VECTOR MESON PRODUCTION AT HERA

B. NAROSKA,
on behalf of the H1 and ZEUS collaborations
University of Hamburg, II. Inst. f. Experimentalphysik
Luruper Chaussee 149, 22600 Hamburg, Germany
e-mail:naroska@mail.desy.de

New results on elastic (exclusive) production of vector mesons are presented, mainly on J/ψ and ϕ mesons with emphasis on an interpretation of the data within pQCD.

1 Introduction

Production of vector mesons at HERA has become a rich field of experimental and theoretical research. In this report only fairly new results will be shown concentrating on J/ψ and ϕ meson. For an overview of data on ρ mesons see [1]. Vector mesons can be produced elastically (i.e. exlusively), i.e. in the reaction $ep \rightarrow eVp$, where V denotes the vector meson and the proton remains a proton. The largest background is the proton dissociative process where the proton breaks up into a low mass system. H1 and ZEUS have developed efficient procedures to remove and correct for this and other backgrounds [2,3,4].

There is by now no doubt that pQCD can describe the elastic production of vector mesons [5,6] via exchange of a colour neutral system of gluons, i.e. in leading order via exchange of two gluons. The QCD scale can be given by the mass of the vector meson, as in the case of the J/ψ or by

Table 1: Kinematical Quantities.

ep center of mass energy squared	$s = (p+k)^2$	k,p incoming lepton, proton
neg. momentum transfer squared	$Q^2 = -q^2 = -(k-k')^2$	k' scattered lepton
scaled energy transfer	$y = (p \cdot q)/(p \cdot k)$	q exchanged photon
γp center of mass energy squared	$W_{\gamma p}^2 = (p+q)^2 = ys - Q^2$	
momentum transfer proton	$t = (p-p')^2$	p' scattered proton

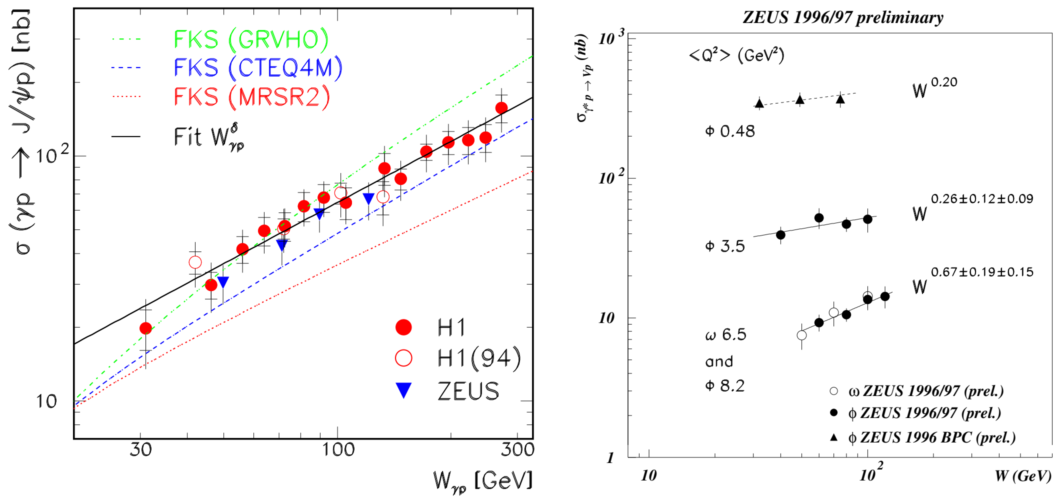

Figure 1: Total cross sections for $\gamma p \to V\,p$ as a function of $W_{\gamma p}$ for $V = J/\psi$ (left) and for $V = \phi$ (right). Fits to the data of the form $W_{\gamma p}^{\delta}$ are shown. In the left plot also results from pQCD calculations are given using various gluon density distributions.

Q^2 as for the "light" vector mesons ρ, ω and ϕ. Whether the momentum transfer t between incoming and outgoing proton (or the outgoing dissociated proton), can also serve as a hard scale is still under experimental investigation [7]. A signature for the "hard" behaviour is the fast rise of the integrated $\gamma\,p$ cross section for vector meson production with $W_{\gamma p}$.

