HFAG-Tau Report, Early 2012

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31 March 2012

1 Introduction

We present averages of a selection of physics quantities related to the tau lepton, where we follow the HFAG methodology [31] to improve the Review of Particle Physics (PDG) [91] results by:

- including a selection of reliable preliminary results, hence obtaining more up-to-date results;
- updating the experimental measurements value and systematic error when it depends on external parameters whose values and uncertainties are updated;
- taking into account the statistical correlation that is induced by the dependence from common systematic contributions.

All published statistical correlations are considered, and a selection of measurements, particularly the most precise and the most recent, were examined to obtain all the significant systematic dependencies. The HFAG techniques are most useful in the global fit of the tau branching fractions (Section 2). We use the branching fraction fit results to obtain updated lepton universality tests (Section 3) and updated determinations of $|V_{us}|$ with tau measurements (Section 5). Finally, we report in Section 6 the most up-to-date limits on the lepton-flavour-violating tau branching fractions.

2 Branching fractions fit

The measurements listed in Table 1 have been used in a minimum χ^2 fit subject to the equality constraints that are listed either in the same table (where some fitted quantities and experimental measurements are expressed as ratios of fit quantities) or in Section 2.2. The fitted quantities and the measurements are labelled using the PDG [91] Γ_n notation, where n is an integer number, which matches the PDG notation for $n < 800$. We use $n \geq 800$ to denote some additional branching fractions, as documented in the former HFAG report [31].

The fitted branching fractions consist on 40 "base nodes" and 45 derived branching fractions, described either as sum of base nodes (see Section 2.2) or as ratios of branching fractions (see Table 1). Furthermore, we define (see Section 2.2) Γ_{All} as the sum of all the base modes, which correspond to all non-overlapping tau decay modes, $\Gamma_{998} = 1 - \Gamma_{\text{All}}$ and $\Gamma_{110} = X_s^- \nu_\tau$, which is the total branching fraction of the tau to modes with the strangeness quantum number equal to one.

The fitted HFAG-Tau averages are reported in Table 1. The fit has $\chi^2/\text{d.o.f.} = 143.5/118$, corresponding to a confidence level CL = 5.5%. We use a total of 157 measurements and 47 constraint equations to fit 86 quantities. The fit is statistically consistent with the unitarity constraint, but the unitarity constraint is not applied.

In several cases, when it is statistically equivalent within the HFAG-Tau fitting procedure, for historical reasons the statistical and systematic errors are added in quadrature and are reported in the above table in the location of the statistical error, reporting zero as systematic error. A scale factor of 5.44 (as in the former report [31]) has been applied in the fit to the quoted errors of the two inconsistent measurements of $\Gamma_{96} = \tau \to KKK\nu$ by *BaBar* and Belle.

With respect to the end-of-2009 HFAG report [31], following comments by M. Davier [62], we have included 3 new modes:

$$\begin{aligned}
\Gamma_{49} &= \pi^-\pi^0K^0\overline{K}^0\nu_\tau, \\
\Gamma_{804} &= \pi^-K^0_LK^0_L\nu_\tau, \\
\Gamma_{805} &= a_1^-(\to\pi^-\gamma)\nu_\tau
\end{aligned}$$

along with the related measurements

$$\begin{aligned}
\Gamma_{46} = \pi^-K^0\overline{K}^0\nu_\tau &= (0.1530 \pm 0.0340 \pm 0.0000)\cdot 10^{-2} \quad \text{(ALEPH [47])}, \\
\Gamma_{49} = \pi^-\pi^0K^0\overline{K}^0\nu_\tau &= (3.1000 \pm 2.3000 \pm 0.0000)\cdot 10^{-4} \quad \text{(ALEPH [50])},
\end{aligned}$$

the estimate

$$\Gamma_{805} = a_1^-(\to\pi^-\gamma)\nu_\tau = (4.0000 \pm 2.0000 \pm 0.0000)\cdot 10^{-4} \quad \text{(ALEPH [96])},$$

and the constraint

$$\Gamma_{46} = \Gamma_{48} + \Gamma_{47} + \Gamma_{804} \ .$$

Furthermore, the following new measurements were added:

$$\begin{aligned}
\Gamma_{128} = K^-\eta\nu_\tau &= (1.4200 \pm 0.1100 \pm 0.0700)\cdot 10^{-4} \quad (\textit{BABAR}\ [24]), \\
\Gamma_{40} = \overline{K}^0\pi^-\pi^0\nu_\tau &= (0.3840 \pm 0.0040 \pm 0.0160)\cdot 10^{-2} \quad \text{(Belle [95])}, \\
\Gamma_{42} = K^-\pi^0K^0\nu_\tau &= (0.1480 \pm 0.0020 \pm 0.0080)\cdot 10^{-2} \quad \text{(Belle [95])}.
\end{aligned}$$

Finally, the constraint parameters (see Section 2.2) have been updated to the PDG 2011 results [91].

Table 1: HFAG Winter 2012 branching fractions fit results.

Tau lepton branching fraction	**Value**	**Exp.**	**Ref.**
$\Gamma_3 = \mu^-\overline{\nu}_\mu\nu_\tau$	$(17.392 \pm 0.040)\cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(17.319 \pm 0.077 \pm 0.000)\cdot 10^{-2}$	ALEPH	[96]
	$(17.325 \pm 0.122 \pm 0.000)\cdot 10^{-2}$	DELPHI	[10]
	$(17.342 \pm 0.129 \pm 0.000)\cdot 10^{-2}$	L3	[13]
	$(17.340 \pm 0.108 \pm 0.000)\cdot 10^{-2}$	OPAL	[5]
$\frac{\Gamma_3}{\Gamma_5} = \frac{\mu^-\overline{\nu}_\mu\nu_\tau}{e^-\overline{\nu}_e\nu_\tau}$	0.9761 ± 0.0028	HFAG	Winter 2012 fit
	$0.9970 \pm 0.0532 \pm 0.0000$	ARGUS	[22]
	$0.9796 \pm 0.0039 \pm 0.0005$	*BABAR*	[42]
	$0.9777 \pm 0.0107 \pm 0.0000$	CLEO	[25]
$\Gamma_5 = e^-\overline{\nu}_e\nu_\tau$	$(17.818 \pm 0.041)\cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(17.837 \pm 0.080 \pm 0.000)\cdot 10^{-2}$	ALEPH	[96]
	$(17.760 \pm 0.180 \pm 0.000)\cdot 10^{-2}$	CLEO	[25]
	$(17.877 \pm 0.155 \pm 0.000)\cdot 10^{-2}$	DELPHI	[10]
	$(17.806 \pm 0.129 \pm 0.000)\cdot 10^{-2}$	L3	[13]
	$(17.810 \pm 0.108 \pm 0.000)\cdot 10^{-2}$	OPAL	[1]
$\Gamma_7 = h^- \geq 0K^0_L\nu_\tau$	$(12.020 \pm 0.055)\cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(12.400 \pm 0.990 \pm 0.000)\cdot 10^{-2}$	DELPHI	[8]
	$(12.470 \pm 0.502 \pm 0.000)\cdot 10^{-2}$	L3	[11]
	$(12.100 \pm 0.860 \pm 0.000)\cdot 10^{-2}$	OPAL	[23]
$\Gamma_8 = h^-\nu_\tau$	$(11.507 \pm 0.054)\cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(11.524 \pm 0.105 \pm 0.000)\cdot 10^{-2}$	ALEPH	[96]
	$(11.520 \pm 0.130 \pm 0.000)\cdot 10^{-2}$	CLEO	[25]

Table 1 – continued from previous page

Tau lepton branching fraction	Value	Exp.	Ref.
	$(11.571 \pm 0.166 \pm 0.000) \cdot 10^{-2}$	DELPHI	[7]
	$(11.980 \pm 0.206 \pm 0.000) \cdot 10^{-2}$	OPAL	[15]
$\Gamma_9 = \pi^- \nu_\tau$	$(10.811 \pm 0.053) \cdot 10^{-2}$	HFAG	Winter 2012 fit
$\frac{\Gamma_9}{\Gamma_5} = \frac{\pi^- \nu_\tau}{e^- \overline{\nu}_e \nu_\tau}$	$(60.675 \pm 0.321) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(59.450 \pm 0.574 \pm 0.248) \cdot 10^{-2}$	*BABAR*	[42]
$\Gamma_{10} = K^- \nu_\tau$	$(0.6955 \pm 0.0096) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.6960 \pm 0.0287 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[49]
	$(0.6600 \pm 0.1140 \pm 0.0000) \cdot 10^{-2}$	CLEO	[52]
	$(0.8500 \pm 0.1800 \pm 0.0000) \cdot 10^{-2}$	DELPHI	[9]
	$(0.6580 \pm 0.0396 \pm 0.0000) \cdot 10^{-2}$	OPAL	[4]
$\frac{\Gamma_{10}}{\Gamma_5} = \frac{K^- \nu_\tau}{e^- \overline{\nu}_e \nu_\tau}$	$(3.9031 \pm 0.0543) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(3.8820 \pm 0.0630 \pm 0.0174) \cdot 10^{-2}$	*BABAR*	[42]
$\Gamma_{13} = h^- \pi^0 \nu_\tau$	$(25.936 \pm 0.090) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(25.924 \pm 0.129 \pm 0.000) \cdot 10^{-2}$	ALEPH	[96]
	$(25.670 \pm 0.010 \pm 0.390) \cdot 10^{-2}$	Belle	[69]
	$(25.870 \pm 0.437 \pm 0.000) \cdot 10^{-2}$	CLEO	[30]
	$(25.740 \pm 0.244 \pm 0.000) \cdot 10^{-2}$	DELPHI	[7]
	$(25.050 \pm 0.610 \pm 0.000) \cdot 10^{-2}$	L3	[11]
	$(25.890 \pm 0.336 \pm 0.000) \cdot 10^{-2}$	OPAL	[15]
$\Gamma_{14} = \pi^- \pi^0 \nu_\tau$	$(25.504 \pm 0.092) \cdot 10^{-2}$	HFAG	Winter 2012 fit
$\Gamma_{16} = K^- \pi^0 \nu_\tau$	$(0.4322 \pm 0.0149) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.4440 \pm 0.0354 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[49]
	$(0.4160 \pm 0.0030 \pm 0.0180) \cdot 10^{-2}$	*BABAR*	[34]
	$(0.5100 \pm 0.1221 \pm 0.0000) \cdot 10^{-2}$	CLEO	[52]
	$(0.4710 \pm 0.0633 \pm 0.0000) \cdot 10^{-2}$	OPAL	[6]
$\Gamma_{17} = h^- \geq 2\pi^0 \nu_\tau$	$(10.803 \pm 0.095) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(9.910 \pm 0.411 \pm 0.000) \cdot 10^{-2}$	OPAL	[15]
$\Gamma_{19} = h^- 2\pi^0 \nu_\tau$ (ex.K^0)	$(9.3044 \pm 0.0972) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(9.2950 \pm 0.1217 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[96]
	$(9.4980 \pm 0.4219 \pm 0.0000) \cdot 10^{-2}$	DELPHI	[7]
	$(8.8800 \pm 0.5597 \pm 0.0000) \cdot 10^{-2}$	L3	[11]
$\frac{\Gamma_{19}}{\Gamma_{13}} = \frac{h^- 2\pi^0 \nu_\tau \text{ (ex.}K^0)}{h^- \pi^0 \nu_\tau}$	$(35.874 \pm 0.442) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(34.200 \pm 1.709 \pm 0.000) \cdot 10^{-2}$	CLEO	[93]
$\Gamma_{20} = \pi^- 2\pi^0 \nu_\tau$ (ex. K^0)	$(9.2414 \pm 0.0997) \cdot 10^{-2}$	HFAG	Winter 2012 fit
$\Gamma_{23} = K^- 2\pi^0 \nu_\tau$ (ex. K^0)	$(0.0630 \pm 0.0222) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.0560 \pm 0.0250 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[49]
	$(0.0900 \pm 0.1044 \pm 0.0000) \cdot 10^{-2}$	CLEO	[52]
$\Gamma_{25} = h^- \geq 3\pi^0 \nu_\tau$ (ex.K^0)	$(1.2349 \pm 0.0650) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(1.4030 \pm 0.3098 \pm 0.0000) \cdot 10^{-2}$	DELPHI	[7]
$\Gamma_{26} = h^- 3\pi^0 \nu_\tau$	$(1.1573 \pm 0.0717) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(1.0820 \pm 0.0926 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[96]
	$(1.7000 \pm 0.4494 \pm 0.0000) \cdot 10^{-2}$	L3	[11]
$\frac{\Gamma_{26}}{\Gamma_{13}} = \frac{h^- 3\pi^0 \nu_\tau}{h^- \pi^0 \nu_\tau}$	$(4.4622 \pm 0.2767) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(4.4000 \pm 0.5831 \pm 0.0000) \cdot 10^{-2}$	CLEO	[93]

