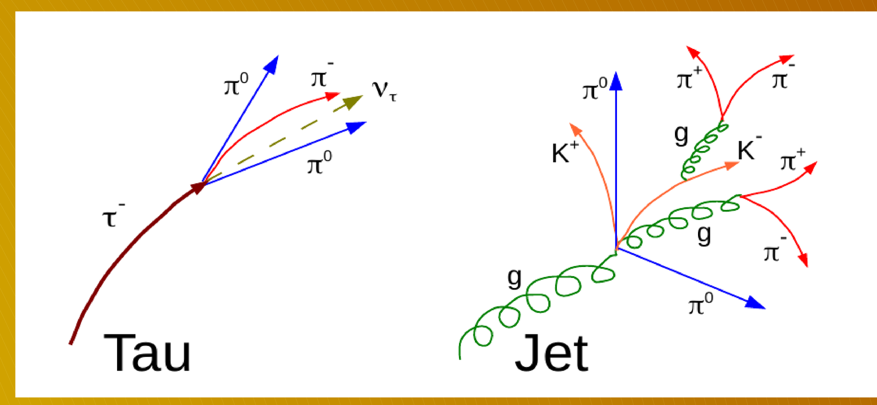
Tau identification in ATLAS is only concerned with hadronically decaying tau leptons since leptonic decays are hard to distinguish from primary electrons or muons.

QCD processes are the most challenging background for tau reconstruction and identification due to their large cross section and similar signatures. Electrons can also fake tau candidates.

Reconstruction cone around tau decay products.



Characteristic differences between quark or gluon jets and taus can be used to distinguish them on a statistical basis.



Tau decay signature compared to gluon jet signature.

Three independent tau identification methods are provided: a cut based one, a projective likelihood and a boosted decision tree. They are based on variables with discrimination power against background processes.

Cut-based Identification

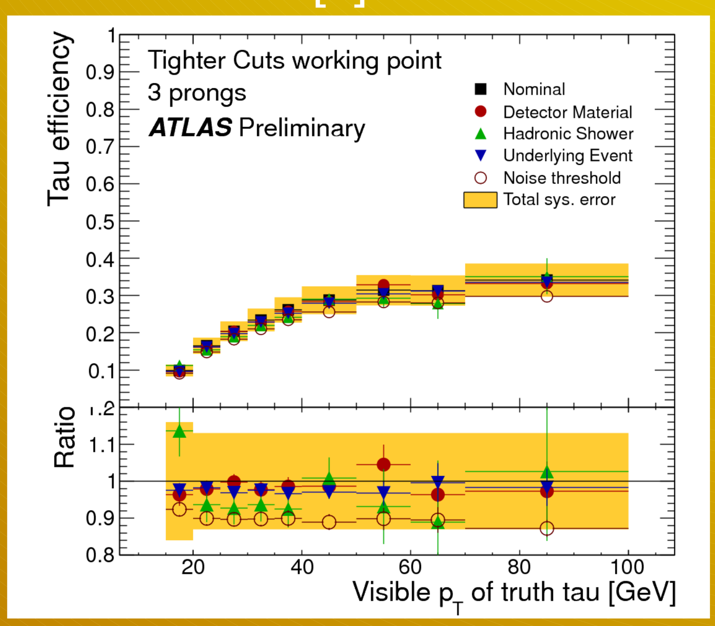
The cut-based tau identification method uses **three variables**: the electromagnetic radius, $\mathbf{R_{EM}}$, the track radius, $\mathbf{R_{track}}$ and the momentum fraction of the leading track, $\mathbf{f_{track}}$.

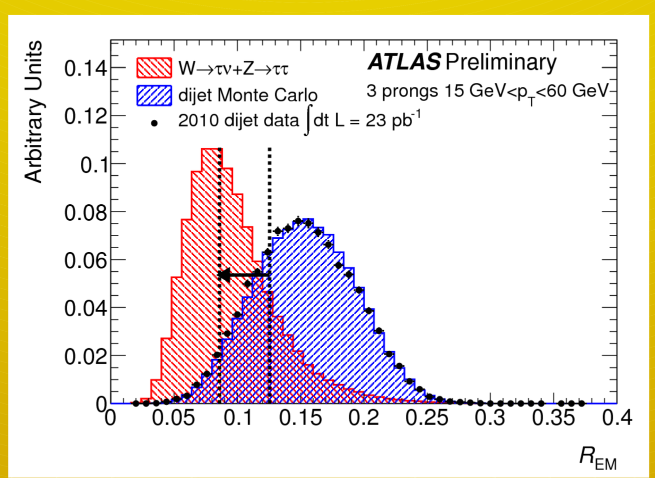
The cuts are optimised for **1-prong** and **3-prong** tau decays separately. The cuts on R_{EM} and R_{track} are **p_T dependent** because of the **Lorentz boost** of the hadronic tau decay products:

