

DIFFRACTION AT H1 AND ZEUS

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The H1 and Zeus collaborations have measured the inclusive diffractive DIS cross section $ep \rightarrow eXp$ and these measurements are in good agreement within a normalisation uncertainty. Diffractive parton density functions (DPDFs) have been extracted from NLO QCD fits to these data and the predictions of these DPDFs compare well with measurements of diffractive dijets in DIS, proving the validity of the factorisation approximations used in their extraction. The inclusive and dijet data are then used in a combined fit to constrain the diffractive singlet and gluon with good precision over the full phase space. The predictions of DPDFs are compared to diffractive dijets in photoproduction where the issue of survival probability in a hadron-hadron environment can be studied. Finally, exclusive diffractive vector meson production and deeply virtual Compton scattering have also been studied; the results compare reasonably well with the expectations of QCD and in particular with GPD models.

1 Inclusive Diffraction at HERA

It has been shown by Collins¹ that the NC diffractive DIS process $ep \rightarrow eXp$ at HERA factorises; a useful additional assumption is often made whereby the proton vertex dynamics factorise from the vertex of the hard scatter - proton vertex factorisation. The kinematic variables used to describe inclusive DIS are the virtuality of the exchanged boson Q^2 , the Bjorken scaling variable x and y the inelasticity. In addition, the kinematic variables x_{IP} and β are useful in describing the diffractive DIS interaction. x_{IP} is the longitudinal fractional momentum of the proton carried by the diffractive exchange and β is the longitudinal momentum fraction of the struck parton with respect to the diffractive exchange; $x = x_{IP}\beta$. The data are discussed in terms of a reduced diffractive cross-section, $\sigma_r^{D(3)}(\beta, Q^2, x_{IP})$, which is related to the measured differential cross section by:

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

In the proton vertex factorisation scheme, the Q^2 and β dependences of the reduced cross section factorise from the x_{IP} dependence. Measurements of the reduced diffractive cross section from both H1 and Zeus are shown in Figure 1, where the new Zeus preliminary measurement has been scaled by a factor of 0.87, a factor consistent with the normalisation uncertainties of the two analyses. The measurements agree rather well.

1.1 Diffractive PDFs from Inclusive data

Using the approximation of proton vertex factorisation, the H1² and Zeus³ collaborations have extracted DPDFs using NLO QCD fits to the β and Q^2 dependencies of the reduced cross

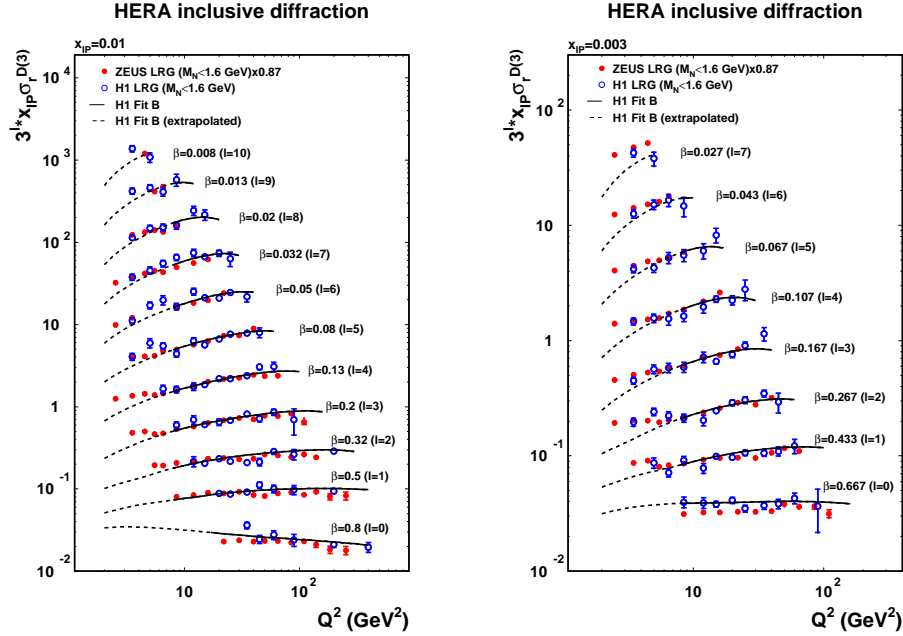


Figure 1: The reduced diffractive cross section as measured by the H1 and Zeus collaborations.

section. H1 obtained two fits of approximately equal quality, Fit A and Fit B, differing only in the number of terms used to parameterise the gluon. The two fits, while fully consistent at low fractional momentum, yield very different results for the diffractive gluon at high fractional momentum. This is due to quark-driven evolution dominating the logarithmic Q^2 derivative of the reduced cross section at high β , which in turn greatly reduces the sensitivity of this quantity to the gluon.

1.2 Diffractive dijets and DPDFs

Diffractive dijets in DIS provide a sensitive experimental probe of the diffractive gluon, as the dominant production mechanism is boson-gluon fusion. The sensitive variable is $z_{IP} = \frac{Q^2 + M_{12}^2}{Q^2 + M_X^2}$, where M_{12} is the invariant mass of the dijet system and M_X is the invariant mass of the total hadronic final state X . Both H1⁴ and Zeus⁶ have measured the diffractive dijet cross section in DIS. Both collaborations find that, at low z_{IP} , where the inclusive data have sensitivity to the diffractive gluon, the results of the predictions are very similar and agree well with the data. This supports the use of the proton vertex factorisation approximation needed to make the NLO QCD fits. At high z_{IP} the data clearly prefer the prediction of Fit B.

