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RESONANCE INTERACTIONS OF K MESONS

Ya. I. GRANOVSKIĬ and A. A. PANTYUSHIN

Nuclear Physics Institute, Academy of Sciences, Kazakh S.S.R.

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Effects in the physics of strange particles due to the resonance $K\pi$ interaction (K^* meson) are considered. It is shown that in a number of cases this interaction determines the main features of the observed phenomena.

1. INTRODUCTION

A characteristic feature of strong interactions is the resonance behavior of cross sections in the region of moderate energies. At present this has been well established both in the physics of π mesons and nucleons, and also in the physics of strange particles. Of particular interest is the study of interactions between the lightest particles— π and K mesons, since peripheral concepts enable us to transfer the properties of the $K\pi$ system to other states.

In this paper this point of view is utilized to investigate those processes in which the resonance properties of the $K\pi$ system are manifested. At the present time we can regard the following characteristics of the $K\pi$ resonance as being well established (cf. [1]):

$$M = 885 \pm 3 \text{ MeV}, \quad \Gamma = 16 \pm 3 \text{ MeV}, \quad T = 1/2, \quad J = 1,$$
$$P = P_K, \quad S = -1. \tag{1}$$

Because this resonance is very narrow we can assume the existence of a quasiparticle—the K^* meson—having the characteristics noted above (cf. [2]).

The interaction

$$\langle K\pi/K^*\rangle = \lambda e_\mu (p_K - p_\pi)_\mu \tag{2}$$

(e_μ is the polarization pseudovector of the K^* meson, and the isotopic part of the matrix element is omitted) then leads to resonance in $K\pi$ scattering. The constant λ is uniquely determined by the width

$$\lambda^2/4\pi = 1.26 \pm 0.25. \tag{3}$$

We shall apply the concept of the K^* meson to the calculation of such processes as $\bar{K}N \to \bar{K}\pi N$ assuming that they occur via the intermediate state containing K^*: $\bar{K}N \to \bar{K}^*N \to \bar{K}\pi N$. Although such a concept is a fairly approximate one, nevertheless, it enables us to elucidate the principal features of the phenomena under consideration.

2. PRODUCTION OF K^* MESONS IN $\bar{K}N$ COLLISIONS

Calculations relative to the $\bar{K}N \to \bar{K}^*N$ process can be carried out with the aid of the diagram shown in Fig. 1. In doing this we shall utilize expression (2) for the vertex. This procedure is valid only in a restricted energy region, for because the K^* meson is nonelementary its properties vary with the energy (the Regge trajectory deviates from a horizontal straight line).

After summing over the polarizations of K^* we obtain

$$\frac{d\sigma}{dq^2} = f_T \frac{\pi}{4p^2W^2}\left(\frac{\lambda g}{4\pi}\right)^2 \frac{q^2}{(q^2+\mu^2)^2}\left[-4K^2 + \left(\frac{q^2+K^2+K^{*2}}{K^*}\right)^2\right], \tag{4}$$

where p, W are the momentum and the energy in the center-of-mass system, q is the momentum transferred to the nucleon, g is the πN coupling constant, f_T is the isotopic multiplier; μ, K, K^* are respectively the masses of the π, K, and K^* mesons.

A characteristic feature of the resultant distribution is that it does not depend strongly on q^2 (and therefore on $\cos\theta$) thus leading to an isotropic angular distribution of K^* mesons. This

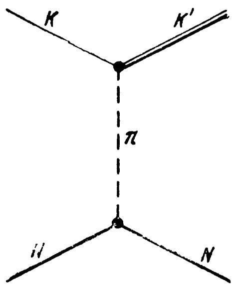

FIG. 1

agrees with experiment[1] and provides evidence in favor of vector K* mesons, since in the case of scalar mesons the factor in square brackets is absent from formula (4) and one obtains an anisotropic angular distribution with a peak backwards.

