Test of Lepton Universality in τ Decays

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on behalf of the LEP collaborations

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Introduction

In the SM the three leptonic families have identical couplings to the gauge bosons.
A wealth of different experimental tests have been performed to check this assumption.

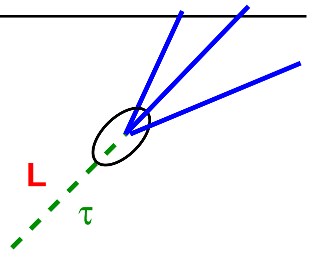
QED	α	g-2 experiments $\sigma(e^+e^- \rightarrow l^+l^-)$
Neutral Currents	g_V^l, g_A^l	$\Gamma(Z \rightarrow l^+l^-)$ Asymmetries
Charged Currents	g_l	τ decays π and K decays W decays

Introduction

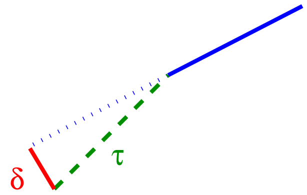
universality test	method	experimental input	W polarization
$e-\mu$	$B_\mu/B_e = 0.9726 \cdot g_\mu^2/g_e^2$	B_e, B_μ	T
$e-\mu$	$R^{exp.}_{\pi\to e/\mu}/R^{theo.}_{\pi\to e/\mu} = g_\mu^2/g_e^2$	$B_{\pi\to e\nu_e}, B_{\pi\to\mu\nu_\mu}$	L
$\tau-\mu$	$\tau_\mu/\tau_\tau(m_\mu/m_\tau)^5 B_e \Delta_W \Delta_\gamma = g_\tau^2/g_\mu^2$	τ_τ, m_τ, B_e	T
$\tau-\mu$	$(2m_\mu^2/m_\tau^2)B_h/(H_\pi + H_K)$	τ_τ, m_τ, B_h	L

- Direct test from leptonic W decays.

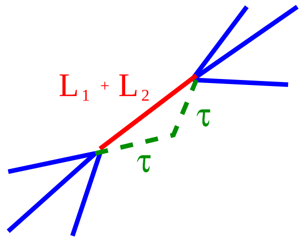
101 ways to measure the τ lifetime



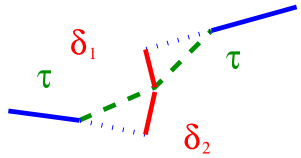
- Decay Length (DL)
  - low systematics but low statistics



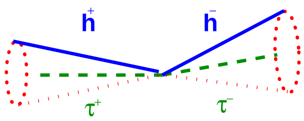
- Impact Parameter (IP)
  - beam size uncertainty (SLD !!)



- Double Decay Length (DDL)
- Impact Parameter Difference (IPD)
  - τ flight direction uncertainty



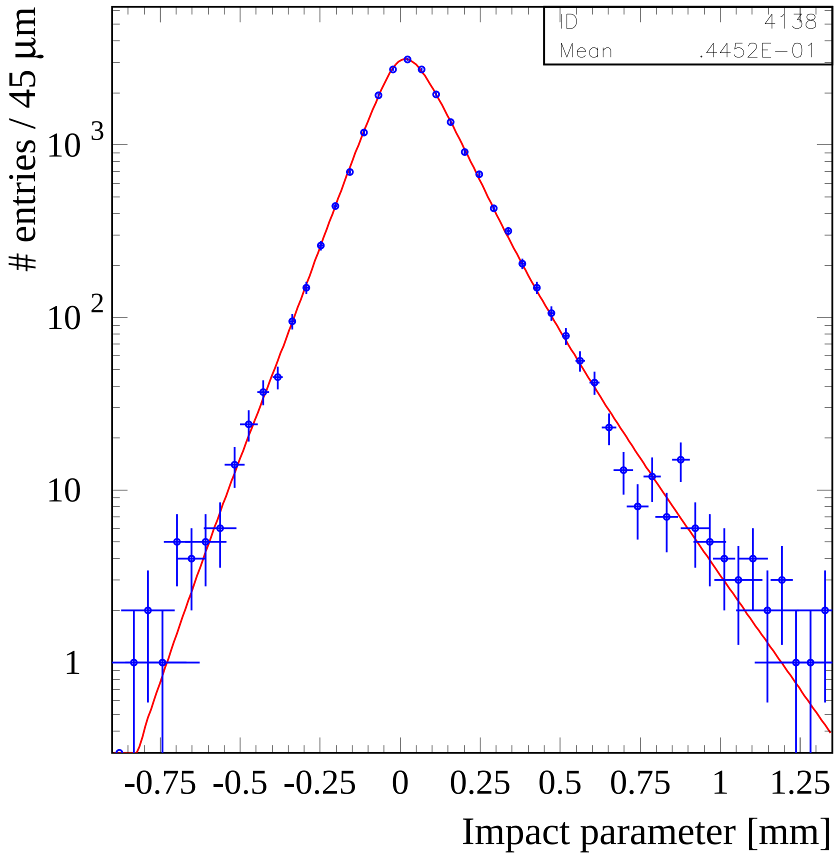
- Impact Parameter Sum(IPS)
  - beam size uncertainty
- Momentum-dependent Impact Parameter Sum (MIPS)



