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Possible Absorptive Corrections in Hard-Scattering Processes at Very High Energies (*).

N. G. ANTONIOU and N. D. TRACAS (**)
Department of Theoretical Physics, University of Athens - Athens 621, *Greece*

S. D. P. VLASSOPULOS
Physics Laboratory II, National Technical University, Zographou - Athens 624, *Greece*

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Summary. – Absorptive effects in hard-scattering processes, which can possibly originate from multiparton final-state interactions, give rise to a vanishingly small logarithmic correction to the parton → parton + parton splitting process, if simulated by Regge amplitudes. When this effect is iterated, within the leading logarithmic approximation of quantum chromodynamics, it may be promoted to a small power correction to the structure (or fragmentation) functions and be observable at very high energies.

Absorptive corrections to the QCD parton model results, due to final-state multiparton interactions, have been argued to be suppressed ([1]). For example, the sum of discontinuities of the Drell-Yan graph for lepton pair production, corrected by pomeron exchanges, vanishes to leading order ([2]), namely

$$\frac{\mathrm{d}\sigma^{ABS}}{\mathrm{d}Q^2}=\frac{\mathrm{d}\sigma}{\mathrm{d}Q^2}, \tag{1}$$

where by the superscript ABS we label the corrected Drell-Yan cross-section.

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(**) Present address: Theoretical Physics Group, National Technical University, Zographou, Athens 624, Greece.
([1]) J. ELLIS and C. T. SACHRAJDA: *Quarks and Leptons* (Cargèse, 1979), edited by M. LÉVY, J.-L. BASDEVANT, D. SPEISER, J. WEYERS, R. GASTMANS and M. JACOB (New York, N.Y., 1979), p. 285 and references therein.
([2]) J. L. CARDY and G. A. WINBOW: *Phys. Lett. B*, **52**, 95 (1974); C. E. DE TAR, S. D. ELLIS and P. V. LANDSHOFF: *Nucl. Phys. B*, **87**, 176 (1975).

However, the effect of such corrections to other deep inelastic processes is very much model dependent and not quite well understood (3). A possible qualitative guide is provided by the old absorption method of Gottfried and Jackson (4). When applied to the simplest possible process, namely $e^+e^- \to \gamma^* \to \bar{q}q \to$ hadrons (fig. 1), this recipe gives

$$R^{ABS}(Q^2) = [1 - \varepsilon(Q^2)]R(Q^2) , \tag{2}$$

where $\varepsilon(Q^2)$ is an, at most, 2% correction to the ratio $R(Q^2)$ of the hadron-production cross-section to the $\mu^+\mu^-$ cross-section at centre-of-mass energy Q.

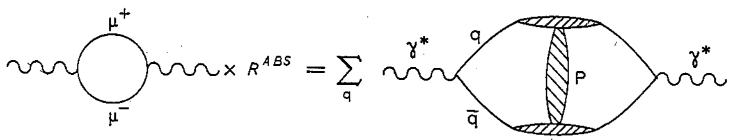

Fig. 1. – Absorptive correction to the $e^+e^- \to q\bar{q} \to$ hadrons total cross-section.

To get this result we assume that the elastic parton-scattering amplitude, for small momentum transfers $-t \leqslant m_p^2$, is given by

$$P(s, t) = is\sigma(s)(\alpha' s)^{\alpha' t} , \tag{3}$$

where $\sigma(s)$ is the total parton cross-section at centre-of-mass energy $\sqrt{s}$ and α' is the slope of the Pomeranchuk trajectory. This amplitude simulates the interactions of many quarks and gluons at small momentum transfers, which lie outside the scope of QCD perturbation theory. One next multiplies all $e^+e^- \to \gamma^* \to q\bar{q}$ amplitudes in the trace giving R with the square root of the $j = 1$ partial-wave S-matrix corresponding to (3), namely

$$S(Q^2) = 1 - \varepsilon(Q^2) , \tag{4}$$

where, for $Q^2 \gg 1/\alpha'$, we have

$$\varepsilon(Q^2) = \frac{\sigma(Q^2)}{8\pi\alpha' \ln \alpha' Q^2} + O(Q^{-2}) . \tag{5}$$

Thus, for $\sigma \sim 1$ mb and $\alpha' \sim 1\ (\text{GeV})^{-2}$, at $Q \simeq 10$ GeV we have $\varepsilon \simeq 0.02$.

