

Impact of coherence and low x effects on decorelations of forward-central jets.

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We report on recent calculation of forward central jets decorelations at LHC energies within High Energy Factorization. We emphasize the role of Sudakov resummation and kinematical effects in description of data.

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1. Introduction

Here we report on recent studies [1], of decorrelations in production of central-forward dijet the High Energy Factorization (HEF) approach. This observable has been recognized to be very usefull in analysis of parton dynamics at small- x and not negligible transversal momentum of initial state gluons [2, 3, 4, 5, 6, 7, 8]. One of the reasons is that small- x effects are inseparably related to the notion of internal transverse momenta of gluons (which due to that are off-shell) inside a hadron, which, according to the Balitsky-Fadin-Kuraev-Lipatov (BFKL) formalism, can be large but cannot be arbitrarily small because of the importance of nonlinear effects absent in the BFKL equation and taken in to account by the BK equation. Furthermore the internal transverse momentum of a gluon can be viewed as a direct source of azimuthal decorrelations, since it creates a jet momentum imbalance on the transverse plane.

It seems the effects that turn out to play a crucial role in the description of data are the kinematical effects enforcing momenta of the gluons to be dominated by the transverse components [9, 10] and the coherence effects effects related to soft gluon radiation of Sudakov type [11].

In situations where the final state populates forward rapidity regions, one of the longitudinal fractions of the hadron momenta is much smaller then the other, $x_A \ll x_B$, and the following ‘hybrid’ HEF formula is used [4]

$$d\sigma_{AB \rightarrow X} = \int \frac{d^2 k_{TA}}{\pi} \int \frac{dx_A}{x_A} \int dx_B \sum_b \mathcal{F}_{g^*/A}(x_A, k_{TA}, \mu) f_{b/B}(x_B, \mu) d\hat{\sigma}_{g^*b \rightarrow X}(x_A, x_B, k_{TA}, \mu), \quad (1.1)$$

where $\mathcal{F}_{g^*/A}$ is a UGD (Unintegrated Gluon Density), $f_{b/B}$ are the collinear PDFs, and b runs over the gluon and all the quarks that can contribute to the production of a multi-particle state X . Note that both $f_{b/B}$ and $\mathcal{F}_{g^*/A}$ depend on the hard scale μ . As we explain below, it is important to incorporate the hard scale dependence also in UGD. The off-shell gauge-invariant matrix elements for multiple final states reside in $d\hat{\sigma}_{g^*b \rightarrow X}$. The condition $x_B \gg x_A$ is imposed by proper cuts on the phase space of X . In our computations, we used several different unintegrated gluon densities $\mathcal{F}_{g^*/A}(x, k_T, \mu)$:

- The nonlinear KS (Kutak-Sapeta) unintegrated gluon density [6], which comes from the extension of the BK (Balitsky-Kovchegov) equation [13] following the prescription of KMS (Kwiecinski-Martin-Stasto)
- The linear KS gluon, determined from the linearized version of the equation described above.
- The KMR hard scale dependent unintegrated gluon density [14]. It is obtained from the standard, collinear PDFs supplemented by the Sudakov form factor and small- x resummation of the BFKL type. The Sudakov form factor ensures no emissions between the scale of the gluon transverse momentum, k_T , and the scale of the hard process, μ .
- The standard collinear distribution $\mathcal{F}_{g^*}(x, k_T, \mu^2) = xg(x, \mu^2)\delta(k_T^2)$, which, when used in Eq. (1.1), reduces it to the collinear factorization formula. In this study we used the CTEQ10 NLO PDF set [15].

