Supersymmetric electroweak corrections to single top quark production at the Fermilab Tevatron

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We calculate the $O(\alpha_{\rm ew}M_t^2/M_W^2)$ supersymmetric (SUSY) electroweak corrections to single top quark production via $q\overline{q'}\to t\overline{b}$ at the Fermilab Tevatron in the minimal supersymmetric model. The supersymmetric electroweak corrections to the cross section are at most a few percent for $\tan\beta>1$, but can exceed 10% for $\tan\beta<1$. The combined effects of SUSY electroweak corrections and the Yukawa corrections can exceed 10% for favorable parameter values, which might be observable at a high-luminosity Tevatron. [S0556-2821(97)04509-8]

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I. INTRODUCTION

The top quark has now been discovered by the Collider Detector at Fermilab (CDF) and D0 Collaborations at the Fermilab Tevatron [1]. Measurements of its mass are 176 ± 9 GeV and 170 ± 18 from CDF and D0, respectively, and the world-average value of the top quark mass from run I at the Tevatron was recently reported to be 175 ± 6 GeV, based on roughly 100 pb^{-1} of data [2]. At the Tevatron the dominant production mechanism of the top quark is the QCD pair production process $q\overline{q}\to t\overline{t}$ [3]. However, because the top quark is so heavy, electroweak production of single top quarks can become significant, particularly at the next Tevatron run II. With $\sqrt{s}=2$ TeV and an integrated luminosity of 2 fb^{-1} one can expect, in the standard model (SM), that for a 175 GeV top quark, there will be about $1.4\times10^4 t\overline{t}$ pairs and 5×10^3 single top quark events produced [4], which is about 35% of the total $t\overline{t}$ rate. After taking into account the b-tagging efficiency and the detection efficiency [5], there are about 1000 single-b-tagged $t\overline{t}$ pairs in the $l+$jets sample, 100 in the dilepton sample, and 250 single top events in the $l+$jets sample available for testing various properties of the top quark. Even with fewer events, single top quark production processes are important because they involve the electroweak interaction and, therefore, can probe the electroweak sector of the theory, in contrast to the QCD pair production mechanism, and provide a consistency check on the measured parameters of the top quark in the QCD pair production. At the Tevatron single top quarks are produced primarily via the W-gluon fusion process [6] and the Drell-Yan-type single top process, $q\overline{q'}\to W^*\to t\overline{b}$ (W^* process) [7], which can reliably be predicted in the SM. The theoretical uncertainty in the cross section is only about a few percent due to QCD corrections [8]. As analyzed in Ref. [9], the statistical error in the measured cross section for the W^* process at the Tevatron will be about $\pm30\%$; however, a high-luminosity Tevatron would allow a measurement of the cross section with a statistical uncertainty of about 6% [9]. At this level of experimental accuracy a calculation of the radiative corrections in the SM is necessary and effects beyond the SM, for example, supersymmetry (SUSY) corrections, should also be considered.

In Ref. [9] the QCD and Yukawa corrections to the W^* process have been calculated in the SM. In a previous paper [10] we calculated the Yukawa corrections to this process from the Higgs sector in the general two-Higgs-doublet model (2HDM) and the minimal supersymmetric standard model (MSSM) [11] and found that the corrections can amount to more than a 15% reduction in the production cross section relative to the tree level result in the 2HDM, and a 10% enhancement in the MSSM. However, in the MSSM, in addition to these Yukawa corrections from the Higgs sector, the supersymmetric (SUSY) corrections due to superparticles (sparticles) should also be taken into account. The dominant virtual effects of sparticles arise from the SUSY electroweak corrections of order $O(\alpha_{\rm ew}M_t^2/M_W^2)$ and the SUSY QCD corrections of order $O(\alpha_s)$ which arise from loops of charginos, neutralinos, and squarks, and gluinos and squarks. It is well known [12] that the anomalous magnetic moment for a spin-1/2 fermion vanishes in the SUSY limit and away from the SUSY limit there is a partial cancellation. Therefore, in general, one can expect the Yukawa corrections from the Higgs sector and the SUSY electroweak corrections from virtual charginos and neutralinos to cancel to some extent.

In this paper we present the calculation of the $O(\alpha_{\rm ew}M_t^2/M_W^2)$ SUSY electroweak corrections at the Fermilab Tevatron in the MSSM, and show the combined effect of including all the $O(\alpha_{\rm ew}M_t^2/M_W^2)$ terms from both Yukawa corrections and SUSY electroweak corrections. The $O(\alpha_s)$ SUSY QCD corrections will be given elsewhere [13]. The paper is organized as follows: In Sec. II we present the analytic results in terms of the well-known standard notation of one-loop Feynman integrals. In Sec. III we give some numerical examples and discuss the implications of our results.

