Single top quark production cross section at hadron colliders

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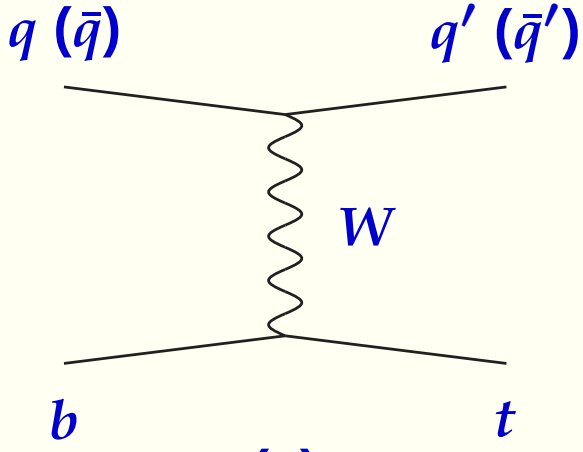
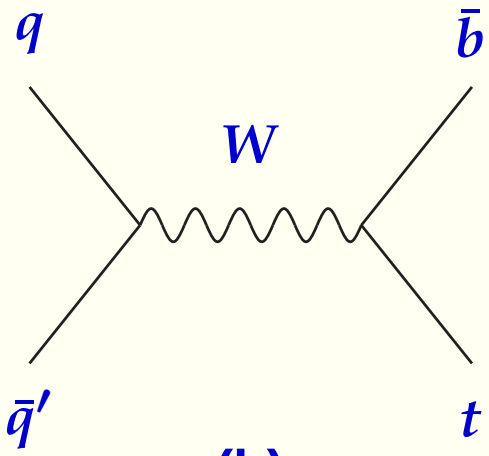
- **Single top production channels**
- **Higher-order two-loop corrections**
- **s-channel production at Tevatron and LHC**
- **Associated production of a top with a W^-**
- **Associated production of a top with a charged Higgs**

Single top quark production

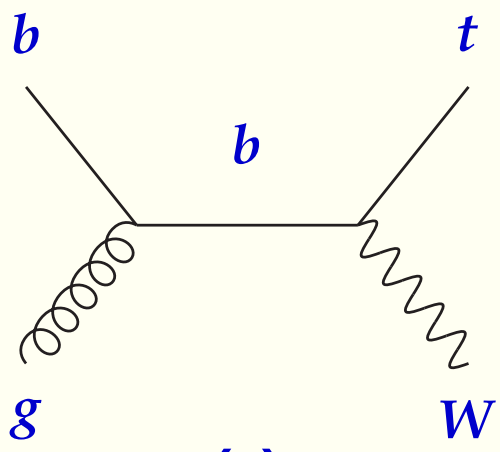
Partonic processes at LO



(a)



(b)

