Track Reconstruction in Hadronic Tau Decays at the ATLAS Detector

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ATLAS

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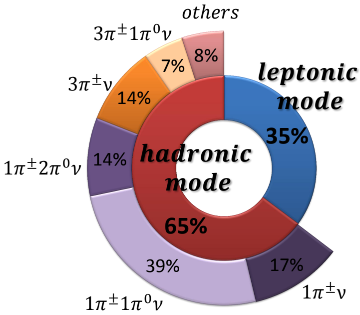
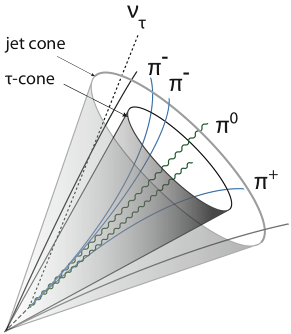
Introduction – Tau Leptons



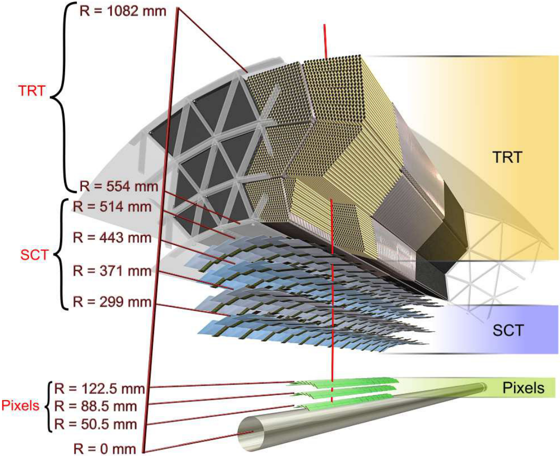
- heaviest known lepton with $m_{\tau} = 1.777\,\mathrm{GeV}$
- decay length $c\tau = 87\,\mu\mathrm{m}$
- leptonic and hadronic decay modes
- in general low multiplicity, i.e. predominantly 1 or 3 charged pions
- physics analyses with tau final states often require reconstructed 1 or 3 prong taus

$\Rightarrow$ it is crucial to associate correct number of tracks to the tau



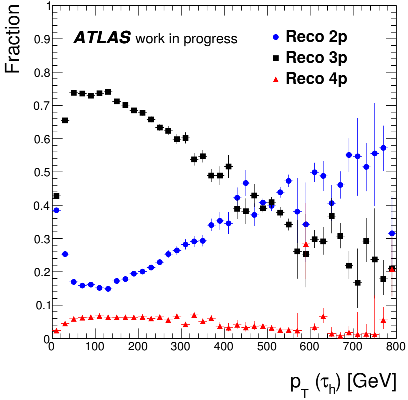
Run 1 tau track reconstruction

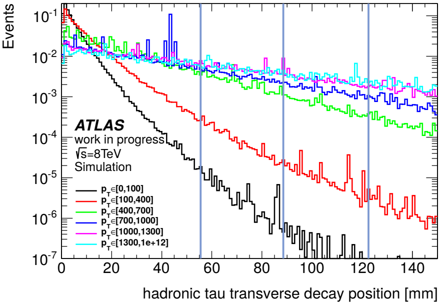
- started from a loose track selection working point
- collect tracks in cone $\Delta R < 0.2$
- apply quality criteria to suppress pileup tracks, etc.
  - $p_T > 1\,\mathrm{GeV}$
  - $\#$ pixel hits ≥ 2
  - $\#$ silicon hits ≥ 7
  - $|z_0 \sin(\theta)| < 1.5\,\mathrm{mm}$
  - $|d_0| < 1\,\mathrm{mm}$



JINST 3 (2008) S08003

Problems during run 1



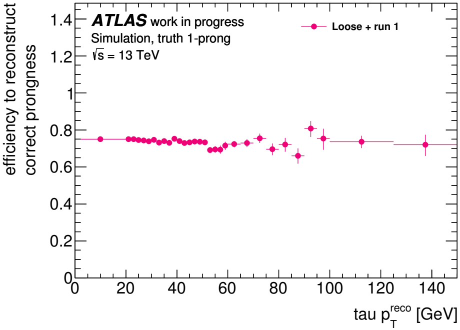


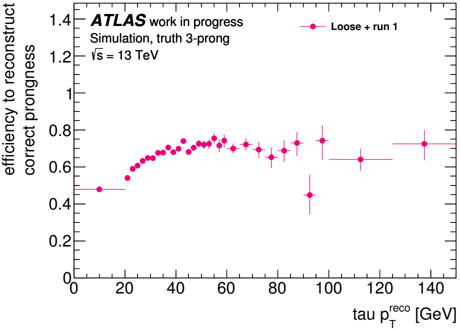
- poor efficiency to reconstruct 3 prong tau decays with 3 tracks at high p_T due to track merging
- non-negligible amount of taus decay inside the pixel detector

