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ATLAS charged-particle reconstruction in energetic jets performance for Run 3 data taking

Abstract

For Run 3 data taking the track reconstruction algorithm used for the ATLAS Inner Detector has been optimized with a particular focus on minimizing the number of erroneous and low-quality tracks processed by rejecting them as early as possible. This ensures a collection of high quality tracks to downstream reconstruction and physics, a key aspect in ATLAS. This poster describes the modeling of track reconstruction in the core of the jets, presenting new measurements of the charged particle reconstruction inefficiency and fake rate inside jets. The measurements rely on Run 2 data reprocessed with the software that will be used for Run 3.

Motivation

Excellent reconstruction of charged particle tracks inside dense hadronic environments (jet core) critical in ATLAS

→ can **improve** the jet energy and mass resolutions;

→ heavily used for hadronically decaying **tau reconstruction**, **boosted object tagging** (e.g.H → bb), or for the quark – gluon jets (or for light jets – bottom/charm quark jets) **separation**, etc.

Quite challenging: jet core ↔ very high particle density

→ tracks of charged particles begin to overlap, thus the pixel clusters in the ATLAS inner detector begin to merge, deteriorating the track reconstruction efficiency, as well as the resolution of measured track parameters

Equally critical: have good Monte Carlo simulations

Reconstruction efficiency & inefficiency

Reconstruction efficiency → the probability to have a charged particle reconstructed as a track

→ around 88% for jets with p_T around 500 GeV, decreasing to 83% (74%) for 1 TeV (2 TeV) jets

Contributions to an inefficiency in the track reconstruction:

→ multiple scattering, and any other effects related to material interactions ⟹ affects mainly the low p_T charged particles; higher effect in the detector end-caps (more material)

→ high particle density ⟹ when the trajectories are very close, tracks can share clusters

Fake rate → the probability to have the majority of energy deposits (hits) used for a reconstructed track not coming from any single charged particle (several orders of magnitude lower in Run 3 wrt. Run 2)

Efficiency measurements: r_{track} and ξ methods

r_{track} method → relies on the observation that, at particle level, the ratio of the charged to neutral energy in the jet core is independent of jet p_T

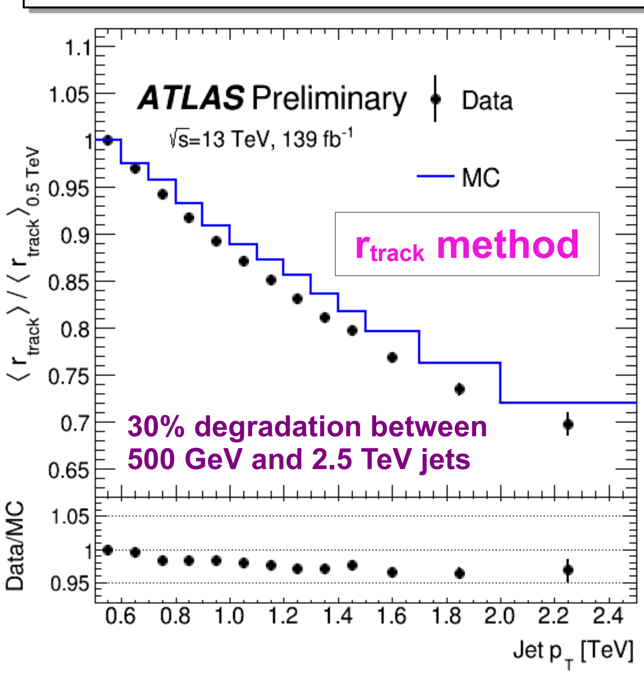
→ however, at detector level this ratio is p_T dependent

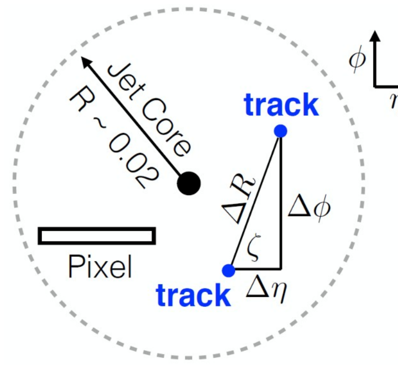
! Data / MC disagreement due to modeling of material interactions

ξ method → uses the angular separation between track pairs (ξ)

