CP-violating observables and top-pair production at LHC

Apurba Tiwari[1] and Sudhir Kumar Gupta[2]
[1]atiwari@myamu.ac.in, [2]sudhir.ph@amu.ac.in

Aligarh Muslim University, Aligarh-202001, UP, India

LHCP2021 Online
The Ninth Annual Conference on Large Hadron Collider Physics
7-12 June 2021 Paris (France), Sorbonne Université

Abstract

We study new physics contributions to CP-violating anomalous couplings of top-quark in the context of top-pair production and their consequent decays into a pair of dilepton and b-jets at the Large Hadron Collider. An estimate of sensitivities to such CP-violating interactions would also be discussed for the pre-existing 13 TeV LHC data and its projections for the proposed LHC run at 14 TeV.

Introduction

- The matter-antimatter asymmetry of the universe is one of the greatest mysteries of modern physics.
- Observation of CP-violation [1] will help to understand the matter-antimatter asymmetry of the universe.
- The Standard-Model [2] is a very rich and successful phenomenology and allows a tiny amount of CP-violation which is not sufficient to explain the matter-antimatter asymmetry of the universe. This indicates the need to explore beyond SM theories.
- Direct CP-violation could be observed through the top induced processes which are abundant at the LHC.
- In this study, we consider top-pair production through the process $\mathbf{pp \to t\bar{t}}$, where the top and anti-top-quark further decays semileptonically into $\mathbf{(bl^+\nu_l)}$ and $\mathbf{(\bar{b}l^-\bar{\nu}_l)}$.
- We study the CP-violating effects in the top-pair production by constructing the T-odd observables.
- The CP-violating asymmetry is constructed using the formula

$$\mathcal{A}_{CP} = \frac{N(\mathcal{C}_i > 0) - N(\mathcal{C}_i < 0)}{N(\mathcal{C}_i > 0) + N(\mathcal{C}_i < 0)}, \qquad (1)$$

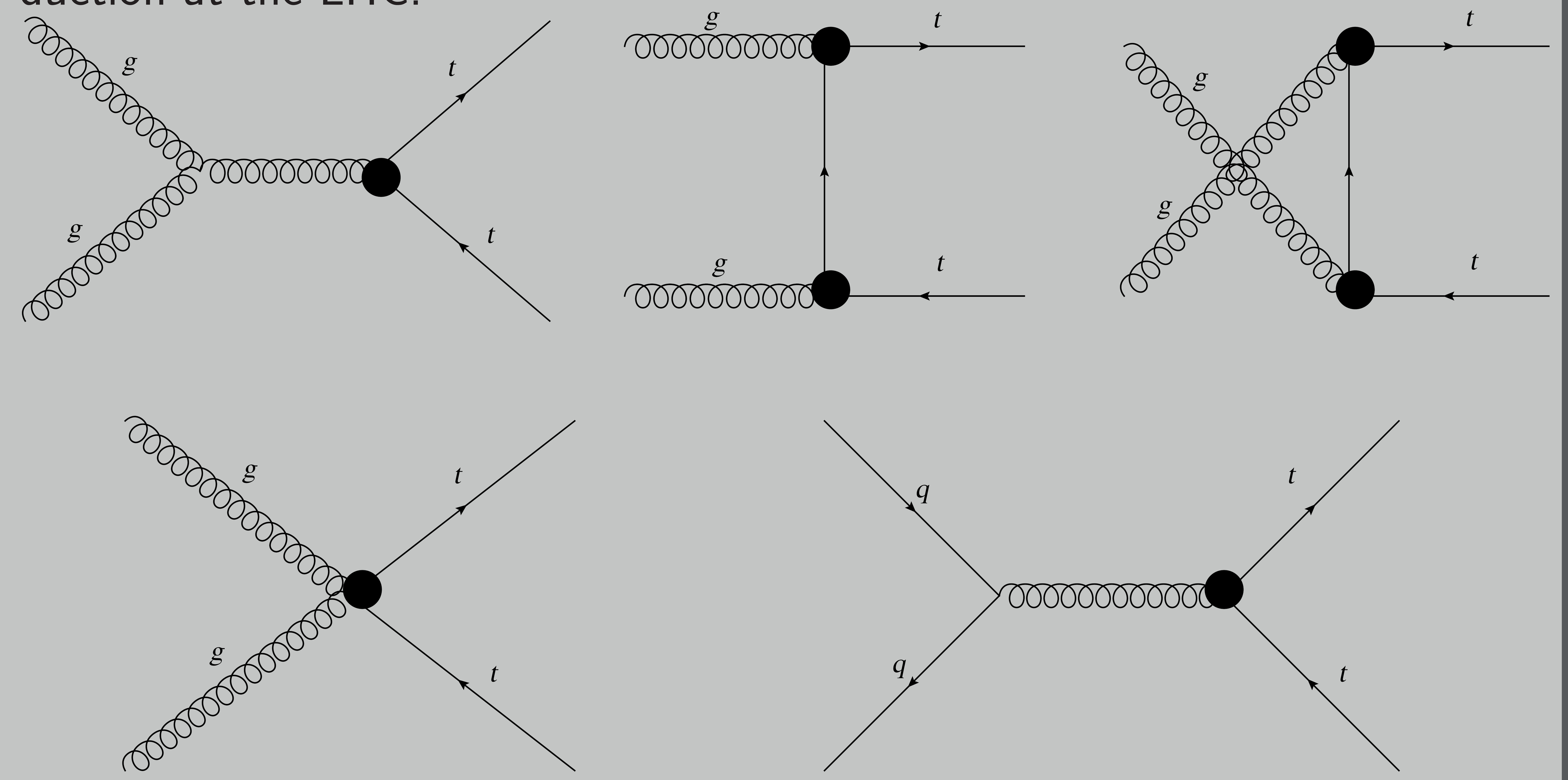
- A non-zero value of asymmetry would be a clear indication of the presence of CP-violation.

