$$\sigma_{\ell}(q^2) = \left(1 - \frac{q^2}{4M^2}\right)\left[Z(G_{E_p}(q^2))^2 + A(A-1) < \Psi_i | \hat{a}_1^E \hat{a}_2^E j_0(qr_{12}) \Psi_i >_{|\omega=0}\right]. \quad (20)$$

Comparing (19) and (20) we obtain

$$E_{\text{Coul}} = (e^2/\pi) \int_0^{\infty} dq [\sigma_{\ell}(q^2)(1 + q^2/4M^2) - Z(G_{E_p}(q^2))^2]. \quad (21)$$

With the aid of (21) we can determine, in principle, the Coulomb energies of the nuclei from experiments on inelastic scattering of electrons.

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CHARGE ASYMMETRY IN DECAYS OF THE SYSTEM $K^0\bar{K}^0$ PRODUCED VIA A ϕ^0 RESONANCE

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The system $K^0\bar{K}^0$, which is produced in the annihilation reaction (e^+e^-, $p\bar{p}$), has highly unique properties in that subsequent decays of the two neutral kaons are not independent; this is particularly valuable for the study of effects of CP violation (these questions were discussed in [1 - 5], and the program for the corresponding investigations with the VEPP-2M apparatus of our Institute was reported in [6]). The correlation of these two decays is a pure effect of quantum-mechanical coherence, first noted in the famour paper of Einstein, Podolsky, and Rosen [7].

The system $K^0\bar{K}^0$ is produced, with high probability, in the reaction

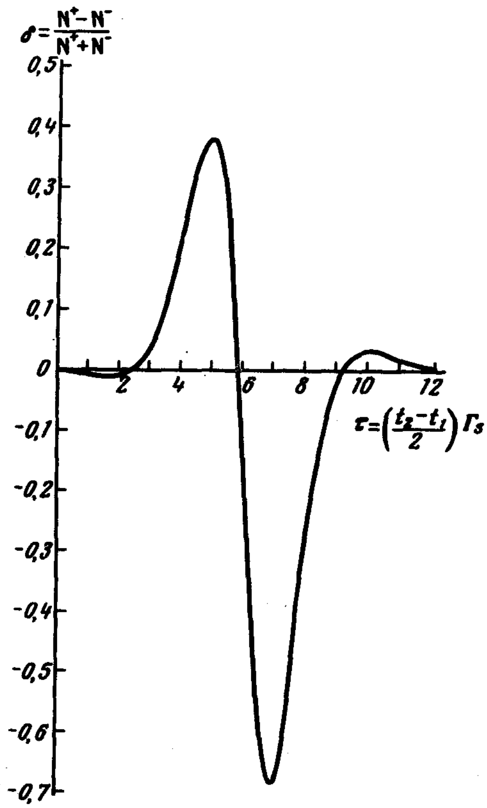
$$e^+e^- \to \phi^0 \to K^0\bar{K}^0, \quad (1)$$

in which an antisymmetrical state is produced (angular momentum I = 1, parity P = -1)

$$\psi_a = \frac{1}{\sqrt{2}}[\,|K^0(1)\bar{K}^0(2)> - |K^0(2)\bar{K}^0(1)>] = \frac{1}{\sqrt{2}}[\,|L(1)S(2)> - |L(2)S(1)>], \quad (2)$$

where $|L>$ ($|S>$) $\equiv |K^0_{L(S)}>$. The cross section of the process (1) at resonance ($2\epsilon = m_\phi$) is $\sigma_R = 1.3 \times 10^{-30}$ cm^2, so that at a luminosity $L = 10^{31}$ cm^{-2}sec^{-1} (which is apparently quite realistic for second-generation installations) approximately 13 $K^0\bar{K}^0$ pairs will be produced per second. The angular distribution in the reaction (1) is $\sigma(\theta) \propto \sin^2\theta$ (θ is the angle between the vectors $\vec{p}_K$ and

$\vec{p}_e$), and the produced kaons are nonrelativistic (v_K = 0.22c in the c.m.s. of the system). An important feature of reaction (1) is that the production of the state (2) is preferred (at $2\varepsilon \approx m_\phi$ the cross section for the production of the symmetrical state is suppressed by a factor 10^9). In other words, the reaction (1) is a means of obtaining a "coherent beam of neutral kaons."



