Study of top-quark decay process and new limits on Wtb anomloaus couplings

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Abstract

We study new physics contributions to Wtb anomalous couplings in top-quark decay process $t \to Wb$ at partonic level. In particular, we compute the limits on anomalous couplings to Wtb vertex at partonic level. Limits were obtained at 13 TeV LHC energy with integrated luminosity of 36.1 fb^{-1} and predictons for future circular colliders, namely, HL-LHC, HE-LHC and FCC-hh were given. For future colliders the projected luminosities of 0.3 to 3 ab^{-1} at HL-LHC, 3 to 12 ab^{-1} at HE-LHC and 10 to 30 ab^{-1} at FCC-hh were explored. We also analyze the CP-violation sensitivity for the process $t \to Wb$ and found that the future colliders with enhanced luminosities give more promising resuls.

Introduction

The Standard-Model (SM) is considered a very successful theory in itself, with a thorough explanation of strong and electromagnetic interactions. But it has some flaws due to which it is considered incomplete such as it could not explain matter-antimatter asymmetry of the universe [1], Leptogenesis, Bariogenesis, unable to explain dark matter and dark energy [2] etc. Particle physicists felt the need to extend SM in order to explain these phenomenons and proposed beyond the SM theories.

CP-violation [3] searches in the top-quark sector are of high interest as top-quark is the heaviest quark among all quark and as a consequence, it offers large phase space to its decay products. Also, It has a lifetime shorter than the hadronization scale so it does not bound and expected to observed directly at the LHC. It is, therefore, worth to study new physics contributions through direct CP-violation in top-quark.

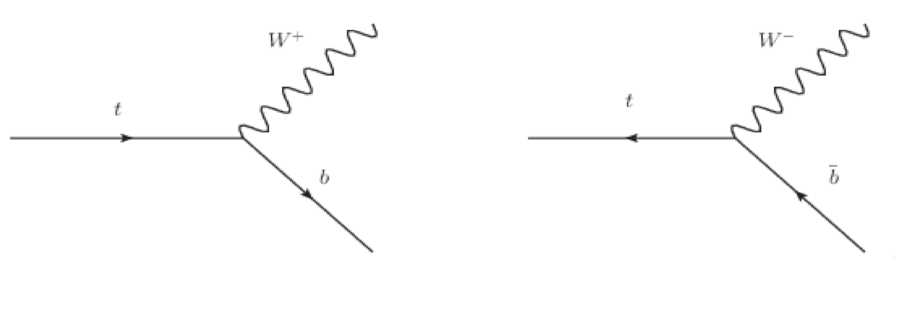
In this article, we consider the top-quark decay process t -> Wb and estimate limits to Wtb anomalous coupling at 99 % C.L. The limits were obtained for the preexisting data of 13 TeV LHC run-1 with the decay-width measurements and with the cross-section measurements as well. Similar studies for HL-LHC with S = 14 TeV, HE-LHC with S = 27 TeV and FCC-hh with S = 100 TeV.

Lagrangian and Process

The corrected Wtb vertex for top is [4],

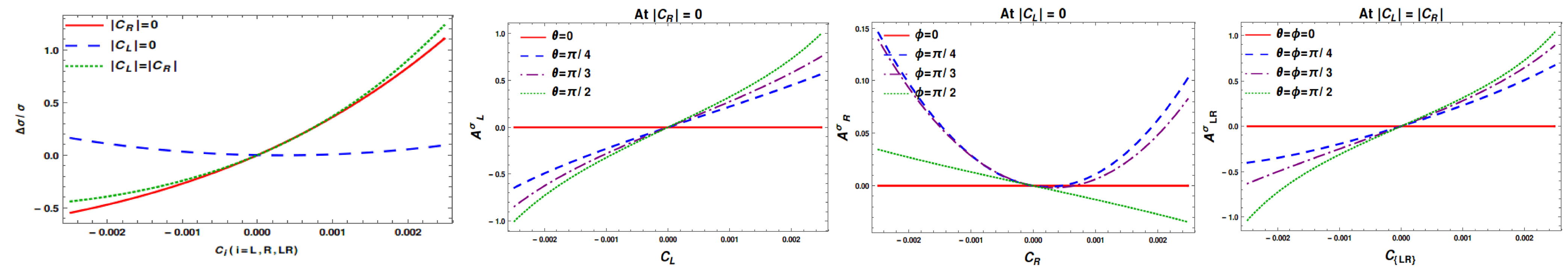
$$L_{tbW} = \frac{g}{\sqrt{2}}\bar{b}\left[\gamma^{\mu}\left(\delta C_{1L}P_L + \delta C_{1R}P_R\right)W^-_{\mu} \pm\sigma^{\mu\nu}\left(\tilde{C}_{2L}P_L + \tilde{C}_{2R}P_R\right)\partial_{\nu}W^-_{\mu}\right]t + h.c.,$$