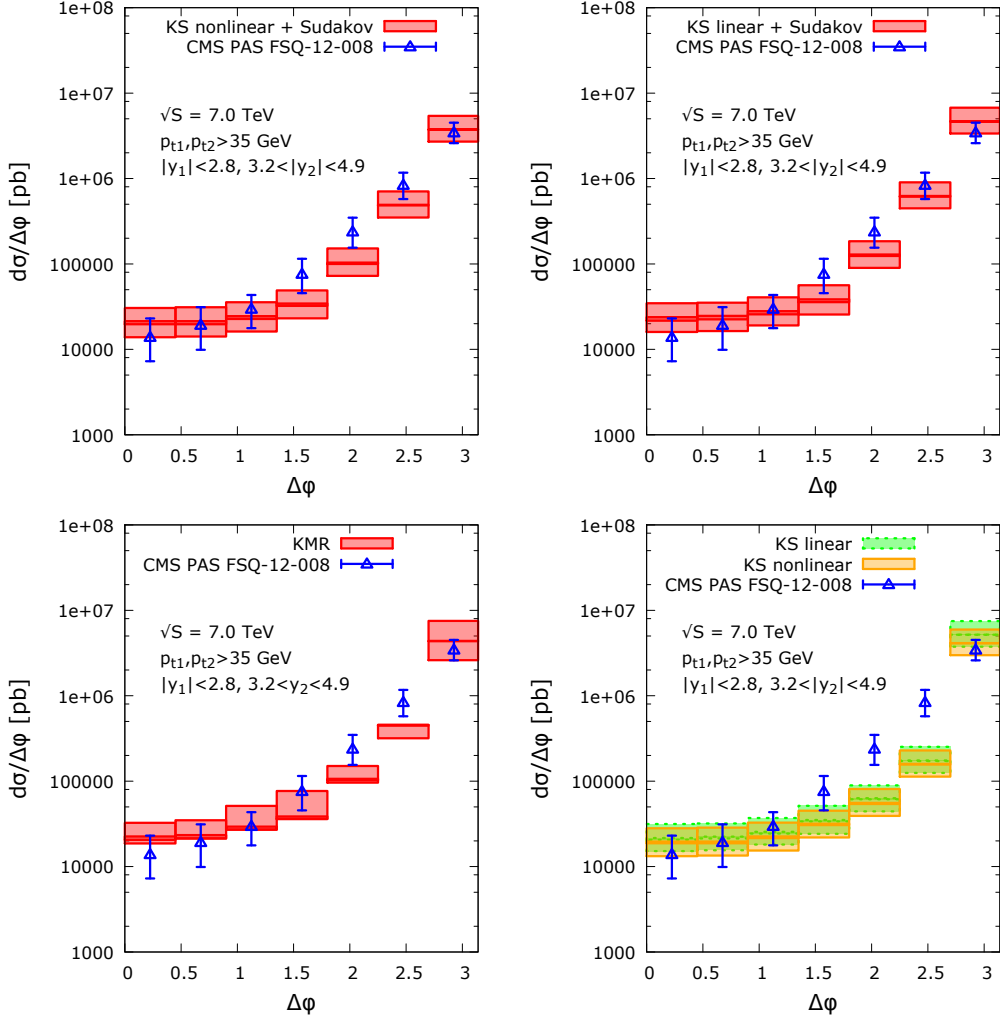


Figure 1: Comparison of CMS data for the inclusive dijet scenario with model predictions.

In addition, we supplement the KS linear and nonlinear UGDs with the Sudakov resummation, which, as we shall see, turns out to be a necessary ingredient needed to describe the data at moderate $\Delta\phi$. The resummation is made on top of the Monte Carlo generated events and it is motivated by the KMR prescription of the Sudakov form factor. It effectively incorporates the dependence on a hard scale μ into the KS gluons, which by themselves do not exhibit such dependence.

Results

In this section, we present the results of our study of the azimuthal decorrelations in the forward-central dijet production. Our framework enables us to describe two scenarios considered in the CMS forward-central dijet measurement [16]:

- *Inclusive scenario*, which, in the experiment, corresponds to selecting events with the two leading jets satisfying the cuts: $p_{T,1,2} > 35$ GeV, $|y_1| < 2.8$, $3.2 < |y_2| < 4.9$ and with no

