Supersymmetric QCD Corrections to Top Quark Pair Production in Photon-Photon Collision

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ABSTRACT

Supersymmetric QCD corrections to top quark pair production by $\gamma\gamma$ fusion are calculated in the minimal supersymmetric standard model taking into account the effects of stops in the corrections to the total cross-section of $t\bar{t}$ production at the future $e^+e^-$ linear collider. We find that the relative correction can be a few percent for reasonable values of the parameters.

PACS number: 14.80Dq; 12.38Bx; 14.80.Gt

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1Work supported by the National Natural Science Foundation of China, the Fundamental Research Foundation of Tsinghua University, and the State Commission of Science and Technology of China
1. Introduction

Recently, the top quark was found experimentally by the CDF and D0 Collaborations at Fermilab\[1\]. The measured top-quark mass, $176 \pm 10^{+13}_{-12}$ GeV, is close to the central value of that obtained from the best fit of the standard model (SM) to the latest LEP data. This is a remarkable success of the SM. However, there are a number of unsolved theoretical puzzles in the SM, and the latest LEP data on the branching ratio $R_b$ of $Z \rightarrow b\bar{b}$ deviates from the SM prediction by 3.7 standard deviation\[2\]. These lead to more interest in considering possible new physics beyond the SM. Processes with top quarks may be good for testing new physics since the top quark is the heaviest particle yet found. Among various models of new physics so far considered, supersymmetry (SUSY) is a promising one at present. The simplest and interesting SUSY model is the minimal supersymmetric extension of the standard model (MSSM) \[3\]. For solving the gauge hierarchy problem, SUSY should be broken at energies around 1 TeV, and thus SUSY particles in the MSSM may be within the reach of future colliders. At the future $e^+e^-$ linear collider with center-of-mass energy 500 GeV to 1.5 TeV, the $e^+e^- \rightarrow t\bar{t}$ event rate would be around $10^4$/yr, comparable with the Tevatron, however, the events would be easier to extract. It is possible to separately measure all of the various production and decay form factors of the top quark at the level of a few percent \[4\]. Thus theoretical calculations of the radiative corrections to the production and decay of the top quark is of importance. SUSY corrections to $t\bar{t}$ pair production in $e^+e^-$ annihilation has been calculated in Ref.\[5\]. At the $e^+e^-$ linear collider, hard photons can be obtained by laser backscattering. The intense $\gamma$ beams are generated by backward Compton scattering of soft photons from a laser of a few eV energy \[6\]. The luminosity distribution over the
γγ invariant mass is broad and contains an abundant number of very energetic photons. The hard photon beam has approximately the same luminosity as the original electron beam. Therefore photon collisions are also good processes for testing new physics.

In this paper we investigate the SUSY QCD correction to the top quark production by the process γγ → t ¯t in MSSM model. In Sec. II, we give our calculation of the SUSY QCD corrections to the scattering cross-section. The numerical results of the cross-section are given in Sec III. In recent years there have been renewed interest in the possibility of very light gluinos, with mass \( m_{\tilde{g}} \leq 5 \text{ GeV} \). Our conclusion is that, with such light gluinos, the corrections can be large enough to be experimentally testable.

2. The Cross-Section

The total cross section of the production of \( t\bar{t} \) in γγ collisions at the \( e^+e^- \) collider is obtained by folding the elementary cross-section for the processes \( \gamma\gamma \rightarrow t\bar{t} \) with the photon luminosity \[\sigma_s = \int_{\sqrt{s}/\sqrt{s}}^{x_{\text{max}}} \frac{dL_{\gamma\gamma}}{dz} \sigma(\gamma\gamma \rightarrow t\bar{t} \text{ at } \hat{s} = z^2 \hat{s}), \]

where \( \sqrt{s}(\sqrt{\hat{s}}) \) is the \( e^+e^- (\gamma\gamma) \) center-of-mass energy and the quantity \( \frac{dL_{\gamma\gamma}}{dz} \) is the photon luminosity defined as \[\frac{dL_{\gamma\gamma}}{dz} = 2z \int_{x_{\text{max}}}^{x_{\text{max}}} \frac{dx}{x} F_{\gamma/e}(x) F_{\gamma/e}(z^2/x). \]

