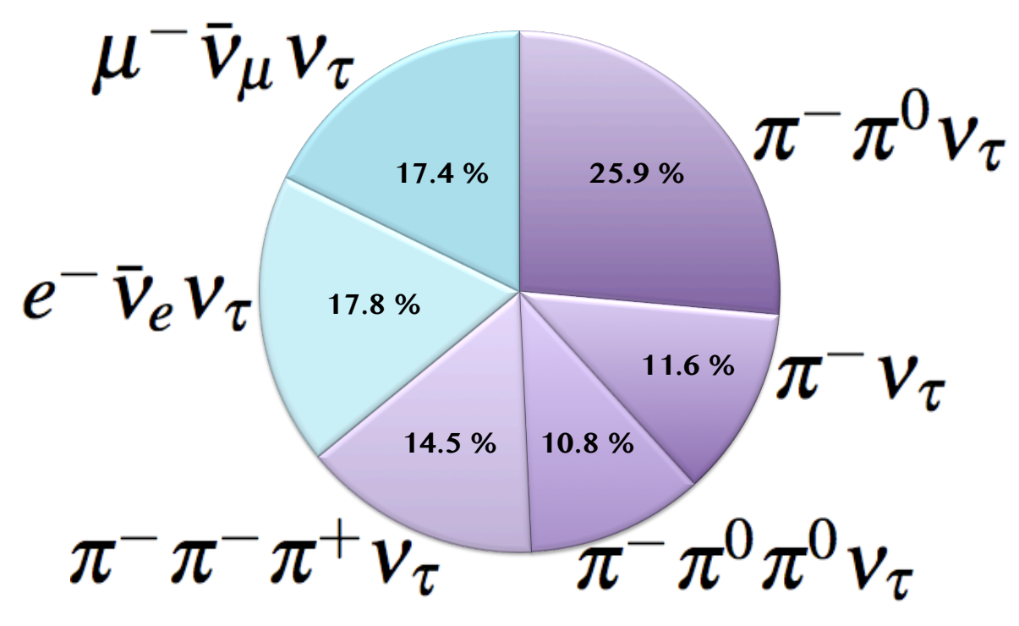
PLHC POSTER SESSION – UBC, JUNE 2012

The Reconstruction and Identification of Hadronically Decaying Tau Leptons at ATLAS

Tau Properties & Motivation

- Discovered at SLAC-LBL in 1970s at the SPEAR electron-positron colliding ring
- Hadronically decaying τ leptons (τ_H) are characterized by isolated and collimated jets of low track multiplicities
- A fraction of τ_H momentum escapes undetected with ν_τ
- Importance and use of τ_H's in physics analyses is growing, leading to innovative tau reconstruction and identification algorithms
- τ_H's can appear in Standard Model and new physics final states including, but not limited to:

$H^+ \rightarrow \tau\nu$: with BR=100%
$Z' \rightarrow \tau\tau$
$H \rightarrow \tau\tau$: in low-mass regime, τ pairs are an important final state
$tt \rightarrow b b \tau l \nu\nu$



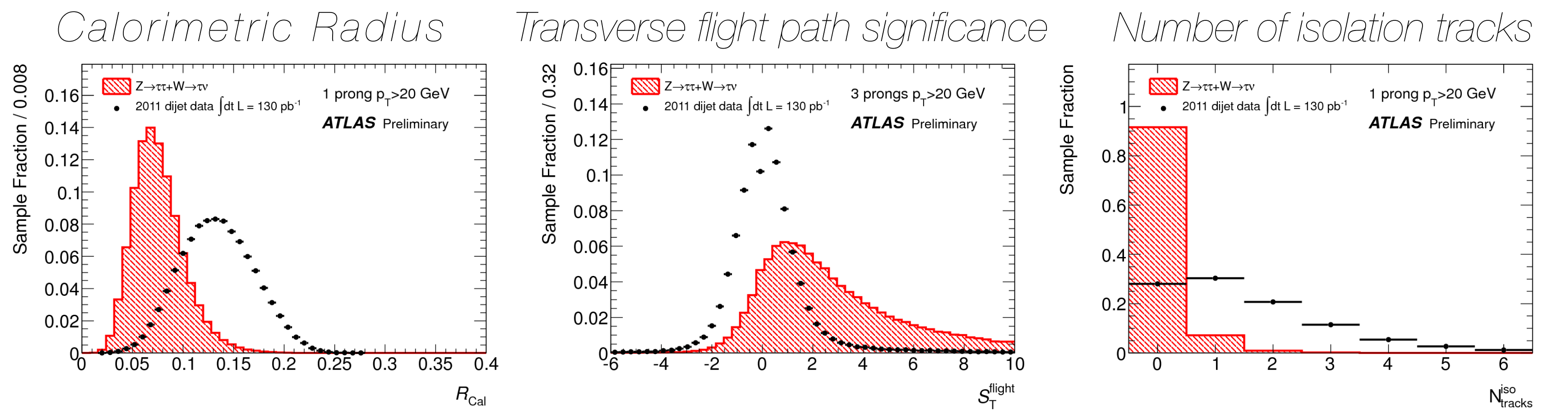
mean lifetime	2.9 x10^{-13} s
ct	87 μm
mass	1.78 GeV