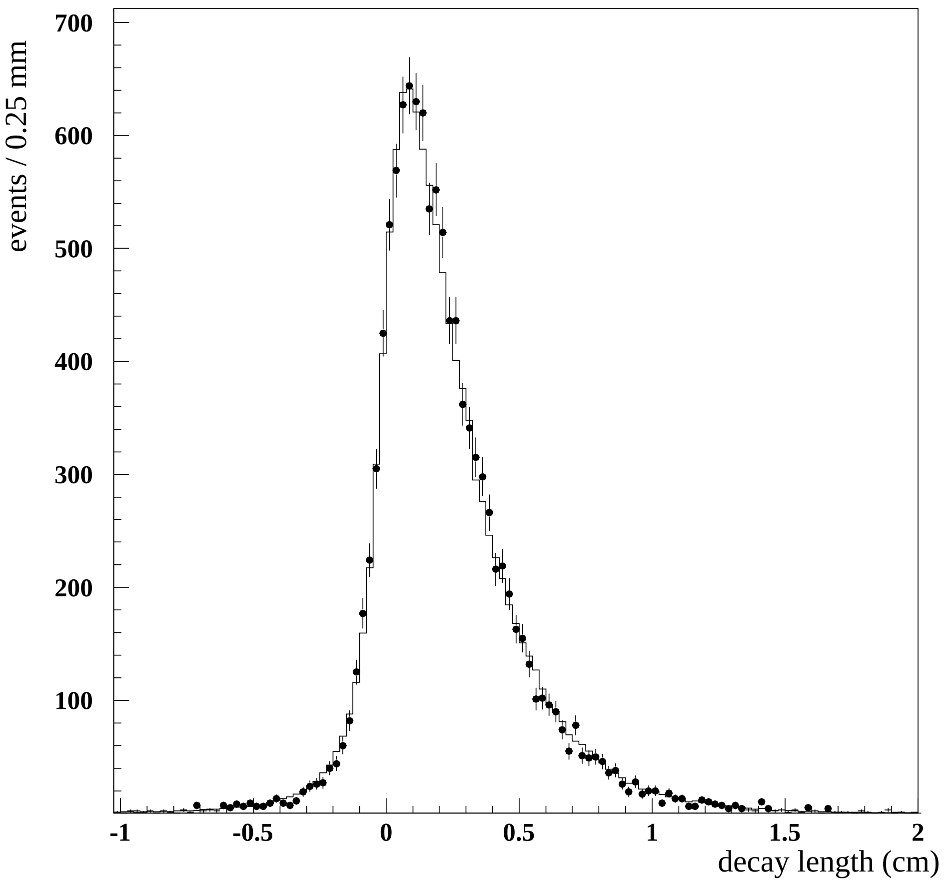
- 3D Impact Parameter (3DIP)
  - low systematics but low statistic

