MEASUREMENT OF τ LEPTON DECAYS TO KAONS AT OPAL

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Abstract

We present preliminary measurements of the branching ratios of τ lepton decays to kaons measured with the OPAL detector at LEP. From around 50000 $e^+e^- \rightarrow Z^0 \rightarrow \tau^+\tau^-$ events recorded during 1990-1993 we obtain

$$\begin{aligned} \mathrm{Br}(\tau^- \rightarrow K^-\nu_\tau) &= 0.59 \pm 0.06 \pm 0.05\ \% \\ \mathrm{Br}(\tau^- \rightarrow K^- \geq 1\pi^0\nu_\tau) &= 0.55 \pm 0.07 \pm 0.07\ \% \\ \mathrm{Br}(\tau^- \rightarrow K^- \geq 0\pi^0 \geq 0K^0\nu_\tau) &= 1.43 \pm 0.08 \pm 0.08\ \% \\ \mathrm{Br}(\tau^- \rightarrow K^0_s X^-\nu_\tau) &= 0.88 \pm 0.07 \pm 0.04\ \% \\ \mathrm{Br}(\tau^- \rightarrow K^0_s\pi^- \geq 0h^0\nu_\tau) &= 0.72 \pm 0.07 \pm 0.04\ \% \\ \mathrm{Br}(\tau^- \rightarrow K^0_s K^- \geq 0h^0\nu_\tau) &= 0.20 \pm 0.04 \pm 0.03\ \%. \end{aligned}$$

In each case the first error is statistical and the second systematic; h^0 includes π^0 and K^0, and X^- is any combination of particles with a total charge of -1. The measurements are consistent with results from the ALEPH, DELPHI and CLEO groups, and also with recent theoretical predictions.

The decays of τ leptons to kaons are of interest theoretically as they provide tests of the strange hadronic weak current. In particular, the branching ratio for $\tau^- \rightarrow K^-\nu_\tau$ has recently been calculated including corrections to $\mathcal{O}(\alpha)$ [1], so a measurement of this branching ratio provides a valuable test of the Standard Model. As branching ratios for τ decays to strange particles are small, around 1% or less, until recently there have been only a few measurements with poor statistics. However many new measurements have recently been published from the LEP experiments [2, 3, 4] and CLEO [5].

We present preliminary results of measurements of the branching ratio of τ leptons to modes including kaons, made using the OPAL detector [6] at LEP. The results were obtained from around 50000 $e^+e^- \rightarrow Z^0 \rightarrow \tau^+\tau^-$ events recorded during 1990-1993, selected using standard OPAL selection cuts[7], with the average polar angle of the two τ candidates satisfying $|\cos\theta| \leq 0.68$. The efficiency of this selection is about 93% within the geometrical acceptance, with a background of 1.8±0.4%.

We first discuss new measurements of one-prong decays to a charged kaon: the inclusive branching ratio for $\tau^- \rightarrow K^- \geq 0\pi^0 \geq 0K^0\nu_\tau$, which we split into the exclusive channels where the kaon is or is not accompanied by neutral pions, $\tau^- \rightarrow K^- \geq 1\pi^0\nu_\tau$ and $\tau^- \rightarrow K^-\nu_\tau$ respectively[1]. We then update our published measurement of the inclusive K^0_s branching ratio [4], and give new results for modes where the K^0_s is accompanied by one charged particle, either a pion or a kaon.

τ Decays to $K^\pm$

We select one-prong τ decays from the $\tau^+\tau^-$ events by demanding that a hemisphere contain only one good track, with scaled momentum $p/E_{beam} \geq 0.05$, and at least 100 hits available for use in the ionisation energy loss measurement, which is used to distinguish kaons from pions. Tracks identified as electrons and muons from calorimeter or muon chamber information are rejected, leaving a sample of 40032 inclusive one-prong τ decays.

The inclusive one-prong sample is split into two subsamples, one enriched in events containing one or more neutral pions accompanying the charged track, the other enriched in events with no extra neutrals. This separation uses the energy in the electromagnetic calorimeter, E, and the invariant mass of the track and electromagmetic clusters, M, calculated according to the first algorithm in reference [8]. Events with no neutral pions are selected by requiring $E/p < 0.8$ and $M < 0.5$ GeV/c^2 (10156 events); events with neutral pions are selected by requiring $M \geq 0.5$ GeV/c^2 (26907 events).

