SUSY Corrections to Hadronic Top Quark Pair Production

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Contents

Motivation

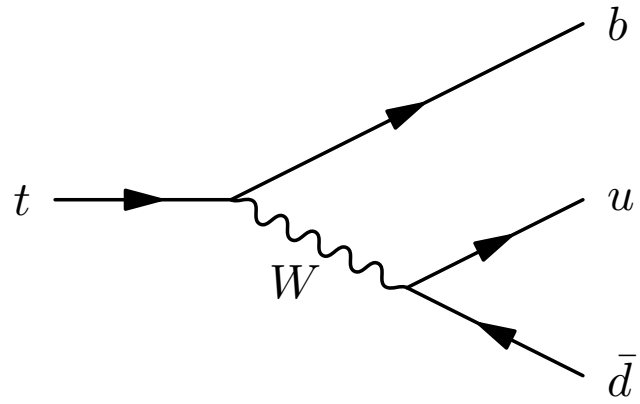
- LHC (at low luminosity) will produce about $8 \cdot 10^6$ $t\bar{t}$ events per year.
- This will allow us to measure the $t\bar{t}$ cross section at percent level accuracy.
- BSM physics could contribute to $t\bar{t}$ production through virtual corrections and lead to percent level effects.

Spin Polarisation

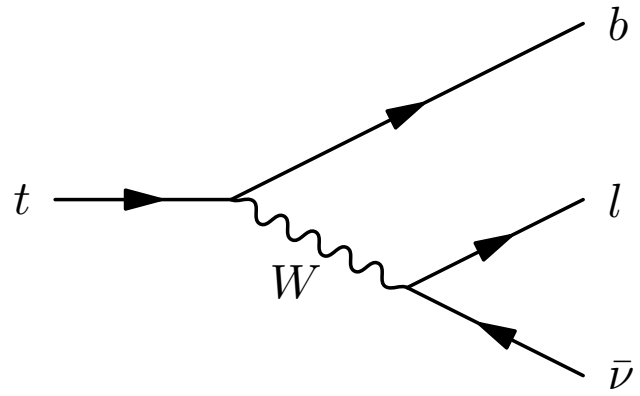
- For light quarks the spin information is lost in the hadronisation process.
- The top quark decays via electroweak interactions before it can hadronise.
- Since the EW interactions violate parity, the spin information is encoded in the angular distribution of the decay products.

Top Decay Modes

- hadronic decays (2/3)



- leptonic decays (1/3)



Observables

Let $d\sigma_{\lambda\bar{\lambda}}$ be the differential cross section for producing a top with helicity λ and an anti-top with helicity $\bar{\lambda}$.

Define the spin correlation dC as

$$dC = \frac{d\sigma_{++} + d\sigma_{--} - d\sigma_{+-} - d\sigma_{-+}}{d\sigma_{++} + d\sigma_{--} + d\sigma_{+-} + d\sigma_{-+}} \quad .$$

Define the left-right asymmetry dA_{LR} as

$$dA_{LR} = \frac{d\sigma_{+-} - d\sigma_{-+}}{d\sigma_{++} + d\sigma_{--} + d\sigma_{+-} + d\sigma_{-+}} \quad .$$

This observable is parity violating. Thus it has no SM QCD contribution.
$\Rightarrow$ Its SM value is of $\mathcal{O}(\alpha^2)$.

Experimental Accuracy

The simulation results and uncertainties for the spin correlation C are

decay mode	C	$\pm$ stat.	$\pm$ sys.
semileptonic	0.422	$\pm$0.020	$\pm$0.081
dileptonic	0.404	$\pm$0.020	$\pm$0.024
combined	0.406	$\pm$0.014	$\pm$0.023

[Hubaut, Monnier, Pralavorio, Smolek, Simak, hep-ex/0508061]

For the left-right asymmetry A_{LR} such a study still needs to be done.

The Calculation

We have calculated

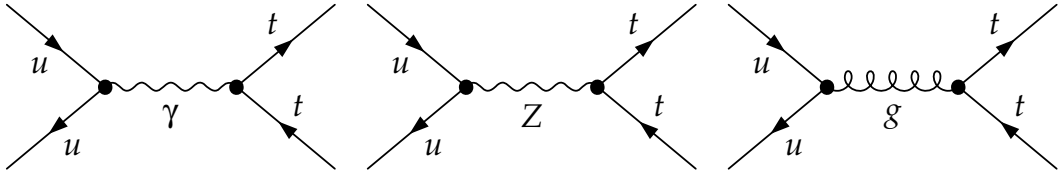
- SUSY corrections to $q\bar{q} \to t\bar{t}$ and $gg \to t\bar{t}$
- at $\mathcal{O}(\alpha_s^3)$ and $\mathcal{O}(\alpha\alpha_s^2)$
- in the on-shell renormalisation scheme
- using FORM for computer algebra
- using Feynman rules from [Rosiek, hep-ph/9511250]
- using LoopTools for tensor integrals [hep-ph/9807565]
- using CTEQ PDFs [hep-ph/0201195]

