VECTOR MESON PRODUCTION AT HERA

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Results on elastic vector meson production at the H1 and ZEUS experiments at HERA ep collider are reviewed, both for photoproduction ($Q^2 \sim 0$) and at high Q^2. The data are compared to models based on either perturbative or non-perturbative QCD.

1 Introduction

The HERA collider (27.5 GeV electrons or positrons on 820 GeV protons) allows diffractive vector meson production (figure 1) to be studied at large centre of mass energies of the γp system, W, up to $\sim$ 150 GeV. HERA also allows such studies to be done both at low $Q^2 = -(k-k')^2$, where the photon is almost real, and at high Q^2. Soft diffractive vector meson production can be described by the vector meson dominance model and soft diffractive hadron-hadron scattering. In the vector meson dominance model the photon behaves as the superposition of vector mesons, a vector meson having the same quantum numbers as the photon ($\mathrm{J^{PC}} = 1^{--}$). The photon-proton interaction can then be considered as a vector meson-proton interaction which displays the characteristics of soft diffractive hadron-hadron interactions, such interactions being described in terms of pomeron exchange. After the interaction, the proton can either remain intact or dissociate into an higher mass state. Only the former case, referred to as elastic production, will be considered here.

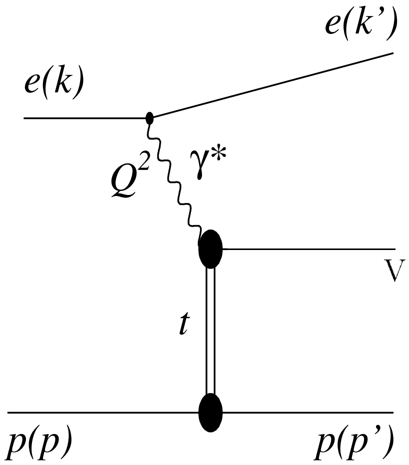

Figure 1:Elastic vector meson production at HERA.

Various models for vector meson production exist which are based on either perturbative[1] or non-perturbative QCD[2]. In the case of perturbative QCD, a hard scale is required which is provided by either high Q^2, high quark mass in the vector meson, or high $t = (p-p')^2$. In the models based on perturbative QCD, the pomeron is represented by a gluon ladder. Thus, the photon-proton cross-section, $\sigma_{\gamma^* p}$, is predicted to rise quickly with W due to the rapid rise in the gluon density in the proton as the Bjorken scaling variable x falls, x being approximately given by Q^2/W^2 at small x. This is in contrast to soft pomeron models where $\sigma_{\gamma^* p}$ is predicted to rise only slowly with W.

