τ PHYSICS AT LEP

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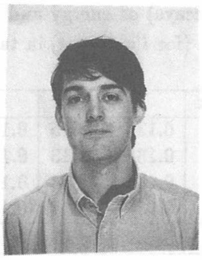

Abstract

Recent results on τ physics obtained by the four LEP experiments are reviewed: neutral currents (polarization), charged currents universality (lifetime and leptonic branching ratios) and vector-axial structure (Michel parameters), hadronic branching ratios, ν_τ mass, electric and magnetic moments. No deviation from the charged current universality is observed at the level of 0.3%. A large increase in the hadronic Branching Ratios precision has been achieved and several new modes have been measured. No hints of new physics have been found.

1 Introduction

During the last years of the first phase of LEP (at $E_{cm} = M_Z$) a large amount of $\tau^+\tau^-$ pairs (about 0.5 millions in total) have been collected by the four LEP experiments, ALEPH, DELPHI, L3 and OPAL, with small biases and backgrounds, since at this centre of mass energy the $\tau^+\tau^-$ are fairly well separated from the $q\bar{q}$ (typical efficiencies $\approx$ 80 % and backgrounds of 1-2%). This large and pure sample, together with the powerful particle ID detectors and the intrinsic τ properties allow a lot of precise Standard Model checks both in the electroweak sector (neutral and charged currents) and QCD. I will review here the latest results obtained by the LEP collaborations.

2 Neutral currents

Only τ polarization is mentioned here, other τ neutral current results already presented in this meeting [1]. Z^o are produced at LEP with longitudinal polarization, dependent on the $Z^o - e$ and $Z^o - \tau$ couplings, the final fermion pair is therefore produced with non zero average helicity. Only in the case of the τ this helicity can be measured, from the study of its decay products momentum (leptonic and single π decays) or energy and decay angle (ρ and a_1). The results are summarized in terms of $A_l \approx 2\frac{g_v^l}{g_a^l}$ (for $l = \tau$ or e) in table 1.

experiment	A_τ	A_e
ALEPH	0.136 ± 0.015	0.129 ± 0.017
DELPHI	0.135 ± 0.013	0.151 ± 0.014
L3	0.152 ± 0.013	0.156 ± 0.017
OPAL	0.134 ± 0.013	0.134 ± 0.016
LEP [2]	0.139 ± 0.007	0.143 ± 0.008

Table 1: τ polarization results (ALEPH [3]; DELPHI, L3 and OPAL preliminary).

The comparison of A_e and A_τ gives a proof of e/τ neutral current universality and their combination a precise measurement of the weak mixing angle if we assume this universality: $\sin^2\theta_W = 0.23229 \pm 0.00066$

3 Charged currents

The analysis of τ weak decay via a W permits two main checks of the charged currents: the universality of the weak coupling W-lepton and the $V - A$ structure of the current.

3.1 Universality

The τ is produced at the Z^o with a high boost so that it flies a few millimeters even though it has a very short lifetime (10^{-13} s). All LEP experiments incorporate now silicon strip detectors that can measure it precisely.

Several methods with independent systematics have been used for one prong decays using the impact parameter: either with single track IP distribution or with combinations of the two track IPs, difference or sum (sometimes including information of decay angles and momentum). Additionally three prong decays with vertex reconstruction and studying the decay length are used. The results are shown in table 2 together with the leptonic Branching Ratios.

The leptonic width can be written as $\Gamma(\tau^- \to l^-\bar{\nu}_e\nu_\tau) \propto g_l^2 f(\frac{m_l}{m_\tau})$ where l stands for e or μ, f(x) is a mass term equal to 1 for electrons and to 0.97256 for muons. The radiative corrections are the same for both leptons. We can then compare B_e and B_μ to test the universality of the

experiment	τ_τ (fs)	BR($\tau^- \to e^- \bar{\nu}_e \nu_\tau$) %	BR($\tau^- \to \mu^- \bar{\nu}_\mu \nu_\tau$) %
ALEPH	292.4 ± 2.3	17.79 ± 0.13	17.31 ± 0.12
DELPHI	291.4 ± 3.0	17.31 ± 0.39	17.02 ± 0.31
L3	290.1 ± 4.0	17.69 ± 0.19	17.36 ± 0.18
OPAL	289.2 ± 2.1	17.78 ± 0.13	17.36 ± 0.27
LEP average	290.7 ± 1.3	17.75 ± 0.09	17.30 ± 0.09
PDG95 [4]	292.0 ± 2.1	17.88 ± 0.18	17.46 ± 0.25

