Track classification in hadronic tau decays

Richard Hartmann

03/30/2017

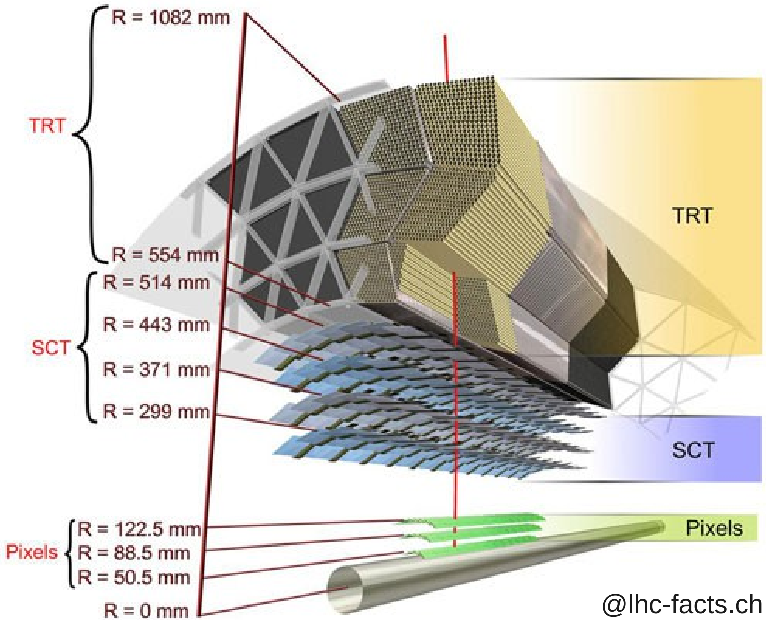
GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

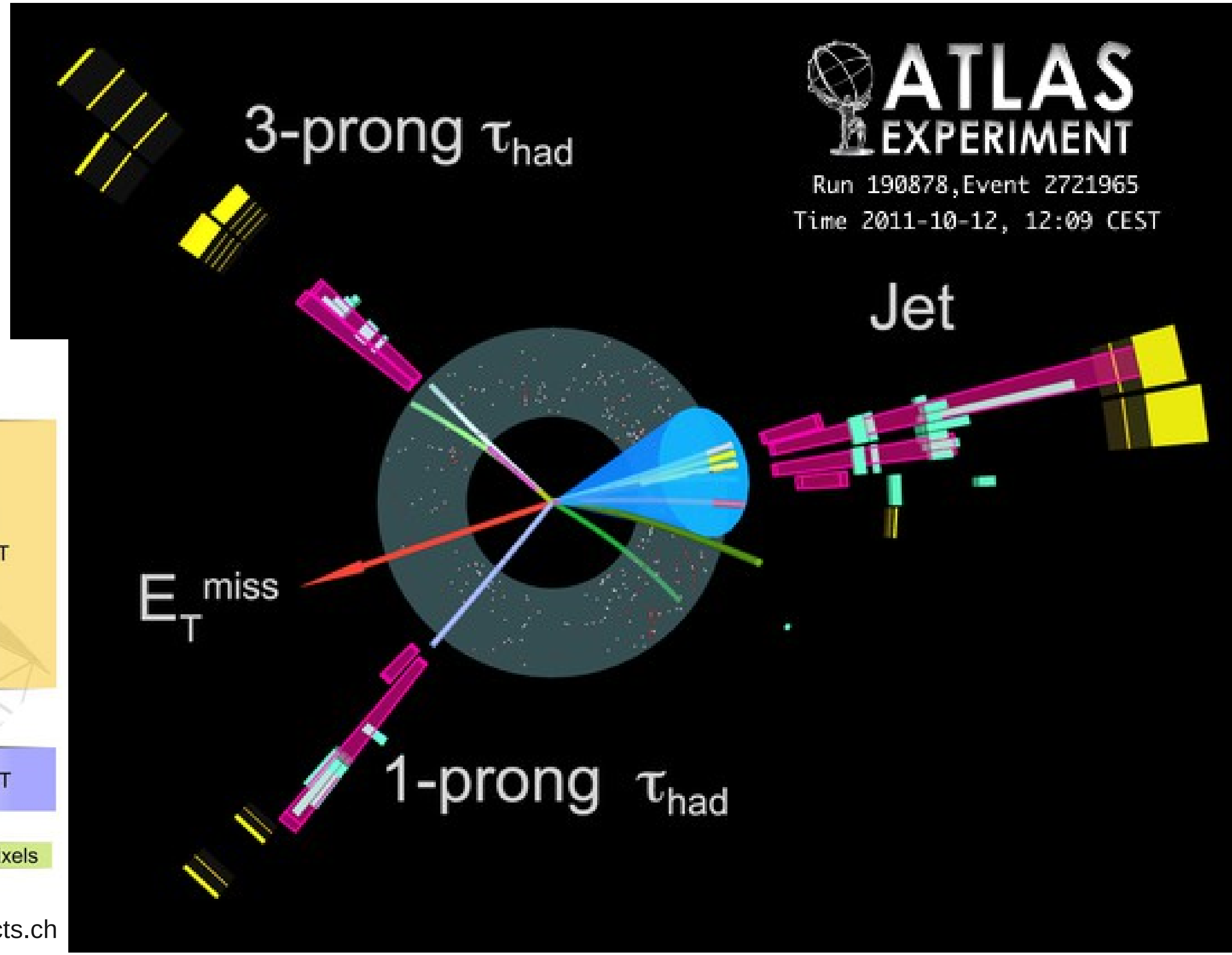
BMBF-Forschungsschwerpunkt
ATLAS-EXPERIMENT
Physik bei höchsten Energien mit dem ATLAS-Experiment am LHC
FSP 103