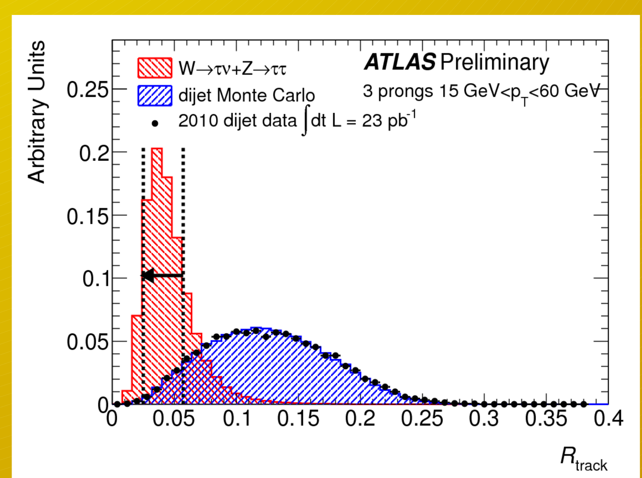
$$R(p_T) \propto 1/p_T$$

A **looser** and a **tighter** working point are available with tau identification efficiencies of approx. **60%** and **40%, respectively.**

Cut-based tau identification efficiency and systematic uncertainties [1].

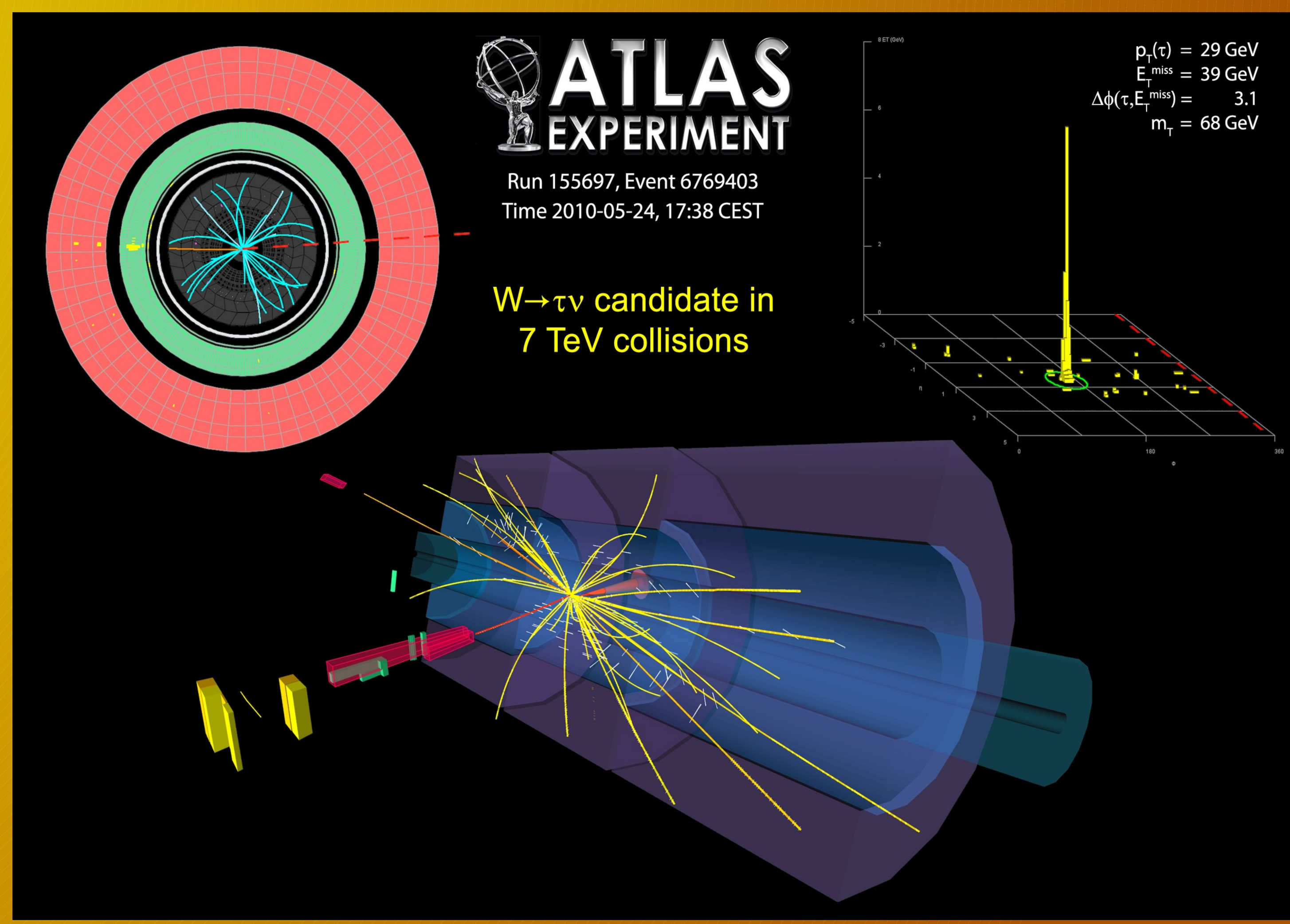






Distributions of discriminating variables used in the cut-based identification. Shown are signal from Monte Carlo