Let us examine the efficiency of the method. In the flux from the moderator, the fraction of neutrons with $v \leq v_{lim}$ is $(1/2)\ (v_{lim}/u_D)^4$; at room temperature ($v_{lim} = 6.8$ m/sec) this amounts to $\sim 3 \times 10^{-11}$ [9]. If the irradiation is by fast neutrons, then a rough estimate based on the age theory yields for the probability of escape of a thermalized neutron $\varepsilon = (\exp(-B^2\tau))B^2L^2/(1 + B^2L^2)$($\tau$ - age of neutron, L - diffusion length; for a moderator in the form of a cube 2a on the side we have $B^2 = 3(\pi/a)^2/4$). For a hydrogen-containing moderator ($\tau = 33$ cm$^2$, f = 2.7 cm) we have $\varepsilon \approx 3 \times 10^{-2}$ (at a = 20 cm), i.e., the UCN generation efficiency amounts to $\sim 10^{12}$ per fast neutron falling into the moderator; cooling of the moderator to helium temperature should increase the efficiency of UCN generation by $\sim 2$ orders of magnitude. If the UCN emitter is made up of a series of thin moderator layers, then the UCN generation efficiency can be increased to $\sim 10^{-9}$. If reactors are used [7, 8] it is possible to accumulate up to $\sim 10^9$ UCN in one cycle. The trap with the accumulated neutron gas can be displaced at a velocity $v_{tr} \ll v_{lim}$.

Thus, the use of a multilayer emitter cooled to low temperatures should increase the UCN yield by several orders of magnitude. The use of a neutron shutter, which stops the leakage of the neutrons through the emitter, should additionally increase the neutron gas density by approximately two orders of magnitude; if the inner walls of the trap are further coated with a material that absorbs neutrons weakly (beryllium or graphite), then the lifetime of the UCN in the trap will practically be determined by the natural neutron decay.

In conclusion, the authors are grateful to Yu. A. Merkul'ev, B. V. Granatkina, and Wo Duc Bang for taking part in a discussion of the work.

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## VERIFICATION OF T-INVARIANCE IN LEPTONIC RADIATIVE DECAYS OF K MESONS

A. N. Safronov
Physics Department of the Moscow State University
Submitted 15 August 1969
ZhETF Pis. Red. 10, No. 8, 385 - 388 (20 October 1969)

Many models have been proposed to explain CP-violation in $K^0$-meson decays. These models, in which the violation is connected with photon emission [1 - 4] explain "naturally" the value $\sim \alpha/\pi$ of the already known CP-odd effects and the large admixture of the $\Delta T = 3/2$ amplitude in the $K_L^0 \to 2\pi$ decay [5]. We note that it is precisely for these attempts were made to find the dynamic mechanism of CP violation [6]. These include, first of all, the hypothesis of strong violation of charge parity in electromagnetic hadron interactions [1]. However, new experimental data [7] reported since the time of publication of that reference apparently exclude this possibility. Models were also proposed with CP violation in weak electromagnetic interactions, i.e., in interactions between hadrons and leptons with photon emission [2 - 4]. A model with charged W bosons, to which an electric dipole moment is ascribed [3], is probably likewise in contradiction with the experimental limit for the electric dipole moment of the neutron. However, this difficulty is not encountered in the model with the triplet of W mesons [4].

In this paper we discuss the possibility of verifying T-invariance in the decays

$$K^{\circ}(p) \rightarrow e^{\pm}(k_1) + \nu(k_2) + \pi^{\pm}(q) + \gamma(\kappa), \tag{1}$$

$$K^{\pm}(q) \rightarrow e^{\pm}(k_1) + \nu(k_2) + \pi^{\circ}(p) + \gamma(\kappa), \tag{2}$$

where the parentheses contain the symbols for the particle four-momenta. These K-meson decay channels are of interest from the point of view of revealing the mechanism responsible for CP-violation. They also yield information on the electromagnetic radiation for transitions with change of strangeness. The influence of bremsstrahlung on the total probability and the distribution of the particles over the Dalitz plot of $K_{e3}$ decays is considered in [8]. We write the matrix element of the processes (1) and (2) in the form

$$M = \frac{G}{\sqrt{2}} \sqrt{4\pi a} \sin\theta f_k \left[ M^B + \sum_{i=1}^{5} a_i M_i^D + \sum_{i=1}^{5} b_i \tilde{M}_i^D \right], \tag{3}$$

where $\theta$ is the Cabibbo angle, $f_k$ is the form factor of the $K_{e3}$ decay, and $\alpha$ is the fine-structure constant. The term $M^B$ is the bremsstrahlung amplitude (for concreteness, we consider production of $e^-\bar{\nu}$ particles)

