Status of HFAG-Tau Subgroup

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MANCHESTER 1824
The University of Manchester

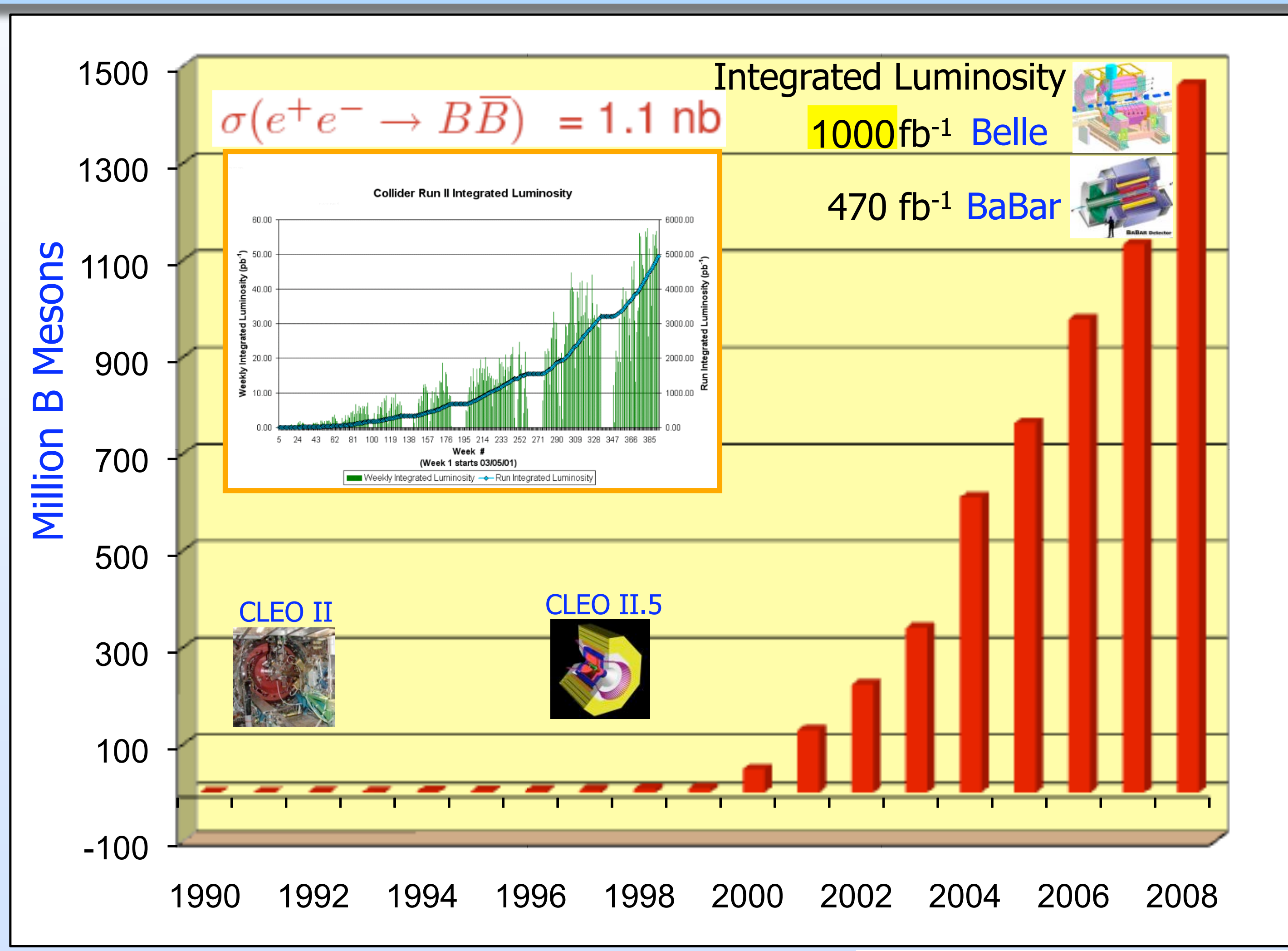
The Tau Subgroup @HFAG

At Tau2008 (Novosibirsk), the newest Tau subgroup of the Heavy Flavor Averaging Group (HFAG) was formed.

