VECTOR MESON PRODUCTION AT HERA

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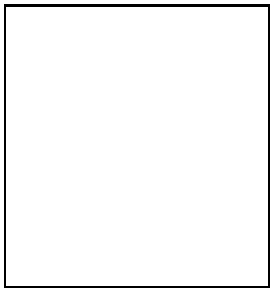


At the HERA collider the experiments H1 and ZEUS have studied the exclusive production of vector mesons over a wide kinematical range. The recent measurements and their discussion within the framework of color dipole models and pQCD are reported.

1 Introduction

Exclusive photo- and electroproduction of light (ρ, ω, ϕ) and heavy ($J/\psi, \psi', \Upsilon$) vector mesons (VM) have been subject of intensive studies at HERA. The accelerator and its general purpose detectors H1 and ZEUS provide a unique opportunity to measure the exclusive diffractive production of vector mesons with different masses M_{VM} in photo- and electroproduction.

1.1 Diffractive vector meson production

The process $ep \to e(VM)p$, drawn in fig. 1, can be described as a two step process. The incoming electron emits a photon. This photon fluctuates into a $q\bar{q}$ state which scattters with the proton by exchanging nothing but momentum.
The kinematical variables which are used to characterize the process are: the 4-momentum transfer squared Q^2 at the electron vertex, the center of mass energy of the γ-proton system W and the 4-momentum transfer squared t at the proton vertex. The dependences of the cross sections on these variables are presented in the ranges: $2 < Q^2 < 100\ GeV^2$, $30 < W < 260$ GeV and $|t| < 1\ GeV^2$.

In the absence of a hard scale the colorless exchange between the vector meson and the proton can be modeled by a soft pomeron trajectory using the Regge approach. In this approach the cross section is predicted to rise slowly with W. In the presence of a hard scale, the vector meson production can be calculated using pertubative QCD (pQCD). In this case the colorless

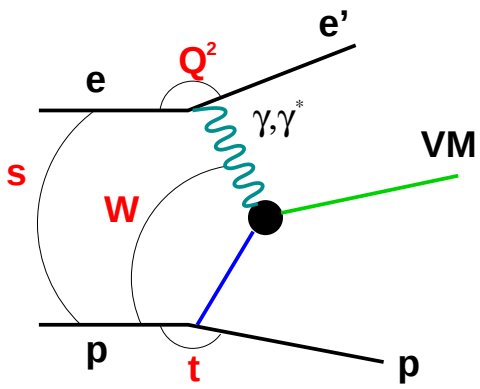


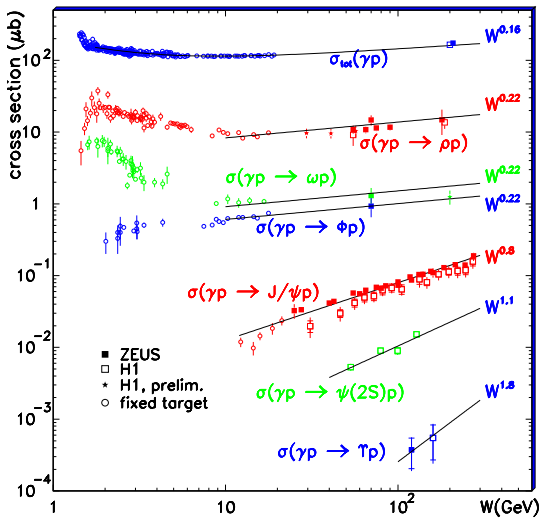
Figure 1: Diagram of exclusive vector meson (VM) production at HERA.

exchange is modeled in leading order by a pair of gluons, the cross section is proportional to the square of the gluon density. This predicts a steep rise with increasing values of W.

2 W dependence

For exclusive photoproduction ($Q^2 \approx 0\ GeV^2$) of vector mesons the W dependence is shown in fig.2a). The lines indicate the rising of the cross sections assuming the form W^δ. For the light vector mesons ρ, ω and ϕ the slope is $\delta \approx 0.22$. This value is very similar to the total photoproduction cross section and is predictied by the Regge approach. For the heavier vector mesons J/ψ, $\psi(2s)$ and Υ the observed slope is higher ($\delta \gtrsim 0.8$) .

a)



b)

