Question 13.7: The neutral K-meson system

We consider the following neutral K-meson decays:

$$K^0 \to \pi\pi, \qquad K^0 \to \pi\pi\pi, \tag{13.124}$$

where we keep the electric charges of the pions implicit. We assume that the isospin and CP symmetries are respected, which turn out to be very good approximations.

1. Explain why, in the CP limit, the two eigenstates, K_S and K_L, must also be CP eigenstates.

2. Explain why the CP-odd state cannot decay into two pions.

3. Examining the data, which of the two states, K_S or K_L, can be identified as the CP even state?

4. Taking into account the experimental values of m_π and m_K, explain why we should expect

$$\Gamma(K^0 \to \pi\pi) \gg \Gamma(K^0 \to \pi\pi\pi). \tag{13.125}$$

5. The $K^0 \to \pi\pi$ is the dominant decay mode of K^0. Check it explicitly by examining $\mathrm{BR}(K_S \to \pi\pi)$. Explain why this fact together with Eq. (13.125) imply that $\Gamma_S \gg \Gamma_L$.

6. Experimentally $y_K \approx 1$. How would the value of y_K change if the kaon were slightly heavier (with the pion mass unchanged)?

   Hint: $y_K = (\Gamma_S - \Gamma_L)/(\Gamma_S + \Gamma_L)$.