samples, and background for both dijet data compared with Monte Carlo predictions. The cuts for tau leptons with p_T of 20 GeV to 60 GeV are indicated as vertical lines.

$W \rightarrow \tau_h \nu$ event candidate in 7 TeV proton-proton collisions measured with the ATLAS detector.



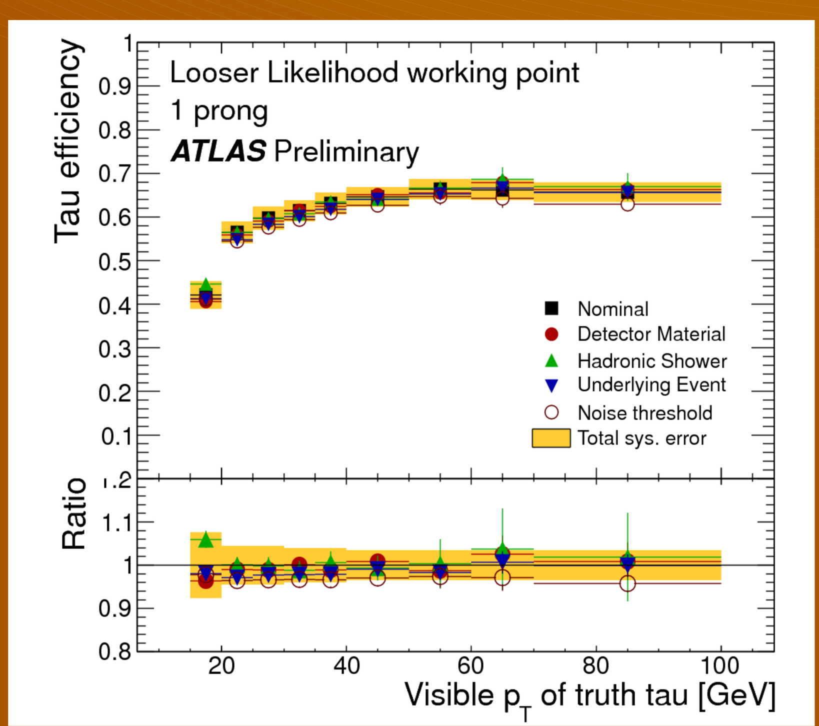
The hadronic tau identification efficiency is measured by $W \rightarrow \tau_h \nu$ and $Z \rightarrow \tau\tau$ events.

