Inclusive Diffraction at HERA

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The H1 and Zeus collaborations have measured the inclusive diffractive DIS cross section $ep \to eXp$ and these measurements are in good agreement within a normalisation uncertainty. Diffractive parton density functions (DPDFs) have been extracted from NLO QCD fits to inclusive measurements of diffractive DIS and the predictions of these DPDFs are compared with measurements of diffractive dijets in DIS, testing the validity of the factorisation approximations used in their extraction. H1 then use these diffractive dijets in DIS data to provide further constraints in a combined QCD fit, resulting in the next generation of DPDFs which have constrained the diffractive gluon at large momentum fractions. Finally, 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.

1. Diffraction at HERA

It has been shown by Collins [1] that the NC diffractive DIS process $ep \to eXp$ 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:

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

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 H1 and Zeus collaborations have extracted DPDFs using NLO QCD fits to the β and Q^2 dependencies of the reduced cross section [2, 3]. 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.

2. Diffractive dijets in DIS

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. Both H1 and Zeus have measured the diffractive dijet cross section in DIS [4, 5]. In Figure 2, the Zeus measurement is compared to the predictions of a Zeus fit to inclusive data and H1 Fit A and Fit B. At low z_{IP},

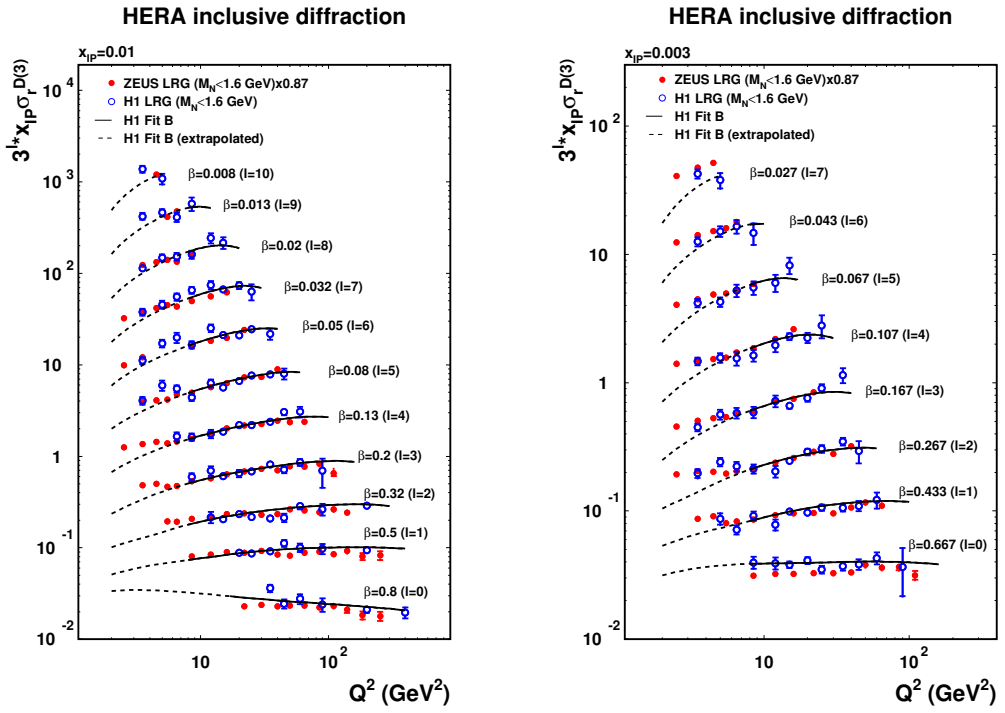

Figure 1: The reduced diffractive cross section as measured by the H1 and Zeus collaborations.

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 data [4]. 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 3. Both singlet and gluon are constrained with similar good precision across the whole kinematic range.

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 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 H1 and Zeus have measured diffractive dijets in photoproduction [6, 7]. The latest preliminary results from H1 [8] are shown in Figure 4 compared to the predictions of Fit A and Fit B and the prediction of the combined fit including dijet data described above. There is 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 of the E_T of the jet. This would be consistent with the Zeus analysis at higher E_T where less suppression is observed.

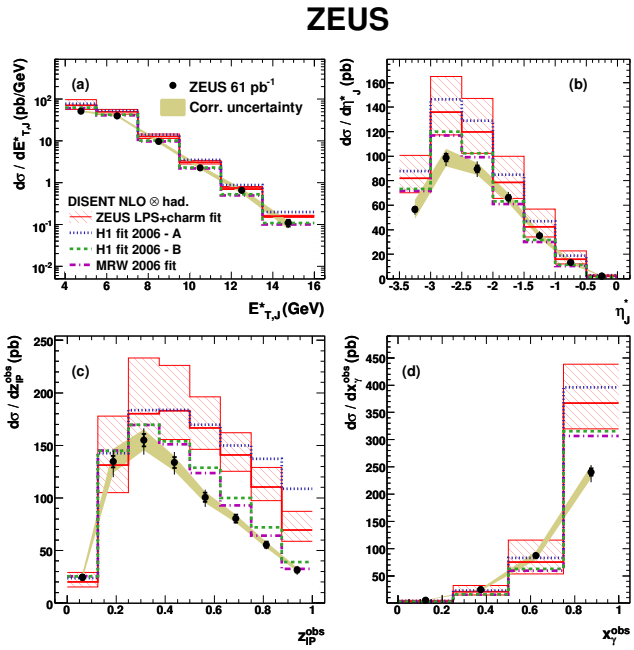

Figure 2: The diffractive dijets in DIS data compared to the predictions of fits to inclusive DIS data.

