EXCLUSIVE DIFFRACTIVE FINAL STATES IN ELECTRON-PROTON COLLISIONS

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The exclusive diffractive production of vector mesons and real photons in *ep* collisions has been studied at HERA in a wide kinematic range. The most recent experimental results are presented.

1. Introduction

The diffractive scattering is a process where the colliding particles scatter at very small angles and without any color flux in the final state. This involves a propagator carrying the vacuum quantum numbers, called Pomeron and described, in the soft regime, within the Regge theory. The discovery of a big amount of diffractive events in DIS regime provided a hard scale which can be varied over a wide range and therefore it is an ideal testing for QCD models.

In particular, the diffractive production of Vector Mesons (VMs) and real photons in *ep* collisions allows to study the transition from the soft to the hard regime in strong interactions. The hard regime (high energy and low Bjorken-x) is dominated by the exchange of a hard Pomeron well described by perturbative QCD (pQCD), while at low-x the interaction is well described within the Regge phenomenology. Indicating with Q^2 the virtuality of the exchanged photon and with M^2 the square mass of the produced VM, HERA data suggested a universal hard scale, $Q^2 + M^2$, for the diffractive exclusive pruduction of VM and real photons, which indicates the transition from the soft to the hard regime.

2. Q^2 and W dependence of the cross section

A new precision measurement of the reaction $\gamma^* p \to \rho^0 p$ was published by ZEUS [1]. It was found that the cross section falls steeply with the increasing of Q^2 but, unlike it was observed for the J/ψ electroproduction [2,3], it cannot be described by a simple propagator term like $\sigma \propto (Q^2 + M^2)^{-n}$, in particular an n value increasing with Q^2 appears to be favored. Figure 1 reports the cross section for the ρ^0 electroproduction versus Q^2 compared with several theoretical predictions: the KWM model [4] based on the saturation model, the FSS model [5] with and without saturation and the DF model [6]. None of the available models gives a good description of the data over the full kinematic range of the measurement.

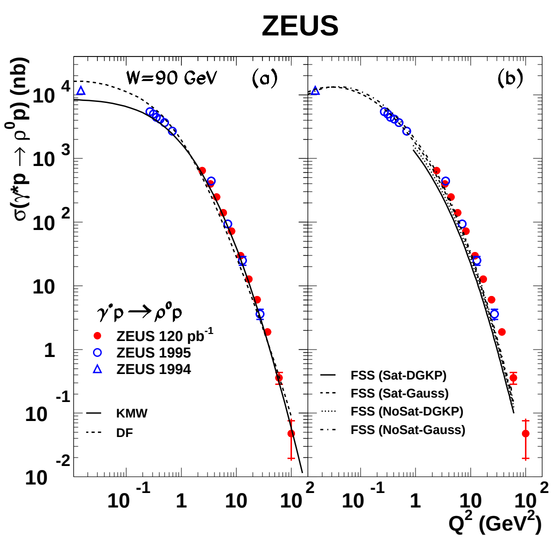

Figure 1. The $\gamma^* p \to \rho^0 p$ cross section as a function of Q^2 measured at $W = 90\ GeV^2$ and comared in (a) and (b) with different models as described in the text.

The soft to hard transition can be observed looking at the dependence of the VM photoproduction ($Q^2 = 0$) cross section from the $\gamma^* p$ centre of mass energy, W, where the scale is provided by M^2. Figure 2 collects the $\sigma(\gamma^* p \to V p)$ as a function of W from the lightest vector meson, ρ^0, to the heaviest, Υ, compared to the total cross section. The cross section rises with the energy as W^δ, where the δ exponent increases with the hard scale M^2 as expected for a transition from the soft to the hard regime. New results on the Υ photoproduction [7], recently published by ZEUS, confirmed the steeper rise of $\sigma(W)$ for higher vector meson masses.