Introduction

tau decay into hadrons

$\tau \rightarrow had$



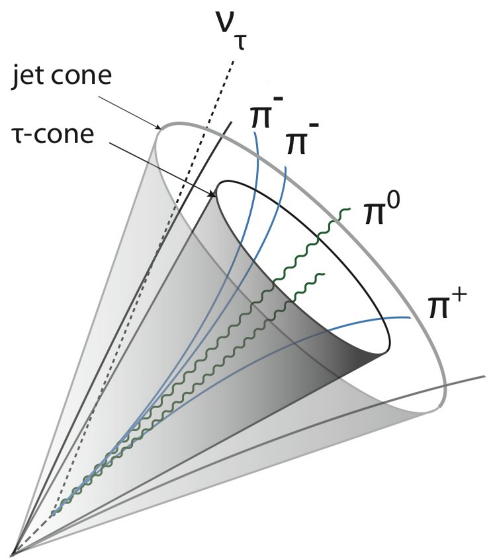


Reconstruction algorithm

Cut based method:

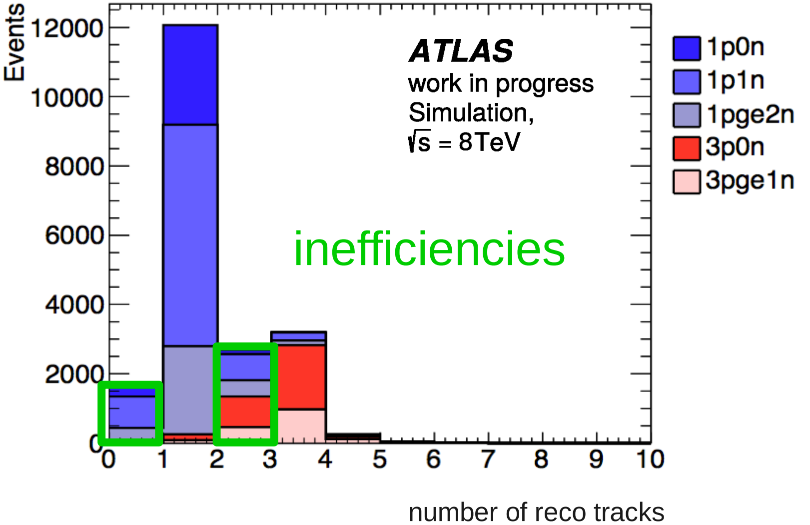
- Take jets with distance parameter ΔR < 0.4
- Select tracks inside this cone and apply quality criteria to suppress unwanted tracks
- Additional separation in
  - Core tracks in ΔR < 0.2:
    - Used to compute charge multiplicity
  - Wide tracks in 0.2 < ΔR < 0.4:
    - Used for tau identification variables

Tau track selection
$p_T > 1$ GeV
nPix ≥ 2
nSi ≥ 7
$d_0 < 1$ mm
$z_0 \sin\theta < 1.5$ mm



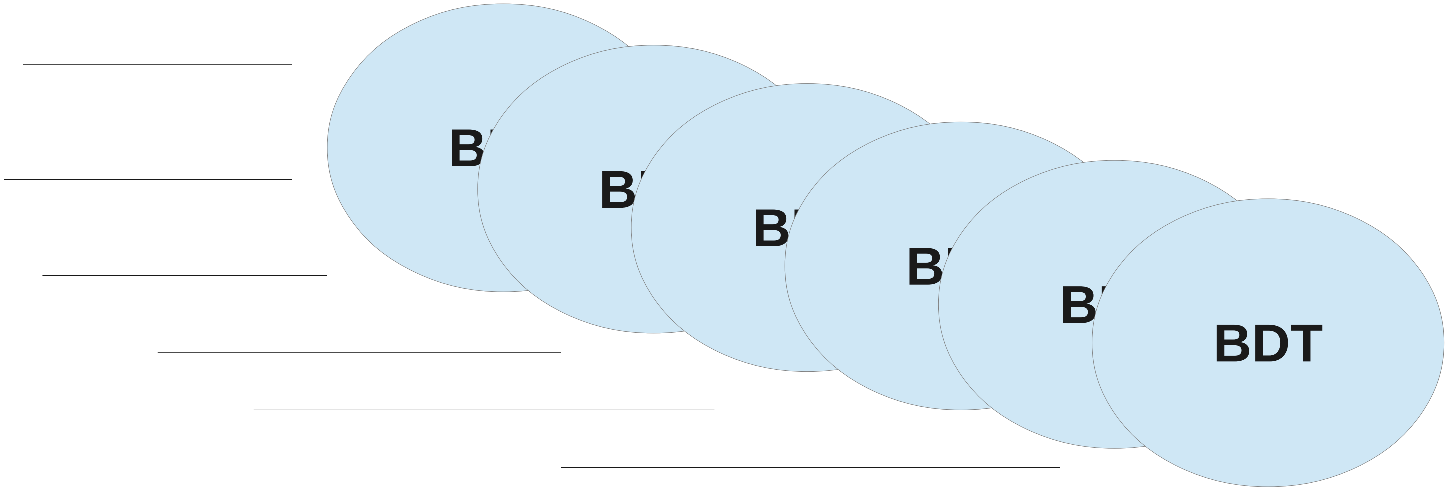
Problems

- Most analysis select taus with 1 or 3 tracks
  - Proper association of tracks directly affects the efficiency
- Major causes of inefficiency:
  - Hadronic interactions
  - Miss-association
  - Merged tracks
  - Missing pixel hits



