Tau Track Reconstruction

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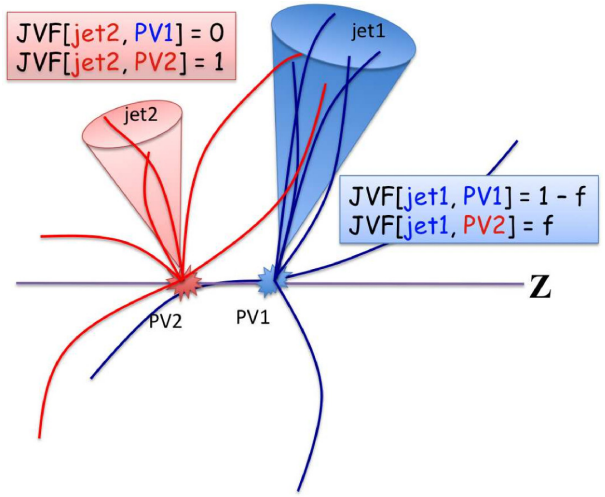
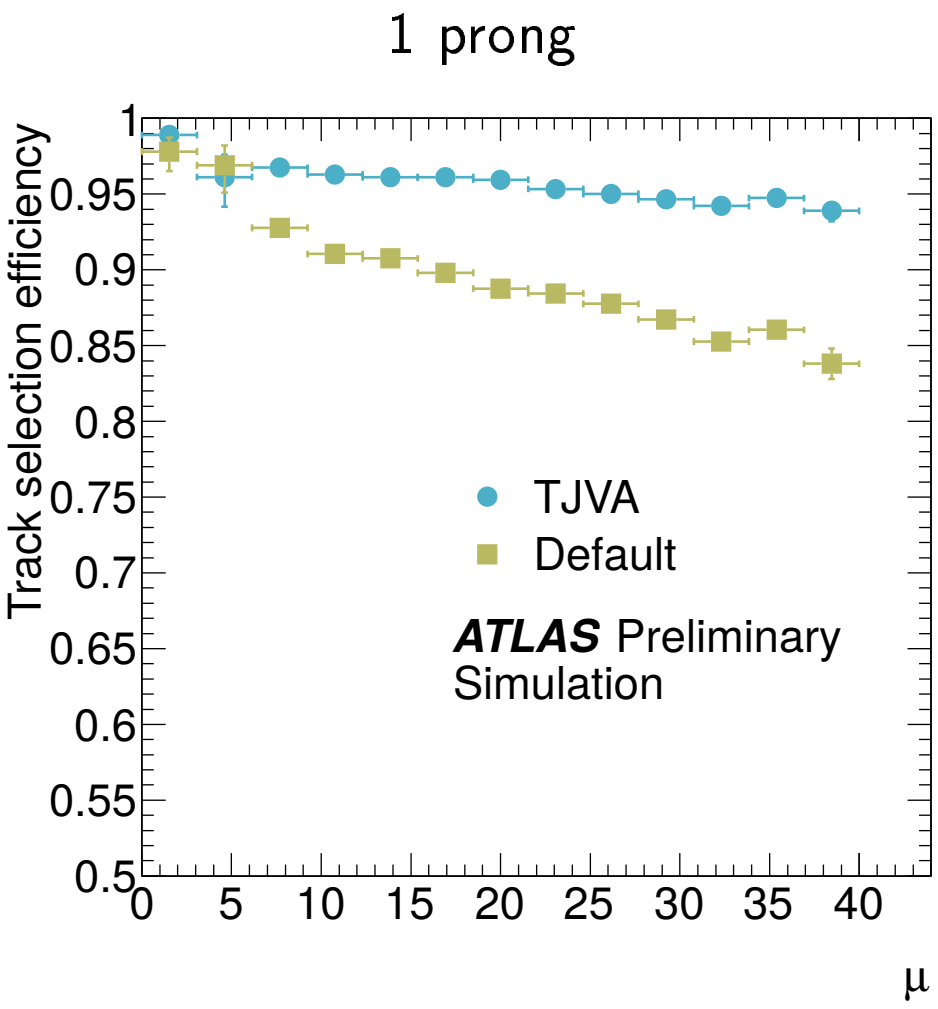
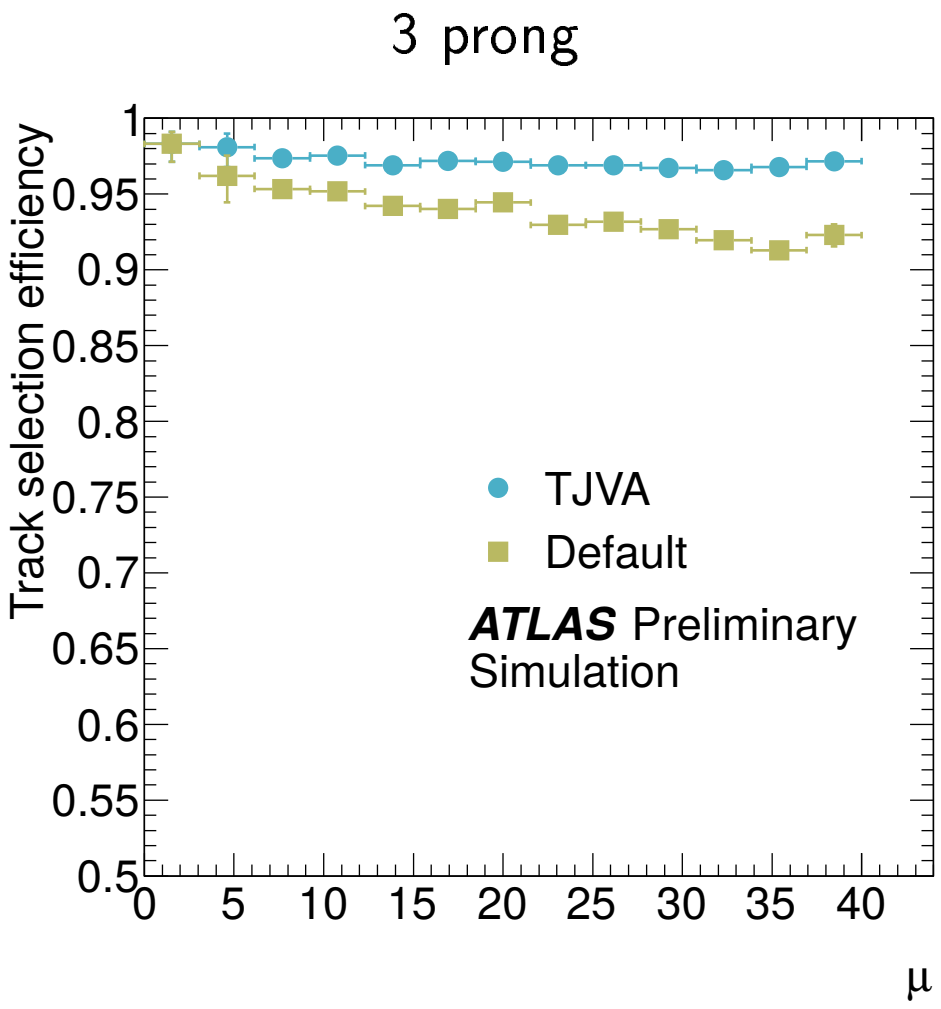
Run 1 tau track reconstruction

- started from a loose track selection working point provided by tracking group
- collect tracks in cone $\Delta R < 0.2$
- apply quality criteria to suppress pileup tracks, etc.
  - $p_{\mathrm{T}} > 1000\ \mathrm{GeV}$
  - # silicon hits ≥ 7
  - # pixel hits ≥ 2
  - $|z_0 \sin(\theta)| < 1.5\ \mathrm{mm}$
  - $|d_0| < 1\ \mathrm{mm}$
- impact parameter were calculated wrt. vertex found by TJVA
- TJVA: find vertex with largest fraction: $f_{\mathrm{JVF}}(\mathrm{jet}|\mathrm{vtx}) = \frac{\Sigma p_{\mathrm{T}}^{\mathrm{trk}|\mathrm{vtx}}}{\Sigma p_{\mathrm{T}}^{\mathrm{trk}}}$

