STUDIES OF THE STRUCTURE OF DIFFRACTION AND OF EXCLUSIVE DIFFRACTIVE FINAL STATES AT HERA

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We present a new measurement of the diffractive structure function at high Q^2 (up to 1600 GeV^2) that is well described by the extension of a DGLAP QCD fit realised on previous data at lower Q^2 (below 120 GeV^2). This clearly illustrates the hard nature of diffractive phenomena for this kinematic domain. Then, we show that exclusive processes are well suited to study more precisely the hard structure of diffraction and we present new results on diffractive photoproduction of J/ψ at large $|t|$. Finally, we describe the latest measurements of production of real photons over a large kinematic range.

1 Inclusive diffraction at large Q^2

A measurement of inclusive diffractive deep inelastic scattering extending to the largest Q^2 values accessed to date has been done by the H1 experiment at HERA in e^+p interactions at $\sqrt{s} = 319$ GeV. In a diffractive process $ep \to eXY$, the hadronic final state consists of two distinct systems X and Y separated by a large gap in rapidity. We define the kinematic variables $x_{\mathbb{P}} \simeq \frac{Q^2+M_X^2}{Q^2+W^2}$, the fraction of the proton beam energy transferred to the longitudinal momentum of the diffractive exchange and $\beta \simeq \frac{Q^2}{Q^2+M_X^2}$, with $\beta = x_{Bj}/x_{\mathbb{P}}$. From the measurement of the differential cross-section, which can be written as

$$\frac{d^3\sigma_{ep\to eXY}}{d\beta dQ^2 dx_{\mathbb{P}}} = \frac{4\pi\alpha_{rm}^2}{\beta Q^4}(1-y+\frac{y^2}{2})\sigma_r^{D(3)}(\beta, Q^2, x_{\mathbb{P}}) \tag{1}$$

the reduced cross-section $\sigma_r^{D(3)}(\beta, Q^2, x_{\mathbb{P}})$ has been extracted in the kinematic range $200 \leq Q^2 \leq 1600$ GeV^2 and $0.0036 \leq x_{\mathbb{P}} \leq 0.05$ using data taken in 1999 and 2000 amounting to an integrated luminosity of 63 pb^{-1} (see Fig. 1). A good agreement is found with predictions based

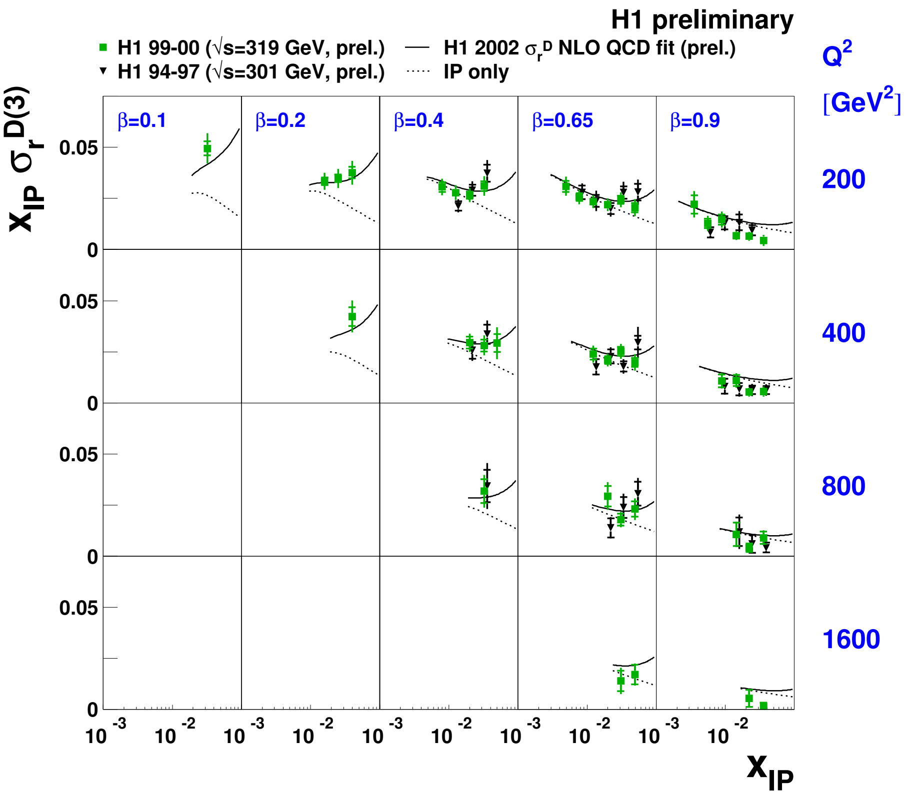

Figure 1: The measured reduced cross-section $x_{\mathbb{P}}\sigma_r^{D(3)}$ plotted as a function of $x_{\mathbb{P}}$ at fixed β, Q^2. Also shown is the prediction from the NLO QCD fit preformed on medium Q^2 data.

on diffractive parton densities obtained from an NLO QCD fit to lower Q^2 data, evolved using the DGLAP equations [1]. This good description by the perturbative QCD prediction illustrates the hard nature of the process under study. This can be confirmed by fitting the $x_{\mathbb{P}}$ dependance of the reduced cross-section, which behaves as $(\frac{1}{x_{\mathbb{P}}})^{2\alpha_{\mathbb{P}}-1}$. We find

$$\alpha_{\mathbb{P}} = 1.173 \pm 0.018(stat) \pm 0.017(syst)^{+0.063}_{-0.035}(model) \tag{2}$$

which is clearly larger than the soft pomeron intercept of 1.08.

