The decays $A_1 \to \pi\gamma$ and $B \to \pi\gamma$

G. V. Efimov, V. A. Kuz'min, and M. M. Solomonovich
Joint Institute for Nuclear Research

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The widths for the decay of the $A_1(1240)$ and $B(1235)$ mesons to $\pi + \gamma$ are calculated in a nonlocal quark model.

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In all the experiments which have been carried out to date, the position, the width, and the very existence of the $A_1(J^{pc} = 1^{++})$ meson have been determined through an analysis of a three-pion system,[1] in which unavoidable difficulties are caused by the "Deck effect."[2] There is accordingly much interest in observing the decay of the A_1 meson in the $\pi\gamma$ mode, where the resonant component could be distinguished more easily from the background. Experiments are already being planned to measure the $A_1 \to \pi\gamma$ decay widths in diffraction proccesses on the Serpukhov accelerator.

In this letter we calculate the widths of the decays $A_1(1^{++}) \to \pi\gamma$ and $B(1^{+-}) \to \pi\gamma$ from a nonlocal quark model.[3]

We write the Lagrangians for the interaction of the quarks with axial-vector mesons in the form[4]

$$\mathcal{L}_I^A(x) = \frac{g_A}{\sqrt{2}} A_\mu^a(x)(\bar{q}(x)\gamma^\mu\gamma^5\lambda_a q(x)),$$

$$\mathcal{L}_I^B(x) = \frac{g_B}{\sqrt{2}} B_\mu^b(x)(\bar{q}(x)\partial^\mu\gamma^5\lambda_b q(x)),$$

where A_μ and B_μ are the meson field operators, and $\lambda_{a(b)}$ are the Gell-Mann matrices. The meson-quark coupling constants were determined in Ref. 4:

$$h_A = \frac{g_A^2}{16\pi^2} = 0.38; \qquad h_B = \frac{g_B^2}{16\pi^2}\left(\frac{2}{L}\right)^2 = 0.34.$$

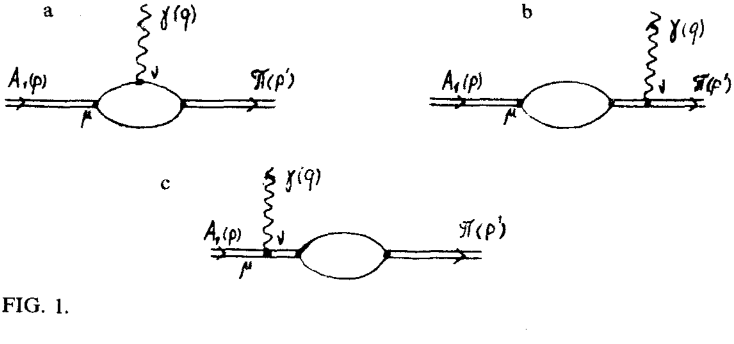

FIG. 1.

The Lagrangians for the interaction of mesons and quarks with the electromagnetic field are chosen in the standard way.[3,5]

The decay $A_1(B) \to \pi\gamma$ is determined by the diagrams in Fig. 1.

The amplitude is written

$$M(A_1 \to \pi\gamma) = 48 i \pi^{3/2} \sqrt{\alpha h_A h_\pi}\, e^\mu(p) e^\nu(q) (M^{a}_{\mu\nu} + M^{b}_{\mu\nu} + M^{c}_{\mu\nu}). \tag{2}$$

Here $e_\mu(p)$ and $e_\mu(q)$ are the meson and photon polarization vectors, $h_\pi = 0.13$ (Ref. 3),

$$M^{\hat{a}}_{\mu\nu} = -\lim_{\delta \to 0} \sum_j (-1)^j A_j \frac{1}{(2\pi)^4 i} \int dk\, \mathrm{Sp}\left\{ S_j(\hat{k}) \gamma_\nu S_j(\hat{k} + \hat{q}) \gamma_5 G(\hat{k} + \hat{p}) \gamma_\mu \gamma_5 \right\}$$

$$= g_{\mu\nu} \frac{2}{\pi^2 L} R_A,$$

$$M^{b}_{\mu\nu} = (p_\nu + p'_\nu) \frac{1}{m_\pi^2 - p^2} \Sigma_\mu(p),$$

and

$$M^{c}_{\mu\nu} = [-(p+p')_\nu g_{\mu\alpha} + p'_\mu g_{\nu\alpha} + p_\alpha g_{\mu\nu}] \frac{-g^{\alpha\beta} + p'^\alpha p'^\beta / M^2_{A_1}}{M^2_{A_1} - p'^2} \Sigma_\beta(p'),$$

where

$$\Sigma_\mu(p) = \frac{1}{(2\pi)^4 i} \int dk\, \mathrm{Sp}\, \{\gamma_\mu \gamma_5 G(\hat{k}) \gamma_5 G(\hat{k} + \hat{p})\} = p_\mu \frac{2}{\pi^2 L} R_A .$$

Standard calculations for the nonlocal quark model[3] yield

$$R_A = \int_0^\infty du\, u^2 A' B \,|_{\xi = 1.4} = 0.15.$$

We finally find

$$M(A_1 \to \pi\gamma) = ie[g_{\mu\nu}(pq) - p_\nu q_\mu] e^\mu(p) e^\nu(q) \frac{G_{A\pi\gamma}}{M^2_{A_1}} , \tag{1}$$

where

$$G_{A\pi\gamma} = 96 \sqrt{h_A h_P} \frac{1}{L} R_A.$$

The amplitude for the decay $B \to \pi\gamma$ is given by an expression similar to (1) with

$$G_{B\pi\gamma} = 96 \sqrt{h_B h_P} \frac{1}{L} R_B ,$$

$$R_B = \frac{1}{2} \int_0^\infty du\, u^2 (AA' + BB'u + \frac{1}{2} B^2) = 0.12.$$

The decay widths are calculated from the standard expression[6]

$$\Gamma(A_1(B) \to \pi\gamma) = \frac{1}{48\pi M^3_{A_1(B)}} (M^2_{A_1(B)} - m^2_\pi) \sum_{\text{tot}} |M(A_1(B) \to \pi\gamma|^2$$

$$= \frac{\alpha}{24 M_{A_1(B)}} \left(1 - \frac{m^2_\pi}{M^2_{A_1(B)}}\right)^3 G^2_{A(B)\pi\gamma} .$$

Using the values

$M_{A_1} = 1240$ MeV (Ref. 7) and $M_B = 1235$ MeV (Ref. 1),

we find

$\Gamma(A_1 \to \pi\gamma) = 250$ keV and $\Gamma(B \to \pi\gamma) = 160$ keV.

These results agree with the only piece of experimental evidence currently available,[8] which is unfortunately, extremely inaccurate.

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