Note that $\varepsilon(Q^2)$ is a logarithmic correction which stays vanishingly small at all energies. This result is presumably consistent with (1). However, when this correction is taken over to deep inelastic scattering, it may be promoted to a small *power* and be important at very large Q^2. This is essentially due to the iterative character of the correction in the successive gluon or quark emission cross-section, which builds up a hadron's structure function or a parton's fragmentation function (5).

(3) P. V. Landshoff and J. C. Polkinghorne: *Phys. Rep. C*, **5**, 1 (1972); F. Henyey and R. Savit: *Phys. Lett. B*, **52**, 71 (1974); also, G. P. Lepage and D. A. Ross: Invited talks at the *XXI International Conference on High-Energy Physics, Paris, July 1982*.

(4) K. Gottfried and J. D. Jackson: *Nuovo Cimento*, **34**, 735 (1964).

(5) A. J. Buras: *Rev. Mod. Phys.*, **52**, 199 (1980); Yu. L. Dokshitzer, D. I. Dyakonov and S. J. Troyan: *Phys. Rep.*, **58**, 269 (1980); E. Reya: *Phys. Rep.*, **69**, 195 (1981).

Indeed, in the nonsinglet case, this cross-section can be built by convoluting successive gluon emission cross-sections for the process $e^+e^- \to \gamma^* \to q\bar{q}g$, calculated in an axial gauge, where only the graph depicted in fig. 2 contributes in the leading-pole approximation (6). We thus have

$$\frac{1}{e_q^2 \sigma_{\mu^+\mu^-}} \frac{d^{2m}\sigma}{dz_1 \dots dz_m\, dt_1 \dots dt_m} = \frac{\alpha_s(t_1)}{2\pi t_1} S(t_1) P_{q\to gq}(z_1) \times \dots \times \frac{\alpha_s(t_m)}{2\pi t_m} S(t_m) P_{q\to gq}(z_m)\,, \tag{6}$$

where e_q is the charge of parton q, $\sigma_{\mu^+\mu^-}$ is the total $e^+e^- \to \mu^+\mu^-$ cross-section, $\alpha_s(t_i)$ is the coupling strength of QCD calculated at the successive (ordered) quark-gluon invariant masses t_i and $P_{q\to gq}(z_i)$ is the usual Altarelli-Parisi splitting function. The correction factors $S(t_i)$ are the $j = \frac{1}{2}$ partial-wave S-matrices corresponding to the amplitude (3). Note that the probabilistic interpretation of the factors of eqs. (6) is unaffected by this correction.

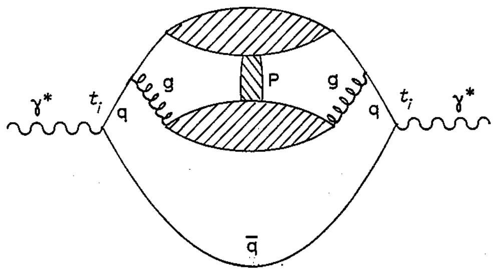

Fig. 2. – Absorptive correction to the gluon emission cross-section $e^+e^- \to q\bar{q}g$, calculated in an axial gauge in the leading-pole approximation.

