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Charged Current Review

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Experimental measurements of the τ lifetime and leptonic branching ratios are combined to give updated world averages for these quantities. The results are then used to test the universality of the electroweak charged current couplings to the three lepton species and are found to be consistent with Standard Model predictions at the level of 0.2%, permitting limits to be derived on non-Standard Model physics such as the mass of the τ neutrino.

1. INTRODUCTION

Decays of τ leptons provide an excellent laboratory for precision testing of the charged current weak interaction. In particular, the Standard Model (SM) provides a robust prediction of the relationship between the τ lifetime and the leptonic branching ratios under the assumption of a $V-A$ structure for the weak charged current and a universal coupling strength. The SM effective charged current Lagrangian is given by

$$\mathcal{L}_{cc} = \frac{\mathrm{g}}{2\sqrt{2}} W_\mu^\dagger \left\{ \sum_{\ell=\mathrm{e},\mu,\tau} \bar{\nu}_\ell \gamma^\mu (1-\gamma_5)\ell + \bar{u}\gamma^\mu(1-\gamma_5)d_\theta \right\} + \ldots \quad , \tag{1}$$

where $d_\theta = (\cos\theta_c d + \sin\theta_c s)$ and θ_c is the Cabibbo angle. τ decays are mediated by a W boson, as shown in Fig. 1, which couples to the initial and final state fermions with strength g. The leptonic branching ratios, $\mathrm{B_e} \equiv \mathrm{B}(\tau^- \to \mathrm{e}^- \bar{\nu}_\mathrm{e} \nu_\tau)$ and $\mathrm{B}_\mu \equiv \mathrm{B}(\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau)$, are given by the expression

$$\mathrm{B}_\ell = \frac{G_{\tau\ell}^2 m_\tau^5 \tau_\tau}{192\pi^3} \; f(m_\ell^2/m_\tau^2) \; r_{ew} \tag{2}$$

where m_τ and τ_τ are the τ mass and lifetime respectively and $\ell = \mathrm{e}, \mu$. The quantity

$$f(x) = 1 - 8x + 8x^3 - x^4 - 12x\ln x \tag{3}$$

is a phase space correction for the final state charged lepton mass and has the values $f(m_\mu^2/m_\tau^2) = 0.97256$ and $f(m_\mathrm{e}^2/m_\tau^2) = 1.00000$ for μ and e final states respectively. The factor

$$r_{ew} = \left[1 + \frac{3m_\tau^2}{5m_W^2}\right] \left[1 + \frac{\alpha(m_\tau)}{2\pi}\left(\frac{25}{4} - \pi^2\right)\right] \tag{4}$$

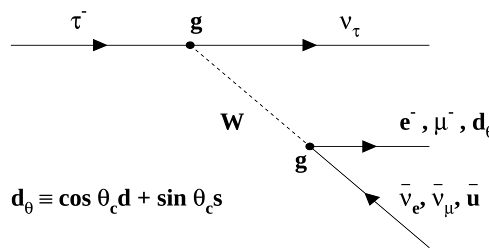

Figure 1. A τ decay via the weak charged current coupling with universal coupling strength g.

contains radiative corrections and corrections for the non-local nature of the W propagator [1] and has the value $r_{ew} \simeq 0.9960$. Under the SM assumption of universality ($\mathrm{g_e} = \mathrm{g}_\mu = \mathrm{g}_\tau$)

$$G_{\tau\ell} = \frac{1}{\sqrt{2}}\left(\frac{\mathrm{g}_\tau \mathrm{g}_\ell}{4m_\mathrm{W}^2}\right) \equiv G_F \tag{5}$$

is the Fermi constant obtained from muon decays.

