Tracker and Calorimeter Performance for the Identification of Hadronic Tau Lepton Decays in ATLAS

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on behalf of the
ATLAS Collaboration

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on High Energy Physics
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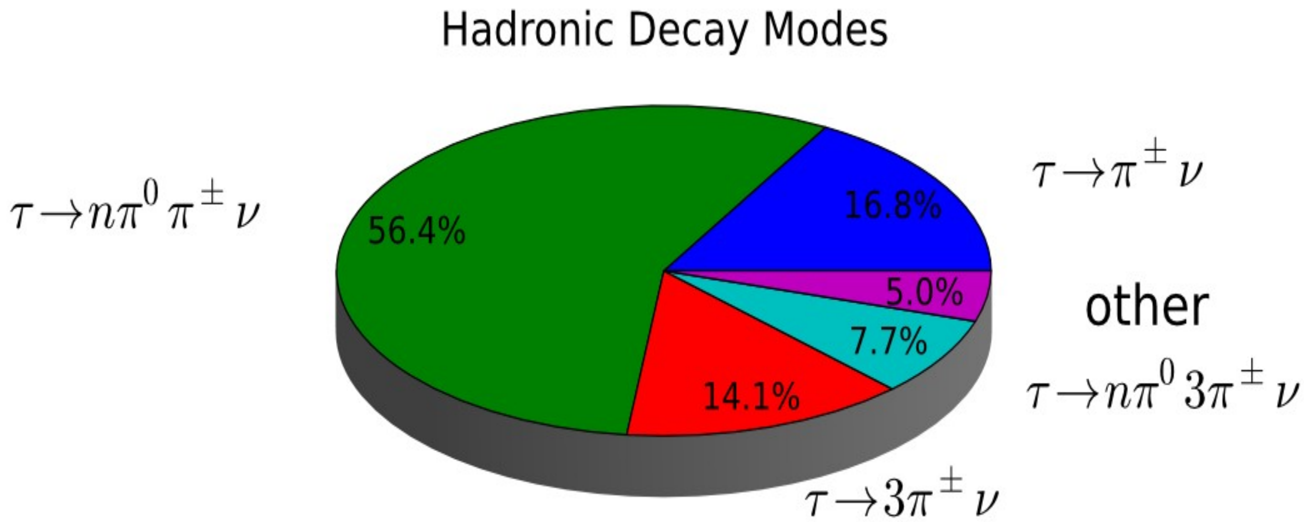
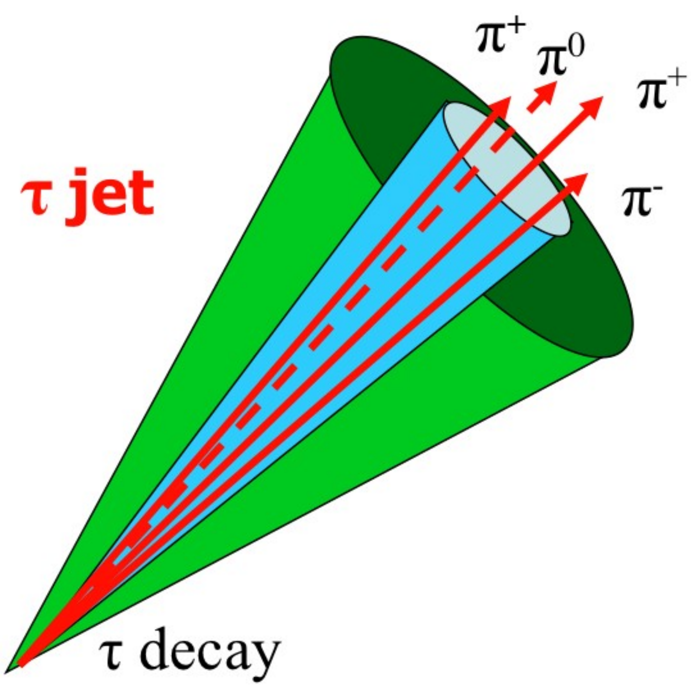
Tau Lepton Properties

Tau Lepton Properties
- m_τ = 1.78 GeV
- $c\tau$ = 87 μm
- BR($\tau \rightarrow l\nu\nu$) = 35.2%
- BR($\tau \rightarrow$hadrons) = 64.8%





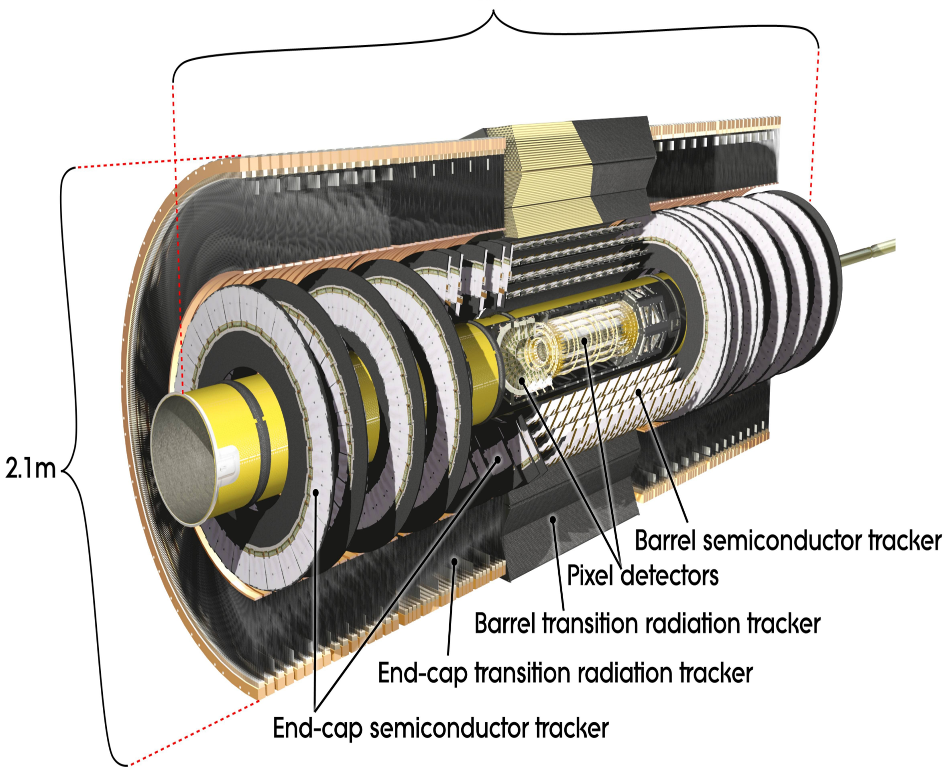
Typical detector signature
- one or three charged tracks
- collimated calorimeter energy deposits
- large leading track momentum fraction
- possible secondary vertex reconstruction

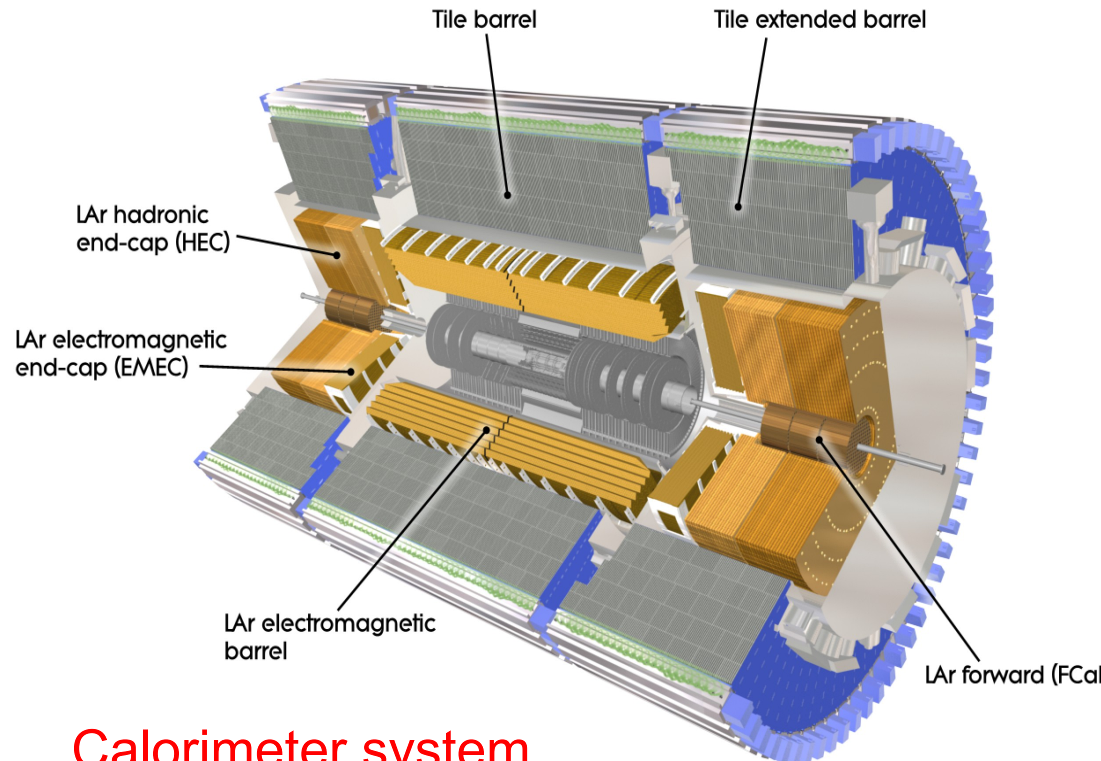
ATLAS Tau Physics Program
- Standard Model cross section measurements
- Higgs searches (SM and beyond)
- Searches for SUSY and exotica

ATLAS Detector Subsystems

Tracking system

Pixel and SCT up to |η| < 2.5
TRT up to |η| < 2.0
(immersed in 2.0 T field)





Calorimeter system

Electromagnetic calorimeter up to |η| < 3.2
- with presampler up to |η| < 1.8

Hadronic calorimeter consists of
- Tile calorimeter up to |η| < 1.7
- Hadronic endcap for 1.5 < |η| < 3.2

