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COMPARISON OF DIFFRACTIVE FINAL STATES WITH LO AND NLO QCD PREDICTIONS

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Measurements of hard diffractive final states performed with the H1 experiment at HERA are presented and confronted with LO and NLO QCD predictions based on diffractive parton densities to test QCD factorisation in diffraction.

1 Introduction

The understanding of the production mechanism of diffractive processes in high energy particle physics has remained one of the most serious challenges in Quantum Chromodynamics (QCD), the theory of strong interactions. QCD predicts that the cross section for diffractive deep-inelastic electron-proton scattering (DDIS) factorises into universal diffractive parton densities (DPDFs) of the proton and process-dependent hard scattering coefficients [1] (QCD factorisation). Leading order (LO) and next-to-leading order (NLO) DPDFs have been determined from DGLAP QCD fits to inclusive DDIS measurements by the H1 collaboration [2,3] and have been found to be dominated by the gluon which carries $\approx 75\%$ of the momentum. Diffractive dijet and D^* meson (heavy quark) production are directly sensitive to the diffractive gluon through the photon-gluon fusion production mechanism (Fig. 1a) and are used to test factorisation. A photon of virtuality Q^2 under-

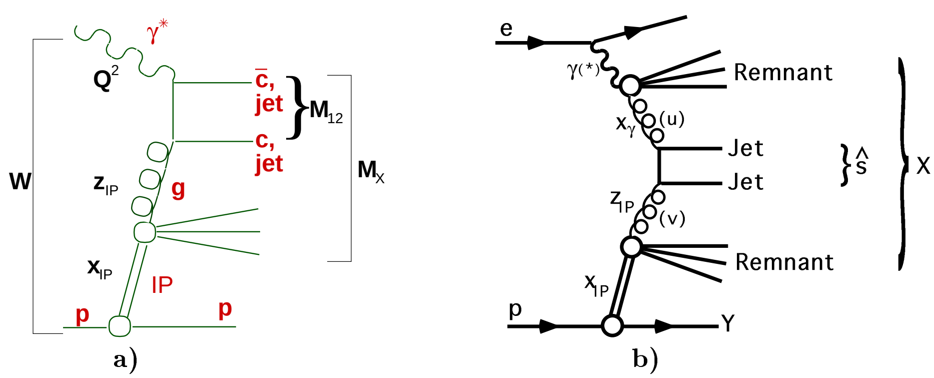

Figure 1. a) Direct photon process (photon-gluon fusion) and b) resolved photon process.

goes a hard scatter with a diffractive gluon forming a $q\bar{q}$ pair. The centre-of-mass energy of the hard scattering process is labelled M_{12}. The gluon carries a fraction

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$z_{I\!P}$ of the momentum of the diffractive exchange which itself carries a fraction $x_{I\!P}$ of the proton momentum. The γp centre-of-mass energy is denoted by W, and M_X labels the mass of the diffractive system. The inelasticity variable y is given by $y\,s = W^2 + Q^2$, in which s is the squared ep centre-of-mass energy. The cross sections are also shown as a function of the pseudorapidity η of the jets and D* mesons. Contributions to the cross section also occur through the process depicted in Fig. 1b where the photon develops hadronic structure of which a single parton with photon momentum fraction x_γ undergoes the hard scatter ("resolved" photon process). In photoproduction ($Q^2 \approx 0$), this process contributes significantly whereas in DIS it is suppressed due to the large photon virtuality.

2 H1 diffractive parton distributions

The H1 collaboration has determined diffractive parton densities from NLO and LO DGLAP QCD fits to inclusive DDIS measurements. The latest fit to the most recent available data has been presented as a preliminary result in [3]. This fit is referred to as 'H1 2002 fit.' Earlier fits have been presented in [2], where the fit which gave the best description of the inclusive process is referred to as 'H1 fit 2.'

