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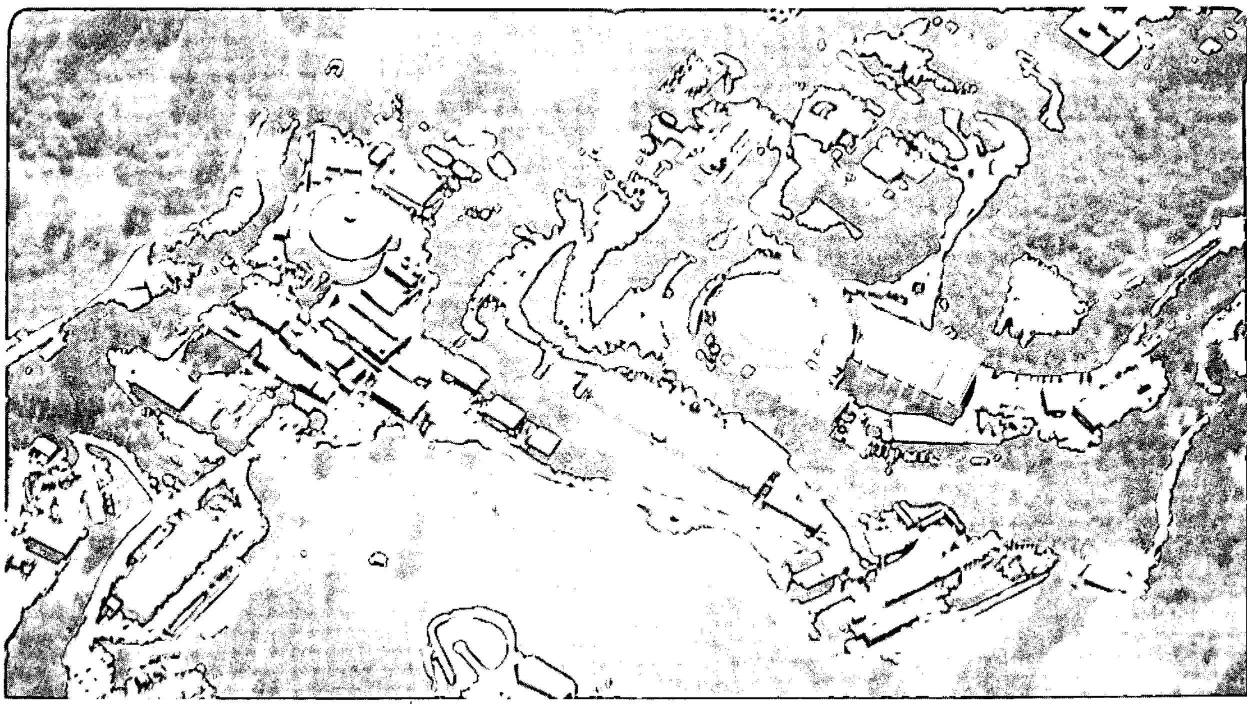

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STRANGE DECAYS OF THE TAU LEPTON*

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ABSTRACT

Measurements of hadronic τ decays to states containing at least one strange meson are reviewed. New results are presented from a self-consistent analysis of one-prong decays including kaons and from a study of the kaon content in three-prong decays. First observations of the resonance contribution to the strange axial-vector channel are reported. The findings are compared to model predictions of K_1 mixing and interference in τ decay.

1. Introduction

1.1 Strange Charged-Current Couplings

For inclusive hadronic decays of the τ lepton within the Standard Model, the τ decays to its neutrino, and through the weak charged current to the $SU(2)_{Weak}$ doublet of an anti-up quark, $\overline{u}$, and an admixture of down and strange quarks, d', as shown in Fig. 1.

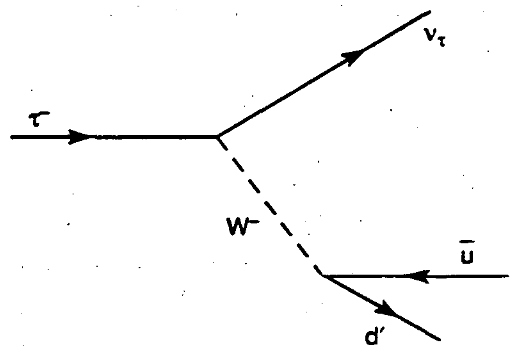

Figure 1: Coupling of the τ lepton to hadronic final states in the Standard Model.

The coupling to the constituent (d, s) quarks can be expressed in terms of the corresponding CKM matrix elements, or simply in terms of the Cabibbo angle as

$$d' = cos(\theta_C)\ d + sin(\theta_C)\ s \tag{1}$$

Thus, to first order we expect strange inclusive decays of the τ to be suppressed at the weak vertex by $\tan^2(\theta_C)$, or about 5%.

