Brief Reports

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Consequences of a possible new light pseudoscalar particle

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The coupling to u and d quarks of a possible new light pseudoscalar particle observed in heavy-ion collisions is estimated to be of the order 10^{-3} from rare π and K decays.

Recently, it has been pointed out[1,2] that a stationary sharp peak in the positron emission spectrum from heavy-ion collisions[3] may be identifiable with a new light pseudoscalar particle a with a mass of about 1.68 MeV. Its coupling g_e to electrons is conjectured to be of the order 10^{-4}, which is just below the limit excluded by the anomalous magnetic moment of the electron. If so, then the rare decay $\pi^0 \to e^+e^-$ may be used to deduce the coupling of a to u and d quarks. The experimental[4] branching fraction for $\pi^0 \to e^+e^-$ is $(1.8 \pm 0.6) \times 10^{-7}$, whereas theoretical calculations[5] based on $\pi^0 \to \gamma\gamma \to e^+e^-$ account for only 0.6×10^{-7}. Hence, there is room for the process $\pi^0 \to a \to e^+e^-$, and a straightforward calculation shows that

$$|g_e(g_u - g_d)| = (4.3^{+1.3}_{-1.7}) \times 10^{-7} , \quad (1)$$

where constructive interference with the $\gamma\gamma$ dispersive amplitude has been assumed.

If g_u and g_d are indeed of the order 10^{-3}, then the process $K^+ \to \pi^+ a$ may be observable. Experimentally, the upper bound[6] of 3.8×10^{-8} on this branching fraction applies only if a is stable within the apparatus, which is not the case here. Also, the measured[7] branching fraction of $(2.6 \pm 0.5) \times 10^{-7}$ for $K^+ \to \pi^+ e^+ e^-$ comes from using only e^+e^- pairs with an invariant mass greater than 140 MeV. Hence, a branching fraction of 10^{-7} for $K^+ \to \pi^+ a$ is quite possible, and if so,

$$A = m_K \left[\left(\frac{g_s}{m_s} + \frac{g_u}{m_u} \right) + \frac{m_\pi^2}{m_K^2} \left(\frac{g_u}{m_u} + \frac{g_d}{m_d} \right) \right] \simeq 1.3 \times 10^{-3} , \quad (2)$$

where the $K^+ \to \pi^+ a$ decay rate has been taken to be given by

$$\Gamma = \frac{G_F^2 \sin^2\theta_C \cos^2\theta_C}{128\pi} \left(1 - \frac{m_\pi^2}{m_K^2} \right) f_\pi^2 f_K^2 m_K A^2 . \quad (3)$$

Comparing Eqs. (1) and (2), and recognizing that Eq. (3) is only approximate, it is clear that for $g_e = 10^{-4}$, g_u and g_d could well be of the order 10^{-3}. Of course, if the coupling of a to quarks is isoscalar, i.e., $g_u = g_d$, it will not contribute to $\pi^0 \to e^+e^-$, and only $K^+ \to \pi^+ a$ serves as a useful constraint.

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