5-1-2011

Top Quark Cross Sections and Differential Distributions

Nikolaos Kidonakis
Kennesaw State University, nkidonak@kennesaw.edu

Top quark cross sections and differential distributions

Nikolaos Kidonakis

Kennesaw State University, Physics #1202, Kennesaw, GA 30144, USA

Abstract

I present results for the top quark pair total cross section and the top quark transverse momentum distribution at Tevatron and LHC energies. I also present results for single top quark production. All calculations include NNLO corrections from NNLL threshold resummation.

TOP-ANTITOP PAIR PRODUCTION

The leading order processes for top-antitop pair production are $q\bar{q} \to t\bar{t}$ (dominant at the Tevatron) and $gg \to t\bar{t}$ (dominant at LHC energies). The QCD corrections for top pair production are significant and receive contributions from soft-gluon corrections which are dominant near threshold. These soft corrections have been resummed through NNLL [1], requiring two-loop calculations of the soft anomalous dimensions [1, 2]. Approximate NNLO differential-level cross sections, using single-particle inclusive kinematics for partonic threshold, can be derived from the expansion of the resummed cross section.

Figures 1 and 2 show the NNLO approximate cross section [1] together with recent data from the corresponding experiments at the Tevatron [3, 4] and the LHC [5, 6]. The theoretical prediction agrees well with the measured cross sections. The upper and lower curves indicate the uncertainty from scale variation and pdf errors. It is important to note that the soft-gluon approximation works very well not only for Tevatron but also for LHC energies because partonic threshold is still important. There is only 1% difference between the first-order approximate and exact corrections as shown in Fig. 3, and thus less than 1% difference between NLO approximate and exact cross sections. For our best prediction in Figs. 1 and 2 we added the NNLO approximate corrections to the exact NLO cross section. In all the results presented here we have used the MSTW 2008 NNLO pdf [7].

At the Tevatron, we find that the NNLO corrections provide a 7.8% enhancement over NLO. For a top quark mass of 173 GeV, we find

$$\sigma_{t\bar{t}}^{\rm NNLOapprox}(m_t = 173\,{\rm GeV},\, 1.96\,{\rm TeV}) = 7.08^{+0.00}_{-0.24}{}^{+0.36}_{-0.27}\ {\rm pb}$$

where the first uncertainty is from scale variation between $m_t/2$ and $2m_t$ and the second is from the MSTW NNLO pdf at 90% C.L. The NNLO approximate corrections reduce the scale dependence greatly over a large range; the separate factorization and renormalization scale dependence has also been calculated in [1].

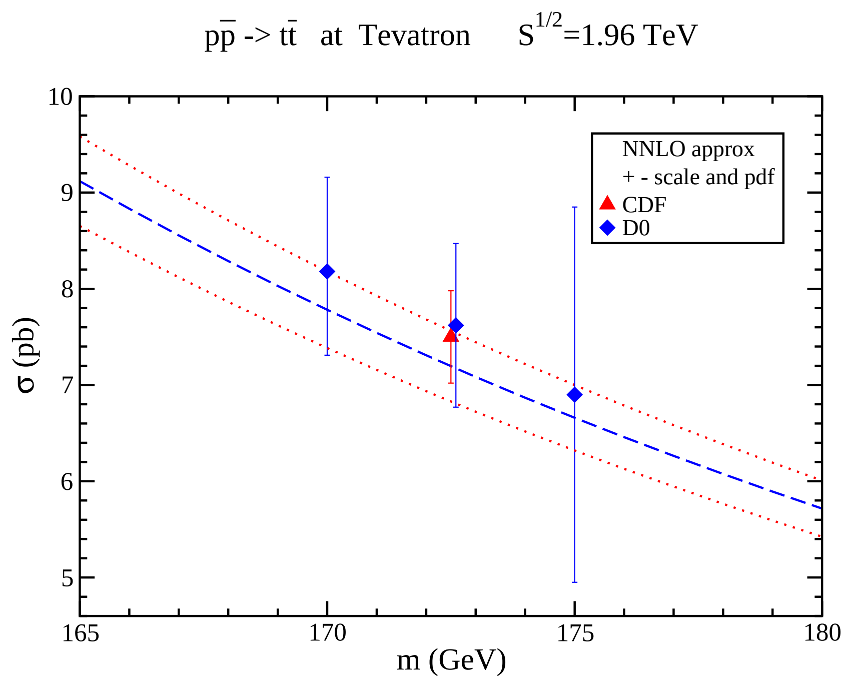

Figure 1: Top-antitop pair cross section at the Tevatron.