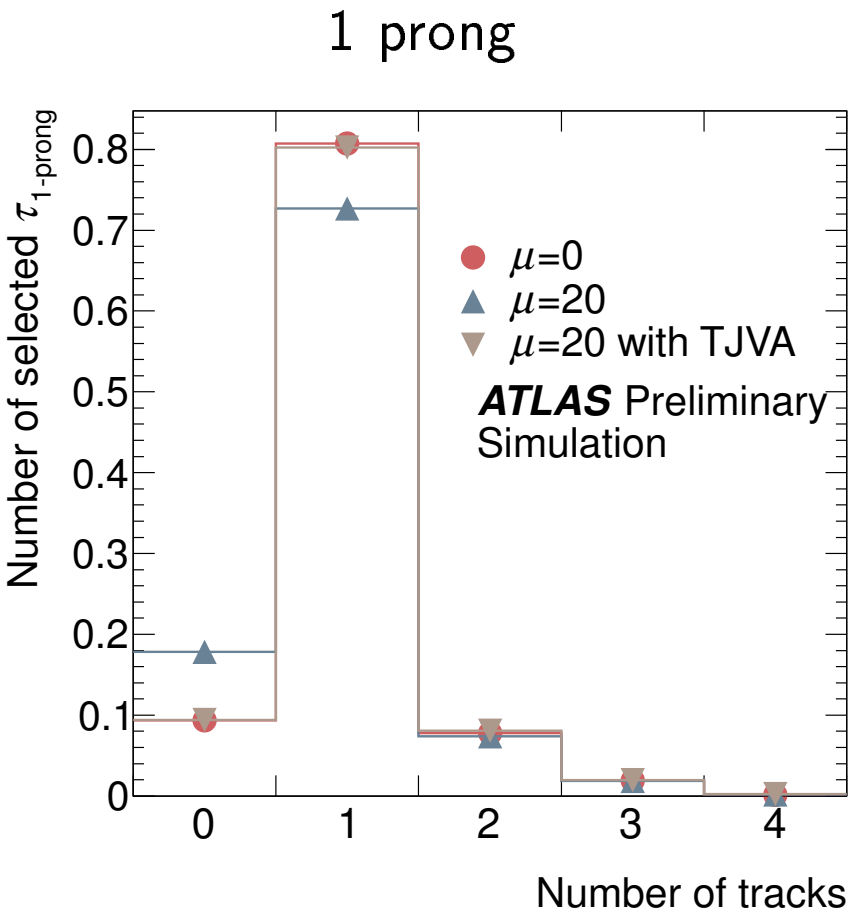


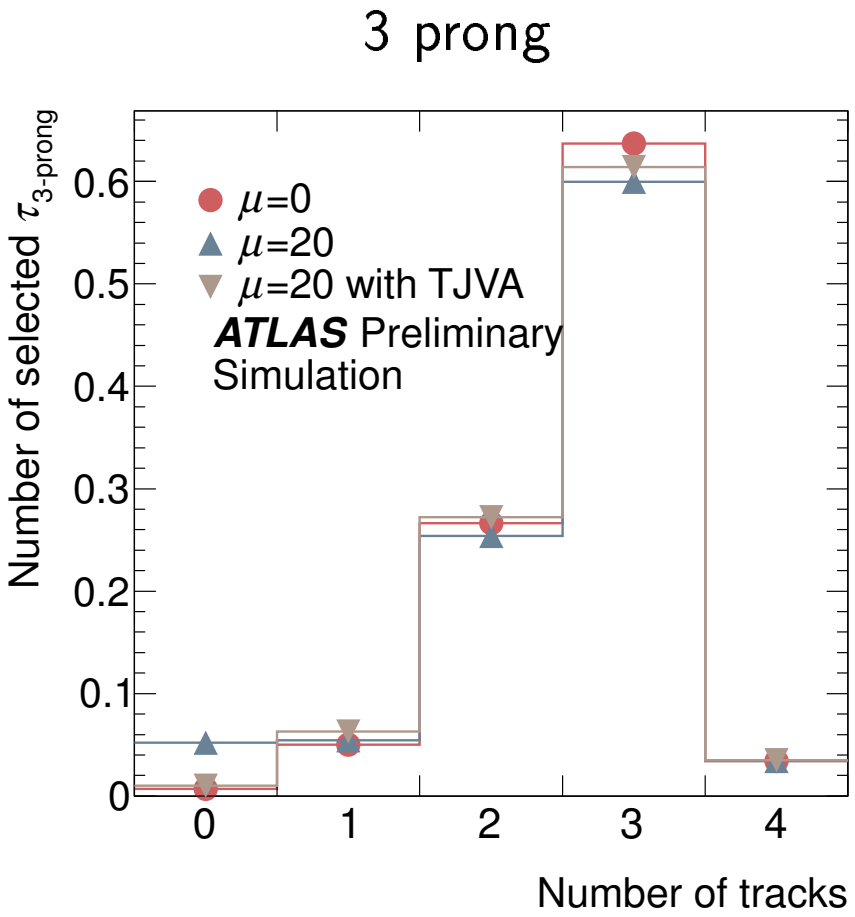
Run 1 track reconstruction performance





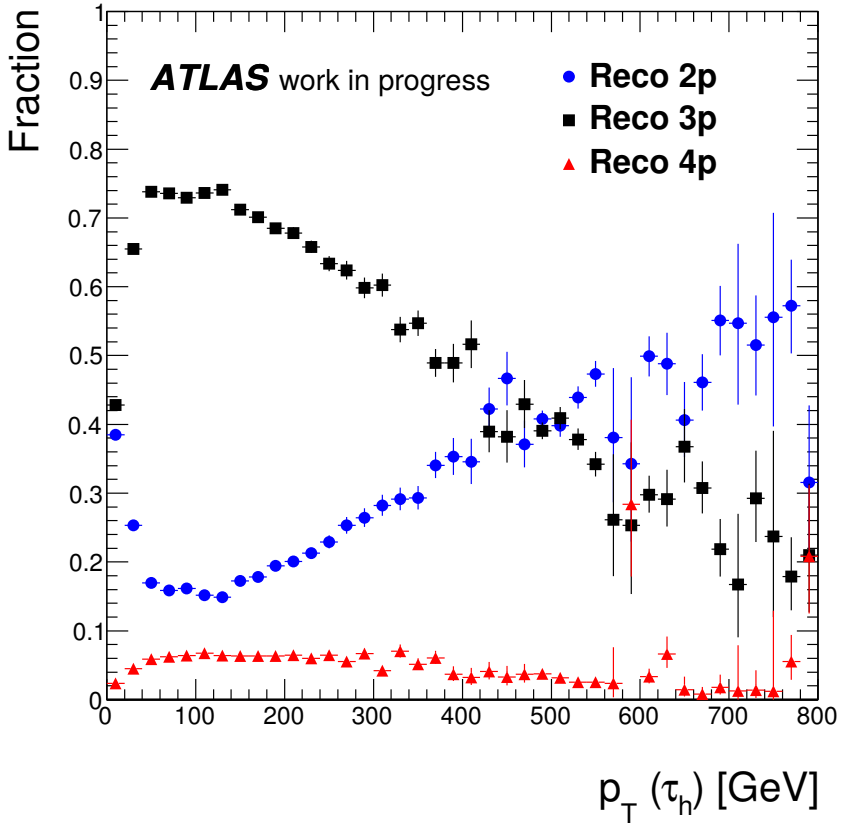
Problems during run 1

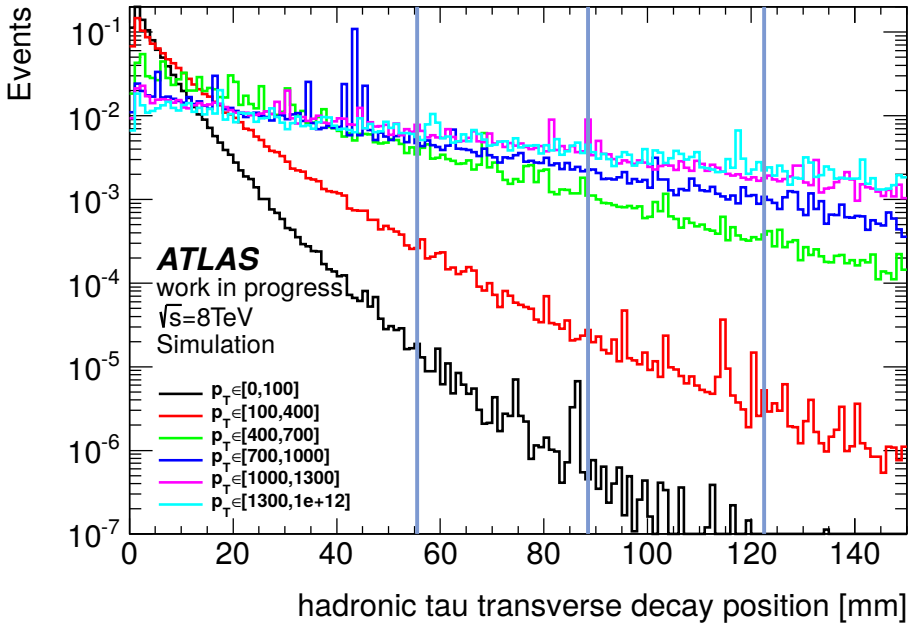




- additional pileup and conversion tracks due to too loose cuts
- lost tau tracks due to too tight cuts or wrong vertex decision

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

$\Rightarrow$ large efficiency drop to reconstruct these tracks due to pixel requirement