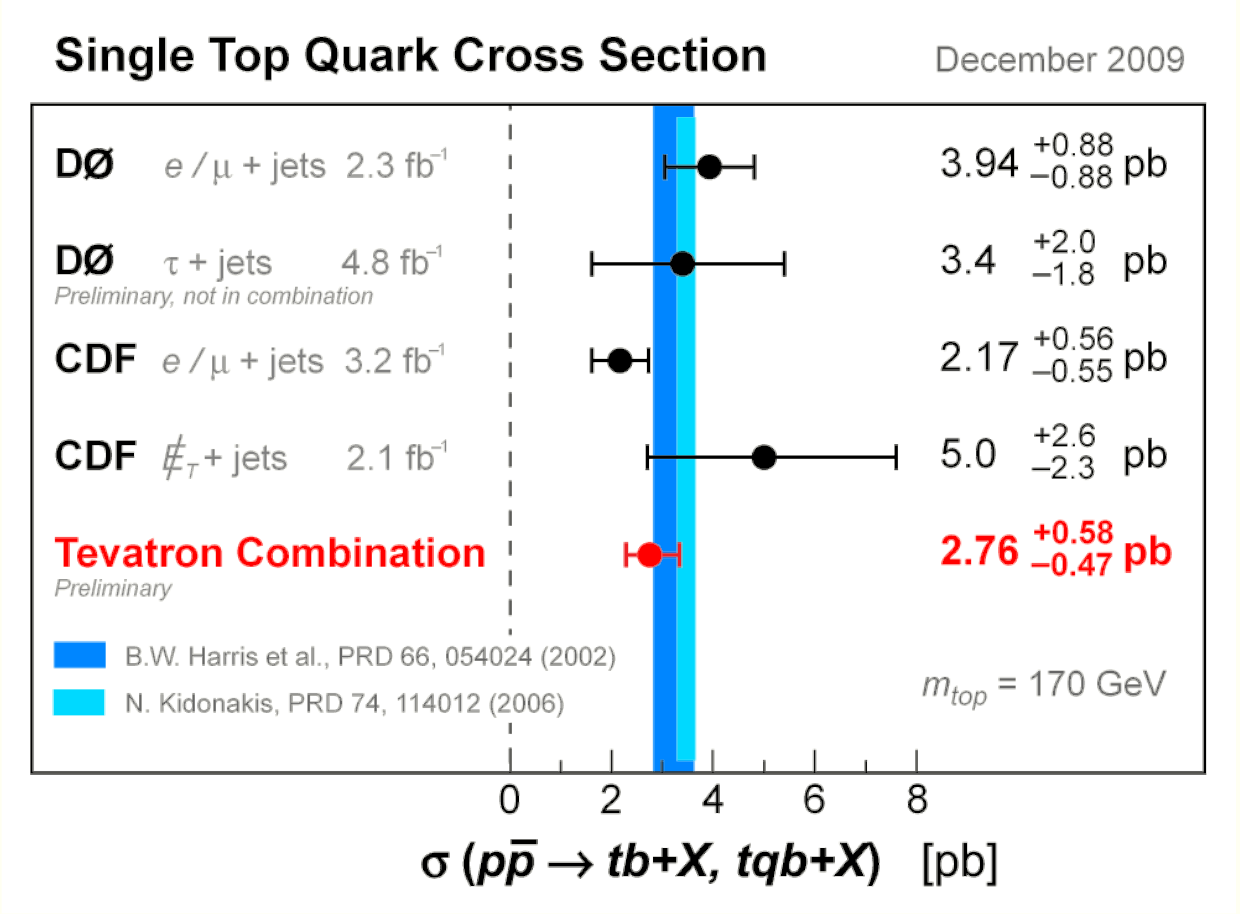


(c)

(a) t channel: $qb \longrightarrow q't$ and $\bar{q}b \longrightarrow \bar{q}'t$ ($ub \longrightarrow dt$ and $\bar{d}b \longrightarrow \bar{u}t$, etc.)

(b) s channel: $q\bar{q}' \longrightarrow \bar{b}t$ ($u\bar{d} \longrightarrow \bar{b}t$, etc)

(c) associated tW production: $bg \longrightarrow tW^-$



Experimental uncertainties are large

Higher-order corrections

QCD corrections significant for 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 (NNLL) accuracy requires one-loop (two-loop) calculations in the eikonal approximation

