Top quark pair and single top production at Tevatron and LHC energies

Nikolaos Kidonakis

(Kennesaw State University)

- $t\bar{t}$ and single top production channels
- Higher-order two-loop corrections
- $t\bar{t}$ cross section at Tevatron and LHC
- Top quark p_T distribution at Tevatron and LHC
- s-channel production at Tevatron and LHC
- Associated production of a top with a W^- or H^-

Partonic processes at LO

Top-antitop pair production

- $q\bar{q} \longrightarrow t\bar{t}$

dominant at Tevatron

- $gg \longrightarrow t\bar{t}$

dominant at LHC

Single top quark production

- t **channel:** $qb \longrightarrow q't$ **and** $\bar{q}b \longrightarrow \bar{q}'t$

dominant at Tevatron and LHC

- s **channel:** $q\bar{q}' \longrightarrow \bar{b}t$

small at Tevatron and LHC

- **associated** tW **production:** $bg \longrightarrow tW^-$

very small at Tevatron, significant at LHC

Related process: $bg \longrightarrow tH^-$

Higher-order corrections

QCD corrections significant for top pair and single top quark production

NLO corrections fully known

Soft-gluon corrections from incomplete cancellations of infrared divergences between virtual diagrams and real diagrams with soft (low-energy) gluons

Soft corrections $\left[\frac{\ln^k(s_4/m^2)}{s_4}\right]_+$ **with** $k \leq 2n-1$ **and** s_4 **distance from threshold**

Soft-gluon corrections are dominant near threshold

Resum (exponentiate) these soft corrections

At NLL accuracy requires one-loop calculations in the eikonal approximation

New results at NNLL–two-loop calculations completed

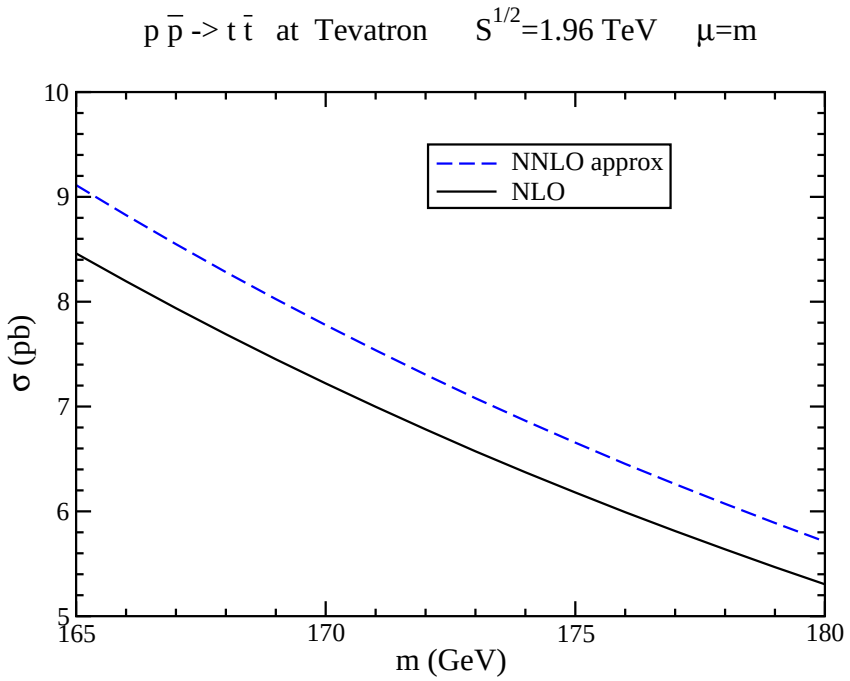
Approximate NNLO cross section from expansion of resummed cross section