New method

Using Boosted Decision Trees to classify tracks



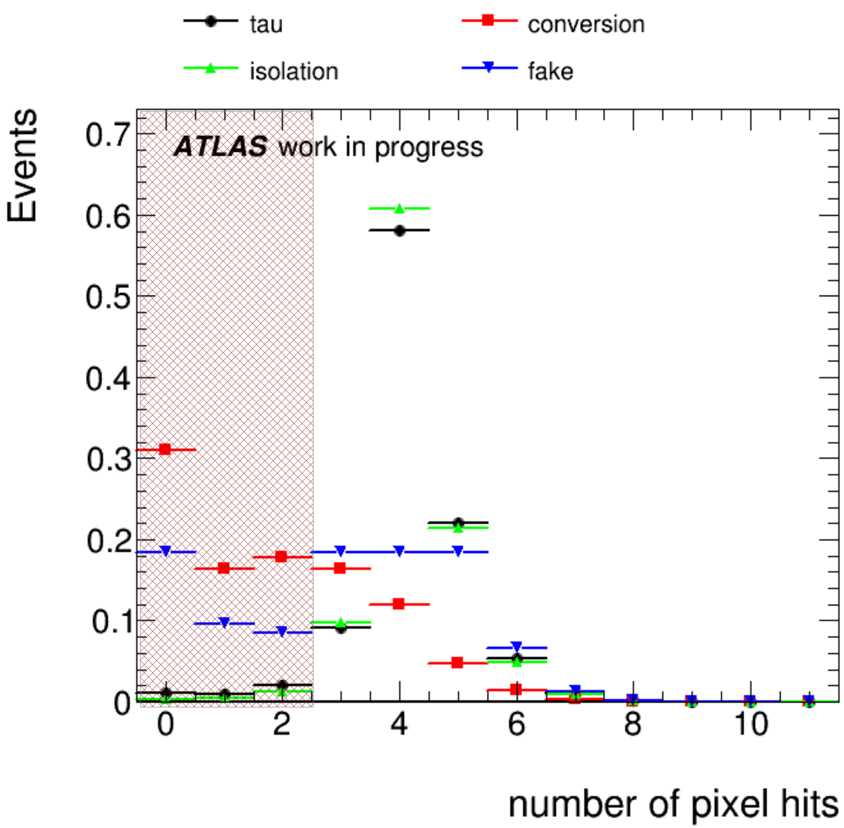
Track categories

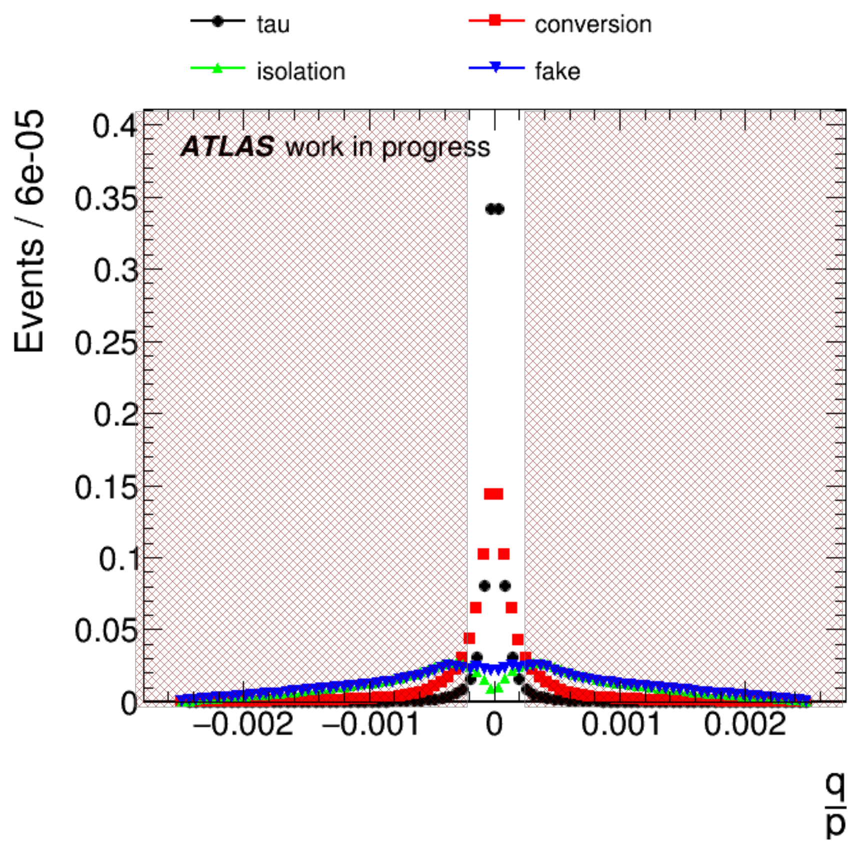
- `TT` / tau: Tracks from the direct tau decay
- `CT` / conversion: Conversion tracks
- `IT` / isolation: Isolation tracks (from underlying event)
- `FT` / fake: Fake tracks, Pileup tracks, (Unclassified tracks)