2 Total Cross Sections for J/ψ and ϕ Mesons

Photoproduction of J/ψ mesons has been measured by the H1 collaboration [4] in the range of $26 \le W_{\gamma p} \le 285$ GeV. Leptonic decays into e^+e^- or $\mu^+\mu^-$ are used depending on the detector region. The data are shown in Fig. 1 and are compared with results from pQCD calculations by Frankfurt et al. [5] using various gluon density functions. The main prediction concerns the slope of the data which is seen to be well represented by the calculation using the CTEQ4M or MRSR2 gluon densities. A fit to the data of the form $W_{\gamma p}^{\delta}$ yields $\delta = 0.83 \pm 0.07$ which is much larger than $\delta \sim 0.3$ found in soft processes.

New data on the production of ϕ mesons at $Q^2 \gtrsim 1$ GeV^2 became available from H1 [8] and ZEUS [7,9] both using the decay to K^+K^-. ZEUS also shows first results on ω production in a range $3 < Q^2 < 20$ GeV^2 using the decay $\omega \to \pi^+\pi^-\pi^0$. The integrated cross sections $\sigma(\gamma^* p \to \phi p)$ and $\sigma(\gamma^* p \to \omega p)$ are shown in Fig. 1. Parameterising them as $W_{\gamma p}^{\delta}$ a clear increase of δ with Q^2 can be seen as has been found for the ρ meson [1] .

We conclude: if the fast increase of $\sigma(\gamma p \to Vp)$ with $W_{\gamma p}$ is indeed a signature for a hard process, either M_V^2 or Q^2 serve as hard scales.

3 Determination of the Regge Trajectory for J/ψ Photoproduction

In order to determine the properties of the exchange mediating the interaction between the J/ψ meson and the proton, Regge language is used. The Regge trajectory is determined by H1 for photoproduction of J/ψ mesons assuming a simple linear form $\alpha(t) = \alpha_0 + \alpha' t$. $\alpha(t)$ determines the dependence of the cross sections on the energy $W_{\gamma p}$ as $W_{\gamma p}^{4(\alpha(t)-1)}$. In "hard" interactions α' is expected to be small [5] while in "soft" reactions $\alpha' \approx 0.25$ GeV^{-2} has been found [10].

H1 determined the trajectory for J/ψ production using data from one experiment only and thus avoiding normalisation problems between data from different experiments. The data in the range $40 \le W_{\gamma p} \le 150$ GeV are used. $d\sigma/dt$ is determined at 5 values of t. For these 5 values

