BFKL Effects in Azimuthal Angle Correlations of Forward Jets

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The azimuthal angle correlation of Mueller-Navelet jets at hadron colliders is studied in the NLO BFKL formalism. We highlight the need of collinear improvements in the kernel to obtain good convergence properties and we obtain better fits for the Tevatron data than at LO accuracy. We also estimate these correlations for larger rapidity differences available at the LHC.

1 BFKL cross sections

In [1] we continue the study initiated in [2] of azimuthal correlations in Mueller-Navelet jets [3] using the Balitsky-Fadin-Kuraev-Lipatov (BFKL) equation in the next-to-leading (NLO) approximation [4]. We investigate normalized differential cross sections which are quite insensitive to parton distribution functions and read

$$\frac{d\hat{\sigma}}{d^2\vec{q}_1 d^2\vec{q}_2} = \frac{\bar{\alpha}_s^2 \alpha_s^2}{2} \frac{1}{\vec{q}_1^{\,2}\vec{q}_2^{\,2}} \int \frac{d\omega}{2\pi i} e^{\omega Y} f_\omega(\vec{q}_1,\vec{q}_2),$$

where $\bar{\alpha}_s = \alpha_s N_c/\pi$, $\vec{q}_{1,2}$ are the transverse momenta of the tagged jets, and Y their relative rapidity. The Green's function carries the Y-dependence and follows the NLO equation, $\omega f_\omega = \hat{1} + \bar{\alpha}_s \hat{K}_0 f_\omega + \bar{\alpha}_s^2 \hat{K}_1 f_\omega$, which acts on the basis including the azimuthal angle, $\langle \vec{q}_j | n, \nu \rangle = \frac{1}{\pi\sqrt{2}} (\vec{q}_j^{\,2})^{i\nu - \frac{1}{2}} e^{in\theta_j}$. As Y increases the azimuthal dependence is driven by the kernel. This is why we use the LO jet vertices which are simpler than at NLO. The differential cross section in the azimuthal angle $\theta = \theta_1 - \theta_2 - \pi$, with θ_i being the angles of the two tagged jets, is

$$\frac{d\hat{\sigma}(\alpha_s, Y, \vec{p}_{1,2}^{\,2})}{d\theta} = \frac{\bar{\alpha}_s^2 \alpha_s^2 \pi^2}{4\sqrt{\vec{p}_1^{\,2}\vec{p}_2^{\,2}}} \sum_{n=-\infty}^{\infty} e^{in\theta} C_n(Y),$$

$$C_n(Y) = \frac{1}{2} \int_{-\infty}^{\infty} d\nu \left(\frac{\vec{p}_1^{\,2}}{\vec{p}_2^{\,2}}\right)^{i\nu} e^{\left(|n|\frac{1}{2} + i\nu, \alpha_s(p_1 p_2)\right) Y},$$

$$\chi(n,\nu,\alpha_s) = \bar{\alpha}_s \chi_0(n,\nu) + \alpha_s^2 \chi_1(n,\nu) - \frac{\chi_0(n,\nu)}{8 N_c} \frac{\chi_0'(n,\nu)}{(1-\nu^2)}.$$

The eigenvalue of the LO kernel is $\chi_0(n,\nu) = 2\left(\psi(1) - \psi\left(\frac{n}{2} + i\nu\right) - \psi\left(\frac{n}{2} - i\nu\right)\right)$, with ψ the logarithmic derivative of the Euler function. The action of $\hat{K}_1$, in $\overline{MS}$ scheme, can be found

Supported by the Graduiertenkolleg "Zukunftige Entwicklungen in der Teilchenphysik"

in [5]. The full cross section only depends on the $n = 0$ component, $\hat{\sigma} = \frac{1}{2}\frac{\alpha_s^3}{p_1^2 p_2^2} C_0(Y)$. The average of the cosine of the azimuthal angle times an integer projects out the contribution from each of these angular components:

$$\frac{\langle \cos(m\,\phi)\rangle}{\langle \cos(n\,\phi)\rangle} = \frac{C_m(Y)}{C_n(Y)} \tag{1}$$

