ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

Дубна

E2 - 6283

V.M.Budnev , A.V.Efremov, I.F.Ginzburg

ЛАБОРАТОРИЯ ТЕОРЕТИЧЕСКОЙ ФИЗИКИ

THE MODEL OF PION AND KAON PHOTOPRODUCTION SUGGESTED BY QUANTUM MESODYNAMICS

1972

E2 - 6283

V.M.Budnev*, A.V.Efremov, I.F.Ginzburg*

THE MODEL OF PION AND KAON PHOTOPRODUCTION SUGGESTED BY QUANTUM MESODYNAMICS

Submitted to *Physics Letters*

---

* Institute of Mathematics SOAN SSSR, Novosibirsk 90.

Буднев В.М., Ефремов А.В., Гинзбург И.Ф. E2-6283

Фоторождение пионов и каонов с точки зрения квантовой мезодинамики

Предложена новая модель фоторождения π- и K-мезонов, которая единым образом описывает поведение дифференциальных сечений обеих реакций при малых передачах импульса. Эта модель состоит из "элементарного" пиона с толлеровским числом $M=0$ и пары конспирирующих траекторий с $M=1$ и является результатом суммирования асимптотик фейнмановских диаграмм в γ^5-теории.

Препринт Объединенного института ядерных исследований.
Дубна, 1972

Budnev V.M., Efremov A.V., Ginzburg I. F. E2-6283

The Model of Pion and Kaon Photoproduction Suggested by Quantum Mesodynamics

A new model for the charged π- and K-photoproduction is proposed which describes near forward differential cross section of both reactions on equal foots. This model includes the elementary pion with Toller number $M = 0$ and the pair of conspiring trajectories with $M = 1$. It is a result of summation of asymptotics of the Feynman diagramms in the γ^5- theory.

Preprint. Joint Institute for Nuclear Research.
Dubna, 1972

The peculiar structure of the differential cross-section of the reactions with the exchange of the pseudoscalar meson quantum numbers in the region of small momentum transfer is one of the reasons for which these reactions are of great intrest. To explain these peculiarities a variety of phenomenological models was proposed /1-5/. The situation is especially distinct in the cross-section $d\sigma_{\parallel}$ for the photoproduction of charged pseudoscalar mesons by the photon polarized in parallel with the reaction plane, while the photoproduction cross-section $d\sigma_{\perp}$ perpendicularly polarized photons is well described by the usual Regge scheme with the π -conspirator or (πP)-Regge cut.

We consider this problem in the mesodynamics with $L = g\bar{\psi}\gamma^5\psi\phi + h\phi^4$ using the previously developed method of extracting the asymptotics of each diagram within an accuracy $1/S$ and a subsequent summation of them. As a result, we obtain a rather interesting picture of the pion and kaon exchange which we illustrate by the example of charged pion and kaon photoproduction (Fig. 1).

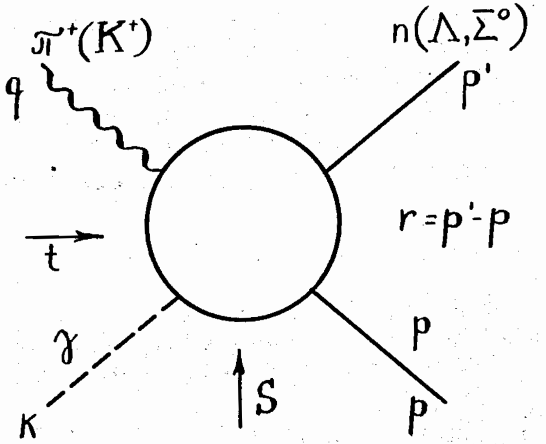

Fig. 1

Let us begin with the pion photoproduction. In the structure of the amplitude with the Toller number $M=0$ there are no Regge trajectories and the main contribution comes from the exchange of "elementary" pion. This contribution is

$$2eg(t)\,\epsilon_{||}\,\frac{\sqrt{-t}}{t-m_\pi^2}\,\bar u\,\gamma^5 u\,, \qquad (1)$$

where $g(t)$ is a pion formfactor of the nucleon normalized by $g^2(m_\pi^2)\,/\,4\pi = 14.8$.

In addition there appear two automatically conspiring trajectories π and π_C with $\alpha_\pi(0)=\alpha_{\pi_C}(0)\equiv\alpha_c(0)$ in the structure with $M=1$[x]. The corresponding contribution is (Fig. I)

$$\frac{2eg_1(t)}{S\sqrt{-t}}\,\bar u(p')\,\frac{(\hat k+\hat q)\hat r}{2}\Big[\epsilon_{||}\gamma^5\alpha_\pi(t)\,\xi_+(\alpha_\pi)\Big(\frac{s}{s_0}\Big)^{\alpha_\pi(t)} - \epsilon_\perp\alpha_C(t)\,\xi_+(\alpha_C)\Big(\frac{s}{s_0}\Big)^{\alpha_c(t)}\big(1+f(t)\hat r\big)\Big]u(p)\,, \qquad (2)$$

where $\xi_+(a)=\frac{\pi}{2}\,\frac{1+\ell^{i\pi a}}{\sin\pi a\,\Gamma(1+a)}$. However we cannot calculate the functions $\alpha(t)$, $g(t)$, $g_1(t)$ and $f(t)$ enterning (I) and (2). Thus we shall suppose that α_π is the usual pion trajectory with $\alpha_\pi(0)\sim 0.02$ and the interaction of the π_C -trajectory with the nucleons is similar to that of the π -trajectory, i.e. $f(t)\equiv 0$. We shall also suppose that the formfactor of the elementary pion is the same as the formfactor of the pion trajectory, i.e. $g_1(t)\equiv g(t)$.

