Detection of the radiative decay $D(1285) \to \phi\gamma$

S. I. Bityukov, G. V. Borisov, V. A. Viktorov, S. V. Golovkin, R. I. Dzhelyadin, V. A. Dorofeev, A. M. Zaĭtsev, A. S. Konstantinov, V. P. Kubarovskiĭ, A. I. Kulyavtsev, 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 March 1987)
Pis'ma Zh. Eksp. Teor. Fiz. **45**, No. 8, 368–371 (25 April 1987)

The radiative decay $D(1285) \to \phi\gamma$ in which 19 ± 5 events were observed has been detected. The relative probability for the decay $BR[D(1285) \to \phi\gamma] = 0.9 \pm 0.2 \pm 0.4) \times 10^{-3}$ and its partial width $\Gamma[D(1285) \to \phi\gamma] = 23 \pm 5 \pm 10$ keV have been determined. It is concluded that the $E(1420)$ meson apparently does not belong to the axial nonet.

In this experimental study we have looked for the radiative decay of neutral axial mesons with quantum numbers $IJ^{PC} = 01^{++}$:

$$(I^{++} - \text{meson}) \to \phi\gamma. \qquad (1)$$

 © 1987 American Institute of Physics

Since the ϕ meson is nearly a pure ss state, the $\phi\gamma$ decay is a good analyzer which identifies the $s\bar{s}$ component in the wave function of the mesons to be studied. Decay (1) may yield important information on the axial-meson nonet. The presently available data cannot be used to unambiguously determine the composition of the axial nonet. Of the two isoscalar states in this family only one may be regarded as incontrovertible: the $D(1285)$ meson. As the other isoscalar the $E(1420)$ meson was usually considered. The data on its quantum numbers are, however, contradictory (the well-known "E/ι problem"; see Refs. 1 and 2). There are also other candidates for this "semivacant" site, e.g., the $D'(1530)$ state.[3] The composition of the 1^{++} nonet and the corresponding mixing angle are therefore questions that remain unresolved.

The search for radiative decay (1) was carried out with the "Lepton-F" apparatus,[4,5] which allowed us to detect processes with charged hadrons and γ rays. The apparatus consisted of a magnetic spectrometer with proportional chambers and a hadoscopic γ-ray spectrometer. Gas-filled Čerenkov counters were used to identify the charged particles in the initial and final states. The experimental studies of the exclusive production of $K^+K^-\pi^0$ and $\pi^+\pi^-\pi^0$ states in the π^-p and K^-p interactions carried out with this apparatus were described in detail elsewhere.[5] The following reactions were also studied in the same exposure at the same time:

$$\pi^-p \to (K^+K^-\gamma)n \quad , \tag{2}$$

$$K^-p \to (\pi^+\pi^-\gamma)n. \tag{3}$$

Reaction (2) was used for the search of $\phi\gamma$ decay of mesons produced in the charge exchange

$$\pi^-p \to Mn; \quad M \to \phi\gamma; \quad \phi \to K^+K^-. \tag{4}$$

Reaction (3) was used to detect the known radiative decay $\eta(\eta') + \pi^+\pi^-\gamma$ and was subsequently used to normalized reaction (4).

During the measurements, 4×10^{11} π mesons with momentum 32.5 GeV/c were transmitted through the target of the Lepton-F apparatus. To set reaction (2) apart from others in the analysis of the data, we have isolated the events with two charged particles and one final-state γ ray with an energy $E_\gamma > 5$ GeV and events with a total energy of the secondary particles $30.8 < E_+ + E_- + E_\gamma < 34$ GeV. We detected $\sim 4.5\times 10^3$ such events, most of which corresponded to the process $\pi^-p \to K^+K^-\pi^0; \pi^0 \to 2\gamma$ with a single lost γ ray. Conditions for the maximum suppression of the lost-γ-ray background were determined when the decay $\eta \to \pi^+\pi^-\gamma$ was separated from the decay $\eta \to \pi^+\pi^-\pi^0$ in the presence of a background.

In the study of process (4) the background due to the reaction

$$\pi^-p \to \phi\pi^0 n; \qquad \phi \to K^+K^- \tag{5}$$

(in which a γ ray is lost) poses a particular danger. Reaction (5) was studied in detail in our previous experiments.[5] We showed that the peak associated with the production of a new vector meson $C(1480)$ is the dominant peak in the mass spectrum of the $\phi\pi^0$ systems. Reaction (5) is characterized by a narrow t' distribution, which is attributed to the single-pion exchange. Accordingly, if the requirement $|t'| > 0.1$ $(\mathrm{GeV}/c)^2$ is introduced to isolate (4), the background of the events in (5) with lost γ rays will be suppressed by a factor of ~ 5. At the same time, this requirement decreases only slightly the probability for the production of axial mesons in the charge-exchange reactions, since the π exchange is forbidden for such processes and since the corresponding t' distribution is a broader distribution. The $D(1285)$ yield at $|t'| > 0.1$ $(\mathrm{GeV}/c)^2$, for example, decreases no more than by 25%.

