ОБЪЕДИНЕННЫЙ
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ИССЛЕДОВАНИЙ

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E - 2614

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A POSSIBLE DIRECT TEST OF CP VIOLATION IN THE K_2^0 INTERACTIONS

ЛАБОРАТОРИЯ ТЕОРЕТИЧЕСКОЙ ФИЗИКИ

1966

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Submitted to Physics Letters

In the previous note[1] we have proposed the CP violating mechanism in interactions of particles with electromagnetic field, the coupling constant of the interaction being $\approx Ge$. We shall discuss here some effects inherent to the interactions of K_2^0-mesons, which are caused by this mechanism. We assume, that the CP noninvariant interaction of baryons with electromagnetic field[1] is the fundamental one. Therefore, to estimate the processes involving K_2^0-mesons, it is necessary to use, for instance, the interaction lagrangian of Λ particles and neutrons N with photons. Following[1], we introduce the CP noninvariant interaction

$$\mathcal{L}_{\Lambda N\gamma} = \frac{G}{\sqrt{2}} e \cdot \xi \sin\theta \cdot \frac{i}{2} [\bar{\Lambda}\gamma_m (1+\gamma_5)\partial_n N - \partial_n \bar{\Lambda}\gamma_m (1+\gamma_5) N] F_{mn} + \text{h.c.} \tag{1}$$

To obtain this expression from the lagrangian (2) of[1] it is sufficient to set there $\Gamma_{N\Lambda} = \Gamma_{\Lambda N} = \sin\theta$ where θ is the Cabibbo angle[2], and $\lambda = \xi/\sqrt{2}$. One may generally define the constant ξ by comparison with the experiment, for instance, from the known probability of the decay $K_2^0 \to \pi^+\pi^-$. Inasmuch as the order of magnitude of the observed CP violating effect ($\epsilon \approx \frac{a}{\pi}$, $a = 1/137$) is accounted for the interaction (2) being proportional to the electron charge e, we may assume that ξ does not much differ from unity ($\xi \approx 1$). The part $\mathcal{L}_A$ of the Lagrangian (1), which contains γ_5 is P and CP noninvariant, whereas the remainder, $\mathcal{L}_V$ is C and CP noninvariant. The decay $K \to 2\pi$ is due to the interaction $\mathcal{L}_A$. In this note we discuss the possible consequences of the interaction $\mathcal{L}_V$.

This interaction gives the effective interaction of pseudoscalar particles with photons. The most interesting consequences are due to the interaction of K_2^0-meson with π^0 (or η, η') and γ:

$$\mathcal{L}_{K\pi\gamma} = \xi' \sin\theta \cdot Ge \cdot \tfrac{1}{2} [\partial_m K_2^0 \partial_n \pi^0 - \partial_n K_2^0 \cdot \partial_m \pi^0] F_{mn} \tag{2}$$

(To obtain this expression from the Lagrangian (4) of [1] one sets $\lambda' = \frac{\xi'}{\sqrt{2}} \sin\theta$). Other Lagrangians of this type may be written in the same way.

The interaction (2) leads to two quite interesting effects, the detection of which could directly confirm the CP violation. First, when CP and C are violated, K_2^0 meson may decay according to the scheme $K_2^0 \to \pi^0 e^+ e^-$ with the internal conversion of the photon into $e^+ e^-$ (see Fig. 1a). This process is forbidden by CP or C invariances. The same mechanism leads to a very exotic phenomenon "the loss of strangeness" by K_2^0 meson in the Coulomb field of a nucleus Z with electric charge Ze i.e. to the process $K_2^0 + Z \to \pi^0(\eta, \eta') + Z$ (see Fig. 1b). This process is forbidden in one-photon exchange approximation on the same grounds, as the preceding one.

To estimate the probabilities of these processes, we have to know the order of magnitude of the quantity ξ'. To find it out, we connect ξ' with ξ considering one of the possible diagrams for the virtual process $K_2^0 \to \pi^0 \gamma$ (see Fig. 2). (strictly speaking, we should take two diagrams of this type). The vertices $\Lambda N K$ and $NN\pi$ are defined by the coupling constants g_K and g_π of the Yukawa pseudoscalar interaction, and the vertex, in which photon is emitted, corresponds to the Lagrangian (1). This diagram turns out to converge and for $|k^2| \ll m^2$ (where m is the proton mass) it has the form (neglecting the terms of the order $\approx (1 - \frac{m_N}{m_\Lambda})^2$)

$$A_{K\pi\gamma} = \frac{i\xi \sin\theta}{4\pi} Ge \cdot \{\frac{g_K}{\sqrt{4\pi}} \cdot \frac{g_\pi}{\sqrt{4\pi}} \cdot (1 - \frac{m_N}{m_\Lambda})\}[p_\mu k^2 - k_\mu (pk)] , \qquad (3)$$

where m_Λ is the mass of the Λ particle. The expression in the curly brackets is near to unity and in what follows we set it to be equal to unity. Then we obtain $\xi' = \frac{\xi}{4\pi}$. Note, that for large values of $|k^2|$ the amplitude decreases in the following way

$$A_{K\pi\gamma} \approx \frac{i\xi \sin\theta}{4\pi} \cdot Ge \cdot [p_\mu k^2 - k_\mu (pk)] \cdot \frac{m_\Lambda^2}{(-k^2)} \log^2(\frac{-k^2}{m_\Lambda^2}) . \qquad (4)$$

We see, that the constant ξ' is slightly less than ξ. This small suppression is due to the factor $(1 - \frac{m_N}{m_\Lambda})$. In calculations of the analogous diagrams for CP invariant interactions (the usual weak and electromagnetic ones) a much stronger suppression $\approx (\frac{m_\pi}{m})^2$ occurs [4]. It should be stressed, that the expression (3) gives only the order of magnitude of the vertex $A_{K\pi\gamma}$. Therefore it is not of much use to take into account the diagrams, which contain other baryons in the intermediate state.