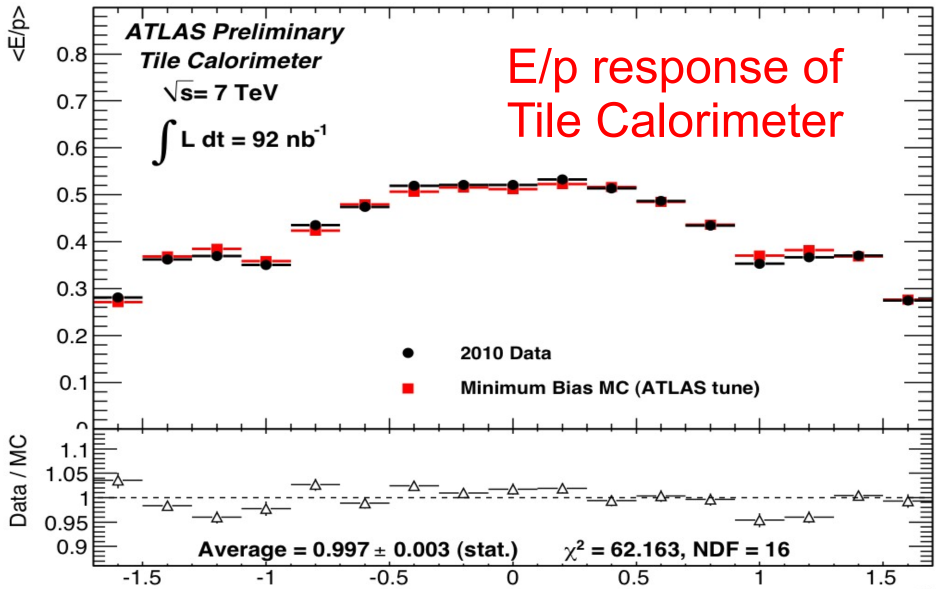
Calorimeter Reconstruction

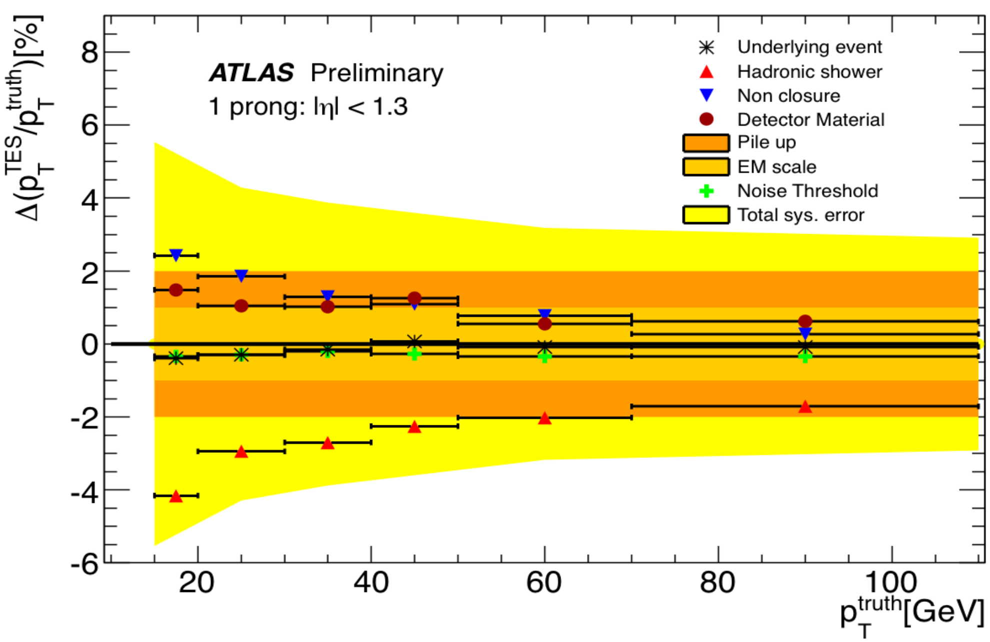
Tau candidates reconstructed from AntiKt jets (R=0.4) seeded from topological clusters

Energy calibration:

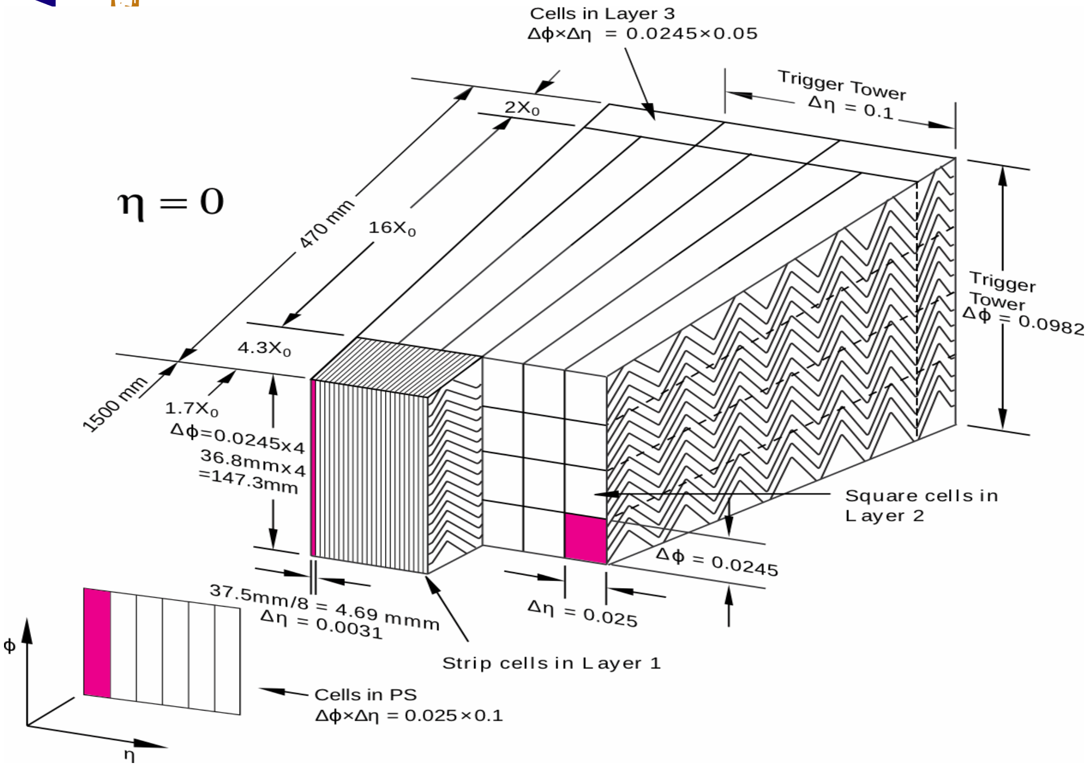
- uses local cluster weighted scale of jet clusters
- further MC-based calibration to tau p_T scale

Uncertainties are evaluated comparing responses in different MC samples

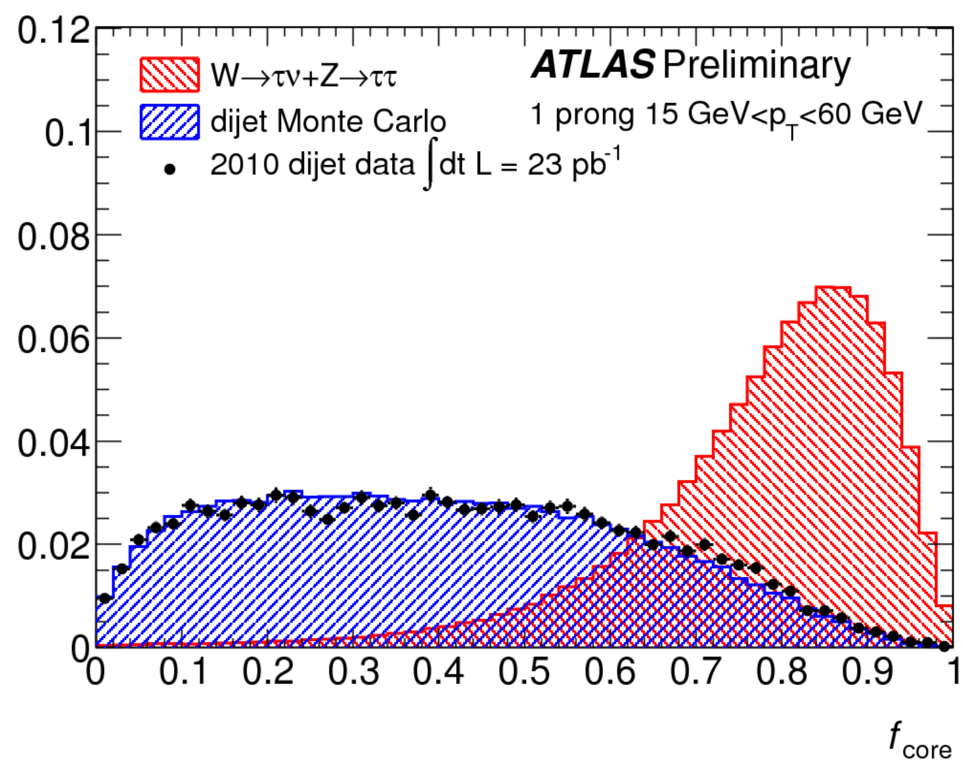




Calorimeter ID



Calorimeter granularity crucial for reconstructing the transverse energy shower profile of hadronic tau decays and jets



Key variables used in tau ID include:

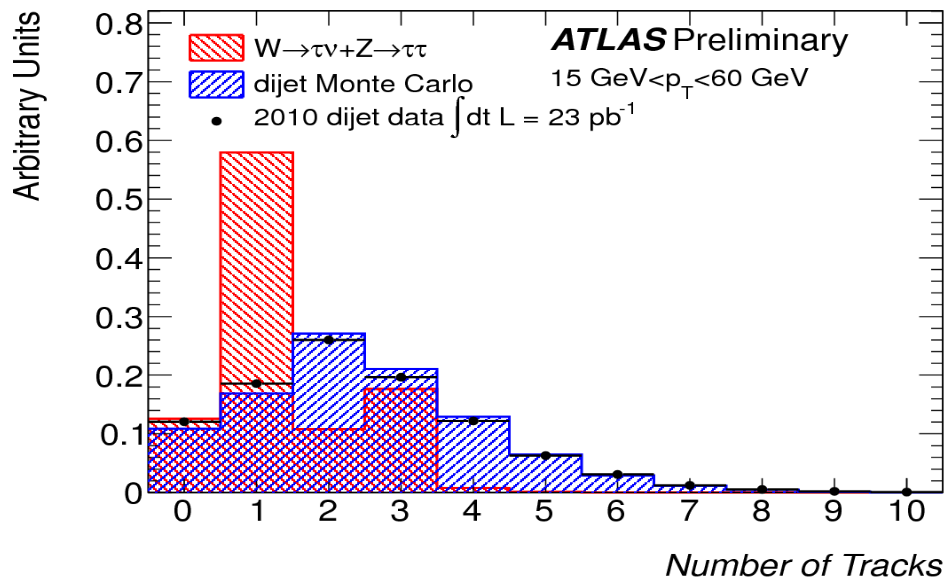
- R_{EM} : shower width in the EM calorimeter
- f_{core} : ΣE_T^{cells} (0.1) / ΣE_T^{cells} (0.4)
- $m_{clusters}$: mass of clusters

