Charge asymmetries in LHC and Tevatron

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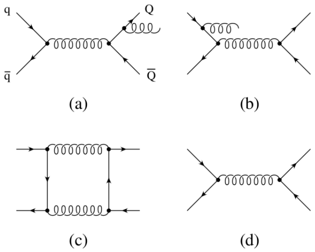
Top quarks, axigluons and charge asymmetries at hadron colliders
Oscar Antunano , Johann H. Kuhn , German Rodrigo
http://arxiv.org/abs/0709.1652v1

Introduction



1. Born processes relevant for top quark production: $q\bar{q} \to t\bar{t}$, $gg \to t\bar{t}$
2. Charge asymmetry rises in NLO reactions thus differential distributions are no longer equal.
3. Radiative corrections of $q\bar{q}$ annihilation and interference between different amplitudes contributing to $qg \to t\bar{t}q$ and $\overline{q}g \to t\overline{tq}$.

QCD Charge asymmetry prediction

Differential charge asymmetry of single quark rapidity distribution is defined as

$$A(y) = \frac{N_t(y) - N_{\bar{t}}(y)}{N_t(y) + N_{\bar{t}}(y)}, \quad N(y) = \frac{d\sigma}{dy}$$

$A(y)$ can be interpreted as A_{FB} because of charge conjugation symmetry i.e. $N_{\bar{t}}(y) = N_t(-y)$. With $m_t = 170.9 \pm 1.1 \pm 1.5$ GeV and $\sqrt{s} = 1.96$ TeV, the total charge asymmetry is

$$A = \frac{N_t(y \geq 0) - N_{\bar{t}}(y \leq 0)}{N_t(y \geq 0) + N_{\bar{t}}(y \leq 0)} = 0.051(6)$$

Define an average rapidity

$$Y = \frac{1}{2}(y_+ + y_-)$$

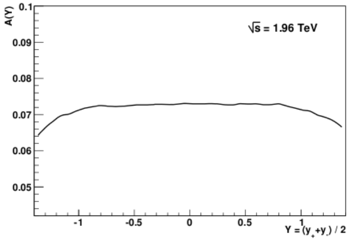
and introduce the differential pair asymmetry $\mathcal{A}(Y)$ for fixed Y as function of y_+, y_-.

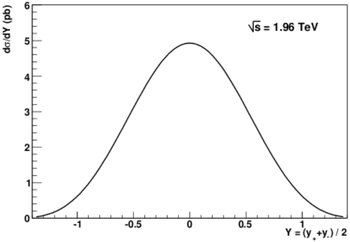
$$\mathcal{A}(Y) = \frac{N_{ev}(y_+ > y_-) - N_{ev}(y_+ < y_-)}{N_{ev}(y_+ > y_-) + N_{ev}(y_+ < y_-)}$$

QCD Charge asymmetry prediction

The integrated pair asymmetry over Y is

$$\mathcal{A} = \frac{\int dY\, N_{ev}(y_+ > y_-) + N_{ev}(y_+ < y_-)}{\int dY\, N_{ev}(y_+ > y_-) - N_{ev}(y_+ < y_-)} = 0.078(9)$$





Looking at $\mathcal{A}$ one studies the forward-backward asymmetry in the $t\bar{t}$ rest frame.

Tevatron results: Charge asymmetry

In lepton and jet events, based on $\mathcal{L} = 695\ \text{pb}^{-1}$ of data, the following result was found

$$A_{FB} = 0.20 \pm 0.11 \pm 0.047$$

Based on a $\mathcal{L} = 955\ \text{pb}^{-1}$ of data the following result was found for an inclusive charge asymmetry

$$A(\Delta y \cdot Q_l) = 0.23 \pm 0.12^{+0.056}_{-0.057}$$

More specific measurements of the charge asymmetry have been measured in the 4- and 5-jet channels.

