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Photoproduction of vector mesons in the Soft Dipole Pomeron model

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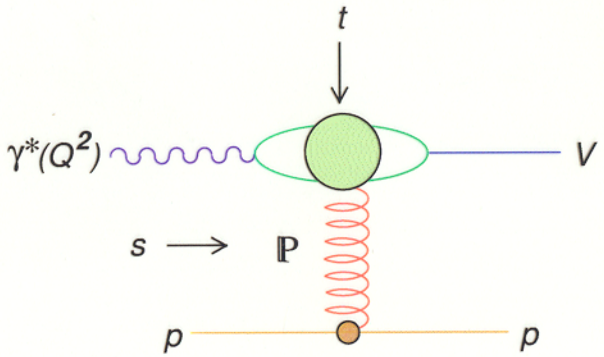


ZEUS Collaboration (EPJC-2002), J/ψ:

$$\frac{d\sigma}{dt} \propto W^{4(\alpha_{\mathcal{P}}-1)} \cdot e^{b(W)t}, \quad (s \equiv W^2 = (p+q)^2) \Rightarrow$$

$$\alpha_{\mathcal{P}}(t) \approx 1.2 + 0.115t.$$

Moreover, if $V = \rho, \omega, \varphi, J/\psi$ then $\alpha_{\mathcal{P}}(0) = \alpha_{\mathcal{P}}(0, M_V)$.

However

COMPETE Collaboration (Phys.Rev.D-2002): $(h = p, \bar{p}, \pi^{\pm}, K^{\pm}, \gamma)$

$$\sigma_{hh} \propto \ln^{\gamma} s(\gamma = 1, 2) \quad \text{or} \quad \sigma_{hh} \propto s^{\alpha}, \quad \alpha \lesssim 0.1$$

Pomeron is a triple ($\gamma = 2$) or double ($\gamma = 1$) pole in j-plane.

Pomeron is a universal singularity, its properties (form of singularity, trajectory) do not depend on the external particles.

Regge approach

$$A(s,t;Q^2) \approx \sum_i \beta_i(t;Q^2) z^{\alpha_i(t)-1}, \quad z \propto \cos\theta_t,$$

$$z = \frac{2(W^2 - M_p^2) + t + Q^2 - M_V^2}{\sqrt{(t + Q^2 - M_V^2)^2 + 4M_V^2 Q^2}}.$$

$$\sigma_{el}^{\gamma p \to Vp}(z, M_V^2, Q^2) = 4\pi \int_{t_-}^{t_+} dt |A^{\gamma p \to Vp}(z,t; M_V^2, Q^2)|^2,$$

$$-1 \leq \cos\theta_s \leq 1 \quad \Rightarrow \quad t_\pm \quad (W \to W_{thr} \Rightarrow t_- \to t_+).$$

$$A(z,t;M_V^2,Q^2) = N_V \left\{ \mathcal{P}(z,t;M_V^2,Q^2) + \mathcal{R}(z,t;M_V^2,Q^2) \right\},$$

$N_\rho = \frac{3}{\sqrt{2}}$; $N_\omega = \frac{1}{\sqrt{2}}$; $N_\phi = 1$; $N_{J/\psi} = 2$. (J.Nemchick *et al.*, Zeit.Phys.-1997)
$N_\Upsilon = N_\phi (N_{J/\psi})$

Pomeron contribution: simple + double j-poles

$$\mathcal{P}(z,t;M_V^2,\tilde{Q}^2) = i f_{\mathcal{P}}(Q^2)(-iz)^{\alpha_{\mathcal{P}}(t)-1} \times \{g_0(t;M_V^2,\tilde{Q}^2) + g_1(t;M_V^2,\tilde{Q}^2) ln(-iz)\}.$$