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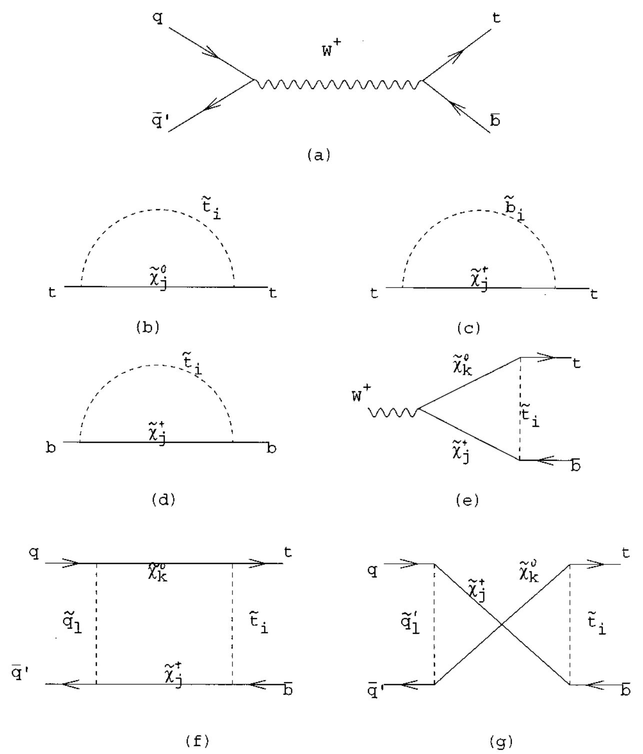

FIG. 1. Feynman diagrams for the SUSY electroweak (SUSY EW) corrections: (a) tree-level, (b)–(g) one-loop corrections.

II. CALCULATIONS

A. Formalism

In our calculations we used dimensional regularization to control all the ultraviolet divergences in the virtual loop corrections and we adopted the on-mass-shell renormalization scheme [14]. Including the $O(\alpha_{\rm ew}M_t^2/M_W^2)$ electroweak corrections, the renormalized amplitude for $q\overline{q'}\to t\overline{b}$ can be written as

$$M_{\rm ren}=M_0+\delta M^{\rm SUSY\ EW}, \tag{1}$$

where M_0 is the tree-level matrix element and $\delta M^{\rm SUSY\ EW}$ represents the SUSY electroweak corrections. The tree-level Feynman diagram for single top quark production via $q\overline{q'}\to t\overline{b}$ is shown in Fig. 1(a). The amplitude M_0 is given by

$$M_0=i\,\frac{g^2}{2}\,\frac{1}{\hat{s}-M_W^2}\,\overline{v}(p_2)\gamma_\mu P_L u(p_1)\overline{u}(p_3)\gamma^\mu P_L v(p_4). \tag{2}$$

The amplitude $\delta M^{\rm SUSY\ EW}$ is given in the following section. Here p_1 and p_2 denote the momentum of the incoming quarks q and $\overline{q'}$, while p_3 and p_4 are used for the outgoing t and $\overline{b}$ quarks, and $\hat{s}$ is the center-of-mass energy of the subprocess.

The renormalized differential cross section for the subprocess is

$$\frac{d\hat{\sigma}}{d\cos\theta}=\frac{\hat{s}-M_t^2}{32\pi\hat{s}^2}\overline{\sum}|M_{\rm ren}|^2, \tag{3}$$

where θ is the angle between the top quark and incoming quark. Integrating this differential cross section over $\cos\theta$ one obtains the cross section for subprocess

$$\hat{\sigma}=\hat{\sigma}_0+\Delta\hat{\sigma}, \tag{4}$$

where the tree-level cross section $\hat{\sigma}_0$ is given by

$$\hat{\sigma}_0=\frac{g^4}{128\pi}\frac{\hat{s}-M_t^2}{\hat{s}^2(\hat{s}-M_W^2)^2}\left[\tfrac{2}{3}(\hat{s}-M_t^2)^2+(\hat{s}-M_t^2)(M_t^2+M_b^2)+2M_t^2M_b^2\right], \tag{5}$$

and $\Delta\hat{\sigma}$ represents the SUSY electroweak corrections.

