Tau Lepton Reconstruction in ATLAS

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Tau lepton properties

– Mass = 1.78 GeV, intermediate lifetime: c$\tau = 87\ \mu$m

– All taus decay before reaching any detector

Final State	B.R. (%)	Decay type	
$e\nu_e\nu_\tau$	17.8	Leptonic	τ_e
$\mu\nu_\mu\nu_\tau$	17.4	35.2	τ_μ
$\pi/K\nu_\tau$	11.8	1-prong	τ_h
$\pi/K \geq 1\pi^0\nu_\tau$	36.9	48.7	
$\pi\pi\pi \geq 0\pi^0\nu_\tau$	13.9	3-prong	

– Challenging at ATLAS!

Why are taus interesting in ATLAS?

– best channel for observing Higgs boson fermionic decays

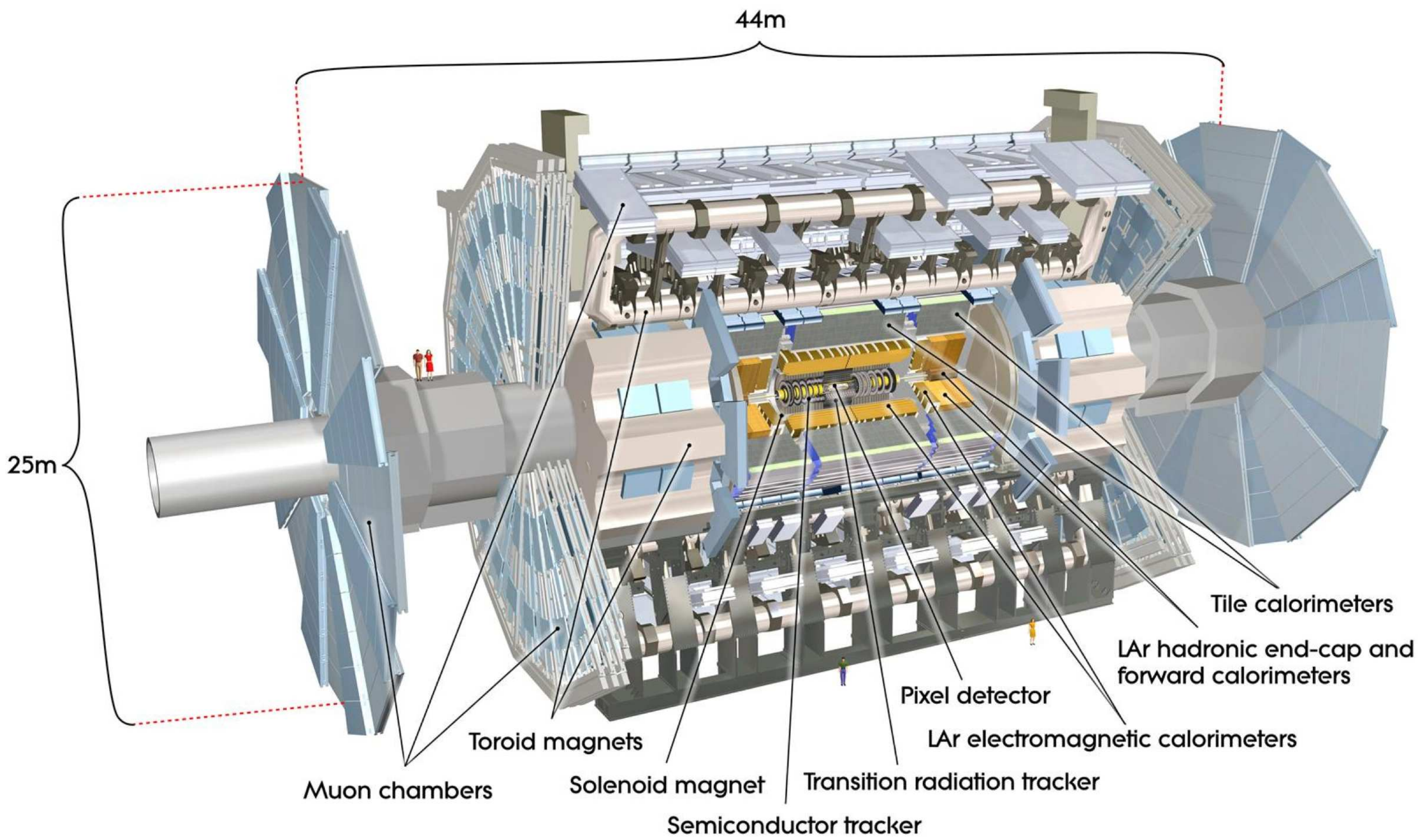
– also the best for finding the neutral MSSM Higgs boson

– add another channel to all searches with leptons

– they are really heavy, so they might be special (recent hints of possible lepton non-universality from LHCb...)

– they are handy for Lepton Flavor Violation searches

The ATLAS detector



– multi-purpose detector for various physics signatures with leptons, photons or jets in p-p collisions at $\sqrt{s} = 7 - 13$ TeV

Tau reconstruction and identification in ATLAS

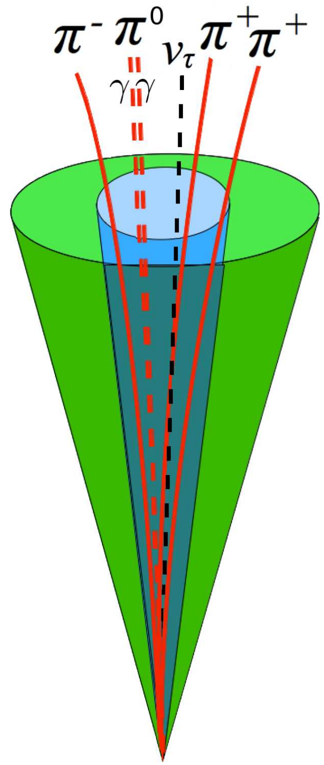
– taus $=$ narrow jets, with low track multiplicity

– tau algorithm seeds: jets formed with the anti-k_t algorithm (R=0.4) with $p_T > 10$ GeV, $|\eta| < 2.5$

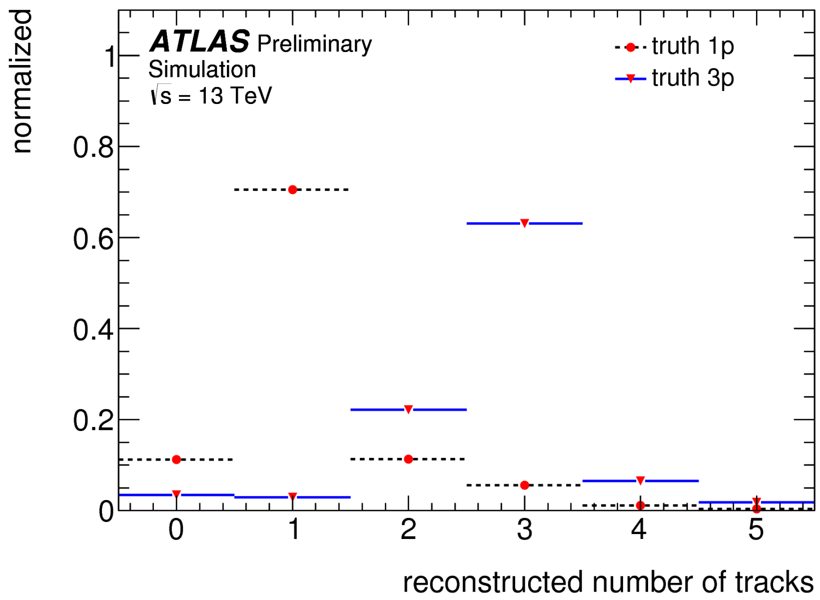
– energy measured in a 0.2 cone and calibrated to true visible energy using a η and p_T dependent scale factor (TES)

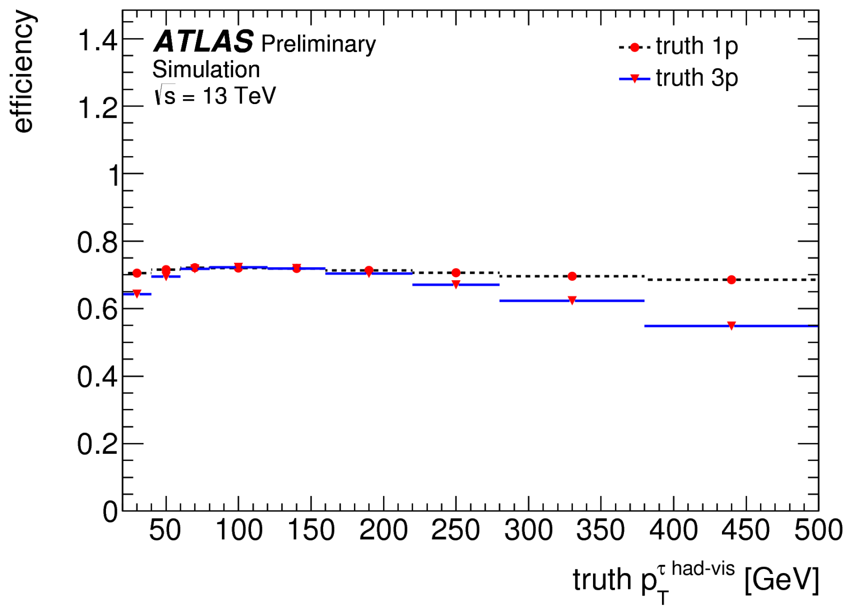
– special vertex association for improved vertex assignement