Pomeron trajectory: $\alpha_{\mathcal{P}}(t) = 1 + \gamma\left(\sqrt{4m_\pi^2} - \sqrt{4m_\pi^2 - t}\right)$

$$\tilde{Q}^2 = Q^2 + M_V^2, \quad f_{\mathcal{P}}(0) = 1.$$

$$g_i(t;M_V^2,\tilde{Q}^2) = \frac{g_i}{(Q_i^2 + \tilde{Q}^2)^2} exp(b_i(t;\tilde{Q}^2)) \quad i = 0,1$$

$$b_i(t;\tilde{Q}^2) = \left(b_{i0} + \frac{b_{i1}}{1 + \tilde{Q}^2/Q_b^2}\right)\left(\sqrt{4m_\pi^2} - \sqrt{4m_\pi^2 - t}\right) \quad i = 0,1$$

Reggeon contributions ($R = f, \pi$)

$$\mathcal{R}(z,t;M_V^2,\tilde{Q}^2) = i f_{\mathcal{R}}(Q^2) g_{\mathcal{R}}(t;M_V^2,\tilde{Q}^2)(-iz)^{\alpha_{\mathcal{R}}(t)-1}, \quad f_{\mathcal{R}}(0) = 1,$$

$$\alpha_{\mathcal{R}}(t) = \alpha_{\mathcal{R}}(0) + \alpha'_{\mathcal{R}} t, \quad \alpha_f(0) = 0.8,\ \alpha_\pi(0) = 0,\ \alpha'_{\mathcal{R}} = 0.85$$

$$g_{\mathcal{R}}(t;M_V^2,\tilde{Q}^2) = \frac{g_{\mathcal{R}} M_p^2}{(Q_{\mathcal{R}}^2 + \tilde{Q}^2)^2 \tilde{Q}^2} exp(b_{\mathcal{R}}(t;\tilde{Q}^2)),$$

$$b_{\mathcal{R}}(t;\tilde{Q}^2) = \frac{b_{\mathcal{R}} t}{1 + \tilde{Q}^2/Q_b^2}$$

f contributes to ρ, ω, ϕ amplitudes. π contributes only to ω one.
Only Pomeron contributes to J/ψ amplitude.

Parameters were determined from the fit to the data.

First step, $Q^2 = 0$.

12 parameters ($Q_0^2 = Q_R^2 = 0$), 357 exp. points ($\sigma_{el}, d\sigma/dt$ for $\rho, \omega, \phi, J/\psi$.)

Result: $\chi^2/dof \approx 1.49$

Second step, $Q^2 \neq 0$.

Parameters determined at $Q^2 = 0$ are fixed.

3 parameters, 283 exp. points (σ_{el} for ρ only.)

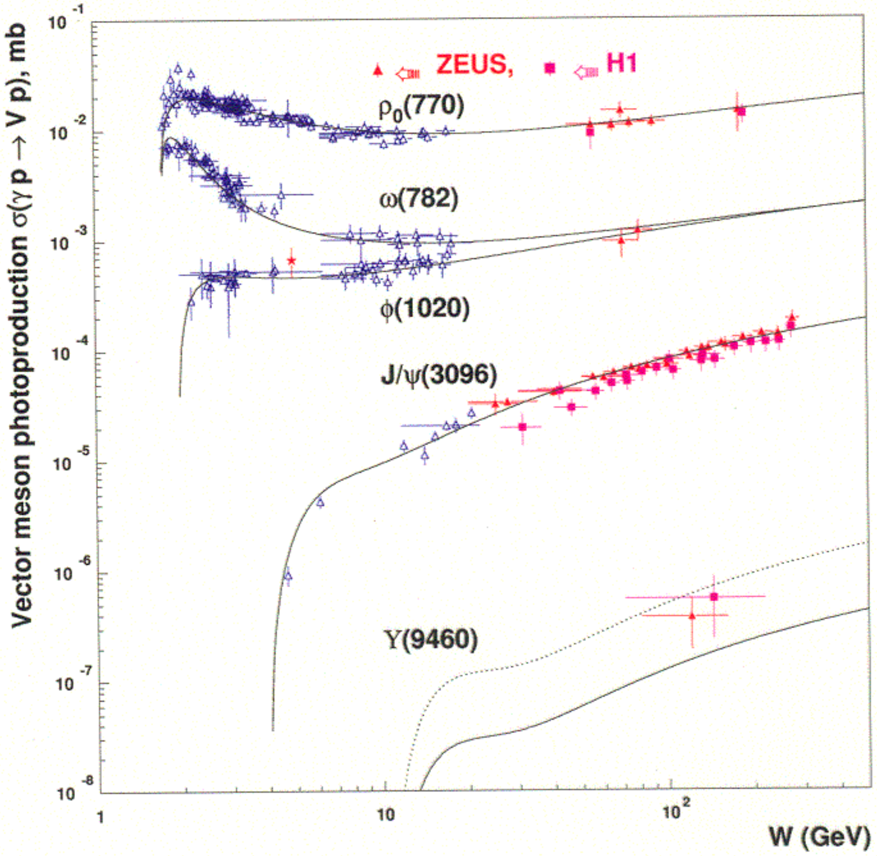
Result: $\chi^2/dof \approx 1.47 - 1.56$ (depending on the choice of fixed $\nu_{\mathcal{P}}, \nu_{\mathcal{R}}$).

