Top quark forward-backward asymmetry in the large invariant mass region

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The forward-backward asymmetry in top-pair production that was observed in 2008 gets a boost in a recent CDF publication. Not only has the forward-backward asymmetry been further confirmed, but also distributional preferences are shown. Strikingly, the forward-backward asymmetry is the most sizable in the large $M_{t\bar{t}}$ invariant mass region and in the large rapidity difference $|\Delta y|$ region. Here we used our previously proposed t-channel exchanged W' boson to explain the new observations. We show that a new particle exchanged in the t channel generically gives rise to such observations. Furthermore, we show that the proposed W' can be directly produced in association with a top quark at the Tevatron and the LHC. We perform a signal-background analysis and show that such a W' is readily observed at the Tevatron with a 10 fb^{-1} luminosity and at the LHC-7 with just a 100 pb^{-1} luminosity.

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I. INTRODUCTION

The top quark was the last piece of quarks that was discovered more than 15 years ago [1,2]. While waiting for the Higgs boson at the LHC, the top quark has been making some noise about the presence of new physics. The forward-backward asymmetry (FBA) in top-quark pair production was found in 2008 by CDF [3] and by D0 [4]. While the standard model (SM) only predicts a level as small as a few percent arising from the higher-loop contributions, the measurement by CDF [3], however, was as large as

$$A^{t\bar{t}} \equiv \frac{N_t(\cos\theta > 0) - N_t(\cos\theta < 0)}{N_t(\cos\theta > 0) + N_t(\cos\theta < 0)} = 0.19 \pm 0.065(\text{stat}) \pm 0.024(\text{syst}), \qquad (1)$$

where θ is the production angle of the top quark t in the $t\bar{t}$ rest frame. The measurement in the $p\bar{p}$ laboratory frame is correspondingly smaller, because of the Lorentz boost (washout) of the partons along the beam axis.

The anomaly did not die out, but gets a reconfirmation in a recent CDF publication [5]. With a larger data set (5.3 fb^{-1}) the FBA persists at the level of $A^{t\bar{t}} = 0.158 \pm 0.074$ [5], which is a less-than-2σ effect after subtracting the SM contribution of $A^{t\bar{t}}_{\text{SM}} = 0.058 \pm 0.009$ [6,7]. Though the deviation is slightly smaller, the most striking feature is that the FBA shows distributional preferences. The FBA is the most obvious in the large $M_{t\bar{t}}$ invariant mass region and in the large rapidity difference $|\Delta y|$ region. The analysis in the CDF paper [5] showed that the FBA is consistent with zero for $M_{t\bar{t}} < 450$ GeV but a larger-than-3σ effect in the $M_{t\bar{t}} > 450$ GeV region. At the same time, the analysis also showed that the FBA is large in the large rapidity difference Δy region, which is a 2σ effect. These are summarized in the third last row in Table I, where we also show in the second last row the SM predictions from the MCFM [6].

If the FBA is true, it will indicate the presence of new physics, because within the SM the asymmetry is only up to about 5% [7]. In the past two years, numerous works have been carried out to explain the anomaly [8–27]. The explanations can be divided into two categories: (i) a t-channel exchanged particle such as a W' or a Z' with flavor-changing couplings between the top quark and the d or u quark, and (ii) a heavy s-channel exchanged particle such as an axial gluon with specific couplings to the top quark and the light quarks. In the latter case, the couplings are somewhat contrived in order to achieve a positive FBA.

In a previous work [21], we proposed an extra W' boson that only couples to the d and t quarks. Thus, the $d\bar{d}$ initial state turns into the $t\bar{t}$ final state via a charged-current exchange of the W' boson in the t channel. We mapped out the suitable parameter space of the W' mass $M_{W'}$ and the coupling g'. In this article, we show that such a t-channel exchanged particle can easily accommodate a FBA and also that it naturally gives rise to a large FBA in the large $M_{t\bar{t}}$ region and in the large $|\Delta y|$ region. We show that for $M_{W'} = 200$–600 GeV with appropriate couplings we can bring the predictions to be within 1–1.5σ of the data. This is our main result.

