THE TOTAL PHOTOPRODUCTION CROSS-SECTION AND LIPKIN'S "THIRD COMPONENT"

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We note the fact that doubling Lipkin's third component $\sum_{\varrho,\omega} (\alpha\pi/\gamma_V^2)\, \sigma_{tot}^{(3)}(Vp)$ contributing to forward Compton scattering in the vector dominance model $\sum_{\varrho,\omega,\phi} (\alpha\pi/\gamma_V^2)\, \sigma_{tot}(Vp)$ one fully saturates $\sigma_{tot}(\gamma p)$. The result can be understood in terms of Preparata's light cone controlled mass dispersion relations if the light cone contribution is identified with $2 \sum_{\varrho,\omega} (\alpha\pi/\gamma_V^2)\, \sigma_{tot}^{(3)}(Vp)$.

Lipkin has systematized deviations from the common additive quark model relations for hadronic total cross-sections, by introducing to all hadronic total cross-sections "the third component" proportional to the product of total quark and non-strange quark numbers [1]. Licht and Pagnamenta inspired by Lipkin's "three-component model", proposed the valence core exchange model [2], which might be considered as a universal five-parameter fit to hadronic total cross-sections. In this model it is assumed that hadrons are built up by valence quarks and a non-strange core. "The third component" is produced by Pomeron and Regge exchanges between valence quarks and core quarks as well as only between core quarks. The couplings of both Pomeron and Reggeon to valence quarks (resp., core quarks) of a hadron are taken to be proportional to the number of valence quarks of a given type (resp., the product of the numbers of strange and non-strange quarks in a hadron)[1]. "The third component" breaks SU(3) and exchange degeneracy.

The described model gives remarkable agreement (within 3%) of predicted hadronic total cross-sections with all available total cross-sections above $p_{lab} = 5$ GeV (Ref. [2b]). The fit uses five parameters for all hadronic total cross-sections[2].

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[1] By comparison of the couplings taken from this assumption with those derived from certain integrals over valence quark (resp., core quark) distribution functions, Licht and Pagnamenta arrive at some new sum rules for deep e^-p scattering, which are in very good agreement with experimental data.

[2] We leave aside the so-called "fourth" component [2b] which was found to be necessary for the description of the channels $p\bar{p}$ and $\bar{p}n$ as it is irrelevant for our purposes.

Using the vector meson-nucleon total cross-section as predicted by Licht and Pagnamenta it is straightforward matter to calculate the total photoproduction cross-section via the vector dominance model (VDM)

$$\sigma_{\text{tot}}^{\text{VDM}}(\gamma p) = \sum_{\varrho,\omega,\phi} \frac{\alpha\pi}{\gamma_V^2}\,\sigma_{\text{tot}}(\text{Vp}). \tag{1}$$

According to the recipes of L. P., $\sigma_{\text{tot}}(\text{Vp})$ has to be written as the sum of a valence part and a third component

$$\sigma_{\text{tot}}(\text{Vp}) = \sigma_{\text{tot}}^{\text{val}}(\text{Vp})+\sigma_{\text{tot}}^{(3)}(\text{Vp}), \tag{2}$$

where $\sigma_{\text{tot}}^{\text{val}}(\text{Vp})$ (resp. $\sigma_{\text{tot}}^{(3)}$ (Vp)) denotes the contribution to $\sigma_{\text{tot}}(\text{Vp})$ of the valence quarks (resp. core quarks) of the vector meson interacting with both components of the nucleon. Inserting (2) into (1) we reproduce the well-known deviation of the VDM prediction from the experimental number of approximately 20%. However, calculating the numbers $\sigma_{\text{tot}}^{\text{val}}(\text{Vp})$ and $\sigma_{\text{tot}}^{(3)}(\text{Vp})$ we observe that by doubling the contribution of $\sum_{\varrho,\omega} \frac{\alpha\pi}{\gamma_V^2}\sigma_{\text{tot}}^{(3)}(\text{Vp})$ one gets to a very good accuracy the experimental number for the $\sigma_{\text{tot}}(\gamma\text{p})$, i. e.,

$$\sum_{\varrho,\omega,\phi} (\alpha\pi/\gamma_V^2)\sigma_{\text{tot}}^{\text{VDM}}(\text{Vp})+ \sum_{\varrho,\omega} (\alpha\pi/\gamma_V^2)\sigma_{\text{tot}}^{(3)}(\text{Vp}) = \sigma_{\text{tot}}(\gamma\text{p}). \tag{3}$$

It is the purpose of this note to point out that Eq. (3) might not be an accident but can be understood in terms of Preparata's mass dispersion relations.

