Modified Lepton Couplings and the Cabibbo Angle Anomaly

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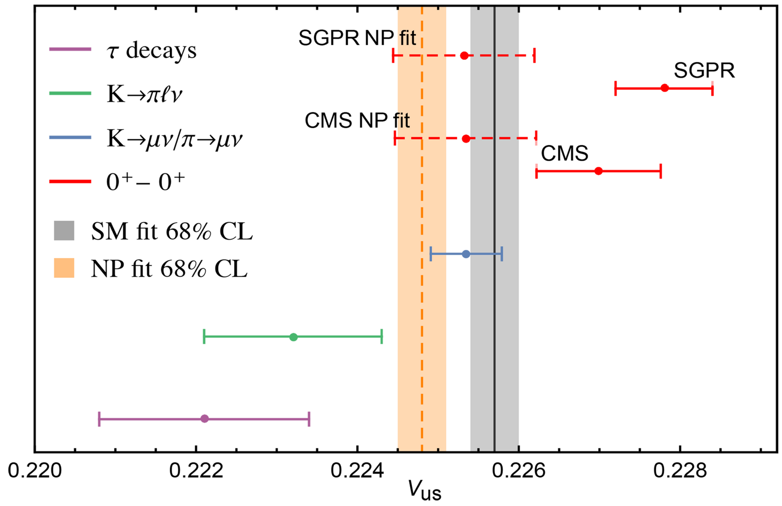


Figure I. Tension in the V_{us} measurements from 3 different processes: $K\to\pi\mu\nu$, $\frac{K\to\mu\nu}{\pi\to\mu\nu}$ and super- allowed β transitions

Observable	Measurement	Pull II
M_W [GeV]	80.379(12)	0.59
Γ_W [GeV]	2.085(42)	-0.02
$\mathrm{BR}(W\to\mathrm{had})$	0.6741(27)	0
$\sin^2\theta^{\mathrm{lept}}_{\mathrm{eff}}(Q^{\mathrm{had}}_{\mathrm{FB}})$	0.2324(12)	-0.1
$\sin^2\theta^{\mathrm{lept}}_{\mathrm{eff(Tev)}}$	0.23148(33)	0.17
$\sin^2\theta^{\mathrm{lept}}_{\mathrm{eff(LHC)}}$	0.23104(49)	-0.03
P^{pol}_{τ}	0.1465(33)	-0.09
A_ℓ	0.1513(21)	0.60
Γ_Z [GeV]	2.4952(23)	-0.11
σ^0_h [nb]	41.541(37)	0.42
R^0_ℓ	20.767(35)	0.06
$A^{0,\ell}_{\mathrm{FB}}$	0.0171(10)	0.12
R^0_b	0.21629(66)	0
R^0_c	0.1721(30)	0
$A^{0,b}_{\mathrm{FB}}$	0.0992(16)	-0.36
$A^{0,c}_{\mathrm{FB}}$	0.0707(35)	-0.20
A_b	0.923(20)	-0.01
A_c	0.670(27)	0
$\frac{K\to\mu\nu}{K\to e\nu}$	0.9978 ± 0.0020	-0.82
$\frac{\pi\to\mu\nu}{\pi\to e\nu}$	1.0010 ± 0.0009	0.38
$\frac{\tau\to\mu\nu\bar\nu}{\tau\to e\nu\bar\nu}$	1.0018 ± 0.0014	1.24
$\frac{K\to\pi\mu\bar\nu}{K\to\pi e\bar\nu}$	1.0010 ± 0.0025	0.11
$\frac{W\to\mu\bar\nu}{W\to e\bar\nu}$	0.996 ± 0.010	-0.17
$\frac{B\to D^{(*)}\mu\nu}{B\to D^{(*)}e\nu}$	0.989 ± 0.012	-0.14
$\frac{\tau\to e\nu\bar\nu}{\mu\to e\bar\nu\nu}$	1.0010 ± 0.0014	-0.15
$\frac{\tau\to\pi\nu}{\pi\to\mu\bar\nu}$	0.9961 ± 0.0027	0.26
$\frac{\tau\to K\nu}{K\to\mu\bar\nu}$	0.9860 ± 0.0070	0.09
$\frac{W\to\tau\bar\nu}{W\to\mu\bar\nu}$	1.034 ± 0.013	-0.03
$\frac{\tau\to\mu\nu\bar\nu}{\mu\to e\nu\bar\nu}$	1.0029 ± 0.0014	1.17
$\frac{W\to\tau\bar\nu}{W\to e\bar\nu}$	1.031 ± 0.013	0.11
$\lvert V^{K_{\mu3}}_{us}\rvert$	0.2234 ± 0.0008	0.74
$\lvert V_{us}/V_{ud}\rvert^{K/\pi}$	0.2313 ± 0.0005	-0.10
$\lvert V^{\tau}_{us}\rvert_{\mathrm{incl.}}$	0.2195 ± 0.0019	0.45
$\lvert V^{\beta}_{ud}\rvert_{\mathrm{CMS}}$	0.97389 ± 0.00018	-
$\lvert V^{\beta}_{ud}\rvert_{\mathrm{SGPR}}$	0.97370 ± 0.00014	2.57

Table I. Observables of the fit

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 $K\to\pi\ell\nu$,
- V_{us}/V_{ud} from $K\to\ell\nu/\pi\to\ell\nu$,
- V_{us} from 0^+-0^+ 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 $Z\to\nu\nu$ and $W\to\ell\nu$ and indirectly in $Z\to\ell^+\ell^-$ observables. In addition they enter in all low energy observables involving neutrinos, like τ, μ and mesons decays. Here, K and π 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.