2 Exclusive diffractive processes

In the last section, we have shown that inclusive diffraction at HERA in the large Q^2 kinematic domain can be described by the DGLAP QCD evolution equations, which allows the extraction of diffractive parton densities (in the same way as it is done for standard DIS). However, these measurements do not address the generic nature of the process of diffraction. To do so, we need to find a process which occurs via photon fluctuations into a small $q\bar{q}$ pair configuration leading to a purely hard process. In the case of inclusive diffraction, also large size γ^* fluctuations are involved which are not necessarily hard enough to be described by perturbative QCD evolution. Vector meson production with a large scale which can be Q^2, the vector meson mass M_{VM} or the 4-momentum transfer $|t|$ are appropriate processes to isolate small size γ^* fluctuations. The H1 and ZEUS collaborations have measured and confirmed the hard behaviour of ρ diffractive production at large Q^2 and J/ψ diffractive photoproduction [2].

2.1 *Diffractive photoproduction of J/ψ at large $|t|$*

The diffractive photoproduction J/ψ cross-section has been measured by the H1 and ZEUS collaborations in a range $2 \leq |t| \leq 30$ GeV^2 with an integrated luminosity of 78 pb^{-1} for H1 and up to $|t|$ values of 7 GeV^2 for 36 pb^{-1} for ZEUS [3]. Fig. 2 illustrates the results as a function of W and $|t|$. We note that the energy dependance is reasonnably well described by the BFKL model over the full range of measurements, whereas the DGLAP model describes the data only for $|t| < 5$ GeV^2.

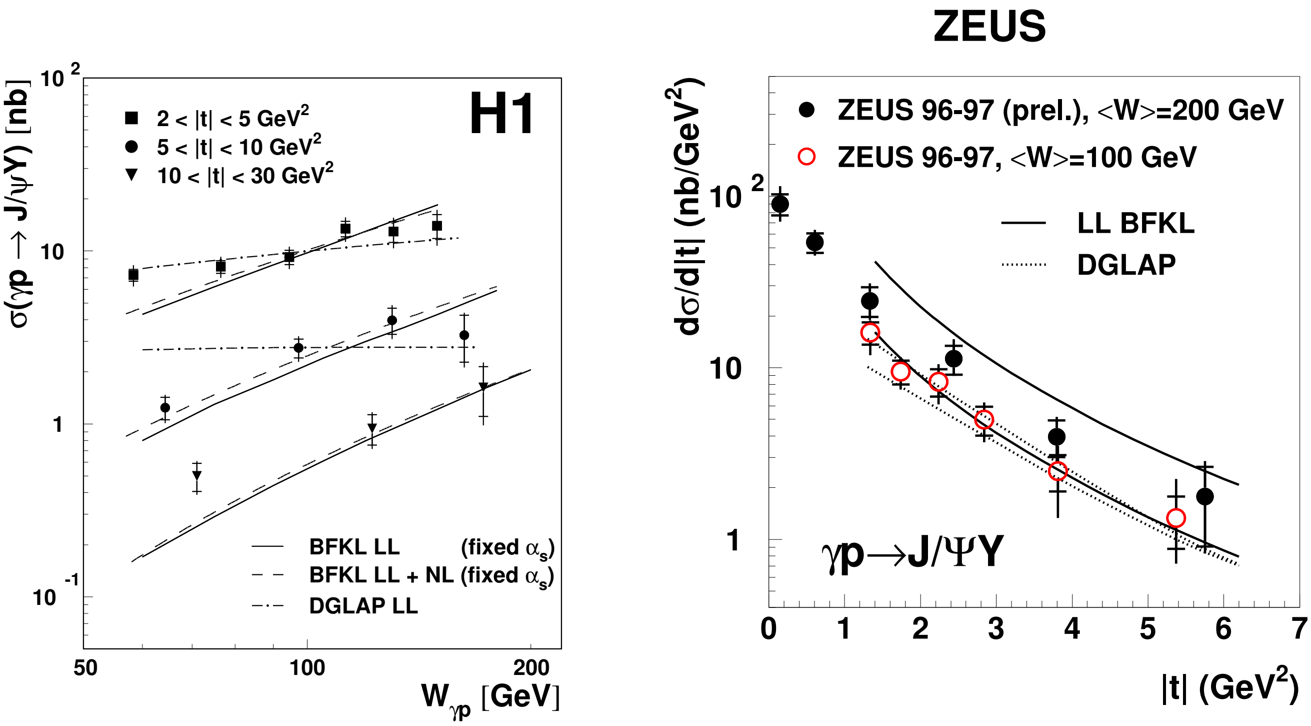

Figure 2: The photon-proton J/ψ cross section as a function of W ind t respectively measured by the H1 and ZEUS experiments. The measurements are compared with predictions based on DGLAP and BFKL predictions.

