New Results on $\not{l}$ Lepton

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Outline

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- hadronic decays
- lepton flavor violation decays
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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

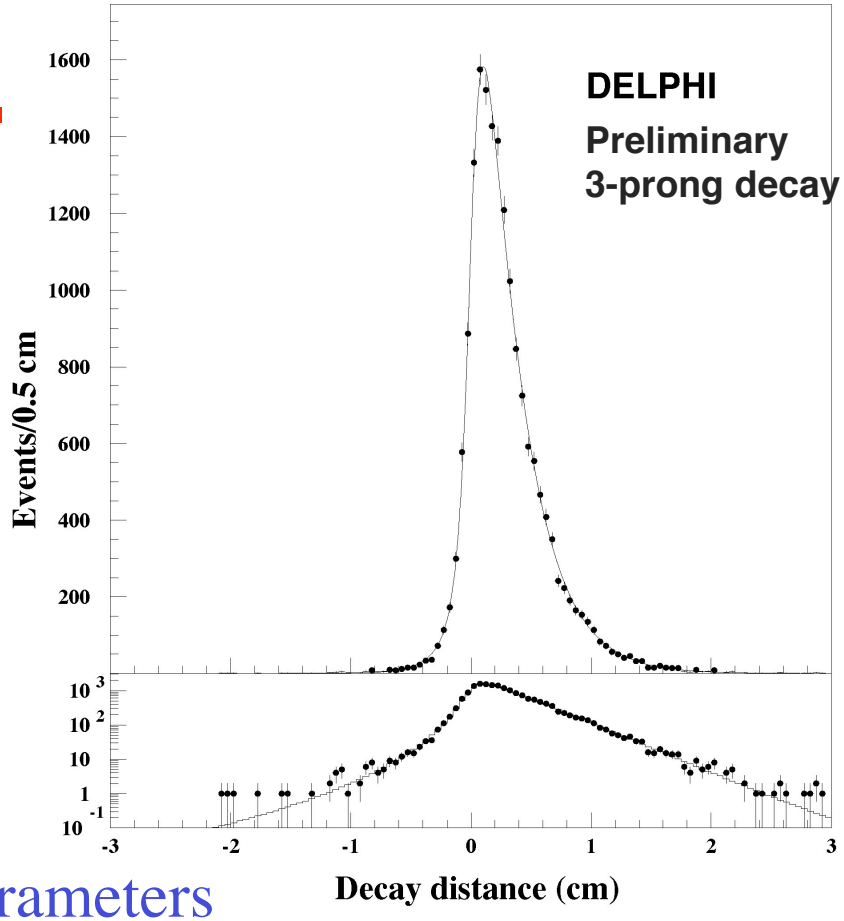
- motivation: test of lepton universality

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

$$\Gamma_{\mu} = \Gamma_{\mu}\left(\frac{g_e}{g_{\mu}}\right)^2\left(\frac{m_{\mu}}{m_{\mu}}\right)^5 B(\mu^- \to e^-\bar{\nu}_{\mu}\nu_e)\cdot R\left(\frac{m_{\mu}}{m_{\mu}}\right)$$

  - ☆ measure: Γ_{μ}, B_e and B_{μ}
    - ⇨ test: g_{μ}/g_{μ} or $g_e/g_{\mu} = 1$?