richard.hartmann@cern.ch

BDT vs. cut based

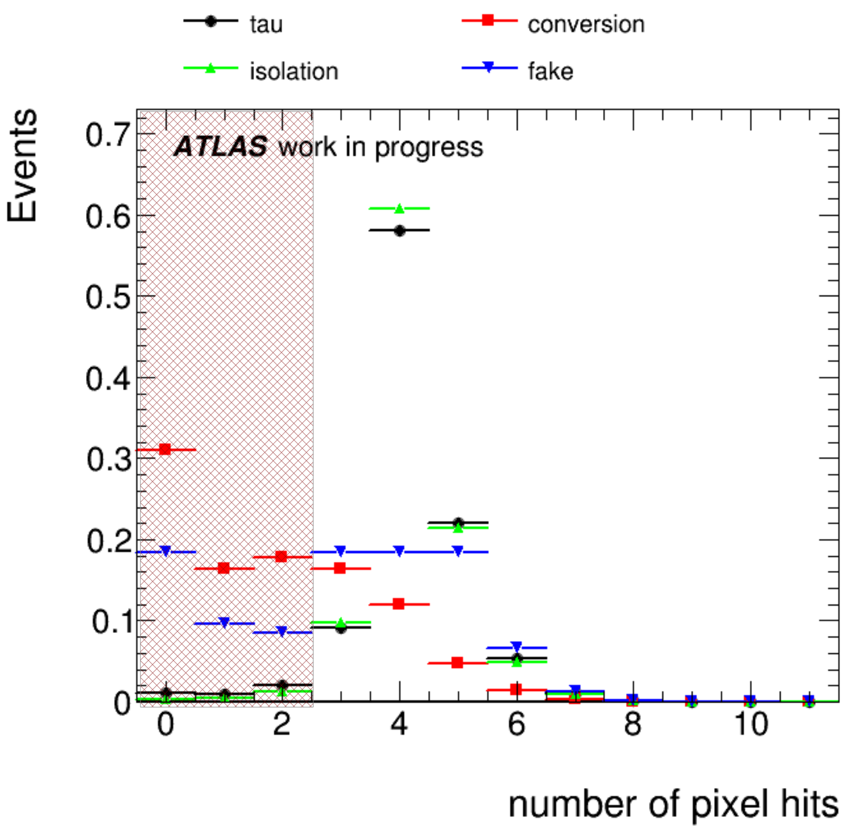
- Cut based selection criteria give good performance to reject conversion, isolation and fake tracks