For exclusive resonant decays of the τ, we can express the relative decay rates to strange and non-strange resonances in terms of the decay constants of the resonances and the available phase space as

$$\frac{B(\tau^- \to \nu_\tau(\overline{u}s))}{B(\tau^- \to \nu_\tau(\overline{u}d))} = \left|\frac{f_{(\overline{u}s)W}}{f_{(\overline{u}d)W}}\right|^2 tan^2(\theta_C)\ \frac{\phi(\overline{u}s)}{\phi(\overline{u}d)} \tag{2}$$

where $f_{(\overline{u}d)W}$, $f_{(\overline{u}s)W}$ are the decay constants and $\phi(\overline{u}d)$, $\phi(\overline{u}s)$ the phase-space factors for the non-strange and strange resonances, respectively. The decay constants are introduced in parameterizing the time-reversed process of decay of the resonance through the weak current, and essentially reflect the overlap of the quark and anti-quark wave functions. We note that the ratio of strange to non-strange decay con-

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stants is typically greater than one. The phase-space for a decay into a strange resonance is less than that for a non-strange resonance of the same spin-parity since the strange resonances are more massive due to the larger constituent mass of the strange quark, i.e. $m_u \sim m_d \sim 0.35$ MeV/c^2 and $m_s \sim 0.5$ MeV/c^2. In the overall ratio of τ decay widths, Eq. (2), these factors tend to cancel and we find that the expected suppression for strange relative to non-strange resonances is approximately 5 - 6%.

1.2 Effective Second-Class Currents

If we look at τ decays in the rest frame of the W^-, as shown in Fig. 2, we note an important difference between strange and non-strange decays. That is, since the W^- couples to a right-handed $\overline{u}$ quark and a left-handed d' quark, decays to resonances with quark spins anti-aligned (singlet spin states) are helicity suppressed. In addition, states with $GP(-1)^J = -1$ are further suppressed in the Standard Model. For non-strange resonances, these second-class current decays are suppressed by a factor[1] of $|m_u - m_d| \;/\; (m_u + m_d)$, and indeed the corresponding mesons (a_0,b_1) have not been observed in τ decays.[2] However, for strange resonances, the overall suppression in the decay amplitudes is of order

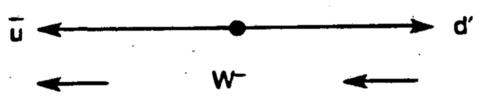

Figure 2: Schematic diagram showing the preferred spin alignment in W to q-$\overline{q}$ coupling in the rest frame of the W, à la Lipkin.[1]

$$\mathrm{O}\left(\frac{|m_u - m_s|}{m_u + m_s}\right) \sim 0.25 \qquad (3)$$

so we may well expect[3] to observe τ decays to the strange scalar, $K_0^*(1430)$, and to the strange analog of the b_1 axial-vector meson, K_B.

In this report, I'll review existing measurements of the strange decay modes of the τ and the observed strangeness suppression in resonant decays. New preliminary one-prong branching ratios from simultaneous measurements of τ decays including kaon categories, and a new result on the kaon content in three-prong decays are presented. Finally, I'll comment on possible strange axial-vector resonant contributions to the measured $\tau \to \nu_\tau K\pi\pi$ decays, and discuss recent theoretical work towards obtaining predictions for effective second-class current decays and for mixing and interference effects in the strange axial-vector channel.

2. Review of Existing Measurements

2.1 Strange One-Prong Decays

Inclusive and exclusive decays to charged kaons: Strange pseudoscalar decays of the τ to a charged kaon have been measured by only two experiments, DELCO[4] and TPC/2γ[5]. The measurements, which include contributions from decays with additional neutrals, are reported as inclusive τ branching ratios into a single charged kaon

$$B_{K^- \geq 0\,neutrals} = \begin{cases} 1.71 \pm 0.29\ \% & \text{DELCO '84} \\ 1.6 \pm 0.4 \pm 0.2\ \% & \text{TPC/2}\gamma\text{ '87} \end{cases}$$

The two experiments use different approaches for separating the decays with additional neutrals: The DELCO experimenters separated the decays with no additional neutrals to obtain

$$B_{K^-} = 0.59 \pm 0.18 \ \% \qquad \text{DELCO '84}$$

while the TPC/2γ group chose to measure the branching ratio to a single charged kaon with at least one neutral by determining the fraction of events where there was additional neutral activity in obtaining

$$B_{K^- \geq 1 neutrals} = 1.2 \pm 0.5^{+0.2}_{-0.4} \ \% \quad \text{TPC/2}\gamma \text{ '87}$$

Unfortunately, the errors in the two measurements from each experiment are correlated so that one can't do a direct comparison of the separation of additional neutrals. However, the results from the two experiments are quite consistent with the observation that approximately two-thirds of the inclusive one-prong K^- decays involve additional neutrals, and that

$$B_{K^-} \simeq 0.6 \pm 0.2 \ \%$$

Exclusive K^{*-} decay: Strange vector decays of the τ have been measured by several experiments in the three-prong topology resulting from $K^{*-} \rightarrow K^0_S \pi^-$ with $K^0_S \rightarrow \pi^- \pi^+$. The Particle Data Group[3] average branching ratio for τ decay into the K^{*-} is

$$\langle B_{K^{*-}} \rangle_{PDG} = 1.42 \pm 0.18 \ \%$$

This decay channel contributes significantly to the one-prong K^- plus neutral decays through the K^{*-} coupling to the $K^-\pi^0$ final state. One expects a contribution of 0.47%, or about one-half of $B_{K^- \geq 1 neutrals}$ as measured by TPC/2γ and inferred from the combined measurements.