– identification: BDT to distinguish taus from other jets



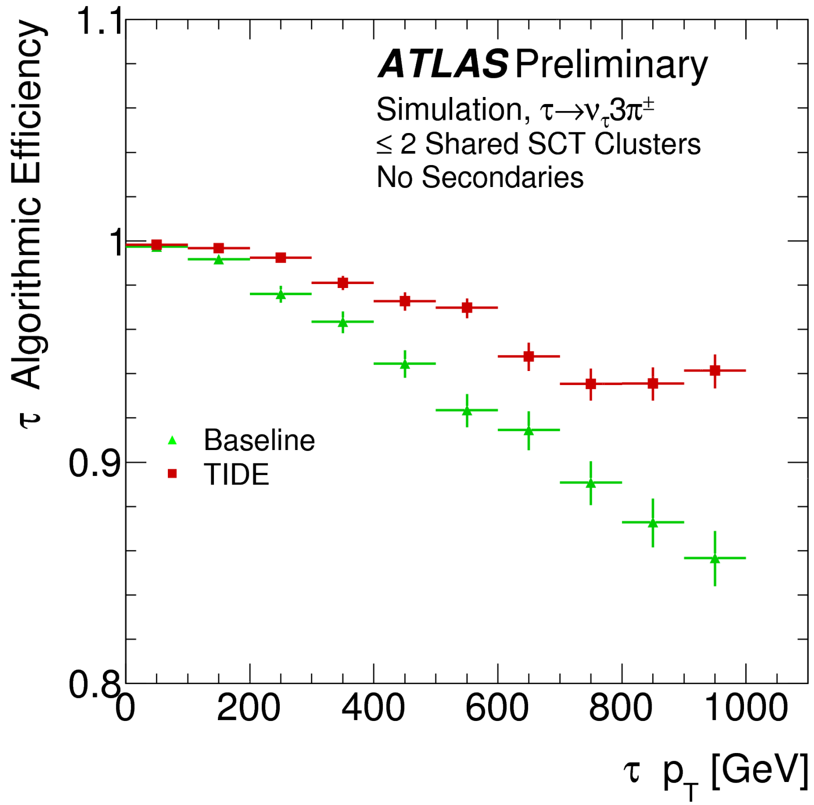
Reconstructing the true number of prongs

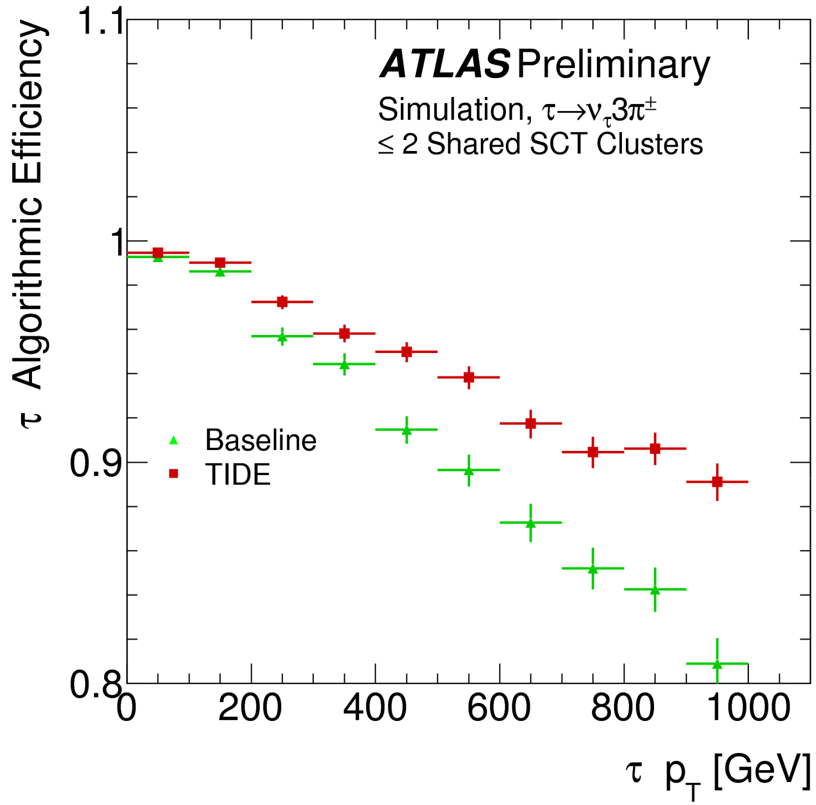




– the systematic uncertainty on reconstructing the true number of tracks is 2-5 %