The normalized differential cross section is

$$\frac{1}{\hat{\sigma}}\frac{d\hat{\sigma}}{d\phi} = \frac{1}{2\pi}\sum_{n=-\infty}^{+\infty} e^{in\phi}\,\frac{C_n(Y)}{C_0(Y)} = \frac{1}{2\pi}\left(1 + 2\sum_{n=1}^{\infty}\cos(n\,\phi)\langle\cos(n\,\phi)\rangle\right) . \tag{2}$$

The BFKL resummation is not stable at NLO [6, 7]. In the gluon–bremsstrahlung scheme our distributions become unphysical. To improve the convergence we impose compatibility with renormalization group evolution in the DIS limit [8] for all angular components. A good scheme is the angular extension of that discussed in [7], first proposed in [6]:

$$\begin{aligned}\omega = {} & \bar{\alpha}_s(1 + A_{n\,\alpha_s})\;\chi^{(1)}\left(\gamma + \frac{|n|}{2} + \frac{\omega}{2} + B_{n\,\alpha_s}\right) \\ & \left(1 + \frac{|n|}{2} + \frac{\omega}{2} + B_{n\,\alpha_s} + \bar{\alpha}_s^2\,\chi_1(|n|,\gamma)\;\frac{\beta_0}{8N_c}\frac{\chi_0(n,\gamma)}{(1-\gamma)}\right) \\ & \left(A_{n\,0}(|n|,\gamma) + \frac{\beta_0}{2}\left(\frac{|n|}{2} + \frac{\beta_0}{2}\left(1 + \frac{|n|}{2}\right)\frac{\chi_0(|n|,\gamma)}{2} + B_n\right)\right);\end{aligned} \tag{3}$$

where A_n and B_n are collinear coefficients. After this collinear resummation our observables have a good physical behavior and are independent of the renormalization scheme.

2 Phenomenology

The D; [10] collaboration analyzed data for Mueller–Navelet jets at $\sqrt{s} = 630$ and 1800 GeV. For the angular correlation LO BFKL predictions were first obtained in [11, 12] and failed to describe the data estimating too much decorrelation. An exact fixed NLO analysis using JETRAD underestimated the decorrelation, while HERWIG was in agreement with the data.

In Fig. 2 we compare the Tevatron data for $\langle\cos\phi\rangle = C_1/C_0$ with our LO, NLO and resummed predictions. For Tevatron's cuts, where the transverse momentum for one jet is 20 GeV and for the other 50 GeV, the NLO calculation is instable under renormalization scheme changes. The convergence of our observables is poor whenever the coefficient associated to zero conformal spin, C_0, is involved. If we eliminate this coefficient by calculating the ratios defined in Eq. (1) then the predictions are very stable, see Fig. 2. The full angular dependence studied at the Tevatron by the D; collaboration was published in [10]. In Fig. 1 we compare this measurement with the predictions obtained in our approach. For the differential cross section we also make predictions for the LHC at larger Y in Fig. 3. Our calculation is not exact and we estimated several uncertainties, which are represented by gray bands.

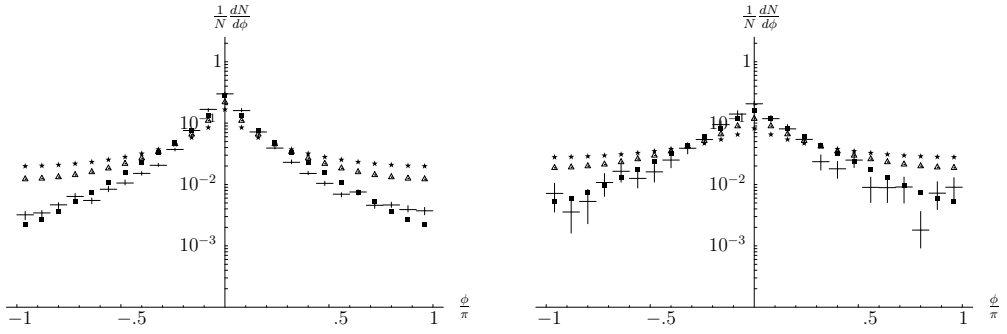

Figure 1: $\frac{1}{N}\frac{dN}{d}$ in a pp collider at $\sqrt{s}$= 1.8 TeV using a LO (stars), NLO (squares) and resummed (triangles) BFKL kernel. Plots are shown for Y = 3 (left) and Y = 5 (right).