In addition, since the $W'^{\pm}$ boson proposed is relatively light, only 200–600 GeV, it can be directly produced in association with a top quark or antiquark at the Tevatron and the LHC. The $W'^{-}(W'^{+})$ produced would then decay right away into $\bar{t}d(t\bar{d})$, giving rise to a top-quark pair plus one jet in the final state. The irreducible background is QCD production of $t\bar{t} + 1j$. We show that the increase in $t\bar{t}$ production by direct W' production is within 1σ error of the measured $t\bar{t}$ cross section. We perform a signal-background analysis based on parton-level calculations.

TABLE I. The forward-backward asymmetry for top-pair production at the Tevatron calculated for various $M_{W'}$ and g'. The data, predictions from MCFM, and contributions needed from new physics are listed in the last three rows.

				$A^{t\bar{t}}$		$A^{t\bar{t}}$	
$M_{W'}$ (GeV)	g'	$\sigma_{t\bar{t}}$ (pb)	$A^{t\bar{t}}$	$\lvert\Delta y\rvert < 1$	$\lvert\Delta y\rvert > 1$	$M_{t\bar{t}} < 450$ GeV	$M_{t\bar{t}} > 450$ GeV
200	0.85	7.99	0.129	0.044	0.321	0.061	0.217
300	1.2	8.28	0.151	0.065	0.348	0.062	0.257
400	1.5	8.24	0.140	0.063	0.324	0.050	0.247
500	1.8	8.21	0.132	0.060	0.305	0.042	0.237
600	2.1	8.19	0.125	0.058	0.290	0.036	0.229
Data (parton)		7.70 ± 0.52	0.158 ± 0.074	0.026 ± 0.118	0.611 ± 0.256	-0.116 ± 0.153	0.475 ± 0.112
MCFM		$7.45^{+0.72}_{-0.63}$	0.058 ± 0.009	0.039 ± 0.006	0.123 ± 0.018	0.04 ± 0.006	0.088 ± 0.0013
New physics		$\cdots$	0.100 ± 0.074	$\cdots$	0.488 ± 0.257	$\cdots$	0.387 ± 0.112

The cleanest signal of W' production would be the sharp peak of the invariant mass M_{tj} distribution. We require one top quark to decay hadronically while the other one semileptonically. In this case, one has less confusion in jet combinations, and one can still fully reconstruct the hadronic top and combine with the light jet to form the peak of W'. We expect the background to give a continuum in the M_{tj} distribution. Thus, we can count the number of events below the peak for the signal and background. At the end, we can see that the Tevatron can observe such a W' up to 400 GeV while the LHC operating at 7 TeV can observe such a W' almost immediately. This is an important result of this work.

Improvements over our previous work are as follows.

(1) We use the top-quark mass $m_t = 172.5$ GeV and the most recent published $t\bar{t}$ cross section, which are the same as in the most recent CDF publications [5,28].
(2) We calculate the FBA as functions of $|\Delta y|$ and $M_{t\bar{t}}$. Through the figures it is clear that larger FBA in the large $|\Delta y|$ and large $M_{t\bar{t}}$ region is a generic feature of a new t-channel exchanged particle.
(3) With the additional charged W' boson that we proposed, we can bring the overall $A^{t\bar{t}}$ to be around the measured value, the $A^{t\bar{t}}(|\Delta y| > 1)$ within 1σ, and $A^{t\bar{t}}(M_{t\bar{t}} > 450\text{ GeV})$ within 1.5σ.
(4) We calculate the direct production of the W' associated with a top quark at the Tevatron and the LHC. We show that in the presence of irreducible background of $t\bar{t}j$ the W' up to about 400 GeV could be observed at the Tevatron. On the hand, the W' all the way to 600 GeV could be easily observed at the LHC.

II. THE FORWARD-BACKWARD ASYMMETRY

The production angle θ in the $t\bar{t}$ rest frame is related to the rapidity of the t and $\bar{t}$ in the $p\bar{p}$ frame by

$$\Delta y \equiv y_t - y_{\bar{t}} = 2\text{arctanh}\left(\sqrt{1 - \frac{4m_t^2}{\hat{s}}}\cos\theta\right), \qquad (2)$$

where $\hat{s}$ is the square of the center-of-mass energy of the $t\bar{t}$ pair. Therefore, the difference Δy between the rapidities of the t and $\bar{t}$ in the $p\bar{p}$ frame is a close measure of the production angle in the $t\bar{t}$ frame. Moreover, the sign of Δy is the same as $\cos\theta$, such that the asymmetry in Eq. (1) can be given by

$$A^{t\bar{t}} \equiv \frac{N_t(\Delta y > 0) - N_t(\Delta y < 0)}{N_t(\Delta y > 0) + N_t(\Delta y < 0)}. \qquad (3)$$

Our parton-level calculation uses this definition to calculate the FBA.

