Global Fits of Tau Branching Fractions

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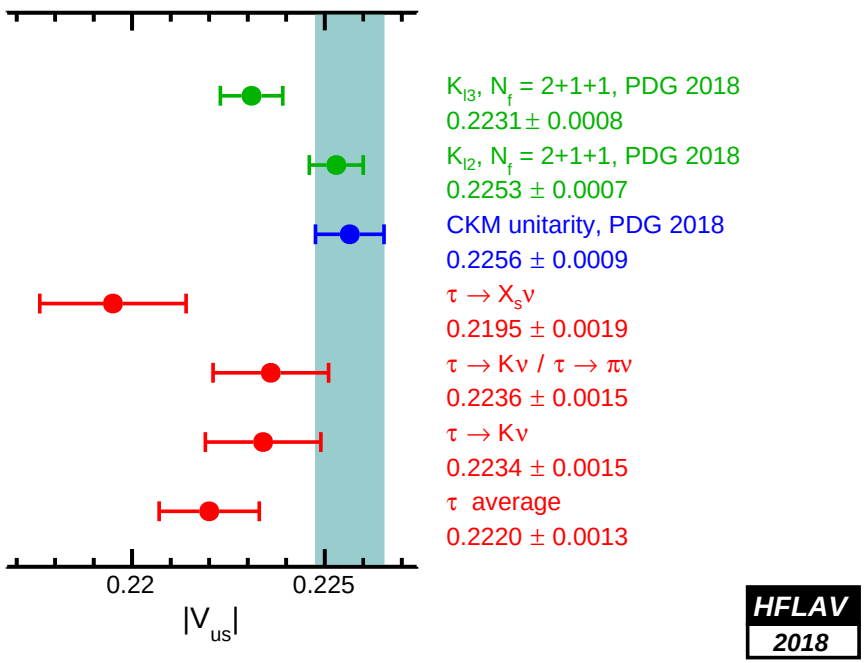
Global fits of τ branching fractions

Motivation:

- determine CKM matrix elements $|V_{ud}|$, $|V_{us}|$ exclusively and inclusively
- test lepton flavor universality
- constrain lepton-number violation, baryon-number violation , etc.



HFLAV observed a 2.9σ tension in $|V_{us}|$ measurements in their interpretation of the data

Global fits of τ branching fractions

Our fit provides

- an independent check with a different statistical formalism (Bayesian)
- using sampling instead of optimization to better understand the tension and pinpoint where experimental effort is best spent.

It fits

- $\approx$ 250 parameters (Γ_i from τ, K, ...) to
- $\approx$ 1000 measurements (Γ_i/Γ, Γ_i/Γ_j, $[\Gamma_i - \Gamma_j]/\Gamma_k$, $\Gamma_i \times \Gamma_j/\Gamma_k$, ...) from
- $\approx$ 150 publications from
- $\approx$ 20 experiments

published in the last 40 years.

Sampling is handled by BAT.jl, the Julia-based Bayesian Analysis Toolkit

The likelihood is formed by our independent framework
for global fits of branching fractions

Global fits of τ branching fractions

Our framework allows for transparency in the data:

- human readable $\rightarrow$ easily reviewed
- handles correlations between measurements
  allowing for easy specifcation across
  publications, data sets, and experiments
- builds likelihoods from raw data inputs
  (especially useful when upper limits are given)
- allows for conditional data specification
  (assume standard model or not, CP conservation or not, . . .)
- allows for specification of simplectic parameter subsets
- handles translation from global fit basis to local measurement basis

Global fits of τ branching fractions

Example data file (in YAML)

```
---
bibtex:
  - @article{Anastassov:1996tc, ... }
  - @article{PhysRevD.58.119904, ... }

experiment: CLEO-II
data set: \SI{3.555}{fb^{-1}}

aliases:
  h^-: (\Ppiminus|\PKminus)

initial state: \Ptauon

measurements:

  - decay: \Pelectron \APnue \Pnut
    value: (17.76 +- 0.06 +- 0.11 +- 0.13) e-2
    uncertainties: [statistical, systematic, '~/N_{\Ptau\Ptau}']

  - decay: \Pmuon \APnum \Pnut // \Pelectron \APnue \Pnut
    value: (97.77 +- 0.63 +- 0.87) e-2
    uncertainties: [statistical, systematic]

  - decay: h^- \Pnut // \Pelectron \APnue \Pnut
    value: (64.84 +- 0.41 +- 0.60) e-2
    uncertainties: [statistical, systematic]

correlation:
  - [ 1.00, -0.42, -0.39]
  - [-0.42,  1.00,  0.45]
  - [-0.39,  0.45,  1.00]

notes: |
  The $5{\times}5$ correlation matrix given in the erratum contains some further error.
  Two of its eigenvalues are small negative numbers. ...
```

Global fits of τ branching fractions

Upper limits can be speficied by using raw information (when it's given!)

```
- decay: \PKshort \PKshort \Ppiminus \Ppizero \Pnut
  # 0 events / (efficiency * N_tautau * 2)
  value: 0 // (3.6 +- 0.3) e-2 * 200300 * 2
  published value: < 0.20e-3 @ 95e-2

- decay: \PKshort \PKminus \Ppizero \Ppizero \Pnut
  # 0+-1 events / (efficiency * N_tautau * 2)
  value: (0 +- 1) // (2.10 +- 0.20) e-2 * 200300 * 2
  published value: 0.5 * < 0.39e-3 @ 95e-2
```

The framework will parse the input and create the proper likelihood.

$\rightarrow$ Poisson / Normal

$\rightarrow$ Normal / Normal

...

(In general, a parabolic cylinder function.)

Global fits of τ branching fractions

Some problems we are encountering:

- Results often given without correlations.
  (In one example, correlations given without results!)
- Incomplete information given about how results are arrived at, complicating
  - deciphering correlations (when not given explicitly)
  - determining appropriate likelihood when only upper limit given
- Asymmetric uncertainties given in multivariate contexts
- Inconsistent results

  ex: combined result only consistent with individual results
  if correlation is outside of [1, -1]
- Invalid results

  ex: singular covariance matrices

In general: results are reported without thought to them being usable

(ex: why are we reporting upper limits?)