τ physics at LEP

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This paper gives an overview of some of the more interesting results obtained at LEP in τ physics: precision measurements in neutral and charged currents universality and structure, τ mass, topological and exclusive Branching Ratios.

1. Introduction

The production and decay of the τ lepton at LEP has provided a large variety of tests of the Standard Model. At LEP I, the first phase of the collider running at centre of mass energies close to M_Z, the τ are predominantly produced in pairs, from the annihilation of an electron-positron pair into a Z boson. In total, about 500000 pairs have been collected by the four LEP experiments, providing a unique environment to study the couplings of the Z to heavy leptons, where many extensions of the Standard Model would induce significant modifications to the expectations.

At these energies, more than 20 charged particles are produced on average in hadronic events, allowing a very efficient and clean separation from the tau pairs. This fact, together with the significant amount of recorded τ, allows further precision studies on its decay: the leptonic decays are a very noticeable place to study the charged current universality and structure; the hadronic decays allow the study of the strong interaction at an intermediate q^2; neutrino physics...

At LEP II, where the centre of mass energy has been progressively increased until 208 GeV, two new broad subjects were opened: the study of the τ production in the decay of a W, permitting additional tests on the charged current and new particles searches, where the τ plays an interesting role. Each experiment recorded about 700 pb^{-1}, which represented about 50000 W pairs produced in total.

Only some these subjects will be reviewed here, more details being available in other talks of this conference [1,2,3].

2. Neutral currents

Different observables in the production of tau pairs through the decay of a Z boson, produced in a e^+e^- annihilation at different energies allow the precise measurement of the weak neutral couplings and as a consequence indirect bounds on new physics are set. The structure of the neutral currents, weak and electromagnetic, was also studied.

2.1. Lineshape at the Z resonance

The production cross section was extensively studied by all LEP experiments, as a function of the centre-of-mass energy. Results are often expressed in terms of the width (Γ_τ=$\Gamma(Z \to \tau\tau)$) or of its ratio to the hadronic width: $R_\tau = \Gamma_{had}/\Gamma_\tau$. Γ_τ is proportional to ${g_a}^2 + {g_v}^2$, the axial and vectorial couplings to the Z. Being the vectorial coupling much smaller than the axial, this observable essentially provides a measurement of the axial coupling. Another observable studied at LEP is the forward-backward charge asymmetry, A_{FB}, defined as the fraction of τ^- produced in the forward direction, defined according to the incoming electron. This quantity, at tree level, at $E_{cm} = M_{\rm Z}$ and neglecting γ exchange, can be expressed as $A_{FB} = \mathcal{A}_e\mathcal{A}_\tau$, where $\mathcal{A}_l = \frac{2g_v g_a}{{g_a}^2+{g_v}^2} \approx 2\frac{g_v}{g_a}$, providing information on the vector coupling, but not on its sign. An example of the angular dependence used to extract the asymmetry is shown in figure 1. Figure 2 shows the dependence of this magnitude with the centre of mass energy.

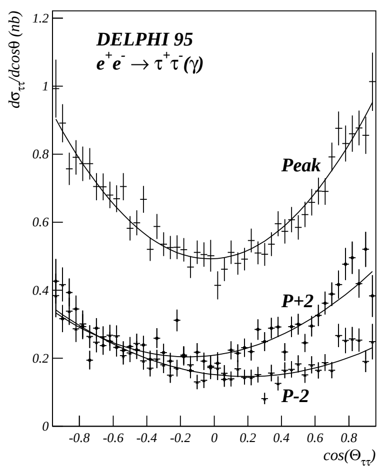

Figure 1. Forward-backward charge asymmetry. Polar angle distribution for tau pairs measured by the DELPHI experiment compared to the fit result.

The final results for each of the LEP collaborations and its combination, together with the comparison with the Standard Model prediction as a function of the top quark and Higgs boson masses are shown in figures 3 and 4 (more details in [4]).

2.2. τ polarisation

The fermions pairs produced in the annihilation of a Z are polarised. This polarisation is only measurable for $\tau^+\tau^-$, because the τ lepton decays inside the detector through a weak interaction, violating parity. The τ spin can be inferred from its decay products. Different polarisation estimators [5] can be built from the measured kinematical quantities, once the decay channel is identified. Figure 5 shows an example of the different distributions used and its sensitivity to the polarisation.

Furthermore, this polarisation depends on the polar angle through the expression (at tree level):

$$\mathcal{P}_\tau(\cos\Theta) = \frac{\mathcal{A}_e \cdot (1+\cos^2\Theta) + \mathcal{A}_\tau \cdot 2\cos\Theta}{(1+\cos^2\Theta) + \frac{4}{3}A_{FB} \cdot 2\cos\Theta}. \quad (1)$$

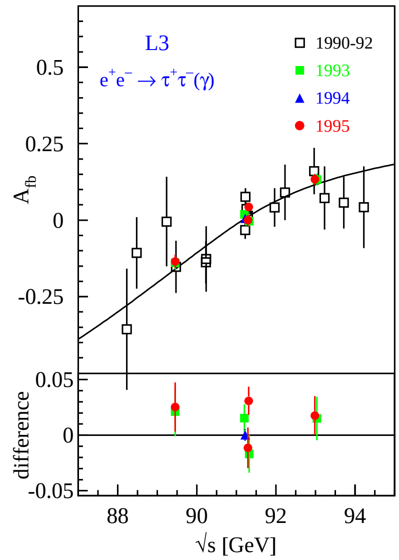

Figure 2. Centre of mass energy dependence of A_{FB} measured by the L3 experiment. compared to the Standard Model prediction. The bottom part of the plot shows the residual difference between the measured points and the expectation.

This dependence was studied by the four experiments, measuring the average polarisation in restricted polar angle ranges. An example of the result is shown in Figure 6. The measurement of the polarisation as a function of the production polar angle provides an almost independent measurement of $\mathcal{A}_e$ and $\mathcal{A}_\tau$, and as a consequence, independent measurement on the τ and electron vector coupling (including its sign).

The final results are shown in figure 7 and 8, together with its combination accounting for common systematic errors[4].

2.3. Universality

The measurements discussed above are treated coherently in the Standard Model framework, including radiative corrections, to extract the vector and axial couplings to the Z to any lepton. The results [4] are summarised in figure 9, where the results from SLD are also included. The

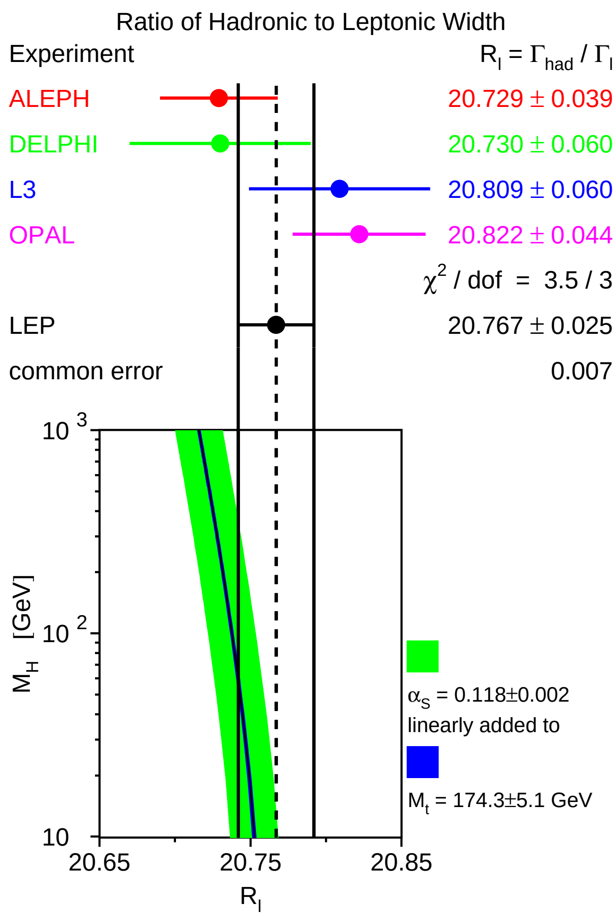

Figure 3. LEP results for the leptonic width of the Z, compared to the Standard Model expectation (see [4] for more details).