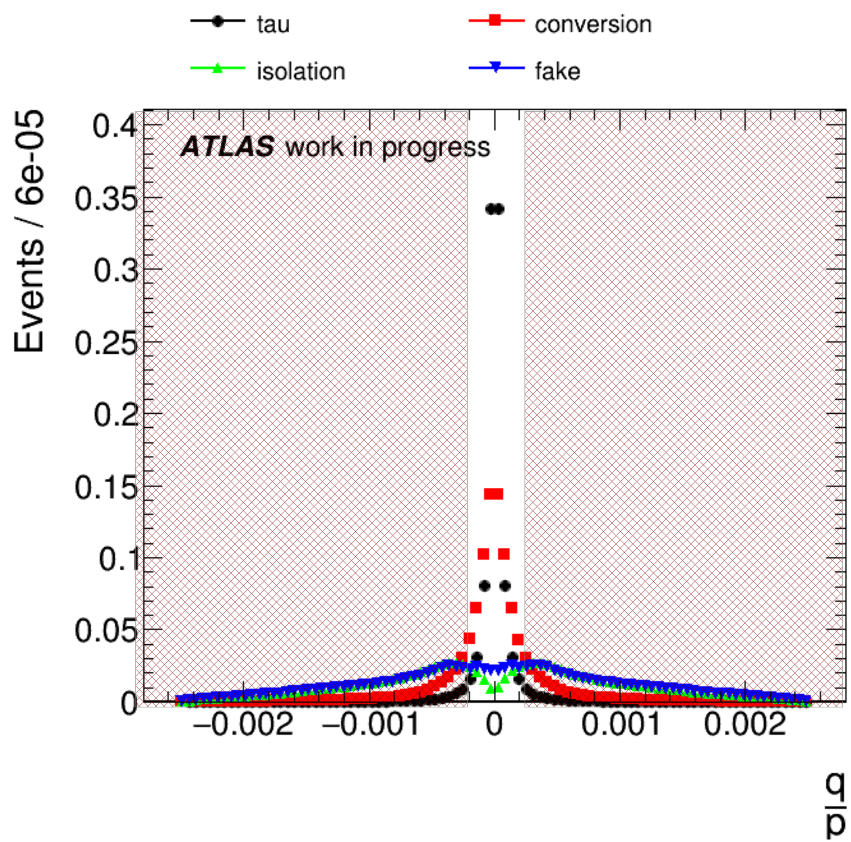




BDT vs. cut based

- But loss in statistics
  - p_T → ~10%
  - nPixHits → ~2%

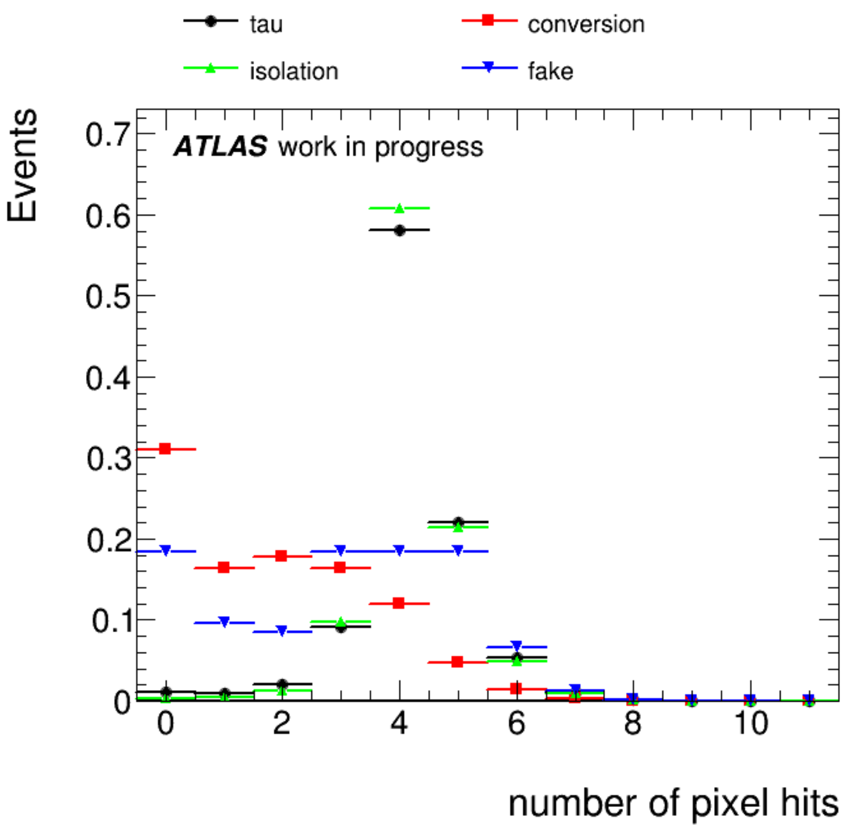


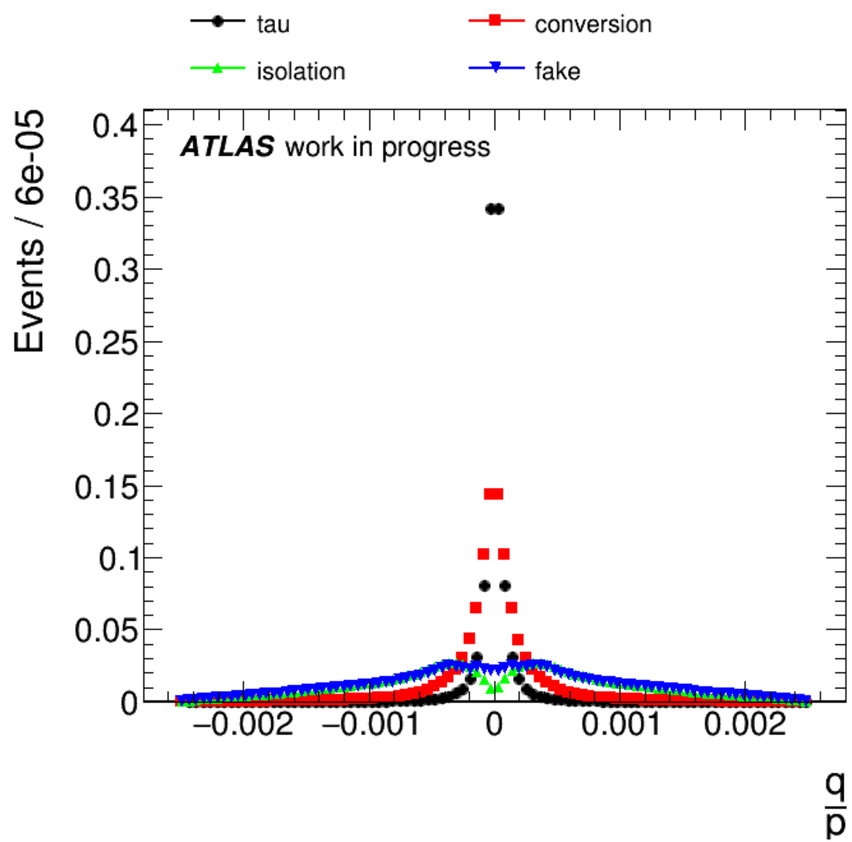


richard.hartmann@cern.ch

BDT vs. cut based

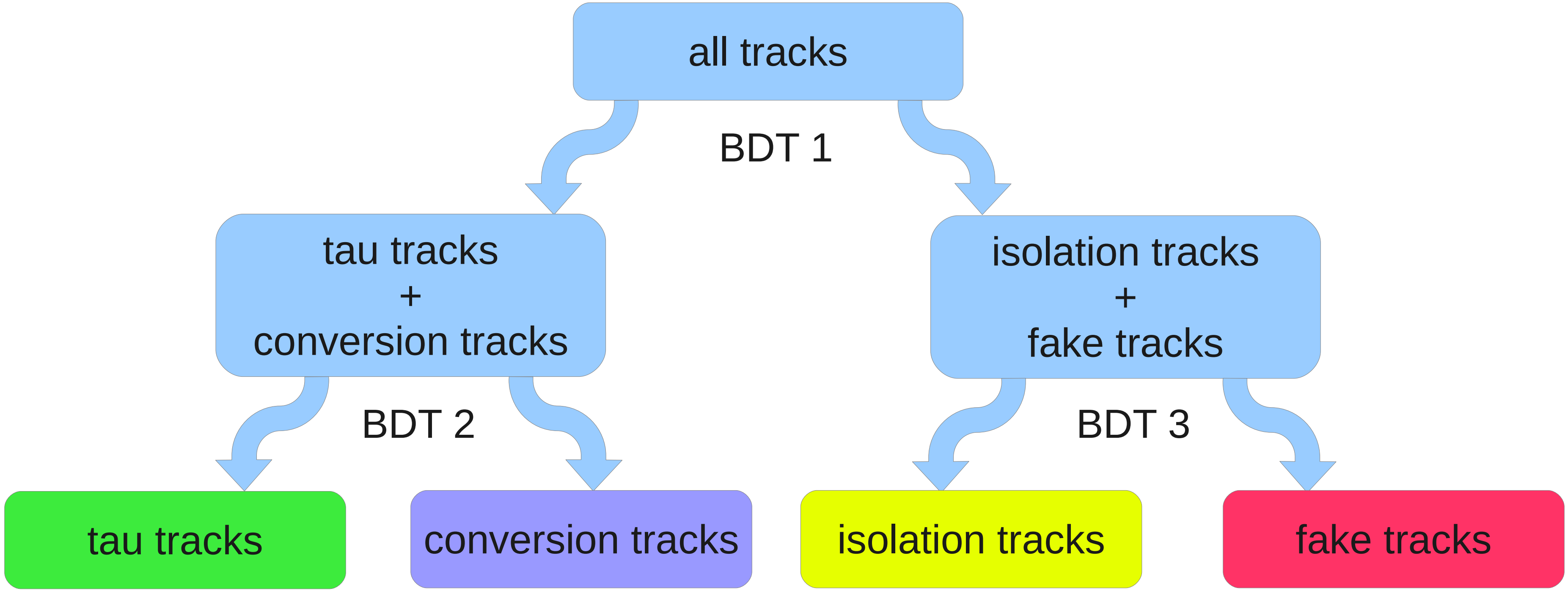
- BDT uses full information





richard.hartmann@cern.ch

