Diffractive PDFs

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Abstract
Results are presented of the inclusive diffractive DIS cross-section and
the data are used to test the proton vertex factorisation hypothesis. This
hypothesis having been shown to be a good approximation to the data,
the diffractive PDFs resulting from a NLO QCD fit to the inclusive
data, which uses this approximation, are shown. The diffractive di-
jet cross-section in DIS is measured and compared to the predictions
based on these DPDFs and reasonable agreement is found, further sup-
porting the factorisation ansatz. Finally, the diffractive dijet and inclu-
sive data are fit simultaneously resulting in diffractive PDFs that have
similar precision in both the quark-singlet and gluon components.

1 Inclusive Diffractive DIS at HERA
A schematic diagram for the inclusive diffractive DIS process \( ep \rightarrow eXp \) at HERA is shown in
figure 1. It has been shown by Collins [1] that the diffractive DIS process factorises; shown in
figure 1 is an additional assumption that the proton vertex dynamics factorise from the vertex of
the hard scatter - proton vertex factorisation. The kinematic variables used to describe inclusive
DIS are:

\[
Q^2 = -q^2 = -(k - k')^2, \quad x = \frac{Q^2}{2p \cdot q}, \quad y = \frac{p \cdot q}{p \cdot k}.
\]

(1)

Here \( Q^2 \) is the virtuality of the exchange boson, \( x \) is the Bjorken scaling variable and \( y \) is the in-
elasticity. They are defined in terms of \( k \) and \( k' \), the four-momenta of the incoming and outgoing
electrons, respectively, and the four-momentum of the incoming proton \( p \). In addition to these
standard DIS variables and the Mandelstam variables \((t, s)\) the kinematic variables \( x_{IP} \) and \( \beta \) are
useful in describing the diffractive DIS interaction. They are defined as:

\[
\beta = \frac{Q^2}{Q^2 + M_X^2 - t}, \quad x_{IP} = \frac{Q^2 + M_X^2 - t}{Q^2 + W^2 - M_p^2} = \frac{x}{\beta}
\]

(2)

where \( M_X \) is the invariant mass of the hadronic system \( X \), \( M_p \) is the mass of the proton and
\( W^2 = (q + p)^2 \) is the square of the centre of mass of the photon-proton system. \( x_{IP} \) is the
fractional momentum of the proton carried by the diffractive exchange and \( \beta \) is the fractional
momentum of the struck parton with respect to the diffractive exchange. The data are then
discussed in terms of a reduced cross-section, \( \sigma_r^{D(3)}(\beta, Q^2, x_{IP}) \), defined as:

\[
\frac{d^3\sigma_{ep \rightarrow eXp}}{d\beta dQ^2 dx_{IP}} = \frac{4\pi\alpha_s^2}{\beta Q^4} \left( 1 - y + \frac{y^2}{2} \right) \sigma_r^{D(3)}(\beta, Q^2, x_{IP}).
\]

(3)
Fig. 1: (top) A schematic illustration of the NC diffractive DIS process $ep \rightarrow eXp$ at HERA. The dotted line indicates where the diagram can be divided under the assumption of proton vertex factorisation. The inclusive diffractive DIS cross section as measured by the H1 collaboration (bottom).
Fig. 2: The ratio of the tagged to untagged cross sections as a function of kinematic variables and (bottom right) the $Q^2$ dependence of the $x_{IP}$ dependence of the data. The proton vertex factorisation hypothesis is a valid approximation within the precision of the data.

1.1 Experimental Methods

The inclusive diffractive DIS process is ideally measured by tagging the final state proton, e.g., [2], but such an experimental method suffers from low detector acceptance. In addition to this proton tagging method, both the H1 and ZEUS experiments use the topology of the hadronic final state to select diffractive events [3–5]; shown in figure 1 are the high statistics results of H1 using the large rapidity gap method. If, as shown in figure 2, the ratio of the two methods, tagged to non-tagged, is taken as a function of the kinematic variables and if the $Q^2$ dependence of $\alpha_{IP}(0)$ (the $x_{IP}$ dependence of the data) is studied it can be seen that, within the current experimental precision, the proton vertex factorisation hypothesis is a valid approximation of the data.

1.2 Inclusive diffractive DIS PDFs

Given the validity of the proton vertex factorisation ansatz, a NLO QCD fit using the proton vertex factorisation approximation is performed to the inclusive data [3], producing the diffractive PDFs shown in figure 3. Also shown in figure 3 are the individual contributions of both the quark and gluon driven terms to the logarithmic $Q^2$ derivative of the inclusive cross section. At high $\beta$, sensitivity to the gluon is all but lost. The result is an ambiguous gluon at high momentum fractions $z$, as seen by the comparison of Fits A and B, which give a similar $\chi^2$ fit probability.
2 Diffractive Dijets in DIS

Shown in figure 4 is a schematic diagram for the diffractive dijets in DIS process at HERA. Assuming that this diagram dominates the production mechanism, this process should provide a sensitive tool with which to probe the diffractive gluon and test the predictions obtained from fits to inclusive diffractive data. Figure 4 shows a comparison of a measurement made by ZEUS of the diffractive dijet cross section in DIS [6] compared to the predictions of both fits to the H1 inclusive data. The prediction of Fit B is favoured. For more comparisons, see the talk on “Factorisation breaking in diffraction, including leading baryons” by A. Bonato in these proceedings.

Fig. 4: A schematic diagram for the diffractive dijets in DIS process (left). The diffractive dijets in DIS data compared to the results of both fits to the inclusive data (right).
2.1 Combined fit of inclusive and dijet data

The diffractive dijet data has been used in combination with the inclusive data to fully constrain both the quark-singlet and gluon terms in a combined NLO QCD fit [7]. The resulting fit is shown compared to the diffractive dijet data in figure 5; it is worth noting that the difference in the description of the inclusive data, when compared to the inclusive-only fit, is negligible. Finally, the diffractive PDFs resulting from the combined fit are shown in figure 6. The gluon and quark components have similar good precision across the whole phase space and in particular the gluon is well constrained at large momentum fractions $z$.

![H1 data compared to a combined NLO QCD fit of the same diffractive dijet data and the inclusive data.](image)

Fig. 5: The diffractive dijet data compared to a combined NLO QCD fit of the same diffractive dijet data and the inclusive data.

3 Conclusion

Results have been presented of the inclusive diffractive DIS cross-section and the data were used to test the proton vertex factorisation hypothesis. Within the current limit of experimental precision, the proton vertex factorisation hypothesis is seen to be a good approximation of the data. Following this, NLO QCD fits of the inclusive data were shown, with the observation that the gluon is not well constrained by the inclusive data alone at large momentum fractions. This was seen to be a direct consequence of the dominance of the quark-driven contributions to the logarithmic $Q^2$ derivative of the cross section at large momentum fractions.
The diffractive dijet cross-section in DIS has been measured and compared to the predictions based on these inclusive DPDFs and reasonable agreement was found, further supporting the factorisation ansatz. Finally, the result of a simultaneous fit to both the diffractive dijet and inclusive data produced diffractive PDFs that have similar precision in both the quark-singlet and gluon components. In particular, the gluon resulting from this combined fit is well constrained at large momentum fractions.

![Graphs showing DPDFs](image)

Fig. 6: The DPDFs resulting from the combined fit to the inclusive and dijet diffractive DIS data.

References