

LETTER TO THE EDITOR

A NOTE ON THE $\tau \rightarrow K_0^*(1430) \nu_\tau$ DECAY RATE

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The decay rate for $\tau \rightarrow K_0^*(1430) \nu_\tau$ is calculated in the standard electroweak theory. The $K_0^*(1430)$ is described through the excited $q\bar{q}$ state of the MIT bag model. The branching ratio $B(\tau \rightarrow K_0^*(1430) \nu_\tau)$ is found to be rather small ($\approx 10^{-6}$) and not feasible to experimental determination.

The τ lepton is massive enough to have hadronic decay channels. These hadronic decays involve decays into nonstrange and strange mesons. The τ lepton decays are very interesting to study with the present experimental precision. The long discussion about »missing« one-prong τ decay events is resolved and there is a hope to have rather precise experimental data.

The investigation of $K\pi$ final hadronic state is particularly important as one-prong event, although it may contribute to the background of three-prong events, when $K^0 \rightarrow \pi\pi$ is near to the vertex. The $K_0^*(1430)$ is only one of possible intermediate states which can contribute to $K\pi$ final state. We find it is important to investigate all possible decay widths in order to know their significance to total decay width. The determination of $\tau \rightarrow K_0^*(1430) \nu_\tau$ decay width is interesting to know not only by itself, but also as an intermediate state for $\tau \rightarrow K\pi\nu_\tau$.

Some time ago the investigation of $\tau \rightarrow a_0(980) \nu_\tau$ was important to test the $\tau \rightarrow \eta\pi\nu$ decay width. The structure of $J^P = 0^+$ still has not been resolved at the τ decays into these states might help to know if they are four quark states of the form $q\bar{q}q\bar{q}$.

In this note we calculate the $\tau \rightarrow K_0^*(1430) \nu_\tau$ decay width motivated by complete study of τ lepton decays into scalar meson states as well as a possible information on $K_0^*(1430)$ structure.

The amplitude for $\tau \rightarrow K_0^*(1430) \nu_\tau$ is given by

$$M = \frac{G}{\sqrt{2}} V_{12} l^\mu \langle K_0^*(1430) | V_\mu - A_\mu | 0 \rangle \quad (1)$$

where $\frac{G}{\sqrt{2}} = \frac{g^2}{8M_w^2}$ is the Fermi constant, V_{12} is the Kobayashi-Maskawa matrix element, $l^\mu = \bar{\nu} \gamma^\mu (1 - \gamma^5) \nu$ is the lepton current and $V_\mu - A_\mu = \bar{s} \gamma_\mu (1 - \gamma^5) u$ is the hadronic current. Only the vector current V_μ can contribute and we define its matrix element

$$\langle K_0^*(1430) | V_\mu | 0 \rangle = F_{K_0^*} p_\mu. \quad (2)$$

Taking the divergence of (2) we obtain

$$F_{K_0^*} = (m_s - m_d) M_{K_0^*}^{-2} I \quad (3)$$

where

$$I = \langle K_0^*(1430) | \bar{s} d | 0 \rangle. \quad (4)$$

We approximate the $K_0^*(1430)$ state as $\bar{s}d$ excited state of the MIT bag model of the quark confinement. Namely, the $K_0^*(1430)$ wave function is taken as the product of two single quark wave functions. We allow quarks to be in the lowest $S_{1/2}$ and $P_{1/2}$ MIT bag states⁴⁾. The $P_{1/2}$ states in this approximation can only contribute to the matrix element of the vector current. The single quark wave functions of the bag model were calculated previously⁴⁾:

$$q_{l j m n}(r) = N_{jl}(x_{jln}) \left[\begin{matrix} i W^+(jln) j_l(x_{jln} r/R) \Phi_{jlm}(\hat{r}) \\ (\bar{l} - l) W^-(jln) j_l^-(x_{jln} r/R) \Phi_{j\bar{l}m}(\hat{r}) \end{matrix} \right] \quad (5)$$

where

$$W_\pm(jln) \equiv \left\{ \frac{\omega_{jln} \pm m_q}{\omega_{jln}} \right\}^{1/2}. \quad (6)$$