Approximate NNLO cross section from expansion of resummed cross section

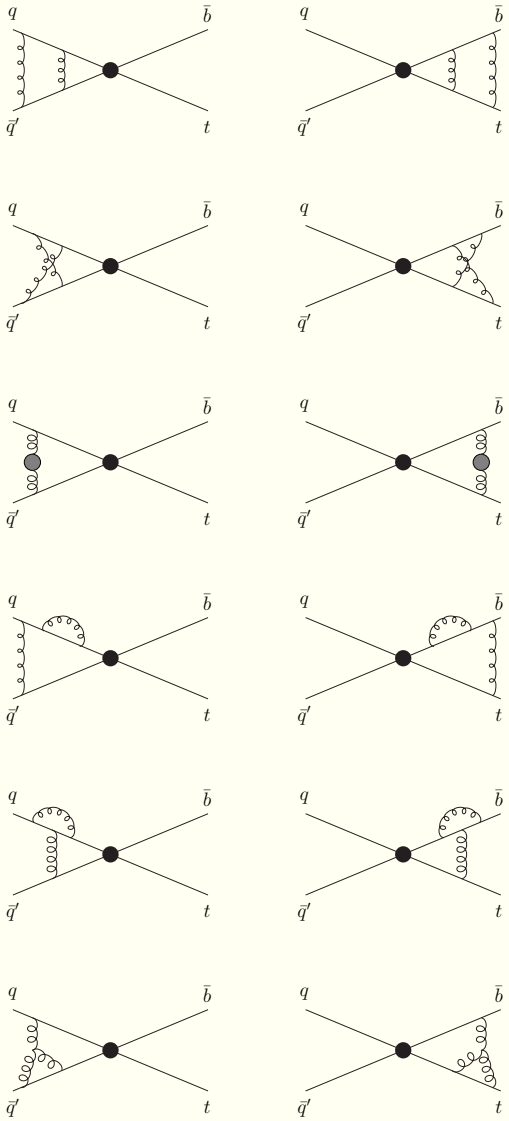
Essential ingredient: two-loop soft anomalous dimension

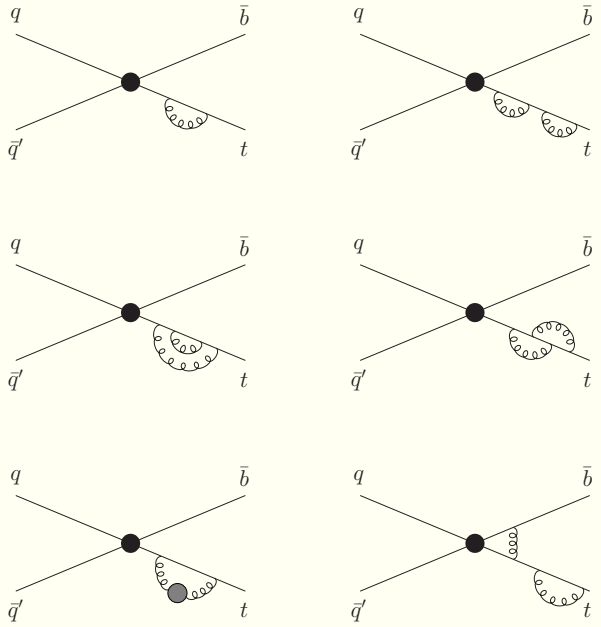
N. Kidonakis, Phys. Rev. Lett. 102, 232003 (2009), arXiv:0903.2561 [hep-ph]