Table 1 – continued from previous page

Tau lepton branching fraction	Value	Exp.	Ref.
$\Gamma_{27} = \pi^- 3\pi^0 \nu_\tau$ (ex. K^0)	$(1.0322 \pm 0.0749) \cdot 10^{-2}$	HFAG	Winter 2012 fit
$\Gamma_{28} = K^- 3\pi^0 \nu_\tau$ (ex. K^0, η)	$(4.1870 \pm 2.1761) \cdot 10^{-4}$	HFAG	Winter 2012 fit
	$(3.7000 \pm 2.3710 \pm 0.0000) \cdot 10^{-4}$	ALEPH	[49]
$\Gamma_{29} = h^- 4\pi^0 \nu_\tau$ (ex.K^0)	$(0.1558 \pm 0.0391) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.1600 \pm 0.0707 \pm 0.0000) \cdot 10^{-2}$	CLEO	[93]
$\Gamma_{30} = h^- 4\pi^0 \nu_\tau$ (ex. K^0, η)	$(0.1091 \pm 0.0391) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.1120 \pm 0.0509 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[96]
$\Gamma_{31} = K^- \geq 0\pi^0 \geq 0K^0 \geq 0\gamma\nu_\tau$	$(1.5481 \pm 0.0310) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(1.7000 \pm 0.2247 \pm 0.0000) \cdot 10^{-2}$	CLEO	[52]
	$(1.5400 \pm 0.2400 \pm 0.0000) \cdot 10^{-2}$	DELPHI	[9]
	$(1.5280 \pm 0.0559 \pm 0.0000) \cdot 10^{-2}$	OPAL	[4]
$\Gamma_{33} = K_S^0(\text{particles})^- \nu_\tau$	$(0.8953 \pm 0.0255) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.9700 \pm 0.0849 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[47]
	$(0.9700 \pm 0.1082 \pm 0.0000) \cdot 10^{-2}$	OPAL	[19]
$\Gamma_{34} = h^- \overline{K}^0 \nu_\tau$	$(0.9797 \pm 0.0233) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.8550 \pm 0.0814 \pm 0.0000) \cdot 10^{-2}$	CLEO	[61]
$\Gamma_{35} = \pi^- \overline{K}^0 \nu_\tau$	$(0.8206 \pm 0.0182) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.9280 \pm 0.0564 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[49]
	$(0.8400 \pm 0.0040 \pm 0.0230) \cdot 10^{-2}$	*BABAR*	[40]
	$(0.8080 \pm 0.0040 \pm 0.0260) \cdot 10^{-2}$	Belle	[67]
	$(0.9500 \pm 0.1616 \pm 0.0000) \cdot 10^{-2}$	L3	[12]
	$(0.9330 \pm 0.0838 \pm 0.0000) \cdot 10^{-2}$	OPAL	[3]
$\Gamma_{37} = K^- K^0 \nu_\tau$	$(0.1591 \pm 0.0157) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.1580 \pm 0.0453 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[47]
	$(0.1620 \pm 0.0237 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[49]
	$(0.1510 \pm 0.0304 \pm 0.0000) \cdot 10^{-2}$	CLEO	[61]
$\Gamma_{38} = K^- K^0 \geq 0\pi^0 \nu_\tau$	$(0.3041 \pm 0.0168) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.3300 \pm 0.0674 \pm 0.0000) \cdot 10^{-2}$	OPAL	[3]
$\Gamma_{39} = h^- \overline{K}^0 \pi^0 \nu_\tau$	$(0.5099 \pm 0.0146) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.5620 \pm 0.0693 \pm 0.0000) \cdot 10^{-2}$	CLEO	[61]
$\Gamma_{40} = \pi^- \overline{K}^0 \pi^0 \nu_\tau$	$(0.3649 \pm 0.0108) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.2940 \pm 0.0818 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[47]
	$(0.3470 \pm 0.0646 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[49]
	$(0.3420 \pm 0.0060 \pm 0.0150) \cdot 10^{-2}$	*BABAR*	[92]
	$(0.3840 \pm 0.0040 \pm 0.0160) \cdot 10^{-2}$	Belle	[95]
	$(0.4100 \pm 0.1237 \pm 0.0000) \cdot 10^{-2}$	L3	[12]
$\Gamma_{42} = K^- \pi^0 K^0 \nu_\tau$	$(0.1450 \pm 0.0071) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.1520 \pm 0.0789 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[47]
	$(0.1430 \pm 0.0291 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[49]
	$(0.1480 \pm 0.0020 \pm 0.0080) \cdot 10^{-2}$	Belle	[95]
	$(0.1450 \pm 0.0412 \pm 0.0000) \cdot 10^{-2}$	CLEO	[61]
$\Gamma_{43} = \pi^- \overline{K}^0 \geq 1\pi^0 \nu_\tau$	$(0.3917 \pm 0.0250) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.3240 \pm 0.0992 \pm 0.0000) \cdot 10^{-2}$	OPAL	[3]
$\Gamma_{44} = \pi^- \overline{K}^0 \pi^0 \pi^0 \nu_\tau$	$(2.6854 \pm 2.3037) \cdot 10^{-4}$	HFAG	Winter 2012 fit
	$(2.6000 \pm 2.4000 \pm 0.0000) \cdot 10^{-4}$	ALEPH	[50]
$\Gamma_{46} = \pi^- K^0 \overline{K}^0 \nu_\tau$	$(0.1562 \pm 0.0209) \cdot 10^{-2}$	HFAG	Winter 2012 fit

Table 1 – continued from previous page

Tau lepton branching fraction	Value	Exp.	Ref.
	$(0.1530 \pm 0.0340 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[47]
$\Gamma_{47} = \pi^- K_S^0 K_S^0 \nu_\tau$	$(2.3957 \pm 0.5026) \cdot 10^{-4}$	HFAG	Winter 2012 fit
	$(2.6000 \pm 1.1180 \pm 0.0000) \cdot 10^{-4}$	ALEPH	[47]
	$(2.3000 \pm 0.5831 \pm 0.0000) \cdot 10^{-4}$	CLEO	[61]
$\Gamma_{48} = \pi^- K_S^0 K_L^0 \nu_\tau$	$(0.1082 \pm 0.0203) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.1010 \pm 0.0264 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[47]
$\Gamma_{49} = \pi^- K^0 \overline{K}^0 \pi^0 \nu_\tau$	$(3.1000 \pm 2.3000) \cdot 10^{-4}$	HFAG	Winter 2012 fit
	$(3.1000 \pm 2.3000 \pm 0.0000) \cdot 10^{-4}$	ALEPH	[50]
$\Gamma_{53} = \overline{K}^0 h^- h^- h^+ \nu_\tau$	$(2.2224 \pm 2.0236) \cdot 10^{-4}$	HFAG	Winter 2012 fit
	$(2.3000 \pm 2.0248 \pm 0.0000) \cdot 10^{-4}$	ALEPH	[47]
$\Gamma_{54} = h^- h^- h^+ \geq 0\text{neutrals} \geq 0 K_L^0 \nu_\tau$	$(15.192 \pm 0.060) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(15.000 \pm 0.500 \pm 0.000) \cdot 10^{-2}$	CELLO	[54]
	$(14.400 \pm 0.671 \pm 0.000) \cdot 10^{-2}$	L3	[17]
	$(15.100 \pm 1.000 \pm 0.000) \cdot 10^{-2}$	TPC	[18]
$\Gamma_{55} = h^- h^- h^+ \geq 0\text{neutrals}\nu_\tau \text{ (ex.} K^0)$	$(14.574 \pm 0.056) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(14.556 \pm 0.130 \pm 0.000) \cdot 10^{-2}$	L3	[14]
	$(14.960 \pm 0.238 \pm 0.000) \cdot 10^{-2}$	OPAL	[20]
$\Gamma_{57} = h^- h^- h^+ \nu_\tau \text{ (ex.} K^0)$	$(9.4404 \pm 0.0530) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(9.5100 \pm 0.2119 \pm 0.0000) \cdot 10^{-2}$	CLEO	[44]
	$(9.3170 \pm 0.1218 \pm 0.0000) \cdot 10^{-2}$	DELPHI	[7]
$\frac{\Gamma_{57}}{\Gamma_{55}} = \frac{h^- h^- h^+ \nu_\tau \text{ (ex.} K^0)}{h^- h^- h^+ \geq 0\text{neutrals}\nu_\tau \text{ (ex.} K^0)}$	$(64.776 \pm 0.294) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(66.000 \pm 1.456 \pm 0.000) \cdot 10^{-2}$	OPAL	[20]
$\Gamma_{58} = h^- h^- h^+ \nu_\tau \text{ (ex.} K^0, \omega)$	$(9.4099 \pm 0.0531) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(9.4690 \pm 0.0958 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[96]
$\Gamma_{60} = \pi^- \pi^- \pi^+ \nu_\tau \text{ (ex.} K^0)$	$(9.0018 \pm 0.0510) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(8.8337 \pm 0.0074 \pm 0.1267) \cdot 10^{-2}$	*BABAR*	[36]
	$(8.4200 \pm 0.0033 \pm 0.2588) \cdot 10^{-2}$	Belle	[81]
	$(9.1300 \pm 0.4627 \pm 0.0000) \cdot 10^{-2}$	CLEO3	[57]
$\Gamma_{62} = \pi^- \pi^- \pi^+ \nu_\tau \text{ (ex. } K^0, \omega)$	$(8.9719 \pm 0.0511) \cdot 10^{-2}$	HFAG	Winter 2012 fit
$\Gamma_{66} = h^- h^- h^+ \pi^0 \nu_\tau \text{ (ex.} K^0)$	$(4.6019 \pm 0.0513) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(4.7340 \pm 0.0767 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[96]
	$(4.2300 \pm 0.2280 \pm 0.0000) \cdot 10^{-2}$	CLEO	[44]
	$(4.5450 \pm 0.1478 \pm 0.0000) \cdot 10^{-2}$	DELPHI	[7]
$\Gamma_{69} = \pi^- \pi^- \pi^+ \pi^0 \nu_\tau \text{ (ex.} K^0)$	$(4.5146 \pm 0.0524) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(4.1900 \pm 0.2326 \pm 0.0000) \cdot 10^{-2}$	CLEO	[66]
$\Gamma_{70} = \pi^- \pi^- \pi^+ \pi^0 \nu_\tau \text{ (ex. } K^0, \omega)$	$(2.7659 \pm 0.0710) \cdot 10^{-2}$	HFAG	Winter 2012 fit
$\Gamma_{74} = h^- h^- h^+ \geq 2\pi^0 \nu_\tau \text{ (ex.} K^0)$	$(0.5231 \pm 0.0311) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.5610 \pm 0.1168 \pm 0.0000) \cdot 10^{-2}$	DELPHI	[7]
$\Gamma_{76} = h^- h^- h^+ 2\pi^0 \nu_\tau \text{ (ex.} K^0)$	$(0.4911 \pm 0.0310) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.4350 \pm 0.0461 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[96]
$\frac{\Gamma_{76}}{\Gamma_{54}} = \frac{h^- h^- h^+ 2\pi^0 \nu_\tau \text{ (ex.} K^0)}{h^- h^- h^+ \geq 0\text{neutrals} \geq 0 K_L^0 \nu_\tau}$	$(3.2326 \pm 0.2024) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(3.4000 \pm 0.3606 \pm 0.0000) \cdot 10^{-2}$	CLEO	[56]
$\Gamma_{77} = h^- h^- h^+ 2\pi^0 \nu_\tau \text{ (ex. } K^0, \omega, \eta)$	$(9.7301 \pm 3.5416) \cdot 10^{-4}$	HFAG	Winter 2012 fit
$\Gamma_{78} = h^- h^- h^+ 3\pi^0 \nu_\tau$	$(3.1986 \pm 0.3124) \cdot 10^{-4}$	HFAG	Winter 2012 fit
	$(2.2000 \pm 0.5000 \pm 0.0000) \cdot 10^{-4}$	CLEO	[26]

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Tau lepton branching fraction	Value	Exp.	Ref.
$\frac{\Gamma_{80}}{\Gamma_{60}} = \frac{K^-\pi^-h^+\nu_\tau\ (\text{ex.}K^0)}{\pi^-\pi^-\pi^+\nu_\tau\ (\text{ex.}K^0)}$	$(4.8482 \pm 0.0808) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(5.4400 \pm 0.5701 \pm 0.0000) \cdot 10^{-2}$	CLEO	[94]
$\frac{\Gamma_{81}}{\Gamma_{69}} = \frac{K^-\pi^-h^+\pi^0\nu_\tau\ (\text{ex.}K^0)}{\pi^-\pi^-\pi^+\pi^0\nu_\tau\ (\text{ex.}K^0)}$	$(1.9323 \pm 0.2660) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(2.6100 \pm 0.6155 \pm 0.0000) \cdot 10^{-2}$	CLEO	[94]
$\Gamma_{82} = K^-\pi^-\pi^+ \geq 0\text{neutrals}\nu_\tau$	$(0.4801 \pm 0.0147) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.5800 \pm 0.1845 \pm 0.0000) \cdot 10^{-2}$	TPC	[53]
$\Gamma_{85} = K^-\pi^-\pi^+\nu_\tau\ (\text{ex.}K^0)$	$(0.2929 \pm 0.0068) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.2140 \pm 0.0470 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[48]
	$(0.2726 \pm 0.0018 \pm 0.0092) \cdot 10^{-2}$	*BABAR*	[36]
	$(0.3300 \pm 0.0013 \pm 0.0166) \cdot 10^{-2}$	Belle	[81]
	$(0.3840 \pm 0.0405 \pm 0.0000) \cdot 10^{-2}$	CLEO3	[57]
	$(0.4150 \pm 0.0664 \pm 0.0000) \cdot 10^{-2}$	OPAL	[6]
$\Gamma_{88} = K^-\pi^-\pi^+\pi^0\nu_\tau\ (\text{ex.}K^0)$	$(8.1122 \pm 1.1680) \cdot 10^{-4}$	HFAG	Winter 2012 fit
	$(6.1000 \pm 4.2950 \pm 0.0000) \cdot 10^{-4}$	ALEPH	[48]
	$(7.4000 \pm 1.3600 \pm 0.0000) \cdot 10^{-4}$	CLEO3	[28]
$\Gamma_{92} = \pi^-K^-K^+ \geq 0\text{neutrals}\nu_\tau$	$(0.1496 \pm 0.0033) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.1590 \pm 0.0566 \pm 0.0000) \cdot 10^{-2}$	OPAL	[2]
	$(0.1500 \pm 0.0855 \pm 0.0000) \cdot 10^{-2}$	TPC	[53]
$\Gamma_{93} = \pi^-K^-K^+\nu_\tau$	$(0.1435 \pm 0.0027) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.1630 \pm 0.0270 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[48]
	$(0.1346 \pm 0.0010 \pm 0.0036) \cdot 10^{-2}$	*BABAR*	[36]
	$(0.1550 \pm 0.0007 \pm 0.0056) \cdot 10^{-2}$	Belle	[81]
	$(0.1550 \pm 0.0108 \pm 0.0000) \cdot 10^{-2}$	CLEO3	[57]
$\frac{\Gamma_{93}}{\Gamma_{60}} = \frac{\pi^-K^-K^+\nu_\tau}{\pi^-\pi^-\pi^+\nu_\tau\ (\text{ex.}K^0)}$	$(1.5940 \pm 0.0305) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(1.6000 \pm 0.3354 \pm 0.0000) \cdot 10^{-2}$	CLEO	[94]
$\Gamma_{94} = \pi^-K^-K^+\pi^0\nu_\tau$	$(0.6113 \pm 0.1829) \cdot 10^{-4}$	HFAG	Winter 2012 fit
	$(7.5000 \pm 3.2650 \pm 0.0000) \cdot 10^{-4}$	ALEPH	[48]
	$(0.5500 \pm 0.1844 \pm 0.0000) \cdot 10^{-4}$	CLEO3	[28]
$\frac{\Gamma_{94}}{\Gamma_{69}} = \frac{\pi^-K^-K^+\pi^0\nu_\tau}{\pi^-\pi^-\pi^+\pi^0\nu_\tau\ (\text{ex.}K^0)}$	$(0.1354 \pm 0.0406) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.7900 \pm 0.4682 \pm 0.0000) \cdot 10^{-2}$	CLEO	[94]
$\Gamma_{96} = K^-K^-K^+\nu_\tau$	$(2.1774 \pm 0.8005) \cdot 10^{-5}$	HFAG	Winter 2012 fit
	$(1.5777 \pm 0.1300 \pm 0.1231) \cdot 10^{-5}$	*BABAR*	[36]
	$(3.2900 \pm 0.1694 \pm 0.1962) \cdot 10^{-5}$	Belle	[81]
$\Gamma_{102} = 3h^-2h^+ \geq 0\text{neutrals}\nu_\tau\ (\text{ex.}K^0)$	$(0.1022 \pm 0.0037) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.0970 \pm 0.0121 \pm 0.0000) \cdot 10^{-2}$	CLEO	[72]
	$(0.1020 \pm 0.0290 \pm 0.0000) \cdot 10^{-2}$	HRS	[60]
	$(0.1700 \pm 0.0341 \pm 0.0000) \cdot 10^{-2}$	L3	[14]
$\Gamma_{103} = 3h^-2h^+\nu_\tau\ (\text{ex. }K^0)$	$(8.2349 \pm 0.3060) \cdot 10^{-4}$	HFAG	Winter 2012 fit
	$(7.2000 \pm 1.5000 \pm 0.0000) \cdot 10^{-4}$	ALEPH	[96]
	$(6.4000 \pm 2.5080 \pm 0.0000) \cdot 10^{-4}$	ARGUS	[21]
	$(8.5600 \pm 0.0500 \pm 0.4200) \cdot 10^{-4}$	*BABAR*	[33]
	$(7.7000 \pm 1.0300 \pm 0.0000) \cdot 10^{-4}$	CLEO	[72]
	$(9.7000 \pm 1.5810 \pm 0.0000) \cdot 10^{-4}$	DELPHI	[7]
	$(5.1000 \pm 2.0000 \pm 0.0000) \cdot 10^{-4}$	HRS	[60]