The transition from the soft to the hard regime can also be studied

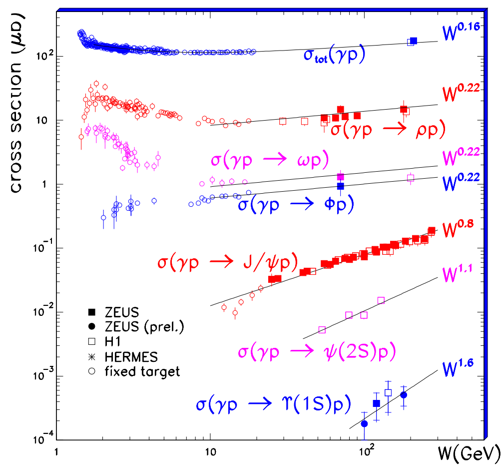

Figure 2. The W dependence of the cross section for exclusive VM photoproduction together with the total photoproduction cross section. Lines are the result of a W^{δ} fit to the data at high W-energy values.

varying Q^2. Recent results were achieved by H1 [8] and ZEUS [9] for the exclusive production of a real photon, the Deeply Virtual Compton Scattering (DVCS), where the hard scale is provided only by the photon virtuality, Q^2. Figure 3 shows the H1 (left) and the ZEUS (right) results. The steep rise with W of the cross section even at low-Q^2, seems to suggest that the most sensitive part to the soft scale comes from the wave function of the pruduced VM. A similar result was obtained for the J/ψ electroproduction [2,3].

The electroproduction of a large variety of VMs was studied at different Q^2 values and the corresponding slope δ is reported in Fig. 4 (left) versus the scale $Q^2 + M^2$, including the DVCS measurements. Data show a logarithmic shape $\sigma \propto \ln(Q^2 + M^2)$ and the behaviour seems to be universal with δ increasing from 0.2 at low scale, as expected from a soft Pomeron exchange [10] to ~ 0.8 at large scale values.

3. t dependence of the cross section

The differential cross section as a function of t can be parametrised by a fit $\frac{d\sigma}{d|t|} \propto e^{b|t|}$. Figure 4 (right) reports the collection of the b values versus the scale $Q^2 + M^2$ for the electroproduction of VMs and DVCS, with b decreasing from $\sim 11\ GeV^{-2}$ to $\sim 5\ GeV^{-2}$ as expected in hard regime.

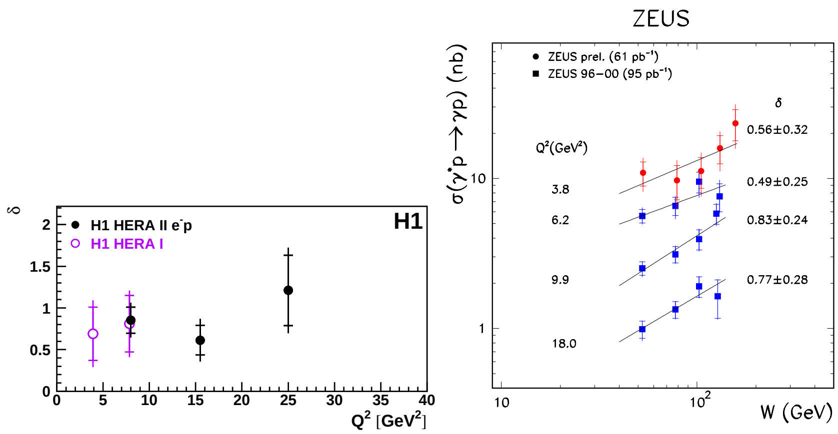

Figure 3. The W dependence of the cross section for a DVCS process. Lines come from a W^{δ} fit to the data. Left: the H1 measurement of the δ slope as a function of Q^2. Right: the new ZEUS preliminary measurement at low Q^2 (dots) together with the published measurements (squares).

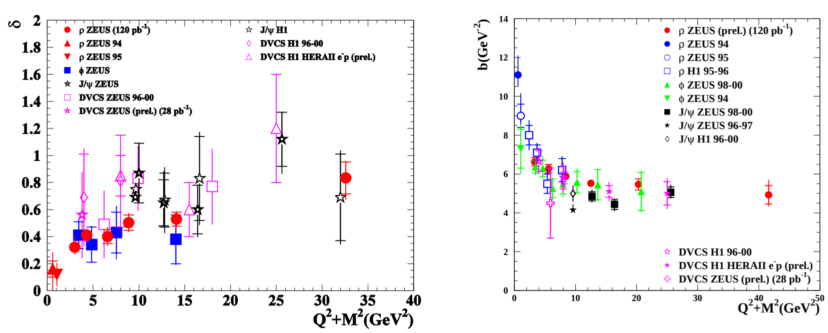

Figure 4. The dependence on the hard scale $Q^2 + M^2$ of the value δ (left) extracted from a fit W^{δ} and of the slope b (right) extracted from a fit $\frac{d\sigma}{dt} \propto e^{b|t|}$ for the exclusive VM electroproduction. DVCS is also included.

