

# Particle Physics Phenomenology II

FS 11, Series 7

Due date: 11.04.2011, 1 pm

## Exercise 1 $K^0$ system without CP violation

The  $K^0$  and  $\bar{K}^0$  are eigenstates of strangeness. They are transformed into each other by CP transformation and are therefore not eigenstates of CP.

$$K^0 \xleftrightarrow{CP} \bar{K}^0$$

Show that

$$|K_1^0\rangle = \frac{1}{\sqrt{2}} (|K^0\rangle + |\bar{K}^0\rangle) \quad (1)$$

$$|K_2^0\rangle = \frac{1}{\sqrt{2}} (|K^0\rangle - |\bar{K}^0\rangle) \quad (2)$$

are eigenstates of CP. We consider the  $K^0$  system without CP violation. These states are decay eigenstates. The  $K_1^0$  and  $K_2^0$  lifetimes are  $T_1$  and  $T_2$ . The time evolution of a state with energy  $E$  and lifetime  $T$  is given by

$$|\phi\rangle(t) = |\phi\rangle(0) \exp(-iEt - \frac{t}{2T})$$

and satisfies the Hamiltonian  $H = -\frac{i}{2}\Gamma$ . Calculate the intensity of  $K^0$  and  $\bar{K}^0$  (i.e.  $|\langle K^0|K^0(t)\rangle|^2$  and  $|\langle \bar{K}^0|K^0(t)\rangle|^2$ ) in a beam which consists of  $K^0$  only at  $t = 0$ .

## Exercise 2 $K^0$ system with CP violation

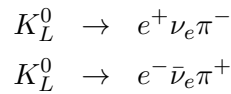
If we consider the  $K^0$  system with CP violation, the linear combinations  $K_1^0$  and  $K_2^0$  are not mass eigenstates anymore, but

$$|K_S^0\rangle = \frac{1}{\sqrt{1+|\epsilon|^2}} (|K_1^0\rangle + \epsilon|K_2^0\rangle) \quad (3)$$

$$|K_L^0\rangle = \frac{1}{\sqrt{1+|\epsilon|^2}} (|K_2^0\rangle + \epsilon|K_1^0\rangle) \quad (4)$$

are.

Consider the reactions



with rates  $R_+$  and  $R_-$ . Calculate the ratio

$$\delta = \frac{R_+ - R_-}{R_+ + R_-}.$$

Mind that the decays

$$\begin{aligned} A_+ & : & K^0 & \rightarrow e^+ \nu_e \pi^- \\ A_- & : & \bar{K}^0 & \rightarrow e^- \bar{\nu}_e \pi^+ \end{aligned}$$

are possible, with  $|A_+| = |A_-|$  for the corresponding amplitudes whereas the decays

$$\begin{aligned} K^0 & \rightarrow e^- \bar{\nu}_e \pi^+ \\ \bar{K}^0 & \rightarrow e^+ \nu_e \pi^- \end{aligned}$$

are forbidden.