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NEUTRAL NON STRANGE 0^- MESON PHOTOPRODUCTION AND REGGE POLES

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Photoproduction of neutral non strange 0^- mesons is considered in the framework of Regge theory. Symmetry relations between coupling constants are widely used. The results are in good agreement with the available experimental data.

Recent measurements [1] of photoproduction at high energy stimulated the application of the Regge pole theory to this problem [2-4]. In particular the π^0 photoproduction has been considered in ref. 2, in which the contribution of the ω pole to the Reggeized CGLN invariant amplitudes [5] is calculated. The authors, assuming for the ω trajectory the same as for the ρ, fit their results to the experimental data; moreover for $E^{\gamma}_{\rm lab}$ = 2 GeV they introduce a direct channel resonance obtaining a better agreement at larger momentum transfer.

The X^0 photoproduction has been treated with Regge poles by Drechsler [4], considering only the contribution of the ρ trajectory in the crossed channel.

In this paper we present an analysis of the process

$$\gamma + p \rightarrow M^0 + p\ , \qquad (1)$$

where M^0 can be π^0, η^0 or X^0. Our aim is to show that, introducing the ρ and ω trajectories in the crossed channel and assuming suitable re-

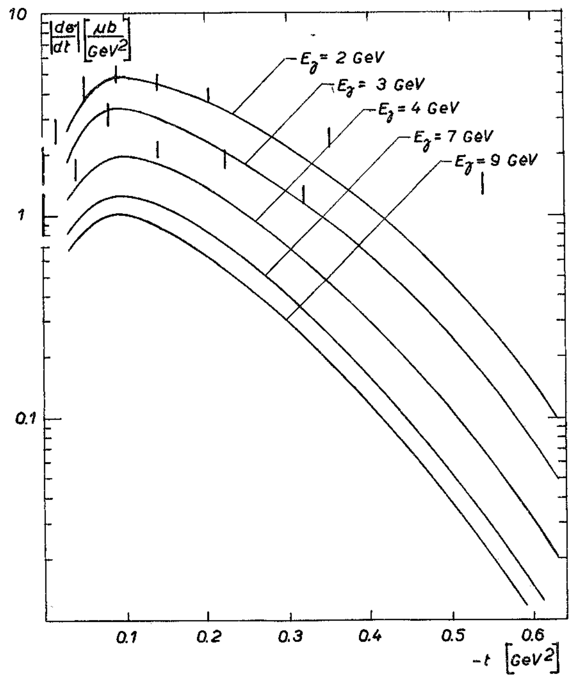

Fig.1a. $d\sigma/d|t|$ for $\gamma + p \rightarrow p + \pi^0$ as a function of $-t$.

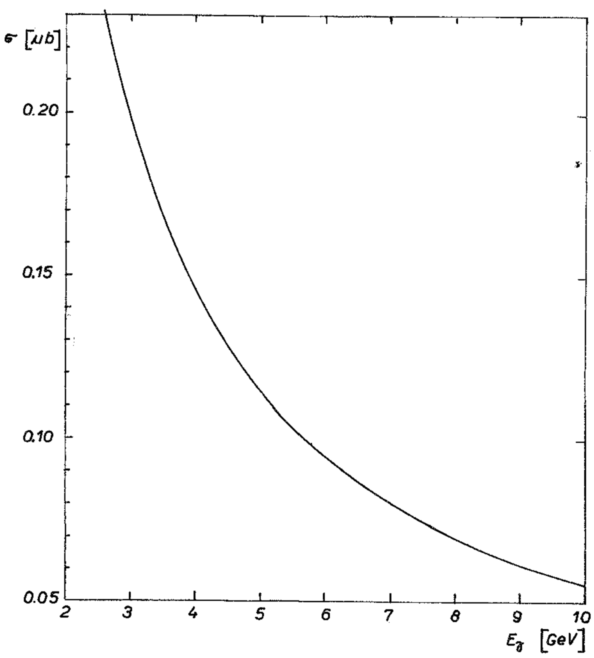

Fig. 1b. Integrated π^0 photoproduction cross section for $|t| \leq 0.5$ GeV^2.

Table 1

$\lambda \backslash \bar{\mu}$	$\frac{1}{2}\ \frac{1}{2}$	$\frac{1}{2}\ -\frac{1}{2}$
1	$\frac{\mu g_V M^3}{6\pi}\left(1+\frac{\gamma t}{4M^2}\right)\left(\frac{q'}{q}\right)^{\frac{1}{2}}$	$-\frac{\mu g_V M^2}{6\pi\sqrt{2}}(1+\gamma)\sqrt{t}\left(\frac{q'}{q}\right)^{\frac{1}{2}}$
-1	$-\frac{\mu g_V M^3}{6\pi}\left(1+\frac{\gamma t}{4M^2}\right)\left(\frac{q'}{q}\right)^{\frac{1}{2}}$	$\frac{\mu g_V M^2}{6\pi\sqrt{2}}(1+\gamma)\sqrt{t}\left(\frac{q'}{q}\right)^{\frac{1}{2}}$

$g_V(g_T)$ = electrical (magnetic) nucleon vertex coupling constants for vector exchange, $\gamma = (g_T/g_V)$.
μ = transition magnetic moment.