Checks

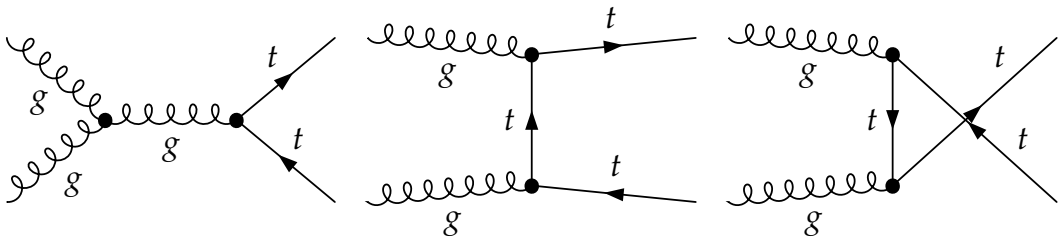
- The whole calculation was re-done with FormCalc
- The SUSY QCD corrections were compared with [Berge, Hollik, Mösle, Wackeroth; hep-ph/0703016] and agree.
- The SUSY EW corrections were published by [Hollik, Mösle, Wackeroth; hep-ph9706218]. Comparison still needs to be done.

Tree Level Diagrams

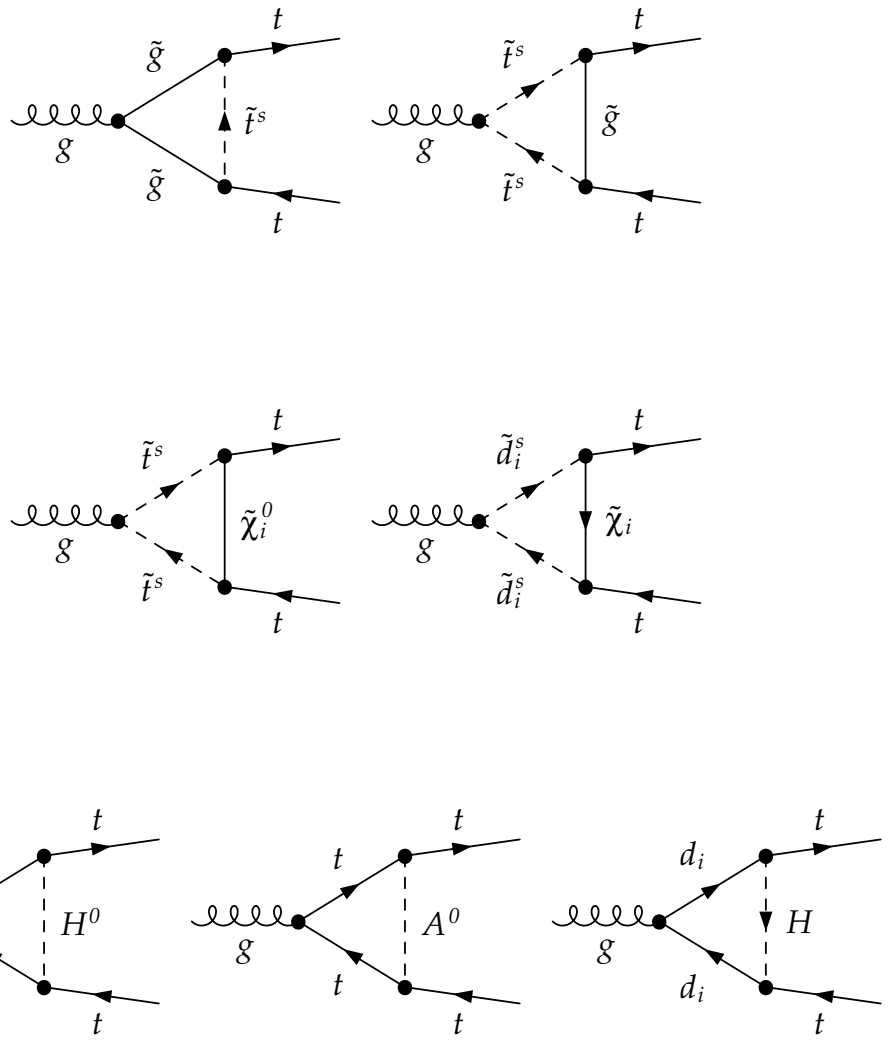
$q\bar{q} \to t\bar{t}$ tree level diagrams:



$gg \to t\bar{t}$ tree level diagrams:

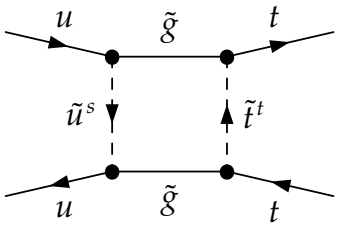


Vertex Corrections

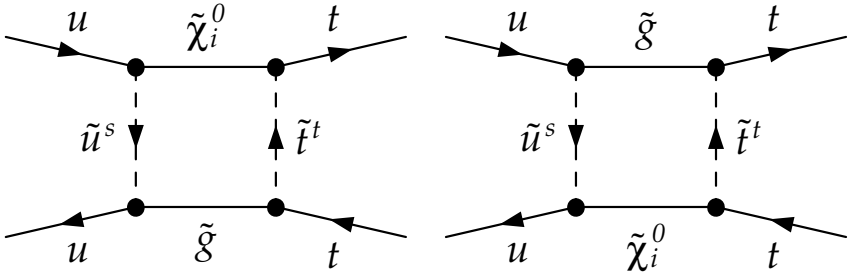


$q\bar{q}$ Box Diagrams

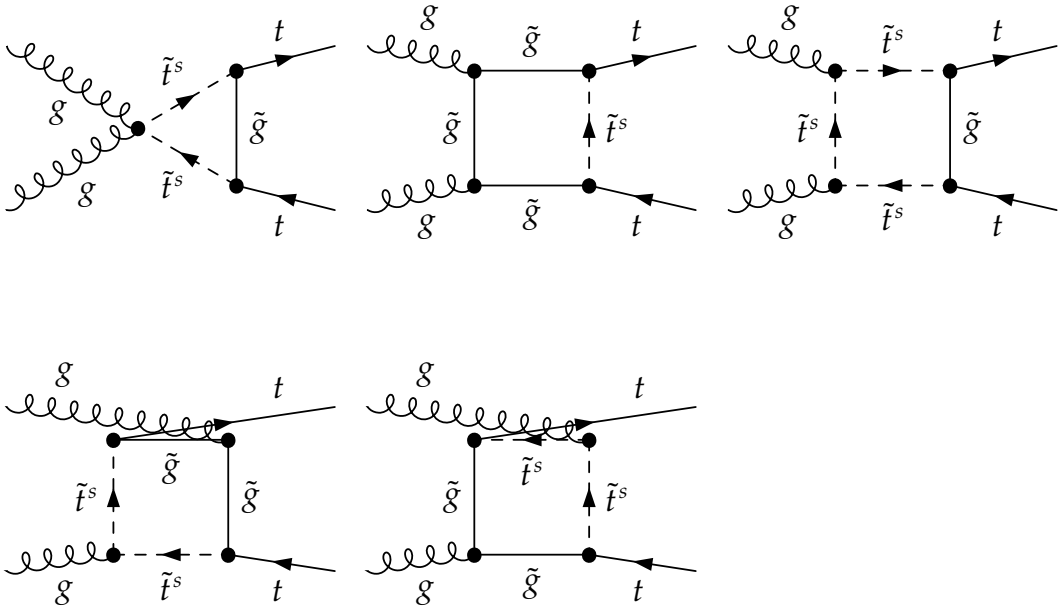
SUSY QCD box diagrams:



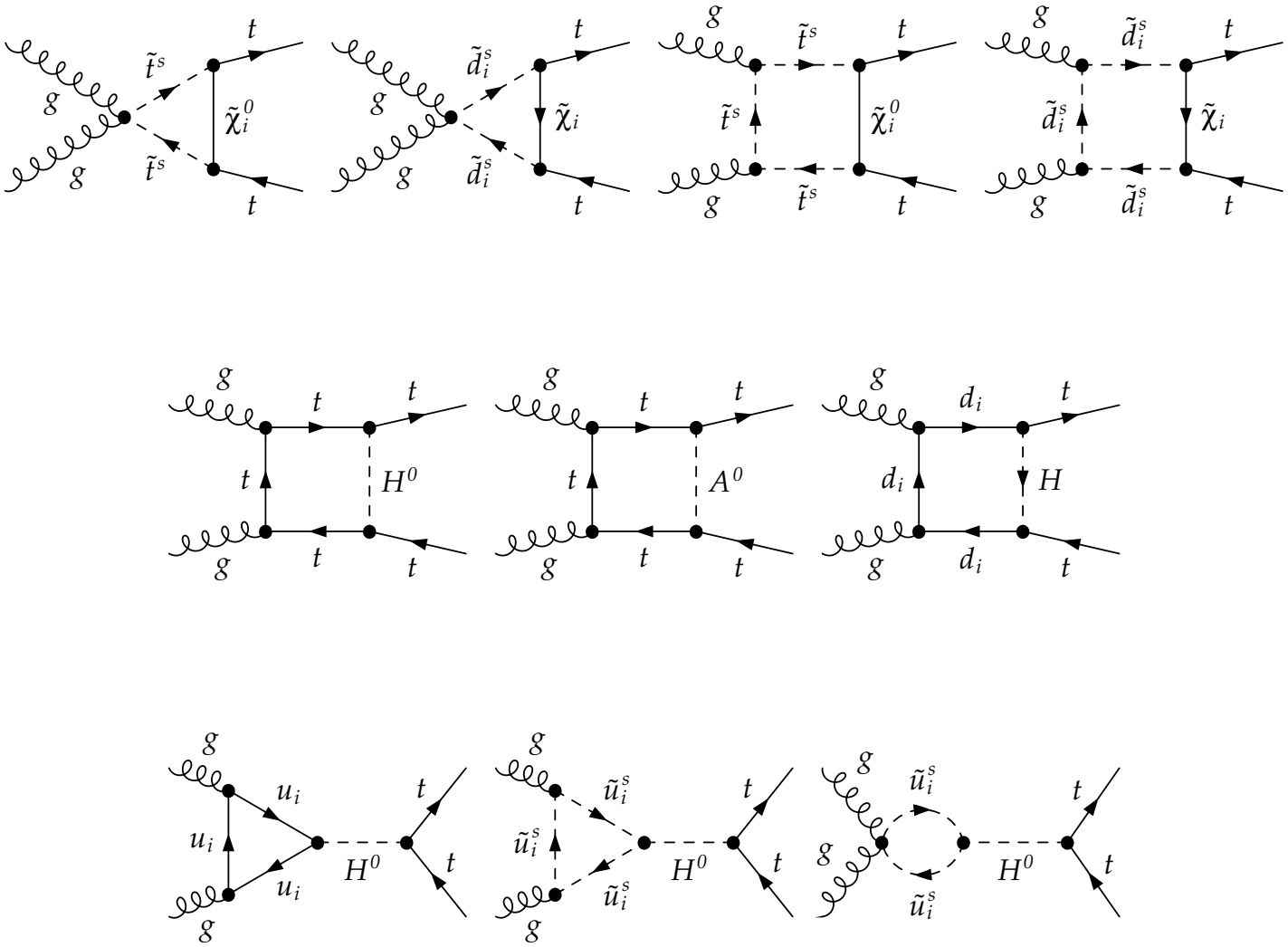
SUSY EW box diagrams:



gg SUSY QCD Box Diagrams



gg SUSY EW Diagrams



MSSM Parameters

- No Higgs coupling to quark generations 1 and 2.
- No (quark or squark) mixing between generations.

down squark masses are determined from the down squark mass matrix:

$$\begin{pmatrix} M^2_{Q^i} - m^2_Z \cos 2\beta(\frac{1}{2} - \frac{1}{3}s^2_W) + m_{d^i} & m_{d^i}(A_{d^i} - \mu \tan\beta) \\ m_{d^i}(A_{d^i} - \mu \tan\beta) & M^2_{D^i} - \frac{1}{3}m^2_Z \cos 2\beta s^2_W + m_{d^i} \end{pmatrix}$$

up squark masses are determined from the up squark mass matrix:

$$\begin{pmatrix} M^2_{Q^i} + m^2_Z \cos 2\beta(\frac{1}{2} - \frac{2}{3}s^2_W) + m_{u^i} & m_{u^i}(A_{u^i} - \mu \cot\beta) \\ m_{u^i}(A_{u^i} - \mu \cot\beta) & M^2_{U^i} + \frac{2}{3}m^2_Z \cos 2\beta s^2_W + m_{u^i} \end{pmatrix}$$

Higgs masses were calculated with FeynHiggs.

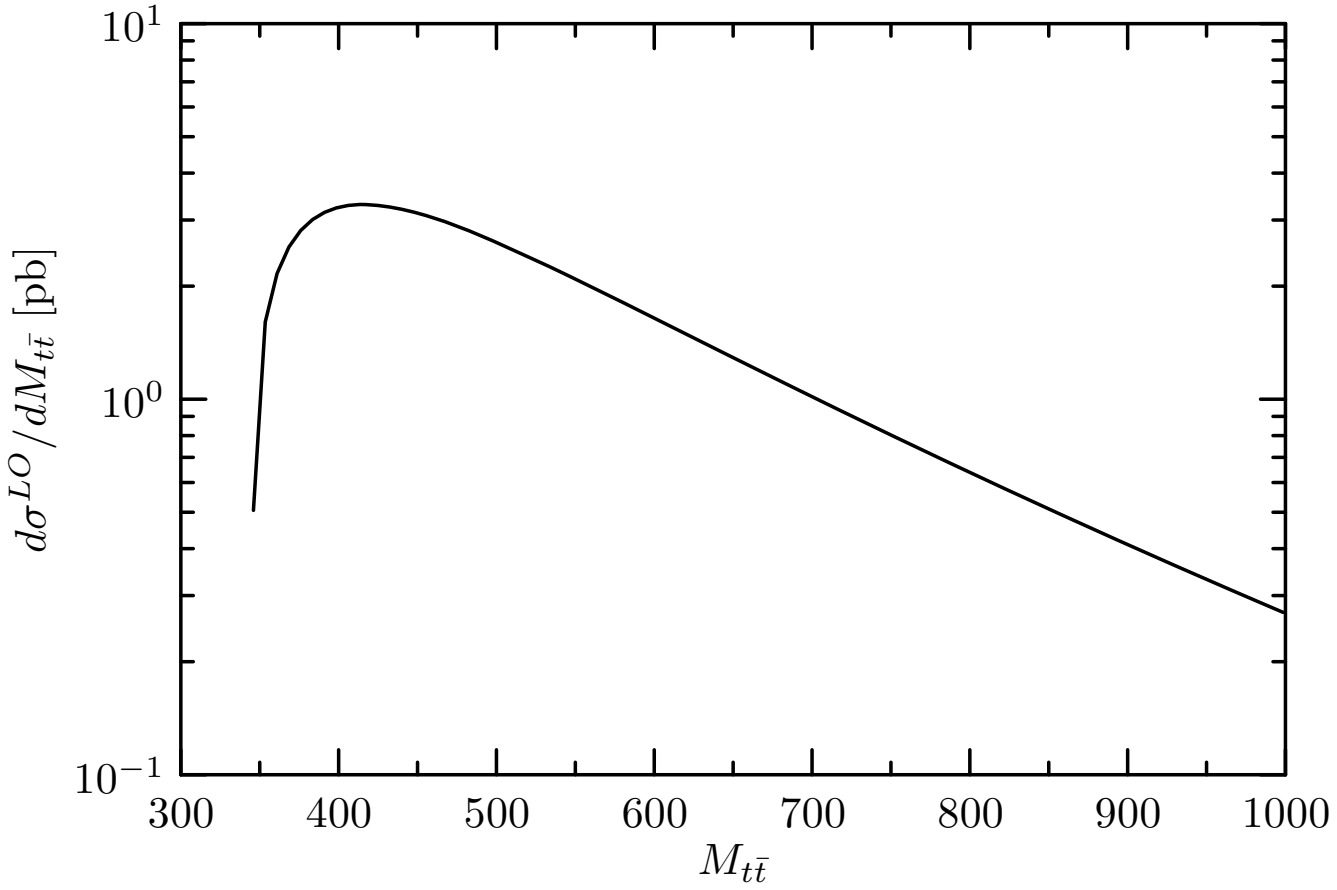
Parameters and Masses

$$\tan\beta = 50 \quad , \quad m_{H^\pm} = 250\,\text{GeV} \quad ,$$
$$M_2 = 130\,\text{GeV} \quad , \quad M_1 \approx 0.5 \cdot M_2 \quad ,$$
$$m_{\tilde{g}} = 350\,\text{GeV} \quad , \quad \mu = 250\,\text{GeV} \quad ,$$
$$M_{Q^i} = M_{D^i} = M_{U^{1,2}} = 400\,\text{GeV} \quad , \quad A_{d^i} = A_{u^{1,2}} = 0 \quad ,$$
$$M_{U^3} = 250\,\text{GeV} \quad , \quad A_{u^3} = 700\,\text{GeV} \quad .$$

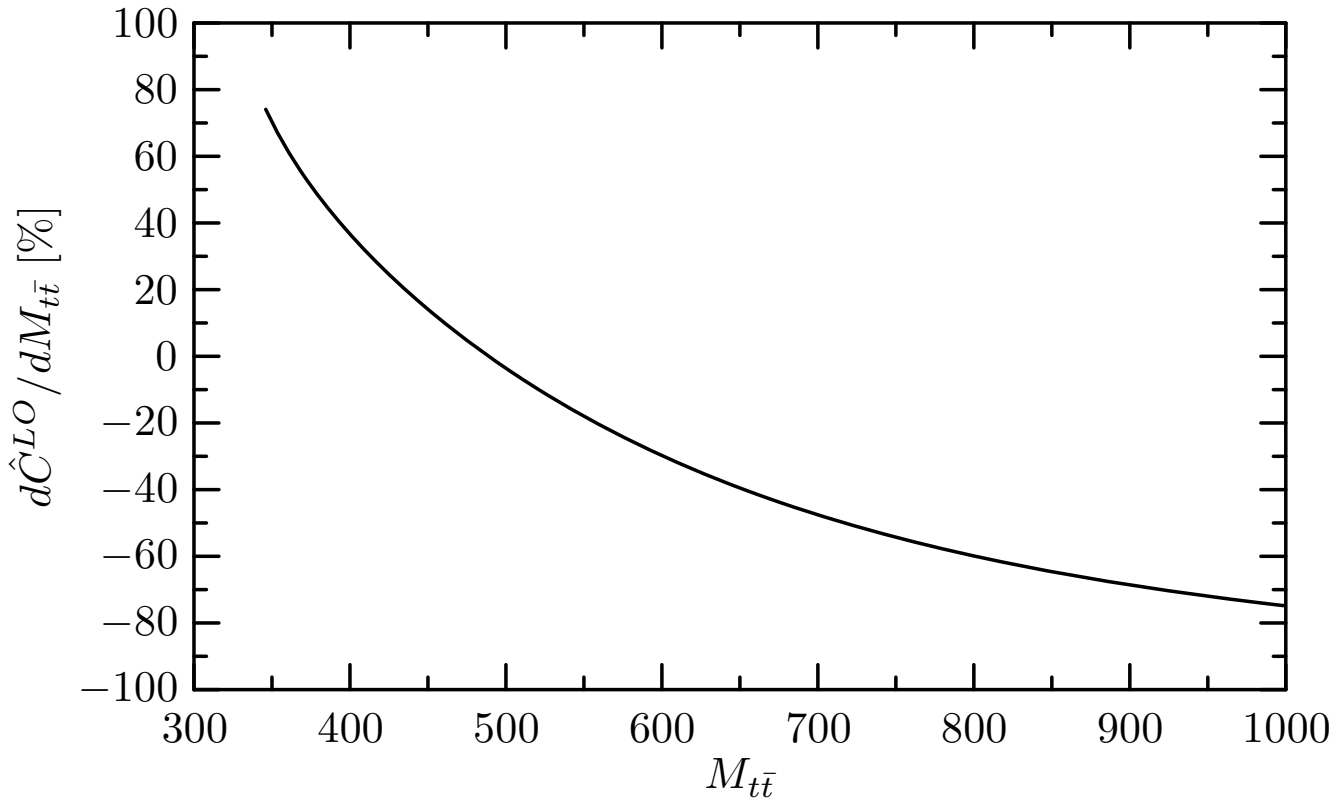
lead to the following masses:

$$m_{h^0} = 120\,\text{GeV} \quad , \quad m_{H^0} = 232\,\text{GeV} \quad , \quad m_{A^0} = 235\,\text{GeV} \quad ,$$
$$m_{\chi_1^\pm} = 115\,\text{GeV} \quad , \quad m_{\chi_1^0} = 60\,\text{GeV}$$
$$m_{\tilde{t}_1} = 99\,\text{GeV} \quad , \quad m_{\tilde{t}_2} = 518\,\text{GeV} \quad ,$$
$$m_{\tilde{b}_1} = 320\,\text{GeV} \quad , \quad m_{\tilde{b}_2} = 471\,\text{GeV}$$
$$m_{\tilde{d}_s^i} \approx m_{\tilde{u}_s^{1,2}} \approx 400\,\text{GeV} \quad .$$

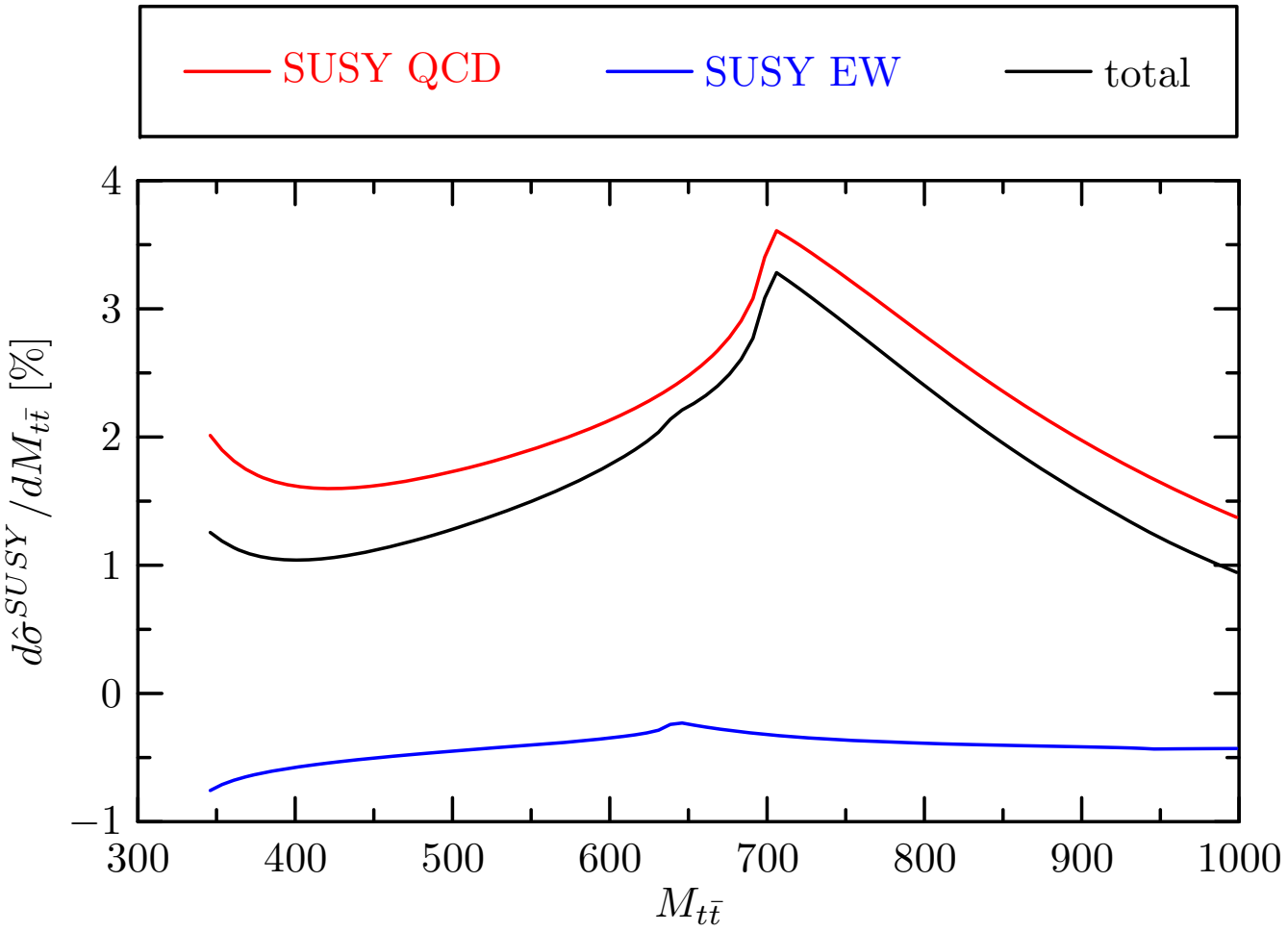
Leading Order $M_{t\bar{t}}$ Differential Cross Section