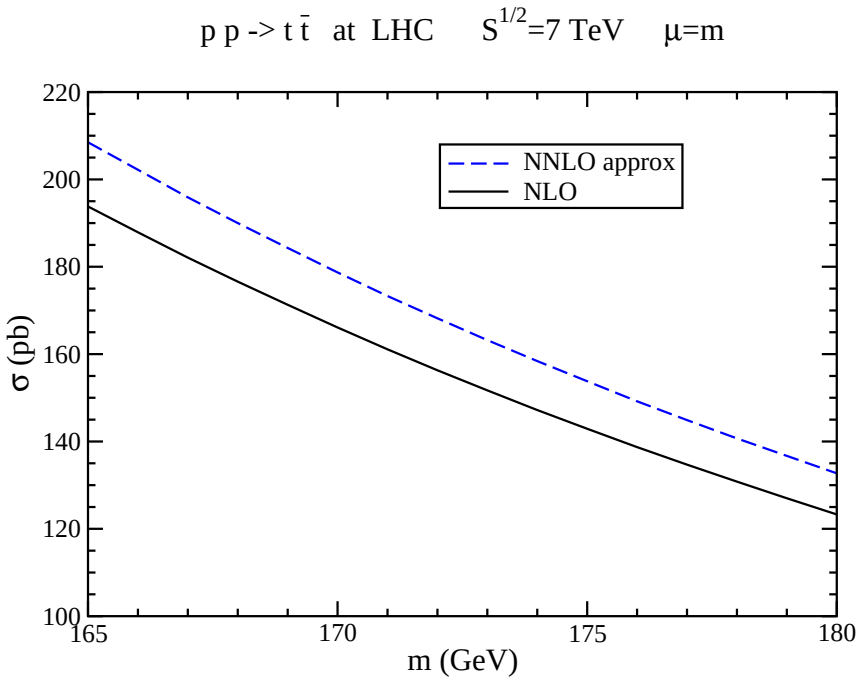
Essential ingredient: two-loop soft anomalous dimension

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

This allows NNLL resummation

$t\bar{t}$ cross section at Tevatron and LHC





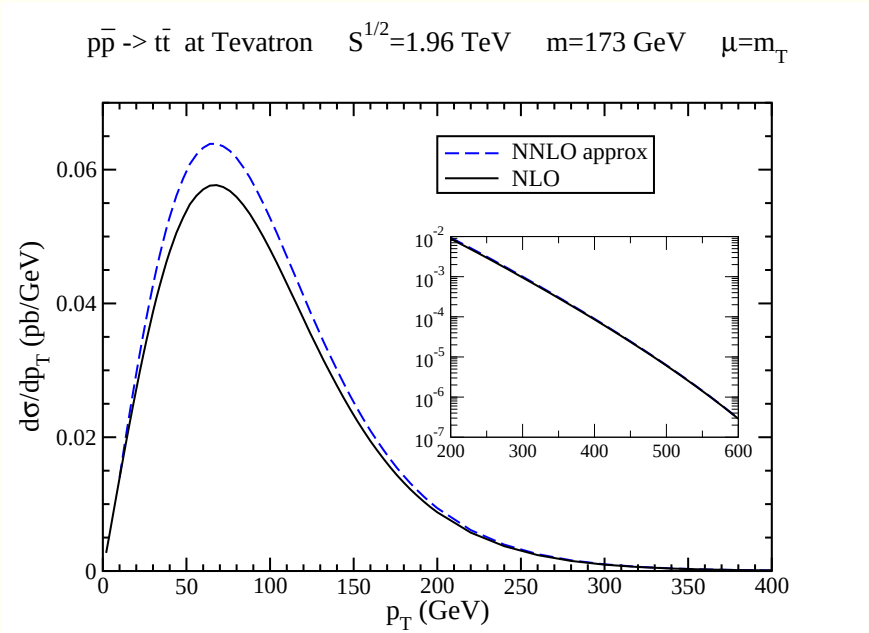
$$\sigma_{t\bar{t}}^{\mathrm{NNLOapprox}}(m_t = 173\,\mathrm{GeV}, 1.96\,\mathrm{TeV}) = 7.08^{+0.00+0.36}_{-0.32-0.27}\ \mathrm{pb}$$