On the way to run 2

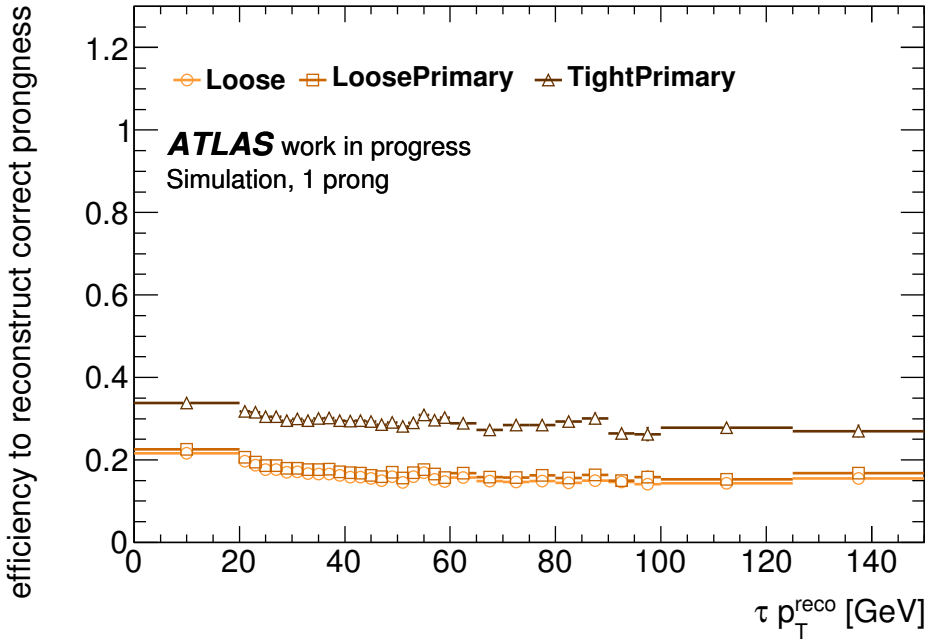
Run I:

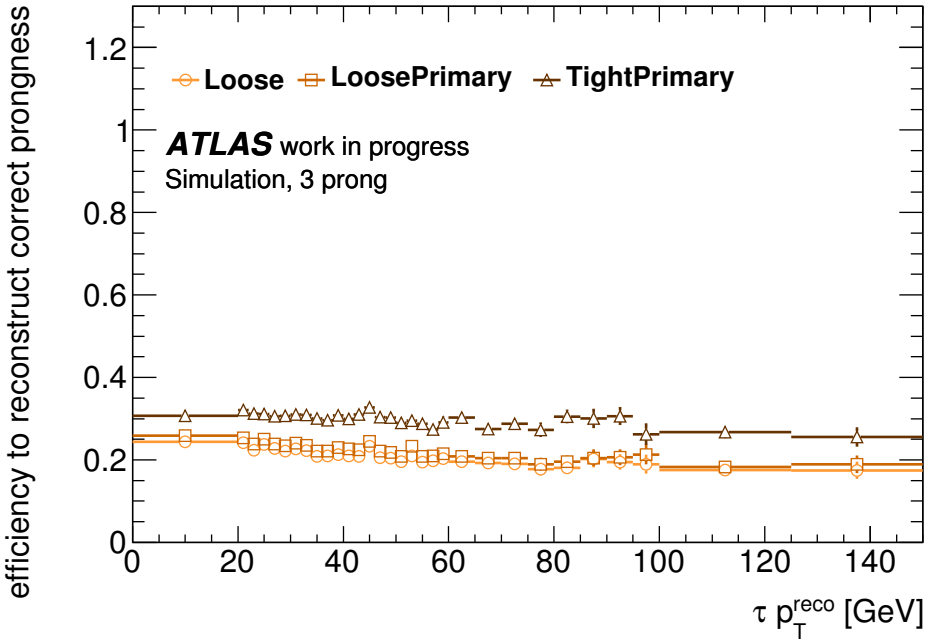
- 2 working points for tracks:
  - "loose": very good charged particle reconstruction efficiency, non-negligible fake rate
  - "tight": negligible fake track contribution, few percent drop for track efficiency

Run II:

- new IBL
- increase in pileup
- 3 working points for tracks:
  - "loose": similar to "loose" in Run I
  - "tight-primary": similar to "tight" in Run I
  - "loose-primary":
    - attempt to harmonize track selection between groups
    - improve track quality and reduction in fake rate
    - expected to be a good baseline for tau decays
- no official recommendation for particle decays behind first measurement plane

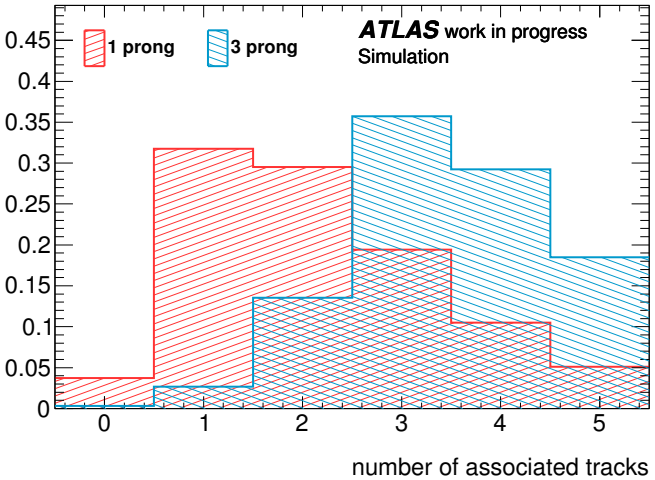
Performance of recommended run 2 working points



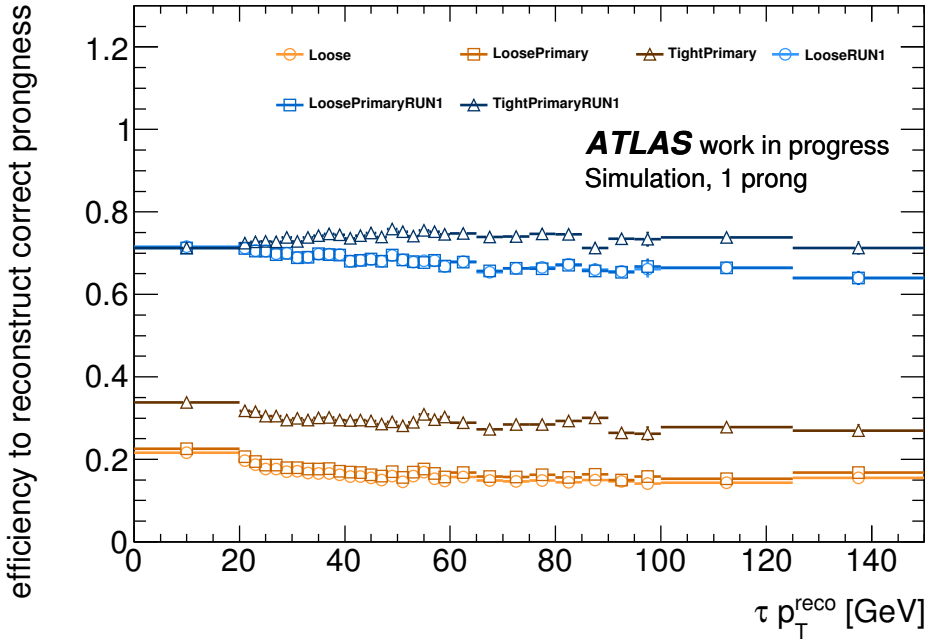


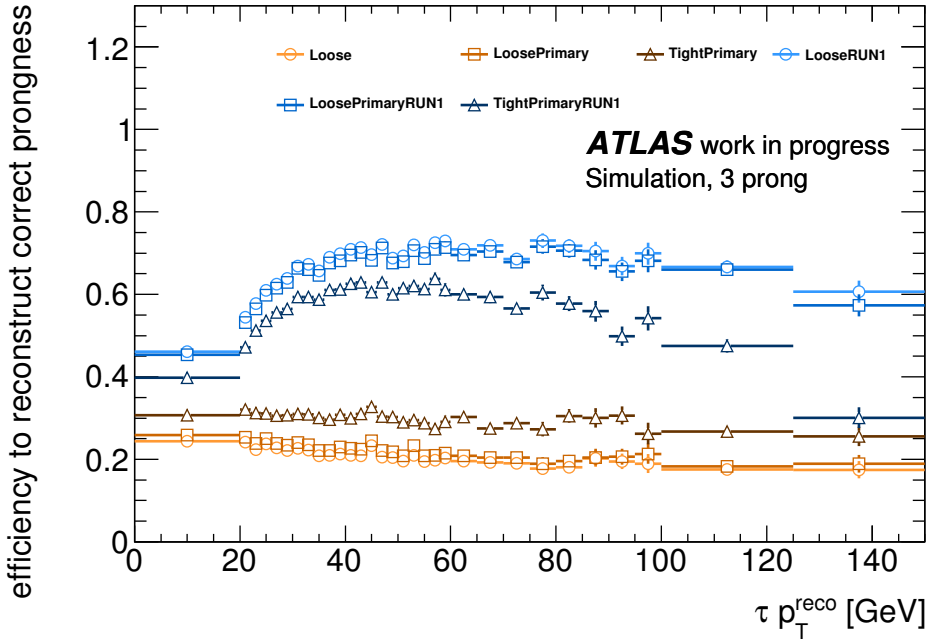
TightPrimary

- very poor performance about 20-30% over whole p_T range
- reason is too loose track quality criteria
- collecting up to many tracks from pileup and conversions



