PROBING BFKL DYNAMICS IN THE DIJET CROSS SECTION AT LARGE RAPIDITY INTERVALS IN D0

C. Royon (for the D0 Collaboration)

CEA, DAPNIA, Service de Physique des Particules, Centre d'Etudes de Saclay, France; Brookhaven National Laboratory, Upton, New York, 11973; University of Texas, Arlington, Texas, 76019

The dijet cross section for large rapidity intervals and low jet transverse momenta has been measured using the D0 detector. The measured partonic cross section increases strongly with the pseudorapidity interval. The growth of the cross section with $\Delta\eta$ is stronger than theoretical predictions based on an analytical Leading Order QCD calculation.

1 Analysis method

At high center-of-mass energies, $\sqrt{s}$, and for momentum transfers, Q, fixed and much smaller than $\sqrt{s}$, in perturbative Quantum Chromodynamics the radiative corrections to the parton-parton scattering contain large logarithms $\ln(s/Q^2)$, which need to be summed to all orders in α_s. This summation is accomplished by the Balitsky-Fadin-Kuraev-Lipatov (BFKL) equation [1] using a space-like chain of an infinite number of gluon emissions.

In high energy hadron–hadron collisions, inclusive dijet production provides an ideal possible signature of BFKL dynamics. For large values of the jet longitudinal momentum fraction, x_j, the large logarithms $\ln(s/Q^2)$ result in large $\ln(\hat{s}/Q^2)$ (where $\sqrt{\hat{s}}$ is the partonic center-of-mass energy) which factorize in the partonic dijet cross section, $\hat{\sigma}$. The $\ln(\hat{s}/Q^2)$ terms are of the order of the pseudorapidity interval, $\Delta\eta$, between the two jets ($\eta = -\ln(\tan(\theta/2))$, where θ is the polar angle of the jet relative to the proton beam).

The total dijet cross section, σ, can be factorized in the partonic cross section convoluted with the parton distributions functions (pdf's), $x_1 P$ and $x_2 P$, in the proton and antiproton: $\sigma = x_1 P(x_1, Q^2)\, x_2 P(x_2, Q^2)\, \hat{\sigma}$ where x_1 and x_2 are the longitudinal momentum fraction of each jet, and Q^2 the momentum transfer. We take the ratio of the cross sections at the same values of x_1, x_2 and Q^2 between the two center-of-mass energies 630 and 1800 GeV. This eliminates the dependence of the cross section on the pdf's and reduces the ratio to that of the partonic cross sections.

Using the BFKL prescription to sum the leading logarithm terms $\alpha_S \ln(\hat{s}/Q^2)$

to all orders in α_S results in an exponential rise [2] of $\hat{\sigma}$ with $\Delta\eta$:

$$\hat{\sigma}_{BFKL} \sim \frac{1}{Q^2}\frac{e^{(\alpha_{BFKL}-1)\Delta\eta}}{\sqrt{\alpha_S \Delta\eta}} \tag{1}$$

with

$$\alpha_{BFKL} - 1 = \frac{\alpha_S(Q^2)N_C}{\pi} 4\ln 2. \tag{2}$$

We take the ratio of the cross sections at the same values of x_1, x_2 and Q^2 between the two center-of-mass energies 630 and 1800 GeV. This eliminates the dependence of the cross section on the pdf's and reduces the ratio to that of the partonic cross sections.

$$R \equiv \frac{\sigma(\sqrt{s_A})}{\sigma(\sqrt{s_B})} = \frac{\hat{\sigma}(\Delta\eta_A)}{\hat{\sigma}(\Delta\eta_B)} = \frac{e^{(\alpha_p - 1)(\Delta\eta_A - \Delta\eta_B)}}{\sqrt{\Delta\eta_A/\Delta\eta_B}}. \tag{3}$$

In other words, variation of $\sqrt{s}$, while keeping x_1, x_2 and Q^2 fixed, is equivalent to variation of $\Delta\eta$, which directly probes the BFKL dynamics.

2 Cross section ratio measurement

The data samples for this analysis were collected during the 1995-1996 Tevatron Collider run. The trigger was measured to be 85% efficient for jets of transverse energy 20 GeV, and fully efficient for jets with $E_T > 30$ GeV. The integrated luminosity of the above trigger in the 1800 GeV sample was 0.7 nb^{-1}, and in the 630 GeV sample 30.3 nb^{-1}. Jets were reconstructed offline using an iterative fixed-cone algorithm with a cone radius of $\mathcal{R} = 0.7$ in (η, ϕ) space [3]. More details about the cuts and the energy corrections can be found elsewhere [4].