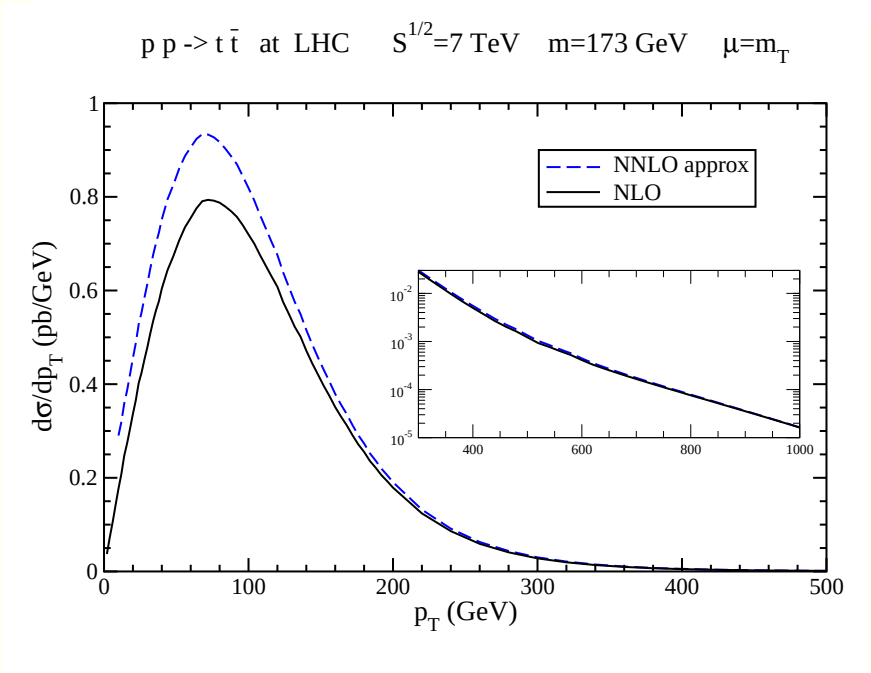
$$\sigma_{t\bar{t}}^{\mathrm{NNLOapprox}}(m_t = 173\,\mathrm{GeV}, 7\,\mathrm{TeV}) = 163^{+4+9}_{-8-9}\ \mathrm{pb}$$

$$\sigma_{t\bar{t}}^{\mathrm{NNLOapprox}}(m_t = 173\,\mathrm{GeV}, 10\,\mathrm{TeV}) = 415^{+17+18}_{-21-19}\ \mathrm{pb}$$

$$\sigma_{t\bar{t}}^{\mathrm{NNLOapprox}}(m_t = 173\,\mathrm{GeV}, 14\,\mathrm{TeV}) = 920^{+50+33}_{-45-35}\ \mathrm{pb}$$

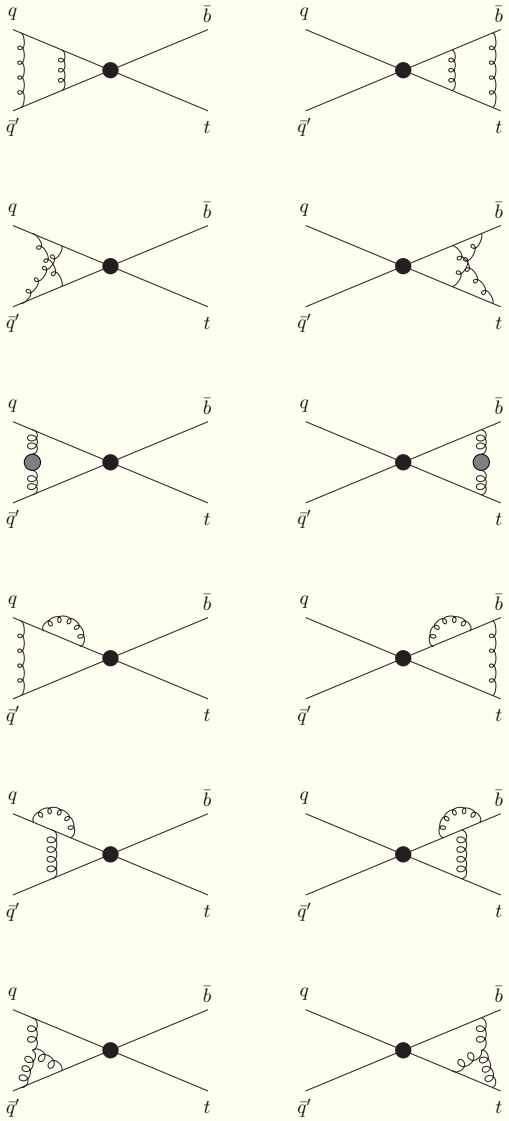
Top quark p_T distribution at Tevatron and LHC

