Relative probability for the decay $\phi\to\eta\gamma$

L. M. Kurdadze, M. Yu. Lel'chuk, N. I. Root, V. A. Sidorov, A. G. Chilingarov, B. A. Shvarts, and S. I. Éĭdel'man

Siberian Branch, Institute of Nuclear Physics, Academy of Sciences of the USSR

(Submitted 25 July 1983)

Pis'ma Zh. Eksp. Teor. Fiz. **38**, No. 6, 306–309 (25 September 1983)

The cross section for the reaction $e^+e^-\to\underset{\to\gamma\gamma}{\eta}\gamma$ in the vicinity of ϕ (1020) has been measured with the OLYa detector on the VÉPP-2M storage ring. The relative probability found for the decay $\phi\to\eta\gamma$ is $B(\phi\to\eta\gamma) = 0.9 \pm 0.2\%$.

PACS numbers: 13.40.Hq, 13.65. + i, 14.40.Aq, 14.40.Cs

The results reported here were obtained from an analysis of data from an experimental search for the decay[1] $\phi\to\pi^+\pi^-$. The OLYa detector, which is described in detail in Ref. 1, consists of four identical quadrants which are positioned around the beam collision region. The total solid angle subtended by the detector is $0.65\cdot4\pi$ steradians. Each quadrant contains scintillation counters, coordinator chambers, a shower detector, and a range system. The shower detector consists of a scintillation sandwich (four lead plates each 1 X_0 thick, alternated with four 10-mm scintillator plates) and two spark chambers, positioned after the second and fourth scintillator plates. Each scintillator plate is monitored by a separate photomultiplier.

The detect events of the type $e^+e^-\to\eta\gamma\to3\gamma$ we use the following triggering conditions: A sandwich must operate in anticoincidence with the scintillation counter preceding the sandwich in at least three quadrants (this condition rules out charged particles). A sandwich is regarded as having operated if the sum of the signals from all four of its scintillation counters exceeds $3A_0$, where A_0 is the most probable amplitude of a signal from a relativistic particle in one scintillator plate.

In the experiment of Ref. 1, the energy (W) interval from 1006 to 1048 MeV was scanned in several cycles ($W = 2E$, where E is the beam energy). The luminosity integral for the experimental data used in this analysis was 770 nb^{-1}.

In the analysis we singled out events containing three γ rays in the shower spark chambers of different quadrants and containing no track in the coordinate chambers. In the shower chambers we determined the coordinates of the γ rays from the centers of gravity of the electromagnetic showers. Through these three points we constructed a plane, whose intersection with the x axis (the axis of the beams) determined the γ production point x_γ and thus the γ emission direction. We then required that (1) $|x_\gamma - x_0| < 80$ mm, where x_0 is the center of the volume in which the e^+ and e^- beams interact, (2) all three photon cannot lie in a common half-plane, and (3) the sum of the signals from the sandwiches of the three quadrants containing γ rays must be greater than $20A_0$. For the selected events we used the known energy W and the emission angles of the γ rays to reconstruct the energies of these γ rays under the assumption of a zero total momentum. The accuracy of the reconstruction of the energy of a γ ray was $\sigma/E\approx4.5\%$. For final analysis we selected events in which the lowest of the

 0021-3640/83/180366-04$01.00

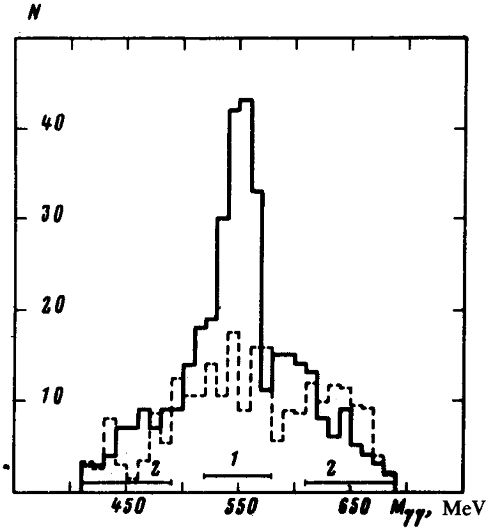

FIG. 1. Distribution $M_{\gamma\gamma}$ of events with three γ rays in the energy region of the ϕ resonance ($m_\phi \pm 3$ MeV). Solid histogram—experimental; dashed—calculated background.

reconstructed γ energies, $E_{\min}$, was greater than 150 MeV. In all, 627 events with three γ rays were selected as a results.

