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Modelling electroweak processes in light nuclei: Nuclear Fermi decays and V_{ud}

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Currently, the most precise extraction of the up-down quark mixing element V_{ud} of the Cabibbo-Kobayashi-Maskawa (CKM) matrix comes from a handful of ft-value measurements for nuclear Fermi decays in light- and medium-mass nuclei. However, a complete extraction of V_{ud} from hadronic decays requires challenging theory determinations of hadronic-structure-dependent electroweak radiative corrections (EWRC) to said decays. In fact, a novel evaluation of the free-hadron part of the dominant correction to nuclear Fermi decays, i.e., the free-hadron γW-box diagram, has led to tension with the Standard Model expectation of CKM unitarity. Moreover, to reach the current precision goals for the CKM unitarity test via extraction of V_{ud} from nuclear Fermi decays, a consistent treatment of the hadronic-structure-dependent EWRCs in the nuclear medium is critical. Confirmation of this tension by way of increasingly precise nuclear theory and experiment would point towards a deficiency in the Standard Model (SM) weak sector.

Ultimately, this amounts to requiring a modern evaluation of the nuclear γW-box diagram utilizing the ever-advancing set of tools available in nuclear many-body theory. Targeting an evaluation of the γW-box diagram for the $^{10}C \rightarrow {}^{10}B$ and $^{14}O \rightarrow {}^{14}N$ Fermi transitions, we apply the no-core shell model (NCSM). The NCSM is a non-relativistic quantum many-body approach for modelling the low-lying bound states of light nuclei starting solely from inter-nucleonic interactions. Augmented by the Lanczos strengths method, the NCSM can be further utilized to target features of the entire many-body spectrum, a capability without which calculations of this kind would not be possible. The approach detailed represents one of the first utilized to compute these corrections in ab initio nuclear theory.

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