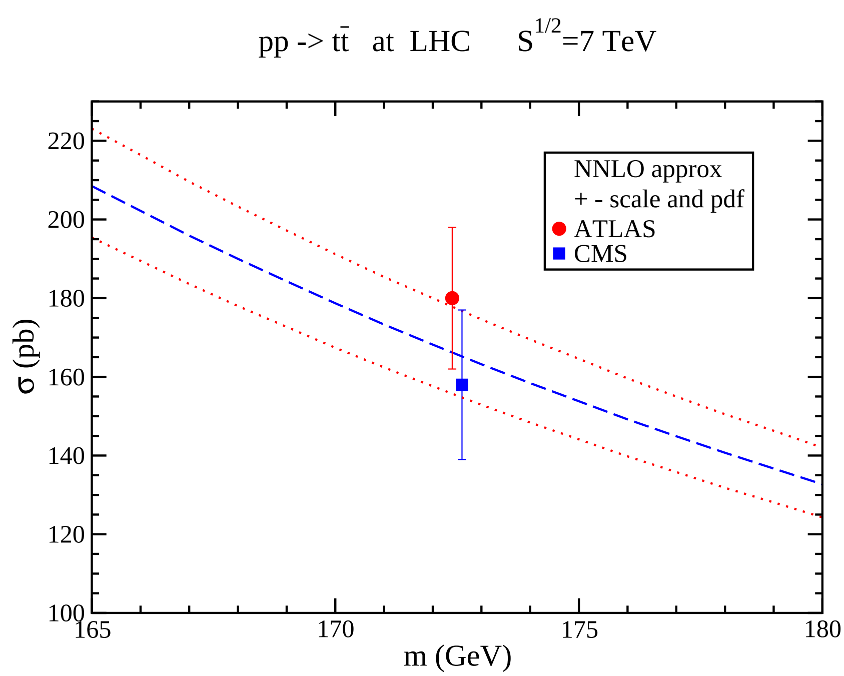

Figure 2: Top-antitop pair cross section at the LHC.

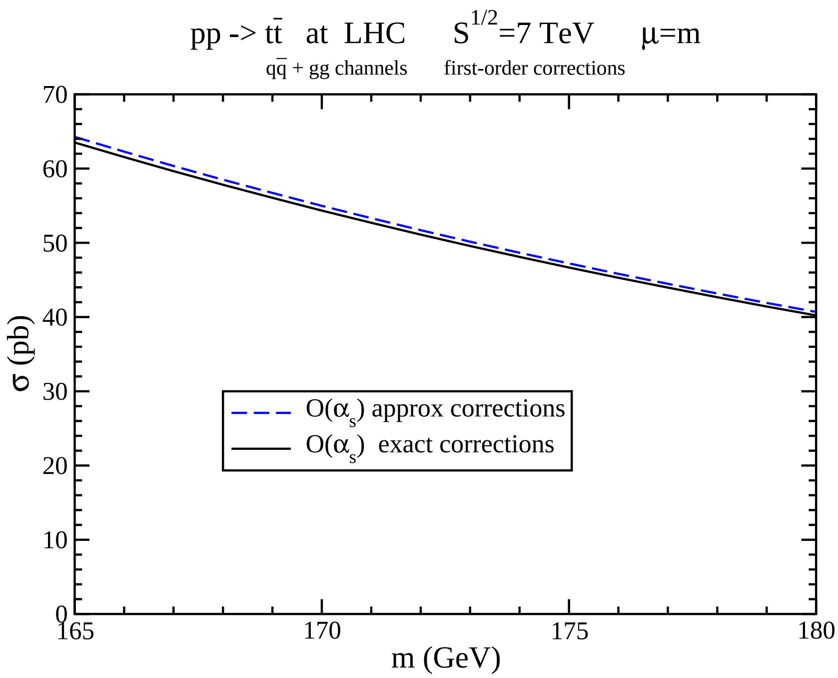

Figure 3: Approximate and exact NLO corrections for $t\bar{t}$ production at the LHC.