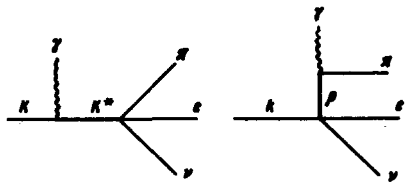
$$M^B = \bar{u}(k_1) \left[ \frac{2(a k_1) + \hat{a}\hat{\kappa}}{2(\kappa k_1)} - \frac{(a q)}{(\kappa q)} \right] \hat{p}(1+\gamma_5)\, v(k_2), \tag{4}$$

and the terms $M_i^D$ and $\tilde{M}_i^D$ correspond to the contribution of the "structure radiation." Their form is determined by the requirements of relativistic and gauge invariance. Neglecting the electron mass, we have in the most general case 10 terms of the structure radiation

$$\begin{aligned} M_1^D &= \mu^{-2} F_{\mu\nu} j_\mu p_\nu, \qquad M_2^D = \mu^{-2} F_{\mu\nu} j_\mu q_\nu, \\ M_3^D &= \mu^{-3} (jp) F_{\mu\nu} p_\mu q_\nu, \qquad M_4^D = \mu^{-3} (j\kappa) F_{\mu\nu} p_\mu q_\nu, \\ M_5^D &= i\mu^{-4} E_{\alpha\beta\sigma\gamma} j_\alpha p_\beta q_\sigma \kappa_\gamma F_{\mu\nu} q_\mu p_\nu, \end{aligned} \tag{5}$$

where $\mu$ is the K-meson mass, $j_\mu = \bar{u}(k_1)\gamma_\mu(1+\gamma_5)v(k_2)$, and $\tilde{M}_i^D$ can be obtained from the presented values by making the substitution $F_{\mu\nu} \rightarrow \tilde{F}_{\mu\nu} = (i/2)E_{\mu\nu\alpha\beta}F_{\alpha\beta}$. The dimensionless form factors $a_i$ and $b_i$ are functions of three kinematic invariants. Accurate to radiative corrections, they should be real quantities if T-invariance is conserved.

In the T-invariant theory, we can attempt to estimate the values of $a_i$ and $b_i$ by using




simple models. The simplest diagrams contributing to the amplitude of the structure radiation are shown in the figure. The interaction constants characterizing the vertices $KK^*\gamma$, $K^*\pi e\nu$, and $K\rho e\nu$ on these diagrams can be connected with the widths of the $\rho \to \pi\gamma$, $K^* \to K\pi$, and $K_{\mu 2}$ decays with the aid of SU(3) symmetry [9], the Cabibbo theory [10], CVC, and PCAC. We are unable to dwell on these estimates here in greater detail. We confine ourselves only to the remark that the diagrams of the figure can make contributions of order of magnitude unity to $a_i$ and $b_i$. To estimate the possible T-odd correlation, we shall assume henceforth that $|a_i, b_i| \sim 1$ and that "maximum" violation of T-invariance takes place, i.e.,

$$|\mathrm{Im}\, a_i,\ b_i| = |\mathrm{Re}\ a_i,\ b_i| \quad .$$

We present an expression for the T-odd part of the square of the matrix element of process (1) in the $K^0$-meson rest system

$$\begin{aligned} W_o = 32\pi\alpha G^2 \sin^2\theta f_k^2 \mu^2 E_1 \xi \Bigg\{ & \mathrm{Im}\, a_1 \left[ \omega - \frac{1}{x}\left(1 + \frac{\xi}{E_1}\right) - \frac{\omega}{E_1 x}(1 - \xi y) + \frac{1+\gamma^2}{2E_1 x} + \frac{\gamma^2}{\xi y} \right] + \mathrm{Im}\, a_2 \left[ \omega + \frac{1}{y} - \frac{1}{x} \right] + \\ & + \mathrm{Im}\, b_1 \left[ \omega - \frac{1}{x}\left(1 + \frac{\xi}{E_1}\right) - \frac{\omega}{E_1 x}\left(1 - \xi y\right) + \frac{1+\gamma^2}{2E_1 x} \right] + \\ & + \mathrm{Im}(a_1^* a_2 + b_1^* b_2)\, \omega^2 (1 - \xi y) + \\ & + \mathrm{Im}(a_1^* b_2 + b_1^* a_2)\, \omega^2 (1 - \xi y - 2E_1 x) \Bigg\} \left( \hat{\kappa}\, [\hat{k}_1, \hat{p}] \right), \end{aligned} \qquad (6)$$