Inclusive K^{*-} decays: An estimate of the neutral activity in events with a K^{*-} can be obtained from measurements of the additional neutral activity in the three-prong topology as determined by HRS[6] and CLEO[7]

$$\begin{array}{lcll} B_{K^0 h^- \geq 0 neutrals} & = & 1.3 \pm 0.3 \ \% & \text{HRS '88} \\ B_{K^{*-} \geq 0 neutrals} & = & 1.43 \pm 0.17 \ \% & \text{CLEO '90} \end{array}$$

These results along with the PDG average for $B_{K^{*-}}$ appear to limit the branching ratio of the τ to a K^{*-} plus additional neutrals to less than a few tenths of a per cent.

2.2 Strange Three-Prong Decays

Topological three-prong decays including charged kaons: Here, we again find contributions from only the DELCO and TPC experiments. From its initial low-field run, the TPC experiment[8] was able to set upper limits for the topological decay of the τ into at least one charged kaon and two additional charged particles

$$B_{K^- h^+ h^- \geq 0 neutrals} < 0.6\% \quad (90\% C.L.) \quad \text{TPC '84}$$

The DELCO experimenters[9] used their total PEP data sample to separately measure τ decays to one and two charged kaons obtaining

$$\begin{array}{lcl} B_{K^-\pi^+\pi^- \geq 0\,neutrals} & = & 0.22\,^{+0.16}_{-0.13}\ \% \\ B_{K^-K^+\pi^-} & = & 0.22\,^{+0.17}_{-0.11}\ \% \end{array} \quad \text{DELCO '85}$$

within the limits determined by the TPC collaboration.

Inclusive decays including K^{*0}ś: Recently, the CLEO collaboration reported related inclusive branching ratios for three-prong topological decays including a neutral K^* reconstructed from identified charged kaons and pions

$$\begin{array}{lcl} B_{\overline{K}^{*0}\pi^- \geq 0\,neutrals} & = & 0.38 \pm 0.17\ \% \\ B_{K^{*0}K^- \geq 0\,neutrals} & = & 0.32 \pm 0.14\ \% \end{array} \quad \text{CLEO '90}$$

Since the K^{*0} branching ratio to the charged $K^+\pi^-$ mode is 2/3, these more recent results together with the earlier results suggest that the strange three-prong modes are dominated by K^{*0} production. Also, we note that the decays with a neutral K^* and a charged π^- or K^- are consistent with the level of a few tenths of a per cent estimated above for the inclusive charged K^* plus neutrals decay.

3. New Experimental Results

In addressing the τ one-prong decay problem,[10] the CELLO and ALEPH experiments[11] have recently reported branching ratios from simultaneous measurements of both inclusive and exclusive τ decays. Using the excellent particle identification capabilities of the PEP-4/9 Time Projection Chamber (TPC), the TPC/2γ collaboration has obtained new preliminary results[12] by measuring one-prong decays in a similar manner and extending the analysis to strange decay modes. In addition, an analysis of the kaon content in three-prong modes has recently been completed.[13] The latter bears on the search for the unobserved strange axial-vector resonant decays of the τ.

The measurements were made from data recorded by the TPC/2γ collaboration during 1982-1983 and 1984-1986 with low-field (4 kG) and high-field (13.2 kG) magnets, respectively.[14] At PEP energies, $E_{CM} = 29$ GeV, τ events are well separated into two hemispheres due to the large boost. In the event selection process, topological and kinematic cuts are applied to obtain a clean separation into standard Tau 1+1 and 1+3 samples, where the numbers refer to the number of charged particles from the decays of the produced tau pair. To reject Bhabha, multihadron and 2-photon backgrounds, additional requirements on the scalar momentum sum and on the invariant mass of the 3 non-isolated tracks are made. In the final analysis, to minimize the uncertainty due to the large QED background, the remaining ee or $\mu\mu$ events categories are removed.

4. One-Prong Tau Decays

One-prong τ decays are analyzed in both the Tau 1+1 and 1+3 samples. The dE/dx particle identification for the resulting 2569 one-prong decay candidates observed in the 70 pb^{-1} high-field sample from the TPC/2γ experiment is shown in Fig. 3. Electromagnetic calorimetry, a nearly-4π muon detection system and the excellent TPC dE/dx particle identification were used to classify tracks into the four possible species: e,μ,π,K. The measured misidentification probabilities were typically less than a few per cent.

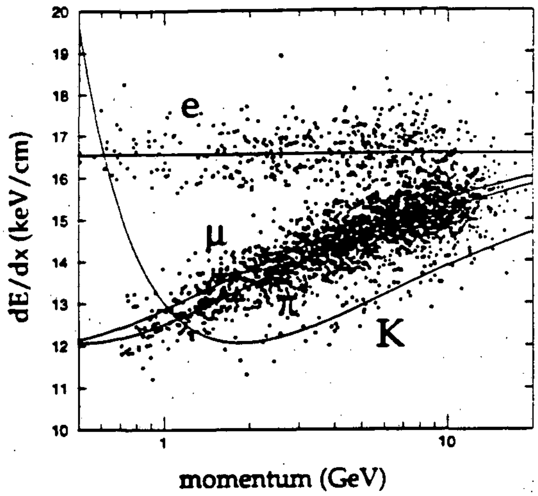

Figure 3: dE/dx ionization loss vs. momentum for 1-prong Tau decays.