For unpolarized initial electrons and laser, the energy spectrum of the back-scattered photon is given by \[F_{\gamma/e} = \frac{1}{D(\xi)} [1 - x + \frac{1}{1 - x} - \frac{4x}{\xi (1 - x)} + \frac{4x^2}{\xi^2 (1 - x)^2}]. \]
\[ D(\xi) = (1 - \frac{4}{\xi} - \frac{8}{\xi^2}) \ln(1 + \xi) + \frac{1}{2} + \frac{8}{\xi^2} - \frac{1}{2(1 + \xi)^2}, \] (4)

where \( \xi = 4E_0\omega_0/m_e^2 \) with \( m_e \) and \( E_0 \) the incident electron mass and energy, respectively, and \( \omega_0 \) the laser-photon energy, \( x \) is the fraction of energy of the incident electron carried by the back-scattered photon. Following Ref.\[8\], we choose \( \xi \) and \( x_{\text{max}} \) to be

\[ \xi = 2(1 + \sqrt{2}) \approx 4.8, \quad x_{\text{max}} \approx 0.83, \quad D(\xi) \approx 1.8. \] (5)

The Feynman diagrams contributing to the SUSY O(\( \alpha_s \alpha_e \)) corrections are shown in Fig.1. In our calculation, we use dimensional regularization and take the on-shell renormalization scheme.

In Fig.1 one has to include the contributions of both stops. As is well-known [4], the supersymmetric partner of left- and right-handed massive quarks mix with each other. The mass eigenstates \( \tilde{q}_1 \) and \( \tilde{q}_2 \) are related to the current eigenstates \( \tilde{q}_L \) and \( \tilde{q}_R \) by

\[ \tilde{q}_1 = \tilde{q}_L \cos \theta_q + \tilde{q}_R \sin \theta_q, \quad \tilde{q}_2 = -\tilde{q}_L \sin \theta_q + \tilde{q}_R \cos \theta_q. \] (6)

The mixing angle \( \theta_q \) as well as the masses \( m_{\tilde{t}_1}, m_{\tilde{t}_2} \) of the physical stops can be calculated from the following mass matrices [10]

\[ M^2_t = \begin{pmatrix} m_{\tilde{t}_L}^2 + m_t^2 + 0.35D_Z & -m_t(A_t + \mu \cot \beta) \\ -m_t(A_t + \mu \cot \beta) & m_{\tilde{t}_R}^2 + m_t^2 + 0.16D_Z \end{pmatrix}, \] (7)

where \( D_Z = M_Z^2 \cos 2\beta \), \( \tan \beta \) is the ratio of the vacuum expectation values of the two neutral Higgs fields of the MSSM, \( m_{\tilde{t}_L}, m_{\tilde{t}_R} \) are soft breaking masses, \( A_t \) are parameters describing the strength of nonsupersymmetric trilinear scalar interactions, and \( \mu \) is the supersymmetric Higgs(ino) mass which also appears in the trilinear scalar vertices.
In the presence of squark mixing, the squark-quark-gluino interaction Lagrangian is given by

\[ L_{\tilde{g}\tilde{q}\bar{q}} = -i\sqrt{2}g_s T^a \tilde{q} \left[ (\cos\theta_q \tilde{q}_1 - \sin\theta_q \tilde{q}_2) \frac{1+i\gamma_5}{2} ight. \\
\left. - (\sin\theta_q \tilde{q}_1 + \cos\theta_q \tilde{q}_2) \frac{1-i\gamma_5}{2} \right] \tilde{g}^a_a + h.c. \]  

(8)

where \( g_s \) is the strong coupling constant and \( T^a \) are \( SU(3)_C \) generators.