Tau Reconstruction

Reconstructed Tau Candidates are seeded by calorimeter anti-k_t R=0.4 jets with p_T > 10 GeV. Tracks within ΔR< 0.2 of the tau jet axis are associated to a τ candidate if they pass quality criteria on p_T, impact parameter and number of hits in tracking detectors. Tracks within 0.2 < ΔR< 0.4 of the tau jet axis are used in isolation variables for tau ID.

Discriminating variables using tracking and calorimetry information are defined at the reconstruction level and used for identification:

- Tracking: Tau jets have low track multiplicities. Taus have displaced secondary vertices.
- Calorimetry: QCD jets are wider than tau jets, for a given p_T. Taus have a lower invariant mass of clusters.



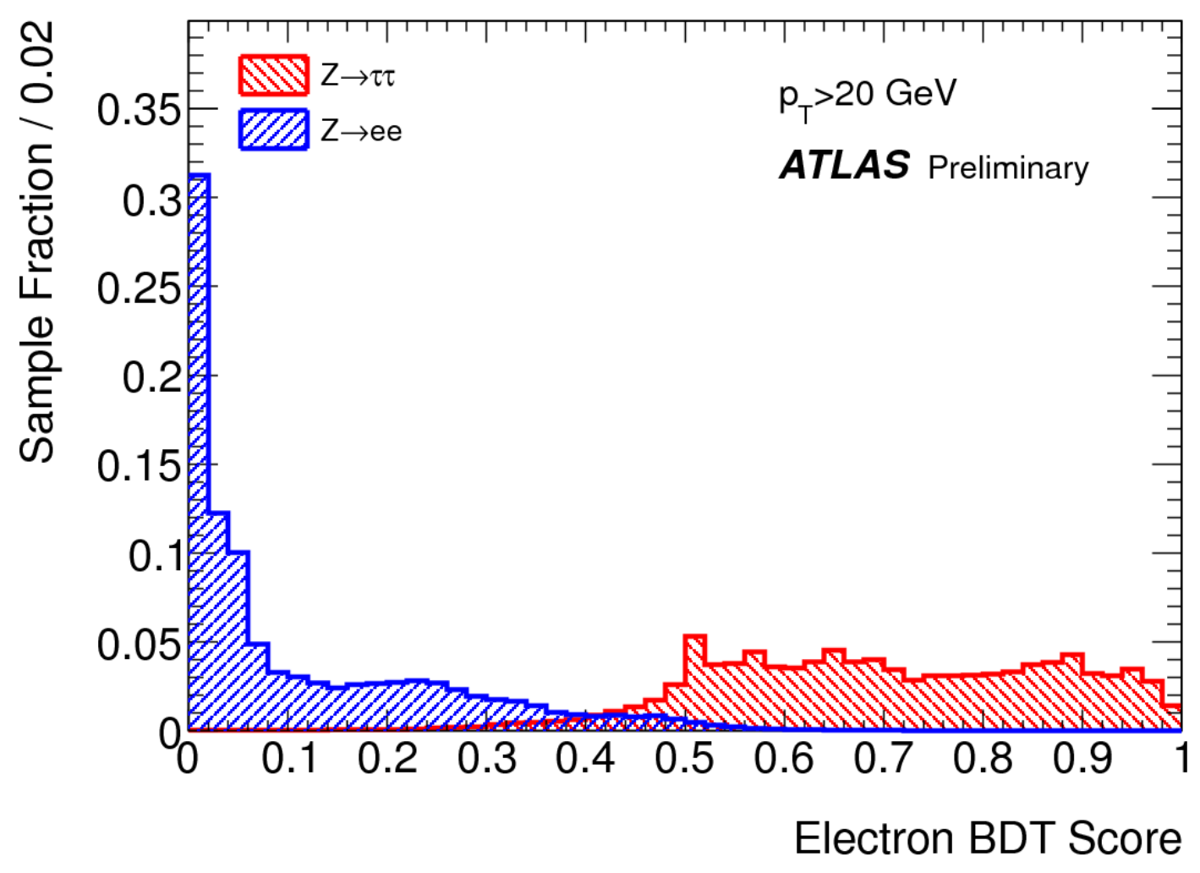
However, little electron and QCD jet rejection is achieved with tau reconstruction alone…

