Modified Lepton Couplings and the Cabibbo Angle Anomaly
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Based on: 1912.08823 (A. Coutinho, A. Crivellin, C.A. Manzari)

Observable | Measurement | Pull II
--- | --- | ---
\( M_W \) [GeV] | 80.378(12) | 0.59
\( \Gamma_W \) [GeV] | 2.085(42) | -0.02
BR(\( W \rightarrow l\ell v \)) | 0.742(38) | 0
sin^2\( \theta \) [Expected] | 0.243(12) | -0.1
sin^2\( \theta \) [Expected] | 0.23148(33) | -0.17
sin^2\( \theta \) [GluPh] | 0.23104(49) | -0.03
\( R_{dd}^{\text{SM}} \) | 0.165(33) | -0.09
\( A_L \) | 0.1513(21) | 0.60
\( \Gamma_2 \) [GeV] | 2.0452(23) | -0.11
\( \alpha_r^{\text{EM}} \) | 4.1541(37) | -0.62
\( R_{t\to b} \) | 2.0767(35) | 0.06
\( A_{R_t}^{\text{SM}} \) | 0.0117(10) | 0.12
\( R_{b\to t}^{\text{SM}} \) | 2.1629(66) | 0
\( A_{R_b}^{\text{SM}} \) | 0.1217(30) | 0
\( \alpha_c^{\text{NP}} \) | 0.0062(16) | -0.36
\( \alpha_s^{\text{NP}} \) | 0.0707(35) | -0.20
\( A_{L}^{\text{SM}} \) | 0.923(20) | 0.01
\( A_{L} \) | 0.670(27) | 0

1. Abstract

At present, there are interesting discrepancies between the determinations of \( V_{us} \) and \( V_{ud} \) from different physical processes assuming CKM unitarity. In particular there is a 3\( \sigma \) – 4\( \sigma \) tension between the following measurements:

- \( V_{us} \) from \( K \rightarrow \pi^0 \nu \)
- \( V_{us} \) from \( K \rightarrow \pi^\pm \pm \nu \)
- \( V_{us} \) from 0\( ^\circ \) - 0\( ^\circ \) nuclear transitions,

as shown in Figure I. We interpret this tension as an evidence of LFUV and investigate whether this anomaly can be solved via modifications of the couplings between neutrinos and Gauge bosons.

These modified couplings enter directly in \( Z \rightarrow \ell \ell \) and \( W \rightarrow \ell \nu \) and indirectly in \( Z \rightarrow \ell^+ \ell^- \) observables. In addition they enter in all low energy observables involving neutrinos, like \( \tau, \mu \) and mesons decays. Here, \( K \) and \( \pi \) decays are the most relevant due to their exquisite experimental and theoretical precision, while the uncertainties in B are still too large to give relevant bounds.

It is therefore clear that a global fit to all these data, reported in Table I, is required to assess consistently the impact of modified neutrino couplings.

3. Analysis & Results

We perform the analysis in the Bayesian framework. To accomplish such endeavour, we have adopted the publicly available HEPfit package [5], whose Markov Chain Monte Carlo determination of posteriors is powered by the Bayesian Analysis Toolkit (BAT). Employing The Metropolis-Hastings algorithm implemented in BAT to sample from the desired distribution, our MCMC runs involved 6 chains with a total of 2 million events per chain.

We find more than 4 sigma preference for NP in neutrino couplings to SM gauge bosons. This, can be seen in Figure II and Figure III, and strongly motivates the investigation of NP models which could give rise to such modified couplings.

<table>
<thead>
<tr>
<th>Prior</th>
<th>NP-I posterior</th>
<th>NP-II posterior</th>
</tr>
</thead>
<tbody>
<tr>
<td>( V_{us}^{\text{SM}} )</td>
<td>0.2224 ± 0.0004</td>
<td>0.2224 ± 0.0004</td>
</tr>
<tr>
<td>( \epsilon_{\text{SM}} )</td>
<td>0.00 ± 0.01</td>
<td>0.00 ± 0.01</td>
</tr>
<tr>
<td>( \epsilon_{\text{us}} )</td>
<td>0.00 ± 0.0002</td>
<td>0.00 ± 0.0002</td>
</tr>
<tr>
<td>( \epsilon_{\text{r}} )</td>
<td>0.00 ± 0.0002</td>
<td>0.00 ± 0.0002</td>
</tr>
<tr>
<td>( \epsilon_{\text{r}} )</td>
<td>0.00 ± 0.0002</td>
<td>0.00 ± 0.0002</td>
</tr>
</tbody>
</table>

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References