This allows NNLL resummation

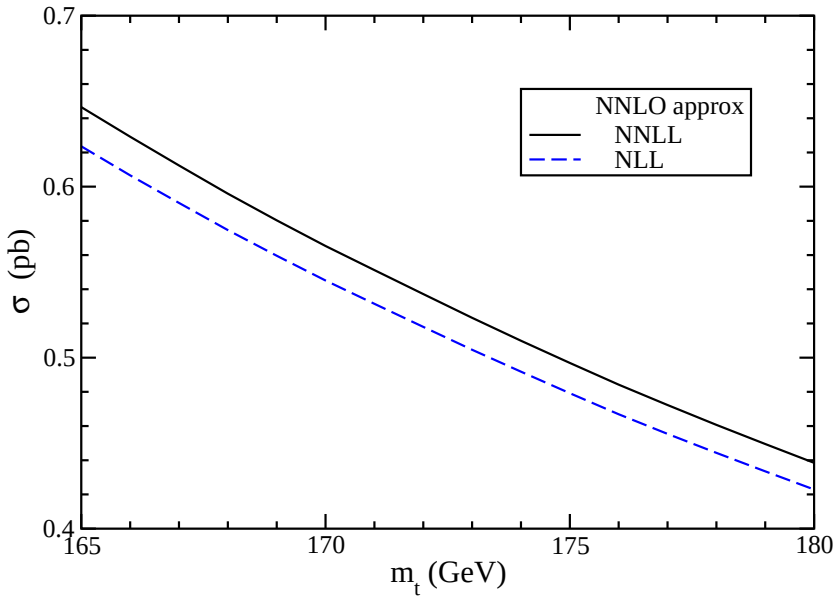
Single top quark production - s channel

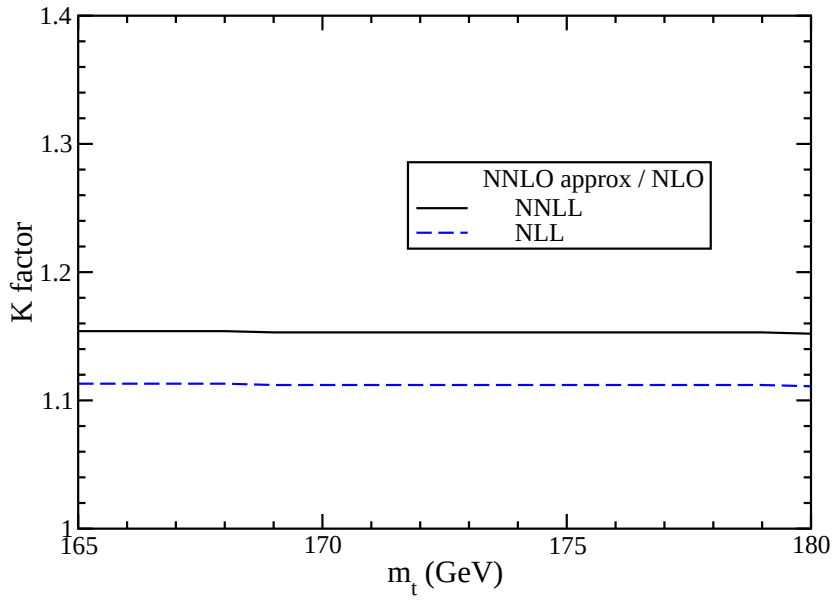
Two-loop eikonal diagrams





s-channel single top cross section at Tevatron