⇒ large efficiency drop to reconstruct these tracks due to pixel hits requirement

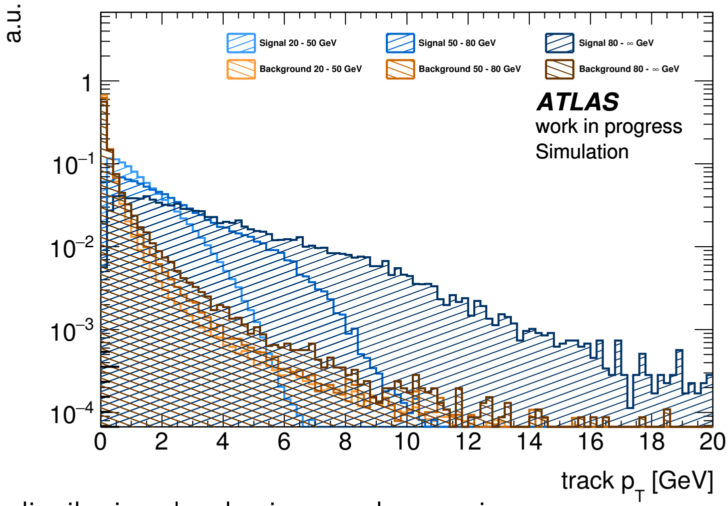
Performance of track selection in run 2

- starting from loose working point
- apply cuts from run 1





track p_T distribution for various tau p_T regions



- distribution already gives good separation power
- strong dependence on tau p_T
- partly similar effects for other distributions

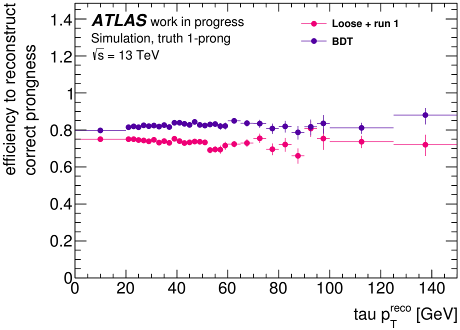
How to increase track selection performance

- optimizing quality cuts in bins of tau p_{T}
  - can get quite challenging to find best thresholds
  - hard to handle correlations
  - not further considered
- use MVA techniques
  - BDT's are trained using TMVA
  - signal: tracks from tau decays
  - background: pileup, conversions, underlying event, mis-reconstructed tracks
  - added tau p_{T} and η to input variables of tracks to account for such dependencies