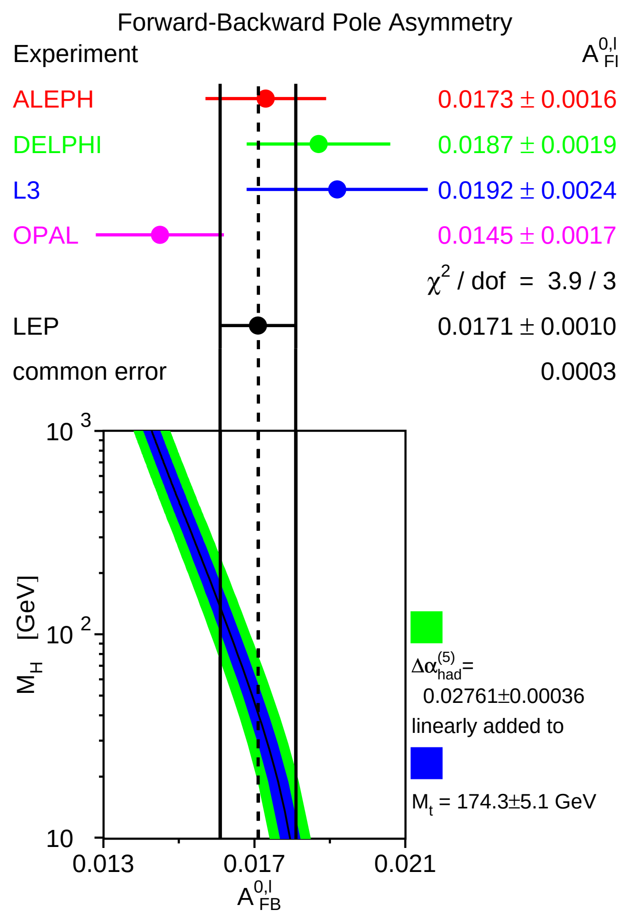

Figure 4. LEP results for the forward backward charge asymmetry, compared to the Standard Model expectation (see [4] for more details).

agreement between the three 68% CL surfaces shows that the universality is fulfilled, setting bounds on unknown Standard Model parameters and new physics (see [4] for more details). It can also be appreciated that the inclusion of tau polarisation measurements improves significantly the precision on the axial coupling to electron and taus. Accepting that the universality is fulfilled, one can extract the value of $\sin^2\theta_W$ from each of these measurements. The results are shown in figure 10 and compared to those obtained through other observables. We can see that the combination of tau observables, give a similar precision to the most precise b quark charge asymmetry.

2.4. Electric and magnetic dipole moments

The structure of the electromagnetic interaction neglecting radiative corrections would be purely vector. However, the radiative corrections distort this picture. The Standard Model predicts a magnetic dipole (a_τ^γ) of 0.11, while the electric dipole (d_τ^γ) is still exactly 0. Models like lepton compositeness or CP violation scenarios predict a non zero electric dipole and an enhancement of the magnetic dipole.

OPAL [6] and L3 [7] use the E_γ differential

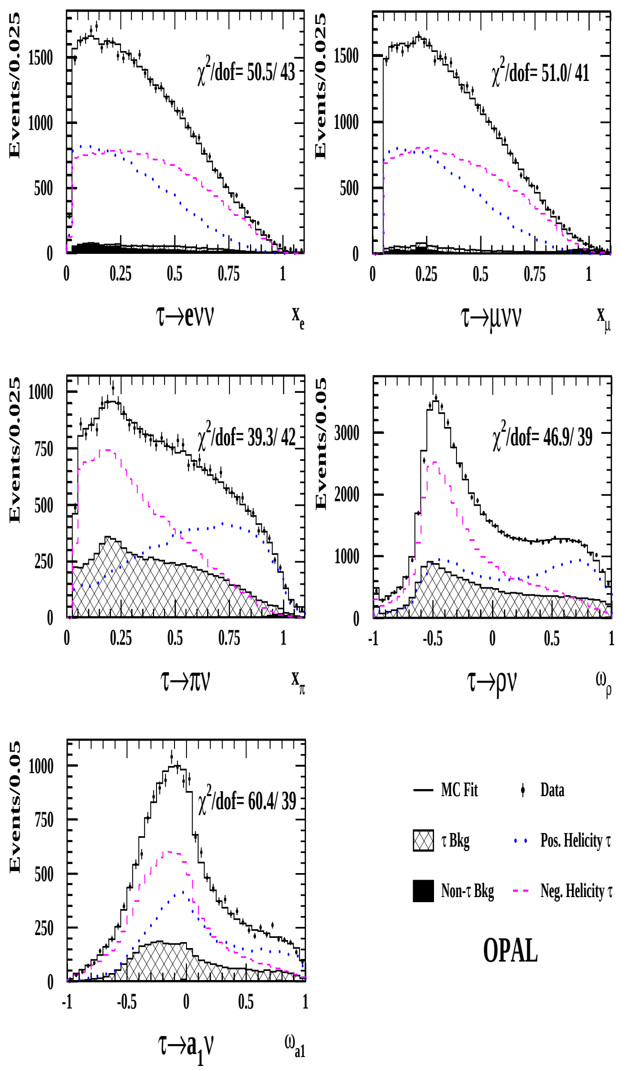

Figure 5. Distribution of the polarisation estimators for the different channels studied by the OPAL experiment, compared with the Standard Model expectation for positive or negative helicity.

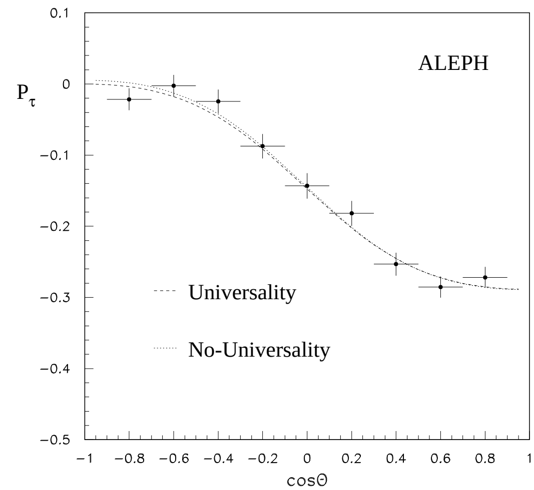

Figure 6. Angular dependence of $\mathcal{P}_\tau$ as measured by the ALEPH experiment, compared with the Standard Model expectation.

cross section in $\tau^+\tau^-\gamma$ events at the Z. The photon energy spectrum is fitted to a linear combination of the **SM** expectation plus an additional contribution from terms with anomalous magnetic or electric dipoles. The limits at 95% CL are:

$-0.052 < a_\tau^\gamma < 0.058$ (L3)
$-0.068 < a_\tau^\gamma < 0.065$ (OPAL)
$-3.1\ 10^{-16} < Re(d_\tau^\gamma) < 3.1\ 10^{-16}$ e cm (L3)
$-3.8\ 10^{-16} < Re(d_\tau^\gamma) < 3.2\ 10^{-16}$ e cm (OPAL)

DELPHI [8] and L3 [9] also used the $\gamma\gamma$ collisions at or above the Z. The production cross section of this process is also sensitive to the anomalous dipole moments, allowing an additional measurement. The preliminary results are:

$-0.062 < F_2 < 0.044$ (L3)
$-0.017 < a_\tau^\gamma < 0.019$ (DELPHI)
$|Re(d_\tau^\gamma)| < 6.7\ 10^{-16}$ e cm (L3)
$|Re(d_\tau^\gamma)| < 3.8\ 10^{-16}$ e cm (DELPHI)

where F_2 is an average form factor not extrapolated to $q^2 = 0$, $a_\tau^\gamma = F_2(q^2 = 0)$.

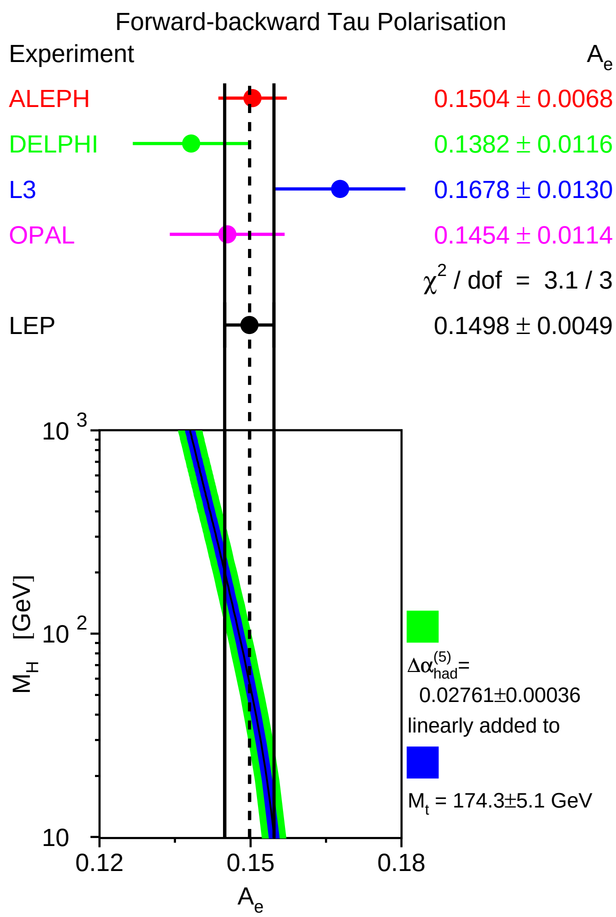

Figure 7. LEP results for $\mathcal{A}_e$ obtained from the tau polarisation, compared to the Standard Model expectation (see [4]).