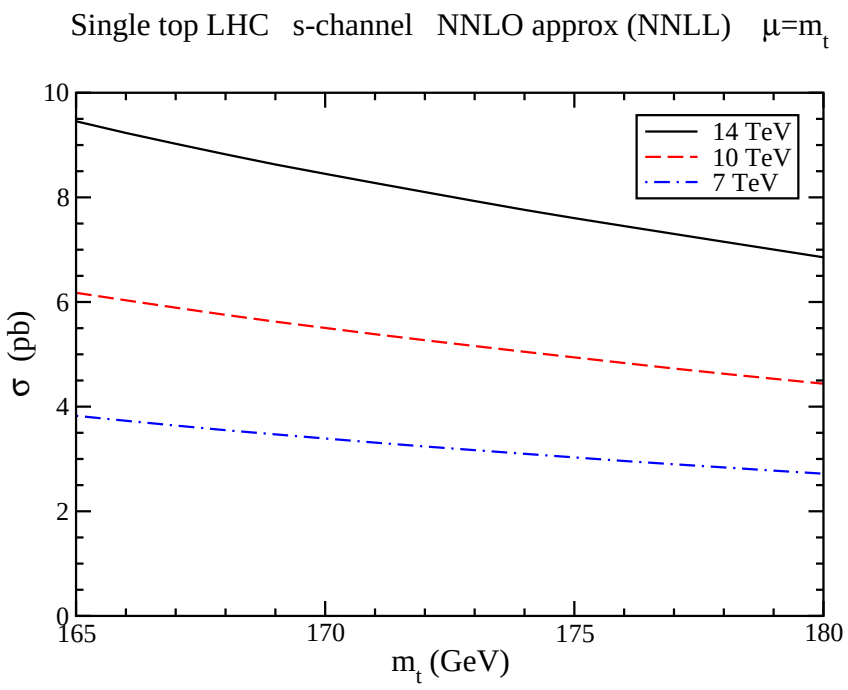


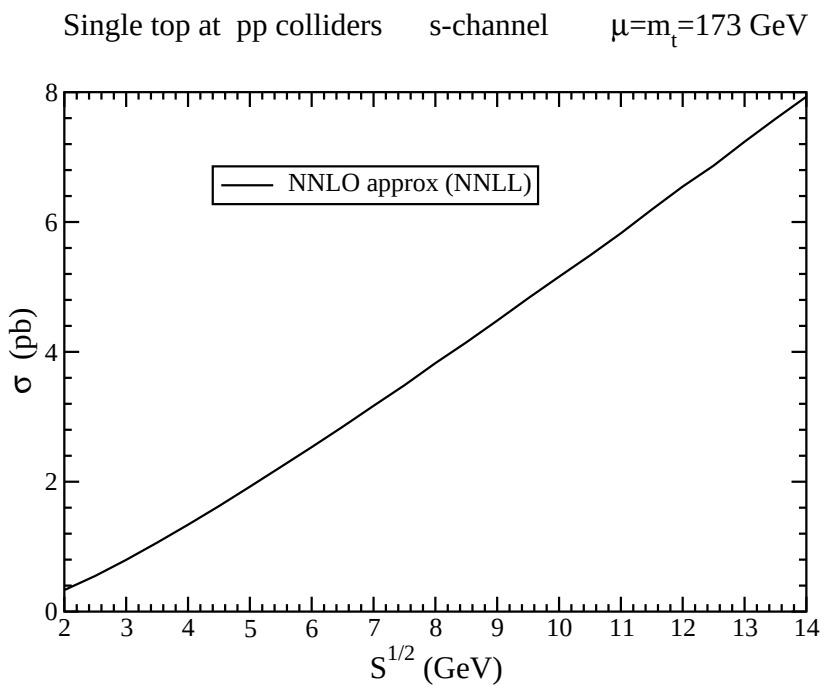
$$\sigma^{\mathrm{NNLOapprox,\,top}}_{s-\mathrm{channel}}(m_t = 173\,\mathrm{GeV}) \quad = \quad 0.523^{+0.001\,+0.030}_{-0.005\,-0.028}\ \mathrm{pb}$$

