Form factor of the decay $\omega \to \pi^0 \mu^+ \mu^-$ in a nonlocal quark model

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

(Submitted 15 November 1980)

Pis'ma Zh. Eksp. Teor. Fiz. **33**, No. 1, 66–68 (5 January 1981)

The electromagnetic characteristics of the decay $\omega \to \pi^0 \mu^+ \mu^-$ are calculated in a nonlocal quark model. An agreement between the decay widths and the recent experimental data is obtained and a prediction of the form factor is given.

PACS numbers: 13.20.Jf, 14.40.Ka, 12.40.Cc, 13.40.Fn

In view of the experiments conducted by Fischer *et al.*[1] and by Landsberg and co-workers,[2] an interest in the investigation of the form factors of the decays $P \to \gamma l^+ l^-$ and $V = P l^+ l^-$ has recently increased. The form factors of these decays in the vector-dominance model[3] are determined by the contribution of only the virtual vector mesons. It is assumed that the structure factors $g_{P \to \gamma\gamma}, g_{V \to P\gamma}, g_{V \to \gamma}$ are independent of the momenta and their numerical value is taken from the experiment. Therefore, the models in which the momentum dependence of these factors is nontrivial, in our opinion, are of interest. The nonlocal quark model,[4] which is a self-consistent relativistic scheme of a quantum-field bag, makes it possible to obtain

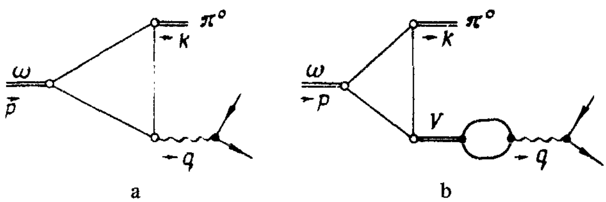

FIG. 1.

numerical values of these factors at the mass surface and gives a fully defined momentum dependence. Efimov and Ivanov[5] calculated the form factors of the $P \to \gamma l^+ l^-$ decays and obtained an agreement with the recent experimental data.[2]

We calculate the form factor and the width of the $\omega \to \pi^0 \mu^+ \mu^-$ decay. The diagrams determining this process are illustrated in Fig. 1. The invariant amplitude has the form

$$M(\omega \to \pi^0 \mu^+ \mu^-) = e^2 g_\omega(q^2)\, \epsilon_{\mu\nu\alpha\beta}\, e^\mu(p)\, k^\alpha q^\beta j^\nu_{em} / q^2$$

where e^μ and p are the polarization and momentum of the ω meson, k is the pion momentum, and j^ν_{em} is the electromagnetic current

$$g_\omega(q^2) = g_{\omega\pi\gamma}(q^2) + q^2 \sum_V \frac{g_{\omega V \pi}}{f_V} \frac{1}{m^2_V - q^2} \,.$$

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

$$g_\omega(q^2) = g_{\omega\pi\gamma}(0)\left[1 + \frac{q^2}{M^2_\omega}\right],$$

where the invariant mass has the following form:

$$\frac{1}{M^2_\omega} = \frac{1}{m^2_\rho} \frac{1}{K^{(0)}_{PV}} \left[\lambda W_1 W_2 + \left(\frac{m_\rho L}{2}\right)^2 K^{(1)}_{PV}\right].$$

The structure integrals are determined by the expressions

$$K^{(0)}_{PV}(\xi) = -8 \int_0^\infty du\, u\, B(u)\, A'(u)\,; \quad K^{(0)}_{PV}(1{,}4) = 2{,}16;$$

$$K^{(1)}_{PV}(\xi) = -8 \int_0^\infty du \left[\frac{1}{6} B(u) A''(u) - \frac{u^2}{4} A''(u) B(u)\right];$$

$$K^{(1)}_{PV}(1,4) = 0{,}26\,;$$

$$W_1(\xi) = 16 \int_0^\infty du\, u\, [A(u) B(u) + \xi e^{-2u}]\, B(u)\,; \; W_1(1{,}4) = 4{,}16;$$

$$W_2(\xi) = 2 \int_0^\infty du\, B(u)\,; \quad W_2(1{,}4) = 2{,}04.$$

TABLE I.

Diagrams Form factor	(a)	(b)	(a) + (b)
M_ω^{-2} (GeV^{-2})	0.3	0.9	1.2

Here

$$A(u) = \cos(\xi\sqrt{u})\exp(-u),$$

$$B(u) = \sin(\xi\sqrt{u})\exp(-u)/\sqrt{u}.$$

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

$$\xi = 1{,}4; \quad L = \frac{1}{320\ \text{MeV}}; \quad \lambda = 0{,}13.$$

Table I lists the numerical values of the contributions from the diagrams (a) and (b) to the measured value $1/M_\omega^2$. We can see that the contribution of the diagram (a) is equal to approximately 30%.

The width of the decay in question can be calculated by using the standard formula

$$\Gamma(\omega\to\pi^0\mu^+\mu^-) = \frac{\alpha^2}{72\pi} m_\omega^2 \int_r^{1-z} \frac{dx}{x^4} g_\omega^2(x^2, m_V^2)\sqrt{x^2-r^2}\,\lambda^{1/2}(1, x^2, z^2)$$

$$\times [\lambda(1, x^2, z^2)(2x^2+r^2) - z^2r^2(2x^2-r^2)/2],$$

where $z = m_\pi/m_\omega$ and $r = 2m_\mu/m_\omega$. The relation

$$B = \frac{\Gamma(\omega\to\pi^0\mu^+\mu^-)}{\Gamma_{tot}(\omega)}.$$

was measured experimentally.[2] The experimental value $B = (9\pm4.5)\times10^{-5}$ is in agreement with our value $B = 7.1\times10^{-5}$.

[1]J. Fisher *et al.*, Phys. Rev. **73B**, 359 (1978).
[2]Yu. B. Bushnin *et al.*, Phys. Lett. **79B**, 147 (1978); Yad. Fiz. **28**, 1207 (1978) [Sov. J. Nucl. Phys. **28**, 622 (1978)]; V. A. Viktorov, S. V. Golovkin, M. V. Gritsuk, R. I. Dzhelyadin, A. M. Zaĭtsev, D. B. Kakauridze, V. A. Kachanov, A. S. Konstantinov, V. F. Konstantinov, V. P. Kubarovskiĭ *et al.*, Pis'ma Zh. Eksp. Teor. Fiz. **30**, 387 (1979) [JETP Lett. **30**, 359 (1979)]; Yad. Fiz. **29**, 1513 (1979] Sov. J. Nucl. Phys. **29**, 777 (1979)].
[3]A. N. Ivanov and V. N. Shekhter, Yad. Fiz. **32**, 726 (1980) [Sov. J. Nucl. Phys. **32**, (1980)].
[4]A. Z. Dubnickova, G. V. Efimov, and M. A. Ivanov, Fortsch. der Phys. **27**, 403 (1979).
[5]G. V. Efimov and M. A. Ivanov, Pis'ma Zh. Eksp. Teor. Fiz. **32**, 60 (1980) [JETP Lett. **32**, 55 (1980)].

Translated by S. J. Amoretty
Edited by Robert T. Beyer