New physics contributions to Wtb anomalous couplings and top-quark decay

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1. Abstract

In this work, we study the new physics effects arising due the presence of anomalous Wtb vertex through the semileptonic decay modes of the top-quark at the Large Hadron Collider. An estimate on the sensitivities of the aforementioned interaction at 5σ C.L. in the context of top-quark decay-width measurements and cross-section measurements would also be discussed for the pre-existing 13 TeV LHC data and its projections for the proposed LHC runs at 14 TeV, 27 TeV and 100 TeV. We also incorporate the CP-violating effects to such interactions by constructing the CP-violating asymmetries.

1. Introduction

So far, the Standard-Model (SM) [1] is considered a very rich and successful model, which explains almost all the data collected from colliders such as the Large Hadron Collider (LHC) [2] and Tevatron at Fermilab. Despite successful interpretation of experimental data, it is still an incomplete model as it is not able to explain phenomena such as CP-violation [3], Leptogenesis [4], Bariogenesis [5], etc. It suggests expanding SM and looking Beyond the SM scenarios. It would be useful and informative to investigate BSM physics in a model-independent way by constructing the effective Lagrangian of higher dimensions. These effective Lagrangians introduce additional interactions by comprising additional terms.

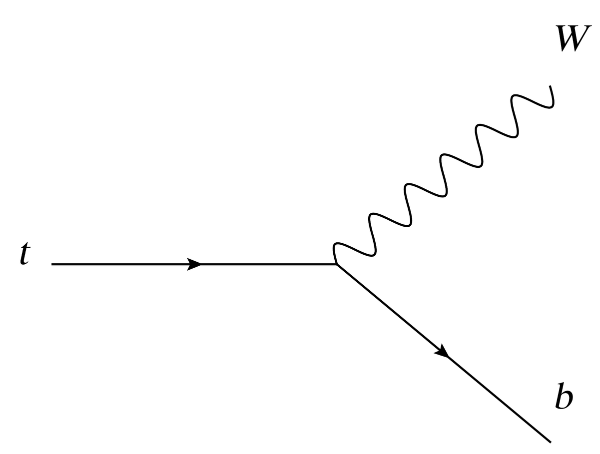
In this article, we investigate the CP-violating effects of the anomalous Wtb vertex in the process of decay of a top (anti-top)-quark to a W^+ (W^-)- boson and a b (anti-b)-quark at the LHC and Future Hadron Colliders, namely HL-LHC, HE-LHC and FCC-HH.

3. Formalism and Lagrangian

The SM Wtb vertex modifies through the following additional term [6]:

$$\mathcal{L}_{Wtb} = -\frac{g}{\sqrt{2}}\bar{b}\left[\gamma^\mu\left(C_{1L}P_L + C_{1R}P_R\right)W_\mu^- - i\sigma^{\mu\nu}\left(\tilde{C}_{2L}P_L + \tilde{C}_{2R}P_R\right)(\partial_\nu W_\mu^-)t + h.c.\right. \tag{1}$$

