Measurements of the form factor of the neutral kaon from 1.06 to 1.40 GeV

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(Submitted 8 June 1982)
Pis'ma Zh. Eksp. Teor. Fiz. **36**, No. 3, 91–94 (5 August 1982)

The cross section for the reaction $e^+e \rightarrow K_S K_L$ has been measured between 1.06 and 1.4 GeV for the first time. The results show that the data on the electromagnetic form factors of the charged and neutral kaons are not described by the vector dominance model with ρ, ω, and ϕ mesons, but they can be explained by allowing for contributions of $\rho'(1600)$ and $\phi'(1650)$.

PACS numbers: 13.40.Fn, 13.65. + i, 12.40.Vv, 14.40.Aq

Until recently, the electromagnetic form factor of the neutral kaon, F_{K^0}, had been measured only near the ϕ resonance (see Ref. 1, for example). In 1981, an observation

 0021-3640/82/15112-04$01.00

of the reaction $e^+e^- \to K_S K_L$ at energies from 1.4 to 2.2 GeV in the DMl experiment at Orsay was reported.[2] In the present letter we are reporting measurements of the cross section for the reaction $e^+e^- \to K_S K_L$ at energies from 1.06 to 1.40 GeV taken at the VÉPP-2M electron-positron storage ring with the OLYa detector.

The $K_S K_{L\,\pi^+\pi^-}$ events were detected with the OLYa detector,[3] as events with two tracks and a single neutral particle. The tracks of charged pions from the decay $K_S \to \pi^+\pi^-$ were observed in the coordinate and shower-range parts of the detector. The position of the pion-emission vertex was determined accurately ($\sigma_y \sim 1$ mm) in the plane perpendicular to the beam. The decay length of the short-lived kaon varied from 10 to 26 mm in the energy range studied. We accordingly selected events for which the distance from the point at which the charged particles were emitted to the beam was greater than 6 mm.

The long-lived kaons which had undergone inelastic nuclear interactions in the shower-range part of the detector were detected on the basis of the signals from scintillation counters and spark chambers. Although the momenta of the particles were not measured by the detector, they can be reconstructed from the π^+, π^-, and K_L emission directions and the total energy of the particles in the event. It was thus possible to select $K_S K_L$ events on the basis of the invariant mass of the $\pi^+\pi^-$ pair. In this method for reconstructing the kinematics, the resolution in the invariant mass is $\sigma_M \sim 10$ MeV.

The efficiency at which the charged pions were detected and the probability for a K_L to reach the shower part of the detector were found through a Monte Carlo simulation.[4] The K_L detection efficiency was calibrated on the basis of experimental $K_S K_L$ events observed near the ϕ meson. The relative change in the efficiency with the energy was found from the energy dependence of the total cross section for the interaction of the K_L with matter.[5]

The energy interval from 1.06 to 1.40 GeV was scanned in steps equal to the energy spread of the electron beam. A luminosity interval of 700 nb^{-1} was adopted. In the data analysis, the data were combined into four energy intervals: 1.06–1.12, 1.12–1.20, 1.20–1.28, and 1.28–1.40 GeV. The resulting cross sections for the reaction $e^+e^- \to K_S K_L$ are, respectively,

$$7.0^{+4.1}_{-3.6}\ ;\ 4{,}0^{+3.6}_{-2.9}\ ;\ 1{,}8^{+2.2}_{-1.6}\ ;\ 0{,}7^{+1.3}_{-0.7}\ \text{nb}.$$

For comparison with the theoretical models, we considered jointly the data on the electromagnetic form factors of the charged and neutral kaons: the data from the present study and from our previous study[3] for the energy interval 1.04–1.40 GeV and the Orsay[2,6] and Frascati[7] data for 1.40–1.85 GeV. As mentioned earlier,[2,3] the results calculated for the kaon form factors on the basis of only the ρ, ω, and ϕ mesons do not describe the experimental data (Figs. 1 and 2). We therefore also considered the isovector resonance $\rho'(1600)$ with a free coupling constant. The contributions of the vector mesons to the kaon form factors were described by

$$F_K = \Sigma a_V \frac{g_{VKK}}{g_V} \frac{m_V^2}{\Delta_V}, \qquad (1)$$

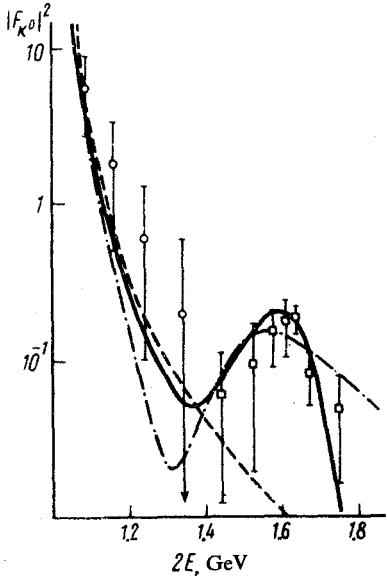

FIG. 1. Energy dependence of the square modulus of the form factor of the neutral kaon. Squares—DCI-DM1; circles—VÉPP-2M-OLYa. Dashed curve—ρ, ω, ϕ; dot-dashed curve—ρ, ω, ψ, $\rho'(1600)$; solid curve—ρ, ω, ψ, $\rho'(1600)$, $\psi'(1650)$.