To extract branching ratios, a four-component column vector $\boldsymbol{M}$ was formed from the number of one-prong tracks classified as e,μ,π or K. The actual number, $\boldsymbol{N}$, of one-prong τ decays in each mode is related by

$$\boldsymbol{M} = \boldsymbol{Q}\boldsymbol{N} \tag{4}$$

where $\boldsymbol{Q}$ is the track misidentification matrix. The misidentification probabilities are evaluated as a function of the momentum of each track to obtain a track weight, $\mathbf{w} = \mathbf{Q}^{-1}(\mathbf{p})\, \boldsymbol{M}$. Summing over all events, values for N_i, the total number of actual τ decays into the i^{th} mode, are obtained.

The weighted momentum spectrum for inclusive $\pi^{\pm}$ decays is displayed in Fig. 4a. The measurements are found to be in excellent agreement with Monte Carlo predictions based on the *KORAL–B* τ generator[15] using previously measured decay branching ratios[2] of one-prong decays with and without additional π^0's. In Fig. 4b, the weighted $K^{\pm}$ momentum spectrum is found to be consistent with present modelling[15] of $\tau \rightarrow \nu_\tau K^-$ and $\tau \rightarrow \nu_\tau K^- \pi^0$.

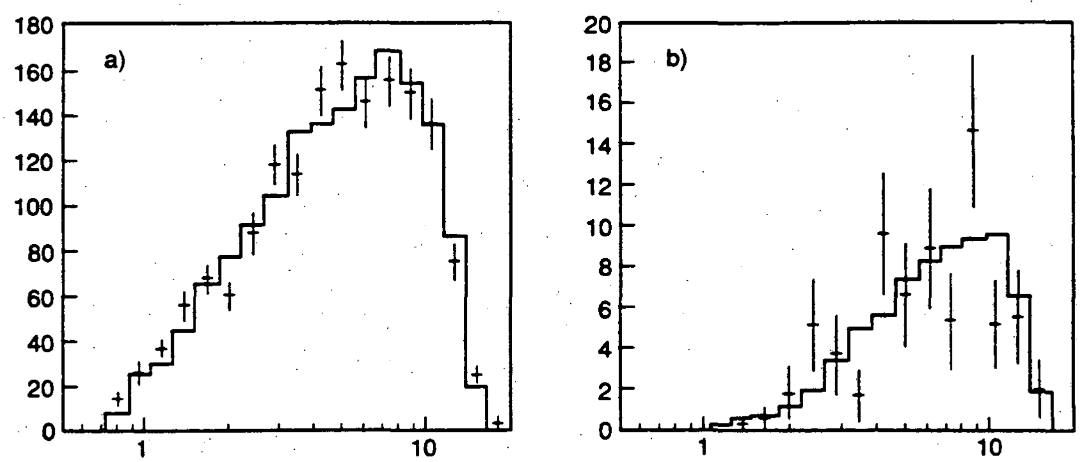

Figure 4: Weighted number of (a) pion and (b) kaon events vs. $\log_{10}$ momentum (in GeV/c).

Exclusive one-prong branching fractions are determined relative to the measured one-prong topological branching ratio to cancel luminosity uncertainties. The following preliminary results[12] were reported

$$\begin{aligned} BR(\tau \rightarrow \nu_\tau e \nu_e) &= 18.3 \pm 1.6\ \% \\ BR(\tau \rightarrow \nu_\tau \mu \nu_\mu) &= 17.4 \pm 1.4\ \% \\ BR(\tau \rightarrow \nu_\tau \pi \geq 0\ neutrals) &= 48.0 \pm 1.6\ \% \\ BR(\tau \rightarrow \nu_\tau K \geq 0\ neutrals) &= 1.6 \pm 0.4\ \%, \end{aligned}$$

where the errors include statistical and systematic terms. The e and μ branching ratios obtained are in good agreement with previous measurements, the separated inclusive $\pi^\pm$ measurement is unique, and the inclusive $K^\pm$ branching ratio is obtained with an error comparable to or better than existing measurements.[2]

5. Strange Scalar Decays

Several experiments have placed upper limits on second-class current τ decays to non-strange scalar states including η's.[16] In addition, in the case of a scalar τ decay to a final state involving kaons, the TPC/2γ experiment[17] was able to determine a stringent upper limit on possible non-strange scalar interactions in τ decay

$$B_{K^- K^0 \geq 0 neutrals} < 0.26\% \quad (95\% C.L.) \quad \text{TPC '87}$$

where the limit has been expressed in the broadest sense.[18]

In the strange sector, however, the possibility of an effective second-class current coupling to strange scalar states due to the finite u - s quark mass difference, Eq. (3), has led to a suggestion[3] for searches for strange scalar mesons in the $\tau \rightarrow \nu_\tau + K + \eta'$ and $\tau \rightarrow \nu_\tau + K + \pi$ decay modes. At this time, there are no experiments reporting attempts to observe scalar states in either of these modes. Some experiments do, however, have sensitivity to the $K\pi$ mode; for example, the measurement of $K^0_S \pi^-$ from ARGUS,[19] shown in Fig. 5b, which doesn't seem to show any evidence for τ decay to $K_0^*(1430)$, could be used to set limits on strange scalar decays.

