CM-P00057787

Archives

Ref. TH.873

HIGH ENERGY PHOTOPRODUCTION WITHOUT CONSPIRACY

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ABSTRACT

A simple mechanism is proposed in order to explain the pronounced forward peaks in reactions which are likely to be dominated by pion exchange. A fit is done for π^+ photoproduction.

Recent experiments ¹⁾ with high resolution in the momentum transfer have shown a sharp forward peak in π^+ photoproduction. This shows a peculiar similarity with peaks in other reactions ($pn \rightarrow np$, $p\bar{p} \rightarrow n\bar{n}$, $\pi p \rightarrow \rho \Delta$), which one would like to explain by means of a pion Regge pole. It has been noted, however, that a pion by itself (evasive pion) would actually show a dip in the forward direction and therefore, in order to explain such a peak, it has been suggested the conspiratorial character of the pion. Explicit calculations with a conspiratorial pion have been attempted for π photoproduction ²⁾ and $pn \rightarrow np$ ³⁾. In both cases, it turned out that a very strong dependence on t of the pion residue is needed in order to explain the peak and the expected value of the residue on the pion mass shell. The strong dependence of the residues is, to our point of view, an uneasy feature in the Regge approach.

On the other hand, the forward peaking in $\pi p \rightarrow \rho \Delta$ ⁴⁾, together with the fact that the ρ is produced dominantly with zero helicity near the forward direction, is a feature that cannot be explained by a conspiratorial pion, as has been noted by Le Bellac ⁵⁾.

We have therefore tried to explore other possible mechanisms which would give rise to forward peaks. The mechanism which we would like to propose here is the one of a weakly t dependent contribution - which for the moment we call background - interfering destructively with a normal (evasive) pion Regge pole. This background can have different origins: it can be originated from a Regge cut (coming, for instance, from a pion Pomeron iteration), or from absorption corrections to an evasive pion Regge pole, or from fixed poles at integer nonsense right signature values.

The last interpretation would be easier to understand for the pion photoproduction than for the other reactions. Indeed, in the last case, unitarity would force the fixed pole to be shadowed by a moving cut in a way similar to that discussed by several authors for nonsense wrong signature values ^{*)}.

^{*)} Let us notice that the mechanisms that could give rise to these fixed poles and moving cuts for right signature have, however, nothing to do with the existence of the third double spectral function giving rise to fixed poles and moving cuts for wrong signature points. Anyhow, the phenomenological implications of the background - if this is related to fixed poles - would not be modified drastically by the moving cuts. Indeed, these cuts shadow the poles at the threshold in the t channel and would have receded far away for the values of t describing the s channel diffractive region.

All these models will give to the background the characteristic feature of being automatically conspiratorial (no definite natural parity exchanged) and non-factorizable. These features are all needed in order to explain the lack of dip in the reactions listed. Every model will allow in principle the calculation of the corresponding background. But, for the moment, we do not want to discuss the details of the models, and so we will parametrize the background in a simple way. We will parametrize it as fixed powers of the energy (s) in those invariant amplitudes which can interfere with the pion contribution and we will leave to the fits the determination of the t dependence.

We show now a fit, done in this way, for π^+ photoproduction. We shall use the notation of Ref. ⁶⁾, expressing the helicity amplitudes in the t channel in terms of the usual invariant functions A_i

$$\overline{f}_{01}^+ = -\frac{1}{2} k_t \sqrt{t} (A_1 - 2m A_4)$$

$$\overline{f}_{01}^- = p_t k_t (A_1 + t A_2)$$

$$\overline{f}_{11}^+ = \frac{1}{2} k_t (2m A_1 - t A_4)$$

$$\overline{f}_{11}^- = -p_t k_t \sqrt{t} A_3$$

In order to parametrize the background contribution in the most economical way, we introduce it only through the invariant amplitude A_1 , which can interfere with A_2 , and which is the amplitude containing the pion contribution. Indicating by A_1^b this background contribution to A_1 , we have chosen the form

$$A_1^b = \left(\frac{c_1}{s} + \frac{c_2}{s^2} \right) e^{\gamma t}$$

with c_1 and c_2 constants.

This form can represent the contribution of right signature fixed poles ⁷⁾ at the nonsense values $J=0, -1$, or it can simulate the absorption or the presence of a cut due to pion Pommeranchuk exchange giving a behaviour

$$\sim \frac{1}{s} \frac{1}{\log s} \sim \frac{1}{s^{1.3}}$$

in the region in which the fit is done ^{*)}.

Let us now discuss the contribution of the Regge poles, which are all considered evasive. In the first place there is of course the pion, then the B meson which is found to be important in π^0 photoproduction. In order to explain the relative flatness of $s^2(d\sigma/dt)$ in the range $0.4 \leq -t \leq 0.8 \text{ (GeV)}^2$ we will consider other trajectories with higher intercept at $t=0$. The two possible candidates are ρ and A_2 . The ρ was disregarded because its coupling to $\pi\gamma$ is well known to be small and, moreover, its contribution vanishes at $t=-0.6$, in the region of interest.