$$\sigma(Q^2, M_V^2) = \sigma_T + \sigma_L = (R(Q^2, M_V^2) + 1)\sigma_T,$$

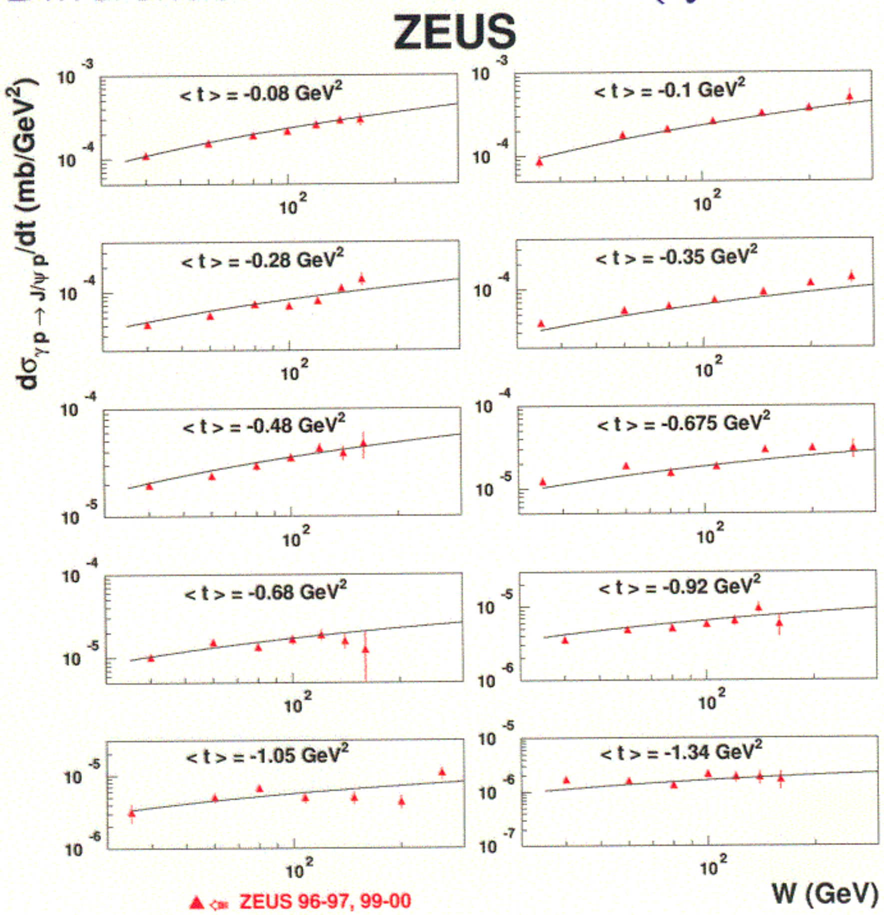
$$R + 1 = \left(\frac{cM_V^2 + Q^2}{cM_V^2}\right)^{\nu},$$

$$f_{\mathcal{P}}(Q^2) = \left(\frac{M_V^2}{M_V^2 + Q^2}\right)^{\nu_{\mathcal{P}}}, \quad f_{\mathcal{R}}(Q^2) = \left(\frac{c_1 M_V^2}{c_1 M_V^2 + Q^2}\right)^{\nu_{\mathcal{R}}}$$

