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DOES THE "SOFT POMERON" COPE WITH THE HERA DATA?

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Abstract

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It is demonstrated that the "soft pomeron" (together with a secondary reggeon) describing cross-sections of hadron-hadron collisions is fairly able to describe the energy dependence of cross-sections of exclusive (virtual) photoproduction of vector mesons ($\rho^0, \varphi, J/\psi$) obtained at HERA. However, these poles are insufficient for the description of the total DIS cross-sections.

Аннотация

Петров А.В., Прокудин В.А. Справляется ли "мягкий померон" с данными ГЕРА?: Препринт ИФВЭ 97-69. – Протвино, 1997. – 6 с., 4 рис., библиогр.: 8.

Продемонстрировано, что "мягкий померон" (вкупе со вторичным реджеоном), описывающий сечения адрон-адронных столкновений, вполне подходит для описания энергетической завсимости сечений эксклюзивного (виртуального) фоторождения векторных мезонов ($\rho^0, \varphi, J/\psi$), полученных на ГЕРА. Однако, для описания полных сечений глубоконеупругого рассеяния указанных полюсов не достаточно.

The effect of acceleration of the cross sections growth with c.m.s. energy $\sqrt{s}$ in the presence of a hard scale (a current virtuality, a high mass in the final state, etc.) revealed at HERA [1] raises a question on validity (or sufficiency) of the Regge-pole model that has a good reputation in the description of cross sections of hadron-hadron scattering [2]. This phenomenon can be described by a simple power-like phenomenological parametrization:

$$\sigma_{tot}^{\gamma^* p} \sim s^\lambda, \quad \lambda \geq 0.2 \tag{1}$$

where the exponent λ not only exceeds its "soft" counterpart $\Delta = \alpha_{\mathbb{P}}(0) - 1 \simeq 0.08$ in the Regge-pole method but also depends on the current virtuality Q^2. In the framework of the complex J-plane (in the t-channel) this means that there are some singularities located to the right of $ReJ = \alpha_{\mathbb{P}}$ and which depend on outer kinematic parameters beyond t so that these poles are not of the Regge type.
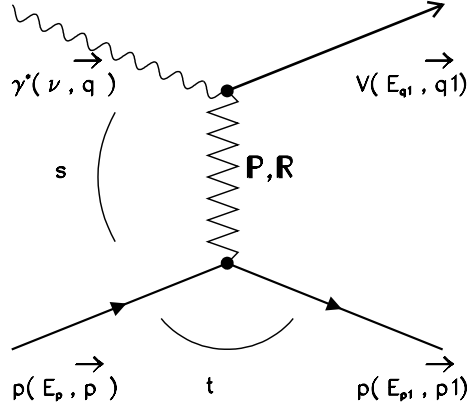
If such poles exist, then one should explore their nature and physical meaning. Besides, one should find out and verify restrictions due to general principles (unitarity in the first rate).

The effect discovered at HERA caused a vivid response of theoreticians. Among numerous phenomenological theories [3] there exists a particular method based on well known school [4] of finding solutions of some specific approximations to the Bethe-Salpeter equation for gluonic amplitudes. In fact, one has to know how QCD works at large distances ("confinement region") in order to work out a full analysis, but as is well known, there is still no theory answering this question. If one adds some assumptions about the behaviour in this region to the perturbative analysis, then one of the practical results will be the prediction of Regge poles with high intercepts ($\alpha(0) - 1 > 0.4$). An evident inconsistency of these poles with observed behaviour of hadron-hadron cross sections was explained by the smallness of corresponding residues [4]. However, a "pomeron" of high intercept (so called "hard pomeron") could be relevant for the description of the cross sections rapid growth revealed at HERA. It is sufficient to assume that in the presence of additional "hard scale" (photon's virtuality) the corresponding residues are not small.

Taking into account the fact that the "hard pomeron" status as a QCD solution is based on additional hypotheses and its intercept can be restricted by unitarity [5], it could be extremely worth trying to analyse a possibility of using the "soft pomeron".

A similar problem was referred to in paper [6]. However, the solution is not satisfactory because of a great number of parameters and the presence of additional factors of non-Regge type energy dependence.