By integrating eqs. (6) and summing them up in the standard fashion (5,6), the corrected moments of a nonsinglet structure (or fragmentation) function are found to be

$$G_n^{ABS}(Q^2) = \exp[-d_{NS}^n \tau(Q^2)]\, G_n^{ABS}(Q_0^2)\,, \tag{7}$$

where, as in the usual case, we have

$$d_{NS}^n = -\frac{6}{33-2f}\int_0^1 dz\, z^{n-1} P_{q\to gq}(z) = \frac{4}{33-2f}\left[1 - \frac{2}{n(n+1)} + 4\sum_{l=2}^{n}\frac{1}{l}\,,\right. \tag{8}$$

f being the number of flavours. The quantity

$$\tau(Q^2) = \xi(Q^2) - \int_{Q_0^2}^{Q^2} \varepsilon(t)\, d\ln\ln t/\Lambda^2\,, \tag{9}$$

(6) R. D. Field: Invited talk presented at the *Conference on Perturbative* QCD *held at Florida State University, Tallahassee, March 26-30, 1981* (UFTP 81-12).

is a modified evolution variable, which replaces the usual one, namely [5]

$$\xi(Q^2) = \ln \frac{\ln Q^2/\Lambda^2}{\ln Q_0^2/\Lambda^2}; \tag{10}$$

where Q_0 is a reference momentum and Λ is the usual QCD scale parameter. Thus, due to the factorization of our correction, the evolution equation (7) retains the structure found in the leading logarithmic approximation of QCD. For $Q_0^2 \gg 1/\alpha'$, the correction factor $\varepsilon(t)$ is given by eq. (5).

If the parton diffractive cross-section $\sigma(s)$ is assumed to be a constant, we find

$$\tau = \xi - \frac{\sigma}{8\pi\alpha' \ln \alpha' \Lambda^2}(\xi - \bar{\xi}), \tag{11}$$

where

$$\bar{\xi} = \ln \frac{\ln \alpha' Q^2}{\ln \alpha' Q_0^2}, \tag{12}$$

and for $Q^2 \to \infty$

$$\tau \sim \xi - \frac{\sigma}{8\pi\alpha' \ln \alpha' \Lambda^2} \ln \frac{\ln \alpha' Q_0^2}{\ln Q_0^2/\Lambda^2}. \tag{13}$$

That is, for $\Lambda \sim 0.2$ GeV and $Q_0 \sim 2$ GeV, we have $\tau \simeq \xi - 0.04$, which gives a no more than 5% correction in the structure function.

However, if $\sigma(s)$ is allowed to rise as a logarithmic power of the energy, namely

$$\sigma(s) = \sigma' \ln^\eta \alpha' s, \qquad \eta \leqslant 2, \quad \sigma' = \text{const}, \tag{14}$$

as suggested by the hadron scattering data, for $Q^2 \gg Q_0^2 \gg 1/\alpha'$ we find

$$\tau \sim \xi - \frac{\sigma'}{8\pi\alpha'} \begin{cases} \text{const}, & \text{if } \eta < 1, \quad (15a) \\ \ln Q^2, & \text{if } \eta = 1, \quad (15b) \\ \dfrac{(\ln Q^2)^{\eta-1}}{\eta - 1}, & \text{if } \eta > 1. \quad (15c) \end{cases}$$

Hence, if $\sigma(s)$ saturates the Froissart bound ($\eta = 2$), one obtains a *power* correction to the structure function. Denoting by $G_n(Q^2)$ the moments of a nonsinglet structure (or fragmentation) function, found in the leading logarithmic approximation of QCD, we have

$$G_n^{ABS}(Q^2)/G_n(Q^2)_{Q^2\to\infty} \sim (Q^2/Q_0^2)^{\delta_n}, \tag{16}$$

where

$$\delta_n = \frac{\sigma'}{8\pi\alpha'} d_{NS}^n > 0. \tag{17}$$

A numerical evaluation of the exponent δ_n is very much dependent on the parametrization (14) of the parton diffractive cross-section. Assuming, very roughly, that this cross-section is a fraction of the proton-proton total cross-section rise [7], although it is difficult to make δ_n larger than 1/100, we can get a correction as large as 10% to $G_n(Q^2)$ at $Q = 100$ GeV. Such an effect can be detectable at collider or LEP energies.

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(7) S. D. Ellis and M. B. Kislinger: *Phys. Rev. D*, **9**, 2027 (1974); E. C. Katsoufis and S. D. P. Vlassopulos: *Phys. Lett. B*, **106**, 231 (1981).