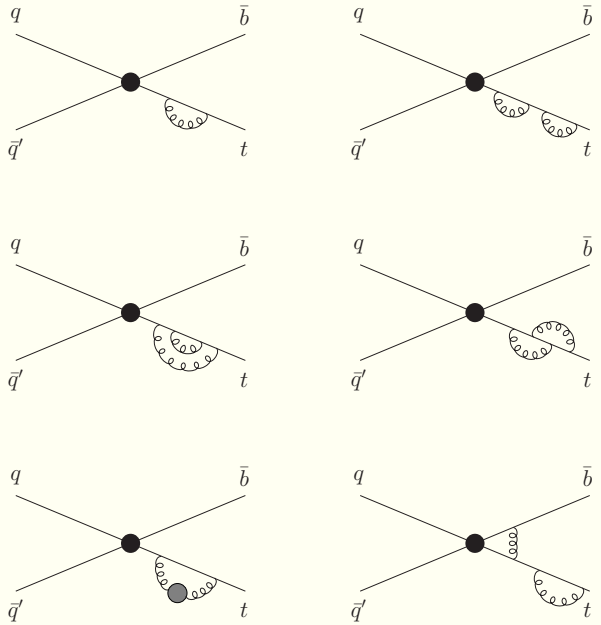




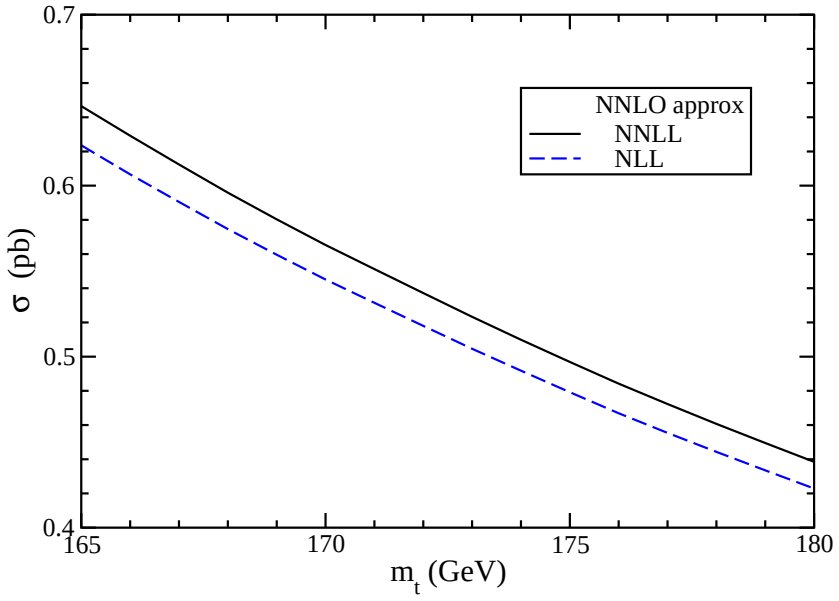
Single top quark production - s channel

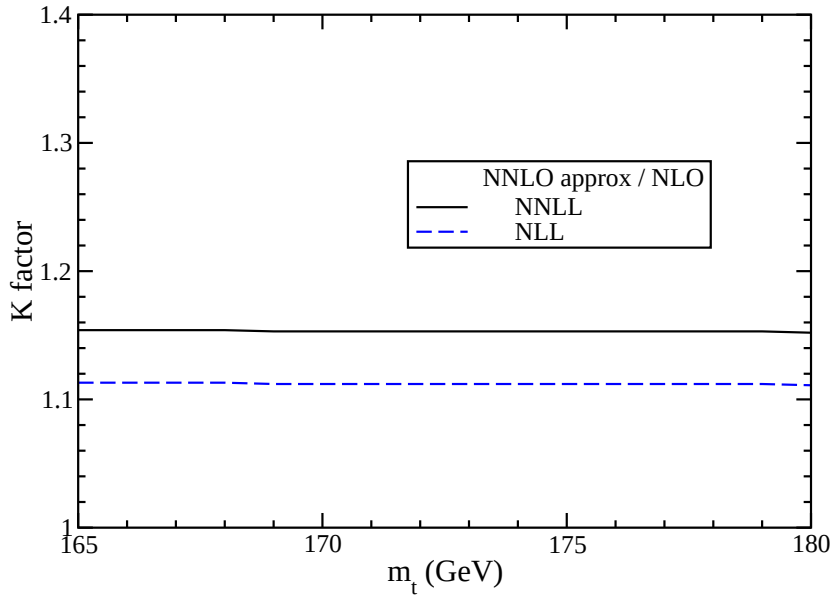
Two-loop eikonal diagrams





s-channel single top cross section at Tevatron