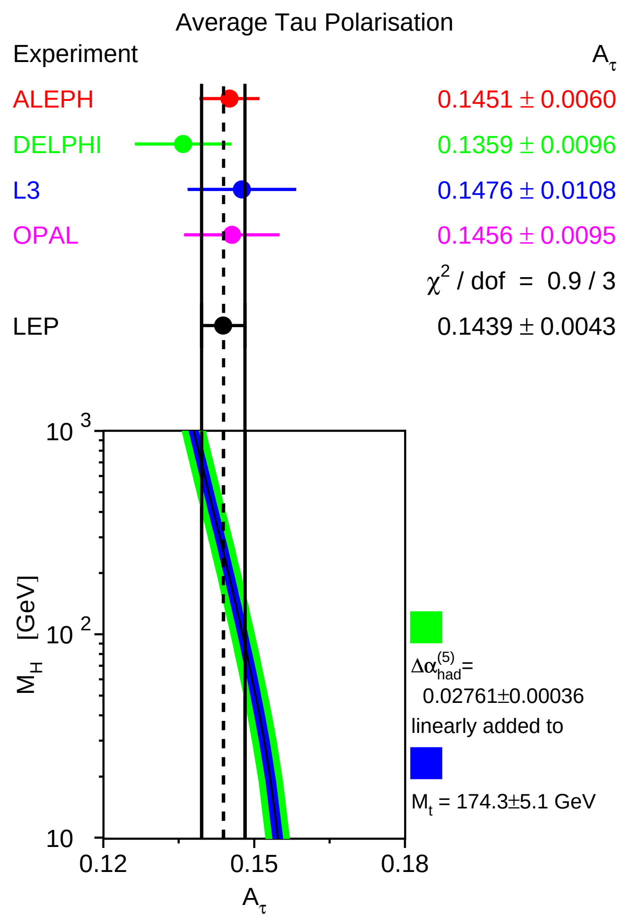

Figure 8. LEP results for $\mathcal{A}_\tau$ obtained from the tau polarisation, compared to the Standard Model expectation (see [4]).

In addition, different studies interpret many precision measurement of tau observables in the framework of a possible non-zero dipoles. One of these studies [10] uses LEP I tau production cross sections, forward-backward asymmetry and polarisation measurements together with LEP II and Tevatron results on W decay to τ to set the limit $-0.007 < a_\tau^\gamma < 0.005$ at 95% CL . A similar study [11] based only on LEP I data sets the limit $-0.004 < a_\tau^\gamma < 0.006$ and $|Re(d_\tau^\gamma)| < 1.1\ 10^{-17}$ e cm at 95% CL.

Similarly, the radiative corrections modify the pure vector/axial−vector structure of the weak neutral current. Very small values are predicted by the Standard Model, but again there is some enhancement in many extensions of the Standard Model. All LEP experiments have studied the existence of a CP-violating electric-weak dipole using a CP-odd observable, based on tau spin correlation. L3 has additionally investigated the weak-magnetic dipole defining several parity odd azimuthal asymmetries in hadronic decays. No new results have been published in the last two years and therefore the interested reader is addressed to previous reviews [12].

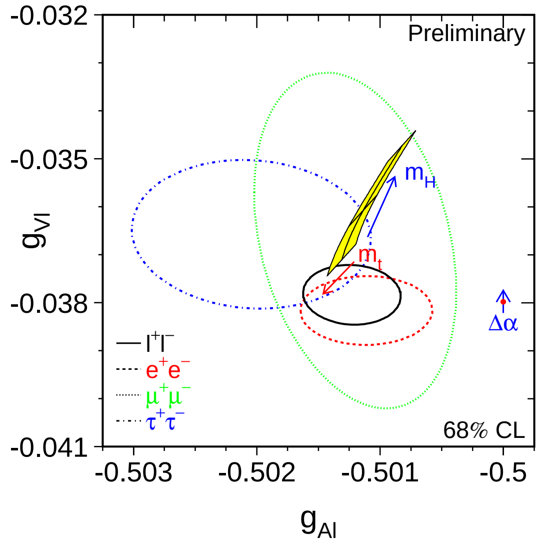

Figure 9. Results on the leptonic vector and axial vector couplings to the Z, obtained from the fit of all observables . The different lines show the 2D contours corresponding to 68% CL, for each of the leptons and for their combination.

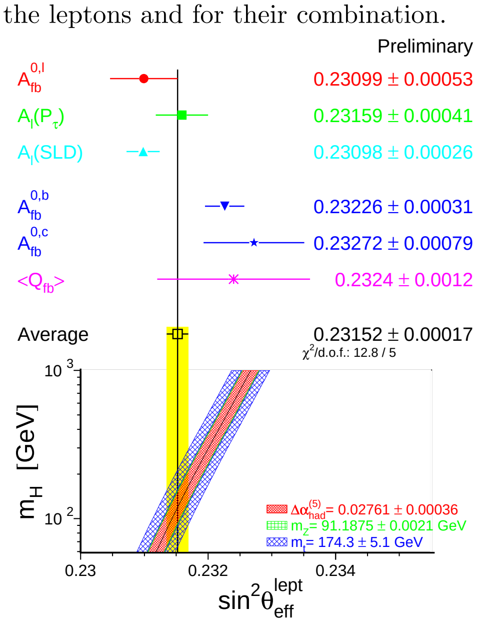

Figure 10. Comparison of the $\sin^2\theta_W$ weak mixing angle as obtained by different methods at LEP and SLD.

2.5. Lineshape above the Z resonance

All LEP experiments have extended the lineshape measurement to the higher energy runs up to centre of mass energy of 208 GeV. At these energies, an additional precision measurement of the $\gamma - Z$ interference is performed. The improvement in the precision of the weak couplings is marginal, but on the contrary there is a significant sensitivity to new physics such as models with additional Z bosons or with contact interactions. Results are shown in figures 11 to 13 [4]. Good agreement with the standard Model was found in all cases and therefore the results were used to set limits on new physics [4]. DELPHI has also measured $\mathcal{P}_\tau$ at higher energies [13], giving a result of $\mathcal{P}_\tau = -0.16 \pm 0.13 \pm 0.05$ for an average centre of mass energy of 190 GeV, consistent with the Standard Model expectation.

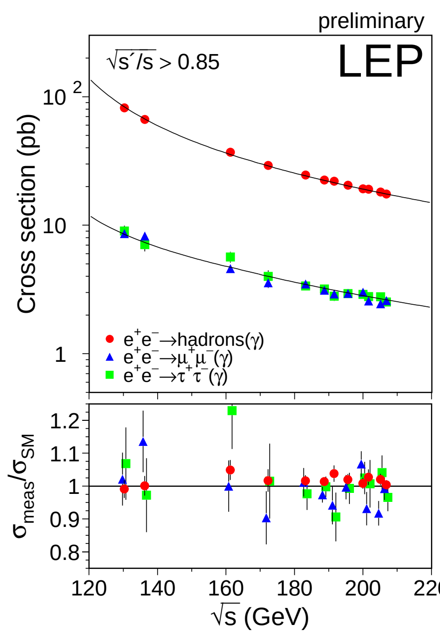

Figure 11. Leptonic cross section e^+e^- annihilation as a function of the centre of mass energy above the Z resonance. The bottom part of the plot shows the residual difference between the measured points and the expectation.

