ATLAS QCD JET MEASUREMENTS*

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This article presents a recent QCD measurement of the jet cross-section ratios from the ATLAS experiment at CERN's Large Hadron Collider, using proton–proton collisions at a center-of-mass energy of 13 TeV. The jet cross-section ratios are derived from multi-differential particle-level cross sections for several inclusive jet multiplicity bins for at least 2, 3, 4, and 5 jets. These ratios improve sensitivity to the strong coupling parameter while reduce sensitivity to uncorrelated systematic uncertainties and parton distribution functions. The three-to-two jet cross-section ratio is reported for the first time at 13 TeV center-of-mass energy. Additionally, higher jet multiplicity ratios are measured experimentally for the first time, providing a crucial reference for future theoretical developments in high-precision QCD predictions involving multiple jets.

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1. Introduction

This contribution reports on the measurement [1] of the jet cross-section ratios performed by the ATLAS experiment [2] using proton–proton collisions at a center-of-mass energy of 13 TeV. The data were recorded during the full Run 2 phase of the Large Hadron Collider (LHC) from 2015 to 2018, corresponding to an integrated luminosity of 140 fb^{-1}. The measurement is based on reconstructed particle flow jets, clustered using the anti-k_{T} algorithm with a jet radius of $R = 0.4$. Detector effects are corrected using

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D'Agostini unfolding method to obtain results at the particle level, which are compared to Monte Carlo (MC) simulations and state-of-the-art NNLO pQCD predictions. These results will contribute to the interpretation of the strong coupling parameter α_{s}, which remains one of the least precisely determined parameters in the Standard Model.

2. Jet cross-section ratio

The multijet cross-section measurement is performed double- and triple-differentially in bins of inclusive jet multiplicity N_{jets} to construct a set of jet cross-section ratios to produce at least m to n jets ($m < n$) defined as

$$R_{\mathrm{mn}} = \frac{\sigma(\mathrm{m\ jets})}{\sigma(\mathrm{n\ jets})}\,. \tag{1}$$

The investigated jet cross-section ratios of R_{32}, R_{43}, R_{42}, and R_{54} benefit from significant cancellations of correlated systematic uncertainties, reduced sensitivity to parton distribution functions (PDF), and enhanced sensitivity to the strong coupling parameter α_{s}.

The measurement includes reconstructed jets with transverse momentum $p_{\mathrm{T}} > 60$ GeV, rapidity $|y| < 4.5$, and a scalar sum of the transverse momenta of the two leading jets, defined as $H_{\mathrm{T},2} = p_{\mathrm{T},1} + p_{\mathrm{T},2} > 250$ GeV. Additionally, several configurations of the third-leading jet transverse momenta $p_{3,\mathrm{T}}$ are considered to explore resummation effects in the forward jet topology relevant to vector-boson scattering and fusion phase spaces. Finally, a minimum of two jets is required, ensuring $N_{\mathrm{jets}} \geq 2$.

Figure 1 shows representative results for the multi-differential cross section, comparing various MC predictions to the unfolded data to assess the effects of parton showers and hadronization. None of the MC models is able to provide a precise prediction.

The measurement is also compared to fixed-order perturbative NLO and state-of-the-art NNLO QCD calculations using the NLOJET++ and OpenLoop2 [3] frameworks. These calculations are performed in the five-flavor scheme ($N_F = 5$) with the MSHT20 PDF set, renormalization and factorization scales set to the scalar sum of all parton p_{T} in the final state as $\mu_{\mathrm{R}} = \mu_{\mathrm{F}} = \hat{H}_{\mathrm{T}}$, and non-perturbative corrections applied.

The representative results for the R_{32} jet cross-section ratios are shown in figure 2 for three investigated configurations of $p_{\mathrm{T},3}$. The first scenario of $p_{\mathrm{T},3} > 60$ GeV provides an increasing R_{32} jet cross-section ratio since the probability of emitting the third jet increases with the energy scale of the event, which can be approximated with the $H_{\mathrm{T},2}$ variable. In the other scenarios, the $p_{\mathrm{T},3}$ cut depends on the $H_{\mathrm{T},2}$ causing different trends in R_{32} figures. For the $p_{\mathrm{T},3} > 0.1 \times H_{\mathrm{T},2}$ scenario, the R_{32} ratio increases