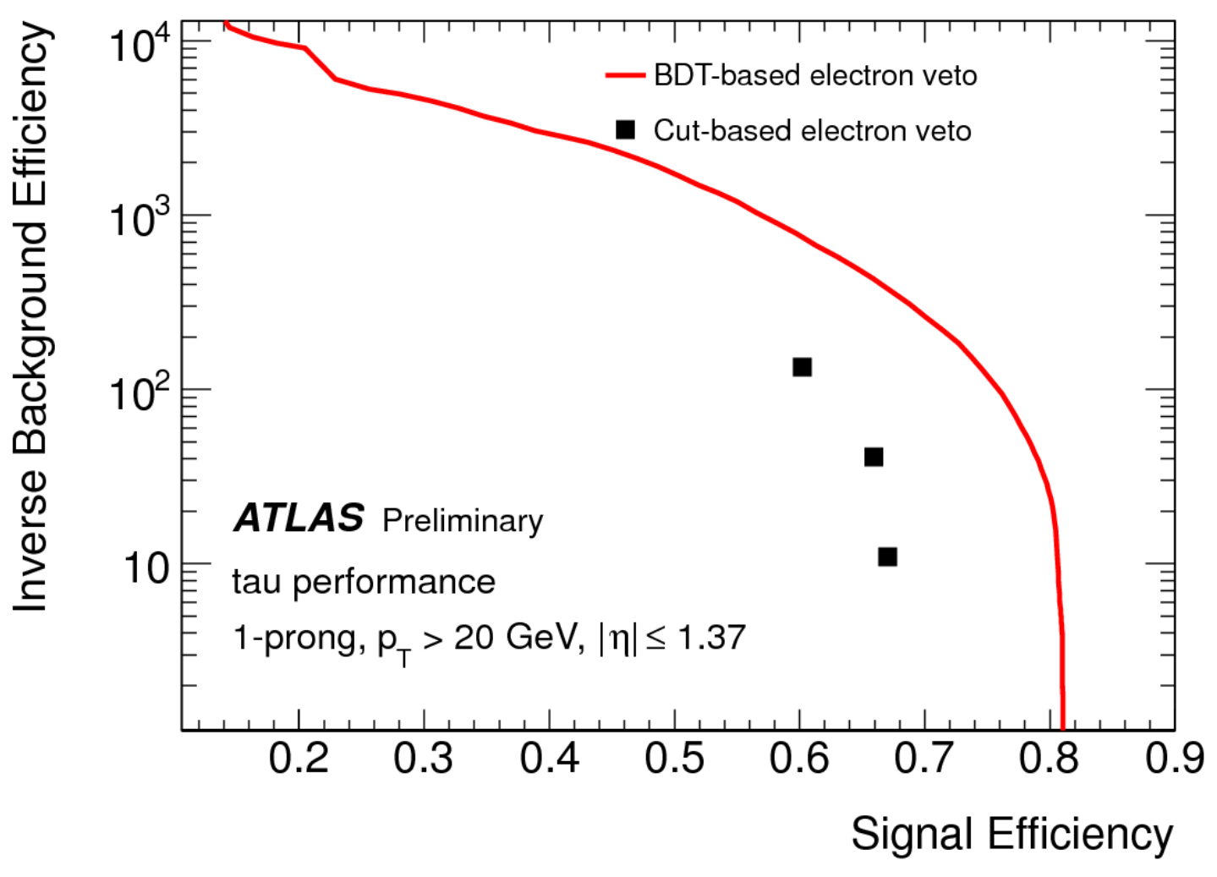
Tau Identification: Electron Rejection

The Idea: Electron signatures in ATLAS are similar to that of 1-prong taus. Make use of discriminating features like transition radiation emission and shower shape to reject electrons not passing good electron quality flags.

Two identification methods have been developed to separate τ_H signatures from electrons:

1. The cut-based algorithm
2. The multivariate Boosted Decision Tree (BDTe) algorithm





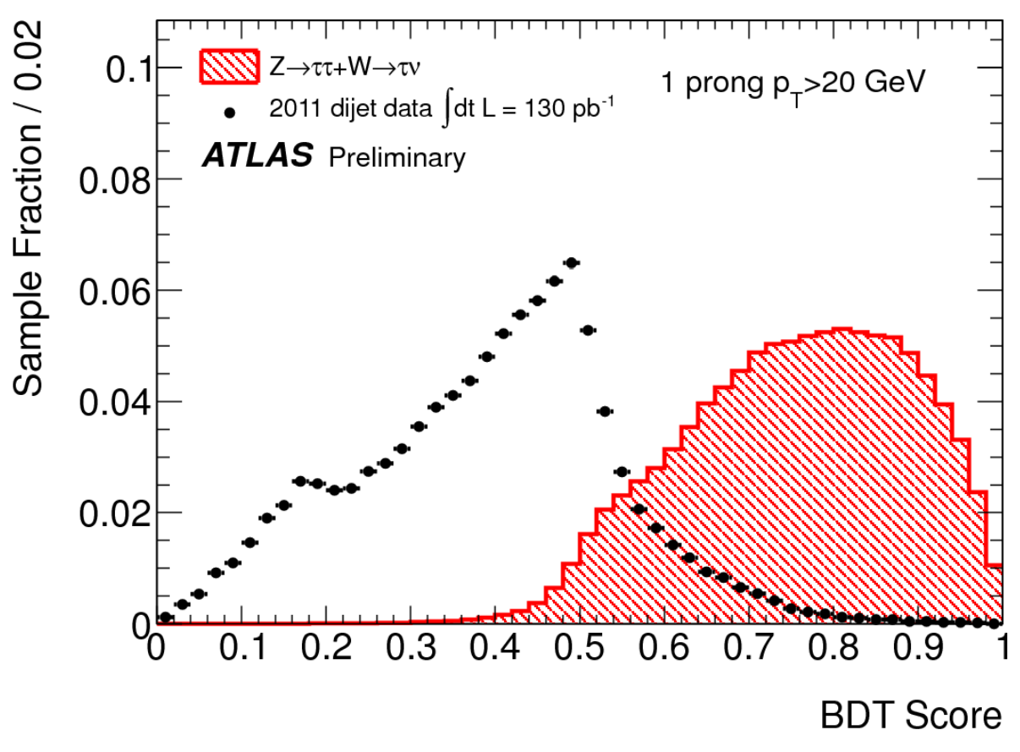
Tau Identification: Jet Rejection

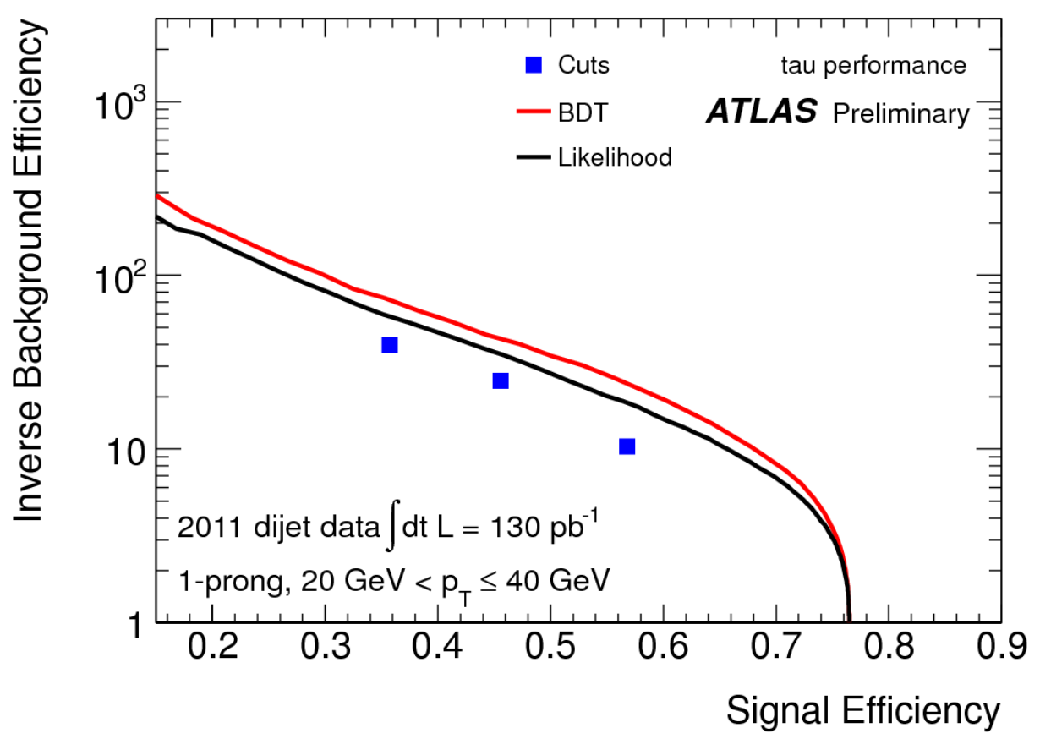
The Idea: Jets are produced much more abundantly than τs in pp collisions. Exploit information on longitudinal and lateral distribution of energy deposits in calorimeter and number of tracks in jet core.

