

**ON POSSIBLE
IMITATIONS OF THE
DECAY $(K_2^0 \rightarrow$
 $\pi^+ + \pi^-)$**

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Abstract

Full Text

PHYSICS

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ON POSSIBLE IMITATIONS OF THE DECAY

$$K_2^0 \rightarrow \pi^+ + \pi^-$$

(Presented by Academician V. I. Veksler on 1 II 1965)

Recently a group at Princeton University succeeded in registering, in a beam of K_2^0 -mesons, two-particle decays in which the mass of the decaying particle (if the decay products are assumed to be pions) coincides with good accuracy with the mass of the K^0 -meson. After an estimate of the background and an analysis of possible imitating processes, the authors concluded that they had observed the decay $K_2^0 \rightarrow \pi^+ \pi^-$ ⁽¹⁾, forbidden by CP -invariance. It should be emphasized, however, that in the experiment under consideration neither the decaying particle nor the products of its decay were identified. Therefore it is in principle possible (although unlikely) that the authors of work ⁽¹⁾ were dealing with a two-particle decay of some other unknown particle. Since systematic searches for new neutral long-lived particles have not yet been carried out, it is of interest to analyze such a possibility.

In the geometry of experiment ⁽¹⁾, for a two-particle decay we have the invariant relation

$$p^2(1 - \cos 2\theta) = \frac{M^2 - 4m^2}{2} = \text{const};$$

$p = p_+ = p_-$ is the momentum of the decay particles with mass m ($m = m_+ = m_-$); θ is their angle of emission; M is the mass of the decaying particle. From this relation, using the data for the decay $K_2^0 \rightarrow \pi^+ \pi^-$ and assigning different masses to the decay products, one can obtain the mass of a decaying particle whose decay could imitate the decay $K_2^0 \rightarrow \pi^+ \pi^-$. As a result, for decays into $K^+ K^-$ we have $M = 1070$ MeV, into $\mu^+ \mu^-$ $M = 464$ MeV, and into $e^+ e^-$ $M = 412$ MeV.

Let us consider the possible properties of these hypothetical particles. In doing so it should be borne in mind that, under the conditions of the experiment, the events registered in ⁽¹⁾ are decays of long-lived particles. The existence of a long-lived particle $X_{1070}^0 \rightarrow K^+ K^-$ does not seem possible. The decays of the other two hypothetical particles, $X_{464}^0 \rightarrow \mu^+ \mu^-$, $X_{412}^0 \rightarrow e^+ e^-$, can occur only through the electromagnetic interaction, since weak processes containing neutral leptonic currents are forbidden. The analysis of possible sets of quantum numbers for $X_{464}^0 \rightarrow \mu^+ \mu^-$ and $X_{412}^0 \rightarrow e^+ e^-$ differs little; however, the second

Figure 1

Figure 1: Figure 1

of these processes will have a noticeably greater probability (other conditions being equal). Therefore we shall restrict ourselves to consideration of the decay $X_{412}^0 \rightarrow e^+e^-$. Most sets of quantum numbers I^{PC} for a particle with mass 412 MeV cannot ensure the stability of such a particle with respect to strong or electromagnetic decays (in first or second order in α). A special place is occupied by the state 0^{+-} , for which the transition to $\pi\pi\gamma$ is possible only for high orbital states ($l_{\pi^+\pi^-} = 2$, $E2$ and $M2$), which causes strong suppression owing to the centrifugal barrier, which may reach $10^{-5} \div 10^{-7}$ for an interaction radius $r = 0.5 \cdot 10^{-13} \div 10^{-13}$ cm. For the indicated state only “direct” emission of a photon is possible, the probability of which (relative to the probability of bremsstrahlung radi-

tion) in processes of this type is apparently small. If the probability of decay, in the principal orbital state, of a particle with mass ~ 400 MeV into $\pi^+\pi^-\gamma$ (with a bremsstrahlung γ -quantum) is taken to be $W \sim 10^{16} \div 10^{17} \text{ sec}^{-1}$ (see, for example, (2)), then one may expect, under certain conditions, that $W(X_{412}^0 \rightarrow 2\pi\gamma) \sim 10^8 \div 10^6 \text{ sec}^{-1}$. For the set of quantum numbers chosen by us (0^{+-} , $S = 0$), the decay $X_{412}^0 \rightarrow 3\gamma$ is also possible. The available estimates (3) give, for the probability of such a decay, the value