Let us now use the vertex (3) for estimating the probability of the decay $K_2^0 \to \pi^0 e^+ e^-$ according to the diagram Fig. 1a. Neglecting the electron mass, we obtain after simple calculations

$$w = 0{,}6 \frac{G^2 m_K^5}{768\,\pi^3} \cdot a^2 \frac{\xi^2 \sin^2\theta}{4} . \tag{5}$$

Inserting $\sin\theta = 0.25$ we find $w \approx \xi^2 \cdot 100\ \mathrm{sec}^{-1}$. The branching ratio of this decay is $w/w_0 \approx \xi^2 \cdot 6 \cdot 10^{-6}$. One cannot compare yet this estimate with the experiment. However, the upper bound for the probability w' of the decay $K^+ \to \pi^+ e^+ e^-$ is known. According to the recent experimental data/5/ the branching ratio is $w'/w_+ < 10^{-6}$ i.e. $w' < 100\ \mathrm{sec}^{-1}$. In virtue of isotopic invariance of strong interactions, the CP violating term in the amplitude of the decay $K^+ \to \pi^+ e^+ e^-$ should be equal to the amplitude of the decay $K_2^0 \to \pi^0 e^+ e^-$. Taking into account the estimate of the CP conserving part of the K^+ decay (see/4/), we conclude, that the values $\xi \lesssim 1$ do not contradict to the experimental evidence.

We estimate now the cross section of the process $K_2^0 + Z \to \pi^0 + Z$ (see Fig. 2) with the aid of the same vertex. Then we obtain

$$\sigma = Z^2 \left(\frac{E_K}{m}\right) \cdot \frac{p'}{p} \cdot \xi^2 \cdot \sin^2\theta \cdot \frac{G^2 a^2}{4\pi} m^2 =$$
$$= Z^2 \left(\frac{E_K}{m}\right)^2 \cdot \frac{p'}{p} \cdot \xi^2 \cdot 10^{-44}\ \mathrm{sm}^2 \tag{6}$$

In this case the angular distribution of π is isotropic. For large momentum transfer $(\vec{p} - \vec{p}\,')^2$ it is necessary, however, to take into account the decrease of the form-factor (see (4)). This does not matter however for the estimate of the total cross section σ. This cross section may have a noticeable magnitude for sufficiently heavy nuclei and for sufficiently high energies E_K. For example, for the nucleus U and for $E_K \approx 10$ GeV, we obtain $\sigma \approx \xi^2 \cdot .10^{-38}\ \mathrm{cm}^2$. The analogous estimate is, of course, valid for the processes $K_2^0 + Z \to \eta(\eta') + Z$. The cross sections for this processes may differ from (6) because of the difference in strong interactions of π, η, η' but the order of magnitude is the same.

The search for the processes, discussed here, seems to be very important to clear the CP problem. First, the detection of these effects would give the direct proof of the CP violation. On the other hand, this could testify strongly to the validy of the mechanism, proposed in paper[1], provided that the effects of C violation in electrodynamics[6] are not detected and the CP violating effects in leptonic decays are not found (see[1]).

The authors are grateful to E.O. Okonov for valuable discussions and to A.N.Tavkhelidze for the interest in the work.

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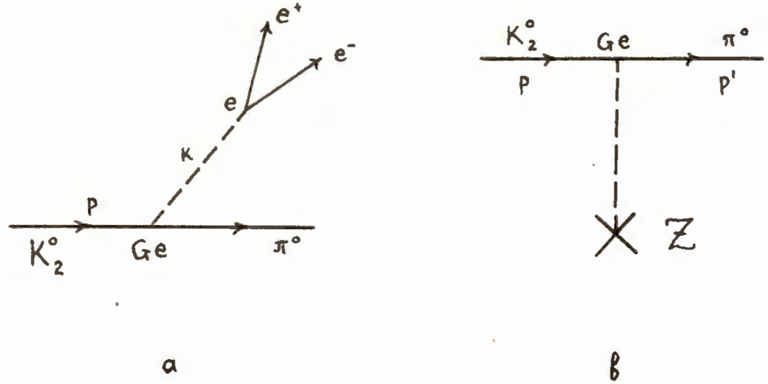
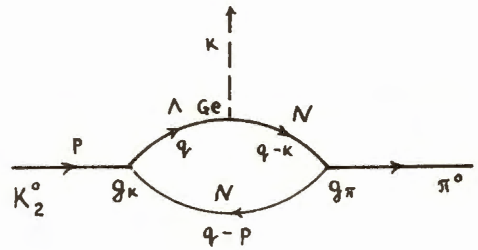
Received by Publishing Department
on March 3, 1966.



F i g. 1



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