4. Conclusions

The H1 and Zeus collaborations have measured the inclusive diffractive DIS cross section $ep \to eXp$ and these measurements are in good agreement within their normalisation uncertainties. The DPDFs from NLO QCD fits to inclusive diffractive DIS data can predict the diffractive dijets in DIS cross section at low z_{IP} while at high z_{IP} the data favour Fit B. Including the diffractive dijet data in a combined fit further constrains the NLO QCD fit, where the inclusive data alone are unable to unambiguously constrain the diffractive gluon. The resulting DPDFs from H1 are constrained with good precision across the whole kinematic range. Finally, when compared to the predictions of DPDFs, diffractive dijets in photoproduction show a suppression of the cross section which is independent of x_γ but which is consistent with an E_T dependence.

References

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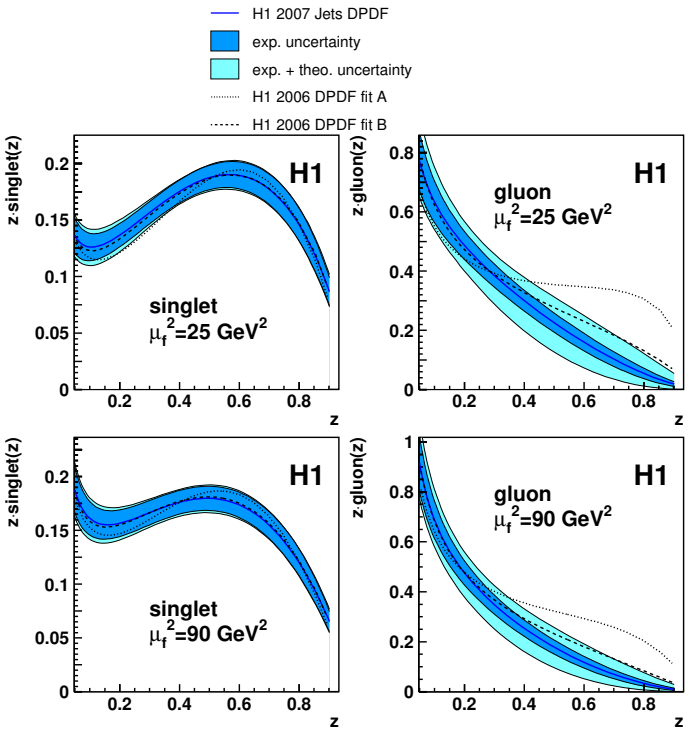

Figure 3: The H1 DPDFs resulting from the combined fit to the inclusive and dijet diffractive DIS data.

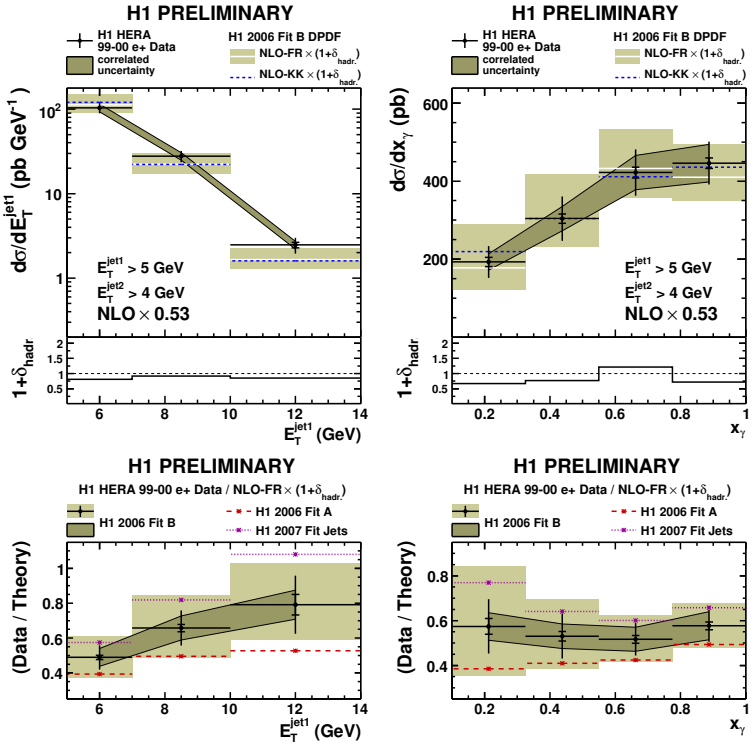

Figure 4: The diffractive dijets in photoproduction data compared to the predictions of fits to inclusive DIS data and a combined fit to inclusive and dijet data.