This model of τ decays provides two aspects of the charged current interaction which can be tested experimentally: the Lorentz structure and the universality of the couplings. The Lorentz structure is accessible principally via measurements of the τ-decay Michel-type parameters. Measurements of these parameters are reviewed in a separate presentation at this workshop [2]. The universality of the couplings can be tested through measurements of the τ branching ratios and lifetime. It is worth noting, however, that even if the coupling strength is universal there may be additional non-SM contributions to the τ leptonic decay widths,

$$\Gamma(\tau^- \to \ell^- \bar{\nu}_\ell \nu_\tau) = (1+\Delta_\ell)\cdot\Gamma(\tau^- \to \ell^- \bar{\nu}_\ell \nu_\tau)_{\rm SM} \quad (6)$$

which may alter the relationship in Eq. 2 between the branching ratios and the lifetime. For example, the existence of an additional contribution to the leptonic widths mediated by a scalar boson, such as a MSSM charged Higgs boson, would manifest itself as a deviation from the SM expectation for the τ decay Michel parameter η, but also as an apparent violation of μ - e universality [3,2] in leptonic τ decays. The various universality tests described in this work therefore are potentially sensitive to many different forms of non-SM physics.

2. MEASUREMENTS

World averages of the τ lifetime and leptonic branching ratios are currently dominated by the measurements reported by CLEO and the four LEP experiments ALEPH, DELPHI, L3 and OPAL. All of the LEP experiments have now either published or reported preliminary results based on essentially the entire LEP1 dataset (up to and including data from 1995). As such, it is unlikely that there will be substantial improvements in the current averages due to new measurements from LEP. In the near future the asymmetric B-factory experiments, Babar and Belle, will likely report new measurements based on data sets with very high statistics compared to LEP and with systematics which are similar to CLEO. It is therefore instructive to consider the differences between τ analyses performed at the Z^0 energy and those at the $\Upsilon(4s)$ resonance.

In e^+e^- collisions at a centre of mass energy of ~ 91 GeV, the decay products of τ-pair events are produced with a large boost relative to the centre of mass frame, resulting in a characteristic signature of two highly collimated, co-linear jets. The high centre of mass energy additionally causes $q\bar{q}$ events to produce a relatively large number of particles, permitting τ-pair events to be cleanly separated from the $q\bar{q}$ background by requiring low particle multiplicity. In the LEP analyses, an inclusive sample of τ-pair events is typically obtained using a selection based on event shapes, multiplicities and kinematic quantities such as the total energy and momentum in the event. This sample is relatively unbiased with respect to τ decay modes and typically has a non-τ background contamination of a few percent. This ability to cleanly and inclusively identify τ events has permitted τ lifetime and branching ratio measurements to be made with relatively small systematic uncertainties. However, τ analyses based on the entire LEP1 dataset typically report statistics of 1 - 2×10^5 τ pairs and consequently all LEP results reported here are statistically limited.

At B-factory energies (~ 10.5 GeV) the particle multiplicity in $q\bar{q}$ events is considerably lower than at LEP, making inclusive selection of τ-pair events much more difficult. In addition, the τ decay products possess a much smaller boost than at LEP and are consequently much less collimated. CLEO has relied on a method in which one of the two τ hemispheres, defined relative to the thrust axis of the event, is used to tag the event while the second hemisphere is used for the measurement [4]. Future branching ratio measurements by Belle and Babar will likely use a similar approach. Lifetime measurements at the two asymmetric B-factories suffer the additional disadvantage that the τ decay length is about an order of magnitude smaller than the ~ 2 mm which is seen at LEP. In contrast to LEP, however, the B-factory datasets already consist of several million τ events and it is expected that Babar and Belle will have samples on the order of 10^8 events within a few years of running. Consequently, τ lifetime and leptonic branching ratio results from the B-factories are expected to be limited by systematic uncertainties. Future measurements will depend critically on how well these systematics can be controlled.

3. BRANCHING RATIOS

Since TAU'98, new preliminary leptonic branching ratio measurements have been reported by L3 and ALEPH. Both of these results utilize the full LEP1 statistics and supersede previous analyses based on smaller datasets. The total number of measurements included in the world averages therefore remains the same. The L3 measurement is described in a separate presentation at this workshop [5] and other measurements which are included in the averages have been described in previous workshops in this series. The preliminary ALEPH measurement [6] is the only result which has not been separately presented and it is therefore summarized in the following section.