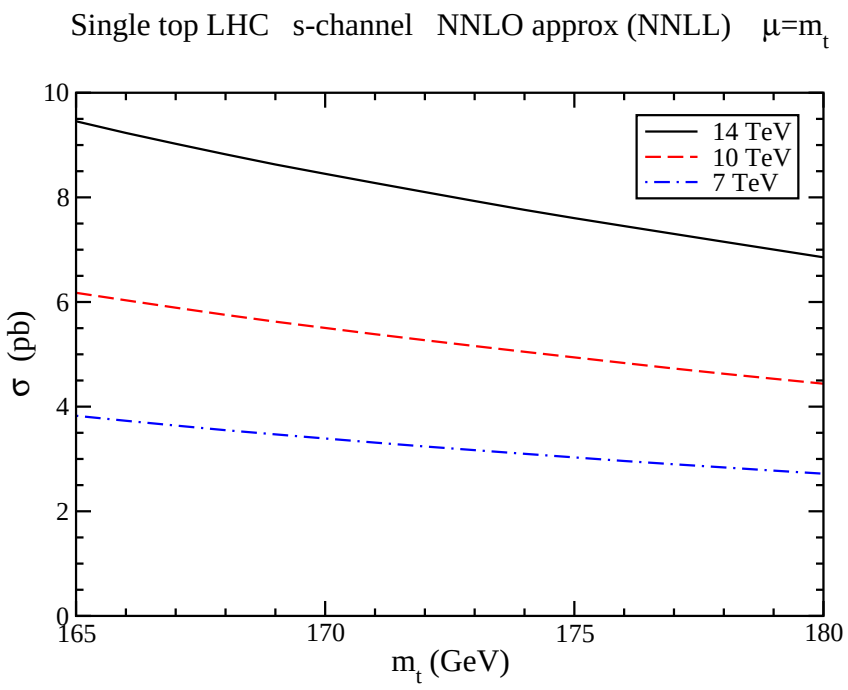


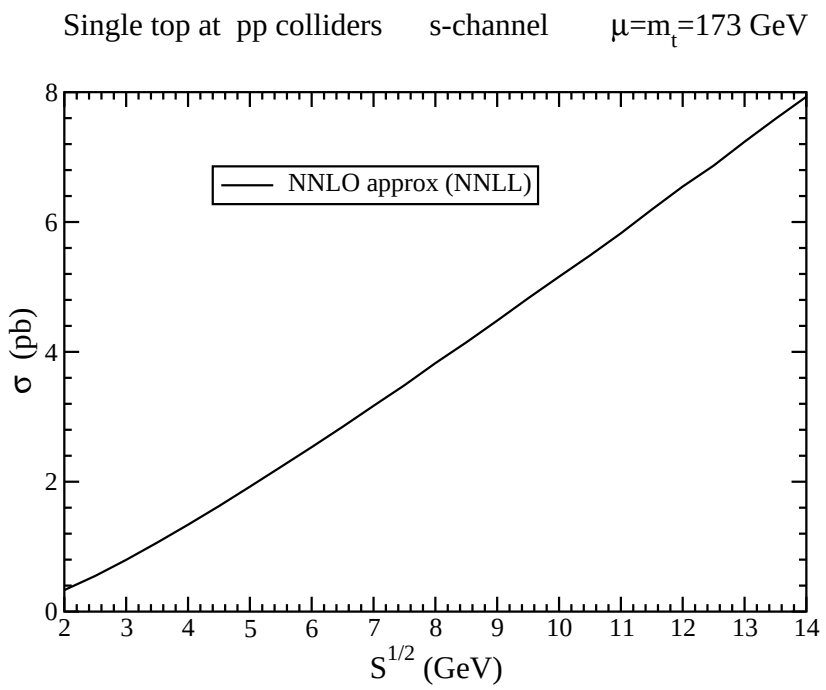
$$\sigma_{s-\text{channel}}^{\text{NNLOapprox, top}}(m_t = 173\,\text{GeV}) \quad = \quad 0.523^{+0.001\,+0.030}_{-0.005\,-0.028}\ \text{pb}$$

