Study of the decay $D(1285) \to K^+K^-\pi^0$

S. I. Bityukov, V. A. Viktorov, S. V. Golovkin, M. V. Gritsuk, R. I. Dzhelyadin, V. A. Dorofeev, A. M. Zaĭtsev, A. S. Konstantinov, V. F. Konstantinov, V.P. Kubarovskiĭ, A. V. Kulik, V. F. Kurshetsov, L. G. Landsberg, V. V. Lapin, V. A. Mukhin, Yu. B. Novozhilov, V. F. Obraztsov, and V. I. Solyanik
Institute of High-Energy Physics

(Submitted 12 December 1983)
Pis'ma Zh. Eksp. Teor. Fiz. **39**, No. 2, 96–98 (25 January 1984)

The decay $D(1285) \to K^+K^-\pi^0$ has been studied. The invariant-mass distribution of the kaon pair has been found with a statistical base an order of magnitude better than in previous studies. Analysis of the differential spectrum $dN/dm_{K^+K^-}$ in the δ-dominance model shows that the $\delta(980)$ meson cannot be described as a Breit-Wigner resonance with a small width. The "effective width" of the δ meson at the point $\sqrt{s} = 1$ GeV/c^2 is $\Gamma_\delta > 180$ MeV/c^2. This result indicates a strong coupling of the δ meson with hadrons.

We have studied the differential probability for the decay

$$D(1285) \to K^+K^-\pi^0 . \tag{1}$$

The experiments were carried out on the Lepton-F apparatus[1] in a beam of 70-GeV secondary negative particles on the accelerator of the Institute of High-Energy Physics with a momentum of 32.5 GeV/c and an intensity of 4×10^6 π^-/cycle. The source of D mesons was the charge-exchange reaction

$$\pi^- p \to K^+K^-\pi^0 n. \tag{2}$$

The apparatus included primary-beam detectors, the target with guard counters, a wide-aperture magnetic spectrometer with proportional chambers, and the GAMS-200 hodoscopic γ spectrometer.[2] The charged particles in the initial and final states were identified with the help of gas-filled threshold Čerenkov counters.

We detected 4×10^6 primary trigger events; this figure corresponds to a flux of 2×10^{11} π^- mesons through the target. The details of the exposure and the data analysis procedure are described in Ref. 1.

Figure 1 shows the distribution in the invariant mass of the $K^+K^-\pi^0$ system produced in reaction (2). In the mass spectrum we can clearly see a peak with $M = 1287 \pm 5$ MeV/c^2, which corresponds to the production of a D meson. The mass and width of this resonance correspond well to the tabulated values when the instrumental resolution is taken into account. The number of events in the peak is $N_D = 353 \pm 20$.

The differential spectrum $dN/dm_{K^+K^-}$ was determined by the following procedure. The complete K^+K^- mass spectrum in reaction (2) was broken up into intervals

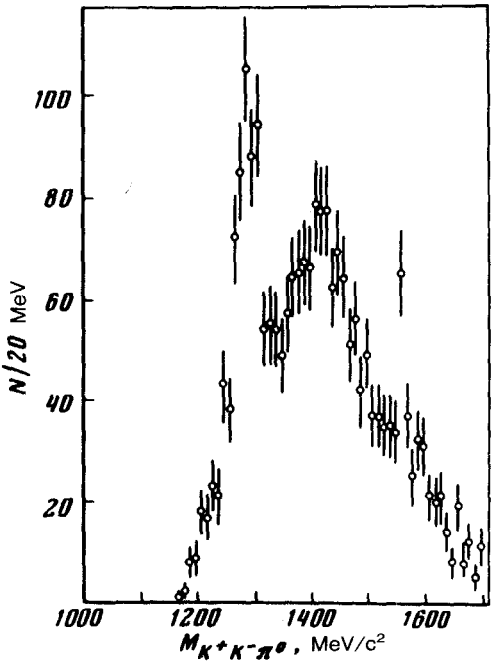

FIG. 1. Mass spectrum of the $K^+K^-\pi^0$ system in the reaction $\pi^-p \to K^+K^-\pi^0 n$.