The total hadronic cross section for the single production of top quarks via $q\overline{q'}$ can be written in the form

$$\sigma(s)=\sum_{i,j}\int dx_1dx_2\hat{\sigma}_{ij}(x_1x_2s,M_t^2,\mu^2)[f_i^A(x_1,\mu)f_j^B(x_2,\mu)+(A\leftrightarrow B)], \tag{6}$$

where

$$s=(P_1+P_2)^2, \tag{7}$$

$$\hat{s}=x_1x_2s, \tag{8}$$

$$p_1=x_1P_1, \tag{9}$$

and

$$p_2=x_2P_2. \tag{10}$$

Here A and B denote the incident hadrons and P_1 and P_2 are their four-momenta, while i,j are the initial partons and x_1 and x_2 are their longitudinal momentum fractions. The functions f_i^A and f_j^B are the usual parton distributions [15,16]. Finally, introducing the convenient variable $\tau=x_1x_2$ and changing independent variables, the total cross section becomes

$$\sigma(s)=\sum_{i,j}\int_{\tau_0}^1\frac{d\tau}{\tau}\left(\frac{1}{s}\frac{dL_{ij}}{d\tau}\right)(\hat{s}\hat{\sigma}_{ij}), \tag{11}$$

where $\tau_0=(M_t+M_b)^2/s$. The quantity $dL_{ij}/d\tau$ is the parton luminosity, which is defined to be

$$\frac{dL_{ij}}{d\tau}=\int_\tau^1\frac{dx_1}{x_1}[f_i^A(x_1,\mu)f_j^B(\tau/x_1,\mu)+(A\leftrightarrow B)]. \tag{12}$$

B. SUSY electroweak corrections

The SUSY electroweak corrections of order $\alpha_{\rm ew}M_t^2/M_W^2$ to the process $q\overline{q'}\to t\overline{b}$ arise from the Feynman diagrams shown in Figs. 1(b)–(g). The matrix element for these corrections can be written as

$$\delta M^{\rm SUSY\ EW}=\delta M_{Wtb}^{\rm SUSY\ EW}+\delta M_{\rm box}+\delta M_{\rm box}^c, \tag{13}$$

where $\delta M_{Wtb}^{\rm SUSY\ EW}$ represents corrections arising from the self-energy diagrams and vertex diagrams [Figs. 1(b)–(e)], while $\delta M_{\rm box}$ and $\delta M^{c}_{\rm box}$ correspond to the box diagram [Fig. 1(f)] and crossed box diagram [Fig. 1(g)], respectively. $\delta M^{\rm SUSY\ EW}_{Wt\bar{b}}$ is given by

$$\delta M^{\rm SUSY\ EW}_{Wt\bar{b}}=i\,\frac{g^2}{2}\,\frac{1}{\hat{s}-M_W^2}\,\overline{v(p_2)}\,\gamma_\mu P_L u(p_1)\overline{u(p_3)}\times[\gamma^\mu P_L(\tfrac{1}{2}\delta Z_L^t+\tfrac{1}{2}\delta Z_L^b+E_1^L)+p_3^\mu P_L E_2^L+p_4^\mu P_L E_3^L]v(p_4). \tag{14}$$

The renormalization constants and form factors in Eq. (14) are

$$\delta Z_L^t=\frac{1}{8\pi^2}\left[|R_{\tilde{t}_i\tilde{\chi}_j^0}|^2\left(-\frac{\Delta}{2}+F_1^{(t\tilde{\chi}_j^0\tilde{t}_i)}\right)+2M_tM_{\tilde{\chi}_j^0}L_{\tilde{t}_i\tilde{\chi}_j^0}R^*_{\tilde{t}_i\tilde{\chi}_j^0}G_0^{(t\tilde{\chi}_j^0\tilde{t}_i)}+M_t^2(|R_{\tilde{t}_i\tilde{\chi}_j^0}|^2+|L_{\tilde{t}_i\tilde{\chi}_j^0}|^2)G_1^{(t\tilde{\chi}_j^0\tilde{t}_i)}\right]+\frac{g^2}{32\pi^2}\,\lambda_t^2L_{\tilde{b}_i}^2|V_{j2}|^2M_t^2G_1^{(t\tilde{\chi}_j^+\tilde{b}_i)}, \tag{15}$$

$$\delta Z_L^b=\frac{g^2}{32\pi^2}\,\lambda_t^2R_{\tilde{t}_i}^2|V_{j2}|^2\left(-\frac{\Delta}{2}+F_1^{(b\tilde{\chi}_j^+\tilde{t}_i)}\right), \tag{16}$$