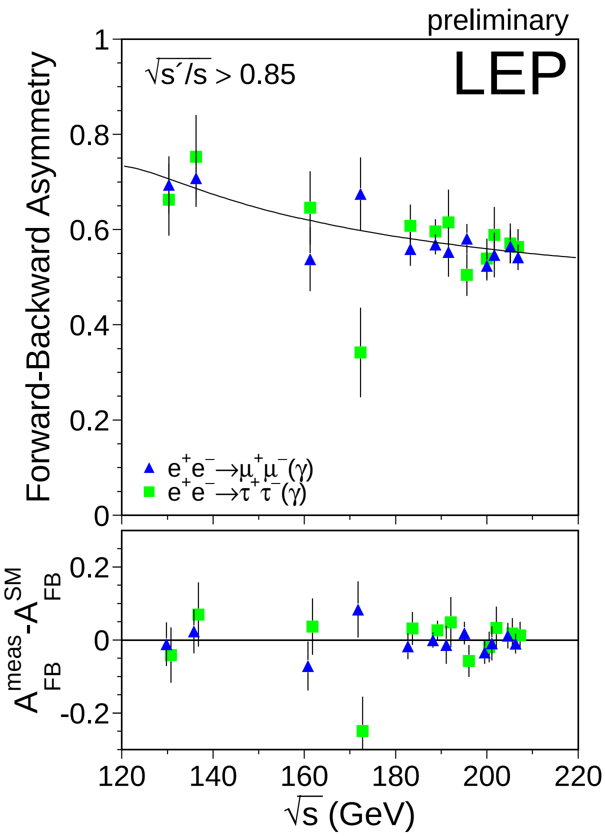

Figure 12. Forward-backward charge asymmetry in e^+e^- annihilation as a function of the centre of mass energy above the Z resonance. The bottom part of the plot shows the residual difference between the measured points and the expectation.

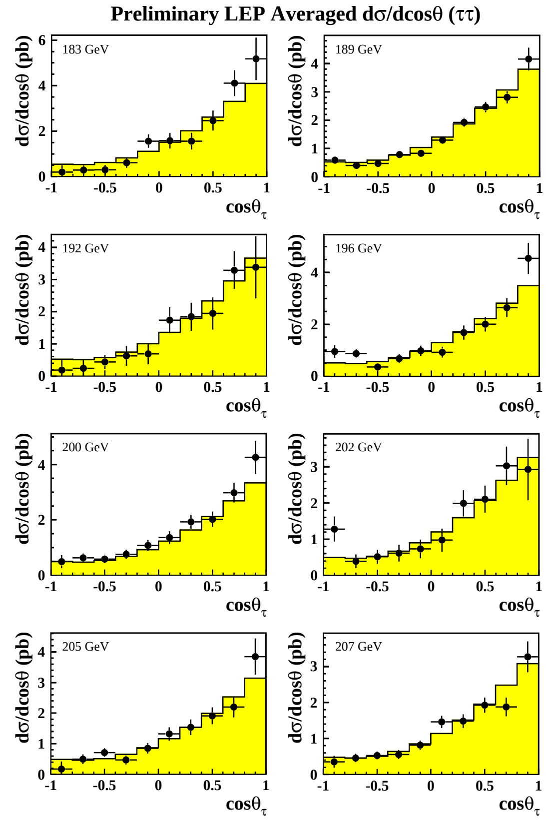

Figure 13. $\tau^+\tau^-$ differential cross section in e^+e^- annihilation as a function of the centre of mass energy above the Z resonance.

3. Charged currents

The weak decay of the tau inside the LEP detectors allows a number of interesting studies of the weak charged current. The W boson decay to leptons provides further information for equivalent tests, but at a different energy scale and with an 'on-shell' W. In particular, the decay $W \to \tau\nu$ is sensitive to many extensions of the Standard Model.

3.1. Universality in tau decays

In the Standard Model and assuming V-A coupling and massless neutrino, the tau decay leptonic widths are given by

$$\Gamma(\tau \to l\nu_\tau\overline{\nu}_l) = \frac{g_{l\tau}^2 m_\tau^5}{192\pi^3} f(\frac{m_l^2}{m_\tau^2}) r_{RC}^\tau \qquad (2)$$

Here, $f(\frac{m_l^2}{m_\tau^2})$ is a phase space factor with value 1.0000 for electrons and 0.9726 for muons. The quantity r_{RC}^τ is a factor due to electroweak radiative corrections, which has the value 0.9960, in both leptonic decays. Then, the ratio of the two leptonic widths (or Branching Ratios), provides a direct comparison of the couplings g_e and g_μ.

$$\frac{B(\tau \to \mu\nu\bar{\nu})}{B(\tau \to e\nu\bar{\nu})} = \frac{g_\mu^2}{g_e^2} \cdot \frac{f(\frac{m_\mu^2}{m_\tau^2})}{f(\frac{m_e^2}{m_\tau^2})} \qquad (3)$$

ALEPH [1] and OPAL [14] have recently presented new preliminary results on the leptonic Branching Ratios, while DELPHI [15] and L3 [16] have published their final results. These results are summarised in figures 14 and 15 together with the results obtained by other experiments [17] and the averages[1]. The comparison between the two Branching Ratios using expression 3 yields $g_\mu/g_e = 0.9999 \pm 0.0020$, perfectly compatible with electron-muon universality. This measurement is almost as precise as the similar test done in pion decay ($g_\mu/g_e = 1.0017 \pm 0.0015$).

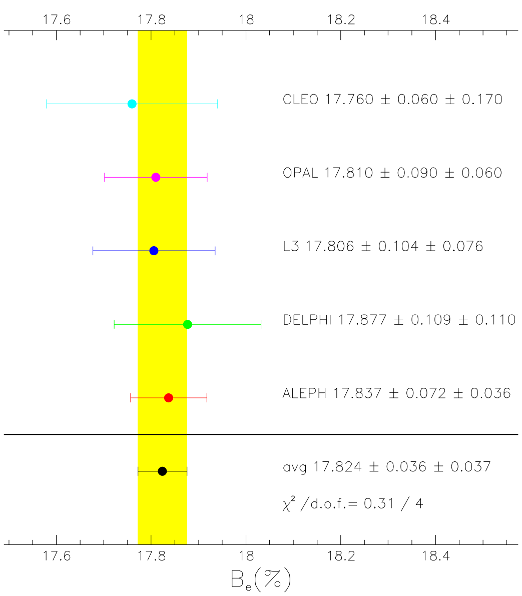

Figure 14. Results on the $\tau \rightarrow e\nu\bar{\nu}$ Branching Ratio.

Using the τ and μ mass and lifetime measurements, together with the analogue of equation 2 for muon decay, a further universality test can be performed, comparing the τ couplings to those of the lighter leptons. Figure 16 shows the current results on the lifetime [18,19,20], including new

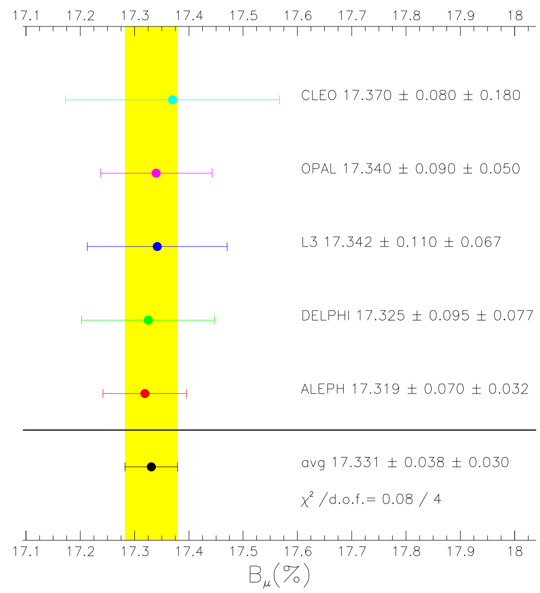

Figure 15. Results on the $\tau \rightarrow \mu\nu\bar{\nu}$ Branching Ratio.

preliminary results from DELPHI [21]. Assuming e - μ universality, we can combine the electron and muon Branching Ratios (correcting the second to account for mass effects) into a single BR for a massless lepton and then the comparison of the muon and tau lifetimes yields: $g_\tau/g_l = 1.0004 \pm 0.0010(BR) \pm 0.0017(\tau_\tau) \pm 0.0004(m_\tau)$. The error is split into the contributions from the leptonic Branching Ratios, the τ lifetime and mass, respectively, being other contributions negligible.

There is another possible test comparing the tau lifetime and the widths $\Gamma(\tau \rightarrow \pi\nu)$ and $\Gamma(\tau \rightarrow K\nu)$ with the π and K lifetimes and the widths $\Gamma(\pi \rightarrow l\nu)$ and $\Gamma(K \rightarrow l\nu)$. ALEPH [1] and DELPHI [30] presented recently new preliminary measurements of the Branching Ratio to $\tau \rightarrow \pi^\pm\nu$. Figure 17 shows these results together with those of other experiments. The comparison gives $g_\tau/g_l = 1.0000 \pm 0.0033(BR) \pm 0.0017(\tau_\tau) \pm 0.0002(m_\tau)$.