It is of great interest to study the charge asymmetry produced when one of the kaons (or both) in the $K^0\bar{K}^0$ system produced in the reaction (1) decays in the channel $K_{\ell 3}(\pi^{\pm}\ell^{\mp}\nu$, $\ell = \mu$ or e). We present here an analysis of this question.

Since the initial state is an eigenstate of the CP operator, observation of charge asymmetry is a direct confirmation of CP violation, without using any other additional assumptions.

Let us consider the decay of a system in the state $f(t_1) \equiv f_1 = \pi\ell\nu$, $f(t_2) \equiv f_2 = \pi^+\pi^-$. If the rule $\Delta Q = \Delta S$, which is valid within the accuracy limits of modern experiments, is satisfied, then the amplitude of the transition to the state $f_1 = \pi^-\ell^+\nu$, $f_2 = \pi^+\pi^-$ is

$$< f_1 f_2 | T | \psi_a > = \frac{1}{2} A^{\ell^+} A_S^{\pi^+\pi^-} e^{-im_L(t_1+t_2)} (1+\epsilon)[g_{21} - \eta_{+-} g_{12}], \qquad (3)$$

where

$$A_S^{fi} = < f_i | T | S(i) >, \qquad A^{\ell^+} = < \pi^- \ell^+ \nu | T | K > ;$$

$$g_{12} \equiv g(t_1, t_2) = e^{i\Delta m t_1 - \frac{\Gamma_S t_1}{2} - \frac{\Gamma_L t_2}{2}}, \quad g_{21} = g(t_2, t_1); \qquad (4)$$

$$\eta_{+-} = A_L^{\pi^+\pi^-} / A_S^{\pi^+\pi^-} = |\eta_{+-}| e^{i\phi_{+-}}, \quad \epsilon = A_L^{(2\pi,\, I=0)} / A_S^{(2\pi,\, I=0)}$$

Γ_S, m_S (Γ_L, m_L) are the width and mass of the $K_S^0(K_L^0)$ meson, and $\Delta m = m_L - m_S = (0.466 \pm 0.003)\Gamma_S$. The amplitude of the transition to the state $f_1 = \pi^+\ell^-\nu$, $f_2 = \pi^+\pi^-$ is

$$< f_1 f_2 | T | \psi_a > = -\frac{1}{2} A^{\ell^-} A_S^{\pi^+\pi^-} e^{-im_L(t_1+t_2)} (1-\epsilon)[g_{21} + \eta_{+-} g_{12}]. \qquad (5)$$

Accurate to terms quadratic in the small parameters, the charge asymmetry δ is given by

$$\delta = \frac{N^+ - N^-}{N^+ + N^-} =$$

$$= \frac{2\left[\mathrm{Re}\,\epsilon - |\eta_{+-}|\, e^{(\Gamma_S - \Gamma_L)\left(\frac{t_2 - t_1}{2}\right)} \cos[\Delta m(t_2 - t_1) - \phi_{+-}]\right]}{1 + |\epsilon|^2 + |\eta_{+-}|^2 e^{(\Gamma_S - \Gamma_L)(t_2 - t_1)} - 4\,\mathrm{Re}\,\epsilon\,|\eta_{+-}|\, e^{(\Gamma_S - \Gamma_L)\left(\frac{t_2 - t_1}{2}\right)} \cos[\Delta m(t_2 - t_1) - \phi_{+-}]}, \qquad (6)$$

where $N^{\pm}$ is the number of events with $e^{\pm}$ production.

This result differs significantly from the form of the charge asymmetry in the case of K_L^0 decay.

1. The charge asymmetry depends not only on Re ε, but also on $|\eta_{+-}|$ and ϕ_{+-}, and is a function of the points t_1 and t_2.