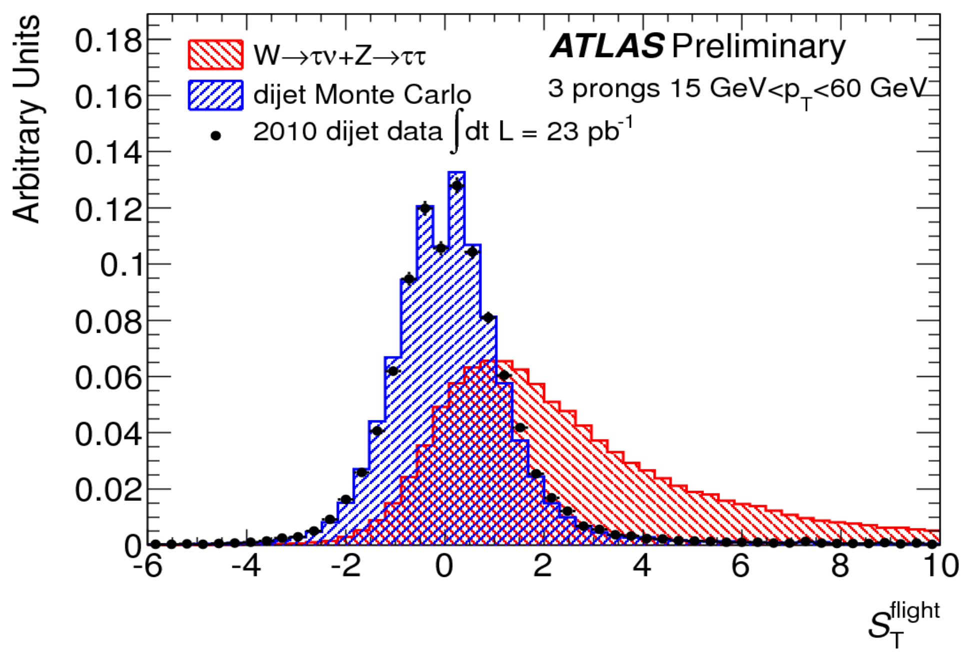
Tracking Performance

Tracks with p_T > 1 GeV and within ΔR<0.2 are associated to the tau candidate

Key tracking variables for ID include:

- m_{tracks} : mass of the track system
- R_{tracks} : average distance of tracks to jet axis
- S_T^{flight} : secondary vertex flight path significance





Multi-variate Tau ID

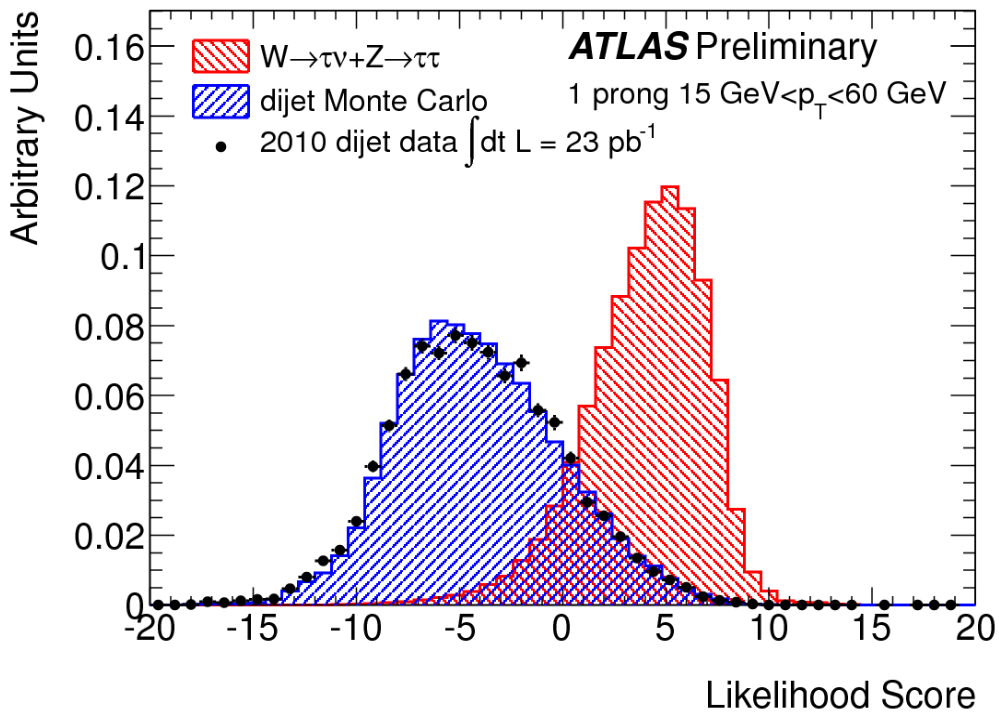
Variables are combined into multi-variate methods to increase discrimination power

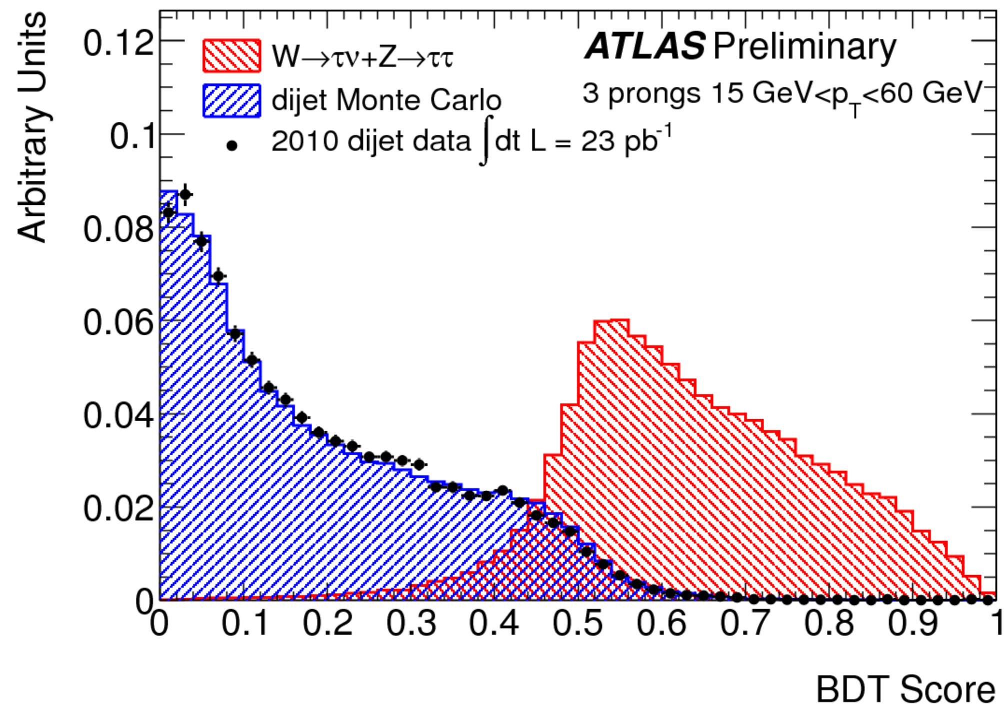
Projective Likelihood

Likelihood ratio formed using signal (MC) and background (dijet data) probability distribution functions

Boosted Decision Tree

uses information from multiple decision trees to form a weighted score for signal and background hypotheses