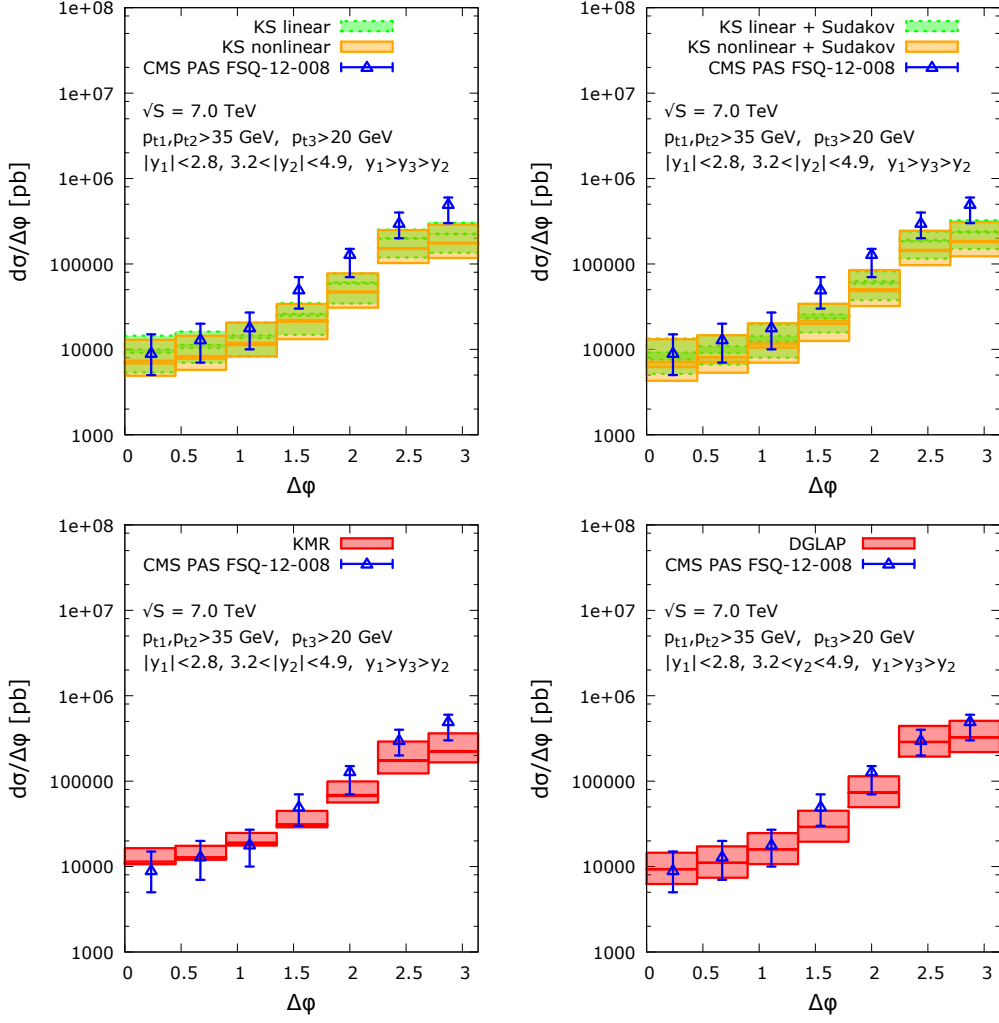


Figure 2: Comparison of CMS data for the dijet inside-jet-tag scenario with model predictions.

extra requirement on further jets. These results are shown in Fig. 1.

- *Inside-jet-tag scenario*, with the same selection on the two hardest jets but, this time, a third jet with $p_T > 20$ GeV is required between the forward and the central region. The corresponding results are shown in Fig. 2.

In Fig. 1, we present our results for the case of the inclusive selection and compare them with the data from CMS. We show the results obtained with the nonlinear and linear KS gluon, supplemented with the Sudakov form factor (top left and top right, respectively), the KMR gluon (bottom left) and an unmodified KS gluon (bottom right). We see that the KS+Sudakov and KMR describe the data well. The error bands on the predictions were obtained by varying the hard scale appearing explicitly in the running coupling, UGDs, and the collinear PDFs by a factor $2^{\pm 1}$. The calculations were performed independently by three programs: LxJet [17], forward [18], and a program implementing the method of [19].

The results presented in Fig. 1 provide evidence in favour of the small- x (or BFKL-like) dynamics. This dynamics produces gluon emissions, unordered in k_T , which build up the non-vanishing $\Delta\phi$ distributions away from $\Delta\phi = \pi$. (A pure DGLAP based approach, without the use of a parton shower, could of course only produce a delta function at $\Delta\phi = \pi$.) Furthermore, combining the above result with the recent analysis performed in [8], we conclude that the effects of higher orders, like kinematical effects that allow for emissions at low $\Delta\phi$ are of crucial importance. This alone is however not enough, since, as shown in Fig. 1, one necessarily needs the Sudakov resummation to improve the moderate $\Delta\phi$ (or equivalently moderate $k_T \sim 50$ GeV) region. These Sudakov effects are needed to resum virtual emissions between the hard scale provided by the external probe and the scale of the emission from the gluonic ladder. In other words, one has to assure that the external scale is the largest scale in the scattering event.

Fig. 2 shows the results obtained in the HEF approach with the $2 \rightarrow 3$ hard matrix elements. We also show the corresponding result from pure DGLAP, i.e. with the HEF formula (1.1) used in the collinear limit. We see that the linear and nonlinear KS results without (top left) and with (top right) the Sudakov form factor nicely follow the experimental data from the inside-jet-tag scenario. The description is also very good when the KMR gluon is used (bottom left). In the case of pure DGLAP calculation (bottom right), the parton produced in the final state allows for generation of the necessary transverse momentum imbalance between the two leading jets. This, in turn, leads to a good description of the experimental data, even without the use of a parton shower.

Our results confirm the necessity of incorporating the hard scale dependence to the unintegrated gluon densities. Further studies with in CCFM-based approaches [20, 21] would be needed in order to get better understanding of these effects.

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