NLO QED Contributions to Top Quark Pair Production and Decay at Hadron Colliders

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Motivation

- The high top quark yield at the LHC will enable high precision studies of top quark properties and may even reveal physics beyond the Standard Model. Predictions for top quark observables need to be under good theoretical control, which requires the calculation of higher order QCD and electroweak corrections and their implementation in Monte Carlo programs.
- A first study of next-to-leading order (NLO) QED corrections to top quark pair production [1] argues that these contributions may be non-negligible in view of the anticipated experimental accuracy. They find that the relative corrections to the total hadronic cross section amount to $\delta \sim 1\%(2.5\%)$ at the LHC (Tevatron). The relative corrections to kinematic distributions can reach the 5% level.
- NLO electroweak corrections to the $t\bar{t}$ forward-backward asymmetry, as calculated in [2], are dominated by the QED corrections and as stated in [2] provide a non-negligible fraction of the QCD-induced asymmetry.
- We are recalculating the NLO QED corrections to $t\bar{t}$ production to provide a cross-check of [1, 2]. In addition, for a more realistic study of the impact of these corrections we are also taking into account top quark decays.

Top-Pair Production at NLO QED

- Top quark pair is mainly produced via strong interaction: $q\bar{q} \longrightarrow t\bar{t}$ and $gg \longrightarrow t\bar{t}$. The hadronic cross section is obtained by convoluting the partonic cross section with Parton Distribution Function (PDF)

$$\sigma(S) = \sum_{i,j} \int dx_1 dx_2 f_i(x_1, \mu_F) f_j(x_2, \mu_F)\, \hat{\sigma}_{ij}(\hat{s}, \alpha_s(\mu_R))$$

where $\hat{s} = x_1 x_2 S$ and $\mu_F = \mu_R = \mu = \frac{m_t}{2},\ m_t,\ 2m_t,\ \ldots$

- Virtual corrections to $d\sigma_{ij}$ read

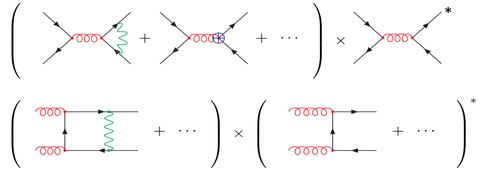
$$\frac{d\hat{\sigma}_{ij}^{1-loop}(\alpha\alpha_s^2)}{d\hat{t}} = \frac{1}{16\pi\hat{s}^2} \cdot 2\, Re \sum_{spin,color} (\delta\mathcal{M}_{ij}(\alpha\alpha_s) \cdot \mathcal{M}_B^{ij*}(\alpha_s))$$

- Real corrections (to cancel IR-Divergence from virtual) include

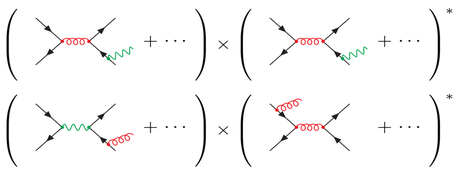
$$\mathcal{M}(\alpha^{\frac{1}{2}}\alpha_s) \cdot \mathcal{M}(\alpha^{\frac{1}{2}}\alpha_s)^*,\ \ \mathcal{M}(\alpha\alpha_s^{\frac{1}{2}}) \cdot \mathcal{M}(\alpha_s^{\frac{3}{2}})^*$$

Sample Feynman Diagrams

- QED virtual corrections



- QED real corrections



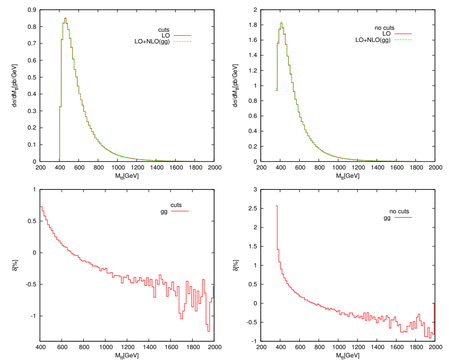
Methods and Tools

- Passarino-Veltman reduction; D-dimensional regularization; On-shell renormalization; Phase space slicing
- FeynArts, Form, QCDLoop (T. Hahn, J. Vermaseren, R. K. Ellis, G. Zanderighi)

Preliminary Result (gluon fusion at LHC)

[pb]	cuts
σ_B	199.72 ± 0.05
$\delta\sigma$	0.477 ± 0.003
δ	0.24%
[pb]	no cuts
σ_B	414.33 ± 0.05
$\delta\sigma$	2.398 ± 0.003
δ	0.58%

$p_T > 100$ GeV
$|\eta| < 2.5$



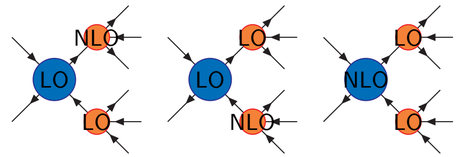
Top Quark Decay

- Top quark decays before hadronization

$$t \longrightarrow bW^+ \longrightarrow bl^+\nu_l,\ \ bu\bar{d},\ \ bc\bar{s},\ \ \ldots$$

$$\tau_t = 1/\Gamma_t \simeq 5 \times 10^{-25} s \gg \tau_{had} \simeq 1/\Lambda_{QCD} \approx 3 \times 10^{-24} s$$

- Narrow width approximation (NWA) effectively results in on-shell top quark and NLO EW can be depicted as follows.



Conclusion and Outlook

- Earlier work on NLO EW correction to top-pair production shows that NLO QED is non-negligible
- Preliminary results for NLO QED corrections to $gg \longrightarrow t\bar{t}$ (hadronic cross section, invariant $M_{t\bar{t}}$ distribution) are available
- Including top decay at NLO QED is in progress (NWA)
- Will enable the study of more realistic QED effects in top quark observables, e.g. asymmetry, invariant $t\bar{t}$ mass distribution

Acknowledgements and References

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