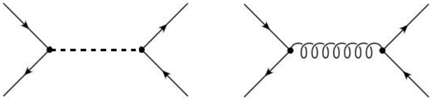
$$A^{4j}(\Delta y \cdot Q_l) = 0.11 \pm 0.14^{+0.036}_{-0.034}$$
$$A^{5j}(\Delta y \cdot Q_l) = 0.37 \pm 0.30^{+0.075}_{-0.066}$$

1. The asymmetry in $t\bar{t}$+jet depends on the jet resolution parameters.
2. The result is dominated by statistical uncertainties.

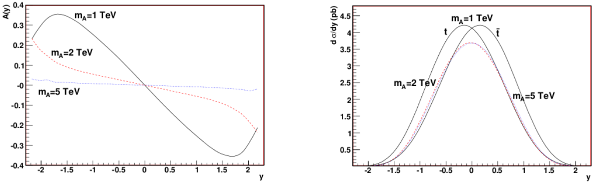
Extension of the Standard Model

BSM theories e.g. $\mathrm{SU(3)_L \times SU(3)_R}$, chiral color theories or technicolor theories predict a massive color-octet gauge boson, the axigluon.

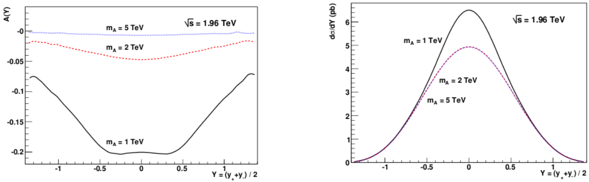
1. It couples to quarks through an axial vector and the same strength as QCD.
2. It can be observed in the $m_{t\bar{t}}$ spectrum or in forward-backward asymmetry.
3. When calculating the Feynman rules the interference term is suppressed by $\frac{1}{m_A^2}$ while the axigluon amplitude term is suppressed by $\frac{1}{m_A^4}$.
4. Previous results from Tevatron exclude axigluons with a $m_A < 1130$ GeV at 95% C.L.



Differential charge- and pair asymmetry with axigluons

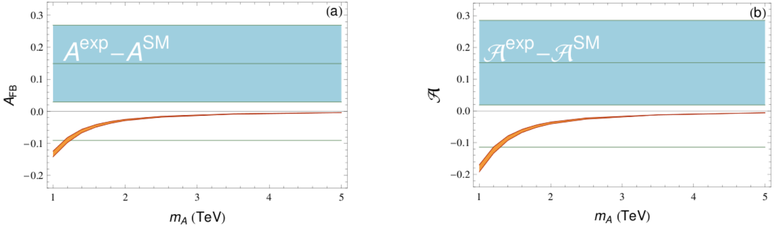


Differential charge asymmetry (left) and rapidity distribution (right).



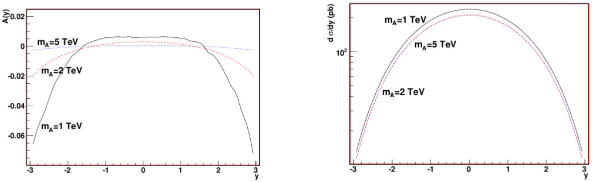
Differential pair asymmetry (left) and average rapidity distribution (right).

Viability of axigluon charge asymmetry



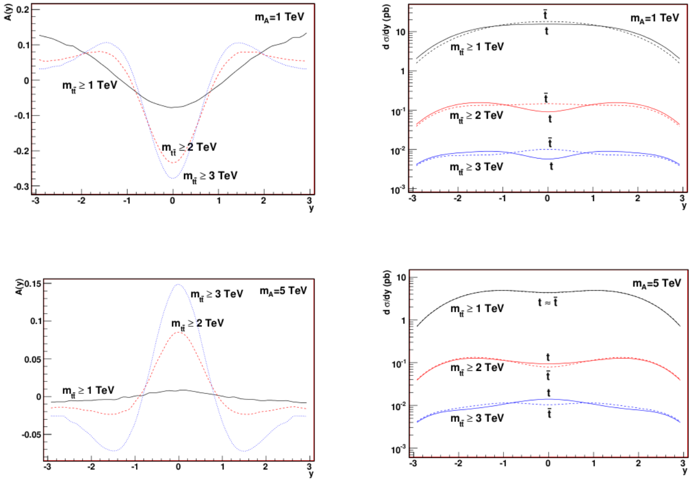
The difference between experimental measurements and SM predictions is compared to the axigluon charge- and pair asymmetry. For $m_A \leq 1.2$ TeV the existence of an axigluon is excluded with a 2σ C.L.

