NLO QCD corrections to inclusive-hadron photoproduction at HERA

D. de Florian and W. Vogelsang

Theory Division, CERN, CH-1211 Geneva 23, Switzerland

Abstract

We briefly discuss the role of the next-to-leading order (NLO) QCD corrections to the 'direct' part of the spin-dependent cross section for single-inclusive charged-hadron photoproduction at HERA.

As pointed out in the preceding contribution [1], a polarized version of the HERA collider with $\sqrt{s} \approx 300$ GeV would be a very promising and useful facility for studying polarized photoproduction reactions. In particular, two of the conceivable processes, single-inclusive hadron production and jet production, show strong sensitivity to the polarized gluon distribution of the proton and also appear likely to yield statistics good enough for a successful measurement [1]. As was also shown in [1], the study of polarized photoproduction at HERA might even allow a measurement of the parton content of polarized *photons* in the long run.

In order to make reliable quantitative predictions for a high-energy process such as polarized inclusive-hadron photoproduction, it is crucial to extend LO studies like [1] to NLO by determining the QCD corrections. The key issue here is to check the perturbative stability of the process considered, i.e. to examine to what extent NLO corrections affect the cross sections and spin asymmetries relevant for experimental measurements. Only when the corrections are reasonably small and under control can a process that shows good sensitivity to, say, Δg at the lowest order, be regarded as a genuine probe of the polarized gluon distribution and be reliably used to extract it from future data. Focusing for simplicity on the direct part of inclusive-hadron photoproduction, the crucial ingredients for a calculation of the polarized cross section to NLO accuracy are the $\mathcal{O}(\alpha\alpha_s^2)$ corrections to the spin-dependent 'direct' hard subprocess cross sections for the inclusive production of a certain parton that fragments into the hadron. The calculation of the latter has very recently been performed in [2] and will be briefly reported here.

Of course, the direct part on its own is no longer a really well-defined quantity at NLO, which is due to the fact that beyond LO mass singularities appear in the calculation of the subprocess cross sections for photon-parton scattering, which are to be attributed to a collinear splitting of the photon into a $q\bar{q}$ pair and need to be absorbed into the photon structure functions. As the latter only appear in the resolved part of the cross section, and since factorizing singularities is never a unique procedure, it follows that only the sum of the direct and the resolved pieces is independent of the factorization prescription chosen and thus is physical. The results presented here will therefore only be the first step in a full calculation of NLO effects to polarized inclusive-hadron photoproduction. Despite the fact that they are not complete in this sense, we believe our results to be important, also phenomenologically: as shown in [1], the direct component dominates even for HERA energies in certain regions of phase space. This means that our NLO results should be rather close to the true NLO answer in these cases even if the resolved component is only taken into account on a LO basis, which in turn implies that our NLO

corrections should already be sufficient to shed light on the question of general perturbative stability of the process.

A detailed account of the NLO calculation has been given in [2]. We will therefore just present here some numerical results for HERA kinematics. They have been obtained employing the same parameters as in the preceding contribution [1], but obviously using NLO parton distributions [3, 4] and fragmentation functions [5] when calculating the NLO cross section.

Fig. 1 shows the K-factors for the direct part of the polarized cross section in the $\overline{\rm MS}$ scheme, vs. p_T (at $\eta = -1$) and η (at $p_T = 5$ GeV). The solid line corresponds to the NLO '$\Delta g = g$ input' set of [4] for the polarized parton densities of the proton, whereas the dashed one displays the best-fit result obtained within the 'valence' scenario of [4]. For the renormalization scale μ and the initial- and final-state factorization scales M, M_F we have chosen $\mu = M = M_F = p_T$. As one can clearly see, the K-factors are of very moderate size, $K \lesssim 1$ for almost all p_T and η examined. Only at very large p_T, near the edge of phase space for the $\eta = -1$ considered, does the K-factor become much larger than unity within the 'fitted Δg' scenario. This finding of generally small NLO corrections is very important and corroborates the LO predictions made in [1].