3.1. The ALEPH measurement

The ALEPH measurement of the τ leptonic branching ratios supersedes an earlier result based on the LEP 1991 - 1993 data sets. Two distinct methods are used to evaluate the branching ratios, following which the two results are combined to obtain the final measurements. The first method closely follows the earlier ALEPH analysis and is similar to that which has been used by other LEP experiments. An inclusive τ-pair sample is selected based primarily on particle multiplicity and total energy in the event. Additional kinematic requirements are applied to further suppress Bhabha and dimuon events. Events within the τ-pair sample are then divided into two τ hemispheres. Candidate $\tau^- \to \ell^- \bar{\nu}_\ell \nu_\tau$ hemispheres are required to contain a single charged track which is identified as an electron or muon using a likelihood-based particle ID algorithm. This method is applied to the 94 - 95 data and the result is combined with the previously published measurement based on the 91 - 93 data.

The second method uses τ hemispheres which are selected without previously applying a τ-pair selection. Electron and muon candidates are identified from the sample of τ hemispheres by requiring a single track with no associated hadronic activity and applying particle ID requirements. Bhabha, dimuon and two-photon events are then rejected using cuts based on event kinematics which are specific to the $\tau^- \to \mathrm{e}^- \bar{\nu}_\mathrm{e} \nu_\tau$ and $\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$ samples. The branching ratios are computed from the number of selected candidates, corrected for backgrounds and selection efficiencies, divided by the estimated number of τ decays in the data sample, which is derived from the integrated luminosity of the sample and an ALEPH measurement of the $\tau^+\tau^-$ cross section.

The two methods produce consistent results with comparable uncertainties. The measurement are combined, taking into account correlations between the two selected samples to give the (preliminary) ALEPH branching ratios

$$\begin{aligned} \mathrm{B_e} &= (17.783 \pm 0.072 \pm 0.032)\% \\ \mathrm{B}_\mu &= (17.290 \pm 0.069 \pm 0.029)\% \end{aligned} \tag{7}$$

where the first uncertainty is statistical in origin and the second is due to systematics. These are the most precise measurements of $\mathrm{B_e}$ and B_μ reported to date by a single experiment.

3.2. World averages

The TAU2000 averages for the τ leptonic branching ratios are obtained by combining the ALEPH and L3 preliminary results with an older preliminary B_μ measurement by OPAL [7] and with published measurements by other experiments [8]. Measurements contributing to the world averages are plotted in Fig. 2 and 3. Combining these results yield

$$\begin{aligned} \mathrm{B_e} &= (17.804 \pm 0.051)\% \\ \mathrm{B}_\mu &= (17.336 \pm 0.051)\% \quad . \end{aligned} \tag{8}$$

The relative precision of these averages is now better than 0.3% and they are clearly dominated by the measurements by CLEO and the four LEP experiments. All other measurements combined contribute less than 3% to the total weight. Unfortunately, the most precise measurements also possess a much higher consistency than would be expected for uncorrelated measurements, suggesting that they suffer from experimenter bias or other correlated systematic effects. The five CLEO + LEP results for $\mathrm{B_e}$ can be combined to give a χ^2 of 0.35, yielding a probability of less than 2%. Similarly, the five most precise B_μ measurements give a χ^2 of 1.41 for a probability of $\sim 15\%$, however in this case including the older measurements in the average reduces the probability even further. The excessively high internal consistencies of these measurements cannot be attributed entirely to conservative overestimation of systematic uncertainties, since the LEP results are all statistically limited.

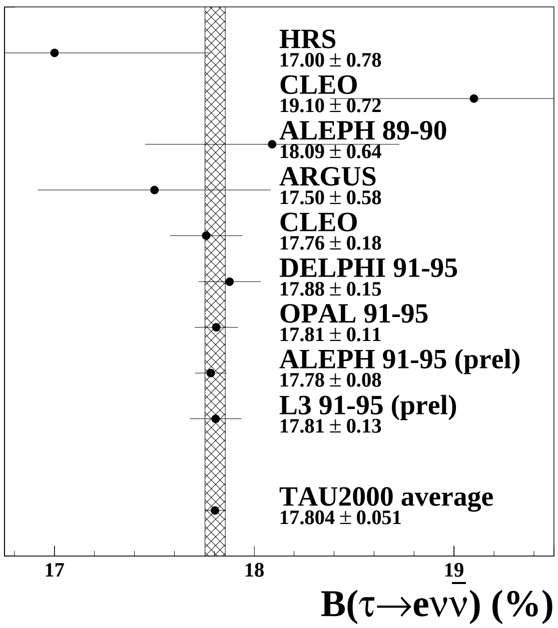

Figure 2. Measurements of B_e contributing to the world average. The hatched region represents the uncertainty on the TAU2000 average.