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

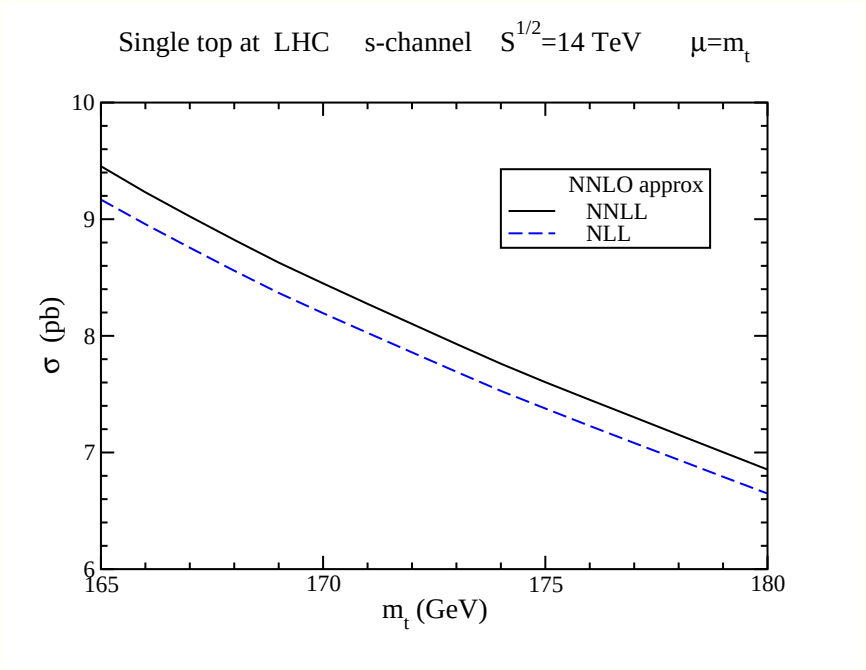


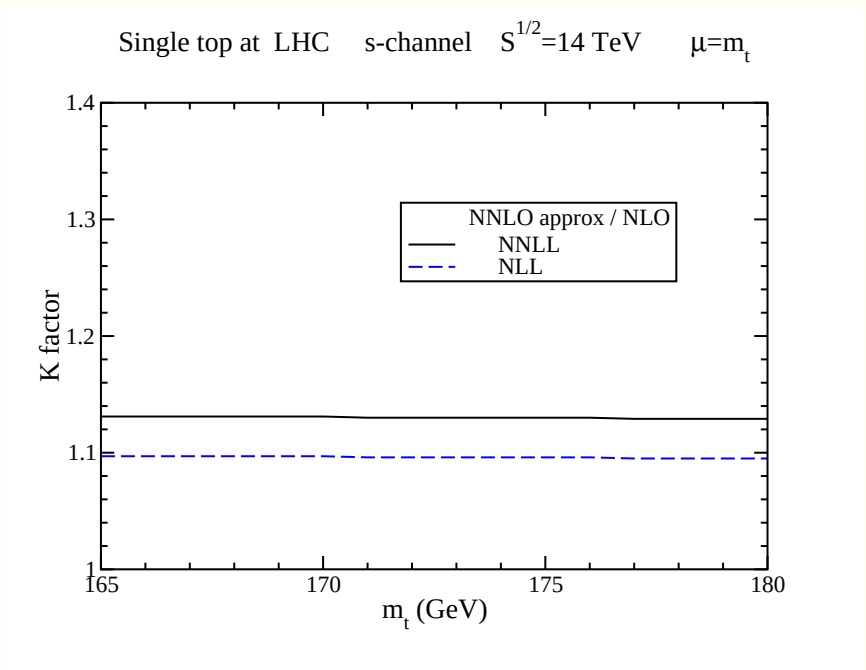


$$\sigma^{\mathrm{NNLOapprox,\,top}}_{s-\mathrm{channel}}(m_t = 173\,\mathrm{GeV}, 7\,\mathrm{TeV}) = 3.17 \pm 0.06^{+0.13}_{-0.10}\ \mathrm{pb}$$

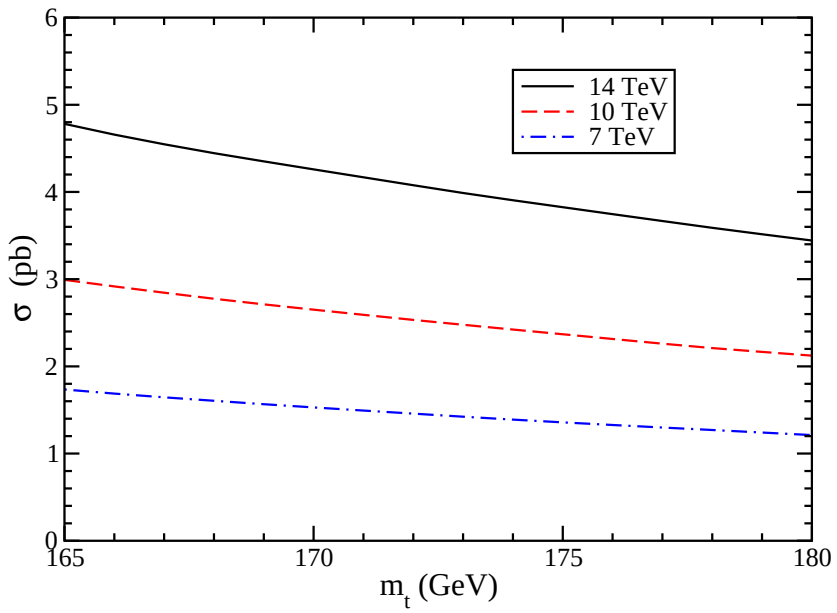
$$\sigma^{\mathrm{NNLOapprox,\,top}}_{s-\mathrm{channel}}(m_t = 173\,\mathrm{GeV}, 10\,\mathrm{TeV}) = 5.16 \pm 0.09^{+0.20}_{-0.14}\ \mathrm{pb}$$