Cross section for anti-top production is identical

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

Single top production at the LHC - s channel



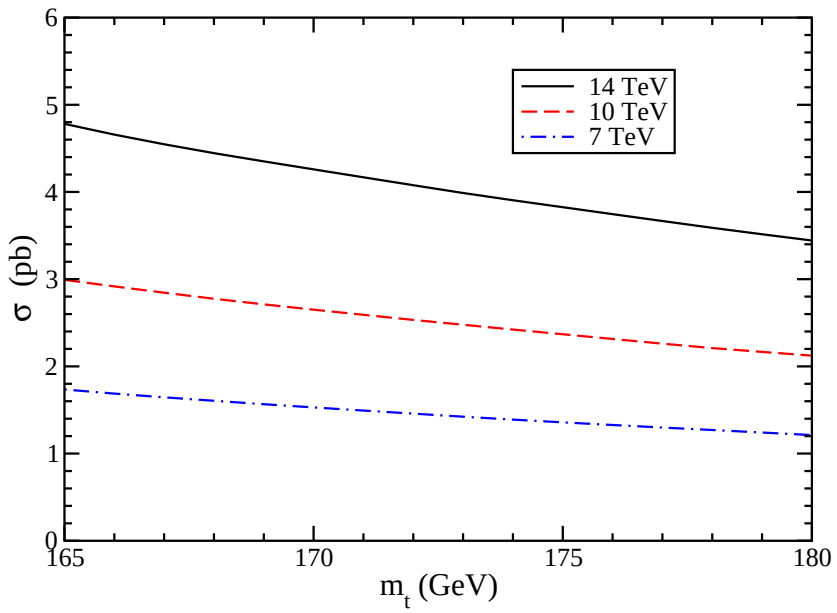


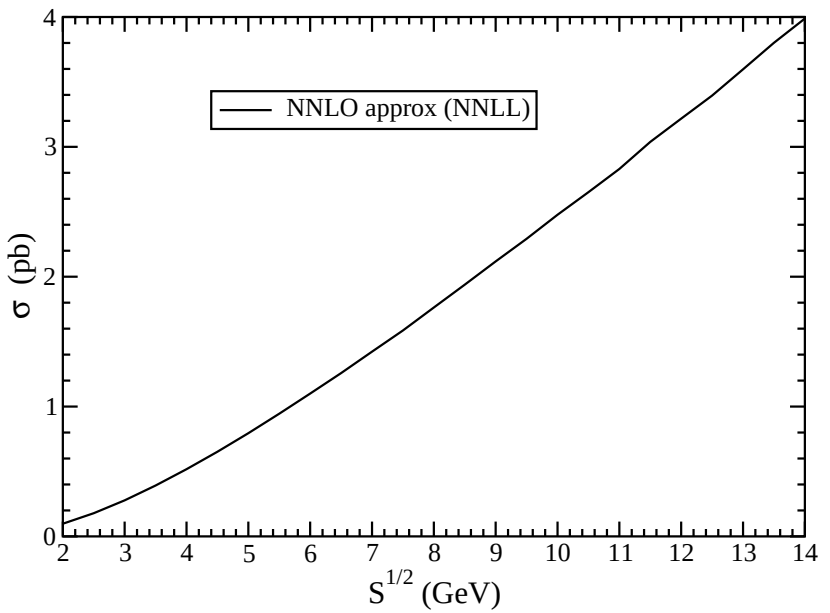
$$\sigma^{\mathrm{NNLOapprox,\,top}}_{s-\mathrm{channel}}(m_t = 173\,\mathrm{GeV}, 7\,\mathrm{TeV}) = 3.17 \pm 0.06^{+0.13}_{-0.10}\ \mathrm{pb}$$

$$\sigma^{\mathrm{NNLOapprox,\,top}}_{s-\mathrm{channel}}(m_t = 173\,\mathrm{GeV}, 10\,\mathrm{TeV}) = 5.16 \pm 0.09^{+0.20}_{-0.14}\ \mathrm{pb}$$

$$\sigma^{\mathrm{NNLOapprox,\,top}}_{s-\mathrm{channel}}(m_t = 173\,\mathrm{GeV}, 14\,\mathrm{TeV}) = 7.93 \pm 0.14^{+0.31}_{-0.28}\ \mathrm{pb}$$

