ЖЭТФ, письма в ред., 30/IX-68
1968, т. 8, в. 9, с. 493-496

ОБЪЕДИНЕННЫЙ
ИНСТИТУТ
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

Дубна

E2 - 4019

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ЛАБОРАТОРИЯ ТЕОРЕТИЧЕСКОЙ ФИЗИКИ

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# CP-VIOLATION IN P-CONSERVING ELECTROMAGNETICALLY-WEAK AND MINI-WEAK INTERACTIONS

Submitted to "ЖЭТФ"

Experimental studies of $K^0$-decays and the search for the CP-violation in other processes do not yet lead to the understanding of the CP-violating mechanism. Furthermore, some recent experimental data [3,4] force us to a new discussion of the mechanism which disagreed with earlier measurements of the parameters $|\eta_{00}|$ and $\phi_{+-}$ [x]. We consider here the class of such models in which the "direct" CP-odd transitions are small as compared to the transitions $K_2 \to K_1 \to 2\pi$ induced by the CP-violation in the mass matrix. These models called in what follows "minimal" ones are characterized by the condition $|\varepsilon_2| \ll |\varepsilon_0|$. By use of the well known phenomenological analysis based on CPT one may then infer that in the minimal models the CP-violating parameters should satisfy the equations

$$\phi_{+-} \simeq \phi_{00} \simeq \phi_\varepsilon \simeq \operatorname{arctg}\left(\frac{2\Delta m}{\Gamma_S}\right) = (42.7 \pm 1.3)^\circ; \quad Re\,\varepsilon_0 \simeq |\eta_{+-}| \cos\phi_\varepsilon = (1.44 \pm 0.10)\, 10^{-3};$$ [3,4].

The experimental result $Re\,\varepsilon_0 = (1.16 \pm 0.18) \cdot 10^{-3}$ obtained from asymmetry in the decays $K_L \to \pi \ell \nu$ and from $\Delta Q = \Delta S$ rule ( see for this [4] ), is in reasonable agreement with these predictions. The recent measurement of $\phi_{+-}$ also does not contradict them; $\phi_{+-} = (46 \pm 15)$ [3], $\phi_{+-} = (51 \pm 11)$ [4]. By use of the Wu Yang triangle we then may obtain[3] $|\eta_{00}| = (0.7 {}^{+1.0}_{-0.7}) \cdot 10^{-3}$. This rather poor accuracy prevents one from any serious conclusions and the direct measurements of this important quantity gave rather controversial results in the range $(0 \div 4) \cdot 10^{-3}$. Bearing in mind this rather obscure situation we want to stress strongly that the large value $|\eta_{00}| = (3.6 \pm 0.6) \cdot 10^{-3}$ contradicting the minimal models and strongly suggested in [5], clearly disagrees with $|\eta_{00}|$ calculated from the Wu-Yang triangle.

The most popular minimal model is the superweak model of Wolfenstein in which the minimality condition $|\varepsilon_2| \ll |\varepsilon_0|$ is produced by the $|\Delta S| = 2$ selection rule. Different models were suggested with $|\varepsilon_2| \ll |\varepsilon_0|$ condition following the $|\Delta T| = 1/2$ rule. We discuss here the new class of minimal models in which this condition is provided by the parity selection rule. Consider CP- odd parity conserving "mini-weak" (MWP) [xx] or electromagnetically weak ( EWP) interactions ( CP- conservation or nonconservation denoted by P or P̸). P- violating direct transitions $K_2 \to 2\pi$ may then go only through the combined action of EWP ( MWP) and W$\not{P}$ so that $|\varepsilon_2| / |\varepsilon_0| \lesssim G_W m^2 \sim 10^{-6} \div 10^{-7}$,

x) See e.g. [1,2] where the extended list of references and the review of the experimental data may be found. The notations of the review [1] are adopted here.

xx) Hypothetical mini-weak interactions are supposed to be $10^2 - 10^3$ times weaker than the usual weak interactions.

where $G_w \simeq \frac{10^{-5}}{m_p^2}$ , $m$ is some characteristic mass of the $K_L \to 2\pi$ decay.

The opinion is widely accepted ( see e.g. [4]) that in minimal models all effects of CP-nonconservation must be small and give only small ( $10^{-2} \div 10^{-3}$) corrections to CP- conserving amplitudes. This opinion is absolutely groundless. For example, a mini-weak interaction with a strong energy dependence may give quite large CP-violating terms in amplitudes of some process, Q-value being large enough. A model of this kind was considered by us previously [6] . Furthermore, an essentially arbitrary EWP-interaction may create significant CP-odd effects in weak radiative decays.

Let us consider now the most important predictions of such interactions [x)].