In each event we singled out two γ rays which presumably resulted from the decay of an η meson, and we calculated their invariant mass $M_{\gamma\gamma}$. These two γ rays were selected by the following rule, which comes from the kinematics of the reaction $e^+e^- \to \underset{\hookrightarrow \gamma\gamma}{\eta}\gamma$. As the first γ we ray adopted that with the lowest energy $E_{\min}$, and as the second we adopted that with the highest energy if $E_{\min} < m_\eta^2/2E$; or that with the intermediate energy if $E_{\min} > m_\eta^2/2E$ (m_η is the mass of the η meson).

Figure 1 shows the distribution in the parameter $M_{\gamma\gamma}$ for the events from the region of the ϕ resonance ($m_\phi \pm 3$ MeV). Against the background we can clearly see a peak at $M_{\gamma\gamma} \approx 550$ MeV, which corresponds to the two-γ decay of the η meson. The width of this peak is determined by the accuracy with which the γ emission angles are measured; this width is (the standard deviation) $\sigma_M \approx 20$ MeV. To single out the reaction $e^+e^- \to \eta\gamma \to 3\gamma$ we used events with $M_{\gamma\gamma} = 550 \pm 30$ MeV (region 1 in Fig. 1). Falling in this region were $N_1 = 290$ of the 627 three-γ events.

The region $|M_{\gamma\gamma} - 550| > 60$ MeV, region 2 in Fig. 1, does not contain $\eta\gamma$ events. This region was used to determine the background level in region 1. The primary sources of the background are the reaction $e^+e^- \to \phi \to K_L K_{\underset{\to \pi^0\pi^0}{S}}$, which is of a resonant nature, and the quantum-electrodynamic process $e^+e^- \to 3\gamma$. The ratio of the number of resonant-background events in regions 1 and 2 was found from the experimental data and also through a modeling[2] of the reaction $e^+e^- \to \phi \to K_L K_{\underset{\to \pi^0\pi^0}{S}}$. This ratio turned out to be 0.80 ± 0.09. The dashed histogram in Fig. 1 shows the $M_{\gamma\gamma}$ distribution for the events corresponding to background processes.

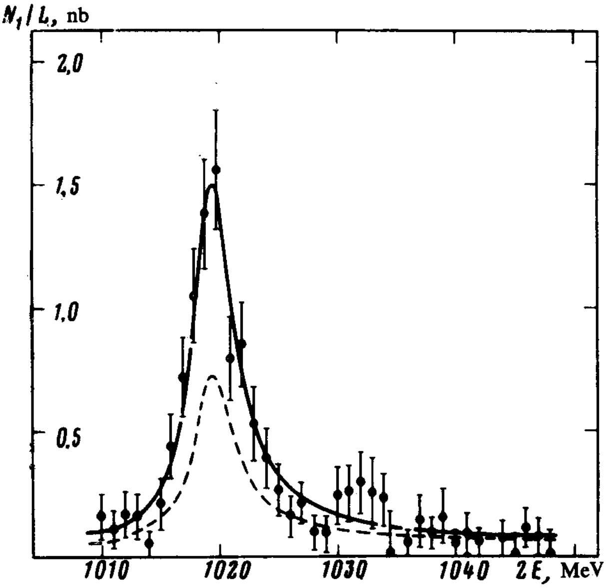

FIG. 2. Ratio of the observed number of events with 520 MeV $< M_{\gamma\gamma} <$ 580 to the luminosity vs the energy. Dashed curve—Contribution of background processes: the nonresonant process ($e^+e^- \rightarrow 3\gamma$) and the resonant process ($e^+e^- \rightarrow K_L K_{S \rightarrow \pi^0\pi^0}$).

