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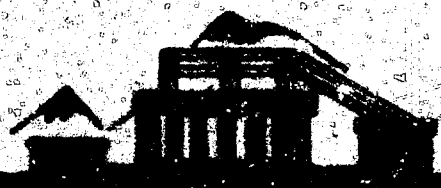
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ЕФИ-76(74)

Yu. F. PIROGOV, N. L. TER-ISAACIAN

ON THE PHOTON FRAGMENTATION INTO
THE NEUTRAL VECTOR MESONS

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Ю.Ф. ПИРОГОВ, Н.Л. ТЕР-ИСААКЯН

О ФРАГМЕНТАЦИИ ФОТОНА В НЕЙТРАЛЬНЫЕ ВЕКТОРНЫЕ
МЕЗОНЫ

Рассматривается процесс инклюзивного фото- и электро-рождения нейтральных векторных мезонов $V^0 = \rho^0, \omega, \varphi$ $\gamma p \rightarrow V^0 X$, $e p \rightarrow e V^0 X$ в трехрегеонной области. На основе имеющихся данных по упругому фото- и электророждению $\gamma p \rightarrow V^0 p$, $e p \rightarrow e V^0 p$ и инклюзивному рождению $pp \rightarrow p X$ делается оценка фрагментации $\gamma \rightarrow V^0$ при высоких энергиях. Отмечается возможность использования инклюзивного электро- и фоторождения V^0 для изучения трехмерной вершины.

Ереванский физический институт
Ереван 1974

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Yu. F. PIROGOV, N. L. TER-ISAAKIAN

ON THE PHOTON FRAGMENTATION INTO
THE NEUTRAL VECTOR MESONS

The processes of inclusive photo- and electroproduction of neutral vector mesons $V^0 = \rho^0, \omega, \varphi$ $\gamma p \rightarrow V^0 X$; $e p \rightarrow e V^0 X$ are considered in the triple-Regge region. On the basis of available experimental data on elastic photo- and electroproduction $\gamma p \rightarrow V^0 p$, $e p \rightarrow e V^0 p$ and inclusive production $pp \rightarrow p X$ the fragmentation of $\gamma \rightarrow V^0$ is estimated at high energies.

The possibility of the utilization of inclusive V^0 photo- and electroproduction processes to study the triple-Pomeron coupling is noted.

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In a number of works [1] some considerations were put forward in favour of the diffractive nature of the φ -meson photoproduction $\gamma p \rightarrow \varphi p$.

In a dual quark model this is ascribed to the fact, that φ -meson being build of strange quarks only cannot be connected to the non-strange quarks composed nucleon. In a Regge scheme this corresponds to the absence of the secondary trajectories.

On the other hand in Ref. [2] it has been shown the possibility to describe the neutral vector mesons photoproduction processes $\gamma p \rightarrow V^0 p$ in a Regge pole model with strong interference of the Pomeron P with the secondary trajectories R in the φ -meson photoproduction. These scheme has been elaborated further in Ref. [3,4]. In Ref. [4] the Pomeron cuts were introduced in addition.

The principal difference between the Regge cuts and non-Regge cuts approaches should be seen at energies much greater those presently available $E \lesssim 18$ GeV. So let us introduce an effective Pomeron which includes both bare Pomeron and accompanying cuts. The effective Pomeron can be used to describe qualitatively correctly the V^0 elastic photoproduction processes up to energies where the triple-Pomeron corrections to the photoproduction amplitude should be taken into account. It is to be noted, that it is the effective

Pomeron which manifests in the inclusive diffractive spectra $pp \rightarrow pX$ up to the ISR energies [5].

In what follows the tensor meson dominance (TMD) model for Pomeron and the quark model for the (γVT) and $(\bar{N}NT)$ vertices are used to describe the photoproduction data $\gamma P \rightarrow V^0 p$ [6]. Here V and T are the vector meson 1^- and tensor meson 2^+ nonets accordingly. The mixture angles $\theta_v = \theta_T \approx \theta_I$ ($\cos \theta_I = 1/\sqrt{3}$) insure the presence only of the strange quarks in the physical φ - and ω -mesons. This leads to the relations $(\gamma P^0 \frac{1}{2}) = 3(\gamma \omega \frac{1}{2})$; $(\gamma \omega A_2) = 3(\gamma P^0 A_2)$ $(\gamma \varphi A_2) = (\gamma P^0 \frac{1}{2}') = (\gamma \omega \frac{1}{2}') = (\gamma \varphi \frac{1}{2}') = (\bar{N} N \frac{1}{2}') = 0$. The TMD model is equivalent to the $U(3)$ -invariance for the meson vertices with an additional assumption $(\bar{N} N \frac{1}{2}') = 0$ for the nucleon vertices.

