New Results on $\not{l}$Lepton

K.K. Gan
The Ohio State University

July 17, 2003

Outline

- introduction
- lifetime
- hadronic decays
- lepton flavor violation decays
- summary

☆ present only new results since Tau2002

Introduction

- τ is the only lepton heavy enough to decay to leptons and hadrons:
  - test of electroweak interaction
  - test of QCD
  - search for forbidden decays to leptons and/or hadrons

Measurement of □ Lifetime

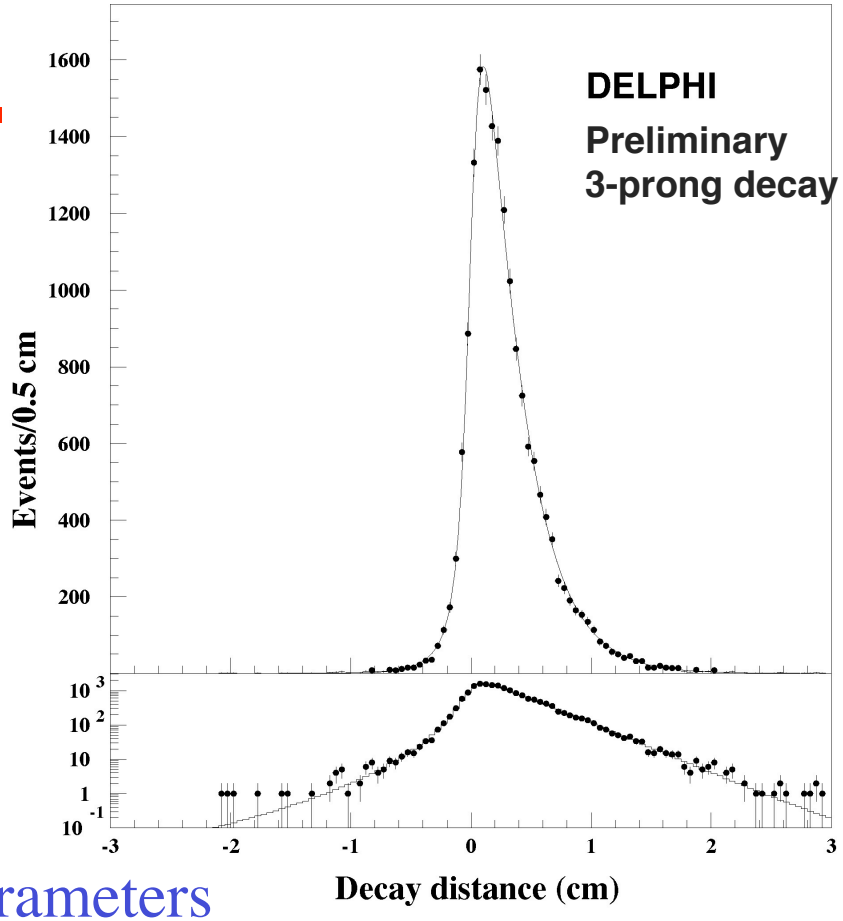
- motivation: test of lepton universality

$$\Gamma_{\square} = \Gamma_{\square}\left(\frac{g_{\square}}{g_{\square}}\right)^2\left(\frac{m_{\square}}{m_{\square}}\right)^5 B(\square \to e\,\bar{\nu}_e\nu_{\square})$$

$$\Gamma_{\square} = \Gamma_{\square}\left(\frac{g_e}{g_{\square}}\right)^2\left(\frac{m_{\square}}{m_{\square}}\right)^5 B(\square \to \square\,\bar{\nu}_{\square}\nu_{\square}) \cdot R\left[\frac{m_{\square}}{m_{\square}}\right]$$

  - ☆ measure: $\Gamma_{\square} B_e$ and $B_{\square}$
    - ⇨ test: $g_{\square}/g_{\square}$ or $g_e/g_{\square} = 1$?

DELPHI: □Lifetime Measurement



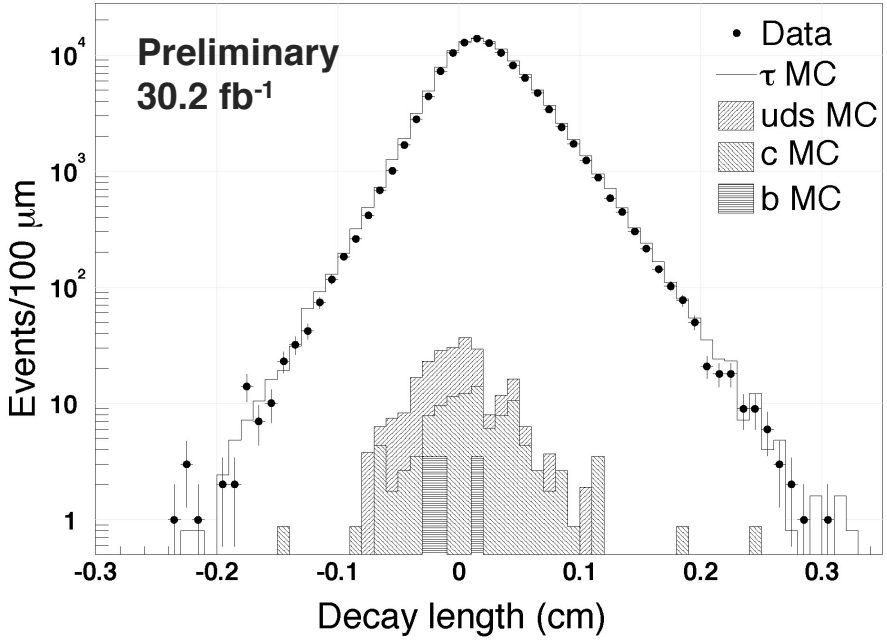
- measured with three methods:
  - 3-prong decay length
  - 1-prong vs 1-prong impact parameters
    - impact parameter difference: $d_1 - d_2$
    - miss distance: $d_1 + d_2$