Figure 2 shows the ratio of the number of detected events to luminosity, $\sigma^{\text{det}}_{\text{expt}} = N_1/L$, vs the energy. The luminosity at each point was determined from the number of $e^+e^- \rightarrow e^+e^-$ elastic-scattering events, which had been distinguished previously.[1] This dependence was approximated by the sum of three terms, $\sigma^{\text{det}} = \sigma_{\eta\gamma} + \sigma_{K_L K_S} + \sigma_{3\gamma}$, which reflect the effect of interest, the resonant background, and the nonresonant background, respectively. The solid curve in Fig. 2 shows the value of σ_{det} found through an optimization. The dashed curve shows the contribution of the background processes ($\sigma_{K_L K_S} + \sigma_{3\gamma}$). The nonresonant background, which is about 3% of the height of the ϕ-meson peak, agrees with the expected contribution from the quantum-electrodynamics process $e^+e^- \rightarrow 3\gamma$.

The radiative corrections were calculated from[3,4]

$$\sigma(W) = \beta e^{\frac{13}{12}\beta} \int_0^E \sigma_0\,(W-\omega)\frac{1}{\omega}\,(\omega/E)^{\beta}\,\left(1 - \frac{\omega}{E} + \frac{\omega^2}{2E^2}\right) d\omega\,,$$

where ω is the energy of the radiation γ, $\beta = \frac{4\alpha}{\pi}\left(\ln\frac{W}{m_e} - \frac{1}{2}\right)$, and $\sigma_0(W)$ is the cross section for the process without the radiative correction. The probability for detecting the process $e^+e^- \rightarrow \eta\gamma \rightarrow 3\gamma$ was found through a Monte Carlo simulation.[2] It turned out to be $6.7 \pm 0.5\%$. Using this value for the cross section for the reaction $e^+e^- \rightarrow \eta\gamma \rightarrow 3\gamma$, we find the value $\sigma^{\max} = 15 \pm 3$ nb at the ϕ-resonance peak by the maximum-likelihood method. To a large extent, this error is determined by the subtraction of the high resonant background. Working from the tabulated values of the relative decay probabilities[5] $B(\phi \to ee)$ and $B(\eta \to \gamma\gamma)$, we find

$$B(\phi \to \eta\gamma) = 0,88 \pm 0.18 \pm 0.08\ \%;$$

the first error indicated here is statistical, while the second is an estimate of the possible systematic error. This value is lower than all earlier results, but it agrees within 1.5 times errors with the most accurate of these earlier results: $1.5 \pm 0.4\%$ (Ref. 6), 1.35 ± 0.29 (Ref. 7), and $1.14 \pm 0.11\%$ (Ref. 8).

We are deeply indebted to the VÉPP-2M staff for maintaining the accelerator complex in good operation during the experiment.

[1] L. M. Kurdadze *et al.*, Yak. Fiz. **35**, 35 (1982) [Sov. J. Nucl. Phys. **35**, 433 (1982)].
[2] A. D. Bukin and S. I. Éĭdel'man, Preprint 77-101, Institute of Nuclear Physics, Novosibirsk, 1977.
[3] S. Tavernier, These du Doctorat 3-eme Cycle, RI 68/7, Orsay, 1968.
[4] Ya. I. Azimov, A. I. Vaĭnshteĭn, L. N. Lipatov, and V. A. Khoze, Pis'ma Zh. Eksp. Teor. Fiz. **21**, 378 (1975) [JETP Lett. **21**, 172 (1975)].
[5] "Review of particle properties," Phys. Lett. **111B**, 1 (1982).
[6] G. Cosme *et al.*, Phys. Lett. **63B**, 352 (1976).
[7] D. E. Andrews *et al.*, Phys. Rev. Lett. **38**, 198 (1977).
[8] A. D. Bukin *et al.*, Preprint 83-80, Institute of Nuclear Physics, Novosibirsk, 1983.

Translated by Dave Parsons
Edited by S. J. Amoretty