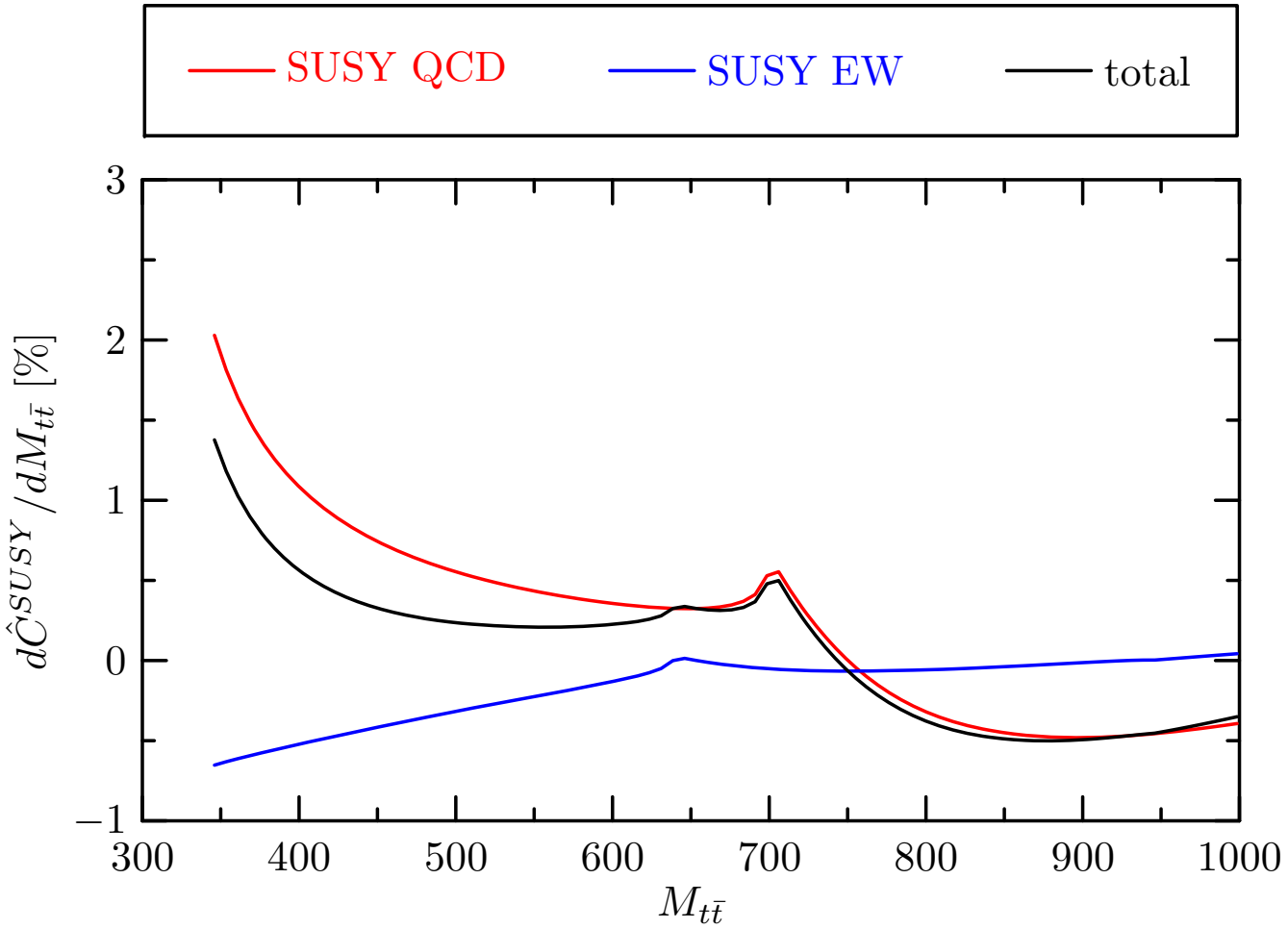
Leading Order $M_{t\bar{t}}$ Spin Correlation