Table 2: τ lifetime and leptonic Branching Ratios (lifetime: DELPHI [5], OPAL [6], ALEPH and L3 preliminary; BR: ALEPH [7], DELPHI [8], OPAL [9], L3 preliminary).

coupling. Using the above LEP averages we can obtain the ratio: $|\frac{g_\mu}{g_e}| = 1.0011 \pm 0.0036$ in perfect agreement with the universality of e and μ.

A further step is to check the τ/μ universality including the τ lifetime information, given by $\tau_\tau = \tau_\mu(\frac{g_\mu}{g_\tau})^2(\frac{m_\mu}{m_\tau})^5 BR(\tau^- \to l^- \bar{\nu}_e \nu_\tau)(1+\epsilon)$, where l is a massless lepton and $\epsilon \approx 0.0004$ accounts for radiative corrections. From the combination of the above results and assuming e/μ universality $|\frac{g_\tau}{g_\mu}| = 0.9994 \pm 0.0028$, compatible with universality.

Both universality checks precision is expected to improve because there is still a large contribution from statistical errors and the full LEP I data not yet used.

3.2 Lorentz structure

Studying the decay of the τ we can also test the V-A structure of the charged current. With the leptonic decays momentum spectra the Michel parameters (ρ, η, ξ and δ) can be fitted and from the $\tau\tau$ correlated decay to hadrons the tau polarization and the chirality (ξ_h or neutrino helicity).

	ALEPH	L3	ARGUS	SM V-A
ρ	0.751 ± 0.045	0.794 ± 0.050	0.74 ± 0.04	$\frac{3}{4}$
η	-0.04 ± 0.19	0.25 ± 0.20	0.03 ± 0.22	0
ξ	1.18 ± 0.16	0.94 ± 0.22	0.97 ± 0.14	1
$\xi\delta$	0.88 ± 0.13	0.81 ± 0.15		1
ξ_h	-1.006 ± 0.037	-0.970 ± 0.054	-1.017 ± 0.039	-1

Table 3: Michel parameters and neutrino helicity (ALEPH [10], L3 preliminary).

All results are compatible with V-A and with only left handed neutrinos.

4 Hadronic decays

In the last year a large improvement has been achieved in the measurement of hadronic Branching Ratios taking advantage of the increased statistics and the better knowledge of the detector, also allowing to analyze modes with very small probabilities. This measurements involve several experimental issues like: π° identification for very close photons and with many collimated $\pi^\pm$ and π° (EM calorimeters granularity), charged π/K discrimination (dE/dx used for 1 prong and RICH for 1 and 3 prongs) and K° identification (K°_s with secondary vertex reconstruction and K°_L with shape in hadron calorimeter).

In the following tables the new LEP results (within one year) for these Branching Ratios are listed and compared to PDG95. The K° component is subtracted except if explicitly stated and some results are quoted without charged π/K separation (h=π or K in this case).

mode	PDG95 (%)	LEP (%)
$\pi^-\nu$	11.3 ± 0.4	11.06 ± 0.18(ALEPH)
		11.20 ± 0.23 (DELPHI)
$\pi^-\pi^\circ\nu$	25.0 ± 0.4	25.30 ± 0.20 (ALEPH)
		24.85 ± 0.40 (DELPHI)
$\pi^-2\pi^\circ\nu$	9.31 ± 0.34	9.29 ± 0.17 (ALEPH)
		11.52 ± 0.40 (DELPHI) ($\geq 2\pi^\circ$)
$h^-3\pi^\circ\nu$	1.24 ± 0.15	1.17 ± 0.14 (ALEPH)
$h^- \geq 4\pi^\circ\nu$	0.19 ± 0.07	0.16 ± 0.10 (ALEPH)