At the LHC at 7 TeV energy, we find

$$\sigma_{t\bar{t}}^{\rm NNLOapprox}(m_t = 173\,{\rm GeV},\, 7\,{\rm TeV}) = 163^{+7+9}_{-5-9}\ {\rm pb},$$

which is an enhancement over NLO of 7.6%.

The top quark transverse momentum distribution at the Tevatron is shown in Fig. 4. The p_T distribution is enhanced by the NNLO corrections but the shape is not significantly affected. Similar results have also been obtained for the LHC [1].

In Fig. 5 we show the theoretical cross sections for $t\bar{t}$ production in $p\bar{p}$ and pp collisions as functions of collider energy and corresponding Tevatron [3, 4] and LHC [5, 6] data, again noting the agreement between theory and experiment.

SINGLE TOP QUARK PRODUCTION

We continue with single top quark production and start by discussing the t-channel processes: $qb \to q't$ and $\bar{q}b \to \bar{q}'t$. The t channel is numerically the largest at the Tevatron and the LHC. We find for the NNLO approximate cross section [8]

$$\sigma_{t-{\rm channel}}^{\rm NNLOapprox,\, top}(m_t = 173\,{\rm GeV},\, 1.96\,{\rm TeV}) = 1.04^{+0.00}_{-0.02} \pm 0.06\ {\rm pb},$$

$$\sigma_{t-{\rm channel}}^{\rm NNLOapprox,\, top}(m_t = 173\,{\rm GeV},\, 7\,{\rm TeV}) = 41.7^{+1.6}_{-0.2} \pm 0.8\ {\rm pb}.$$

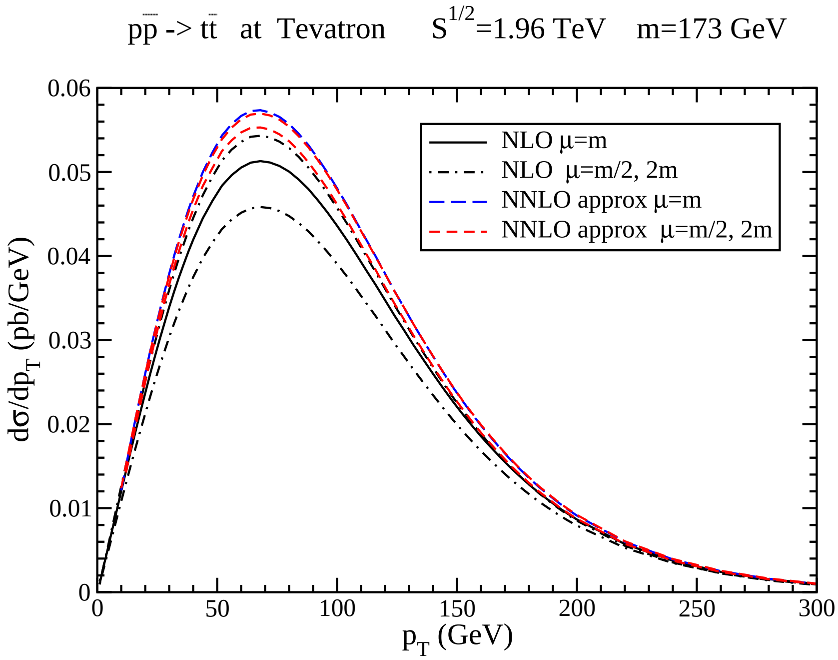

Figure 4: Top quark p_T distribution at the Tevatron.