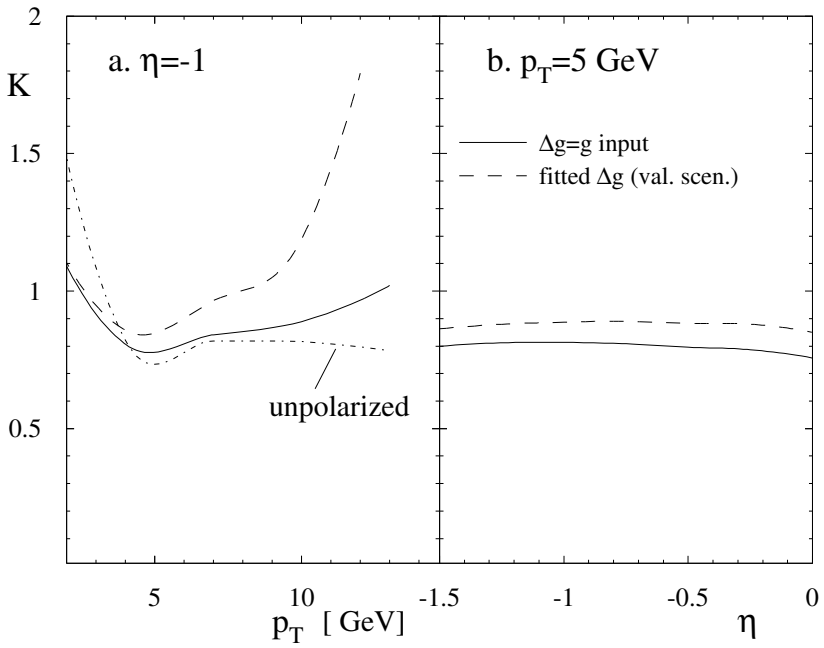

Figure 1: K-factors for the direct part of the polarized cross section at HERA energies for different GRSV [4] parton distributions. In a. the K-factor for the total unpolarized cross section is also shown.

Fig. 1 also presents the K-factor for the *full* (direct + resolved) unpolarized cross section, which of course is scheme-independent. The ingredients for the calculation of the unpolarized cross section to NLO can be found in [6]. It turns out that the unpolarized K-factor is very similar in size and shape to the K-factors we have obtained for the direct part of the polarized cross section. This, again, is a very satisfactory finding, as it suggests that our K-factor for the direct part might not be too far off the result for the one of the full polarized cross section, to be eventually determined when the NLO corrections to the resolved part of the polarized cross section will have been calculated.

Another important issue when going beyond the LO is the expected reduction in the dependence of the results on the unphysical scales μ, M, M_F introduced previously. We now set $\mu^2 = M^2 = M_F^2 = \xi p_T^2$ and plot in fig. 2 the LO and NLO direct cross sections as functions of ξ for

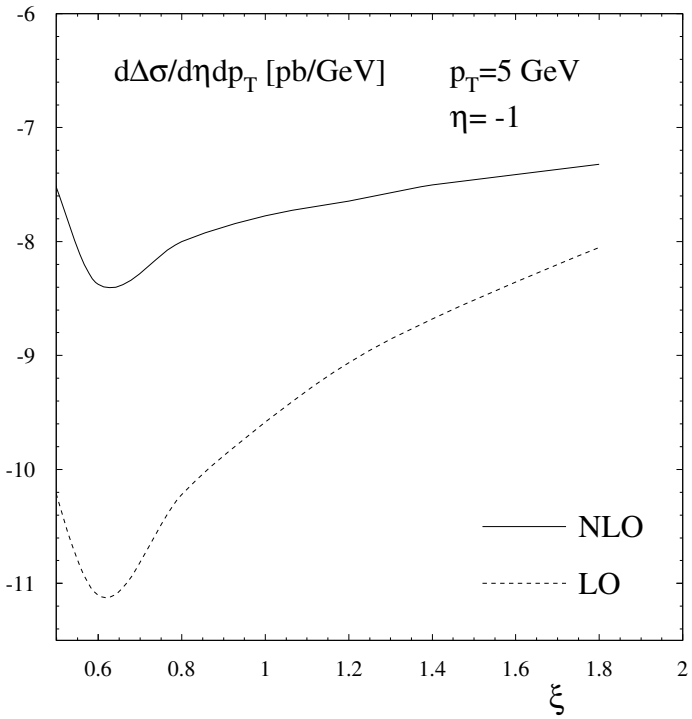

Figure 2: Scale dependence of the direct part of the polarized inclusive-hadron photoproduction cross section at $p_T = 5$ GeV and $\eta = -1$ for HERA energies. All scales have been set equal to $\sqrt{\xi} p_T$, and the parton distributions used correspond to the '$\Delta g = g$ input' set of [4]. The NLO cross section has been calculated in the $\overline{\rm MS}$ scheme.

fixed $\eta = -1$, $p_T = 5$ GeV. Even though we can only consider the direct part, the improvement in the scale dependence when going from LO to NLO becomes already clearly visible.

In conclusion, we have found generally moderate NLO corrections for the direct part of the cross section, the K-factor being close to unity over a wide kinematical range at HERA energies.

References

[1] J.M. Butterworth, N. Goodman, M. Stratmann, and W. Vogelsang, CERN-TH/97-310, `hep-ph/9711250`, these proceedings.

[2] D. de Florian and W. Vogelsang, CERN-TH/97-280, `hep-ph/9712273`.

[3] M. Glück, E. Reya, and A. Vogt, *Z. Phys.* **C67** (1995) 433.

[4] M. Glück, E. Reya, M. Stratmann, and W. Vogelsang, *Phys. Rev.* **D53** (1996) 4775.

[5] J. Binnewies, B.A. Kniehl, and G. Kramer, *Phys. Rev.* **D52** (1995) 4947.

[6] P. Aurenche, A. Douiri, R. Baier, M. Fontannaz, and D. Schiff, *Phys. Lett.* **135B** (1984) 164; *Nucl. Phys.* **B286** (1987) 553; L.E. Gordon, *Phys. Rev.* **D50** (1994) 6753; F. Aversa, P. Chiappetta, M. Greco, and J.Ph. Guillet, *Phys. Lett.* **B210** (1988) 225; **B211** (1988) 465; *Nucl. Phys.* **B327** (1989) 105.