To the precision of the \( \mathcal{O}(\alpha_s\alpha_e) \) SUSY corrections, the renormalized amplitude for \( \gamma\gamma \rightarrow t\bar{t} \) is

\[ M_{\text{ren}} = M_0 + \delta M^{\text{self}} + \delta M^{\text{vertex}} + \delta M^{\text{box}} + \delta M^{s}, \]  

(9)

where \( M_0 \) is the tree-level amplitude and \( \delta M \) represents SUSY QCD corrections, which are

\[ M_0 = \epsilon^\mu(p_4)e^{\nu}(p_3)\bar{u}(p_2), T_{\mu\nu}(p_1) \]  

(10)

with

\[ T_{\mu\nu} = \frac{-i4\pi\alpha_e}{t - m_t^2} \gamma_\mu(p_3 - \not{p}_1 + m_t)\gamma_\nu + \frac{-i4\pi\alpha_e}{u - m_t^2} \gamma_\nu(p_4 - \not{p}_1 + m_t)\gamma_\mu, \]  

(11)

and

\[ \delta M^{\text{self}} = \delta M^{\text{self}(t)} + \delta M^{\text{self}(u)} \]  

(12)

\[ \delta M^{\text{vertex}} = \delta M^{\text{vertex}(t)} + \delta M^{\text{vertex}(u)} \]  

(13)

\[ \delta M^{\text{box}} = \delta M^{\text{box}(t)} + \delta M^{\text{box}(u)}, \]  

(14)

\[ \delta M^{\text{self}(t)} = \epsilon^\mu(p_4)e^{\nu}(p_3)\bar{u}(p_2) \frac{Q_t^2}{(t - m_t^2)^2} \gamma_\mu(p_2 - \not{p}_1 + m_t)(-i\hat{\Sigma}) \\\n\times(p_3 - \not{p}_1 + m_t)\gamma_\nu v(p_1), \]  

(15)

\[ \delta M^{\text{vertex}(t)} = \epsilon^\mu(p_4)e^{\nu}(p_3)\bar{u}(p_2) \left\{ \frac{i}{t - m_t^2} [i\hat{\Lambda}_\mu^{(1)}(p_3 - \not{p}_1 + m_t) \\\n\times(-iQ_t^2\gamma_\nu) + (-iQ_t^2\gamma_\mu)(p_2 - \not{p}_1 + m_t)i\hat{\Lambda}_\mu^{(2)}] \right\} v(p_1), \]  

(16)
\[
\delta M^{\text{box}(t)} = \epsilon^\mu(p_4)\epsilon^{\nu}(p_3)\bar{u}(p_2)Q_t^2 \left\{ \gamma_\nu\gamma_\mu f_1^{\text{box}(t)} + \gamma_\mu\gamma_\nu f_2^{\text{box}(t)} + \gamma_1^{\nu}\gamma_\mu f_3^{\text{box}(t)} + \gamma_\mu\gamma_\nu f_4^{\text{box}(t)} + \gamma_\nu\gamma_\mu f_5^{\text{box}(t)} + \gamma_\mu\gamma_\nu f_6^{\text{box}(t)} + \gamma_\nu\gamma_\mu f_7^{\text{box}(t)} + \gamma_\mu\gamma_\nu f_8^{\text{box}(t)} + \gamma_\nu\gamma_\mu f_9^{\text{box}(t)} + \gamma_1^{\nu}\gamma_\mu f_{10}^{\text{box}(t)} + \gamma_\mu\gamma_\nu f_{11}^{\text{box}(t)} + \gamma_\nu\gamma_\mu f_{12}^{\text{box}(t)} + \gamma_\mu\gamma_\nu f_{13}^{\text{box}(t)} + \gamma_\nu\gamma_\mu f_{14}^{\text{box}(t)} + \gamma_\mu\gamma_\nu f_{15}^{\text{box}(t)} + \gamma_\nu\gamma_\mu f_{16}^{\text{box}(t)} + \gamma_1^{\nu}\gamma_\mu f_{17}^{\text{box}(t)} + \gamma_\mu\gamma_\nu f_{18}^{\text{box}(t)} + \gamma_\nu\gamma_\mu f_{19}^{\text{box}(t)} + \gamma_1^{\nu}\gamma_\mu f_{20}^{\text{box}(t)} \right\} v(p_1),
\]