DELPHI: □ Lifetime Measurement



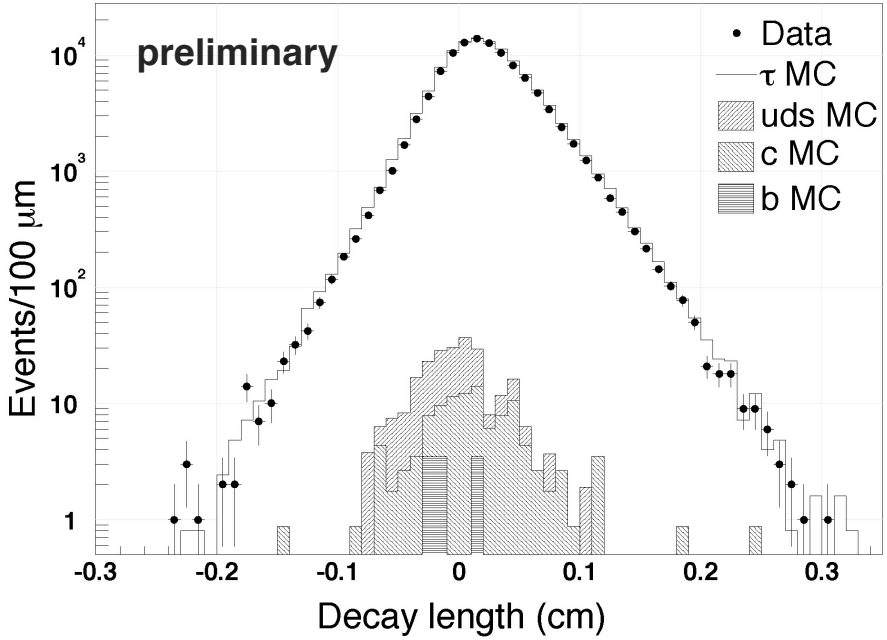
- measured with three methods:
  - 3-prong decay length
  - 1-prong vs 1-prong impact parameters
    - impact parameter difference: $d_1 - d_2$
    - miss distance: $d_1 + d_2$