- Tau Physics
  - Kiyoshi Hayasaka (Nagoya University, BELLE)
  - Boris Shwartz (BINP, BELLE)
  - Hisaki Hayashii (Nara Woman's University, BELLE)
  - Swagato Banerjee (University of Victoria, BABAR)
  - Alberto Lusiani (INFN Pisa, BABAR)
  - Mike Roney (University of Victoria, BABAR)

http://www.slac.stanford.edu/xorg/hfag/org/index.html

B-Factories are also Tau-Factories



Cross Section at 10.58 GeV

$\sigma(\tau^+\tau^-)=(0.919\pm0.003)$nb

S. Banerjee, et. al. PRD77, 054012 (2008)

Experiment	Number of τ Pairs
LEP	$\sim3\times10^5$
CLEO	$\sim1\times10^7$
BaBar	$\sim5\times10^8$
Belle	$\sim9\times10^8$

Mandate

HFAG: Tau Physics Parameters

Purpose:

Provide latest results and averages of Branching Fractions and Upper Limits of the Tau Lepton

Scope:

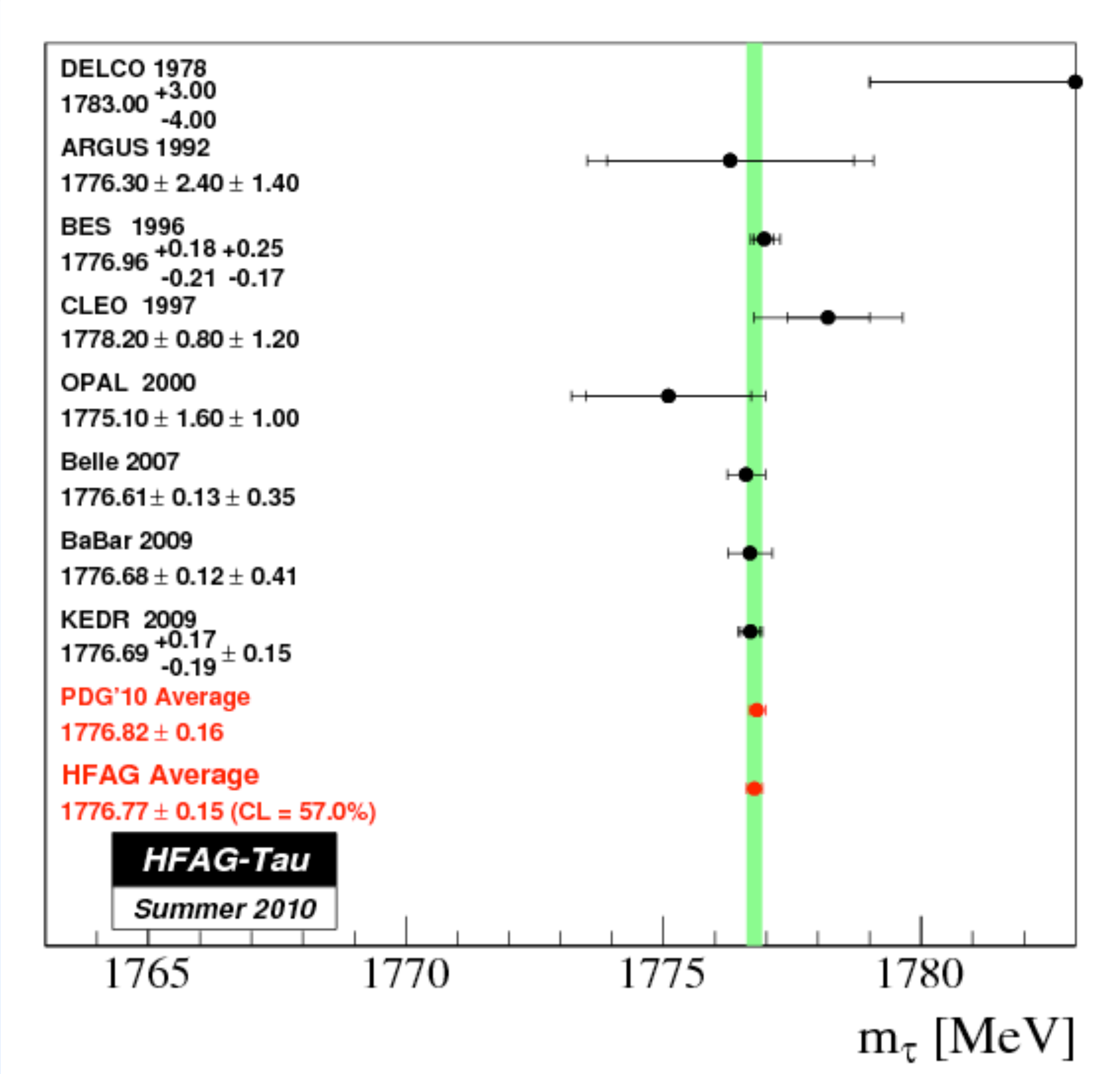
- Tau Mass
- Leptonic Branching Fractions
- Strange Branching Fractions
- Non-Strange Branching Fractions
- Extraction of |Vus|
- Lepton Flavour Violating Upper Limits