Having shown the sensitivity of the diffractive dijets in DIS data, H1 have included their data in a combined fit with the inclusive diffractive DIS data⁴. The resulting fit is indistinguishable from Fit A and Fit B in its description of the inclusive data and produces a better description of the diffractive dijet data, consistent with that of Fit B. The resulting DPDFs from this combined fit, are shown in Figure 2. Both singlet and gluon are constrained with similarly good precision across the whole kinematic range. A parametrisation of the DPDFs is publically available⁵.

1.3 Diffractive dijets in photoproduction

Despite the success of factorisation in diffractive DIS at the HERA experiments, there is a long-standing issue that the predictions obtained with HERA DPDFs grossly overshoot the diffractive

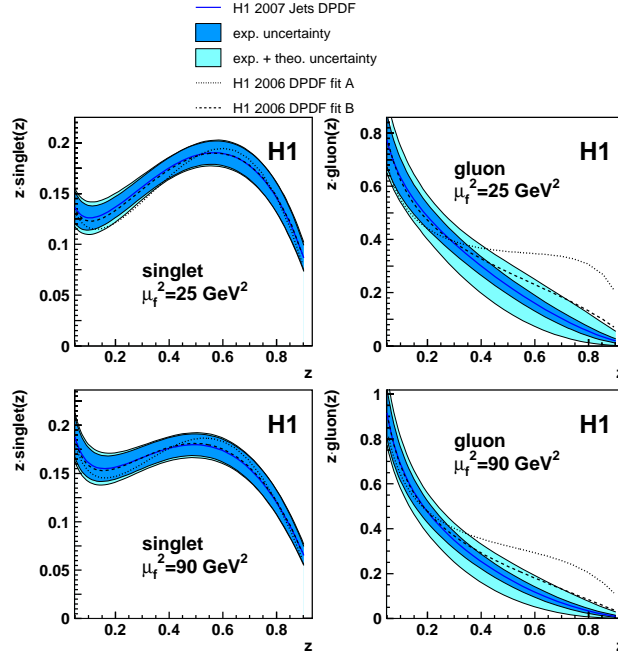


Figure 2: The H1 DPDFs resulting from the combined fit to the inclusive and dijet diffractive DIS data.

dijet cross section at the Tevatron. At HERA, photoproduction events, where $Q^2 \sim 0$, provides an environment similar to a hadron-hadron collider. The variable x_γ is the fraction of the four momentum of the photon transferred to the hard interaction; the lower the value of x_γ the more hadron-like the photon. Both H1⁷ and Zeus⁸ have measured diffractive dijets in photoproduction. The latest preliminary results from H1⁹ show a suppression of the cross section with respect to the predictions and this suppression is independent of x_γ . There is also a suggestion that this suppression is dependent on the E_T of the jet. This would be consistent with the Zeus analysis at higher E_T where less suppression is observed. It should be noted in addition that the current measurements have large experimental and theoretical uncertainties.

2 Exclusive vector meson production and DVCS

Exclusive vector meson production provides an ideal experimental testing ground for QCD, as the experimental signature is clean and the theoretical calculations are often simplified. Measured at H1¹⁰, the exclusive production of photons at high momentum transfer t at the proton vertex allows comparison of the experimental results with BFKL calculations which do not suffer from uncertainty on the final state vector meson wave function. The W dependence of the high- t photon cross-section is shown in figure 3 (left); this is certainly one of the hardest diffractive processes yet measured and is consistent with the BFKL predictions, although the precision of the data is limited.

Deeply virtual Compton scattering is a process with sensitivity to the transverse correlations of partons in the proton and thus has sensitivity to models of Generalised Parton Densities (GPDs)¹¹. Figure 3 (right) shows the Q^2 dependence of (top) a dimensionless variable S related to the amplitude for the process with the t -dependence removed; (bottom) the Q^2 dependence of a variable R related to the ratio of GPD to PDF. The data can discriminate between GPD models and favour a full GPD model rather than one with only kinematical skewing.

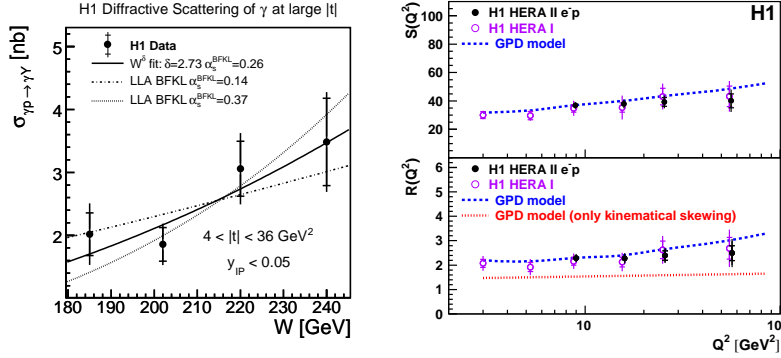


Figure 3: The W dependence of the high- t photon cross-section (left) and (right) the Q^2 dependence of quantities sensitive to GPD models (see text).

3 Conclusions

The H1 and Zeus collaborations have measured the inclusive diffractive DIS cross section $ep \rightarrow eXp$ and these measurements are in good agreement within their normalisation uncertainties. The DPDFs from NLO QCD fits to the inclusive data can successfully describe diffractive dijet data in the DIS regime and including these dijet data in a further NLO QCD fit results in DPDFs constrained with good precision across the whole kinematic range. Comparing the predictions of DPDFs with diffractive dijets in photoproduction shows evidence of a suppression of the cross section which is independent of x_γ but which is consistent with an E_T dependence. Exclusive vector meson production has also been studied by both the H1 and Zeus collaborations. H1 have measured exclusive high- t photon production, a process with one of the hardest W -dependences ever measured. Measurements of DVCS have been shown to have enough sensitivity to discriminate between models of GPDs.

References

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