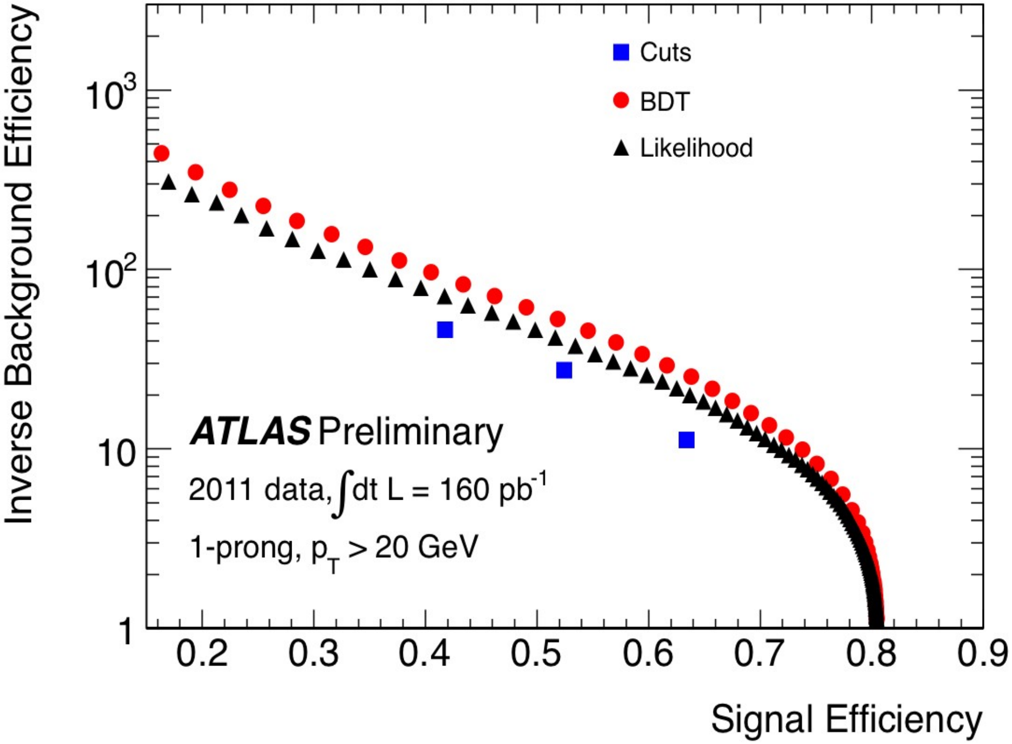


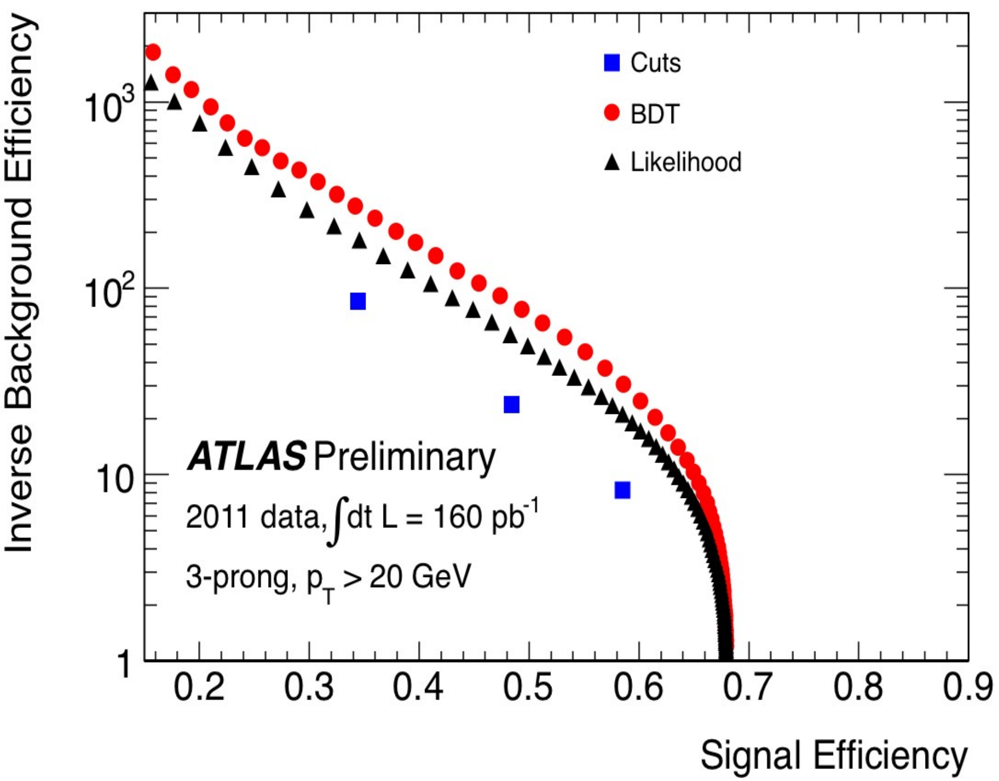


Tau Identification Performance

Signal efficiency from $W \to \tau\nu$
and $Z \to \tau\tau$ Monte Carlo samples

Rejection measured from
di-jet selection in data





$R = 1 / \varepsilon(\text{bkgd})$

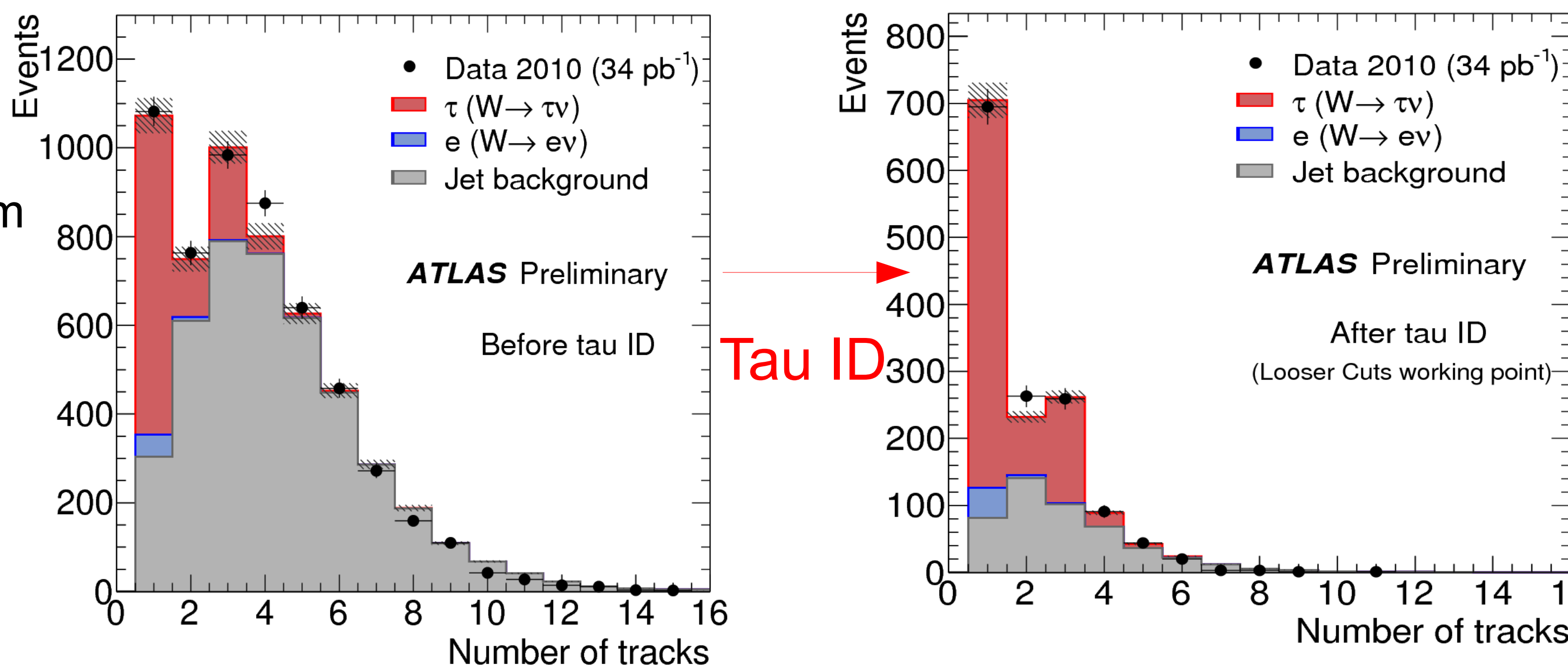
Efficiency Measurements with W→τν (2010 data)

Tag & Probe method, using E_T^{miss} significance to tag events

The N_{trk} spectrum of tau leptons vs. jets fit to extract the $W \rightarrow \tau\nu$ fraction

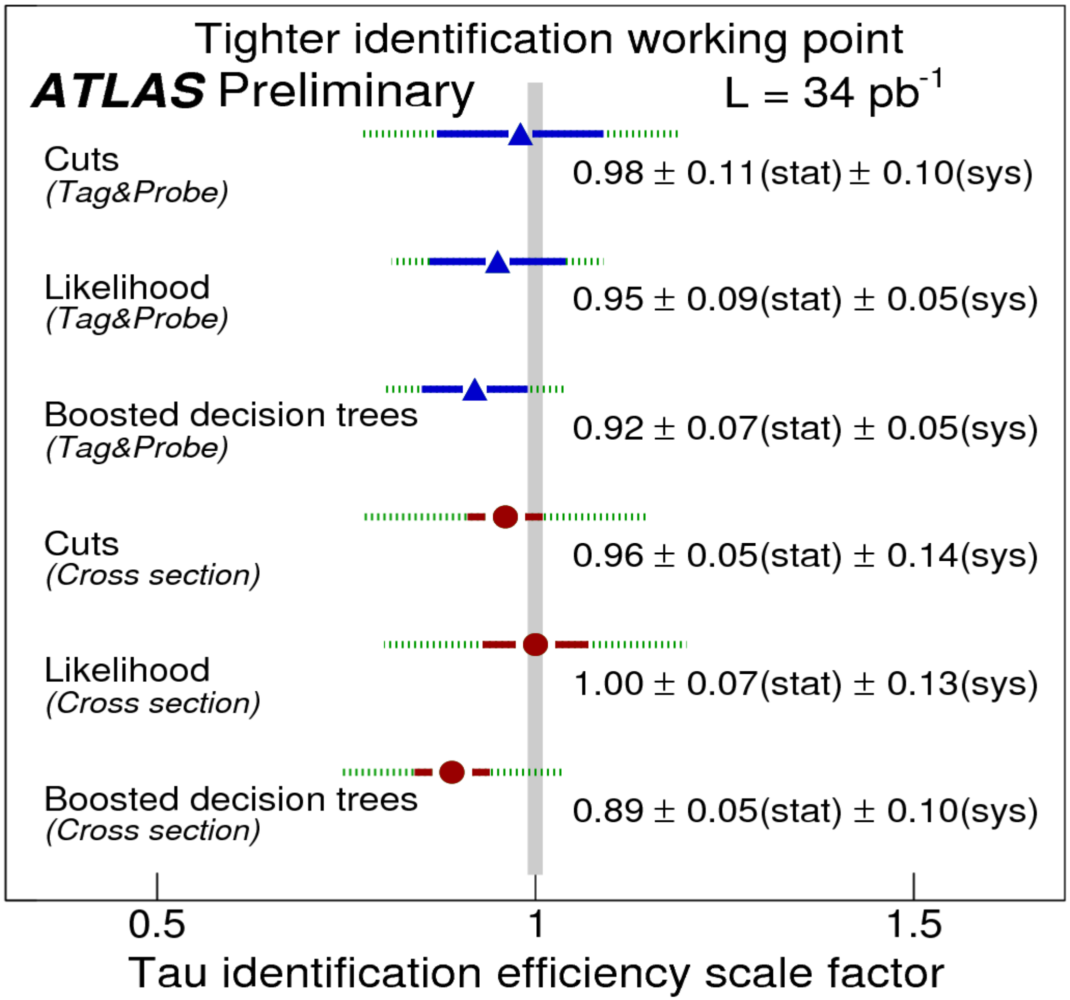
multi-jet N_{trk} spectrum taken from low E_T^{miss} significance control region

Excellent agreement of data with MC efficiencies



Cross-checked with cross section normalization method, normalizing $W \rightarrow \tau\nu$ to measured W cross-section in leptonic channels

Summary of Results (Efficiency)



55-60% Efficiency

Measured efficiencies consistent with Monte Carlo $W \rightarrow \tau\nu$ events

Tag & Probe method limited by background statistics in control region for multi-jet N_{trk} spectrum

