Applications of Lipatov's high energy effective action to NLO BFKL jet phenomenology

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We report on recent progress in the evaluation of next-to-leading order observables using Lipatov's QCD high energy effective action. We calculate both real and virtual corrections to the quark induced forward jet vertex at NLO, making use of a new regularization method and a subtraction mechanism. As a new result we determine the real part of the NLO Mueller-Tang impact factor which is the only missing element for a complete NLO BFKL description of dijet events with a rapidity gap.

1 Introduction

Due to its large center of mass energy the LHC provides an ideal opportunity to test BFKL-driven observables [1, 2]. Among them we find both central production processes, such as heavy quark production (see *e.g.* [3]) and forward production of different systems such as high p_T jets, heavy quark pairs [4] or Drell-Yan pairs [5, 6]. In the case of two tagged forward/backward jets there might be a rapidity gap between them ('Mueller-Tang') or not ('Mueller-Navelet'). These jet events allow then to test the forward (Mueller-Navelet) and non-forward (Mueller-Tang) BFKL kernel. While Mueller-Navelet jet events are currently one of the few examples where a complete description at next-to-leading logarithmic (NLL) accuracy exists [7, 8, 9, 10, 11, 12], for Mueller-Tang jets we so far have at NLO accuracy the non-forward BFKL kernel [13], while impact factors are known only to leading order (LO). The limitation to LO impact factors is currently one of the main drawbacks of BFKL phenomenology. A promising tool to overcome this limitation is given by Lipatov's effective action [14]. So far this action has been mainly applied for the determination of LO transition kernels [15, 16, 17, 18]. In this contribution we show that it can be further used to calculate NLO correction. In particular, we re-derive the NLO Mueller-Navelet quark-jet impact factor and determine the missing real NLO correction to the Mueller-Tang quark-initiated jet impact factors. For details we refer to [19, 20].

2 The high energy effective action

The effective action adds to the QCD action an induced term, $S_{\text{eff}} = S_{\text{QCD}} + S_{\text{ind.}}$, which describes the coupling of the reggeized gluon field $A_\pm(x) = -it^a A^a_\pm(x)$ to the usual gluonic field $v_\mu(x) = -it^a v^a_\mu(x)$. This induced term reads

$$S_{\text{ind.}}[v_\mu, A_\pm] = \int \mathrm{d}^4x \, \mathrm{tr}\left[\Big(W_+[v(x)] - A_+(x)\Big)\partial^2_\perp A_-(x)\right] + \int \mathrm{d}^4x \, \mathrm{tr}\left[\Big(W_-[v(x)] - A_-(x)\Big)\partial^2_\perp A_+(x)\right]. \quad (1)$$

The infinite number of couplings of the gluon field to the reggeized gluon field are encoded in two functionals $W_\pm[v] = v_\pm \frac{1}{D_\pm}\partial_\pm$ where $D_\pm = \partial_\pm + g v_\pm$. Note that the reggeized gluon fields are special in the sense that they are invariant under local gauge transformations, while they transform globally in the adjoint representation of the $\mathrm{SU}(N_c)$ gauge group. In addition, strong ordering of longitudinal momenta in high energy factorized amplitudes leads to the kinematical constraint of the reggeized gluon fields,

$$\partial_+ A_-(x) = \partial_- A_+(x) = 0, \quad (2)$$

which is always implied. Quantization of the gluonic field requires to add gauge fixing and ghost terms, which we have included in the QCD action. Feynman rules have been derived in [21]. We

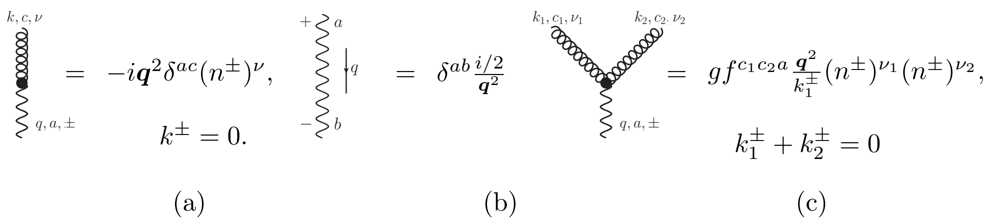
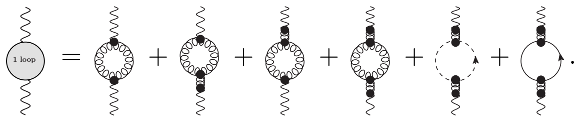