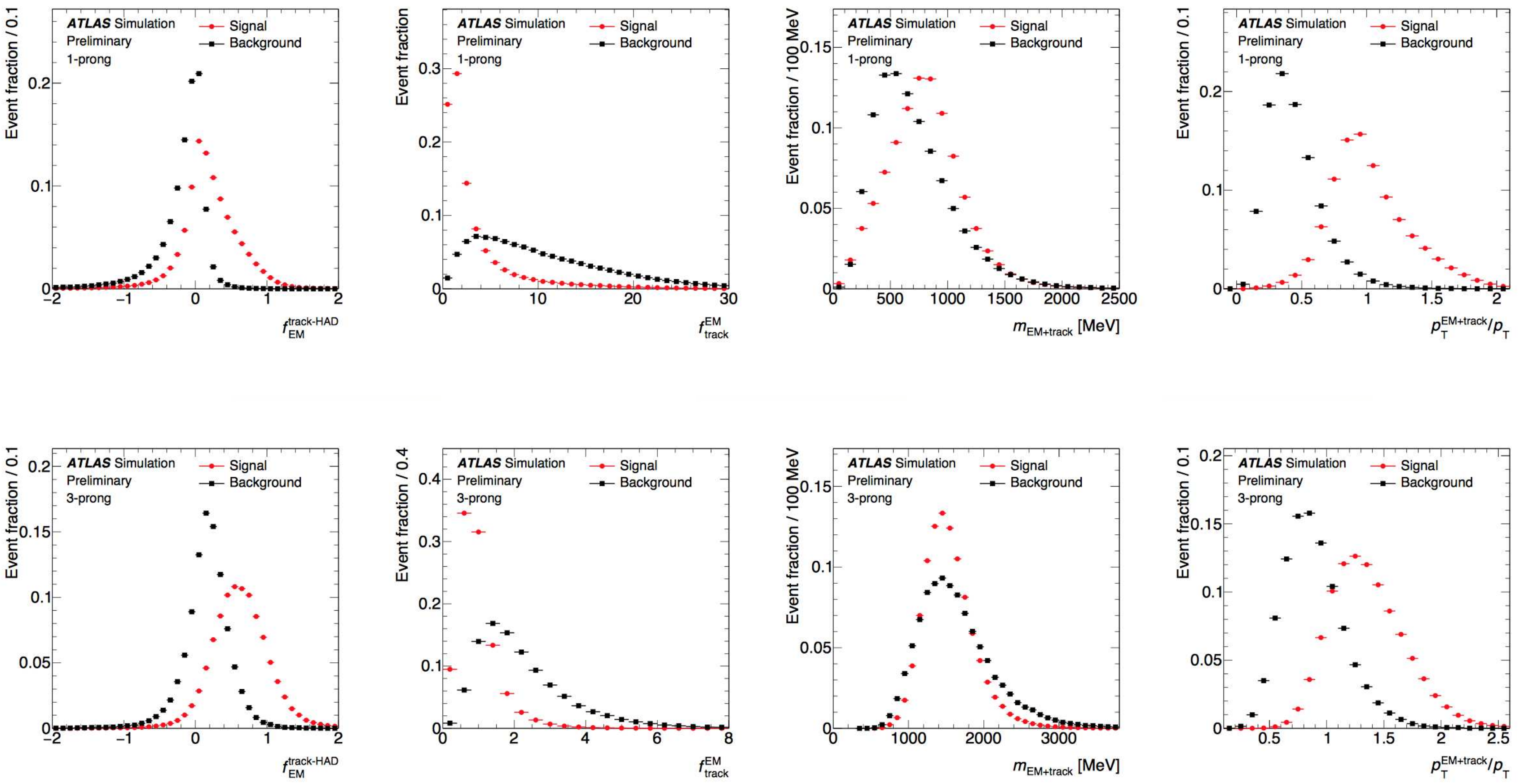
Tracking improvements for 3-prong taus





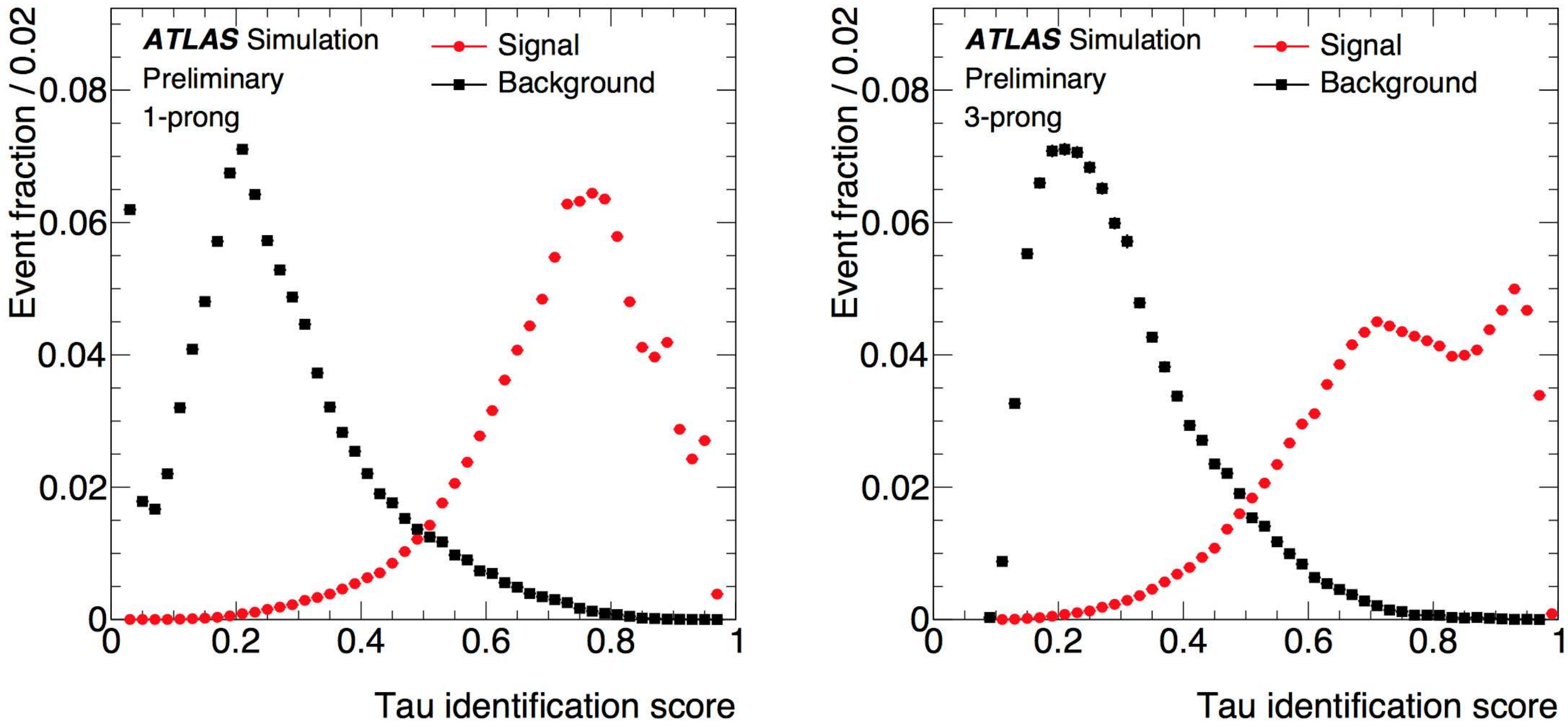
– inclusion of special prescriptions for merged hits increases the 3-prong reconstruction efficiency significantly at high-p_T

Tau identification - input variables for BDT



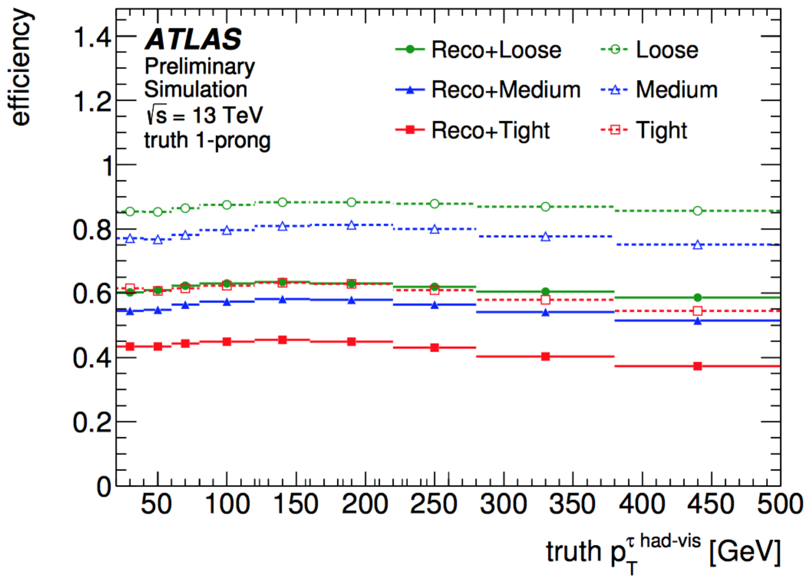
– signal: taus from $Z \to \tau\tau$ MC; background: jets from MC multijet events

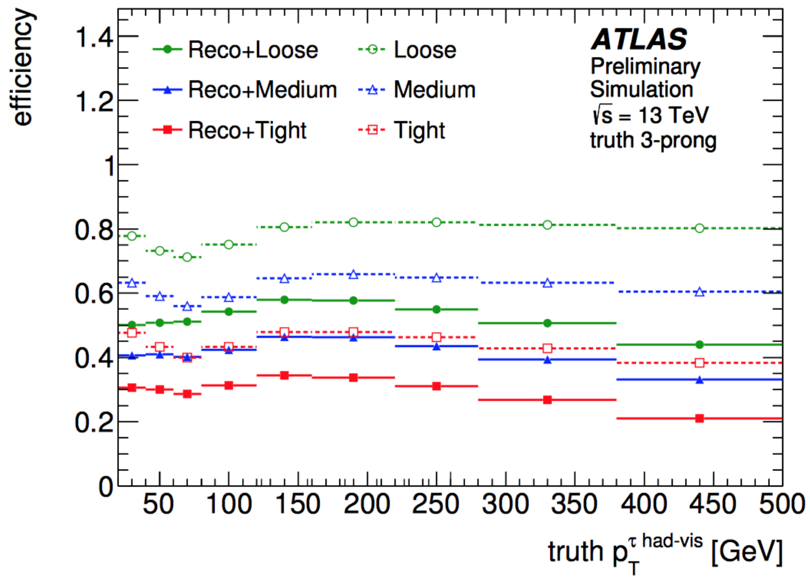
Tau identification - BDT output



– signal: taus from $Z \to \tau\tau$ MC; background: jets from MC multijet events

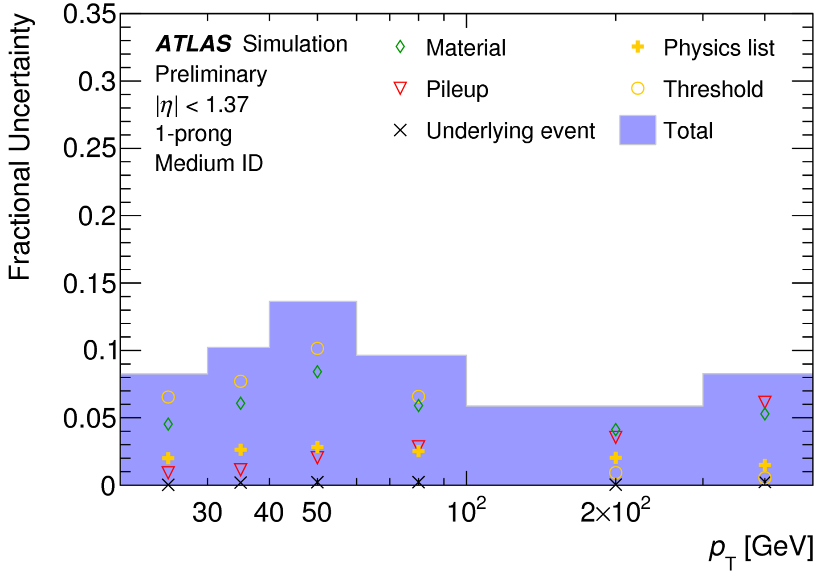
Tau reconstruction and identification efficiency

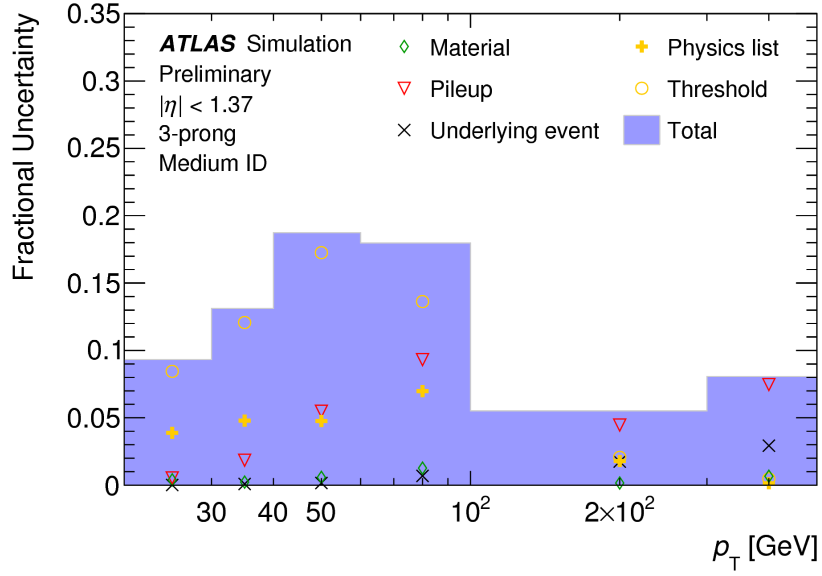




– different working points (Loose, Medium, Tight) correspond to increasing BDT cuts; they have decreasing efficiencies and increasing background rejection