Suppose the interaction vertex for the W' boson with the down and top quarks is given by

$$\mathcal{L} = -g' W'^{+}_{\mu} \bar{t}\gamma^{\mu}(g_L P_L + g_R P_R)d + \text{H.c.}, \qquad (4)$$

where $P_{L,R} = (1 \mp \gamma^5)/2$ are the chirality projection operators, $g_{L,R}$ are the chiral couplings of the W' boson with fermions, and g' is the coupling constant. In Ref. [21], we demonstrated that the pure right-handed coupling where $g_L = 0$ and $g_R = 1$ can fit the data in a more consistent way. Also, the pure right-handed W' is less constrained by the $SU(2)_L$ symmetry. We therefore focus on this case of pure right-handed coupling in what follows.

The process $d(p_1)\bar{d}(p_2) \to t(k_1)\bar{t}(k_2)$ is described by two Feynman diagrams, one s-channel diagram from the one gluon exchange and one t-channel diagram from the W' exchange. Ignoring the d quark mass, the spin- and color-summed amplitude squared is given by

$$\begin{aligned}\sum|\mathcal{M}|^2 = {}& \frac{9g'^4}{t_{W'}^2}\Big[4((g_L^4 + g_R^4)u_t^2 + 2g_L^2 g_R^2 \hat{s}(\hat{s} - 2m_t^2)) \\ & + \frac{m_t^4}{m_{W'}^4}(g_L^2 + g_R^2)^2(t_t^2 + 4m_{W'}^2\hat{s})\Big] \\ & + \frac{16g_s^4}{\hat{s}^2}(u_t^2 + t_t^2 + 2\hat{s}m_t^2) + \frac{16g'^2 g_s^2}{\hat{s}t_{W'}}(g_L^2 + g_R^2) \\ & \times\Big[2u_t^2 + 2\hat{s}m_t^2 + \frac{m_t^2}{m_{W'}^2}(t_t^2 + \hat{s}m_t^2)\Big], \end{aligned} \qquad (5)$$

where $\hat{s} = (p_1 + p_2)^2$, $t = (p_1 - k_1)^2$, $u = (p_1 - k_2)^2$ and

$$t_t = t - m_t^2 = -\frac{1}{2}\hat{s}(1 - \beta\cos\theta),$$
$$u_t = u - m_t^2 = -\frac{1}{2}\hat{s}(1 + \beta\cos\theta), \qquad t_{W'} = t - m_{W'}^2, \tag{6}$$

with $\beta = \sqrt{1 - 4m_t^2/\hat{s}}$. The initial spin- and color-averaged amplitude squared is given by

$$\overline{\sum|\mathcal{M}|^2} = \frac{1}{4}\frac{1}{9}\sum|\mathcal{M}|^2. \tag{7}$$

The differential cross section versus the cosine of the production angle θ is

$$\frac{d\hat{\sigma}}{d\cos\theta} = \frac{\beta}{32\pi\hat{s}}\overline{\sum|\mathcal{M}|^2}, \tag{8}$$

where $\hat{\sigma}$ denotes the cross section for the subprocess which is then folded with the parton distribution functions to obtain the measured cross section. The FBA is obtained by integrating over the positive and negative range of the $\cos\theta$ variable.

We can also easily calculate the invariant mass $M_{t\bar{t}}$ distribution in the forward and backward directions, through which we can calculate the FBA versus the invariant mass. We show the FBA versus $M_{t\bar{t}}$ for various values of $M_{W'}$ and g' in Fig. 1. The values are chosen such that the predictions can be brought within 1–1.5σ of the data without violating the constraints on total cross sections and invariant mass distribution [21]. We also use the Δy distribution, in which the forward direction ($\Delta y > 0$) has more events than the backward direction ($\Delta y < 0$), to calculate the FBA versus $|\Delta y|$, as shown in Fig. 2. It is clear from Figs. 1 and 2 that the FBA becomes large in the large $M_{t\bar{t}}$ region and in the large $|\Delta y|$ region. This is a generic feature for a new particle exchanged in the t channel, whether it is a W', Z', or a scalar boson.

