PROCEEDINGS OF SCIENCE

Status of anomalous triple gauge couplings in the light of recent results from muon $(g-2)$ and other flavor observables.

Kuldeep Deka,[a,*] **Suvam Maharana**[a] **and Lalit Kumar Saini**[a]

[a] *Department of Physics and Astrophysics, University of Delhi, Delhi-110007, India*

E-mail: kuldeepdeka.physics@gmail.com, smaharana@physics.du.ac.in, sainikrlalit@gmail.com

We review the status of triple gauge couplings in the light of the recent $(g-2)_\mu$ measurement at FNAL, the new lattice QCD result of $(g-2)_\mu$ and the updated measurements of several B-decay processes. Contributions to such low-energy observables from three bosonic dimension-6 SMEFT operators parametrizing physics beyond the Standard Model are computed. Constraints on the corresponding Wilson coefficients are presented from fits to the current experimental bounds on the observables and compared with the most stringent ones available from the 13 TeV LHC data in the W^+W^- and $W^\pm Z$ production channels.

41st International Conference on High Energy physics - ICHEP2022
6-13 July, 2022
Bologna, Italy

*Speaker

PoS(ICHEP2022)1211

1. Introduction

The Standard Model (SM) of particle physics has been successful in explaining a myriad of experimental observations with a great deal of accuracy. However, there are certain pressing issues which the model has not been able to address like the observation of neutrino masses and mixings, anomalies in B-decays, deviations in the anomalous magnetic moments of the muon and the electron or that in the forward-backward asymmetry in $e^+e^- \to b\bar{b}$ at the Z-peak etc. Some of these issues can be addressed in a straightforward manner while others require more complicated solutions.

In this proceeding, we reexamine possible anomalous self-interactions of the electroweak gauge bosons in the light of the recent results on $(g-2)_\mu$, both from the experimental measurement at FNAL and the Lattice QCD results from the Budapest-Marseille-Wuppertal (BMW) collaboration, the R_K anomaly and $BR(B_s \to \mu^+\mu^-)$ [1]. In particular, we concentrate on three dimension-6 operators in the SMEFT Lagrangian that lead to anomalous triple gauge boson couplings (TGCs). We then evaluate the corresponding one-loop contributions to both $(g-2)_\mu$ and $(g-2)_e$, and some electroweak precision observables where these operators leave the largest imprint. We show that radiative and rare B and K decays such as $B \to X_s\gamma$, $B_s \to \mu^+\mu^-$, $B \to X_s\ell^+\ell^-$, $B \to K^{(*)}\mu^+\mu^-$, $B_s \to \phi\mu^+\mu^-$, $K \to \pi\nu\bar{\nu}$ provide important constraints if we assume that these three operators are the dominant ones. Although these assumptions seem to be restrictive, and a unified explanation with the full SMEFT set would provide more comprehensive results, we find that these assumptions can indeed constrain certain classes of new physics models that can explain the mentioned discrepancies more efficiently.

2. The framework

The operators of our interest are:

$$O_{WWW} = \frac{c_{WWW}}{\Lambda^2}\mathrm{Tr}\left[\hat{W}^{\nu}_{\mu}\hat{W}^{\rho}_{\nu}\hat{W}^{\mu}_{\rho}\right] \quad O_W = \frac{c_W}{\Lambda^2}\left(D_\mu\Phi\right)^\dagger \hat{W}^{\mu\nu}\left(D_\nu\Phi\right) \quad O_B = \frac{c_B}{\Lambda^2}\left(D_\mu\Phi\right)^\dagger \hat{B}^{\mu\nu}\left(D_\nu\Phi\right), \quad (1)$$

Here we have assumed the other operators to be absent.

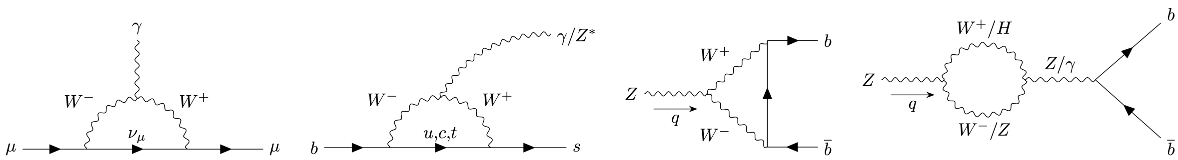

Figure 1: *Contributing diagrams to the processes relevant in our analysis. First diagram contributes to $(g-2)_\mu$ through anomalous $WW\gamma$ vertex. Second one contributes to $b \to s$ transition observables. The last two contributes to the $Z \to b\bar{b}$ observables*

Although we have assumed a seemingly ad-hoc prescription that the Wilson coefficients (WC) for the bosonic operators are larger than those of the 4-fermionic operators, there exist many scenarios where this could emerge naturally. The most famous of these scenarios are Randall-Sundrum-like scenarios with bulk fermions and bosons. The localizations of the light fermions as dictated by the warping, whether a single one or a multiple and nested one results in the overlap integrals for the KK-gauge bosons with the SM fermions being much smaller than those with the SM bosons. This, immediately, leads to an hierarchy in the Wilson coefficients as examined in this analysis.

