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Comment on the τ decay puzzle

C.O. Escobar[a], O.L.G. Peres[b], V. Pleitez[b]
and
R. Zukanovich Funchal[a]

[a] *Instituto de Física*
Universidade de São Paulo
Caixa Postal 20516
01498-970 - São Paulo, S.P.
Brazil

[b] *Instituto de Física Teórica*
Universidade Estadual Paulista
Rua Pamplona, 145
014005-900 - São Paulo, S.P.
Brazil

Instituto de Física Teórica
Universidade Estadual Paulista
Rua Pamplona, 145
01405 - São Paulo, S.P.
Brazil

Telephone: 55 (11) 288-5643
Telefax: 55 (11) 36-3449
Telex: 55 (11) 31870 UJMFBR
Electronic Address: LIBRARY@IFT.UESP.ANSP.BR
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C.O. Escobar[a], O.L.G. Peres[b], V. Pleitez[b] and R. Zukanovich Funchal[a]

[a] Instituto de Física da Universidade de São Paulo,
01488-970–São Paulo, SP, Brazil.

[b] Instituto de Física Teórica
Universidade Estadual Paulista, Rua Pamplona, 145
01405-900–São Paulo, SP, Brazil.

Abstract

We analyze the current data on τ-lepton decays and show that they are consistent with the Standard Model.

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There has been recently great interest on possible problem with decays of the τ-lepton. These range from deviations of universality [1] to problems with branching ratios into particular decay channels [2,3].

In this note we point out that, provided an adequate analysis is adopted when comparing theoretical predictions with experimental data, there is no such problem.

First of all it should be stressed that the only theoretical prediction that can be actually made is the prediction for the partial rate into a particular channel (Γ_i^τ), where Γ_i^τ is the τ partial width of the decay into the i charged particle. It is not possible to theoretically predict branching ratios if we do not know all the decay channels. This is precisely the case of the τ lepton.

Now that we have defined what is theoretically predictable, it is rather clear what should be the procedure for comparison with experimental data. We should compare theory (Γ_i^τ) with those experiments which measure the same quantity, i.e., experiments having both measurements for branching ratios ($B.R$) and τ lifetime (τ_τ). We will use the notation $B_i^\tau = B.R.(\tau \to i + X)$ where i means the charged particle (lepton or hadron) and X denotes the corresponding neutrinos. We do not adopt the procedure of averaging the existent world data since this ignores the fact that not all experiments have measured both quantities. It is more sound to make comparison on a experiment by experiment basis, which is what we now present.

Let us start by the theoretical result for the partial width from the paper of Marciano [5,6], which includes radiative corrections, using the current data from Ref. [4]

$$
\begin{aligned}
\Gamma(\tau \to e^- \nu_\tau \bar{\nu}_e) &= (4.11^{+0.03}_{-0.04}) \times 10^{-13}\text{GeV}, \\
\Gamma(\tau \to \mu^- \nu_\tau \bar{\nu}_\mu) &= (4.00^{+0.03}_{-0.04}) \times 10^{-13}\text{GeV}, \\
\Gamma(\tau \to \pi \nu_\tau) &= (2.55 \pm 0.07) \times 10^{-13}\text{GeV}, \\
\Gamma(\tau \to K \nu_\tau) &= (1.66 \pm 0.04) \times 10^{-14}\text{GeV}, \\
\Gamma(\tau \to h \nu_\tau) &= (2.71 \pm 0.07) \times 10^{-13}\text{GeV}.
\end{aligned} \tag{1}
$$

The asymmetric errors come from the errors in the τ mass (m_τ) in Ref. [4], $m_\tau = 1784.1^{+2.7}_{-3.6}$MeV. These results are compatible with calculations using the preliminary more precise measurement from BES experiment at BEPC in Beijing, $m_\tau = 1776.9 \pm 0.4 \pm 0.3$ MeV [7].

With the above theoretical values the following ratios can be computed:

$$\Gamma^\tau_{\mu e} = 0.973^{+0.010}_{-0.014},$$

$$\Gamma^\tau_{he} = 0.660^{+0.017}_{-0.018},$$
$$\Gamma^\tau_{h\mu} = 0.678^{+0.017}_{-0.018}, \qquad (2)$$

where we have defined $\Gamma^\tau_{ij} = \Gamma^\tau_i/\Gamma^\tau_j$ and $\Gamma^\tau_h = \Gamma^\tau_\pi + \Gamma^\tau_K$.