Due to $\alpha_\pi(t)\sim 0$, for small t we can disregard the dependence (2) on S (for $S=$ 100 GeV^2 $(S/S_0)^{\alpha_\pi(0)}\sim 0.91$), so that our choice of the parameters for pion photoproduction at small t gives the same result as the electric Born model /4/ which is in good agreement with experiment in this region. The contribution of the elementary pion (I) to the cross-section vanishes at $t=0$ contrary to the contributions of the conspiring trajectories (2) which are finite. The interference of the two contributions results in a sharp pick for $|t|\leq m_\pi^2$. The contributions of other trajectories in $d\sigma_{||}$ rapidly vanish with increasing S and moreover they are zero at $t=0$. Thus $d\sigma_{||}$ could be calculated from (I) and (2) (Fig. 2). In the cross-section $d\sigma_\perp$ the ρ -trajectory contribution is essential. But for $t\to 0$ it is zero so that for $|t|\leq m_\pi^2$ could be well described by the second term of (2) which guarantees

$$d\sigma_\perp(0) = d\sigma_{||}(0) \qquad (3)$$

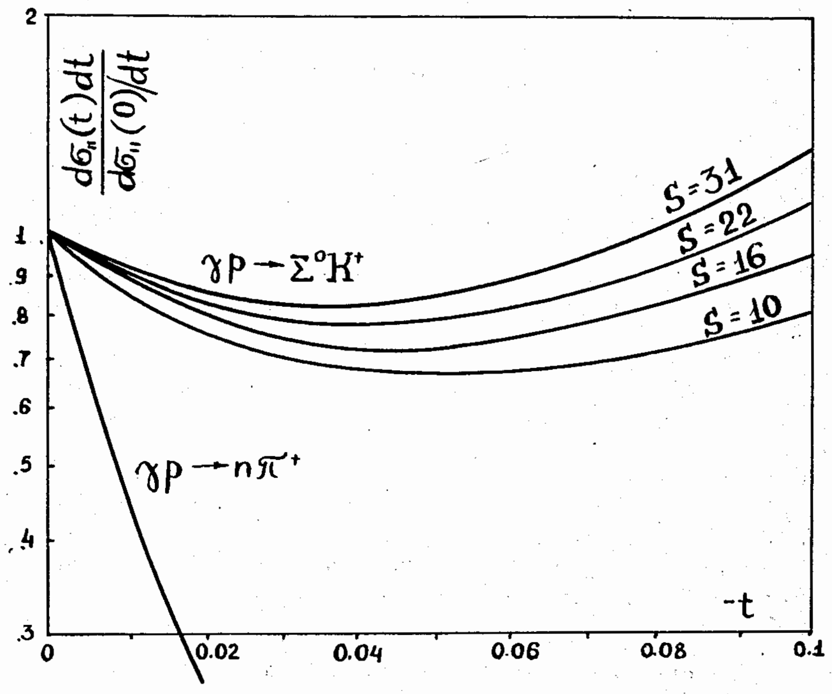

Fig. 2

---

[x] We note, that there are no poles at $\alpha_\pi=0$ and $\alpha_C=0$ because of the proportionality of the corresponding residues to α_π and α_C . Thus there is no trouble with the experimental evidence against the parity partner of the pion.

In addition to the moving poles there also appear standing branchpoints but their contribution is negligible.

For the charged kaon photoproduction $\gamma p \to K^+\Lambda$, $\gamma p \to K^+\Xi^0$ the contributions similar to (1), (2) appear with α_K, m_K instead of α_π, m_π and with equality (3). But an analogous choice of the constants results in a quite different behaviour of the cross-section because of the nonzero value of $\alpha_K(0)$ and the mass difference of the baryons. Since $\alpha_K(0) \simeq -0.2$ the contribution of the conspiring trajectories for high energies is noticeably suppressed and instead of the pick for small $|t|$ we find here a dip in agreement with experiment /1/. Nevertheless, very near $t = 0$ a small ascent must be observed (Fig. 2). Simple calculation with the help of (1) and (2) gives for the cross-section

$$s^2 \frac{d\sigma_{||}}{dt} \sim \frac{e^2 g_K^2(t)}{4\pi} \left[-\frac{m_K^2 \delta_B t}{(m_K^2 - t)^2} + \left| \frac{t}{t - m_K^2} - \eta_K \right|^2 \right] \qquad (4)$$