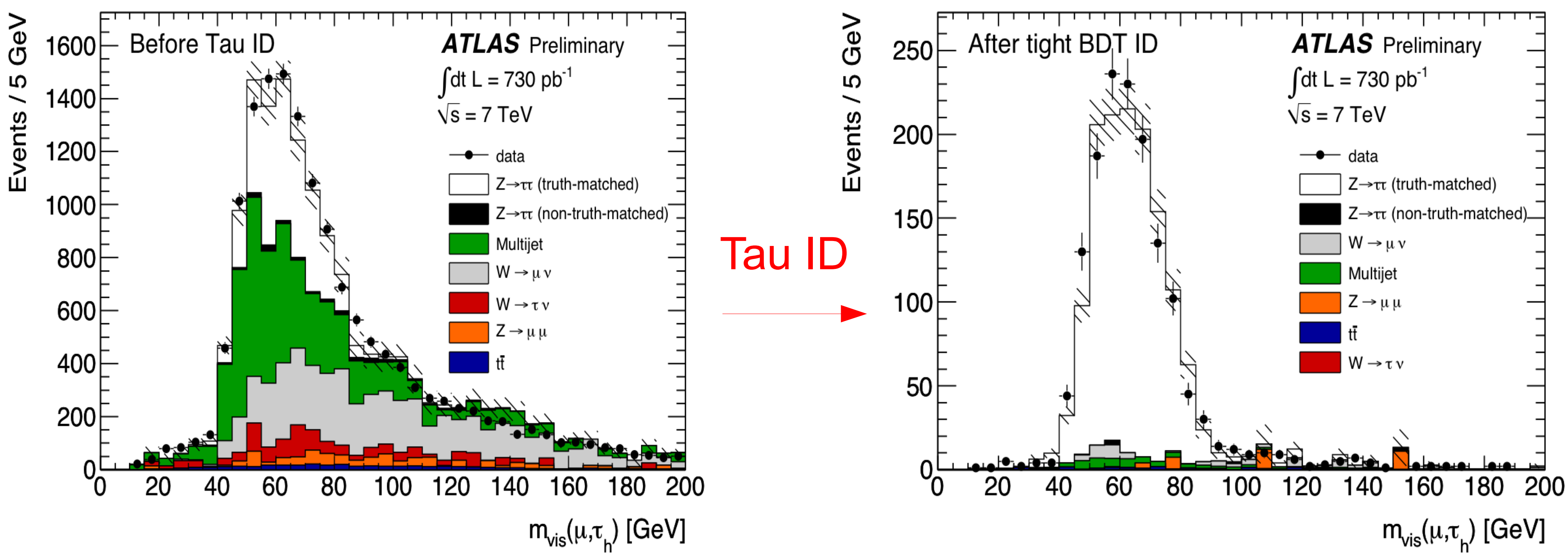
Cross section normalization method limited by systematic uncertainties on signal acceptance

Scale Factor = ε(data) / ε(MC)

Toward Efficiency Measurement with Z→ττ in 2011 data

Using 730 pb^{-1}, tau identification efficiency studied in Z→ττ events where one tau decays via τ→μνν (tag), and the other decays hadronically (probe)

Agreement between MC and data very well described (distribution of visible mass between muon-tau candidates shown)



Summary & Outlook

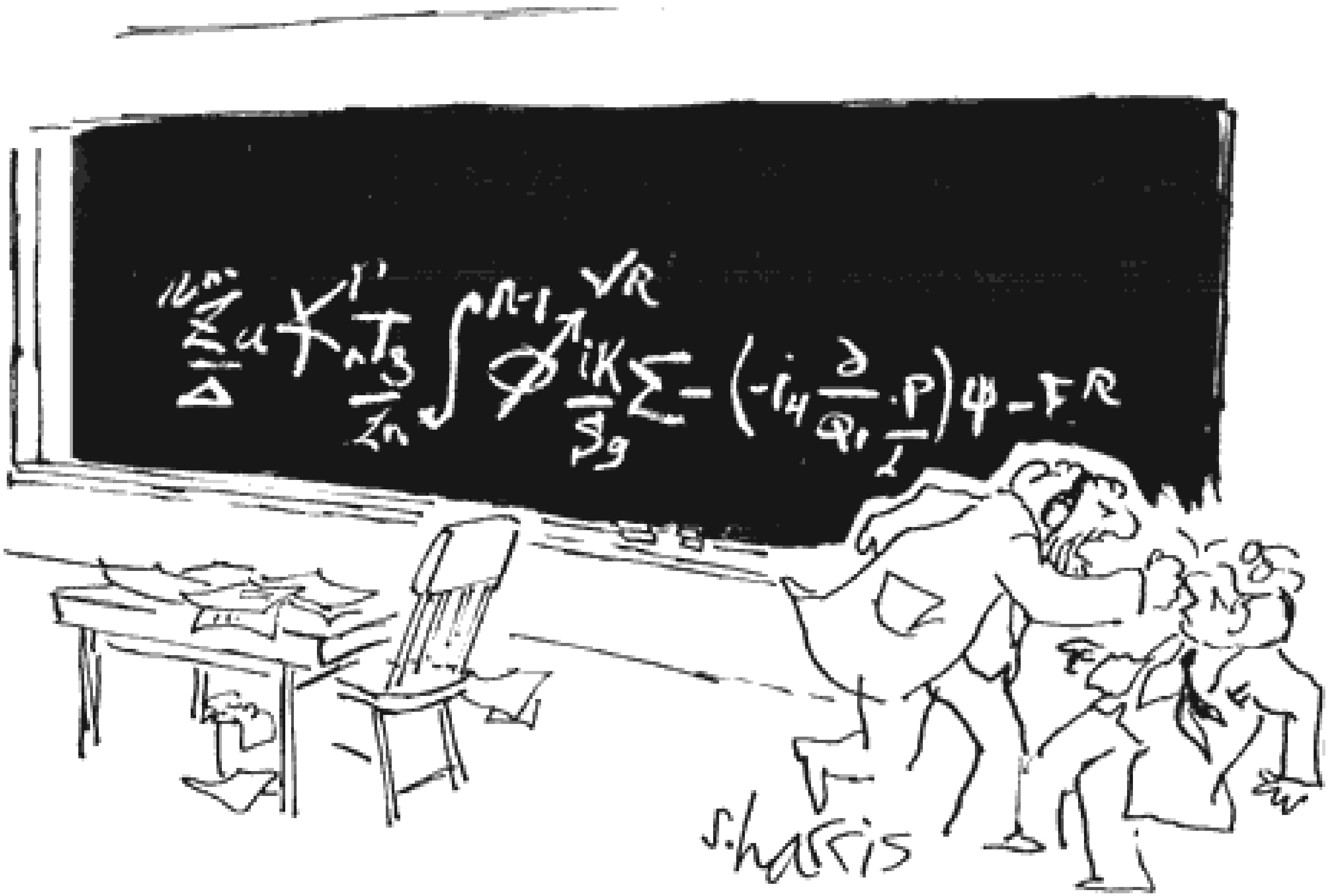
Summary

- good detector performance enables high performing tau identification
- identification variables and methods well understood
- efficiency measurements confirm accuracy of Monte Carlo predictions

Outlook

- tau reconstruction and identification algorithms still evolving
- continued optimization and investigation of tau substructure underway
- use data to continue to study ID efficiency, energy scale, and other properties
- lots to look forward to in the ATLAS tau physics program

Extra Slides



"You want proof? I'll give you proof!"

Further References

ATLAS-CONF-2011-077
Reconstruction, Energy Calibration, and Identification of Hadronically Decaying Tau Leptons

ATLAS-CONF-2011-093
Measurement of Hadronic Tau Decay Identification Efficiency using $W \to \tau\nu$ Events

Other talks about tau lepton physics at ATLAS during EPS:

Martin Flechl, 11:00 Friday,
"Search for MSSM neutral and charged Higgs in ATLAS"

Ryan Reece, 11:00 Friday,
"Measurement of W and Z boson production cross sections with the ATLAS detector"

Frank Seifert, Poster,
"Performance of Tau Identification and Associated Systematic Uncertainties in ATLAS"

Justin Griffiths, Poster,
"Measurement of the Z->tautau and W->taunu cross sections with the ATLAS detector"

Local Cluster Weighting

From: ATLAS-CONF-2010-053

Calorimeter cells in clusters are weighted according to the cluster energy and the cell energy density to account for the lower response of hadrons in the calorimeter

The cluster is weighted according to the energy measured around the cluster and the longitudinal depth of the barycentre of the cluster in the calorimeter to account for energy deposited but not contained within the cluster

The cluster is also weighted according to its energy and the fractional energy deposited in each calorimeter layer to account for energy deposited in the dead material and thus not measured by the calorimeter

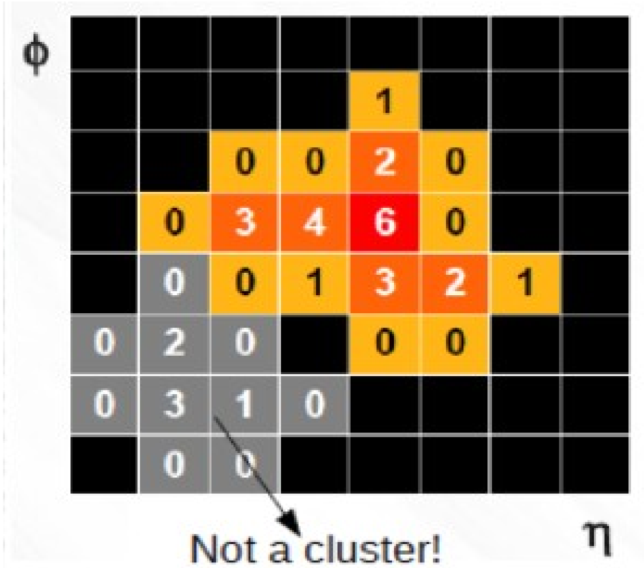
Topological Clustering

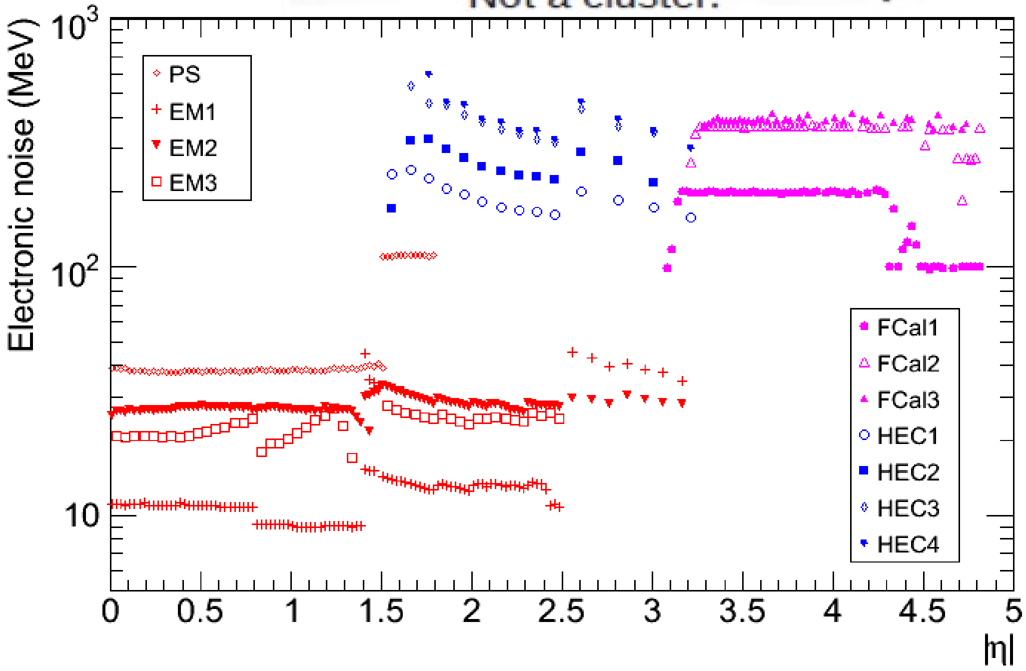
Topological clustering is an algorithm that associates calorimeter cells into a cluster