Fit to the data

The data [5], the predictions from MCFM [6], and the contributions from the new physics needed to explain the data are summarized in the last three rows of Table I. The entries for the total cross section, $A^{t\bar{t}}(|\Delta y| < 1)$, and $A^{t\bar{t}}(M_{t\bar{t}} < 450 \text{ GeV})$ are consistent between the data and the MCFM, so that no contributions are needed from new physics, as indicated by "· · ·" in the last row. The deviations for $A^{t\bar{t}}(|\Delta y| > 1)$ and $A^{t\bar{t}}(M_{t\bar{t}} > 450 \text{ GeV})$ are about 2σ and 3.5σ, respectively. In Table I, we show the results for $M_{W'} = 200$–600 GeV with appropriate g's. They all give consistent total cross sections with the $\sigma_{t\bar{t}}$ [28] within 1σ. Also, it was shown in our previous work [21] that the choices are consistent with the invariant mass $M_{t\bar{t}}$ distribution [29] as well. The predictions for low $|\Delta y| < 1$ and small $M_{t\bar{t}} < 450$ GeV are consistent with the data. Most strikingly, the predictions for large $|\Delta y| > 1$ and large $M_{t\bar{t}} > 450$ GeV can be brought to be within 1σ and 1.5σ, respectively, of the difference between the data and the MCFM prediction.

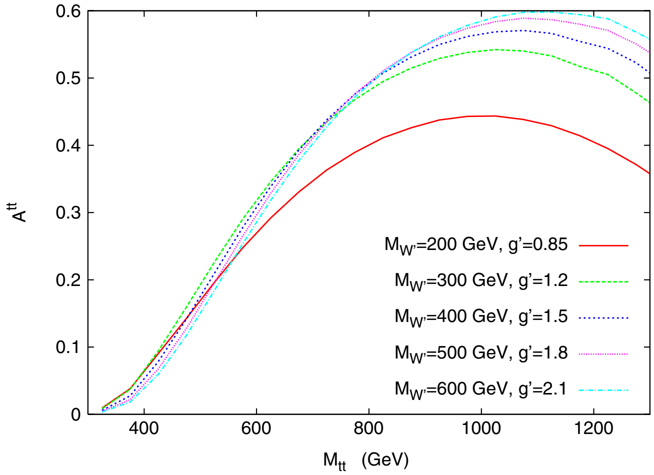

FIG. 1 (color online). The forward-backward asymmetry of top-pair production versus the invariant mass $M_{t\bar{t}}$ at the Tevatron for various values of $M_{W'}$ and g'.

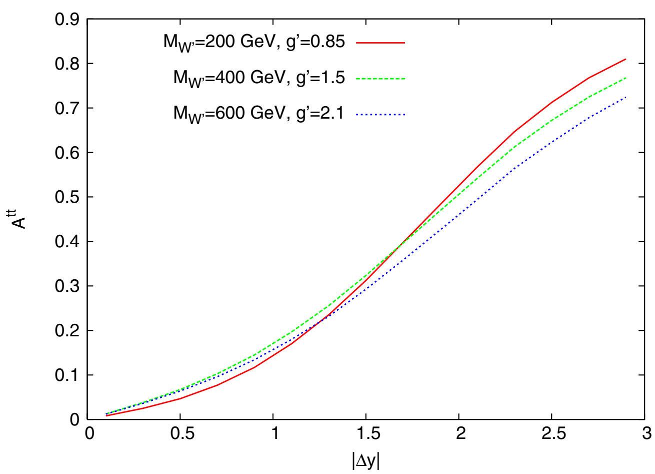

FIG. 2 (color online). The forward-backward asymmetry of top-pair production versus $|\Delta y| \equiv |y_t - y_{\bar{t}}|$ at the Tevatron for various values of $M_{W'}$ and g'.