After the introduction of all these selections, we see in the mass spectrum of the K^+K^- system in reaction (2) a clearly defined peak corresponding to the production of a ϕ meson in (4). The position of the peak ($\overline{M}_{K^+K^-} = 1022 \pm 1$ MeV) is consistent with the tabulated value of the ϕ-meson mass; the width of the peak (7.3 ± 1.2 MeV) is determined by the instrumental resolution of the spectrometer. The events in (4) were taken from the neighborhood of the ϕ peak ($1018 < M_{K^+K^-} < 1026$ MeV). The background contribution was taken into account by subtracting the average number of events in the neighboring mass intervals ($1006 < M_{K^+K^-} < 1014$ MeV and $1030 < M_{K^+K^-} < 1038$ MeV). The total number of events in (4) was found to be 87 ± 14.

To further analyze the $\phi\gamma$ system and to further search for the radiative decay of axial mesons, we have studied the angular distributions in (4). According to the well-known Landau-Yang theorem, a particle with spin 1 cannot decay into two massless γ rays. Since the ϕ meson is a massive vector particle, decay (1) is not forbidden by this theorem, although it has only the component of ϕ with zero helicity, $\lambda_\phi = 0$ (this component is absent in massless photons). To single out the ϕ mesons with $\lambda_\phi = 0$, we studied the distribution through an angle $\theta_{K^-\gamma}$ in the rest mass of a ϕ meson. For $\lambda_\phi = 0$ [i.e., for decay (1)] this distribution should have the form $dN/d\cos\theta_{K^-\gamma} \sim \cos^2\theta_{K^-\gamma}$. In the decay of pseudoscalar mesons $(0^{++}) \rightarrow \phi\gamma$ the ϕ mesons are produced only in the states with $\lambda_\phi = \pm 1$ and the corresponding angular distribution has the form $dN/d\cos\theta_{K^-\gamma} \sim \sin^2\theta_{K^-\gamma}$. The requirement $\cos\theta_{K^-\gamma} > 2/3$ may therefore play an important role in the isolation of decays of the type (1), since this requirement decreases the number of events by only 30% for the radiative decay of axial mesons. At the same time, the decay of pseudoscalar particles in this case is suppressed by a factor of > 6.

The resultant effective-mass spectrum of the $\phi\gamma$ events (with $\cos\theta_{K^-\gamma} > 2/3$) is shown in Fig. 1. The peak with the mass $M = 1278 \pm 10$ MeV and width $\Gamma = 77 \pm 18$ MeV is the dominant peak in this spectrum. This peak contains 19 ± 5 events. The position of the peak agrees well with the tabulated value of the mass of the $D(1285)$ meson, while its width is determined by the instrumental resolution. The statistical dependence of this peak is greater than seven standard deviations. The combined data on the mass, width, and angular resolution for this peak thus show that in our experiment we have observed the radiative decay

$$D(1285) \rightarrow \phi\gamma. \tag{6}$$

We found the relation

$$BR[D(1285) \rightarrow \phi\gamma]/BR[D(1285) \rightarrow \bar{K}K\pi] = (0.8 \pm 0.2 \pm 0.2) \times 10^{-2}. \tag{7}$$

It follows from this relation and from the tabulated values for $BR(D \to K\overline{K}\pi)$ and Γ_D (Ref. 1) that

$$BR[D(1285) \to \phi\gamma] = (0.9 \pm 0.2 \pm 0.4) \times 10^{-3}, \quad (8)$$

$$\Gamma[D(1285) \to \phi\gamma] = 23 \pm 5 \pm 10 \text{ keV}. \quad (9)$$

The systematic errors include normalization-related uncertainties and tabulated-parameter errors.

The value of $\Gamma[D(1285) \to \phi\gamma]$ in (9) was compared with the predictions for various theoretical models.[6,7] This comparison shows that the mixing angle θ_A for the axial nonet should differ substantially from the ideal angle $(\theta_A^0 = 35.26°)$: $|\alpha| = |\theta_A - \theta_A^0| > 30°$; i.e., the wave function of the $D(1285)$ meson should have an appreciable ss component. We have independently estimated the mixing angle ($|\alpha| = 25$–$35°$) from the known data on the decay-probability ratio $J/\psi \to \phi D(1285)$; $\omega D(1285)$.[8] This estimate is in agreement with the data on the radiative-decay probability (6).