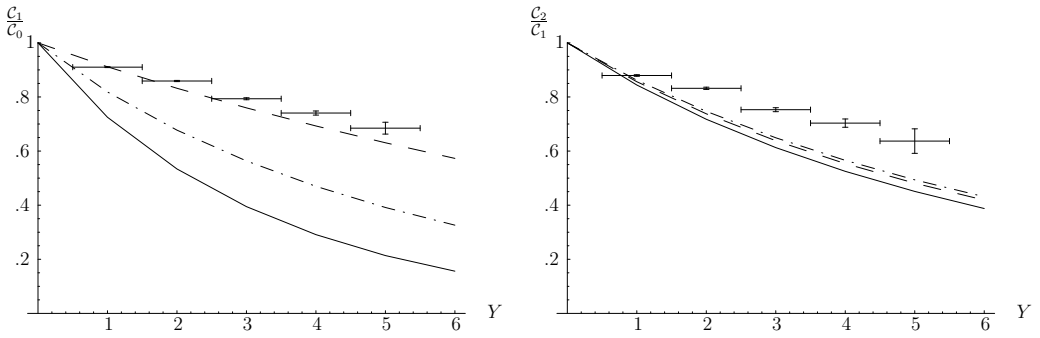

Figure 2: Left: hcos i = C_1/C_0 and Right: $\frac{<\cos 2>}{<\cos>} = \frac{C_2}{C_1}$, at a pp collider with $\sqrt{s}$ = 1.8 TeV for BFKL at LO (solid) and NLO (dashed). The results from the resummation presented in the text are shown as well (dash{dotted).

3 Conclusions

We have presented an analytic study of NLO BFKL corrections in azimuthal angle decorrelations for Mueller–Navelet jets at hadron colliders. We found that the intercepts for non–zero conformal spins have good convergence. The zero conformal spin component needs of a collinear improvement to get stable results. Uncertainties in our study can be reduced using Monte Carlo techniques. We compared to the data extracted at the Tevatron many years ago. Our results improve with respect to the LO BFKL predictions but show too much azimuthal angle decorrelation. The LHC at CERN will have larger rapidity diferences and will be a very useful tool to investigate the importance of BFKL effects in multijet production [14].

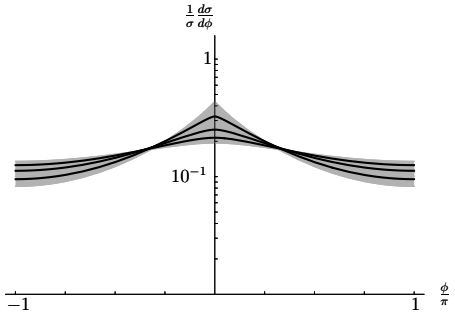

Figure 3: $\frac{1}{\sigma}\frac{d\sigma}{d\phi}$ in our resummation scheme for rapidities $Y = 7, 9, 11$ from top to bottom. The gray band reflects the uncertainty in s_0 and in the renormalization scale μ.

References

[1] A. Sabio Vera, F. Schwennsen, Nucl. Phys. B 776 (2007) 170.

[2] A. Sabio Vera, Nucl. Phys. B 746 (2006) 1.

[3] A. H. Mueller, H. Navelet, Nucl. Phys. B 282 (1987) 727.

[4] V. S. Fadin, L. N. Lipatov, Phys. Lett. B 429, 127 (1998);
G. Camici, M. Ciafaloni, Phys. Lett. B 430, 349 (1998).

[5] A. V. Kotikov, L. N. Lipatov, Nucl. Phys. B 582 (2000) 19.

[6] G. P. Salam, JHEP 9807, 019 (1998).

[7] A. Sabio Vera, Nucl. Phys. B 722 (2005) 65.

[8] M. Ciafaloni, D. Colferai, G. P. Salam, A. M. Stasto, Phys. Rev. D 68 (2003) 114003.

[9] B. Abbott et al., Phys. Rev. Lett. 84 (2000) 5722.

[10] S. Abachi et al., Phys. Rev. Lett. 77 (1996) 595.

[11] V. Del Duca, C. R. Schmidt, Phys. Rev. D 49 (1994) 4510.

[12] W. J. Stirling, Nucl. Phys. B 423 (1994) 56.

[13] C. L. Kim, FERMILAB-THESIS-1996-30.

[14] J. Bartels, A. Sabio Vera, F. Schwennsen, JHEP 0611 (2006) 051.