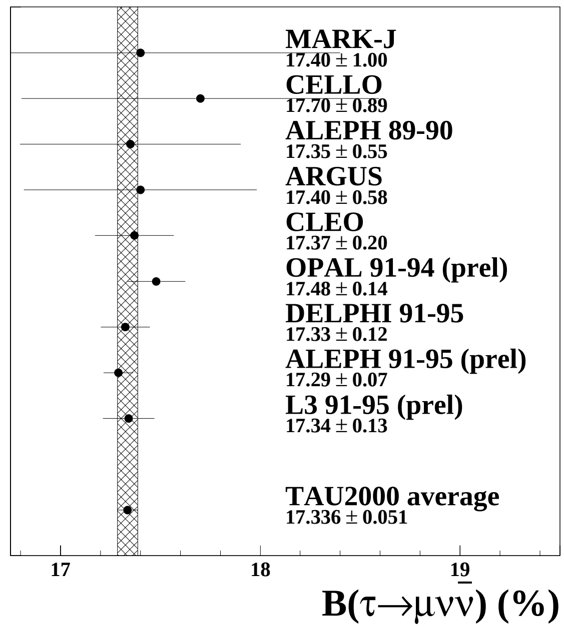

Figure 3. Measurements of B_μ contributing to the world average. The hatched region represents the uncertainty on the TAU2000 average.

3.3. μ - e universality

A test of μ - e universality can be obtained from these averages by comparing the ratio of the leptonic branching ratios and correcting for phase space effects:

$$\left(\frac{g_\mu}{g_e}\right)^2 = \frac{f(m_e^2/m_\tau^2)}{f(m_\mu^2/m_\tau^2)} \cdot \frac{B_\mu}{B_e} \quad . \tag{9}$$

Possible non-SM contributions to the partial decay widths, as expressed in Eq. 6, would contribute an additional term of $(1+\Delta_\mu)/(1+\Delta_e)$ to the left hand side of Eq. 9. This test therefore has sensitivity to non-SM physics which contributes differently to the $\tau^- \to e^-\bar{\nu}_e\nu_\tau$ and $\tau^- \to \mu^-\bar{\nu}_\mu\nu_\tau$ widths, such as for example the mass-dependent coupling of a charged Higgs boson.

The four LEP experiments and CLEO have independently reported values for the ratio g_μ/g_e determined from B_e and B_μ measurements by each collaboration [4–7,9]. These results are plotted in Fig. 4. The world average for the ratio g_μ/g_e is obtained by combining g_μ/g_e values reported by individual experiments when available, with the value obtained using the average of branching ratio measurements plotted in Fig. 2 and 3 for analyses which do not report a value of g_μ/g_e. This approach allows correlated systematic uncertainties in B_e and B_μ measurements to be properly taken into account by the individual experiments, resulting in an increased precision in the g_μ/g_e average. Since the combined LEP and CLEO measurements contribute almost all of the weight, the world average is numerically equal to that obtained with only these five results. The average,

$$\left(\frac{g_\mu}{g_e}\right) = 1.0010 \pm 0.0020 \quad , \tag{10}$$

is consistent with μ - e universality. Some caution must be exercised in the interpretation of limits derived using Eq. 10, since the high consistency of the experimental results could be evidence for an experimental bias toward the SM prediction, which would potentially mask non-SM effects.