here the C_{1L}, C_{1R}, C_{2L} and C_{2R} are dimensionless complex constants. At tree level in SM $C_{1L} = 1$ and other anomalous couplings are zero, however these may get corrections from new physics contributions.



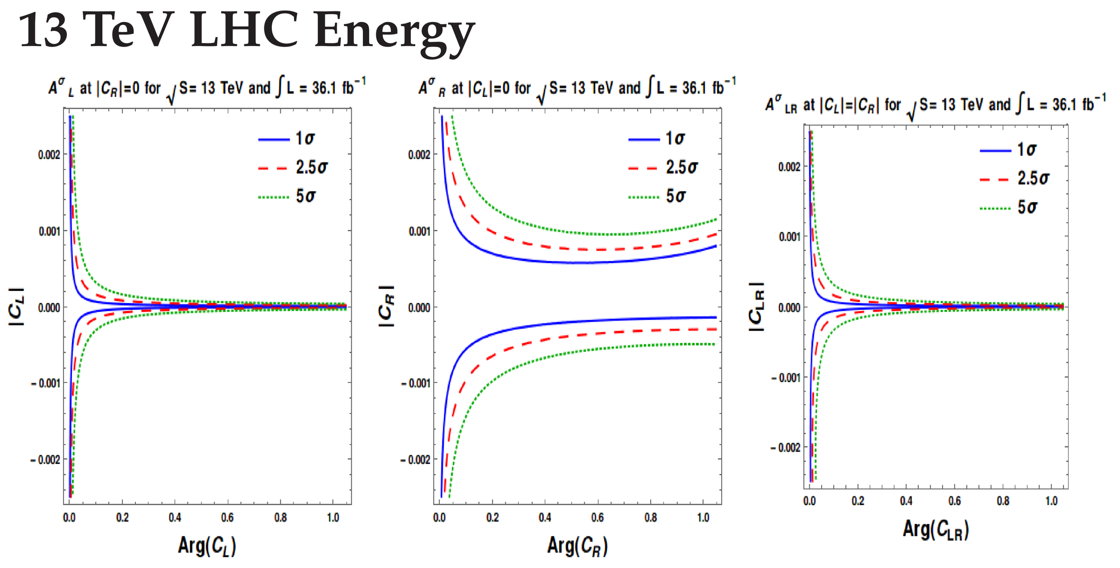
Analysis with Cross-Section

The plots given below show the relative change of cross-section as a function of anomalous couplings.