$$\eta_K = \frac{\pi \alpha(t)(1 + e^{i\pi\alpha_K})}{4 \sin \pi\alpha \, \Gamma(1+\alpha)} \left(\frac{s}{s_0}\right)^{\alpha_K} \sim 0{,}41(1 - 0{,}32 i)\left(\frac{s}{s_0}\right)^{\alpha_K} = \eta_R - i\eta_I , \qquad (5)$$

where $\delta_B m_K^2 = (m_B^2 - m_p^2)$; $\delta_\Lambda = 0.12$; $\delta_\Sigma = 0.25$.
Neglecting the t-dependence of g_K and α_K which holds for $|t| \lesssim 0.1\,\mathrm{GeV}^2$ it is easy to find the position of the minimum in $d\sigma_{||}/dt$ and the relative depth of it

$$|t_{min}| = m_K^2 \frac{\eta_R - \delta/2}{1 - \eta_R - \delta/2} ; \quad \frac{d\sigma_{||}(t_{min})}{d\sigma_{||}(0)} = \frac{\delta(\eta_R - \eta_R^2 - \delta/4) + \eta_I(1-\delta)}{(1-\delta)\,|\eta|^2} . \qquad (6)$$

It is easy to see from (6) and (5) that the position and the depth of the minimum depend on the energy. With the growth of energy it is displaced to the region of positive unphysical t and then disappears. For $\gamma p \to K^+\Sigma^0$ it becomes practically invisible already at $E \sim 20$ GeV but for $\gamma p \to K\Lambda$ it must be observed up to a few hundreds of GeV. These properties are illustrated by Table I.

Table 1

Process	$\gamma p \to K^+\Lambda$					$\gamma p \to K^+\Sigma^0$				
Lab. Energy E (GeV)	5	8	15	25	50	5	8	15	25	50
t_{min} (GeV^2)	0.07	0.06	0.05	0.04	0.03	0.05	0.04	0.03	0.02	0.01
$d\sigma_{\|\|}(t_{min})/d\sigma_{\|\|}(0)$	0.42	0.46	0.50	0.54	0.60	0.69	0.78	0.83	0.91	0.91

In the region 5-15 GeV $\eta_\pi = 0.5$ and $\eta_K \sim 0.3$. These numbers are in good agreement with the empirical parameters of paper [2] λ_π $1 - \eta_\pi \sim 0.5$; $\lambda_K = 1 - \eta_K \sim 0.7$.

Among the other π - and K-photoproduction models only the quasioptical model with Regge cuts [5] describes the experiment without additional parameters. It gives practically the same result in the experimentally known region of small $|t|$. Like our model, it gives a small peak for K-photoproduction near $t \sim 0$ but the position of the minimum and its relative depth are independent of energy. This fact is connected with the practically identical behaviour of the K-trajectory and (KP)-cut playing the same role as the elementary pion (1) and the conspiring trajectories (2) of our model which have different energy dependence. Thus experiments of a not so distant future allow to distinguish between these two models. This would answer the important question as to whether the pseudoscalar mesons are elementary particles or not.

Notice in conclusion, that the experimental study of the charge exchange processes $pn \to np$ and $p\bar{p} \to n\bar{n}$ shows for the selected pion exchange contribution a zero slope of the pion trajectory. Our model gives a natural explanation of this fact since the contribution (1) with $\alpha_{eff} = 0$ is predominant for large energy. From our point of view, a similar behaviour is expected in the reactions $p\bar{p} \to \Lambda\bar{\Lambda}$, $p\bar{p} \to \Sigma\Sigma$ and $\Sigma p \to p\Sigma$.

References

1. K. Lübelsmeyer. Proc. of 1969 Intern.Symp. on Electron and Photon.
2. J.S. Ball, W.R. Frazer, M. Jacob. Phys.Rev.Lett., 20, 518 (1968).
3. J.D. Jackson and C. Quigg. Nucl.Phys., 22B, 301 (1970).
4. G. Kramer and P. Stichel. Zeits. f.Phys., 178, 519 (1964); S.P. Direkk, J.A. Sallivan. Phys.Rev.Lett., 19, 268 (1967).
5. A.B. Kaydalov, B.M. Karnakov. Sov.Nucl.Phys., 11, 216 (1970). J. Frøyland, D. Gordon. Phys.Rev., 177, 2500 (1969).
6. I.F. Ginzburg, A.V. Efremov, V.G. Serbo. Sov.Nucl.Phys., 9, 451 (1969). I.F. Ginzburg, V.G. Serbo. Sov.Nucl.Phys., 9 868 (1969).
7. V.M. Budnev, I.F. Ginzburg, V.G. Serbo. Theor. and Math. Phys., 6, 55 (1971).
8. H. Schopper. The Charge Exchange Reactions $np \to pn$ and $\bar{p}p \to \bar{n}n$. Proc. of Intern.Symp. on Binary React., Dubna, D-6004, 1972.

Received by Publishing Department
on February 14, 1972.