Three identification methods have been developed to separate τ_H signatures from quark/gluon-seeded jets:

1. The cut-based algorithm with minimized pileup dependence, parameterized by p_T
2. The projective liklihood ratio algorithm, parameterized by number of vertices
3. The multivariate Boosted Decision Tree (BDTj) algorithm

- Signal Efficiencies of 60%, 45% 30% for three working points, uniform for all ID algorithms.





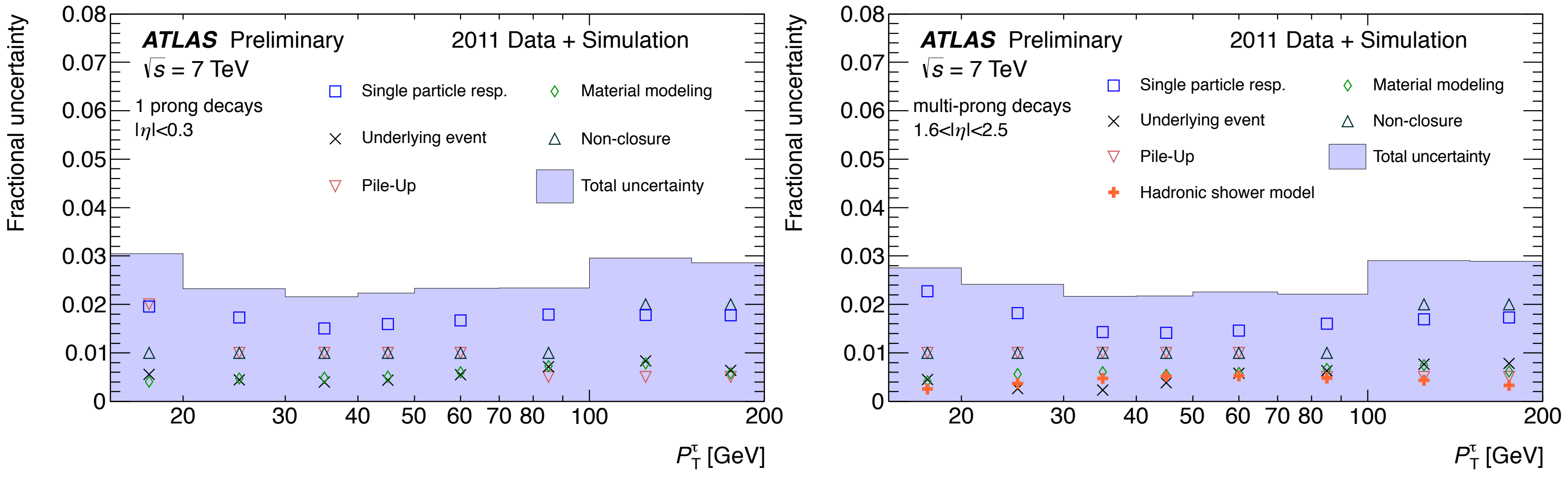
Tau Energy Calibration and Uncertainties

