Towards a theory consensus for neutron decay

Based of many discussion over the last years, including

MITP 2022: “Electroweak precision physics from beta decays to the Z pole”

INT-23-1b: “New physics searches at the precision frontier”

which form the basis to try again now

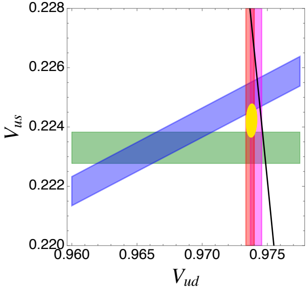
INT-26-95W: “Testing the Standard Model in charged-weak decays”

Jan 13, 2026

Starting point: hadronic matrix elements

Table 2
Various contributions to $\Box_A^{\gamma W}$ in units of 10^{-3}. The different columns are based on the references as indicated, but modified to correspond to the same conventions as far as possible (see main text), in particular, we use $Q_0^2 = 2\,\text{GeV}^2$ in the separation of low- and high-energy parts and include the running of α in the evaluation of the DIS region (using the corrections from Ref. [11] where necessary; modified entries are indicated by an asterisk and not assigned an uncertainty estimate). The DIS contribution enters for $Q^2 \geq Q_0^2$ in Eq. (A.1), the rest for $Q^2 \leq Q_0^2$. Note that the elastic contribution from Ref. [8] is only integrated up to $1\,\text{GeV}^2$, which explains the slightly smaller value. The resonance and Regge regions in Refs. [6,7] are separated as indicated by Ref. [9]. For Refs. [8,10] the inelastic contributions for $Q^2 \leq Q_0^2$ are booked in the "Regge" category. This compilation is inspired by Table I in Ref. [11].

	[11]	[6,7]	[9]	[8]	[10]	our estimate
Elastic	1.05(4)	1.06(6)	1.06(6)	0.99(10)	1.06(6)	1.06(6)
Resonance	0.04(1)	0.05(1)	0.05(1)	–	–	0.04(1)
Regge	0.52(7)	0.51(8)	0.56(9)	0.38*	0.46*	0.49(11)
DIS	2.29(3)	2.26*	2.26*	2.24*	2.32*	2.28(4)



Cirigliano, Crivellin, MH, Moulson 2022

- Back in 2022, we suggested a measurement of $K_{\mu3}/K_{\mu2}$ at NA62 to try and clarify the $K_{\ell3}$ vs. $K_{\ell2}$ tension
- Wanted to show "state-of-the-art" bands for V_{ud}, but this proved difficult
  $\hookrightarrow$ many competing calculations for "γW box" $\Box_{\gamma W}$, not clear what to do
- Performed a quick-and-dirty average to get a realistic representation of the situation at the time, but this should be done properly

Subsequent discussions and developments

- Differences among evaluations discussed at
  - MITP 2022 organizers: M. Blanke, A. Crivellin, M. Hoferichter, C.-Y. Seng, M. Gorshteyn
  - INT 2023 organizers: V. Cirigliano, P. Shanahan, R. Stroberg

  $\hookrightarrow$ reasons for differences among evaluations better understood

- Idea to write a "consensus note" that makes a recommendation for $\Box_{\gamma W}$
- In the meantime:
  - Lattice-QCD calculation 2308.16755
  - EFT formulation 2306.03138
  - QFT understanding of Fermi function 2501.17916
  - NLL resummation 2510.27648
- Now appears a good point to try and forge a theory consensus that takes all these developments into account
- Main goal: master formula that relates τ_n, λ, V_{ud}

How to organize this

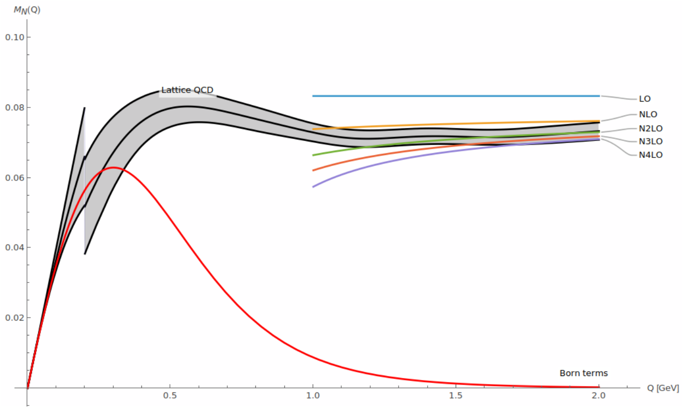
- Possible precedent: Muon $g-2$ Theory Initiative

  $\hookrightarrow$ similar situation, many competing SM predictions
- Pros and cons:
  - Plus: consensus recommendation community service, helps experimentalists and users outside the field, increases impact
  - Minus: citation recommendations for underlying works often ignored, even when making such lists available with minimal effort
- My personal impression: ultimately net positive, and now for neutron decay there is a strong need to converge on a consensus
- Recruiting authors: should include all relevant theory work in the last years, can start with participants of the three workshops and invite people who are missing
- Final results to be published in a journal article, also made available at a website (NTNP topical collaboration? https://a51.lbl.gov/~ntnp/TC/), including citation recommendations

A possible outline

- Have an Overleaf project with rough outline
  1. Introduction
  2. Decomposition of the decay rate
  3. Short-distance corrections and resummation of large logarithms
  4. Fermi function
  5. Hadronic contributions
  6. A master formula for neutron decay
  7. BSM consequences
  8. Towards nuclear corrections
  9. Conclusions
- Next steps: recruit volunteers for the different sections
- In some cases additional work necessary, e.g., for the hadronic contributions
- Not just collection of results but reasonably self-contained review, e.g., to explain connection between EFT and Sirlin formalism

Matching of hadronic integrand



- In some cases additional work necessary, e.g., for the hadronic contributions
  - New evaluation by combining lattice-QCD and phenomenological input at the level of the Q^2 integrand
  - Born terms for low Q^2, pQCD for large Q^2, lattice QCD for intermediate range

Possible future extensions

- First step neutron decay only, pure “theory exercise”
- Superallowed β decays
  - Not there yet, theory still in flux, expect many developments over the next years
  - Need more ab-initio calculations before it makes sense to try and forge a consensus
  - Need to involve experimentalists
  - Could be considered as a future extension in a few years
- What about V_{us}?
  - There is already something similar FlaviaNet, 1005.2323
  - To make real progress, need new data under analysis at NA62 and lattice calculations of $f_+(0)$ and F_K/F_π, the latter depending on choice of isospin scheme FLAG recommendation
  - τ decays continue to be challenging, would need to check carefully in which cases theory errors can really be controlled
  - Could be considered as a future extension in a few years