  } 36% correlation

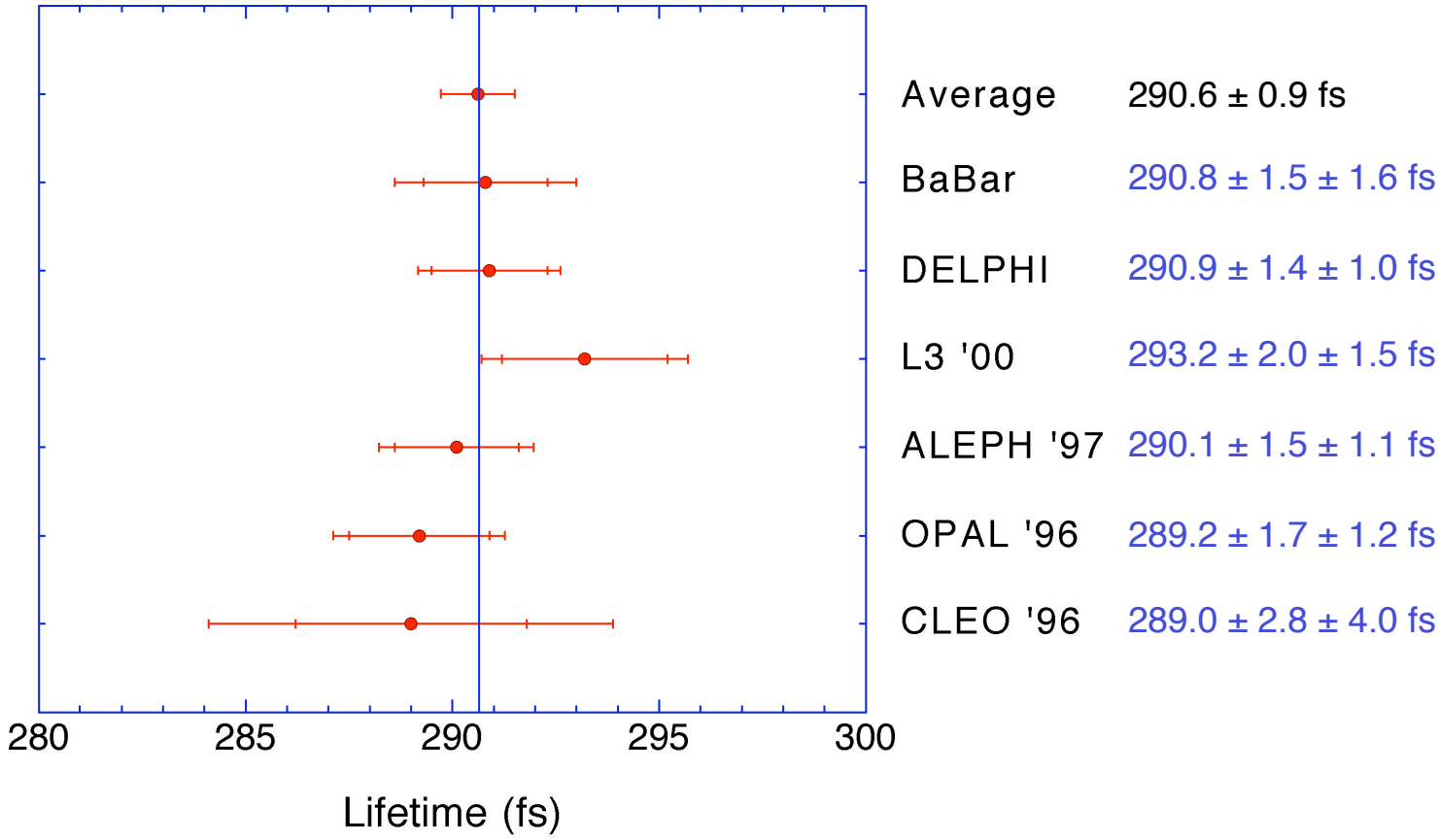
  ⇨ □□= 290.9 ± 1.4 ± 1.0 fs

BaBar: □Lifetime Measurement

- measure 3-prong decay length
- blind analysis: good for high precision measurement
  - ⇨ □ = 290.8 ± 1.5 ± 1.6 fs
- ☆ measurement is still statistics limited
  - ⇨ good prospect for improvements by BaBar and Belle