$$E_1^L=\frac{g}{8\sqrt{2}\pi^2}\,\lambda_tV_{j2}^*R_{\tilde{t}_i}\{R_{\tilde{t}_i\tilde{\chi}_k^0}O_{kj}^{R*}M_{\tilde{\chi}_j^+}M_{\tilde{\chi}_k^0}c_0+L_{\tilde{t}_i\tilde{\chi}_k^0}O_{kj}^{R*}M_{\tilde{\chi}_j^+}M_t(c_0+c_{12})+L_{\tilde{t}_i\tilde{\chi}_k^0}O_{kj}^{L*}M_{\tilde{\chi}_k^0}M_tc_{12}+R_{\tilde{t}_i\tilde{\chi}_k^0}O_{kj}^{L*}[M_t^2(c_{22}-c_{23})+\hat{s}(c_{12}+c_{23})+2c_{24}-\tfrac{1}{2}]\}, \tag{17}$$

$$E_2^L=-\frac{g}{4\sqrt{2}\pi^2}\,\lambda_tV_{j2}^*R_{\tilde{t}_i}O_{kj}^{L*}[L_{\tilde{t}_i\tilde{\chi}_k^0}M_{\tilde{\chi}_k^0}c_{12}+R_{\tilde{t}_i\tilde{\chi}_k^0}M_t(c_{12}+c_{22})], \tag{18}$$

and

$$E_3^L=\frac{g}{4\sqrt{2}\pi^2}\,\lambda_tV_{j2}^*R_{\tilde{t}_i}[L_{\tilde{t}_i\tilde{\chi}_k^0}O_{kj}^{R*}M_{\tilde{\chi}_j^+}(c_0+c_{11})-R_{\tilde{t}_i\tilde{\chi}_k^0}O_{kj}^{L*}M_t(c_{12}+c_{23})], \tag{19}$$

where sums over i,j,k are implied and the functions $c_{ij}(p_4,p_3,M_{\tilde{\chi}_j^+},M_{\tilde{t}_i},M_{\tilde{\chi}_k^0})$ are the three-point Feynman integrals [17]. $\Delta\equiv(1/\epsilon)-\gamma_E+\ln 4\pi$ with γ_E being the Euler constant and $D=4-2\epsilon$ is the space-time dimension. The functions $F_{0,1}^{(ijk)}$, $G_{0,1}^{(ijk)}$ and constants in the above equations are defined as

$$F_n^{(ijk)}=\int_0^1 dy\,y^n\ln\left[\frac{m_i^2y(y-1)+m_j^2(1-y)+m_k^2y}{\mu^2}\right], \tag{20}$$

$$G_n^{(ijk)}=-\int_0^1 dy\,\frac{y^{n+1}(1-y)}{m_i^2y(y-1)+m_j^2(1-y)+m_k^2y}, \tag{21}$$

$$\lambda_t=\frac{M_t}{M_W\sin\beta}, \tag{22}$$

$$L_{\tilde{q}_1}=\cos\theta_{\tilde{q}},\quad L_{\tilde{q}_2}=-\sin\theta_{\tilde{q}}, \tag{23}$$

$$R_{\tilde{q}_1}=\sin\theta_{\tilde{q}},\quad R_{\tilde{q}_2}=\cos\theta_{\tilde{q}}, \tag{24}$$

$$L_{\tilde{q}_1\tilde{\chi}_j^0}=A_j\cos\theta_{\tilde{q}}-C_j\sin\theta_{\tilde{q}}, \tag{25}$$

$$L_{\tilde{q}_2\tilde{\chi}_j^0}=-A_j\sin\theta_{\tilde{q}}-C_j\cos\theta_{\tilde{q}}, \tag{26}$$

$$R_{\tilde{q}_1\tilde{\chi}_j^0}=-A_j^*\sin\theta_{\tilde{q}}+B_j\cos\theta_{\tilde{q}}, \tag{27}$$

$$R_{\tilde{q}_2\tilde{\chi}_j^0}=-A_j^*\cos\theta_{\tilde{q}}-B_j\sin\theta_{\tilde{q}}, \tag{28}$$

$$O_{ij}^L=-\frac{1}{\sqrt{2}}\,N_{i4}V_{j2}^*+N_{i2}V_{j1}^*, \tag{29}$$

and

$$O_{ij}^R=\frac{1}{\sqrt{2}}\,N_{i3}^*U_{j2}+N_{i2}^*U_{j1}, \tag{30}$$

where θ_q is the mixing angle of squark $\tilde{q}$, the matrix elements U_{ij} and V_{ij} depend on parameters M, μ, $\tan\beta$, whose expressions can be found in Ref. [11], and

$$A_j=\frac{gm_qN_{j4}^*}{2M_W\sin\beta},\quad B_j=C_j^*+\frac{gN_{j2}'}{2C_W}, \tag{31}$$