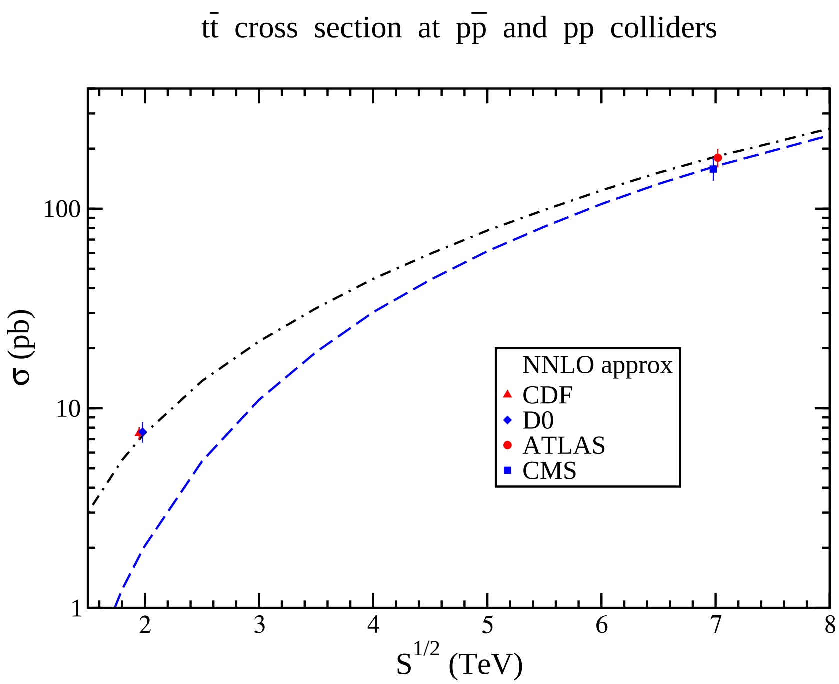

Figure 5: Top-antitop pair cross sections in $p\bar{p}$ (dash-dotted line) and pp (dashed line) collisions versus collider energy.

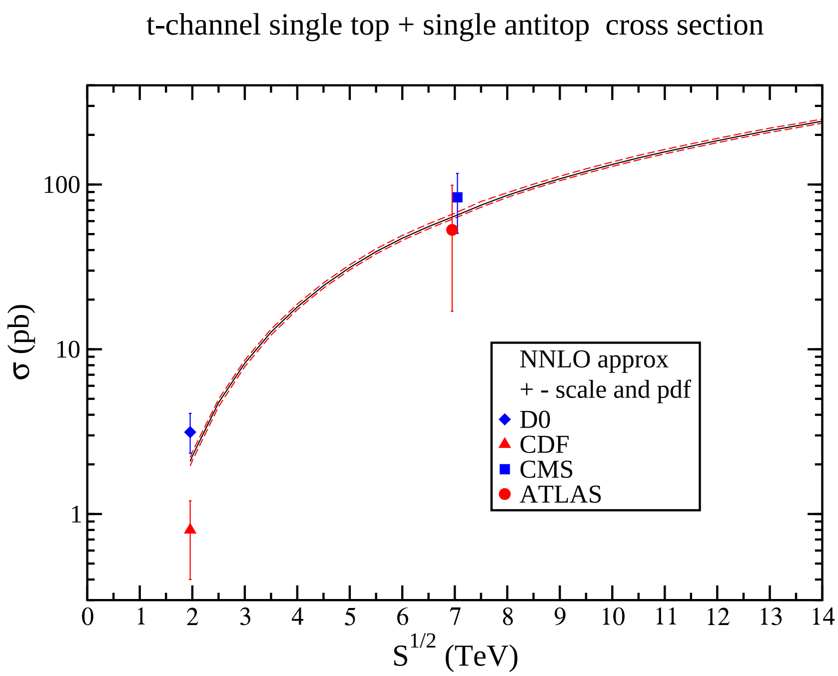

Figure 6: Single top plus single antitop t-channel cross section versus collider energy.

The NNLO approximate corrections contribute a 4% increase over NLO at the Tevatron and a 1% decrease at the LHC at 7 TeV.