3 Diffractive dijet production in DIS

Cross sections for diffractive dijets production in the kinematic range $Q^2 > 4$ GeV^2, $E_T^{*,\mathrm{jet}}(1,2) > 4$ GeV, $x_{I\!P} < 0.05$ and $x_{I\!P} < 0.01$ have been measured by H1 in [4] using a cone jet algorithm. To facilitate comparisons with NLO calculations the measured distributions have been corrected to asymmetric cuts $E_T^{*,\mathrm{jet}}(1) > 5$ GeV and $E_T^{*,\mathrm{jet}}(2) > 4$ GeV using Monte Carlo generated events [5]. To obtain NLO predictions, the NLO versions of the 'H1 2002 fit' DPDFs were interfaced to the DISENT program [6] as suggested in [7]. The renormalisation and factorisation scales were set to the average p_T of the two highest p_T partons. The strong coupling α_s is calculated from $\Lambda^{\overline{\mathrm{MS}}}_{n=4} = 200$ MeV. The same α_s is used in the DGLAP evolution of the DPDFs. The NLO parton jet cross sections have been corrected for hadronisation effects using the Monte Carlo program RAPGAP [8] with parton showers and Lund string fragmentation. Comparisons of the NLO and LO prediction with the measurement are shown in Fig. 2a and 3. The NLO correction amounts to more than a factor 2 on average and is decreasing with $E_T^{*,\mathrm{jet}}$ (not shown) and Q^2. The inner band around the NLO results indicate the $\approx 20\%$ uncertainty resulting from a variation of the renormalisation scale by factors 0.5 and 2. The outer band includes a $\approx 10\%$ hadronisation uncertainty added linearly. The uncertainty in the diffractive gluon distribution is not shown. For $z_{I\!P} > 0.7$ it is larger than 50%. Within the experimental and theoretical uncertainties, the cross section is well described by the NLO calculation assuming QCD factorisation.

In Fig. 2b, a comparison is shown of the cross section in the range $E_T^{*,\mathrm{jet1,2}} > 4$ GeV and $x_{I\!P} < 0.01$ with LO predictions of the RAPGAP Monte Carlo program based on LO DPDFs. Higher-order effects are modelled by using parton showers. The 'H1 fit 2' prediction describes the measurement well. The new 'H1 2002 fit' DPDFs lead to a $\approx 25\%$ lower cross section. The difference is of the order of the uncertainty arising from that of the gluon distribution.

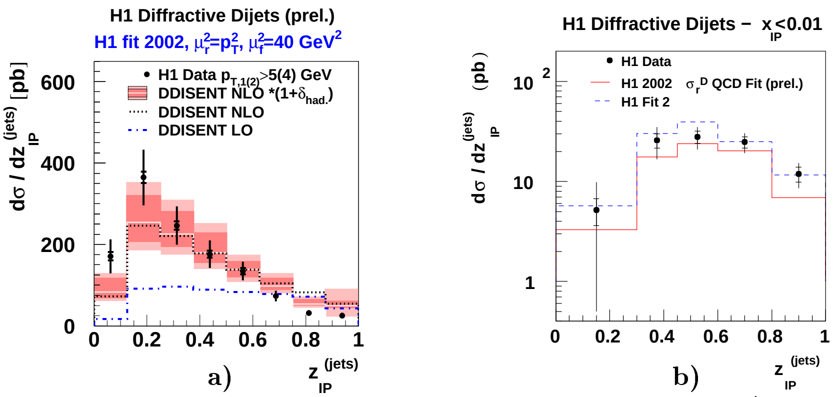

Figure 2. Diffractive DIS dijet cross section as a function of the estimator $z_{IP}^{\rm jets}$ of the parton momentum fraction of the diffractive exchange entering the hard scatter. a) For $E_T^{*,\rm jet1(2)} > 5(4)$ GeV and $x_{IP} < 0.05$ compared with NLO and LO DISENT based on the 'H1 2002 fit' DPDFs. b) For $E_T^{*,\rm jet1,2} > 4$ GeV, $x_{IP} < 0.01$ compared with the LO Monte Carlo RAPGAP with parton showers based on LO DPDFs.