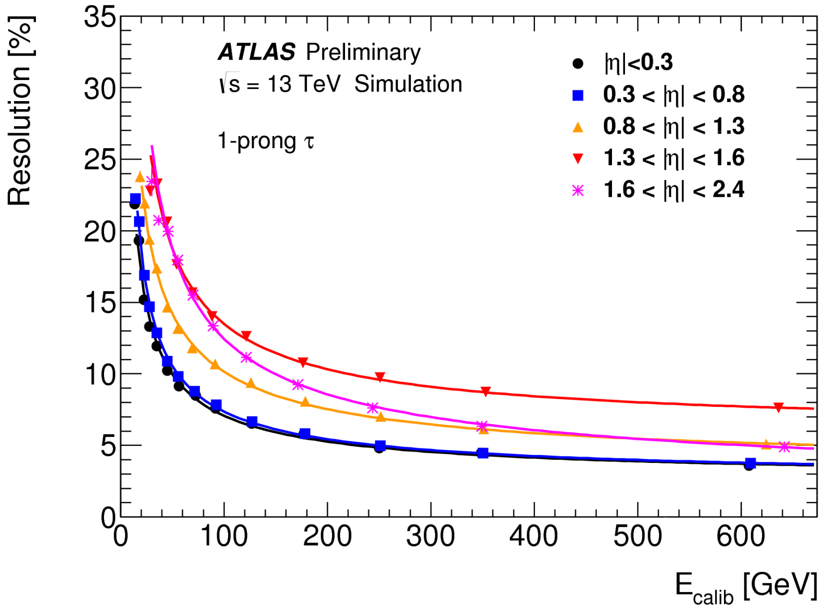
Tau identification uncertainty

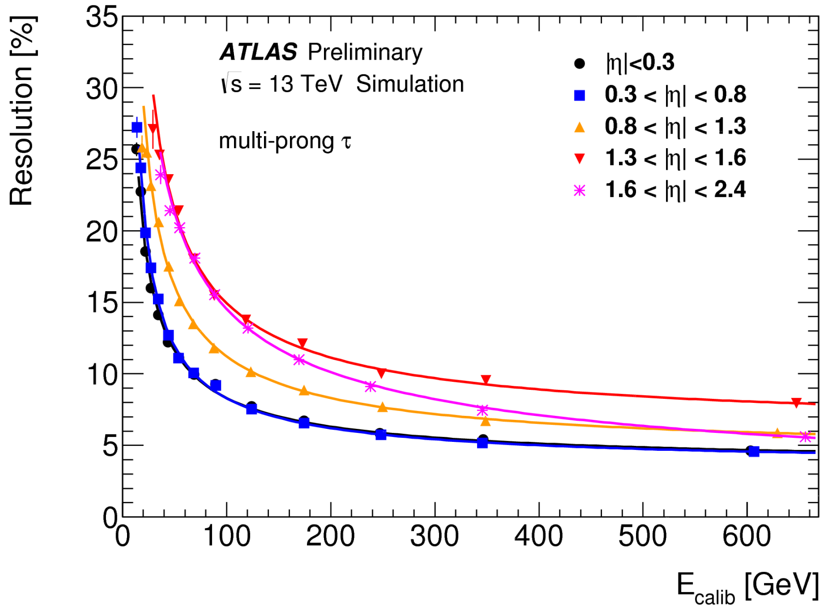




– largest uncertainty due to the calorimeter calibration and performance, which causes shape variation in the BDT input variables

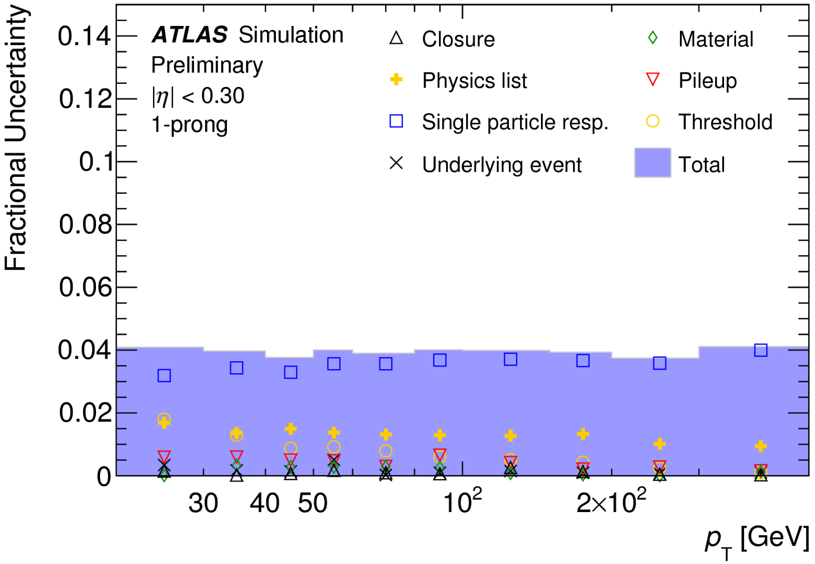
Tau energy resolution

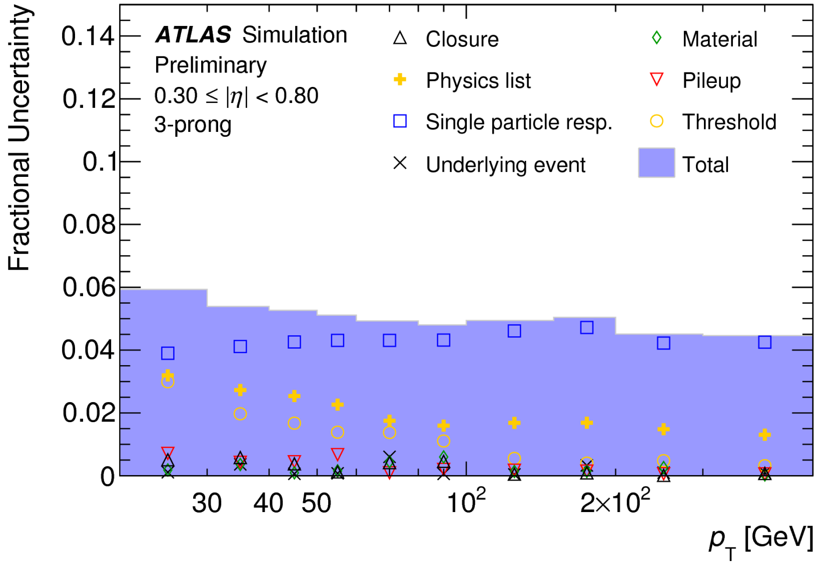




– the use of tracking information will significantly improve the energy resolution at low momentum (see slide 23)

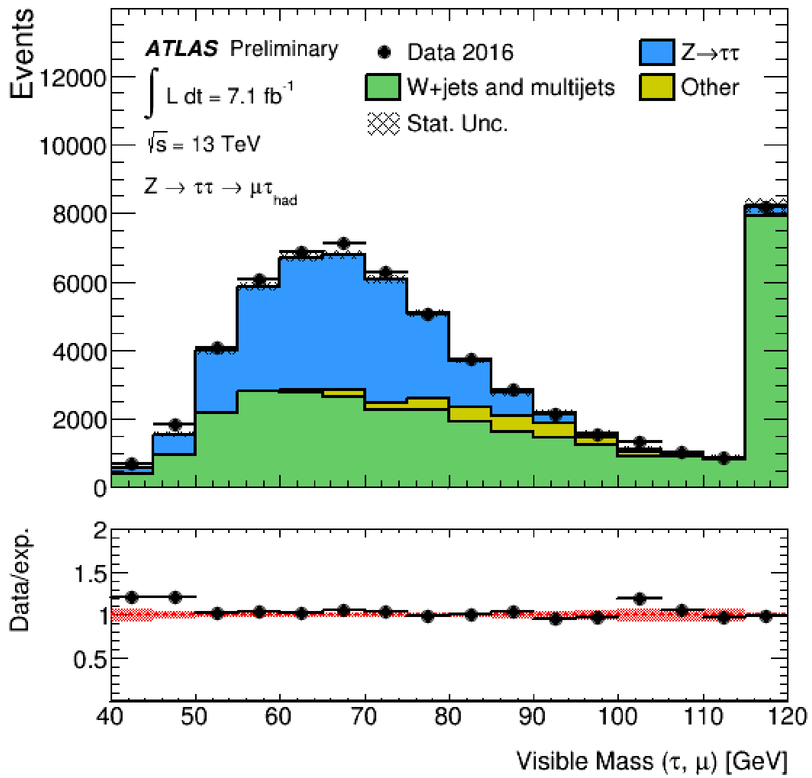
Tau Energy Scale uncertainty

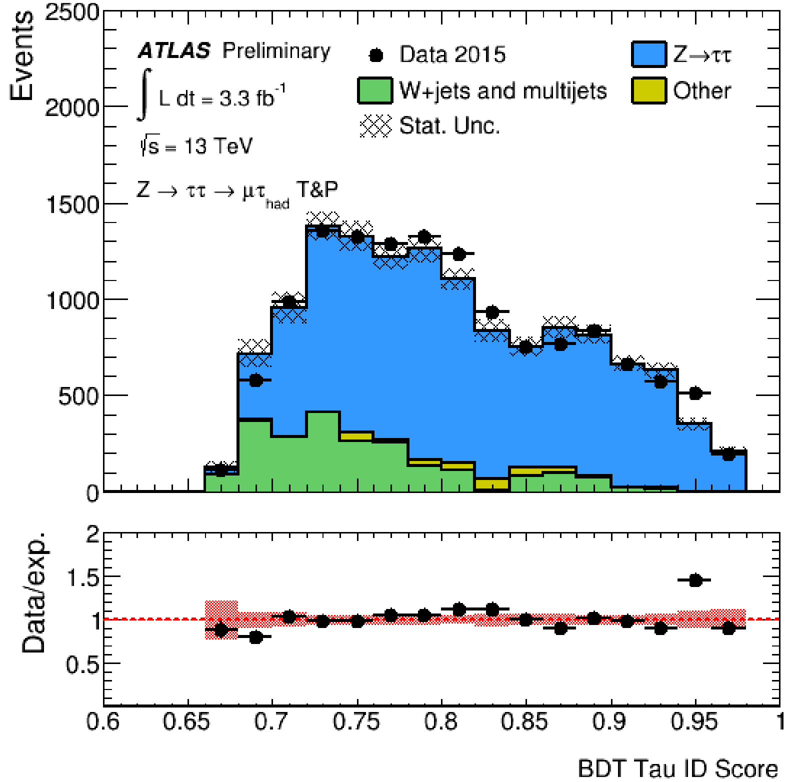




– the uncertainty is obtained from MC using the same method as in Run 1, with some uncertainties for which measurements are not yet available inflated by a factor of 2