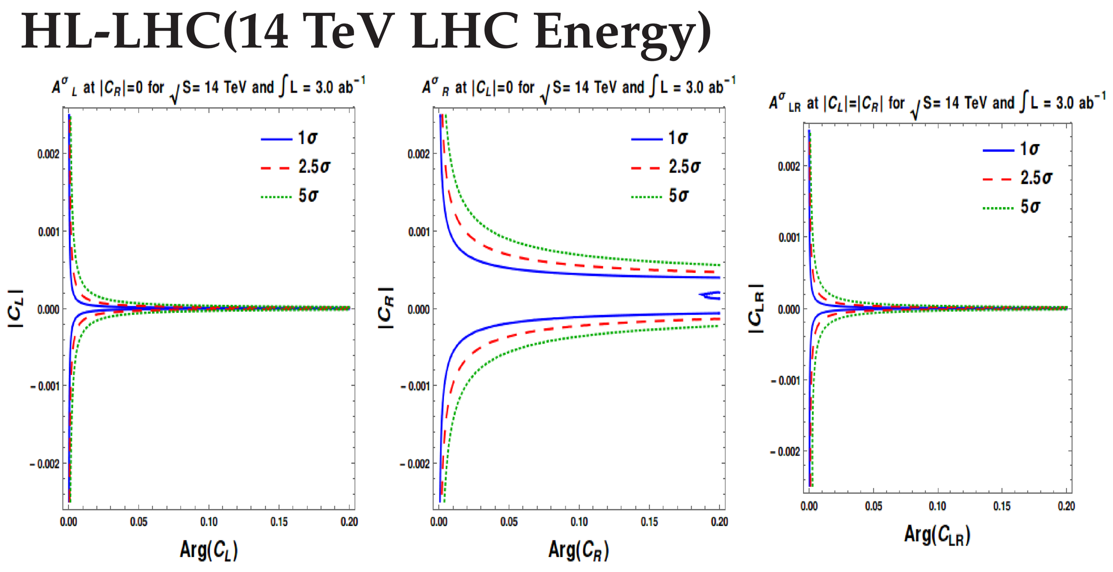


The contour plots given below, show the asymmetries obtained from cross-section at 1σ, 2.5 σ, and 5σ C.L. for 13 TeV LHC energy, HL-LHC with center-of-mass(CMS) energy of 14 TeV, HE-LHC with CMS energy of 27 TeV and FCC-hh with CMS energy of 100 TeV.

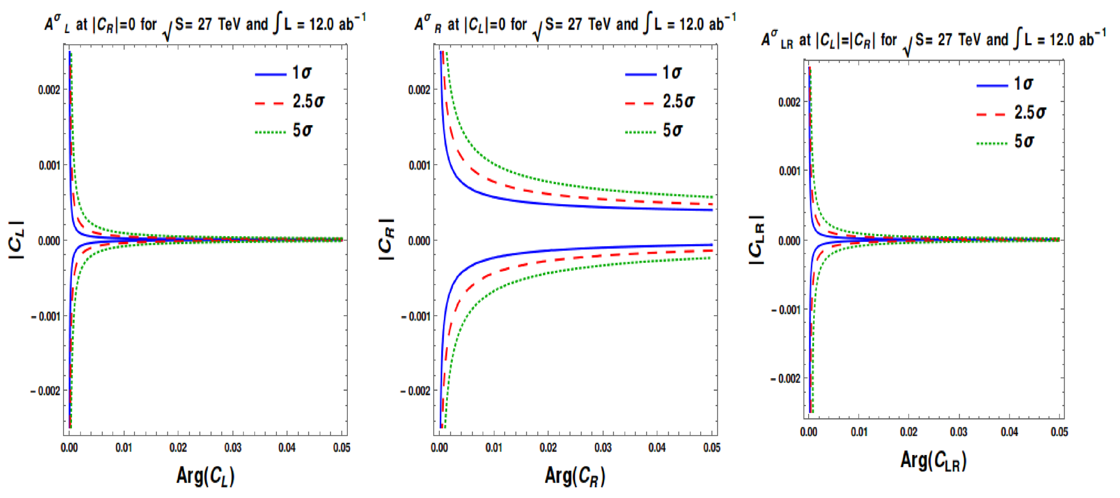
13 TeV LHC Energy



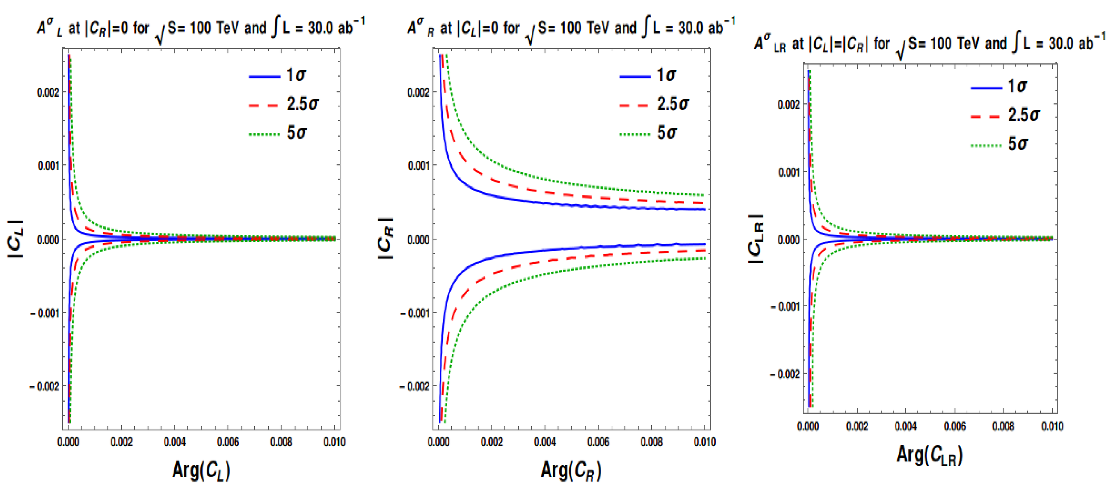
HL-LHC(14 TeV LHC Energy)