Table 4: Hadronic single prong decays not involving kaons (ALEPH [11]), DELPHI preliminary).

mode	PDG95 (%)	LEP (%)
$3h\nu$	8.39 ± 0.31	9.50 ± 0.15 (ALEPH)
		9.87 ± 0.26 (OPAL)
$3h \geq 1\pi^\circ\nu$	5.53 ± 0.30	4.30 ± 0.12 (ALEPH) ($= 1\pi^\circ$)
		5.09 ± 0.25 (OPAL)
$3h2\pi^\circ\nu$	0.48 ± 0.05	0.50 ± 0.10 (ALEPH)
$3h \geq 3\pi^\circ\nu$		0.11 ± 0.06 (ALEPH)
$5h\nu$	0.071 ± 0.009	0.080 ± 0.017 (ALEPH)
$5h\pi^\circ\nu$	0.021 ± 0.008	0.018 ± 0.014 (ALEPH)

Table 5: Hadronic multiprong decays not involving kaons (ALEPH [11]), OPAL [12]).

mode	PDG95 (%)	LEP (%)
$K^-\nu$	0.67 ± 0.05	0.72 ± 0.06 (ALEPH)
$K^-\pi^\circ\nu$	0.52 ± 0.07	0.52 ± 0.06 (ALEPH)
$K^-2\pi^\circ\nu$	0.045 ± 0.034	0.08 ± 0.03 (ALEPH)
$\pi^-K^\circ\nu$	0.88 ± 0.17	0.79 ± 0.13 (ALEPH)
		0.95 ± 0.16 (L3)
		1.04 ± 0.13 (OPAL)
$\pi^-K^\circ\pi^\circ\nu$	0.33 ± 0.16	0.32 ± 0.12 (ALEPH)
		0.41 ± 0.12 (L3)
		0.48 ± 0.14 (OPAL) $\geq 1\pi^\circ$
$\pi^-\bar{K}^\circ K^\circ\nu$		0.31 ± 0.12 (L3)
$K^-K^\circ\nu$	0.29 ± 0.12	0.26 ± 0.09 (ALEPH)
		0.10 ± 0.07 (OPAL)
$K^-K^\circ\pi^\circ\nu$	0.05 ± 0.05	0.10 ± 0.06 (ALEPH)
		0.18 ± 0.09 (OPAL) $\geq 1\pi^\circ$
$K^-K^+\pi^- \geq 0\pi^\circ\nu$	0.15 ± 0.09	0.22 ± 0.04 (DELPHI)
$K^-K^+\pi^-\nu$	0.22 ± 0.17	0.18 ± 0.04 (DELPHI)
$K^-K^+\pi^- \geq 1\pi^\circ\nu$	0.07 ± 0.19	0.04 ± 0.02 (DELPHI)
$K^-\pi^+\pi^- \geq 0\pi^\circ\nu$	0.38 ± 0.19	0.63 ± 0.09 (DELPHI)
$K^-\pi^+\pi^-\nu$		0.49 ± 0.08 (DELPHI)
$K^-\pi^+\pi^- \geq 1\pi^\circ\nu$		0.14 ± 0.04 (DELPHI)

Table 6: Hadronic decays involving charged or neutral kaons (ALEPH [11]), L3 [13]), DELPHI and OPAL preliminary).

mode	PDG95 (%)	LEP (%)
$\omega\pi^-\nu$	1.6 ± 0.5	1.91 ± 0.09 (ALEPH)
$\omega h^-\pi^o\nu$	0.39 ± 0.06	0.43 ± 0.09 (ALEPH)
$\eta K\nu$	< 0.047	0.029 ± 0.014 (ALEPH)
$\eta\pi^-\pi^o\nu$	0.170 ± 0.028	0.18 ± 0.04 (ALEPH)
$\eta\pi^-\nu$	< 0.034	< 0.062 (ALEPH)

Table 7: Decays involving η or ω (preliminary).

