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Heavy quark impact factor for the LHC phenomenology

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We comment on the calculation of the finite part of the heavy quark impact factor at next-to-leading logarithmic (NLx) accuracy. The result is presented in a form suitable for phenomenological studies such as the calculation of the cross-section for single heavy quark production at the LHC within the k_T-factorization scheme.

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1. Introduction

Significant developments in the last two decades in small-x physics made possible the phenomenological analysis of deep inelastic scattering (DIS) and other high energy scattering processes within the k_T-factorization scheme. They were mainly driven by the Balitsky-Fadin-Kuraev-Lipatov (BFKL) framework for the resummation of high center-of-mass energy logarithms at leading (Lx) [1] and next-to-leading (NLx) [2] logarithmic accuracy.

A key ingredient for studying high energy scattering processes within the k_T-factorisation scheme is the impact factor, a process dependent object. The impact factors for gluons and massless quarks have been calculated in Ref. [3], at NLx accuracy. This allows for the calculation of various processes with massless quarks and gluons in the initial state. The generalization to hadron-hadron collisions has also been established [4–6].

The NLx impact factor for a massive quark in the initial state has been calculated in Ref. [7]. However, the result was given in the form of a sum of an infinite number of terms. To make the result of Ref. [7] available for phenomenological studies we recalculate the NLx heavy quark impact factor in a compact and resummed form which is more suitable for numerical applications.

2. High energy factorisation

In the high energy limit: $\Lambda_{QCD} \ll |t| \ll s$, the partonic cross-section of $2 \to 2$ processes factorises into the impact factors $h_{\mathsf{a}}(\mathbf{k}_1)$ and $h_{\mathsf{b}}(\mathbf{k}_2)$ of the two colliding partons a and b, and the gluon Green's function $\mathscr{G}_\omega(\mathbf{k}_1,\mathbf{k}_2)$ (here in Mellin space) so that the differential cross-section can be written as

$$\frac{\mathrm{d}\sigma_{\mathsf{ab}}}{\mathrm{d}[\mathbf{k}_1]\,\mathrm{d}[\mathbf{k}_2]} = \int \frac{\mathrm{d}\omega}{2\pi i\,\omega}\, h_{\mathsf{a}}(\mathbf{k}_1)\,\mathscr{G}_\omega(\mathbf{k}_1,\mathbf{k}_2)\,h_{\mathsf{b}}(\mathbf{k}_2)\left(\frac{s}{s_0(\mathbf{k}_1,\mathbf{k}_2)}\right)^{\omega} ,$$

where ω is the dual variable to the rapidity Y, and $\mathrm{d}[\mathbf{k}] = \mathrm{d}^{2+2\varepsilon}\mathbf{k}/\pi^{1+\varepsilon}$ is the transverse space measure. The Lx quark impact factor can be expressed by a very simple formula:

$$h^{(0)}(\mathbf{k}) = \sqrt{\frac{\pi}{N_c^2-1}}\,\frac{2C_F\,\alpha_s N_\varepsilon}{\mathbf{k}^2\,\mu^{2\varepsilon}} , \quad N_\varepsilon = \frac{(4\pi)^{\varepsilon/2}}{\Gamma(1-\varepsilon)} ,$$

and it is the same (up to a color factor) for quarks and gluons. Variables μ and ε are the renormalization scale and the dimensional regularization parameter respectively.

3. The analytic impact factor

Collecting all the contributions, the impact factor of a heavy quark at NLx accuracy reads $h_{\mathsf{q}}(\mathbf{k}) = h^{(0)}(\mathbf{k}) + h_{\mathsf{q}}^{(1)}(\mathbf{k})$, and can be expressed in terms of a singular and a finite contribution

$$h_{\mathsf{q}}(\mathbf{k}) = h_{\mathsf{q}}^{(1)}(\mathbf{k})|_{\text{sing}} + h_{\mathsf{q}}(\mathbf{k})|_{\text{finite}} .$$

The singular term $h_{\mathsf{q}}^{(1)}(\mathbf{k})|_{\text{sing}}$ is given in [7].

The finite contribution, which is our main result, finally reads

$$h_{\mathrm{q}}(\mathbf{k})|_{\mathrm{finite}} = h^{(0)}(\mathbf{k},\alpha_s(\mathbf{k}))\left\{1+\frac{\alpha_s N_c}{2\pi}\left[\mathscr{K}-\frac{\pi^2}{6}+1-R\log(4R)-\log(Z)\,(1+2R)\sqrt{\frac{1+R}{R}}\right.\right.$$
$$-2\log(Z)^2-3\sqrt{R}\left(\mathrm{Li}_2(Z)-\mathrm{Li}_2(-Z)+\log(Z)\,\log\left(\frac{1-Z}{1+Z}\right)\right)$$
$$\left.\left.+\mathrm{Li}_2\,(4R)\;\Theta_{mk}+\left(\frac{1}{2}\log\,(4R)+\frac{1}{2}\log^2\,(4R)+\mathrm{Li}_2\left(\frac{1}{4R}\right)\right)\Theta_{km}\right]\right\},$$

with $R=\mathbf{k}^2/(4m^2)$ and $Z=(\sqrt{1+R}+\sqrt{R})^{-1}$. As in Ref. [7], we have absorbed the singularities proportional to the beta function into the running of the strong coupling $\alpha_s(\mathbf{k})$ [8], for details we refer the reader to Ref. [9]. The heavy quark impact factor, as described here, will be applied to high-energy phenomenology study of the cross section for single heavy quark forward production at the LHC [10].

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