HE-LHC(27 TeV LHC Energy)

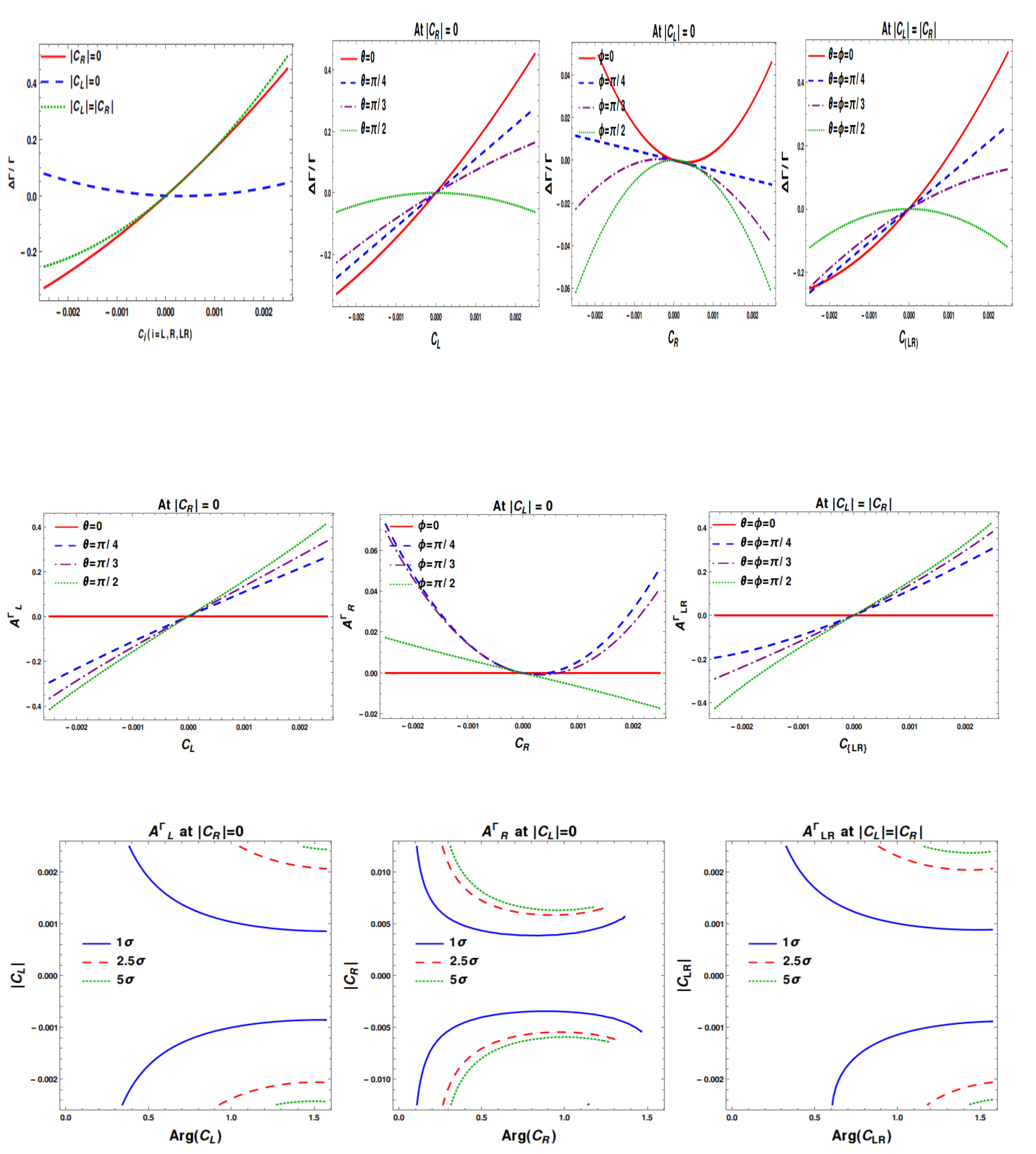


FCC-hh(100 TeV LHC Energy)