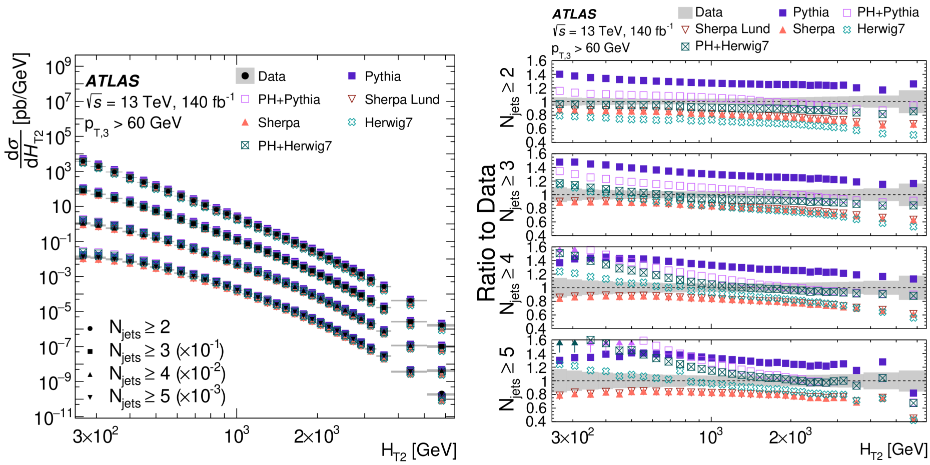

Fig. 1. Differential cross section of $H_{\mathrm{T},2}$ for various inclusive jet multiplicities N_{jets}, comparing unfolded ATLAS data to different MC predictions at the particle level (left) and their ratios to data (right), including statistical and systematic uncertainties. The transverse momentum of the third-leading jet is required to satisfy $p_{\mathrm{T},3} > 60$ GeV. Taken from Ref. [1].

smoothly until the point of 60 GeV/0.10 = 600 GeV and then suddenly drops. The drop is caused since the event topology at the highest $H_{\mathrm{T},2}$ values includes a back-to-back jet configuration when the third-leading jet is mostly produced very close to one of the two. Thus, the third-leading jet can be merged easily together with one of the leading or subleading jets. For the third $p_{\mathrm{T},3}$ scenario, the dependence on $H_{\mathrm{T},2}$ is so strong that the R_{32} decreases only due to the steeply falling third-leading jet $p_{\mathrm{T},3}$ spectra.

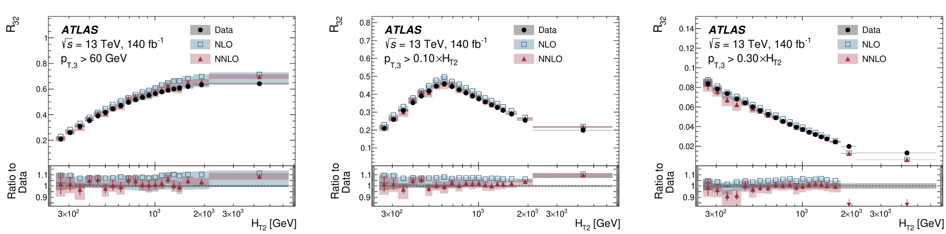

Fig. 2. Jet cross-section ratio R_{32} to produce at least three-to-two jets comparing unfolded data to theoretical predictions of perturbative QCD at NLO and NNLO accuracy for three investigated scenarios of third-leading jet transverse momenta $p_{\mathrm{T},3} > 60$ GeV (left), $p_{\mathrm{T},3} > 0.10 \times H_{\mathrm{T},2}$ (middle), and $p_{\mathrm{T},3} > 0.30 \times H_{\mathrm{T},2}$ (right). Taken from Ref. [1].

This measurement of R_{32} jet cross-section ratio at 13 TeV proton–proton collisions is published for the first time, and it should be used for the $\alpha_{\rm s}$ extraction. Thanks to the large LHC Run 2 dataset, higher jet cross-section ratios are experimentally accessible for the first time. These data points are publicly available at HEP data [4] and Rivet routine [5] to serve as a reference for future theoretical developments in high jet multiplicity predictions, as no precise theoretical framework currently exists for this regime.

3. Conclusion

This paper summarizes a unique QCD multijet measurement for the jet cross-section ratios from the ATLAS experiment at the Large Hadron Collider, focusing on various aspects of QCD modeling to provide a reference for future theoretical developments in multiple-jet production. The measurement is also sensitive to the strong coupling parameter $\alpha_{\rm s}$ and could be used for its extraction.

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