On integrating over the angles we obtain for the total cross section

$$\sigma = f_T\,(\lambda^2/4\pi)\,f(E) \tag{5}$$

(cf. the graph for the function f(E) in Fig. 2). For the reaction

$$K^- + p \to K^{*(-)} + p \tag{6}$$

($f_T = 1/5$) at E = 760 MeV (p_L = 1150 MeV/c) we obtain $\sigma = 0.2\,(\lambda^2/4\pi) \times 8.2 = (2.1 \pm 0.5)$ mb —a value agreeing with that observed by Alston et al[1]. As the energy increases the cross section reaches a plateau of 2.5 mb.

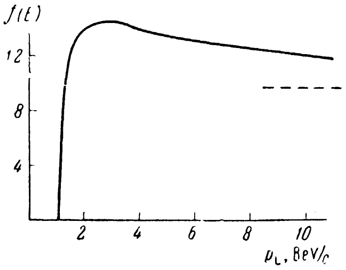

FIG. 2

In K^-n collisions the cross section for the production of K* mesons is by a factor of five smaller than in K^-p collisions.

3. PRODUCTION OF K* MESONS IN πN COLLISIONS

In this case the πKK* vertex is connected to the nucleon line by means of a K meson. The nucleon transforms into a hyperon, and the cross section depends on the relative parity of the K meson and the hyperon. If $P_K P_Y = -1$, then

$$\frac{d\sigma}{dq^2} = f_T\,\frac{\pi}{4p^2W^2}\left(\frac{\lambda g_Y}{4\pi}\right)^2\frac{q^2+(Y-N)^2}{(q^2+K^2)^2}\left[-4\mu^2+\left(\frac{q^2+\mu^2+K^{*2}}{K^*}\right)^2\right] \tag{7}$$

(g_Y is the coupling constant describing the coupling of the K meson and the baryons, Y, N are the masses of the hyperon and the nucleon). If $P_K P_Y = +1$ then instead of $(Y-N)^2$ we must introduce $(Y+N)^2$.

This formula leads to an anisotropic angular distribution of K mesons with a forward maximum. The degree of anisotropy increases with energy, and this manifests itself in the angular distribution of the K mesons—the products of the decay of K* (cf. [3]). In the case of an incident π^- the K mesons are produced in the ratio

$$N(K^+) : N(K^0) = 2 : 1\,. \tag{8}$$

This ratio is inverted if a π^+ is incident.

The energy dependence of the cross section for the production of K* depends on the parity of P_{KY} —cf. Fig. 3. At high energies the total cross section is constant

$$\sigma = \sigma_0 = f_T\left(\frac{\lambda^2}{4\pi}\right)\left(\frac{g_Y^2}{4\pi}\right)\frac{\pi}{2K^{*2}} \tag{9}$$

and does not depend on the parity of the strange particles. A measurement of this quantity would enable us to evaluate the coupling constant for the coupling between K mesons and baryons, since

$$\sigma(\pi N)\,/\,\sigma(\bar{K}N) = (g_\Sigma^2 + 3g_\Lambda^2)\,/\,g_N^2. \tag{10}$$

If we utilize the constants obtained in [4], then we have

$$\sigma_{K^{*(0)}} = 1.6\text{ mb.} \qquad \sigma_{K^0} = 0.5\text{ mb.} \tag{11}$$

(cf. [3]). The principal contribution to this quantity is made by the production of (ΣK*) pairs, since the frequency of production of (ΛK*) pairs is less by a factor of $g_\Sigma^2/3g_\Lambda^2 \approx 10$. Recently this conclusion was verified experimentally[5].

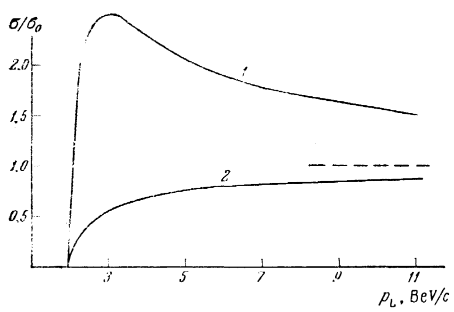

FIG. 3. Excitation curves for the reaction $\pi^- + p \to K^{*(0)} + Y^0$ for different relative parities of the hyperons. Curve 1 – for $P_K P_Y = +1$, curve 2 – for $P_K P_Y = -1$.