101 ways to measure the τ lifetime

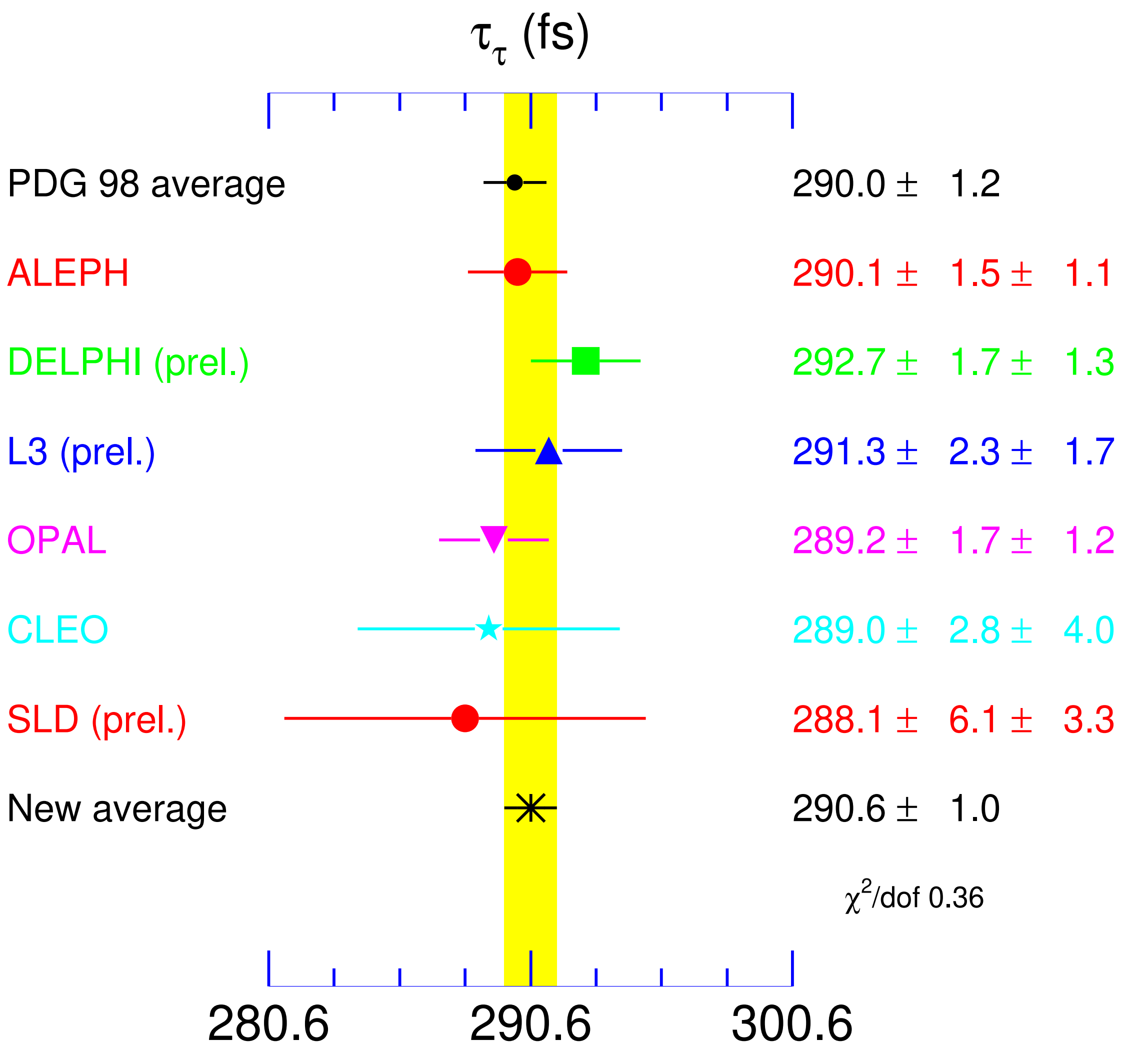
Impact Parameter
(L3 preliminary)



Decay Length
(DELPHI preliminary)