Current limits	
Observable($\mathcal{F}$)	1σ limit
$\Delta a_\mu^{\text{DISP}}$(WP20)	$251 \pm 59 \times 10^{-11}$
$\Delta a_\mu^{\text{BMW}}$(BMW)	$107 \pm 69 \times 10^{-11}$
ΔC_7	-0.03 ± 0.03
$\Delta C_{9\mu\mu}$	-1.03 ± 0.13
$\Delta C_{10\mu\mu}$	0.41 ± 0.23
ΔC_{9ee}	0.70 ± 0.60
ΔC_{10ee}	-0.50 ± 0.50
δg_L	0.0016 ± 0.0015
δg_R	0.019 ± 0.007

Table 1: *Current experimental limits on various observables affected by anomalous TGCs*

The contributions to the observables of our interest emanates from the Feynman diagrams shown in Fig 1. The analytical expressions for those can be found in Section 3 of [1]. On the experimental side, ATLAS and CMS have analysed multiple diboson production channels like W^+W^-, $W^\pm\gamma$ and $W^\pm Z$ with the first channel proving to be the most restrictive. The experimentally measured values of the observables of our interest can be found in Table 1. The 1 σ bands and the collider limits can be seen in Figure 2 where we have used the BMW result to illustrate $(g-2)_\mu$.

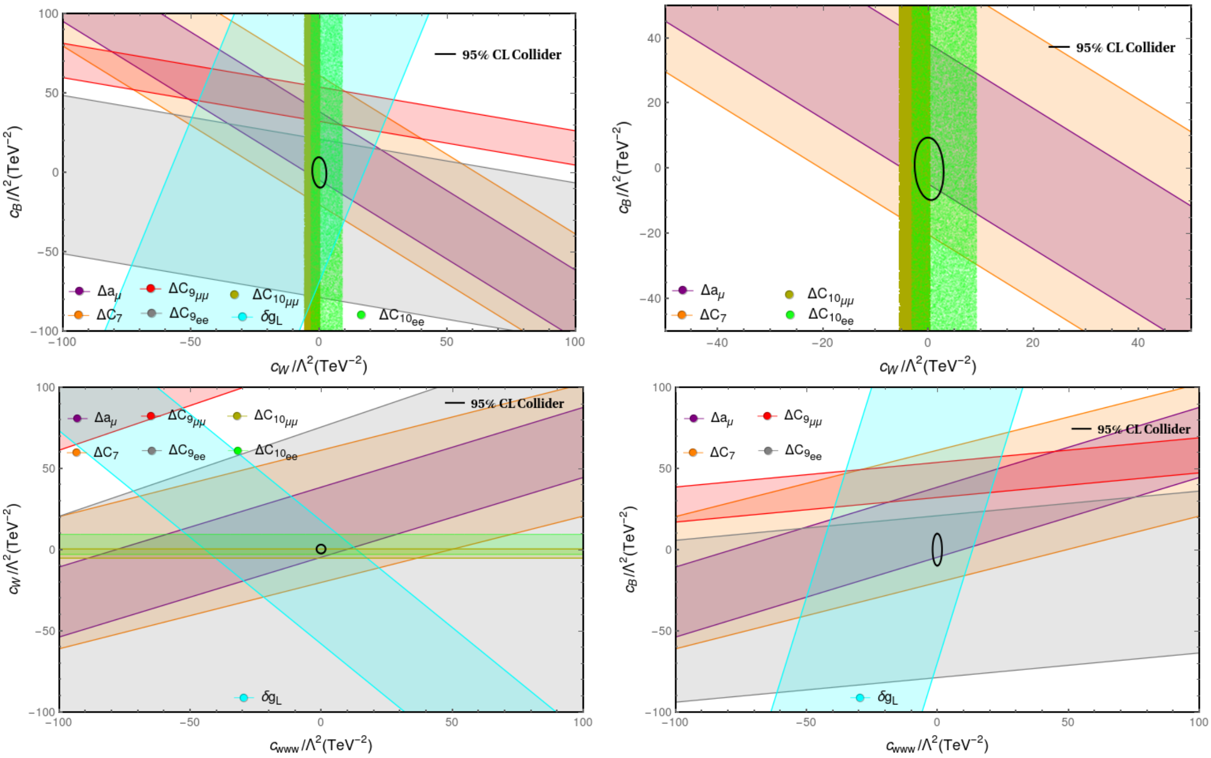

Figure 2: 1σ *limits on the observable of interest, allowing two operators at a time and keeping the third to zero. Upper right plot is zoomed version of the upper left plot to emphasize on the* $(g-2)_\mu$.