  } 36% correlation

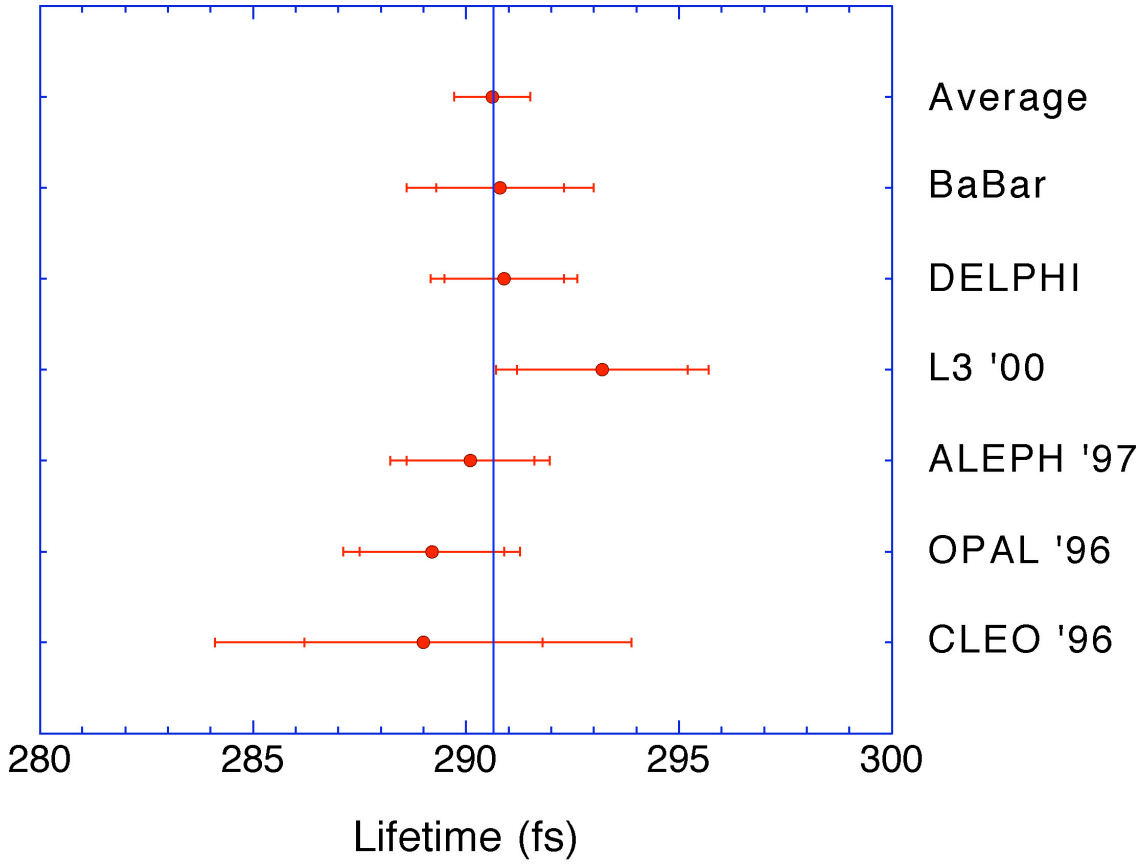
  ⇨ □ = 290.9 ± 1.4 ± 1.0 fs

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

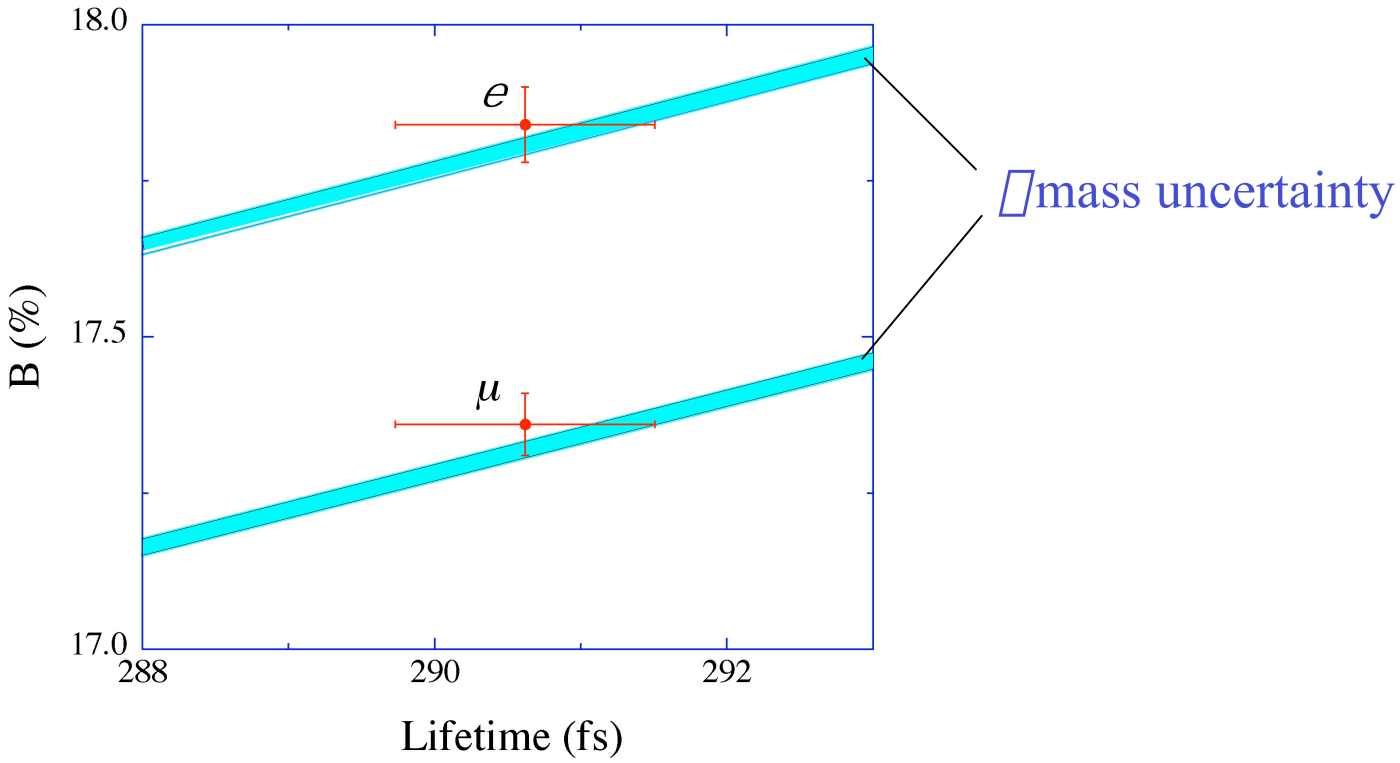


Summary of □Lifetime Measurements



- all measurements are consistent with each other
  - ⇨ □□= 290.6 ± 0.9 fs

Test of Lepton Universality

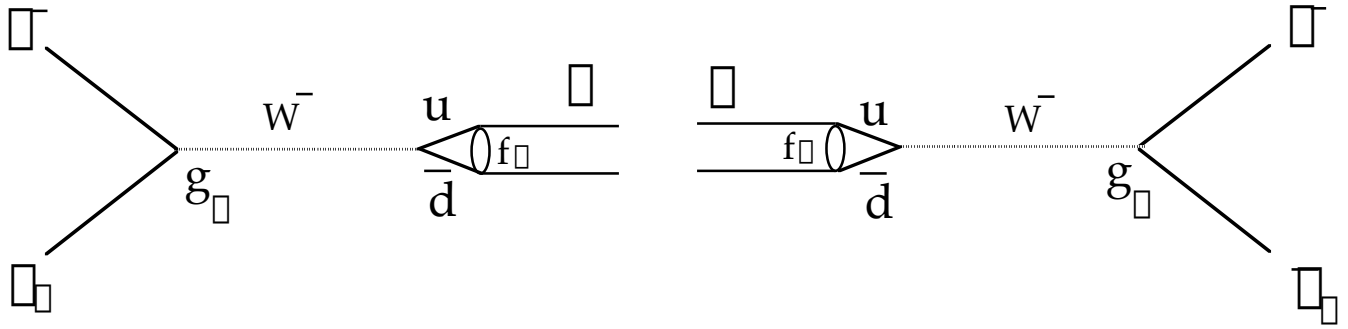


- $g_\tau/g_\mu = 0.9990 \pm 0.0023$