$$W \sim 10^8 \text{ sec}^{-1}.$$

In this case, in higher orders in the electromagnetic interaction there will also occur the decay $X_{412}^0 \rightarrow e^+e^-$ with probability $\sim 10^4 \text{ sec}^{-1}$ (taking into account phase-volume corrections). The estimates presented show that the decay $X_{412}^0 \rightarrow e^+e^-$ ($S = 0$, $I^{PC} = 0^{+-}$) could imitate the decay process $K_2^0 \rightarrow \pi^+\pi^-$; in this case the principal decay modes of this hypothetical particle could until now have remained unnoticed. The existing particle-classification schemes also do not exclude the possibility of the existence of such a particle. Moreover, in the Sternheimer scheme (4) there is an “unfilled” place for a particle with mass 412 MeV.

Fig. 1. Dependence of the number of decays $K^0 \rightarrow \pi^+\pi^-$ on time for large $\lambda_1 t$. Decay amplitude $K_2^0 \rightarrow \pi^+\pi^-$, $\varepsilon = 2.3 \cdot 10^{-3}$. $1 - W(K_1^0 \rightarrow 2\pi + K_2^0 \rightarrow 2\pi)$; $2 - W(K_1^0 \rightarrow 2\pi)$

All the considerations presented, despite their speculative character, once again show that, in order to prove the existence of the decay $K_2^0 \rightarrow \pi^-\pi^+$, identification of the decay products is necessary. However, even in this case there remain possibilities that would require additional experiments. We have in mind such processes as $K_2^0 \rightarrow \pi^+\pi^-\gamma$, which at small γ -quantum energies (≤ 1 MeV) can imitate the decay $K_2^0 \rightarrow \pi^+\pi^{*-}$. Estimates show that it is sufficient to assume

a 10-percent contribution of resonantly interacting pions in $K_2^0 \rightarrow \pi^+\pi^-\gamma$ in order to explain the effect observed in (1). Obviously, it is extremely difficult to identify the pions in the decay $K_2^0 \rightarrow \pi^+\pi^-\gamma$ and at the same time to register the soft γ -quantum and measure its energy. It is possible, however, to perform an experiment that makes it possible to distinguish any imitating process from the true decay $K_2^0 \rightarrow \pi^+\pi^-$. For this, one must study the dependence of the number of decays $K^0 \rightarrow \pi^+\pi^-$ on time t , i.e., on the distance from the point of production of the $K^0(K^0)$ -meson. If the effect observed in (1) is the result of imitation, then the curve of this dependence will be the sum of two exponentials. If, however, the decay $K_2^0 \rightarrow \pi^+\pi^-$ really exists, this dependence will no longer be purely exponential, since it will contain an interference term whose relative contribution grows with t (6). The deviation from the exponential character of the curve amounts to $3 \div 4\%$ for the region $t = 4 \div 5\tau_1$ and $20 \div 30\%$ for the region $t = 7 \div 9\tau_1$. This effect proves to be quite striking at large t , where the amplitudes $K_1^0 \rightarrow \pi^+\pi^-$ and $K_2^0 \rightarrow \pi^+\pi^-$ are comparable in magnitude (see Fig. 1). Thus, in the interval $10 \div 12\tau_1$ (i.e., within several centimeters of path length) the number of decays $K^0 \rightarrow \pi^+\pi^-$ decreases by more than a factor of 300, while in the subsequent interval $12 \div 14\tau_1$ it again increases by a factor of 50**.

* Other imitating processes of this type are also possible (see, for example, (5)).

** The interference pattern turns out to be very sensitive to the value Δm of the mass difference between K_1^0 and K_2^0 . In the calculations it was assumed that $\Delta m = 0.8$; at the same time we neglected the possible phase difference between the amplitudes of the transitions $K_1^0 \rightarrow \pi^+\pi^-$ and $K_2^0 \rightarrow \pi^+\pi^-$.

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