PoS(ICHEP2022)1211

3. Results

The most sensitive observables as seen from Fig. 2 are $\Delta C_{10\mu\mu}$ and ΔC_{10ee} followed by $\Delta C_{9\mu\mu}$ and $(g-2)_\mu$. The experimental bounds on the observables of our interest and their corresponding theoretical expressions can then be used to define a χ^2 function which gives us a combined 1σ fit. The result of the χ^2 analysis is shown in Table 2 for both cases of $(g-2)_\mu$. As expected, the χ^2 decreases once we invoke the non-standard couplings. We also see that c_{WWW} does not have a siginificant effect on the χ^2. The 1σ ellipses resulting from our fit can then be compared with the

Calculation	Descriptor	$(c_B, c_W, c_{WWW})/\Lambda^2$ [TeV^{-2}]	χ^2
WP20	SM	(0,0,0)	101.76
	2-param B.F.	$(39.26, -1.64, 0)$	25.76
	3-param B.F.	$(38.48, -1.63, -2.97)$	25.71
BMW	SM	(0,0,0)	86.121
	2-param B.F.	$(35.05, -1.83, 0)$	28.663
	3-param B.F.	$(36.65, -1.85, 6.41)$	28.446

Table 2: *Results of the different χ^2 analyses described in the text.*

current collider limits as shown in the left plot of Figure 3. Due to the higher sensitivity of ΔC_{10} and $\Delta C_{9\mu\mu}$, the ellipse from our fit is further away from the collider one. However, once we reduce the error of $(g-2)_\mu$ as expected in future measurements, our ellipse comes closer to the collider contour.

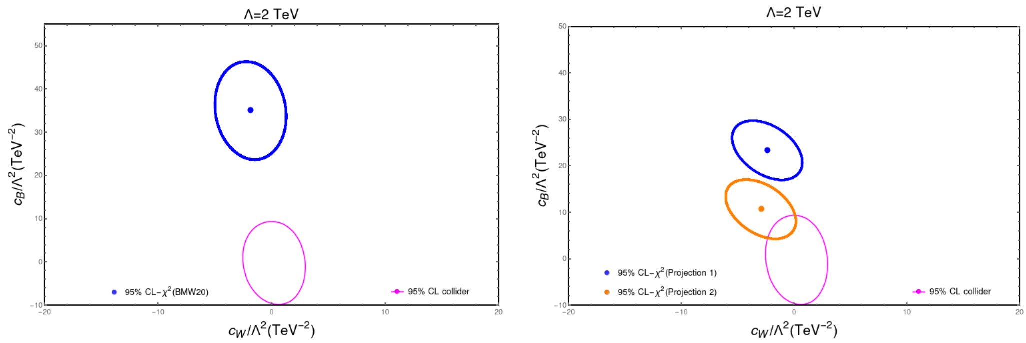

Figure 3: *The χ^2-fit and the collider result at 95% confidence level for $\Lambda = 2$ TeV in the c_W/Λ^2- c_B/Λ^2 plane: (left plot) Current limit using BMW result for $(g-2)_\mu$ and (right plot) Future projections with blue ellipse assuming same deviations as of BMW result and corresponding errors reduced by a factor of 4 and orange ellipse assuming no deviations from the SM result and errors reduced by a factor of 4.*

Thus we see that a global fit in the $(c_W/\Lambda^2, c_B/\Lambda^2)$ plane, while imposing significantly stronger constraints on the WCs, currently exhibits disagreement with the LHC results. Although future projections in $(g-2)_\mu$ with the BMW lattice theory result show better agreements, the collider ellipse is also likely to shrink further in the future, thereby maintaining the disgreements. We also see that ΔC_{10} prefers values very close to the origin which indicates that any new physics model designed to explain the discrepancies that we have addressed must generate O_W with a suppressed coefficient or, otherwise, one must account for the c_W generated therein while performing their fits.

References

[1] D. Choudhury, K. Deka, S. Maharana and L. K. Saini, [arXiv:2203.04673 [hep-ph]].