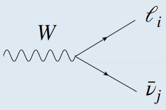
It is therefore clear that a **global fit** to all these data, reported in Table I, is required to asses consistently the impact of modified neutrino couplings.

2. Coupling Modifications

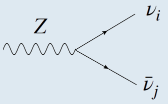
At the dimension 6 level, there is just one operator which only modifies the couplings of gauge bosons to neutrinos but does not affect other couplings [3,4]:

$$\bar{L}_i\gamma_\mu\tau^I L_j H^\dagger i\tau^I H \qquad \tau^I=\left(1,-\sigma_1,-\sigma_2,-\sigma_3\right)$$

where σ 's are the Pauli matrices. The Wilson coefficient of this operator leads to modifications of neutrino couplings to gauge bosons, parametrised as follows:



$$\frac{-ig_2}{\sqrt{2}}\Rightarrow\frac{-ig_2}{\sqrt{2}}\left(\delta_{ij}+\frac{1}{2}\varepsilon_{ij}\right)$$



$$\frac{-ig_2}{2c_W}\Rightarrow\frac{-ig_2}{2c_W}\left(\delta_{ij}+\varepsilon_{ij}\right)$$

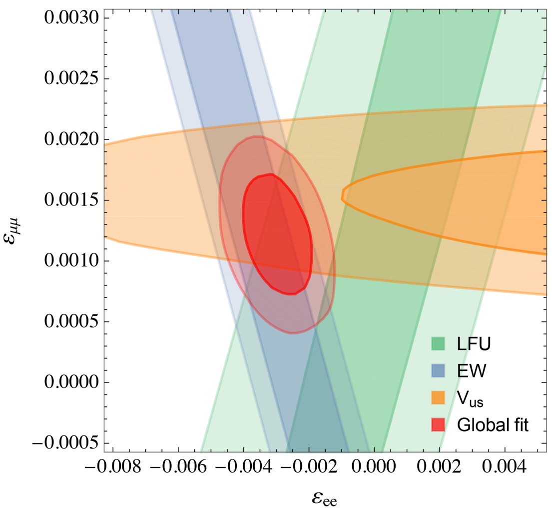


Figure II.

3. Analysis & Results

We perform the analysis in the Bayesian framework.To accomplish such endeavour, we ha
ve 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.

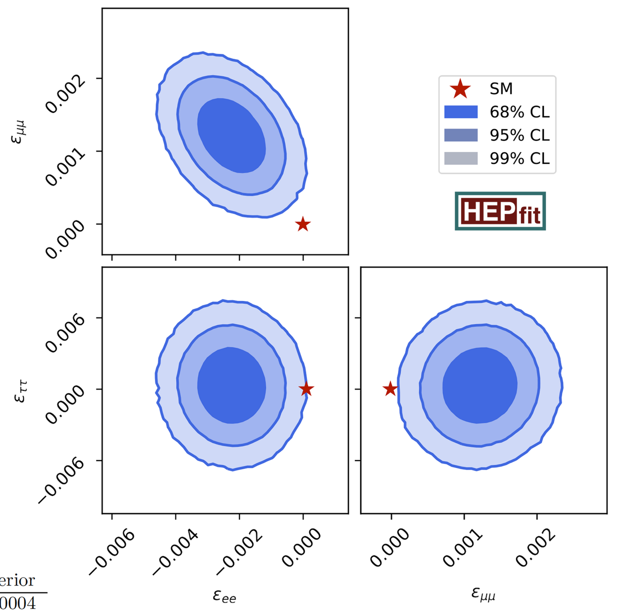


Figure III. Global Fit

Table II. Parameters of the fit

	Prior	NP-I posterior	NP-II posterior
$V^{\mathcal{L}}_{us}$	0.225 ± 0.010	0.2248 ± 0.0004	0.2248 ± 0.0004
ε_{ee}	0.00 ± 0.05	-0.0018 ± 0.0006	-0.0022 ± 0.0007
$\varepsilon_{\mu\mu}$	0.00 ± 0.05	0.0008 ± 0.0004	0.0012 ± 0.0003
$\varepsilon_{\tau\tau}$	0.00 ± 0.05	-0.0002 ± 0.0020	-0.0003 ± 0.0020

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