High-energy resummation in inclusive hadroproduction of Higgs plus jet

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Abstract

Using the standard Balitsky-Fadin-Kuraev-Lipatov (BFKL) approach, with partial inclusion of next-to-leading order effects, we propose the inclusive hadroproduction of a Higgs boson and of a jet, featuring large transverse momenta and well separated in rapidity, as a new channel to probe the BFKL dynamics. Predictions are presented for cross-sections and azimuthal angle correlations in different kinematics configurations for the final-state transverse momenta. We find that the large energy scales provided by the emission of a Higgs boson stabilize the BFKL series.

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1 Introduction

The Balitsky-Fadin-Kuraev-Lipatov (BFKL) [1–4] approach represents a suitable framework for the theoretical description of the QCD dynamics in the high energy-limit. During the last years, the investigation of semi-hard processes [5] to probe the BFKL dynamics has become a theoretical and experimental challenge. Typical BFKL observables at the LHC are the azimuthal-angle correlations of the tagged particles in the final state, which are separated in rapidity, here the experimental challenge being a good resolution in the azimuthal plane, while the theoretical challenge is the incorporation of NLO corrections to impact factors, so as to treat different processes with consistent accuracy, and make predictions to be compared with data. Recently, a number of probes for BFKL signals have been proposed for different collider environments: the diffractive leptoproduction of two light vector mesons [6–9], the total cross section of two highly-virtual photons [10], the inclusive hadroproduction of two jets with large transverse momenta and well separated in rapidity (Mueller-Navelet channel [11]), for which several phenomenological studies have carried out so far (for more details see [12] and references therein), the inclusive detection of two light-charged hadrons [13–15], three- and four-jet hadroproduction [16–21], J/Ψ-jet [22], hadron-jet [23–25], the inclusive production of rapidity-separated Λ-Λ or Λ-jet pairs [26], and recently, double Λc or of a Λc plus a light-flavored jet system [27], Drell-Yan-jet [28, 29] and heavy-quark pair photoproduction [30,31] and hadroproduction [32,33].

In this work the inclusive production at the LHC of a Higgs boson and of a jet, well separated in rapidity, is suggested as a further probe of the BFKL resummation [34]. For a Higgs boson with mass \(M_H = 125\) GeV, the fraction of the longitudinal momentum of the parent proton carried by the struck gluon \(x \sim M_H/p_s \sim 0.008\) is rather small, making it describable within the BFKL approach.

2 Theoretical Set Up

The process of our consideration is the concurrent inclusive production of a Higgs boson and a jet (see Fig. 1):

\[
\text{proton}(p_1) + \text{proton}(p_2) \rightarrow H(\vec{p}_H, y_H) + X + \text{jet}(\vec{p}_J, y_J),
\]

(1)

emitted with large transverse momenta, \(|\vec{p}_{H,J}| \gg \Lambda_{QCD}\), and separated by a large rapidity interval, \(\Delta Y = y_H - y_J\), while \(p_1\) and \(p_2\) are taken as Sudakov light cone base vectors. The cross section of the process can be presented as a Fourier series of the so-called azimuthal coefficients, and it reads

\[
\frac{d\sigma}{dy_H dy_J d|\vec{p}_H| d|\vec{p}_J| d\varphi_H d\varphi_J} = \frac{1}{(2\pi)^2} \left[ C_0 + \sum_{n=1}^{\infty} 2 \cos(n\varphi) C_n \right],
\]

(2)

where \(\varphi = \varphi_H - \varphi_J - \pi\), with \(\varphi_{H,J}\) the Higgs and the jet azimuthal angles, and \(C_0\) gives the total cross section, while the coefficients \(C_{n>0}\) determine their azimuthal-angle distribution.
3 Numerical results

The numerical analysis was performed using JETHAD [12], a promising standard software under development in our group, suited for the analysis of inclusive semi-hard reactions. As for the renormalization for quarks and gluon PDFs, the MMHT2014 NLO PDF set [35] was employed. We considered three different kinematical configurations for the final-state transverse momentum of detected particles, and constrained the Higgs and jet inside the rapidity acceptances of CMS detector, \(|y_H| < 2.5\) and \(|y_J| < 4.7\), respectively. First, we studied the \(\varphi\)-summed cross section \(C_0(\Delta Y, s)\), the azimuthal-correlation moments, \(R_{n0} = C_n/C_0 \equiv \cos(n\varphi)\), and their ratios, \(R_{nm} = C_n/C_m\) as functions of the Higgs-jet rapidity distance \(\Delta Y\). We considered the \(p_T\)-distribution for two different values of rapidity interval \((\Delta Y = 3, 5)\). A detailed study on this observable covering all the high \(p_T\) regions would rely on a unified formalism where distinct resummations are concurrently embodied. We summarized our results in Figs. 2 and 3. We adopted the MSbar renormalization scheme, obtaining, for all the considered observables, that the NLA patterns are close to LLA ones. This indicates good stability of the perturbative series, with no need to use scale optimization procedures as for other semihard processes.

![Diagram](image1)

Figure 1: Higgs-jet hadroproduction process

4 Conclusions

In conclusion, the Higgs-jet process shows a fair stability under higher order corrections. The high energy resummation approach is valid and available in the symmetric and intermediate regions of the \(p_T\) values, beyond that, the description for Higgs momentum distribution would be relied on many-sided resummation formalism unifying different approaches.

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Figure 2: $\Delta Y$-dependence of the $C_0$ and several ratios $R_n m \equiv C_n / C_m$, for the inclusive Higgs-jet hadroproduction

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Figure 3: $p_H$-dependence of the cross section for the inclusive Higgs-jet hadroproduction

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