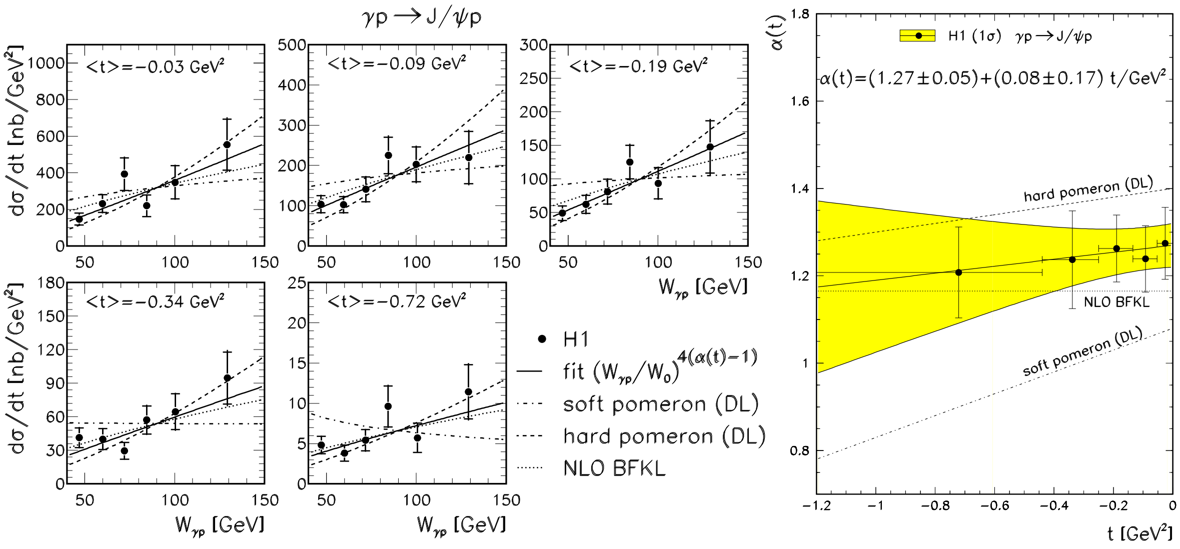

Figure 2: Left: The differential cross section $d\sigma/dt$ as a function of $W_{\gamma p}$ in five bins of t together with a fit of the form $d\sigma/dt = N \cdot (W_{\gamma p}/W_0)^{4(\alpha(t)-1)}$ (solid line). Predictions of models using soft and hard pomeron trajectories are shown. Right: The measured Regge trajectory for the process $\gamma p \to J/\psi\, p$. The solid line shows the result of the fit. The one standard deviation contour is indicated by a shaded band. Also shown are the soft and the hard Donnachie-Landshoff pomeron trajectories [10] and a result based on a NLO BFKL calculation [11].

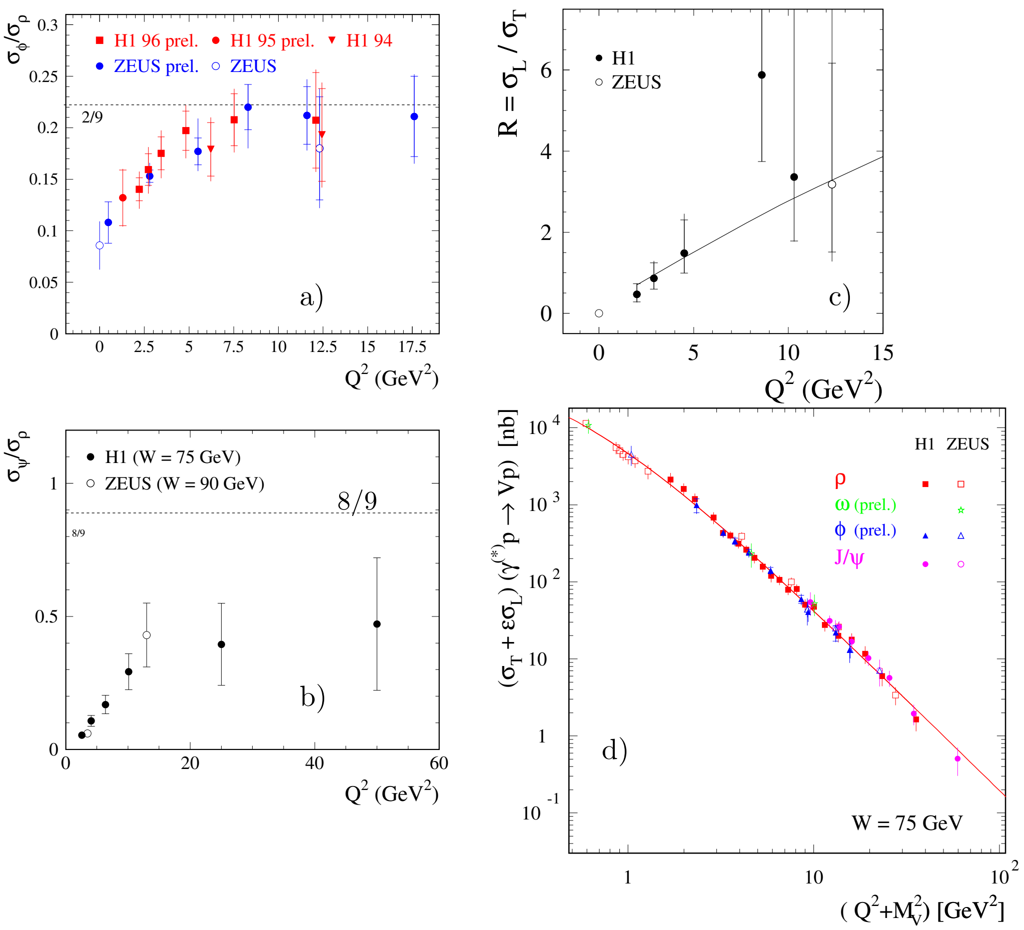

Figure 3: The ratio of the integrated cross sections (a) σ_ϕ/σ_ρ and (b) $\sigma_{J/\psi}/\sigma_\rho$ as a function of Q^2. (c)$R = \frac{\sigma_L}{\sigma_T}$ for ϕ meson production as a function of Q^2. The curve is a result from a pQCD calculation [6]. (d) The integrated cross sections for vector mesons scaled by the SU(4) ratios as a function of $Q^2 + M_V^2$. The data are scaled to $W_{\gamma p} = 75$ GeV.