101 ways to measure the τ lifetime



Systematic errors are assumed uncorrelated

τ leptonic branching fractions

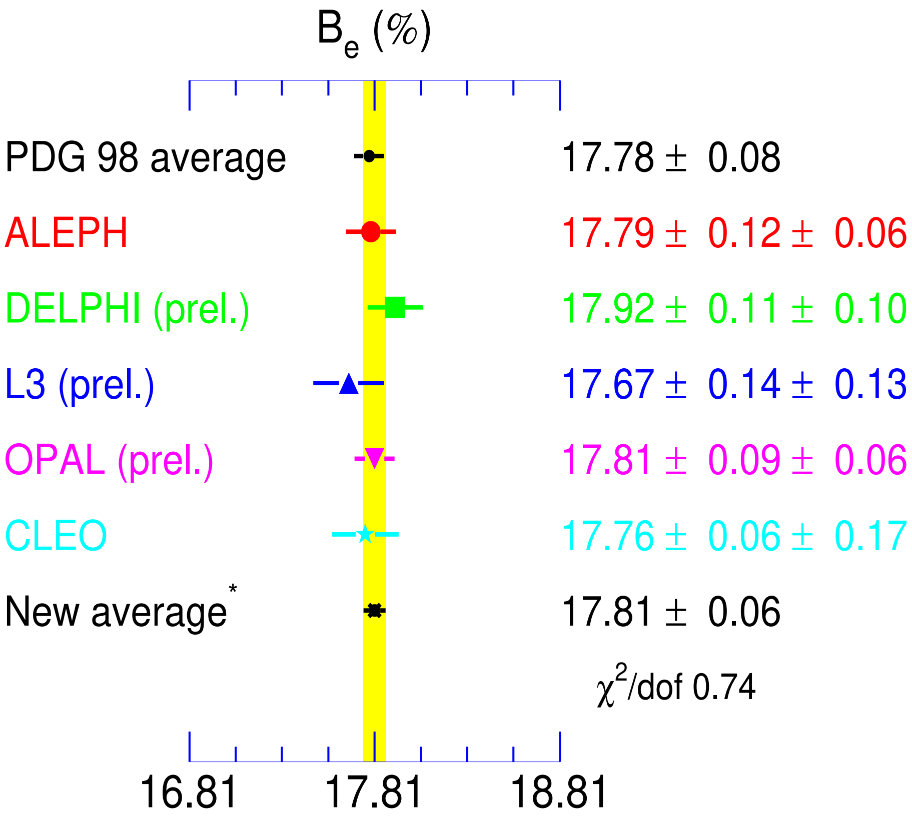
Detailed study of efficiencies and background in order to keep the systematic error low

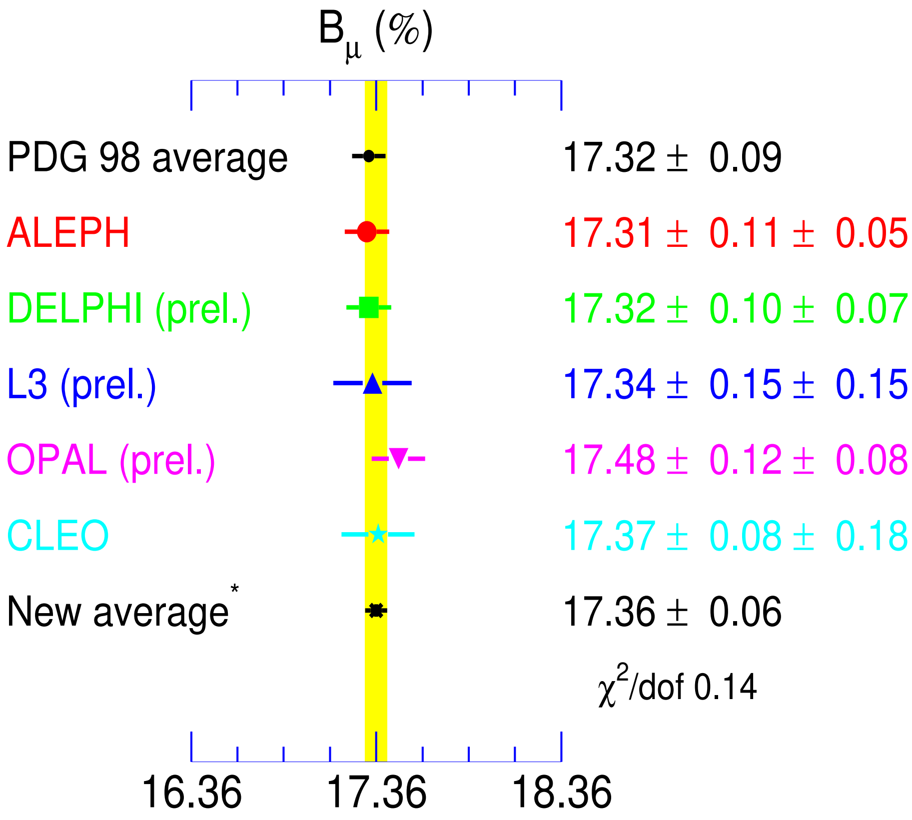
1) Preselection of $Z \to \tau\tau$ independent as much as possible of the τ decay mode

2) Background and efficiencies estimated directly from data or from MC with a careful cross check with control data samples

