HFLAV-Tau status

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New experimental inputs

tau branching fractions

- Belle, Aug 2019, doi:10.1103/PhysRevD.100.071101: $\mathcal{B}(\tau \to \pi \nu e^+ e^-)$
  - not a total BR for the mode (just the structure-dependent part is measured)
  - not included in tau BR global fit

tau LFV upper limits

- CMS, Jul 2020, doi:10.1007/JHEP01(2021)163: 1 LFV BR $\mathcal{B}(\tau \to 3\mu)$
- Belle, Oct 2020, doi:10.1103/PhysRevD.102.111101: 6 baryon/lepton violating BRs $\mathcal{B}(\tau \to p\ell\ell)$
- Belle, Mar 2021, BELLE-CONF-2101: 2 LFV BRs $\mathcal{B}(\tau \to e\gamma)$, $\mathcal{B}(\tau \to \mu\gamma)$

Status of updates with respect to End of 2018 report

tau BR fit

- ☑ take note of new results
- ☐ stop using our special elaboration of ALEPH tau BRs
- ☐ remove non-published old preliminary results [BABAR ICHEP 2018 $\mathcal{B}(\tau \to K\ n\pi^0\nu)$]

lepton universality tests and $|V_{us}|$ from tau BRs

- ☐ provide information to facilitate computing $|V_{us}|$ from tau BRs with the replacement of the radiative correction used so far with the new estimates by RM123 (Lattice QCD+QED)

tau LFV upper limits

- ☑ take note of new results
- ☐ add new tau LFV upper limits
  (on hold, since Marcin is recovering from broken arm accident)

Status summary

- we started working on all due updates (which require a limited amount of work)
- will consider possible enhancements once due updates are completed

Backup Slides

New ideas

improve reproducibility of Tau fit by documenting treatment of systematics

- non trivial amount of work, which so far discouraged working on it

publish Tau results in electronic format

- easy to do with our software framework
- we already transmit most of our results electronically to the PDG
- it would be nice to also design a stable data format, suitable for general use
- some personal ideas
  - use YAML (main format of HEPData)
  - use PDG identifiers (stable and well maintained)
  - PDG is working on providing electronic access, but there is no schedule that I know of

revise upper limit combinations

- each upper limit is based on a measurement with uncertainty, or likelihood
- recover these measuremens from the papers and average them just like other HFLAV averages
  - easy treatment of common systematics, correlations (now unaccounted)
- compute the upper limits using the averages and their uncertainties
- Glen Cowan recommends following this route

Recent HFLAV Tau reports

End 2018

- report preprint in September 2019, accepted and about to be published on EPJC
- web report, September 2019
- *BABAR* ICHEP 2018 $\mathcal{B}(\tau \to K\ n\pi^0 \nu)$ results improved $|V_{us}|$
- added back $|V_{us}|_{K\nu}$ now with proper complete rad.corr.

Tau Spring 2017 corresponding to HFLAV version #2 of "as of summer 2016"

- report published on EPJC in December 2017 (version #2 of "as of summer 2016")
- web report, May 2017
- review for publication
  - minor improvements to $|V_{us}|$ since preprint: $|V_{ud}|$, rad.corr. refinements, drop $|V_{us}|_{K\nu}$
  - no change to tau BR fit

version #1 of "as of summer 2016"

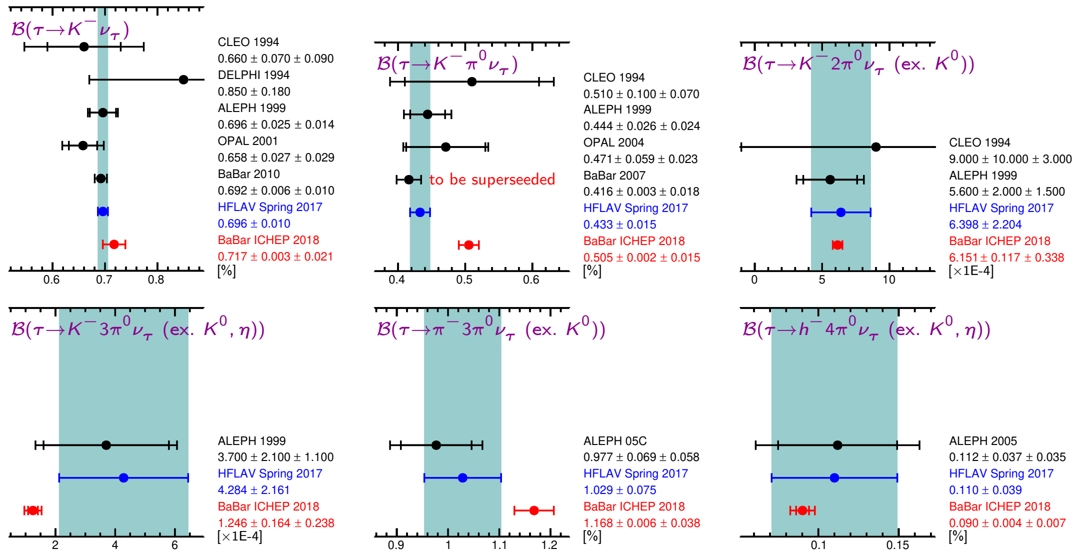
- preprint in October 2016
- web report in October 2016

