Two-photon width of the δ meson

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The true radiative width of the δ meson is found to be $\Gamma_{\delta\gamma\gamma} \approx 1$ keV. The reason for the very high experimental value of $\Gamma_{\delta\gamma\gamma}$ found in the literature is explained.

The preliminary value of the two-photon decay width of the scalar resonance $\delta(980)$, calculated from the data on the reaction $e^+e^- \to e^+e^-\eta\pi^0$, is[1]

$$\Gamma_{\delta\gamma\gamma} BR(\delta \to \eta\pi^0) = 0.100 \pm 0.025 \pm 0.100 \text{ keV}. \tag{1}$$

Since estimates in the literature show that $\Gamma_{\delta\gamma\gamma} \approx 5$ keV (Refs. 2 and 3) if the δ meson is a $\bar{q}q$ bound system and $\Gamma_{\delta\gamma\gamma} \approx 0.27$ keV (Ref. 3) if the δ meson corresponds to the $\bar{q}^2q^2$ configuration, result (1) gave rise to treating the δ resonance as though it were a four-quark system.[4] Such a conclusion is not fully justifiable for the reasons given below. First, we note that a quantitative calculation of the $\bar{q}q$ scheme with the help of an effective chiral Lagrangian does in fact yield[5]

$$\Gamma_{\delta\gamma\gamma}(m_\delta) = \frac{m_\delta}{\pi}\left(\frac{\alpha\, m_\delta}{12\pi F_\pi}\right)^2 \approx 1.3 \text{ keV}. \tag{2}$$

As for the estimate $\Gamma_{\delta\gamma\gamma} \approx 0.27$ keV in the $\bar{q}^2q^2$ scheme, we note that it was obtained without calculating specific diagrams of any sort and can easily be raised to 1–2 keV. This can be seen by estimating $\Gamma_{\delta\gamma\gamma}$ by means of the diagrams in Fig. 1, for example. In the $m_\delta = 2m_K$ approximation, we would then have

$$\Gamma^{(K\bar{K})}_{\delta\gamma\gamma} = \frac{\alpha^2(\pi^2/4-1)^2}{16\pi^2 m_\delta}\,\frac{g^2_{\delta K\bar{K}}}{4\pi} \tag{3}$$

and using $g^2_{\delta K\bar{K}}/4\pi = 2.3$ GeV^2 or 3 GeV^2 in the $\bar{q}^2q^2$ scheme,[8] we find $\Gamma^{(K\bar{K})}_{\delta\gamma\gamma} = 1.7$ keV or 2.2 keV, respectively.

The diagrams in Fig. 1 yield $\Gamma^{(K\bar{K})}_{\delta\gamma\gamma} = 0.61$ keV in the $\bar{q}q$ scheme, since the chiral theory predicts[6,7] $g^2_{\delta K\bar{K}}/(4\pi) = 0.82$ GeV^2.

The amplitude cannot be accurately determined by calculating the loop diagram with a single intermediate physical state. Such a calculation indicates only the scale of its actual values. In the case of the $\bar{q}^2q^2$ scheme, this scale is the same as the scale of the $\bar{q}q$ scheme, so that result (1) appears to be too small.

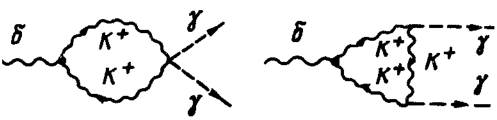

FIG. 1.

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We note, however, that this result was obtained from the data on the reaction $e^+e^- \to e^+e^-\eta\pi^0$ by assuming that the δ resonance is narrow[9]: $\Gamma_\delta = 54$ MeV. On the other hand, the true value of Γ_δ is approximately six times larger in both the $\bar{q}q$ and the $\bar{q}^2q^2$ scheme.[6-8] This result is found to be consistent (see Refs. 6–8 and 10) with the narrow peak in the reaction $K^-d \to \Sigma^+(1385)\eta\pi^-$.