2 Elastic Vector Meson Photoproduction

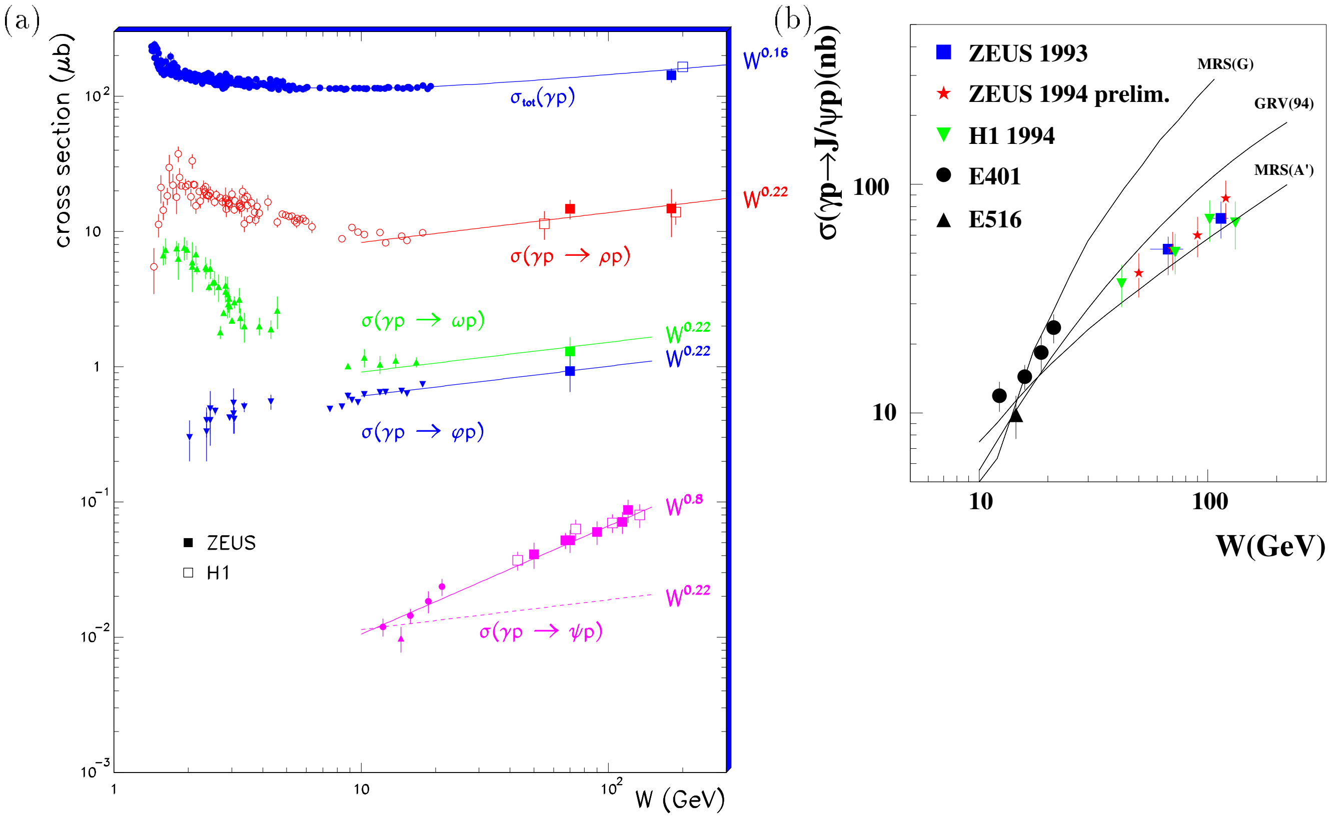

Figure 2:(a) The W dependence of the cross-section for the ρ°, ω, ϕ and J/ψ vector mesons. (b) A comparison of the W dependence of the cross-section for the J/ψ vector meson with perturbative QCD predictions for different parton density distributions in the proton.

The ρ°, ω, ϕ and J/ψ vector mesons have been observed in photoproduction at HERA [3,4,5,6,7,8]. They all show an exponential fall of $d\sigma_{\gamma^* p}/dt$ with $|t|$, e^{bt}, characteristic of diffraction, with the value of $b = 4.0 \pm 0.2 \pm 0.2$ GeV^{-2} for J/ψ production being found to be smaller than for the other vector mesons, eg. $b = 9.6 \pm 0.8 \pm 1.2$ GeV^{-2} for the ρ°. For the soft pomeron, the value of b is expected to rise with W, referred to as shrinkage, whereas most hard models predict no or little shrinkage. When compared to low energy data, the values of b obtained for the ρ°, ω and ϕ vector mesons are consistent with shrinkage. For the J/ψ vector meson, no conclusions about shrinkage can be drawn from HERA data with present statistics or when compared with low energy data.

Another characteristic property of diffraction, referred to as s-channel helicity conservation, is that the vector meson has the same helicity as the photon. The angular distribution of the vector meson decay products is found to be consistent with the vector mesons being produced with helicity 1. As the initial real photon also has helicity 1, ie. is transversely polarised, this is consistent with s-channel helicity conservation.

The W dependence of $\sigma_{\gamma^* p}$ for the ρ°, ω, ϕ and J/ψ vector mesons are shown in figure 2(a). The ρ°, ω and ϕ vector mesons all show a slow rise with W as predicted by the soft pomeron models, however, the J/ψ vector meson shows a fast rise described by the hard pomeron models where the hard scale is provided by the mass of the charm quark. In figure 2(b), the J/ψ data is compared to perturbative QCD predictions [1] for different parton density distributions in the proton. As there are large uncertainties in the normalisation of the predicted curves, only the shapes of the predicted curves should be compared with the data.