Seed cells are used to form clusters with $E_{cell} > 4\sigma_{noise}$

Neighbouring cells iteratively are added with $E_{cell} > 2\sigma_{noise}$

Cells surrounding the cluster are added in a final step

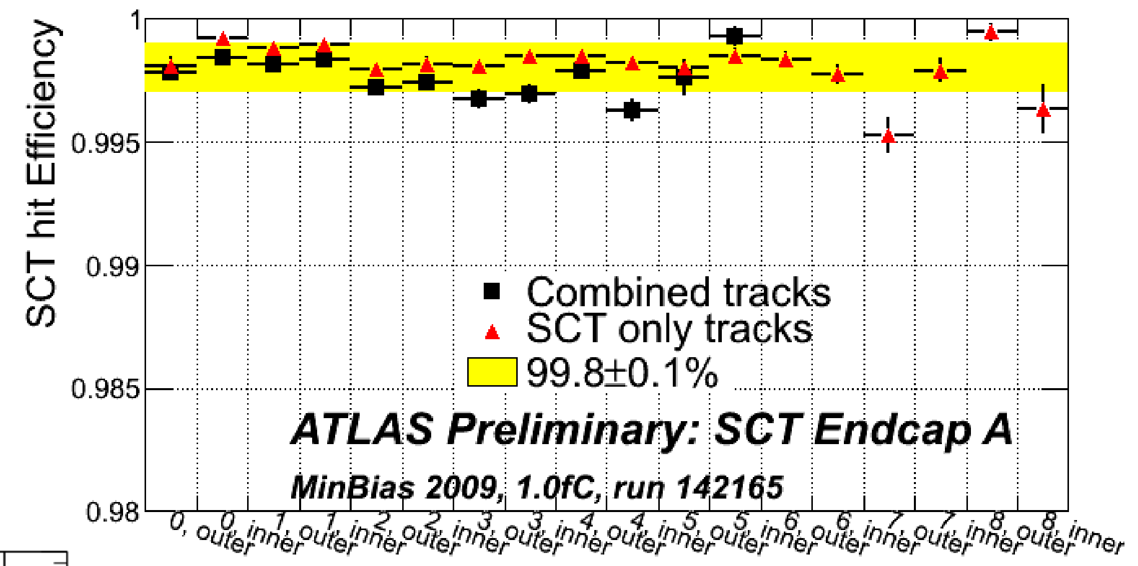


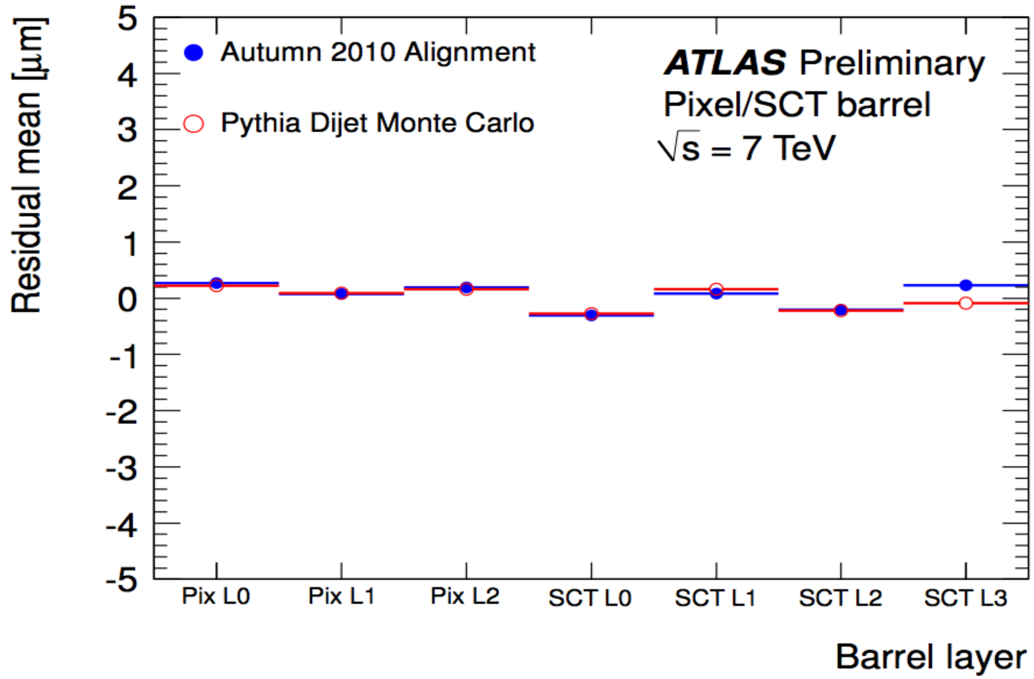


Tracking Performance Plots

Track Quality Criteria for tau candidates

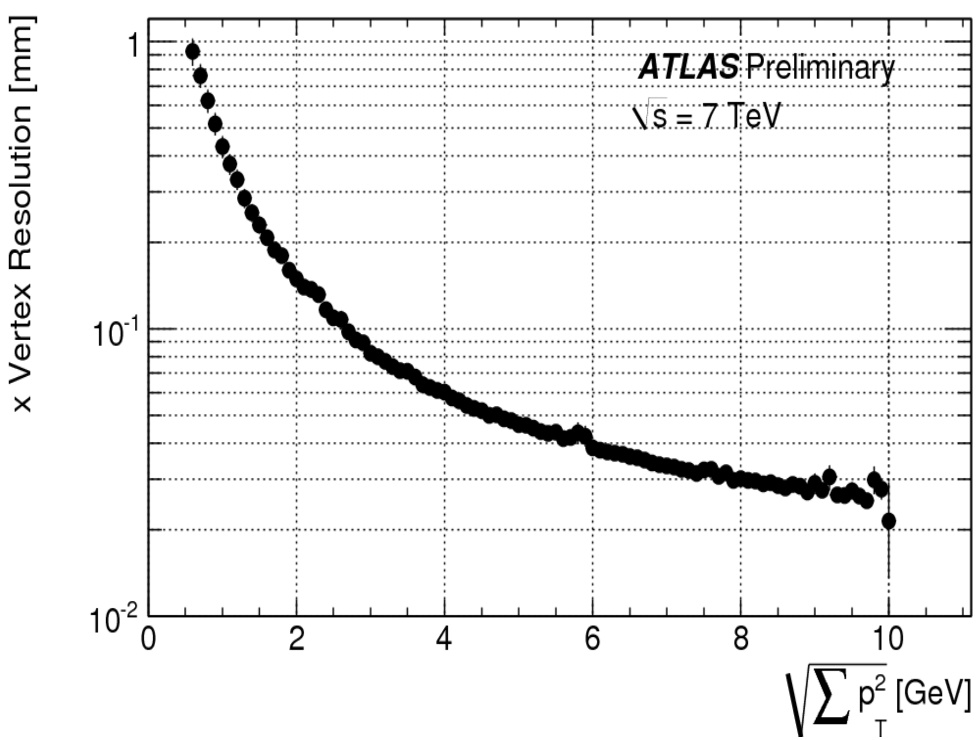
- $N_{pixel} \geq 2$
- $N_{pixel} + N_{SCT} \geq 7$
- $d_0 < 1.0$ mm
- $z_0 \sin(\theta) < 1.5$ mm
- b-layer hit (removed for 2011)

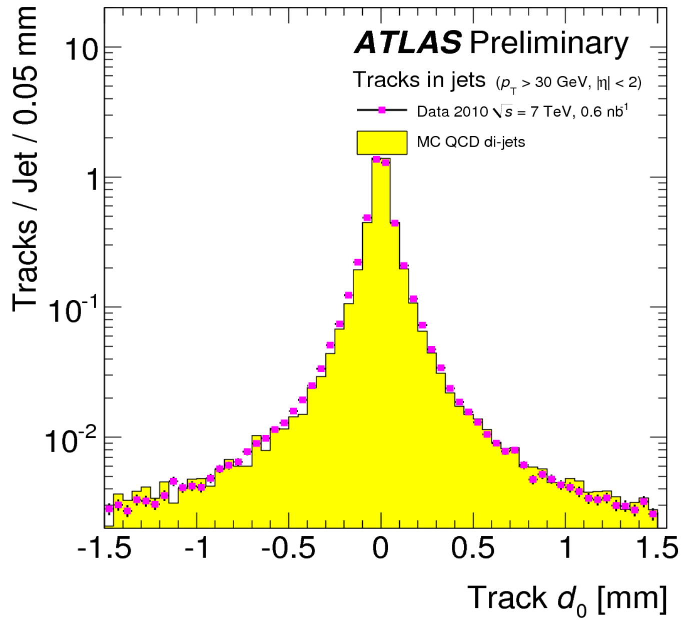


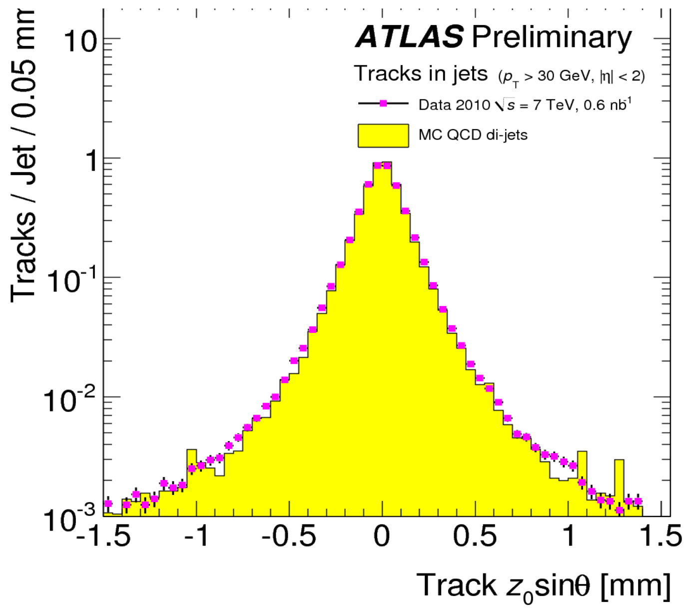


Resolutions from Tracking Variables

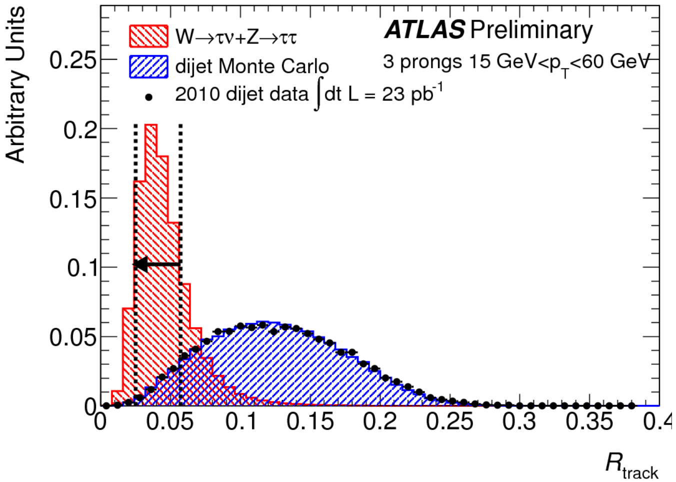
Good resolutions are necessary for precision tracking and secondary vertexing for tau candidates