Lagrangain and Process

- The following anomalous interaction term modifies the SM Lagrangian in the presence of T-odd interactions of top-quark with gluon

$$\mathcal{L}_{int} = -i\frac{g_s}{2}\left(\frac{d_g}{\Lambda}\right)\bar{t}\sigma_{\mu\nu}\gamma_5\, G^{\mu\nu}\, t, \qquad (2)$$

- The figure represents Feynman diagrams responsible for top-quark pair production at the LHC.



Observables

We consider the following T-odd correlations:

$$\begin{aligned}
\mathcal{C}_1 &= \epsilon(p_b, p_{\bar{b}}, p_{l^+}, p_{l^-})\\
\mathcal{C}_2 &= \tilde{q}\cdot(p_{l^+} - p_{l^-})\ \epsilon(p_{l^+}, p_{l^-}, p_b + p_{\bar{b}}, \tilde{q})\\
\mathcal{C}_3 &= \tilde{q}\cdot(p_{l^+} - p_{l^-})\ \epsilon(p_b, p_{\bar{b}}, p_{l^+} + p_{l^-}, \tilde{q})\\
\mathcal{C}_4 &= \epsilon(P, p_b - p_{\bar{b}}, p_{l^+}, p_{l^-})\\
\mathcal{C}_5 &= \epsilon(p_b + p_{l^+}, p_{\bar{b}} + p_{l^-}, p_b + p_{\bar{b}}, p_{l^+} - p_{l^-}),
\end{aligned} \qquad (3)$$