[1] The averages are done here and thereafter assuming uncorrelated systematic errors between experiments.

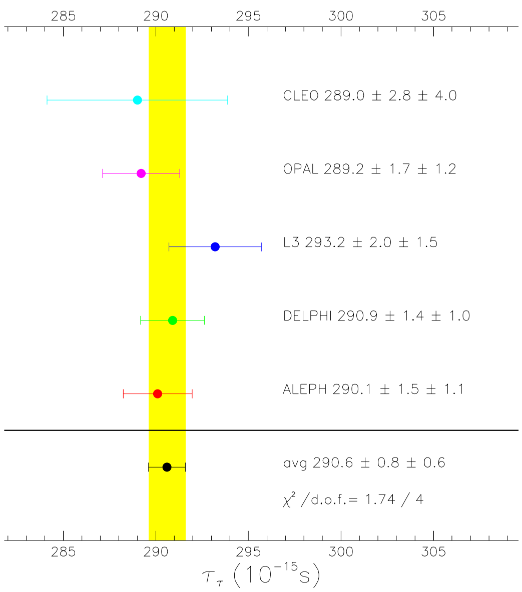

Figure 16. Results on the τ lifetime.

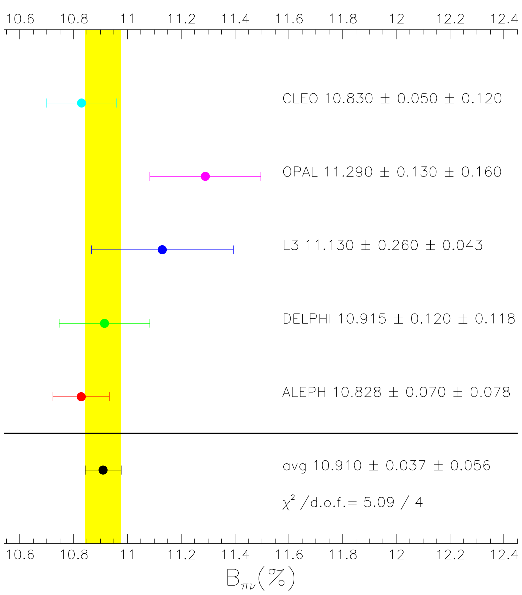

Figure 17. Results on the $\tau \to \pi^{\pm}\nu$ Branching Ratio.

3.2. W leptonic decays

Similar tests can be performed with the comparison of the decay widths of the W to the different leptons, $\Gamma(W \to l\nu) \propto g_l^2$. The preliminary analysis of the 40000 W pairs selected at LEP gives the Branching Ratios summarised in figure 18 [4]. They yield the following ratios of the leptonic couplings:

$g_\mu/g_e = 1.000 \pm 0.011$
$g_\tau/g_\mu = 1.026 \pm 0.014$
$g_\tau/g_e = 1.026 \pm 0.014$
$g_\tau/g_l = 1.026 \pm 0.010$ (e-μ univ. assumed)

improving significantly the current Tevatron measurements [17]:

$g_\mu/g_e = 0.986 \pm 0.029$
$g_\tau/g_e = 0.988 \pm 0.025$
$g_\tau/g_\mu = 1.002 \pm 0.038$ (not ind. from the above)
$g_\tau/g_l = 0.988 \pm 0.025$ (e-μ univ. assumed)

The combination of both sets of measurements give:

$g_\mu/g_e = 0.998 \pm 0.010$
$g_\tau/g_l = 1.021 \pm 0.009$ (e-μ univ assumed)

which are significantly less precise than those from the tau decays, but are sensitive to different potential new physics, because the intervening W is 'on-shell' and the q^2 is much higher. It is interesting to note that there is an intriguing hint of a departure from universality between the τ and light lepton couplings, a discrepancy at 2.3 standard deviations. However, this discrepancy is clearly compatible with a statistical fluctuation and it is still to be confirmed with the final publication of the results.

3.3. Summary on charged current universality and implications

The current state of the art is summarised in figures 19 and 20. These results can be translated into limits on new physics. The limits on a charged higgs are discussed in the next section in combination with the Michel parameters. Here I will just mention an example of bounding the tau neutrino mass and the mixing with an hypothetical 4^{th} family neutrino. If the ν_τ mass is

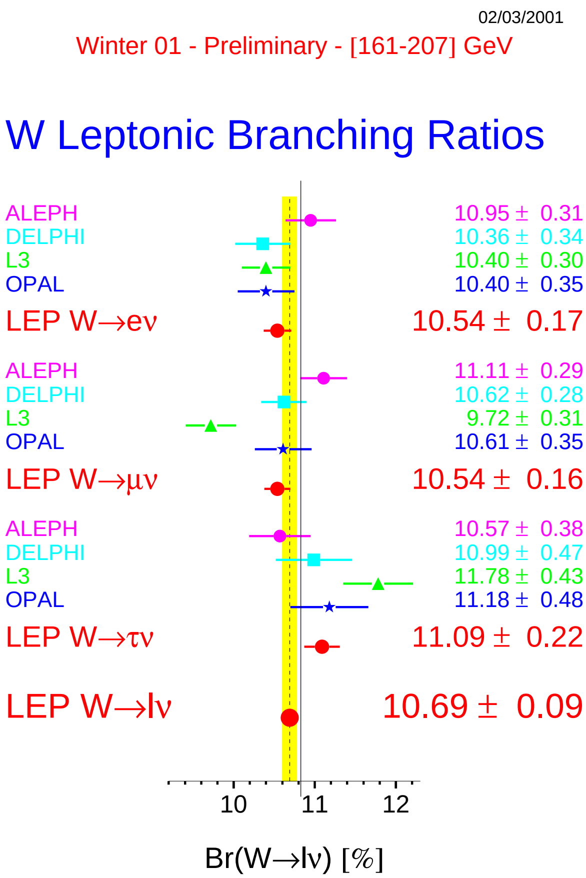

Figure 18. LEP results on W leptonic Branching Ratios.

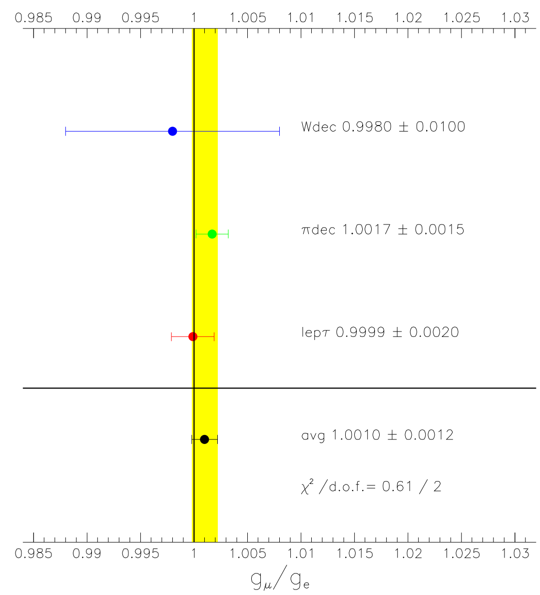

Figure 19. Summary of the status of muon-electron Universality measurements with different methods: W decay, pion decay and τ leptonic decays.

different from 0 or a 4^{th} family neutrino with non-zero mixing exist, the different decay amplitudes will be affected [22], with the consequent reflect on the universality of the couplings. The current measurements allow to set the following limits at 95% C.L.:

$m_{\nu\tau} < 32$ MeV
$|\sin\theta_{\nu\tau-\nu4}| < 0.057$

3.4. Lorentz structure

In the Standard Model the charged current interaction is assumed to be of the type V-A, a vector and an axial-vector couplings with the same magnitude and opposite sign. However, there is no fundamental reason for that and the existence of more general couplings is still possible.

There are stringent experimental results that this assumption is correct on the muon decay. Assuming the lepton number conservation, derivative free, local and Lorentz invariant 4-fermion point interaction, the most general form for the amplitude of the tau (muon) decay involves 12 complex couplings [23] two of which must be exactly 0. The tau decay products energy spectra can be expressed in this general form in terms of five parameters, the ν_τ helicity and the so called 'Michel parameters', η, ρ, ξ and δ, in addition of the momentum and $\mathcal{P}_\tau$. Therefore, these parameters are experimentally accessible from these distributions and as a consequence information on the couplings can be inferred.