Table 2

	π^0	η^0	X^0
ρ^0	g	$\sqrt{3}(\cos\alpha + \sqrt{2}\operatorname{sen}\alpha)g$	$\sqrt{3}(\sqrt{2}\cos\alpha - \operatorname{sen}\alpha)g$
ω^0	$3g$	$\frac{1}{\sqrt{3}}(\cos\alpha + \sqrt{2}\operatorname{sen}\alpha)g$	$\frac{1}{\sqrt{3}}(\sqrt{2}\cos\alpha - \operatorname{sen}\alpha)g$

For the ω-φ mixing angle we assumed $\cos\lambda = \sqrt{2/3}$, $\operatorname{sen}\lambda = 1/\sqrt{3}$; α is the η^0-X^0 mixing angle: using the Gell-Mann/Okubo mass formula and the actual mass of η^0 and X^0, one gets: $\cos\alpha = 0.98$, $\operatorname{sen}\alpha = \pm 0.18$.

lations between the quantities involved, it is possible to reduce greatly the number of parameters in Regge pole phenomenology. The results so obtained are in good agreement with the available experimental data.

The Regge pole contribution to our process can be calculated using the helicity representation [6] * in the t-channel $p + \bar{p} \rightarrow M^0 + \gamma$ together with crossing relations [7]. It can be shown that the contribution of a Reggeized vector meson to the helicity amplitudes, for azimutal angle equal to zero, is given by [7]

$$F^{t}_{\lambda\bar{\lambda};\mu\bar{\mu}} = \frac{\pi\alpha'(0)}{4(qq')^{\frac{1}{2}}}[2\alpha(t)+1] \times \times \frac{1-\exp\{i\pi\alpha(t)\}}{\operatorname{sen}\pi\alpha(t)}\left(\frac{qq'}{M^2}\right)^{\alpha(t)} C_{\lambda\bar{\lambda};\mu\bar{\mu}}\, \bar{d}^{\alpha(t)}_{\lambda-\bar{\lambda};\bar{\mu}-\mu}(-z)\ , \tag{2}$$

where q, q' = initial, final momenta in the crossed channel c.m. system, $z = \cos\theta_t$, $\alpha(t)$ = Regge trajectory, M = nucleon mass. The $\bar{d}^{\alpha}_{\rho\sigma}$ functions in eq. (2) are not the ordinary reduced rotation matrices, and are defined in ref. 7.

The momentum transfer distribution for the process (1) is then

* Our normalization convention here is different from that of Jacob and Wick [6]. The two are related by
$$F_{\lambda\mu;\nu\rho} = (q/q')^{\frac{1}{2}} F^{J.W.}_{\lambda\mu;\nu\rho}.$$

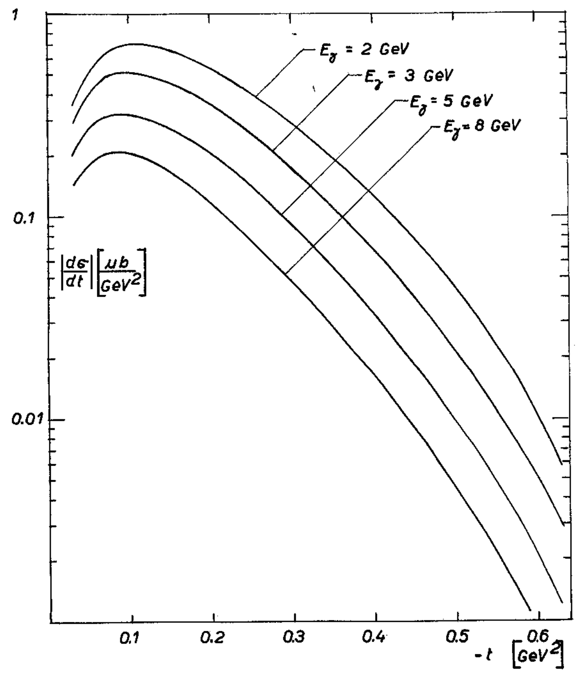

Fig. 2a. $d\sigma/d|t|$ for $\gamma + p \rightarrow p + \eta^0$ as a function of $-t$.