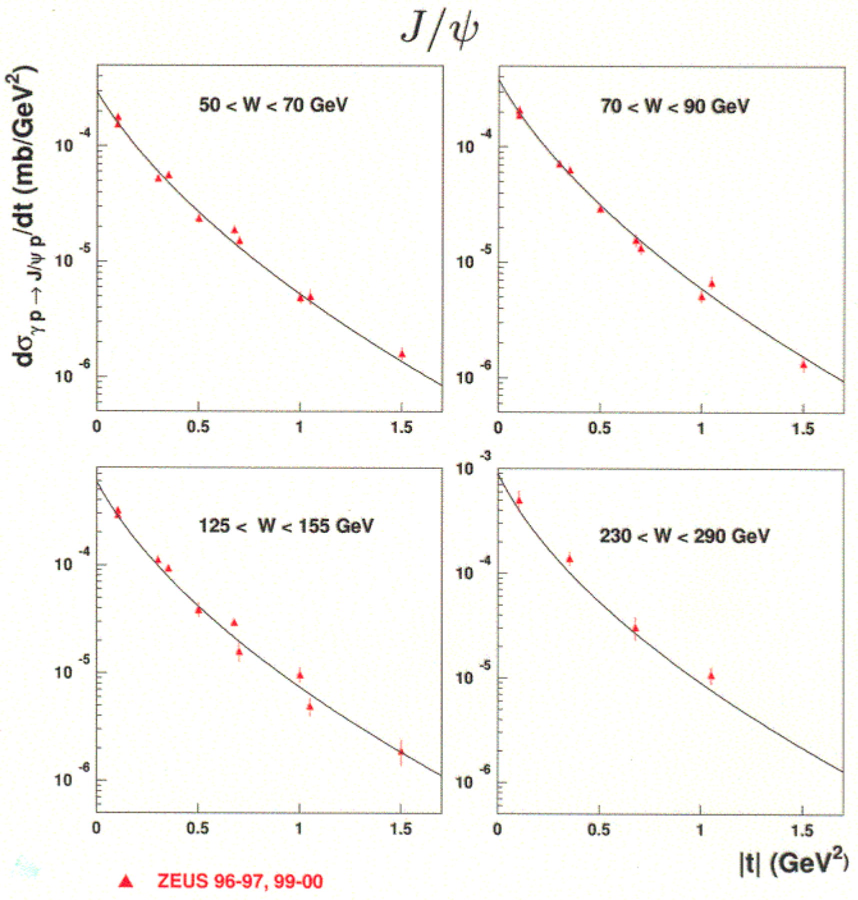
Integrated cross-sections ($Q^2 = 0$)

