CONCERNING THE ELECTROMAGNETIC STRUCTURE OF THE K MESON

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An expression for the isovector part of the electromagnetic form factor of the K meson has been deduced by applying the dispersion relation technique to the problem of the electromagnetic structure of the K meson. The electromagnetic radius of the K meson is calculated under the assumption of a narrow $\pi\pi$ resonance.

SEVERAL authors have in recent times successfully applied the double dispersion relation technique to the discussion of reactions involving π mesons and nucleons as well as to the problem of the electromagnetic structure of the nucleon and the pion. We are thus encouraged to go on to the consideration of reactions involving strange particles. In the same way as the pion-pion interaction plays a fundamental role in the problem of the scattering of nucleons and pions, the πK interaction is the determining factor in reactions involving strange particles. This last interaction has been given considerable attention in recent times. Since direct experiments on πK scattering are at present impossible, one may obtain information on the πK interaction from the analysis of various reactions in which K mesons participate. Thus the analysis of experiments on K^-N scattering[1] and K^+N scattering[2] with the help of the double dispersion representation leads to certain conclusions concerning the amplitude of the process $\pi + \pi \rightarrow K + \bar{K}$.

In view of the success of the dispersion representation approach in the investigation of the electromagnetic form factor of the nucleon[3] and of the K^-N scattering[1] and the K^+N scattering[2] it is possible to obtain some information on the electromagnetic structure of the K meson.

Let us consider the current density operator of the K meson taken between a kaon-antikaon state and the vacuum. Owing to Lorentz and gauge invariance it can be written in the form

$$\langle p_1 p_2 | j_\mu (0) | 0 \rangle = (p_1 - p_2)_\mu F_K(t)/\sqrt{p_{10} p_{20}}, \tag{1}$$

where p_1 and p_2 are the four-momenta of the kaon and antikaon, and

$$t = -(p_1 - p_2)^2 = (p_{10} - p_{20})^2 - (\mathbf{p}_1 - \mathbf{p}_2)^2.$$

The form factor of the K meson $F_K(t)$ can be divided up into an isoscalar and an isovector part:

$$F_K(t) = F_K^S(t) + \tau_3 F_K^V(t), \quad F_K^S(0) = F_K^V(0) = e/2.$$

We shall restrict our discussion to the isovector part $F_K^V(t)$, which satisfies the dispersion relation

$$F_K^V(t) = \frac{e}{2} + \frac{t}{\pi} \int_{4\mu^2}^{\infty} \frac{\operatorname{Im} F_K^V(t')\, dt'}{t'(t'-t)} \tag{2}$$

We have performed a subtraction in order to improve the convergence of the integral.

In calculating $\operatorname{Im} F_K^V(t)$ with the help of the unitarity condition we shall take only two-pion intermediate states into account. We have then

$$\operatorname{Im} F_K^V(t) = \frac{e}{2\pi} \frac{q^3}{4E} b_1^+(t) F_\pi(t), \tag{3}$$

where $q^2 = t/4 - \mu^2$, $E = \sqrt{q^2 + m_K^2}$, $F_\pi(t)$ is the form factor of the pion, and $b_1(t)$ is the partial amplitude for the process $\pi + \pi \rightarrow K + \bar{K}$ in the state $T = J = 1$.

Assuming a narrow resonance of the $\pi\pi$ interaction in the state $T = J = 1$, we can express $b_1(t)$ approximately as[4]

$$b_1(t) = (\xi/4\pi) F_\pi(t),$$

where ξ is some phenomenological constant. Hence

$$F_K^V(t) = \frac{e}{2}\left[1 + \frac{t}{\pi^2}\left(\frac{\xi}{4\pi}\right) \int_{4\mu^2}^{\infty} \frac{q'^3}{4E'} \frac{|F_\pi(t')|^2}{t'(t'-t)} dt'\right]. \tag{4}$$

We shall use the following expression for F_π:[5]

$$F_\pi(t) = \frac{11.3}{11.5 - t - i\,2.32}.$$

This expression agrees roughly with the pion form factor of Frazer and Fulco,[3] but is more convenient for calculations. To simplify matters, we make the replacement

$$|F_\pi(t)|^2 = \frac{(11.3)^2}{2.32} \frac{\gamma}{(t-t_r)^2 + \gamma^2} \rightarrow \frac{(11.3)^2}{2.32} \pi\delta(t_r - t), \tag{5}$$

where $t_r = 11.5\mu^2$ and $\gamma = 2.32\mu^2$. Then

$$F_K^V(t) = \frac{e}{2}\left(1 + A\frac{\xi}{4\pi} \frac{t}{t_r - t}\right), \tag{6}$$

where A ≈ 0.576.

With the help of (6) we can calculate the isovector radius of the K meson:

$$\langle (r_K^V)^2 \rangle \approx 6A\xi/t_r 4\pi \approx 0.3\xi/4\pi.$$

The analysis of the energy dependence of the K^-N and K^+N scattering phases [1,2] shows that $0.5 \le \xi/4\pi \le 1$ for $t_r = 11.5\mu^2$. We then obtain

$$5.4 \cdot 10^{-14}\text{cm} \leqslant r_K^V \leqslant 7.8 \cdot 10^{-14}\text{ cm},$$

which is in approximate agreement with the electromagnetic dimensions of the nucleon.

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[1] Ferrari, Frye, and Pusterla, Phys. Rev. Lett. **4**, 615 (1960).

[2] B. W. Lee, Phys. Rev. **121**, 1550 (1961).

[3] W. R. Frazer and J. R. Fulco, Phys. Rev. Lett. **2**, 365 (1959); Phys. Rev. **117**, 1609 (1960).

[4] B. W. Lee and K. S. Cho, Modified Static Equations for the πK Interaction. Effect of Pion-pion Resonance (preprint).

[5] S. C. Frautschi and J. D. Walecka, Phys. Rev. **120**, 1486 (1960).

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