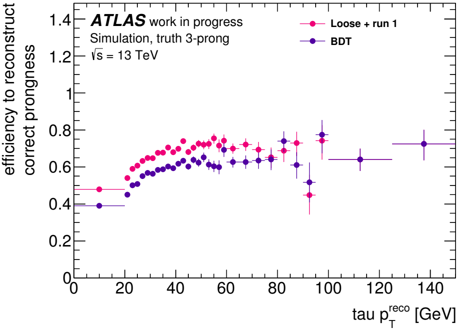
Results using the BDT approach

- better efficiency for 1 prong
- worse performance for 3 prong

1 prong

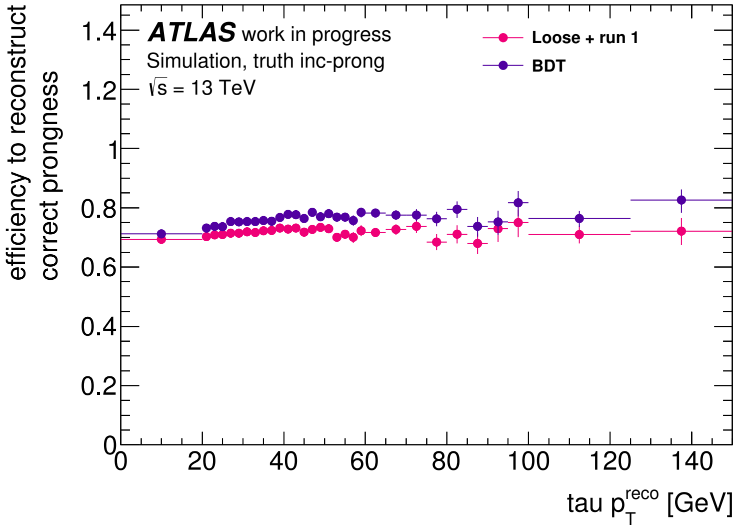


3 prong



Results using the BDT approach

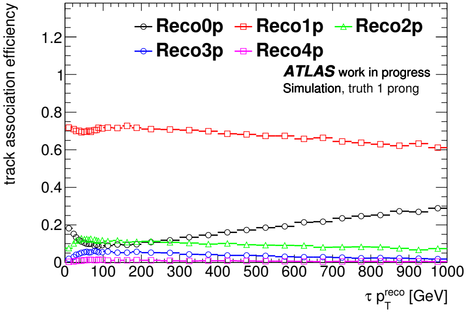
- overall better efficiency for 1 and 3 prong combined



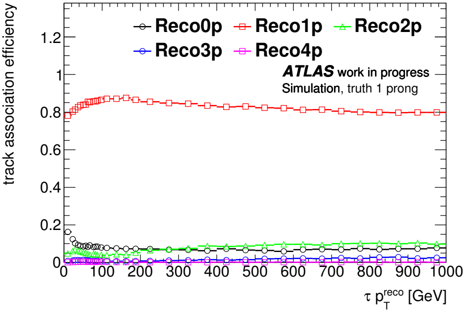
High p_T track association efficiency

- extended training to very large p_T using high mass $Z/\gamma^* \to \tau\tau$ samples

loose + run 1 selection



BDT based selection

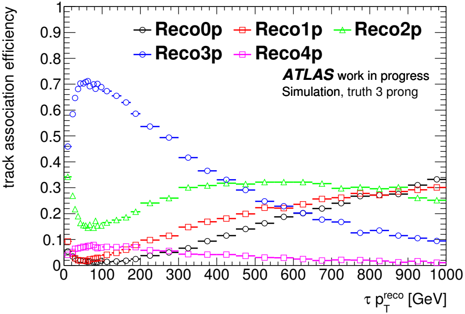


- overall better performance than standard selection
- small p_T dependence for loose + run 1 selection is reduced

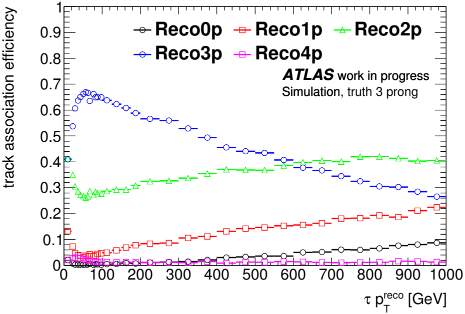
High p_T track association efficiency

- extended training to very large p_T using high mass $Z/\gamma^* \to \tau\tau$ samples

loose + run 1 selection



BDT based selection



- BDT approach shows better performance than standard selection at high p_T
- reconstruction as 0 prong is strongly reduced
- increase from 9% to 26% in the highest bin

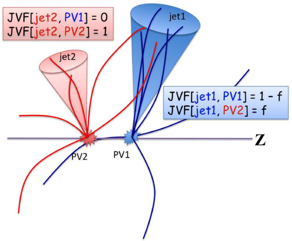
Conclusions

- BDT approach shows better performance compared to standard selection
- BDT trained for high p_{T} taus reduces problem of track merging and decays within the pixel detector
- large room for improvements in optimizing training, especially input variables, options, thresholds on BDT score

