VERIFICATION OF CPT-INVARIANCE IN EXPERIMENTS WITH K^0 MESONS

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Knowledge of the parameter ϕ_{00} is essential for a verification of CPT-invariance, but its measurement entails great experimental difficulties. We derive in this paper, on the basis of the unitarity condition for unstable particles a relation that holds in the case of CPT-invariance and does not contain the parameter ϕ_{00}.

The unitarity condition for a system of neutral K mesons is of the form [1]

$$-\,i(M_L^{*} - M_S)\,\langle K_L | K_S \rangle = \sum_F \langle F|T|K_L\rangle^{*}\,\langle F|T|K_S\rangle. \qquad (1)$$

It actually represents two equations for real quantities [2]

$$\mathrm{Im}\,\langle K_L | K_S \rangle = \frac{2}{4m^2 + \Gamma^2}\,(2m\,\mathrm{Re}\,\Sigma + \Gamma\,\mathrm{Im}\,\Sigma)\,, \qquad (2)$$

$$\mathrm{Re}\,\langle K_L | K_S \rangle = \frac{2}{4m^2 + \Gamma^2}\,(\Gamma\,\mathrm{Re}\,\Sigma - 2m\,\mathrm{Im}\,\Sigma)\,, \qquad (3)$$

where $m \equiv m_L - m_S$, $\Gamma = \Gamma_L + \Gamma_S$, and $\mathrm{im}\Sigma$ and $\mathrm{Re}\Sigma$ are the imaginary and real parts of the sum in Eq. (1).

Under CPT-invariance conditions, $\mathrm{Im}\,\langle K_L|K_S\rangle = 0$ and $\mathrm{Re}\,\langle K_L|K_S\rangle$ is connected with the charge asymmetry in the $K_L \to \pi^{\pm}\ell\,\nu(\nu)$ decays [3]

$$\mathrm{Re}\,\langle K_L | K_S \rangle = \delta_{\ell}\,\frac{|1 - x|^2}{1 - |x|^2} \qquad (4)$$

($x = 0$ if the rule $\Delta Q = \Delta S$ holds).

We confine ourselves in the sum over F to the channels of decay into 2π [4], and then the CPT-invariance requirements yields on the basis Of Eqs. (2) and (3) the following relation

$$[\,|\eta_{00}|\,W(K_S \to \pi^0\pi^0)\,]^2 =$$

$$[\,|\eta_{+-}|\,W(K_S \to \pi^+\pi^-)\,]^2 + \frac{4m^2 + \Gamma^2}{4}\,\langle K_L | K_S \rangle^2 -$$

$$-\,2m\,|\eta_{+-}|\,W(K_S \to \pi^+\pi^-)\left[\frac{\Gamma}{2m}\cos\phi_{+-} + \sin\phi_{+-}\right]\langle K_L | K_S \rangle.$$

Here η_{00} and η_{+-} are the CP-violation parameters in the channels $\pi^0\pi^0$ and $\pi^+\pi^-$, respectively, and $W(K_S \to \pi^0\pi^0)$ and $W(K_S \to \pi^+\pi^-)$ are the probabilities of these processes.

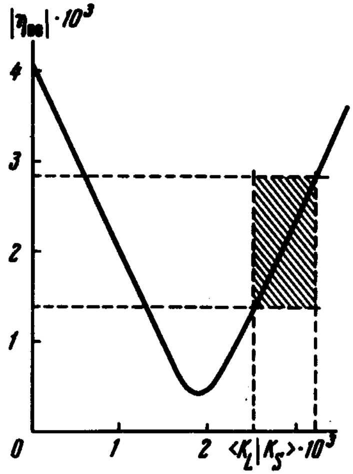
This relation is more convenient for the verification of CPT-invariance than the Wu and Yang triangle [3], since it does not call for knowledge of the phase ϕ_{00}. It therefore becomes most important to refine the experimental data on the parameters $|\eta_{00}|$, δ_{ℓ}, and x.

The figure shows a plot of $|\eta_{00}|$ against $\langle K_L|K_S\rangle$ for the mean value $\phi_{+-} = 43 \pm 8°$. Taking into account the experimental value $\langle K_L|K_S\rangle = (2.84 \pm 0.34) \times 10^{-3}$ [5], we can state that

$$1{,}4 \cdot 10^{-3} \leqslant |\eta_{00}| \leqslant 2{,}9 \cdot 10^{-3}.$$

Further experiments aimed at measuring x and δ_ℓ may narrow down the range of variation of $|\eta_{00}|$ allowed by CPT invariance, and conversely, a reliable measurement of $|\eta_{00}|$ can predict the value of $\langle K_L|K_S\rangle$.

If the intersection of the uncertainty regions of the experimental values of $|\eta_{00}|$ and $\langle K_L|K_S\rangle$ has no point in common with the plot of $|\eta_{00}| = f[\langle K_L|K_S\rangle]$ from Eq. (5), then this indicates violation of invariance to CPT transformation.



We note that the inaccuracies in the measurement of $|\eta_{00}| = (1.90 \pm 0.05) \times 10^{-3}$ are insignificant, and the errors in ϕ_{+-} cause practically no change in the value of $\frac{\Gamma}{rm}\cos\phi_{+-} + \sin\phi_{+-}$, and furthermore this quantity varies slowly in the range 37 - 47°; relation (5) will therefore be stable against further refinements of $|\eta_{+-}|$ and ϕ_{+-} (provided, of course, they do not lead to appreciable changes of these quantities).

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