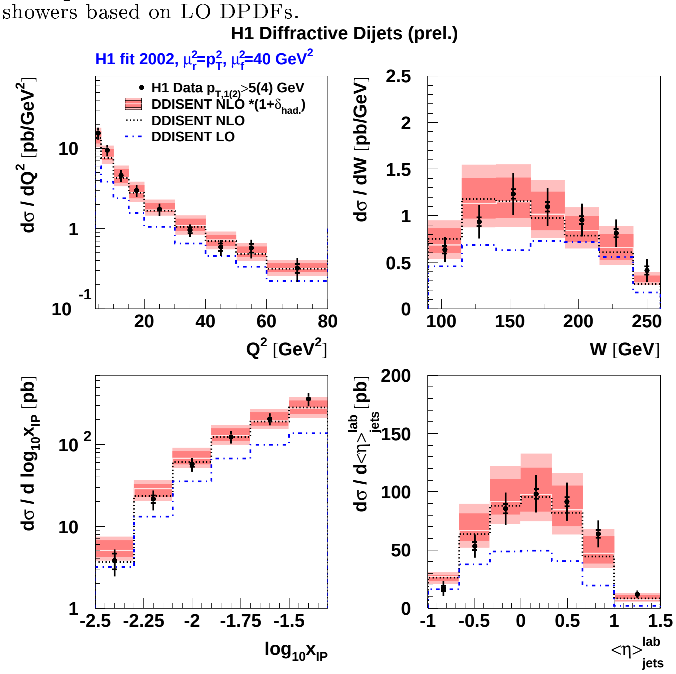

Figure 3. Diffractive DIS dijet cross section as a function of various variables compared with NLO and LO predictions of the DISENT program based on the 'H1 2002 fit' DPDFs.

4 Diffractive production of D* mesons in DIS

Cross sections for diffractive D* meson production in DIS have been measured by H1 in [9] in the kinematic range $2 < Q^2 < 80$ GeV^2, $x_{IP} < 0.04$, and $p_T^{D^*} > 2$ GeV. QCD calculations based on the H1 DPDFs have been performed at LO and NLO using the diffractive extension [10] of the HVQDIS program [11]. The renormalisation and factorisation scales were set to $\mu^2 = Q^2 + 4m_c^2$. Other parameter values used include the charm quark mass $m_c = 1.5$ GeV, the hadronisation fraction $f(c \to D^*) = 0.233$, and $\varepsilon = 0.078$ for the Peterson fragmentation function [12].

Comparisons of LO and NLO predictions with measured cross sections are shown in Fig. 4. The NLO correction amounts to a factor ≈ 1.3 on average. The inner error band around the calculation indicates the renormalisation scale uncertainty, the outer band includes variations of m_c and ε. Within the experimental uncertainties the cross section is well described.

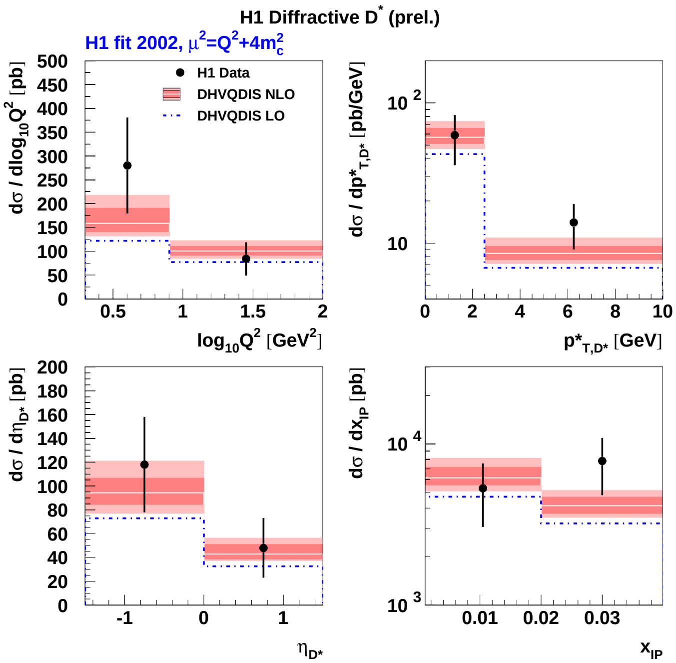

Figure 4. Diffractive DIS D* cross section as a function of various variables compared with NLO and LO predictions of the HVQDIS program extended for diffraction and using the 'H1 2002 fit' DPDFs.

5 Diffractive photoproduction of dijets

A measurement of dijet cross sections in diffractive photoproduction has been presented by H1 in [13] for the kinematic range $Q^2 < 0.01$ GeV, $x_{I\!P} < 0.03$, $E_T^{\rm jet}(1) > 5$ GeV and $E_T^{\rm jet}(2) > 4$ GeV where jets are identified using the inclusive k_T cluster algorithm [14]. In Fig. 5 and 6, the measured distributions are compared with RAPGAP predictions with parton showers enabled to simulate higher-order corrections. The contribution of direct photon processes ($x_\gamma = 1$ at the generator level) amounts to approximately half of the cross section and is shown as the hatched histogram in Fig. 5a. The cross section is well described by the prediction based on the recent 'H1 2002 fit' PDFs throughout the measured x_γ range which covers regions that are dominated by either direct or resolved processes. The 'H1 fit 2' prediction overestimates the rate by a factor ≈ 1.4 (Fig. 5b). The normalised cross section is shown as a function of y, $p_T^{\rm jet1}$, M_X and M_{12} in Fig. 6. The shapes of all measured distributions are well described by both predictions.