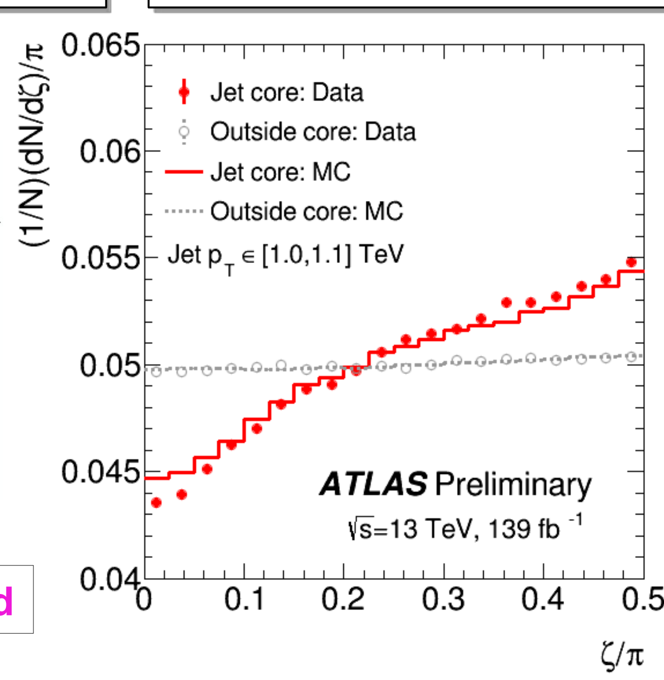
→ exploits the asymmetry in the pixel dimensions: 50 μm (transverse) vs 250 ↔ 400 μm (longitudinal)

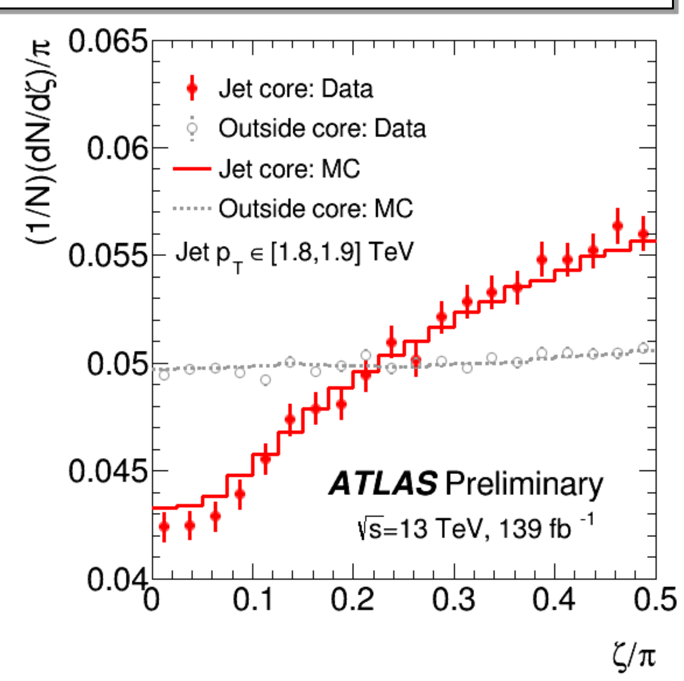
→ for a given ΔR: tracks more likely to be merged for small ξ





ξ method





Note for both r_{track} and ζ methods: no reweighting to correct the jet and track p_T distributions in MC to Data is applied;

Note for r_{track}: the significant decrease of r_{track} with jet p_T is due to the loss of track reconstruction efficiency in the core of jets due to pixel & SCT clusters merging;

Note for ζ: in the jet core, track pairs are lost due to cluster merging if the particles are close-by in the η direction due to the asymmetry in the pixel pitch, leading to a visible slope in ζ.

A measure of the modelling of fake tracks in data (using di-jet events)

Origin of fake tracks ↔ according to Monte Carlo (MC) simulations

→ the rate of fake tracks due to associating wrong hits from nearby high p_T charged particles inside the core of jets is not negligible

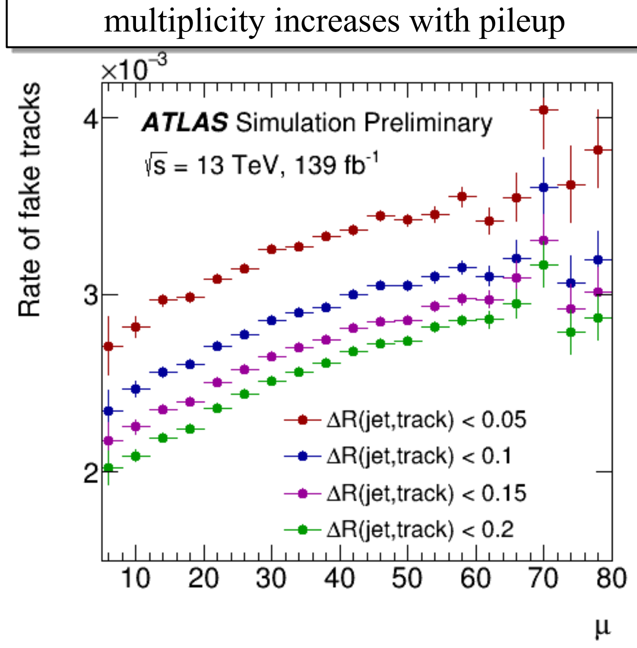
→ equally important: fake tracks from random combinations of hits, and their multiplicity increases with pileup