Table 1 – continued from previous page

Tau lepton branching fraction	Value	Exp.	Ref.
	$(9.1000 \pm 1.5230 \pm 0.0000) \cdot 10^{-4}$	OPAL	[16]
$\Gamma_{104} = 3h^- 2h^+ \pi^0 \nu_\tau$ (ex. K^0)	$(1.9801 \pm 0.2437) \cdot 10^{-4}$	HFAG	Winter 2012 fit
	$(2.1000 \pm 0.9220 \pm 0.0000) \cdot 10^{-4}$	ALEPH	[96]
	$(1.7000 \pm 0.2828 \pm 0.0000) \cdot 10^{-4}$	CLEO	[26]
	$(1.6000 \pm 1.3420 \pm 0.0000) \cdot 10^{-4}$	DELPHI	[7]
	$(2.7000 \pm 2.0120 \pm 0.0000) \cdot 10^{-4}$	OPAL	[16]
$\Gamma_{110} = X_s^- \nu_\tau$	$(2.8746 \pm 0.0498) \cdot 10^{-2}$	HFAG	Winter 2012 fit
$\Gamma_{126} = \pi^- \pi^0 \eta \nu_\tau$	$(0.1386 \pm 0.0072) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.1800 \pm 0.0447 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[59]
	$(0.1350 \pm 0.0030 \pm 0.0070) \cdot 10^{-2}$	Belle	[78]
	$(0.1700 \pm 0.0283 \pm 0.0000) \cdot 10^{-2}$	CLEO	[29]
$\Gamma_{128} = K^- \eta \nu_\tau$	$(1.5285 \pm 0.0808) \cdot 10^{-4}$	HFAG	Winter 2012 fit
	$(1.4200 \pm 0.1100 \pm 0.0700) \cdot 10^{-4}$	*BABAR*	[24]
	$(1.5800 \pm 0.0500 \pm 0.0900) \cdot 10^{-4}$	Belle	[78]
$\Gamma_{130} = K^- \pi^0 \eta \nu_\tau$	$(0.4825 \pm 0.1161) \cdot 10^{-4}$	HFAG	Winter 2012 fit
	$(0.4600 \pm 0.1100 \pm 0.0400) \cdot 10^{-4}$	Belle	[78]
	$(1.7700 \pm 0.9043 \pm 0.0000) \cdot 10^{-4}$	CLEO	[55]
$\Gamma_{132} = \pi^- \overline{K}^0 \eta \nu_\tau$	$(0.9364 \pm 0.1491) \cdot 10^{-4}$	HFAG	Winter 2012 fit
	$(0.8800 \pm 0.1400 \pm 0.0600) \cdot 10^{-4}$	Belle	[78]
	$(2.2000 \pm 0.7338 \pm 0.0000) \cdot 10^{-4}$	CLEO	[55]
$\Gamma_{136} = \pi^- \pi^- \pi^+ \eta \nu_\tau$ (ex.K^0)	$(1.4921 \pm 0.0968) \cdot 10^{-4}$	HFAG	Winter 2012 fit
	$(1.6000 \pm 0.0500 \pm 0.1100) \cdot 10^{-4}$	*BABAR*	[37]
	$(2.3000 \pm 0.5000 \pm 0.0000) \cdot 10^{-4}$	CLEO	[26]
$\Gamma_{150} = h^- \omega \nu_\tau$	$(1.9945 \pm 0.0641) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(1.9100 \pm 0.0922 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[59]
	$(1.6000 \pm 0.4909 \pm 0.0000) \cdot 10^{-2}$	CLEO	[51]
$\dfrac{\Gamma_{150}}{\Gamma_{66}} = \dfrac{h^- \omega \nu_\tau}{h^- h^- h^+ \pi^0 \nu_\tau \ (\text{ex.} K^0)}$	$(43.340 \pm 1.389) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(43.100 \pm 3.300 \pm 0.000) \cdot 10^{-2}$	ALEPH	[58]
	$(46.400 \pm 2.335 \pm 0.000) \cdot 10^{-2}$	CLEO	[44]
$\Gamma_{151} = K^- \omega \nu_\tau$	$(4.1000 \pm 0.9220) \cdot 10^{-4}$	HFAG	Winter 2012 fit
	$(4.1000 \pm 0.9220 \pm 0.0000) \cdot 10^{-4}$	CLEO3	[28]
$\Gamma_{152} = h^- \pi^0 \omega \nu_\tau$	$(0.4049 \pm 0.0418) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(0.4300 \pm 0.0781 \pm 0.0000) \cdot 10^{-2}$	ALEPH	[59]
$\dfrac{\Gamma_{152}}{\Gamma_{76}} = \dfrac{h^- \omega \pi^0 \nu_\tau}{h^- h^- h^+ 2\pi^0 \nu_\tau \ (\text{ex.} K^0)}$	$(82.453 \pm 7.575) \cdot 10^{-2}$	HFAG	Winter 2012 fit
	$(81.000 \pm 8.485 \pm 0.000) \cdot 10^{-2}$	CLEO	[56]
$\Gamma_{800} = \pi^- \omega \nu_\tau$	$(1.9535 \pm 0.0647) \cdot 10^{-2}$	HFAG	Winter 2012 fit
$\Gamma_{801} = K^- \phi \nu_\tau (\phi \to KK)$	$(3.7002 \pm 1.3604) \cdot 10^{-5}$	HFAG	Winter 2012 fit
$\Gamma_{802} = K^- \pi^- \pi^+ \nu_\tau$ (ex. K^0, ω)	$(0.2923 \pm 0.0068) \cdot 10^{-2}$	HFAG	Winter 2012 fit
$\Gamma_{803} = K^- \pi^- \pi^+ \pi^0 \nu_\tau$ (ex. K^0, ω, η)	$(4.1074 \pm 1.4286) \cdot 10^{-4}$	HFAG	Winter 2012 fit
$\Gamma_{804} = \pi^- K_L^0 K_L^0 \nu_\tau$	$(2.3957 \pm 0.5026) \cdot 10^{-4}$	HFAG	Winter 2012 fit
$\Gamma_{805} = a_1^- (\to \pi^- \gamma) \nu_\tau$	$(4.0000 \pm 2.0000) \cdot 10^{-4}$	HFAG	Winter 2012 fit
	$(4.0000 \pm 2.0000 \pm 0.0000) \cdot 10^{-4}$	ALEPH	[96]
$\Gamma_{998} = 1 - \Gamma_{\text{All}}$	$(0.0704 \pm 0.1060) \cdot 10^{-2}$	HFAG	Winter 2012 fit

2.1 Correlation between base nodes uncertainties

The following tables report the correlation coefficients between base nodes, in percent.

Table 2: Base nodes correlation coefficients in percent, section 1

	Γ_{3}	Γ_{5}	Γ_{9}	Γ_{10}	Γ_{14}	Γ_{16}	Γ_{20}	Γ_{23}	Γ_{27}	Γ_{28}	Γ_{30}	Γ_{35}	Γ_{37}	Γ_{40}
Γ_{5}	23													
Γ_{9}	7	5												
Γ_{10}	3	6	1											
Γ_{14}	-13	-14	-12	-3										
Γ_{16}	-0	-1	2	-1	-16									
Γ_{20}	-5	-5	-7	-1	-40	2								
Γ_{23}	0	0	-0	-2	2	-12	-22							
Γ_{27}	-4	-3	-8	-1	0	3	-36	6						
Γ_{28}	0	0	-0	-1	2	-12	4	-19	-29					
Γ_{30}	-5	-4	-11	-2	-9	-0	6	0	-42	0				
Γ_{35}	-0	-1	1	0	-0	2	-1	1	-0	1	-0			
Γ_{37}	0	0	-1	-1	1	-8	3	-12	4	-12	0	-6		
Γ_{40}	-0	-1	1	-0	-0	0	1	-2	-2	-2	-0	0	-3	

Table 3: Base nodes correlation coefficients in percent, section 2

	Γ_{3}	Γ_{5}	Γ_{9}	Γ_{10}	Γ_{14}	Γ_{16}	Γ_{20}	Γ_{23}	Γ_{27}	Γ_{28}	Γ_{30}	Γ_{35}	Γ_{37}	Γ_{40}
Γ_{42}	-0	-0	0	-0	0	-3	1	-5	-1	-5	0	-0	-7	30
Γ_{44}	0	0	-0	0	-0	0	-0	0	0	0	0	-2	-2	-4
Γ_{47}	-0	-0	-0	-0	-0	0	0	0	0	0	0	-0	-0	-0
Γ_{48}	0	0	0	0	0	0	-0	1	-0	0	-0	-4	-3	-3
Γ_{53}	0	0	0	0	0	-0	0	0	0	0	0	-0	-0	-0
Γ_{62}	-3	-5	8	0	-4	5	-7	-1	-5	-1	-5	4	-1	3
Γ_{70}	-6	-6	-7	-1	-9	-1	-1	0	-1	0	3	-1	0	-1
Γ_{77}	-1	-0	-3	-1	-2	-0	-0	0	2	0	2	-0	0	-0
Γ_{78}	1	1	2	0	1	1	-0	-0	-0	-0	0	1	-0	1
Γ_{93}	-1	-1	2	0	-1	2	-1	-0	-1	-0	-1	2	-0	1
Γ_{94}	-0	-0	-0	-0	-0	-0	-0	0	-0	0	0	-0	0	-0
Γ_{103}	0	0	2	0	0	1	-1	-0	-0	-0	-1	1	-0	1
Γ_{104}	-1	-1	-1	-0	-1	0	0	-0	0	-0	-1	0	-0	0
Γ_{126}	0	0	0	0	0	0	-1	-0	0	-0	-2	0	-0	0

Table 4: Base nodes correlation coefficients in percent, section 3

	Γ_{3}	Γ_{5}	Γ_{9}	Γ_{10}	Γ_{14}	Γ_{16}	Γ_{20}	Γ_{23}	Γ_{27}	Γ_{28}	Γ_{30}	Γ_{35}	Γ_{37}	Γ_{40}
Γ_{128}	-0	-0	1	-0	-0	1	-0	-1	-0	-1	-0	1	-0	1
Γ_{130}	0	0	0	0	0	0	-0	-0	0	-0	-0	0	-0	0
Γ_{132}	0	0	-0	0	-0	0	-0	-0	0	-0	-0	0	-0	0
Γ_{151}	-0	-0	-0	-0	-0	0	-0	-0	-0	-0	0	-0	-0	-0
Γ_{152}	-1	-0	-3	-1	-2	-0	-1	0	2	0	2	-0	0	0
Γ_{800}	-2	-2	-2	-0	-3	-0	-0	0	-0	0	1	-0	0	-0
Γ_{801}	-0	-0	0	-0	-0	0	-0	-0	0	-0	-0	-0	-0	-0
Γ_{802}	-1	-1	0	0	-1	-1	-2	0	-2	0	-1	-1	-0	-0
Γ_{803}	-0	-0	-0	-0	-0	-0	-0	0	-0	0	0	-0	-0	-0
Γ_{805}	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 5: Base nodes correlation coefficients in percent, section 4

	Γ_{42}	Γ_{44}	Γ_{47}	Γ_{48}	Γ_{53}	Γ_{62}	Γ_{70}	Γ_{77}	Γ_{78}	Γ_{93}	Γ_{94}	Γ_{103}	Γ_{104}	Γ_{126}
Γ_{44}	-2													
Γ_{47}	-0	-0												
Γ_{48}	-2	-5	-19											
Γ_{53}	-0	0	0	-0										
Γ_{62}	1	-0	-0	-0	-0									
Γ_{70}	-0	0	0	-0	-0	-19								
Γ_{77}	0	-0	-0	0	0	-1	-7							
Γ_{78}	0	-0	-0	-0	-0	2	-2	-1						
Γ_{93}	0	-0	-0	-0	-0	14	-4	-0	1					
Γ_{94}	0	0	0	-0	-0	-0	-2	-0	-0	-0				
Γ_{103}	0	-0	-0	-0	-0	3	-1	-0	4	1	-0			
Γ_{104}	-0	-0	0	0	0	-0	0	1	-36	0	0	-11		
Γ_{126}	0	-0	-0	-0	-0	1	-0	-5	0	0	-0	0	0	

Table 6: Base nodes correlation coefficients in percent, section 5

	Γ_{42}	Γ_{44}	Γ_{47}	Γ_{48}	Γ_{53}	Γ_{62}	Γ_{70}	Γ_{77}	Γ_{78}	Γ_{93}	Γ_{94}	Γ_{103}	Γ_{104}	Γ_{126}
Γ_{128}	0	-0	-0	-0	-0	2	-0	-0	0	1	-0	1	0	4
Γ_{130}	0	-0	-0	-0	-0	0	-0	-1	0	0	-0	0	0	1
Γ_{132}	-0	-0	-0	-0	-0	0	-0	-0	0	0	-0	0	-0	2
Γ_{151}	0	0	0	-0	-0	0	12	0	0	0	-0	0	0	0
Γ_{152}	0	-0	-0	0	0	-1	-11	-64	-1	-0	-0	-0	1	-0
Γ_{800}	-0	0	0	-0	-0	-8	-69	-2	-0	-1	0	-0	0	-0
Γ_{801}	-0	-0	-0	-0	-0	-1	-0	-0	0	1	-0	0	0	0
Γ_{802}	-0	0	0	-0	-0	17	-6	-0	-0	-0	-0	-0	-0	-0
Γ_{803}	-0	0	0	0	-0	-1	-19	-0	-0	-0	-2	-0	0	-0
Γ_{805}	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 7: Base nodes correlation coefficients in percent, section 6

	Γ_{128}	Γ_{130}	Γ_{132}	Γ_{151}	Γ_{152}	Γ_{800}	Γ_{801}	Γ_{802}	Γ_{803}	Γ_{805}
Γ_{130}	1									
Γ_{132}	1	0								
Γ_{151}	0	0	-0							
Γ_{152}	-0	-0	0	0						
Γ_{800}	-0	-0	-0	-14	-3					
Γ_{801}	0	0	-0	-0	-0	-0				
Γ_{802}	-0	-0	-0	-2	-0	-1	1			
Γ_{803}	-1	-0	-0	-58	-0	9	-0	1		
Γ_{805}	0	0	0	0	0	0	0	0	0	

2.2 Equality constraints

We use equality constraints that relate a branching fraction to a sum of branching fractions. As mentioned above, the tau branching fractions are denoted with Γ_n labels. In the constraint relations we use the values of some non-tau branching fractions, denoted e.g. with the self-describing notation $\Gamma_{K_S\to\pi^0\pi^0}$. We also use probabilities corresponding to modulus square amplitudes describing quantum mixtures of states such as K^0, $\overline{K}^0$, K_S, K_L, denoted with e.g. $\Gamma_{<K^0|K_S>} = |{<}K^0|K_S{>}|^2$. In the fit, all non-tau quantities are taken from the PDG 2011 [91] fits (when available) or averages, and are used without accounting for their uncertainties, which are however in general small with respect to the uncertainties on the tau branching fractions. The tau branching fractions are illustrated in Table 1. The equations in the following permit the computation of the values and uncertainties for branching fractions that are not listed in Table 1, once they are expressed as function of the quantities that are listed there. The following list does not include the (non-linear) constraints already introduced in Section 2, and illustrated in Table 1, where some measured branching fractions are expressed as ratios of "base" branching fractions.