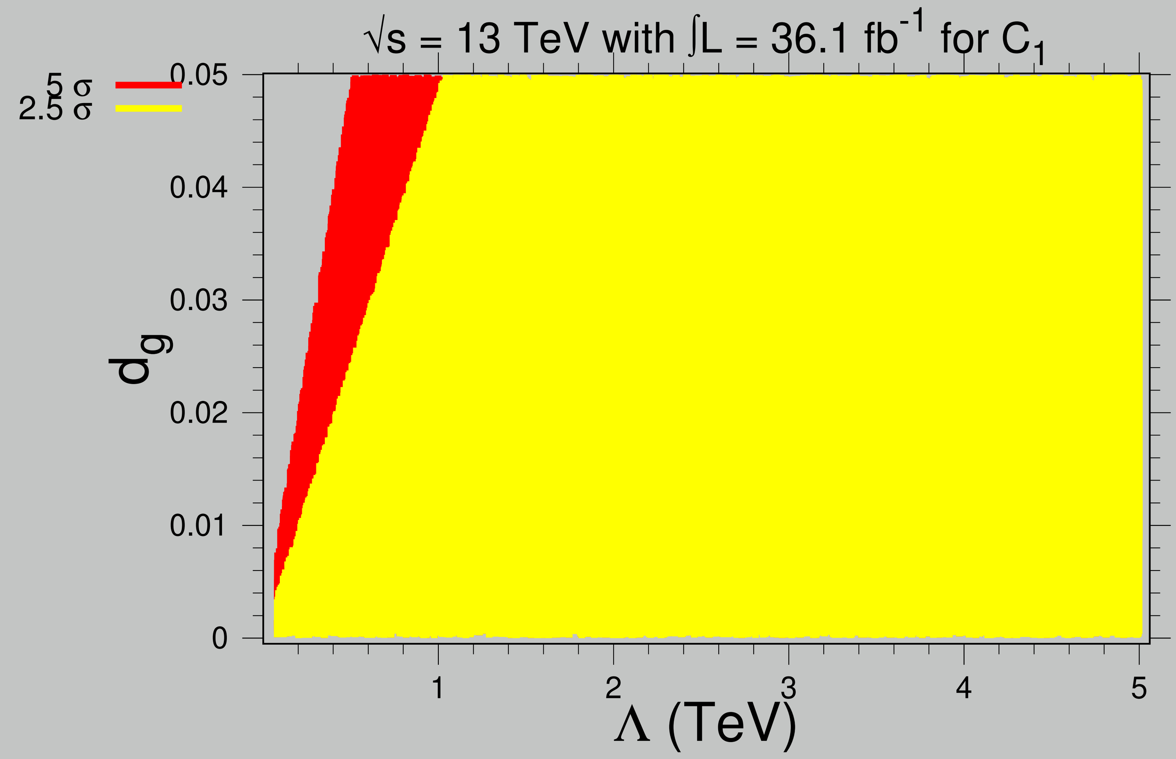
CP-violating observables and top-pair production at LHC