New results from DELPHI and OPAL

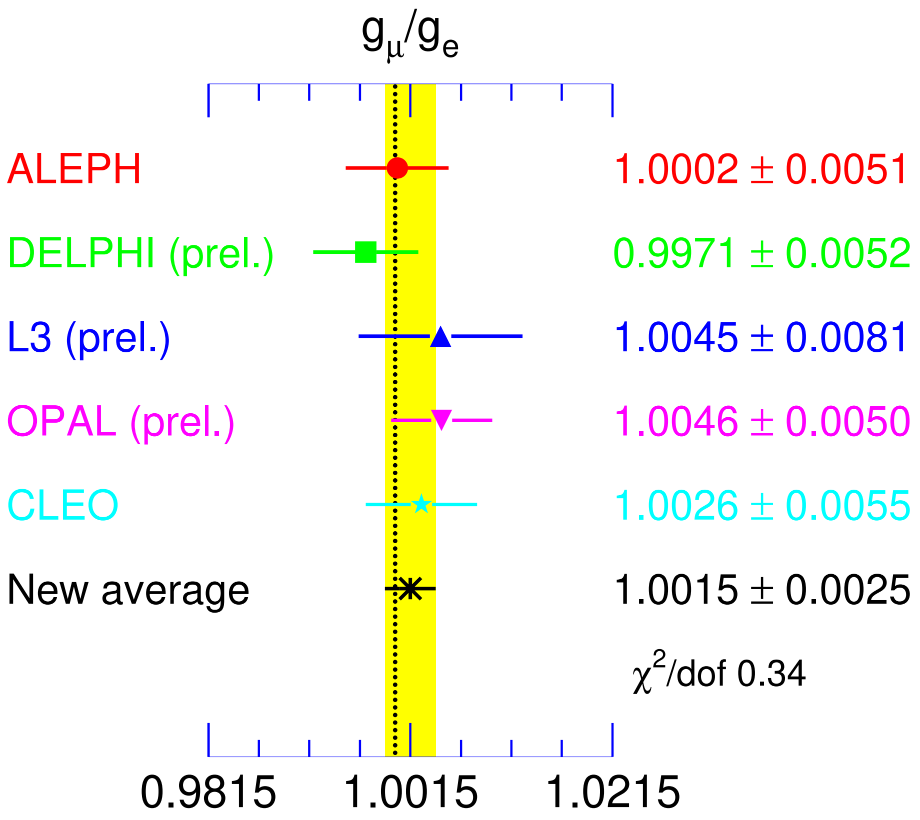
τ leptonic branching fractions

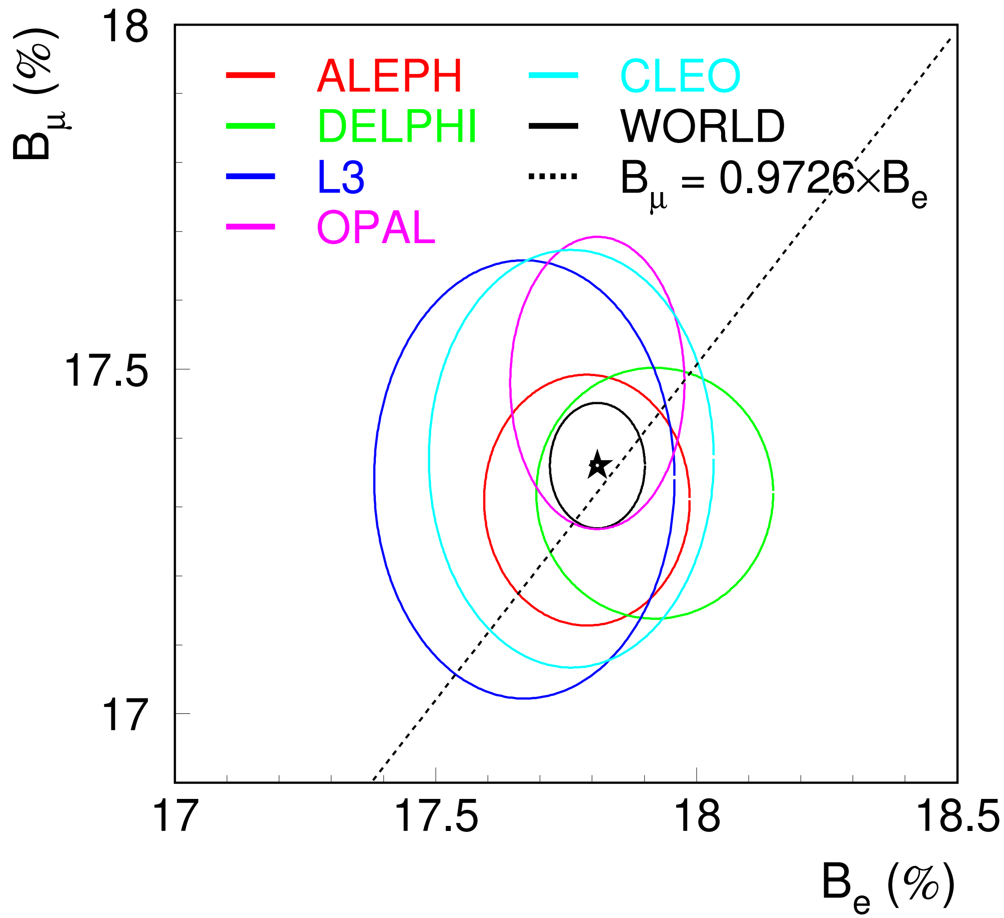