Single antitop production at the LHC - s channel





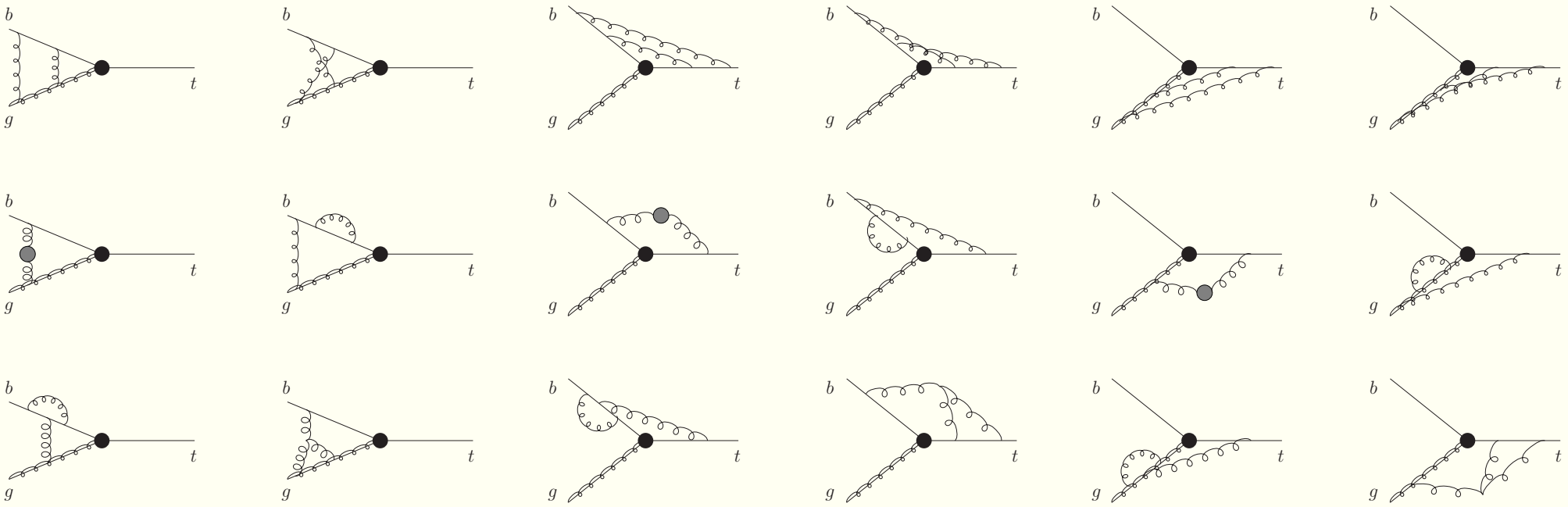
$$\sigma^{\mathrm{NNLOapprox,\,antitop}}_{s-\mathrm{channel}}(m_t = 173\,\mathrm{GeV}, 7\,\mathrm{TeV}) = 1.42 \pm 0.01^{+0.06}_{-0.07}\ \mathrm{pb}$$

$$\sigma^{\mathrm{NNLOapprox,\,antitop}}_{s-\mathrm{channel}}(m_t = 173\,\mathrm{GeV}, 10\,\mathrm{TeV}) = 2.48 \pm 0.02^{+0.09}_{-0.13}\ \mathrm{pb}$$

$$\sigma^{\mathrm{NNLOapprox,\,antitop}}_{s-\mathrm{channel}}(m_t = 173\,\mathrm{GeV}, 14\,\mathrm{TeV}) = 3.99 \pm 0.05^{+0.14}_{-0.21}\ \mathrm{pb}$$

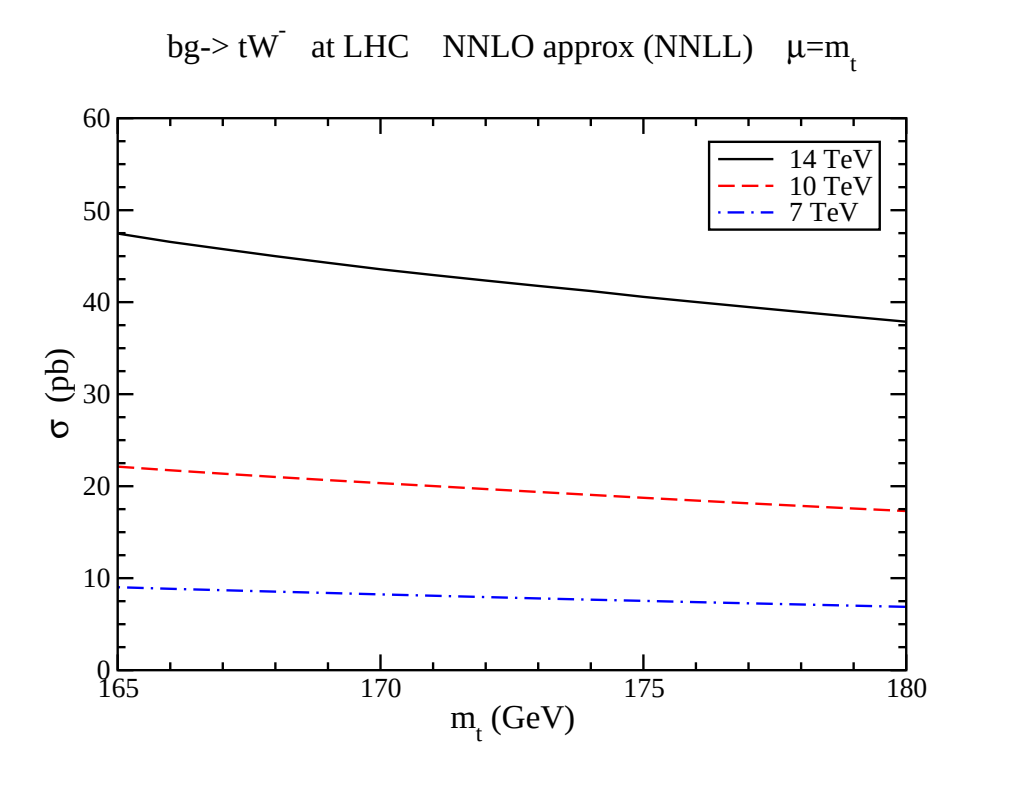
Associated production of a top quark with a W^-