To start with we derive relations (1) and (3) using the parametrization from Ref. [2b]. One obtains, for the pure VDM part, the following:

$$\begin{aligned}\sum_{\varrho,\omega,\phi} \frac{\alpha\pi}{\gamma_V^2}\,\sigma_{\text{tot}}(\text{Vp}) &= (1+\eta\ln\nu)\,[(2k^0+16\lambda^0)\,(3k^0+36\lambda^0)\\ &\quad\times(g_{\varrho\gamma}^2+g_{\omega\gamma}^2)+2k^0(2k^0+36\lambda^0)g_{\phi\gamma}^2]\\ &\quad+\frac{1}{\sqrt{\nu}}\{\tfrac{3}{2}\,(k^2+12k\lambda+32\lambda^2)\,(g_{\varrho\gamma}^2+g_{\omega\gamma}^2)\},\end{aligned} \tag{4}$$

where $\nu = \dfrac{s-u}{2}$, $k^0 = 1.065\sqrt{\text{mb}}$, $\lambda^0 = 0.049\sqrt{\text{mb}}$, $k = 3.12\sqrt{\text{mb}}$, $\lambda = 0.249\sqrt{\text{mb}}$, $\eta = 0.09$. "The third component" $\sum_{\varrho,\omega} (\alpha\pi/\gamma_V^2)\,\sigma_{\text{tot}}^{(3)}(\text{Vp})$ is given by

$$\left[16\lambda^0(3k^0+36\lambda^0)\,(1+\eta\ln\nu)+(18k\lambda+48\lambda^2)\,\frac{1}{\sqrt{\nu}}\right](g_{\varrho\gamma}^2+g_{\omega\gamma}^2). \tag{5}$$

From (3), (4) and (5), we get

$$\sigma_{\text{tot}}(\gamma\text{p}) = 64.79(1+\eta\ln\nu)+153.7/\sqrt{\nu}\;(\mu\text{b}), \tag{6}$$

where $g_{\varrho\gamma}^2 = (\alpha\pi/\gamma_\varrho^2)$, $\gamma_\varrho^2/4\pi = 0.64$ and SU(3) relations for the other coupling constants were used[3].

Following Ref. [2b], one can calculate from (4) the ratio $\alpha = \mathrm{Re}\, f_{\gamma p}\,(t = 0)/\mathrm{Im}\, f_{\gamma p}(t = 0)$ doubling again the third component. This is given by

$$\alpha_{\gamma p} = \frac{9.159 - \sigma_{\text{tot}}^{R}(\gamma p)}{\sigma_{\text{tot}}(\gamma p)}\,. \tag{7}$$

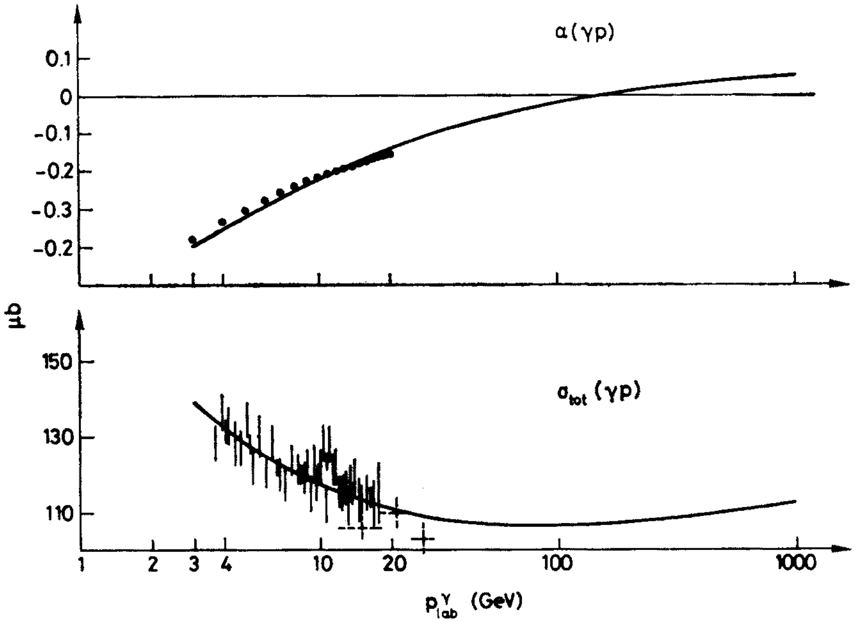

Fig. 1. $\alpha(\gamma p)$ and $\sigma_{\text{tot}}\,(\gamma p)$ as functions of p_{lab}^{γ}. For. details see text

The values $\sigma_{\text{tot}}(\gamma p)$ and $\alpha_{\gamma p}$ are shown in Fig. 1 as functions of p_{lab}^{γ}. One sees very good agreement of data with both theoretical curves. The data for $\sigma_{\text{tot}}(\gamma p)$ are taken from Refs [3] and for α those calculated by Damashek and Gilman [4].

We compare our results with those obtained by Preparata via light cone controlled mass dispersion relations [5].