- $g_e/g_\mu = 0.9988 \pm 0.0021$
  - ⇨ universality is tested with 3rd generation to 0.2%

Measurements of Hadronic Decays

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

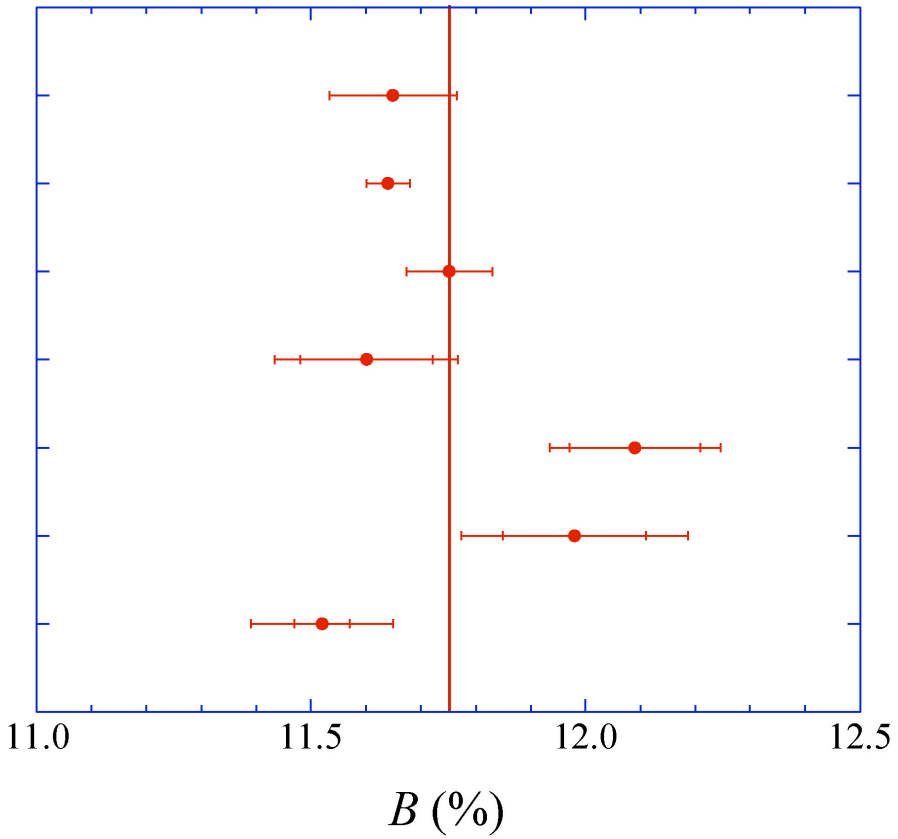
Theory of $\tau \to \nu_\tau$



$$\frac{B(\tau \to \mu \nu_\tau)}{B(\tau \to e \bar{\nu}_e)} = \left(\frac{g_\mu}{g_e}\right)^2 \cdot \frac{m_\tau}{m_\tau} \cdot PS$$