15 MeV wide. For each such interval we constructed a spectrum of the $K^+K^-\pi^0$ system, which we analyzed to determine how many D mesons it included. Figure 2 shows the results of this analysis for one of these spectra. The parameters describing the resonance ($M_D = 1287$ MeV, $\Gamma_D = 46$ MeV) were determined from the total spectrum of the $K^+K^-\pi^0$ system (Fig. 1) and held constant for all distributions. The background under the peak was described by a smooth curve with two adjustable parameters. Following this procedure, and taking the efficiency of the apparatus into account, we found the final spectrum $dN/dm_{K^+K^-}$ for decay (1), which is shown in Fig. 3. The resolution of the apparatus with respect to $m_{K^+K^-}$ is ± 5 MeV/c² in the range of measurements.[1]

The primary experimental result of this study is thus the differential mass spectrum of the K^+K^- pair in the decay $D(1285) \to K^+K^-\pi^0$, with a statistical base an order of magnitude better than for previous data.[3]

It was shown in Ref. 4 that an analysis of the spectrum $dN/dm_{K^+K^-}$ can reveal the nature of the scalar meson $\delta(980)$. The reason is that the set of quantum numbers of the K^+K^- system in the decay of the D meson ($I = 0$, $J^{PC} = J^{++}$) is limited: $I = 1$, $J^{PC} = 0^{++}$, 2^{++},... . The s wave would naturally be expected to be predominant because of the small energy evolution.

To test this assumption, we attempted to describe the experimental spectrum of kaon pairs with a d-wave phase space (Fig. 3):

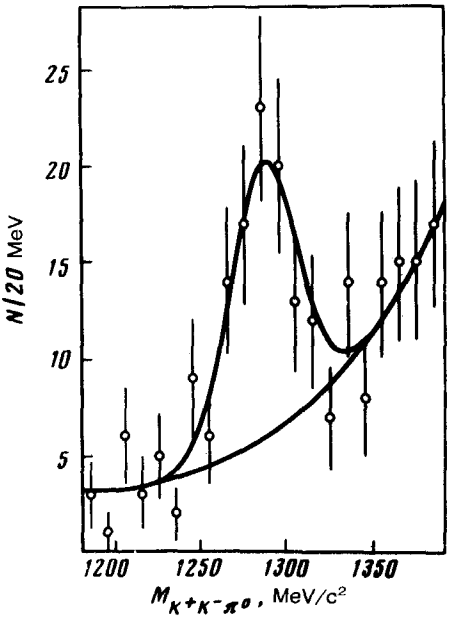

FIG. 2. Mass spectrum of the $K^+K^-\pi^0$ system for 1000 MeV/c^2 $< m_{K^+K^-} <$ 1015 MeV/c^2.

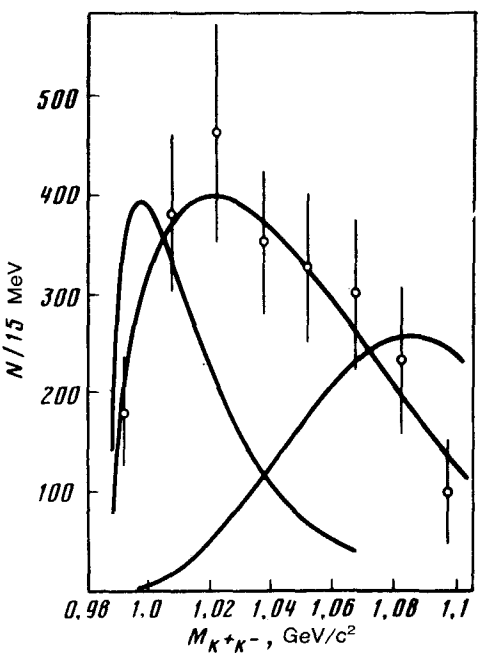

FIG. 3. Experimental differential spectrum $dN/dm_{K^+K^-}$ in the decay $D(1285) \to K^+K^-\pi^0$. The curves are fits of the experimental data. a—The d-wave phase space according to Eq. (3); b—formula (5) with a propagator in the form of a relativistic Breit-Wigner resonance with the parameters $M = 983$ MeV/c^2 and $\Gamma = 54$ MeV/c^2; c—formula (5) with $D_\delta(s)$ from Ref. 8.