$$\Gamma_7 = \Gamma_{35} \cdot \Gamma_{<\overline{K}^0|K_L>} + \Gamma_9 + \Gamma_{804} + \Gamma_{37} \cdot \Gamma_{<K^0|K_L>} + \Gamma_{10}$$

$$\Gamma_{8} = \Gamma_{9} + \Gamma_{10}$$

$$\begin{aligned}\Gamma_{17} = {} & \Gamma_{128} \cdot \Gamma_{\eta\to 3\pi^0} + \Gamma_{30} + \Gamma_{23} + \Gamma_{28} + \Gamma_{35} \cdot (\Gamma_{<K^0|K_S>} \cdot \Gamma_{K_S\to\pi^0\pi^0}) \\ & + \Gamma_{40} \cdot (\Gamma_{<K^0|K_S>} \cdot \Gamma_{K_S\to\pi^0\pi^0}) + \Gamma_{42} \cdot (\Gamma_{<K^0|K_S>} \cdot \Gamma_{K_S\to\pi^0\pi^0}) + \Gamma_{20} + \Gamma_{27} \\ & + \Gamma_{47} \cdot (\Gamma_{K_S\to\pi^0\pi^0} \cdot \Gamma_{K_S\to\pi^0\pi^0}) + \Gamma_{48} \cdot \Gamma_{K_S\to\pi^0\pi^0} + \Gamma_{126} \cdot \Gamma_{\eta\to 3\pi^0} + \Gamma_{37} \cdot (\Gamma_{<K^0|K_S>} \cdot \Gamma_{K_S\to\pi^0\pi^0}) \\ & + \Gamma_{130} \cdot \Gamma_{\eta\to 3\pi^0}\end{aligned}$$

$$\Gamma_{19} = \Gamma_{23} + \Gamma_{20}$$

$$\Gamma_{25} = \Gamma_{128} \cdot \Gamma_{\eta\to 3\pi^0} + \Gamma_{30} + \Gamma_{28} + \Gamma_{27} + \Gamma_{126} \cdot \Gamma_{\eta\to 3\pi^0} + \Gamma_{130} \cdot \Gamma_{\eta\to 3\pi^0}$$

$$\Gamma_{26} = \Gamma_{128} \cdot \Gamma_{\eta\to 3\pi^0} + \Gamma_{28} + \Gamma_{40} \cdot (\Gamma_{<K^0|K_S>} \cdot \Gamma_{K_S\to\pi^0\pi^0}) + \Gamma_{42} \cdot (\Gamma_{<K^0|K_S>} \cdot \Gamma_{K_S\to\pi^0\pi^0}) + \Gamma_{27}$$

$$\Gamma_{29} = \Gamma_{30} + \Gamma_{126} \cdot \Gamma_{\eta\to 3\pi^0} + \Gamma_{130} \cdot \Gamma_{\eta\to 3\pi^0}$$

$$\begin{aligned}\Gamma_{31} = {} & \Gamma_{128} \cdot \Gamma_{\eta\to\mathrm{neutral}} + \Gamma_{23} + \Gamma_{28} + \Gamma_{42} + \Gamma_{16} + \Gamma_{37} + \Gamma_{10} \\ & + \Gamma_{801} \cdot (\Gamma_{\phi\to K_S K_L} \cdot \Gamma_{K_S\to\pi^0\pi^0})/(\Gamma_{\phi\to K^+K^-} + \Gamma_{\phi\to K_S K_L})\end{aligned}$$

$$\begin{aligned}\Gamma_{33} = {} & \Gamma_{35} \cdot \Gamma_{<\overline{K}^0|K_S>} + \Gamma_{40} \cdot \Gamma_{<\overline{K}^0|K_S>} + \Gamma_{42} \cdot \Gamma_{<K^0|K_S>} + \Gamma_{47} + \Gamma_{48} + \Gamma_{37} \cdot \Gamma_{<K^0|K_S>} \\ & + \Gamma_{132} \cdot (\Gamma_{<\overline{K}^0|K_S>} \cdot \Gamma_{\eta\to\mathrm{neutral}}) + \Gamma_{44} \cdot \Gamma_{<\overline{K}^0|K_S>} + \Gamma_{801} \cdot \Gamma_{\phi\to K_S K_L}/(\Gamma_{\phi\to K^+K^-} + \Gamma_{\phi\to K_S K_L})\end{aligned}$$

$$\Gamma_{34} = \Gamma_{35} + \Gamma_{37}$$

$$\Gamma_{38} = \Gamma_{42} + \Gamma_{37}$$

$$\Gamma_{39} = \Gamma_{40} + \Gamma_{42}$$

$$\Gamma_{43} = \Gamma_{40} + \Gamma_{44}$$

$$\Gamma_{46} = \Gamma_{48} + \Gamma_{47} + \Gamma_{804}$$

$$\begin{aligned}\Gamma_{54} = {} & \Gamma_{128} \cdot \Gamma_{\eta\to\mathrm{charged}} + \Gamma_{152} \cdot (\Gamma_{\omega\to\pi^+\pi^-\pi^0} + \Gamma_{\omega\to\pi^+\pi^-}) + \Gamma_{35} \cdot (\Gamma_{<K^0|K_S>} \cdot \Gamma_{K_S\to\pi^+\pi^-}) \\ & + \Gamma_{40} \cdot (\Gamma_{<K^0|K_S>} \cdot \Gamma_{K_S\to\pi^+\pi^-}) + \Gamma_{42} \cdot (\Gamma_{<K^0|K_S>} \cdot \Gamma_{K_S\to\pi^+\pi^-}) + \Gamma_{78} \\ & + \Gamma_{47} \cdot (2 \cdot \Gamma_{K_S\to\pi^+\pi^-} \cdot \Gamma_{K_S\to\pi^0\pi^0}) + \Gamma_{77} + \Gamma_{48} \cdot \Gamma_{K_S\to\pi^+\pi^-} + \Gamma_{94} + \Gamma_{62} + \Gamma_{70} + \Gamma_{93} \\ & + \Gamma_{126} \cdot \Gamma_{\eta\to\mathrm{charged}} + \Gamma_{37} \cdot (\Gamma_{<K^0|K_S>} \cdot \Gamma_{K_S\to\pi^+\pi^-}) + \Gamma_{802} + \Gamma_{803} \\ & + \Gamma_{800} \cdot (\Gamma_{\omega\to\pi^+\pi^-\pi^0} + \Gamma_{\omega\to\pi^+\pi^-}) + \Gamma_{151} \cdot (\Gamma_{\omega\to\pi^+\pi^-\pi^0} + \Gamma_{\omega\to\pi^+\pi^-}) + \Gamma_{130} \cdot \Gamma_{\eta\to\mathrm{charged}} \\ & + \Gamma_{132} \cdot (\Gamma_{<\overline{K}^0|K_L>} \cdot \Gamma_{\eta\to\pi^+\pi^-\pi^0} \\ & + \Gamma_{<\overline{K}^0|K_S>} \cdot \Gamma_{K_S\to\pi^0\pi^0} \cdot \Gamma_{\eta\to\pi^+\pi^-\pi^0} + \Gamma_{<\overline{K}^0|K_S>} \cdot \Gamma_{K_S\to\pi^+\pi^-} \cdot \Gamma_{\eta\to 3\pi^0}) \\ & + \Gamma_{53} \cdot (\Gamma_{<\overline{K}^0|K_S>} \cdot \Gamma_{K_S\to\pi^0\pi^0} + \Gamma_{<\overline{K}^0|K_L>}) \\ & + \Gamma_{801} \cdot (\Gamma_{\phi\to K^+K^-} + \Gamma_{\phi\to K_S K_L} \cdot \Gamma_{K_S\to\pi^+\pi^-})/(\Gamma_{\phi\to K^+K^-} + \Gamma_{\phi\to K_S K_L})\end{aligned}$$

$$\begin{aligned}\Gamma_{55} = {} & \Gamma_{128} \cdot \Gamma_{\eta\to\mathrm{charged}} + \Gamma_{152} \cdot (\Gamma_{\omega\to\pi^+\pi^-\pi^0} + \Gamma_{\omega\to\pi^+\pi^-}) + \Gamma_{78} + \Gamma_{77} + \Gamma_{94} + \Gamma_{62} + \Gamma_{70} + \Gamma_{93} \\ & + \Gamma_{126} \cdot \Gamma_{\eta\to\mathrm{charged}} + \Gamma_{802} + \Gamma_{803} + \Gamma_{800} \cdot (\Gamma_{\omega\to\pi^+\pi^-\pi^0} + \Gamma_{\omega\to\pi^+\pi^-}) \\ & + \Gamma_{151} \cdot (\Gamma_{\omega\to\pi^+\pi^-\pi^0} + \Gamma_{\omega\to\pi^+\pi^-}) + \Gamma_{130} \cdot \Gamma_{\eta\to\mathrm{charged}} \\ & + \Gamma_{801} \cdot \Gamma_{\phi\to K^+K^-}/(\Gamma_{\phi\to K^+K^-} + \Gamma_{\phi\to K_S K_L})\end{aligned}$$

$$\Gamma_{57} = \Gamma_{62} + \Gamma_{93} + \Gamma_{802} + \Gamma_{800} \cdot \Gamma_{\omega\to\pi^+\pi^-} + \Gamma_{151} \cdot \Gamma_{\omega\to\pi^+\pi^-} + \Gamma_{801} \cdot \Gamma_{\phi\to K^+K^-}/(\Gamma_{\phi\to K^+K^-} + \Gamma_{\phi\to K_S K_L})$$

$$\Gamma_{58} = \Gamma_{62} + \Gamma_{93} + \Gamma_{802} + \Gamma_{801} \cdot \Gamma_{\phi\to K^+K^-}/(\Gamma_{\phi\to K^+K^-} + \Gamma_{\phi\to K_S K_L})$$

$$\Gamma_{60} = \Gamma_{62} + \Gamma_{800} \cdot \Gamma_{\omega\to\pi^+\pi^-}$$

$$\Gamma_{66} = \Gamma_{128} \cdot \Gamma_{\eta\to\pi^+\pi^-\pi^0} + \Gamma_{152} \cdot \Gamma_{\omega\to\pi^+\pi^-} + \Gamma_{94} + \Gamma_{70} + \Gamma_{803} + \Gamma_{800} \cdot \Gamma_{\omega\to\pi^+\pi^-\pi^0} + \Gamma_{151} \cdot \Gamma_{\omega\to\pi^+\pi^-\pi^0}$$

$$\Gamma_{68} = \Gamma_{152} \cdot \Gamma_{\omega\to\pi^+\pi^-} + \Gamma_{40} \cdot (\Gamma_{<K^0|K_S>} \cdot \Gamma_{K_S\to\pi^+\pi^-}) + \Gamma_{70} + \Gamma_{800} \cdot \Gamma_{\omega\to\pi^+\pi^-\pi^0}$$

$$\Gamma_{69} = \Gamma_{152} \cdot \Gamma_{\omega\to\pi^+\pi^-} + \Gamma_{70} + \Gamma_{800} \cdot \Gamma_{\omega\to\pi^+\pi^-\pi^0}$$

$$\Gamma_{74} = \Gamma_{152} \cdot \Gamma_{\omega\to\pi^+\pi^-\pi^0} + \Gamma_{78} + \Gamma_{77} + \Gamma_{126} \cdot \Gamma_{\eta\to\pi^+\pi^-\pi^0} + \Gamma_{130} \cdot \Gamma_{\eta\to\pi^+\pi^-\pi^0}$$

$$\Gamma_{76} = \Gamma_{152} \cdot \Gamma_{\omega\to\pi^+\pi^-\pi^0} + \Gamma_{77} + \Gamma_{126} \cdot \Gamma_{\eta\to\pi^+\pi^-\pi^0} + \Gamma_{130} \cdot \Gamma_{\eta\to\pi^+\pi^-\pi^0}$$

$$\begin{aligned}\Gamma_{82} = {} & \Gamma_{128} \cdot \Gamma_{\eta\to\mathrm{charged}} + \Gamma_{42} \cdot (\Gamma_{<K^0|K_S>} \cdot \Gamma_{K_S\to\pi^+\pi^-}) + \Gamma_{802} + \Gamma_{803} + \Gamma_{151} \cdot (\Gamma_{\omega\to\pi^+\pi^-\pi^0} + \Gamma_{\omega\to\pi^+\pi^-}) \\ & + \Gamma_{37} \cdot (\Gamma_{<K^0|K_S>} \cdot \Gamma_{K_S\to\pi^+\pi^-})\end{aligned}$$

$$\Gamma_{85} = \Gamma_{802} + \Gamma_{151} \cdot \Gamma_{\omega\to\pi^+\pi^-}$$

$$\Gamma_{88} = \Gamma_{128} \cdot \Gamma_{\eta\to\pi^+\pi^-\pi^0} + \Gamma_{803} + \Gamma_{151} \cdot \Gamma_{\omega\to\pi^+\pi^-\pi^0}$$

$$\Gamma_{92} = \Gamma_{94} + \Gamma_{93}$$

$$\Gamma_{96} = \Gamma_{801} \cdot \Gamma_{\phi\to K^+K^-}/(\Gamma_{\phi\to K^+K^-} + \Gamma_{\phi\to K_S K_L})$$

$$\Gamma_{102} = \Gamma_{103} + \Gamma_{104}$$

$$\Gamma_{110} = \Gamma_{10} + \Gamma_{16} + \Gamma_{23} + \Gamma_{28} + \Gamma_{35} + \Gamma_{40} + \Gamma_{128} + \Gamma_{802} + \Gamma_{803} + \Gamma_{151} + \Gamma_{130} + \Gamma_{132} + \Gamma_{44} + \Gamma_{53} + \Gamma_{801}$$

$$\Gamma_{136} = \Gamma_{104} \cdot \Gamma_{\eta\to\pi^+\pi^-\pi^0} + \Gamma_{78} \cdot \Gamma_{\eta\to 3\pi^0}$$

$$\Gamma_{150} = \Gamma_{800} + \Gamma_{151}$$

$$\Gamma_{804} = \Gamma_{47} \cdot (\Gamma_{<K^0|K_L>} \cdot \Gamma_{<K^0|K_L>})/(\Gamma_{<K^0|K_S>} \cdot \Gamma_{<K^0|K_S>})$$

$$\begin{aligned}\Gamma_{\mathrm{All}} = {} & \Gamma_{3} + \Gamma_{5} + \Gamma_{9} + \Gamma_{10} + \Gamma_{14} + \Gamma_{16} + \Gamma_{20} + \Gamma_{23} + \Gamma_{27} + \Gamma_{28} + \Gamma_{30} + \Gamma_{35} + \Gamma_{37} + \Gamma_{40} + \Gamma_{42} + \Gamma_{47} \\ & + \Gamma_{48} + \Gamma_{62} + \Gamma_{70} + \Gamma_{77} + \Gamma_{78} + \Gamma_{93} + \Gamma_{94} + \Gamma_{104} + \Gamma_{126} + \Gamma_{128} + \Gamma_{802} + \Gamma_{803} + \Gamma_{800} + \Gamma_{151} \\ & + \Gamma_{130} + \Gamma_{132} + \Gamma_{44} + \Gamma_{53} + \Gamma_{49} + \Gamma_{804} + \Gamma_{805} + \Gamma_{801} + \Gamma_{152} + \Gamma_{103}\end{aligned}$$

2.3 Fit procedure

The fit procedure is functionally equivalent to the one employed in the former HFAG report [31] and consists in a minimum χ^2 fit subject to linear and non-linear constraints. The fit code has been improved to automatize the treatment of non-linear constraints, which are iteratively Taylor-expanded to obtain numerically approximate linear constraints, which permit an analytical solution for the χ^2 minimization when, as it happens in this case, the χ^2 is a quadratic function of the fitted quantities.