PDG collaboration

- since 2016, HFLAV Tau provides the PDG Tau branching fraction fit

BABAR ICHEP 2018 prelim. results

BABAR $\mathcal{B}(\tau \to K, \pi\, n\pi^0 \nu)$ ICHEP 2018 prelim.



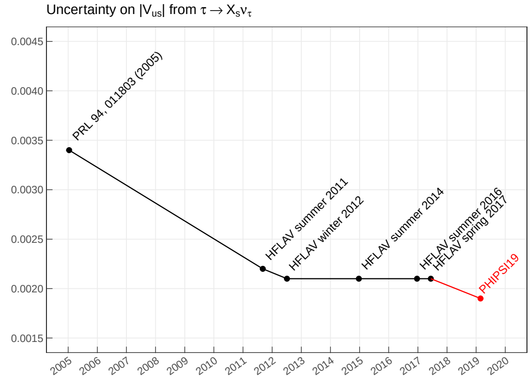
"End 2018" report shows first significant improvement on $|V_{us}|$ since 2011

Updated $|V_{us}|$ from $\tau \to X_s \nu_\tau$ uncertainty budget

$\pi^- \bar{K}^0 2\pi^0 \nu_\tau$ (ex. K^0)	0.3933
$K^- 2\pi^0 \nu_\tau$ (ex. K^0)	0.0464
$K^- 3\pi^0 \nu_\tau$ (ex. K^0, η)	0.0449
$\bar{K}^0 h^- h^- h^+ \nu_\tau$	0.3452
$K^- \pi^0 \nu_\tau$	0.1575
$K^- \pi^- \pi^+ \pi^0 \nu_\tau$ (ex. K^0, ω, η)	0.2438
$\pi^- \bar{K}^0 \nu_\tau$	0.2373
$\pi^- \bar{K}^0 \pi^0 \nu_\tau$	0.2201
$K^- \nu_\tau$	0.1453
$K^- \omega \nu_\tau$	0.1573
$K^- \nu_\tau$	0.1453
$K^- \pi^- \pi^+ \nu_\tau$ (ex. K^0, ω)	0.1148
$\pi^- \bar{K}^0 \eta \nu_\tau$	0.0254
$K^- \pi^0 \eta \nu_\tau$	0.0198
$K^- \eta \nu_\tau$	0.0137
$K^- \phi \nu_\tau$ ($\phi \to K^+ K^-$)	0.0136
$K^- \phi \nu_\tau$ ($\phi \to K_S^0 K_L^0$)	0.0094
$K^- 2\pi^- 2\pi^+ \nu_\tau$ (ex. K^0)	0.0021
$K^- 2\pi^- 2\pi^+ \pi^0 \nu_\tau$ (ex. K^0)	0.0010
$\tau \to$ non-strange	0.0855
$\mathcal{B}_e^{\text{univ}}$	0.0044
theory	0.4863

- shaded magenta bars report HFLAV Spring 2017 uncertainties before *BABAR* ICHEP 2018 results

Uncertainty on $|V_{us}|$ ($\tau \to X_s \nu$)



News later than "End 2018" and not included in present report

New rad.corr. for π and K semilept. decays, lattice QCD + QED

		$\delta R_{\pi\ell 2}$	$\delta R_{K\ell 2}$	
chiral pert. th.	Cirigliano & Neufeld 2011	1.76(21)%	0.64(24)%	
QCD+QED lattice	Di Carlo *et al.* [RM123 collab.] 2019	1.53(19)%	0.24(10)%	new

$|V_{ud}|$ updates

- PDG 2018 $\rightarrow$ 2020
  new estimates of universal electroweak radiative corrections to superallowed nuclear beta decays
  [Seng *et al.* 2018, Czarnecki *et al.* 2019, Seng *et al.* 2019]
  $\Rightarrow$ tension in CKM first row unitarity