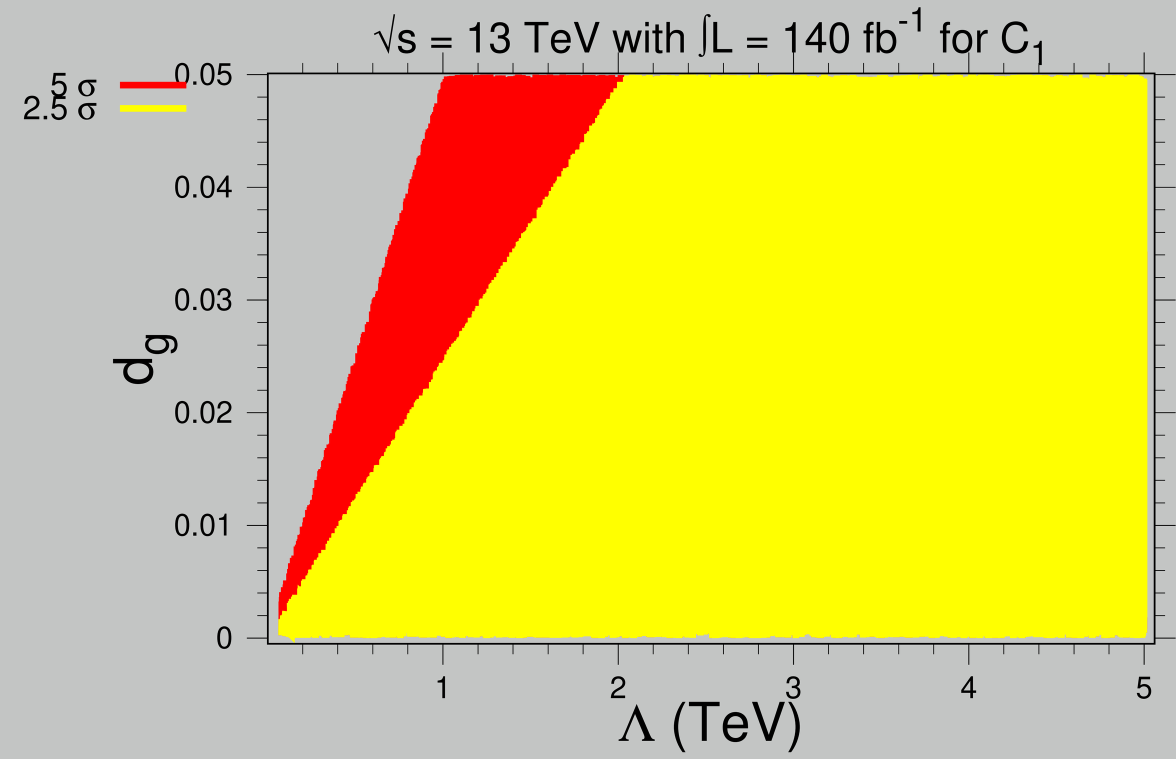
Apurba Tiwari[1] and Sudhir Kumar Gupta[2]
[1]atiwari@myamu.ac.in, [2]sudhir.ph@amu.ac.in
Aligarh Muslim University, Aligarh-202001, UP, India

Results

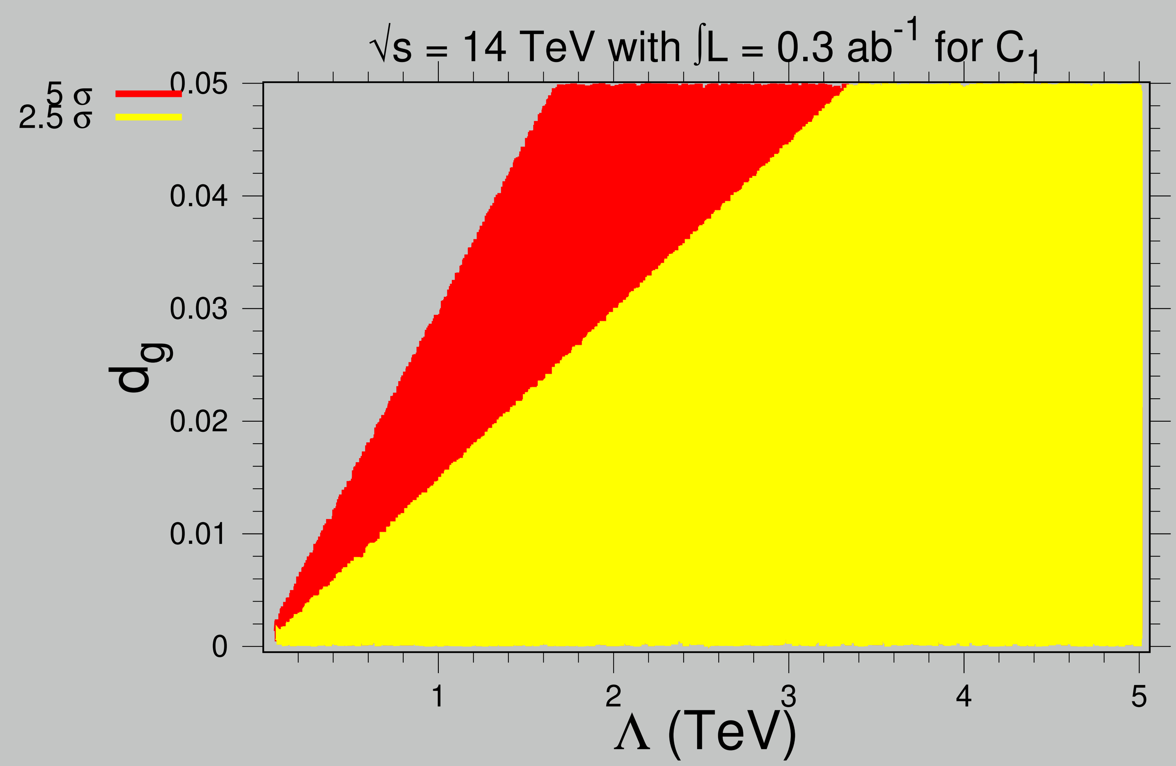
The Figures show possible $\mathbf{d_g} - \mathbf{\Lambda}$ space allowed at 2.5 σ and 5 σ respectively for the given C.M. energy and Luminosities.

