SOVIET PHYSICS JETP VOLUME 15, NUMBER 3 SEPTEMBER, 1962

ON THE REACTION $\pi^- + p \rightarrow \Lambda^0 + K^0$

J. WOLF and G. DOMOKOS

Joint Institute for Nuclear Research

Submitted to JETP editor October 10, 1961

J. Exptl. Theoret. Phys. (U.S.S.R.) **42**, 871-874 (March, 1962)

The differential cross section of the reaction $\pi^- + p \rightarrow \Lambda^0 + K^0$ is calculated with one K′ "particle" in the intermediate state. Radiation corrections to the propagator and vertices are taken into account. The results indicate that K′ has spin one.

1. INTRODUCTION

ACCORDING to the experimental data,[1] the differential cross section for the process

$$\pi^- + p \rightarrow \Lambda^0 + K^0 + n\pi$$

has two well-defined regions. The statistical theory satisfactorily explains the behavior of the differential cross section in the region of large momentum transfers. It is natural to regard the region of small momentum transfers as representing peripheral interactions.

In the reaction, this would correspond to the exchange of the K and π particles. However, according to Alston et al.[2] there is a narrow resonance K′ in the $K\pi$ system. Some authors[3] therefore considered the process $\pi^- + p \rightarrow \Lambda^0 + K^0$ in the pole approximation with an exchange of a K′ particle. But since $M_{K'} > m_K + m_\pi$ it is apparently necessary to take into account the radiative correction to the basic process.

2. DIFFERENTIAL CROSS SECTION FOR THE REACTION $\pi^- + p \rightarrow \Lambda^0 + K'$

We choose the system of units in which $\hbar = c = m_\pi = 1$ and we denote the K′ mass by M, and the mass of the K meson by m. The process is described by the diagram shown in Fig. 1. The complete propagator for the K′ "particle" is given by the expression

$$\Delta_1^c(q^2) = O_{\mu\nu} / [M^2 - q^2 + \Pi(q^2)], \tag{1}$$

where $O_{\mu\nu} = 1$ if the K′ spin is zero and $O_{\mu\nu} = g_{\mu\nu} - q_\mu q_\nu / M^2$ if the spin is unity.

We now calculate

$$\Pi(q^2) = (q^2 - M^2) \int_{(m+1)^2}^{\infty} \frac{\sigma(t')}{(t' - q^2)} \frac{dt'}{(t' - M^2)}, \tag{2}$$

where

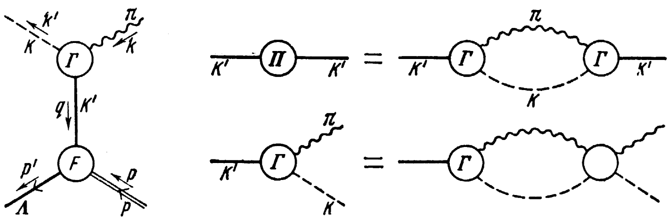

FIG. 1. Diagrams for the scattering amplitude of the vertex and eigen-energy parts.

$$\sigma_{S,V}(t) = -\frac{g^2_{S,V}}{4}(2\pi)^4 \frac{K(t)}{t} |\Gamma_{S,V}|^2 Q_{S,V}(t),$$

$$K(t) = \sqrt{(t+\Delta)^2 - 4m^2 t}, \quad \Delta = (m^2 - 1). \tag{3}$$

We denote the coupling constant of the $K'K\pi$ interaction by $g_{S,V}$; $Q_S = 1$ if the K′ spin is zero and $Q_V = [t - 2(m^2 + 1)]$ if the spin is unity.

If in the expression for Γ —the vertex part of the $K'K\pi$ interaction—only states with one K meson and one pion are taken into account, then $\Gamma(t)$ satisfies the equation

$$\Gamma_{S,V}(t) = \frac{1}{\pi} \int_{(m+1)^2}^{\infty} \frac{dt'}{t' - t} \Gamma_{S,V}(t') e^{-i\delta(t')} \sin\delta(t'), \tag{4}$$

where δ is the S or P phase shift of the $K\pi$ scattering in the scalar or vector case, respectively. Taking into account the resonance character of δ, we obtain an approximate expression for the narrow resonance:

$$\Gamma_S(t) = \frac{\gamma}{2M} \frac{M^2 - t}{(M^2 - t)^2 + \gamma^2/4}, \tag{5a}$$

$$\Gamma_V(t) = \frac{\gamma}{2M\nu_0} \frac{M^2 - t}{(M^2 - t)^2 + \gamma^2/4}. \tag{5b}$$

Here, γ is the half-width of the K′ resonance, $\nu_0 = K^2(M^2)/4M$.

The quantity g^2 is expressed in terms of γ in the following way:[4]

$$\frac{1}{g^2} = \frac{d}{dt} \sqrt{\frac{\nu}{t}} \operatorname{ctg} \delta(t) \Big|_{t=M^2}. \tag{6*}$$

*ctg = cot.

