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BFKL azimuthal imprints in inclusive three-jet production at 7 and 13 TeV

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Abstract

We propose the study of new observables in LHC inclusive events with three tagged jets, one in the forward direction, one in the backward direction and both well-separated in rapidity from the each other (Mueller–Navelet jets), together with a third jet tagged in central regions of rapidity. Since non-tagged associated mini-jet multiplicity is allowed, we argue that projecting the cross sections on azimuthal-angle components can provide several distinct tests of the BFKL dynamics. Realistic LHC kinematical cuts are introduced.

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1. Introduction

In recent years the steady running of the Large Hadron Collider (LHC) has opened up new avenues for the study of the high energy limit of Quantum Chromodynamics (QCD). This is particularly important in the context of jet production since the abundance of data allows for the possibility to study more exclusive observables, needed to isolate regions of phase hidden in

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more inclusive, previous, analysis. In this work we focus on the investigation of jet production in the so-called multi-Regge kinematics. When jets are produced at large relative rapidities the Balitsky–Fadin–Kuraev–Lipatov (BFKL) approach in the leading logarithmic (LL) [1–6] and next-to-leading logarithmic (NLL) approximation [7,8] offers an effective framework to calculate the bulk of the cross sections.

Mueller–Navelet jets [9] correspond to the inclusive hadroproduction of two jets[1] with large and similar transverse momenta, $k_{A,B}$, and a significant relative separation in rapidity $Y = \ln(x_1 x_2 s/(k_A k_B))$, where $x_{1,2}$ are the longitudinal momentum fractions of the partons generating the jets and s is the center-of-mass-energy squared s. Different studies [12–23] of the average values, $\langle \cos(m\,\phi) \rangle$, for the azimuthal-angle formed by the two tagged jets, ϕ, have shown the presence of a large soft gluon activity populating the rapidity gap. These observables are, however, strongly affected by collinear effects [24,25], stemming from the $n = 0$ Fourier component in ϕ of the BFKL kernel. This dependence is removed if instead the ratios of projections on azimuthal-angle observables $\mathcal{R}_n^m = \langle \cos(m\,\phi) \rangle / \langle \cos(n\,\phi) \rangle$ [24,25] (where m, n are integers and ϕ the azimuthal angle between the two tagged jets) are introduced. In particular, these also offer a more clear signal of BFKL effects than the standard predictions for the growth of hadron structure functions $F_{2,L}$ (well fitted within NLL approaches [26,27]). The comparison of different NLL predictions for these ratios $\mathcal{R}_n^m$ [28–32] with LHC experimental data has been very successful.

We understand the current situation as the beginning of precision physics using the BFKL formalism. Within the framework itself there exist many theoretical questions to be answered. Some of these include to find out what is the more accurate way to implement the running of the coupling, if there is any onset of saturation effects at the level of exclusive observables, how to isolate BFKL dynamics from multiple interaction effects, etc. To address these issues it is important to investigate even more exclusive final states.

Here we advance in this direction by proposing new observables associated to the inclusive production of three jets: two of them are the original Mueller–Navelet jets and the third one is a tagged jet in central regions of rapidity (see Fig. 1). Experimentally, they have the advantage to belong to the already recorded Mueller–Navelet events, it only requires of further binning in the internal jets. Theoretically, they will allow us to better understand distinct features of the BFKL ladder, in other words, to find out which ones of its predictions cannot be reproduced by other approaches such as low order exact perturbation theory or general-purpose Monte Carlo event generators. Parton-level studies have been recently presented in [33] while here we focus on calculating realistic cross-sections at the LHC.

In order to focus our discussion, we will present results for the above mentioned $\mathcal{R}_n^m$ ratios but now with a further dependence on the p_t and rapidity of the central jet. As a novel result, we will also present predictions for the new ratios

$$\mathcal{R}_{PQ}^{MN} = \frac{\langle \cos(M\,\phi_1)\cos(N\,\phi_2) \rangle}{\langle \cos(P\,\phi_1)\cos(Q\,\phi_2) \rangle}, \tag{1}$$

where ϕ_1 and ϕ_2 are, respectively, the azimuthal angle difference between the first and the second (central) jet and between this one and the third jet (see Fig. 2).

A further natural development in this direction has been the extension of these observables to the case of four-jet production in multi-Regge kinematics with a second tagged jet being pro-

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[1] Another interesting idea, suggested in [10] and investigated in [11], is the study of the production of two charged light hadrons, $\pi^{\pm}$, $K^{\pm}$, p, $\bar{p}$, with large transverse momenta and well separated in rapidity.