The Idea: The energy of the reconstructed tau, initially at the Local Hadron (LC) Scale, is recalibrated at the Tau Energy Scale (TES) to get the full visible tau energy.

- The LC accounts for non-compensation of ATLAS calorimeters using weights applied to clusters. The reconstructed tau energy at LC scale is the sum of all clusters within the inner core (ΔR< 0.2) of the tau. LC improves the τ_H energy resolution but does not fully restore the τ_H energy.
- TES is the additional correction applied to move the scale up to truth value.
- The tau energy calibration factors are determined using the response of MC simulated taus in bins of |η|, LC calibrated energy, and single or multi-prong.

TES Uncertainties: Single particle response measurements can be used to determine the calorimeter response uncertainty. Decompose τ_H decay into its decay products and convolve the constituent's response with the particle composition by the uncertainty on E/p measurements($\pi^\pm$) or from electromagnetic energy scale(π^0). TES uncertainty receives contributions from: Calorimeter energy response, Monte Carlo event generator with underlying event model, Hadronic shower model, et al.

TES uncertainty for 1-prong (left) and multi-prong (right) τ_H decays:

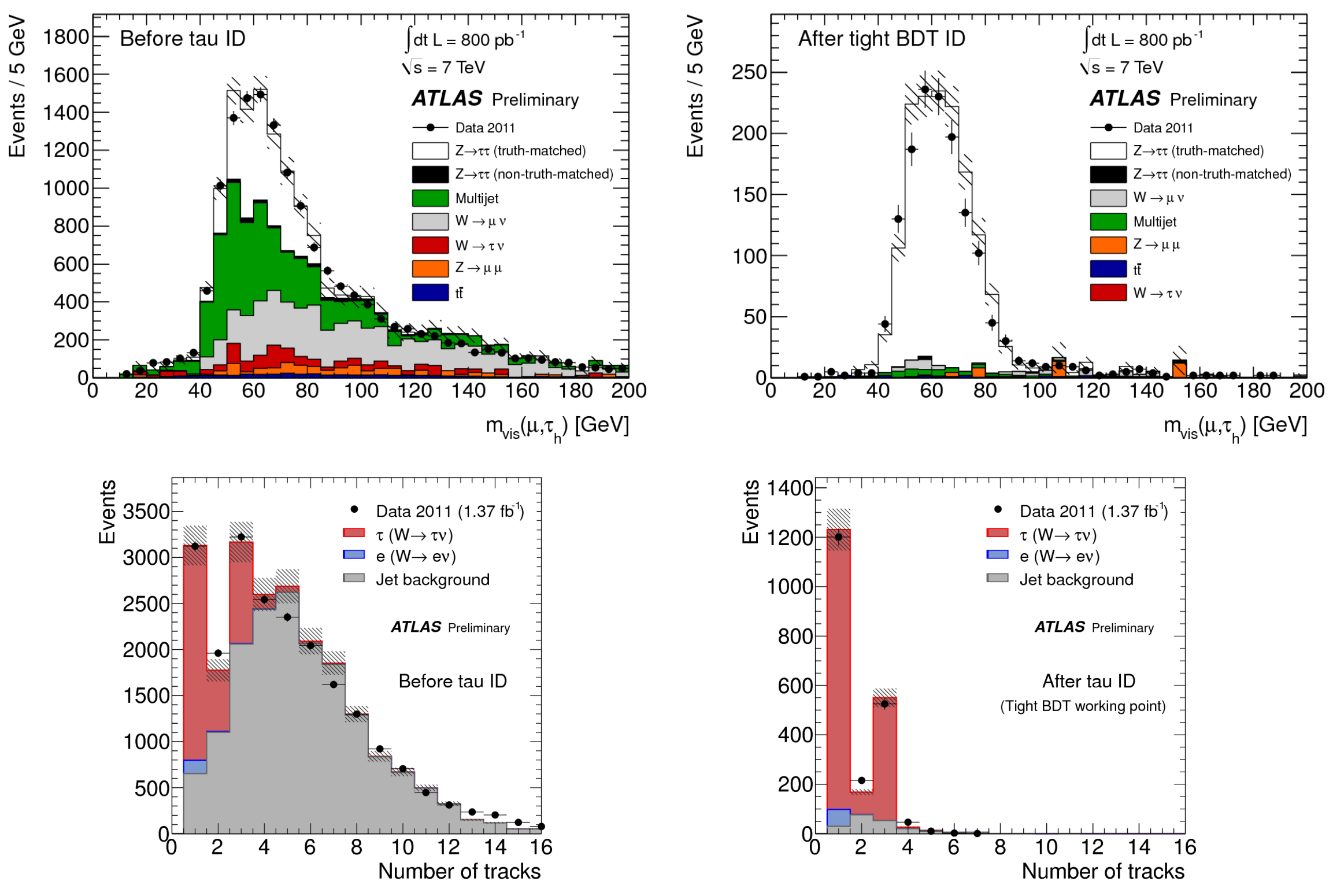


Tau ID Performance and Efficiency

The performance of the identification algorithms is evaluated using tau candidates selected from data using tag and probe methods.

