hep-ph/9712263[1]
TTP97-53

Theoretical Aspects of $\tau \to K\pi\pi\nu_\tau$ Decays

J.H. Kühn, E. Mirkes and J. Willibald

Institut für Theoretische Teilchenphysik, Universität Karlsruhe,
D-76128 Karlsruhe, Germany

Abstract. Predictions based on the chirally normalized vector meson dominance model for decay rates and distributions of τ decays into $K\pi\pi\nu_\tau$ final states are discussed. Disagreements with experimental results can be traced back to the K_1 widths.

Hadronic τ decays into final states with kaons can provide detailed information about low energy hadron physics in the strange sector. Predictions for final states with 2 and 3 meson final states [1, 2] based on the "chirally normalized vector meson dominance model" are in good agreement with recent experimental results [3]. Problems in the axial vector part in the $K\pi\pi$ final states are discussed in this contribution. We believe that these can be traced back to the K_1 widths.

The matrix element $\mathcal{M}$ for the hadronic τ decay into $K\pi\pi$ final states $\tau(l,s) \to \nu(l',s') + K(q_1,m_1) + \pi(q_2,m_\pi) + \pi(q_2,m_\pi)$ can be expressed in terms of a leptonic and a hadronic current as $\mathcal{M} = G/\sqrt{2}\sin\theta_c\, M_\mu J^\mu$ with $M_\mu = \bar{u}(l',s')\gamma_\mu(1-\gamma_5)u(l,s)$. The most general ansatz for the matrix element of the hadronic current $J^\mu(q_1,q_2,q_3)$ is characterized by four form factors F_i, which are in general functions of $s_1=(q_2+q_3)^2$, $s_2=(q_1+q_3)^2$, $s_3=(q_1+q_2)^2$ and Q^2 (chosen as an additional variable)

$$J^\mu = T^{\mu\nu}\left[(q_1-q_3)_\nu\, F_1 + (q_2-q_3)_\nu\, F_2\right] + i\,\epsilon^{\mu\alpha\beta\gamma} q_{1\,\alpha} q_{2\,\beta} q_{3\,\gamma}\, F_3 \qquad (1)$$

In Eq. (1) $T_{\mu\nu} = g_{\mu\nu} - (Q_\mu Q_\nu)/Q^2$ denotes a transverse projector. A possible pseudo-scalar form factor F_4 is neglected in Eq. (1). The form factors F_1 and $F_2(F_3)$ originate from the $J^P=1^+$ axial vector hadronic current ($J^P=1^-$ vector current) and correspond to a hadronic system in a spin one state.

The resulting choice for the form factors F_i for the $\pi^0\pi^0K^-$, $K^-\pi^-\pi^+$, $\pi^-\overline{K^0}\pi^0$ decay modes is summarized by [2]

$$F_{1,2}^{(abc)}(Q^2,s_2,s_3) \quad = \frac{2\sqrt{2}A^{(abc)}\sin\theta_c}{3f_\pi} G_{1,2}^{(abc)}(Q^2,s_2,s_3) \qquad (2)$$

$$F_3^{(abc)}(Q^2,s_1,s_2,s_3) = \frac{A_3^{(abc)}\sin\theta_c}{2\sqrt{2}\pi^2 f_\pi^3} G_3^{(abc)}(Q^2,s_1,s_2,s_3) \qquad (3)$$

where the Breit-Wigner amplitudes $G_{1,2,3}$ are listed in table. 1. The normalization factors are $A^{(\pi^0\pi^0K^-,K^-\pi^-\pi^+,\pi^-\overline{K^0}\pi^0)} = 1/4, -1/2, 3/(2\sqrt{2})$ and $A_3^{(\pi^0\pi^0K^-,K^-\pi^-\pi^+,\pi^-\overline{K^0}\pi^0)} = 1, 1, \sqrt{2}$. The form factors F_1 and F_2 are gov-

[1] Talk given by E. Mirkes at the International Europhysics Conference on High-Energy Physics (HEP 97), Jerusalem, Israel, 19-26 Aug 1997.