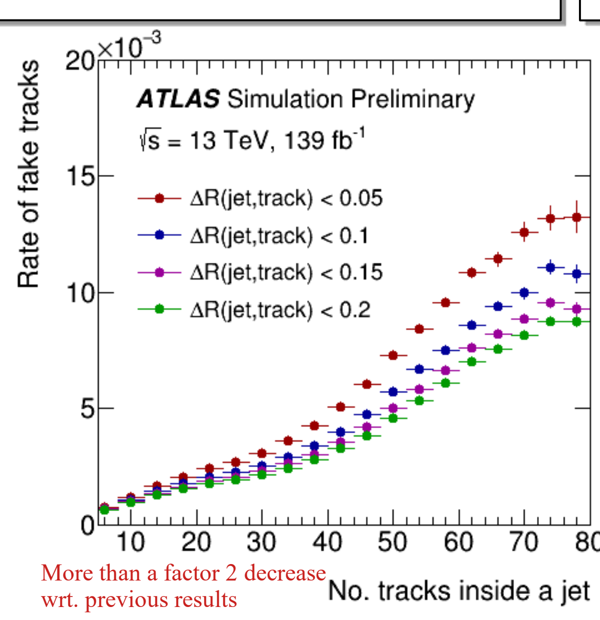
Rate of fake tracks ($f^{fakeTrk}$)

→ obtained e.g. from a fit of data (MLE) in a control region (CR), using the shape of the real and fake tracks distributions from MC simulations

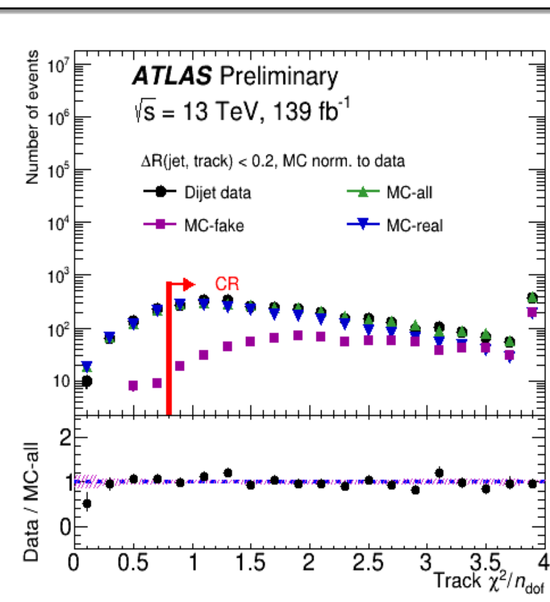
→ extrapolated to the pre-selection level (see ATL-PHYS-PUB-2017-016)

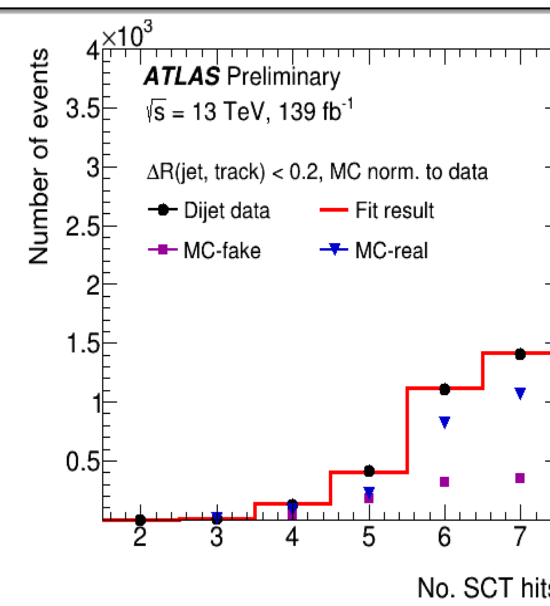
→ key variables: track χ^2 / DOF; number of SCT hits, of SCT holes, of shared hits





More than a factor 2 decrease wrt. previous results





Selected variable	$f^{fakeTrk}_{CR}$		
	MLE	toys	histo χ^2/n_{dof}
track χ^2/n_{dof}	0.25 ± 0.02	0.24 ± 0.03	0.23 ± 0.03
n_{SCT} hits	0.29 ± 0.06	0.33 ± 0.06	0.33 ± 0.06
n_{SCT} holes	0.28 ± 0.04	0.34 ± 0.05	0.34 ± 0.05
n_{SCT} shared hits	0.29 ± 0.04	0.23 ± 0.04	0.23 ± 0.04

In the di-jet CR enriched in fake tracks

29% in MC simulations

Selected variable	$f^{fakeTrk}_{pre\text{-}Sel}$	
	Data	MC
track χ^2/n_{dof}	0.0021	0.0024
n_{SCT} hits	0.0024	0.0024
n_{SCT} holes	0.0023	0.0024
n_{SCT} shared hits	0.0024	0.0024

At pre-selection level

Compared to 0.77% obtained with MC, in ATL-PHYS-PUB-2017-016

MLE = maximum likelihood estimation; n_{dof} = number of degrees of freedom; SCT = ATLAS semiconductor tracker

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Plots & captions: IDTR-2022-05

Previous public results: ATL-PHYS-PUB-2017-016

ATLAS EXPERIMENT