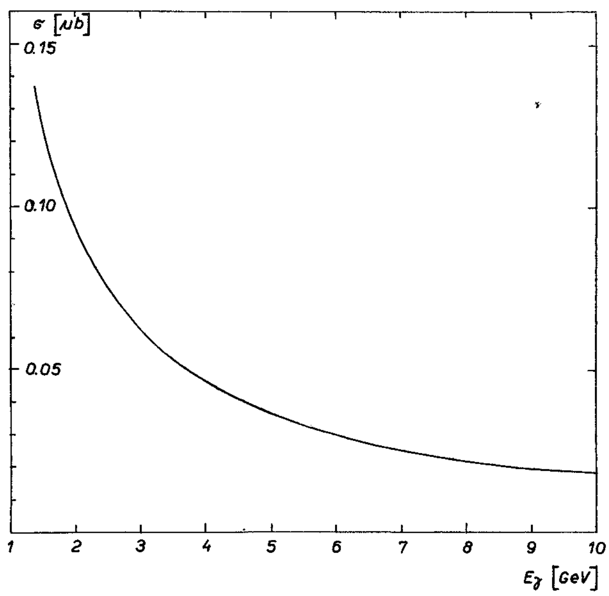

Fig. 2b. Integrated η^0-photoproduction cross section for $|t| \leqslant 0.5\ GeV^2$. The value $\sin\alpha = +0.18$ is used.

$$\frac{d\sigma}{dt} = \frac{\pi t}{K^2 s}\,\frac{1}{4}\sum_{\text{hel.}}\left|F^{t(\rho)}_{\lambda\bar{\lambda};\mu\bar{\mu}} + F^{t(\omega)}_{\lambda\bar{\lambda};\mu\bar{\mu}}\right|^2 , \qquad (3)$$

where K is the initial momentum in the production channel.

The $C_{\lambda\bar{\lambda};\mu\bar{\mu}}$ are the residue functions from which we have explicitly factorized the threshold behavior $(qq'/M^2)^{\alpha}$: they are determined by the type of interaction and contain the coupling constants and some kinematical factors. We assume that the functions $C_{10;\frac{1}{2}\frac{1}{2}}$, $C_{10,-\frac{1}{2}-\frac{1}{2}}$, $C_{-10;\frac{1}{2}\frac{1}{2}}$, $C_{-10,-\frac{1}{2}-\frac{1}{2}}$ contain a factor $[\alpha(\alpha+1)]^{\frac{1}{2}}$ and the remaining others a factor $\alpha(\alpha+1)$. Roughly speaking, the $[\alpha(\alpha+1)]^{\frac{1}{2}}$ comes from the fact that $\alpha = 0$ is a sense-nonsense [8] value for $F^t_{10;\frac{1}{2}\frac{1}{2}}$, while the $\alpha(\alpha+1)$ factor comes from the fact that $\alpha = 0$ is a nonsense-nonsense value for $F^t_{10;\frac{1}{2}-\frac{1}{2}}$ [9].

We make now a pole approximation in the t-plane: i.e. we require that the Regge amplitude, eq. (2), reduces to the simple Born term for $t \to m^2_{ex}$ *. The result of the matching at the pole is presented in table 1.

From the experimentally known decay width [11] $\Gamma(\omega \to \pi\gamma) = 1.27 \pm 0.22$ MeV we get for the $\omega\pi\gamma$ vertex $\mu = 0.94\ \text{GeV}^{-1}$ **. The transition magnetic moments for the other vertices $VM\gamma$ can be found assuming the $SU(6)_W$ symmetry [e.g. 12] and are given in table 2. For the $Vp\bar{p}$ vertex, assuming pure F-coupling, we obtain also from $SU(6)_W$ [13]:

$$g^{\omega}_{V} = 3g^{\rho}_{V}, \qquad g^{\varphi}_{V} = 0$$
$$g^{\omega}_{T} = \tfrac{3}{5}g^{\rho}_{T}, \qquad g^{\varphi}_{T} = 0 \qquad (4)$$

g^{ρ}_{V} is well known experimentally: $g^{\rho 2}_{V}/4\pi = 0.74$ [e.g. 14]. The γ^{ρ} parameter can be connected with the electromagnetic structure of the baryons obtaining [e.g. 15] $\gamma^{\rho} = 3.7$.

We first discuss π^0-production. We assumed for the ρ the trajectory found by Logan and Sertorio [16]:

$$\alpha_{\rho}(t) = 0.58 + 0.90\,t \qquad t \text{ in GeV}^2$$

(compare also ref. 17).