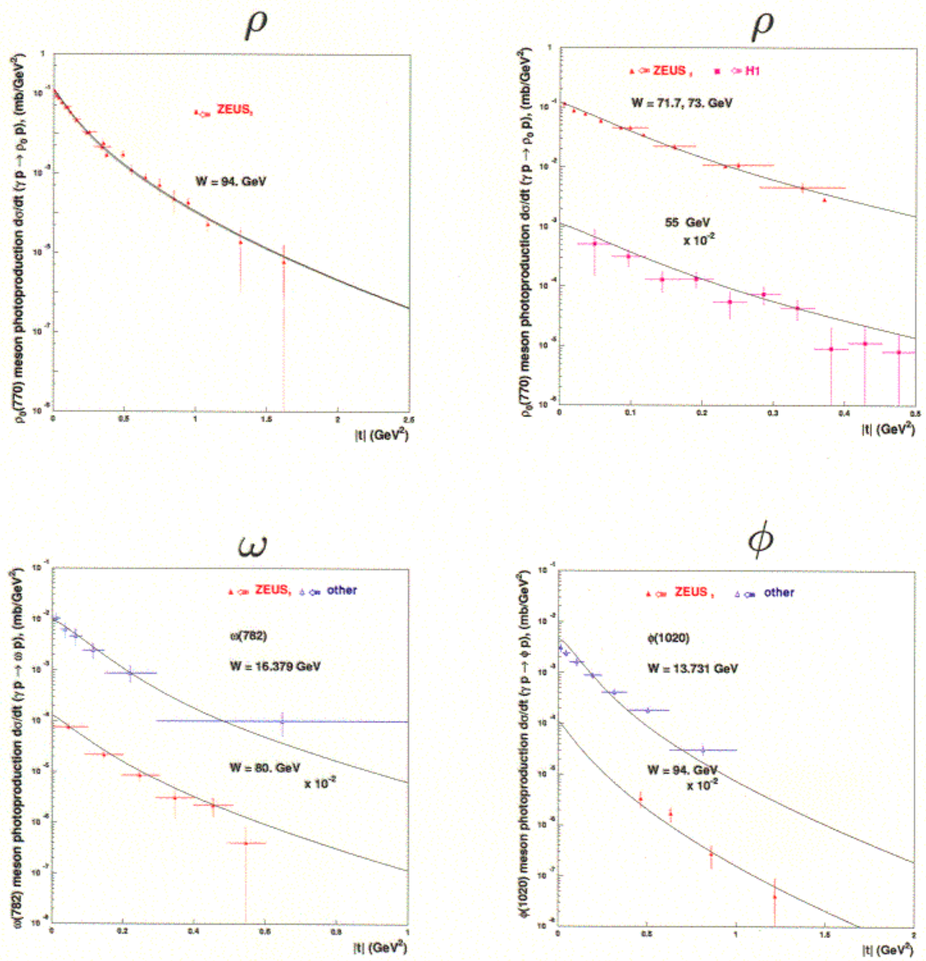


Differential cross-sections ($Q^2 = 0$)



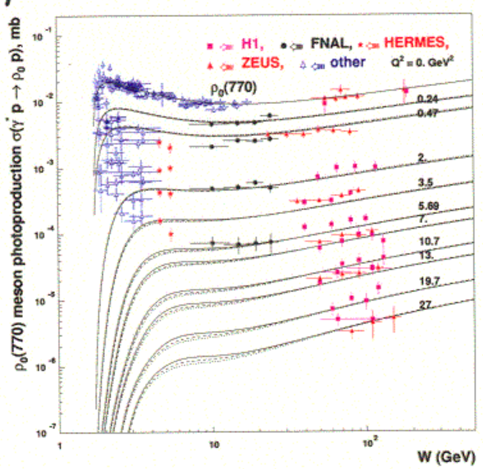
Differential cross-sections (at $Q^2 = 0$)