Performance of recommended run 2 working points

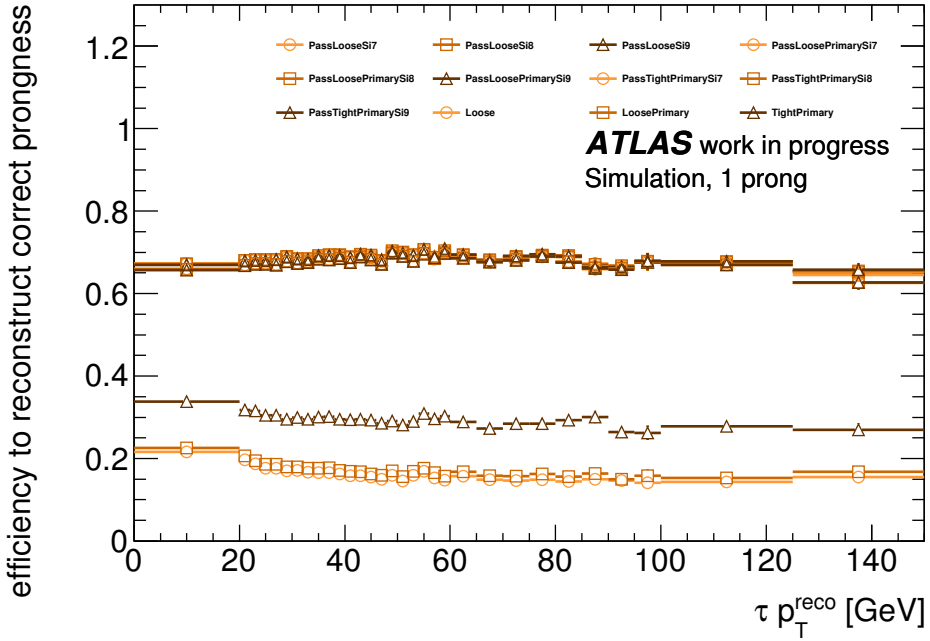


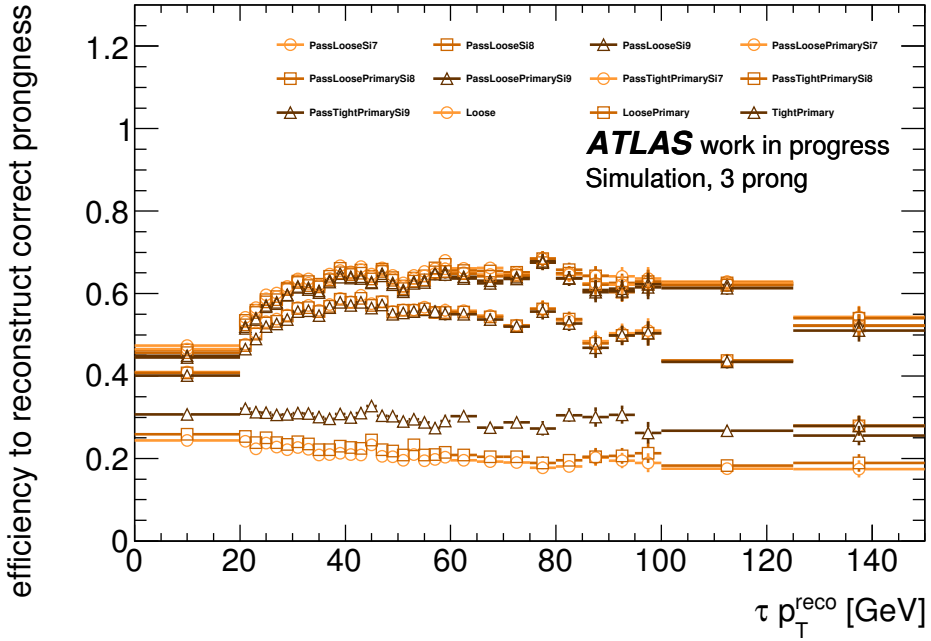


- applying run 1 selection on top of recommended working points improves efficiency to reconstruct the correct number of tracks a lot
- TightPrimary + Run1 gives best performance for 1 prong
- Loose + Run1 is best for 3 prong
- TightPrimary + Run1 falls steeply for 3 prong

Variation of silicon hits requirement

- tested track association performance for varied silicon hits requirement
- not counted conversion tracks to observe, what best effect a dedicated conversion tagger could be achieved
- requirements on # silicon hits greater than 7, 8, 9 has shown to give best performances





- similar performance as applying run 1 selection on top of recommended working points

Parameter scan

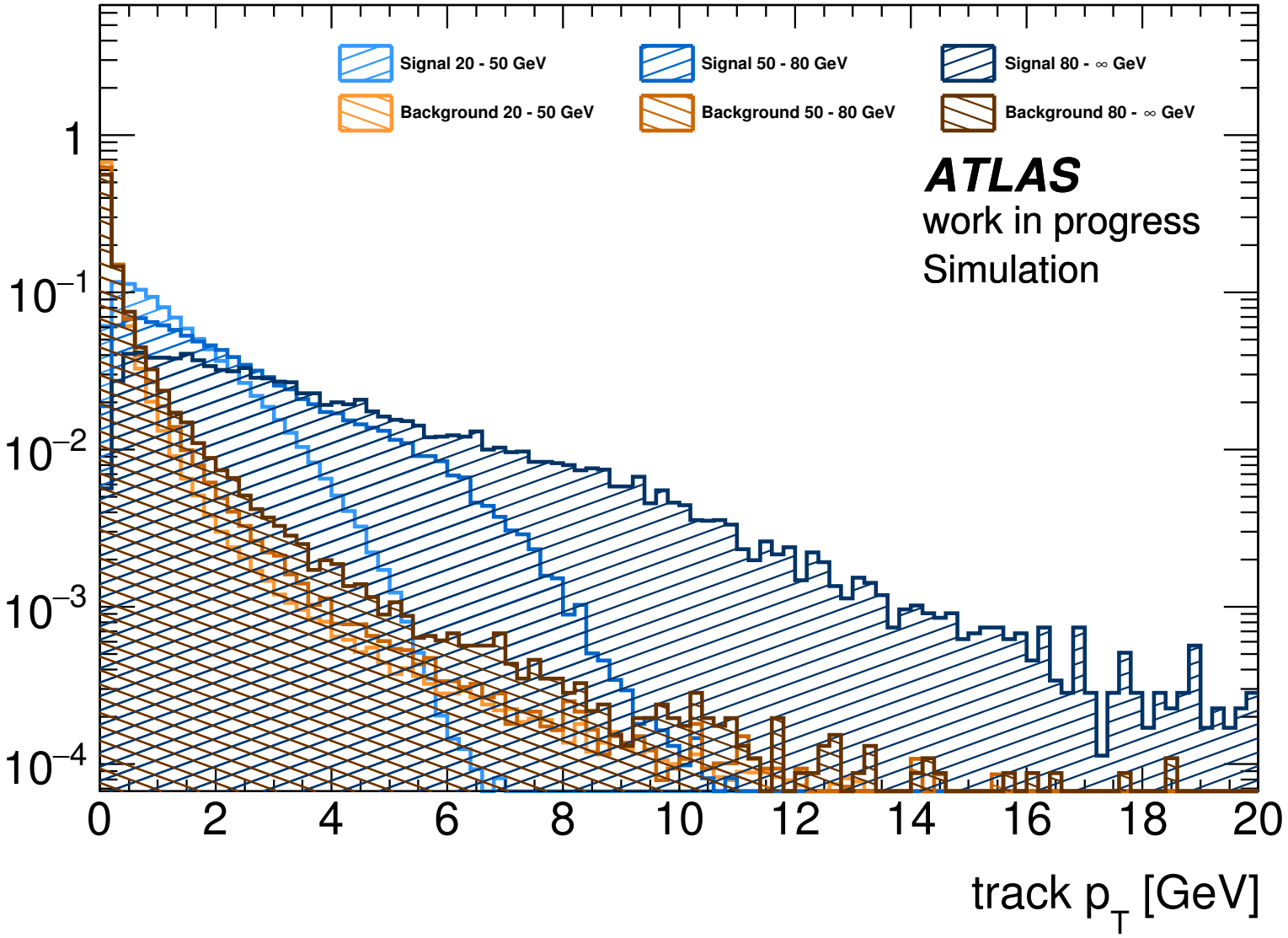
- scanned for efficiencies to reconstruct correct prongness for various modifications of run 1 track requirements
- possible improvements:
  - $p_T > 1.5\ \mathrm{GeV} \Rightarrow +1.22\%$
  - $\#$ pixel hits $\geq 3 \Rightarrow +1.64\%$
  - $d_0 < 0.5\ \mathrm{mm} \Rightarrow +0.61\%$