where

$$x = 1 - (\hat{\kappa},\ \hat{k}_1), \quad y = 1 - \sqrt{1 - \gamma^2/\xi^2}\,(\hat{p},\ \hat{\kappa}), \quad E_1 = k_{10}/\mu,$$

$$\xi = p_0/\mu, \quad \omega = \kappa_0/\mu, \quad \gamma = m/\mu, \quad m - \text{pion mass},$$

and $\hat{\kappa}$, $\hat{k}_1$, and $\hat{p}$ are unit vectors along the particle momenta. For simplicity we confine ourselves to structural-radiation terms with a minimum 4-momentum numbers. Under the assumptions made above, the angular asymmetry due to the T-odd correlation in the hard part of the spectrum of the emitted phonons and at large angles between the particle momenta can amount to 10 - 20%.

In conclusion we note that the main background in the detection of the processes (1) and (2) is due to $K_{e4}$ decays. They can interpreted as reactions (1) and (2), if one of the $\gamma$ quanta produced in the decay of the $\pi^0$ meson escapes observation. Consequently, a high gamma registration efficiency is necessary. The background conditions for the observations of the process (1) are more favorable, for it is necessary here to detect only one photon in the final state. In the long-lived component of the $K^0$-meson beam, the partial width of the processes (2), inasmuch as in the former case the corresponding photonless processes is one of the main decay channels.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## INSTABILITY OF OSCILLATIONS WITH FREQUENCY EQUAL TO HALF THE ION-CYCLOTRON FREQUENCY


A. V. Timofeev


Submitted 18 August 1969
ZhETF Pis. Red. 10, No. 8, 389 - 392 (20 October 1969)


1. It is known that in adiabatic traps the plasma can be unstable against the buildup of ion-cyclotron oscillations, i.e., oscillations with frequencies close to the ion-cyclotron frequency $\omega_i$ or to its harmonics $n\omega_i$. However, buildup of oscillations with frequencies that were multiples of half the cyclotron frequency, $\omega = n\omega_i/2$, was observed in experiments with the Phoenix apparatus [1] and with Ogra-1 (unpublished) in addition to the ion-cyclotron instability. In our opinion, the excitation of such oscillations may be connected with parametric resonance. Let us explain this statement. The ion-cyclotron instability begins to build up at a plasma density such that the frequency of the magnetized electronic Langmuir oscillations becomes comparable with the ion-cyclotron frequency [2, 3]. In a homogeneous and unbounded plasma, the spectrum of the frequencies of the magnetized electron Langmuir oscillations is given by the formula $\omega = \omega_{pe}k_{\parallel}/k \leq \omega_{pe}$, where $\omega_{pe}$ is the electron Langmuir frequency and $k_{\parallel}$ is the component of the wave vector along the magnetic field. In bounded systems, the spectrum is discrete and in order for the oscillation to build up it is necessary that the maximum frequency in this spectrum be comparable with $\omega_i$. (This frequency is smaller than $\omega_{pe}$, since oscillations with $k_{\perp} \neq 0$ are built up). The oscillations with lower frequencies remain stable within the framework of the linear theory. In the presence of instability at the ion-cyclotron frequency, however, the plasma parameters become alternating in time, and this creates conditions for parametric buildup of oscillations with $\omega = \omega_i/2$. At much higher values of the density, $\omega_{pe} > n\omega_i$ and parametric buildup of oscillations with $\omega \approx \ell\omega_i/2$ becomes possible ($\ell = 1, 2, \ldots, 2n$).

2. Let us assume that oscillations of the electric potential are excited in an adiabatic trap at the ion-cyclotron frequency. The systems of interest to us (Phoenix, Ogra-1) have axial symmetry (the symmetry axis is parallel to the magnetic field and to the OZ axis). Therefore, the perturbations of the potential will be of the form $\phi_1(r, t) = \phi_1(r,z)\cos(\omega_i t - n_1\theta)$, where $\theta$ is the azimuthal angle. In the analysis of the evolution of the oscillations with $\omega \approx \omega_i/2$, we shall use asymptotic methods developed in the theory of the