⇨ test of lepton universality

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

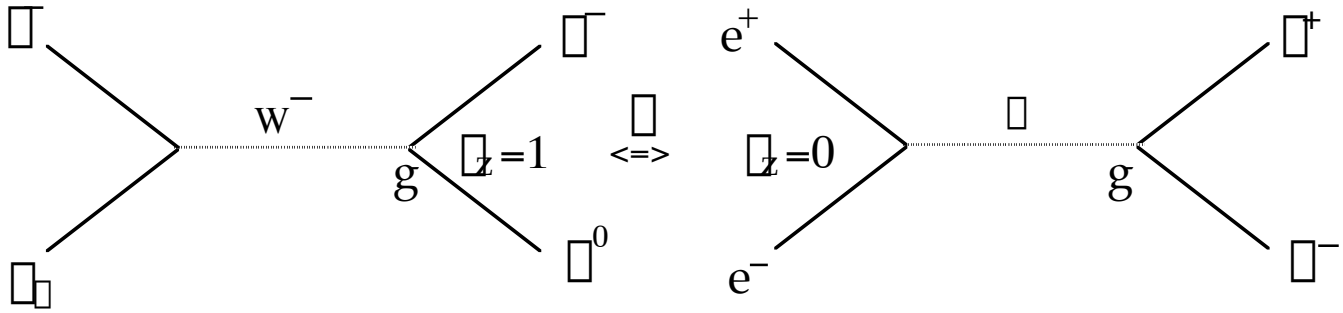


Marciano	(11.65 ± 0.12)%
Decker et al.	(11.64 ± 0.04)%
Average	(11.75 ± 0.08)%
DELPHI	(11.60 ± 0.12 ± 0.12)%
L3	(12.09 ± 0.12 ± 0.10)%
OPAL '98	(11.98 ± 0.13 ± 0.16)%
CLEO '97	(11.52 ± 0.05 ± 0.12)%

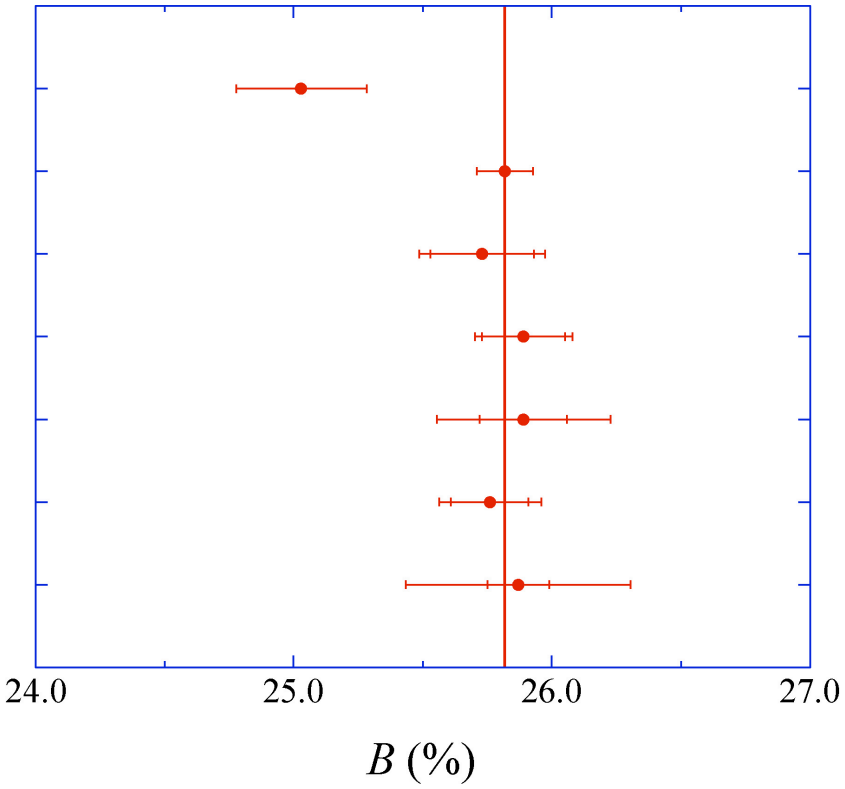
- not good consistency between experiments: $\chi^2 = 9.9$ for 3 DOF
- result consistent with lepton universality