$$dN/dm_{K^+K^-} \sim (P^*_{\pi^0})^3 (P^*_K)^5 , \tag{3}$$

where $P^+_{\pi^0}$ is the momentum of the π^0 in the c.m. frame of the D meson, and P^*_K is the momentum of the K meson in the frame of the dikaon. The fit is clearly unsatisfactory (confidence level $< 10^{-11}$). The assumption of s-wave dominance is thus correct, and the scalar meson δ (980) can contribute substantially to decay (1). In this (δ-dominance) model, the decay (1) proceeds in accordance with

$$D \to \delta\pi \hookrightarrow K^+K^- , \tag{4}$$

and the differential spectrum is described by

$$dN/dm_{K^+K^-} \sim (P^*_{\pi^0})^3 P^*_K / |D_\delta(s)|^2 , \tag{5}$$

where $D_\delta(s)$ is the δ-meson propagator.

For narrow resonances lying substantially above the thresholds for the primary decay channels, the relativistic Breit-Wigner formula is valid for $D(s)$. This is the approach which has been taken to describe the δ resonance observed in the $\eta\pi$ mode.[5] However, a description of our experimental spectrum by expression (5) with this propagator has a confidence level of 3×10^{-9} and is unsatisfactory (Fig. 3). This result shows that the nature of the propagator for the δ meson, $D_\delta(s)$, is more complicated: The "effective width" of the resonance depends strongly on the invariant mass of the decay products, because the pole is near the threshold for one of the primary (K^+K^-) decay channels. This factor was taken into account in Refs. 7–9.

Curve c in Fig. 3 is a fit of the differential spectrum with the formulas of Ref. 8. For the "dynamic width" of the δ meson at the point $\sqrt{s} = 1$ GeV/c^2 we find the limitation Γ_δ ($\sqrt{s} = 1$ GeV/c^2) > 180 MeV/c^2 (at a 98% confidence level). The value of this parameter suggests a strong coupling of the δ meson with the hadrons and eliminates the problem of the "puzzling" narrowness of the δ meson.

We wish to thank N. N. Achasov, S. A. Devyanin, and G. N. Shestakov for useful discussions.

[1]S. I. Bityukov, V. A. Viktorov, N. K. Vishnevskiĭ, *et al.*, Preprint 83-109, Institute of High-Energy Physics, Serpukhov, 1983.
[2]F. Binon, K. Bricman, M. Goanere, *et al.*, Preprint IHEP 80-141, Serpukhov, 1980; Nucl. Instrum. **188**, 1263 (1981).
[3]M. J. Corden, J. D. Duowell, J. Garvey, *et al.*, Nucl. Phys. **B144**, 253 (1978).
[4]N. N. Achasov, S. A. Devyanin, and G. N. Shestakov, Preprint TF-117, Institute of Mathematics, Siberian Branch, Academy of Sciences of the USSR, Novosibirsk, 1981.
[5]J. B. Gay, V. Chaloupka, Ph. Gavillet, *et al.*, Phys. Lett. **63B**, 220 (1976).
[6]M. Roos, F. C. Porter, M. Aguilar-Benitez, *et al.*, Phys. Lett. **111B**, 1 (1982).
[7]S. M. Flatte, Phys. Lett. **63B**, 224, 228 (1976).
[8]N. N. Achasov, S. A. Devyanin, and G. N. Shestakov, Preprint TF-121, Institute of Mathematics, Siberian Branch, Academy of Sciences of the USSR, Novosibirsk, 1981; Phys. Lett. **96B**, 168 (1980); **32**, 1098 (1980); Phys. Lett. **102B**, 196 (1981).
[9]N. A. Törnqvist, Preprint HU-TET-81-1, University of Helsinki, Helsinki, 1982; Phys. Lett. **49**, 624 (1982).

Translated by Dave Parsons
Edited by S. J. Amoretty