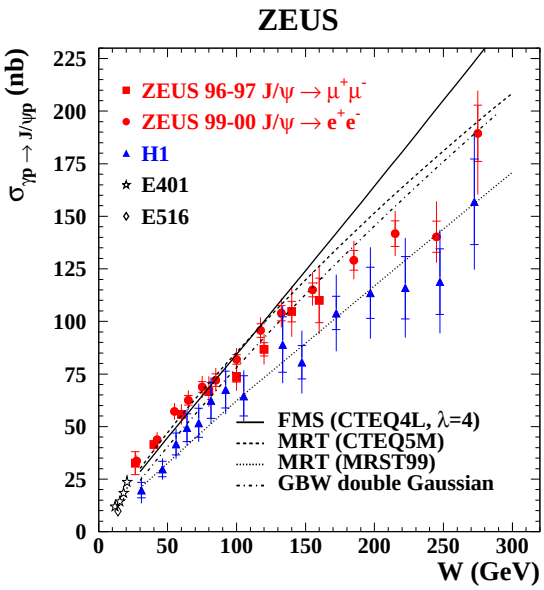


Figure 2: a) Compilation of W dependences for exclusive photoproduction of light and heavy vector mesons. The lines show the behaviour of the cross section assuming the form W^δ. The values for δ are given at the right edge. b) W dependence of the J/ψ photoproduction cross section in comparison with theoretical models based on pQCD.

For the heavy vector mesons the masses of the charm and the bottom quarks provide a hard scale which allows the use of pQCD to calculate the cross sections. Such models are able to describe the J/ψ [1,2] cross section as it is shown in fig.2b). In particular the steep rise as a

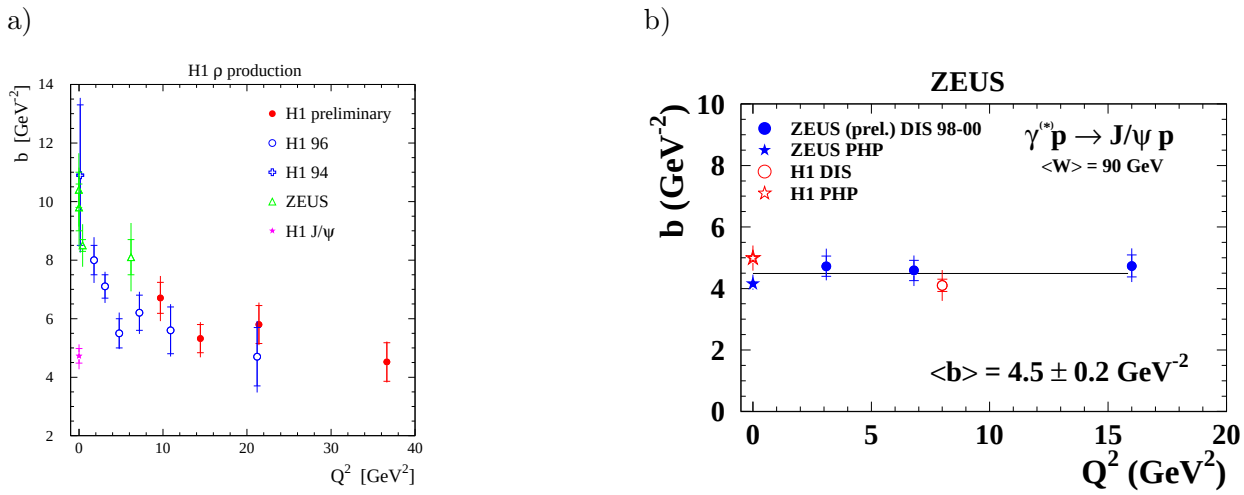


Figure 3: a) Fitted values of the b-slope as a function of Q^2 in ρ photo- and electroproduction. b) Fitted values of the b-slope as a function of Q^2 in J/ψ photo- and electroproduction.

function of the energy W is well described by pQCD [3].

3 Q^2 and $|t|$ dependence

The $|t|$ dependence of the cross section for exclusive vector meson production is well described by the form $\frac{d\sigma}{dt} \propto e^{-b|t|}$ for small values of t ($|t| < 1\ GeV^2$). Fig.3a+b) show the dependence of the slope b as a function of Q^2 for ρ [4] and J/Ψ [5] in photo- and electroproduction. The slope of the ρ cross section decreases with increasing Q^2. This indicates that the size of the interacting region is changing with Q^2. On the right hand side one can see that, in contrast to the ρ, the J/ψ has is no change in the slope with Q^2. The production mechanism for J/ψ at the photoproduction limit is already the same as in the higher $Q^2 > 0$ range. This is interpreted as due to the fact that the J/ψ mass alrady provides a hard scale at $Q^2 = 0$, in contrast to exclusive ρ electroproduction.