Projective Likelihood

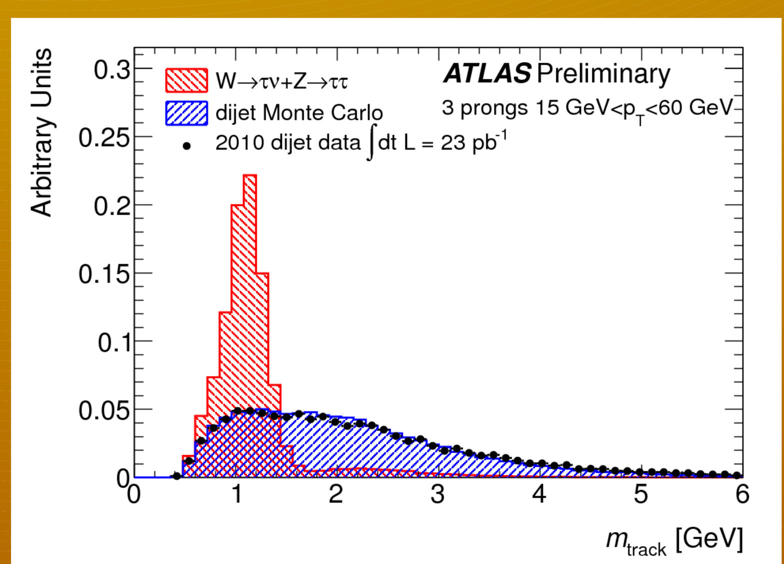
The **likelihood-based identification** uses three discriminating variables for 1-prong tau decays and five for 3-prong tau decays.

The likelihood function is a product of the **probability density functions** of the variables for signal and background:

$$L_{S(B)} = \prod_i p_i^{S(B)}(x_i)$$



Tau identification efficiency and systematic uncertainties for the likelihood as a function of p_T of the tau candidate [1]. The overall systematics is shown as a yellow band.

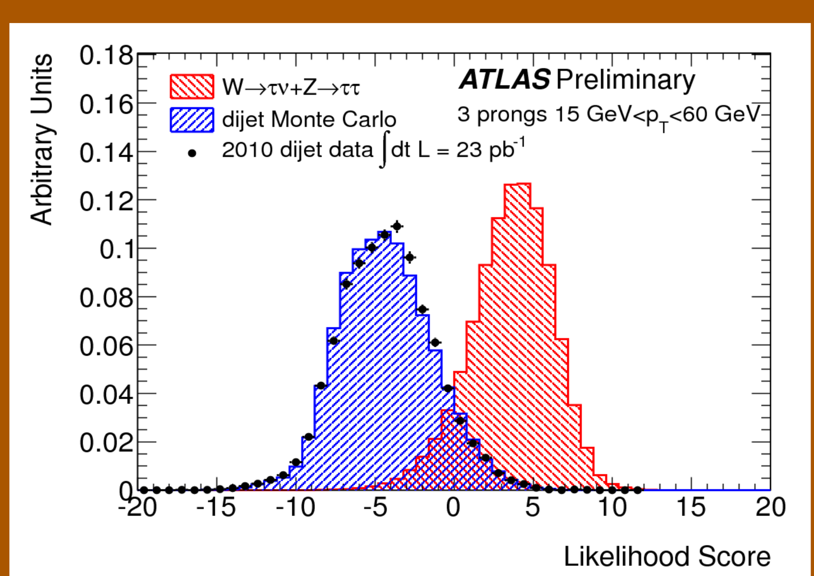


The likelihood score to discriminate signal and background is calculated as:

$$d = \ln\left(\frac{L_S}{L_B}\right) = \Sigma_i \ln\left(\frac{p_i^S(x_i)}{p_i^B(x_i)}\right)$$

A looser and a tighter cut on the likelihood score are defined to have identification efficiencies of approx. 60%, and 40%, respectively.

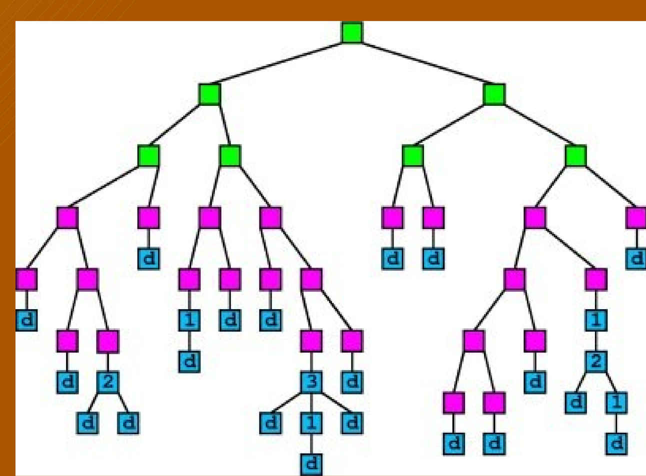
Likelihood score for signal Monte Carlo and dijet collision data compared with Monte Carlo predictions.