III. DIRECT W' PRODUCTION AT THE TEVATRON AND LHC

The flavor-changing W' considered in this work is indeed quite light. It can be directly produced at the Tevatron and the LHC. In the following, we calculate the production cross sections of the W' associated with a top quark/antiquark at the Tevatron and the LHC, as well as compare it to the irreducible QCD background.

There are two Feynman diagrams for W' production at the hadron collider via the subprocess $g(p_1) + d(p_2) \to t(k_1) + W'^-(k_2)$ with the s and t channel of down and top-quark exchange, respectively. Ignoring the d quark mass, the spin- and color-summed amplitude squared for this process is given by

$$\sum|\mathcal{M}|^2 = 8g_s^2 g'^2(g_L^2 + g_R^2) \times \left[\frac{1}{\hat{s}^2}F_s + \frac{1}{(t-m_t^2)^2}F_t + \frac{2}{\hat{s}(t-m_t^2)}F_{st}\right] \quad (9)$$

with

$$F_s = -\hat{s}\left[\hat{s} + 2t - 2m_t^2 - \frac{1}{M_{W'}^2}(\hat{s}-m_t^2)(\hat{s}+t-m_t^2)\right], \quad (10)$$

$$F_t = -[m_t^4 - 2m_t^2\hat{s} + t(2\hat{s}+t)] + 4m_t^2 M_{W'}^2 + \frac{t}{M_{W'}^2}[m_t^4 - m_t^2(\hat{s}+4t) + t(\hat{s}+t)], \quad (11)$$

$$F_{st} = (\hat{s}-m_t^2)(t-m_t^2) + [m_t^2 + 2(\hat{s}+t)]M_{W'}^2 - 2M_{W'}^4 - \frac{t}{M_{W'}^2}[m_t^4 - 2m_t^2\hat{s} + \hat{s}(\hat{s}+t)], \quad (12)$$

where $\hat{s} = (p_1+p_2)^2$, $t = (p_1-k_1)^2$, and $u = (p_1-k_2)^2$. The initial spin- and color-averaged amplitude squared is given by

$$\overline{\sum|\mathcal{M}|^2} = \frac{1}{2\cdot 2}\frac{1}{3\cdot 8}\sum|\mathcal{M}|^2. \quad (13)$$

The differential cross section versus the angle θ (the angle between the momenta of outgoing top and the incoming gluon) is then

$$\frac{d\hat{\sigma}}{d\cos\theta} = \frac{1}{32\pi\hat{s}}\left(\frac{p_f}{p_i}\right)\overline{\sum|\mathcal{M}|^2}, \quad (14)$$

where $p_i = \sqrt{\hat{s}}/2$ and

$$p_f = \frac{1}{2\sqrt{\hat{s}}}[\hat{s}^2 - 2\hat{s}(m_t^2 + M_{W'}^2) + (m_t^2 - M_{W'}^2)^2]^{1/2}. \quad (15)$$

We show in Fig. 3 the total cross section for production of $p\bar{p} \to tW'^-$ and $\bar{t}W'^+$ at the Tevatron and $pp \to tW'^-$ and $\bar{t}W'^+$ at the LHC. Even if the W' decays 100% into $t\bar{d}$ or $\bar{t}d$, the size of the $t\bar{t}$ production cross section that it can increase is at most 0.8 pb (for a 200 GeV W') for the Tevatron case, which is about the same size as the 1σ error in the $t\bar{t}$ cross section measurement at the Tevatron.

In our scenario, the $W'^-(W'^+)$ decays 100% into the $\bar{t}d(t\bar{d})$. Therefore, the final state consists of a top-quark pair plus a jet, among which one of the top quarks and the jet reconstructed at the W' mass. The irreducible background would be QCD production of $t\bar{t} + 1j$.