BDT training - workflow



richard.hartmann@cern.ch

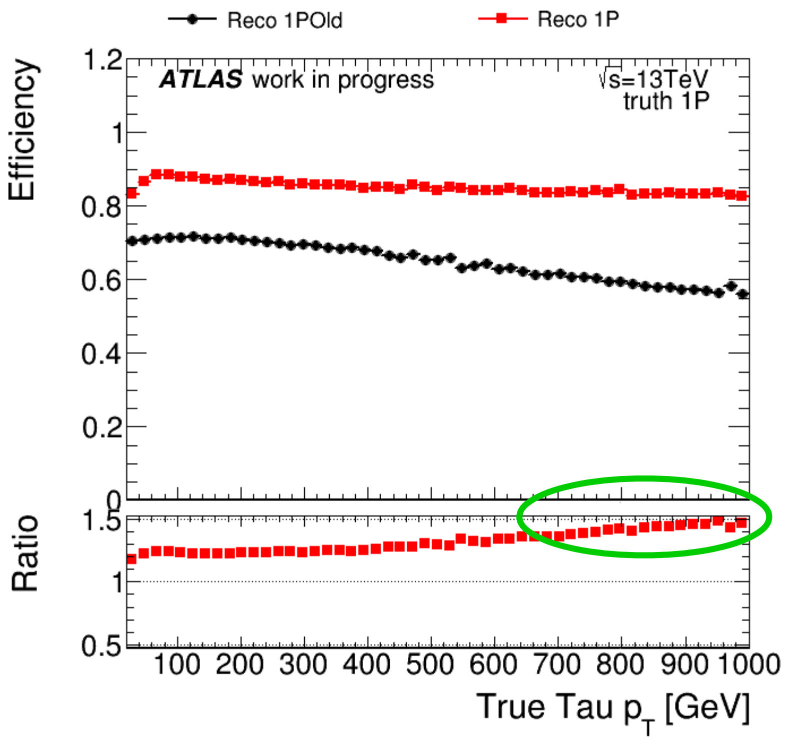
BDT training - parameter

- Input variables:
  - Various pixel detector hit variables
  - Impact parameter
  - Track eta
  - Track and tau momentum

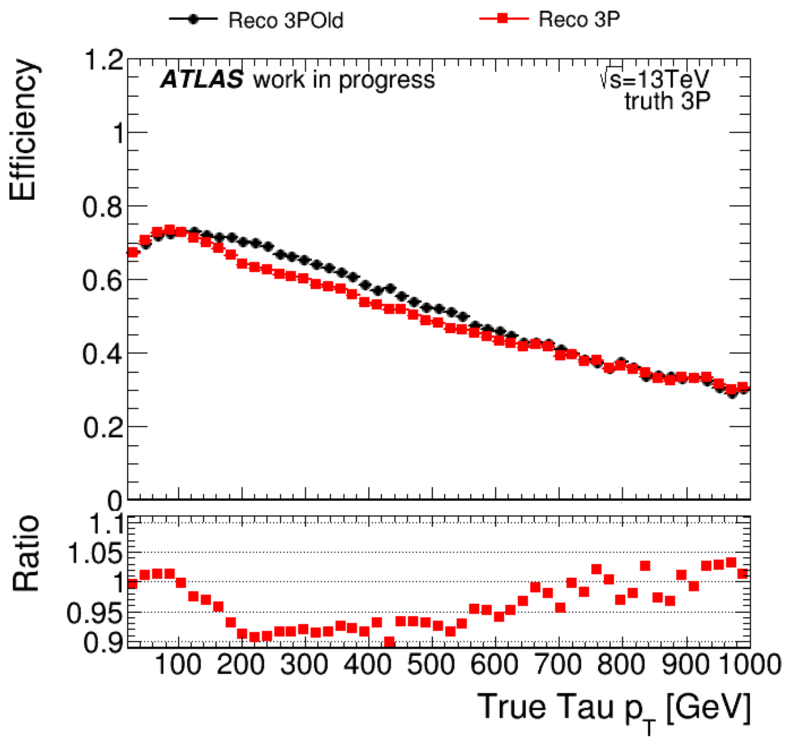
- Input samples
  - Monte Carlo Simulations
    of DYtautau and Ztautau (mc15)