Two-loop eikonal diagrams



+ top quark self-energy graphs

Cross section for tW^- production



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

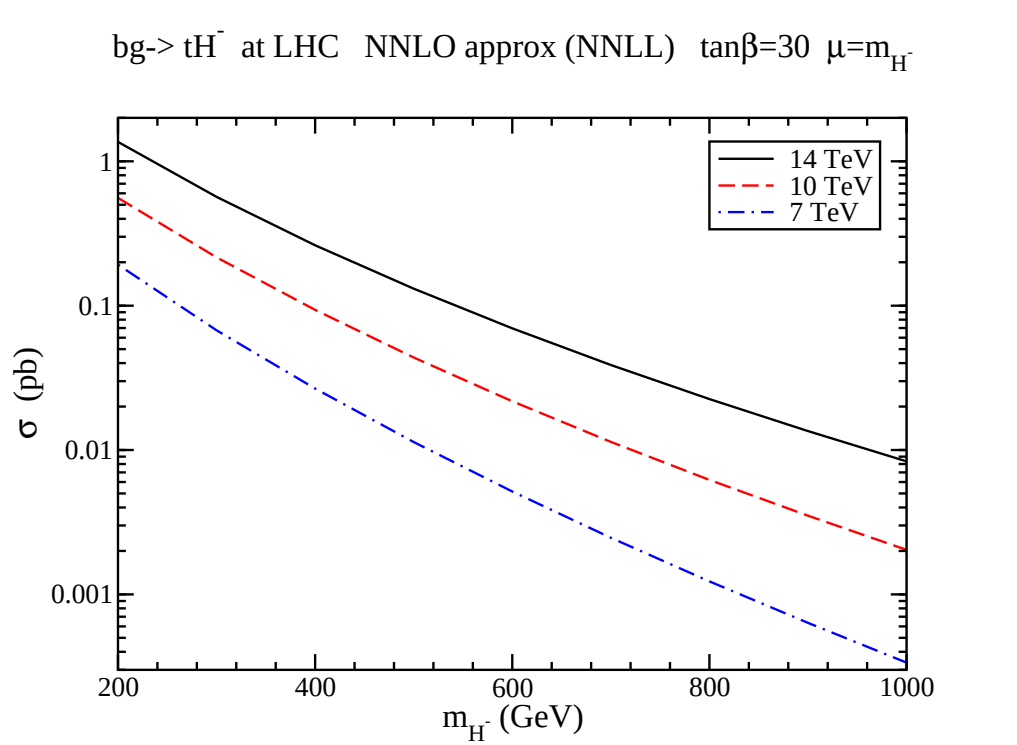
$$\sigma_{tW}^{\mathrm{NNLOapprox}}(m_t = 173\,\mathrm{GeV}, 10\,\mathrm{TeV}) = 19.4 \pm 0.5^{+1.0}_{-1.1}\ \mathrm{pb}$$

$$\sigma_{tW}^{\mathrm{NNLOapprox}}(m_t = 173\,\mathrm{GeV}, 14\,\mathrm{TeV}) = 41.8 \pm 1.0^{+1.5}_{-2.4}\ \mathrm{pb}$$

NNLO approx corrections increase NLO cross section by $\sim 8\%$

Cross section for $\bar{t}W$ production is identical

Associated production of a top quark with a charged Higgs



NNLO approx corrections increase NLO cross section by $\sim$ 15 to $\sim$ 20%

Summary

- **NNLL resummation for top quark pair and single top production**
- **$t\bar{t}$ production - cross section and p_T distributions**
- **s-channel single top production cross section**
- **$bg \to tW^-$ and $bg \to tH^-$ at LHC**
- **NNLO approx corrections for top pair and single top production are significant at Tevatron and LHC**