Extending the idea of the resonance production of K mesons it can be assumed that the $K_0\bar{K}_0$ pairs observed by Wang et al[3] originated in the decay

$$K^{\prime\prime(0)} \to \begin{cases} K_0 + \bar{K}_0 \\ K^+ + K^-. \end{cases} \tag{12}$$

For vector K″ mesons the magnitude of the cross section can be estimated as $f_T(\gamma^2/4\pi) \times (g^2/4\pi)(\pi/2K''^2)$. If we take a trial value for the mass of K″ equal to 1.2 BeV, and if we take the coupling constant for the coupling between K″ and π mesons, as in formula (3), to be given by $\gamma^2/4\pi$ = 1.5, we obtain for the cross section for the production of $K''^{(0)}$ by π^- mesons $\sigma_{lim} \approx 3.2$ mb.

The statistical weight of the $(K\bar{K})$ state is smaller by a factor of three than the statistical weight of $(\pi\pi)$. Therefore, the $K\bar{K}$ pairs will be produced with a cross section $\sigma_{lim}/4 = 0.8$ mb, while $\sigma(K_0\bar{K}_0) = 0.4$ mb. This agrees with the estimate of $\sigma(K_0\bar{K}_0)$ given in [3].

The isospin of the vector K″ meson is equal to unity by virtue of the symmetry of the 2π-meson state. Therefore, together with $K''^{(0)}$ some $K''^{(-)}$ mesons will also be formed which decay in accordance with the scheme

$$K''^{(-)} \rightarrow K^- + K_0. \tag{13}$$

The cross sections for the production of $K''^{(0)}$ and $K''^{(-)}$ are in the ratio of 2:1 and, therefore, $N(K^-K_0):N(K_0\bar{K}_0) = 1:1$. Experimentally this ratio is found[3] to be equal to $1.5^{+1.5}_{-0.7}$. If the isospin of K″ is equal to zero, then the mechanical angular momentum must be even. For $J = 0$ the cross section for the production of K″ falls off with energy as $E^{-2} \ln E$, while for $J = 2$ it increases as E^2 (up to the limit permitted by unitarity). The widths also differ appreciably: for $J = 2$ the parameters adopted above yield $\Gamma \approx 50$ MeV, while for $J = 1$ $\Gamma \approx 200$ MeV (the increase in the K″ width compared to the ρ meson is due to the increase in the phase volume).

Apparently, the resonance pairs $K_0\bar{K}_0$ and $\pi\pi$ observed in[6,7] are products of the decay of K″. Indications of this are the nearly equal values of the masses and the preliminary estimates of the values of J and T.

4. CONCLUSION

We have investigated the effects of including the πKK^* vertex in the nucleon interaction. If the parameters of the K* meson are chosen as in [1] then it is possible to explain a number of regularities in various processes associated with the formation of resonance $K\pi$ systems. We should also mention the results of Tiomno[2] who explains the characteristic angular distribution of Λ hyperons in the process of associated production of ΛK by forces arising as a result of exchanging a K* meson. These same forces can also play an essential role in the theory of the $\pi\Lambda$ interaction. The K* meson can also be associated with the resonance[8,9] in $\bar{K}N$-scattering at $E = 650$ MeV, $T = 0$: a sharp increase in the cross section for the inelastic process $\bar{K}N \rightarrow K^*\bar{N}$ (cf., Sec. 2) leads to a resonance in the total cross section[10].

Nevertheless, the method described above—treating the K* meson as a particle—is inconsistent. The point is that the K* meson decays rapidly, and its decay products interact strongly with the other particles, and this can alter in an essential manner the whole picture of the phenomenon. In the cases considered by us this effect, as a rule, is not great (cf., for example, [1]), and comparison with experiment yields satisfactory agreement. However, it is clear that the nonresonance background and the interference phenomena associated with it already lie beyond the framework of this approach. For their explanation we require a consistent treatment of the $K\pi$ interaction which in addition to the resonance interaction also includes the nonresonant ones.

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