1) There must exist the decay forbidden by CP-invariance: $K_2 \xrightarrow{EWP} \pi^0\gamma \xrightarrow{E} \pi^0 e^+e^-$ with partial width $\sim 10^{-6}$.

2) In the decays $K_{L,S} \to 2\gamma$ must exist the interference, which is forbidden by CP-conservation, photons being unpolarized. The observation of this interference is not a difficult task if $\Gamma(K_S \to 2\gamma) \gg \Gamma(K_L \to 2\gamma)$ but we do not know any serious arguments suggesting such inequality. It is quite possible that $\Gamma(K_S \to 2\gamma) \sim \Gamma(K_L \to 2\gamma)$ and in this case the interference effect is observable only near the $K^0$-meson generation point, the minimal distance growing with the energy of $K^0$. One may eventually observe that the P-conservation in the CP-violating transition $K^0 \to 2\gamma$ may be tested by the measurement of the correlation between the $(e^+e^-)$ planes in the decay $K_L \to 2\gamma \to (e^+e^-)$

3) $E$ and $EW\!\!\not{P}$ mechanisms predict the quite large CP-forbidden interference in $K_{L,S} \to \pi^+\pi^-\gamma$ decays [2]. For the EWP this effect should be small. In fact the bremsstrahlung amplitude $K_1 \xrightarrow{W\!\not{P}} \pi^+\pi^- \xrightarrow{E} \pi^+\pi^-\gamma$ is P-odd and the CP-odd direct emission process $K_{L2} \xrightarrow{EWP} \pi^+\pi^-\gamma$ conserves P. Thus, only the direct emission amplitudes may interfere. For the same reason the charge asymmetry parameters in $K^\pm \to \pi^\pm\pi^0\gamma$ appear to be small. ( In $E$ and $WE\!\not{P}$ mechanism they might be of the order 10-30%. See e.g. [6] ).

4) In $K \to 3\pi\gamma$ decays quite large effects of CP-violation must be observable As a matter of fact $K \to 3\pi$ decay is P-conserving and so the bremsstrahlung amplitude $K \xrightarrow{WP} 3\pi \xrightarrow{E} 3\pi\gamma$ may interfere with the CP-odd direct emission amplitudes. Thus, for example, the partial widths $\Gamma(K^+ \to 2\pi^+\pi^-\gamma)$, $\Gamma(K^- \to 2\pi^-\pi^+\gamma)$ must be quite different, the photon energies being such that the bremsstrahlung and the direct emission amplitudes are

x) We consider here only the large effects of the CP-violation and so may put $K_S \simeq K_1, K_L \simeq K_2$

comparable. In the decay $K_L \to 3\pi^\circ\gamma$ only $\not{P}$,CP and P,$\not{CP}$ interactions may contribute and so the observation of the term $\vec{p}(\vec{q}\times\vec{k})$ in the momentum dependence of its probability would be the direct proof of the CP-violation. This effect for EWP interaction may be of the order 10÷30% but its observation is an extremely difficult task, for $\Gamma(K_L \to 3\pi^\circ\gamma) \lesssim 10^{-7}\Gamma_L$

5) The important prediction of EWP mechanisms is the smallness of the electric dipole moments. For the neutron e.g. $d_n \lesssim G_w^2 m_p^3 e \sim 2\cdot 10^{-4}\ e\cdot cm$

6) In conclusion, we should like to point out that the EWP- coupling constant $(\sim G_w e)$ may be estimated if we know $|\eta_{+-}|$. If in the mass matrix we take into account only the transition $K_2 \xrightarrow{\not{CP}} \pi^\circ\gamma \xrightarrow{CP} K_1$ then, making a cut-off in the corresponding Feynman integral on the virtual momenta $\sim m_p$ we find the vertex $K_2 \to \pi^\circ\gamma$ thus estimating $K_L \to \pi^\circ e^+e^-$. An EWP- model with the photon coupled to the strange conserved vector current may also be constructed. In such a model all the CP-violation parameters may be calculated without any ambiguites.

We should also like to stress that the previously discussed EWP model with coupling constant $\sim G_w e$ predicts too large[6] widths of the K-meson and baryon radiative decays and so it is in poor agreement with experimental facts. In contrast with this the EWP- model discussed here is in good agreement with all the firmly established experimental data and predicts quite large CP-violation effects in the decays $K_L \to \pi^\circ e^+e^-$, $K_{L,S} \to 2\gamma$, $K \to 3\pi\gamma$ and in some other weak radiative processes which we did not consider here.

The useful discussions with Drs. S.M.Bilenky, A.N.Tavkhelidze and B.N.Valuev are kindly acknowledged.

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Received by Publishing Department
on July 6, 1968.