http://www.slac.stanford.edu/xorg/hfag/tau/index.html

Methodology

- PDG averages published results, subject to a cut off date.
- HFAG also uses preliminary results, and tries to update at least once a year. Preliminary results not published over a long period of time (~2 years) are discarded.
- HFAG tries to take into account correlations between measurements, as well as dependence on common external parameters such as tau-pair cross-section and background normalization errors between experiments.
- As much as possible, HFAG tries to avoid inflating measured uncertainties using PDG-style scale factors to account for spread between the different measurements. Instead, a confidence level (CL) for the average is quoted.

Tau Mass


DELCO 1978
1783.00 +3.00 -4.00
ARGUS 1992
1776.30 ± 2.40 ± 1.40
BES 1996
1776.96 +0.18 +0.25 -0.21 -0.17
CLEO 1997
1778.20 ± 0.80 ± 1.20
OPAL 2000
1775.10 ± 1.60 ± 1.00
Belle 2007
1776.61 ± 0.13 ± 0.35
BaBar 2009
1776.68 ± 0.12 ± 0.41
KEDR 2009
1776.69 +0.17 -0.19 ± 0.15
PDG'10 Average
1776.82 ± 0.16
HFAG Average
1776.77 ± 0.15 (CL = 57.0%)
HFAG-Tau
Summer 2010
1765
1770
1775
1780
m_τ [MeV]

Branching Fraction Measurements

Leptonic Branching Fractions:

Decay Mode	Experiment	Reference	Result
$(\tau^- \to \mu^- \bar{\nu} \nu)/(\tau^- \to e^- \bar{\nu} \nu)$	BaBar	Phys.Rev.Lett.105:051602,2010.	$(0.9796 \pm 0.0016 \pm 0.0036)$
			$\lvert g_\mu / g_e \rvert = (1.0036 \pm 0.0020)$
			$B^{univ}(\tau^- \to e^- \bar{\nu} \nu) = (17.833 \pm 0.030) \times 10^{-2}$
			$B^{univ}(\tau^- \to \text{hadrons}^- \nu) = (64.823 \pm 0.059) \times 10^{-2}$
			$R^{univ}(\tau^- \to \text{hadrons}^- \nu) = (3.6350 \pm 0.0094)$
			(Top of the Page)

Branching Fraction Measurements

Strange Branching Fractions:

Decay Mode	Experiment	Reference	Result
$(\tau^- \to K^- \nu)/(\tau^- \to e^- \bar{\nu} \nu)$	BaBar	Phys.Rev.Lett.105:051602,2010	$(0.03882 \pm 0.00032 \pm 0.00057)$
			$\mid g_\tau / g_\mu \mid = (0.9836 \pm 0.0087)$
$\tau^- \to K^- \pi^0 \nu$	BaBar	Phys.Rev.D76:051104,2007	$(0.416 \pm 0.003 \pm 0.018) \times 10^{-2}$
$\tau^- \to \bar{K}^0 \pi^- \nu$	BaBar	arXiv:0808.1121 [hep-ex]	$(0.840 \pm 0.004 \pm 0.023) \times 10^{-2}$
	Belle	Phys.Lett.B654:65-73,2007	$(0.808 \pm 0.004 \pm 0.026) \times 10^{-2}$
$\tau^- \to \bar{K}^0 \pi^- \pi^0 \nu$	BaBar	arXiv:0910.2884 [hep-ex]	$(0.342 \pm 0.006 \pm 0.015) \times 10^{-2}$
$\tau^- \to K^- \pi^- \pi^+ \nu$ (excl. K_S^0)	BaBar	Phys.Rev.Lett.100:011801,2008	$(0.273 \pm 0.002 \pm 0.009) \times 10^{-2}$
	Belle	Phys.Rev.D81:113007,2010	$(0.330 \pm 0.001\ ^{+0.016}_{-0.017}) \times 10^{-2}$
$\tau^- \to K^- \pi^- K^+ \nu$	BaBar	Phys.Rev.Lett.100:011801,2008	$(1.346 \pm 0.010 \pm 0.036) \times 10^{-3}$
	Belle	Phys.Rev.D81:113007,2010	$(1.55 \pm 0.01\ ^{+0.06}_{-0.05}) \times 10^{-3}$
$\tau^- \to K^- K^- K^+ \nu$	BaBar	Phys.Rev.Lett.100:011801,2008	$(1.58 \pm 0.13 \pm 0.12) \times 10^{-5}$
	Belle	Phys.Rev.D81:113007,2010	$(3.29 \pm 0.17\ ^{+0.19}_{-0.20}) \times 10^{-5}$
$\tau^- \to K^- \phi \nu$	BaBar	Phys.Rev.Lett.100:011801,2008	$(3.39 \pm 0.20 \pm 0.28) \times 10^{-5}$
	Belle	Phys.Lett.B643:5-10,2006	$(4.05 \pm 0.25 \pm 0.26) \times 10^{-5}$
$\tau^- \to K^+ K^- \nu$	Belle	arXiv:0808.1059 [hep-ex]	$(1.56 \pm 0.02 \pm 0.09) \times 10^{-3}$
$\tau^- \to K^+ K^- \pi^0 \nu$	Belle	arXiv:0808.1059 [hep-ex]	$(2.39 \pm 0.46 \pm 0.26) \times 10^{-5}$
$\tau^- \to K^- \eta \nu$	Belle	Phys.Lett.B672:209-218,2009	$(1.58 \pm 0.05 \pm 0.09) \times 10^{-4}$
$\tau^- \to K^- \pi^0 \eta \nu$	Belle	Phys.Lett.B672:209-218,2009	$(4.6 \pm 1.1 \pm 0.4) \times 10^{-5}$
$\tau^- \to K_S^0 \pi^- \eta \nu$	Belle	Phys.Lett.B672:209-218,2009	$(4.4 \pm 0.7 \pm 0.2) \times 10^{-5}$
$\tau^- \to K^{*-} \eta \nu$	Belle	Phys.Lett.B672:209-218,2009	$(1.34 \pm 0.12 \pm 0.09) \times 10^{-4}$
			(Top of the Page)

Branching Fraction Measurements

Non-Strange Branching Fractions:

Decay Mode	Experiment	Reference	Result
$(\tau^- \to \pi^- \nu)/(\tau^- \to e^- \bar{\nu} \nu)$	BaBar	Phys.Rev.Lett.105:051602,2010.	$(0.5945 \pm 0.0014 \pm 0.0061)$
			$\lvert g_\tau / g_\mu \rvert = (0.9859 \pm 0.0057)$
$\tau^- \to \pi^- \pi^0 \nu$	Belle	Phys.Rev.D78:072006,2008	$(25.24 \pm 0.01 \pm 0.39)$ X 10^{-2}
			$a_\mu^{\pi\pi} = 523.5 \pm 1.5$ (exp) ± 2.6 (BR) ± 2.5 (isospin)
$\tau^- \to \pi^- \pi^- \pi^+ \nu$ (excl. K_S^0)	BaBar	Phys.Rev.Lett.100:011801,2008	$(8.83 \pm 0.01 \pm 0.13) \times 10^{-2}$
	Belle	Phys.Rev.D81:113007,2010	$(8.42 \pm 0.01\ ^{+0.26}_{-0.25}) \times 10^{-2}$
$\tau^- \to \pi^- \pi^0 \eta \nu$	Belle	Phys.Lett.B672:209-,2009	$(1.35 \pm 0.03 \pm 0.07) \times 10^{-3}$
$\tau^- \to \pi^- \eta \nu$ **(Second Class Current)**	Belle	EPS2009	$(4.4 \pm 1.6 \pm 0.8) \times 10^{-5}$
			$< 7.3 \times 10^{-5}$ @ 90% C.L.
$\tau^- \to f_1(1285) \pi^- \nu$	BaBar	Phys.Rev.D77:112002,2008	$(3.19 \pm 0.18 \pm 0.16 \pm 0.99) \times 10^{-4}$
$\tau^- \to f_1(1285) \pi^- \nu \to 2\pi^- \pi^+ \eta \nu$	BaBar	Phys.Rev.D77:112002,2008	$(1.11 \pm 0.06 \pm 0.05) \times 10^{-4}$
$\tau^- \to 2\pi^- \pi^+ \eta \nu$	BaBar	Phys.Rev.D77:112002,2008	$(1.60 \pm 0.05 \pm 0.11) \times 10^{-4}$
$\tau^- \to \pi^- \eta' \nu$ **(Second Class Current)**	Belle	EPS2009	$(-0.47\ ^{+3.97}_{-3.85} \pm 0.26) \times 10^{-6}$
			$< 6.1 \times 10^{-6}$ @ 90% C.L.
$\tau^- \to \pi^- \eta' \nu$ **(Second Class Current)**	BaBar	Phys.Rev.D77:112002,2008	$< 7.2 \times 10^{-6}$ @ 90% C.L.
$\tau^- \to \pi^- \omega \nu$ **(Second Class Current)**	BaBar	Phys.Rev.Lett.103:041802,2009	(Second Class Current)/(First Class Current) < 0.69% @ 90% C.L.
$\tau^- \to \pi^- \phi \nu$	BaBar	Phys.Rev.Lett.100:011801,2008	$(3.42 \pm 0.55 \pm 0.25) \times 10^{-5}$
			(Top of the Page)

