

Improved determination of $|V_{us}|$ from tau decays



Alberto Lusiani

Scuola Normale Superiore and INFN, sezione di Pisa



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$|V_{us}|$ determinations using tau decays

$$\Gamma(\tau \rightarrow X_{\text{strange}} \nu) / |V_{us}|^2 = \Gamma(\tau \rightarrow X_{\text{non-strange}} \nu) / |V_{ud}|^2 - \delta R_{\tau, \text{SU3 breaking}}$$

 $\tau \rightarrow X_s \nu$

$$\frac{\Gamma(\tau^- \rightarrow K^- \nu_\tau)}{\Gamma(\tau^- \rightarrow \pi^- \nu_\tau)} = \frac{|V_{us}|^2}{|V_{ud}|^2} \left(\frac{f_{K^\pm}}{f_{\pi^\pm}} \right)^2 \frac{(1 - m_K^2/m_\tau^2)^2}{(1 - m_\pi^2/m_\tau^2)^2} \frac{R_{\tau/K}}{R_{\tau/\pi}} R_{K/\pi}$$

 $\tau \rightarrow K / \tau \rightarrow \pi$

$$\Gamma(\tau^- \rightarrow K^- \nu_\tau) = \frac{G_F^2}{16\pi\hbar} f_{K^\pm}^2 |V_{us}|^2 m_\tau^3 \left(1 - \frac{m_K^2}{m_\tau^2}\right)^2 R_{\tau/K} R_{K\mu 2}$$

 $\tau \rightarrow K$

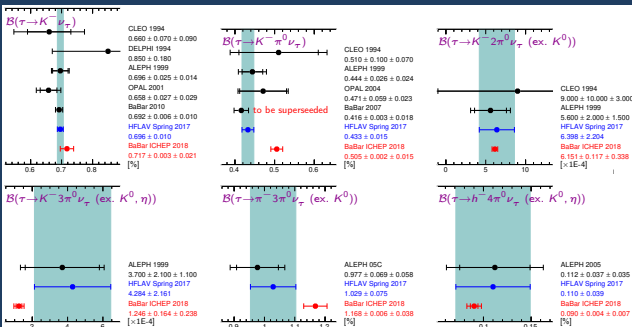
- ▶ $\Gamma(\tau^- \rightarrow X)$, $R(\tau \rightarrow X) = \Gamma(\tau \rightarrow X) / \Gamma(\tau \rightarrow e \nu \bar{\nu})$ from HFLAV tau branching ratio fit 2018
- ▶ $\delta R_{\tau, \text{SU3 breaking}}$ from Gamiz *et al.* JHEP 01 (2003) 06, PRL 94 (2005) 011803
 - ▶ perturbative QCD (OPE, finite energy sum rules), requires m_s value (lattice QCD)
- ▶ (f_{K^\pm}/f_{π^\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

Updates and on-going work since EPS-HEP 2019

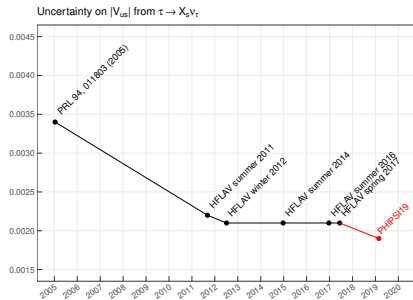
BABAR 2018 prelim. results on $\mathcal{B}(\tau \rightarrow K n \pi^0 \nu)$ paper in preparation (not yet ready unfortunately)

$|V_{us}|$ from tau decays is limited by experimental precision on tau branching fractions

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



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



QCD+QED lattice determinations of pseudoscalar decay radiative corrections

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

Updated $|V_{us}|$ from tau decays

$|V_{ud}|$ updates

- ▶ PDG 2018 → 2020
 $|V_{ud}|$: new estimates of universal electroweak radiative corrections to superallowed nuclear beta decays [Seng *et al.* 2018, Czarnecki *et al.* 2019, Seng *et al.* 2019]
 ⇒ tension in CKM first row unitarity

Other updates since EPS-HEP 2019

- ▶ FLAG 2016 → FLAG 2019 lattice QCD averages
- ▶ HFLAV 2018 report accepted by EPJC Jun 2020

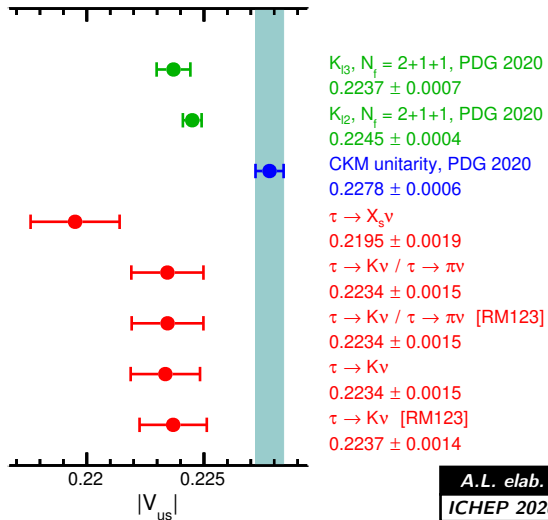
$|V_{us}|$ from tau status at ICHEP 2020

- ▶ $|V_{us}|_{\tau \rightarrow X_s \nu} - |V_{us}|_{uni} = -4.2\sigma$ (was -2.9σ)
- ▶ other $|V_{us}|$ from tau more than -2σ apart

Alternative $|V_{us}|$ ($\tau \rightarrow X_s \nu$) determinations

- ▶ R.J.Hudspith *et al.*, PLB 781 (2018) 206, P.Boyle *et al.*, PRL 121/20 (2018) 202003 are consistent with kaon $|V_{us}|$ values

$|V_{us}|$ from tau decays, ICHEP 2020



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- ▶ RM123 determinations use Di Carlo 2019 isospin-limit f_K/f_π and f_K elaborations based on FLAG 2019