For t-channel antitop production the cross section at the Tevatron is identical to that for top production. However, at the LHC the cross section is different

$$\sigma^{\rm NNLOapprox,\, antitop}_{t-{\rm channel}}(m_t = 173\,{\rm GeV},\, 7\,{\rm TeV}) = 22.5 \pm 0.5^{+0.7}_{-0.9}\ {\rm pb}.$$

Figure 6 shows the combined single top plus single antitop t-channel cross section as a function of energy together with data from the Tevatron [9, 10] and the LHC [11, 12]. Again, the theory is consistent with the measured cross sections.

We continue with s-channel single top quark production: $q\bar{q}' \to \bar{b}t$, which is numerically small at both Tevatron and LHC energies [13]. For top production we find

$$\sigma^{\rm NNLOapprox,\, top}_{s-{\rm channel}}(m_t = 173\,{\rm GeV},\, 1.96\,{\rm TeV}) = 0.523^{+0.001}_{-0.005}{}^{+0.030}_{-0.028}\ {\rm pb},$$

$$\sigma^{\rm NNLOapprox,\, top}_{s-{\rm channel}}(m_t = 173\,{\rm GeV},\, 7\,{\rm TeV}) = 3.17 \pm 0.06^{+0.13}_{-0.10}\ {\rm pb}.$$

The NNLO approximate corrections are an enhancement over NLO of 15% at the Tevatron and 13% at the LHC. Figure 7 shows the s-channel top cross section as a function of top quark mass at the Tevatron. The antitop cross section at the Tevatron is the same.

For s-channel antitop production at the LHC we have

$$\sigma^{\rm NNLOapprox,\, antitop}_{s-{\rm channel}}(m_t = 173\,{\rm GeV},\, 7\,{\rm TeV}) = 1.42 \pm 0.01^{+0.06}_{-0.07}\ {\rm pb}.$$

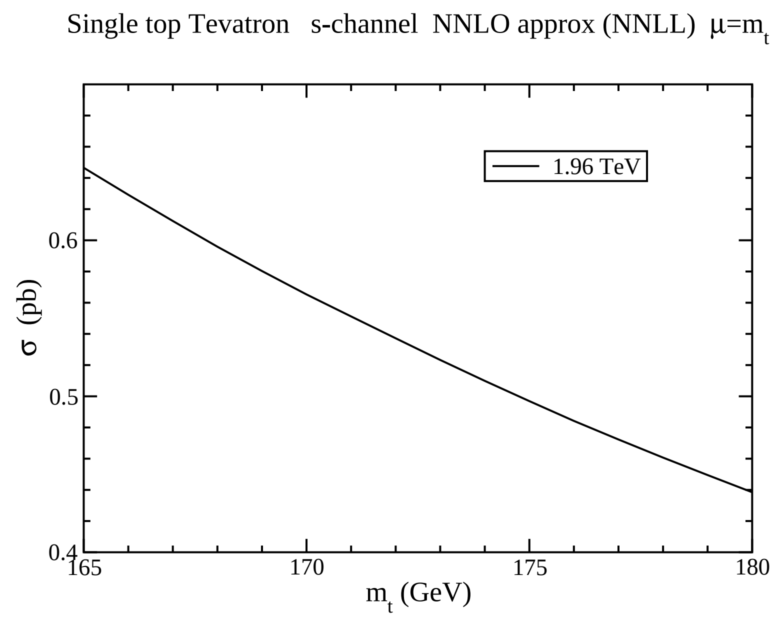

Figure 7: Single top s-channel cross section at the Tevatron.

Finally, we present results for associated tW production, $bg \to tW^-$ [14]. The cross section for this process is very small at the Tevatron, but significant at the LHC. We find that the NNLO approximate corrections increase the NLO cross section by $\sim 8\%$ and

$$\sigma_{tW}^{\rm NNLOapprox}(m_t = 173\,{\rm GeV},\, 7\,{\rm TeV}) = 7.8 \pm 0.2^{+0.5}_{-0.6}\ {\rm pb}.$$

Figure 8 shows the tW cross section at the LHC at both 7 TeV and 14 TeV energy. We note that the $\bar{t}W$ cross section is the same as that for tW production.