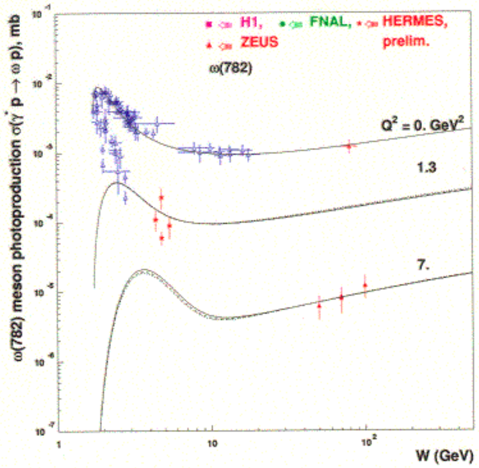


Photoproduction cross-sections at $Q^2 \neq 0$

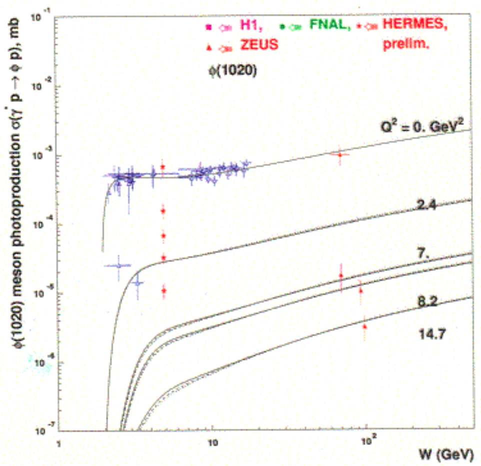
ρ



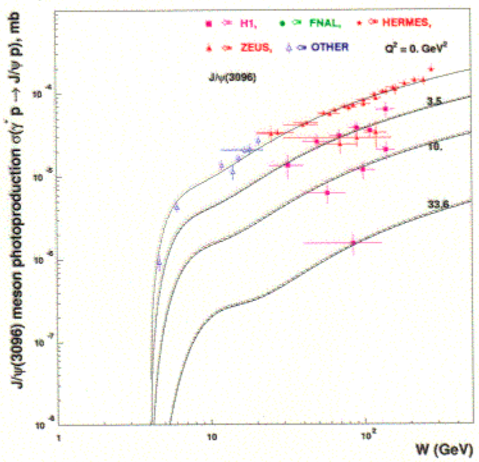
ω



ϕ



J/ψ



Conclusions.

1. The available experimental data on exclusive vector meson photoproduction can be well described within the Soft Dipole Pomeron model with pomeron as a double pole having intercept $\alpha_{\mathcal{P}}(0) = 1$). There is no a hard pomeron contribution.

2. The new ZEUS data (in confront to the old ones) quite definitely point towards of the nonlinearity of the pomeron trajectory: $(\alpha_{\mathcal{P}}(t) = 1 + 0.054(\pm 0.016)(\sqrt{4m_\pi^2} - \sqrt{4m_\pi^2 - t}))$.

3. The definite conclusion about the ratio σ_L/σ_T can be derived only with new precise data on it, especially for high Q^2.

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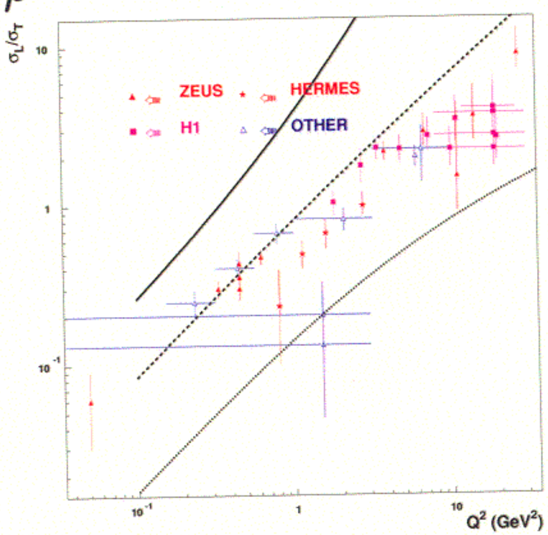
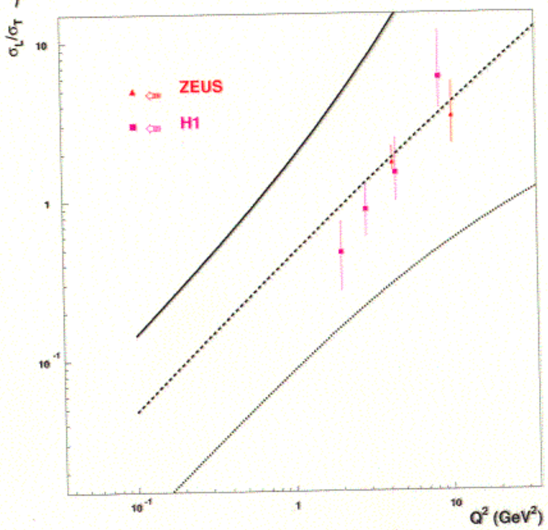
Ratio σ_L/σ_T.

ρ



ϕ



J/ψ