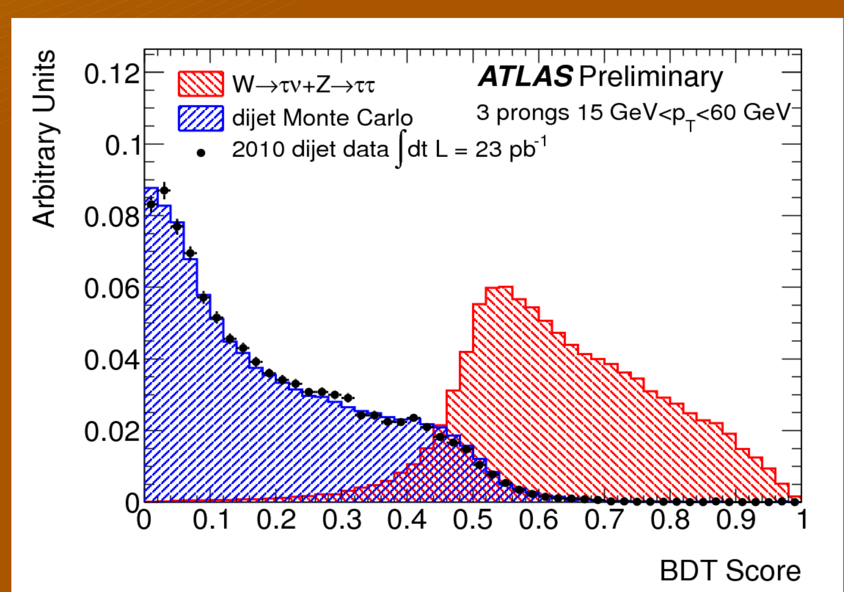


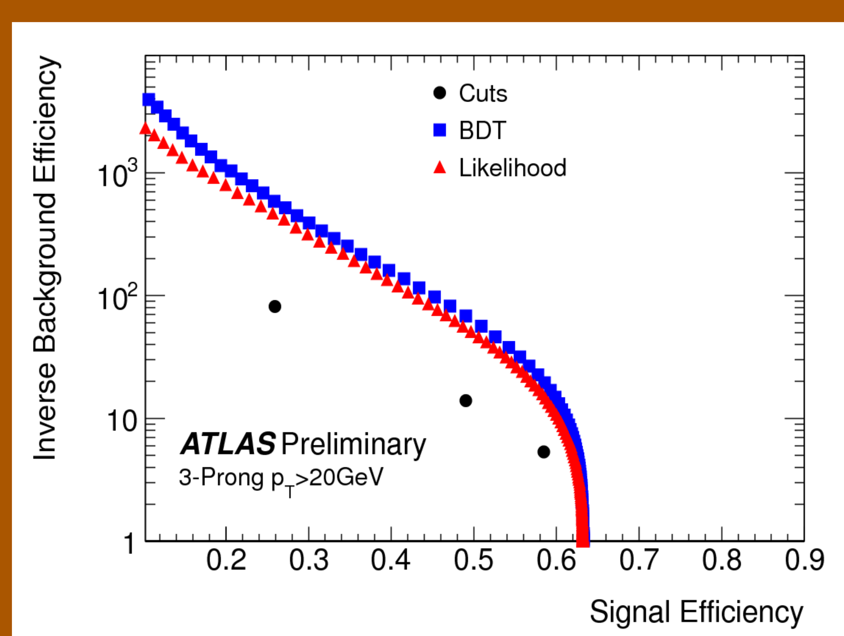
Boosted Decision Tree

The identification with **boosted decision trees** uses up to **nine variables** in a **series of cuts**.

These cuts are applied **recursively** to classify tau candidates by assigning a **continuous score** between 0 (backg.-like) and 1 (signal-like).







Multiple decision trees are used, where each tree is aimed to correctly classify tau candidates misclassified by the previous decision tree.

The **training** is done **separately** for **1-prong** and **3-prong** tau candidates, and also for events with 1-2 or more than two **primary vertices**.

The p_T dependent cuts on the BDT score are optimised to provide approx. **flat signal or background efficiency**.

Comparison of the performance of the three tau identification methods, for 3-prong tau decays.

[1] The ATLAS Collaboration, *Reconstruction, Energy Calibration, and Identification of Hadronically Decaying Tau Leptons*, ATLAS-CONF-2011-077.