$$C_j=\frac{2}{3}\,eN_{j1}'^*-\frac{2}{3}\,\frac{gS_W^2}{C_W}\,N_{j2}'^*, \tag{32}$$

$$N_{j1}'=N_{j1}C_W+N_{j2}S_W, \tag{33}$$

$$N_{j2}'=-N_{j1}S_W+N_{j2}C_W. \tag{34}$$

In the above $S_W\equiv\sin\theta_W$ and $C_W\equiv\cos\theta_W$. m_q is the mass of the quark whose corresponding squark $\tilde{q}$ appears in Eqs. (25)–(28). The chargino masses $M_{\tilde{j}}$ depend on parameters M, μ, and $\tan\beta$, whose expressions can be found in Ref. [11]. The neutralino masses $M_{\tilde{\chi}_j^0}$ and matrix elements N_{ij} are obtained by diagonalizing the neutralino mass matrix Y [11]. Given the values of the parameters M, M', μ and $\tan\beta$, the matrix N and $M_{\tilde{\chi}_j^0}$ can be obtained numerically. Here, μ is the coefficient of the H_1-H_2 mixing term in the superpotential and M and M' are the masses of gauginos corresponding to SU(2) and U(1), respectively. With the grand unification assumption, i.e., SU(2)×U(1) is embedded in some grand unified theory, we have the additional relation $M'=5/3(g'^2/g^2)M$.

The box diagram amplitude $\delta M_{\rm box}$ is

$$\delta M_{\rm box}=i\overline{u(p_3)}[(f_1^bP_R+f_2^bP_L+f_3^b\not p_4P_R+f_4^b\not p_4P_L)u(p_1)\overline{v(p_2)}\not p_3P_L+(f_5^b\gamma^\mu P_R+f_6^b\gamma^\mu P_L)u(p_1)\overline{v(p_2)}\gamma^\mu P_L]v(p_4). \tag{35}$$

Here the form factors $f_{1,3,5}^b$ are

$$f_1^b=-\frac{g^2}{8\sqrt{2}\pi^2}\lambda_tV_{j1}V_{j2}^*R_{\tilde{t}_i}L_{\tilde{q}_l}L^*_{\tilde{q}_l\tilde{\chi}_k^0}[L_{\tilde{t}_i\tilde{\chi}_k^0}M_t(D_{12}-D_{13}+D_{22}-D_{26})+R_{\tilde{t}_i\tilde{\chi}_k^0}M_{\chi_k^0}(D_{12}-D_{13})], \tag{36}$$

$$f_3^b=-\frac{g^2}{8\sqrt{2}\pi^2}\lambda_tV_{j1}V_{j2}^*R_{\tilde{t}_i}L_{\tilde{q}_l}L^*_{\tilde{q}_l\tilde{\chi}_k^0}L_{\tilde{t}_i\tilde{\chi}_k^0}\times(D_{12}-D_{13}+D_{24}-D_{2k}), \tag{37}$$

$$f_5^b=-\frac{g^2}{8\sqrt{2}\pi^2}\lambda_tV_{j1}V_{j2}^*R_{\tilde{t}_i}L_{\tilde{q}_l}L^*_{\tilde{q}_l\tilde{\chi}_k^0}L_{\tilde{t}_i\tilde{\chi}_k^0}D_{27}, \tag{38}$$

and $f_{2,4,6}^b$ can be obtained through the permutation

$$f_{2,4,6}^b=f_{1,3,5}^b|_{L_{\tilde{t}_i\tilde{\chi}_k^0}\leftrightarrow R_{\tilde{t}_i\tilde{\chi}_k^0},L_{\tilde{q}_l\tilde{\chi}_k^0}\to R_{\tilde{q}_l\tilde{\chi}_k^0}}. \tag{39}$$

The sums over i,j,k,l are implied and the functions $D_{ij}(p_4,p_3,-p_1,M_{\tilde{\chi}_j^+},M_{\tilde{t}_i},M_{\tilde{\chi}_k^0},M_{\tilde{q}_l})$ are the four-point Feynman integrals [17].