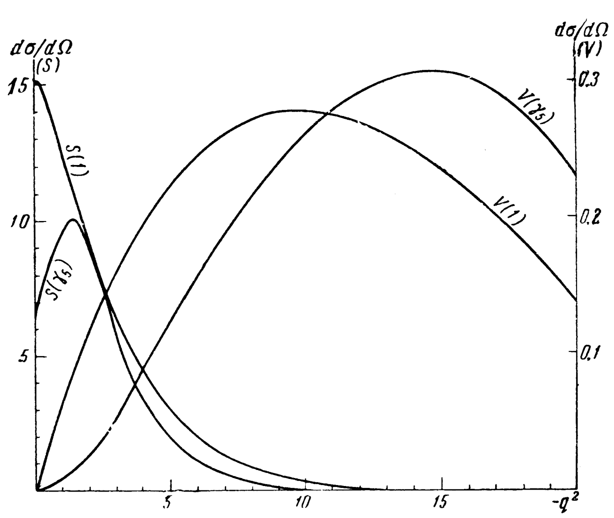

FIG. 2. Differential cross section for the $\pi^- + p \to \Lambda^0 + K^0$ in arbitrary units. The curves are normalized over the interval $0 \le -q^2 \le 20$. The notation $S(1),\ldots,V(\gamma_5)$ indicate the spin of the K' particle and the relative parity at the $K'\Lambda N$ vertex.

This gives

$$g_S^2 = \gamma/K(M^2) \tag{7a}$$

in the scalar case, and

$$g_V^2 = \tfrac{1}{4}\gamma K(M^2) \tag{7b}$$

in the vector case.

With the aid of the foregoing formulas and the general Feynman rules, we obtain the c.m.s. differential cross section for unpolarized baryons.

$$\left(\frac{d\sigma}{d\Omega}\right)_S = \frac{G_S^2}{16(2\pi)^4}\frac{|\mathbf{p}'|\gamma}{W|\mathbf{p}|k_0'K(M^2)}[(M_\Lambda+\varepsilon M_N)^2 - q^2]\frac{|F(q^2)|^2|\Delta_{1S}^c|^2}{(M^2-q^2)^2}, \tag{8a}$$

$$\frac{1}{\Delta_{1S}^c} = M^2 - q^2 + \frac{\pi(2\pi)^4\gamma^2}{4M^2K(M^2)}\left\{\frac{M^2-m^2-1}{M^2K(M^2)} + \frac{K(M^2)}{M^4} - \frac{K(M^2)}{M^2(M^2-q^2)}\right\};$$

$$\left(\frac{d\sigma}{d\Omega}\right)_V = \frac{G_V^2}{32(2\pi)^4}\frac{|\mathbf{p}'|\gamma K(M^2)}{W|\mathbf{p}|k_0'M^4}[(M_\Lambda+\varepsilon M_N)^2-q^2] \times(-q^2)|F(q^2)|^2|\Delta_{1V}^c|^2,$$

$$\frac{1}{\Delta_{1V}^c} = M^2 - q^2 + \frac{\pi(2\pi)^4\gamma^2K(M^2)}{64\,M^2V_0^2}\left\{\frac{2(m^2+1)-M^2}{M^2}\times\left(\frac{M^2-m^2-1}{K(M^2)} - \frac{K(M^2)}{M^2}\right) - \frac{K(M^2)}{M^2}\left(\frac{q^2-2(m^2+1)}{q^2-M^2}\right)\right\}. \tag{8b}$$

Here $W = p_0 + k_0$ is the total c.m.s. energy; $\epsilon = P_{\Lambda p}P_{K'}$, where $P_{\Lambda p}$ is the relative parity for Λp; and $P_{K'} = 1$ if K' is scalar (0^+) or pseudovector (1^+) and $P_{K'} = -1$ if K' is pseudoscalar (0^-) or vector (1^-). The quantity $F(q^2)$ is the formfactor for the $p\Lambda K'$ vertex and is taken into account here in effective-radius approximation, where $\langle r^2\rangle \approx (m+1)^{-2}$. Using the experimental data of Alston et al.,[2] we obtain the curves shown in Fig. 2.

3. DISCUSSION OF RESULTS

The obtained results indicate that the radiative correction to the propagator of K' is very small. The corrections to the vertex part, however, have an important effect on the final result. Comparing the obtained distribution with the experimental data of Veksler et al,[1] we conclude that K' is apparently a vector or pseudovector. In order to determine the parity, more accurate measurements are needed.

We should still like to remark that in our opinion the pions produced together with the Λ^0 and K^0 in the final state should not play an important role in peripheral interactions. In fact, it can be expected that in peripheral collisions the pions are produced as a result of the production and decay of a K' or Λ^* in the final state. If the latter is sufficiently long-lived and the Λ^* spin is $1/2$, the pions will have little effect on the shape of the q^2 distribution.

The authors express their sincere gratitude to Academician V. I. Veksler, E. N. Kladnitskaya, and A. Mikhul for valuable discussions.

[1] Veksler, Vrana, Kladnitskaya, Kuznetsov, Mikhul, Mikhul, Nguyen, Penev, Solov'ev, Hofmokl, and Cheng, Joint Institute for Nuclear Research, Preprint D-806, 1961.

[2] Alston, Alvarez, Eberhard, Good, Graziano, Ticho, and Wojcicki, Phys. Rev. Lett. **5**, 520 (1960).

[3] Chia-Hwa Chan, Phys. Rev. Lett. **6**, 383 (1961); M. A. B. Bég and P. C. de Celles, ibid. **6**, 145 (1961).

[4] M. Gell-Mann and F. Zachariasen, Preprint, Cal. Tech., 1961.

Translated by E. Marquit
139