3 Elastic Vector Meson Production at High Q^2

The ρ°, ϕ and J/ψ vector mesons have been observed at high Q^2 at HERA [9,10,11]. They all show a fast rise of $\sigma_{\gamma^* p}$ with W at high Q^2 when compared to the low energy data, in contrast to the behaviour of the ρ° and ϕ vector mesons in photoproduction. This fast rise of the W dependence of $\sigma_{\gamma^* p}$ is predicted by hard pomeron models in which the hard scale is provided by Q^2. Figure 3(a) shows the W dependence of $\sigma_{\gamma^* p}$ for the ρ° meson at different values of Q^2, including measurements made at $Q^2 = 0.48\text{GeV}^2$ where the slow rise of $\sigma_{\gamma^* p}$ with W as in photoproduction is still seen.

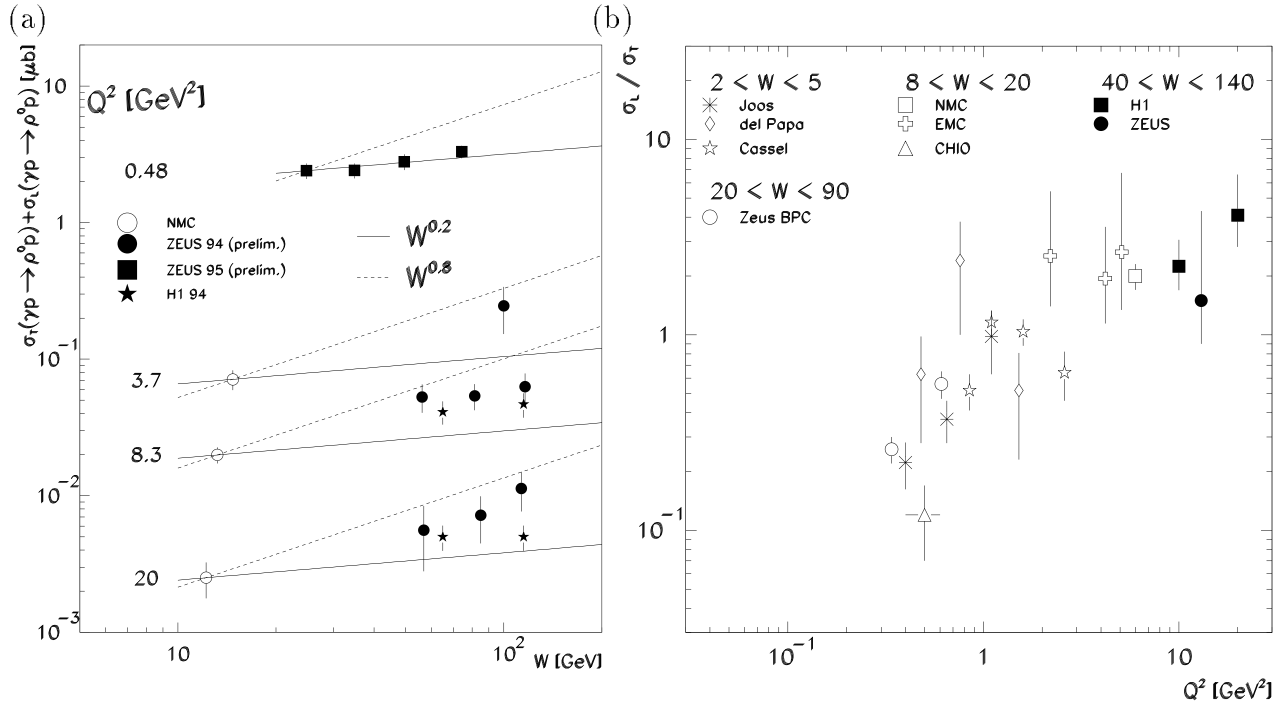

Figure 3:(a) The W dependence of the cross-section for the ρ° meson at high Q^2. (b) The Q^2 dependence of $R = \sigma_L/\sigma_T$ for the ρ° meson.