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

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



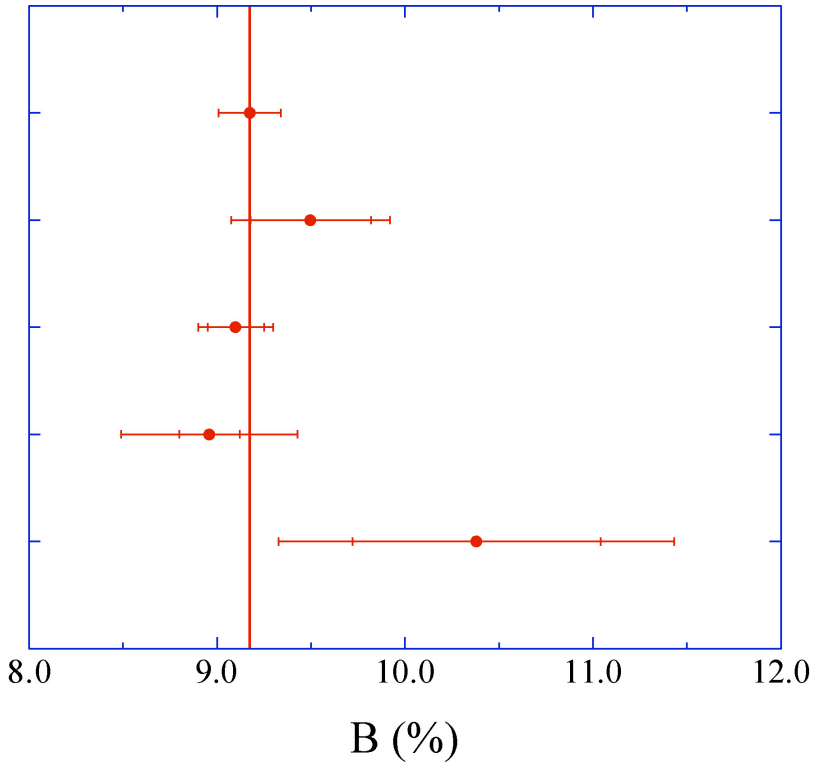
Measurements of B(τ⁻ → h⁻π⁰ν_τ)



Eidelman	(25.03 ± 0.25)%
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 '96	(25.87 ± 0.12 ± 0.42)%