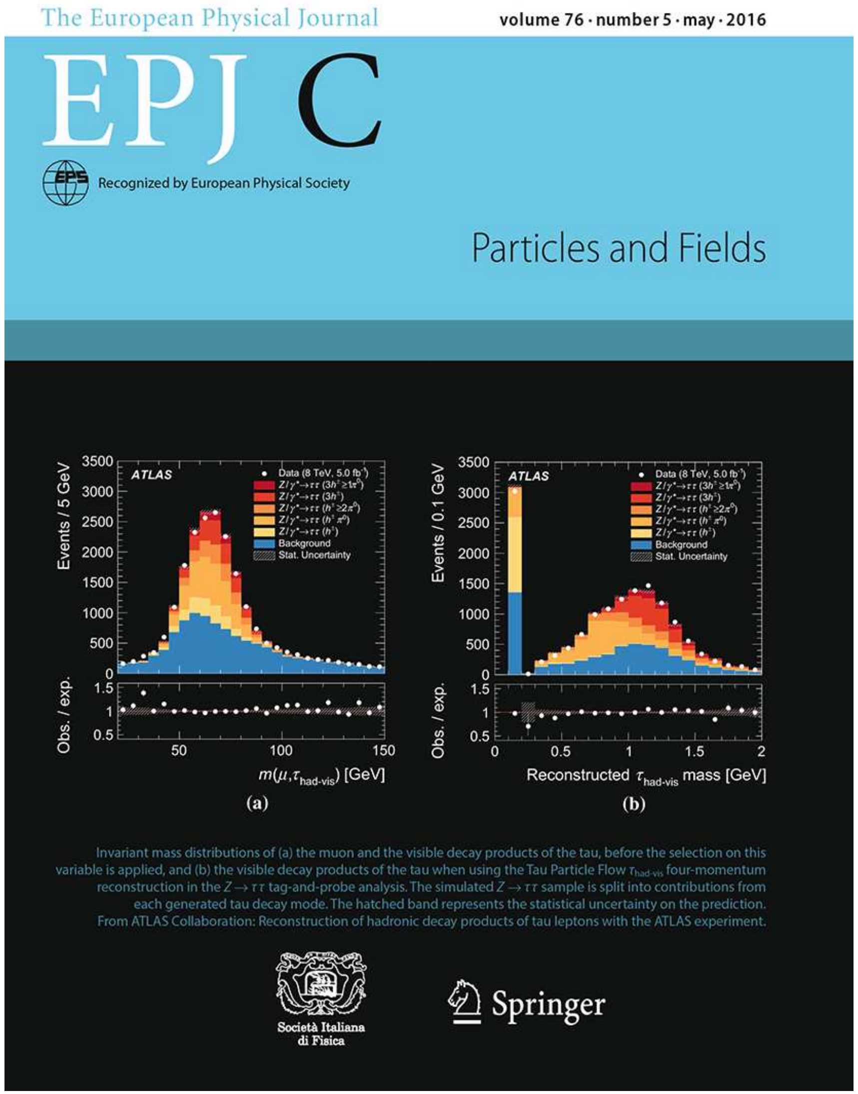
Tau modelling in 2016 data





– simulation provides good modelling of the most recent ATLAS data

Taus on the cover of EPJC!



Tau substructure algorithm

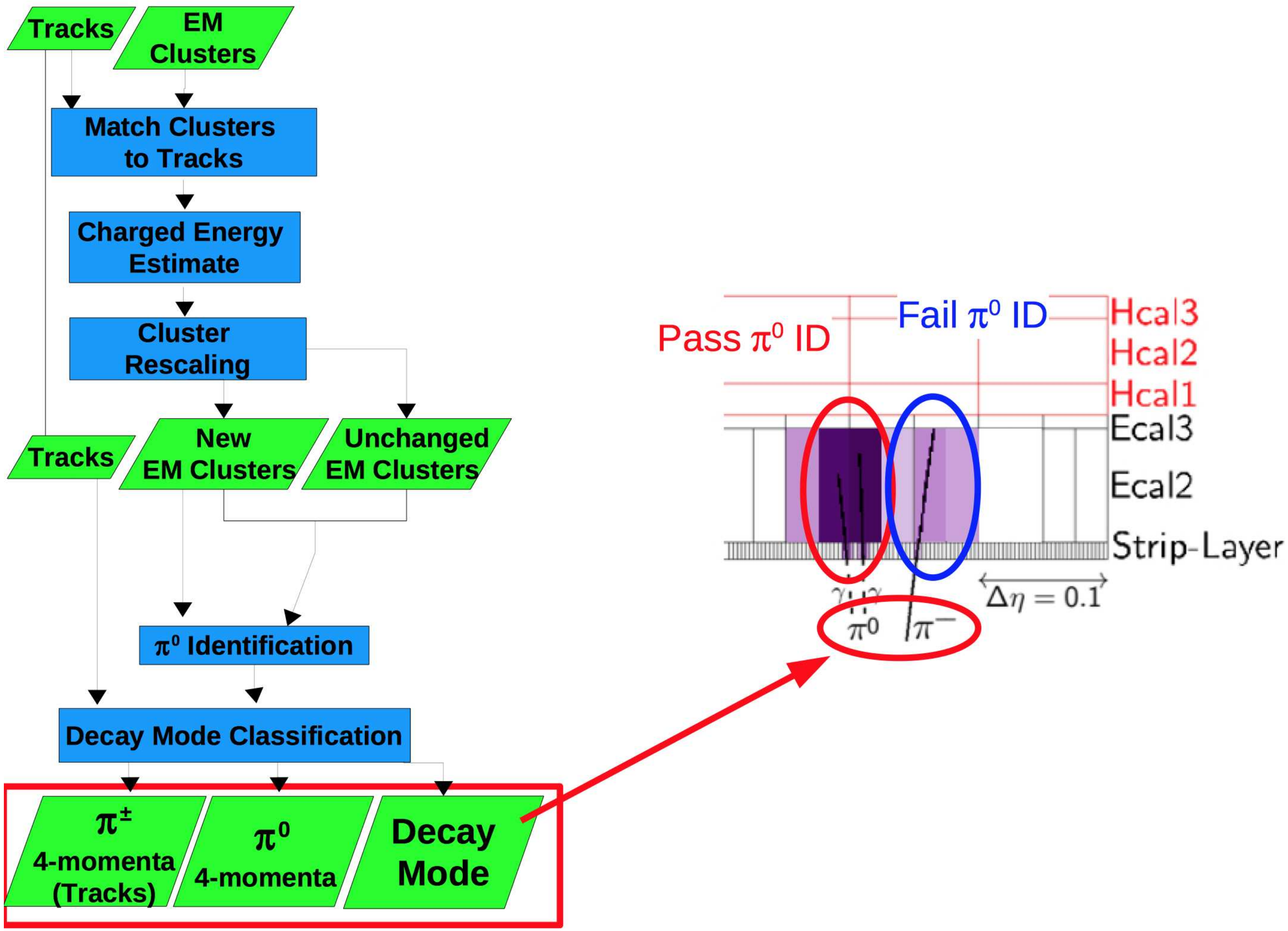
– a new particle-flow type of algorithm

– the $\pi^{\pm}$ from τ decay are reconstructed using tracks in a 0.2 cone matched to the τ vertex

– the energy in the calorimeter deposited by the $\pi^{\pm}$ is subtracted, and from the remaining clusters the π^{0}s are reconstructed and identified using a BDT

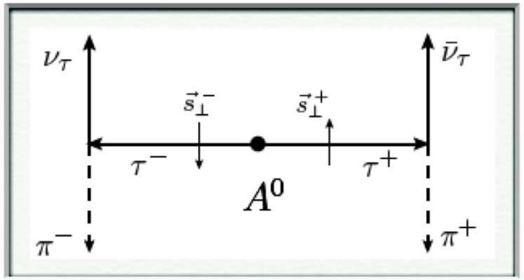
– the final decay mode classification is done using another BDT

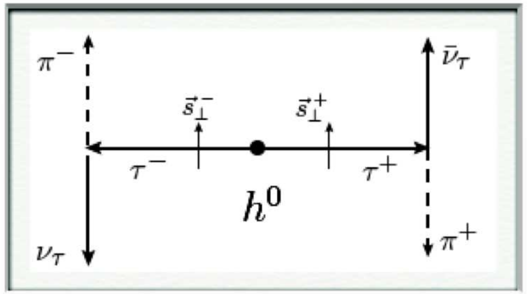
Tau substructure algorithm



Nice way to measure Higgs CP

Higgs CP measurement by correlating **transverse** τ polarizations:

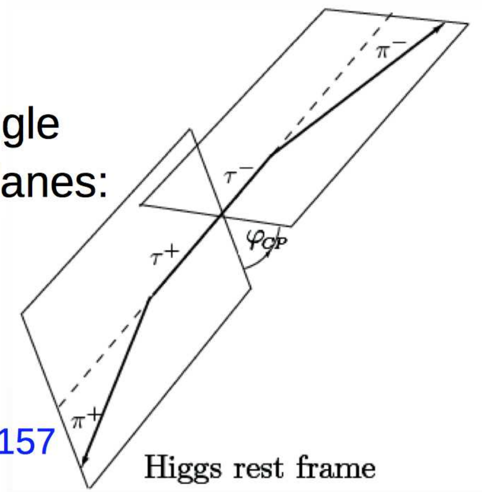


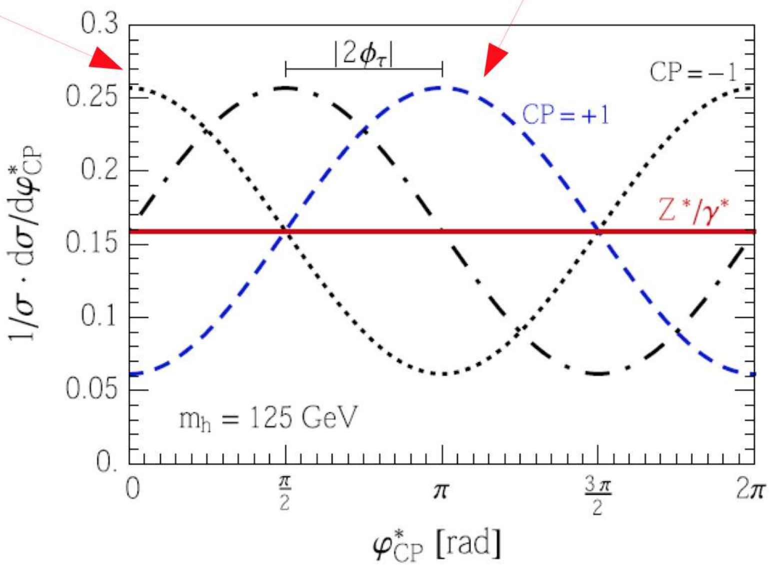


π^+ and π^- preferably parallel

π^+ and π^- preferably antiparallel

Measured using angle between τ decay planes:

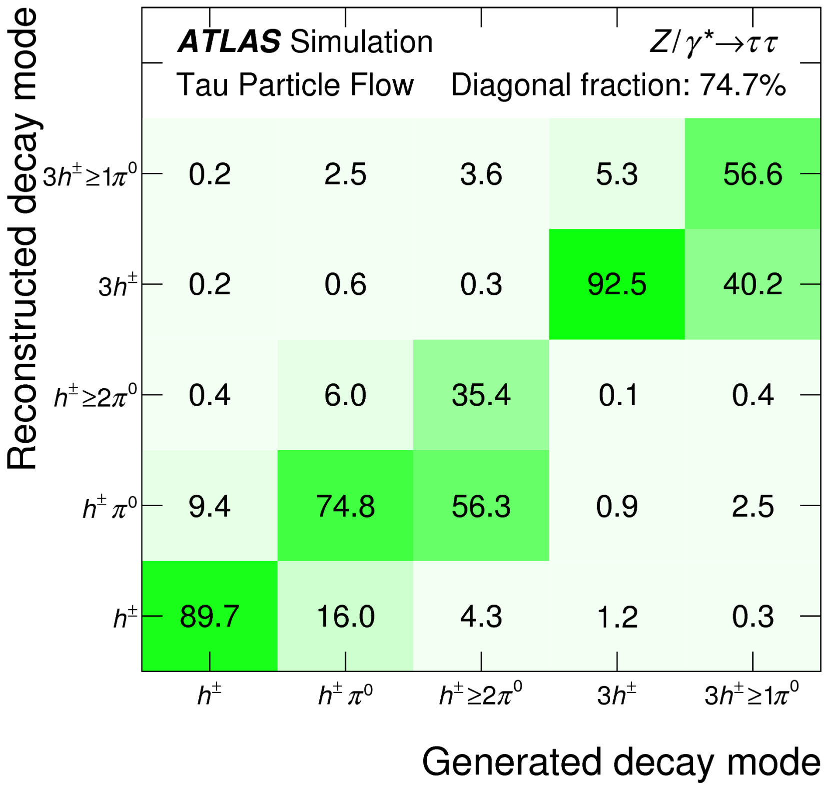




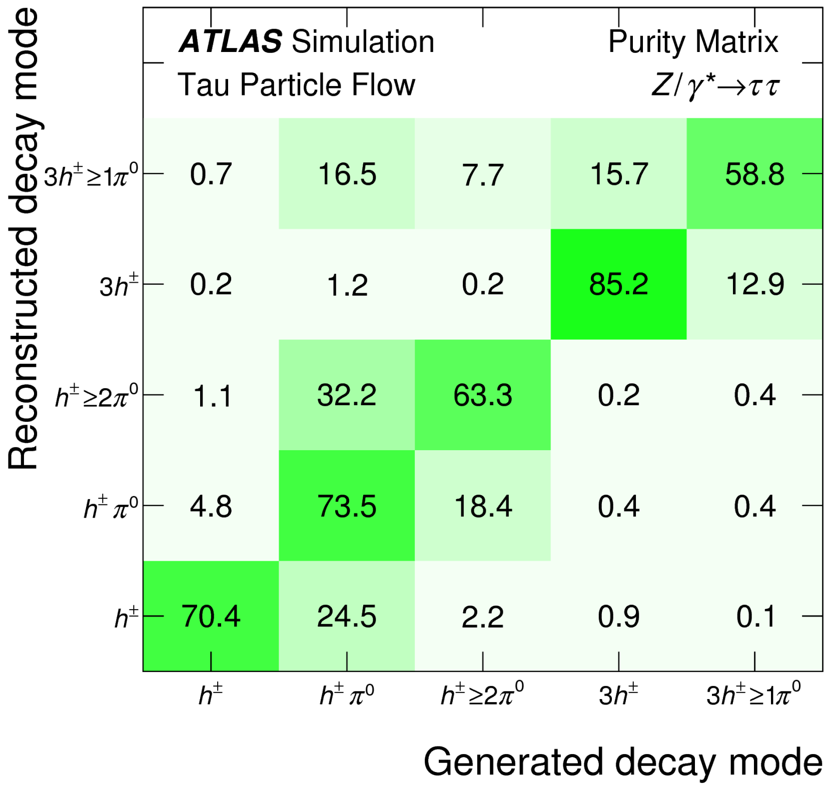
Desch et al,
Phys. Lett. B 579 (2004) 157
Berge et al,
Eur. Phys. J. C 74 (2014) 3164