Figure 1: The direct transition vertex (a), the reggeized gluon propagator (b) and the unregulated order g induced vertex (c)

show them using curly lines for the conventional QCD gluon field and wavy (photon-like) lines for the reggeized gluon field. There exist an infinite number of higher order induced vertices. For the present analysis only the order g induced vertex in fig. 1.c is needed. In the determination of loop corrections we must fix a regularization of the light-cone singularity present in fig. 1.c. As suggested by one of us in [22] this pole should be treated as a Cauchy principal value.

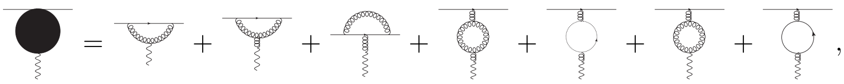
3 NLO quark jet impact factors

When calculating quantum corrections new divergences in longitudinal components appear. As it was demonstrated in [19, 23] these can be regularized by deforming the light cone using a parameter ρ which is considered in the limit $\rho \to \infty$. In this new setup, the Sudakov projections take place on the vectors $n_a = e^{-\rho}n^+ + n^-$ and $n_b = n^+ + e^{-\rho}n^-$. To obtain the virtual corrections we are seeking for it is needed to calculate the one-loop self energy corrections to the reggeized gluon propagator. Diagrammatically, these are



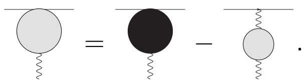
(3)

The 1-loop corrections to the quark-quark-reggeized gluon vertex are



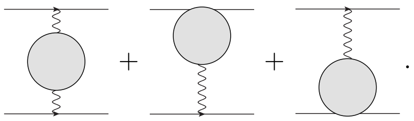
(4)

from which it is needed to subtract the factorizing contribution



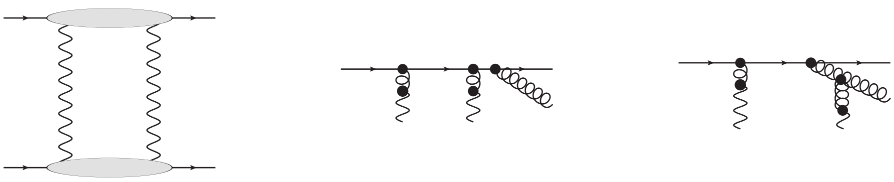
(5)

The one-loop quark-quark scattering amplitude in the high energy limit is then given by the following sum



(6)

The sum of this three contributions is finite in the limit $\rho \to \infty$ and the dependence on the regulator vanishes. The result is in agreement with calculations using more standard techniques, performed in [24] and confirmed in [25]. A similar result holds for the real corrections, see [19] for details. All of these results are needed for Mueller-Navelet jets. The determination of the Mueller-Tang impact factor requires to consider diagrams where two reggeized gluons couple to the quark induced jet, see Fig. 2.a. Due to the condition Eq. (2), the integration over the minus component of the loop momentum of the reggeized gluon loop is absorbed into the definition of the impact factor. With the virtual NLO corrections already known [26], we focus on the real NLO corrections. The relevant diagrams split into two groups: the two reggeized gluon



(a) (b) (c)

Figure 2:

state couples either to a single parton (Fig. 2.b) or to two different partons (Fig. 2.c). While the integration over the longitudinal loop momentum is divergent for individual diagrams, this divergence is found to cancel for their sum.

Our results show the use of the high energy effective action in the determination of higher order corrections in multi-Regge and quasi-multi-Regge kinematics. In addition to the calculations here presented, these methods have been successfully applied to the determination of the quark contributions to the two-loop gluon Regge trajectory [23]. Determination of the gluonic NLO corrections to jet impact factor and gluon trajectory are currently in progress [27].

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