# VECTOR MESON COUPLINGS AND THE OBSERVABILITY OF THE $K^* \to K\pi\pi$ DECAYS*

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The $K^* \to K\pi\pi$ rate is calculated using vector meson pole dominance in several recent coupling-constant models. Including the effects of the contact interaction, the various models give results ranging from 8 to 86 keV for the decay rate. Taking the $\omega \to 3\pi$ and $\phi \to 3\pi$ decays into account, we believe the result of 50 keV to be a more reliable upper bound. This is significantly higher than older estimates and within the realm of experimental measurement.

The vector meson dominance model has been used in the past in several calculations [1–4] of the $K^{*o} \to K\pi\pi$ rate with estimates ranging from a low of 1.2 keV [1] to a high of 34 keV [3]. The low result of ref. [1] is unreliable because it includes only the $\rho$-pole contribution and ignores the more important $K^*$-pole term. Those calculations which do include the $K^*$-pole term have suffered from the lack of a reliable value for the associated coupling constant $g_{K^*K^*\pi}$. Estimates of this coupling constant have varied depending on the model used; for example, the algebra of charges together with single particle saturation of the sum rules [3] yields a value of this coupling constant which is considerably larger than the value obtained from some higher symmetry arguments [2,4]. In view of recent developments in the analysis of meson decays, we have re-examined the calculation of this decay rate using several models and find that the $K^{*o} \to K\pi\pi$ rate may be higher than previously estimated and within the realm of experimental measurement.

In this note, we focus our attention on the decays $K^{*o} \to K^o\pi^+\pi^-$ and $K^{*o} \to K^+\pi^-\pi^o$. We parameterize the vector-vector-pseudoscalar (VVP) and vector-pseudoscalar-pseudoscalar (VPP) vertices through the Lagrangians

$$\mathcal{L}_{VVP} = \tfrac{1}{2}\, g_{VVP} d_{abc} \epsilon_{\mu\nu\rho\sigma} \partial^\mu V_a^\nu \partial^\rho V_b^\sigma P_c, \qquad (1)$$

and

$$\mathcal{L}_{VPP} = g_{VPP} f_{abc} P_b \partial_\mu P_c V_a^\mu, \qquad (2)$$

where a, b and c are internal symmetry labels. Using the vector meson poles one then finds that the $T$-matrix for $K^{*o} \to K^o\pi^+\pi^-$ is given by

$$T(K^{*o} \to K^o\pi^+\pi^-) = -g_{VVP} g_{VPP} \epsilon^\mu k^\nu k_-^\rho k_+^\sigma \times \left\{ \frac{1}{S_{+-} - m_\rho^2} + \frac{1}{S_{o+} - m_{K^*}^2} \right\}, \qquad (3)$$

where the 4-momenta $k$, $k_-$, $k_+$ and $k_o$ refer to $K^{*o}$, $\pi^-$, $\pi^+$ and $K^o$ respectively, and $\epsilon^\mu$ is the $K^{*o}$ polarization vector; $S_{+-} = (k_+ + k_-)^2$ and $S_{o+} = (k_o + k_+)^2$. We use $g_{VPP}^2/4\pi = 2.90$ derived from the currently accepted $\rho \to \pi\pi$ rate [5]. The value of $g_{VVP}$ is calculated in three different models:

(A) The strong-anomaly approach [6] allows one to obtain $g_{VVP}$ through the SU(3) invariant relation

$$g_{VVP} = -(3 g_{VPP}^2 / 8\pi^2 F_\pi), \qquad (4)$$

where the pion decay constant is normalized so that $F_\pi = 94$ MeV. Eq. (4) then yields

$$\frac{g_{VVP}^2}{4\pi} = 17.27 \text{ GeV}^{-2}. \qquad (5)$$

(B) A baryon loop model [7] can be used to calculate the effective VVP coupling constant, with the result that