The unitary singlet Pomeron interaction with particles in the TMD model is mediated by the Pomeron virtual transition into the tensor mesons $\frac{1}{2}$ and $\frac{1}{2}'$. Masses of $\frac{1}{2}$ and $\frac{1}{2}'$ being different the part turning into $\frac{1}{2}'$ is effectively connected with particles $\tau(0) = \frac{1 - \alpha_{\frac{1}{2}}(0)}{1 - \alpha_{\frac{1}{2}'}(0)} \approx 0.6$ times weaker than that one turning into $\frac{1}{2}$ ($\alpha_{\frac{1}{2}}(0) = 0.5$, $\alpha_{\frac{1}{2}'}(0) \approx 0.15$). This results in the effective presence in P of the octet part $P = |1\rangle + \sqrt{2}|8\rangle$ where $\sqrt{2} = \frac{1 - \tau(0)}{\sqrt{2} + \tau(0)/\sqrt{2}} \approx 0.2$ is an universal quantity determined by the ratio $\frac{\sigma(\gamma N)}{\sigma(\bar{N}N)} = \frac{1 + \tau(0)}{2}$. This results are equivalent to the quark model with the Pomeron being coupled to the λ -quarks $\tau(0) = 0.6$ times weaker than to the nonstrange quarks.

Finally the photoproduction amplitudes are

$$\begin{aligned} T(\gamma P \rightarrow P^0 p) &= (1 + \sqrt{2})P + \frac{1}{3}A_2 \\ T(\gamma P \rightarrow \omega p) &= \frac{1}{3}(1 + \sqrt{2})P + \frac{1}{3}\frac{1}{2} + A_2 \\ T(\gamma P \rightarrow \varphi p) &= -\frac{\sqrt{2}}{3}(1 - \sqrt{2}\sqrt{2})P \end{aligned} \quad (1)$$

where P, ρ, A_2 are the contributions of the proper trajectories.

To ω -meson photoproduction the π -meson pole contributes significantly in addition.

However, the universal $\alpha = 0,2$ is insufficient to account for experimentally observed considerable φ -meson photoproduction suppression $\frac{d\sigma}{dt}(\gamma \rightarrow \rho^0) : \frac{d\sigma}{dt}(\gamma \rightarrow \varphi) \Big|_{t \approx 0} \approx 50$. An additional symmetry breaking must be introduced due to the vector meson mass differences.

[3,4]. Attributing this to the Regge propagators we shall write the latter in the general case of the virtual photoproduction in the form $\left[\frac{s-u}{\lambda(m_v^2 - q^2)} \right]^{\alpha(t)} = (y_v)^{\alpha(t)}$, m_v being the vector meson and $\sqrt{q^2}$ the virtual photon masses.

Neglecting by the separation to the longitudinal and transversal parts the data on the photoproduction of ρ^0 - and φ -meson [6] and the electroproduction of ρ -meson [9] can be parametrised in the form

$$\frac{d\sigma}{dt}(\gamma^* p \rightarrow \rho^0 p) = \frac{m_\rho^2}{m_\rho^2 - q^2} \frac{e^{3t}}{s^2} \left[5.3 \cdot i (y_\rho)^{1+\alpha_\rho t} + 7.1(i-1)(y_\rho)^{0.5+\alpha_\rho t} \right]^2$$

$$\frac{d\sigma}{dt}(\gamma^* p \rightarrow \varphi p) = \frac{m_\varphi^2}{m_\varphi^2 - q^2} \frac{e^{3t}}{s^2} 2.4 (y_\varphi)^{2(1+\alpha_\varphi t)} \quad (2)$$

where $\alpha_\rho \approx 0.4$; $\alpha_\varphi \approx 0.8$.

The residues $(\gamma^* v \cdot p)$ and $(\gamma^* v \cdot j)$ are taken to be the universal functions $\beta_i(q^2, t) \approx \beta_i(0,0) \left(\frac{m_v^2}{m_v^2 - q^2} \right)^{0.5} e^{3t}$ in accordance with the (TMD) hypothesis and an universal asymptotic formula [10]

$$\beta_i(q^2) \approx (-q^2)^{-1/2} \text{ at } -q^2 \rightarrow \infty$$

As in Ref. [11] the A_2 -trajectory contribution to the ρ^0 -photoproduction is neglected.

An analogous parametrisation has been used in Ref. [12].