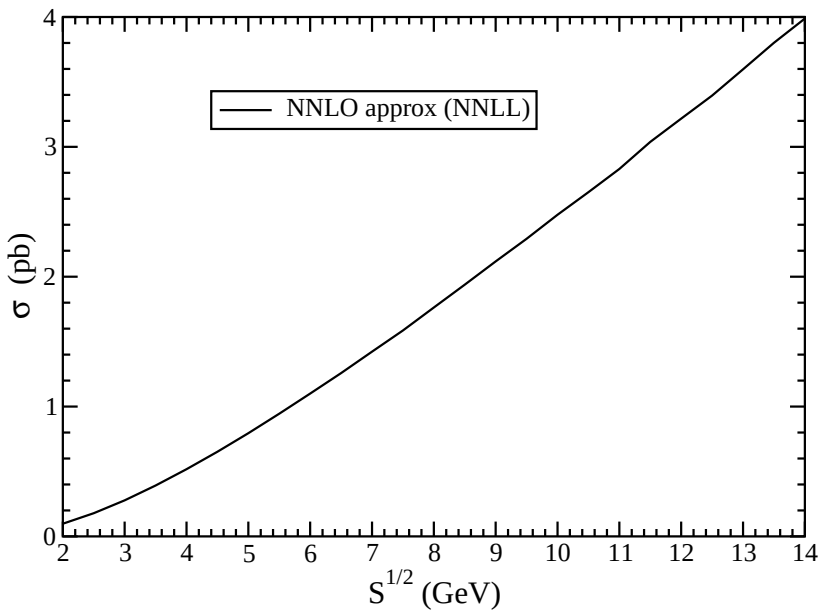
$$\sigma^{\mathrm{NNLOapprox,\,top}}_{s-\mathrm{channel}}(m_t = 173\,\mathrm{GeV}, 14\,\mathrm{TeV}) = 7.93 \pm 0.14^{+0.31}_{-0.28}\ \mathrm{pb}$$


Single top at LHC s-channel $S^{1/2}$=14 TeV $\mu=m_t$
NNLO approx
NNLL
NLL
σ (pb)
m_t (GeV)
10
9
8
7
6
165
170
175
180


Single top at LHC s-channel $S^{1/2}$=14 TeV $\mu=m_t$
NNLO approx / NLO
NNLL
NLL
K factor
m_t (GeV)
1.4
1.3
1.2
1.1
1
165
170
175
180

Single antitop production at the LHC - s channel





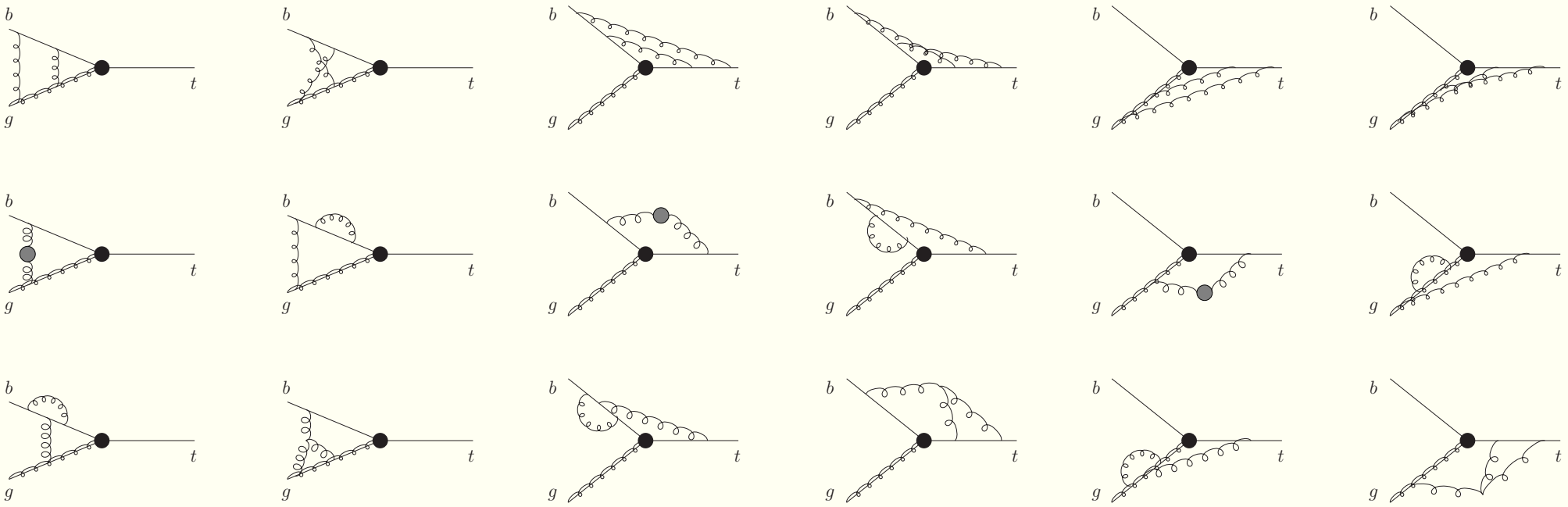
$$\sigma^{\text{NNLOapprox, antitop}}_{s-\text{channel}}(m_t = 173\,\text{GeV}, 7\,\text{TeV}) = 1.42 \pm 0.01^{+0.06}_{-0.07}\ \text{pb}$$