* The new average includes also some old measurements used by the PDG

Test of $e - \mu$ universality

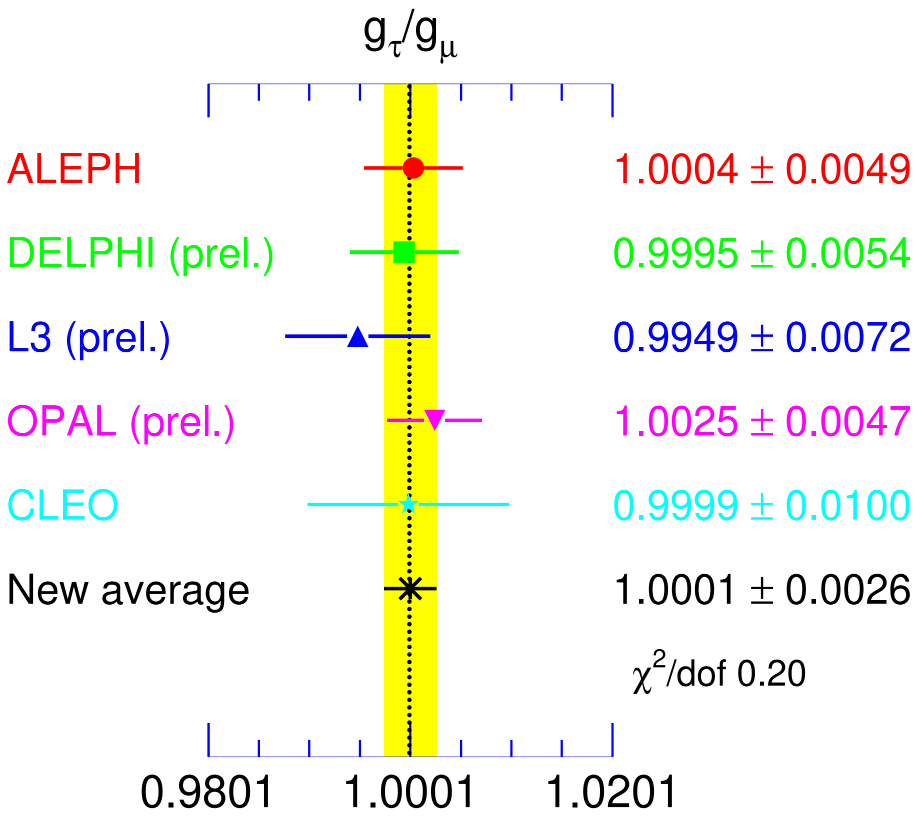