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Table 1
Total decay widths for $K^{*0} \to K\pi\pi$ predicted by models A, B and C. We note that $\Gamma(K^{*0} \to K^+\pi^-\pi^0) \simeq 2\Gamma(K^{*0} \to K^0\pi^+\pi^-)$ and that $\Gamma(K^{*0} \to K^0\pi^0\pi^0)$ is at most 30 eV.

| Model | Pole terms (keV) | Pole + contact terms (keV) |
|---|---|---|
| A | 40.2 | 49.9 |
| B | 21.2 | 85.7 |
| C | 8.2 | 10.7 |

$$g_{VVP} = -(g/\pi^2 m)[d(3\phi^2 - \delta^2) + 6f\delta\phi]. \tag{6}$$

Here, $d$ and $f$ are the $d$- and $f$-type fractional couplings ($d + f = 1$) of the pseudoscalar meson to the octet and $\delta$ and $\phi$ are the corresponding $d$- and $f$-type couplings of the vector meson to the baryons. The quantity $m$ is the average baryon mass in the loop, which we take to be 1 GeV. Using $g^2/4\pi = 14.6$, $d/f = 1.8$, $\delta/\phi = -0.5$ and $\phi = 3.35$ from [7], we get

$$g^2_{VVP}/4\pi = 9.11\ \mathrm{GeV}^{-2}. \tag{7}$$

(C) A model for SU(3) breaking, the ABCD model of ref. [8], has been used to fit the radiative decays of the vector mesons (decays of the kind $V \to P\gamma$). One can extract the effective VVP vertex by amputating the photon via vector meson dominance. In this approach, the best fit to the radiative decay rates yields.

$$\frac{g^2_{VVP}}{4\pi} = 9.35\ \mathrm{GeV}^{-2}. \tag{8}$$

However, since this model contains SU(3) symmetry breaking, the unit residue of the $\rho$ pole in eq. (3) changes to 1.466, while that of the $K^*$ pole changes to 0.068. The results for models A, B and C (pole terms only) are given in table 1.

The contact term can be calculated but in a model-dependent way. We define the $g_{VPPP}$ coupling constant via

$$\mathcal{L}_c = g_{VPPP}\epsilon_{\mu\nu\sigma\tau}P_i d_{ijk}\partial^\mu \phi^\nu_j f_{krs}\partial^\sigma P_r \partial^\tau P_s. \tag{9}$$

In the case of model A one uses the result of Wess and Zumino [9] based on a nonlinear realization of SU(3) ⊗ SU(3) to obtain

$$\frac{g_{VPPP}}{g_{VPP}g_{VVP}} = 0.302\ \mathrm{GeV}^{-2}, \tag{10}$$

where we have also assumed that the pseudoscalar mesons are to be included in the vector field-current identity. In the baryon loop model (B) [7] one finds

$$\frac{g_{VPPP}}{g_{VPP}g_{VVP}} = 2.67\ \mathrm{GeV}^{-2}. \tag{11}$$

As far as model (C) is concerned we use a naive generalization of eq. (10). The results are presented in column 3 of table 1. Note the substantial increase of the rate in model B, from 21 to 86 keV.

One can test the magnitude of the contact term by calculating the $3\pi$ decay rates of the $\omega$ meson. For models A and C we find the $\omega \to 3\pi$ rates are 8.6 MeV and 9.2 MeV, in good agreement with experiment (9.0 MeV) [5]. In these cases, the pole terms dominate. For model B, the rate is predicted to be 14.6 MeV, due mainly to the very large contact term. This result, and the fact that $\phi \to 3\pi$ is dominated by $\phi \to \rho\pi$ [11], indicates that the contact term of model B may be an overestimate.

Thus, we conclude that the $K^* \to K\pi\pi$ rate could be as large as 50 keV. An accurate experimental determination of the rate or even a lowering of the present upper bound of 100 keV [10] would be invaluable in testing the validity of the various theoretical models we have discussed here. If it is found that the rate is in the 10 keV region, then there must be large SU(3) symmetry breaking, as indicated by the analysis of the $K^* \to K\gamma$ rate [5] given by model C [8].

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