The Idea: Select $Z \rightarrow \tau_L \tau_H$ and $W \rightarrow \tau_H \nu$ events in data before the tau ID, count events which pass.
Multijet background estimation is a challenge: exploit charge correlation and isolation, or track counting, to estimate its size.

For $Z \rightarrow \tau_L \tau_H$, the visible mass between the μ and τ_H is shown and for $W \rightarrow \tau_H \nu$ the track multiplicity is shown, for both Monte Carlo and 2011 ATLAS Data, after the full event selection, before (left) and after(right) BDT tau ID.



Tau ID Efficiency

± statistical uncertainty, then ± systematic		$Z \rightarrow \tau_L \tau_H$ with 0.8 fb^{-1} of 2011 Data
Cut-Based	Loose	1.03 ± 0.05 ± 0.08
	Medium	0.80 ± 0.05 ± 0.07
	Tight	0.63 ± 0.04 ± 0.06
Liklihood	Loose	0.83 ± 0.05 ± 0.08
	Medium	0.56 ± 0.04 ± 0.05
	Tight	0.32 ± 0.02 ± 0.03
BDT	Loose	0.88 ± 0.05 ± 0.08
	Medium	0.61 ± 0.04 ± 0.06
	Tight	0.40 ± 0.03 ± 0.04

± statistical uncertainty, then ± systematic		$W \rightarrow \tau_H \nu$ with 1.37 fb^{-1} of 2011 Data
Cut-Based	Loose	0.87 ± 0.02 ± 0.02
	Medium	0.79 ± 0.02 ± 0.03
	Tight	0.65 ± 0.02 ± 0.03
Liklihood	Loose	0.70 ± 0.02 ± 0.02
	Medium	0.46 ± 0.02 ± 0.03
	Tight	0.27 ± 0.01 ± 0.02
BDT	Loose	0.81 ± 0.02 ± 0.03
	Medium	0.63 ± 0.02 ± 0.03
	Tight	0.42 ± 0.01 ± 0.03

As shown, the tau ID successfully eliminates much of the background.

References: ATLAS-CONF-2011-152 , ATLAS-CONF-2012-054

Susie Bedikian, Yale University, on behalf of the Tau Working Group of the ATLAS Collaboration