If instead we want to use all available data we compare the ratios of branching ratios (2), since this is also a clear theoretical prediction, with the ratios of experimental ratios $R_{ij} = B^\tau_i/B^\tau_j$. This comparison is displayed in Fig. 1. We see that there is also no conflict between two standard deviations.

The experimental results [8,9] are presented in Table 1.

We compare the theoretical predictions (1) with the data B^τ_i/τ_τ in Table 2. For those experiments having measurements of the branching ratios and lifetime we clearly see from Table 2 and Eqs. (1) that there is no conflict between theory and experiments within two standard deviations.

The ratio between the leptonic and the hadronic width is particularly useful as a theoretical prediction since this ratio does not depend on the τ lifetime but is dependent on the τ mass as m^2_τ. The agreement we just pointed out makes less important the issue of τ mass determination as stressed in Ref. [5]

Let us finally remark that mixing with a fourth generation although solving the τ lifetime problem [2,3], will not solve discrepancies in individual branching ratios [5].

We conclude that the present experimental data on the τ lepton decays are compatible with the Standard Model.

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References

[1] X. Li and E. Ma, Phys. Rev. Lett. **47**, (1981)1788.

[2] M. Shin and D. Silverman, Phys. Lett. **B213**, (1988)379.

[3] S. Rajpoot and M. Samuel, Mod. Phys. Lett. **A3**(16), (1988)1625.

[4] Particle Data Group, Phys. Rev. **D45**, Part II, (1992).

[5] W.J. Marciano, Phys. Rev. **D45**, (1992)R721.

[6] W.J. Marciano and A. Sirlin, Phys. Rev. Lett **61**, (1988)1815.

[7] Nading Qi, Preliminary Results of the Tau Mass Measurement from BES, Talk given at the 1992 Joint April meeting of APS, 20-24 April 1992, Washington DC.

[8] M. Dam,CERN-PPE/92-82
P. D. Acton et al. (OPAL), Phys. Lett. **B273**, (1991)355.
B. Adeva et al. (L3), Phys. Lett. **B265**, (1991)451.
H. Albrecht et al. (ARGUS), Phys. Lett. **B199**, (1987)580.
C. Bebek et al. (CLEO), Phys. Rev. **D36**, (1987)690.
P. Abreu et al. (DELPHI), CERN-PPE/91-115.

[9] D. Decamp et al. (ALEPH), Z. Phys. **C54**, (1992),211.
G. Alexander et al. (OPAL), Phys. Lett. **B266**, (1991)201.
B. Adeva et al. (L3), Phys. Lett. **B265**, (1991)451.
M. Dam, CERN-PPE/92-82.
R. Ammar et al. (CLEO), Phys. Rev. **D45**, (1992)3976.
H.J. Behrend et al. (CELLO), Z. Phys. **C46**, (1990)537.
H. Albrecht et al. (ARGUS), Z. Phys. **C53**, (1992)367.