Recall that the top quark has a branching ratio ~ 0.7 decaying hadronically and a branching ratio ~ 0.22 decaying semileptonically (only counting the e, μ modes). We

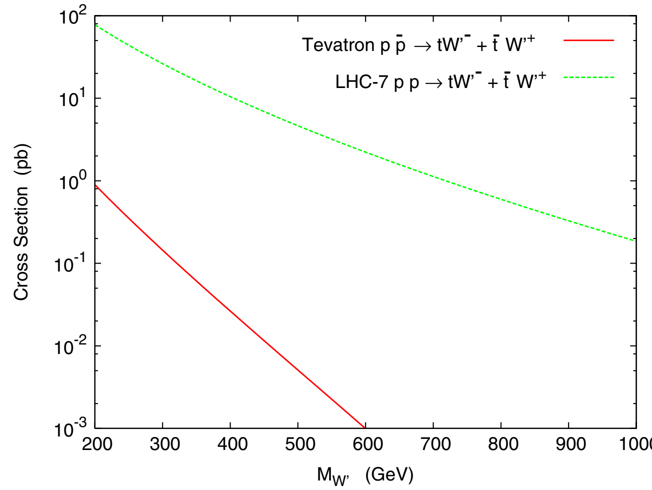

FIG. 3 (color online). Total cross section in pb for production of $p\bar{p} \to tW'^-$ and $\bar{t}W'^+$ at the Tevatron and $pp \to tW'^-$ and $\bar{t}W'^+$ at the LHC.

require the top quark that comes from the W' decay decays hadronically, in order to have a fully reconstructed top quark. On the other hand, we require the other top to decay semileptonically, in order to have cleaner jet combinations in the final state. We adopt a simple parton-level analysis with the energy momentum of the jets and leptons smeared by

$$\frac{\Delta E}{E} = \frac{1.0}{\sqrt{E}} \oplus 0.02.$$

We impose the following kinematic cuts for detection of the leptons and the jets

$$\text{Tevatron:}\begin{cases} p_{T_\ell} > 15\ \text{GeV}, & |\eta_\ell| < 2 \\ p_{T_j} > 15\ \text{GeV}, & |\eta_j| < 2 \end{cases} \quad (16)$$

at the Tevatron. The kinematic cuts for the LHC are

$$\text{LHC:}\begin{cases} p_{T_\ell} > 20\ \text{GeV}, & |\eta_\ell| < 2.5 \\ p_{T_j} > 20\ \text{GeV}, & |\eta_j| < 2.5. \end{cases} \quad (17)$$

We anticipate the most distinguishable distributions between the signal and background are the invariant mass M_{tj} and the cosine of the angle between the top quark (coming from the W' or the hadronic top in the background) and the jet. These distributions can show the difference between the signal and the background mainly due to the decay from the W' in the signal. On the other hand, the jet in the background most of the time radiates off an initial quark or gluon leg. Thus, there is no particular separable angle between the hadronic top and the quark, or a specific invariant mass for the (t, j). We show these distributions for the Tevatron in Fig. 4 and for the LHC-7 (7 TeV) in Fig. 5. For each W' of mass $M_{W'}$ we use the value of g' given in Table I. It is clear that the M_{tj} for the background is a continuum while that of the signal peaks around the W'

