Search for the decay $K_S \to 2\gamma$

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An upper limit has been found for the branching ratio for the decay $K_S \to 2\gamma$ in an experiment on the reaction $e^+e^- \to \phi \to K_S K_L$ in the neutral detector at the VEPP-2M e^+e^- storage ring. This limit is $B(K_S \to 2\gamma) < 2 \times 10^{-4}$ at a 90% confidence level.

The decay $K_S \to 2\gamma$ has yet to be observed. The strongest limitation on the branching ratio for this decay, $B(K_S \to 2\gamma) < 4 \times 10^{-4}$, was found in an experiment with a liquid-xenon-filled bubble chamber.[1] Kohara[2] derived a theoretical value of 2×10^{-6} from dispersion relations and unitarity in the approximation of two-pion intermediate state. In this decay, one may see manifestations of a breaking of CP invariance at a level of 10^{-3} of the calculated value.[3]

In the present study we sought the decay $K_S \to 2\gamma$ in the reaction $e^+e^- \to \phi \to K_S K_L$. The experiment was carried out at the VEPP-2M e^+e^- storage ring with the neutral detector.[4] This detector is basically an electromagnetic calorimeter consisting of 168 counters with NaI(Tl) crystals weighing a total of 2.6 metric tons. The detector has a solid angle of 65% of 4π and can measure the energies and angles at which γ rays and charged particles are emitted. The experiment was carried out over the energy range $2E = 1000$–1050 MeV. The integrated intensity was[5] $2.8\pi\sigma^{-1}$.

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In selecting events in which to seek the decay $K_S \to 2\gamma$, we took into account the particular features of the passage of the K_L meson through the detector material. The experimental results and the results of a Monte Carlo simulation[6,7] show that a K_L meson from the decay $\phi \to K_S K_L$ which enters the sensitive volume of the detector has a probability of about 10% for not being detected, while in 60% of the cases it will appear to be a single γ ray. Taking this circumstance into account, we selected events with three "γ rays" in search for this decay. We assume that two γ rays come from the decay $K_S \to 2\gamma$, while the third "γ ray" is the detected K_L meson.

The primary source of background for events of this type is the process

$$e^+e^- \to \phi \to K_S K_L \quad (K_S \to 2\pi^0)\,, \tag{1}$$

in which four γ rays from the decay $K_S \to 2\gamma$ create a configuration similar to that of the decay $K_S \to 2\gamma$, since not all of the γ rays are detected in the detector and also because closely spaced γ rays merge. To suppress this background, we took into account the circumstance that the minimum spatial angle between the γ rays in the decay $K_S \to 2\gamma$ is 155°. Consequently, taking into account the angular resolution, we selected only those events in which there was a pair of γ rays with a spatial angle between 145° and 170°. The limit of 170° makes it possible to reduce the number of background events of the process $e^+e^- \to 3\gamma$. We then applied a kinematic reconstruction procedure[4] which made it possible to select events satisfying energy and momentum conservation. As the K_L meson we selected all three of the "γ rays" in turn. We ignored the energy evolution of the K_L meson in the reconstruction. For each version, we calculated the parameter χ^2, which is a measure of how well the conservation laws hold. We selected the version with the smallest value of χ^2, and we used it for the subsequent data analysis. The choice of version determined which of the γ rays was tentatively identified as the K_L meson. In this manner we found 146 events satisfying the selection rules listed above. Figure 1 shows the detection cross section as a function of the energy for these events. The efficiency at which the decay being sought would be detected is $10.2 \pm 0.6\%$, while that for the background process is $(2.3 \pm 0.8) \times 10^{-4}$. The detection cross section found was approximated by the excitation curve of a ϕ-meson resonance, with allowance for background process (1). Using the maximum likelihood method we determined the branching ratio for the decay $K_S \to 2\gamma$ and the level of the nonresonant background. The solid line in Fig. 1 shows the calculated detection cross section at the optimum values of the parameters. The observed cross section is determined entirely by background process (1), so that we can only deduce

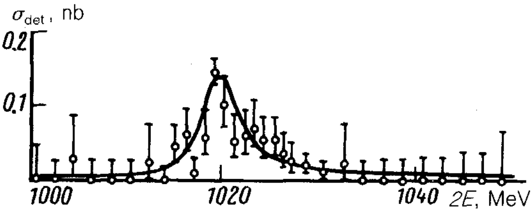

FIG.1. Detection cross section versus the energy for events with three γ rays. The solid line is the result of an optimization.

an upper limit on the branching ratio for the decay $K_S \to 2\gamma$ at a 90% confidence level:

$$B(K_S \to 2\gamma) < 2 \cdot 10^{-4}. \quad (2)$$

To a large extent, this result is determined by the large error in the efficiency at which background (1) is detected; that efficiency is determined in turn by the limited number of stimulated events, $\sim 3 \times 10^4$.

To search for the decay $K_S \to 2\gamma$, we also analyzed events with two γ rays. We assumed that the γ rays are produced in the decay being sought, while the K_L meson is not detected in the detector. Taking this approach, we found an upper limit of 2.8×10^{-3} on the branching ratio for the decay $K_S \to 2\gamma$, so that there was no change in the result given above.

The limit found in this experiment, (2), is half the tabulated value but two orders of magnitude larger than the theoretical value. The accuracy could be improved severalfold with the neutral detector if the integrated intensity and the statistics of the simulation of the background process, (1), were increased significantly. Any radical improvement in the accuracy of a study of the decay $K_S \to 2\gamma$ in colliding beams will require a detector with a larger solid angle, which provides a better suppression of the background from process (1) by means of the separation of nearby γ rays and by means of a low γ detection threshold, < 10 MeV.

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[1]V. V. Barmin, V. G. Barylov, G. V. Davidenko, *et al.*, Phys. Lett. **47B**, 463 (1973).
[2]Y. Kohara, Prog. Theor. Phys. **48**, 261 (1972).
[3]L. Chan and H. Cheng, Phys. Rev. Lett. **54**, 786 (1985).
[4]V. B. Golubev, V. Druzhinin, and V. N. Ivanchenko, Nucl. Instrum. Methods **227**, 467 (1964).
[5]V. P. Druzhinin, V. B. Golubev, V. N. Ivanchenko, *et al.*, Phys. Lett. **144B**, 136 (1984).
[6]A. D. Bukin, V. P. Druzhinin, V. N. Ivanchenko, *et al.*, Preprint 86-18, Institute of Nuclear Physics, Novosibirsk, 1986.
[7]A. D. Bukin, V. N. Ivanchenko, M. Yu. Lel'chuk, *et al.*, Preprint 84-33, Institute of Nuclear Physics, Novosibirsk, 1984.

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