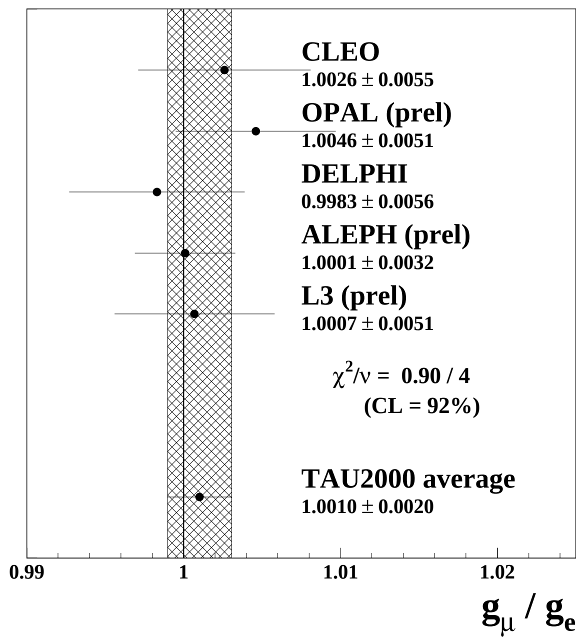

Figure 4. g_μ/g_e universality results reported by CLEO and the four LEP experiments. The hatched region represents the uncertainty on the TAU2000 average and the vertical line is the SM expectation.

However, it is worth noting that this result is becoming competitive with the most precise μ - e universality test currently available. This test compares the branching ratios of the helicity-suppressed decays $\pi^- \to \mu^-\bar{\nu}_\mu$ and $\pi^- \to e^-\bar{\nu}_e$. The current experimental data yield [10]

$$\left(\frac{g_\mu}{g_e}\right)_L = 1.0020 \pm 0.0016 \quad . \tag{11}$$

This test should not be thought of as equivalent to that of Eq. 10 though, since the decay of the spinless pion requires that the W be in a longitudinal state. It therefore has a different sensitivity to new physics than the test from Eq. 10 using leptonic τ decays.

4. TAU LIFETIME

Since TAU'98, there have been updated τ lifetime measurements reported by the L3 and

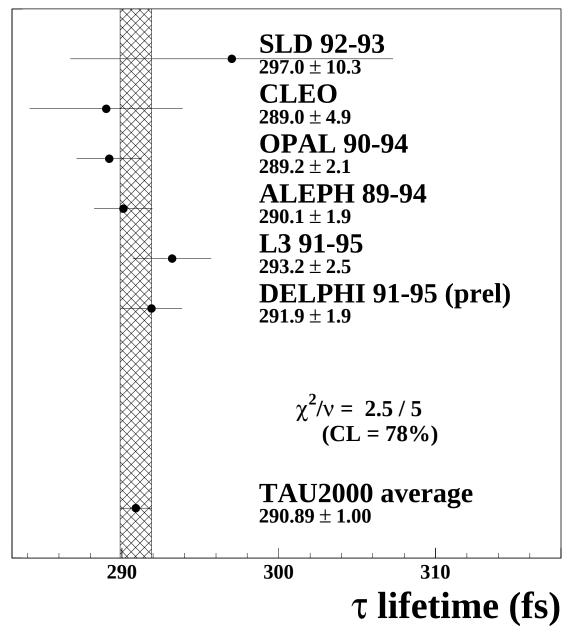

Figure 5. τ lifetime measurements contributing to the world average. The hatched region represents the uncertainty on the TAU2000 average.

DELPHI experiments using both the impact parameter and decay length methods. Both of the new measurements are based on essentially the entire LEP1 dataset and supersede earlier measurements by these experiments. The L3 measurement has recently been published [11], while the DELPHI result remains preliminary. Both of these analyses are described in separate presentations at this workshop [5,12].

The TAU2000 average is formed using the six measurements [8,13] shown in Fig. 5. Several earlier measurements with larger measurement uncertainties are not included since their inclusion has a negligible effect on the average. As is the case with the leptonic branching ratios, the consistency of the lifetime measurements is higher than should be expected, with only a 12% χ^2 probability[1].

