Top Anti-Top Forward-Backward Asymmetry in the Economical 331 Model

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Abstract: Within the economical 331 model the top-antitop asymmetry at the Tevatron where the quark-antiquark annihilation subprocess dominates is calculated. The results are also discussed.

Keywords: Beyond standard model, top quark, Tevatron
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INTRODUCTION

Among the various extensions of the Standard Model (SM), $SU_c(3)\otimes SU_N(3)\otimes U_X(1)$ (331) models have the attractive feature of addressing the problem of fermion family replications. The puzzle is partially solved through the requirement of anomaly cancellations [1]–[10], since in the 331 framework the number of quarks families turns out to be related to the number of colors. In addition, 331 models show a rich phenomenology, including the presence of new scalars and heavy quarks, and offer the possibility of see-saw mechanisms to generate neutrino masses, dark matter candidates , gauge couplings unification [1]-[10], etc. On the other hand, the top quark with its high mass may play a crucial role in electroweak symmetry breaking. Hence the top sector may be sensitive to new physics effects that could be revealed through careful measurements of top quark properties. The top quark pair production in proton-antiproton collisions at the Tevatron collider with a center-of-mass energy of $\sqrt{s} = 1.96\, TeV$ is dominated by the partonic process $q + \bar{q} \rightarrow t + \bar{t}$ Recently, the CDF experiment has reported a measurement of forward-backward asymmetry in $t\bar{t}$ production which appears to deviate from the standard model (S.M.)predictions.The CDF collaboration measured the forward-backward asymmetry (A_{FB}) in top quark pair production in the $t\bar{t}$ rest frame to be $A_{FB}^{t\bar{t}} = 0.475 \pm 0.774$ for the invariant mass $M_{t\bar{t}} > 450\, GeV$ [11], which is 3.4 σ deviations from the next-to leading order (NLO) SM prediction $A_{FB}^{t\bar{t}} \approx 0.088$ [12]–[15]. The DØ collaboration also observed a larger than predicted asymmetry [16].The goal of this paper is to study the top anti-top forward-backward symmetry in the context of the 331 model and show that unlike the standard model does not vanish at the tree level at least at the subprocess level.

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RESULTS

To be more explicit and to keep our argument clear and transparent, we give the following analytical expressions of the difference for $y > 0$ and $y < 0$ u-quark and d-quark subprocess contributions to the top anti-top forward-backward asymmetry in the physical process $pp \rightarrow t + \bar{t}$ but jut considering the Z' and W in the intermediate state.

$$\Delta|M|^2_{s-s-tunnel}(u - quark) = \frac{\Omega_1}{\Omega_2}\sinh\left(e^{2y}\right) \tag{1}$$

$$\Delta|M|^2_{s-s-tunnel}(d - quark) = \frac{\Omega_3}{\Omega_2}\sinh\left(e^{2y}\right) \tag{2}$$

$$\Delta|M|^2_{t-t-tunnel}(d - quark) = \frac{\Omega_4 e^{-2y} + \Omega_5}{\Omega_6 + (\Omega_7 - 2\Omega_8 e^{-y})^2} - \frac{\Omega_4 e^{2y} + \Omega_5}{\Omega_6 + (\Omega_7 - 2\Omega_8 e^{y})^2}) \tag{3}$$

$$\Delta|M|^2_{s-t-tunnel}(d - quark) = \frac{(-\Omega_8 e^{-y} + \Omega_7)\sqrt{(\Omega_2 - \Omega_9)} + \sqrt{\Omega_6\Omega_9}}{((-\Omega_8 e^{-y} + \Omega_7)^2 + \Omega_6)\Omega_2}\Omega_{10}(\Omega_8)^2 \sinh\left(e^{2y}\right) \tag{4}$$

where

$$\Omega_1 = 96\hat{s} g3_A g3_V g4_A g4_V ({m_{top}}^2 + {p_T}^2)$$

$$\Omega_2 = {\Gamma_{z'}}^2 {M_{z'}}^2 + (\hat{s} - {M_{z'}}^2)^2$$

$$\Omega_3 = 32\hat{s} g4_V g5_A (2g4_A + g5_A) g5_V ({m_{top}}^2 + {p_T}^2)$$

$$\Omega_4 = 8\hat{s}({g_A}^4 - g_V {g_A}^3 + 5{g_V}^2{g_A}^2 + {g_V}^4)({m_{top}}^2 + {p_T}^2)$$