(17)

\[
\delta M^s = \epsilon^\mu(p_4)\epsilon^{\nu}(p_3)\bar{u}(p_2)Q_t^2 S v(p_1),
\]

(18)

with

\[
-i\hat{\Sigma} = f^{t\Sigma}_1 + \hat{f}^{t\Sigma}_2
\]

(19)

\[
i\hat{\Lambda}^{(1)}_\mu = \gamma_\mu f^{(1)}_1 + p_2\nu f^{(1)}_2 + \hat{p}_4p_2\nu f^{(1)}_3
\]

(20)

\[
i\hat{\Lambda}^{(2)}_\nu = \gamma_\nu f^{(2)}_1 + p_1\nu f^{(2)}_2 + \hat{p}_3p_1\nu f^{(2)}_3
\]

(21)

where \(Q_t = 2/3\), \(S\) and the form-factors \(f_i\) are given in the Appendix. Instead of calculating the square of the amplitudes explicitly, we calculate the amplitudes numerically by using the method of Ref. [11]. This greatly simplifies our calculations.

We only explicitly give the results for the t-channel contributions to the SUSY corrections. The u-channel results can be obtained by the following substitutions

\[
p_3 \leftrightarrow p_4, \quad T^u \leftrightarrow T^b, \quad \hat{t} \leftrightarrow \hat{u}.
\]

(22)

3. Numerical Results and Conclusion

Now we present the numerical results. We take \(m_t = 176\) GeV, and use the two-loop running coupling constant \(\alpha_s\) and the input \(\alpha_e = 1/128\). For the SUSY
parameters involved in our calculations, we see that once \( \tan \beta \) and \( m_{\tilde{t}_L} \) are fixed, we are, in general, free to choose two independent parameters in the stop mass matrix, namely \( m_{\tilde{t}_R} \) and \( A_t + \mu \cot \beta \), or equivalently \( m_{\tilde{t}_R} \) and \( m_{\tilde{t}_L} \). To avoid the singularities at small angles, we take the following kinematical cuts

\[
|\eta| < 2.5, \quad p_T > 20 \text{ GeV}. \tag{23}
\]

In this kinematical region the relative corrections are actually large. In the numerical calculation, we have checked our program with the requirement of gauge invariance to the accuracy \( 10^{-10} \).

In Figs.2-8 we give the numerical results in a simple case in which we set \( \tan \beta = 1 \) and \( m_{\tilde{t}_L} = m_{\tilde{t}_R} = m_{\tilde{q}} \) (corresponding to the mixing angle equal to \( \pi/4 \)). We choose \( m_{\tilde{t}_1} \) as the light stop mass and require it to be heavier than 45 GeV \[ \Pi \].

Fig.2 (Fig.3) show the dependence of the corrections on \( m_{\tilde{t}_1} \) for fixed \( m_{\tilde{g}} = 3 \text{ GeV}, m_{\tilde{q}} = 150 \text{ GeV} \) (450 GeV) and \( \sqrt{s} = 0.5 \text{ TeV} \) (1.5 TeV). We see that the corrections can be either positive or negative depending on the light stop mass. The corrections become their negative maxima at \( m_{\tilde{t}_1} = 170 \text{ GeV} \). Fig.4 (Fig.5) show the dependence of the corrections on \( \sqrt{s} \) for fixed \( m_{\tilde{g}} = 3 \text{ GeV}, m_{\tilde{q}} = 450 \text{ GeV} \) and \( m_{\tilde{t}_1} = 50 \text{ GeV} \) (150 GeV). The corrections are positive when \( m_{\tilde{t}_1} = 50 \text{ GeV} \), and negative when \( m_{\tilde{t}_1} = 150 \text{ GeV} \). When \( \sqrt{s} \) varies from 0.5 TeV to 1.5 TeV, the corrections vary from 2\% (−3.6\%) to 0.9\% (−3.8\%) in the case of \( m_{\tilde{t}_1} = 50 \text{ GeV} \) (150 GeV).