[1] The DELPHI τ lifetime result reported by [12] is 1.2 fs lower than the value from [13] which was used in the average. Using the value from [12] results in a world average of $\tau_\tau = 290.57 \pm 0.98$ with $\chi^2/\nu = 2.1/5$

4.1. τ - e and τ - μ universality

The τ lifetime can be combined with the leptonic branching ratios to test $\tau - \mathrm{e}$ and $\tau - \mu$ universality. Using Eq. 2 and an analogous expression for the decay $\mu^- \to \mathrm{e}^- \bar{\nu}_\mathrm{e} \nu_\mu$, the following expressions can be derived:

$$\left(\frac{\mathrm{g}_\tau}{\mathrm{g}_\mu}\right)^2 = 0.9996 \cdot \frac{\tau_\mu m_\mu^5}{\tau_\tau m_\tau^5} \cdot \mathrm{B_e} \tag{12}$$

$$\left(\frac{\mathrm{g}_\tau}{\mathrm{g_e}}\right)^2 = 0.9996 \cdot \frac{\tau_\mu m_\mu^5}{\tau_\tau m_\tau^5} \cdot \frac{\mathrm{B}_\mu}{f(m_\mu^2/m_\tau^2)} \tag{13}$$

where the numerical factor accounts for electroweak propagator and radiative corrections in the τ and μ decays. Using PDG [8] values for the μ mass (m_μ) and lifetime (τ_μ), the BES measurement of the τ mass [14] and TAU2000 averages for the τ lifetime and leptonic branching ratios yields the results

$$\left(\frac{\mathrm{g}_\tau}{\mathrm{g}_\mu}\right) = 0.9994 \pm 0.0023 \tag{14}$$

and

$$\left(\frac{\mathrm{g}_\tau}{\mathrm{g_e}}\right) = 1.0000 \pm 0.0023 \quad . \tag{15}$$

Both ratios are consistent with the SM expectation to a precision of better than a quarter of a percent. The relationship given by Eq. 2 between the τ lifetime and leptonic branching ratios is plotted in Fig. 6, with the SM prediction indicated by the diagonal band. The width of the band, representing the uncertainty introduced by the experimental uncertainty in the τ mass, is not negligible compared to the current precision of the τ lifetime and branching ratio world averages.

Since the τ is significantly more massive than the other two charged leptons, it is reasonable to postulate that new physics will couple more strongly to the τ than to the other lepton generations. Under the assumption of $\mu - \mathrm{e}$ universality, the two τ leptonic branching ratios can be combined, correcting for phase space, to give the effective branching ratio for a τ decaying into massless leptons. The result,

$$\mathrm{B}_\ell = (17.814 \pm 0.036)\% \quad , \tag{16}$$

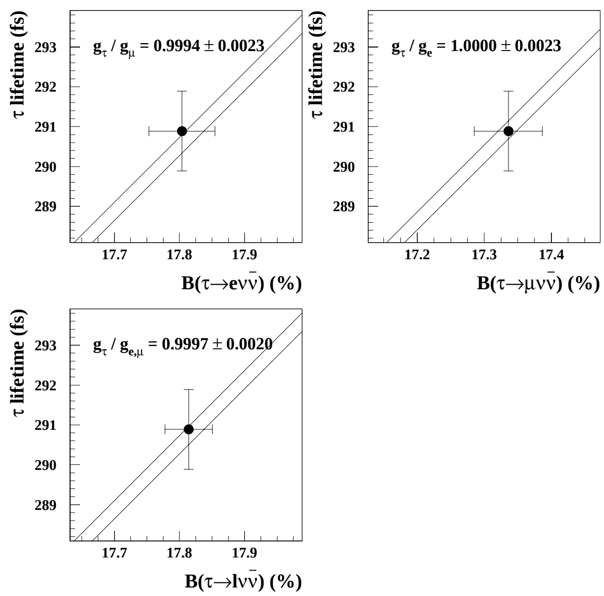

Figure 6. The τ lifetime plotted versus the leptonic branching ratios $\mathrm{B_e}$, B_μ and the effective branching ratio for a massless lepton, B_ℓ. The diagonal band represents the SM prediction, with the width reflecting the uncertainty in the τ mass. Note that the displayed region represents a range of $\pm 1\%$ of the central value of each axis, illustrating that the measurement uncertainty on τ_τ is comparable to that of $\mathrm{B_e}$ and B_μ, but is much large than that of B_ℓ.