LHC: Charge asymmetry



1. In LHC, the $t\bar{t}$ production is dominated by gg fusion thus the charge asymmetry is negligible.
2. Selecting events with high $m_{t\bar{t}}$ enhances the charge asymmetry due to a higher contribution from $q\overline{q}$ annihilation events.
3. A large asymmetry is predicted in the central rapidity region.

LHC: Differential charge asymmetry, rapidity distribution



Differential charge asymmetry of the top quark (left) and rapidity distribution (right) for different $m_{t\bar{t}}$ cuts and $m_A = 1, 5$ TeV.

LHC: Central charge asymmetry

Focusing on central region, a new charge asymmetry can be defined as

$$A_C(y_C) = \frac{\sigma_t(|y| \leq y_C) - \sigma_{\bar{t}}(|y| \leq y_C)}{\sigma_t(|y| \leq y_C) + \sigma_{\bar{t}}(|y| \leq y_C)}$$

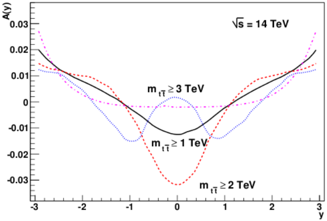
The largest values of A_C are obtained for $y_C = 1$ and integrating.

		QCD	$m_A = 1$ TeV	$m_A = 2$ TeV	$m_A = 5$ TeV
$\sqrt{\hat{s}} \geq 1$ TeV	$A_C(y_C = 1)$	$-0.0086(4)$	$-0.055(4)$	$0.025(3)$	$0.002(1)$
	$\sigma_t(\lvert y\rvert \leq 1)$	9.7(2.7) pb	34(4) pb	15(2) pb	11(2) pb
$\sqrt{\hat{s}} \geq 2$ TeV	$A_C(y_C = 1)$	$-0.0207(14)$	$-0.10(2)$	$-0.048(5)$	$0.031(9)$
	$\sigma_t(\lvert y\rvert \leq 1)$	0.19(6) pb	0.28(8) pb	1.7(2) pb	0.26(7) pb
$\sqrt{\hat{s}} \geq 3$ TeV	$A_C(y_C = 1)$	$-0.0151(7)$	$-0.10(3)$	$-0.11(2)$	$0.057(13)$
	$\sigma_t(\lvert y\rvert \leq 1)$	0.011(4) pb	0.019(6) pb	0.024(7) pb	0.031(8) pb

Summary

1. A more sensitive charge asymmetry, the pair asymmetry $\mathcal{A}$, has been defined.
2. The differential charge- and pair asymmetry has been calculated based on results from Tevatron and the Standard model.
3. From the Tevatron results, the existence of an axigluon with a mass $m_A < 1.2$ TeV is excluded with a 95% C.L.
4. In LHC, the differential charge asymmetry is much smaller due to gg fusion cross section being larger.
5. Selecting events with large $m_{t\bar{t}}$ and $|y| < 1$ the axigluon induced charge asymmetry can be studied at the LHC.

Backup


A(y)
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
√s = 14 TeV
m tt̄ ≥ 3 TeV
m tt̄ ≥ 1 TeV
m tt̄ ≥ 2 TeV
-3
-2
-1
0
1
2
3
y