Analysis with Decay-Width

In the plots below, the first four plots show the dependency of the relative change of decay-width on anomalous couplings, the middle three plots show the dependency of asymmetry obtained from decay-width on anomalous coupling and the last three contour plots show the asymmetry at 1σ, 2.5σ and 5σ C.L.



Conclusions

In this article, new limits are established on the anomalous couplings to Wtb vertex. The limits are obtained at 13 TeV LHC energy, HL-LHC with $\sqrt{S}$ = 14 TeV, HE-LHC with $\sqrt{S}$ = 27 TeV and FCC-hh with $\sqrt{S}$ = 100 TeV. These limits are presented in the tables given below, the first table presents the results obtained from decay-width and the second table presents the results obtained from cross-section. Also, the CP-violating asymmetries at Wtb vertex are measured and presented at 1σ, 2.5σ and 5σ C.L..

Constraints obtained from Decay-Width.

		$\|C_R\|$=0	$\|C_L\|$=0	$\|C_L\|$=$\|C_R\|$
	$\left(\frac{\Delta\Gamma}{\Gamma}\right)_{t\to bW}(\times 10^{-2})$	$-1.8 \leq C_L \leq 0.2$	$-0.5 \leq C_R \leq 0.6$	$-0.9 \leq C_{L,R} \leq 0.2$
$\left(\frac{\Delta\sigma}{\sigma}\right)_{pp\to tt\to(t\to bW)(\bar{t}\to\bar{b}W^-)}(\times 10^{-2})$	$\sqrt{S}$ = 13 TeV	$-1.6 \leq C_L \leq 0.05$	$-0.25 \leq C_R \leq 0.3$	$-0.8 \leq C_{L,R} \leq 0.05$

Constraints obtained from Cross-Section.

$\sqrt{S}$(TeV)	$\int L$dt	σ_{NLO}(pb)	Bounds on $\|C_L\|$ $(\times 10^{-4})$ at $\|C_R\| = 0$	Bounds on $\|C_R\|$ $(\times 10^{-4})$ at $\|C_L\| = 0$	Bounds on $\|CC\|$ $(\times 10^{-4})$ at $\|C_L\| = \|C_R\|$
13	36.1 fb^{-1}	870.7	$C_L \leq 0.16$	$-2.74 \leq C_R$	$C_{L,R} \leq 0.168$
14	0.3ab^{-1}	1024.08	$C_L \leq 0.052$	$-1.07 \leq C_R$	$C_{L,R} \leq 0.054$
	2ab^{-1}		$C_L \leq 0.020$	$-0.45 \leq C_R$	$C_{L,R} \leq 0.021$
	2.5ab^{-1}		$C_L \leq 0.018$	$-0.41 \leq C_R$	$C_{L,R} \leq 0.019$
	3ab^{-1}		$C_L \leq 0.016$	$-0.37 \leq C_R$	$C_{L,R} \leq 0.017$
27	3.0 ab^{-1}	3907.2	$C_L \leq 0.009$	$-0.21 \leq C_R$	$C_{L,R} \leq 0.009$
	7.0 ab^{-1}		$C_L \leq 0.006$	$-0.14 \leq C_R$	$C_{L,R} \leq 0.006$
	12.0 ab^{-1}		$C_L \leq 0.005$	$-0.11 \leq C_R$	$C_{L,R} \leq 0.005$
100	10.0 ab^{-1}	37418.9	$C_L \leq 0.002$	$-0.04 \leq C_R$	$C_{L,R} \leq 0.002$
	20.0 ab^{-1}		$C_L \leq 0.001$	$-0.03 \leq C_R$	$C_{L,R} \leq 0.001$
	30.0 ab^{-1}		$C_L \leq 0.001$	$-0.026 \leq C_R$	$C_{L,R} \leq 0.001$

References

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