The ω-trajectory is not well known: it has been studied by Phillips and Rarita [18]; however in their paper Regge-poles are used in a way which is quite different from our approach, so that their parametrization cannot be used directly in our work. If however we tentatively assume a straight ω-trajectory with the intercept and slope given by them, we obtain the right behavior and order of magnitude for the cross section. We can improve the agreement fitting $\alpha_{\omega}(t)$ with the available data at 3 GeV, getting

$$\alpha_{\omega}(t) = 0.60 + 0.75\,t .$$

The results given in fig. 1 are in good agreement with the experimental data up to t =

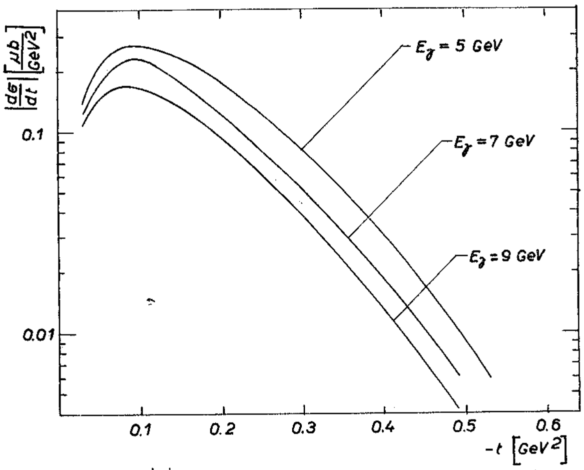

Fig. 3a. $d\sigma/d|t|$ for $\gamma + p \to p + X^0$ as a function of $-t$.

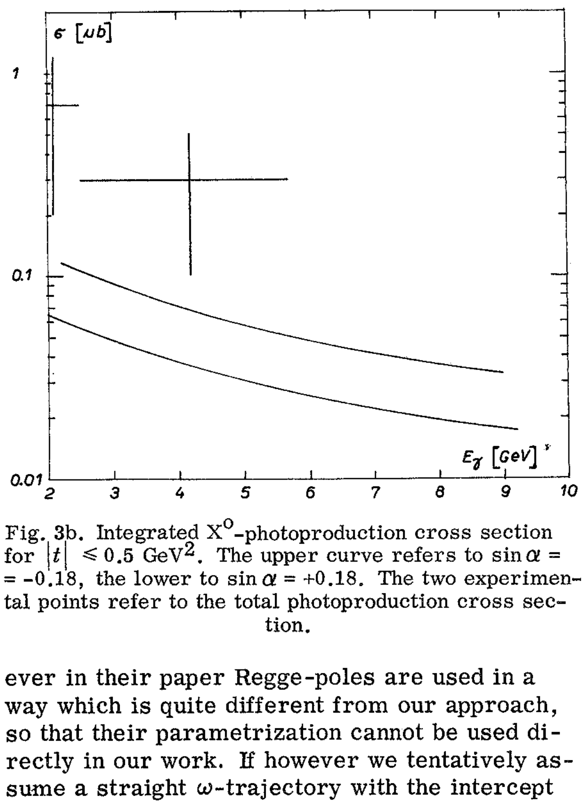

Fig. 3b. Integrated X^0-photoproduction cross section for $|t| \leq 0.5\ \text{GeV}^2$. The upper curve refers to $\sin\alpha = -0.18$, the lower to $\sin\alpha = +0.18$. The two experimental points refer to the total photoproduction cross section.

* This method has been successfully applied several times [e.g. 3, 10]: it permits to assign a definite physical interpretation to the residue of the Regge pole in the J-plane.

** The transition magnetic moment μ is defined by the phenomenological Lagrangian $\mathcal{L} = \mu\epsilon^{\mu\nu\rho\sigma}\partial_{\mu}A_{\nu}\partial_{\rho}\omega_{\sigma}\pi$. Its dimension is a length in the natural system of units ($\hbar = c = 1$).

$= -0.5\ \mathrm{GeV}^2$: obviously it is possible to improve the agreement fitting some of the many parameters involved, but in this paper we are not so much interested in the phenomenological description, as in the question to what extent a Regge picture, complemented by symmetry relations, may be applicable for inelastic processes like photoproduction, in spite of the difficulties encountered by the model in the elastic case. For larger values of t our simple model with constant residues is no longer able to fit $d\sigma/dt$ with sufficient accuracy; however our model may be still valid at larger momentum transfer, but at these energies the resonance effects can be important, as suggested in ref. 2.

It should be noted that the contribution of the ρ trajectory, though small, is not at all negligible.

We give also the cross section for the η^0 and X^0 photoproduction, figs. 2 and 3, for which there are practically no data at high energy.

In order to test better the theory, it should be interesting to obtain other experimental data at higher energies where the resonance effects are less pronounced.

The polarization of the recoil proton results very small in our model: this may be easily understood since the ρ and ω trajectories are very close and have the same signature. However this result is probably not reliable in the energy range covered by the experiments where the resonances should contribute to the polarization (compare ref. 16).

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