Track Classification Performance

- Better classification efficiency than cut based methods



BR(1P)$_{had}$ ~ 80%



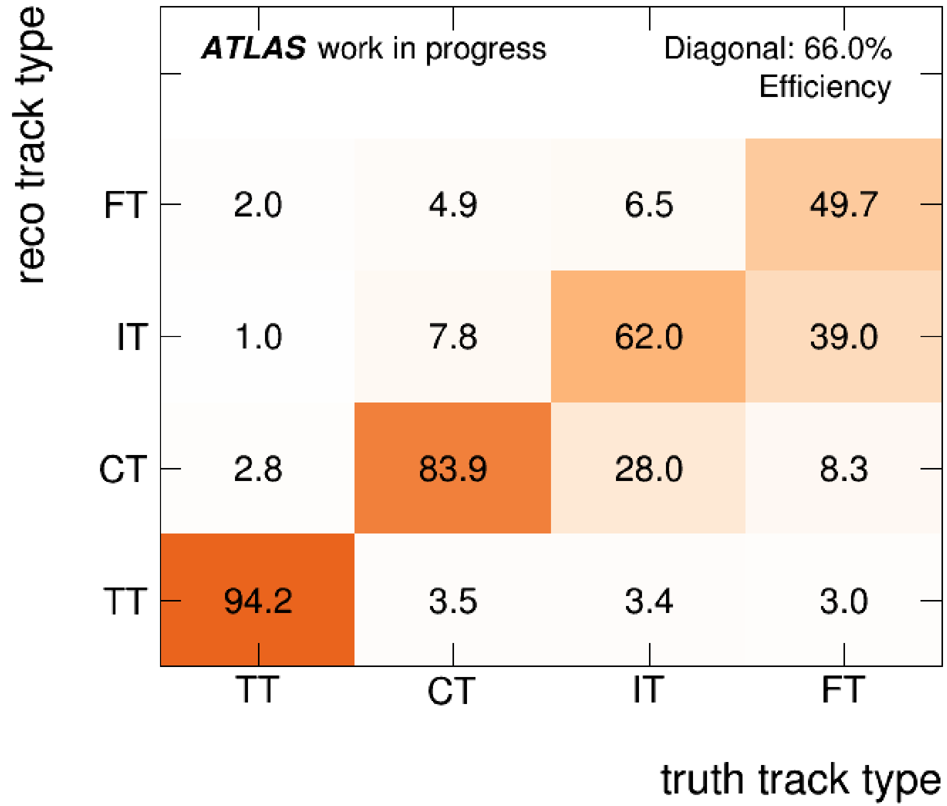
BR(3P)$_{had}$ ~ 20%

richard.hartmann@cern.ch

Classification Performance

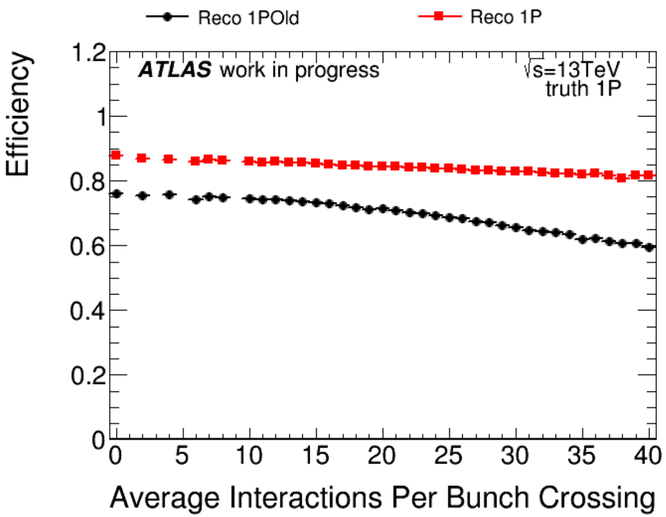
- Good classification of tau tracks
- Lack of statistics in isolation tracks causes reduced discrimination of isolation and fake tracks

TT – tau tracks
CT – conversion tracks
IT – isolation tracks
FT – fake tracks



Summary and Outlook

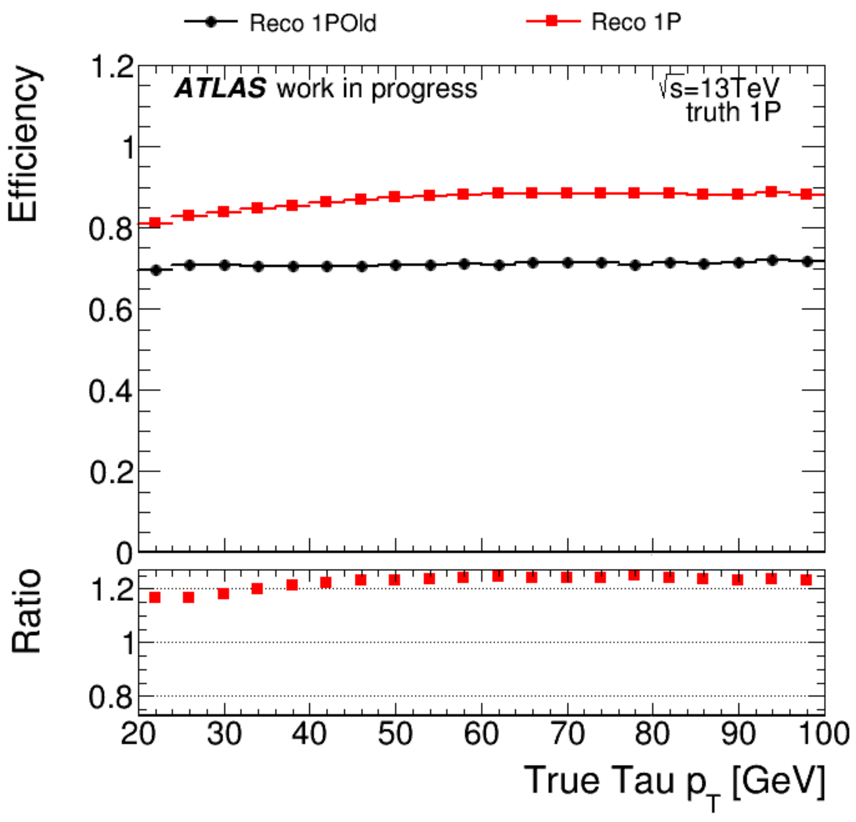
- Track classification via BDTs give improvements in tau reconstruction and identification
- Biggest effect in high τ-p_T region
- Increased robustness against pileup
- Use of ATLAS integrated software