3 Tests of lepton universality

In the Standard Model, the partial widths of a heavier lepton L decaying to a lighter lepton ℓ are, neglecting neutrino masses and including radiative corrections [84],

$$\Gamma(L \to \nu_L \ell \overline{\nu}_\ell(\gamma)) = \frac{B(L \to \nu_L \ell \overline{\nu}_\ell)}{\tau_L} = \frac{G_L G_\ell m_L^5}{192\pi^3} f\left(\frac{m_\ell^2}{m_L^2}\right) r_W^L r_\gamma^L ,$$

where

$$G_\ell = \frac{g_\ell^2}{4\sqrt{2}M_W^2} \qquad f(x) = 1 - 8x + 8x^3 - x^4 - 12x^2 \ln x$$

$$r_W^L = 1 + \frac{3}{5}\frac{m_L^2}{M_W^2} \qquad r_\gamma^L = 1 + \frac{\alpha(m_L)}{2\pi}\left(\frac{25}{4} - \pi^2\right)$$

We use $r_\gamma^\tau = 1 - 43.2 \cdot 10^{-4}$ and $r_\gamma^\mu = 1 - 42.4 \cdot 10^{-4}$ [84] and M_W from PDG 2011 [91] as usual.

Proper ratios of the above partial widths, corrected by the suitable above-illustrated factors to remove the dependencies from masses and radiative corrections, measure ratios of charged weak lepton coupling constants. Using the HFAG-Tau fit values where available and using PDG 2011 for the remaining quantities, we measure, accounting for the statistical correlations emerging from the HFAG-Tau fit:

$$\left(\frac{g_\tau}{g_\mu}\right) = 1.0006 \pm 0.0021 , \qquad \left(\frac{g_\tau}{g_e}\right) = 1.0024 \pm 0.0021 , \qquad \left(\frac{g_\mu}{g_e}\right) = 1.0018 \pm 0.0014 .$$

Tau decays partial widths to hadrons compared to the same hadron decay to muons measure the tau-muon universality of charged weak couplings as follows:

$$\left(\frac{g_\tau}{g_\mu}\right)^2 = \frac{B(\tau \to h\nu_\tau)}{B(h \to \mu\overline{\nu}_\mu)} \frac{2m_h m_\mu^2 \tau_h}{(1+\delta_h) m_\tau^3 \tau_\tau} \left(\frac{1 - m_\mu^2/m_h^2}{1 - m_h^2/m_\tau^2}\right)^2 ,$$

where $h = \pi$ or K and the radiative corrections are $\delta_\pi = (0.16 \pm 0.14)\%$ and $\delta_K = (0.90 \pm 0.22)\%$ [64]. Using the HFAG-Tau data and PDG 2011 we measure:

$$\left(\frac{g_\tau}{g_\mu}\right)_\pi = 0.9956 \pm 0.0031 \ , \qquad \left(\frac{g_\tau}{g_\mu}\right)_K = 0.9853 \pm 0.0072 \ .$$

Similar tests could be performed with decays to electrons, however they are less precise because the hadron two body decays to electrons are helicity-suppressed. Averaging the three g_τ/g_μ ratios we obtain

$$\left(\frac{g_\tau}{g_\mu}\right)_{\tau+\pi+K} = 0.9996 \pm 0.0020 \ ,$$

accounting for statistical correlations. Table 8 reports the statistical correlation coefficients for the fitted coupling ratios:

Table 8: Universality coupling ratios correlation coefficients (%)

$\left(\frac{g_\tau}{g_e}\right)$	77			
$\left(\frac{g_\mu}{g_e}\right)$	-35	34		
$\left(\frac{g_\tau}{g_\mu}\right)_\pi$	49	50	2	
$\left(\frac{g_\tau}{g_\mu}\right)_K$	23	21	-2	14
	$\left(\frac{g_\tau}{g_\mu}\right)$	$\left(\frac{g_\tau}{g_e}\right)$	$\left(\frac{g_\mu}{g_e}\right)$	$\left(\frac{g_\tau}{g_\mu}\right)_\pi$

4 Universality improved $B(\tau \to e\nu\overline{\nu})$ and R_{had}

Following Ref. [63], we assume lepton universality to obtain a more precise experimental determination of $B_e = B(\tau \to e\overline{\nu}_e\nu_\tau)$ using the tau branching fraction to muon and the tau lifetime, by averaging the B_e direct measurement, the B_e determination from assuming that $g_\mu/g_e = 1$ hence (see also Section 3) $B_e = B_\mu \cdot f(m_e^2/m_\tau^2)/f(m_\mu^2/m_\tau^2)$, and B_e from assuming that $g_\tau/g_\mu = 1$ hence $B_e = B(\mu \to e\overline{\nu}_e\nu_\mu) \cdot (\tau_\tau/\tau_\mu) \cdot (m_\tau/m_\mu)^5 \cdot f(m_e^2/m_\tau^2)/f(m_e^2/m_\mu^2) \cdot (\delta^\tau_\gamma\delta^\tau_W)/(\delta^\mu_\gamma\delta^\mu_W)$ where $B(\mu \to e\overline{\nu}_e\nu_\mu) = 1$. Accounting for statistical correlations, we obtain

$$B_e^{\mathrm{uni}} = (17.839 \pm 0.028)\%.$$

We use B_e^{uni} to obtain the ratio

$$R_{\mathrm{had}} = \frac{\Gamma(\tau \to \mathrm{hadrons})}{\Gamma(\tau \to e\nu\overline{\nu})} = 3.6279 \pm 0.0094.$$

Here $\Gamma(\tau \to \mathrm{hadrons})$ is obtained by summing all tau hadronic decay modes.

5 $|V_{us}|$ measurement

The CKM coefficient $|V_{us}|$ can be measured in several ways from the comparison of tau partial widths to strange and non-strange final states.

5.1 Inclusive tau partial width to strange

The tau hadronic partial width is the sum of the tau partial width to strange and to non-strange hadronic final states, $\Gamma_{\mathrm{had}} = \Gamma_s + \Gamma_{VA}$. Dividing by the partial width to electron, Γ_e, we obtain partial width ratios (which are equal to the respective branching fraction ratios) for which $R_{\mathrm{had}} = R_s + R_{VA}$. In terms of such ratios, $|V_{us}|$ is measured as

$$|V_{us}| = \sqrt{R_s / \left[\frac{R_{VA}}{|V_{ud}|^2} - \delta R_{\mathrm{theory}}\right]} \ , \qquad (1)$$

where $\delta R_{\mathrm{theory}}$ can be determined in the context of low energy QCD theory, partly relying on experimental low energy scattering data. We use $\delta R_{\mathrm{theory}} = 0.240 \pm 0.032$ [70], which induces a systematic error on $|V_{us}|$ that lies between two more recent estimates [71, 83].

Table 9: HFAG Winter 2012 Tau branching fractions to strange final states.

Branching fraction	HFAG Winter 2012 fit
$\Gamma_{10} = K^-\nu_\tau$	$(0.6955 \pm 0.0096) \cdot 10^{-2}$
$\Gamma_{16} = K^-\pi^0\nu_\tau$	$(0.4322 \pm 0.0149) \cdot 10^{-2}$
$\Gamma_{23} = K^-2\pi^0\nu_\tau$ (ex. K^0)	$(0.0630 \pm 0.0222) \cdot 10^{-2}$
$\Gamma_{28} = K^-3\pi^0\nu_\tau$ (ex. K^0, η)	$(0.0419 \pm 0.0218) \cdot 10^{-2}$
$\Gamma_{35} = \pi^-\overline{K}^0\nu_\tau$	$(0.8206 \pm 0.0182) \cdot 10^{-2}$
$\Gamma_{40} = \pi^-\overline{K}^0\pi^0\nu_\tau$	$(0.3649 \pm 0.0108) \cdot 10^{-2}$
$\Gamma_{44} = \pi^-\overline{K}^0\pi^0\pi^0\nu_\tau$	$(0.0269 \pm 0.0230) \cdot 10^{-2}$
$\Gamma_{53} = \overline{K}^0h^-h^-h^+\nu_\tau$	$(0.0222 \pm 0.0202) \cdot 10^{-2}$
$\Gamma_{128} = K^-\eta\nu_\tau$	$(0.0153 \pm 0.0008) \cdot 10^{-2}$
$\Gamma_{130} = K^-\pi^0\eta\nu_\tau$	$(0.0048 \pm 0.0012) \cdot 10^{-2}$
$\Gamma_{132} = \pi^-\overline{K}^0\eta\nu_\tau$	$(0.0094 \pm 0.0015) \cdot 10^{-2}$
$\Gamma_{151} = K^-\omega\nu_\tau$	$(0.0410 \pm 0.0092) \cdot 10^{-2}$
$\Gamma_{801} = K^-\phi\nu_\tau(\phi \to KK)$	$(0.0037 \pm 0.0014) \cdot 10^{-2}$
$\Gamma_{802} = K^-\pi^-\pi^+\nu_\tau$ (ex. K^0, ω)	$(0.2923 \pm 0.0068) \cdot 10^{-2}$
$\Gamma_{803} = K^-\pi^-\pi^+\pi^0\nu_\tau$ (ex. K^0, ω, η)	$(0.0411 \pm 0.0143) \cdot 10^{-2}$
$\Gamma_{110} = X_s^-\nu_\tau$	$(2.8746 \pm 0.0498) \cdot 10^{-2}$

In the following, we use the universality improved B_e^{uni} (see Section 4) to compute the R ratios. The most direct experimental determination of R_s and $R_{VA} = R_{\text{had}} - R_s$ come from the tau inclusive branching fractions to hadronic and strange hadronic states, B_{had} and B_s. However often the total hadronic branching fraction has been replaced by the indirect but more precise expression $B_{\text{had}}^{\text{uni}} = 1 - B_e - B_\mu$ (or similar expressions based on B_e^{uni}), using unitarity, see for example the 2009 HFAG report [31]. We depart from this choice here, and we use the most direct determination of R_{had}, for two reasons: first there is no significant statistical gain in the final errors, because of statistical correlations in the R_{had} expression $(1 - B_e - B_\mu)/B_e^{\text{univ}}$, and second the indirect determination of $R_{VA} = R_{\text{had}}^{\text{uni}} - R_s$ would absorb the effect of possible unobserved hadronic states entirely in R_{VA}, while they could also be strange final states.

With the above choices, using $|V_{ud}| = 0.97425 \pm 0.00022$ [73], using HFAG values of this report, including the above-mentioned B_e^{univ}, $B_s = (2.872 \pm 0.050)\%$ (see also Table 9), $B_{VA} = (61.85 \pm 0.11)\%)$ and the PDG 2011 averages, we obtain $|V_{us}|_{\tau s} = 0.2172 \pm 0.0022$, which is 3.4σ lower than the unitarity CKM prediction $|V_{us}|_{\text{uni}} = 0.2255 \pm 0.0010$, from $(|V_{us}|_{\text{uni}})^2 = 1 - |V_{ud}|^2$. The $|V_{us}|_{\tau s}$ uncertainty includes a systematic error contribution of 0.0010 from the theory uncertainty on δR_{theory}.

If we use the alternative above mentioned definitions of B_{had}, the mismatch remains 3.4σ. Using a unitarity-constrained tau branching fraction fit, the mismatch remains 3.4σ. The 3.4σ discrepancy is close to the unconstrained fit result of the 2009 HFAG report, 3.6σ [31], and also to the 3.3σ from the HFAG-Tau 2011 intermediate document [46], based on a unitarity-constrained fit.

5.2 $|V_{us}|$ from $B(\tau \to K\nu)/B(\tau \to \pi\nu)$ and from $B(\tau \to K\nu)$

We use the ratio of branching fractions $B(\tau^- \to K^-\nu_\tau)/B(\tau^- \to \pi^-\nu_\tau) = 0.0643 \pm 0.0009$ to measure $|V_{us}|$ from the equation

$$\frac{B(\tau^- \to K^-\nu_\tau)}{B(\tau^- \to \pi^-\nu_\tau)} = \frac{f_K^2|V_{us}|^2}{f_\pi^2|V_{ud}|^2}\frac{\left(1 - m_K^2/m_\tau^2\right)^2}{\left(1 - m_\pi^2/m_\tau^2\right)^2}\frac{r_{\text{LD}}(\tau^- \to K^-\nu_\tau)}{r_{\text{LD}}(\tau^- \to \pi^-\nu_\tau)} \ .$$

In this ratio, the short-distance radiative corrections cancel. The term $r_{\text{LD}}(p) = 1 + \delta_{\text{LD}}(p)$ corresponds to the long-distance electroweak radiative correction factor for the process p. Following Ref. [45], the ratio of radiative correction factors is estimated as $r_{\text{LD}}^{K\pi} = r_{\text{LD}}(\tau^- \to K^-\nu/K^- \to \mu^-\nu)/r_{\text{LD}}(\tau^- \to \pi^-\nu/\pi^- \to \mu^-\nu) \cdot r_{\text{LD}}(K^- \to \mu^-\nu)/r_{\text{LD}}(\pi^- \to \mu^-\nu)$, where the first ratio is $[1 + (0.90 \pm 0.22)\%]/[1 + (0.16 \pm 0.14)\%]$ [65] and the second ratio is $(0.9930 \pm 0.0035)\%$ [85], hence assuming independent errors $r_{\text{LD}}^{K\pi} = 1.0003 \pm 0.0044$. The ratio f_K/f_π is estimated in lattice QCD to be 1.1936 ± 0.0053 [80]. We measure $|V_{us}|_{\tau K/\pi} = 0.2229 \pm 0.0020$, 1.2σ below the CKM unitarity prediction.

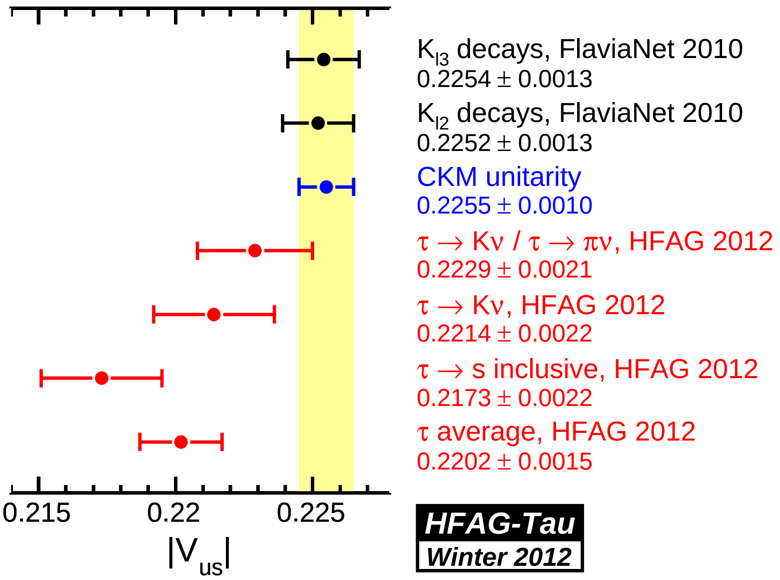

Figure 1: $|V_{us}|$ averages of this document compared with the FlaviaNet results [27].