ATLAS work in progress

	1 p	3 p	inc p
Loose	17.81%	21.74%	18.82%
LoosePrimary	18.73%	23.09%	19.85%
TightPrimary	30.57%	30.35%	30.52%
LooseRUN1	69.90%	64.40%	68.44%
LoosePrimaryRUN1	69.80%	63.41%	68.09%
TightPrimaryRUN1	73.61%	56.17%	69.02%
LooseRUN1_Pt500	64.27%	61.79%	63.60%
LooseRUN1_Pt1000	69.90%	64.40%	68.44%
LooseRUN1_Pt1500	72.02%	61.43%	69.22%
LooseRUN1_Pt2000	73.00%	56.76%	68.75%
LooseRUN1_Pt3000	73.30%	46.19%	66.21%
LooseRUN1_Pt4000	72.34%	35.91%	62.83%
LooseRUN1_Pt5000	70.52%	27.54%	59.31%
LooseRUN1_SI6	69.90%	64.40%	68.44%
LooseRUN1_SI7	69.90%	64.40%	68.44%
LooseRUN1_SI8	69.78%	63.41%	68.08%
LooseRUN1_SI9	69.60%	62.02%	67.58%
LooseRUN1_SI10	69.47%	59.84%	66.90%
LooseRUN1_Pix1	68.41%	64.38%	67.32%
LooseRUN1_Pix2	69.90%	64.40%	68.44%
LooseRUN1_Pix3	72.57%	63.11%	70.08%
LooseRUN1_Pix4	72.38%	55.87%	68.05%
LooseRUN1_D00.5	71.18%	63.09%	69.05%
LooseRUN1_D00.75	70.49%	64.05%	68.78%
LooseRUN1_D01.0	69.90%	64.40%	68.44%
LooseRUN1_D01.25	69.51%	64.42%	68.16%
LooseRUN1_D01.5	69.30%	64.63%	68.05%
LooseRUN1_Z01.0	69.91%	64.22%	68.39%
LooseRUN1_Z01.25	69.88%	64.32%	68.40%
LooseRUN1_Z01.5	69.90%	64.40%	68.44%
LooseRUN1_Z01.75	69.82%	64.41%	68.38%
LooseRUN1_Z02.0	69.80%	64.37%	68.35%