Table 1. Parametrization of the form factors F_1 F_2 and F_3 in Eqs. (2,3) for $K\pi\pi$ decay modes.

channel (abc)	$G_1^{(abc)}(Q^2,s_2,s_3)$	$G_2^{(abc)}(Q^2,s_1,s_3)$
$\pi^0\pi^0K^-$	$T_{K_1}^{(a)}(Q^2)T_{K^\star}^{(2m)}(s_2)$	$T_{K_1}^{(a)}(Q^2)T_{K^\star}^{(2m)}(s_1)$
$K^-\pi^-\pi^+$	$T_{K_1}^{(a)}(Q^2)T_{K^\star}^{(2m)}(s_2)$	$T_{K_1}^{(b)}(Q^2)T_{\rho}^{(1)}(s_1)$
$\pi^-\overline{K^0}\pi^0$	$\frac{2}{3}T_{K_1}^{(b)}(Q^2)T_{\rho}^{(2m)}(s_2)$ $+\frac{1}{3}T_{K_1}^{(a)}(Q^2)T_{K^\star}^{(2m)}(s_3)$	$\frac{1}{3}T_{K_1}^{(a)}(Q^2)\times$ $\left[T_{K^\star}^{(2m)}(s_1)-T_{K^\star}^{(2m)}(s_3)\right]$

	$G_3^{(abc)}(Q^2,s_1,s_2,s_3)$
$\pi^0\pi^0K^-$	$\frac{1}{4}T_{K^\star}^{(3m)}(Q^2)\left[T_{K^\star}^{(2m)}(s_1)-T_{K^\star}^{(2m)}(s_2)\right]$
$K^-\pi^-\pi^+$	$\frac{1}{2}T_{K^\star}^{(3m)}(Q^2)\left[T_{\rho}^{(2m)}(s_1)+T_{K^\star}^{(2m)}(s_2)\right]$
$\pi^-\overline{K^0}\pi^0$	$\frac{1}{4}T_{K^\star}^{(3m)}(Q^2)\left[2T_{\rho}^{(2m)}(s_2)+T_{K^\star}^{(2m)}(s_1)+T_{K^\star}^{(2m)}(s_3)\right]$

erned by the $J^P=1^+$ three particle resonances with strangeness

$$
\begin{aligned}
T_{K_1}^{(a)}(Q^2) &= \frac{1}{1+\xi}\left[\mathrm{BW}_{K_1(1400)}(Q^2)+\xi\mathrm{BW}_{K_1(1270)}(Q^2)\right] \\
T_{K_1}^{(b)}(Q^2) &= \mathrm{BW}_{K_1(1270)}(Q^2)
\end{aligned}
\tag{4}
$$

with $\xi=0.33$ [2]. Here, BW denote normalized Breit-Wigner propagators

$$
\mathrm{BW}_{K_1}[s]\equiv\frac{-m_{K_1}^2+im_{K_1}\Gamma_{K_1}}{[s-m_{K_1}^2+im_{K_1}\Gamma_{K_1}]}
\tag{5}
$$

with [4] (all numbers in GeV)

$$
\begin{array}{ll}
m_{K_1}(1400)=1.402 & \Gamma_{K_1}(1400)=0.174 \\
m_{K_1}(1270)=1.270 & \Gamma_{K_1}(1270)=0.090
\end{array}
\tag{6}
$$

The three meson vector resonance in the form factor F_3, denoted by $T_{K^\star}^{(3m)}$, and the two meson ρ and $K^\star$ resonances, denoted by $T_{\rho}^{(2m)}$ and $T_{K^\star}^{(2m)}$ in table 1, are discussed in detail in [2].

Our predictions for the branching ratios of the various $K\pi\pi$ final states based on the above parameterization are listed in the second column of table 2. The predictions are considerably larger than the world averages for the experimental results presented at the TAU96 conference (fourth column in

Table 2. Predictions for the branching ratios $\mathcal{B}(abc)$ in % for the $K\pi\pi$ decay modes. Results for K_1 parameters in Eq. (6) (second column, vector contribution in parentheses) and for $\Gamma_{K_1}(1400) = \Gamma_{K_1}(1270) = 0.250$ GeV (third column) are compared with the experimental world average (WA) as given at the TAU96 conference (fourth column).

channel (abc)	Γ_{K_1} [Eq. (6)]	$\Gamma_{K_1} = 0.250$GeV	WA (TAU96) [3]
$\pi^0\pi^0 K^-$	0.14 (0.012)	0.095	0.098 ± 0.021
$K^-\pi^-\pi^+$	0.77 (0.077)	0.45	0.228 ± 0.047
$\pi^-\overline{K^0}\pi^0$	0.96 (0.010)	0.53	0.399 ± 0.048

table 2). The predictions in the second column in table 2 are based on the particle data group values for the widths of the two K_1 resonances (see Eq. (6)). We believe that these numbers are considerably too small (see below). The strong sensitivity of the branching ratios to the K_1 width is demonstrated by the numbers in the third column of table 2, where predictions based on $\Gamma_{K_1} = 0.250$ GeV are shown. The results are now much closer to the measured values. Our direct fit to recently measured differential decay distributions for the $\tau \to K^-\pi^-\pi^+\nu_\tau$ decay mode by the ALEPH [5] and DELPHI [6] collaborations shown in Fig. 1 yields for the K_1 widths (numbers in GeV):

$$\begin{array}{lll} \Gamma_{K_1}(1270) = 0.37 \pm 0.1 & \Gamma_{K_1}(1400) = 0.63 \pm 0.12 & \text{ALEPH} \\ \Gamma_{K_1}(1270) = 0.19 \pm 0.07 & \Gamma_{K_1}(1400) = 0.31 \pm 0.08 & \text{DELPHI} \end{array} \tag{7}$$

with $\chi^2 = 38/30$ and $\chi^2 = 15.8/12$, respectively. The predicted two meson resonance structure based on these values is shown in Fig. 2 and is in good agreement with the experimental data.