The fractions of kaons in the inclusive sample, and the two samples enriched and depleted in π^0's, are measured using the ionisation energy loss, $\mathrm{d}E/\mathrm{d}x$, measured in the drift chamber [9]. In the momentum region of interest, $\mathrm{d}E/\mathrm{d}x$ does not provide a clean separation between pions and kaons, hence we use a maximum likelihood fit to measure the fraction of each particle type in ranges of momentum. The likelihood function is of the form

$$\mathcal{L} = \prod_{j=1}^{nevts} \sum_{i=e,\mu,\pi,K} \frac{f_i}{\sqrt{2\pi} S_i S_\sigma \sigma_i} \exp(-D_i^2/2) , \quad \text{with} \quad D_i = \frac{(\mathrm{d}E/\mathrm{d}x)^{measured} - S_i(\mathrm{d}E/\mathrm{d}x)_i^{expected}}{S_i S_\sigma \sigma_i}$$

where f_i is the fraction of each type of particle (e,μ,π,K), $(\mathrm{d}E/\mathrm{d}x)_i^{expected}$ is the expected value of $\mathrm{d}E/\mathrm{d}x$ for each type of particle, σ_i is the rms error on $\mathrm{d}E/\mathrm{d}x_i$ and S_i, S_σ are scaling factors.

A clean sample of $\tau \rightarrow \mu\nu\bar{\nu}$ events was used to validate the fit procedure, checking that the distribution of the difference between measured and expected $\mathrm{d}E/\mathrm{d}x$ was consistent with a single Gaussian, and to determine the momentum-independent scaling factor for the errors, S_σ=1.097±0.008. The value of S_e was determined from a pure sample of $\tau \rightarrow e\nu\bar{\nu}$ events. The free parameters in the fit were thus three of the particle fractions (f_K, f_μ, f_e), the fourth, f_π, being constrained such that the sum of the fractions be unity, and the scaling factors S_π and S_K. These scaling factors are consistent between samples, and are typically about 0.996. Figure 1 shows the result of the maximum likelihood fit to a typical momentum bin of the inclusive sample. The χ^2 between the measured and fitted distributions is good for all samples.

The final step in the analysis is to convert the measured fractions into branching ratios. To do this, we calculate the efficiency of the selection cuts using Monte Carlo events generated with KO-

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[1] Charge conjugate processes are also implied throughout this report.

RALZ4.0/TAUOLA2.5 [10] and full detector simulation [11]; average values are around 70%. Background from $\tau^- \rightarrow K^0K^- \geq 0h^0\nu_\tau$ is subtracted from the exclusive modes assuming a branching ratio of 0.30±0.05%.

The main systematic errors arise from the selection cuts used to separate the events with or without neutral pions, multihadron background, the $\tau^- \rightarrow K^0K^- \geq 0h^0\nu_\tau$ branching ratio and the dE/dx resolution. The preliminary results are:

$$\begin{aligned} \mathrm{Br}(\tau^- \rightarrow K^-\nu_\tau) &= 0.59 \pm 0.06 \pm 0.05\ \% \\ \mathrm{Br}(\tau^- \rightarrow K^- \geq 1\pi^0\nu_\tau) &= 0.55 \pm 0.07 \pm 0.07\ \% \\ \mathrm{Br}(\tau^- \rightarrow K^- \geq 0\pi^0 \geq 0K^0\nu_\tau) &= 1.43 \pm 0.08 \pm 0.08\ \% \end{aligned}$$

where the first error is statistical and the second systematic in each case.

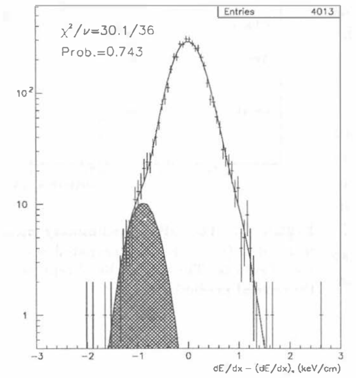

Figure 1: Difference between the measured ionisation energy loss and that expected under the pion hypothesis for tracks in the momentum range 20-25 GeV/c in the $\tau^- \rightarrow K^- \geq 0\pi^0 \geq 0K^0\nu_\tau$ sample (points with error bars). The curve shows the result of the maximum likelihood fit with the contribution from kaons shown as the cross-hatched area.

