LOOP-INDUCED SUSY EFFECTS IN STRONG TOP PAIR PRODUCTION

D. WACKEROTH

Theory Group F1, Paul Scherrer Institut,
CH-5232 Villigen PSI, Switzerland
E-mail: wackeroth@psi.ch

We present some results of the calculation of MSSM one-loop contributions to strong \( t\bar{t} \) production in hadronic collisions. Here we concentrate on the MSSM electroweak-like \( O(\alpha) \) and SQCD \( O(\alpha_s) \) corrections to the main production mechanism at the Fermilab Tevatron \( pp \) collider, \( q\bar{q} \rightarrow g \rightarrow t\bar{t} \). We give results for the total \( t\bar{t} \) production rate and for parity violating asymmetries in the production of left and right handed top quark pairs.

1 Introduction

The potential of future hadron colliders to perform precision measurements of top quark observables is the motivation for an ongoing study on loop effects in strong \( t\bar{t} \) production within the Electroweak Standard Model (SM) and beyond. While the SM electroweak (EW) corrections have only marginal effects on \( t\bar{t} \) observables such as the total \( t\bar{t} \) production rate \( \sigma(S) \), the invariant \( t\bar{t} \) mass distribution \( d\sigma/dM_{t\bar{t}} \) and parity violating asymmetries \( A_{LR} \) in the production of left and right handed top quark pairs, there is the possibility of considerable enhancements within supersymmetric models. The ongoing study of radiative corrections to these observables within the Minimal Supersymmetric extension of the SM (MSSM) reveals promisingly large effects at both the upgraded Tevatron and the LHC. At the LHC, for instance, the MSSM EW-like corrections typically diminish the leading order production cross section \( \sigma_B \) by \( \lesssim 10\% \), they can significantly distort \( d\sigma/dM_{t\bar{t}} \) and they induce asymmetries of \( A_{LR} \sim 3\% \). In this contribution we will concentrate on combining the MSSM EW-like \( O(\alpha) \) and SQCD \( O(\alpha_s) \) corrections to the main production mechanism at the Fermilab Tevatron \( pp \) collider, \( q\bar{q} \rightarrow g \rightarrow t\bar{t} \). We will present first results for \( \sigma(\sqrt{S} = 2 \text{ TeV}) \) and \( A_{LR} \).

2 Loop-induced SUSY effects in \( pp, pp \rightarrow t\bar{t}X \)

At the parton level, the next-to-leading order differential cross sections for polarized \( t\bar{t} \) production via the \( q\bar{q} \) annihilation and gluon fusion subprocesses

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are obtained by contracting the corresponding matrix elements describing the loop contributions \( \delta M_i(i = q\bar{q}, gg) \) with the Born matrix elements \( M'_{li} \):

\[
\frac{d\sigma_i(\hat{s}, \hat{t}, \lambda_i, \lambda_{\bar{i}})}{d\cos\theta} = \frac{\beta_t}{32\pi\hat{s}} \sum\left[ |M'_{li}|^2 + 2Re\sum(\delta M_i \times M'_{li}) \right] + \text{higher order},
\]

where \( \beta_t \) is the top quark velocity and \( \lambda_i, \lambda_{\bar{i}} \) denote the \( t(\bar{t}) \) helicity states. \( s, \hat{t} \) are Mandelstam variables and \( \hat{\theta} \) is the scattering angle of the top quark in the parton CMS. \( \delta M_{gq} \) comprises the EW(-like) \( \mathcal{O}(\alpha) \) and SQCD \( \mathcal{O}(\alpha_s) \) corrections. So far we only included EW(-like) corrections to the gluon fusion subprocess described by \( \delta M_{gg} \); the SQCD calculation is work in progress.

We studied the effects of EW(-like) corrections on unpolarized \( t\bar{t} \) observables\(^2\). Parity violating effects in the production of left and right handed top quark pairs which are loop induced through EW(-like) interactions are discussed in \(^3\). In the following calculation of the SQCD \( \mathcal{O}(\alpha_s) \) corrections we will closely follow the notation of \(^4\) and \(^6\) and refer to it for more details.