The amplitude for the crossed box diagram $\delta M^c_{\rm box}$ is

$$\delta M^c_{\rm box}=-i\overline{u(p_3)}[f_1^cP_L+f_2^cP_R+f_3^c\not p_4P_L+f_4^c\not p_4P_R]u(p_2)\overline{v(p_1)}P_Lv(p_4), \tag{40}$$

where the form factors f_n^c are

$$f_1^c=-\frac{g^2}{8\sqrt{2}\pi^2}\lambda_tU_{j1}^*V_{j2}^*R_{\tilde{t}_i}L_{\tilde{q}'_l}L'_{\tilde{q}'_l\tilde{\chi}_k^0}M_{\chi_j^+}\times[M_tR_{\tilde{t}_i\tilde{\chi}_k^0}(D_0+D_{12})+M_{\chi_k^0}L_{\tilde{t}_i\tilde{\chi}_k^0}D_0], \tag{41}$$

$$f_2^c=-\frac{g^2}{8\sqrt{2}\pi^2}\lambda_tU_{j1}^*V_{j2}^*R_{\tilde{t}_i}L_{\tilde{q}'_l}R'_{\tilde{q}'_l\tilde{\chi}_k^0}M_{\chi_j^+}\times[M_tL_{\tilde{t}_i\tilde{\chi}_k^0}(D_0+D_{12})+M_{\chi_k^0}R_{\tilde{t}_i\tilde{\chi}_k^0}D_0], \tag{42}$$

$$f_3^c=-\frac{g^2}{8\sqrt{2}\pi^2}\lambda_tU_{j1}^*V_{j2}^*R_{\tilde{t}_i}L_{\tilde{q}'_l}L'_{\tilde{q}'_l\tilde{\chi}_k^0}M_{\chi_j^+}R_{\tilde{t}_i\tilde{\chi}_k^0}(D_0+D_{11}), \tag{43}$$

and

$$f_4^c=-\frac{g^2}{8\sqrt{2}\pi^2}\lambda_tU_{j1}^*V_{j2}^*R_{\tilde{t}_i}L_{\tilde{q}'_l}R'_{\tilde{q}'_l\tilde{\chi}_k^0}M_{\chi_j^+}L_{\tilde{t}_i\tilde{\chi}_k^0}(D_0+D_{11}). \tag{44}$$

The sums over i,j,k,l are again implied and the functions $D_{ij}(p_4,p_3,-p_2,M_{\tilde{\chi}_j^+},M_{\tilde{t}_i},M_{\tilde{\chi}_k^0},M_{\tilde{q}'_l})$ are the four-point Feynman integrals [17]. The constants $L'_{\tilde{q}_i\tilde{\chi}_j^0},R'_{\tilde{q}_i\tilde{\chi}_j^0}$ are defined by

$$L'_{\tilde{q}_1\tilde{\chi}_j^0}=A'_j\cos\theta_{\tilde{q}}-C'_j\sin\theta_{\tilde{q}}, \tag{45}$$

$$L'_{\tilde{q}_2\tilde{\chi}_j^0}=-A'_j\sin\theta_{\tilde{q}}-C'_j\cos\theta_{\tilde{q}}, \tag{46}$$

$$R'_{\tilde{q}_1\tilde{\chi}_j^0}=-A'^*_j\sin\theta_{\tilde{q}}+B'_j\cos\theta_{\tilde{q}}, \tag{47}$$

and

$$R'_{\tilde{q}_2\tilde{\chi}_j^0}=-A'^*_j\cos\theta_{\tilde{q}}-B'_j\sin\theta_{\tilde{q}}, \tag{48}$$

with

$$A'_j=\frac{gm_qN_{j3}^*}{2M_W\cos\beta},\quad B'_j=C'^*_j-\frac{gN'_{j2}}{2C_W}, \tag{49}$$

and

$$C'_j=-\frac{1}{3}eN'^*_{j1}+\frac{1}{3}\frac{gS_W^2}{C_W}N'^*_{j2}. \tag{50}$$

III. NUMERICAL RESULTS AND CONCLUSION

In the following we present numerical results for the corrections to the total cross section for single top quark production via $q\overline{q'}\to t\overline{b}$ at the Fermilab Tevatron with $\sqrt{s}=2$ TeV. In our numerical calculations we used the Martin-Roberts-Stirling set G (M.R.S.G.) parton distribution functions [16] and chose the scale $\mu=\sqrt{\hat{s}}$. Also we neglected SUSY corrections to the parton distribution functions. For the parameters involved, we chose $M_Z=91.188$ GeV, $M_W=80.33$ GeV, $M_t=175$ GeV, $M_b=5$ GeV, and $\alpha_{\rm ew}=\frac{1}{128}$. Other parameters were determined as follows.

(i) The upper bound on $\tan\beta$; viz., $\tan\beta<0.52\ {\rm GeV}^{-1}M_{H^+}$, was determined from data on $B\to\tau\nu X$ [18]. The lower limits on $\tan\beta$ are $\tan\beta>0.6$ from perturbative bounds [19] and $\tan\beta>0.25$ (for $M_t=175$ GeV) from perturbative unitarity [19]. We limited the value of $\tan\beta$ to be in the range of 0.25 to 5, as larger values of $\tan\beta$ are not interesting, although allowed by the current data [18], since the effects are negligibly small.