The normalization constant is given by

$$N_{jl}^{-2}(x) = \frac{R_l^3 j_l^2(x)}{\omega(x) [\omega(x) - m_q]} \times \\ \times (2\omega(x) \{ \omega(x) - (\bar{l} - l) [(j + 1/2)/R] \} + m_q/R). \quad (7)$$

The spin wave function of $K_0^*(1430)$ is determined as

$$|K_0^*\rangle = 1/\sqrt{2} (a_s^+(t) b_n^+(t) - b_n^+(t) a_s^+(t)) |0\rangle. \quad (8)$$

In order to perform the calculation using the MIT bag states normalized to unity we perform the transition from the covariantly normalized states to states normalized to unity using the prescription given in the Ref. 5:

$$|K_0^*(p)\rangle = [(2\pi)^3 2E \delta^3(O)]^{1/2} |K_0^*(T)\rangle \tag{9}$$

where $\langle K_0^*(T) | K_0^*(T') \rangle = \delta_{TT'}$.

We determine the integral I to be:

$$I^2 = \frac{16}{3} \pi M_{K_0^*} N_s^2 N_d^2 \int_0^R dr r^2 (W_d^- W_s^+ j_0^d j_1^s + W_s^- W_d^+ j_0^s j_1^d)^2. \tag{10}$$

In Table 1 we present numerical value for $F_{K_0^*}$ corresponding to the plausible range of the MIT bag meson radius and s and d quark masses fixed to standard properties of the lowest laying meson states. The $F_{K_0^*}$ is found to range from $3.9 \cdot 10^{-3}$ GeV to $8.6 \cdot 10^{-3}$ GeV. The partial decay width is given by

$$\Gamma(\tau \rightarrow K_0^*(1430) \nu_\tau) = \frac{G^2}{16\pi} V_{12}^2 F_{K_0^*}^2 m_\tau^2 \left(1 - \frac{M_{K_0^*}^2}{m_\tau^2}\right)^2 \tag{11}$$

what results in the following range for branching ratio

$$1.35 \times 10^{-6} < B(\tau \rightarrow K_0^*(1430) \nu_\tau) < 6.47 \times 10^{-6}. \tag{12}$$

This branching ratio does not depend drastically on the choice of the bag radius, as it was the case when the same radii were taken for $a_0(980)^2$. Although this decay is suppressed by V_{12}^2 this calculation can help to better know all possibilities in τ decay.

TABLE 1.

| $R(\text{GeV}^{-1})$ | $m_d = 0, m_s = 0.279 \text{ GeV}$ | | $m_d = 0.1 \text{ GeV}, m_s = 0.353 \text{ GeV}$ | |
|----------------------|------------------------------------|---------------------------------------|--|---------------------------------------|
| | $F_{K_0^*}(1430) (\text{GeV})$ | $Br(\tau \rightarrow K_0^* \nu_\tau)$ | $F_{K_0^*}(1430) (\text{GeV})$ | $Br(\tau \rightarrow K_0^* \nu_\tau)$ |
| 3 | 8.62×10^{-3} | 6.59×10^{-6} | 7.97×10^{-3} | 5.33×10^{-6} |
| 4 | 5.73×10^{-3} | 2.76×10^{-6} | 6.42×10^{-3} | 3.46×10^{-6} |
| 5 | 4.19×10^{-3} | 1.48×10^{-6} | 3.94×10^{-3} | 1.30×10^{-6} |

The structure constant $F_{K_0^*}(1430)$ and the branching ratio of $\tau \rightarrow K_0^*(1430) \nu_\tau$ are given for various R and m_d, m_s given in Ref. 3.

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KOMENTAR O OMJERU RASPADA $\tau \rightarrow K_0^*(1430) \nu_\tau$

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Originalni naučni rad

Omjer raspada $\tau \rightarrow K_0^*(1430) \nu_\tau$ proračunat je u standardnoj elektroslaboj teoriji. $K_0^*(1430)$ skalarni mezon opisan je kao pobuđeno stanje $q\bar{q}$ tipa uz upotrebu MIT bag modela. Omjer raspada $B(\tau \rightarrow K_0^*(1430) \nu_\tau)$ je veoma mali, te ga je eksperimentalno teško detektirati.