Averaging Branching Fractions

- Most of the branching fractions are highly correlated.
- Sources of correlation between the same experiment:
  - Track reconstruction ~ 1% for 1-vs-1 topology
  - Secondary vertex reconstruction ~ 1.5% for K_S
  - Calorimeter bump reconstruction ~ 3% for π^0
  - Particle identification ~ 2-4 %
  - Luminosity uncertainty ~ 1%
- Sources of correlation between different experiments:
  - Tau-pair cross-section uncertainty ~ 0.36%
  - Uncertainty on Branching Fractions of backgrounds

➡ Simultaneous averaging of all branching fractions

Averaging Branching Fractions

- Global Fit performed on 150 measurements:
  - 37 from ALEPH
  - 2 from ARGUS
  - 11 from BaBar
  - 10 from Belle
  - 1 from CELLO
  - 35 from CLEO
  - 5 from CLEO3
  - 14 from DELPHI
  - 2 from HRS
  - 11 from L3
  - 19 from OPAL
  - 3 from TPC

PDG was kind to provide the
list of 129 measurements
from pre B-Factory era
used for their averages and global fits:

THANKS!

Using these inputs, we are able to
reproduce the PDG averages as well as
global fit values, errors and
their S-Factor estimates to within 1E-04.

Special Handling of ALEPH inputs

242 ALEPH Collaboration / Physics Reports 421 (2005) 191–284

Table 15
Correlation matrix of the statistical errors on the branching fractions

	μ	h	$h\pi^0$	$h2\pi^0$	$h3\pi^0$	$h4\pi^0$	$3h$	$3h\pi^0$	$3h2\pi^0$	$3h3\pi^0$	$5h$	$5h\pi^0$
e	−0.21	−0.15	−0.25	−0.09	−0.01	0.00	−0.15	−0.10	0.03	−0.06	0.00	0.01
μ	1.00	−0.13	−0.21	−0.07	−0.06	0.00	−0.09	−0.07	0.00	−0.02	0.00	−0.04
h		1.00	−0.31	−0.02	0.01	−0.06	−0.12	−0.06	−0.02	0.01	−0.01	0.02
$h\pi^0$			1.00	−0.40	0.05	0.00	−0.11	−0.06	−0.02	0.00	−0.04	−0.04
$h2\pi^0$				1.00	−0.51	0.26	−0.09	0.01	−0.07	0.06	−0.01	0.03
$h3\pi^0$					1.00	−0.75	0.01	−0.03	0.05	−0.02	−0.01	0.01
$h4\pi^0$						1.00	−0.02	−0.02	−0.03	0.01	0.02	−0.03
$3h$							1.00	−0.33	0.08	−0.05	−0.04	0.00
$3h\pi^0$								1.00	−0.45	0.19	−0.02	−0.02
$3h2\pi^0$									1.00	−0.65	0.03	0.02
$3h3\pi^0$										1.00	−0.01	−0.04
$5h$											1.00	−0.24
$5h\pi^0$												1.00

ALEPH quotes the correlation matrix for hadronic modes, but PDG translates the matrix into pion modes, which are obtained by subtracting the kaon contribution. We use the total hadronic branching fraction also quoted in the paper.