of t the dependence of $d\sigma/dt$ on $W_{\gamma p}$ is shown in Fig. 2 (left). A fit to the form $W_{\gamma p}^{4(\alpha(t)-1)}$ is performed and the resulting values for $\alpha(t)$ are shown in Fig. 2 (right). A linear fit to $\alpha(t)$ yields the parameters of the fitted trajectory which are also given in the figure. The 1σ contour is shown as are results of various predictions for the pomeron based on non-perturbative models and on a NLO BFKL calculation [11]. In contrast to the results for the ρ and ϕ mesons α_0 for the J/ψ is larger and α' is compatible with 0.

4 The Scale for Production of Vector Mesons

When Q^2 increases the exchanged photon acquires a longitudinal component. $R = \sigma_L/\sigma_T$ has previously been measured for the ρ and J/ψ meson [1,3]. In Fig. 3c the ratio R is shown for the ϕ meson as a function of Q^2 and is seen to increase. The curve based on pQCD and parton hadron duality [6] gives a good description of the data.

If in elastic vector meson production the photon couples indeed to quarks (as opposed to coupling to a hadron) and the interaction of the quark pair of the vector meson with the proton is universal the ratio of cross sections should only depend on the quark content of the vector mesons. This is indeed observed in Fig. 3a,b where σ_ϕ/σ_ρ and $\sigma_{J/\psi}/\sigma_\rho$ are plotted as functions of Q^2. The ratio is seen to approach the value of 2/9 for the ϕ expected from the simple SU(4) quark counting. The ratio $\sigma_{J/\psi}/\sigma_\rho$ increases slowly and is still below the expected value of 8/9 at $Q^2 \sim 40$ GeV^2, but the errors are still large. A universal behaviour of the cross section for all vector mesons is observed in Fig. 3d, where all available data, for ρ, ω, ϕ and J/ψ mesons are shown as a function of $Q^2 + M_V^2$. The data have been scaled to a common $W_{\gamma p} = 75$ GeV using the measured $W_{\gamma p}$ dependence. They have been scaled by the quark charges assuming the SU(4) ratio $\rho : \omega : \phi : J/\psi = 9 : 1 : 2 : 8$. The data are seen to agree well with each other and can be described by a function $(Q^2 + M_V^2 + a)^b$ with $a = 0.42 \pm 0.09$ GeV^2 and $b = -2.37 \pm 0.10$, which was fitted to the ρ data. We can conclude that within present errors $(Q^2 + M_V^2)$ is a good scale for photoproduction of vector mesons at low values of t.

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References

1. ZEUS Coll., J. Breitweg et al., Eur. Phys. J. **C6** (1999) 603; H1 Coll., C. Adloff et al., Eur. Phys. J. **C13** (2000) 371; ZEUS Coll., J. Breitweg et al., Eur. Phys. J. **C12** (2000) 393; B. Clerbaux, Hard Diffraction in Vector Meson Production at HERA, Moriond 1999
2. ZEUS Coll., J. Breitweg et al., Z. Phys. **C75** (1997) 215
3. H1 Coll., C. Adloff et al., Eur. Phys. J. **C10** (1999) 373
4. H1 Coll., C. Adloff et al., DESY 00-037; hep-ex 0003020
5. L. Frankfurt, W. Koepf and M. Strikman, Phys. Rev. **D57** (1998) 512
6. A.D. Martin, M.G. Ryskin, T.Teubner, DTP 99/98, hep-ph 9912551;
   T. Teubner, DESY 99-154 (1999), hep-ph/9910329
7. ZEUS Coll., contributed paper 499 to Int. Europhys. Conf. HEP99, Tampere (1999)
8. H1 Coll., C Adloff et al., DESY 00-070; hep-ex/0005010
9. ZEUS Coll., contributed paper 793 to ICHEP98, 1998, Vancouver
10. A. Donnachie and P. V. Landshoff, Phys. Lett. **B348** (1995) 213; ibid. **B437** (1998) 408
11. S.J. Brodsky et al., JETP Lett. **70** (1999) 155