Fig.6 (Fig.7) shows the dependence of the corrections on \( m_{\tilde{q}} \) for fixed \( m_{\tilde{g}} = 3 \text{ GeV}, m_{\tilde{t}_1} = 50 \text{ GeV} \) (150 GeV) and \( \sqrt{s} = 0.5 \text{ TeV} \) (1.5 TeV). The relative corrections increase (decrease) as \( m_{\tilde{q}} \) varies from 50 GeV to 450 GeV in the case of \( m_{\tilde{t}_1} = 50 \text{ GeV} \) (150 GeV). The largest relative correction in Fig.7 can exceed −5\%. Fig.8
shows the dependence of the corrections on $m_{\tilde{g}}$ for fixed $m_{\tilde{t}_1} = 150$ GeV, $m_{\tilde{q}} = 450$ GeV and $\sqrt{s} = 0.5$ TeV (1.5 TeV). If the gluinos are light\[7\], e.g. $m_{\tilde{g}} = 3$ GeV, the corrections can reach $-4\%$. Whereas for heavy gluinos as $m_{\tilde{g}} \geq 100$ GeV, the corrections are less than 1%.

We have also done the numerical calculations for $\tan\beta = 10$ and found that the corrections are not sensitive to the value of $\tan\beta$. For example, with $m_{\tilde{g}} = 3$ GeV, $m_{\tilde{t}_1} = 150$ GeV, $m_{\tilde{q}} = 450$ GeV and $\sqrt{s} = 0.5$ TeV, we get $\Delta\sigma = -3.60$ for $\tan\beta = 1$ and $\Delta\sigma = -3.58$ for $\tan\beta = 10$.

We conclude that, in the case with stop mixing and light gluinos like $m_{\tilde{g}}$ around a few GeV, the SUSY QCD corrections to the cross-section of top quark pair production in $\gamma\gamma$ fusion at the $e^+e^-$ collider can be as large as a few percent of the tree-level cross-section. This is experimentally testable.
Appendix

We give here the form factors for the matrix element. They are written in terms of the usual one-, two-, three- and four-point scalar loop integrals of Ref. [12].

\[ F_i = m_\tilde{g}(a_1^2 - b_1^2), \quad G_i = a_1^2 + b_1^2 \]  

(24)

\[ a_1 = -b_2 = \frac{1}{\sqrt{2}}(\cos \theta - \sin \theta), \quad a_2 = b_1 = \frac{1}{\sqrt{2}}(\cos \theta + \sin \theta) \]  

(25)

\[ f_{1\Sigma}^{(t)} = \frac{i4\alpha_s\alpha_e}{3} \sum_i [(F_iB_0 - m_iZV_i - DM_i)] \]  

(26)

\[ f_{2\Sigma}^{(t)} = \frac{i4\alpha_s\alpha_e}{3} \sum_i [G_i(B_0 + B_1) + ZV_i], \]  

(27)

where \( B_0, B_1(t, m_{\tilde{t}_i}, m_{\tilde{g}}) \) are 2-point Feynman integrals [12].

\[ f_{1\tilde{A}^{(t)}} = -\frac{i4\alpha_s\alpha_e}{3} \sum_i [2G_iC_{24} + ZV_i] \]  

(28)

\[ f_{2\tilde{A}^{(t)}} = -\frac{i4\alpha_s\alpha_e}{3} \sum_i [2G_im_i(C_{11} + C_{21}) - 2F_i(C_0 - C_{11})] \]  

(29)

\[ f_{5\tilde{A}^{(t)}} = -\frac{i4\alpha_s\alpha_e}{3} \sum_i [2G_i(-C_{12} - C_{23})], \]  