2. The quantity δ oscillates as a function of the times t_1 and t_2 (of the distances between the decay points $\ell_{1,2} = v_K t_{1,2}$ and the production point).

3. If $(t_2 - t_1)\Gamma_S \gg 1$ so that $|\eta_{+-}|\exp[\Gamma_S(t_2 - t_1)/2] \sim 1$, the charge asymmetry takes on values on the order of unity (see the figure, in which δ is plotted as a function of $\tau = \Gamma_S(t_2 - t_1)/2$). The number of such events is small and amounts to $\sim|\eta_{+-}|^2\Gamma_L/\Gamma_S$ of the total number of decays (since the channels in question predominates). To fall into the region where $\delta \sim 1$ it is necessary to produce $\gtrsim 10^8$ $K^0\bar{K}^0$ pairs, and to fall in the region $\delta \sim 0.1$ one must have $\sim 10^6$ pairs. The period of the oscillations in the figure is ~ 3 (in kaon free paths), so that the experimental detection of a region with a given sign of δ is perfectly realistic.

If the $\Delta Q = \Delta S$ rule does not hold, then an additional factor $(1 - x^2)$ appears in the numerator of formula (6) ($x = A^{\ell}(\Delta Q = -\Delta S)/A^{\ell}(\Delta Q = \Delta S)$), and the denominator in (6) must be replaced by

$$\begin{aligned} &|1 - x|^2 - 4\,\mathrm{Im}\,x\,\mathrm{Im}\,\epsilon + |\epsilon|^2 |1 + x|^2 - 4|\eta_{+-}|\, e^{(\Gamma_S - \Gamma_L)\left(\frac{t_2 - t_1}{2}\right)} \times \\ &\times \{\mathrm{Re}\,\epsilon(1 + |x|^2)\cos[\Delta m(t_2 - t_1) - \phi_{+-}] - \\ &- (2\,\mathrm{Re}\,x\,\mathrm{Im}\,\epsilon - \mathrm{Im}\,x)\sin[\Delta m(t_2 - t_1) - \phi_{+-}]\} + \\ &+ |\eta_{+-}|^2 e^{(\Gamma_S - \Gamma_L)(t_2 - t_1)} |1 + x|^2 . \end{aligned} \qquad (7)$$

We note that if $|\eta_{+-}|\exp[\Gamma_S(t_2 - t_1)/2] \sim 1$ and $\Delta m(t_2 - t_1) - \phi_{+-} \simeq 3\pi/2$, the term in the curly brackets of (7) is sensitive to the value of Im x.

Let us discuss also the case when both kaons decay in the $\pi\ell\nu$ channel. If $f_1 = f_2 = \pi^{\mp}\ell^{\pm}\nu$, then the amplitude of the decay ($\Delta Q = \Delta S$) is

$$\langle f_1 f_2 | T | \psi_o \rangle = \pm \frac{(1 \pm \epsilon)^2}{2\sqrt{2}\,(1 + |\epsilon|^2)} (A^{\ell^{\pm}})^2 e^{-im_L(t_1 + t_2)} (g_{21} - g_{12}), \qquad (8)$$

and the amplitude of the decay in the state $f_1 = \pi^{\mp}\ell^{\pm}\nu$, $f_2 = \pi^{\pm}\ell^{\mp}\nu$ is

$$< f_1 f_2 | T | \psi_a > = \pm \frac{(1-\epsilon^2)}{2\sqrt{2}(1+|\epsilon|^2)} |A\ell|^2 e^{-im_L(t_1+t_2)}(g_{21}+g_{12}). \quad (9)$$

Violation of CP invariance leads here, too, to charge asymmetry, for example $(N^{++} - N^{--})/(N^{++} + N^{--}) \approx 4\mathrm{Re}\,\varepsilon$.

Thus, a study of charge asymmetry in decays of the $K^0\bar{K}^0$ system yields extremely important physical information, but calls for the production of a rather large number of $K^0\bar{K}^0$ pairs ($\gtrsim 10^6$).

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