Jet Production in Regge-Limit of QCD

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Abstract

Current issues on jet production in hadron collisions for Regge-limit of QCD are briefly discussed.

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1 Introduction

The energy reached in hadron collisions and deep inelastic scattering provides data on jet production whose understanding requires an account of the resummation of the leading energy logarithms for QCD. This motivates additional efforts on building an effective field theory for Regge-limit of QCD. Among them are reduction to two-dimensional theory, analysis of symmetry properties of the effective theory, considerations in the large-\(N_c\) limit, with nonlocal Wilson-string operators, with particular emphasis on the renormalization group, and with the renormalization group at high parton density. These theories are presumably intended for any processes, exclusive or inclusive ones. It turns out that one can build an economical effective field theory for inclusive processes. In any case, for phenomenological implications one needs to involve somehow hadron structure (parton distribution functions and/or wave functions). To this end one needs to discuss a problem of factorization in hadron collisions.

2 Factorization Schemes for Regge-limit of QCD

In perturbative QCD there are two important kinematical regimes: hard scattering regime \(s \approx -t = Q^2 \gg \Lambda^2\) and Regge (semi-hard) regime \(s \gg -t = Q^2 \gg \Lambda^2\). In hard scattering regime there are strong \(k_\perp\)-ordering: \(k_{1,\perp} > k_{2,\perp} > ... > k_{i,\perp} > k_{i+1,\perp} > ... > k_{n,\perp}\) and locality in rapidity \(y_1 \sim y_2 \sim ... \sim y_i \sim y_{i+1} \sim ... \sim y_n\).

In (multi-)Regge regime there is strong rapidity ordering: \(y_1 > y_2 > ... > y_i > y_{i+1} > ... > y_n\) and \(k_{1,\perp} \sim k_{2,\perp} \sim ... \sim k_{i,\perp} \sim k_{i+1,\perp} \sim ... \sim k_{n,\perp}\). So, in semi-hard kinematics the BFKL subprocess is nonlocal in rapidity space.

Unlike the hard scattering regime, where there is factorization theorem for inclusive processes (see and references therein), in the Regge regime the factorization property is only a well-desired conjecture at the moment.

At present there are several factorization schemes for hadron collision in the Regge-limit of QCD. One can divide it into three types which are transparent in the case of dijet production in hadron collisions. First one is \(k_\perp\)-factorization scheme (Fig. 1a). \(k_\perp\)-factorization scheme allows to calculate processes in central region on rapidity, while second one, Mueller-Navelet(MN)-factorization scheme (Fig. 1b), for processes in most forward and backward regions which are separated by large rapidity interval. In other words, \(k_\perp\)-factorization scheme uses BFKL-like parton distributions and hard subprocess (Fig. 1a), and MN-factorization scheme uses BFKL-subprocess and hard parton distribution functions (Fig 1b). There are another scheme: BFKL-factorization scheme (Fig. 1c) which allows to calculate processes for any rapidity region. Within this scheme one can calculate complete inclusive jet cross section, while MN-factorization is dealing with selection of most forward/backward jets.
3 Tests of BFKL Predictions in Hadron Collisions

Azimuthal decorrelation in dijet production with most forward/backward jet selection calculated in [18] is under study by D0 [19, 20] at the Fermilab Tevatron. Analysis with selection of most forward/backward jets seems to be not so promising since preliminary D0 data [20] and predictions of standard Monte Carlo (MC) generators, like Herwig and Pythia, as well as the new BFKL MC generators [21] are close to each other.

Futher progress for experimental tests of BFKL predictions in hadron collisions should invoke new observables sensitive to BFKL-effects [22]. One of them can be azimuthal decorrelation of inclusive dijet production [17, 23] (Fig. 2a) without most forward/backward jet selection. Incorporation of complete next-to-leading order (NLO) [25] to BFKL predictions is desirable too.
4 Discussion, Remarks and Conclusion

Under these circumstances, it is crucial to have qualitative predictions from the conventional QCD-improved parton model (without resummation of the energy logarithms) for the new kinematic domain. There is such prediction [26] which can be tested at the Fermilab Tevatron, the CERN LHC [28] and the VLHC [29] under discussion. Namely, the QCD-improved parton model predicts that the ratio of scaled inclusive jet cross sections is not a monotonic function of its arguments, i.e. the inclusive jet production cross section, if measured in the natural units of the same cross section taken at another (higher) energy of the collision, has extrema — “dips” [26]. If one does not observe the minima experimentally, radical changes are motivated such as an alternative model of the elementary constituents inside the hadrons for semi-hard asymptotics. One example might be the color dipole model [27].

To conclude, more deep understanding of factorization property for Regge-limit of QCD is needed. Experimental tests of BFKL-predictions and finding of good observables for BFKL-effects are very important for studying of the new domain of QCD.

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Figure 2: (a) Inclusive dijet production: azimuthal decorrelation for BFKL LO 17,23 and for BFKL conformal NLO 23,24; (b) Inclusive single jet production: scaled cross section ratio 3.
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