6. Strangeness Suppression in Tau Decays

6.1 Pseudoscalar Resonance Suppression

Using the pseudoscalar decay constants for the π^- and K^- obtained from measurements of their semileptonic decay[2]

$$\begin{aligned} f_\pi &= 130\, MeV \\ f_K &= 160\, MeV \end{aligned}$$

and the relative phase space factor of 0.86 in Eq. (2), one would expect the relative τ branching ratios for these strange and non-strange pseudoscalars to be

$$\frac{B_{K^-}}{B_{\pi^-}} = \left| \frac{f_K}{f_\pi} \right|^2 tan^2(\theta_C) \left(\frac{p_K^{max}}{p_\pi^{max}} \right)^2 = 0.064$$

From the PDG average values for B_{K^-} and B_{π^-}, we find

$$\frac{B_{K^-}}{B_{\pi^-}} = \frac{(0.67 \pm 0.23)\%}{(11.6 \pm 0.4)\%} = 0.058 \pm 0.020$$

in excellent agreement with the expectations.

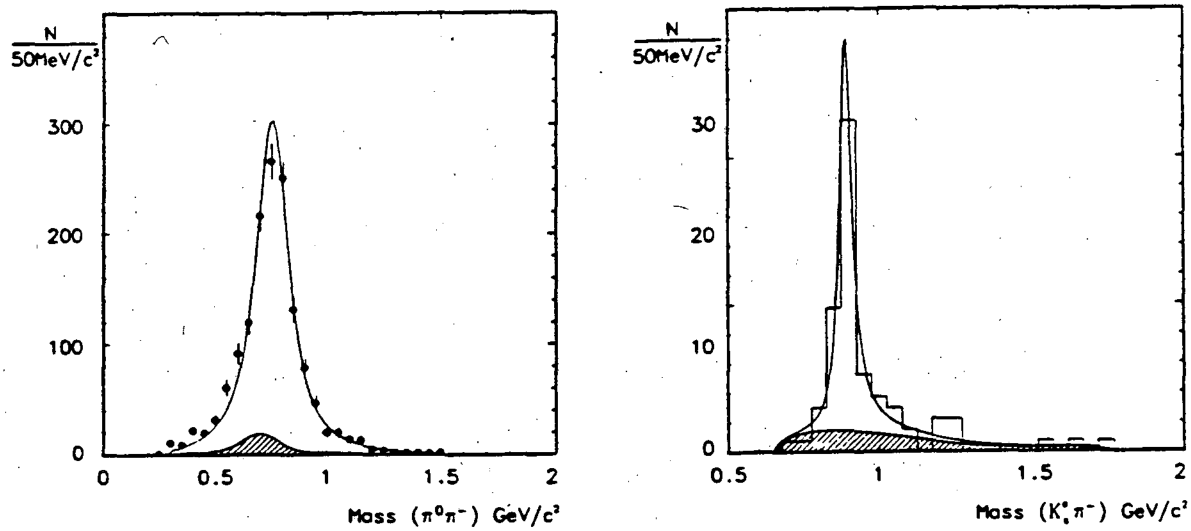

Figure 5: Invariant mass spectra for (a) $\pi^0\pi^-$ and (b) $K_S^0\pi^-$ events showing a clear dominance of ρ^- and K^{*-} production from ARGUS measurements.[19]

6.2 Vector Resonance Suppression

From the ARGUS measurements[19] of τ to $\pi^-\pi^0$ and $K_S^0\pi^-$, shown in Fig. 5, one observes that these decays are dominated by the ρ^- and K^{*-} resonances, respectively. Given the PDG average values[2] for $B_{K^{*-}}$ and $B_{\rho^-} = B_{\pi^-\pi^0}$, we find that the strangeness suppression in the vector channel is

$$\frac{B_{K^{*-}}}{B_{\rho^-}} \simeq \frac{(1.42 \pm 0.18)\%}{(24.0 \pm 0.6)\%} = 0.059 \pm 0.008$$

in agreement with the level of 5-6% as expected. Factoring out $\tan^2(\theta_C)$ and the relative spin-1 phase space factor of 0.92 as given in Eq. (2), we can use the above result to determine the modulus squared of the ratio of decay constants to be

$$\left|\frac{f_{K^*}}{f_\rho}\right|^2 = 1.35 \pm 0.17$$

This result is in excellent agreement with the Das-Mathur-Okubo sum rule prediction[20] of

$$\left|\frac{f_{K^*}}{f_\rho}\right|^2 = \frac{m_{K^*}^2}{m_\rho^2} = 1.35$$

6.3 Axial-Vector Resonance Suppression

Finally, assuming full coupling to one strange axial-vector meson or the other, $K_1(1270)$ or $K_1(1400)$, we can make a naive estimate of their branching ratios from the observed τ decay to the non-strange axial-vector meson, $a_1(1260)$, e.g. as measured by ARGUS[19] in Fig. 6. We take a range