In this paper we consider that the amplitude for vector meson production in the process

$$\gamma^* + p \rightarrow V + p$$

is

$$T_{\gamma^* p \rightarrow Vp}(s, t, Q^2) = C_{\mathbb{P}}(t, Q^2) \left(i + \cot \frac{\pi \alpha_{\mathbb{P}}(t)}{2} \right) \left(\frac{s}{Q^2 + m_V^2} \right)^{\alpha_{\mathbb{P}}(t)} +$$

$$C_{\mathbb{R}}(t, Q^2) \left(i + \cot \frac{\pi \alpha_{\mathbb{R}}(t)}{2} \right) \left(\frac{s}{Q^2 + m_V^2} \right)^{\alpha_{\mathbb{R}}(t)}. \tag{2}$$

Here Q^2 is the photon's virtuality, $s = W^2 = (p+q)^2$, $\mathbb{P}$ stands for the pomeron, $\mathbb{R}$ for a secondary reggeon, Regge trajectories have the following form in a linear approximation

$$\alpha_{\mathbb{P},\mathbb{R}}(t) = \alpha_{\mathbb{P},\mathbb{R}}(0) + \alpha'_{\mathbb{P},\mathbb{R}}(0)t,$$

$$\alpha_{\mathbb{P}}(0) - 1 \equiv \epsilon = 0.071 \pm 0.018, \quad \alpha_{\mathbb{R}}(0) - 1 \equiv -\mu = 0.46 \pm 0.25,$$

$$\alpha'_{\mathbb{P}}(0) = 0.25, \quad \alpha'_{\mathbb{P}}(0) = 1.00.$$

The values $\alpha_{\mathbb{P},\mathbb{R}}(0)$ are taken from papers [2,7], wherein a good description of hadron-hadron processes is achieved by means of these Regge poles. The Q^2 dependence of residues $C_{\mathbb{P},\mathbb{R}}$ is not fixed in the Regge approximation and we assume the t dependence in the form $\exp\left[\frac{1}{4} R^2_{\mathbb{P},\mathbb{R}}(Q^2)t\right]$ where $R_{\mathbb{P},\mathbb{R}}$ are pomeron and reggeon "radii".

Figs. 1,2,3 show the results of the description of cross sections for the processes

$$\begin{aligned} \gamma^* + p &\rightarrow \rho^0 + p \\ \gamma^* + p &\rightarrow \varphi + p \\ \gamma^* + p &\rightarrow J/\psi + p \end{aligned} \tag{3}$$
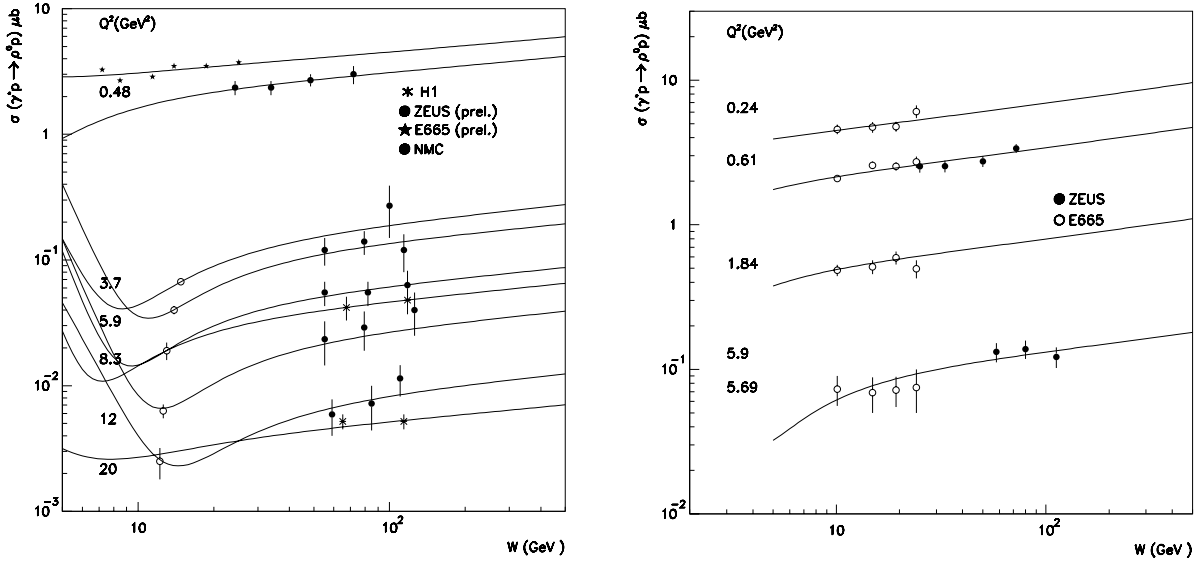
by means of formula (2).