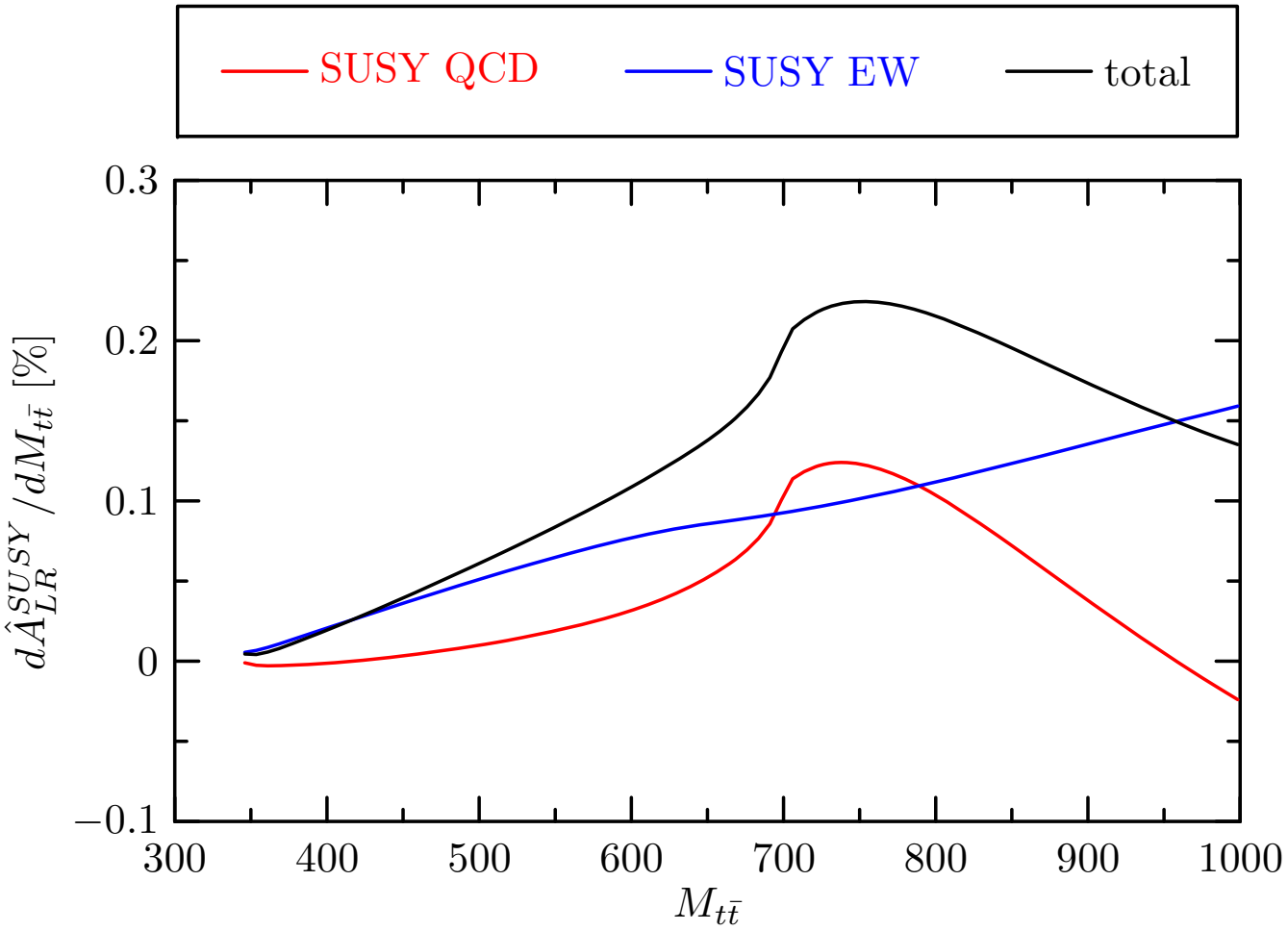
SUSY Corrections to the Differential Cross Section



SUSY Corrections to the Spin Correlation



SUSY Corrections to the Left-Right Asymmetry



Conclusions

- Virtual corrections of SUSY particles yield interesting and possibly measurable structures in $M_{t\bar{t}}$ distributions.
- Both, $\mathcal{O}(\alpha_s^3)$ and $\mathcal{O}(\alpha\alpha_s^2)$ contributions have to be taken into account.
- The SUSY corrections to the left-right asymmetry are small, but so is its SM background.