If the $D(1285)$ and $E(1420)$ mesons would belong to the axial nonet, then a simple quark model could be used to determine the expected ratio for the number of

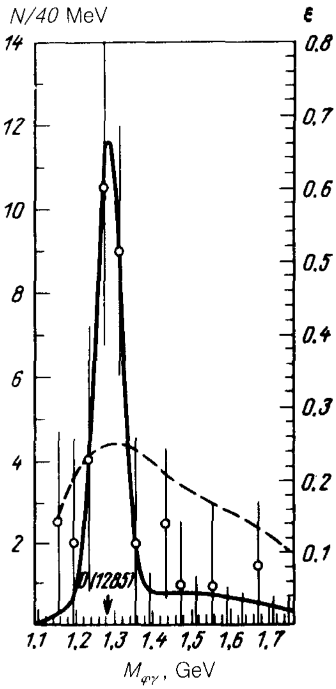

FIG. 1. Spectrum of the effective masses of the $\phi\gamma$ system in the reaction $\pi^- p \to \phi\gamma n$ for the events with $\cos\theta_{K\gamma} > 2/3$. The arrow indicates the tabulated value of the mass of the $D(1285)$ meson. The dashed curve and the scale on the right (ϵ)—the acceptance of the apparatus.

events in the radiative decay (1):

$$R = \frac{N[E(1420) \to \phi\gamma]}{N[D(1285) \to \phi\gamma]} = \left[\frac{\sigma(\pi^- p \to En)}{\sigma(\pi^- p \to Dn)}\right]\left[\frac{BR(E \to \phi\gamma)}{BR(D \to \phi\gamma)}\right]$$

$$= [\tan^{-2}\alpha][(K_E/K_D)^3(\Gamma_D/\Gamma_E)\tan^2\alpha] = (K_E/K_D)^3(\Gamma_D/\Gamma_E) = 1.4. \qquad (10)$$

[K_E and K_D are photon momenta in (1), and Γ_D and Γ_E are the total meson widths.]

The upper limit for this ratio is found, from our experiment (Fig. 1), to be

$R_{\rm exp} < 0.6$ (90% certainty).

The result of our experiment, in which the radiative decay of a $D(1285)$ meson was detected but the same decay was not detected near an axial meson with a 1420-MeV mass and 55-MeV width, thus shows that the $E(1420)$ meson does not belong to the axial nonet [under the assumption that the simple quark ratio (10) holds; note that the validity of this treatment was verified in experiments on the charge exchange of pseudoscalar mesons (η,η') and vector mesons (ω,ϕ) (Ref. 10)]. If instead of the $E(1420)$ meson the axial nonet would contain a meson with a mass $M \gtrsim 1.5$–1.6 GeV and $\Gamma \gtrsim 150$–200 MeV, then the expected number of events in the $\phi\gamma$ decay would be consistent with the data of our experiment.

[1]M. Aguilar-Benitez, *et al.*, Phys. Lett. **170B**, 1 (1986).
[2]B. Dickmann, Preprint CERN EP/86-112, Geneva, 1986.
[3]P. Gavillet, *et al.*, Z. Phys. **C16**, 119 (1982).
[4]S. I. Bityukov *et al.*, Yad. Fiz. **39**, 1165 (1984) [Sov. J. Nucl. Phys. **39**, 735 (1984)].
[5]S. I. Bityukov *et al.*, Pis'ma Zh. Eksp. Teor. Fiz. **42**, 310 (1985) [JETP Lett. **42**, 384 (1985)]; Preprint IHEP 86-110 and 86-242 Serpukhov, 1986.
[6]M. K. Volkov, Preprint JINR P2-83-701, Dubna, 1983.
[7]M. Dineĭkhan *et al.*, Preprint JINR P2-82-359, Dubna, 1982.
[8]B. Jan-Marie, Proc. of XIII Int. Conf. on High Energy Phys., Berkeley, July, 1986.
[9]V. V. Anisovich and V. M. Shekhter, Yad. Fiz. **18**, 701 (1973) [Sov. J. Nucl. Phys. **18**, 359 (1973)].
[10]V. D. Apel' *et al.*, Yad. Fiz. **29**, 1513 (1979) [Sov. J. Nucl. Phys. **29**, 777 (1979)]; D. S. Ayres *et al.*, Phys. Rev. Lett. **37**, 1463 (1975).

Translated by S. J. Amoretty