Quality of Global Fit

Using pre B-Factory era measurements:
sum of all branching fractions from unconstrained fit
= 0.9990 ± 0.0011 (0.9 σ lower than unity).
χ^2 of unconstrained fit = 78.1/93 d.o.f. ⇒ CL = 86.6%
χ^2 of constrained fit = 78.9/94 d.o.f. ⇒ CL = 86.8%

Including measurements from B-Factories era:
sum of all branching fractions from unconstrained fit
= 0.9985 ± 0.0010 (1.5 sigma lower than unity).
χ^2 of unconstrained fit = 158.0/114 d.o.f. ⇒ CL = 0.4%
χ^2 of constrained fit = 160.0/115 d.o.f. ⇒ CL = 0.4%

Results from this unconstrained fit are presented here.

Preliminary Fit Results

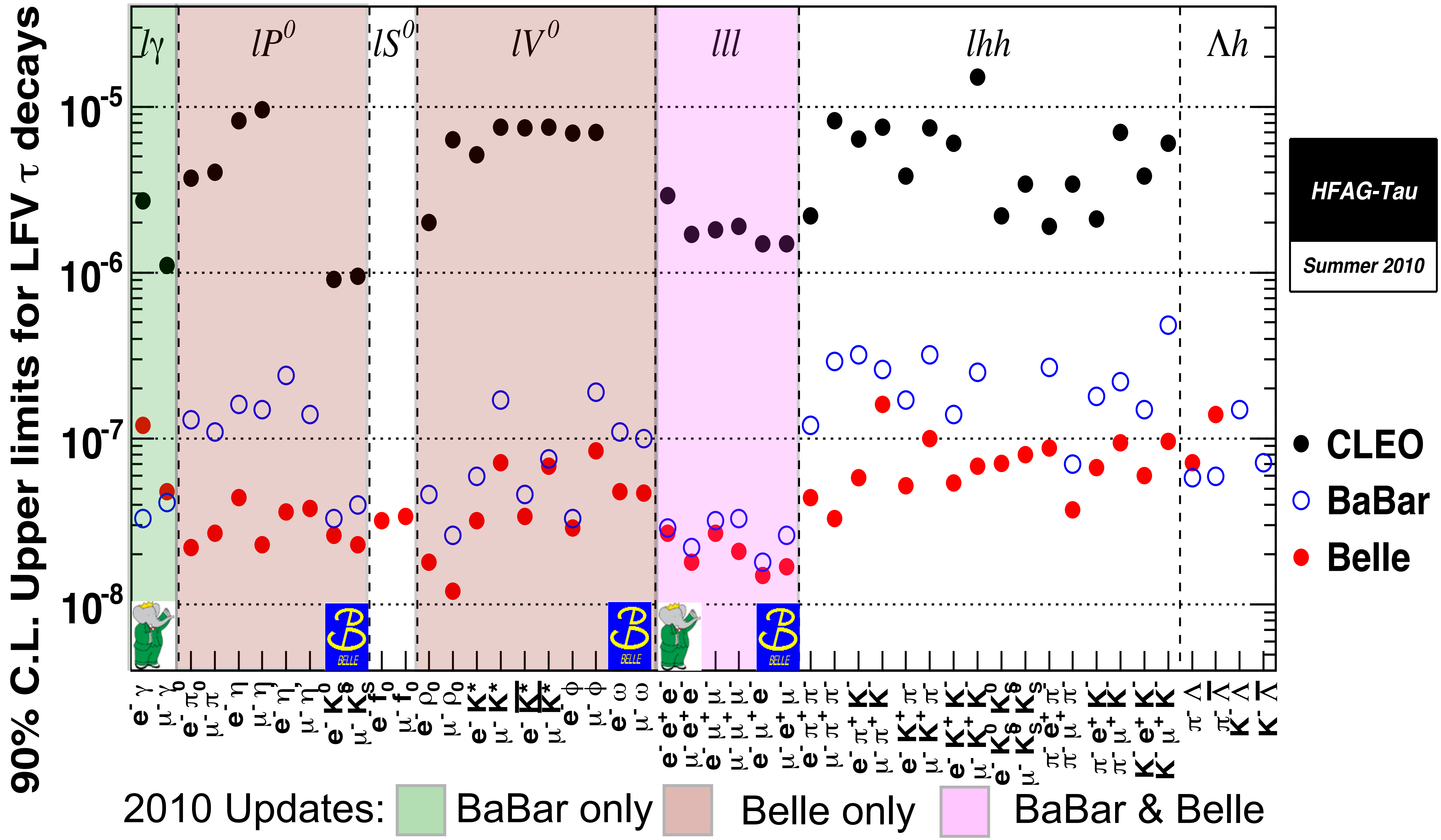
$e^-\bar{\nu}\nu$	0.17816 ± 0.00041	$\pi^-\pi^+\pi^-\nu\ (ex.K^0,\omega)$	0.08968 ± 0.00051
$\mu^-\bar{\nu}\nu$	0.17393 ± 0.00040	$\pi^-\pi^+\pi^-\pi^0\nu\ (ex.\ K^0,\omega)$	0.02739 ± 0.00070
$\pi^-\nu$	0.10814 ± 0.00053	$h^-h^-h^+2\pi^0\nu\ (ex.\ K^0,\omega,\eta)$	0.00100 ± 0.00036
$K^-\nu$	0.00696 ± 0.00010	$h^-h^-h^+3\pi^0\nu$	0.00022 ± 0.00005
$\pi^-\pi^0\nu$	0.25508 ± 0.00091	$K^-\pi^+\pi^-\nu\ (ex.\ K^0)$	0.00294 ± 0.00007
$K^-\pi^0\nu$	0.00432 ± 0.00015	$K^-\pi^+\pi^-\pi^0\nu\ (ex.\ K^0,\eta)$	0.00078 ± 0.00012