### 2.1 SQCD \( \mathcal{O}(\alpha_s) \) corrections to \( q\bar{q} \rightarrow g \rightarrow t\bar{t} \)

In Fig. \(^1\) we display the Feynman diagrams contributing to the SQCD \( \mathcal{O}(\alpha_s) \) corrections to \( q\bar{q} \rightarrow g \rightarrow t\bar{t} \). The corresponding contribution to \( d\sigma q\bar{q} \) of Eq. \(^1\) reads \( z = \cos\hat{\theta} \):

\[
2Re\sum (\delta M_{\bar{q}q}^{SQCD} \times M'_{B}) = \sum |M'_{B}|^2 \frac{\alpha_s}{2\pi}Re\left(F_V(s, m_q) + F_V(s, m_t) + \tilde{\Pi}(s)\right) + \frac{4\pi\alpha_s^3}{9}Re\left(\beta_t^2(1 - z^2)(1 + 4\lambda_\lambda_{\bar{t}})F_M(s, m_t) + 2(\lambda_t - \lambda_{\bar{t}})[2zG_A(s, m_q) + \beta_t(1 + z^2)G_A(s, m_t)]\right) + \frac{32\pi\alpha_s^3}{9\hat{s}} \frac{1}{4}Re\left( -\frac{7}{3}B_t - \frac{2}{3}B_u \right)(s, \hat{t}),
\]

where the vertex corrections are parametrized in terms of UV finite form factors \( F_V, F_M \) and \( G_A \), \( \Pi(s) = \Pi(s) - \Pi(0) \) denotes the subtracted gluon vacuum polarization and \( B_t \) and \( B_u \), respectively, parametrize the \( t \) and \( u \) channel box contributions. Their explicit expressions will be provided in \(^6\). In Fig. \(^2\)(a) we show separately their numerical impact on the total \( t\bar{t} \) production rate. We observe large cancellations between the vertex and box contributions\(^b\). Since we differ from \(^8\) in the overall sign of the box diagrams we feel a brief explanation is in order: to determine the relative sign between the \( t \) and \( u \) channel box diagram (as well as between box and Born contribution) we apply the rules of \(^9\). Fixing the reference order as
2.2 Loop-induced EW-like and SQCD effects in $p\bar{p} \rightarrow t\bar{t}X$ at the Tevatron

The hadronic cross section $\sigma_{\lambda_1,\lambda_2}(S)$ to polarized $t\bar{t}$ production is obtained by convoluting $\hat{\sigma}_i$ of Eq. 1 with the corresponding parton distribution functions. We introduce a relative correction $\Delta = \sigma/\sigma_B - 1$ (with $\sigma = \sum_{\lambda_1,\lambda_2} \sigma_{\lambda_1,\lambda_2}$) which reveals the numerical impact of the radiative corrections on the total $t\bar{t}$ production rate. In Fig. 2(b) we show $\Delta$ in dependence of the gluino mass $m_{\tilde{g}}$ for different choices of the light stop quark mass $m_{\tilde{t}_2}$, the sbottom quark mass $m_{\tilde{b}_L}$ and the stop mixing angle $\Phi_{\tilde{t}}$. While the MSSM EW-like corrections are only of the order of a few % (apart from the threshold region $m_t \approx m_{\tilde{t}_2} + M_{\tilde{\chi}^0}$ where they can reach 30%), the SQCD one-loop corrections can considerably diminish/enhance $\sigma_B$ when the gluino is not too heavy. We only need to assign an additional minus sign to the $t$ channel box contribution.
now combine the MSSM EW-like corrections of [4] with the SQCD corrections of Sec. 2.1. The resulting relative correction $\Delta$ and integrated left-right asymmetry $A_{LR} = \frac{\sigma_{+1} - \sigma_{-1}}{\sigma_{+1} + \sigma_{-1}}$, respectively, are shown in Fig. 3(a) and (b) for different choices of the MSSM input parameters. For comparison we also display the SM results when varying the SM Higgs boson mass. The SQCD $O(\alpha_s)$ contribution induces parity violating asymmetries when the squarks are non-degenerate in mass (and $\Phi_\tilde{t} \neq \pi/4$). Then the asymmetries induced by EW(-like) corrections can be considerably enhanced and are possibly observable at the upgraded Tevatron with $\mathcal{L} = 10\text{pb}^{-1}$.

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\[ A_{LR} = \frac{\sigma_{+1} - \sigma_{-1}}{\sigma_{+1} + \sigma_{-1}}, \]

\( c \) When summing over the $\ell$ helicities the resulting asymmetry $\mathcal{A}$ is statistical significant ($N_\alpha \geq 4$) when $|\mathcal{A}| \gtrsim 1.8\%$ which corresponds to $|A_{LR}| \gtrsim 2.4\%$. 

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