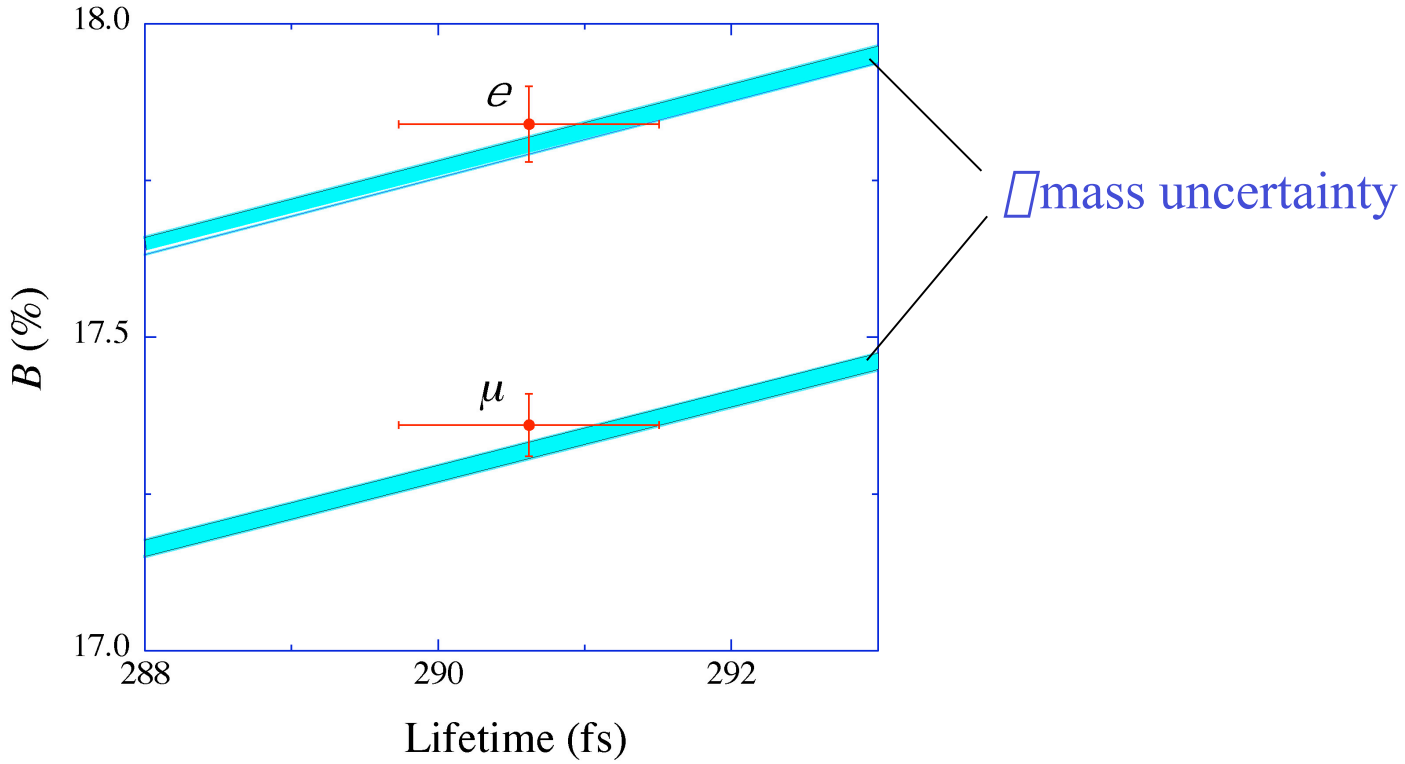
Summary of Lifetime Measurements



Average	290.6 ± 0.9 fs
BaBar	290.8 ± 1.5 ± 1.6 fs
DELPHI	290.9 ± 1.4 ± 1.0 fs
L3 '00	293.2 ± 2.0 ± 1.5 fs
ALEPH '97	290.1 ± 1.5 ± 1.1 fs
OPAL '96	289.2 ± 1.7 ± 1.2 fs
CLEO '96	289.0 ± 2.8 ± 4.0 fs

- all measurements are consistent with each other

Test of Lepton Universality

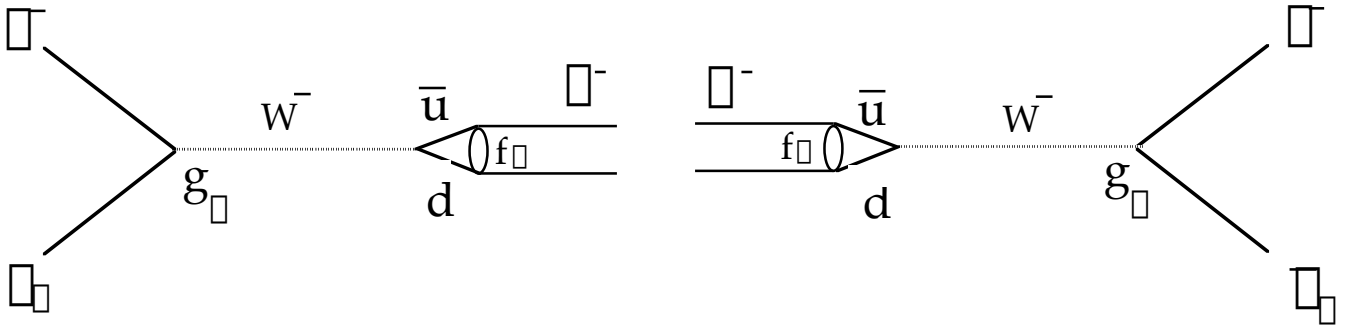


- $g_{\square}/g_{\square} = 0.9990 \pm 0.0023$
- $g_e/g_{\square} = 0.9988 \pm 0.0021$
  - ⇨ universality is tested with 3rd generation to 0.2%