We confine ourselves to inspect the (leading) Pomeron part of the forward amplitude[4]. Consider the following expression:

$$\frac{\sigma_{\text{tot}}^{P}(\gamma p)}{\sum\limits_{\varrho,\omega,\phi} (\alpha\pi/\gamma_V^2)\sigma_{\text{tot}}^{P}(Vp)}$$

$$= \frac{\sum\limits_{V} (\alpha\pi/\gamma_V^2)\sigma_{\text{tot}}^{P}(Vp) - \sum\limits_{V} (\alpha\pi/\gamma_V^2)\sigma_{\text{tot}}^{P(3)}(Vp)}{\sum\limits_{V} (\alpha\pi/\gamma_V^2)\sigma_{\text{tot}}^{P}(Vp)} + \frac{2\sum\limits_{V} (\alpha\pi/\gamma_V^2)\sigma_{\text{tot}}^{P(3)}(Vp)}{\sum\limits_{V} (\alpha\pi/\gamma_V^2)\sigma_{\text{tot}}^{P}(Vp)}\,. \tag{8}$$

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[3] Using alternatively Lipkin's original parametrization (where the core would be taken proportional to $q \cdot q_{\text{ns}}$) one produces a nearly identical result for the Regge part: $\sigma_{\text{tot}}^{R}(\gamma p) = 148.4/\sqrt{\nu}$.

[4] For Regge parts the analogous identification might be not so straightforward.

From (2) and (3), we get for (6)

$$(1) \quad (1-0.235)+0.47,$$

which has to be compared with Preparata's [5] expression

$$\sum_{V} (b_P^V/2\gamma_V)\left(1-\frac{m_V^2}{M^2}\right)-2\frac{\lambda_P}{M^2} = [(1)\,(0.75)+0.50]\times \text{const} \tag{9}$$

where b_P^V is the Pomeron part of V meson photoproduction amplitude, m_V vector meson mass, $M^2 \cong 2\,\text{GeV}^2$, $\lambda_p \cong 0.3$. The identifications of $2\sum(\alpha\pi/\gamma_V^2)\,\sigma_{tot}^{P(3)}(Vp)$, with light cone contribution $2\lambda_p/M^2$ and

$$\sum(\alpha\pi/\gamma_V^2)\,(\sigma_{tot}^{P}(Vp)-\sigma_{tot}^{P(3)}(Vp)) = \sum(\alpha\pi/\gamma_V^2)\sigma_{tot}^{P(valence)}(Vp)$$

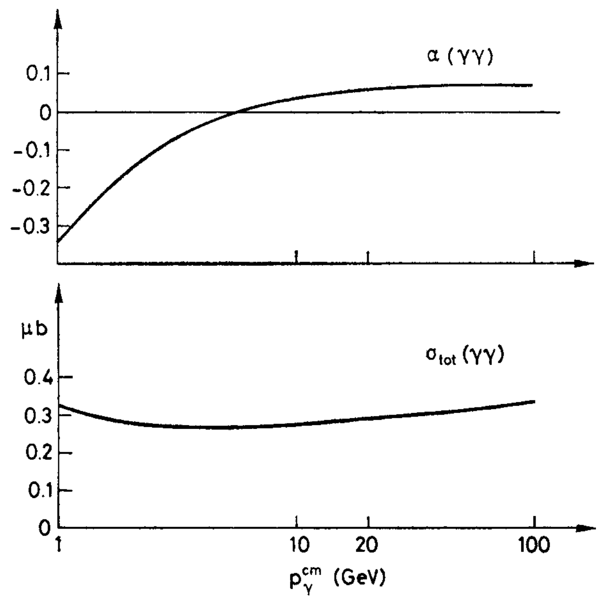

Fig. 2. $\alpha(\gamma\gamma)$ and $\sigma_{tot}(\gamma\gamma)$ as functions of s. For details see text

with the VDM part screened by the continuum $\sum_V (b_P^V/2\gamma_V)\,(1-m_V^2/M^2)$ is suggestive.

Our ansatz was inspired first by the picture of the photon as a hadronic state and second by the apparent universality of Lipkin's three-component (five parameter) fit. We saw that we can identify the different pieces of the Compton scattering amplitude so obtained astonishingly accurately with the various parts of the amplitude deduced from a light cone controlled mass dispersion relation.

Moreover, the model predicts $\sigma_{tot}(\gamma n) = \sigma_{tot}(\gamma p)$ which is not in contradiction with the data [6].

Encouraged by very good agreement of data with relations (4) and (5) we give formulae for $\sigma_{tot}(\gamma\gamma)$ and $\alpha = \text{Re} f_{\gamma\gamma}(t = 0)/\text{Im} f_{\gamma\gamma}(t = 0)$.

$$\sigma_{tot}(\gamma\gamma) = 0.17(1+\eta \ln s)+0.27/\sqrt{s}\,(\mu\text{b}), \tag{10}$$

$$\alpha_{\gamma\gamma} = \frac{0.024-0.27/\sqrt{s}}{\sigma_{tot}(\gamma\gamma)}, \tag{11}$$

where $s = 4(p^{cm})^2$.

We note the factorization property of the Pomeron part of cross-section σ_{tot}, e. g.,

$$\sigma_P^{\gamma\gamma}\sigma_P^{pp} = \sigma_P^{\gamma p}\sigma_P^{\gamma p}.$$

The theoretical curves for $\sigma_{tot}(\gamma\gamma)$ and $\alpha(\gamma\gamma)$ are given in Fig. 2.

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