where $\Delta_V = m_V^2 - s - im_V\Gamma_V(s)$, and α_V is a phase factor, equal to 1 for the ω and ϕ mesons and ± 1 for the ρ meson for K^+ and K^0, respectively. According to the tabulated values of the parameters of the ρ, ω, and ϕ resonances[8] and the relation $g_{\rho KK} = g_{\omega KK} = g_{\phi KK}/\sqrt{2}$ [SU(3) with ideal mixing], we would have

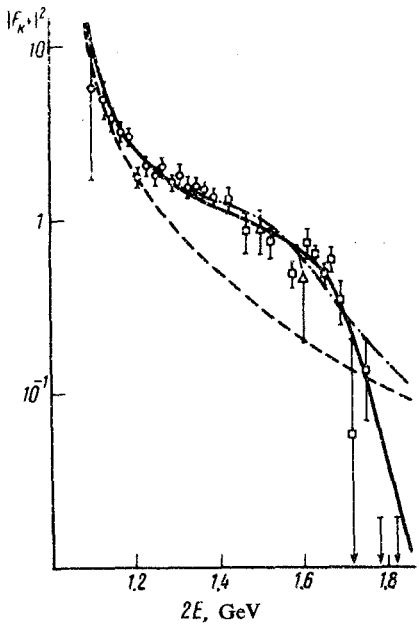

FIG. 2. Energy dependence of the square modulus of the form factor of the charged kaon. Triangles—ADONE-MEA; other notations—the same as in Fig. 1.

$g_{\rho KK}/g_\rho = 0.62$; $g_{\omega KK}/g_\omega = 0.19$; $g_{\phi KK}/g_\phi = 0.33$.

A fit of the experimental data yielded the following values: $m_{\rho'} = 1.52 \pm 0.02$ GeV, $\Gamma_{\rho'} = 0.37 \pm 0.04$ GeV, $g_{\rho'KK}/g_{\rho'} = 0.12 \pm 0.01$, and a relative phase of $114 \pm 9°$ between the $\rho'(1600)$ and the ρ meson. In this fit it was found possible to describe the behavior of the kaon form factors up to 1.75 GeV. However, the small values of $|F_{K^+}|^2$ at $2E$ from 1.75 to 1.85 GeV made a large contribution to χ^2 ($\chi^2 = 73$, with 41 degrees of freedom).

The similar introduction of another, this time isoscalar, resonance in expression (1) made it possible to also describe the rapid decrease in the kaon form factors in the region 1.75–1.85 GeV, which was observed at Orsay.[2,6] A resonance of this type was found in the channels $e^+e^- \to K_S K^\pm \pi^\mp$, $\omega\pi^+\pi^-$ and is regarded as a candidate for the role of $\phi'(1650)$ (Ref. 9). In the fit shown in Figs. 1 and 2, the relative phases between $\rho'(1600)$ and ρ and also between $\phi'(1650)$ and ϕ were fixed at 180°. The results of the fit are $m_{\rho'} = 1.54 \pm 0.02$ GeV, $\Gamma_{\rho'} = 0.33 \pm 0.04$ GeV, $g_{\rho'KK}/g_{\rho'} = 0.091 \pm 0.018$, $M_{\phi'} = 1.66 \pm 0.01$ GeV, $\Gamma_{\phi'} = 0.20 \pm 0.04$ GeV, and $g_{\phi'KK}/g_{\phi'} = 0.057 \pm 0.016$ ($\chi^2 = 54$ with 39 degrees of freedom).

This study has shown that it is sufficient to consider the contributions of $\rho'(1600)$ and $\psi'(1650)$ in order to explain the behavior of the kaon form factors up to 1.85 GeV, including the region 1.15–1.40 GeV—in contrast with the fits in Refs. 2 and 9 (where experimental data exclusively from the region 1.40–1.85 GeV were used).

We wish to thank the entire VÉPP-2M staff for maintaining the apparatus in good operation during the experiment, and we also thank A. D. Bukin, A. I. Vaĭnshteĭin, and G. N. Shestakov for some fruitful discussions.

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Translated by Dave Parsons
Edited by S. J. Amoretty