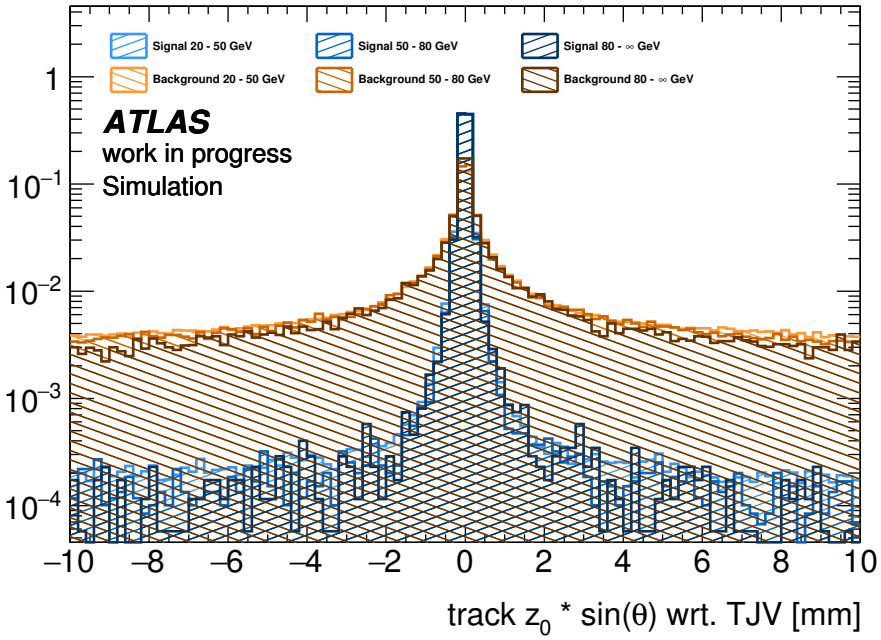
distribution of quality parameters

run 1: $p_T > 1$ GeV

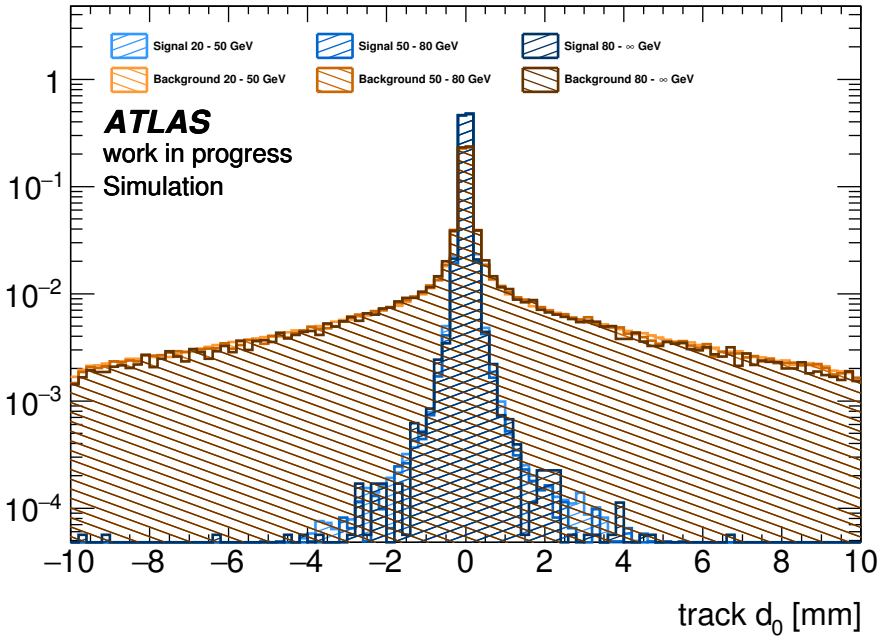


distribution of quality parameters

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

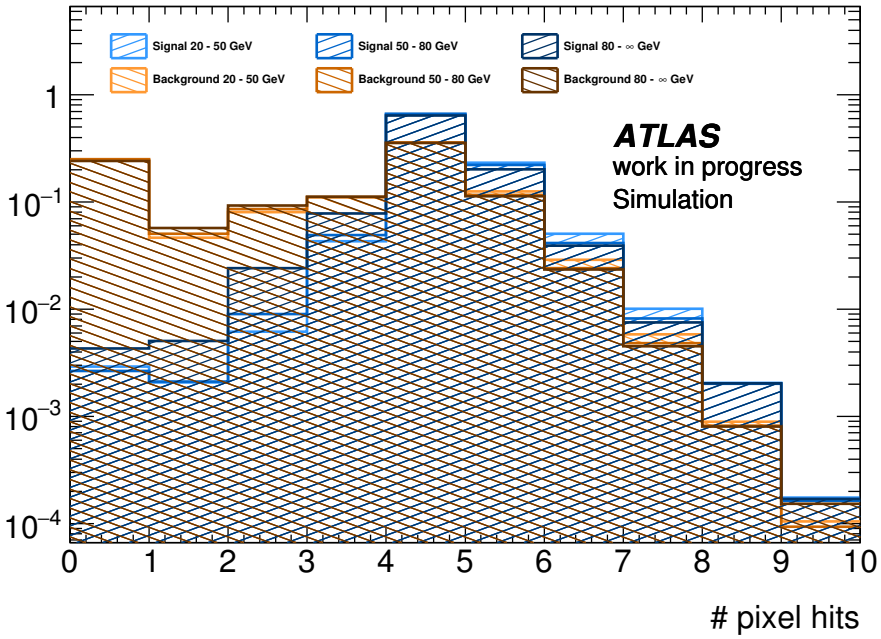


run 1: $|d_0| < 1\ \mathrm{mm}$

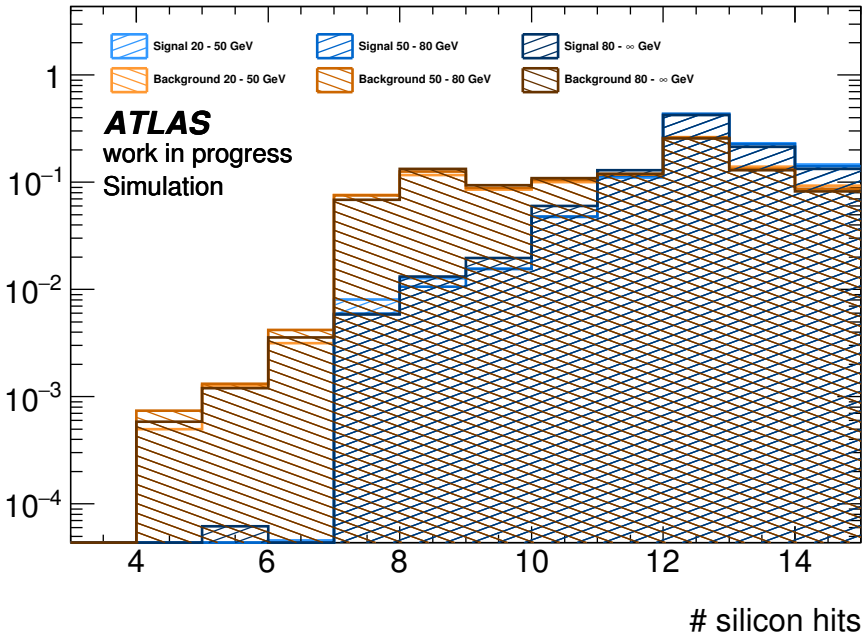


distribution of quality parameters

run 1: # pixel hits ≥ 2



run 1: # silicon hits ≥ 7



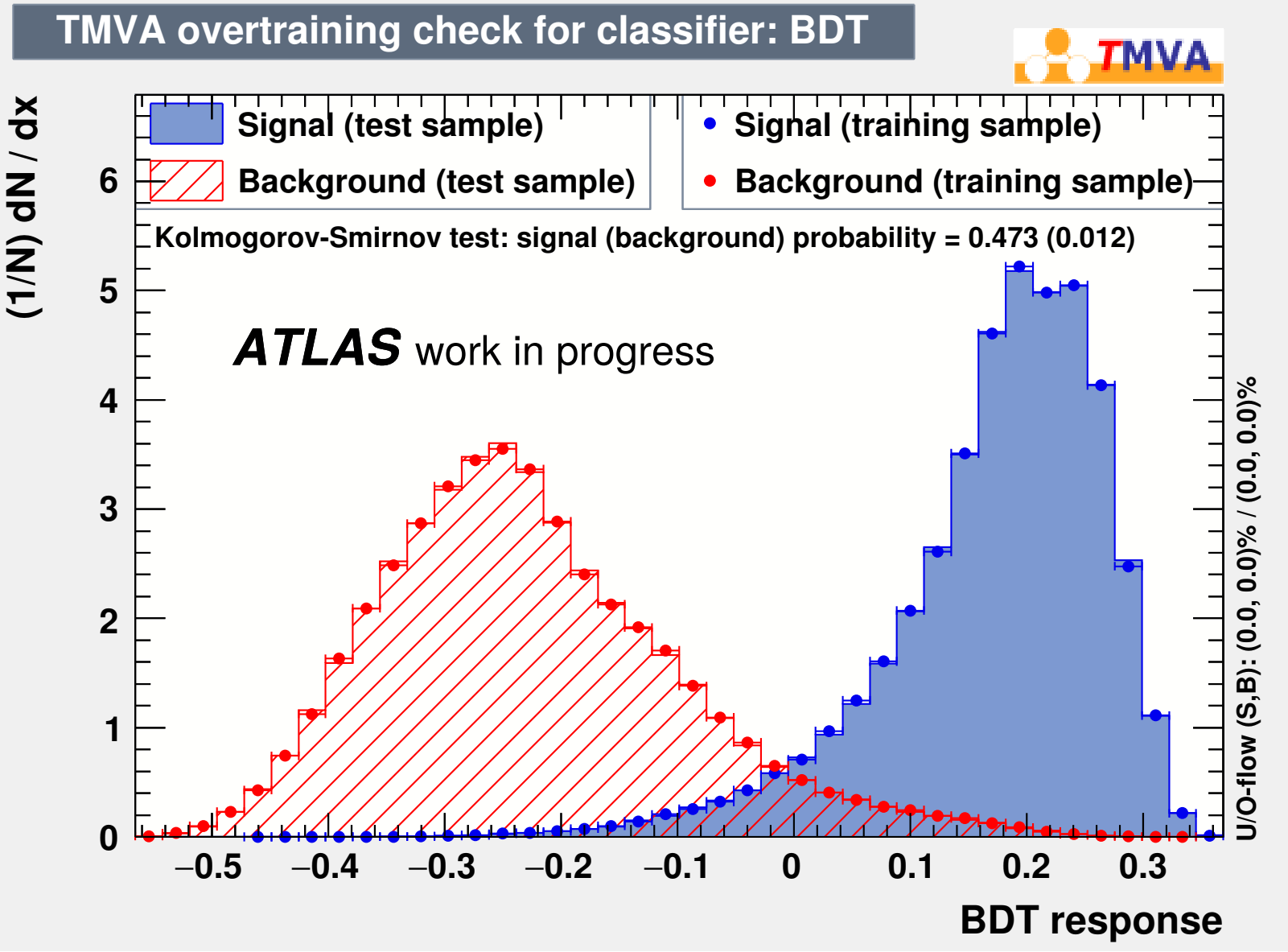
How to increase track selection performance

- parameter distributions already give good separation power
- partly strong dependence on tau p_T
- two possible approaches:
  - optimizing quality cuts in bins of tau p_T
    - $\Rightarrow$ can get quite challenging to find best thresholds
    - $\Rightarrow$ hard to handle correlations
  - use MVA techniques
    - $\Rightarrow$ here I used to train BDT's using TMVA
    - $\Rightarrow$ signal: tracks from tau decays
    - $\Rightarrow$ background: pileup, conversions, underlying event, mis-reconstructed tracks
    - $\Rightarrow$ added tau p_T and η to input variables of tracks to account for such dependencies

