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7 Text sample

QCD is an essential ingredient of the Standard Model, and it is well tested in hard processes when transferred momentum is of the order of the total collision energy (Bjorken limit: $Q^2 \sim s \to \infty$). The cornerstones of perturbative QCD at this kinematic regime (QCD-improved parton model): the Gribov–Lipatov–Altarelli–Parisi–Dokshitzer (GLAPD) evolution equation and factorization of inclusive hard processes provides a basis for the successful QCD-improved parton model. The factorization theorem for inclusive hard processes ensures that the inclusive cross section factorizes into partonic subprocess(es) and parton distribution function(s). The GLAPD evolution equation governs the $\log Q^2$-dependence (at $Q^2 \to \infty$) of the parton distribution functions and the hard subprocess cross-sections at fixed scaling variable $x = Q^2/s$.

Another kinematic domain that is very important at high-energy is given by the (Balitsky–Fadin–Kuraev–Lipatov) BFKL limit [1,2], or QCD Regge limit, whereby at fixed $Q^2 \gg \Lambda^2_{QCD}$, $s \to \infty$. In the BFKL limit, the BFKL evolution in the leading order (LO) governs $\log(1/x)$ evolution (at $x \to 0$) of inclusive processes.

Note that the BFKL evolution in the next-to-leading order (NLO) [3,4,5], unlike the LO BFKL [1,2], partly includes GLAPD evolution with the running coupling constant of the LO GLAPD, $\alpha_S(Q^2) = 4\pi/\beta_0 \log(Q^2/\Lambda^2_{QCD})$.

Photon–photon collisions, particularly $\gamma^*\gamma^*$ processes, play a special role in QCD [6], since their analysis is under much better control than the calculation of lepton–hadron and hadron–hadron processes, which require the input of non-perturbative hadronic structure functions or wave functions. In addition, unitarization (screening) corrections due to multiple Pomeron exchange should be less important for the scattering of γ^* of high virtuality than for hadronic collisions.

Figure 1. The energy dependence of the total cross section for highly virtual photon–photon collisions predicted by the BLM scale-fixed NLO BFKL [10] compared with recently finalized OPAL [11] and L3 [12] data from LEP2 at CERN. The (solid) dashed curves correspond to the (N)LO BFKL predictions for two different choices of the Regge scale: $s_0 = Q^2$ for upper curves and $s_0 = 4Q^2$ for lower curves

The high-energy asymptotic behaviour of the $\gamma\gamma$ total cross section in QED can be calculated [7] by an all-orders resummation of the leading terms: $\sigma \sim \alpha^4 s^\omega$, $\omega = \frac{11}{32}\pi\alpha^2 \simeq 6 \times 10^{-5}$. However, the slowly rising asymptotic behaviour of the QED cross section is not apparent since large contributions come from other sources, such as the cut of the fermion-box contribution: $\sigma \sim \alpha^2(\log s)/s$ [6] (which although subleading in energy dependence, dominates the rising contributions by powers of the QED coupling constant) and QCD-driven processes.

The photon–photon cross sections with LO BFKL resummation was considered in Refs. [2,8,9].

Although the complete NLO impact factor of the virtual photon is not known yet, one can use the LO impact factor of Refs. [7,9], assuming that the main energy-dependent NLO corrections come from the NLO BFKL subprocess rather than from the photon impact factors [10].

Fig. 1 compares the LO and BLM scale-fixed NLO BFKL predictions $\sigma \sim \alpha^2 \alpha_S^2 s^\omega$ [5,10] with recent CERN LEP2 data from OPAL [11] and L3 [12].

Acknowledgements

We thank all DIS'03 participants for their contributions to the DIS'03 Proceedings. This work was supported in part by the High Energy Foundation and the World Science Agency.

Appendix

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