Analysis of the experimental data[1] with use of the equations corresponding to a broad δ resonance (see Refs. 7, 8, and 10)

$$\sigma_{\gamma\gamma\to\eta\pi}(W) = 8\pi\,\Gamma_{\delta\gamma\gamma}(W)\,\Gamma_{\delta\eta\pi}(W)\,|W^2 - m_\delta^2 + i m_\delta \Gamma_\delta(W)|^{-2}, \qquad (4)$$

where

$$\Gamma_\delta \cong \Gamma_{\delta\eta\pi^0} + \Gamma_{\delta K\bar{K}}$$

and

$$\Gamma_{\delta\eta\pi^0}(W) = \frac{g^2_{\delta\eta\pi^0}}{16\pi W}\left[1 - \frac{2(m_\eta^2 + m_\pi^2)}{W^2} + \frac{(m_\eta^2 - m_\pi^2)^2}{W^4}\right]^{1/2},$$

$$\Gamma_{\delta\gamma\gamma}(W) = (W/m_\delta)^3\,\Gamma_{\delta\gamma\gamma}(W),$$

$$\Gamma_{\delta K\bar{K}}(W) = \frac{g^2_{\delta K\bar{K}}}{16\pi W}\begin{cases}\sqrt{1 - 4m_K^2/W^2}, & W \geqslant 2m_K\\ i\sqrt{4m_K^2/W^2 - 1}\left(1 - \dfrac{2}{\pi}\arctan\sqrt{4m_K^2/W^2 - 1}\right), & W \leqslant 2m_K\end{cases} \qquad (5)$$

shows that $\Gamma_{\delta\gamma\gamma}$ is substantially larger. This is evident from the analysis of the curve in Fig. 2, where the data of Ref. 1 and the theoretical curve corresponding to the contribution from the δ and A_2 resonances are shown. The contribution from the δ resonance was calculated from Eqs. (4) and (5) with the constants $g_{\delta\eta\pi^0} = -4.8$ GeV, $-g_{\delta K^0\bar{K}^0} = g_{\delta K^+K^-} = -3.2$ GeV (Ref. 7), and $\Gamma_{\delta\gamma\gamma} = 0.5$ keV. The contribution

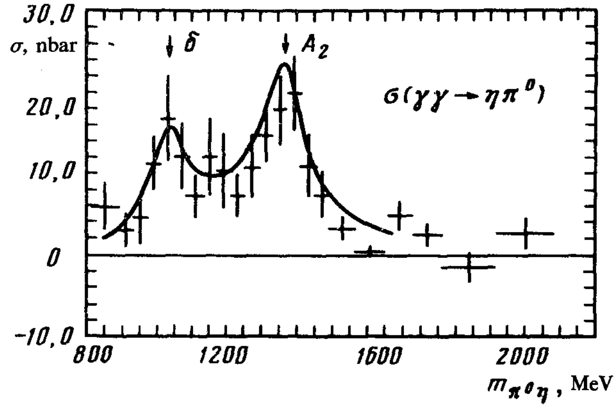

FIG. 2

from the A_2 resonance was described by the equation for a narrow resonance with the parameters taken from Ref. 9 and with $\Gamma_{A_2\gamma\gamma} = 0.6$ keV. We have used a value for $\Gamma_{A_2\gamma\gamma}$ slightly smaller than the universal average because some of the events occurring at the A_2 resonance had to be linked with the events corresponding to the right wing of the broad δ resonance.

Figure 2 shows that $\Gamma_{\delta\gamma\gamma}(m_\delta)$ may be roughly five times larger than the value obtained in Ref. 1. If we take into account, however, that the systematic error in determining the width at the δ resonance is estimated to be 100%, it is conceivable that the photon width is even greater, reaching $\Gamma_{\delta\gamma\gamma} \approx 1$ keV, as predicted by the $\bar{q}q$ scheme. Improving the accuracy of the data and the analysis of these data with the help of Eqs. (4) and (5) will make it possible to determine more accurately the true two-photon width of the δ meson.

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