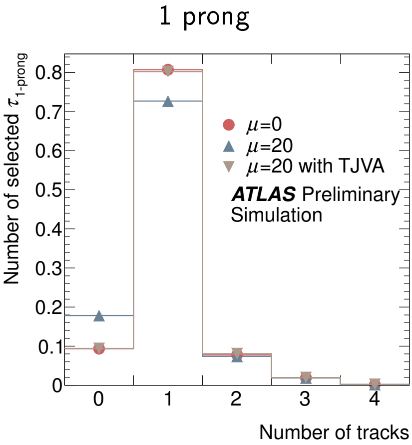
BACKUP

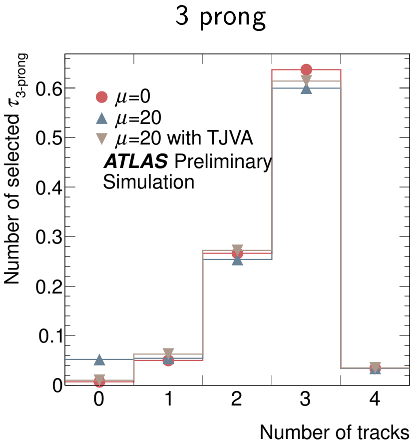
Run 1 tau track reconstruction

- started from a loose track selection working point
- collect tracks in cone $\Delta R < 0.2$
- apply quality criteria to suppress pileup tracks, etc.
  - $p_T > 1\,\mathrm{GeV}$
  - $\#$ silicon hits ≥ 7
  - $\#$ pixel hits ≥ 2
  - $|z_0 \sin(\theta)| < 1.5\,\mathrm{mm}$
  - $|d_0| < 1\,\mathrm{mm}$
- impact parameter were calculated wrt. tau vertexfound by Tau Jet Vertex Association (TJVA)
- TJVA: find vertex with largest fraction: $f_{JVF}(\text{jet}|\text{vtx}) = \frac{\Sigma p_T^{\text{trk}|\text{vtx}}}{\Sigma p_T^{\text{trk}}}$



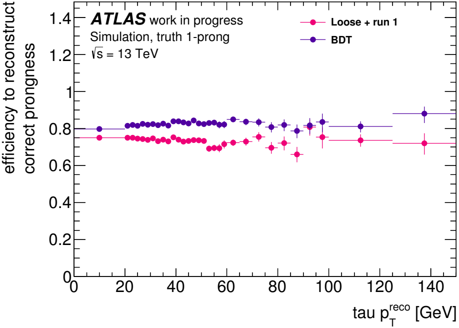
Problems during run 1

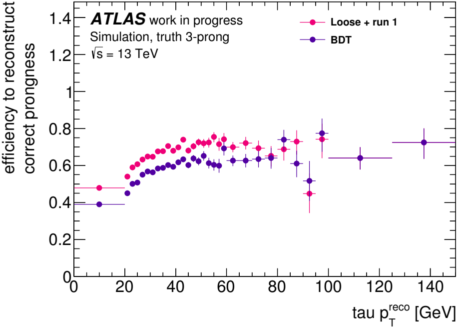




- additional pileup and conversion tracks due to too loose cuts
- lost tau tracks due to too tight cuts or wrong vertex decision

Results using the BDT approach

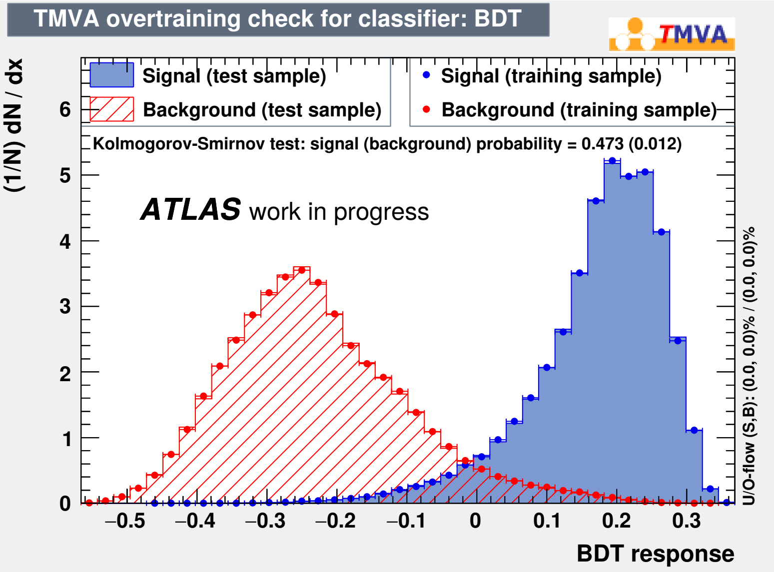




- overall better performance for 1 prong
- slighly worse performance for 3 prong

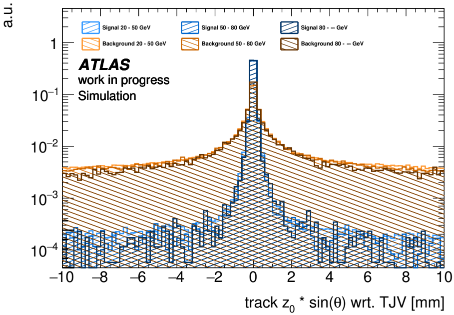
Rank	Variable	Separation
1	qOverP	4.080e-01
2	z0sinThetaTJVA	3.264e-01
3	d0	2.423e-01
4	nPixHits	2.422e-01
5	numberOfPixelHits	2.152e-01
6	nSiHits	2.123e-01
7	numberOfBLayerHits	2.116e-01
8	expectBLayerHit	1.333e-01
9	numberOfSCTHits	1.191e-01
10	numberOfTRTHighThresholdHits	4.636e-02
11	numberOfTRTHits	4.080e-02
12	z0sinTheta	1.651e-02
13	theta	1.410e-02
14	TrackEta	1.333e-02
15	tauEta	9.745e-03
16	numberOfPixelDeadSensors	5.838e-03
17	numberOfSCTSharedHits	4.787e-03
18	numberOfPixelSharedHits	2.285e-03
19	tauPt	5.426e-04
20	numberOfSCTDeadSensors	3.901e-04