(ii) For the parameters $M_{\tilde{t}_R}$, $M_{\tilde{t}_L}$, $\tan\beta$, and $M_{LR}\equiv A_t+\mu\cot\beta$ in top squark mass matrix [20]

$$M^2_{\tilde{t}}=\begin{pmatrix} M^2_{\tilde{t}_L}+m_t^2+0.35\cos(2\beta)M_Z^2 & -m_t(A_t+\mu\cot\beta) \\ -m_t(A_t+\mu\cot\beta) & M^2_{\tilde{t}_R}+m_t^2+0.16\cos(2\beta)M_Z^2 \end{pmatrix}, \tag{51}$$

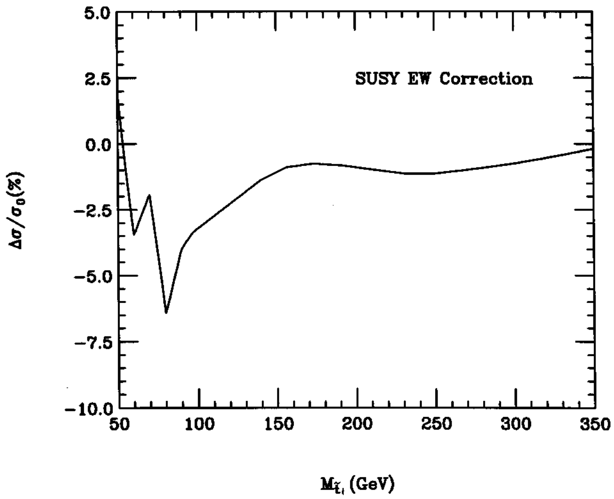

FIG. 2. The SUSY electroweak (SUSY EW) correction $\Delta\sigma/\sigma_0$ as a function of $M_{\tilde{t}_1}$, assuming tan β=1 and $M_{LR}=m_t$.

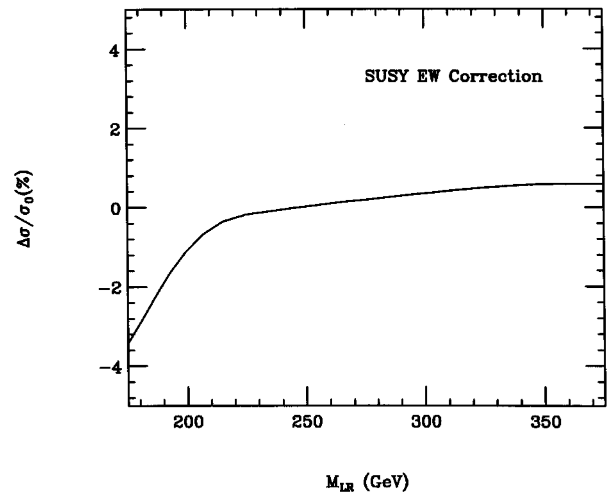

FIG. 3. The SUSY electroweak (SUSY EW) correction as a function of M_{LR}, assuming tan β=1 and $M_{\tilde{t}_1}=60$ GeV.

we assumed $M_{\tilde{t}_R}=M_{\tilde{t}_L}$. There are then three free parameters in the top squark sector and we chose the mass of the lighter top squarks $m_{\tilde{t}_l}$, M_{LR}, and tan β to be the three independent parameters. The best current lower bound on the top squark mass is 55 GeV coming from the CERN e^+e^- collider LEP, operating at $\sqrt{s}=130-140$ GeV [21]. We conservatively took the lower bound to be 50 GeV for $m_{\tilde{t}_1}$. For the other squarks; i.e., $\overline{q}, \overline{q'}$, and $\tilde{b}$, we neglected the mixing between left- and right-handed states and assumed $M_{\tilde{q}1}=M_{\tilde{q}2}M_{\tilde{q}'_1}=M_{\tilde{q}'_2}=M_{\tilde{b}_1}=M_{\tilde{b}_2}$ which was then determined by [20]

$$m^2_{\tilde{b}_1}=m^2_b+M^2_{\tilde{t}_L}+\cos(2\beta)(-\tfrac{1}{2}+\tfrac{1}{3}S^2_W)M^2_Z. \quad (52)$$

(iii) For the parameters M, M', μ, and tan β in the chargino and neutralino matrix, we put $M=200$ GeV, $\mu=-100$ GeV, and then used the relation $M'=(5/3)(g'^2/g^2)M$ [11] to determine M'.