- measurement is ~ 3σ above CVC prediction

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

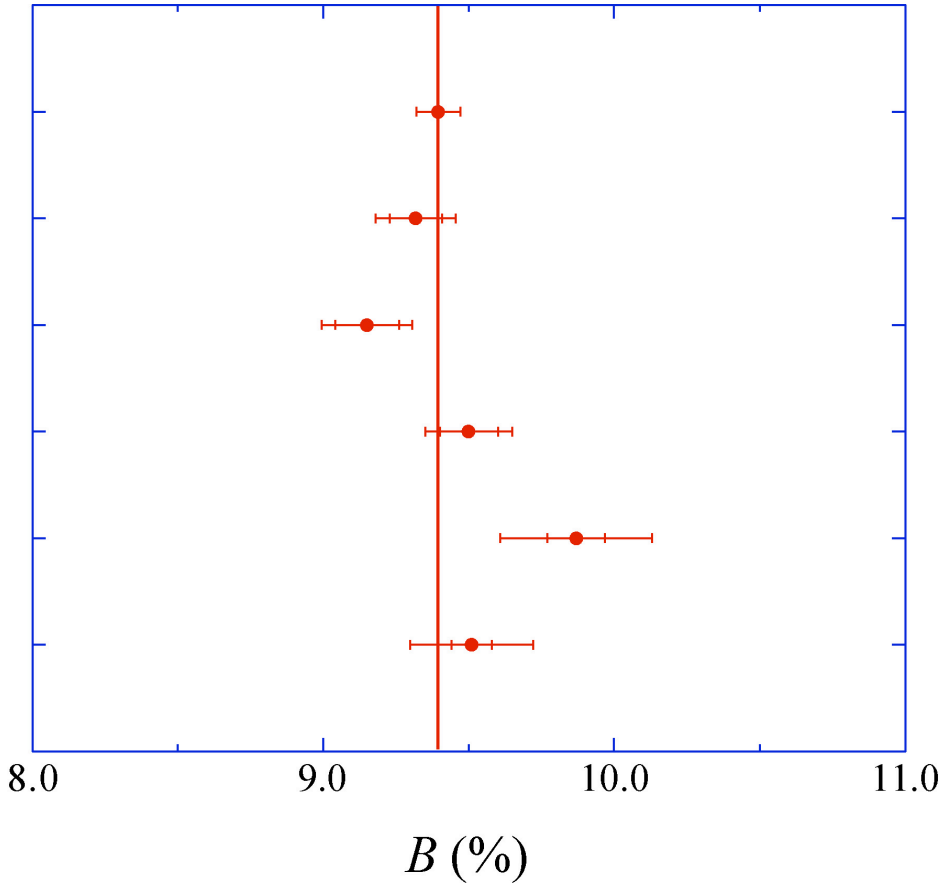


average	$(9.18 \pm 0.17)\%$
DELPHI	$(9.50 \pm 0.32 \pm 0.28)\%$
L3	$(9.10 \pm 0.15 \pm 0.13)\%$
CLEO '93	$(8.96 \pm 0.16 \pm 0.44)\%$
ALEPH '92	$(10.38 \pm 0.66 \pm 0.82)\%$

- 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)



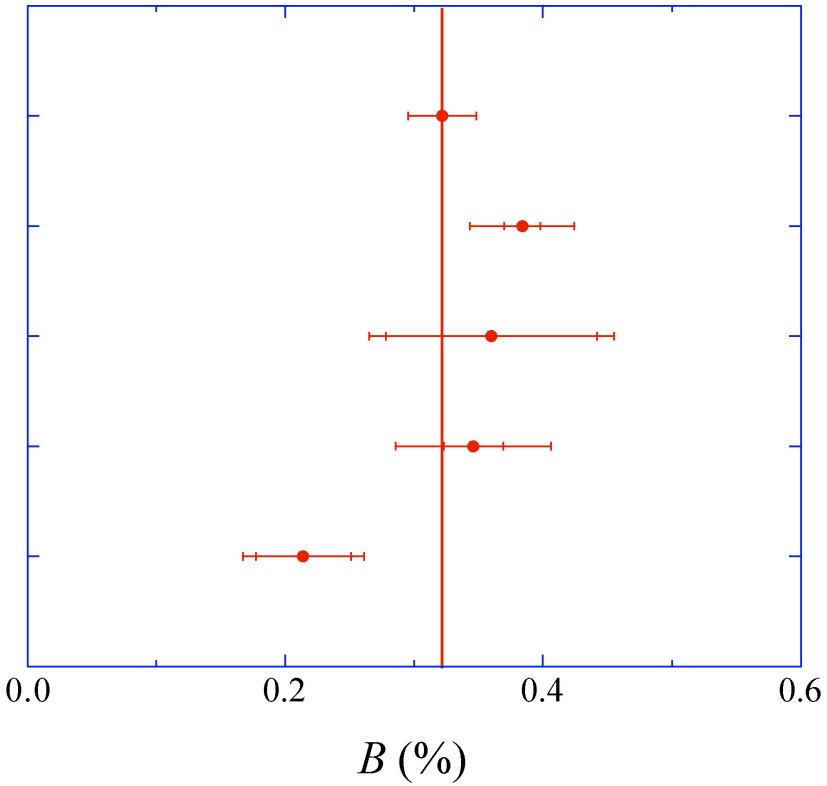
average	(9.40 ± 0.08)%
DELPHI	(9.32 ± 0.09 ± 0.11)%
L3	(9.15 ± 0.11 ± 0.11)%
ALEPH '96	(9.50 ± 0.10 ± 0.11)%
OPAL '95	(9.87 ± 0.10 ± 0.24)%
CLEO '95	(9.51 ± 0.07 ± 0.20)%

- measurements are consistent with each other

CLEO: Measurements of $B(\Lambda_c^+ \to \Lambda^0 \pi^+ \pi^0 \pi^0)$

- use ring imaging Cherenkov (RICH) detector to identify π/K
- $B(\Lambda_c^+ \to \Lambda^0 \pi^+ \pi^0 \nu_e) = (9.13 \pm 0.05 \pm 0.46)\%$ first