It has been shown that πK mode is dominated by the $K^*(892)$ resonance (BR(πK^o)<0.17 % and BR($K^*(1430)$)<0.11 % at 95% CL, L3 [13]) and under this assumption BR($\tau \to K^*(892)\nu$) is: $1.39 \pm 0.13\%$ (ALEPH), $1.42 \pm 0.24\%$ (L3), $1.56 \pm 0.23\%$ (OPAL) to be compared with the PDG95 average of $1.45 \pm 0.12\%$

Mass distribution studies made by DELPHI suggest that the $KK\pi$ and $K\pi\pi$ are dominated by the $K^*(892)K$ and $K^*(892)\pi$ modes respectively. Assuming that, we can combine all BR given here to 3 particle final states with one or two kaons to give BR($\tau \to K^*(892)\pi\nu)_{LEP} = 0.91 \pm 0.12\%$ (combination with $\chi^2 = 1.6/2$) and BR($\tau \to K^*(892)K\nu)_{LEP} = 0.50 \pm 0.10\%$ (combination with $\chi^2 = 2.8/2$).

It can be appreciated the important reduction in errors in most modes during this year as well as new measurements and evidence for new modes. The agreement with previous results is good, except in the $3h\nu$ mode where a discrepancy exist with older measurements (see [14] for a discussion on the subject). However, this two new LEP measurements agree to each other and are more precise than PDG95 world average.

5 ν_τ mass

The mass of the τ neutrino has been bounded by different methods at LEP, either using 5 prong events 2-D Energy vs mass distributions (ALEPH, OPAL) using 3-prong masses (DELPHI) or using kinematical estimations of ν energy and mass from 3-prong tau decays (OPAL). The present LEP results are: $m_{\nu_\tau} < 23.1\ MeV/c^2$ ALEPH (prel.), $m_{\nu_\tau} < 34\ MeV/c^2$ DELPHI (prel.), $m_{\nu_\tau} < 29.9\ MeV/c^2$ OPAL [16] to be compared with PDG95 [4] $m_{\nu_\tau} < 31\ MeV/c^2$ (all at 95 % confidence level).

6 Other results

Some other new results are briefly reported here:

- forbidden decays (neutrinoless), DELPHI [15]: BR($\tau \to e\gamma$)< 1.1 10^{-4} (PDG95 < 1.2 10^{-4}), BR($\tau \to \mu\gamma$)< 6.2 10^{-5} (PDG95 < 4.2 10^{-6}), all at 95% CL
- anomalous magnetic moment, L3 (prel.): $|a_\tau| < 0.049$ (90%)
- electric and magnetic weak dipoles, L3 (prel.): $d_\tau^W < 1.39\ 10^{-16}$ e cm (95%), $a_\tau^W < 0.026$ e cm (95%)

Conclusions

LEP is giving plenty of results (not only on Z^{o} related Physics) competitive with lower energy experiments or even better. The errors have been significantly reduced during the last year and they are still expected to improve when the full LEP sample will be analyzed.

The charged current coupling universality (e/μ and μ/τ) has been proved to the level of ≈ 0.3 %. The current structure is compatible with vector-axial and the existence only of left handed ν.

Very good precision has been obtained in decays with few hadrons and progresively increased for other decays with more π and with K. A new mode has been observed ($K^-K^+\pi^-\nu$), the existence of several modes with some previous indication has been confirmed ($\pi^-\bar{K}^o\pi^o\nu$, $K^-K^o\nu$, $K^-K^o\pi^o\nu$, $K^-K^+\pi^- \geq 0\pi^o\nu$,$K^-K^+\pi^-\nu$ and $K^-\pi^+\pi^- \geq 0\pi^o\nu$) and indication exist for another four new modes ($3h \geq 3\pi^o\nu$, $\pi^-\bar{K}^oK^o\nu$, $K^-K^+\pi^- \geq 1\pi^o\nu$ and $K^-\pi^+\pi^- \geq 1\pi^o\nu$)

New limits on the neutrino mass have been obtained. The combination the data of all LEP experiments using the full statistics (and all methods) could reach a sensitivity to the level of ≈ 10 MeV.

There are no hints of new physics or deviation from the minimal standard model.

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