(30)

where \( C_0, C_{ij}(-p_2, p_4, m_{\tilde{g}}, m_{\tilde{t}_i}, m_{\tilde{t}_i}) \) are 3-point Feynman integrals [12].

\[ f_{1\tilde{A}^{(t)}} = -\frac{i4\alpha_s\alpha_e}{3} \sum_i [2G_iC_{24} + ZV_i] \]  

(31)

\[ f_{2\tilde{A}^{(t)}} = -\frac{i4\alpha_s\alpha_e}{3} \sum_i [2G_im_i(-C_{11} - C_{21}) + 2F_i(C_0 + C_{11})] \]  

(32)

\[ f_{5\tilde{A}^{(t)}} = -\frac{i4\alpha_s\alpha_e}{3} \sum_i [-2G_i(C_{12} + C_{23})], \]  

(33)

where \( C_0, C_{ij}(p_1, -p_3, m_{\tilde{g}}, m_{\tilde{t}_i}, m_{\tilde{t}_i}) \) are the 3-point Feynman integrals [12].

\[ f_{1\text{box}^{(t)}} = \frac{i4\alpha_s\alpha_e}{3} \sum_i [2F_iD_{27} - 2G_im_tD_{311}] \]  

(34)

\[ f_{2\text{box}^{(t)}} = \frac{i4\alpha_s\alpha_e}{3} \sum_i [2F_iD_{27} - 2G_im_tD_{311}] \]  

(35)
\[ f_{3}^{\text{box}(t)} = i \frac{4\alpha_s \alpha_e}{3} \sum_i [4G_i(D_{27} + D_{312})] \] (36)

\[ f_{4}^{\text{box}(t)} = i \frac{4\alpha_s \alpha_e}{3} \sum_i [4G_i D_{313}] \] (37)

\[ f_{5}^{\text{box}(t)} = i \frac{4\alpha_s \alpha_e}{3} \sum_i [4G_i(-D_{311} + D_{312})] \] (38)

\[ f_{6}^{\text{box}(t)} = i \frac{4\alpha_s \alpha_e}{3} \sum_i [4G_i(-D_{27} - D_{311} + D_{313})] \] (39)

\[ f_{7}^{\text{box}(t)} = i \frac{4\alpha_s \alpha_e}{3} \sum_i [4F_i(D_{13} + D_{26}) - 4G_i m_t(D_{25} + D_{310})] \] (40)

\[ f_{8}^{\text{box}(t)} = i \frac{4\alpha_s \alpha_e}{3} \sum_i [4F_i(-D_{25} + D_{26}) + 4G_i m_t(D_{35} - D_{310})], \] (41)

\[ f_{9}^{\text{box}(t)} = i \frac{4\alpha_s \alpha_e}{3} \sum_i [4F_i(-D_0 - D_{11} + D_{13} - D_{12} - D_{24} + D_{26}) + 4G_i \times m_t(D_{11} + D_{21} - D_{25} + D_{24} + D_{34} - D_{310})], \] (42)

\[ f_{10}^{\text{box}(t)} = i \frac{4\alpha_s \alpha_e}{3} \sum_i [4F_i(D_{11} - D_{12} + D_{21} - D_{24} - D_{25} + D_{26}) + 4G_i \times m_t(-D_{21} + D_{24} - D_{31} + D_{34} + D_{35} - D_{310})], \] (43)

\[ f_{11}^{\text{box}(t)} = i \frac{4\alpha_s \alpha_e}{3} \sum_i [2G_i(D_{312} - D_{313})] \] (44)

\[ f_{12}^{\text{box}(t)} = i \frac{4\alpha_s \alpha_e}{3} \sum_i [2G_i(D_{312} - D_{313})] \] (45)

\[ f_{13}^{\text{box}(t)} = 0 \] (46)

\[ f_{14}^{\text{box}(t)} = 0 \] (47)

\[ f_{15}^{\text{box}(t)} = 0 \] (48)

\[ f_{16}^{\text{box}(t)} = 0 \] (49)