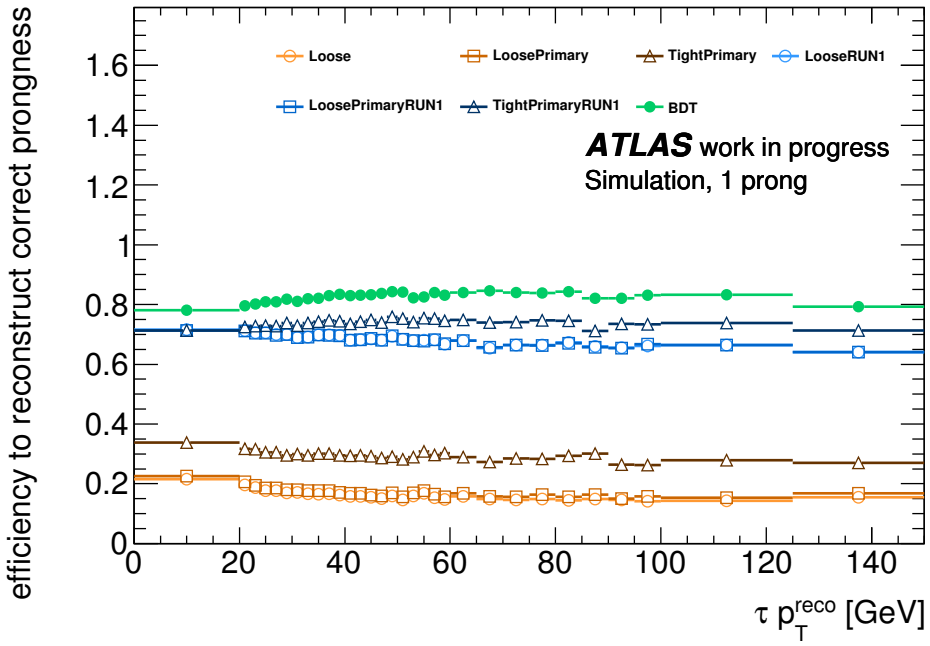
variables used for training

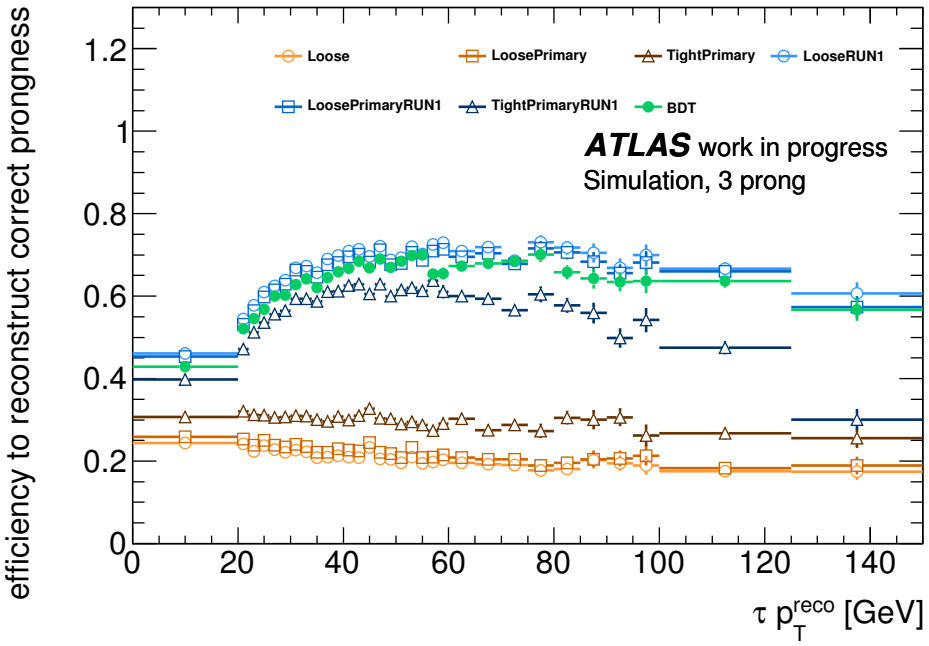
```
--------------------------------------------------
Rank : Variable                      : Separation
--------------------------------------------------
   1 : qOverP                        : 4.080e-01
   2 : z0sinThetaTJVA                : 3.264e-01
   3 : d0                            : 2.423e-01
   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



Results using the BDT approach

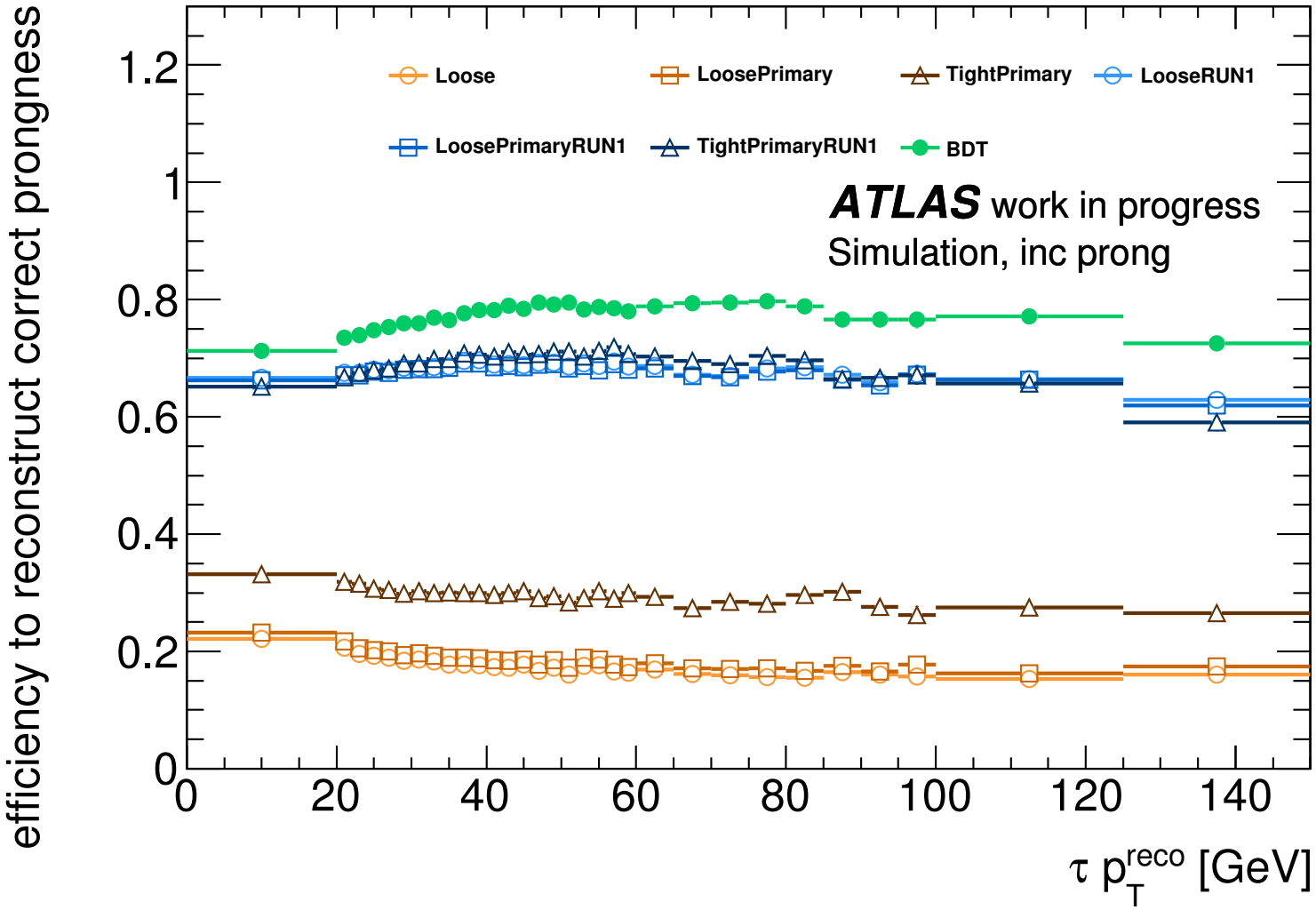




- overall better performance for 1 prong
- slighly worse performance for 3 prong

Results using the BDT approach

- but overall better efficiency for 1 and 3 prong combined



Results using the BDT approach

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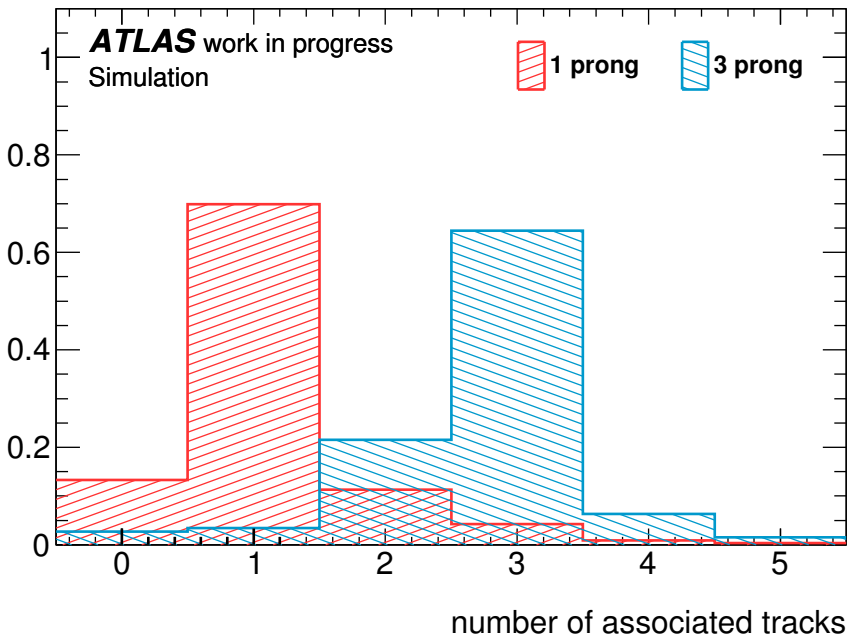
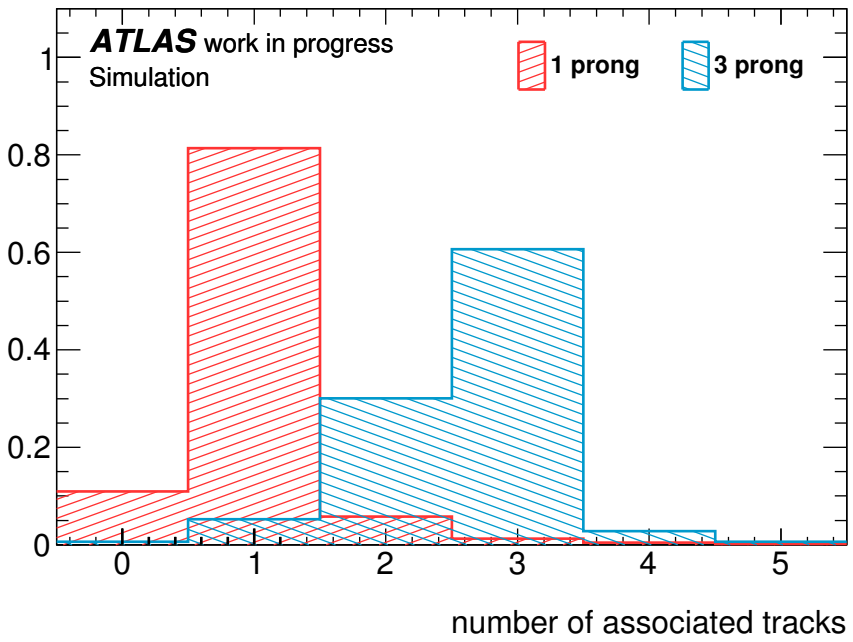
LooseRUN1_Pix3	72.57%	63.11%	70.08%
LooseRUN1_D00.5	71.18%	63.09%	69.05%
LooseRUN1_Z01.5	69.90%	64.40%	68.44%
BDT	81.59%	60.53%	76.07%

Track distribution comparison

Loose + run 1



BDT approach

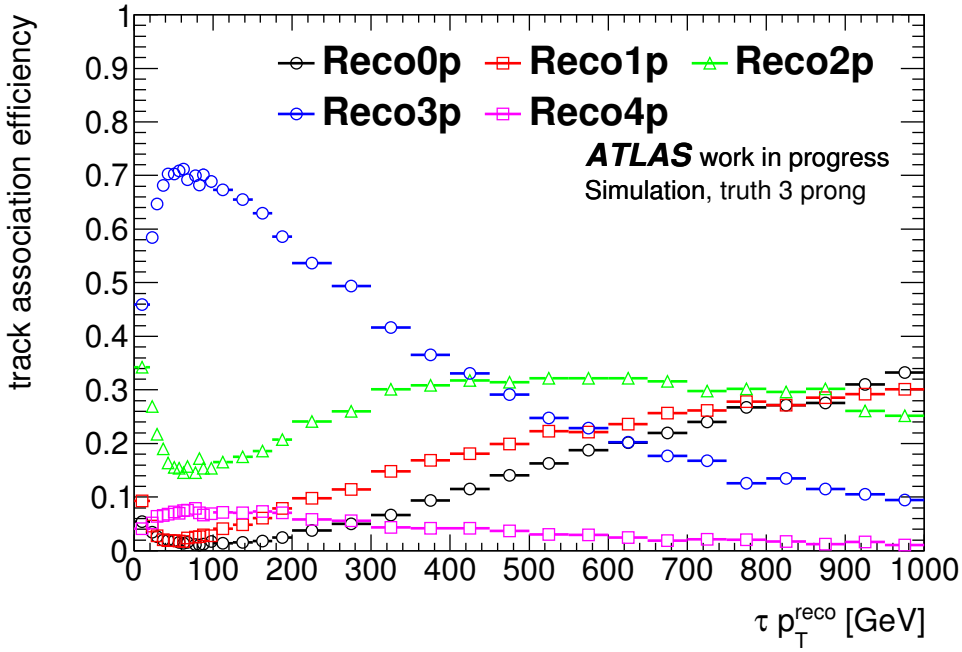


- 1 prong
  - BDT approach is able to reduce taus being reconstructed with 3 tracks
  - but also 2 and 0 prong is reduced
- 3 prong
  - more taus are reconstructed with 2 prong for the BDT approach than for Loose + run 1