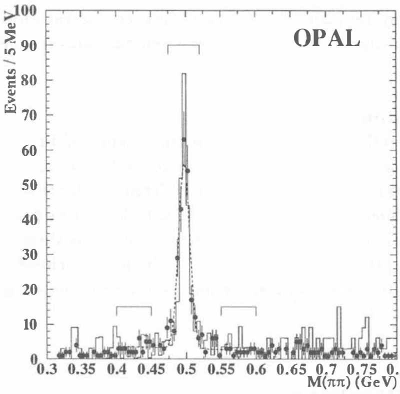

Figure 2: The $\pi^+\pi^-$ invariant mass distribution for K_s^0 candidates in OPAL data (points with error bars). The peak and sideband regions used for signal and background determination are shown. The histogram is the prediction of a Monte Carlo simulation of all τ decay modes, while the dashed curve is the result of a fit to a Gaussian plus linear background used for systematic studies.

τ Decays to K_s^0

The reconstruction of $K_s^0 \rightarrow \pi^+\pi^-$ candidates from the $e^+e^- \rightarrow Z^0 \rightarrow \tau^+\tau^-$ events is the same as for the OPAL published results [4]. K_s^0 candidates are formed from two oppositely charged, good quality, tracks which form a good vertex displaced from the primary vertex. The angle between the K_s^0 momentum vector and flight path is required to be less than 4 mrad, and conversions are rejected by requiring the invariant mass of the two tracks to be greater than 150 MeV/c^2 when treated as electrons. The invariant mass distribution of the K_s^0 candidates is shown in figure 2. K_s^0 signal events are required to lie in the mass range 475-520 MeV/c^2, corresponding to about 3σ of the mass resolution. To estimate the background to the signal we use sideband subtraction, using the two regions indicated in figure 2; the inclusive K_s^0 signal is 243 events, with a background of 10.0±1.5%.

$\tau^- \rightarrow K_s^0h^- \geq 0h^0\nu_\tau$ events are selected by requiring one good track, from the primary vertex, with $p_t > 0.5$ GeV/c and at least 40 dE/dx hits, in the same hemisphere as the K_s^0 (191 events). The fraction of these tracks which are kaons is measured using a maximum likelihood fit to dE/dx in momentum bins, as for the one-prong τ decays. As the statistics in this case are rather poor, we take the scaling factors from the one-prong analysis, and the only free parameters in the fit are the pion and kaon fractions. The fitted kaon fraction increases with momentum. Efficiencies are again taken from Monte Carlo simulation; for the inclusive K^0_s channel, we use values of the efficiencies for exclusive channels weighted with measured branching ratios [2]; efficiencies depend strongly on momentum, and overall are around 20%.

The main sources of systematic error arise from uncertainties in the K^0_s finding efficiency, and were estimated as in the previous analysis [4]. The parameterisation of the energy loss is also significant for the exclusive channels.

The preliminary results are:

$$\begin{aligned} \mathrm{Br}(\tau^- \to K^0_s X^- \nu_\tau) &= 0.88 \pm 0.07 \pm 0.04\ \% \\ \mathrm{Br}(\tau^- \to K^0_s \pi^- \geq 0h^0 \nu_\tau) &= 0.72 \pm 0.07 \pm 0.04\ \% \\ \mathrm{Br}(\tau^- \to K^0_s K^- \geq 0h^0 \nu_\tau) &= 0.20 \pm 0.04 \pm 0.03\ \% \end{aligned}$$

where the first errors quoted are statistical and the second are systematic, X^- refers to any configuration of particles with charge -1, and h^0 is any neutral hadron other than the K^0_s.

Summary

The OPAL preliminary measurements of branching ratios of the τ lepton to modes including kaons, presented in the previous two sections, are consistent with other recent measurements of these modes [2, 3, 5, 12]. For example, a compilation of recent results for $\tau^- \to K^-\nu_\tau$ is shown in figure 3. The OPAL value for the $\tau^- \to K^-\nu_\tau$ branching ratio is also within 2 standard deviations of a recent theoretical calculation [1].

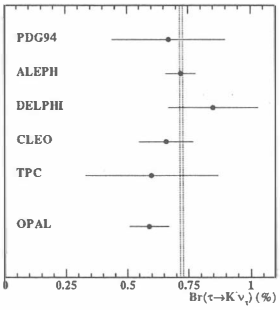

Figure 3: The OPAL preliminary measurement of $\mathrm{Br}(\tau^- \to K^-\nu_\tau)$ compared with other recent results. The vertical band represents the theoretical prediction [1].

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