For the amplitudes phases $\alpha = \left(\frac{\partial \sigma}{\partial \ln T} \right)_{t=0}$ we have $\alpha(\gamma \rightarrow \varphi) = 0$

$$\alpha(\gamma \rightarrow \rho^0) = - \frac{0.6}{\sqrt{s}}$$

For $\gamma \rightarrow \rho^0$ this is consistent with the exper-

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perimental value $\alpha(r \rightarrow \varphi) = -0,2 \pm 0,1$ at $E = 4,1 - 6,1$ GeV /13/. As to the experimentally with great uncertainty observed value $\alpha(r \rightarrow \varphi) = -0,48 \pm 0,33$ [14] at $E_\gamma = 6 \div 7,4$ GeV it should be described in the present approach by the secondary trajectories, cuts contributions and the really observed t being non-zero.

It should be remarked, that the real mixture angles being taken into account instead of ideal ones leads to a small destructive interference of the Pomeron with the secondary trajectories and as a result to the positive phase.

In the virtual photon fragmentation region $S \gg M^2 \gg -q^2 - t - m_v^2$ M being the hadron cluster mass (Fig.1), the triple-Regge description is valid. The factorization property gives

$$\frac{d\sigma}{dt dM^2} (r^*P \rightarrow V^0X) = \frac{\frac{d\sigma^P}{dt} (PP \rightarrow PX) \frac{d\sigma^P}{dt} (r^*P \rightarrow V^0P)}{\frac{d\sigma}{dt} (PP \rightarrow PP)} + (P \rightarrow R) \quad (3)$$

where the indices P and R designate the Pomeron and secondary trajectories contributions to the corresponding cross sections, P describing the diffractive triple-Pomeron peak, R - the underground beneath it. The P and R interference is neglected.

At Serpukhov energies one has

$$\left. \frac{d\sigma}{dt} (PP \rightarrow PP) \right|_{t=0} = \left| i g_P^2 + \frac{i-1}{\sqrt{S}} g_t^2 - \frac{i+1}{\sqrt{S}} g_w^2 \right|^2 \quad (4)$$

where $g_P^2 \approx 8.8 \frac{mb}{(GeV)^2}$; $g_t^2 \approx 10.3 \frac{mb}{(GeV)^2}$; $g_w^2 \approx 6.8 \frac{mb}{(GeV)^2}$ (S in $(GeV)^2$)

the ρ - and A_2 -trajectory contributions being neglected.

For the scaling part of the hadron spectra $pp \rightarrow pX$ in the triple-Regge Region one has [5]

$$\frac{d^3\sigma}{dP^3} = \frac{G_{PPP}}{(1-x)^{1+2\alpha_P t}} + G_{RRP}(1-x)^{-\lambda_1 t} \quad (5)$$

where $x = 1 - \frac{M^2}{s}$. The effective triple-Reggeon couplings G_{ppp} and G_{RRP} which include the real triple-Reggeon couplings, signature factors and Reggeon-particle couplings are $G_{PPP} = g_P^2 g_{PPP} = 0.65 \frac{mb}{(GeV)^2}$
 $G_{RRP} = g_{\omega}^2 g_{RRP} + g_{\omega}^2 g_{\omega RP} = 5 \frac{mb}{(GeV)^2}$
 at $\alpha_P = 0.15 (GeV)^{-2}$; $\alpha_R = 0.75 (GeV)^{-2}$

As to the inclusive φ -meson photoproduction $\gamma P \rightarrow \varphi X$ here the $\{$ -trajectory contribution can manifest, $\{$ being decoupled in the elastic $\gamma P \rightarrow \varphi P$ for $(\bar{N}N\{)$ being zero. To estimate the value of the $(\gamma\varphi\{)$ residue we use $U(3)$ -invariance which leads to $(\gamma\varphi\{) = -\frac{2}{3}(\gamma P^0\{)$. The triple-Regge coupling $g_{\{PP}$ we estimate according to the quark model ($g_{\{PP} = \alpha(0) g_{\{PP}$). For $g_{\{PP}$ we put $g_{\{PP} \approx g_{\omega RP}$ in the $pp \rightarrow pX$ spectra.

This is enough to estimate the $\gamma^* P \rightarrow V^0 X$ processes cross-sections

$$E \frac{d^3\sigma}{dP^3} (\gamma^* P \rightarrow P^0 X) = \frac{m_P^2}{m_P^2 - q^2} \left\{ \frac{\Gamma_{PPP}^P}{(1-x)^{1+0.3t}} \left(\frac{1}{m_P^2 - q^2} \right)^{2+0.3t} + \Gamma_{RRP}^P (1-x)^{-1.5t} \left(\frac{1}{m_P^2 - q^2} \right)^{1+1.5t} \right\} \quad (6)$$

