SEARCH FOR $\pi^0 \to 3\gamma$ DECAY

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The decay of a neutral pion into three γ quanta

$$\pi^0 \to 3\gamma \quad (1)$$

is of great interest in connection with the fact that its investigation makes it possible to verify whether C-parity is conserved. Interest in this decay has recently increased, especially in connection with the observed $K_2^0 \to 2\pi$ decay, which violates CP invariance [1]. According to theoretical estimates, the branching ratio of the decay of a neutral pion into two and three γ quanta, $\lambda = W(\pi^0 \to 3\gamma)/W(\pi^0 \to 2\gamma)$, can apparently range from 10^{-6} to 10^{-11}. The decay (1) was investigated earlier in several papers (see Table II). The experimental estimates obtained in the latest paper for the upper limit of λ was 9×10^{-4} (90% confidence level). The purpose of the present paper 1) was a further investigation of the possibility of the decay (1).

To register this decay, we used the apparatus previously employed in a study of the rare processes of pion decay and capture [2]. The experiments were performed with the synchrocyclotron of the JINR Laboratory of Nuclear Problems. The π^- mesons with initial energy 70 MeV passed through a series of scintillation counters and decelerating filters and were stopped in a liquid-nitrogen target, where the following charge exchange took place

$$\pi^- + p \to \pi^0 + n. \quad (2)$$

To register the γ quanta produced in the decay (1), we used three Cerenkov total-absorption spectrometers placed around the target and connected in a nanosecond coincidence circuit [3]. Scintillation counters, connected for anticoincidence and preventing registration of charged particles from the target by the spectrometers, were placed between the target and the spectrometers. The pulses from all the counters and spectrometers were photographed on the screen of a 5-beam high-speed oscilloscope [4], making multidimensional time and pulse-height analysis of the registered events possible. The spectrometers were calibrated beforehand with an electron beam of energy 10 - 300 MeV. In these experiments we measured the energy characteristics of the spectrometers and determined the γ-quantum registration efficiency.

The Cerenkov spectrometers were arranged in a plane perpendicular to the π^--meson beam, at mutual angles of 90, 135, and 135°. The efficiency of the apparatus in this configuration was determined on the basis of the known number of stopped π^- mesons in the target, using the spectra and angular distributions of [5], and also from the counting rate of the $\pi^0 \to 2\gamma$ decays, obtained in supplementary experiments with two spectrometers placed at 180°. The counting efficiency of the $\pi^0 \to 3\gamma$ decay under the assumed criteria for the selection of the events (see below) was 1%. One count corresponded under the conditions of our experiment to $\lambda = 1.7 \times 10^{-6}$.

The measurements yielded 550 oscillograms, 66 of which contained pulses from all three spectrometers and from the scintillation counters that registered the π^- mesons. These pulses were subjected to a pulse-height and time analysis, the results of which are listed in Table I.

Table I

Selection criterion	Number of events remaining after selection	Value of λ corresponding to the events remaining after selection
Total	66	6×10^{-5}
No pulses from anticoincidences centers	54	5×10^{-5}
Pulses from three spectrometers coincide within $\pm 1.5 \times 10^{-9}$ sec	33	3.6×10^{-5}
Pulse heights from counters of the beam particles limited to an interval ±20%	16	1.9×10^{-5}
Some of the pulse heights from three spectrometers less than the value corresponding to 210 MeV	6	8×10^{-6}
Coincidence from pulses from spectrometers and beam-particle counters within $\pm 1.2 \times 10^{9}$ sec	1	1.7×10^{-6}
Background events (in neighboring intervals)	3	

The resultant estimate of the upper limit of the branching ratio λ was found to be 2.2×10^{-6} at the 1/e confidence level. At the 90% confidence level,

$$\lambda < 5 \times 10^{-6}.$$

Table II

Reference	Method	Apparatus	Upper limit of λ (90% confidence
Ely, Frisch [6]	Angular correlation of 2 γ quanta from the reaction $p + Li^7 \rightarrow Be^8 + \pi^0$	Counters	2.5×10^{-2}
Vasilevskii, Vishnyakov, Dunaitsev, Prokoshkin, Rykalin, Tyapkin [7]	Angular correlation of 2 γ quanta from the reaction $\pi^- + p \rightarrow \pi^0 + n$	Counter hodoscope	2×10^{-3}
Cline, Dowd [8]	Registration of 3 γ quanta in the reaction $K^+ \rightarrow \pi^+ + \pi^0$	Bubble chamber	9×10^{-4}
Present work	Registration of 3 γ quanta in the reaction $\pi^- + p \rightarrow \pi^0 + n$	Cerenkov spectrometers	5×10^{-6}

Table II shows a comparison of our data with the results of earlier investigations at Harvard, Dubna, and Berkeley.

If we assume that a second neutral meson, having the same mass as the π^0 meson, exists but is capable, unlike the other, of decaying into three γ quanta, then we obtain from our data the following maximum estimates for the relative probability of production and decay of such a meson: 6×10^{-6} at an average lifetime $\tau_{3\gamma} < 10^{-10}$ sec, 1.3×10^{-5} ($\tau_{3\gamma} < 5 \times 10^{-10}$ sec), 2×10^{-5} ($\tau_{3\gamma} < 10^{-9}$ sec), and 1.5×10^{-4} ($\tau_{3\gamma} < 10^{-7}$ sec).

The method used in the present paper to register the $\pi^0 \to 3\gamma$ decay allows us, in our opinion, to advance into a region of even lower values of λ.

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1) Reported at the June Session of the Nuclear Physics Division of the USSR Academy of Sciences.

FEATURES OF OPTICAL ABSORPTION OF METALLIC FILMS IN THE REGION WHERE THE METAL TURNS INTO A DIELECTRIC

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1. It is well known that the character of the conductivity of many metals is governed by the overlapping of the valence and conduction bands. Any cause which leads to elimination of this overlap transforms the metal into a dielectric (at 0°K). In particular, the transformation of a metal into a dielectric in a quantizing electric field was discussed in [1].

A similar result is expected in the case of thin metallic films, in which conditions for size quantizations of the energy spectrum of the carriers is realized. The quantization of the energy spectrum, as is well known, leads to a shift of the bottom of the conduction band and of the top of the valence band by an amount $\Delta\epsilon = \pi^2\hbar^2/2md^2$ (in the approximation where $\epsilon = p^2/2m$), where d is the thickness of the film and m the effective mass of the carriers in the band in question. With decreasing d, the energy corresponding to the bottom of the con-