We use the branching fraction $B(\tau^- \to K^- \nu_\tau)$ to measure $|V_{us}|$ from the equation

$$B(\tau^- \to K^- \nu_\tau) = \frac{G_F^2 f_K^2 |V_{us}|^2 m_\tau^3 \tau_\tau}{16\pi \hbar} \left(1 - \frac{m_K^2}{m_\tau^2}\right)^2 S_{EW} \ ,$$

where $f_K = 156.1 \pm 1.1\,\text{MeV}$ [80] is the kaon decay constant estimated with lattice QCD, and $S_{EW} = 1.0201 \pm 0.0003$ [68] accounts for the radiative corrections. We obtain $|V_{us}|_{\tau K} = 0.2214 \pm 0.0022$, wich is 1.7σ below the CKM unitarity prediction. CODATA 2006 results [90] and PDG 2011 have been used for the physics constants.

5.3 $|\mathbf{V_{us}}|$ from tau summary

We summarize the $|V_{us}|$ results reporting the values, the discrepancy with respect to the $|V_{us}|$ determination from CKM unitarity, and an illustration of the measurement method:

$$\begin{aligned}
|V_{us}|_{\text{uni}} &= 0.2255 \pm 0.0010 & & \text{from } \sqrt{1 - |V_{ud}|^2} \quad \text{(CKM unitarity)} \ , \\
|V_{us}|_{\tau s} &= 0.2172 \pm 0.0022 & -3.4\sigma \quad & \text{from } \Gamma(\tau^- \to X_s^- \nu_\tau) \ , \\
|V_{us}|_{\tau K/\pi} &= 0.2229 \pm 0.0020 & -1.2\sigma \quad & \text{from } \Gamma(\tau^- \to K^- \nu_\tau)/\Gamma(\tau^- \to \pi^- \nu_\tau) \ , \\
|V_{us}|_{\tau K} &= 0.2214 \pm 0.0022 & -1.7\sigma \quad & \text{from } \Gamma(\tau^- \to K^- \nu_\tau) \ .
\end{aligned}$$

Thanks to the improved lattice QCD determination of f_K [80], the uncertainty on $|V_{us}|_{\tau K}$ has been significantly reduced with respect to the previous HFAG report. Averaging the three above $|V_{us}|$ determinations we obtain:

$$|V_{us}|_\tau = 0.2203 \pm 0.0015 \qquad -2.9\sigma \quad \text{average of 3 } |V_{us}| \text{ tau measurements.}$$

We could not find a published estimate of the correlation of the uncertainties on f_K and f_K/f_π, but even if we assume ±100% correlation, the uncertainty on $|V_{us}|_\tau$ does not change more than about ±5%. Figure 1 summarizes the $|V_{us}|$ results.

6 Upper limits on tau LFV branching fractions

We list in Table 10 the up-to-date upper limits on the tau LFV branching fractions.

Table 10: HFAG Winter 2012 upper limit for the lepton flavor violating τ decay modes. For convenience, the decay modes are grouped in categories labelled according to their particle content. The label "(L)" in the category column means that the decay mode implies lepton number violation as well as the lepton flavor violation.

Decay mode	**Category**	**90% CL Limit**	**Exp.**	**Ref.**
$\Gamma_{156} = e^- \gamma$	$l\gamma$	$< 12.0 \cdot 10^{-8}$	Belle	[76]
		$< 3.3 \cdot 10^{-8}$	BaBar	[43]
$\Gamma_{157} = \mu^- \gamma$		$< 4.5 \cdot 10^{-8}$	Belle	[76]
		$< 4.4 \cdot 10^{-8}$	BaBar	[43]
$\Gamma_{158} = e^- \pi^0$	lP^0	$< 2.2 \cdot 10^{-8}$	Belle	[75]
		$< 13.0 \cdot 10^{-8}$	BaBar	[35]
$\Gamma_{159} = \mu^- \pi^0$		$< 2.7 \cdot 10^{-8}$	Belle	[75]
		$< 11.0 \cdot 10^{-8}$	BaBar	[35]
$\Gamma_{162} = e^- \eta$		$< 4.4 \cdot 10^{-8}$	Belle	[75]
		$< 16.0 \cdot 10^{-8}$	BaBar	[35]
$\Gamma_{163} = \mu^- \eta$		$< 2.3 \cdot 10^{-8}$	Belle	[75]
		$< 15.0 \cdot 10^{-8}$	BaBar	[35]
$\Gamma_{172} = e^- \eta'(958)$		$< 3.6 \cdot 10^{-8}$	Belle	[75]
		$< 24.0 \cdot 10^{-8}$	BaBar	[35]
$\Gamma_{173} = \mu^- \eta'(958)$		$< 3.8 \cdot 10^{-8}$	Belle	[75]
		$< 14.0 \cdot 10^{-8}$	BaBar	[35]
$\Gamma_{160} = e^- K^0_S$		$< 2.6 \cdot 10^{-8}$	Belle	[88]
		$< 3.3 \cdot 10^{-8}$	BaBar	[41]
$\Gamma_{161} = \mu^- K^0_S$		$< 2.3 \cdot 10^{-8}$	Belle	[88]
		$< 4.0 \cdot 10^{-8}$	BaBar	[41]
$\Gamma_{174} = e^- f_0(980)$	lS^0	$< 3.2 \cdot 10^{-8}$	Belle	[87]
$\Gamma_{175} = \mu^- f_0(980)$		$< 3.4 \cdot 10^{-8}$	Belle	[87]
$\Gamma_{164} = e^- \rho^0$	lV^0	$< 1.8 \cdot 10^{-8}$	Belle	[86]
		$< 4.6 \cdot 10^{-8}$	BaBar	[39]
$\Gamma_{165} = \mu^- \rho^0$		$< 1.2 \cdot 10^{-8}$	Belle	[86]
		$< 2.6 \cdot 10^{-8}$	BaBar	[39]
$\Gamma_{168} = e^- K^*(892)^0$		$< 3.2 \cdot 10^{-8}$	Belle	[86]
		$< 5.9 \cdot 10^{-8}$	BaBar	[39]
$\Gamma_{169} = \mu^- K^*(892)^0$		$< 7.2 \cdot 10^{-8}$	Belle	[86]
		$< 17.0 \cdot 10^{-8}$	BaBar	[39]
$\Gamma_{170} = e^- \overline{K}^*(892)^0$		$< 3.4 \cdot 10^{-8}$	Belle	[86]
		$< 4.6 \cdot 10^{-8}$	BaBar	[39]
$\Gamma_{171} = \mu^- \overline{K}^*(892)^0$		$< 7.0 \cdot 10^{-8}$	Belle	[86]
		$< 7.3 \cdot 10^{-8}$	BaBar	[39]
$\Gamma_{176} = e^- \phi$		$< 3.1 \cdot 10^{-8}$	Belle	[86]
		$< 3.1 \cdot 10^{-8}$	BaBar	[39]
$\Gamma_{177} = \mu^- \phi$		$< 8.4 \cdot 10^{-8}$	Belle	[86]
		$< 19.0 \cdot 10^{-8}$	BaBar	[39]
$\Gamma_{166} = e^- \omega$		$< 4.8 \cdot 10^{-8}$	Belle	[86]
		$< 11.0 \cdot 10^{-8}$	BaBar	[38]
$\Gamma_{167} = \mu^- \omega$		$< 4.7 \cdot 10^{-8}$	Belle	[86]
		$< 10.0 \cdot 10^{-8}$	BaBar	[38]
$\Gamma_{178} = e^- e^+ e^-$	lll	$< 2.7 \cdot 10^{-8}$	Belle	[77]
		$< 2.9 \cdot 10^{-8}$	BaBar	[82]
$\Gamma_{181} = \mu^- e^+ e^-$		$< 1.8 \cdot 10^{-8}$	Belle	[77]
		$< 2.2 \cdot 10^{-8}$	BaBar	[82]
$\Gamma_{179} = e^- \mu + \mu -$		$< 2.7 \cdot 10^{-8}$	Belle	[77]
		$< 3.2 \cdot 10^{-8}$	BaBar	[82]
$\Gamma_{183} = \mu^- \mu + \mu -$		$< 2.1 \cdot 10^{-8}$	Belle	[77]
		$< 3.3 \cdot 10^{-8}$	BaBar	[82]

Table 10 – continued from previous page

Decay mode	Category	90% CL Limit	Exp.	Ref.
$\Gamma_{182} = e^- \mu + e^-$		$< 1.5 \cdot 10^{-8}$	Belle	[77]
		$< 1.8 \cdot 10^{-8}$	BaBar	[82]
$\Gamma_{180} = \mu^- e^+ \mu-$		$< 1.7 \cdot 10^{-8}$	Belle	[77]
		$< 2.6 \cdot 10^{-8}$	BaBar	[82]
$\Gamma_{184} = e^- \pi^+ \pi^-$	*lhh*	$< 2.3 \cdot 10^{-8}$	Belle	[89]
		$< 12.0 \cdot 10^{-8}$	BaBar	[32]
$\Gamma_{186} = \mu^- \pi^+ \pi^-$		$< 2.1 \cdot 10^{-8}$	Belle	[89]
		$< 29.0 \cdot 10^{-8}$	BaBar	[32]
$\Gamma_{188} = e^- \pi^+ K^-$		$< 3.7 \cdot 10^{-8}$	Belle	[89]
		$< 32.0 \cdot 10^{-8}$	BaBar	[32]
$\Gamma_{194} = \mu^- \pi^+ K^-$		$< 8.6 \cdot 10^{-8}$	Belle	[89]
		$< 26.0 \cdot 10^{-8}$	BaBar	[32]
$\Gamma_{189} = e^- K^+ \pi^-$		$< 3.1 \cdot 10^{-8}$	Belle	[89]
		$< 17.0 \cdot 10^{-8}$	BaBar	[32]
$\Gamma_{195} = \mu^- K^+ \pi^-$		$< 4.5 \cdot 10^{-8}$	Belle	[89]
		$< 32.0 \cdot 10^{-8}$	BaBar	[32]
$\Gamma_{192} = e^- K^+ K^-$		$< 3.4 \cdot 10^{-8}$	Belle	[89]
		$< 14.0 \cdot 10^{-8}$	BaBar	[32]
$\Gamma_{198} = \mu^- K^+ K^-$		$< 4.4 \cdot 10^{-8}$	Belle	[89]
		$< 25.0 \cdot 10^{-8}$	BaBar	[32]
$\Gamma_{191} = e^- K^0_S K^0_S$		$< 7.1 \cdot 10^{-8}$	Belle	[88]
$\Gamma_{197} = \mu^- K^0_S K^0_S$		$< 8.0 \cdot 10^{-8}$	Belle	[88]
$\Gamma_{185} = e^+ \pi^- \pi^-$	(L)	$< 2.0 \cdot 10^{-8}$	Belle	[89]
	(L)	$< 27.0 \cdot 10^{-8}$	BaBar	[32]
$\Gamma_{187} = \mu^+ \pi^- \pi^-$	(L)	$< 3.9 \cdot 10^{-8}$	Belle	[89]
	(L)	$< 7.0 \cdot 10^{-8}$	BaBar	[32]
$\Gamma_{190} = e^+ \pi^- K^-$	(L)	$< 3.2 \cdot 10^{-8}$	Belle	[89]
	(L)	$< 18. \cdot 10^{-8}$	BaBar	[32]
$\Gamma_{196} = \mu^+ \pi^- K^-$	(L)	$< 4.8 \cdot 10^{-8}$	Belle	[89]
	(L)	$< 22.0 \cdot 10^{-8}$	BaBar	[32]
$\Gamma_{193} = e^+ K^- K^-$	(L)	$< 3.3 \cdot 10^{-8}$	Belle	[89]
	(L)	$< 15.0 \cdot 10^{-8}$	BaBar	[32]
$\Gamma_{199} = \mu^+ K^- K^-$	(L)	$< 4.7 \cdot 10^{-8}$	Belle	[89]
	(L)	$< 48.0 \cdot 10^{-8}$	BaBar	[32]
$\Gamma_{211} = \pi^- \Lambda$	$\Lambda\ h$	$< 3.0 \cdot 10^{-8}$	Belle	[74]
		$< 5.8 \cdot 10^{-8}$	BaBar	[79]
$\Gamma_{212} = \pi^- \overline{\Lambda}$		$< 2.8 \cdot 10^{-8}$	Belle	[74]
		$< 5.9 \cdot 10^{-8}$	BaBar	[79]
$\Gamma_{xx} = K^- \Lambda$		$< 4.2 \cdot 10^{-8}$	Belle	[74]
		$< 15. \cdot 10^{-8}$	BaBar	[79]
$\Gamma_{xx} = K^- \overline{\Lambda}$		$< 3.1 \cdot 10^{-8}$	Belle	[74]
		$< 7.2 \cdot 10^{-8}$	BaBar	[79]

A Branching Fractions Fit Measurement List by Reference

Table 11 reports the measurements used for the HFAG-Tau branching fraction fit grouped by their bibliographic reference.

Table 11: By-reference measurements list.

Reference / Branching Fraction	**Value**
ALEPH pub SCHAEL 05C [96]	

