τ-DECAY BRANCHING FRACTIONS

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The goal in making fits to the experimental measurements of τ branching ratios is to get "best estimates" of the branching fractions. For a constrained fit, it is necessary to define a set of exclusive basis modes whose branching fractions sum exactly to unity. In principle, one would choose the modes at the top of the decay chain as the basis modes: e, μ, π, K, ρ, $K^*(892)$, a_1, ρ', *etc.*, as well as states involving more than one of these particles. Since experimental data do not yet allow this, a compromise has to be made between clean theoretical modes and the quantities that are actually measured.

Historically, experiments have distinguished electrons, muons, charged hadrons, and "neutrals;" that is, electromagnetic activity presumed to be the result of π^0 decay. Older papers reported the charged hadrons as $\pi^{\pm}$, but this is no longer sufficient, given present precision. Newer experiments are also providing good π^0 reconstruction and good vertex reconstruction. Most papers still report the nonleptonic modes as "m charged hadrons + $(\geq)n\pi^0$'s," where $m = 1, 3$, or 5.

Charged-prong topological branching modes (1-, 3-, or 5-charged-prong events) remain important, although only the 5-prong mode survives as one of our basis modes. However, we have slightly generalized the idea of topological branching fractions to include $(\geq)n\pi^0$'s. These are *topological*, in the sense that they classify what is observed, rather than *physical*, which would classify the modes at the top of the decay chain.

The basis modes are chosen to reflect the state of the art, and hence evolve with the data. For this edition, we use 12 basis modes:

$e^-\overline{\nu}_e\nu_\tau$	$K^*(892)^-\nu_\tau$	$h^-4\pi^0\nu_\tau$
$\mu^-\overline{\nu}_\mu\nu_\tau$	$\pi^-\pi^0\nu_\tau$	$2h^-h^+\nu_\tau$
$\pi^-\nu_\tau$	$h^-2\pi^0\nu_\tau$	$2h^-h^+ \geq 1$ neutrals ν_τ
$K^-\nu_\tau$	$h^-3\pi^0\nu_\tau$	$3h^-2h^+ \geq 0$ neutrals ν_τ

(Charge conjugate states are assumed, and $h^{\pm}$ indicates a $\pi^{\pm}$ or $K^{\pm}$.) The $K^*(892)$ is the only resonance included because the $\tau^- \to K^*(892)^-\nu_\tau$ and $K^*(892)^-$ branching fractions are very well measured. By comparison, the $\pi^-\pi^0\nu_\tau$ mode is predominantly $\rho^-\nu_\tau$, but also includes $\rho'^-\nu_\tau$ and any nonresonant component.

Kaons present several of special problems at the 0.5% level, whether they come directly from τ^- decay or from the decay of an intermediate K^*. This comes about for several reasons:

(a) Most experiments lack charged particle identification, and hence our basis modes of the form "m charged hadrons + $(\geq)n\pi^0$'s" must include directly produced kaons but exclude those from $K^*(892)$ decay.

(b) K_L's are usually undetected.

(c) $K_S \to \pi^+\pi^-$ causes confusion even for the topological branching ratios, since it is only recently that they can be sorted out with practical efficiency. Even so, branching ratios to final states containing K_S's (exclusive of those with an intermediate $K^*(892)$) are poorly known. For the moment, events containing such decays are counted with the 3-prong modes.

Experimenters often make corrections for various kaon backgrounds. Because of our present definition of the basis modes, the *only* background defined in our Listings for the "m charged hadrons + $(\geq)n\pi^0$'s" modes are the contributions from $K^*(892)$ decay. Thus, all results must be corrected for the different assumptions that the experimenters made about background definitions, at least to the degree that they are documented in the papers. The $K^*(892)^-$ branching fractions to the final states are as follows:

$$
\begin{array}{llll}
K^*(892)^- \to K^-\pi^0 & & & 1/3 \\
\quad \hookrightarrow K^0\pi^- \to K_L\pi^- & & & 1/3 \\
\qquad\qquad \hookrightarrow K_S\pi^- \to \pi^-\pi^+\pi^- & & & 0.2286 \\
\qquad\qquad\qquad\qquad \hookrightarrow \pi^-\pi^0\pi^0 & & & 0.1046
\end{array}
$$

These branching fractions appear throughout the listings. For example, the topological 1-prong mode includes 0.771 B$(K^*(892)^-\nu_\tau)$ (since 1/3 + 1/3 + 0.1046 = 0.7712), while the 3-prong fraction includes the remaining 0.229 B$(K^*(892)^-\nu_\tau)$. Similarly, B$(h^-\nu_\tau)$ = B$(\pi^-\nu_\tau)$ + B$(K^-\nu_\tau)$ + $\frac{1}{3}$B$(K^*(892)^-\nu_\tau)$

because of the unseen K_L's, and $\mathrm{B}(h^-\pi^0\nu_\tau) = \mathrm{B}(\pi^-\pi^0\nu_\tau) + \frac{1}{3}\mathrm{B}(K^*(892)^-\nu_\tau)$ because of the $K^-\pi^0$ final states from $K^*(892)^-$ decay.

The present basis mode definitions contain many inconsistencies at the few tenths of a percent level. In principle, the above examples should contain contributions from $\pi^- K_L \overline{K}_L$, $K^-\overline{K}_L$, nonresonant $(\pi K)^-$ states, *etc.* We also define $\mathrm{B}(h^- \geq 3\pi^0\nu_\tau)$ as the sum of states containing 3 π^0's and 4 π^0's, neglecting those with 5 or more neutral pions. Hopefully, these inconsistencies enter at levels well below the uncertainties of present experiments. The set of basis modes is under constant reevaluation, and in fact has been changed in each of our last three editions. Revision will continue, as better detectors record larger numbers of τ decays with better-understood systematics. Perhaps one day most events containing $K_S \to \pi^+\pi^-$ will be classified as 1-prong events, and high-quality older results will be corrected accordingly.