Of all these parameters, only η affects the partial widths, while the remaining ones distort the differential cross section but do not change the normalization. In particular, assuming that the experiments have a leptonic selection whose effi-

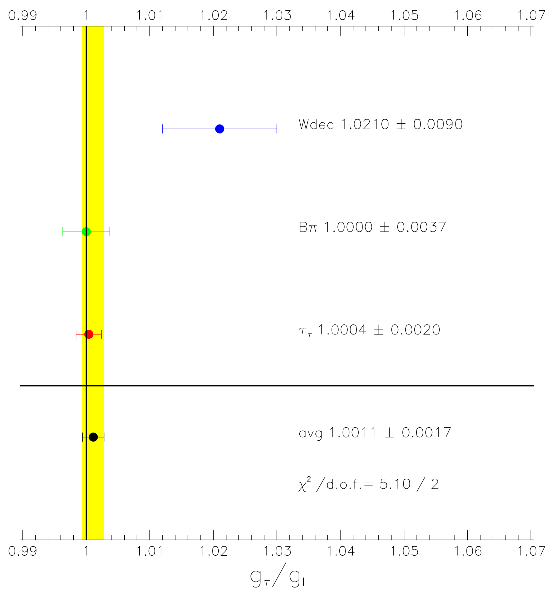

Figure 20. Summary of the status of tau-light lepton Universality measurements with different methods: W decay, tau decay to pion and τ lifetime.

ciency does not depend on the momentum and with an infinite momentum resolution $BR(\tau \to l\nu\nu) \propto (1 + \alpha\eta\frac{m_l}{m_\tau})$, with $\alpha = 4$. Then the ratio of the Branching Ratios provides a measurement of η. However, experimental effects make $\alpha < 4$, but often the experiments do not calculate (or do not quote) the precise value for their particular conditions (see [24] for a thorough discussion on the subject).

Figures 21 to 23 show the final results from LEP experiments [25,26,27,28], compared to other recent results [17] and with the Standard Model expectation for a pure V-A structure, on the assumption of lepton universality for the parameters. ALEPH, DELPHI and OPAL have also measured the parameters on the assumption that they might be different for electrons and muons, not showing any deviations. DELPHI includes in the fit a constraint from universality, with the correct α. For the remaining experiments, the η is also shown as obtained from the universality on the assumption that $\alpha = 4$ (known to be a reasonably good approximation for LEP experiments [24]).

DELPHI has studied [26] an additional anomalous tensor coupling predicted by a model in which the Lagrangian containing derivatives [29]. In a similar manner this term distorts the momentum distributions of the decays products and its strength is measurable. This strength has been bounded to $\kappa < 0.050$ (95% CL).

3.5. Bounds on new physics

The precision tests on the universality and on the Lorentz structure, set bounds on different extensions of the Standard Model.

The existence of a charged Higgs would influence the Michel parameters. Within MSSM, the η parameter would have a non-zero value of $\eta_l \approx \frac{m_l m_\tau}{2M_H^2}\tan\beta^2$, while the rest of the parameters would remain unchanged or with a variation of second order on $\frac{m_l m_\tau}{2M_H^2}$. From the previous results we can set the limit at 95% CL: $M_{H^\pm} > 2.4\tan(\beta)$, which is only competitive with direct searches for high $\tan(\beta)$.

DELPHI [26] and OPAL [28] have also interpreted their results in the light of the possible existence of an additional vector boson. DELPHI sets the limit at 95% CL: $M_{W_2} > 189\ GeV$ for any mixing with the standard W or $-0.141 < \eta < 0.125$ rad for the mixing and any boson mass. OPAL sets the limit at 95% CL: $M_{W_2} > 137\ GeV$ for any mixing with the standard W or $|\eta| < 0.12$ rad for the mixing and any boson mass.

4. Hadronic Branching Ratios

In addition to the previously mentioned $\tau \to \pi^\pm\nu$ decay, ALEPH [1] and DELPHI [30] have recently presented new preliminary results for the Branching Ratios not involving kaon identification for a large variety of hadronic decays (with up to 6 neutral or charged hadrons). Figures 24 to 32, summarise these results, together with other existing precise measurements [17]. When possible, the results are quoted with the kaon component subtracted. For ALEPH and some CLEO measurements, this subtraction is done by the

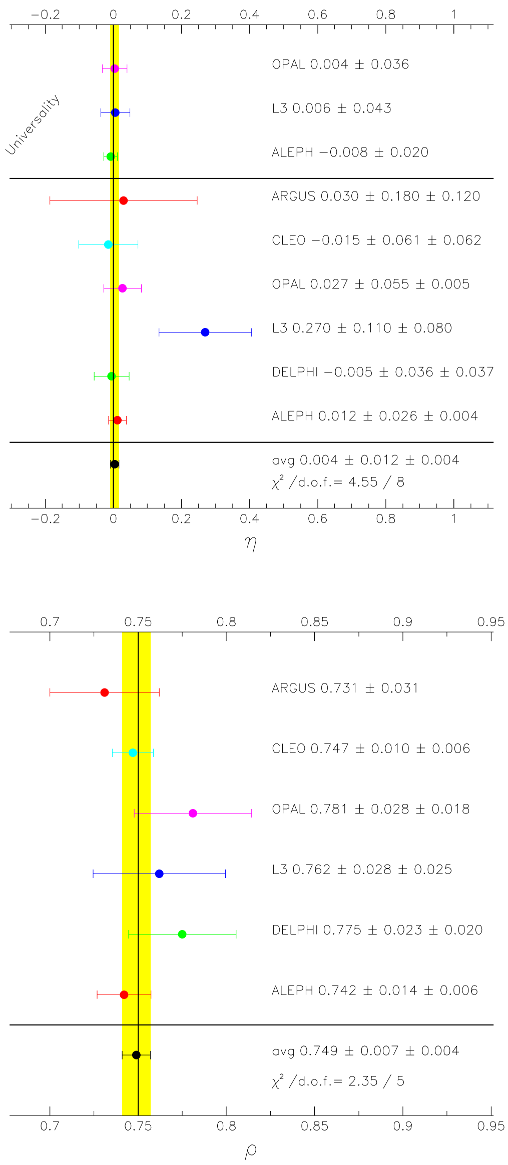

Figure 21. Results on the Michel parameters η and ρ. The vertical line shows the Standard Model expectation for V-A structure in the charged current current.

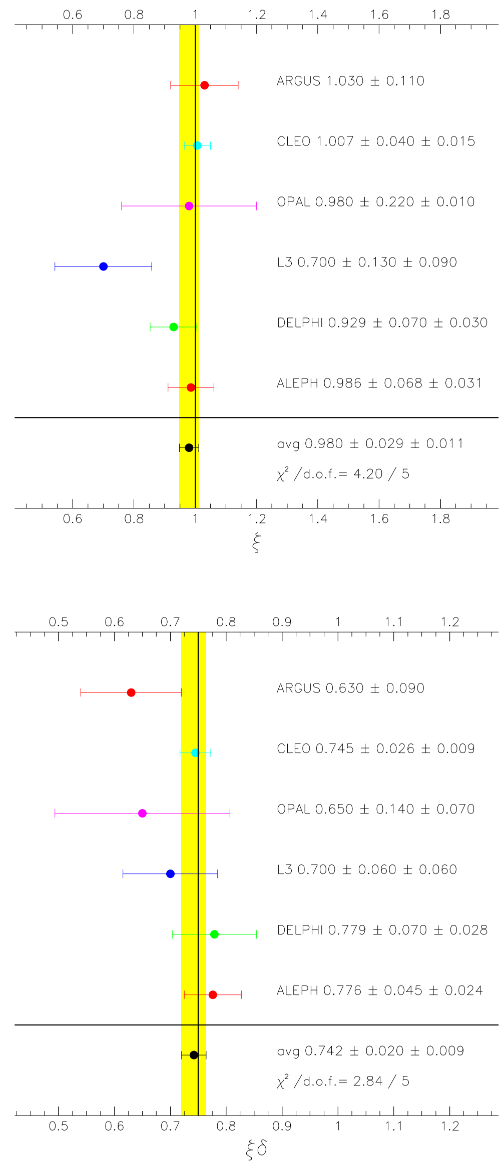

Figure 22. Results on the Michel parameters ξ and $\xi\delta$. The vertical line shows the Standard Model expectation for V-A structure in the charged current current.