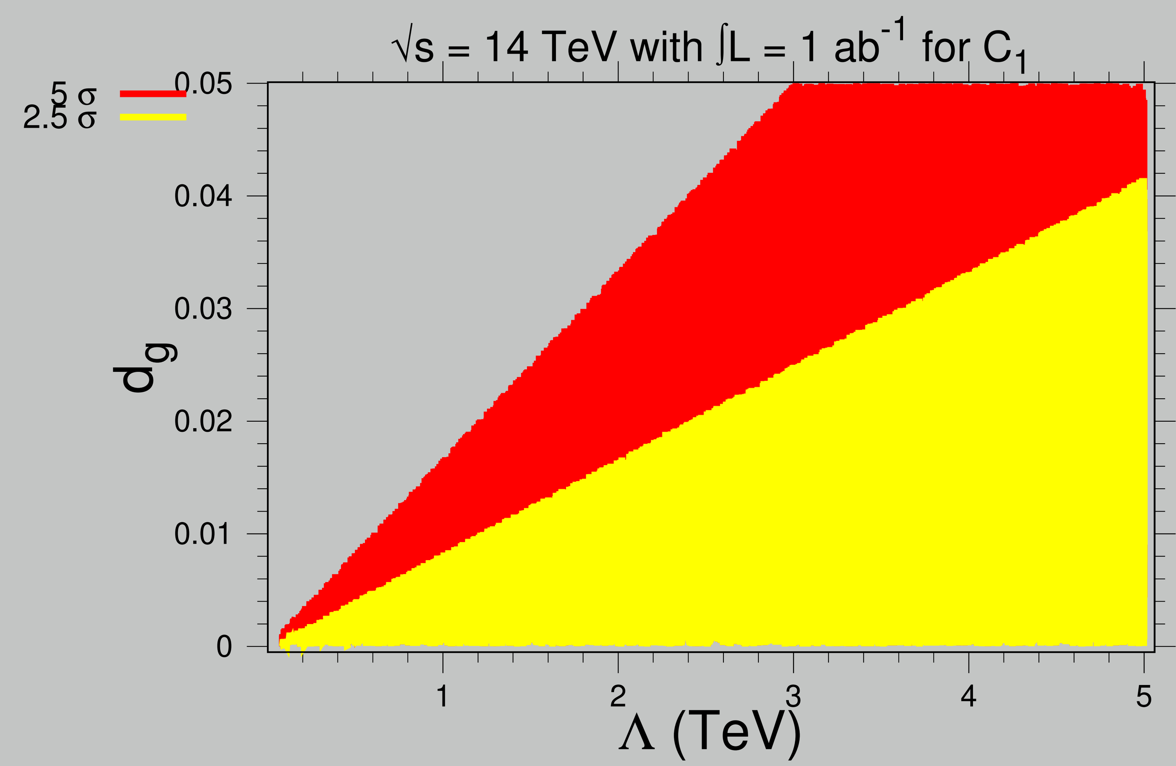
13 TeV LHC Energy

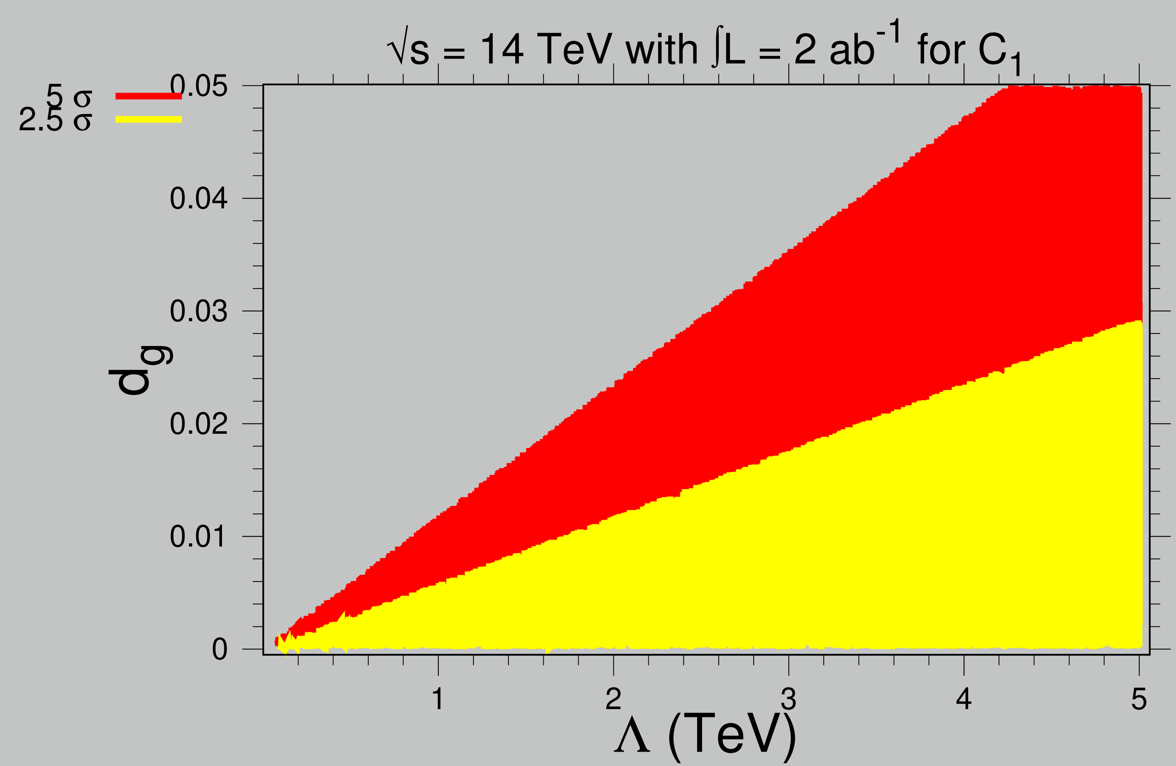


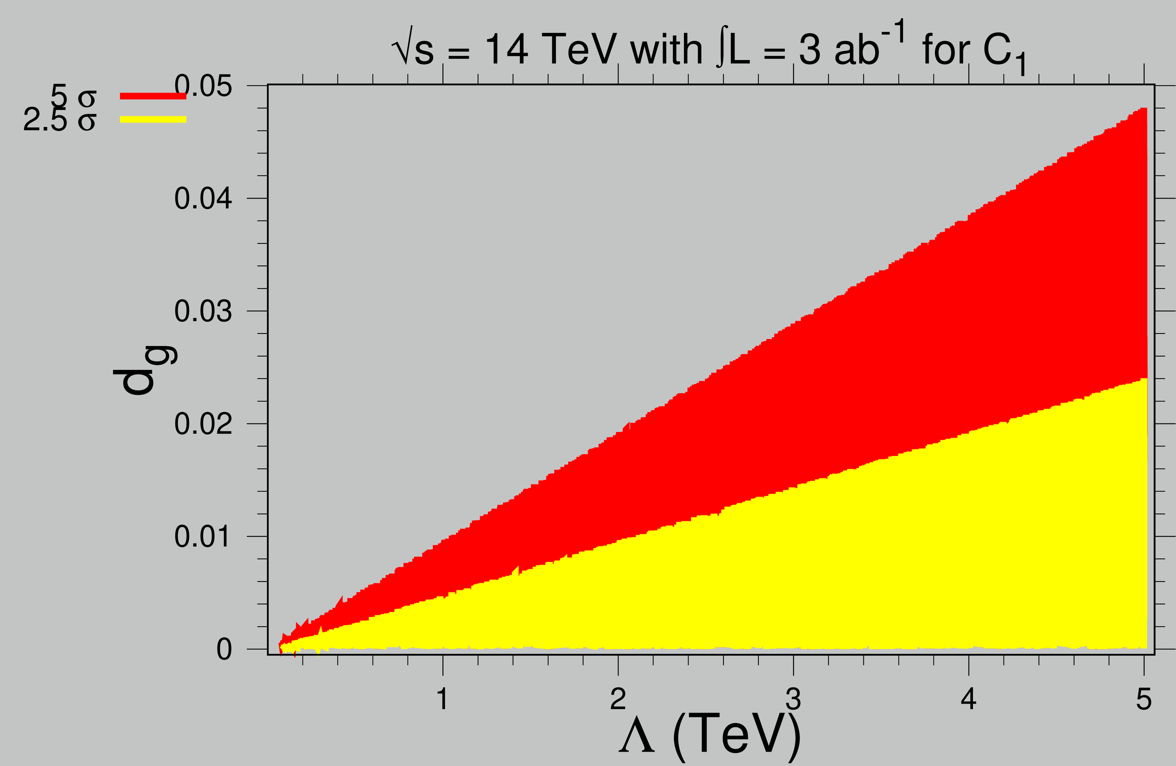


HL-LHC (14 TeV LHC energy)









Conclusions

- The present study acheived stringent bounds on CP-violating anomalous couplings of the top-quark.
- We have presented 5σ sensitivities for 13 TeV C.M. energy at LHC with the integrated luminosities of 36.1 fb^{-1} , 140 fb^{-1} and predicted that we can achieve 5σ sensitivity