Table 11 – continued from previous page

Reference / Branching Fraction	Value
$\Gamma_{3} = \mu^- \overline{\nu}_\mu \nu_\tau$	$0.17319 \pm 0.000769675 \pm 0$
$\Gamma_{5} = e^- \overline{\nu}_e \nu_\tau$	$0.17837 \pm 0.000804984 \pm 0$
$\Gamma_{8} = h^- \nu_\tau$	$0.11524 \pm 0.00104805 \pm 0$
$\Gamma_{13} = h^- \pi^0 \nu_\tau$	$0.25924 \pm 0.00128973 \pm 0$
$\Gamma_{19} = h^- 2\pi^0 \nu_\tau$ (ex.K^0)	$0.09295 \pm 0.00121655 \pm 0$
$\Gamma_{26} = h^- 3\pi^0 \nu_\tau$	$0.01082 \pm 0.000925581 \pm 0$
$\Gamma_{30} = h^- 4\pi^0 \nu_\tau$ (ex. K^0, η)	$0.00112 \pm 0.000509313 \pm 0$
$\Gamma_{58} = h^- h^- h^+ \nu_\tau$ (ex.K^0, ω)	$0.09469 \pm 0.000957758 \pm 0$
$\Gamma_{66} = h^- h^- h^+ \pi^0 \nu_\tau$ (ex.K^0)	$0.04734 \pm 0.000766942 \pm 0$
$\Gamma_{76} = h^- h^- h^+ 2\pi^0 \nu_\tau$ (ex.K^0)	$0.00435 \pm 0.000460977 \pm 0$
$\Gamma_{103} = 3h^- 2h^+ \nu_\tau$ (ex. K^0)	$0.00072 \pm 0.00015 \pm 0$
$\Gamma_{104} = 3h^- 2h^+ \pi^0 \nu_\tau$ (ex. K^0)	$0.00021 \pm 9.21954 \cdot 10^{-5} \pm 0$
$\Gamma_{805} = a_1^- (\rightarrow \pi^- \gamma) \nu_\tau$	$4 \cdot 10^{-4} \pm 2 \cdot 10^{-4} \pm 0$
ALEPH pub BARATE 99K [49]	
$\Gamma_{10} = K^- \nu_\tau$	$0.00696 \pm 0.0002865 \pm 0$
$\Gamma_{16} = K^- \pi^0 \nu_\tau$	$0.00444 \pm 0.0003538 \pm 0$
$\Gamma_{23} = K^- 2\pi^0 \nu_\tau$ (ex. K^0)	$0.00056 \pm 0.00025 \pm 0$
$\Gamma_{28} = K^- 3\pi^0 \nu_\tau$ (ex. K^0, η)	$0.00037 \pm 0.0002371 \pm 0$
$\Gamma_{35} = \pi^- \overline{K}^0 \nu_\tau$	$0.00928 \pm 0.000564 \pm 0$
$\Gamma_{37} = K^- K^0 \nu_\tau$	$0.00162 \pm 0.0002371 \pm 0$
$\Gamma_{40} = \pi^- \overline{K}^0 \pi^0 \nu_\tau$	$0.00347 \pm 0.0006464 \pm 0$
$\Gamma_{42} = K^- \pi^0 K^0 \nu_\tau$	$0.00143 \pm 0.0002915 \pm 0$
ALEPH pub BUSKULIC 97C [59]	
$\Gamma_{126} = \pi^- \pi^0 \eta \nu_\tau$	$0.0018 \pm 0.0004472 \pm 0$
$\Gamma_{150} = h^- \omega \nu_\tau$	$0.0191 \pm 0.000922 \pm 0$
$\Gamma_{152} = h^- \pi^0 \omega \nu_\tau$	$0.0043 \pm 0.000781 \pm 0$
ALEPH pub BUSKULIC 96 [58]	
$\frac{\Gamma_{150}}{\Gamma_{66}} = \frac{h^- \omega \nu_\tau}{h^- h^- h^+ \pi^0 \nu_\tau \text{ (ex.}K^0\text{)}}$	$0.431 \pm 0.033 \pm 0$
ALEPH pub BARATE 98E [47]	
$\Gamma_{33} = K^0_S(\text{particles})^- \nu_\tau$	$0.0097 \pm 0.000849 \pm 0$
$\Gamma_{37} = K^- K^0 \nu_\tau$	$0.00158 \pm 0.0004531 \pm 0$
$\Gamma_{40} = \pi^- \overline{K}^0 \pi^0 \nu_\tau$	$0.00294 \pm 0.0008184 \pm 0$
$\Gamma_{42} = K^- \pi^0 K^0 \nu_\tau$	$0.00152 \pm 0.0007885 \pm 0$
$\Gamma_{46} = \pi^- K^0 \overline{K}^0 \nu_\tau$	$0.00153 \pm 0.00034 \pm 0$
$\Gamma_{47} = \pi^- K^0_S K^0_S \nu_\tau$	$0.00026 \pm 0.0001118 \pm 0$
$\Gamma_{48} = \pi^- K^0_S K^0_L \nu_\tau$	$0.00101 \pm 0.0002642 \pm 0$
$\Gamma_{53} = \overline{K}^0 h^- h^- h^+ \nu_\tau$	$0.00023 \pm 0.000202485 \pm 0$
ALEPH pub BARATE 99R [50]	
$\Gamma_{44} = \pi^- \overline{K}^0 \pi^0 \pi^0 \nu_\tau$	$0.00026 \pm 0.00024 \pm 0$
$\Gamma_{49} = \pi^- K^0 \overline{K}^0 \pi^0 \nu_\tau$	$0.00031 \pm 0.00023 \pm 0$
ALEPH pub BARATE 98 [48]	
$\Gamma_{85} = K^- \pi^- \pi^+ \nu_\tau$ (ex.K^0)	$0.00214 \pm 0.0004701 \pm 0$
$\Gamma_{88} = K^- \pi^- \pi^+ \pi^0 \nu_\tau$ (ex.K^0)	$0.00061 \pm 0.0004295 \pm 0$
$\Gamma_{93} = \pi^- K^- K^+ \nu_\tau$	$0.00163 \pm 0.0002702 \pm 0$
$\Gamma_{94} = \pi^- K^- K^+ \pi^0 \nu_\tau$	$0.00075 \pm 0.0003265 \pm 0$
ARGUS pub ALBRECHT 88B [21]	

Table 11 – continued from previous page

Reference / Branching Fraction	**Value**
$\Gamma_{103} = 3h^-2h^+\nu_\tau$ (ex. K^0)	$0.00064 \pm 0.0002508 \pm 0$
ARGUS pub ALBRECHT 92D [22]	
$\frac{\Gamma_3}{\Gamma_5} = \frac{\mu^-\overline{\nu}_\mu\nu_\tau}{e^-\overline{\nu}_e\nu_\tau}$	$0.997 \pm 0.05315 \pm 0$
BABAR pub AUBERT,B 05W [33]	
$\Gamma_{103} = 3h^-2h^+\nu_\tau$ (ex. K^0)	$0.000856 \pm 5 \cdot 10^{-6} \pm 4.2 \cdot 10^{-5}$
BABAR pub AUBERT 10F [42]	
$\frac{\Gamma_3}{\Gamma_5} = \frac{\mu^-\overline{\nu}_\mu\nu_\tau}{e^-\overline{\nu}_e\nu_\tau}$	$0.9796 \pm 0.00390406 \pm 0.00052753$
$\frac{\Gamma_9}{\Gamma_5} = \frac{\pi^-\nu_\tau}{e^-\overline{\nu}_e\nu_\tau}$	$0.5945 \pm 0.00574448 \pm 0.00248413$
$\frac{\Gamma_{10}}{\Gamma_5} = \frac{K^-\nu_\tau}{e^-\overline{\nu}_e\nu_\tau}$	$0.03882 \pm 0.000630207 \pm 0.000173608$
BABAR pub DEL-AMO-SANCHEZ 11E [24]	
$\Gamma_{128} = K^-\eta\nu_\tau$	$0.000142 \pm 1.1 \cdot 10^{-5} \pm 7 \cdot 10^{-6}$
BABAR pub AUBERT 08AE [37]	
$\Gamma_{136} = \pi^-\pi^-\pi^+\eta\nu_\tau$ (ex.K^0)	$0.00016 \pm 5 \cdot 10^{-6} \pm 1.1 \cdot 10^{-5}$
BABAR pub AUBERT 07AP [34]	
$\Gamma_{16} = K^-\pi^0\nu_\tau$	$0.00416 \pm 3 \cdot 10^{-5} \pm 0.00018$
BABAR prelim ICHEP08 [40]	
$\Gamma_{35} = \pi^-\overline{K}^0\nu_\tau$	$0.0084 \pm 4 \cdot 10^{-5} \pm 0.00023$
BABAR prelim DPF09 [92]	
$\Gamma_{40} = \pi^-\overline{K}^0\pi^0\nu_\tau$	$0.00342 \pm 6 \cdot 10^{-5} \pm 0.00015$
BABAR pub AUBERT 08 [36]	
$\Gamma_{60} = \pi^-\pi^-\pi^+\nu_\tau$ (ex.K^0)	$0.088337 \pm 7.4 \cdot 10^{-5} \pm 0.00126724$
$\Gamma_{85} = K^-\pi^-\pi^+\nu_\tau$ (ex.K^0)	$0.0027257 \pm 1.8 \cdot 10^{-5} \pm 9.2441 \cdot 10^{-5}$
$\Gamma_{93} = \pi^-K^-K^+\nu_\tau$	$0.0013461 \pm 1 \cdot 10^{-5} \pm 3.6413 \cdot 10^{-5}$
$\Gamma_{96} = K^-K^-K^+\nu_\tau$	$1.5777 \cdot 10^{-5} \pm 1.3 \cdot 10^{-6} \pm 1.2308 \cdot 10^{-6}$
Belle pub INAMI 09 [78]	
$\Gamma_{126} = \pi^-\pi^0\eta\nu_\tau$	$0.00135 \pm 3 \cdot 10^{-5} \pm 7 \cdot 10^{-5}$
$\Gamma_{128} = K^-\eta\nu_\tau$	$0.000158 \pm 5 \cdot 10^{-6} \pm 9 \cdot 10^{-6}$
$\Gamma_{130} = K^-\pi^0\eta\nu_\tau$	$4.6 \cdot 10^{-5} \pm 1.1 \cdot 10^{-5} \pm 4 \cdot 10^{-6}$
$\Gamma_{132} = \pi^-\overline{K}^0\eta\nu_\tau$	$8.8 \cdot 10^{-5} \pm 1.4 \cdot 10^{-5} \pm 6 \cdot 10^{-6}$
Belle pub FUJIKAWA 08 [69]	
$\Gamma_{13} = h^-\pi^0\nu_\tau$	$0.2567 \pm 1 \cdot 10^{-4} \pm 0.0039$
Belle pub EPIFANOV 07 [67]	
$\Gamma_{35} = \pi^-\overline{K}^0\nu_\tau$	$0.00808 \pm 4 \cdot 10^{-5} \pm 0.00026$
Belle prelim PHIPSI11 [95]	
$\Gamma_{40} = \pi^-\overline{K}^0\pi^0\nu_\tau$	$0.00384 \pm 0.00004 \pm 0.00016$
$\Gamma_{42} = K^-\pi^0K^0\nu_\tau$	$0.00148 \pm 0.00002 \pm 0.00008$
Belle pub LEE 10 [81]	
$\Gamma_{60} = \pi^-\pi^-\pi^+\nu_\tau$ (ex.K^0)	$0.0842 \pm 3.3211 \cdot 10^{-5} \pm 0.0025879$
$\Gamma_{85} = K^-\pi^-\pi^+\nu_\tau$ (ex.K^0)	$0.0033 \pm 1.274 \cdot 10^{-5} \pm 0.00016625$
$\Gamma_{93} = \pi^-K^-K^+\nu_\tau$	$0.00155 \pm 6.575 \cdot 10^{-6} \pm 5.5579 \cdot 10^{-5}$
$\Gamma_{96} = K^-K^-K^+\nu_\tau$	$3.29 \cdot 10^{-5} \pm 1.6941 \cdot 10^{-6} \pm 1.9621 \cdot 10^{-6}$
CELLO pub BEHREND 89B [54]	
$\Gamma_{54} = h^-h^-h^+ \geq 0\text{neutrals} \geq 0K_L^0\nu_\tau$	$0.15 \pm 0.005 \pm 0$
CLEO3 pub ARMS 05 [28]	
$\Gamma_{88} = K^-\pi^-\pi^+\pi^0\nu_\tau$ (ex.K^0)	$0.00074 \pm 0.000136 \pm 0$

Table 11 – continued from previous page

Reference / Branching Fraction	**Value**
$\Gamma_{94} = \pi^- K^- K^+ \pi^0 \nu_\tau$	$5.5 \cdot 10^{-5} \pm 1.844 \cdot 10^{-5} \pm 0$
$\Gamma_{151} = K^- \omega \nu_\tau$	$0.00041 \pm 9.21954 \cdot 10^{-5} \pm 0$
CLEO3 pub BRIERE 03 [57]	
$\Gamma_{60} = \pi^- \pi^- \pi^+ \nu_\tau$ (ex.K^0)	$0.0913 \pm 0.004627 \pm 0$
$\Gamma_{85} = K^- \pi^- \pi^+ \nu_\tau$ (ex.K^0)	$0.00384 \pm 0.000405 \pm 0$
$\Gamma_{93} = \pi^- K^- K^+ \nu_\tau$	$0.00155 \pm 0.0001082 \pm 0$
CLEO pub GIBAUT 94B [72]	
$\Gamma_{102} = 3h^- 2h^+ \geq 0\text{neutrals}\nu_\tau$ (ex.K^0)	$0.00097 \pm 0.0001208 \pm 0$
$\Gamma_{103} = 3h^- 2h^+ \nu_\tau$ (ex. K^0)	$0.00077 \pm 0.000103 \pm 0$
CLEO pub ANASTASSOV 01 [26]	
$\Gamma_{78} = h^- h^- h^+ 3\pi^0 \nu_\tau$	$0.00022 \pm 5 \cdot 10^{-5} \pm 0$
$\Gamma_{104} = 3h^- 2h^+ \pi^0 \nu_\tau$ (ex. K^0)	$0.00017 \pm 2.828 \cdot 10^{-5} \pm 0$
$\Gamma_{136} = \pi^- \pi^- \pi^+ \eta \nu_\tau$ (ex.K^0)	$0.00023 \pm 5 \cdot 10^{-5} \pm 0$
CLEO pub BATTLE 94 [52]	
$\Gamma_{10} = K^- \nu_\tau$	$0.0066 \pm 0.00114 \pm 0$
$\Gamma_{16} = K^- \pi^0 \nu_\tau$	$0.0051 \pm 0.001221 \pm 0$
$\Gamma_{23} = K^- 2\pi^0 \nu_\tau$ (ex. K^0)	$9 \cdot 10^{-4} \pm 0.001044 \pm 0$
$\Gamma_{31} = K^- \geq 0\pi^0 \geq 0K^0 \geq 0\gamma \nu_\tau$	$0.017 \pm 0.002247 \pm 0$
CLEO pub ARTUSO 92 [29]	
$\Gamma_{126} = \pi^- \pi^0 \eta \nu_\tau$	$0.0017 \pm 0.0002828 \pm 0$
CLEO pub BISHAI 99 [55]	
$\Gamma_{130} = K^- \pi^0 \eta \nu_\tau$	$0.000177 \pm 9.04268 \cdot 10^{-5} \pm 0$
$\Gamma_{132} = \pi^- \overline{K}^0 \eta \nu_\tau$	$0.00022 \pm 7.33757 \cdot 10^{-5} \pm 0$
CLEO pub ARTUSO 94 [30]	
$\Gamma_{13} = h^- \pi^0 \nu_\tau$	$0.2587 \pm 0.004368 \pm 0$
CLEO pub BALEST 95C [44]	
$\Gamma_{57} = h^- h^- h^+ \nu_\tau$ (ex.K^0)	$0.0951 \pm 0.002119 \pm 0$
$\Gamma_{66} = h^- h^- h^+ \pi^0 \nu_\tau$ (ex.K^0)	$0.0423 \pm 0.00228 \pm 0$
$\frac{\Gamma_{150}}{\Gamma_{66}} = \frac{h^- \omega \nu_\tau}{h^- h^- h^+ \pi^0 \nu_\tau \ (\text{ex.}K^0)}$	$0.464 \pm 0.02335 \pm 0$
CLEO pub BARINGER 87 [51]	
$\Gamma_{150} = h^- \omega \nu_\tau$	$0.016 \pm 0.004909 \pm 0$
CLEO pub BORTOLETTO 93 [56]	
$\frac{\Gamma_{76}}{\Gamma_{54}} = \frac{h^- h^- h^+ 2\pi^0 \nu_\tau \ (\text{ex.}K^0)}{h^- h^- h^+ \geq 0\text{neutrals} \geq 0K_L^0 \nu_\tau}$	$0.034 \pm 0.003606 \pm 0$
$\frac{\Gamma_{152}}{\Gamma_{76}} = \frac{h^- \omega \pi^0 \nu_\tau}{h^- h^- h^+ 2\pi^0 \nu_\tau \ (\text{ex.}K^0)}$	$0.81 \pm 0.08485 \pm 0$
CLEO pub PROCARIO 93 [93]	
$\frac{\Gamma_{19}}{\Gamma_{13}} = \frac{h^- 2\pi^0 \nu_\tau \ (\text{ex.}K^0)}{h^- \pi^0 \nu_\tau}$	$0.342 \pm 0.01709 \pm 0$
$\frac{\Gamma_{26}}{\Gamma_{13}} = \frac{h^- 3\pi^0 \nu_\tau}{h^- \pi^0 \nu_\tau}$	$0.044 \pm 0.005831 \pm 0$
$\Gamma_{29} = h^- 4\pi^0 \nu_\tau$ (ex.K^0)	$0.0016 \pm 0.0007071 \pm 0$
CLEO pub COAN 96 [61]	
$\Gamma_{34} = h^- \overline{K}^0 \nu_\tau$	$0.00855 \pm 0.0008139 \pm 0$
$\Gamma_{37} = K^- K^0 \nu_\tau$	$0.00151 \pm 0.0003041 \pm 0$
$\Gamma_{39} = h^- \overline{K}^0 \pi^0 \nu_\tau$	$0.00562 \pm 0.0006931 \pm 0$
$\Gamma_{42} = K^- \pi^0 K^0 \nu_\tau$	$0.00145 \pm 0.0004118 \pm 0$
$\Gamma_{47} = \pi^- K_S^0 K_S^0 \nu_\tau$	$0.00023 \pm 5.831 \cdot 10^{-5} \pm 0$