Fig. 1. Cross section $\sigma_{\gamma^*p \to \rho^0 p}(W, Q^2)$ (the left picture includes the experimental data from $H1$ and $ZEUS$, the right one includes those from $E665$ and $ZEUS$).
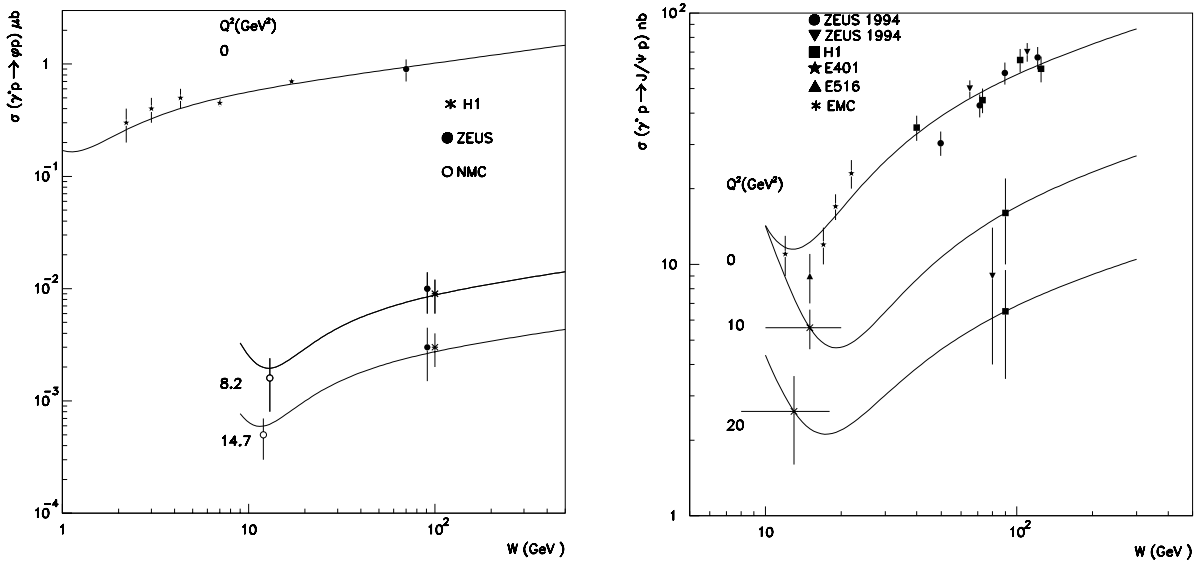

Fig. 2. Cross section $\sigma_{\gamma^*p \to \phi p}(W, Q^2)$ (the left picture) and cross section $\sigma_{\gamma^*p \to J/\Psi p}(W, Q^2)$ (the right picture).
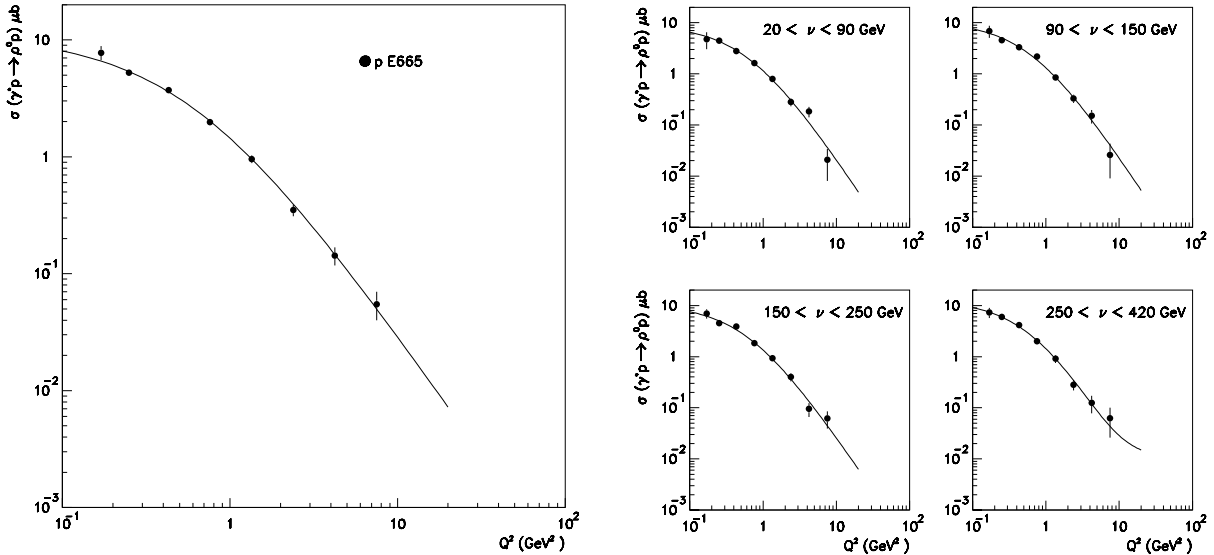
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Fig. 3. The Q^2-dependence of cross section $\sigma_{\gamma^*p\to\rho^0 p}(Q^2)$ ($W = 15\ GeV$ in the left picture, $W = 10.1, 14.9, 19.3, 24.1\ GeV$ in the right one).

