T-odd correlation effects and top pair production at LHC

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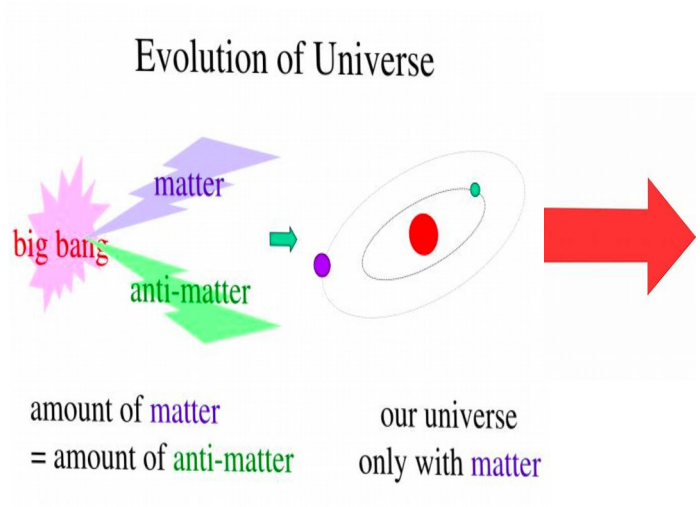
Outline

- Introduction
- Model
- Numerical Analysis
- Observations and Outlook

Motivation


Evolution of Universe
matter
big bang
anti-matter
amount of matter
= amount of anti-matter
our universe
only with matter


antimatter
matter

First obsevation of CP-violation was in the kaon decay

$$K^0 \rightarrow \pi^+\pi^-$$

Problem!!

CP violation in the kaon decays can be explained by the Standard Model.

$\Leftrightarrow$

CP violation in the universe cannot be explained by the Standard Model.

LHC Experiment will look for CP-violation beyond the SM in Particle world.

CP-violation in quark sector

CP-Violation has been observed in strange, bottom and top quark.

Top quark is the only hope to search for direct CP violation in quark sector

Why top quark

- It is much heavier than the other quarks.
- It has lifetime lesser than a quark takes to hadronise.

Interaction Lagrangian

We consider the $t\bar{t}$ pair production at the LHC which could take place via the glon fusion or $q\bar{q}$ annihilaion.

$$\mathrm{gg} \rightarrow t\bar{t} \rightarrow (bl^{+}\nu_{l})(\bar{b}l^{-}\bar{\nu}_{l})$$

The $t\bar{t}$ production cross-section is modified by the interaction Lagrangian

$$\mathrm{L}_{int} = -i\frac{g_s}{2}\frac{d_g}{\Lambda}\bar{t}\,\sigma_{\mu\nu}\gamma_5\,G^{\mu\nu}\,t$$

Observables

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

In $b\bar{b}$ CM frame

$$\mathcal{C}_1 = \epsilon(P_b, P_{\bar{b}}, P_{l+}, P_{l-}) \xrightarrow{(b\bar{b})_{CM}} \propto \vec{P}_b.(\vec{P_{l+}} \times \vec{P_{l-}})$$

Now

$$\vec{P}_b.(\vec{P_{l+}} \times \vec{P_{l-}}) \xrightarrow{C} \vec{P}_{\bar{b}}.(\vec{P_{l-}} \times \vec{P_{l+}}) = -\vec{P}_{\bar{b}}.(\vec{P_{l+}} \times \vec{P_{l-}}) = \vec{P}_b.(\vec{P_{l+}} \times \vec{P_{l-}})$$

$$\vec{P}_b.(\vec{P_{l+}} \times \vec{P_{l-}}) \xrightarrow{P} -\vec{P}_b.(-\vec{P_{l+}} \times -\vec{P_{l-}}) = -\vec{P}_b.(\vec{P_{l+}} \times \vec{P_{l-}}) \quad (1)$$