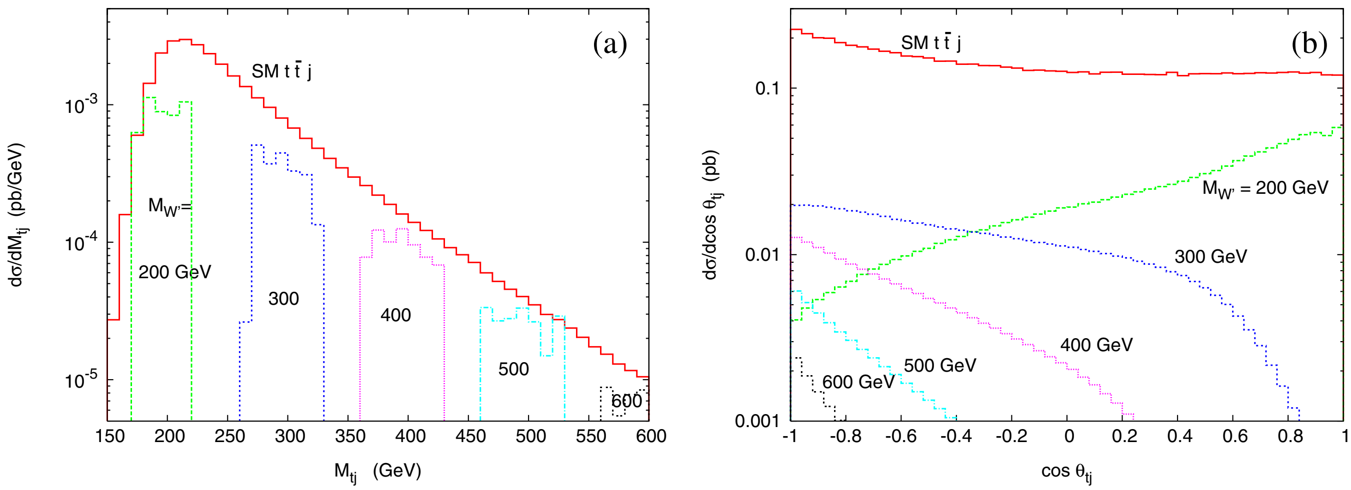

FIG. 4 (color online). Distributions of (a) the invariant mass and (b) cosine of the angle between the top quark and the jet for the Tevatron. Kinematic cuts given in Eq. (16) have been imposed.

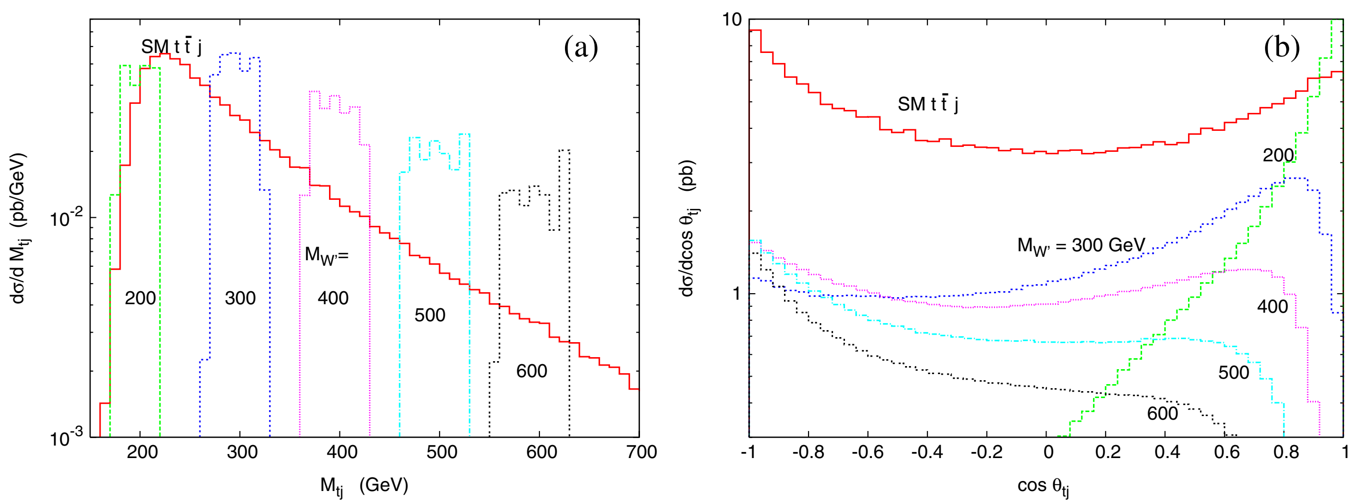

FIG. 5 (color online). Distributions of (a) the invariant mass and (b) cosine of the angle between the top quark and the jet for the LHC-7 (7 TeV). Kinematic cuts given in Eq. (17) have been imposed.

mass. Also, the $\cos\theta_{tj}$ shows that when the W' is light ($\sim$ 200 GeV) the opening angle between the top and the jet tends to be quite narrow, but this feature is lost when W' becomes heavier.

We perform an event counting for both the signal and background at the Tevatron and the LHC. For example, if we are searching for a 200 GeV W' we will look at the M_{tj} distribution and count the number of events under the range $200 \pm \Delta$ GeV. As indicated in Fig. 4 the spread of the resonance peak is about 10% of the W' mass at the Tevatron, so we choose $\Delta = 0.1 M_{W'}$. That is, we look under 200 ± 20, 300 ± 300, 400 ± 40, 500 ± 50 GeV for searches of 200–500 GeV W' resonances. In addition, we impose a cut of $\cos\theta_{tj} > 0$ for the search of 200 GeV W' but not the others. We show the number of events for the signal and background at the Tevatron for an integrated luminosity of 10 fb^{-1} in Table II. We repeat the same exercise for the LHC choosing the same $\Delta = 0.1 M_{W'}$, and show the number of events with an integrated luminosity of 0.1 and 1 fb^{-1} in Table III.

