$\tau^- \to K^+K^-\pi^-\nu_\tau$ at CLEO III

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Based on 3.26 fb^{-1} data sample collected at CLEO III, we study the decay $\tau^- \to K^+K^-\pi^-\nu_\tau$, and improve the measurement of the branching ratio $\mathcal{B}(\tau^- \to K^+K^-\pi^-\nu_\tau) = (1.59 \pm 0.06 \pm 0.13) \times 10^{-3}$, the results are preliminary.

1. Introduction

For τ hadronic decays, final states with kaons provide a powerful probe of the strange sector of the weak charged current. The decay channel $\tau^- \to K^+K^-\pi^-\nu_\tau$, together with $\tau^- \to \eta\pi^-\pi^0\nu_\tau$ and $\tau^- \to K^-\pi^+\pi^-\nu_\tau$ can be used [1] to measure the contribution from the Wess-Zumino anomaly [2]. Furthermore, $\tau^- \to K^+K^-\pi^-\nu_\tau$ with sizable branching ratio and higher hadronic mass, can be used to give more stringent constraints on the τ neutrino mass [3].

Table 1 lists the recent measurements of $\tau^- \to K^+K^-\pi^-\nu_\tau$ branching fraction [4]. These measurements are based on the particle separation provided by dE/dx. There exists the discrepancy between the result from OPAL and those from the other two. At CLEO III, we have about 9.2 fb^{-1} data (full dateset) taken at $\sqrt{s} \sim 10.58$ GeV, out of which 3.26 fb^{-1} (corresponding to 2.97×10^6 $\tau^+\tau^-$ pairs) is available for this analysis. The RICH detector at CLEO III provides good particle separation, allowing us to improve the measurement of $\tau^- \to K^+K^-\pi^-\nu_\tau$ branching fraction.

Table 1
Measurements of $\mathcal{B}(\tau^- \to K^+K^-\pi^-\nu_\tau)$.

Group	$\tau^+\tau^-(\times 10^6)$	$\mathcal{B}(\%)$
OPAL	0.15	$0.087 \pm 0.056 \pm 0.040$
ALEPH	0.15	$0.163 \pm 0.021 \pm 0.017$
CLEO II	4.3	$0.145 \pm 0.013 \pm 0.028$

2. Event Selection

We use 1-prong τ leptonic decay (e/μ) or hadronic decay ($\rho/\pi(K)$) to tag the other $\tau^- \to K^+K^-\pi^-\nu_\tau$. We select the events with the 1 vs. 3 topology. And a event is required to have 4 tracks, passing the track quality cuts with net zero charge. An electron candidate is selected based on dE/dx information and the ratio of the associated shower energy in the calorimeter to the measured track momentum. A muon candidate must penetrate at least three or five absorption lengths of material depending on its momentum. Any hadron candidate is required not to be identified as an electron or a muon.

The events that do not satisfy the lepton criteria are classified as hadron tags. To find a ρ, we use the most energetic π^0 candidate in the tagging hemisphere within $(-3.0, 2.5)\sigma$ of the π^0 nominal mass, the π^0 candidate with a charged pion in the tagging hemisphere must be consistent with the ρ mass. All other tags with an invariant mass in the tagging hemisphere less than 0.5 GeV are classified as π. To select the photon candidates from π^0 decays, unmatched showers with $|\cos\theta| < 0.95$ are required to have energies greater than 30 MeV in the good section of the barrel or 50 MeV in the endcap. To get better mass resolution, we require that at least one photon candidate from π^0 decays must be in the good section of the barrel.

A typical signal event should not deposit any significant extra energy in the calorimeter. In

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most cases, extra unmatched energy deposited in the calorimeter is a signature of various backgrounds with one or more π^0's. To suppress these backgrounds, we don't allow any extra unmatched shower with energy $E_\gamma > 0.1$ GeV in the tagging hemisphere or in the signal hemisphere.

In order to reject the two photon background which is characterized by the missing momentum along the beam pipe and a small visible energy, we require $|\cos\theta_{miss}| < 0.95$, $E_{vis}/E_{cm} > 0.4$. For $\tau^- \to K^+K^-\pi^-\nu_\tau$ decay with ν_τ undetected, the $K^+K^-\pi^-$ system has high transverse momentum, we require $p_t^{KK\pi} > 2.0$ GeV/c

To get better particle separation, $\sigma_{\pi,K}$ (the standard deviation of the measured dE/dx from the expected one) and RICH loglikelihood difference $\chi^2_\pi - \chi^2_K$ under pion and kaon hypotheses were combined together. The particle identification (PID) cuts $\Delta\chi^2 = \chi^2_\pi - \chi^2_K + \sigma^2_\pi - \sigma^2_K$ and the number of Cherenkov photons N_γ^K are evaluated based on generic τ MC and generic continuum MC, and are determined as $N_\gamma^K \geq 3$, $\Delta\chi^2 > 0$ for kaons; and $|\sigma_\pi| < 3.0$ for pion.