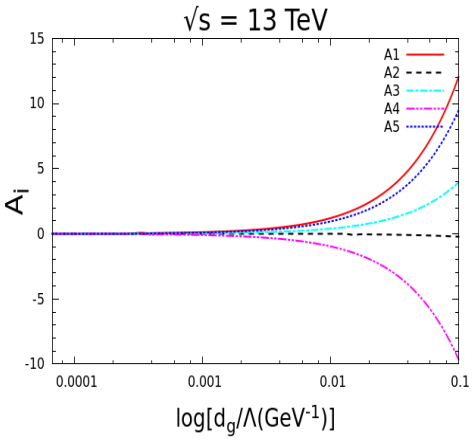
CP Asymmetry

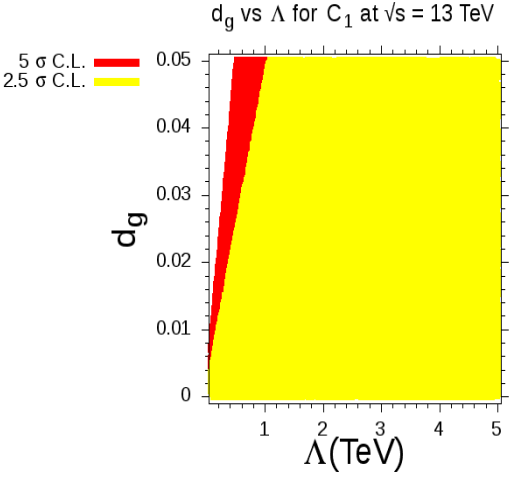
Asymmetry is calculated using the formula

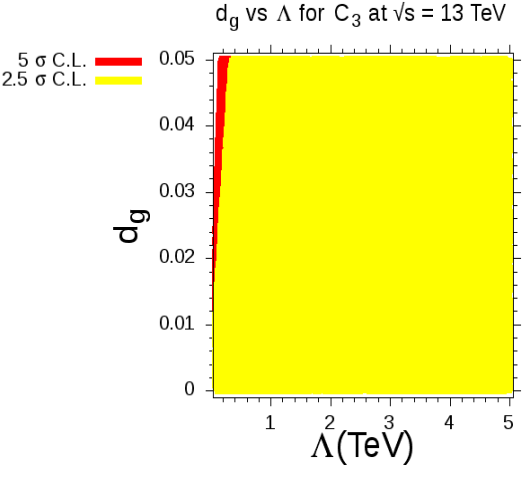
$$A_{CP} = \frac{N_{events}(C_i>0) - N_{events}(C_i<0)}{N_{events}(C_i>0) + N_{events}(C_i<0)}$$

Observations

Λ	d_g	$\mathcal{A}_1$	$\mathcal{A}_3$	$\mathcal{A}_4$	$\mathcal{A}_5$
	SM	0.07	0.11	-0.02	0.11
M_W	0.005	1.11	0.30	-0.87	0.84
	0.01	2.28	0.65	-1.91	1.59
	0.05	6.49	2.22	-5.18	5.13
0.5 TeV	0.005	1.11	0.30	-0.87	0.84
	0.01	0.35	0.29	-0.28	0.35
	0.05	1.77	0.45	-1.54	1.39
1 TeV	0.005	0.13	0.11	-0.14	0.07
	0.01	0.11	-0.01	-0.12	0.03
	0.05	0.75	0.26	-0.62	0.63
1.5 TeV	0.005	0.10	0.12	-0.03	0.02
	0.01	0.15	0.23	-0.30	0.10
	0.05	0.79	0.24	-0.47	0.47
2 TeV	0.005	0.06	-0.03	0.09	-0.15
	0.01	-0.12	-0.05	0.08	0.01
	0.05	0.31	0.04	-0.39	0.33




d_g vs Λ for C_1 at $\sqrt{s}$ = 13 TeV
5 σ C.L.
2.5 σ C.L.
0.05
0.04
0.03
0.02
0.01
0
d_g
1
2
3
4
5
Λ(TeV)


d_g vs Λ for C_3 at $\sqrt{s}$ = 13 TeV
5 σ C.L.
2.5 σ C.L.
0.05
0.04
0.03
0.02
0.01
0
d_g
1
2
3
4
5
Λ(TeV)

Outlook

- Top quark could be an effective tool to measure a CP Asymmetry present at the Large Hadron Collider through $t\bar{t}$ pair production.
- An LHC sensitivity of 5σ would be $|d_t| = |\frac{d_g}{\Lambda} m_t| \leq 0.01$ at 13 TeV LHC energy for an integrated luminosity of 36.1 fb^{-1} .


Thanks