Measurements of Hadronic Decays

- new preliminary results by DELPHI
- new results by L3
- new results by CLEO III with π/K identification

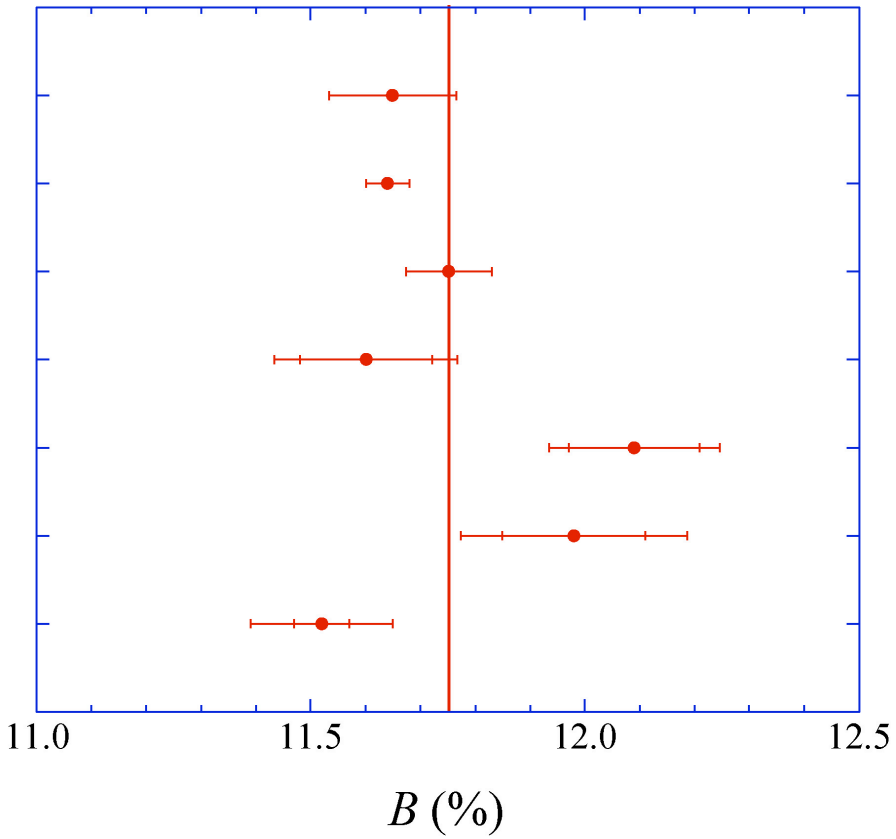
Theory of $\tau^- \to \nu_\tau$



$$\frac{B(\tau^- \to \pi^- \nu_\tau)}{B(\pi^- \to \mu^- \bar{\nu}_\mu)} = \frac{g_\tau^2}{g_\mu^2} \cdot \frac{m_\tau}{m_\mu} \cdot PS$$

⇨ test of lepton universality

Measurements of B(τ⁻ → h⁻ν_τ)

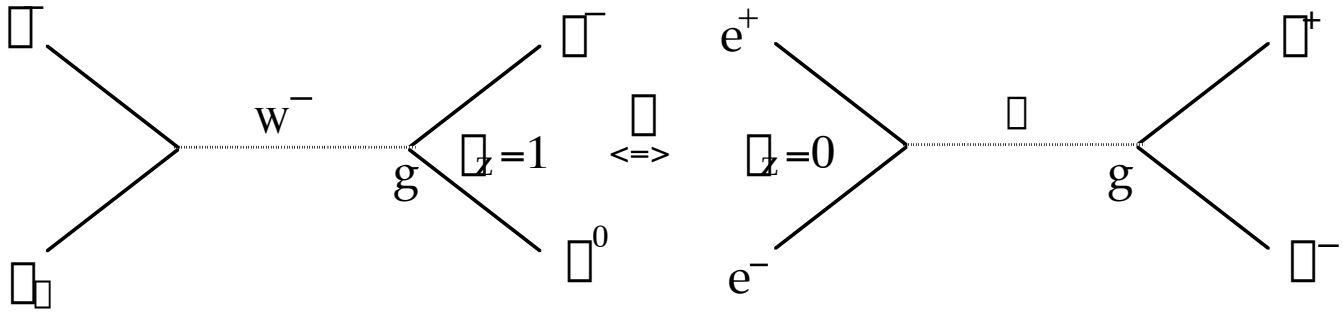


Marciano et al.	(11.65 ± 0.12)%
Decker et al.	(11.64 ± 0.04)%
Average	(11.75 ± 0.08)%
DELPHI	(11.60 ± 0.12 ± 0.12)%
L3	(12.09 ± 0.12 ± 0.10)%
OPAL '98	(11.98 ± 0.13 ± 0.16)%
CLEO '97	(11.52 ± 0.05 ± 0.12)%