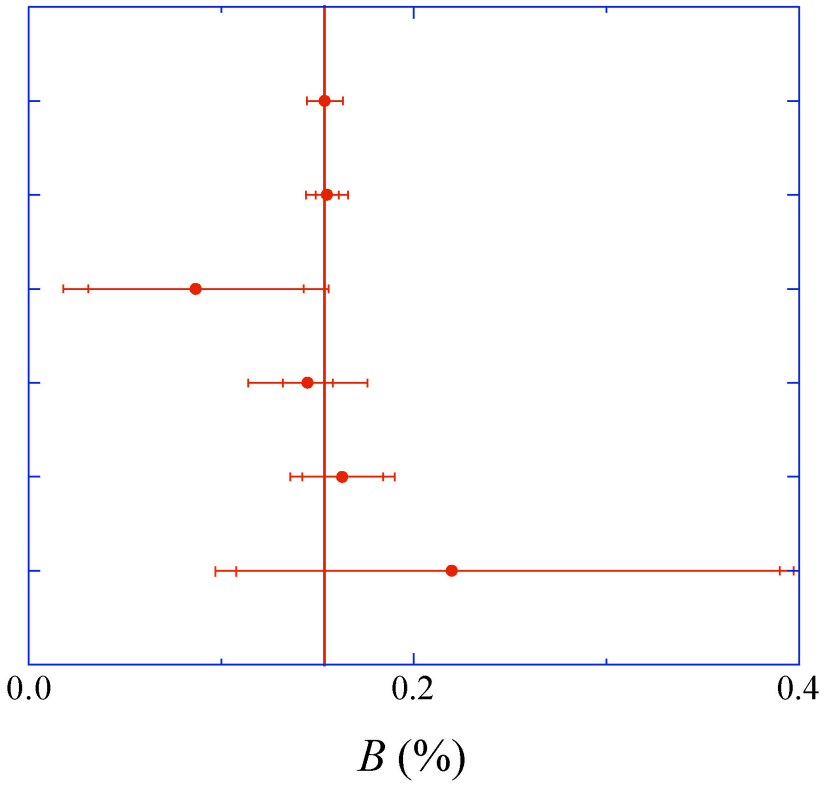
CLEO: Measurements of $B(D^0 \to K^-\pi^+\pi^0)$



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 $B(\Lambda_c^+ \to K^- K^+ \pi^+)$



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

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

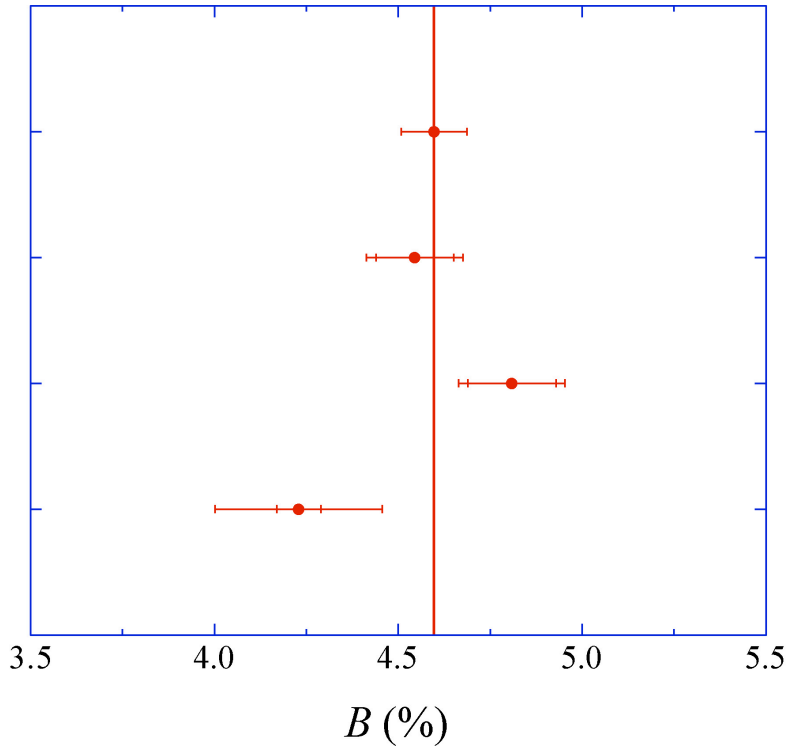
} Sum ~ $(9.6 \pm 0.5)\%$

✔ 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 $\sigma(e^+e^- \to 4\pi)$:
  $B(\tau^- \to \pi^-\pi^+\pi^-\pi^0\nu_\tau) = (3.84 \pm 0.17)\%$
- neglecting expected small contributions from decays with kaons
  ⇨ measurement is significantly 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}
    - ⇨ 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 better than 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