A related process is associated charged Higgs production, $bg \to tH^-$, where the NNLO approximate corrections increase the NLO cross section by ~ 15 to $\sim 20\%$ [14].

ACKNOWLEDGMENTS

This work was supported by the National Science Foundation under Grant No. PHY 0855421.

References

[1] N. Kidonakis, *Phys. Rev. D* **82**, 114030 (2010) [arXiv:1009.4935 [hep-ph]].

[2] N. Kidonakis, *Phys. Rev. Lett.* **102**, 232003 (2009) [arXiv:0903.2561 [hep-ph]].

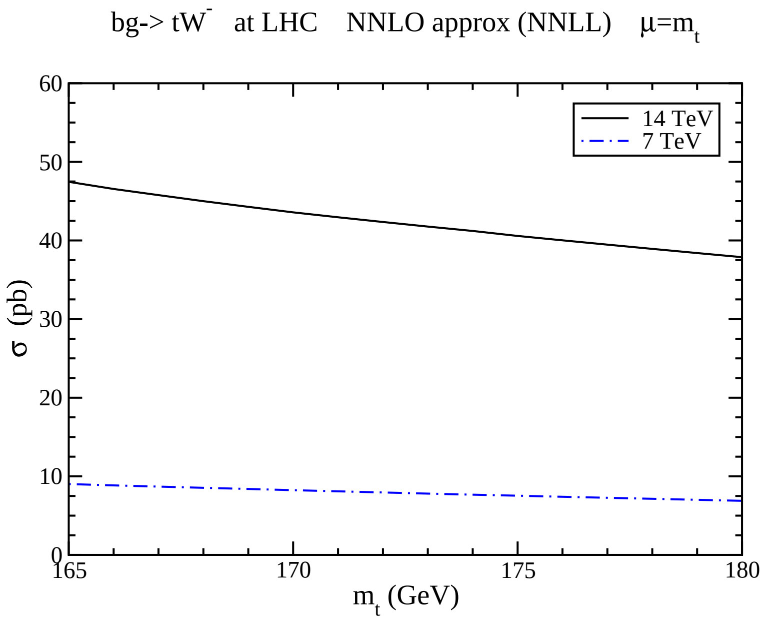

Figure 8: tW cross section at the LHC.

[3] CDF Collaboration, Conf. Note 9913.

[4] D0 Collaboration, *Phys. Rev. Lett.* **100**, 192004 (2008) [arXiv:0803.2779 [hep-ex]]; *Phys. Rev. D* **80**, 071102(R) (2009) [arXiv:0903.5525 [hep-ex]]; *Phys. Rev. D* **82**, 032002 (2010) [arXiv:0911.4286 [hep-ex]].

[5] ATLAS Collaboration, ATLAS-CONF-2011-040.

[6] CMS Collaboration, CMS-PAS-TOP-11-001.

[7] A. Martin, W. Stirling, R. Thorne, and G. Watt, *Eur. Phys. J. C* **63**, 189 (2009) [arXiv:0901.0002 [hep-ph]].

[8] N. Kidonakis, *Phys. Rev. D* **83**, 091503(R) (2011) [arXiv:1103.2792 [hep-ph]].

[9] D0 Collaboration, *Phys. Lett. B* **682**, 363 (2010) [arXiv:0907.4259 [hep-ex]].

[10] CDF Collaboration, *Phys. Rev. Lett.* **103**, 092002 (2009) [arXiv:0903.0885 [hep-ex]].

[11] CMS Collaboration, CMS-PAS-TOP-10-008.

[12] ATLAS Collaboration, ATLAS-CONF-2011-027.

[13] N. Kidonakis, *Phys. Rev. D* **81**, 054028 (2010) [arXiv:1001.5034 [hep-ph]].

[14] N. Kidonakis, *Phys. Rev. D* **82**, 054018 (2010) [arXiv:1005.4451 [hep-ph]].