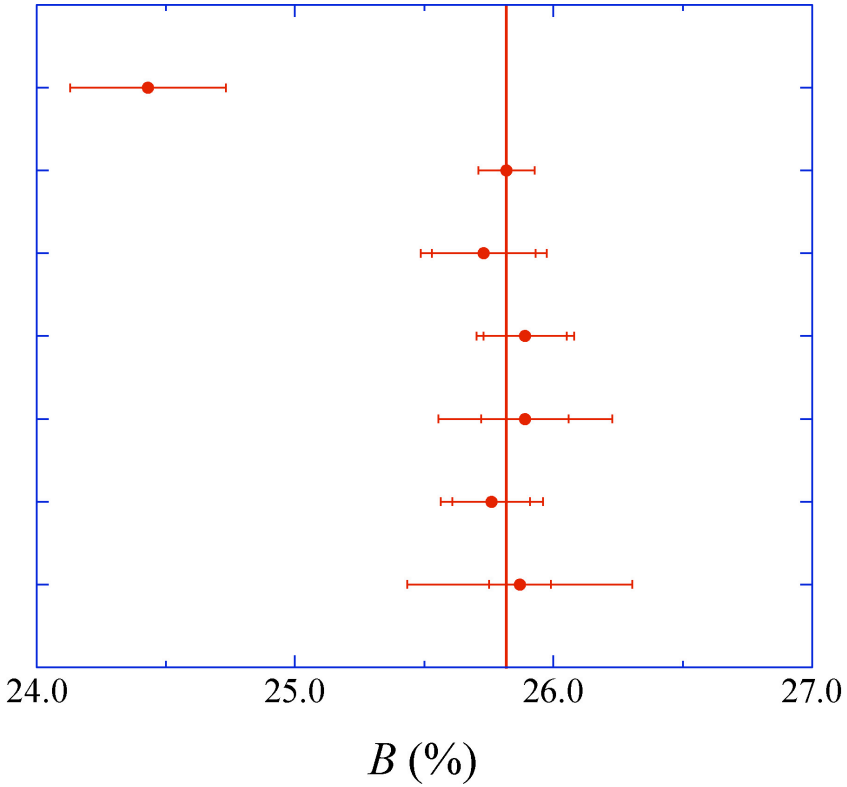
- not good consistency between experiments: $\chi^2 = 9.9$ for 3 DOF
- average is consistent with lepton universality

Theory of $\tau^- \to \pi^-\pi^0\nu_\tau$

- conserved vector current (CVC) hypothesis:
  $B(\tau^- \to \pi^-\pi^0\nu_\tau)$ can be calculated from $\sigma(e^+e^- \to \pi^+\pi^-)$



Measurements of B(τ⁻ → h⁻π⁰ν_τ)



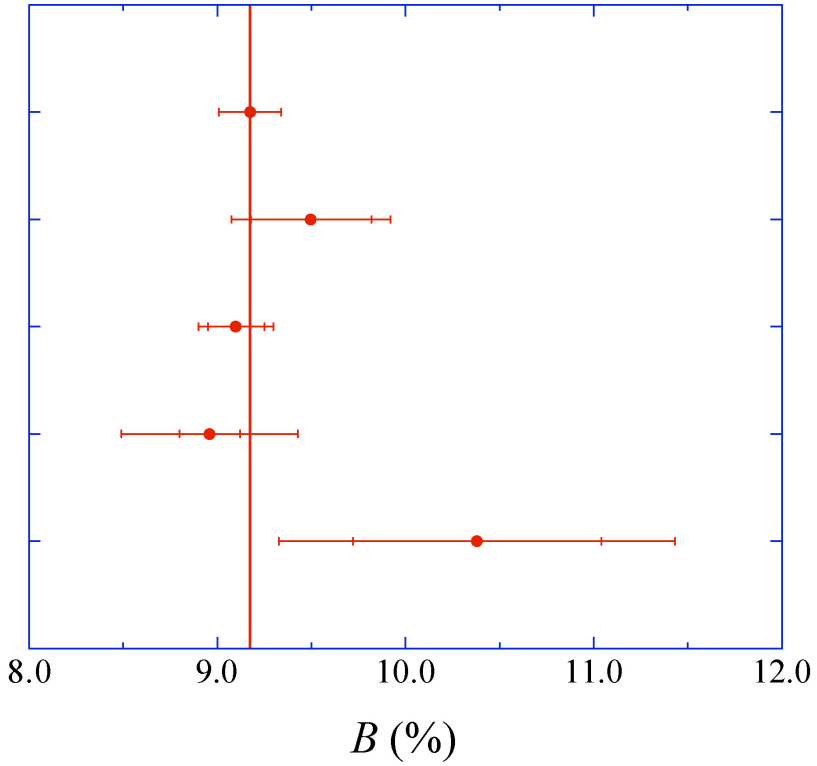
CVC*	(24.43 ± 0.30)%
Average	(25.82 ± 0.11)%
DELPHI	(25.73 ± 0.20 ± 0.14)%
L3	(25.89 ± 0.16 ± 0.10)%
OPAL '98	(25.89 ± 0.17 ± 0.29)%
ALEPH '96	(25.76 ± 0.15 ± 0.13)%
CLEO '94	(25.87 ± 0.12 ± 0.42)%

- measurement is ~ 4.3σ above CVC prediction

⇨ absolute normalization problem (5%) in σ(e⁺e⁻ → π⁺π⁻)?