$$E \frac{d^3\sigma}{dP^3} (\gamma^* P \rightarrow \varphi X) = \frac{m_\varphi^2}{m_\varphi^2 - q^2} \left\{ \frac{\Gamma_{PPP}^\varphi}{(1-x)^{1+0.3t}} \left(\frac{1}{m_\varphi^2 - q^2} \right)^{2+0.3t} + \Gamma_{\{PP}^\varphi (1-x)^{0.7-1.5t} \left(\frac{1}{m_\varphi^2 - q^2} \right)^{2.3+1.5t} \right\}$$

where m_P^2 and q^2 are in $(GeV)^2$

The effective triple-Regge couplings

$$\Gamma_{PPP}^P = 0.14 \frac{mb}{(GeV)^2} \quad \Gamma_{RRP}^P = 1.64 \frac{mb}{(GeV)^2}$$

$$\Gamma_{PPP}^\varphi = 0.02 \frac{mb}{(GeV)^2} \quad \Gamma_{\{PP}^\varphi = 0.44 \frac{mb}{(GeV)^2}$$

are taken to be t -independent for the experimental data on the

photoproduction $\gamma p \rightarrow V^0 p$ and on inclusive production $pp \rightarrow pX$ are consistent with a parametrization when the whole t - dependence of these processes is attributed to the Reggeon-proton vertices.

The results of the estimates are shown in Fig.2. Here the thick lines are the $\gamma p \rightarrow f^0 X$ and $\gamma p \rightarrow \varphi X$ processes cross-sections and the thin ones are the triple - Pomeron contributions to these processes. It is to be remarked, that the background in these processes is less than that in $pp \rightarrow pX$. For example at $X = 0,95$ the background is equal to 15% for $\gamma p \rightarrow f^0 X$ and 10% for $\gamma p \rightarrow \varphi X$ at $p_{\perp}^2 = 0$ and at $p_{\perp}^2 = 0,5$ the background is practically absent ($\sim 2\%$) being of order of 30% in $pp \rightarrow pX$ all conditions being equal.

The estimates show, that the inclusive photoproduction of the neutral vector mesons could be very useful to study the triple-Pomeron coupling $g_{PPP}(t)$ at $-t \approx -t_{min} = (1-X)m_V^2$

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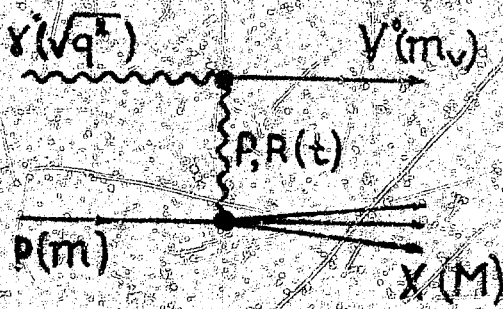


Fig. 1

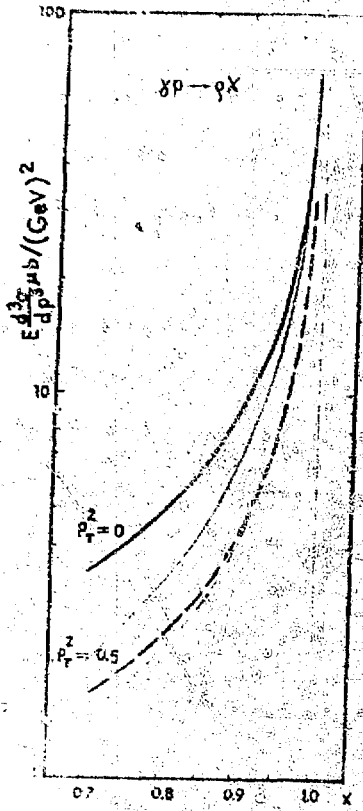


Fig. 2

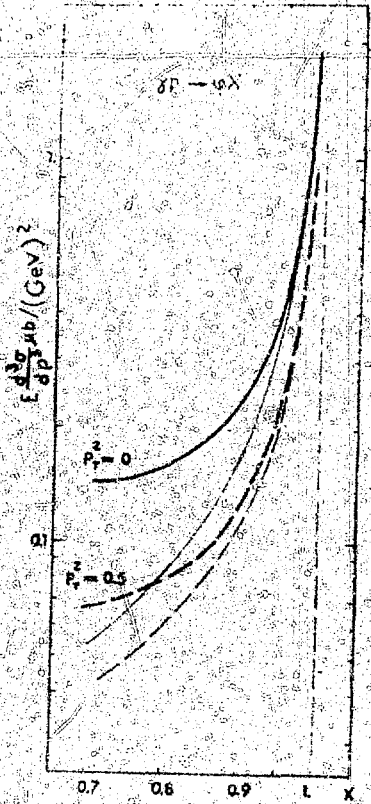


Fig. 3

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