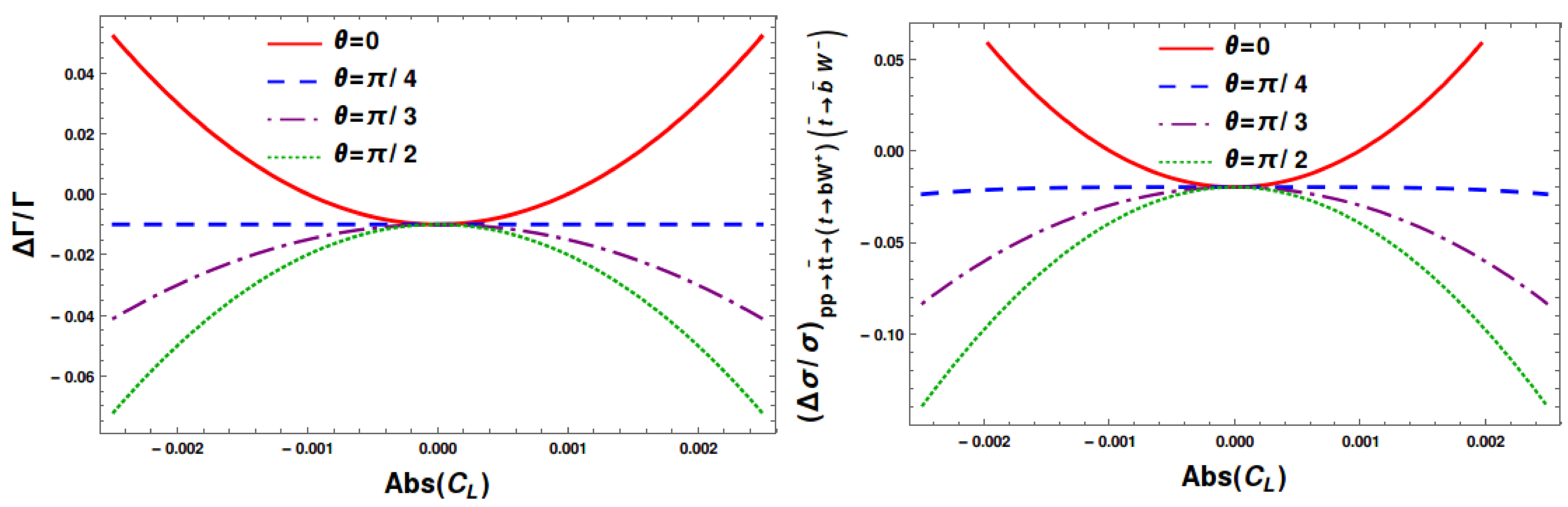
where, $\tilde{C}_{2L,2R} = \frac{C_{2L,2R}}{\Lambda}$, $P_{L,R} = \frac{1}{2}(1 \mp \gamma_5)$, and Λ is the energy scale. $C_{1L,1R}$ and $C_{2L,2R}$ are left- and right-handed vector and tensor couplings, respectively. In SM, value of C_{1L} is equal to unity and the other anomalous couplings are equal to zero. Clearly non-zero values of any of the above couplings would indicate the presence of BSM interactions of top quarks.