* M. Davier , S. Eidelman, A. Hocker, Z. Zhang, Eur. J. C 27, 497 (2003)

Measurements of $B(\tau^- \to h^- 2\pi^0 \nu_\tau)$

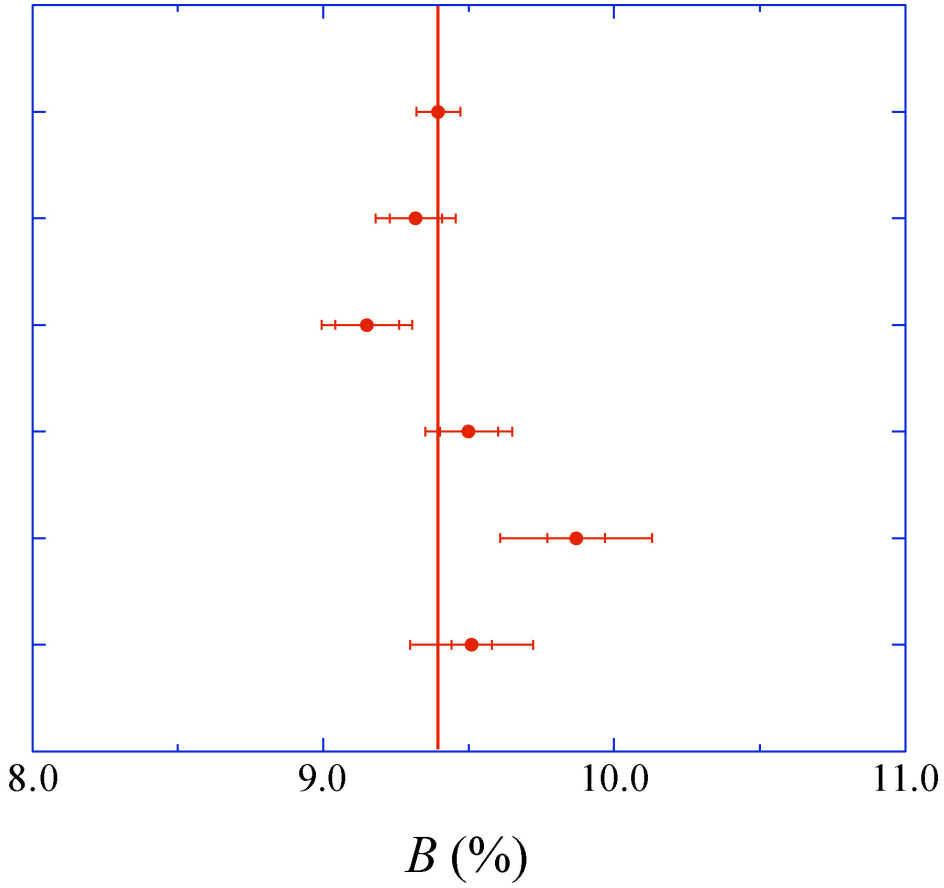


average	(9.18 ± 0.17)%
DELPHI	(9.50 ± 0.32 ± 0.28)%
L3	(9.10 ± 0.15 ± 0.13)%
CLEO '93	(8.96 ± 0.16 ± 0.44)%
ALEPH '92	(10.38 ± 0.66 ± 0.82)%

- correcting for small contribution of $\tau^- \to K^- 2\pi^0 \nu_\tau$

⇨ $B(\tau^- \to \pi^- 2\pi^0 \nu_\tau) = (9.12 \pm 0.17)\%$

Measurements of B(τ⁻ → h⁻h⁺h⁻ν_τ)