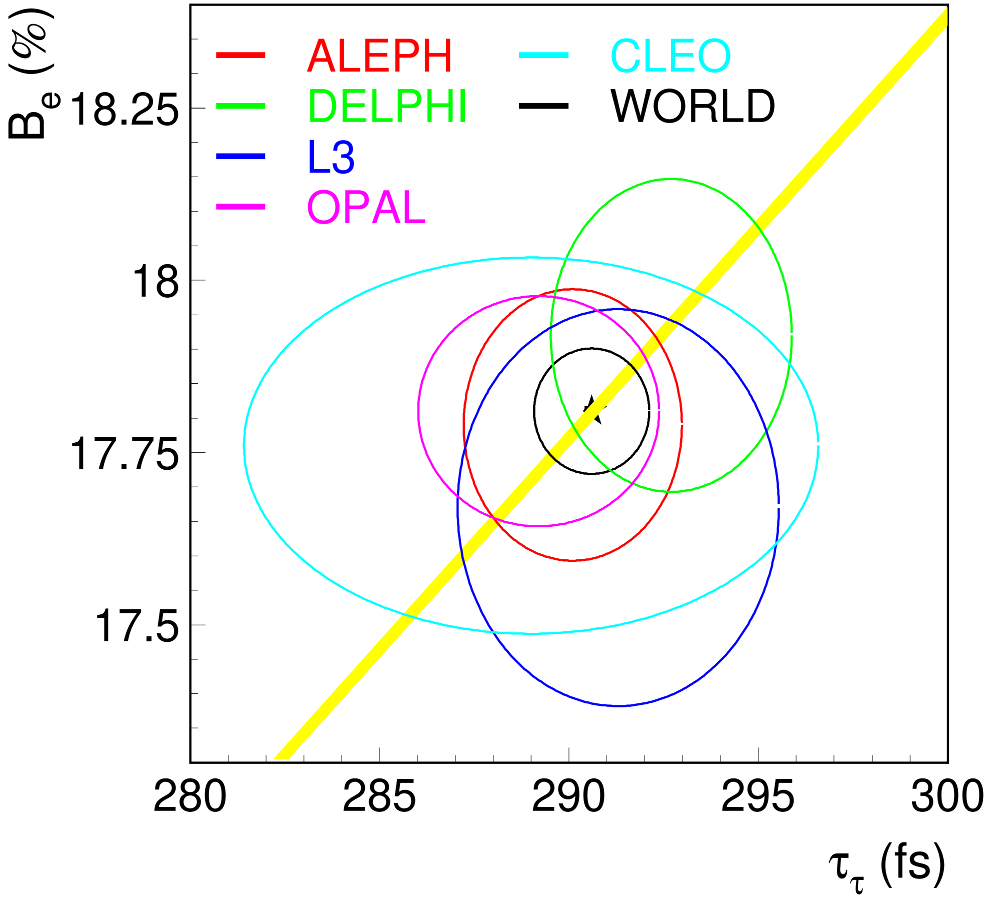


The average is done using the values of g_μ/g_e given by the experiments in order to take into account properly the correlations