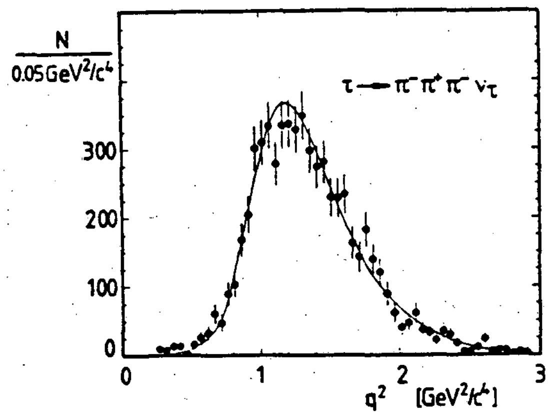

Figure 6: Invariant mass spectra for $\pi^-\pi^+\pi^-$ events showing a clear dominance of a_1 production from ARGUS measurements.[19]

of values for $|f_{K_1(1270)}/f_{a_1}|^2$ of 1.-1.2 and $|f_{K_1(1400)}/f_{a_1}|^2$ of 1.2-1.5, and the relative phase space factors of 1.0 and 0.55,[21] for decays to the $K_1(1270)$ and $K_1(1400)$, respectively. Using an estimated

$$B_{a_1} \sim (16-20)\%$$

we obtain

$$\begin{aligned} B_{K_1(1270)} &= (0.8-1.2)\% \\ B_{K_1(1400)} &= (0.6-0.8)\% \end{aligned}$$

Since about 4/9 of the $K_1(1270)$'s decay through the ρ^0, or through either the $K_0^*(1430)$, K^*, or $K\omega$ to $K^-\pi^+\pi^-$ plus ≥ 0 neutrals, and 4/9 of the $K_1(1400)$'s decay through the K^{*0} to $K^-\pi^+\pi^-$, we find that the branching ratios to the $K^-\pi^+\pi^-$ final state are expected to be

$$\begin{aligned} B_{K_1(1270)\to K^-\pi^+\pi^-} &\sim (0.35-0.5)\% \\ B_{K_1(1400)\to K^-\pi^+\pi^-} &\sim (0.2-0.3)\% \end{aligned}$$

Thus, for equal couplings, one would expect a somewhat larger contribution to the $K^-\pi^+\pi^-$ final state from the $K_1(1270)$ due to the larger available phase space.

7. Three-Prong Tau Decays

In hadronic decays of the τ, each good track must be either a charged pion or kaon. The dE/dx particle identification of the TPC/2γ detector for three-prong decays, with electrons from photon conversion removed, is shown in Fig. 7.

Based on individual track assignments similar to those described in Sec. 4, each event was counted in an eight-component vector, $\boldsymbol{M}$, representing the different possible permutations for the decay modes: $\nu_\tau\pi^-\pi^+\pi^-$, $\nu_\tau K^-\pi^+\pi^-$, $\nu_\tau K^-K^+\pi^-$ or $\nu_\tau K^-K^+K^-$, where in each case additional neutrals could be present.

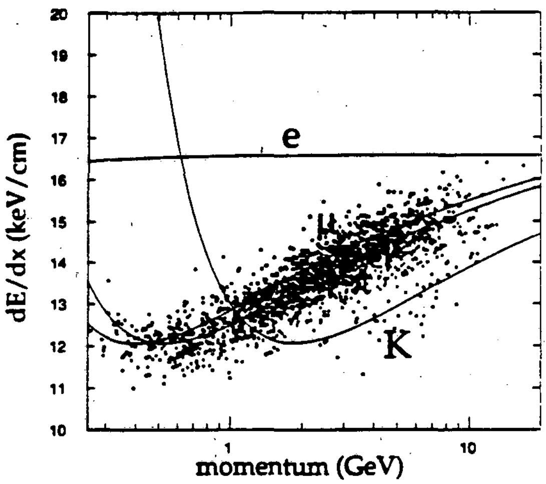

Figure 7: dE/dx ionization loss vs. momentum for 3-prong Tau decays.

The true population of the different modes, $\boldsymbol{N}$, is related by the equation

$$\boldsymbol{M} = \boldsymbol{P}\boldsymbol{N} \tag{5}$$

where $\boldsymbol{P}$ is the event misclassification matrix. This six-dimensional tensor can be expressed as an outer product of track misidentification matrices, $\boldsymbol{Q}$:

$$\boldsymbol{P}^a \equiv \boldsymbol{Q}^a(p_1) \otimes \boldsymbol{Q}^a(p_2) \otimes \boldsymbol{Q}^a(p_3). \tag{6}$$

where a is an event label and p_i are the measured parameters for the i^{th} track in the event. Inverting the $\boldsymbol{Q}$ matrices for each track, the inverse of the misclassification matrix is determined in obtaining an estimator of the true identity of each event, $\mathbf{w} = (\boldsymbol{P}^a)^{-1}\boldsymbol{M}$. This estimator is then used in obtaining weighted distributions and upon summing gives the total numbers of events in each mode.

To provide a check of the event counting, an extended maximum likelihood fit of the track dE/dx distributions in each event was performed to different decay mode hypotheses. The following numbers of events in each decay mode were obtained: 470.3 ± 22.0 $\pi\pi\pi$, $23.6\ ^{+6.6}_{-5.7}$ $K\pi\pi$, $4.3\ ^{+2.7}_{-1.9}$ $KK\pi$, 0.0 ± 0.5 KKK events.

Backgrounds were estimated to be less than 0.5 and 0.3 events in the $K\pi\pi$ and $KK\pi$ channels, respectively, and less than 4 events in the remaining 3π mode. The estimated systematic error of 20% in these three-prong measurements is mainly due to uncertainties in dE/dx parameterization and in estimation of event selection efficiencies.