2.1. The Backgrounds

After the event selection, two photon backgrounds are totally negligible. The main backgrounds come from τ decays to three charged tracks with or without neutrals. We use the generic continuum MC and generic τ MC to study the continuum and τ backgrounds. With RICH, the continuum backgrounds are suppressed to about 2% level, and the τ backgrounds are also well suppressed to about 9% level.

3. Results

After the event selection, we observe 938 events, out of which, 19 and 86 events are from the continuum and τ backgrounds, respectively. After the backrounds subtraction, we observe 833 ± 32 signal events, the overall efficiency is $(12.28 \pm 0.11)\%$. From those, we determine the branching ratio $\mathcal{B}(\tau^- \to K^+K^-\pi^-\nu_\tau) = (1.59 \pm 0.06(stat)) \times 10^{-3}$.

The substructure of $\tau^- \to K^+K^-\pi^-\nu_\tau$ decay provides a way to measure the Wess-Zomino anomaly [1]. In Fig. 1, we show the mass spectra of hadronic systems. It is clear that $\tau \to K^+K^-\pi^-\nu_\tau$ is dominated by the intermediate state $\tau^- \to K^-K^{*0}\nu_\tau$ with $K^{*0} \to K^+\pi^-$, there is no evidence for the ϕ production. The nomalized continuum and τ backgrounds are overlaid. The comparison between the data and MC (all=backgrounds+signal) shows that the decay is not well modelled in korb [6]. The modelling of the substructure needs improvement.

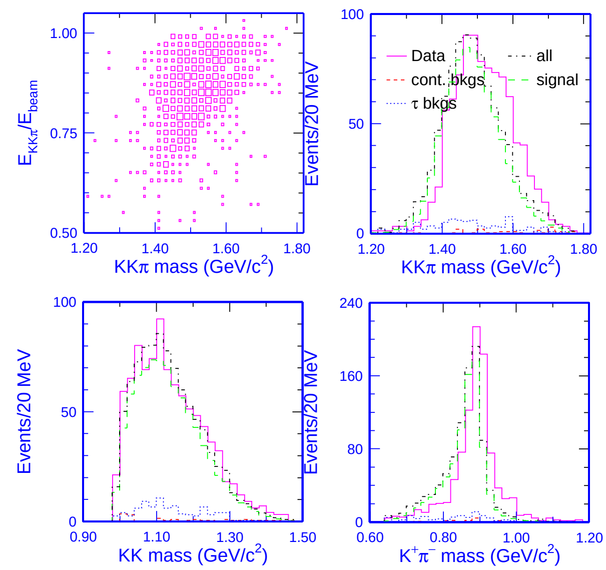

Figure 1. $\tau \to K^+K^-\pi^-\nu_\tau$ mass spectra.

4. Systematics

The systematics mainly comes from the event selection efficiencies. To get the systematics, we vary the cuts by 10% (or more) or 1σ at the determined values and calculate the new yields, efficiencies and branching ratios to obtain the systematics. The systematics from the $E_\gamma < 0.10$ GeV requirement for the extra shower is less than 1%. Since $\tau^- \to K^+K^-\pi^-\nu_\tau$ is not well modeled in Korb [6], we use phase space generator to generate $\tau^- \to K^+K^-\pi^-\nu_\tau$ and $\tau^- \to K^-K^{*0}\nu_\tau$ where $K^{*0} \to K^+\pi^-$, and find the systematics from the model dependent efficiency to be 1.5%

and 1.8%, respectively. The systematics from the τ background subtraction due to the uncertainties in the branching ratios for τ three prong decays is 1.3%. The systematics from the continuum background subtraction is estimated to be 1.5%. The systematics from the cut on the number of tracks in a event is 1.7%. The tracking efficiency systematics is 0.2% per track, the PID efficiency systematics is 3.0% per kaon and 1.0% per pion. Systematics also includes the uncertainties from the τ pair cross section (1%), the integrated luminosity (2%) and MC statistics (1%). The total systematics is 8.1%, the dominant contribution comes from the PID efficiency systematics, and we have $\mathcal{B}(\tau^- \to K^+K^-\pi^-\nu_\tau) = (1.59 \pm 0.06(stat) \pm 0.13(sys)) \times 10^{-3}$ (preliminary).

