Electromagnetic characteristics of $P \to \gamma l^+ l^-$ decays in the nonlocal quark model

G. V. Efimov and M. A. Ivanov
Joint Institute for Nuclear Research

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The electromagnetic characteristics of the pseudoscalar-meson decay $P \to \gamma l^+ l^-$ were calculated in the nonlocal quark model. An agreement with the recently obtained experimental data for η mesons is obtained and a prediction for the η' meson is given.

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An interest in studying the $P \to \gamma l^+ l^-$ decays has increased recently. Fischer *et al.*[1] have determined experimentally the sign and the absolute value of a in the π-meson form factor for the $\pi^0 \to \gamma e^+ e^-$ decay. The characteristics of the $\eta \to \mu^+ \mu^- \gamma$ and $\eta' \to \mu^+ \mu^- \gamma$ decays have recently been observed and measured at Serpukhov.[2,3]

In this paper we examine these processes in the nonlocal quark model,[4] a self-consistent, relativistic scheme of the quantum-field bag. Using only two free parameters characterizing the quark field, this model can describe with good accuracy a rather large number of decays of the pseudoscalar mesons and vector mesons and of the baryon octet and decuplet.[4,5]

The diagrams corresponding to the $P \to \gamma l^+ l^-$ decay are shown in Fig. 1. The invariant amplitude has the form

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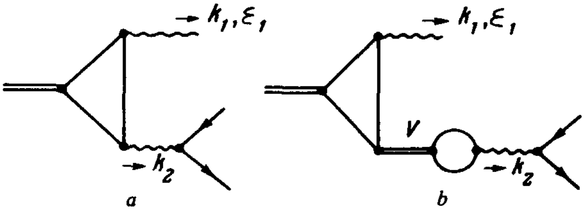

FIG. 1.

$$M(P\to\gamma l^+l^-) = -e^3\,\Phi_P(k_2^2)\epsilon_{\mu\rho\nu\sigma}\,\epsilon^{\mu}(k_1)k_1^{\rho}k_2^{\sigma}j^{\nu}_{em}\,|\,k_2^2.$$

Here,

$$\Phi_P(k_2^2) = g_{P\gamma\gamma}(k_2^2) + k_2^2\sum_v \frac{g_{Pv\gamma}}{f_v}\frac{1}{m_v^2 - k_2^2}.$$

We have the following parametrization for sufficiently small k_2^2:

$$\Phi_P(k_2^2) = g_{P\gamma\gamma}(0)\left[1+\frac{k_2^2}{M_P^2}\right],$$

where

$$\frac{1}{M_P^2} = \frac{L^2}{4}\,\frac{1}{1+\mu_P^2\left[1+\frac{1}{2}\xi^2\right]/12}\left[\left(1+\frac{1}{2}\xi^2\right)/12 + F(\xi)\,r_P\right],$$

$$\mu_P^2 = \left(\frac{m_P L}{2}\right)^2,$$

$$F(\xi) = 2\lambda\xi^2 S_0(\xi)[\,1+2S_1(\sqrt{2}\,\xi) - C_0(\sqrt{2}\,\xi)\,]\frac{4}{m_\rho^2 L^2},$$

$$r_{\pi^0} = 2,$$

$$r_\eta = \frac{10}{3}\,\frac{\cos\theta - \sqrt{2}\sin\theta}{\cos\theta - 2\sqrt{2}\sin\theta},$$

$$r_{\eta'} = \frac{10}{3}\,\frac{\sqrt{2}\cos\theta + \sin\theta}{2\sqrt{2}\cos\theta + \sin\theta}.$$

The structure integrals have the form

TABLE I.

	M_P^{-2} (GeV^{-2})	
	Experiment	Theory
$\pi^0 \to \gamma e^+ e^-$	5.5 ± 1.7 [1]	2.3
$\eta \to \gamma \mu^+ \mu^-$	3 ± 1 [2, 3]	2.6
$\eta' \to \gamma \mu^+ \mu^-$	——	1.4

$$C_n(\xi) = \frac{2}{n!} \int_0^\infty dt\, t^{2n+1} e^{-t^2} \cos \xi t,$$

$$S_n(\xi) = \frac{2}{n!} \int_0^\infty dt\, t^{2n+1} e^{-t^2} \frac{\sin \xi t}{\xi t}.$$

The model parameters are equal to the following values[4]:

$$\xi = 1.4, \quad L = 3.12 \text{ GeV}^{-1}, \quad \lambda = 0.13.$$

It turns out that the contribution of the first diagram relative to the second is

$$P = \pi^0 - 22\%, \quad P = \eta - 16\%, \quad P = \eta' - 28\%.$$

The numerical values for M_P^{-2} (the angle η-η' is the mixing angle $\theta = -11°$) are given in Table I. In the case of the π^0 meson our result, which is about a factor of 2 too low as compared with the experimental value, is comparable to the prediction.[6] The result for the η meson is in total agreement with a recently obtained experiment.[2,3] An experimental value for the η' meson is not available at this time.

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