To cancel luminosity uncertainties, the exclusive three-prong branching fractions were determined relative to the three-prong topological branching ratio measured in the experiment, $B_3 = (14.8 \pm 1.7)\%$, in obtaining

$$\begin{aligned} BR(\tau \to \nu_\tau \pi\pi\pi) &= 13.7 \pm 0.7\ \% \\ BR(\tau \to \nu_\tau K\pi\pi) &= 0.78\ ^{+0.22}_{-0.19}\ \% \\ BR(\tau \to \nu_\tau KK\pi) &= 0.18\ ^{+0.11}_{-0.08}\ \% \\ BR(\tau \to \nu_\tau KKK) &< 0.26\ \%\ (95\% C.L.) \end{aligned}$$

$KK\pi$ decay: The $KK\pi$ decay mode of the τ is expected to arise from the decay of an excited ρ resonance or through $s\bar{s}$ production in an inclusive non-strange decay. The TPC/2γ result for this mode is in good agreement with the previous result from DELCO.[9]

$K\pi\pi$ decay: The preliminary measurement from TPC/2γ for $BR(\tau \to \nu_\tau K\pi\pi)$ is notably higher than DELCO's published result[9] of $(0.22\ ^{+0.16}_{-0.13})\%$. The naive estimates given above for the expected contributions to this final state, for full strange axial-vector coupling to either the $K_1(1270)$ or $K_1(1400)$, correspond to about 13 or 8 events, respectively, where a total of 24 events are observed with a negligible background.[12,13]

7.1 Resonance Contributions

As we have seen in the strange vector and in the non-strange vector and axial-vector channels, resonances appear to totally dominate their respective channels, Fig. 5,6; thus, we might also expect to see dominant contributions to the $K^-\pi^+\pi^-$ channel from one or both of the strange axial-vector mesons, $K_1(1270)$ and $K_1(1400)$. In Fig. 8a, the weighted $K\pi\pi$ invariant mass spectrum obtained from the TPC/2γ data is plotted in 160 MeV bins. The data show no evidence for a substantial contribution from the lower-mass $K_1(1270)$ in the bin centered at 1200 MeV. However, an excess of about 12 events is observed in the next bin, at a mass closer to the $K_1(1400)$. The weighted $K^-\pi^+$ mass distribution is found to peak at the K^{*0} mass, as shown in Fig. 8b. These observations together with the dominance of the decays[2] $K_1(1270) \to \rho K$ and $K_1(1400) \to K^*\pi$ suggest that if the τ decays mainly to a strange axial-vector meson in the $K^-\pi^+\pi^-$ channel as it does in other channels, then the dominant decay appears to be to the $K_1(1400)$ and not the $K_1(1270)$.

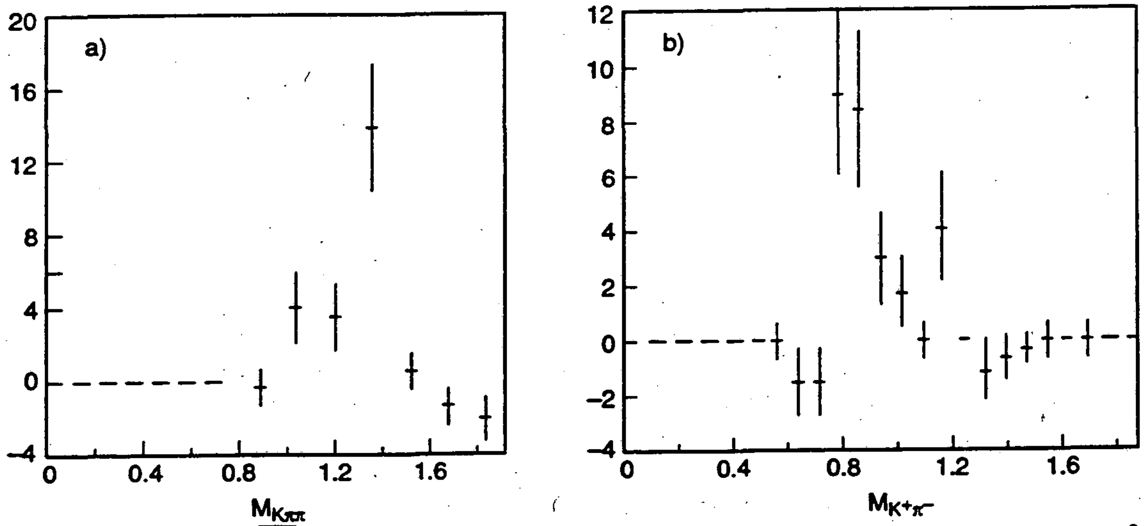

Figure 8: Number of weighted events versus a.) $K\pi\pi$, and b.) $K^+\pi^-$ invariant mass in GeV/c^2 from TPC/2γ.[12]

8. Strange Axial-Vector Decays

As we demonstrated in Sec. 6.3, one can straight-forwardly obtain a naive prediction for τ decay to either of the strange axial-vector mesons. However, both decays are allowed and one needs to take both possibilities into account.