We have then the following leading contributions :

$$\overline{f}_{01}^+ = - \frac{k_t \sqrt{t}}{2} \left[A_1^b + (t a_1^{A_2} - 2m a_4^{A_2}) \overline{f}_{A_2} \right]$$

$$\overline{f}_{01}^- = p_t k_t \left[A_1^b + \frac{t}{t-\mu^2} a_2^\pi \overline{f}_\pi + t a_2^B \overline{f}_B \right]$$

$$\overline{f}_{11}^+ = \frac{k_t}{2} \left[2m A_1^b + t(2m a_1^{A_2} - a_4^{A_2}) \overline{f}_{A_2} \right]$$

^{*)}

From a numerical point of view, our background contribution to A_1 may be compared with the contribution of a Regge trajectory with non-defined parity proposed by Dietz and Korth ⁸⁾. The physical meaning and the implications of this approach are, however, completely different from ours.

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where

$$\xi_{\pi} = \alpha_{\pi}(\alpha_{\pi}+1)(\alpha_{\pi}+2)(\alpha_{\pi}+3) \frac{1+e^{-i\pi\alpha_{\pi}}}{\sin\pi\alpha_{\pi}} \left(\frac{s}{s_0}\right)^{\alpha_{\pi}-1}$$

$$\alpha_{\pi} = t - \mu^2$$

$$\xi_B = \alpha_B(\alpha_B+1)(\alpha_B+2)(\alpha_B+3) \frac{1-e^{-i\pi\alpha_B}}{\sin\pi\alpha_B} \left(\frac{s}{s_0}\right)^{\alpha_B-1}$$

$$\alpha_B = t - 0.3$$

$$\xi_{A_2} = \alpha_{A_2}(\alpha_{A_2}+2) \frac{1+e^{-i\pi\alpha_{A_2}}}{\sin\pi\alpha_{A_2}} \left(\frac{s}{s_0}\right)^{\alpha_{A_2}-1}$$

$$\alpha_{A_2} = 0.4 + 0.5t$$

The cross-section is given by

$$\frac{d\sigma}{dt} = \frac{2}{\pi s k_s^2} \left[(|\bar{f}_{01}^-|^2 + |\bar{f}_{01}^+|^2) \sin^2\theta_t + (1 + \cos^2\theta_t) |\bar{f}_{11}^+|^2 \right]$$

The pion residue is determined from perturbation theory by

$$s_0 a_2^{\pi} = \sqrt{2} e g_{\pi} / 48 = 7.8 \sqrt{\mu b} \times (\text{GeV}/c)$$

and the B residue from π^0 photoproduction ⁶⁾

$$a_2^B = -34 \sqrt{2} \sqrt{\mu b} (\text{GeV}/c)^{-3}$$

The fit which reproduces better the experimental data is shown in the Figures 1 and 2. The corresponding parameters are found to be

$$a_1^{A_2} = 2 \sqrt{\mu b} (\text{GeV}/c)^{-3} \quad a_4^{A_2} = -3 \sqrt{\mu b} (\text{GeV}/c)^{-2}$$

and for the background

$$C_1 = -12.75 \sqrt{\mu b} (\text{GeV}/c), C_2 = -58. \sqrt{\mu b} (\text{GeV}/c)^2, \gamma = 2. (\text{GeV}/c)^{-2}$$

which imply indeed a slow t dependence of the background. If we parametrize the background contribution in the form

$$\frac{R(t)}{s - m^2} = \frac{R}{s} \left[1 + \frac{m^2}{s} + \dots \right]$$

(which is, for instance, the form of the Born contribution to A_1), m is found to be of the order of 2.5 GeV, which is a reasonable number if we think the background to be originated by low energy contributions.

It is clear one can obtain, in an analogous way, the fits for the other processes we have discussed, in which the pion is likely to be responsible for the forward peak. But it has not much meaning to attempt other fits, without trying to understand, and therefore correlate - in the framework of a specific model - the parameters of the background for the different processes. This is under investigation for the case of the absorptive model.

The dip in the forward direction which is present for π^0 and K photoproduction would imply that the background is unimportant when the contribution of the Regge pole corresponding to the pseudoscalar meson is absent (π^0) or very small (K). It is interesting to note that in both cases, and contrary to π^+ photoproduction, a strong contribution to the processes is due to the vector meson Regge pole (ω and K^* , respectively).

We are grateful to M. Jacob for useful discussions.

R E F E R E N C E S

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FIGURE CAPTIONS

Figure 1 : The differential cross-section $s^2 d\sigma/dt$ plotted versus $\sqrt{-t}$, for $\gamma p \rightarrow n\pi^+$. The data points are from Ref. 1).

Figure 2 : The differential cross-section $d\sigma/dt$ plotted versus t .

Fig.1

$$s^2 \frac{d\sigma}{dt} (\mu b - GeV^2)$$

- 5 GeV
- × 8 GeV
- 11 GeV
- 16 GeV