Combined analysis of diffractive and inclusive structure functions in the semiclassical framework

W. Buchmüller[a], T. Gehrmann[b] and A. Hebecker[c]

[a]Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22603 Hamburg, Germany

[b]Institut für Theoretische Teilchenphysik, Univ. Karlsruhe, Engesser Str. 7, 76131 Karlsruhe, Germany

[c]Institut für Theoretische Physik der Univ. Heidelberg, Philosophenweg 16, 69120 Heidelberg, Germany

Small-x DIS is described as the scattering of a partonic fluctuation of the photon off a superposition of target color fields. Diffraction occurs if the emerging partonic state is in a color singlet. Introducing a specific model for the averaging over all relevant color field configurations, both diffractive and inclusive parton distributions at some low scale Q_0^2 can be calculated. A conventional DGLAP analysis results in a good description of diffractive and inclusive structure functions at higher values of Q^2.

At this workshop, several numerical analyses of recent precise measurements of the diffractive structure function [1,2] have been reported [3–6]. In this contribution, a combined description of inclusive and diffractive DIS in the semiclassical framework is discussed [7].

From the target rest frame point of view, leading order diffractive DIS is the color singlet production of a $q\bar{q}$ pair, as shown on the l.h. side of Fig. 1a. The process is dominated by kinematic configurations corresponding to Bjorken's aligned jet model, i.e., one of the quarks carries most of the photon's longitudinal momentum and the transverse momenta are small. The dependence of the cross section on the target color field is encoded in the expression

$$\int d^2x_\perp \, \mathrm{tr} W_{x_\perp}(y_\perp) \, \mathrm{tr} W^\dagger_{x_\perp}(y'_\perp) \,, \qquad (1)$$

where the function

$$W_{x_\perp}(y_\perp) = U(x_\perp) U^\dagger(x_\perp + y_\perp) - 1 \qquad (2)$$

is built from two SU(3) matrices, U and $U^\dagger$, corresponding to the non-Abelian phase factors picked up by the quark and antiquark penetrating the color field at transverse positions $x_\perp$ and $x_\perp + y_\perp$.

In the Breit frame, leading order diffractive DIS is most naturally described by photon-quark scattering, with the quark coming from the diffractive parton distribution of the target hadron [8]. This is illustrated on the r.h. side of Fig. 1a. Identifying the leading twist part of the $q\bar{q}$ pair production cross section (l.h. side of Fig. 1a) with the result of the conventional partonic calculation (r.h. side of Fig. 1a), the diffractive quark distribution of the target is expressed in terms of the color field dependent function given in Eq. (1).

Similarly, the cross section for the color singlet production of a $q\bar{q}g$ state (l.h. side of Fig. 1b) is identified with the boson-gluon fusion process based on the diffractive gluon distribution of the target (r.h. side of Fig. 1b). This allows for the calculation of the diffractive gluon distribution in terms of a function similar to Eq. (1) but with the U matrices in the adjoint representation.

In the semiclassical approach, the cross sections for inclusive DIS are obtained from the same calculations as in the diffractive case where, however, the color singlet condition for the final state parton configuration is dropped. As a result, the $q\bar{q}$ production cross section (cf. the l.h. side of Fig. 1a) receives contributions from both the aligned jet and the high-$p_\perp$ region. In the latter, the logarithmic $dp_\perp^2/p_\perp^2$ integration gives rise to a $\ln Q^2$ term in the full cross section.

In the leading order partonic analysis, the full cross section is described by photon-quark scattering. The gluon distribution is responsible for the scaling violations at small x,

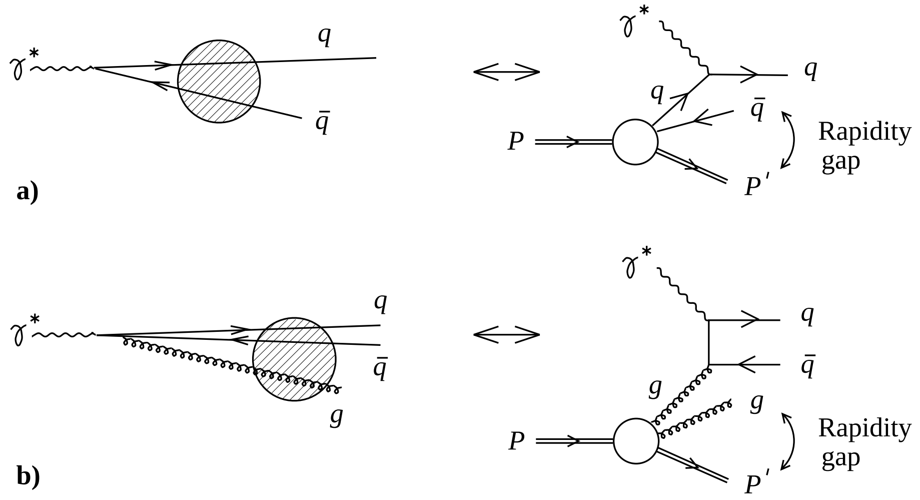

Figure 1. Diffractive DIS in the proton rest frame (left) and the Breit frame (right); asymmetric quark fluctuations correspond to diffractive quark scattering, asymmetric gluon fluctuations to diffractive boson-gluon fusion.