FIGURE CAPTIONS

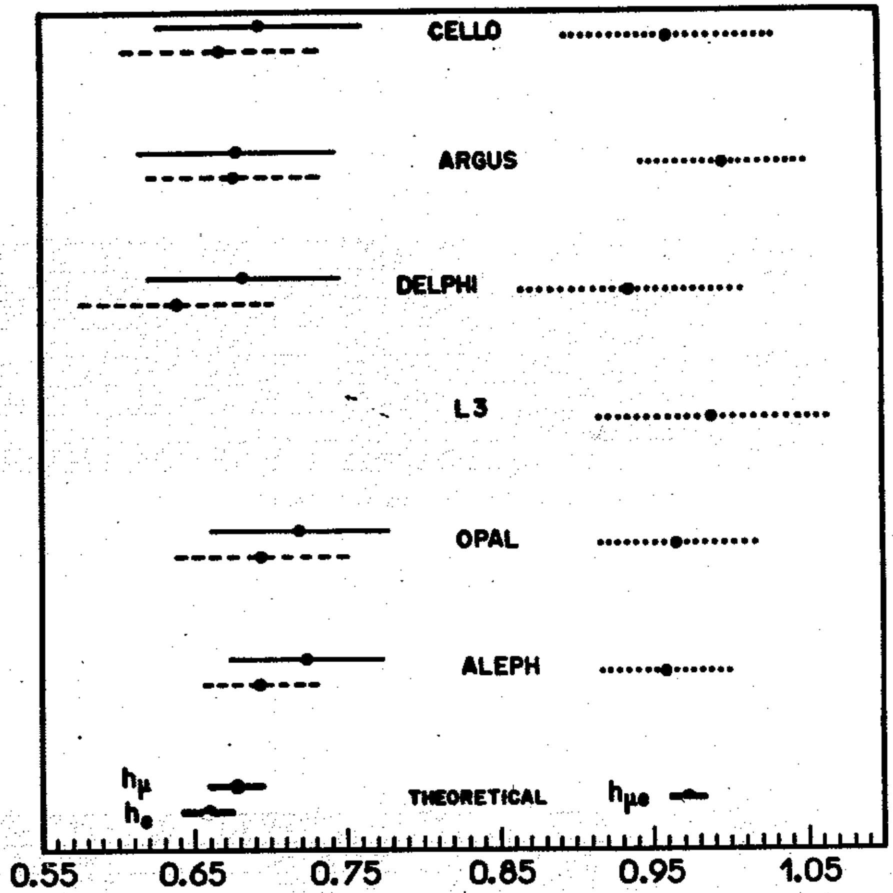
Fig. 1 Comparison of the theoretical (thick line) and experimental results for: (a) ratio of the branching ratios for hadronic and leptonic decays, $R_{h\mu} = B_h^\tau / B_\mu^\tau$ (continuous line) and $R_{he} = B_h^\tau / B_e^\tau$ (dashed line); (b) ratio of the leptonic branching ratios, $R_{\mu e} = B_\mu^\tau / B_e^\tau$ (dotted line).

Experiment	$\tau_\tau\,(10^{-13} sec)$ [8]	$B_e^\tau(\%)$ [9]	$B_\mu^\tau(\%)$ [9]	$B_h^\tau(\%)$ [9]
$ALEPH$	$2.95 \pm 0.10 \pm 0.05$	$18.09 \pm 0.45 \pm 0.45$	$17.35 \pm 0.41 \pm 0.37$	12.55 ± 0.55
$OPAL$	3.08 ± 0.13	$17.4 \pm 0.5 \pm 0.4$	$16.8 \pm 0.5 \pm 0.4$	$12.1 \pm 0.7 \pm 0.5$
$L3$	$3.09 \pm 0.23 \pm 0.30$	$17.7 \pm 0.7 \pm 0.6$	$17.5 \pm 0.8 \pm 0.5$	———
$DELPHI$	$3.14 \pm 0.23 \pm 0.04$	$18.6 \pm 0.8 \pm 0.6$	$17.4 \pm 0.7 \pm 0.6$	$11.9 \pm 0.7 \pm 0.7$
$ARGUS$	$2.95 \pm 0.14 \pm 0.11$	$17.3 \pm 0.4 \pm 0.5$	$17.2 \pm 0.4 \pm 0.5$	$11.7 \pm 0.6 \pm 0.8$
$CLEO$	$3.25 \pm 0.14 \pm 0.18$	$19.2 \pm 0.4 \pm 0.6$	———	———
$CELLO$	———	$18.4 \pm 0.8 \pm 0.4$	$17.7 \pm 0.8 \pm 0.4$	$12.3 \pm 0.9 \pm 0.5$

Table 1: Experimental data for τ-decays.

Experiment	$R_e^\tau/\tau_\tau \times 10^{-13}$GeV [8,9]	$R_\mu^\tau/\tau_\tau \times 10^{-13}$GeV [8,9]	$R_h^\tau/\tau_\tau \times 10^{-13}$GeV [8,9]
$ALEPH$	4.04 ± 0.21	3.87 ± 0.19	2.80 ± 0.16
$OPAL$	3.72 ± 0.21	3.59 ± 0.20	2.59 ± 0.21
$L3$	3.77 ± 0.50	3.73 ± 0.50	———
$DELPHI$	3.90 ± 0.37	3.65 ± 0.35	2.50 ± 0.29
$ARGUS$	3.86 ± 0.27	3.84 ± 0.28	2.61 ± 0.27
$CLEO$	3.89 ± 0.31	———	———

Table 2: Experimental partial widths, with the same notation of Table 1.



CELLO
ARGUS
DELPHI
L3
OPAL
ALEPH
h_μ
h_e
THEORETICAL
$h_{\mu e}$
0.55
0.65
0.75
0.85
0.95
1.05