5. Numerical Analysis

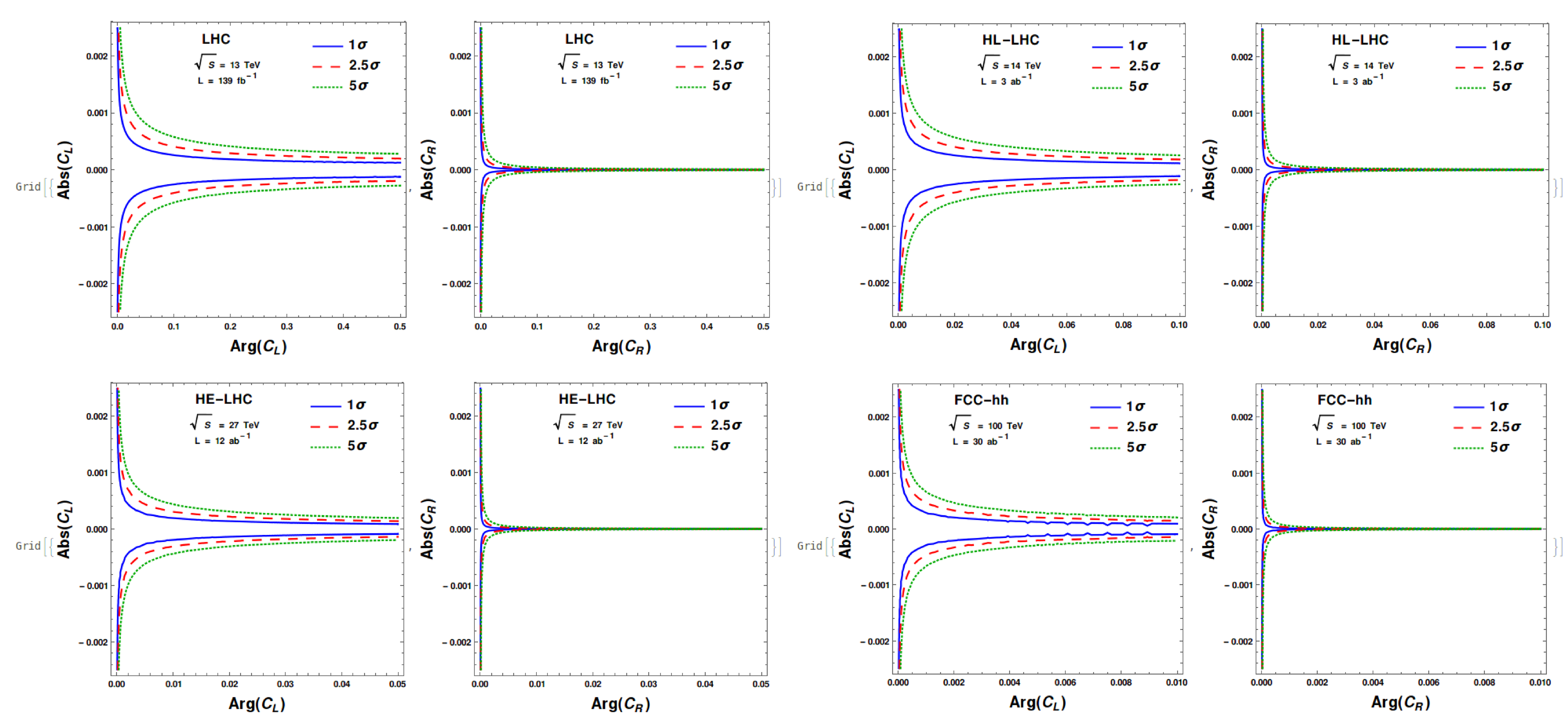
The expression for the relative decay width of the top-quark in presence of the anomalous couplings to the SM decay width is

$$R^\Gamma = \frac{\Gamma_{t\to bW}}{\Gamma^{SM}_{t\to bW}} = 1 - \frac{M_W}{(1+2\eta^2)}[6\eta C_R - M_W(\eta^2+2)(C_L^2 + C_R^2)] \tag{2}$$



The expression for the production asymmetry is as follows:

$$\mathcal{A}^\sigma_{SM} = \frac{\Delta\sigma_{t\to bW}}{\sigma_{t\to bW}} \simeq \left(\frac{\mathrm{Im}\left(|\mathcal{M}|^2_{t\to bW}\right)}{\mathrm{Re}\left(|\mathcal{M}|^2_{t\to bW}\right)}\right) \tag{3}$$



6. Conclusions

1. Our results conclude that coupling C_R mostly contributes to production asymmetry.
2. The upper limits imposed on the couplings C_L and C_R by the decay width and cross-section at 2.5σ C.L. are $(5.9, 2.6)\times10^{-3}$ and $(2.0, 0.4)\times10^{-3}$, respectively.
3. Production asymmetries set the upper bounds on (C_L, C_R) of about $(1.82, 0.03)\times 10^{-4}$ at 2.5 C.L. at the LHC with $\sqrt{S} = 13$ TeV and an integrated luminosity of $\int L = 139$ fb^{-1}. These are of about $(0.81, 0.006)\times10^{-4}$, $(0.44, 0.0017)\times10^{-4}$ and $(0.21, 0.0004)\times10^{-4}$ for Future Hadron Colliders, namely HL-LHC, HE-LHC and FCC-HH with the projected luminosities of 3 ab^{-1}, 12 ab^{-1} and 30 ab^{-1}, respectively at 2.5 C.L..

7. References

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