References

[1] J.H. Kühn, A. Santamaria, Z. Phys. C48 (1990) 445.
[2] M. Finkemeier, E. Mirkes, Z. Phys. C69 (1996) 243.
[3] M. Finkemeier, J.H. Kühn and E. Mirkes, Proceedings of the Fourth Workshop on Tau Lepton Physics (TAU 96).
[4] Rev. of Particle Physics, Particle Data Group, Phys. Rev. D 54 (1996) 1.
[5] M. Daview, Proceedings of the Fourth Workshop on Tau Lepton Physics (TAU 96).
[6] DELPHI coll., W. Hao. et al., DELPHI 96-76 Conf. 8, ICHEP'96.

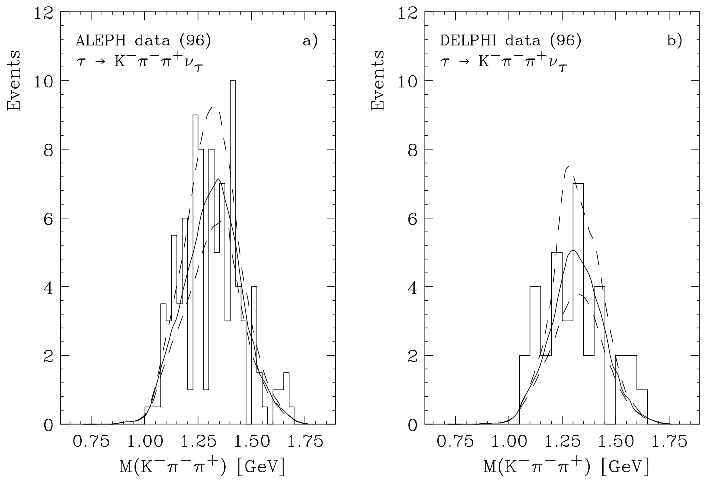

Fig. 1. Invariant mass $m(K^-\pi^-\pi^+)$ distributions for the $\tau \to K^-\pi^-\pi^+\nu_\tau$ decay mode. The histograms show recent data from (a) ALEPH [5] and (b) DELPHI [6]. The solid line shows the fit result to the K_1 widths parameters in Eq. (5) yielding the values in Eq. (7). The dashed lines represent the errors given in Eq. (7) for the K_1 widths. The experimental branching ratios are 0.23 $\pm$ 0.05 % (ALEPH) and 0.49 $\pm$ 0.08 % (DELPHI). The theoretical predictions for these branching ratios based on the values in Eq. (7) are in good agreement with these numbers.

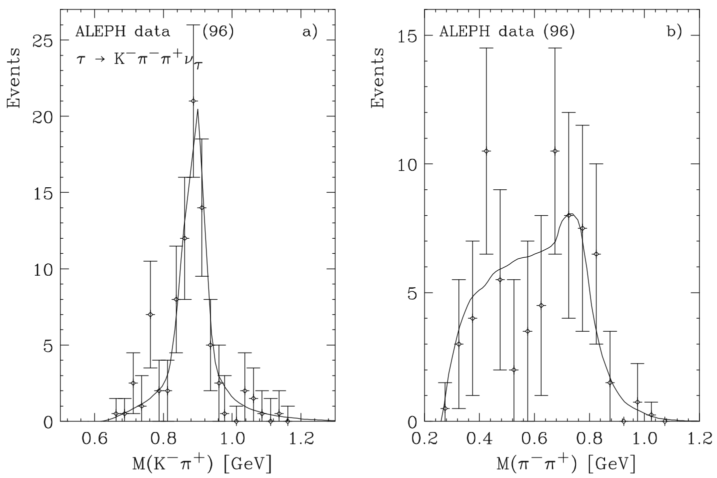

Fig. 2. $K^-\pi^+$ (a) and $\pi^+\pi^-$ (b) invariant mass distributions for the $\tau \to K^-\pi^-\pi^+\nu_\tau$ decay mode. Data are shown from ALEPH [5]. The solid line is the theoretical prediction based on the K_1 parameters in Eq. (7).