In the diffractive picture b is related to the radii of the colliding objects i.e. of the proton and the VM: $b \propto r^2_{VM} + R^2_{\text{proton}}$. The values of $b \approx 4.5\ GeV^{-2}$ measured in the hard regime implies a combined radius of the order of the size of the proton. This observation suggests that the transverse size of the $q\bar{q}$ fluctuation producing the J/ψ in photoproduction and the ρ at high Q^2 is smaller than that of the proton.

4 Decay angular distributions

The production and decay of a VM into a pair of oppositely charged particles can be described in terms of three angles: Φ_h, the angle between the VM production plane and the lepton scattering plane; θ_h and ϕ_h, the polar and azimuthal angles of the positively charged decay lepton in the s-channel helicity frame.

Under the assumption of s-channel helicity conservation (SCHC), the angular distribution for the decay of the VM depends only on two angles, θ_h and $\psi_h = \phi_h - \Phi_h$. From the θ_h distribution the spin density matrix element r^{04}_{00} can be extracted which is proportional to the the helicity amplitude T_{00}. T_{00} corresponds to an amplitude, where a longitudinally polarized photon yields a longitudinally polarized VM. Also under the assumption of SCHC the ratio R of cross sections for longitudinally and transverse polarized photons can be calculated using r^{04}_{00}; ($R = \frac{1}{\epsilon}\frac{r^{04}_{00}}{1-r^{04}_{00}}$). This measurement for ρ electroproduction is shown in fig.4). The left plot shows the rise of R;

a)

b)

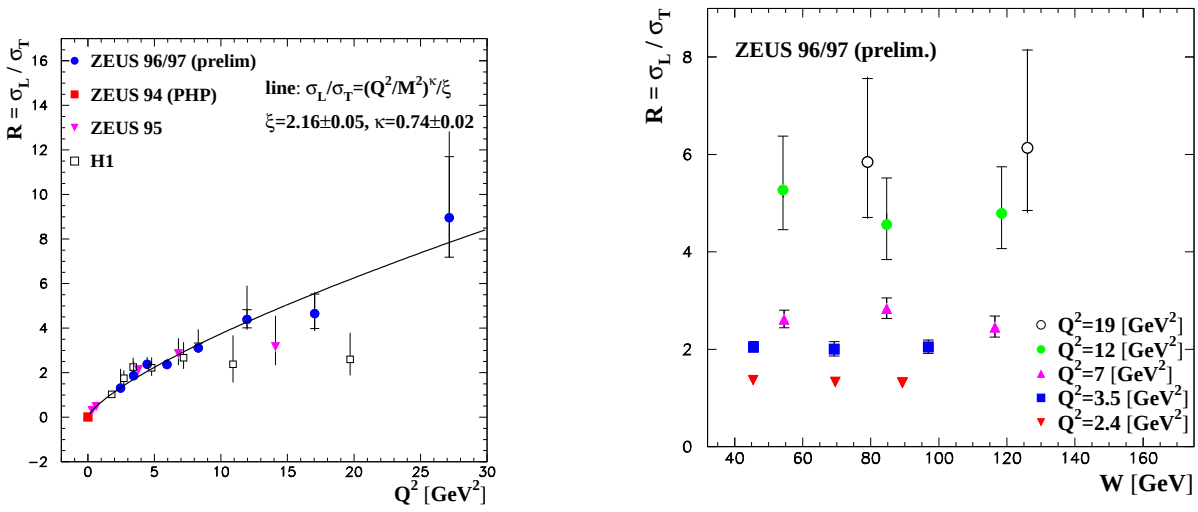


Figure 4: a) Q^2 dependence of R in ρ electroproduction. b) W dependence of R in ρ electroproduction in different bins of Q^2.

it indicates that the longitudinal dipole configuration becomes more dominant when increasing the value of Q^2. Within pQCD models a small dipole is most likely to be produced if the virtual photon is longitudinally polarized, which predicts that $|T_{00}|$ is the dominant amplitude.

Fig.4b) shows the ratio R in ρ electroproduction for different values of Q^2 regions as a function of W. The data is consistent with no W dependence.

Acknowledgments

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