can then be compared to τ_τ using Eq. 12 to give a more precise test of τ - ℓ universality:

$$\frac{\mathrm{g}_\tau}{\mathrm{g}_{\mathrm{e},\mu}} = 0.9997 \pm 0.0020 \quad , \tag{17}$$

which also shows no evidence for non-SM effects. It is clear from Fig. 6 that the uncertainty in $\mathrm{g}_\tau/\mathrm{g}_{\mathrm{e},\mu}$ is dominated by the uncertainty in the τ lifetime world average. Future improvements in the sensitivity of this universality test will therefore be due primarily to improvements in the determination of the τ lifetime rather than in the leptonic branching ratios.

4.2. τ neutrino mass

An hypothetical non-zero τ neutrino mass would introduce an additional phase space correction to Eq. 2, altering the relation between the lifetime and branching ratios. Assuming that the τ neutrino is significantly more massive than the other two neutrino generations, then there is no corresponding phase space correction to $\mu^- \to e^- \bar{\nu}_e \nu_\mu$ decays. In this scenario the relationships in Eq. 12 and 13 are modified by a factor Δ_ℓ ($\ell = \mu$,e) given by [15]

$$\Delta_\ell = -8 \cdot (m_{\nu_\tau}^2/m_\tau^2) \cdot (1 - m_\ell^2/m_\tau^2)^3 + ... \quad , (18)$$

permitting a limit to be placed on m_{ν_τ} using this universality test. Assuming that the W coupling is in fact universal, the result given in Eq. 17 implies a limit of $m_{\nu_\tau} < 37$ MeV at the 95% confidence level. This result is not competitive with direct limits from endpoint measurements [16] but it is an independent and complementary limit.

4.3. Semi-hadronic decays

An additional test of τ - μ universality can be obtained by comparing the branching ratios for $\tau \to \pi \nu_\tau$ and $\tau \to K \nu_\tau$ with leptonic decays of π and K mesons. The ratio of the coupling constants is given by

$$\left(\frac{g_\tau}{g_\mu}\right)^2 = \left\{\frac{2m_\mu^2}{m_\tau^2}\right\} \frac{B(\tau^- \to h^- \nu_\tau)}{H_\pi + H_K} \qquad (19)$$

where $h = \pi, K$ and

$$H_h = (1 + \delta_h) \left(\frac{\tau_\tau m_\tau}{\tau_h m_h}\right) \left[\frac{1-(m_h/m_\tau)^2}{1-(m_\mu/m_h)^2}\right]^2 \times B(h^- \to \mu^- \bar{\nu}_\mu) \qquad (20)$$

where τ_h and m_h are the pion and kaon lifetimes and masses respectively and δ_h accounts for radiative corrections [17]. In forming this ratio, the CKM matrix elements and decay constants $f_{\pi,K}$ associated with the meson production and decay vertices cancel, enabling a comparatively clean test of τ - μ universality to be obtained.

Using the TAU2000 average for τ_τ, the TAU'98 average [18] for $B(\tau^- \to h^- \nu_\tau) = (11.71 \pm 0.09)\%$ and PDG values for the other quantities, yields

$$\left(\frac{g_\tau}{g_\mu}\right)_L = 1.0029 \pm 0.0042 \quad . \qquad (21)$$

The precision of this universality test is currently about a factor of two worse than the tests from leptonic τ decays, but again it should be noted that this test is complementary since it has different sensitivity to potential forms of new physics.