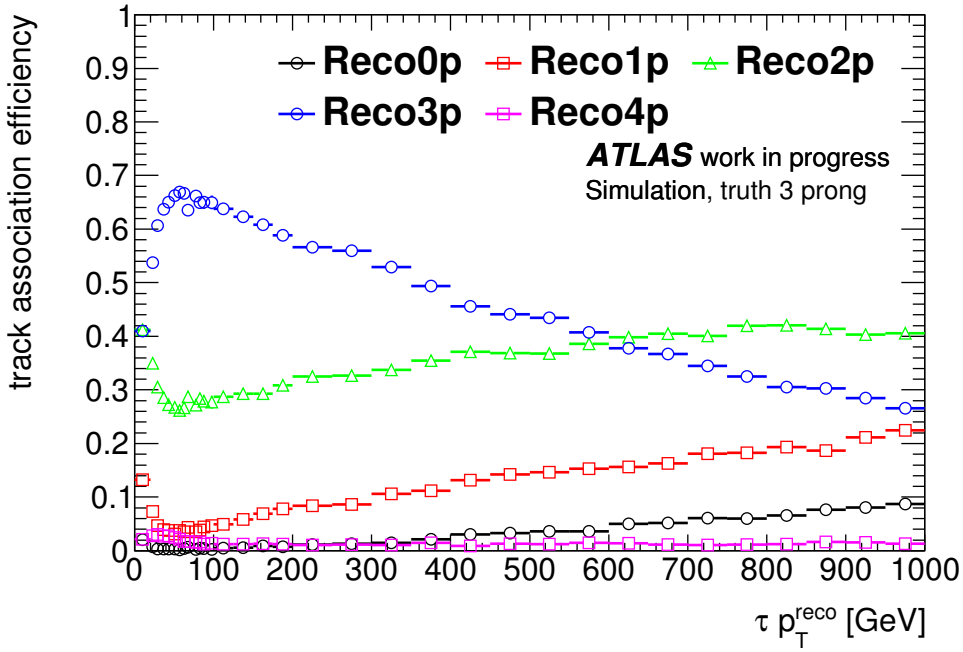
High p_T track association efficiency

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

loose + run 1 selection



BDT based selection

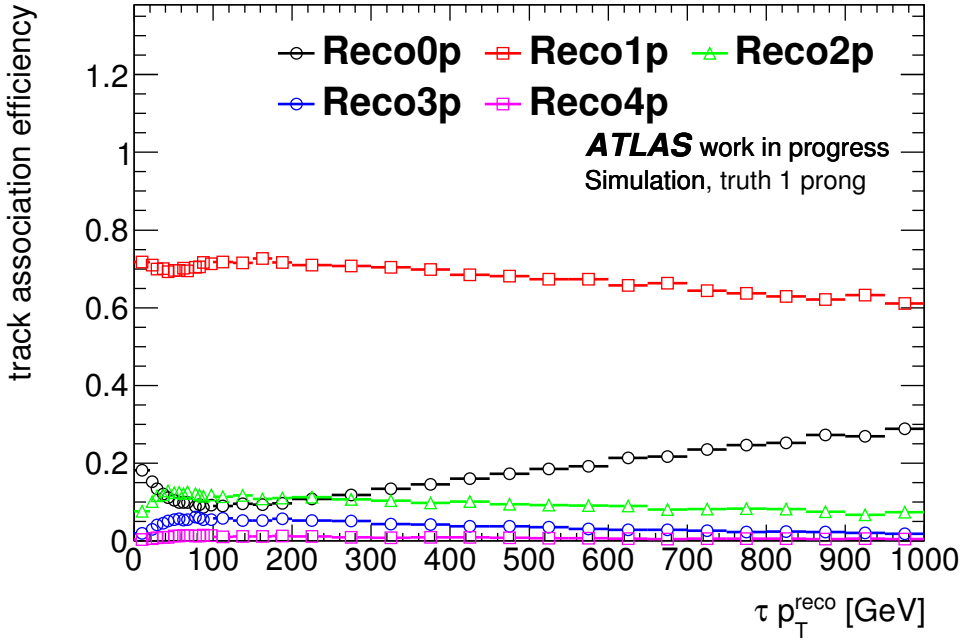


- BDT approach shows better performance than standard selection at high p_T
- reconstruction as 0 prong is strongly reduced
- increase from 9% to 26% in the highest bin

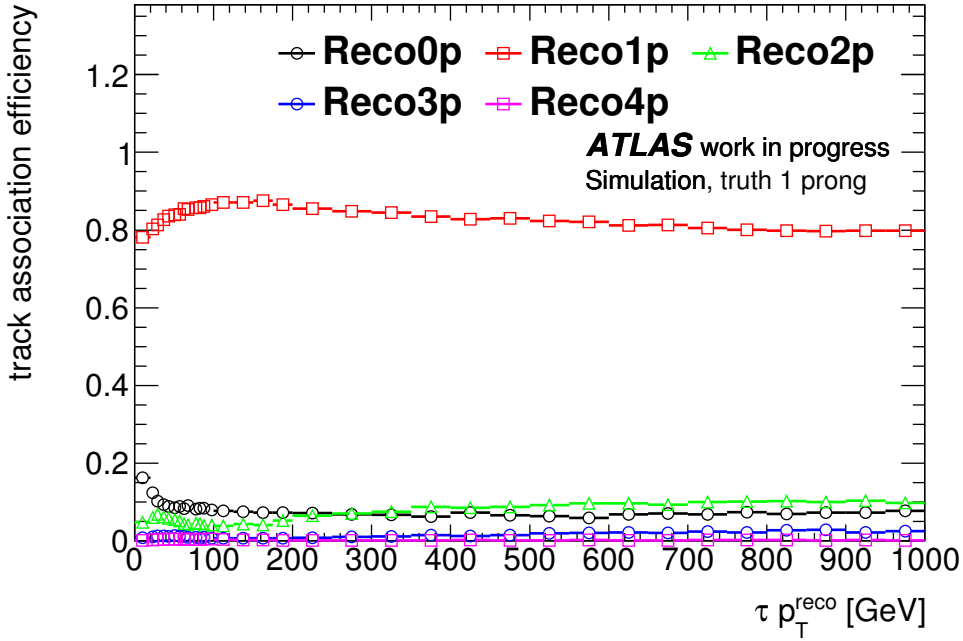
High p_T track association efficiency

- 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

conclusions

- track selection needs to be optimized to increase efficiency of reconstructing correct number of tracks
- most important for high p_T
- standard working points didn't show satisfiable efficiencies
- application of quality criteria from run 1 have shown quite good performance, with not much room for improvement
- problem of high p_T tracking still remains for cut based selection
- BDT approach shows better performance of about 7.63%
- BDT trained for high p_T taus reduces problem of track merging and is able to recover a significant amount of 3 prong taus compared to standard selection
- large room for improvements in optimizing training, especially input variables, options, thresholds on BDT score

BACKUP

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