The results for diffractive dijet production in DIS and photoproduction can be compared to examine a possible suppression in photoproduction relative to DIS which is expected by gap survival probability models. The ratio of LO prediction to data, where the RAPGAP Monte Carlo prediction with parton showers is used in both DIS and photoproduction, is found to be a factor 1.3 ± 0.3 (exp.) larger in photoproduction. The uncertainty is estimated from the total experimental errors of the two measurements only. The factor is independent of the DPDFs used in the comparison. This LO suppression is not significant at the present level of precision and there is no evidence that it differs between direct and resolved photon processes.

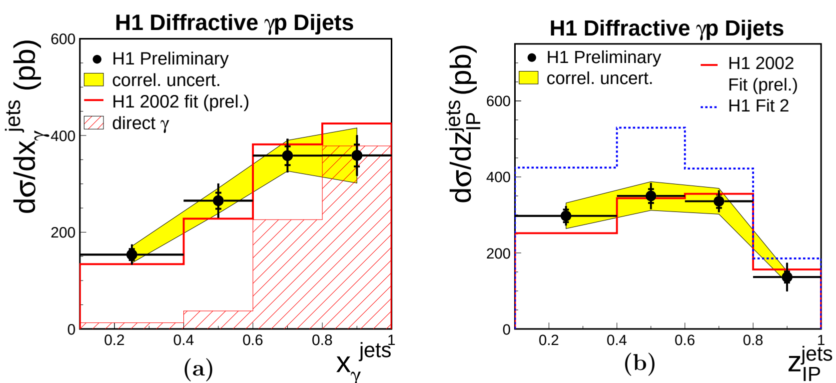

Figure 5. Diffractive γp cross section as a function of a) $x_\gamma^{\rm jets}$ and b) $z_{IP}^{\rm jets}$ compared with LO predictions of the RAPGAP Monte Carlo program with parton showers to simulate higher-order corrections. The predictions are based on LO DPDFs.

6 Conclusions

NLO QCD calculations based on NLO diffractive parton densities and assuming QCD factorisation are compatible within the experimental and theoretical uncertainties with measurements of diffractive dijet and D* production in DIS. The concept of QCD factorisation holds in diffractive DIS. LO Monte Carlo QCD calculations based on LO diffractive parton densities and using parton showers to simulate higher-order corrections are in agreement with measurements of diffractive dijet production in DIS and photoproduction within the uncertainties. A leading order suppression factor for diffractive dijet photoproduction relative to the same process in DIS of 1.3 ± 0.3 (exp.) is found. This factor does not deviate from unity at the present level of precision and it does not differ between direct and resolved photon processes.

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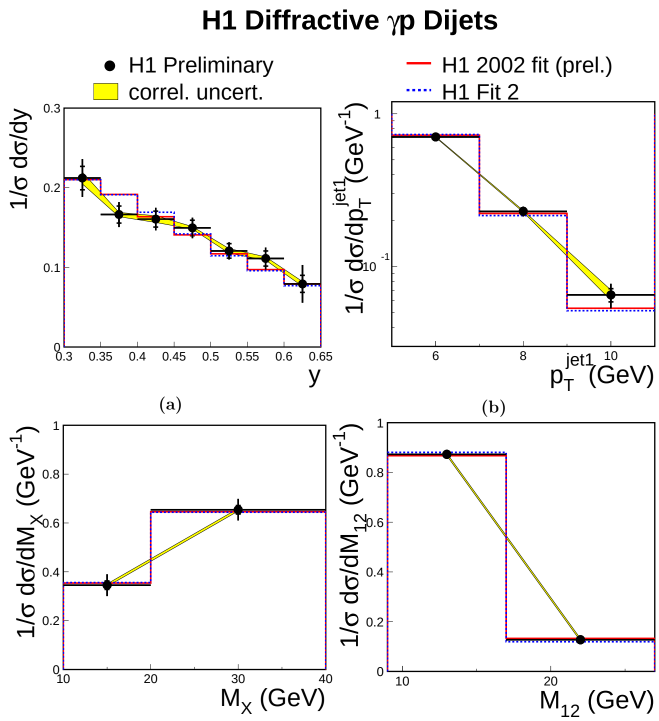

(a) (b) (c) (d)

Figure 6. Normalised differential cross sections for diffractive dijet photoproduction compared with LO predictions of the RAPGAP Monte Carlo program with parton showers to simulate higher-order corrections. The predictions are based on LO DPDFs.

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