The angular distribution of the decay products of the ρ° and ϕ mesons are found to be consistent with vector meson production becoming predominantly longitudinally polarised at high Q^2. Assuming s-channel helicity conservation, the ratio of the longitudinal and transverse cross-sections, $R = \sigma_L/\sigma_T$, can be determined from the ratio of the longitudinal and transverse polarisation of the vector mesons and the expected increase of R with Q^2 is observed (figure 3(b)).

The ρ°, ϕ and J/ψ vector mesons are found to have exponential t distributions at high Q^2 as in photoproduction but for the ρ° and ϕ the value of the b slope is found to be smaller than for photoproduction as can be seen in figure 4(a) for the ρ°. For the J/ψ the $b = 3.8 \pm 1.2^{+2.0}_{-1.6}$ GeV^{-2} slope is found to be similar to the value for photoproduction, $b = 4.0 \pm 0.2 \pm 0.2$ GeV^{-2}. For the ρ° meson, there is an indication that b falls with Q^2 (figure 4(a)) which can be understood in terms of the photon becoming more compact with increasing Q^2. Figure 4(b) shows the W dependence of b for the ρ° meson from which no conclusions can be drawn about shrinkage.

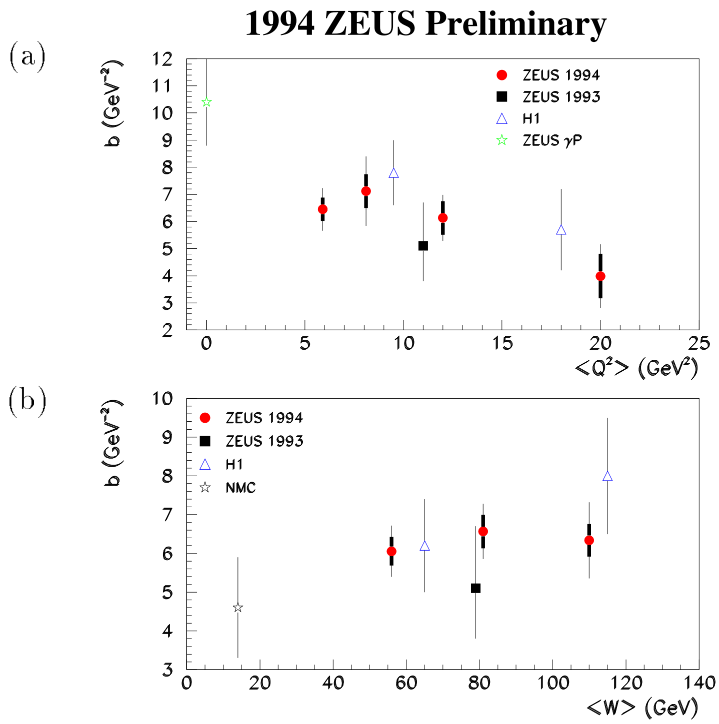

Figure 4:(a) The Q^2 dependence of b for the ρ^O meson. (b) The W dependence of b for the ρ^O meson.

4 Summary

Elastic vector meson production has been studied at HERA both in photoproduction and at high Q^2. In photoproduction the ρ°, ω and ϕ vector mesons show a slow rise of $\sigma_{\gamma^* p}$ with W consistent with the soft pomeron whereas the J/ψ shows a fast rise of $\sigma_{\gamma^* p}$ with W as predicted by hard pomeron models in which the hard scale is provided by charm quark mass.

The ρ°, ω, ϕ and J/ψ data are consistent with s-channel helicity conservation and ρ°, ω and ϕ mesons show shrinkage in their t distributions when compared to low energy data.

At high Q^2, the ω, ϕ and J/ψ mesons show a fast rise of $\sigma_{\gamma^* p}$ with W as predicted by hard pomeron models with the hard scale being provided by Q^2. The ρ° and ϕ mesons are found to be produced predominantly longitudinally polarised and the ρ° meson shows a fall in b with Q^2.

References

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