5. τ HADRONIC WIDTH

The τ leptonic branching ratios and lifetime have sensitivity to the total hadronic width through the quantity R_τ, defined as

$$R_\tau \equiv \frac{\Gamma(\tau^- \to \text{hadrons } \nu_\tau)}{\Gamma(\tau^- \to e^- \bar{\nu}_e \nu_\tau)} \simeq 3 \cdot (1 + \delta_{QCD}) \quad (22)$$

where $\delta_{QCD} \simeq 0.2$ are QCD corrections to the parton-level prediction. The inclusive τ branching ratio to hadronic final states is simply unity minus the leptonic branching ratios, allowing R_τ to be obtained directly from B_e and B_μ. Assuming μ - e universality,[2] R_τ can be expressed as

$$R_\tau = \frac{1}{B_\ell} - 1.97256 \qquad (23)$$

or alternatively, it can be expressed in terms of the lifetime as

$$R_\tau = 0.9996 \cdot \frac{\tau_\mu m_\mu^5}{\tau_\tau m_\tau^5} - 1.97256 \quad . \qquad (24)$$

Substituting the TAU2000 averages into these equations yield

$$R_\tau = \begin{cases} 3.641 \pm 0.011 & \text{(branching ratios)} \\ 3.636 \pm 0.019 & (\tau \text{ lifetime}) \\ 3.640 \pm 0.010 & \text{(combined)} \end{cases} \qquad (25)$$

resulting in a combined experimental precision on R_τ of $\sim 0.25\%$. From the theoretical perspective, R_τ can be expressed as an operator product expansion

$$R_\tau = 3\left(|V_{ud}|^2 + |V_{us}|^2\right) S_{EW} \times \left\{1 + \delta_{EW} + \delta^{(0)} + \textstyle\sum_{D=2,4,...} \delta^{(D)}\right\} \qquad (26)$$

where S_{EW} and δ_{EW} are electroweak corrections and $\delta^{(D)}$ are non-perturbative and quark mass corrections [19]. The perturbative expansion, $\delta^{(0)}$, is know to $\mathcal{O}({\alpha_s}^3)$ and the $\mathcal{O}({\alpha_s}^4)$ term has been estimated:

$$\delta^{(0)} = \left(\frac{\alpha_s}{\pi}\right) + 5.2023\left(\frac{\alpha_s}{\pi}\right)^2 + 26.366\left(\frac{\alpha_s}{\pi}\right)^3 + (78.00 + d_3)\left(\frac{\alpha_s}{\pi}\right)^4 \qquad (27)$$

[2] A similar but less precise result may be obtained without this assumption.

where $d_3 = 27.5 \pm 27.5$ [20]. The perturbative contribution completely dominates $\delta_{\rm QCD}$, giving R_τ significant sensitivity to the strong coupling $\alpha_{\rm s}(m_\tau^2)$. The current experimental precision on R_τ from Eq. 25 translates into an uncertainty of approximately ± 0.003 on the extracted value of $\alpha_{\rm s}(m_\tau^2)$, compared with theoretical uncertainties of ~ 0.015. Recent papers describing leptonic branching ratio and lifetime measurements have quoted values of $\alpha_{\rm s}(m_{\rm Z}^2)$ with uncertainties of ~ 0.002, which are obtained by extracting $\alpha_{\rm s}(m_\tau^2)$ using this method and then evolving it to the $\rm Z^0$ scale. Although the consistency of these results with measurements of $\alpha_{\rm s}(m_{\rm Z}^2)$ obtained at higher energy scales is a remarkable test of the running of $\alpha_{\rm s}$, it is clear that such measurements will not benefit from future improvements in the experimental precision of τ branching ratio or lifetime measurements unless there are corresponding improvements in the theoretical uncertainties.

6. CONCLUSIONS

World averages of measurements of the τ lifetime and leptonic branching ratios currently have a relative precision of $\sim 0.3\%$, enabling the universality of the charged current couplings to be verified to an impressive precision of better than 0.2%. Unfortunately, the existing experimental measurements suggest of a degree of experimental bias which could reduce the sensitivity of these universality tests and thus potentially obscure evidence for non-SM physics. With all LEP experiments reporting statistically limited measurements based on essentially the entire LEP1 data set, it is not likely that there will be significant improvements in the world averages in the future due to new LEP results. Instead, future measurements will come from B-factory experiments and will most likely be limited by systematic, rather than statistical, uncertainties. Consequently, these measurements will potentially be even more susceptible to experimental bias. In order to maintain the integrity of these measurements it will be essential that appropriate steps be taken to reduce these biases.

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