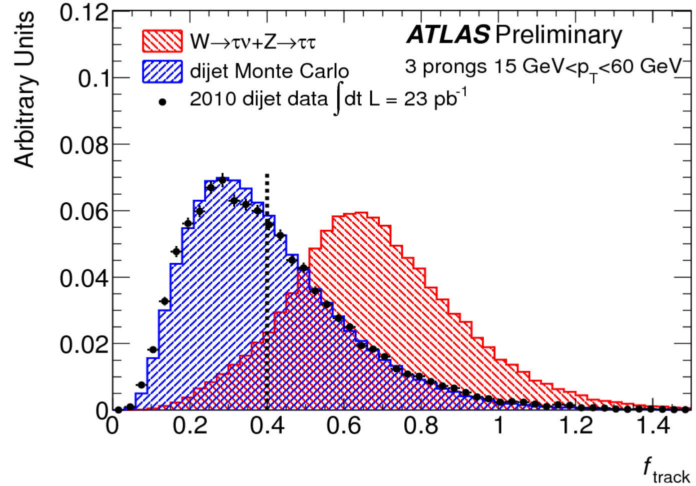


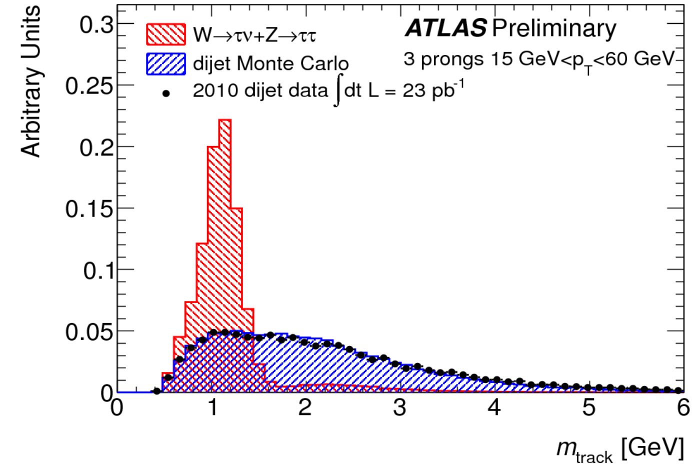


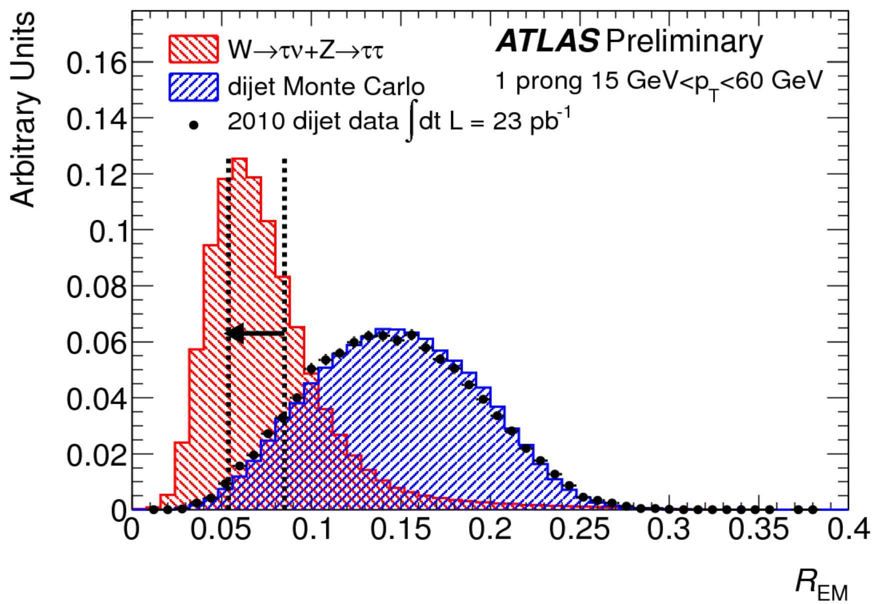


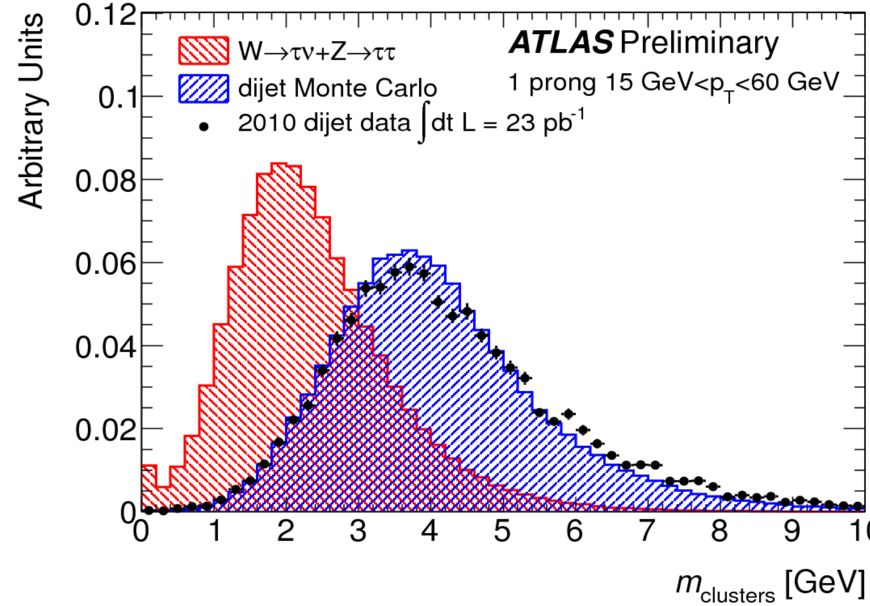
Other Tau ID Variables



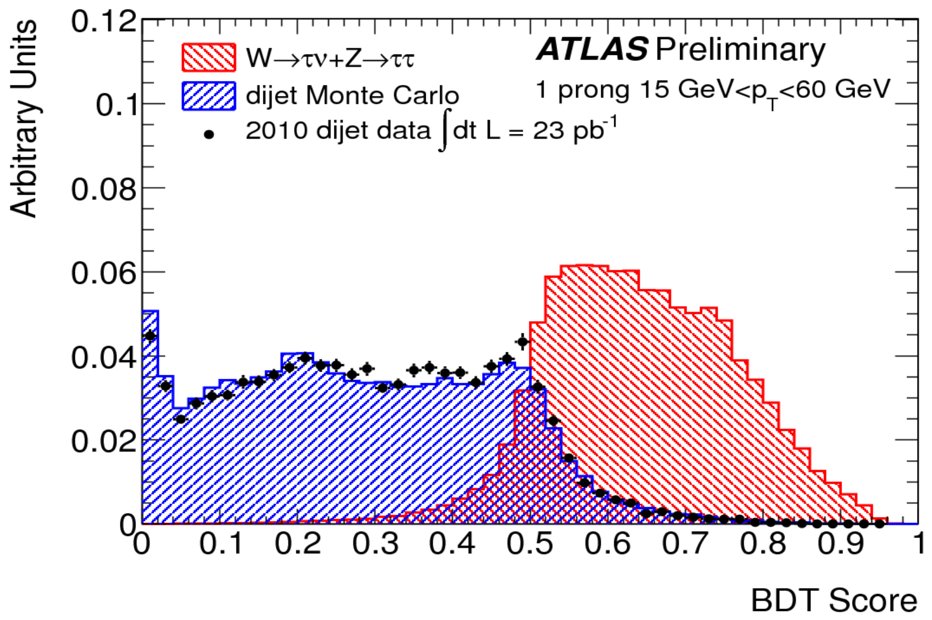


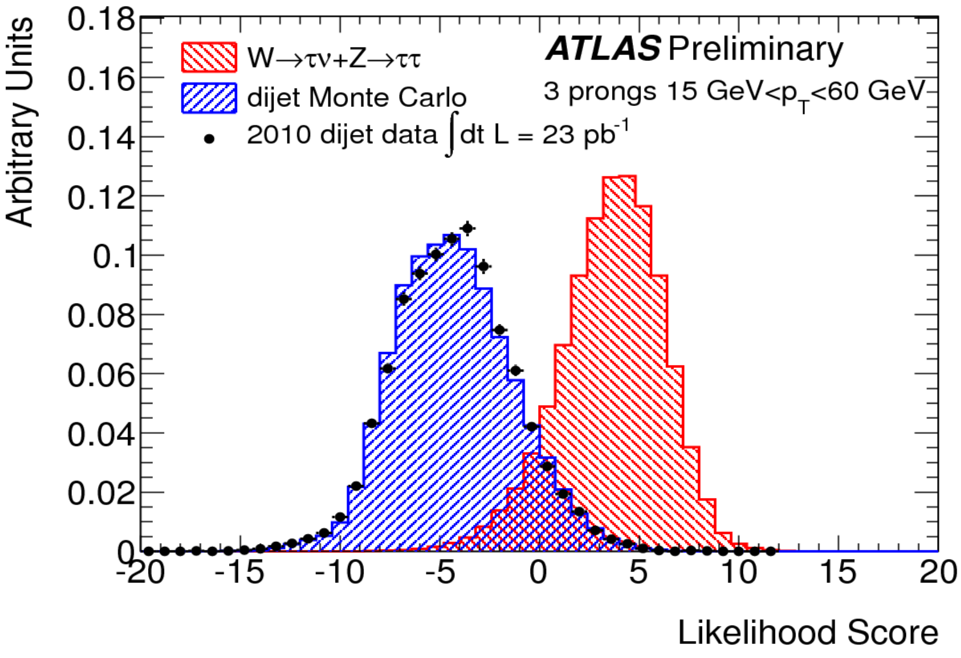




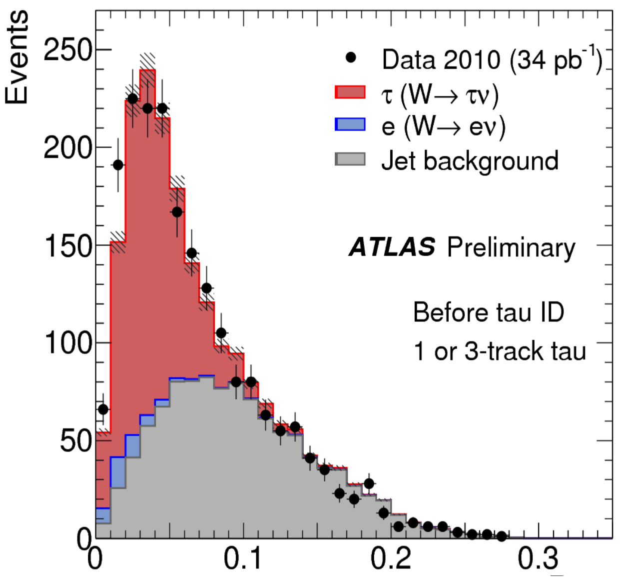


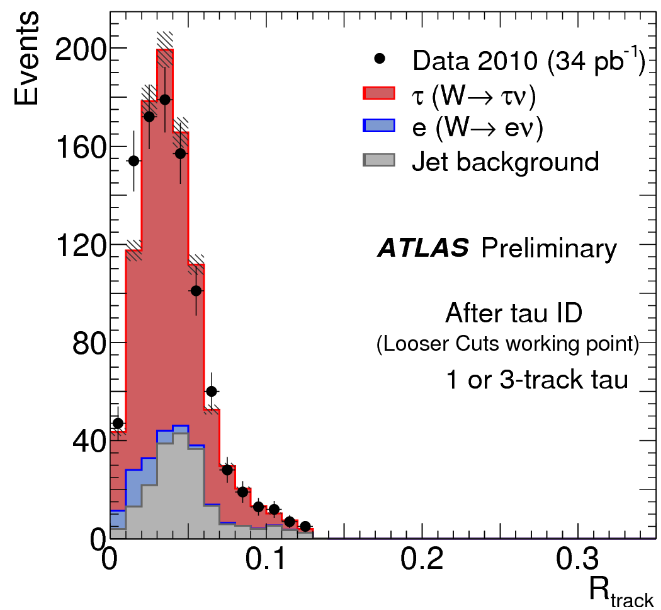
More Info on LLH/BDT

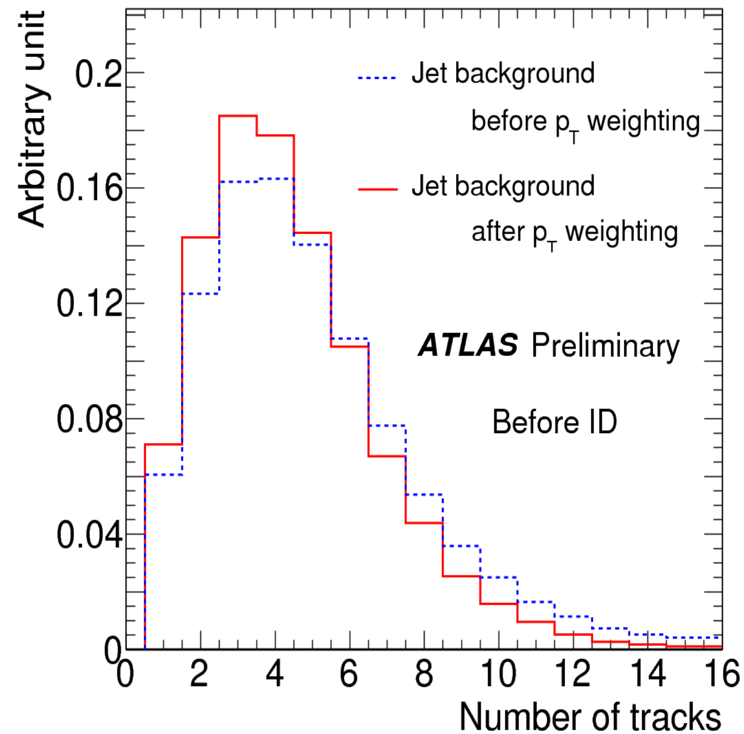


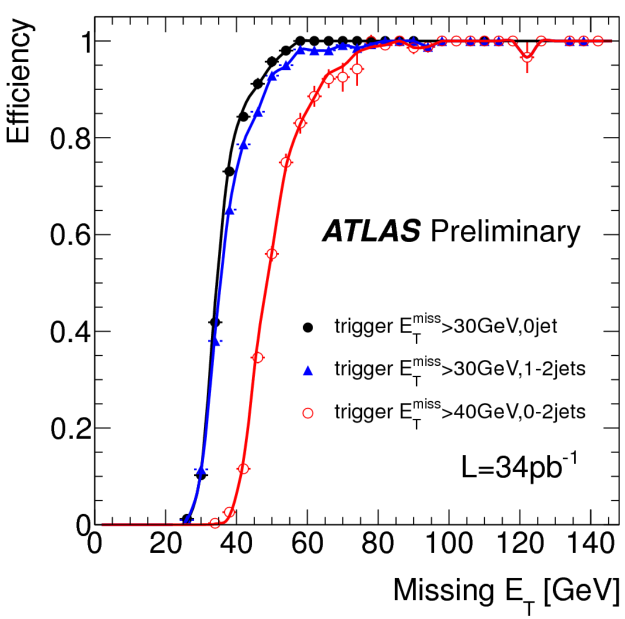


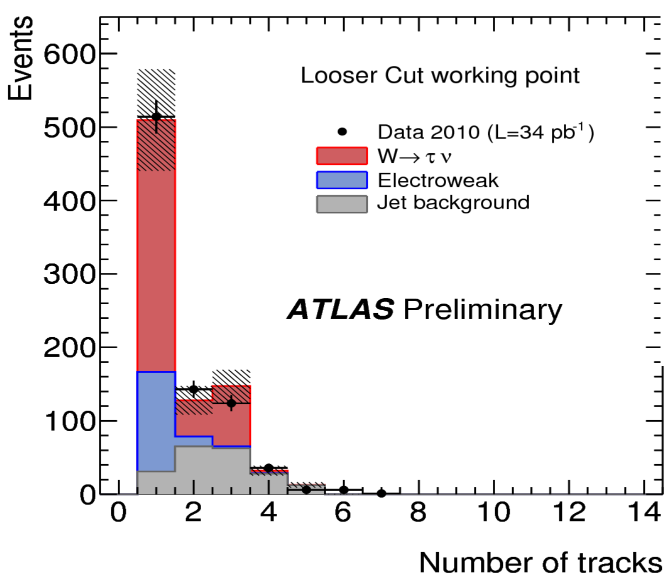
Other Plots using W→τν events



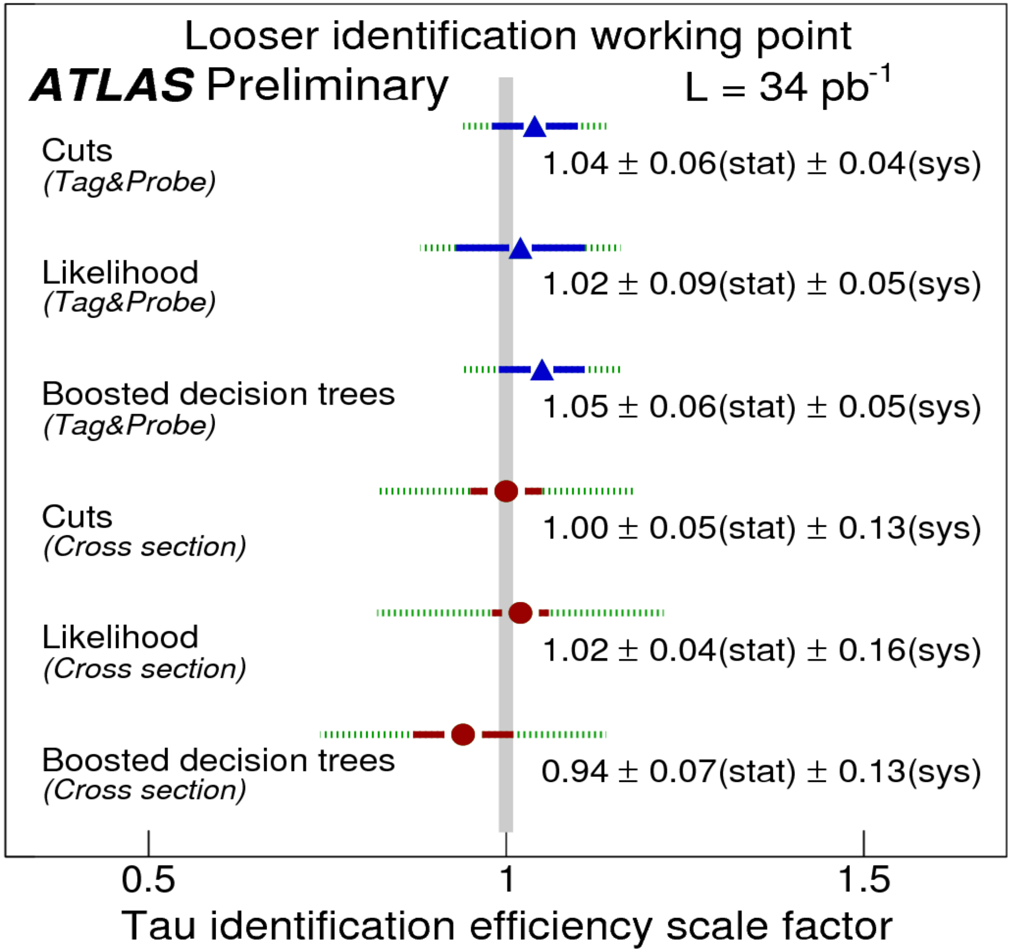








Systematic Uncertainties for W→τν Efficiency Measurement



~80% Efficiency

E_T^{miss} trigger	0.7%
Jet modelling (p_T-weighting)	0.4%
Jet modelling ($S_{E_T^{miss}}$)	0.6%
Electron misidentification	1.6%
Pileup condition	1.4%
Shower model	2.6%
Detector geometry	0.9%
Underlying event	1.3%
Total systematic uncertainty	3.7%

Jet modelling	1.1%
W cross-section	5.1%
Trigger efficiency	2.7%
Electron reconstruction	1.7%
Electron misidentification	4.8%
Tau energy scale	7.7%
Jet energy scale	0.1%
Electron energy scale	0.8%
Pileup	0.2%
Underlying event	6.8%
Total systematic uncertainty	12.9%

Efficiency with Z→ττ cross section normalization