As is noticed in [8], unitarity corrections contribute to the cross section less than 10%, so with the present experimental accuracy we decided to consider the Born term only. It is seen that the Regge method is relevant enough for processes (3) description and hence there is no need to take into account new poles (probably of non-Regge type) besides well known $\mathbb{P}$ and $\mathbb{R}$.

Now let us consider the total cross section for the DIS process

$$\gamma^* + p \to X.$$

The result of using formula similar to (2) is shown in Fig.4. It is obvious that in this case poles $\mathbb{P}$ and $\mathbb{R}$ are insufficient. Since

$$\sigma_{tot}^{\gamma^*p} = \sum_V \sigma_{\gamma^*p\to Vp} + \sigma_{inel}^{\gamma^*p},$$

the insufficiency of "usual" Regge poles stems from the behaviour of $\sigma_{inel}^{\gamma^*p}$ which is connected with processes of multiple production.

Does it mean that for a successful description of the total cross-sections we need poles with a high intercept? Not at all. If one adds "secondary" Regge poles with $\alpha(0) < 1$, then one will have a good description as is seen in Fig.4. They have the following intercepts:

$$\alpha_{\mathbb{R}_1}(0) - 1 = -0.08;$$
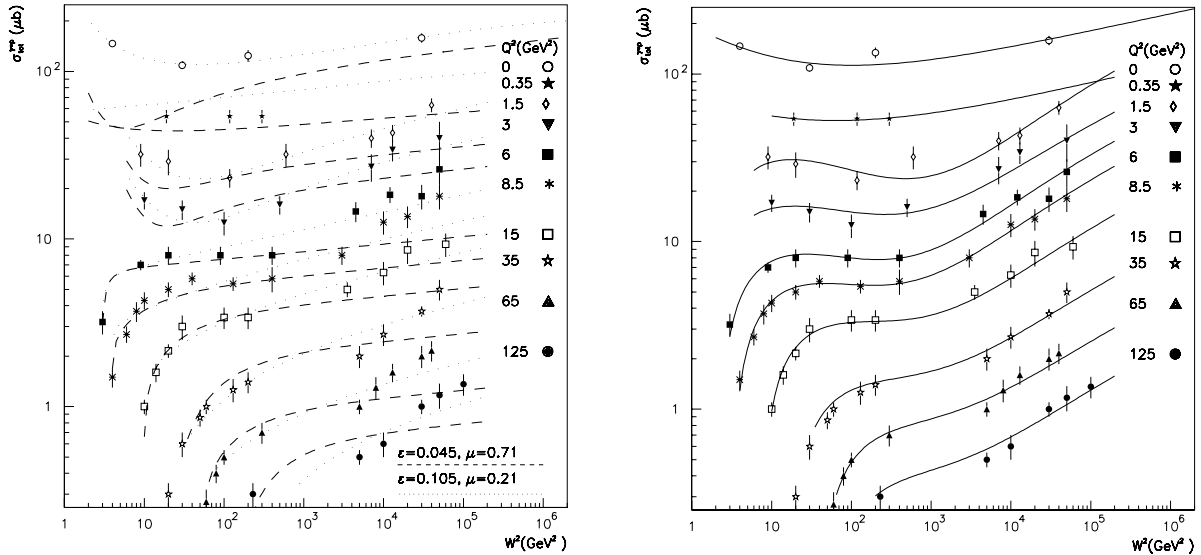$$\alpha_{\mathbb{R}_2}(0) - 1 = -0.1.$$

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Fig. 4. The total cross section $\sigma_{\gamma^* p \to X}(s = W^2 \ GeV^2, Q^2)$ (the left picture shows the result of using the two pole model, the right one shows that of using the four pole model).

The problem of interpretation of these new poles, which have intercepts lying close to each other and to 1, rises immediately. One should also include these poles into the fit of exclusive cross-sections.

Thus, we have demonstrated that the Regge poles describing hadron-hadron processes do cope with a rapid growth of exclusive vector meson production cross sections at HERA and we explain this growth as a "threshold effect". Meanwhile, it is not possible to do the same for the total cross sections unless one adds new poles, which are not "hard" however.

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