$\partial F_2(x,Q^2)/\partial \ln Q^2 \sim xg(x,Q^2)$. Thus, the semi-classical result for $q\bar{q}$ production, with its $\ln Q^2$ contribution, is sufficient to calculate both the inclusive quark and the inclusive gluon distribution. The results are again expressed in terms of the function in Eq. (1) where now the color trace is taken *after* the two W matrices (corresponding to the amplitude and its complex conjugate) have been multiplied.

To obtain explicit formulae for the above parton distributions, a model for the averaging over the color fields, which underlie the eikonal factors in Eq. (2), has to be introduced. In the case of a very large hadronic target [9], such a model is naturally obtained from the observation that, even in the aligned jet region, the transverse separation of the $q\bar{q}$ pair remains small [10]. This is a result of the saturation of the dipole cross section at smaller dipole size. Under the additional assumption that color fields in distant regions of the large target are uncorrelated, a simple Glauber-type exponentiation of the averaged local field strength results in explicit formulae for all the relevant functions of the type shown in Eq. (1).

Thus, diffractive and inclusive quark and gluon distributions at some small scale Q_0^2 are expressed in terms of only two parameters, the average color field strength and the total size of the large target hadron. The energy dependence arising from the large-momentum cutoff applied in the process of color field averaging can not be calculated from first principles. It is described by a $\ln^2 x$ ansatz, consistent with unitarity, which is universal for both the inclusive and diffractive structure function [11]. This introduces a further parameter, the unknown constant that comes with the logarithm.

A conventional leading order DGLAP analysis of data at small x and $Q^2 > Q_0^2$ results in a good four parameter fit (Q_0 being the fourth parameter) to both the inclusive and diffractive structure function. Diffractive data with $M^2 < 4\,\text{GeV}^2$ is excluded from the fit since higher twist effects are expected to affect this region. As an illustration, the β dependence of $F_2^{D(3)}$ at different values of Q^2 is shown in Figs. 2 and 3 (see [7] for further plots, in particular of the inclusive structure function, and more details of the analysis).

Finally, two important qualitative features of the approach should be emphasized. First, the diffractive gluon distribution is much larger than the diffractive quark distribution, a result reflected in the pattern of scaling violations of $F_2^{D(3)}$. This feature is also present in the analysis of [12], where, in contrast to the present ap-

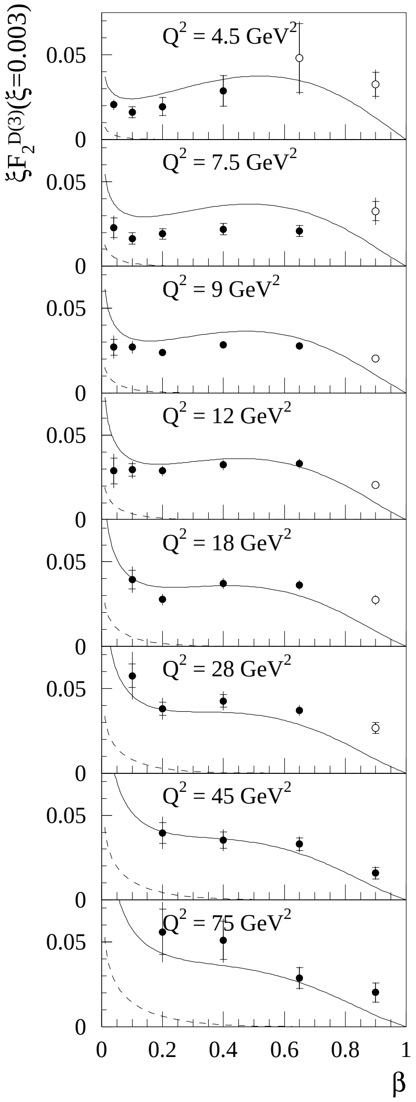

Figure 2. The diffractive structure function $F_2^{D(3)}(\xi,\beta,Q^2)$ with data from H1 [1]. Open circles correspond to $M^2 \leq 4\ \mathrm{GeV}^2$. The charm content is indicated as a dashed line.

proach, the target is modelled as a small color dipole. Second, the inclusive gluon distribution, calculated from $q\bar{q}$ pair production at high $p_\perp$ and determined by the small-distance structure of the color field, is large and leads to the dominance of inclusive over diffractive DIS.

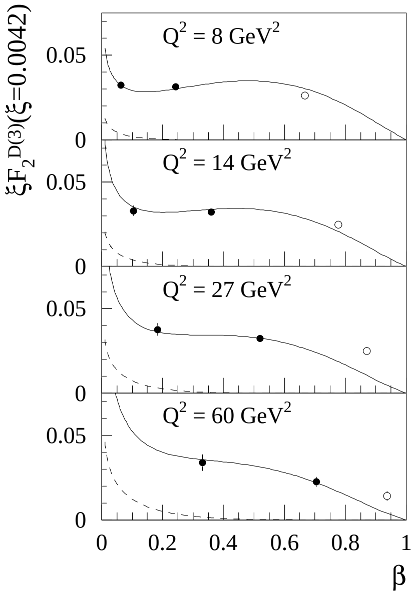

Figure 3. Diffractive structure function $F_2^{D(3)}$ (conventions of Fig. 2) with data from ZEUS [2].

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