Classification performance

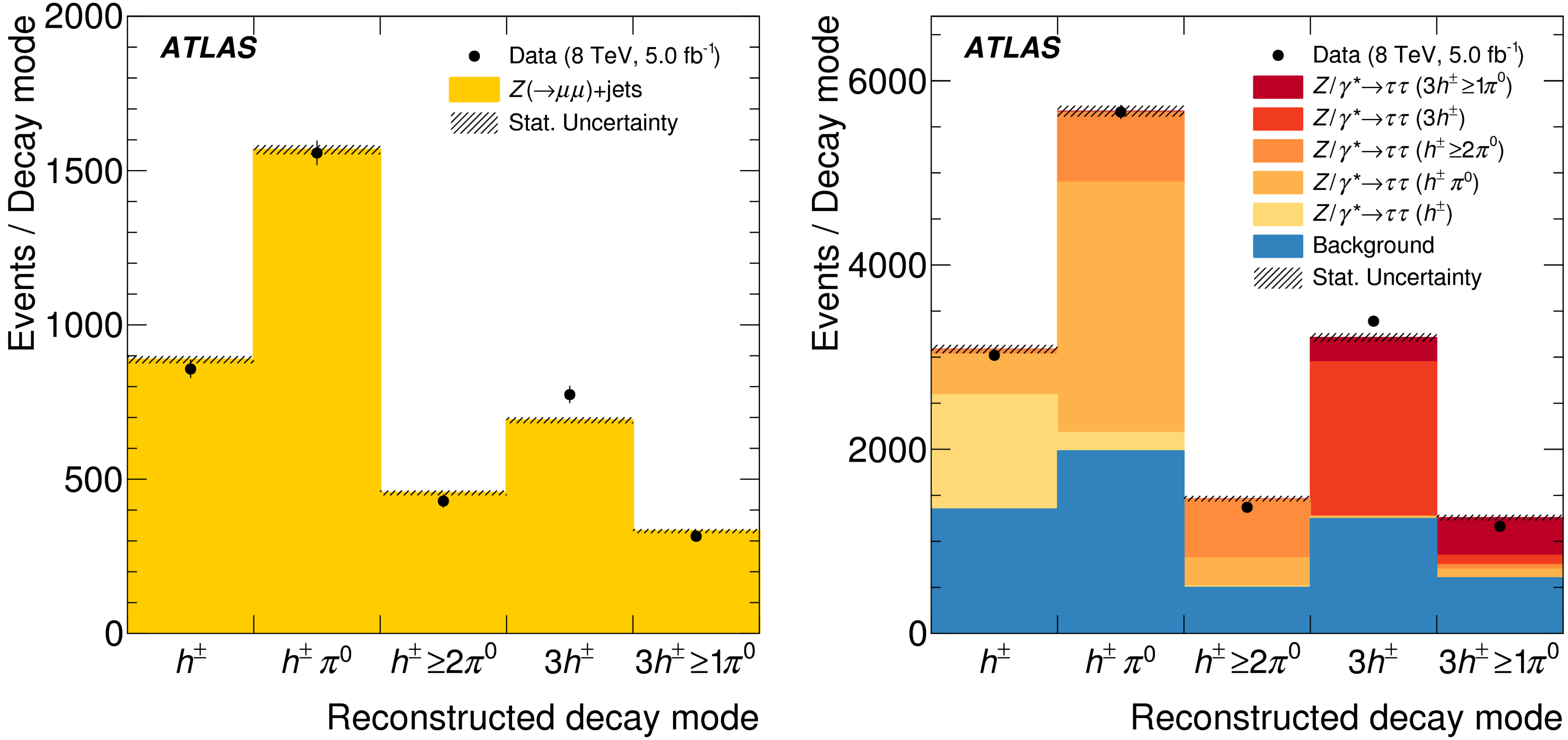
Efficiency



Purity

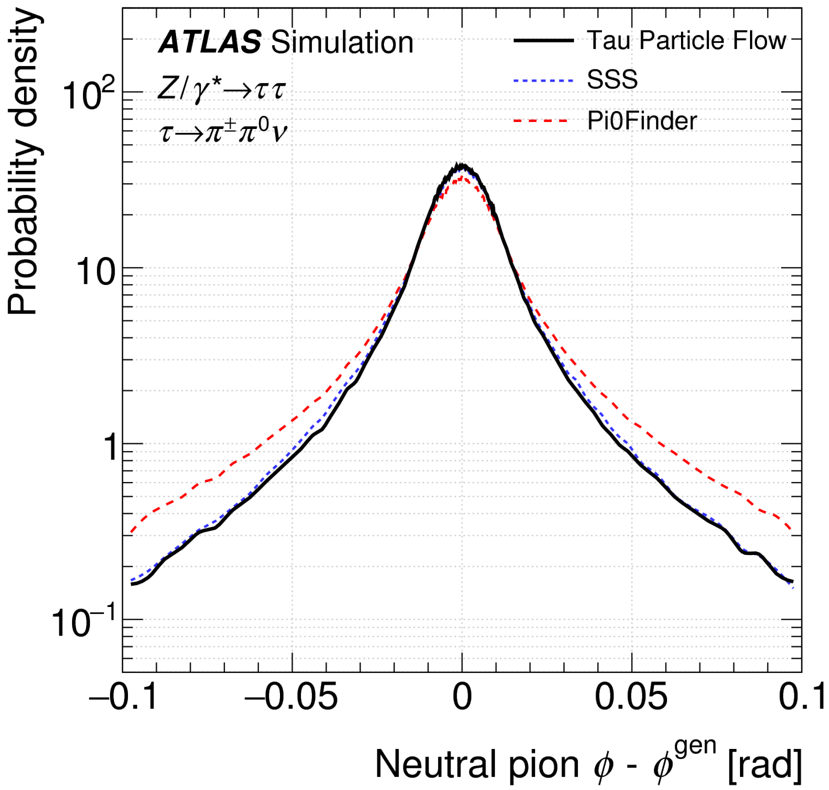


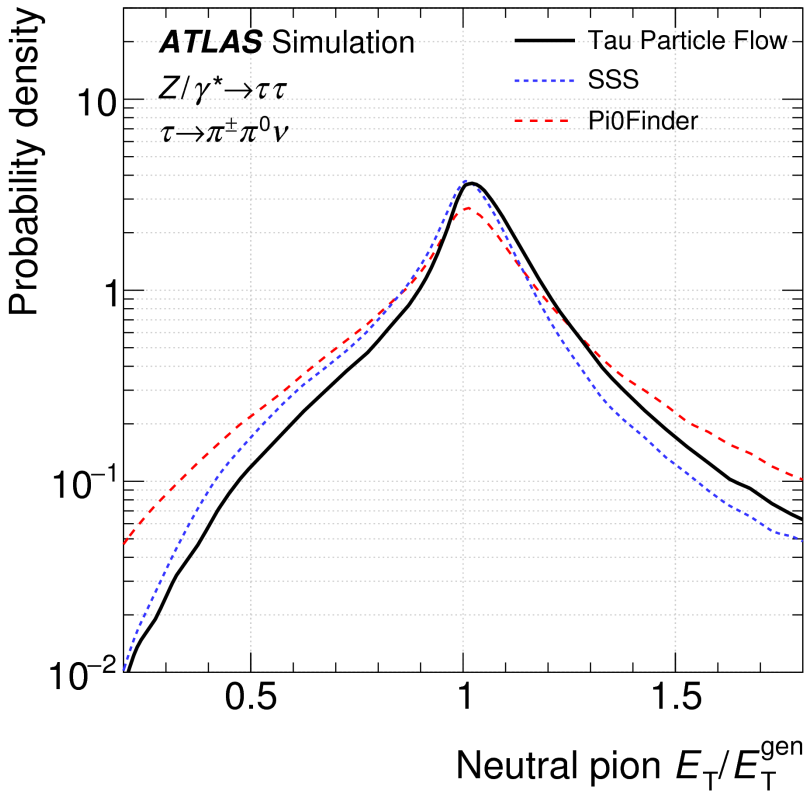
Classification modelling



– good modelling is observed for both true taus (right) and jets that fake a tau (left)

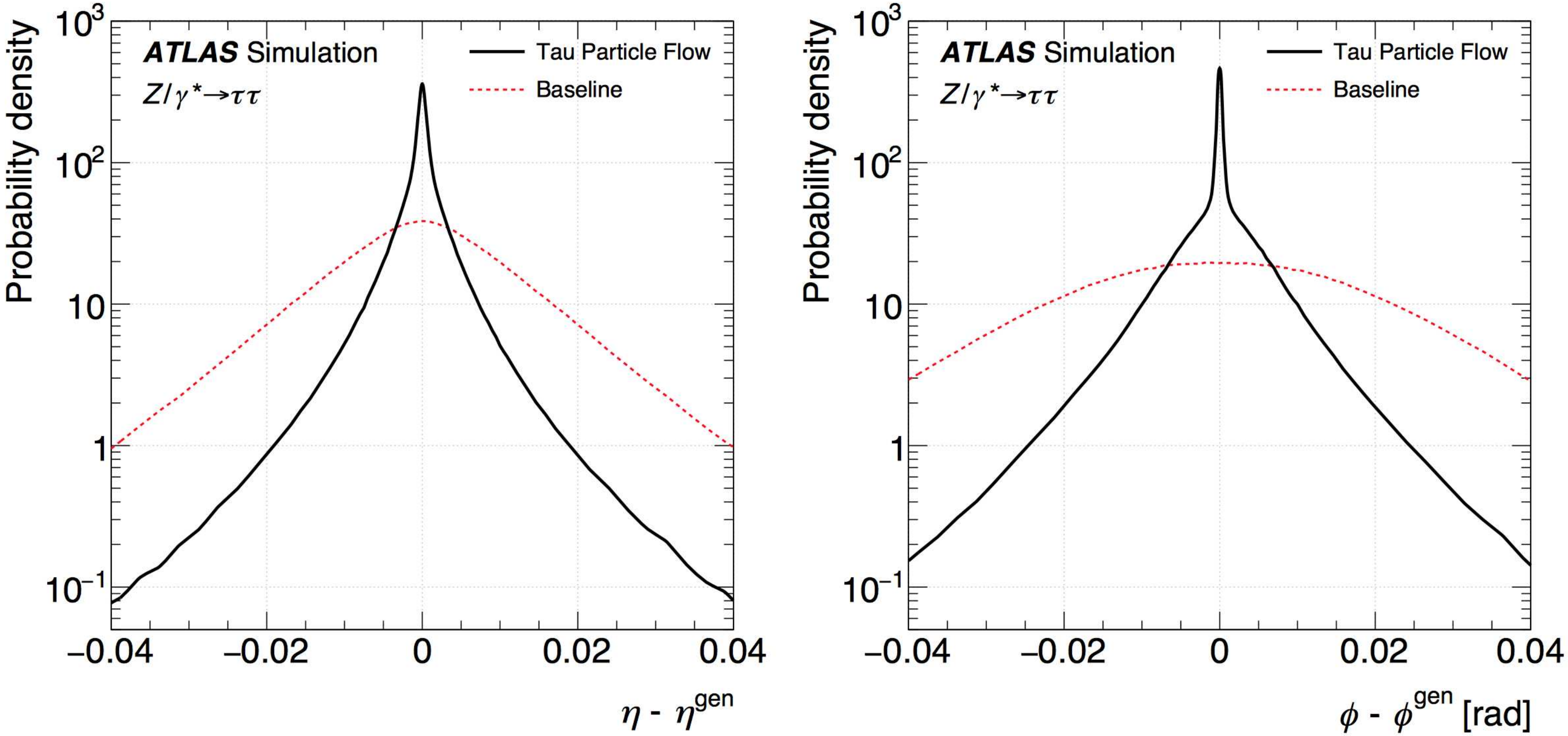
π^0 angular and energy resolution





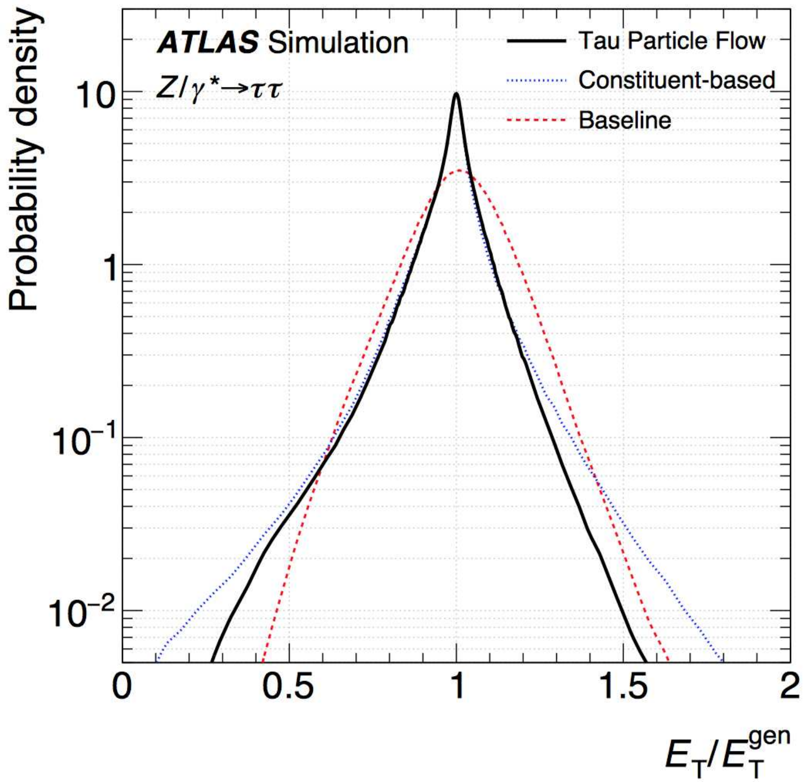
– good angular and energy resolution is observed for the reconstructed π^0s