$|V_{us}|$ from tau decays

- $$\frac{R(\tau \to X_{\text{strange}}\, \nu)}{|V_{us}|^2} = \frac{R(\tau \to X_{\text{non-strange}}\, \nu)}{|V_{ud}|^2} - \delta R_{\tau,\text{SU3 breaking}},$$ $\tau \to X_s \nu$
- $$\frac{\Gamma(\tau^- \to K^- \nu_\tau)}{\Gamma(\tau^- \to \pi^- \nu_\tau)} = \frac{|V_{us}|^2}{|V_{ud}|^2} \left(\frac{f_{K\pm}}{f_{\pi\pm}}\right)^2 \frac{\left(1 - m_K^2/m_\tau^2\right)^2}{\left(1 - m_\pi^2/m_\tau^2\right)^2} \frac{R_{\tau/K}}{R_{\tau/\pi}} R_{K/\pi}$$ $\tau \to K / \tau \to \pi$
- $$\Gamma(\tau^- \to K^- \nu_\tau) = \frac{G_F^2}{16\pi\hbar} f_{K\pm}^2 |V_{us}|^2 m_\tau^3 \left(1 - \frac{m_K^2}{m_\tau^2}\right)^2 R_{\tau/K} R_{K\mu 2}$$ $\tau \to K$

- $\Gamma(\tau^- \to X)$, $R(\tau \to X) = \Gamma(\tau \to X) \,/\, \Gamma(\tau \to e\nu\overline{\nu})$ from HFLAV tau branching ratio fit 2018
- $\delta R_{\tau,\text{SU3 breaking}}$ from Gamiz *et al.* JHEP 01 (2003) 06, PRL 94 (2005) 011803
  - perturbative QCD (OPE, finite energy sum rules), requires m_s value (lattice QCD)
- $(f_{K\pm}/f_{\pi\pm})$, $f_{K\pm}$ from lattice QCD, FLAG 2019
- $R_{K\mu 2}$, $R_{K/\pi}$ from Cirigliano & Neufeld 2011, Di Carlo *et al.* 2019
- $R_{\tau/K}/R_{\tau/\pi}$ from Decker & Finkemeier 1995
- remaining inputs are very precisely known

Small inconsistencies in HFLAV inclusive ALEPH BFs reconstruction

$\mathcal{B}(\tau \to h\nu)$ in SCHAEL 05C fig.42 is inconsistent

$\mathcal{B}(\tau \to \pi\nu)$ ALEPH SCHAEL 05C (%)	$10.828 \pm 0.070 \pm 0.078$
$\mathcal{B}(\tau \to K\nu)$ ALEPH BARATE 99K (%)	$0.696 \pm 0.025 \pm 0.014$
$\mathcal{B}(\tau \to h\nu)$ combining (*) above two measurements (%)	$11.524 \pm 0.070 \pm 0.073$
$\mathcal{B}(\tau \to h\nu)$ HFLAV (SCHAEL 05C fig.42) (%)	$11.524 \pm 0.070 \pm 0.078$

(*) combination assuming $\mathcal{B}(\tau \to \pi\nu)$ was computed subtracting $\mathcal{B}(\tau \to K\nu)$ from $\mathcal{B}(\tau \to h\nu)$, with the total error of $\mathcal{B}(\tau \to K\nu)$ added in quadrature to the systematic error. This procedure appears to be the one generally followed in SCHAEL 05C.

Using $\mathcal{B}(\tau \to h\nu)$ in SCHAEL 05C fig.42 makes $\mathcal{B}(\tau \to \pi\nu)$ less precise in HFLAV

- PDG $\mathcal{B}(\tau \to \pi\nu) = 10.828 \pm 0.070 \pm 0.078$
  - using SCHAEL 05C exclusive modes, directly
- HFLAV $\mathcal{B}(\tau \to \pi\nu) = 10.828 \pm 0.070 \pm 0.083$
  - subtracting $\mathcal{B}(\tau \to K\nu)$ from $\mathcal{B}(\tau \to h\nu)$ (they are uncorrelated)
- note that the ALEPH measurement is the most precise for this mode
- numbers in the figures of the ALEPH SCHAEL 05C paper seem inconsistent with numbers in the tables, which are apparently the only ones meant to be published
- however, central values are consistent, just uncertainties do not seem to be consistent

Small inconsistencies in HFLAV inclusive ALEPH BFs reconstruction

- inconsistencies similar to $\mathcal{B}(\tau \to \pi\nu)$ exist also for the other modes
- these inconsistencies are small and were obfuscated by computing and listing total uncertainties for the inclusive modes, instead of computing and listing separately statistical and systematic uncertainties

personal attitude and plan

- use the PDG values also for HFLAV, dropping our reconstructed ALEPH values
- just add proper correlation terms between ALEPH pion and kaon modes measurements, to account for pions being computed from inclusive modes minus ALEPH kaons
  $\Rightarrow$ expect slight improvement in the fit precision w.r.t. the present fit
- possibly adjust the pion modes correlation matrix
  (PDG uses the inclusive modes correlation matrix for pion modes, since ALEPH only publishes that)