

Improved determination of $|V_{us}|$ with τ decays

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The HFLAV end 2018 τ branching fractions fit results and FLAG 2019 lattice QCD results are used to compute updated $|V_{us}|$ determinations using recently published radiative corrections for $\mathcal{B}(K^- \rightarrow \mu^- \bar{\nu}_\mu)$ and $\mathcal{B}(K^- \rightarrow \mu^- \bar{\nu}_\mu)/\mathcal{B}(\pi^- \rightarrow \mu^- \bar{\nu}_\mu)$.

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1. Updated determination of $|V_{us}|$ with τ decays

$|V_{us}|$ is computed as documented in the HFLAV end 2018 report [1] using the inclusive τ branching fraction to non-strange final states and the τ branching fractions $\mathcal{B}(\tau^- \rightarrow K^- \nu_\tau)/\mathcal{B}(\tau^- \rightarrow \pi^- \nu_\tau)$ and $\mathcal{B}(\tau^- \rightarrow K^- \nu_\tau)$. The two calculations that rely on the exclusive branching fractions use theory estimates of the radiative corrections to $\mathcal{B}(K^- \rightarrow \mu^- \bar{\nu}_\mu)$ and $\mathcal{B}(K^- \rightarrow \mu^- \bar{\nu}_\mu)/\mathcal{B}(\pi^- \rightarrow \mu^- \bar{\nu}_\mu)$ [2–4] as follows:

$$|V_{us}|_{\tau K/\pi} = |V_{ud}| \frac{f_{\pi^\pm} m_\tau^2 - m_\pi^2}{f_{K^\pm} m_\tau^2 - m_K^2} \sqrt{\frac{\mathcal{B}(\tau^- \rightarrow K^- \nu_\tau) R_{\tau/\pi}}{\mathcal{B}(\tau^- \rightarrow \pi^- \nu_\tau) R_{\tau/K} R_{K/\pi}}} \frac{1}{R_{K/\pi}} = 0.2236 \pm 0.0015,$$

$$|V_{us}|_{\tau K} = \sqrt{\frac{\mathcal{B}(\tau^- \rightarrow K^- \nu_\tau) 16\pi\hbar}{f_{K^\pm}^2 \tau_\tau m_\tau^3} \frac{m_\tau^2}{G_F^2} \frac{1}{m_\tau^2 - m_K^2} \frac{1}{R_{\tau/K} R_{K\mu 2}}} = 0.2234 \pm 0.0015,$$

where f_{K^\pm}/f_{π^\pm} and f_{K^\pm} come from the FLAG 2019 lattice QCD averages [5].

Recently, new moderately more precise radiative corrections have been estimated with lattice QCD techniques adapted to include QED interactions [6]: $\delta R_{\pi^- \rightarrow \mu^- \nu}^{\text{phys}} = 1.53(19)\%$, $\delta R_{K^- \rightarrow \mu^- \nu}^{\text{phys}} = 0.24(10)\%$, where $R_{K\mu 2} = 1 + \delta R_{K^- \rightarrow \mu^- \nu}^{\text{phys}}$, $R_{K/\pi} = (1 + \delta R_{K^- \rightarrow \mu^- \nu}^{\text{phys}})/(1 + \delta R_{\pi^- \rightarrow \mu^- \nu}^{\text{phys}})$. These corrections include the isospin-breaking correction and are intended to be used in combination with the isospin-limit values obtained using the FLAG 2019 [5] decay constants, $f_K = 156.11 \pm 0.21$, $f_K/f_\pi = 1.1966 \pm 0.0018$ [6].

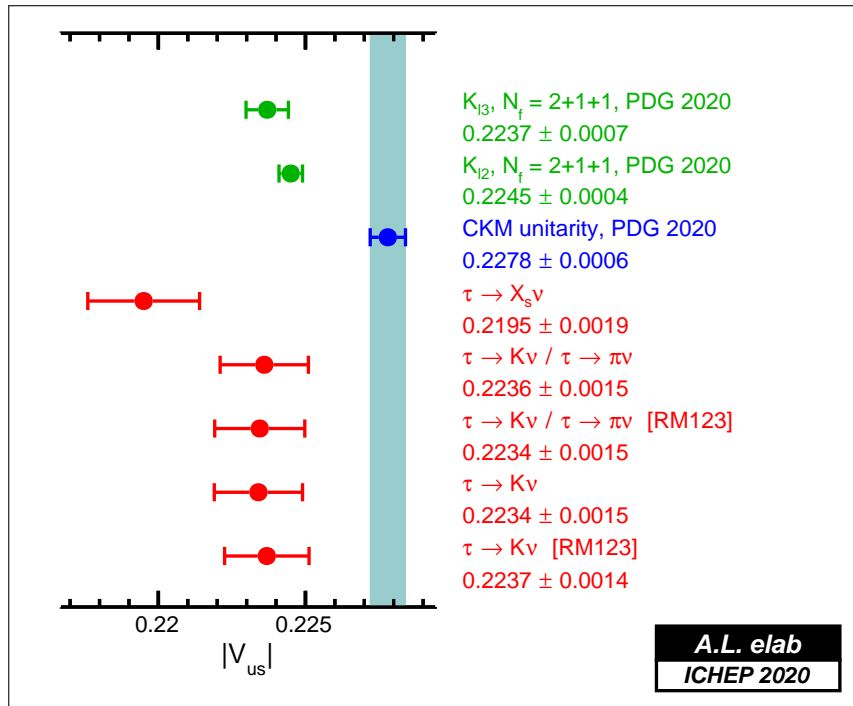


Figure 1: $|V_{us}|_{\tau S}$ determinations. The label RM123 denotes the $|V_{us}|$ determinations obtained using the π and K decay radiative corrections estimated in Ref. [6]. See the text for further details.

Figure 1 summarizes the $|V_{us}|$ determinations using the τ branching fractions with both sets of radiative corrections, and compares them with $|V_{us}|$ reported by the Review of Particle Physics 2020 [7], using measurements on the kaon mesons and assuming the unitarity of the first row of the CKM matrix given the present measurements of $|V_{ud}|$ and $|V_{ub}|$. With the new radiative corrections, there is a modest improvement and a small shift for $|V_{us}|$ obtained using $\mathcal{B}(\tau^- \rightarrow K^- \nu_\tau)$, and no noticeable change for $|V_{us}|$ from $\mathcal{B}(\tau^- \rightarrow K^- \nu_\tau)/\mathcal{B}(\tau^- \rightarrow \pi^- \nu_\tau)$.

References

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