In Table II, the value of g' used for each $M_{W'}$ is according to what has been used to explain the top FBA. The ratio of S/B is about 0.5 for all $M_{W'}$ but the significance $S/\sqrt{B}$ ranges from about 11 to 1 for $M_{W'} = 200$–600 GeV. It is implied from Table II that Tevatron would have a good chance observing the W' up to about 400 GeV that could be the explanation for the top FBA. Furthermore, the observability improves substantially at the LHC-7. The chance of observing the W' all the way to 600 GeV is very promising at the LHC-7 with just 100 pb^{-1} luminosity, as shown by

TABLE II. The number of events for the W' signal and the background under the distribution $0.9M_{W'} < M_{tj} < 1.1M_{W'}$ with an integrated luminosity of 10 fb^{-1} at the Tevatron. An additional cut of $\cos\theta_{tj} > 0$ for the 200 GeV W' only.

$M_{W'}$ (GeV)	g'	Number of signal events S	Number of background events B	S/B	$S/\sqrt{B}$
200	0.85	285	640	0.44	11
300	1.2	210	460	0.46	9.8
400	1.5	67	130	0.52	5.9
500	1.8	19	40	0.48	3.0
600	2.1	5	14	0.36	1.3

TABLE III. The number of events for the W' signal and the background under the distribution $0.9M_{W'} < M_{tj} < 1.1M_{W'}$ with an integrated luminosity of $0.1(1\ \text{fb}^{-1})$ at the LHC. An additional cut of $\cos\theta_{tj} > 0$ for the 200 GeV W' only.

$M_{W'}$ (GeV)	g'	Number of signal events S	Number of background events B	S/B	$S/\sqrt{B}$
200	0.85	180(1800)	130(1300)	1.4	16(50)
300	1.2	270(2700)	170(1700)	1.6	21(65)
400	1.5	200(2000)	98(980)	2.0	20(64)
500	1.8	140(1400)	60(600)	2.3	18(57)
600	2.1	96(960)	39(390)	2.4	15(49)

the significance $S/\sqrt{B} = 15$–21 in Table III. Further improvement by increasing the luminosity to 1 fb^{-1} can push the significance to more than 50 at the LHC.

Similar analysis at the LHC can be found in Refs. [30,31]. There was another work using charge asymmetry at the LHC to probe the W' boson [32].

IV. CONCLUSIONS

We have shown that with a new particle exchanged in the t channel the forward-backward asymmetry in $t\bar{t}$ production increases with the invariant mass $M_{t\bar{t}}$ and the rapidity difference $|\Delta y|$. This is a generic feature for any particle exchanged in the t channel. We have also demonstrated that the new CDF data on FBA can be accommodated using a flavor-changing pure right-handed W' boson, which couples only to the d and t quarks with an appropriate coupling constant g'. We can bring the FBA to within 1.5σ of the data in the large $M_{t\bar{t}} > 450$ GeV region and within 1σ in the large rapidity difference $|\Delta y|$ region. The specific W' model that we proposed is consistent with existing data on the direct search and with flavor-changing current data. Some attempts to find a realistic model for such a flavor-changing gauge boson were in Ref. [33].

Furthermore, we have shown that such a W' up to about 400 GeV is readily observed at the Tevatron with an integrated luminosity of 10 fb^{-1}, and at the LHC with an integrated luminosity of 100 pb^{-1}, which should be within the current year of running. The signal-background analysis that we performed is based on parton-level calculations. More realistic simulation may be necessary. Nevertheless, the present work has indicated that the W' really has a good chance to be seen. The cleanest signal of the W' would be the sharp peak in the invariant mass M_{tj} distribution. By counting the number of events below the peak for the signal and background, the significance of the signal can reach a level of 10 at the Tevatron and a level of 60 at the LHC.

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