$\pi^-2\pi^0\nu\ (ex.\ K^0)$	0.09243 ± 0.00100	$K^-K^+\pi^-\nu$	0.00144 ± 0.00003
$K^-2\pi^0\nu\ (ex.\ K^0)$	0.00061 ± 0.00022	$K^-K^+\pi^-\pi^0\nu$	0.00006 ± 0.00002
$\pi^-3\pi^0\nu\ (ex.\ K^0)$	0.01041 ± 0.00079	$3h^-2h^+\nu\ (ex.\ K^0)$	0.00083 ± 0.00003
$K^-3\pi^0\nu\ (ex.\ K^0,\eta)$	0.00040 ± 0.00022	$3h^-2h^+\pi^0\nu\ (ex.\ K^0)$	0.00018 ± 0.00003
$h^-4\pi^0\nu\ (ex.\ K^0,\eta)$	0.00108 ± 0.00039	$\eta\pi^-\pi^0\nu$	0.00139 ± 0.00007
$\pi^-\bar{K}^0\nu$	0.00827 ± 0.00018	$\eta K^-\nu$	0.00016 ± 0.00001
$K^-K^0\nu$	0.00157 ± 0.00016	$h^-\omega\nu$	0.01996 ± 0.00064
$\pi^-\bar{K}^0\pi^0\nu$	0.00348 ± 0.00015	$h^-\omega\pi^0\nu$	0.00405 ± 0.00042
$K^-K^0\pi^0\nu$	0.00159 ± 0.00020	$K^-K^+K^-\nu$	0.00002 ± 0.00000
$\pi^-K^0_SK^0_S\nu$	0.00024 ± 0.00005	$\eta K^-\pi^0\nu$	0.00005 ± 0.00001
$\pi^-K^0_SK^0_L\nu$	0.00113 ± 0.00025	$\eta\pi^-\bar{K}^0\nu$	0.00009 ± 0.00001
		$\pi^-\bar{K}^02\pi^0\nu$	0.00023 ± 0.00023
		$\bar{K}^02h^+h^-\nu$	0.00023 ± 0.00020

$$\mathcal{B}(\tau^- \to X_s^-\nu) = 0.02856 \pm 0.00052$$

$$\Rightarrow |V_{us}| = 0.2164 \pm 0.0023$$

(3.6 σ lower than unitary prediction)