8.1 K_A - K_B Mixing

The strange axial-vector mass eigenstates are actually admixtures of the two quark-spin eigenstates, K_A and K_B, which as strange analogues of the a_1 and b_1 resonances are, in spectroscopic notation, the $^3P_1$ and the $^1P_1$ states in the quark model, respectively. Mixing between these states can be parameterized[21] in terms of a strange axial-vector mixing angle θ_K as

$$\begin{aligned} K_1(1400) &= K_A\, cos(\theta_K) - K_B\, sin(\theta_K) \\ K_1(1270) &= K_A\, sin(\theta_K) + K_B\, cos(\theta_K) \end{aligned}$$

From the observed mixing in the decays of the $K_1(1270)$ to mainly $K\rho$ and of the $K_1(1400)$ to mainly $K^*\pi$, along with the axial-vector nonet masses, one finds[21] two possible solutions for the mixing, $\theta_K \sim 33°$ or $\sim 57°$. Assuming K_A production only, the predicted ratio of partial widths for $\tau \rightarrow \nu_\tau K_1(1270)$ to that for $\tau \rightarrow \nu_\tau K_1(1400)$ depends strongly on the mixing angle and is found[21] to be:

$$\begin{aligned} \frac{B_{K_1(1270)}}{B_{K_1(1400)}} &= tan^2(\theta_K) \times (\text{phase space and kinematic factors}) \\ &= \begin{cases} 0.76^{+0.42}_{-0.11} & \text{for } \theta_K = (33\ ^{+6}_{-2})° \\ 4.3^{+0.7}_{-0.9} & \text{"} \quad = (57\ ^{+2}_{-3})° \end{cases} \end{aligned}$$

Based on the experimental observations described in Sec. 7, one would have a hard time reconciling a large $K_1(1270)$ to $K_1(1400)$ ratio as given by the latter solution; thus, one is led to tentatively choose the opposite solution, $\theta_K \sim 33°$, which predicts a suppression of $\tau \rightarrow \nu_\tau K_1(1270)$.

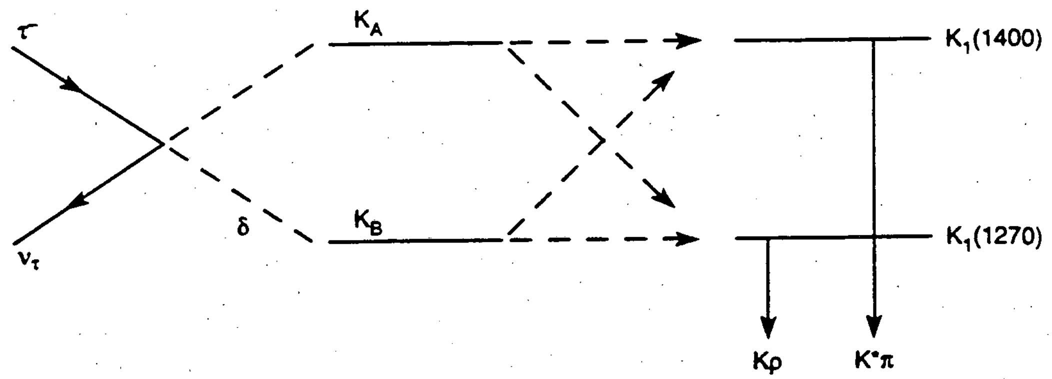

Figure 9: Schematic diagram indicating the various allowed paths in τ decays through the quark-spin eigenstates and their mixing to the final state strange axial-vector mesons.

8.2 Interference Effects

If the τ decays through an effective second-class coupling to the K_B as well as to the quark-spin favored K_A, then one also needs to take into account interference effects since the τ will decay through the two quark-spin eigenstates to the final state K_1 mass eigenstates, as sketched in Fig. 9.

From a determination of SU(3) symmetry breaking effects in the static quark-model limit, one can estimate[21] the relative decay amplitudes to be

$$\delta \sim \frac{1}{\sqrt{2}}\left(\frac{m_s - m_u}{m_s + m_u}\right) \sim 0.18$$

Assuming that there is no relative phase in the decay amplitudes, one would expect[21] relative partial widths of 0.32 for destructive or 1.6 for constructive interference in τ decay to $K_1(1270)$. The experimental observations would then favor destructive interference and suggest a strong suppression of $\tau \to \nu_\tau K_1(1270)$

$$\frac{B_{K_1(1270)}}{B_{K_1(1400)}} \sim 0.3.$$

For the $K_1(1400)$, one would then expect an enhancement of order 30% over the naive estimate, or about 10 events in the TPC/2γ sample from $\tau \to \nu_\tau K_1(1400)$ through the K^* to the $K^-\pi^+\pi^-$ final state, compared to the observed excess of 12 events.

9. Conclusions

The basic measurements of the strange decays of the τ are in place. However, the uncertainties in various τ decay mode definitions due to strange decays are of order 0.5% and need to be corrected.[18] Additional measurements of separated non-strange and strange decays are required to perform these corrections, and to more accurately determine the strange axial-vector decay rates.

There is much work to be done in the strange sector at the 0.1% level in determining exclusive charged plus neutral decay rates, searching for strange scalar decays, and in determining interference effects in the K_1 system by measuring both $K_1(1270)$ and $K_1(1400)$ decays.

Given the ideal environment of a τ decay laboratory, one looks forward to further elucidation of the nature of the strange charged-current couplings of the τ, and to the possibility of splendid interference measurements in the strange axial-vector system at future Tau/Charm factories.

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