Some typical numerical calculations of the SUSY electroweak corrections are given in Figs. 2–4.

Figure 2 shows the SUSY electroweak correction $\Delta\sigma/\sigma_0$ as a function of lighter top squark mass $M_{\tilde{t}_1}$, assuming tan β=1 and $M_{LR}=m_t$. The correction is only a few percent of the tree-level value σ and is quite sensitive to the lighter top squark mass. There are two peaks at about $M_{\tilde{t}_1}=75$ and 67 GeV due to the fact that $m_t=175$ GeV, $M_{\tilde{\chi}^0_j}=(100,107,128,221)$ GeV, and the threshold for open top decay into a neutralino and a lighter top squark is crossed in these regions.

Figure 3 gives the SUSY electroweak correction as a function of M_{LR}, assuming tan β=1 and $M_{\tilde{t}_1}=60$ GeV. This correction is also sensitive to M_{LR}. With increasing M_{LR} the mass splitting between the two top squarks increases. Since we fixed the mass of $\tilde{t}_1$, the mass of $\tilde{t}_2$ then increases with M_{LR}. Furthermore, with an increase of M_{LR},$M_{\tilde{t}_L}$ increases and thus the sbottom masses also increase, as seen from Eq. (52). Since we assumed the masses of the squarks $\tilde{q}_1$, $\tilde{q}_2$, $\tilde{q}_1$, and $\tilde{q}'_2$ are degenerate with the sbottoms, these masses then also increase with M_{LR}. So, with an increase of M_{LR}, all the squark masses except the lighter stop increase and their virtual effects decrease due to decoupling effects. From Fig. 3 one sees that for $M_{LR}>200$ GeV the magnitude of the correction drops below one percent.

In Fig. 4 we present both the SUSY electroweak correction and the Yukawa correction [10] as a function of tan β. For the SUSY electroweak correction we assumed $M_{LR}=m_t$. Since both these corrections are proportional to $M^2_t/M^2_W\sin^2\beta$, they can be very large for small tan β. From Fig. 4 one sees that the SUSY electroweak correction exceeds -10% for tan $\beta<0.5$, and grows rapidly in size with decreasing tan β. As in the case of the Yukawa corrections, the SUSY electroweak corrections are negligibly small for tan $\beta>1$. Also, comparing the SUSY electroweak correction with the Yukawa correction in Fig. 4, one notes that the SUSY electroweak correction and Yukawa correction have opposite signs, and thus cancel to some extent. If the lighter

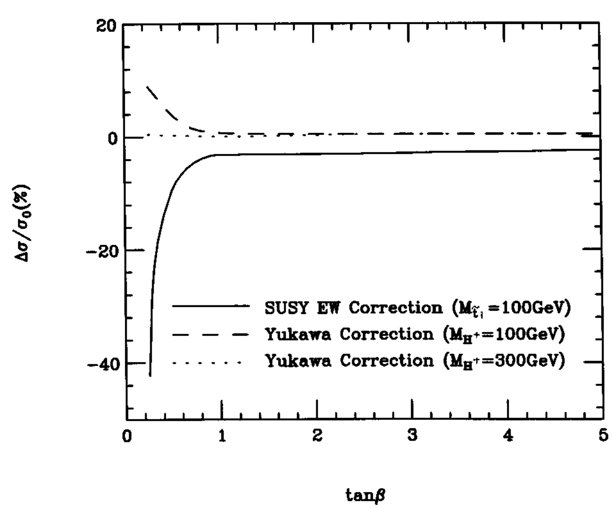

FIG. 4. The SUSY electroweak (SUSY EW) correction and the Yukawa correction as a function of tan β. $M_{LR}=m_t$ was assumed for the SUSY EW correction.

top squark has the same mass as the charged Higgs boson, the cancellation is appreciable. However, as seen in Fig. 4, if the charged Higgs boson is much heavier than the lighter top squark, the magnitude of Yukawa correction is much smaller than the SUSY electroweak correction and there is very little cancellation. In such a case the combined effects can exceed -10% for $\tan\beta<1$. Note that in Ref. [9] the QCD and leading electroweak corrections were calculated in the SM. While the QCD corrections were found to be quite large, the leading electroweak corrections were found to be negligibly small.

To summarize, the combined effects of SUSY electroweak corrections and the Yukawa corrections can exceed 10% for favorable values of the parameters. Since the cross section for single top quark production can be reliably predicted in the SM [9] and the statistical error in the measurement of the cross section will be about 6% at a high-luminosity Tevatron [9], these corrections may be observable; at the least, interesting new constraints on these models can be established.

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