Summary of Lepton Flavor Violation



Summary and Outlook

PDG 2010

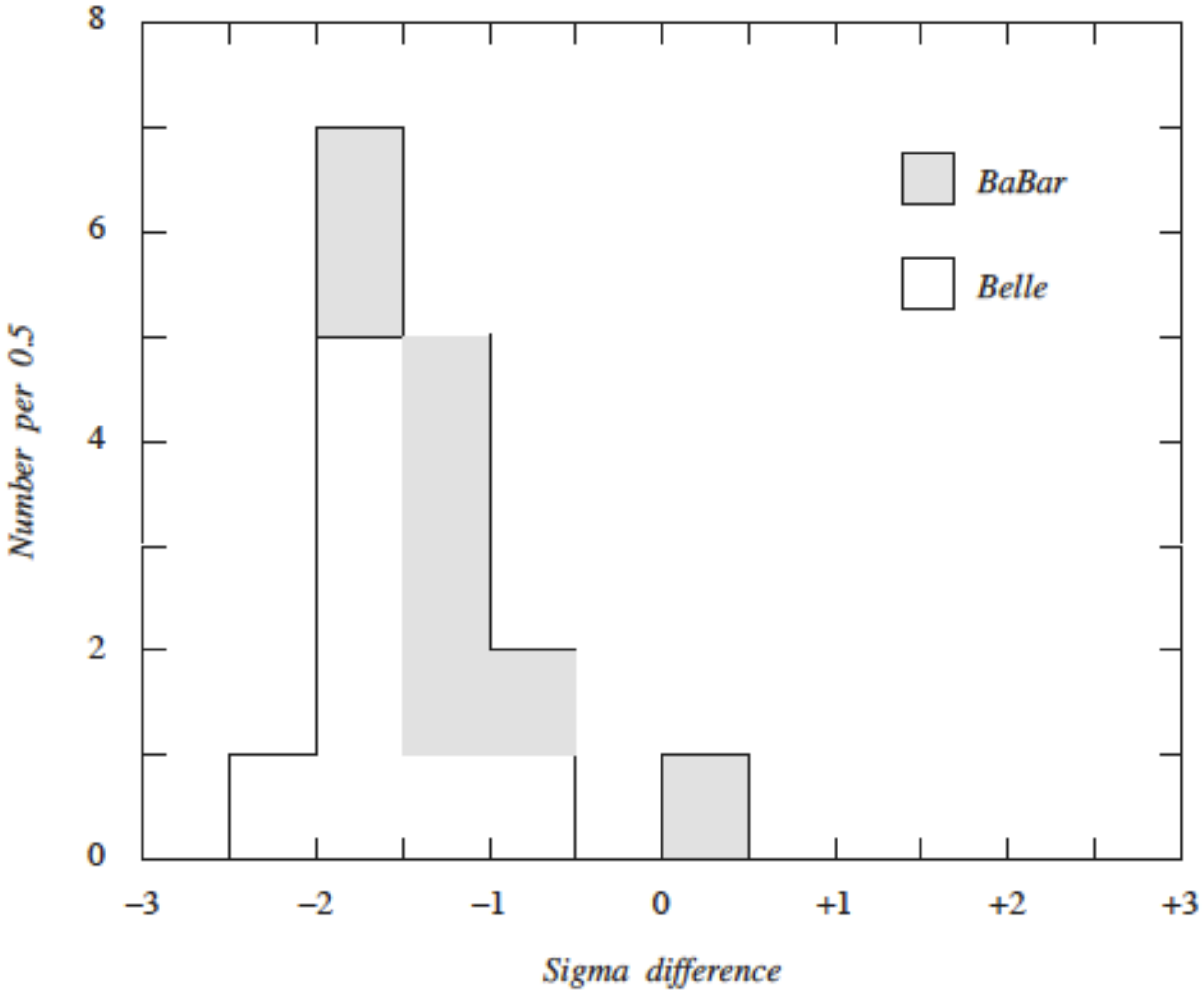


Figure 1: Distribution of the normalized difference between the 16 B-factory measurements of conventional τ-decay branching fractions and non-B-factory measurements. The Belle and BaBar collaborations have each published 8 measurements.

Measurements from B-Factories are more precise than before. However, in general, the newer branching fractions are lower; the spread between the measurements are quite large in some cases. This makes CL of the fit to be low and averaging a rather challenging task. However, we hope to converge upon acceptable results soon...

Please stay tuned!