$$\Omega_5 = 2\hat{s}[-2({g_A}^4 + g_V {g_A}^3 - {g_V}^2{g_A}^2 + {g_V}^4){m_{top}}^2$$
$$+\hat{s}({g_A}^4 + g_V {g_A}^3 - {g_V}^2{g_A}^2 + {g_V}^4)]$$

$$\Omega_6 = {\Gamma_w}^2 {M_w}^2 \tag{5}$$

$$\Omega_7 = {m_{top}}^2 - {M_w}^2$$

$$\Omega_8 = 2\sqrt{\hat{s}({m_{top}}^2 + {p_T}^2)}$$

$$\Omega_9 = {\Gamma_{z'}}^2 {M_{z'}}^2$$

$$\Omega_{10} = 4\Big(\big(g4_V g5_V + g4_A(g5_A + g5_V)\big){g_A}^2 - 2g_V g4_V g5_A g_A + {g_V}^2\big(g4_V g5_V + g4_A(g5_A + g5_V)\big)\Big)$$

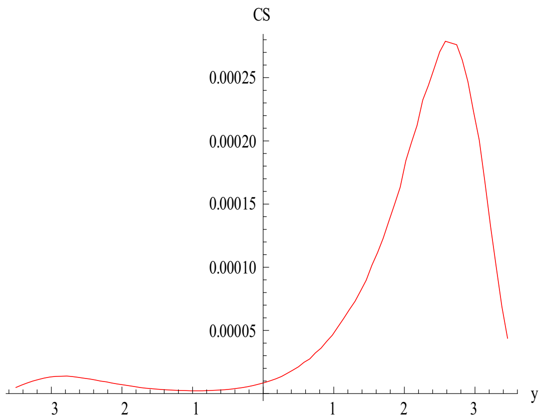

FIGURE 1. Asymmetry in the subprocess differential cross section in arbitrary units as a function of the pseudo rapidity y

Here $g3_A$, , $g4_A$, $g5_A$ and g_A, are the axial couplings in the Z' neutral current and W charged current [16] of the up, top down quark with the Z' boson in the s-tunnel and down quark with the W boson in the t-tunnel respectively. Similarly $g3_V$, $g4_V$, $g5_V$ and g_V are the corresponding vector couplings. Moreover, $\Delta|M|^2$ stands for $|M|^2(y > 0) - |M|^2(y < 0)$ and $\Gamma_{z'}$, Γ_w ,$M_{z'}$, M_w are the disintegration widths and masses of the Z' and W bosons. Moreover, the parameters , $\hat{s}$, m_{top}, and p_T denote the pseudo rapidity, the subprocess Mandelstam variable, mass and transverse momentum of the top quark respectively.

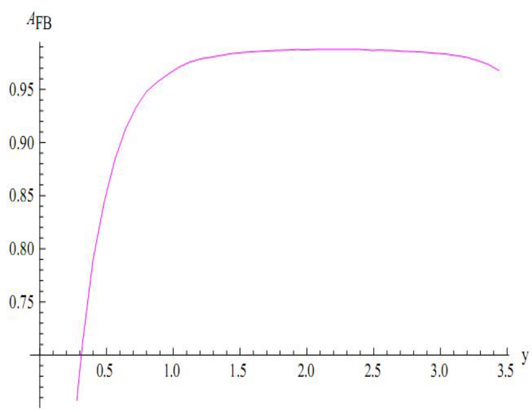

FIGURE 2. $A_{FB}^{t\bar{t}}$ as a function of the pseudo rapidity y

Figure 1. displays the total contribution $\Delta|M|^2$ for the top anti-top forward-backward asymmetry $A_{FB}^{t\bar{t}}$as a function of the pseudo rapidity y for $p_T = 60$ GeV and $\sqrt{\hat{s}} = 1.96\ TeV$. This implies and contrary to the standard model that $A_{FB}^{t\bar{t}} \neq 0$ at the tree level. Figure 2, represents $A_{FB}^{t\bar{t}}$at the subprocess level as a function of the pseudo rapidity y. Notice that in the kinematical region of the pseudo rapidity, $A_{FB}^{t\bar{t}}$ is an

increasing function of y (More realistic study with the physical process including the partons distribution functions (pdf's) are under investigation).

CONCLUSION

We have shown that contrary to the standard model, the 331 model predicts that the top anti-top forward-backward asymmetry at the subprocess level is different from zero. This, gives hope, one considering the physical process with the pdf's that $A_{FB}^{t\bar{t}}$can be explained by this model.

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