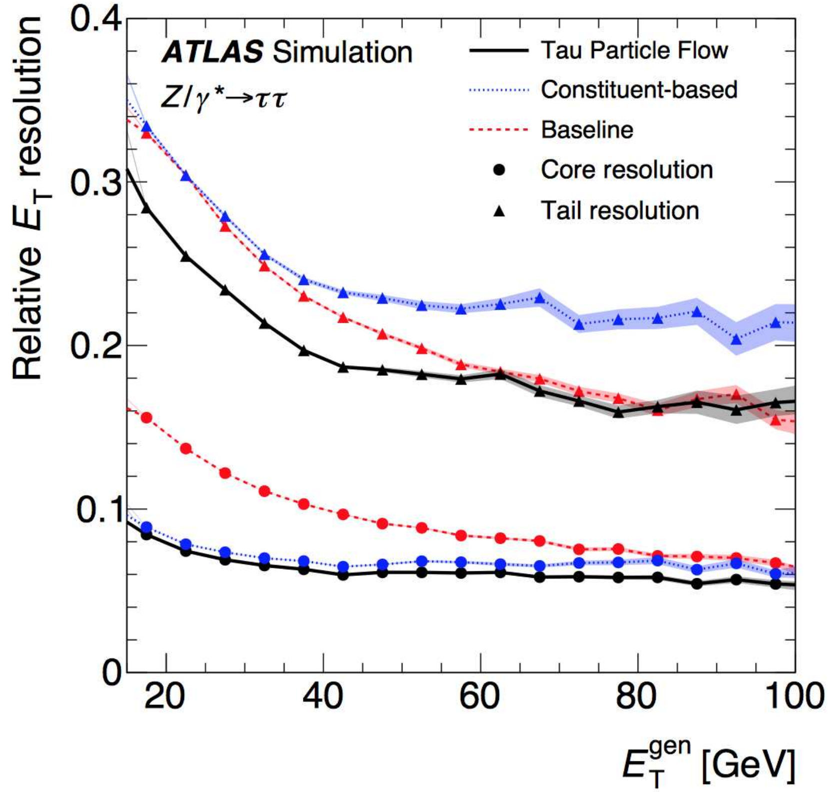
Tau angular resolution improvement



– a factor of 5 improvement in angular resolution with respect to the calorimeter-based measurement used in Run 1

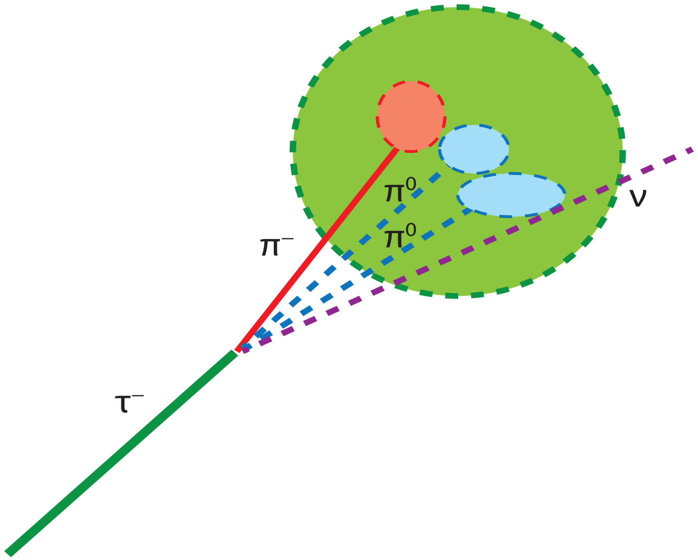
Tau energy resolution improvement





– a factor of 2 improvement in energy resolution with respect to the calorimeter-only measurement at low p_T

Alternative energy measurement (D0-like)

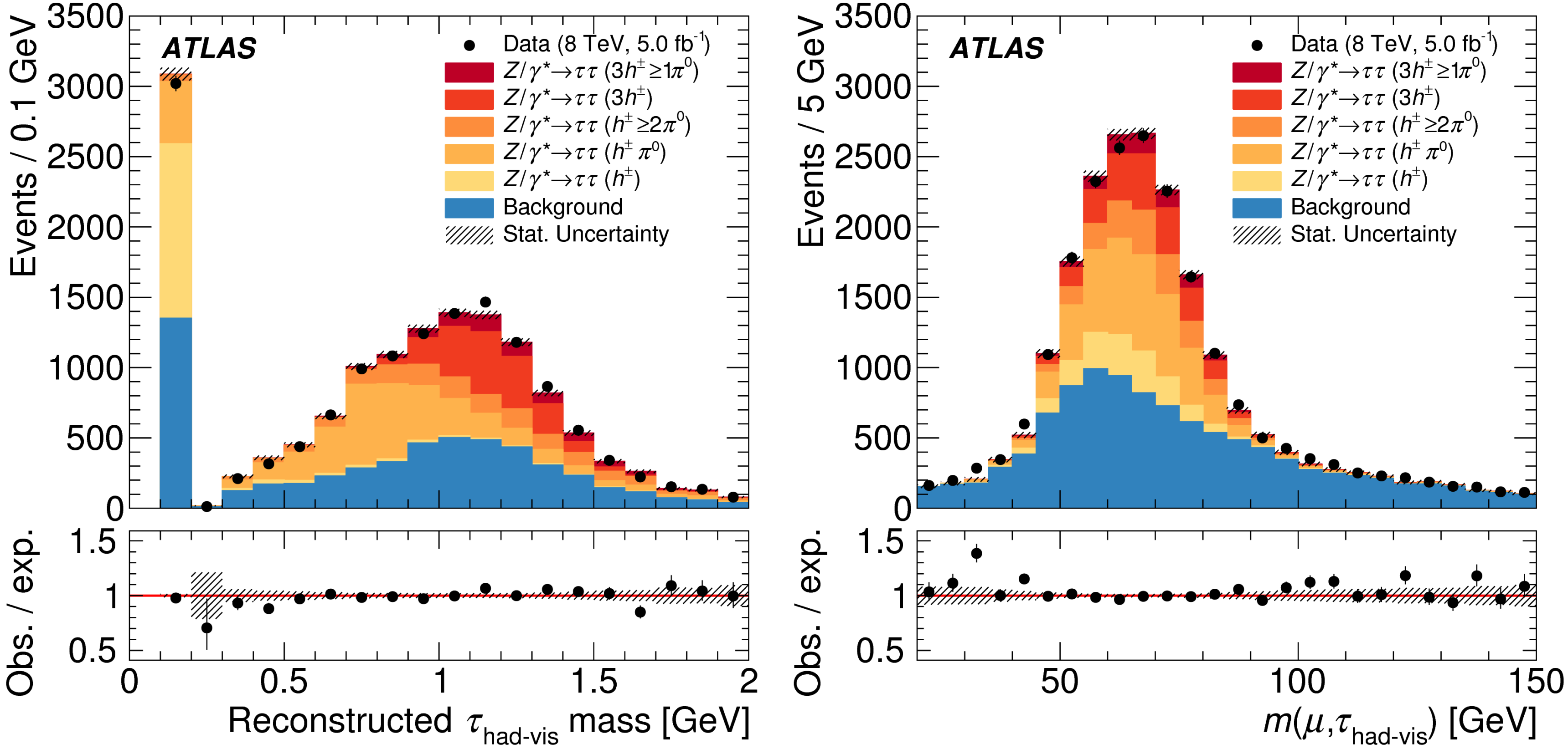


- no π^0s: $p_T^\tau = \sum p_T^{\tau trk}$

- decays with π^0s: average calorimeter-only measurement with $p_T^\tau = E_T^{CAL} + \sum p_T^{trk} - \sum R_{Ch.Pion}(\eta, p_T^{trk}) * p_T^{trk}$

- energy resolution very similar to Tau Particle Flow method

Kinematic modelling



– good modelling is observed for both the tau mass reconstruction (left) and the Z mass reconstruction (right)

Conclusions and references

- tau reconstruction in ATLAS resumed in Run 2 with algorithms and performance similar to Run 1, in spite of increased instantaneous luminosity (reference)
- inclusion of special prescriptions for merged hits increases the 3-prong reconstruction efficiency significantly at high-p_T (reference)
- a new algorithm which identifies π^0s in tau decays is now available, leading to a better decay mode classification, significant improvement in angular and energy resolution, and new possibilities of measuring the Higgs boson CP with tau leptons (reference)