Table 11 – continued from previous page

Reference / Branching Fraction	Value
CLEO pub ANASTASSOV 97 [25]	
$\frac{\Gamma_3}{\Gamma_5} = \frac{\mu^- \overline{\nu}_\mu \nu_\tau}{e^- \overline{\nu}_e \nu_\tau}$	$0.9777 \pm 0.01074 \pm 0$
$\Gamma_5 = e^- \overline{\nu}_e \nu_\tau$	$0.1776 \pm 0.001803 \pm 0$
$\Gamma_8 = h^- \nu_\tau$	$0.1152 \pm 0.0013 \pm 0$
CLEO pub EDWARDS 00A [66]	
$\Gamma_{69} = \pi^- \pi^- \pi^+ \pi^0 \nu_\tau$ (ex.K^0)	$0.0419 \pm 0.002326 \pm 0$
CLEO pub RICHICHI 99 [94]	
$\frac{\Gamma_{80}}{\Gamma_{60}} = \frac{K^- \pi^- h^+ \nu_\tau \text{ (ex.} K^0)}{\pi^- \pi^- \pi^+ \nu_\tau \text{ (ex.} K^0)}$	$0.0544 \pm 0.005701 \pm 0$
$\frac{\Gamma_{81}}{\Gamma_{69}} = \frac{K^- \pi^- h^+ \pi^0 \nu_\tau \text{ (ex.} K^0)}{\pi^- \pi^- \pi^+ \pi^0 \nu_\tau \text{ (ex.} K^0)}$	$0.0261 \pm 0.006155 \pm 0$
$\frac{\Gamma_{93}}{\Gamma_{60}} = \frac{\pi^- K^- K^+ \nu_\tau}{\pi^- \pi^- \pi^+ \nu_\tau \text{ (ex.} K^0)}$	$0.016 \pm 0.003354 \pm 0$
$\frac{\Gamma_{94}}{\Gamma_{69}} = \frac{\pi^- K^- K^+ \pi^0 \nu_\tau}{\pi^- \pi^- \pi^+ \pi^0 \nu_\tau \text{ (ex.} K^0)}$	$0.0079 \pm 0.004682 \pm 0$
DELPHI pub ABDALLAH 06A [7]	
$\Gamma_8 = h^- \nu_\tau$	$0.11571 \pm 0.001655 \pm 0$
$\Gamma_{13} = h^- \pi^0 \nu_\tau$	$0.2574 \pm 0.002438 \pm 0$
$\Gamma_{19} = h^- 2\pi^0 \nu_\tau$ (ex.K^0)	$0.09498 \pm 0.004219 \pm 0$
$\Gamma_{25} = h^- \geq 3\pi^0 \nu_\tau$ (ex.K^0)	$0.01403 \pm 0.003098 \pm 0$
$\Gamma_{57} = h^- h^- h^+ \nu_\tau$ (ex.K^0)	$0.09317 \pm 0.001218 \pm 0$
$\Gamma_{66} = h^- h^- h^+ \pi^0 \nu_\tau$ (ex.K^0)	$0.04545 \pm 0.001478 \pm 0$
$\Gamma_{74} = h^- h^- h^+ \geq 2\pi^0 \nu_\tau$ (ex.K^0)	$0.00561 \pm 0.001168 \pm 0$
$\Gamma_{103} = 3h^- 2h^+ \nu_\tau$ (ex. K^0)	$0.00097 \pm 0.0001581 \pm 0$
$\Gamma_{104} = 3h^- 2h^+ \pi^0 \nu_\tau$ (ex. K^0)	$0.00016 \pm 0.0001342 \pm 0$
DELPHI pub ABREU 94K [9]	
$\Gamma_{10} = K^- \nu_\tau$	$0.0085 \pm 0.0018 \pm 0$
$\Gamma_{31} = K^- \geq 0\pi^0 \geq 0K^0 \geq 0\gamma \nu_\tau$	$0.0154 \pm 0.0024 \pm 0$
DELPHI pub ABREU 99X [10]	
$\Gamma_3 = \mu^- \overline{\nu}_\mu \nu_\tau$	$0.17325 \pm 0.001223 \pm 0$
$\Gamma_5 = e^- \overline{\nu}_e \nu_\tau$	$0.17877 \pm 0.001549 \pm 0$
DELPHI pub ABREU 92N [8]	
$\Gamma_7 = h^- \geq 0K_L^0 \nu_\tau$	$0.124 \pm 0.009899 \pm 0$
HRS pub BYLSMA 87 [60]	
$\Gamma_{102} = 3h^- 2h^+ \geq 0\text{neutrals} \nu_\tau$ (ex.K^0)	$0.00102 \pm 0.00029 \pm 0$
$\Gamma_{103} = 3h^- 2h^+ \nu_\tau$ (ex. K^0)	$0.00051 \pm 2 \cdot 10^{-4} \pm 0$
L3 pub ACHARD 01D [14]	
$\Gamma_{55} = h^- h^- h^+ \geq 0\text{neutrals} \nu_\tau$ (ex.K^0)	$0.14556 \pm 0.001296 \pm 0$
$\Gamma_{102} = 3h^- 2h^+ \geq 0\text{neutrals} \nu_\tau$ (ex.K^0)	$0.0017 \pm 0.0003406 \pm 0$
L3 pub ACCIARRI 95 [11]	
$\Gamma_7 = h^- \geq 0K_L^0 \nu_\tau$	$0.1247 \pm 0.005025 \pm 0$
$\Gamma_{13} = h^- \pi^0 \nu_\tau$	$0.2505 \pm 0.006103 \pm 0$
$\Gamma_{19} = h^- 2\pi^0 \nu_\tau$ (ex.K^0)	$0.0888 \pm 0.005597 \pm 0$
$\Gamma_{26} = h^- 3\pi^0 \nu_\tau$	$0.017 \pm 0.004494 \pm 0$
L3 pub ACCIARRI 95F [12]	
$\Gamma_{35} = \pi^- \overline{K}^0 \nu_\tau$	$0.0095 \pm 0.001616 \pm 0$
$\Gamma_{40} = \pi^- \overline{K}^0 \pi^0 \nu_\tau$	$0.0041 \pm 0.001237 \pm 0$
L3 pub ACCIARRI 01F [13]	

Table 11 – continued from previous page

Reference / Branching Fraction	Value
$\Gamma_3 = \mu^- \overline{\nu}_\mu \nu_\tau$	$0.17342 \pm 0.001288 \pm 0$
$\Gamma_5 = e^- \overline{\nu}_e \nu_\tau$	$0.17806 \pm 0.001288 \pm 0$
L3 pub ADEVA 91F [17]	
$\Gamma_{54} = h^- h^- h^+ \geq 0\text{neutrals} \geq 0 K_L^0 \nu_\tau$	$0.144 \pm 0.006708 \pm 0$
OPAL pub ACKERSTAFF 99E [16]	
$\Gamma_{103} = 3h^- 2h^+ \nu_\tau$ (ex. K^0)	$0.00091 \pm 0.0001523 \pm 0$
$\Gamma_{104} = 3h^- 2h^+ \pi^0 \nu_\tau$ (ex. K^0)	$0.00027 \pm 0.0002012 \pm 0$
OPAL pub ABBIENDI 01J [4]	
$\Gamma_{10} = K^- \nu_\tau$	$0.00658 \pm 0.0003962 \pm 0$
$\Gamma_{31} = K^- \geq 0\pi^0 \geq 0K^0 \geq 0\gamma \nu_\tau$	$0.01528 \pm 0.0005587 \pm 0$
OPAL pub ACKERSTAFF 98M [15]	
$\Gamma_8 = h^- \nu_\tau$	$0.1198 \pm 0.002062 \pm 0$
$\Gamma_{13} = h^- \pi^0 \nu_\tau$	$0.2589 \pm 0.003362 \pm 0$
$\Gamma_{17} = h^- \geq 2\pi^0 \nu_\tau$	$0.0991 \pm 0.004111 \pm 0$
OPAL pub ABBIENDI 04J [6]	
$\Gamma_{16} = K^- \pi^0 \nu_\tau$	$0.00471 \pm 0.0006332 \pm 0$
$\Gamma_{85} = K^- \pi^- \pi^+ \nu_\tau$ (ex.K^0)	$0.00415 \pm 0.000664 \pm 0$
OPAL pub AKERS 94G [19]	
$\Gamma_{33} = K_S^0(\text{particles})^- \nu_\tau$	$0.0097 \pm 0.001082 \pm 0$
OPAL pub ABBIENDI 00C [3]	
$\Gamma_{35} = \pi^- \overline{K}^0 \nu_\tau$	$0.00933 \pm 0.0008382 \pm 0$
$\Gamma_{38} = K^- K^0 \geq 0\pi^0 \nu_\tau$	$0.0033 \pm 0.0006742 \pm 0$
$\Gamma_{43} = \pi^- \overline{K}^0 \geq 1\pi^0 \nu_\tau$	$0.00324 \pm 0.000991564 \pm 0$
OPAL pub ABBIENDI 03 [5]	
$\Gamma_3 = \mu^- \overline{\nu}_\mu \nu_\tau$	$0.1734 \pm 0.001082 \pm 0$
OPAL pub AKERS 95Y [20]	
$\Gamma_{55} = h^- h^- h^+ \geq 0\text{neutrals}\nu_\tau$ (ex.K^0)	$0.1496 \pm 0.002377 \pm 0$
$\frac{\Gamma_{57}}{\Gamma_{55}} = \frac{h^- h^- h^+ \nu_\tau \text{ (ex.} K^0)}{h^- h^- h^+ \geq 0\text{neutrals}\nu_\tau \text{ (ex.} K^0)}$	$0.66 \pm 0.01456 \pm 0$
OPAL pub ABBIENDI 99H [1]	
$\Gamma_5 = e^- \overline{\nu}_e \nu_\tau$	$0.1781 \pm 0.001082 \pm 0$
OPAL pub ALEXANDER 91D [23]	
$\Gamma_7 = h^- \geq 0K_L^0 \nu_\tau$	$0.121 \pm 0.008602 \pm 0$
OPAL pub ABBIENDI 00D [2]	
$\Gamma_{92} = \pi^- K^- K^+ \geq 0\text{neutrals}\nu_\tau$	$0.00159 \pm 0.0005665 \pm 0$
TPC pub AIHARA 87B [18]	
$\Gamma_{54} = h^- h^- h^+ \geq 0\text{neutrals} \geq 0K_L^0 \nu_\tau$	$0.151 \pm 0.01 \pm 0$
TPC pub BAUER 94 [53]	
$\Gamma_{82} = K^- \pi^- \pi^+ \geq 0\text{neutrals}\nu_\tau$	$0.0058 \pm 0.001845 \pm 0$
$\Gamma_{92} = \pi^- K^- K^+ \geq 0\text{neutrals}\nu_\tau$	$0.0015 \pm 0.00085515 \pm 0$

B Upper Limits on Tau LFV Branching Fractions: Summary Plot

Figure 2 summarizes the upper limits on the tau lepton-flavor-violating branching fractions.

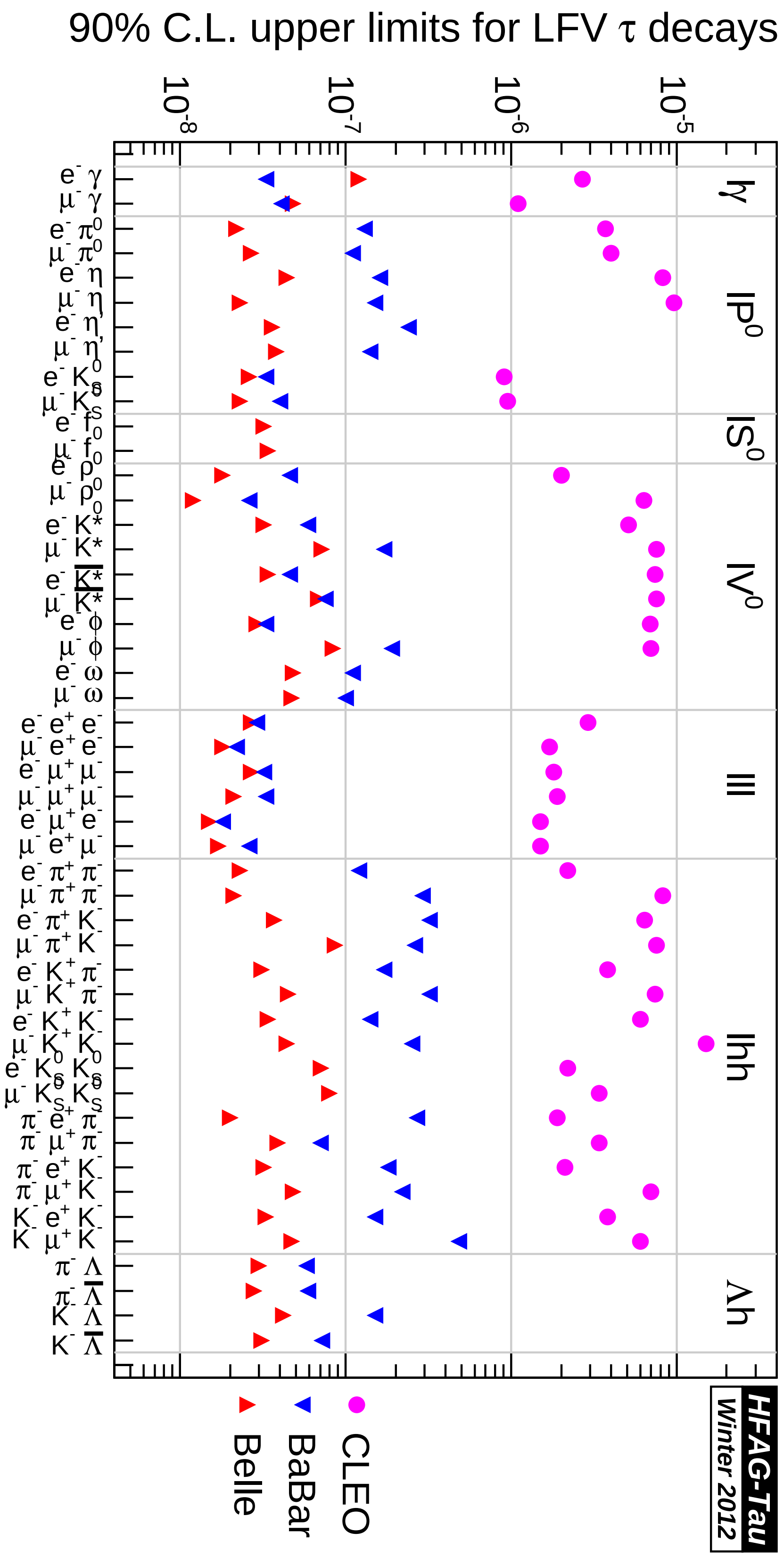

Figure 2: Tau lepton-flavor-violating branching fraction upper limits summary.

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