at 14 TeV LHC energy with projected luminosities of 0.3 ab^{-1} , 1 ab^{-1} , 2 ab^{-1} and 3 ab^{-1}. The results are summarised in the following table.

$\sqrt{S}$ (TeV)	$\int \mathcal{L}dt$	$\left\lvert\frac{d_g}{\Lambda}\right\rvert$ (in GeV^{-1})	
		at 3σ C.L.	at 5σ C.L.
13	36.1 fb^{-1}	0.29×10^{-4}	0.6×10^{-4}
	140 fb^{-1}	0.52×10^{-5}	0.2×10^{-4}
14 (HL-LHC)	0.3 ab^{-1}	0.39×10^{-5}	0.6×10^{-5}
	1.0 ab^{-1}	0.11×10^{-4}	0.5×10^{-5}
	2.0 ab^{-1}	0.13×10^{-4}	0.9×10^{-5}
	3.0 ab^{-1}	0.14×10^{-4}	0.1×10^{-4}

Table: Sensitivity to CP-violating anomalous couplings at 3σ C.L. and 5σ C.L. in the process $pp \to t\bar{t} \to (bl^+\nu_l)(\bar{b}l^-\bar{\nu}_l)$ at $\sqrt{S}$ of 0.3 ab^{-1}, 1 ab^{-1}, 2 ab^{-1} and 3 ab^{-1}.

References

J. H. Christenson, J. W. Cronin, V. L. Fitch and R. Turlay, Phys. Rev. Lett. **13**, 138-140 (1964) doi:10.1103/PhysRevLett.13.138

J. D. Wells, [arXiv:1911.04604 [physics.hist-ph]].