5. Cross Check: Measurement of $\mathcal{B}(\tau^- \to \pi^+\pi^-\pi^-\nu_\tau)$

As a cross check, we present the measurement of $\mathcal{B}(\tau^- \to \pi^+\pi^-\pi^-\nu_\tau)$. We use $N_\gamma^\pi \geq 3$ and $\Delta\chi^2 = \chi_\pi^2 - \chi_K^2 + \sigma_\pi^2 - \sigma_K^2 < 0$ to identify three pions. After the event selection, we observe 43,432 events, the continuum background is 151.6 events, the τ background is 3,207 events. After the backgrounds subtracted, we observe 40,073±216 signal events. Fig. 2 show the comparison of the mass sepectra between the data and MC. The agreement is quite good. The overall efficiency is (10.21±0.17)%, and we have $\mathcal{B}(\tau^- \to \pi^+\pi^-\pi^-\nu_\tau) = (9.21 \pm 0.05)\%$. The pion PID efficiency systematics is 1% per pion, MC statistics is 2%, the total systematics is about 5% (reference to Sec. 4). Thus we obtain $\mathcal{B}(\tau^- \to \pi^+\pi^-\pi^-\nu_\tau) = (9.21 \pm 0.05 \pm 0.46)\%$. The result is in good agreement with the PDG value $\mathcal{B}(\tau^- \to \pi^+\pi^-\pi^-\nu_\tau) = (9.18 \pm 0.11)\%$.

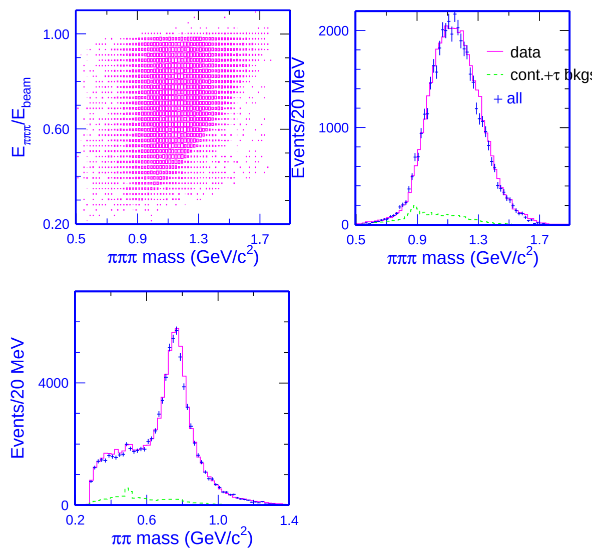

Figure 2. $\tau \to \pi^+\pi^-\pi^-\nu_\tau$ mass spectra.

6. Summary

Based on 3.26 fb^{-1} (2.97×10^6 $\tau^+\tau^-$) data collected at CLEO III, we improve the measurement of $\mathcal{B}(\tau^- \to K^+K^-\pi^-\nu_\tau) = (1.59 \pm 0.06 \pm 0.13) \times 10^{-3}$ which is in good agreement with the PDG result $(1.61 \pm 0.18) \times 10^{-3}$ [5], the errors are statistical and systematic, respectively. The systematics is dominated by the PID efficiency systematics which we'll further study after more data available. The results are preliminary. The modelling of the substructure is under study.

REFERENCES

1. R. Decker *et al.*, Phys. Rev. D **47**, 4012 (1993).
2. J. Wess and B. Zumino, Phys. Lett. **B37**, 95 (1971).
3. G. B. Mills *et al.*, Phys. Rev. Lett. **54**, 624 (1985).
4. OPAL Collaboration, G. Abbiendi *et al.*, Eur. Phys. J. C **13**, 197 (2000); CLEO Collaboration, S. Richichi *et al.*, Phys. Rev. D **60**, 112002 (1999); ALEPH Collaboration, R. Barate *et al.*, Eur. Phys. J. C **1**, 65 (1998);
5. D. E. Groom *et al.*, PDG Group, Eur. Phys. J. **C 15**,1 (2000).
6. A. Weinstein, http://www.lns.cornell.edu/public/CLEO/soft/korb/korb_doc.html and the references therein.