A minimum rapidity interval between the most forward and most backward jet was required: $\Delta\eta > 2$. In the final samples, the most forward and most backward jets have approximately the same E_T; this ensures that the phase space for jet production via Q^2 evolution is suppressed. The data at 1800 GeV are within $0.01 < x_{1,2} < 0.30$. At 630 GeV, most of the data lie within $0.03 < x_{1,2} < 0.60$. The region of maximum overlap, $0.06 < x_{1,2} < 0.30$, was divided in six equal bins of x_1 and x_2. Due to limited statistics, only one bin in Q^2 was used: $400 < Q^2 < 1000$ GeV^2.

The dijet cross section at low (x_1, x_2) is affected by the acceptance of the E_T >20 GeV and $\Delta\eta$ >2 requirements. To avoid this bias, $x_1 \times x_2$ >0.01 is required. Similarly, the cross section at high (x_1, x_2) is biased by the $|\eta|$ <3 requirement, $x_{1,2} < 0.22$ is required. A total of ten (x_1, x_2) bins satisfy both requirements.

The ratio of the dijet cross sections for $\Delta\eta > 2$ is given in Ref. [4]. The largest sources of systematic uncertainties on the ratio of the cross sections and the BFKL intercept are the jet energy scale and the jet energy resolutions. The total systematic uncertainty amounts to 11% on the ratio of the cross sections and 3% on the BFKL intercept, yielding the final results [4,5]:
$R \equiv \sigma_{1800}/\sigma_{630} = 2.9 \pm 0.3\,(\text{stat}) \pm 0.3\,(\text{syst}) = 2.9 \pm 0.4$, $\alpha_p = 1.65 \pm 0.05\,(\text{stat}) \pm 0.05\,(\text{syst}) = 1.65 \pm 0.07$

Several theoretical predictions can be compared to our measurement. Leading Order QCD predicts the ratio of the cross sections to fall asymptotically toward unity. The HERWIG MC [6] provides a more realistic prediction. It calculates the exact $2 \to 2$ subprocess including initial and final state radiation and angular ordering of the emitted partons and yields $R_{\text{HERWIG}} = 1.6 \pm 0.1\,(\text{stat})$. The LLA BFKL intercept according to Eq. (1) for $\alpha_S(20\,\text{GeV}) = 0.17$ [7] is equal to $\alpha_{\text{BFKL, LLA}} = 1.45$. For $\Delta\eta_{1800} = 4.6$ and $\Delta\eta_{630} = 2.4$, Eq. (3) yields $R_{\text{BFKL, LLA}} = 1.9$. It should be noted again, however, that the leading log approximation is too simplistic, and that exact quantitative predictions including the Next-to-Leading Logarithmic [8] corrections to the BFKL kernel are not yet available. It is evident that the growth of the dijet cross section with $\Delta\eta$ (from $\overline{\Delta\eta} = 2.4$ to 4.6) is stronger in the data than in any theoretical model we considered. Namely, the measured ratio is higher by 4.3 standard deviations than the LO prediction, 3.3 deviations than the HERWIG prediction, and 2.5 deviations than the LLA BFKL one.

References

1. L.N. Lipatov, Sov. J. Nucl. Phys. **23**, 338 (1976);
   E.A. Kuraev, L.N. Lipatov, and V.S. Fadin, Sov. Phys. JETP 44 (1976) 443; Sov. Phys. JETP **45**, 199 (1977);
   Y.Y. Balitsky and L.N. Lipatov, Sov. J. Nucl. Phys. **28**, 822 (1978).
2. A.H. Mueller and H. Navelet, Nucl. Phys. **B282** 727 (1987).
3. D0 Collab., Fermilab-Pub-97/242-E (1997).
4. D0 Collab., Phys. Rev. Lett. **84**, 5722 (2000).
5. J.G. Contreras, R. Peschanski, C. Royon, **hep-ph/0002057** , to be published by Phys.Rev. **D**.
6. G. Marchesini *et al.*, Comp. Phys. Comm. **67** 465 (1992).
7. L.H. Orr and W.J. Stirling, Phys. Lett. B **429** 135 (1998).
8. V.S. Fadin and L.N. Lipatov, Phys. Lett. B **429**, 127 (1998); G. Camici and M. Ciafaloni, Phys. Lett. B **430**, 349 (1998).