The contours (68% CL) are drawn assuming no correlations

Test of $\tau - \mu$ universality



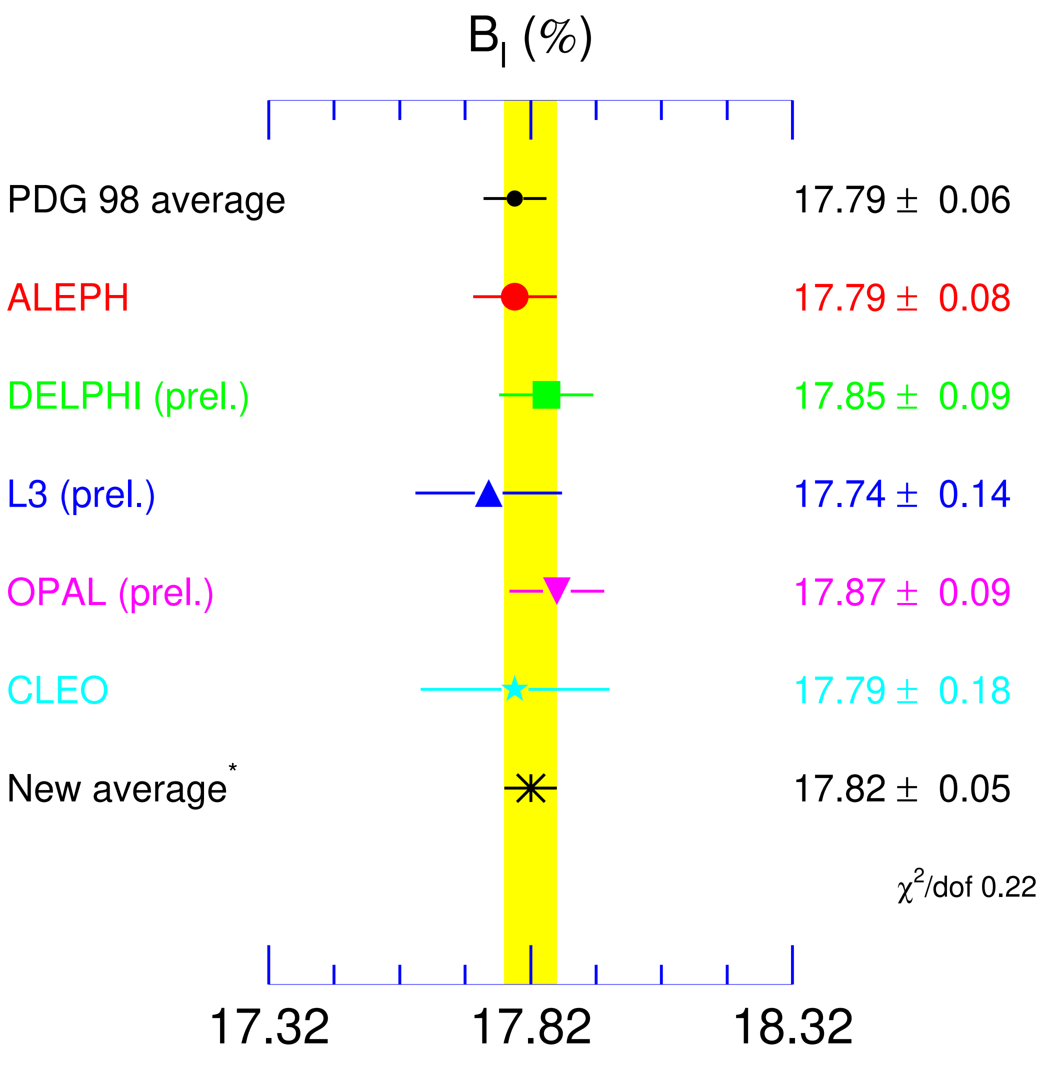


The values of g_τ/g_μ are calculated using the τ lifetime and B$_e$

68% CL contours. The width of the yellow band corresponds to the error on m_τ

The combined leptonic branching fraction

Having tested the lepton universality one can combine B_e and B_μ:



* Whenever possible the average is done by using the values of B_l given by the experiments.

Results on lepton universality

g_μ/g_e	method
1.0015 ± 0.0025	$\mathrm{B}_\mu/\mathrm{B}_e$
1.0012 ± 0.0015	$R^{exp.}_{\pi\to e/\mu}/R^{theo.}_{\pi\to e/\mu}$
0.94 ± 0.06	LEP, W decays *
1.01 ± 0.04	hadron colliders

g_τ/g_μ	method
1.0001 ± 0.0026	τ_τ, m_τ, B_e
1.0061 ± 0.0062	$\tau \to h\nu_\tau$
0.97 ± 0.08	LEP, W decays *
0.99 ± 0.05	hadron colliders

$g_\tau/g_e = 0.91 \pm 0.08^*$

tested directly from W decays at LEP

* see talk by L. Malgeri

Conclusions

With about 430K τ pairs collected by LEP+SLD and 3×10^6 collected by CLEO the precision in the measurement on τ lifetime and leptonic branching fraction has seen an impressive progress since the beginning of LEP

The history of ten years of measurements:

year	lifetime (fs)	δ_τ/τ (%)	B_e (%)	$\delta B_e/B_e$ (%)	g_τ/g_μ
1988	304 ± 9	3.0	17.8 ± 0.5	2.8	0.918 ± 0.057
1994	295.6 ± 3.1	1.0	17.90 ± 0.17	0.9	0.9941 ± 0.0071
1998	290.6 ± 1.0	0.34	17.81 ± 0.06	0.34	1.0001 ± 0.0026

$\mathrm{G_F}$ (1988)	$(1.13 \pm 0.024) \times 10^{-5}$ GeV $^{-2}$
$\mathrm{G_F}$ (1998)	$(1.1665 \pm 0.0028) \times 10^{-5}$ GeV^{-2}
$\mathrm{G_F}$ from τ_μ	$(1.16639 \pm 0.00002) \times 10^{-5}$ GeV^{-2}

Conclusions

$e - \mu$ and $\tau - \mu$ universality are tested at the 0.25% from τ decays, an accuracy comparable with the most precise result on g_μ/g_e (0.15%) from π decays

Direct tests of lepton universality (by far less precise!) available from W decays at LEP II.

An improvement at the level of 10% is to be expected from the full LEP I statistics.