The measurement of $d\sigma/d|t|$ for the DVCS process, recentrly published by the H1 Collab [8], where t was obtained from the transverse momentum distribution of the photon, studied b versus Q^2 and W as shown in Fig. 5. b seems to decrease with Q^2 up to the value expected for a hard process but it doesn't depend on W. A new preliminary ZEUS measurement [9] of $d\sigma/d|t|$ has been achieved from a direct measurement of the proton final

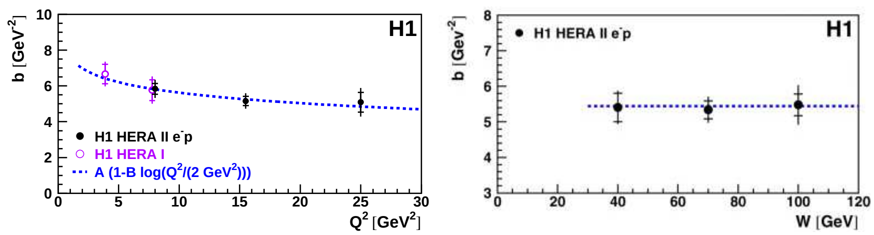

Figure 5. The t slope parameter b as a function of Q^2 (left) and W (right).

state of using a spectrometer based on the roman pot thechnique. The result $b = 4.4 \pm 1.3\ (stat.) \pm 0.4\ (syst.)\ GeV^{-2}$, measured at $Q^2 = 5.2\ GeV^2$ and $W = 104\ GeV$, is consistent, within the large uncertainties due to the low acceptance of the spectrometer, with the H1 result [8] of $b = 5.45 \pm 0.19\ (stat.) \pm 0.34\ (syst.)\ GeV^{-2}$ at $Q^2 = 8\ GeV^2$ and $W = 82\ GeV$.

Since b value can be related via a Fourier transform to the impact parameter and assuming that the exclusive process in the hard regime is dominated by gluons, the relation $\langle r^2 \rangle = b(\hbar c)^2$ can be used to obtain the radius of the gluon confinement area in the proton. $b \sim 5\ GeV^2$ corresponds to $\langle r^2 \rangle \sim 0.6\ fm$ smaller than the proton radius ($\sim 0.8\ fm$) indicating that the gluons are well contained within the charge-radius of the proton.

References

1. ZEUS Coll., S.Chekanov et al., *Exclusive ρ^0 Production in Deep Inelastic Scattering at HERA*, *PMC Phys.* **A**, 1 (2007).
2. ZEUS Coll., S.Chekanov et al., *Exclusive Electroproduction of J/ψ mesons at HERA*, *Nuc. Phys.* **B695**, 3 (2004).
3. H1 Coll., S.Chekanov et al., *Elastic J/ψ Production at HERA*, *Eur. Phys. J.* **C46**, 585 (2006).
4. H. Kowalski, L. Motyka and G. Watt, *Exclusive diffractive processes at HERA within the dipole picture*, *Phys. Rev.* **D74**, 074016 (2006).
5. J.R. Forshaw, R. Sandapen and G. Shaw, *Color dipoles and ρ, ϕ electroproduction*, *Phys. Rev.* **D69**, 094013 (2004).
6. H.G. Dosch and E. Ferreira, *Nonperturbative and perturbative aspects of photo- and electroproduction of vector mesons*, *Eur. Phys. J.* **C51**, 83 (2007).
7. ZEUS Coll., S.Chekanov et al., *ZEUS-prel-07-015*.
8. H1 Coll., F.D. Aaron et al., *Measurement of Deeply Virtual Compton Scattering and its t-dependence at HERA*, *Phys. Lett.* **B659**, 796 (2008).
9. ZEUS Coll., S.Chekanov et al., *ZEUS-prel-07-016*.
10. A. Donnachie and P.V. Landshoff, *Phys. Lett.* **B296**, 227 (1992).