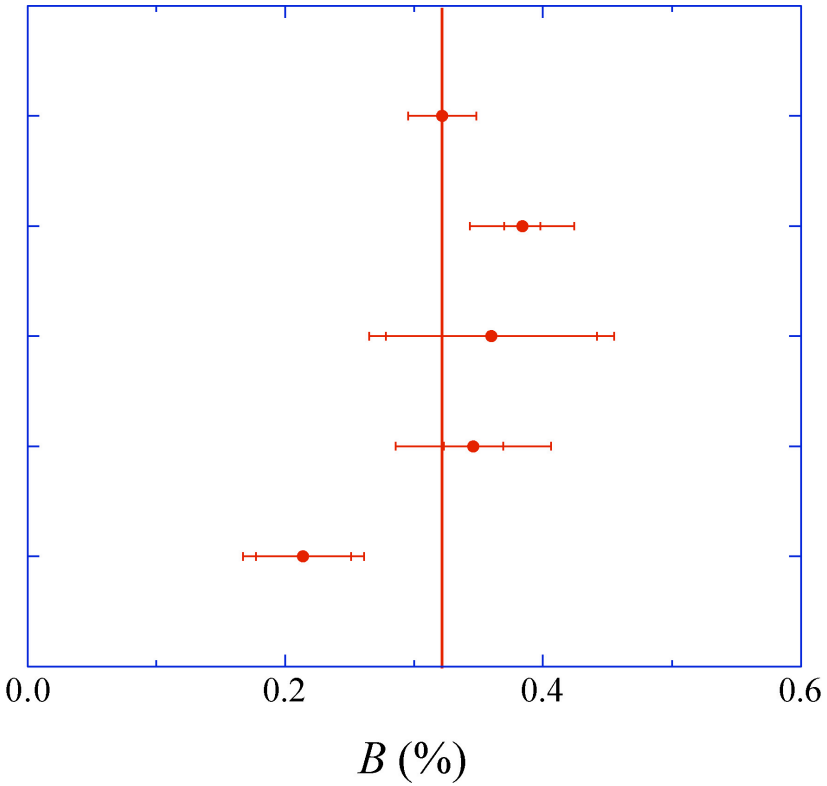
average	(9.40 ± 0.08)%
DELPHI	(9.32 ± 0.09 ± 0.11)%
L3	(9.15 ± 0.11 ± 0.11)%
ALEPH '96	(9.50 ± 0.10 ± 0.11)%
OPAL '95	(9.87 ± 0.10 ± 0.24)%
CLEO '95	(9.51 ± 0.07 ± 0.20)%

- measurements are consistent with each other

CLEO: Measurements of $B(\tau^- \to \pi^-\pi^+\pi^-\nu_\tau)$

- use ring imaging Cherenkov (RICH) detector to identify π/K
- $B(\tau^- \to \pi^-\pi^+\pi^-\nu_\tau) = (9.13 \pm 0.05 \pm 0.46)\%$ first

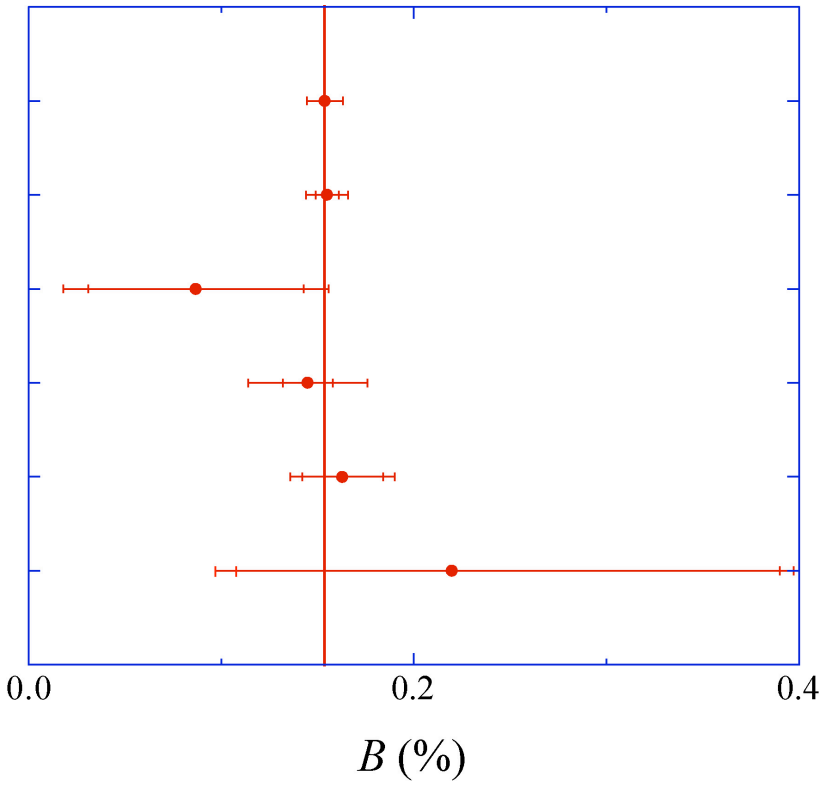
CLEO: Measurements of $B(D^0 \to K^-\pi^+\pi^-\pi^+)$



average	(0.322 ± 0.026)%
CLEO	(0.384 ± 0.014 ± 0.038)%
OPAL '00	(0.360 ± 0.082 ± 0.048)%
CLEO '99	(0.346 ± 0.023 ± 0.056)%
ALEPH '98	(0.214 ± 0.037 ± 0.029)%

- measurements are consistent with each other

CLEO: Measurements of $B(\Xi_c^0 \to K^0 K^+ \Xi^- \pi^+)$



average	$(0.154 \pm 0.009)\%$
CLEO	$(0.155 \pm 0.006 \pm 0.009)\%$
OPAL '00	$(0.087 \pm 0.056 \pm 0.040)\%$
CLEO '99	$(0.145 \pm 0.013 \pm 0.028)\%$
ALEPH '98	$(0.163 \pm 0.021 \pm 0.017)\%$
DELCO '85	$(0.22\ ^{+0.17}_{-0.11} \pm 0.05)\%$

