

# The $K_{\ell 3}$ form factor from four-flavor lattice QCD and $|V_{us}|$

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Using HISQ  $N_f = 2 + 1 + 1$  MILC ensembles at five different lattice spacings, including four ensembles with physical quark masses, we perform the most precise computation to date of the  $K \rightarrow \pi \ell \nu$  vector form factor at zero momentum transfer. This is the first calculation that includes the dominant finite-volume effects, as calculated in chiral perturbation theory at next-to-leading order. Our result for the form factor provides a direct determination of the Cabibbo-Kobayashi-Maskawa matrix element  $|V_{us}|$ , when combined with the corresponding experimental average. For the first time, the resulting theory error on  $|V_{us}|$  is commensurate with the experimental uncertainty. We find that this determination of  $|V_{us}|$  is in tension at the  $2 - 2.6\sigma$  level both with determinations from leptonic decays and with the unitarity of the CKM matrix.

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