\[ f_{17}^{\text{box}(t)} = i \frac{4\alpha_s \alpha_e}{3} \sum_i [4G_i(-D_{23} + D_{26} + D_{38} - D_{39})] \] (50)

\[ f_{18}^{\text{box}(t)} = i \frac{4\alpha_s \alpha_e}{3} \sum_i [4G_i(D_{37} + D_{38} - D_{39} - D_{310})], \] (51)

\[ f_{19}^{\text{box}(t)} = i \frac{4\alpha_s \alpha_e}{3} \sum_i [4G_i(D_{13} - D_{12} - D_{23} - D_{24} + D_{25} + 2D_{26} - D_{22} - D_{36} + D_{38} - D_{39} + D_{310})], \] (52)
\[ f_{20}^{\text{box}(t)} = \frac{i4\alpha_s\alpha_e}{3} \sum_i [4G_i(-D_{22} + D_{24} - D_{25} + D_{26} + D_{34} - D_{35} - D_{36} + D_{37} + D_{38} - D_{39})], \]

\[ S = \frac{8}{3} \alpha_s\alpha_e \sum_i [G_i m_t C_{11} - F_i C_0](-p_2, p_4, p_3, m_{\tilde{g}}, m_{\tilde{t}_i}, m_{\tilde{t}_i}), \]

where \( D_0, D_{ij}, D_{ijk}(-p_2, p_4, p_3, m_{\tilde{g}}, m_{\tilde{t}_i}, m_{\tilde{t}_i}, m_{\tilde{t}_i}) \) are 4-point Feynman integrals.[12]

The renormalization constants are

\[ ZV_i = -G_i[B_0 + B_1](p, m_{\tilde{t}_i}, m_{\tilde{g}})|_{p^2=m_t^2} - [2m_t^2G_i \frac{\partial^2}{\partial p^2}(B_0 + B_1) - 2m_t F_i \frac{\partial^2}{\partial p^2}B_0](p, m_{\tilde{t}_i}, m_{\tilde{g}})|_{p^2=m_t^2}, \]

\[ DM_i = [F_i B_0 + m_t G_i(B_0 + B_1)](p, m_{\tilde{t}_i}, m_{\tilde{g}})|_{p^2=m_t^2}. \]
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Figure Captions

**Fig.1** Tree-level Feynman diagrams and $O(\alpha_s \alpha_e)$ SUSY QCD corrections to $\gamma \gamma \to t\bar{t}$.

**Fig.2** Relative SUSY QCD corrections to $\gamma \gamma$ fusion cross-section versus $m_{\tilde{t}_1}$ for $m_{\tilde{g}} = 3$ GeV, $m_{\tilde{q}} = 150$ GeV.

**Fig.3** Same as fig.2, but for $m_{\tilde{g}} = 3$ GeV, $m_{\tilde{q}} = 450$ GeV.

**Fig.4** Same as Fig.2, but versus $\sqrt{s}$ for $m_{\tilde{g}} = 3$ GeV, $m_{\tilde{t}_1} = 50$ GeV, $m_{\tilde{q}} = 450$ GeV.

**Fig.5** Same as Fig.2, but versus $\sqrt{s}$ for $m_{\tilde{g}} = 3$ GeV, $m_{\tilde{t}_1} = 150$ GeV, $m_{\tilde{q}} = 450$ GeV.

**Fig.6** Same as Fig.2, but versus $m_{\tilde{q}}$ for $m_{\tilde{g}} = 3$ GeV, $m_{\tilde{t}_1} = 50$ GeV.

**Fig.7** Same as Fig.2, but versus $m_{\tilde{q}}$ for $m_{\tilde{g}} = 3$ GeV, $m_{\tilde{t}_1} = 150$ GeV.

**Fig.8** Same as Fig.2, but versus $m_{\tilde{g}}$ for $m_{\tilde{g}} = 450$ GeV, $m_{\tilde{t}_1} = 150$ GeV.
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