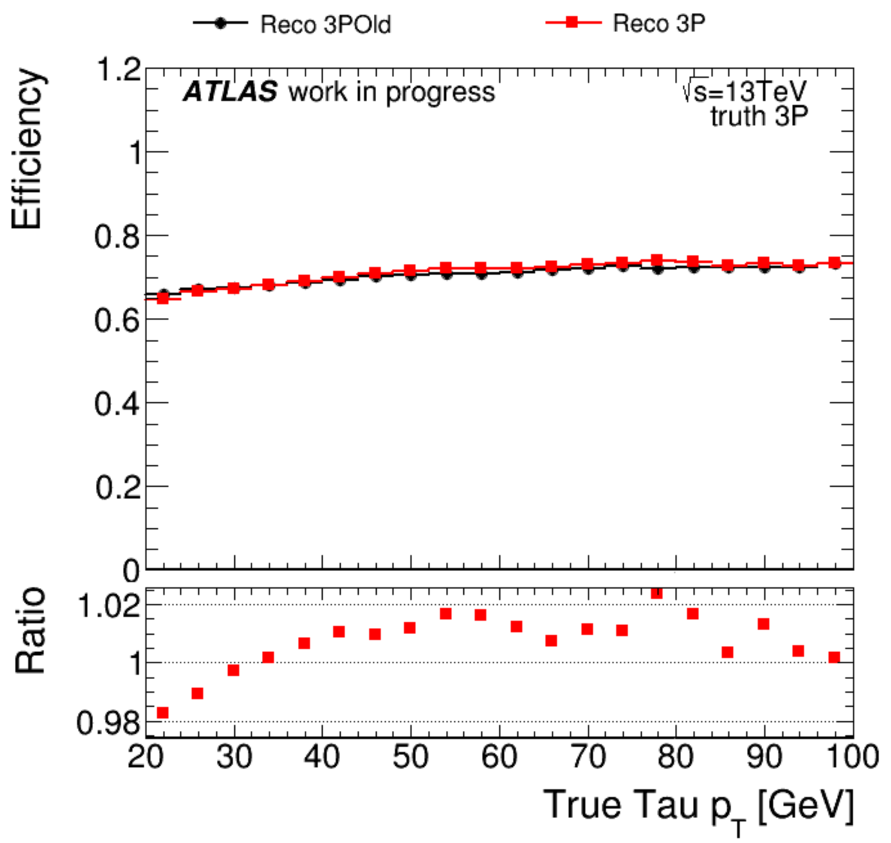


- Further studies ongoing to improve separation power and reconstruction efficiency, like:
  - different truth categories
  - Multi-classification algorithms
  - Vertex reconstruction

BACK UP

Further plots





richard.hartmann@cern.ch

BDT Input Variables

Used for all BDTs

Variable	Discrimination power against / comments
track η	CT
qOverP	IT and FT, but also CT
ΔR wrt. jet seed axis	IT and FT, but also CT
$z_0 \cdot \sin(\theta)$ (wrt. TJV)	FT, but also CT
d_0	CT, but also FT
rConv	IT, but also CT
rConvII	IT, but also CT
numberOfInnermostPixelLayerHits	CT
numberOfPixelSharedHits	Intended to recover merged tracks
numberOfSCTSharedHits	Intended to recover merged tracks
nPixHits	CT
nSiHits	CT
eProbabilityHT	CT, IT and FT, used instead of TRT variables
jet seed p_T	None

$$\mathbf{rConv} = \sqrt{|d_0| \cdot p_T / (0.3)}$$
$$\mathbf{rConvII} = \mathbf{rConv}, \text{ if } d_0 \cdot q > 0$$
$$= -\mathbf{rConv}, \text{ otherwise}$$

work in progress

richard.hartmann@cern.ch

Variable ranking from TMVA

	TT-CT vs. IT-FT		TT vs. CT		IT vs. FT	
Rank	Variable	Importance	Variable	Importance	Variable	Importance
1	dRJetSeedAxis	5.884e-01	numberOfInnermostPixelLayerHits	5.297e-01	nSiHits	3.441e-01
2	qOverP	5.183e-01	nPixHits	4.970e-01	nPixHits	1.715e-01
3	z0sinThetaTJVA	3.381e-01	d0	4.528e-01	numberOfTRTHits	1.465e-01
4	eProbabilityHT	1.057e-01	nSiHits	3.331e-01	d0	1.368e-01
5	numberOfInnermostPixelLayerHits	4.176e-02	rConv	2.219e-01	numberOfSCTSharedHits	1.283e-01
6	nPixHits	4.134e-02	qOverP	1.648e-01	numberOfInnermostPixelLayerHits	8.982e-02
7	nSiHits	2.859e-02	eProbabilityHT	1.634e-01	z0sinThetaTJVA	7.219e-02
8	numberOfTRTHits	1.953e-02	z0sinThetaTJVA	1.608e-01	dRJetSeedAxis	4.587e-02
9	trackEta	1.278e-02	rConvII	1.583e-01	eProbabilityHT	3.997e-02
10	numberOfPixelSharedHits	1.192e-02	dRJetSeedAxis	9.920e-02	trackEta	3.661e-02
11	numberOfSCTSharedHits	9.636e-03	trackEta	4.092e-02	qOverP	3.586e-02
12	rConv	7.176e-03	numberOfTRTHits	2.021e-02	jetSeedPt	2.891e-02
13	rConvII	6.502e-03	numberOfPixelSharedHits	2.016e-02	numberOfPixelSharedHits	2.214e-03
14	d0	2.956e-03	jetSeedPt	1.562e-02	rConvII	7.356e-04
15	jetSeedPt	8.368e-04	numberOfSCTSharedHits	7.943e-03	rConv	5.912e-04

work in progress

richard.hartmann@cern.ch

Migration matrix

- prong selection