2.2 *Deeply Virtual Compton Scattering (DVCS)*

The $e^+p \to e^+\gamma p$ DVCS process has been measured by the H1 and ZEUS experiments in an extended kinematic domain, up to $Q^2 = 80$ GeV^2 for 26 pb^{-1} for H1 and up to $Q^2 = 100$ GeV^2 for 95 pb^{-1} for ZEUS [4]. Compared to a vector meson analysis, DVCS is interesting as its cross-section is less suppressed by a factor Q^2 and the interpretation of data is easier due to the lack of vector meson wave function effects. The perturbative QCD calculations for this reaction assume that the exchange involves two partons, having different longitudinal and transverse momenta, in a colourless configuration. These unequal momenta are a consequence of the "mass" difference between the incoming virtual photon and the outgoing real photon. Therefore, the DVCS process gives access to the Generalised Partons Distributions (GPDs), which are generalisations of the familiar parton distributions and incorporate information on correlations between the momenta of partons in the proton.

The DVCS cross-section shows a W dependance compatible with a hard process ($\sigma_{DVCS} \propto W^\delta$ with $\delta \sim 0.8$), which allows us to compare it with perturbative QCD calculations. The DVCS cross-section is shown as a function of Q^2 in Fig. 3 and compared with a NLO QCD prediction [5] using a GPD parametrisation based on MRST2001 and an exponential t dependance e^{Bt} with $B = 7$ GeV^{-2}. Moreover, we notice the good agreement between H1 and ZEUS measurements.

If we had ignored the correlations between parton momenta, i.e. replacing the GPDs by standard parton densities, the prediction would have been lower by a factor of about four. This clearly indicates the sensitivity of these measurements to GPDs, which could be extracted in the future with larger statistics and measurements of asymetries.

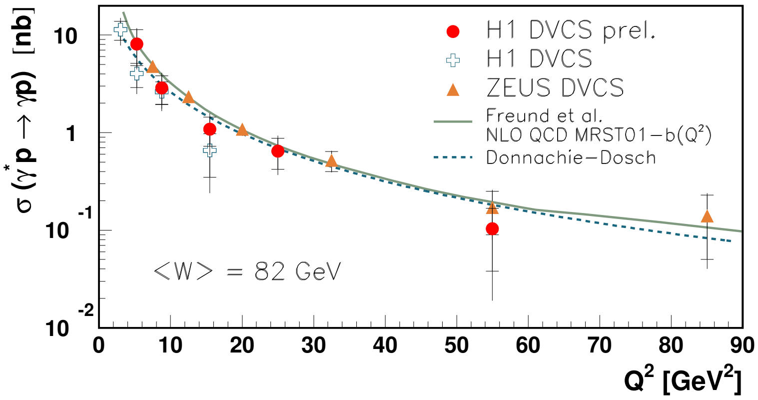

Figure 3: The $\gamma^* p \to \gamma p$ DVCS cross section as a function of Q^2 for $< W >= 82$ GeV with data from the H1 and ZEUS collaborations. The measurement is compared with a NLO QCD prediction using a GPD parametrisation.

3 Conclusions

HERA has achieved important progress in the understanding of diffractive phenomena with the language of perturbative QCD. Predictions based on the DGLAP evolution of diffractive parton densities can describe the highest Q^2 data. We have also shown that the class of hard diffractive processes, such as exclusive vector meson production and DVCS, fulfill the properties expected from perturbative QCD. In addition, DVCS cross-sections have been compared sucessfully for the first time with an NLO prediction based on GPDs.

References

1. H1 collaboration, *contributed paper to EPS 03, Aachen, Abstract* **090** (2003).
2. ZEUS collaboration, *contributed paper to ICHEP 02, Amsterdam, Abstract* **813** (2002) ; H1 collaboration, *contributed paper to EPS, Abstract* **092** (2003).
3. H1 collaboration, *Phys. Lett.* B **568**, 205 (2003) ; ZEUS collaboration, *contributed paper to EPS, Abstract* **549** (2003).
4. ZEUS collaboration, *Phys. Lett.* B **573**, 46 (2003) ; H1 collaboration, *contributed paper to EPS, Abstract* **115** (2003).
5. A. Freund and M.F. McDermott, *Eur. Phys. J.* C **23** (2002) ; Freund, *hep-ph/0306012.*