- measurements are consistent with each other
- CLEO result has significantly better precision

Summary of 3-prong Decays

- $B(\tau^- \to \pi^- 2\pi^0 \nu_\tau) = (9.12 \pm 0.17)\%$
- $B(\tau^- \to h^- h^+ h^- \nu_\tau) = (9.40 \pm 0.08)\%$
- $B(\tau^- \to \pi^- \pi^+ \pi^- \nu_\tau) = (9.13 \pm 0.05 \pm 0.46)\%$
- $B(\tau^- \to K^- \pi^+ \pi^- \nu_\tau) = (0.322 \pm 0.026)\%$
- $B(\tau^- \to K^- K^+ \pi^- \nu_\tau) = (0.154 \pm 0.009)\%$

} Sum ~ $(9.6 \pm 0.5)\%$

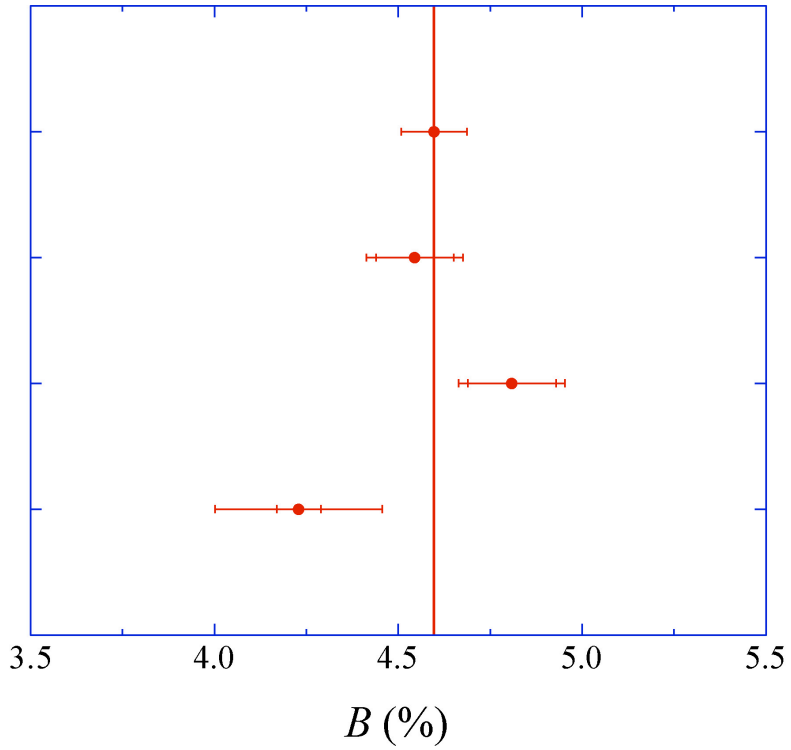
- $B(\tau^- \to K^- K^+ K^- \nu_\tau) < 0.0037\%$ @ 90% CL (CLEO)

✔ sum of exclusive 3-prong decays is consistent with inclusive decay

✔ result is consistent with isospin symmetry:

$B(\tau^- \to \pi^- 2\pi^0 \nu_\tau) \leq B(\tau^- \to \pi^- \pi^+ \pi^- \nu_\tau)$

Measurements of $B(\tau \to h^- h^+ h^- \pi^0 \nu_\tau)$



average	(4.60 ± 0.09)%
DELPHI	(4.55 ± 0.11 ± 0.08)%
L3	(4.81± 0.12 ± 0.08)%
CLEO '95	(4.23± 0.06 ± 0.22)%

- CVC prediction based on measured $\sigma(e^+e^- \to 4\pi)$:
  $B(\tau^- \to \pi^-\pi^+\pi^-\pi^0\nu_\tau) = (3.63 \pm 0.21)\%$
- neglecting expected small contributions from decays with kaons
  ⇨ measurement is ~ 4σ above CVC prediction

Search for Lepton Flavor Violation Decays

- conservation laws are supposed to have associated symmetries in SM
- lepton flavor conservation is experimentally observed phenomena
  - ☆ no associated symmetry in SM
- searching for lepton flavor violation is like living in fantasy land
- observation of neutrino oscillations by SuperK and SNO
  - ⇨ searching for lepton flavor violation is like day dreaming
- many extensions of the Standard Model allow lepton flavor violation
- some theoretical calculations of lepton flavor violation branching fractions close to experimental sensitivity

Summary of Search for LFV Decays

- has searched in 41 decay modes with sensitivity of ~ 10^{-6}
- new 90% CL upper limits from Belle (preliminary):
  - Belle: $B(\tau^- \to \mu^-\mu)$ < 3.2 x 10^{-7}
  - Belle: $B(\tau^- \to \mu^-\mu)$ < 3.4 x 10^{-7}
    - ⇨ sensitive to pseudoscalar Higgs: exclude tanβ vs. m_A region similar to CDF
    - ⇨ see talk by Ohshima on Friday
- expect results on new searches from BaBar and Belle

Summary

- test lepton universality to precision of 0.2%
- has began new era of □physics with kaons
  - ☆ expect new results from CLEO III, BaBar, Belle
- reach a new level of precision in □physics
  but no hint of physics beyond Standard Model