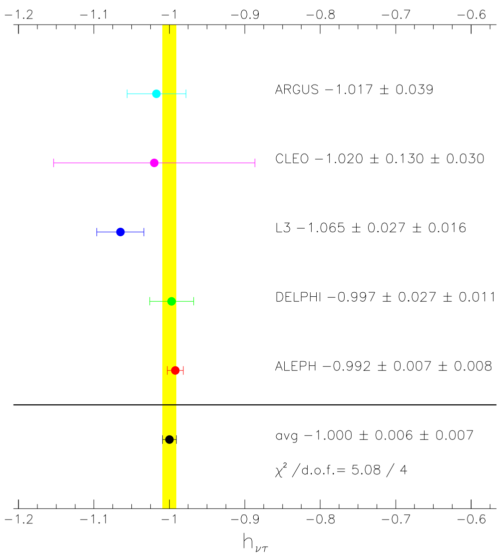

Figure 23. Results on the ν_τ helicity. The vertical line shows the Standard Model expectation for V-A structure in the charged current current.

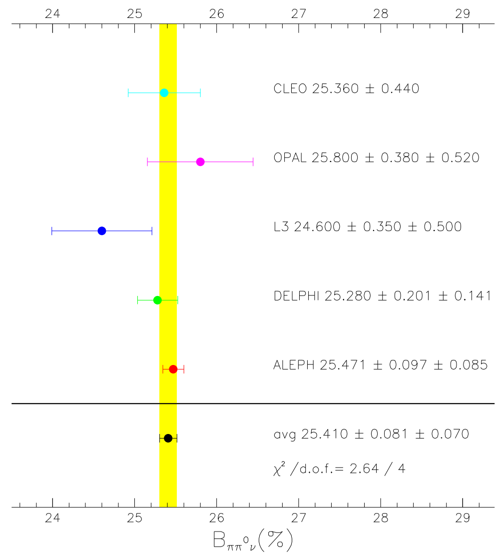

Figure 24. Branching Ratio for the decay $\tau \to \pi^{\pm}\pi^0\nu$.

same experiment using their own data, while for the remaining cases the w.a. [17] were used.

DELPHI [31] and L3 [32] have also published new measurements on the topological Branching Ratios. The results are shown in figures 33 to 35. In these measurements, the K^0 are considered as neutral particles, regardless of its decay, and therefore their possible decays products were not counted as "primary charged tracks" in the definition. These new results basically supersede all the previous results for one and three prongs, solving some remaining inconsistencies.

As an interesting check of the completeness of the τ decays, or the consistency of the measurements, we can show the perfect agreement between the current average for the direct measurement of the Branching Fraction to one-prong, $85.265 \pm 0.078\%$ with the sum of all the exclusive modes contributing to this topology as measured by ALEPH, $85.265 \pm 0.110\%$. It is important to remark that these two numbers are totally independent experimentally and that ALEPH result

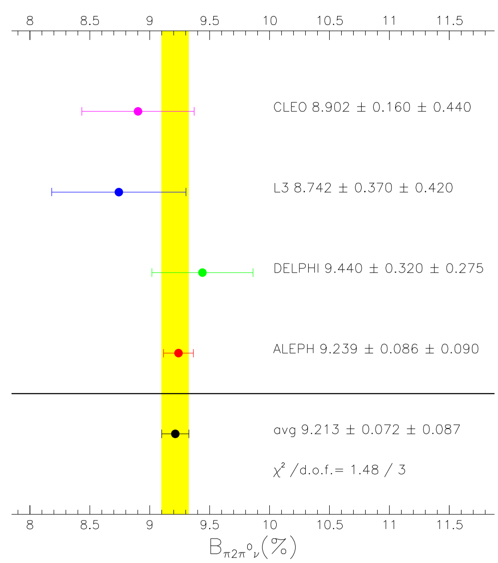

Figure 25. Branching Ratio for the decay $\tau \to \pi^{\pm}2\pi^0\nu$.

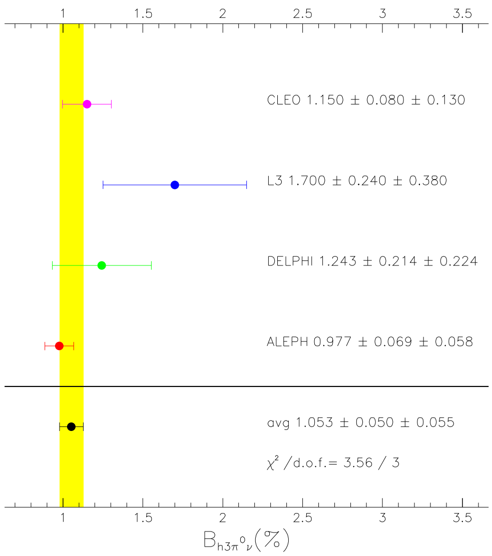

Figure 26. Branching Ratio for the decay $\tau \to h^{\pm}3\pi^{0}\nu$.

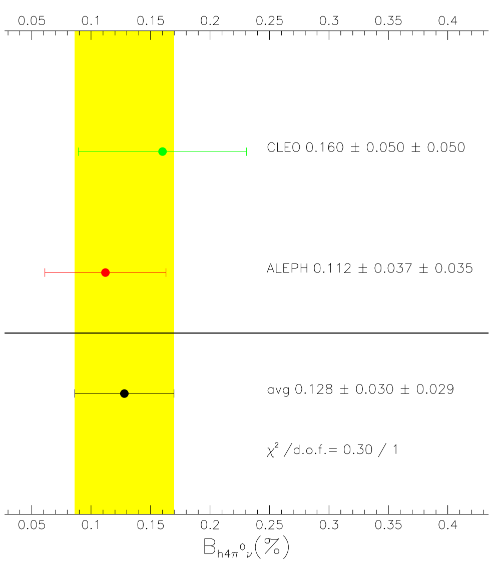

Figure 27. Branching Ratio for the decay $\tau \to h^{\pm}4\pi^{0}\nu$.

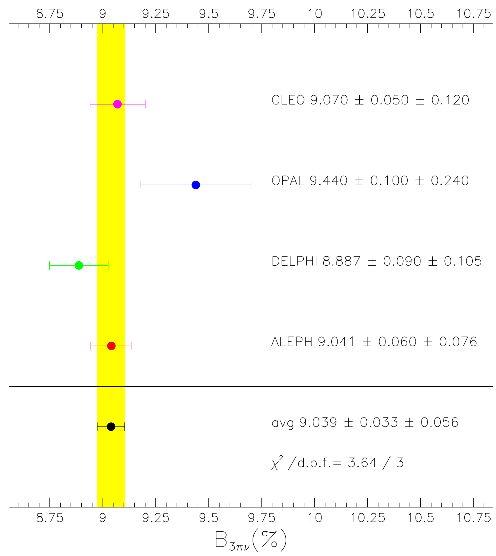

Figure 28. Branching Ratio for the decay $\tau \to 3\pi^{\pm}\nu_{\tau}$.

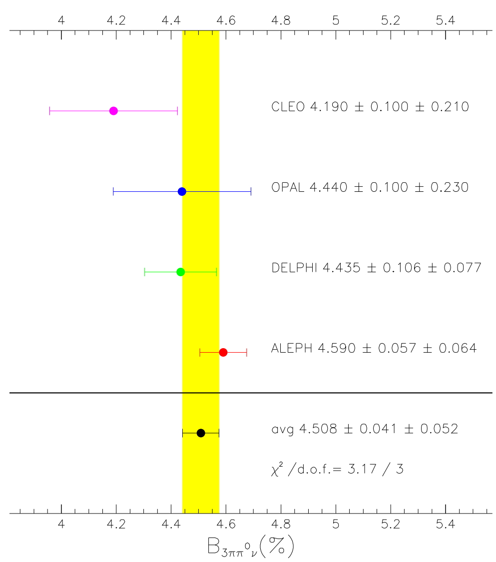

Figure 29. Branching Ratio for the decay $\tau \to 3\pi^{\pm}\pi^{0}\nu_{\tau}$.

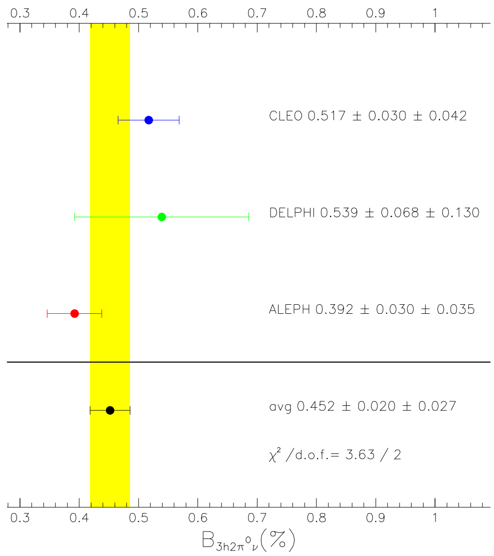

Figure 30. Branching Ratio for the decay $\tau \to 3h^{\pm}2\pi^{0}\nu_{\tau}$.