BDT Score distribution

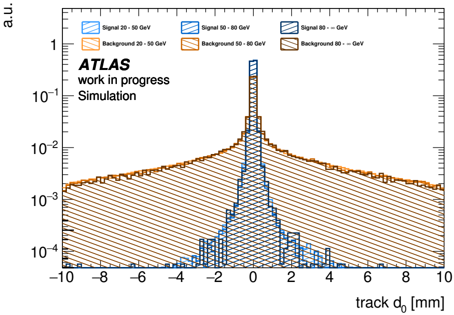


distribution of quality parameters

run 1: $\left|z_0^{\mathrm{TJV}}\right| \cdot \sin(\theta) < 1.5\,\mathrm{mm}$

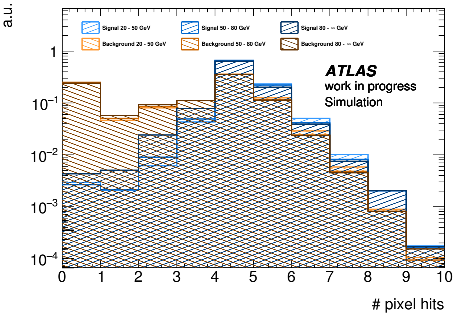


run 1: $|d_0| < 1\,\mathrm{mm}$

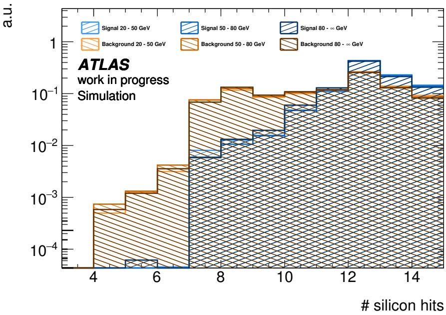


distribution of quality parameters

run 1: # pixel hits ≥ 2

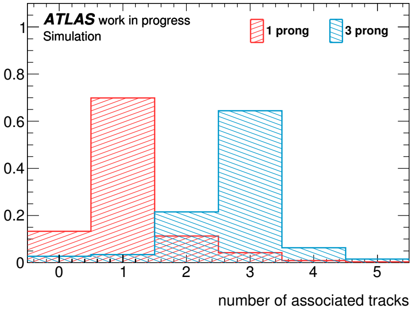


run 1: # silicon hits ≥ 7

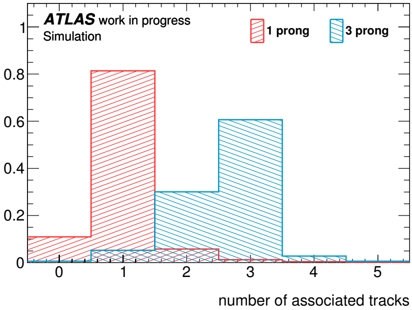


Track distribution comparison

Loose + run 1



BDT approach



- 1 prong
  - BDT approach is able to reduce taus being reconstructed with 3 tracks
  - but also 2 and 0 prong is reduced
- 3 prong
  - more taus are reconstructed with 2 prong for the BDT approach than for Loose + run 1

track selection definitions

ATLAS work in progress

RUN1 track selection:

minPt	1000
minNSiHits	7
minNPixelHits	2
maxZ0SinTheta	1.5
maxD0	1

RUN2 Loose selection:

minPt	400.0
maxAbsEta	2.5
minNSiHits	7
maxNPixelSharedHits	1
maxNSCTSharedHits	2
maxOneSharedModule	true
maxNSiHoles	2
maxNPixelHoles	1

RUN2 Loose-primary track selection:

minNSiHitsIfSiSharedHits	10
useEtaDependentMaxChiSq	true

RUN2 Tight-primary selection:

minNSiHits	9
minEtaForStrictNSiHitsCut	1.65
minNSiHitsAboveEtaCutoff	11
minNBLayerHits	1
maxNPixelHoles	0