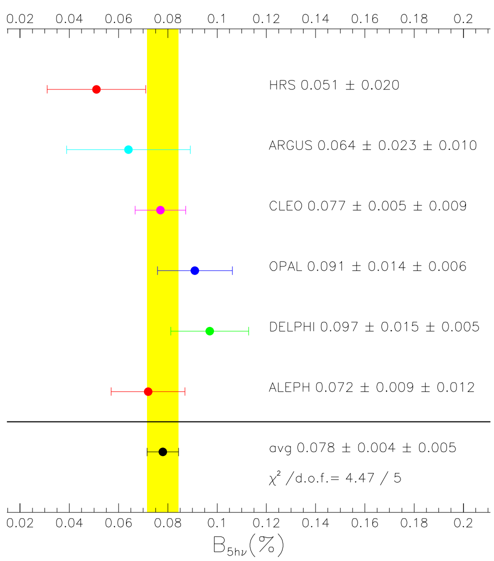

Figure 31. Branching Ratio for the decay $\tau \to 5\pi^{\pm}\nu_{\tau}$.

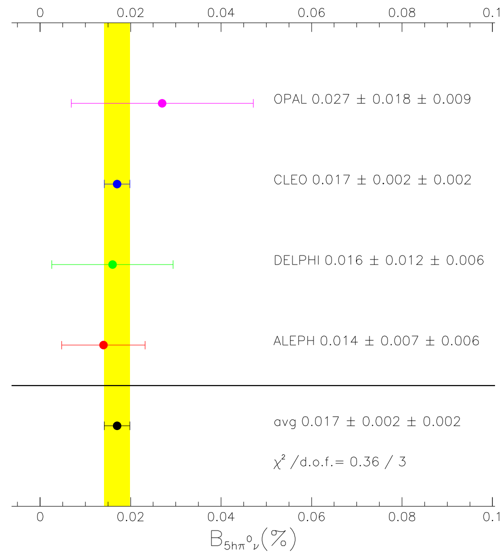

Figure 32. Branching Ratio for the decay $\tau \to 3\pi^{\pm}\pi^{0}\nu_{\tau}$.

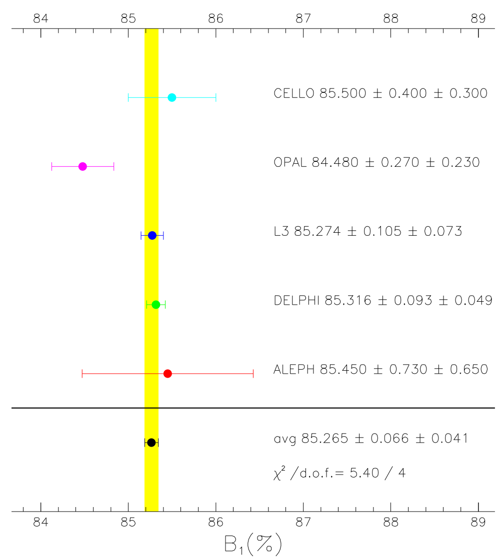

Figure 33. Branching Ratio to one charged particle (1-prong).

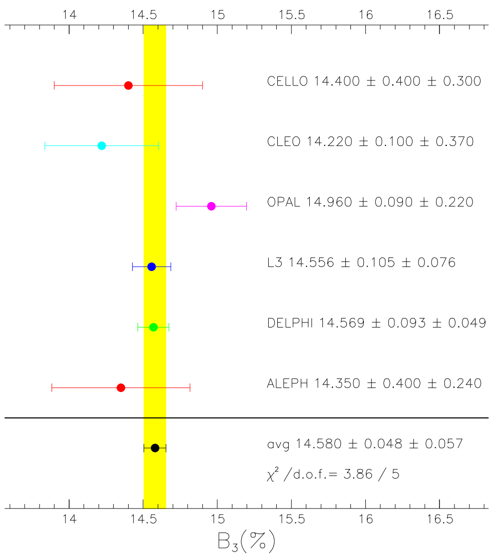

Figure 34. Branching Ratio to three charged particles (3-prongs).

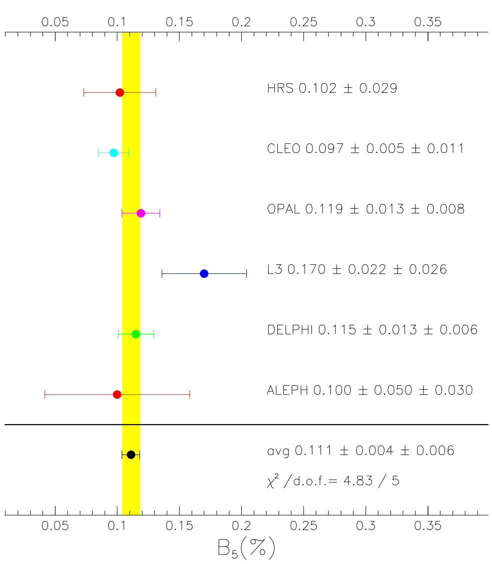

Figure 35. Branching Ratio to five charged particles (5-prongs).

is the most precise result for this sum, obtained from a single experiment and fully independent from the topologic result and accounting for all correlations ($DELPHI$ results are strongly correlated with the topological BR). This comparison shows that there is no hint of the "missing one-prong problem" as observed in the eighties, nor of some remaining discrepancies on the late nineties.

5. Other topics in τ physics

5.1. Lepton flavour violation

The possible violation of the lepton flavour conservation in the weak neutral current was studied looking for Z decays to $e\mu$, $e\tau$ or $\mu\tau$. This measurement benefited from the high statistics of Z available at LEP. The following bounds were set at 95% CL:

$BR(Z \to e\mu) < 1.7\ 10^{-6}$
$BR(Z \to e\tau) < 9.8\ 10^{-6}$
$BR(Z \to \mu\tau) < 1.2\ 10^{-6}$

5.2. τ mass

OPAL has measured the τ mass at LEP [33] using a pseudomass estimator, and fitting the mass from the endpoint of this distribution (figure 36). The same figure also shows the comparison with other experiments. More interesting is that this method can be applied separately to the τ^+ and τ^-, providing for the first time some information on the difference between the mass of positive and negative tau and therefore checking CPT invariance. A limit of $\frac{\Delta(M)}{M} < 0.3\%$ was set at 90% CL.

6. Conclusions

The study of the τ lepton production and decay at LEP has provided a lot of Standard Model precision measurements both in the electroweak sector, neutral and charged current universality and structure. No deviation from the Standard Model has been observed and therefore indirect bounds on extensions to Standard Model were set.

LEP experiments are also contributing to the improvement on the hadronic decays Branch-

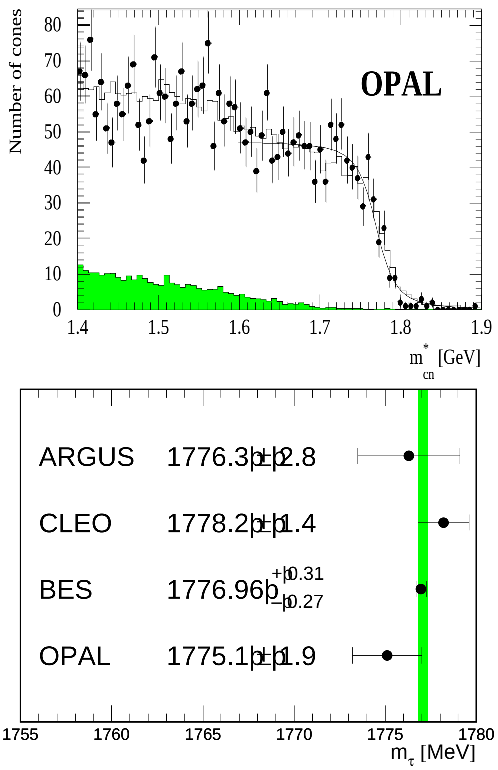

Figure 36. Pseudomass distribution used to obtain m_τ (top) and comparison of current results on m_τ (bottom).

ing Ratios measurement. These, together with more precise measurements at LEP on topological Branching Ratios rule out the remaining discrepancy in the 'missing one prong problem' at the 0.1% level.

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