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

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

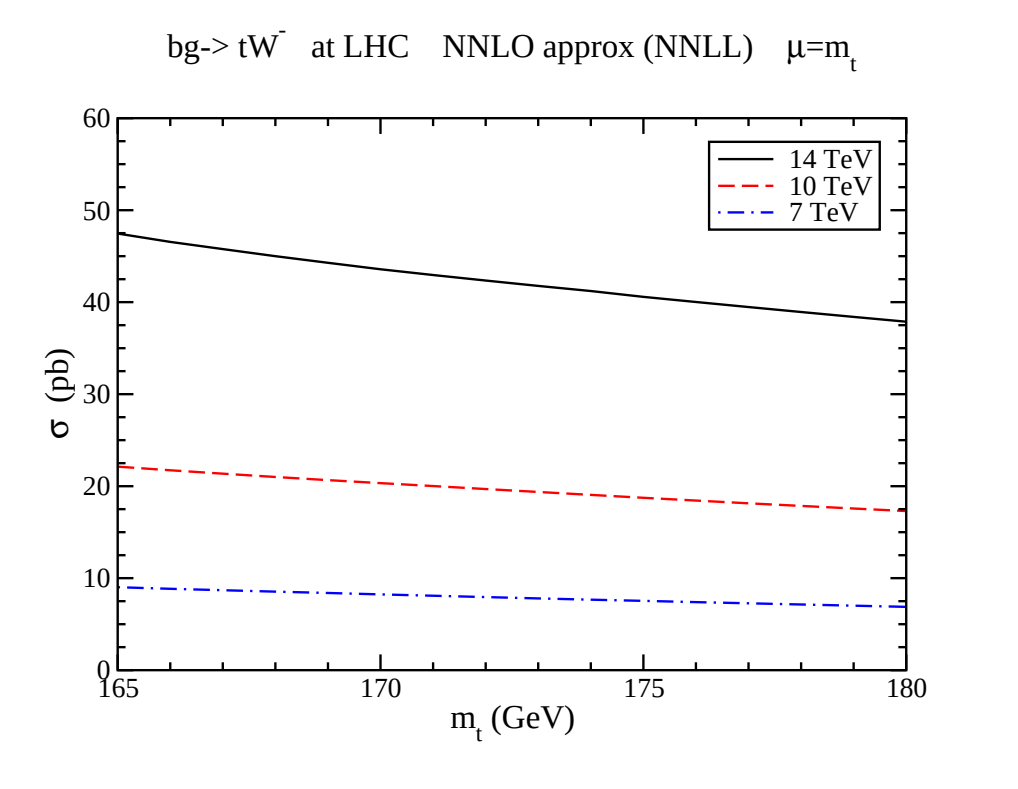
Associated production of a top quark with a W^-

Two-loop eikonal diagrams



+ top quark self-energy graphs

Cross section for tW^- production



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

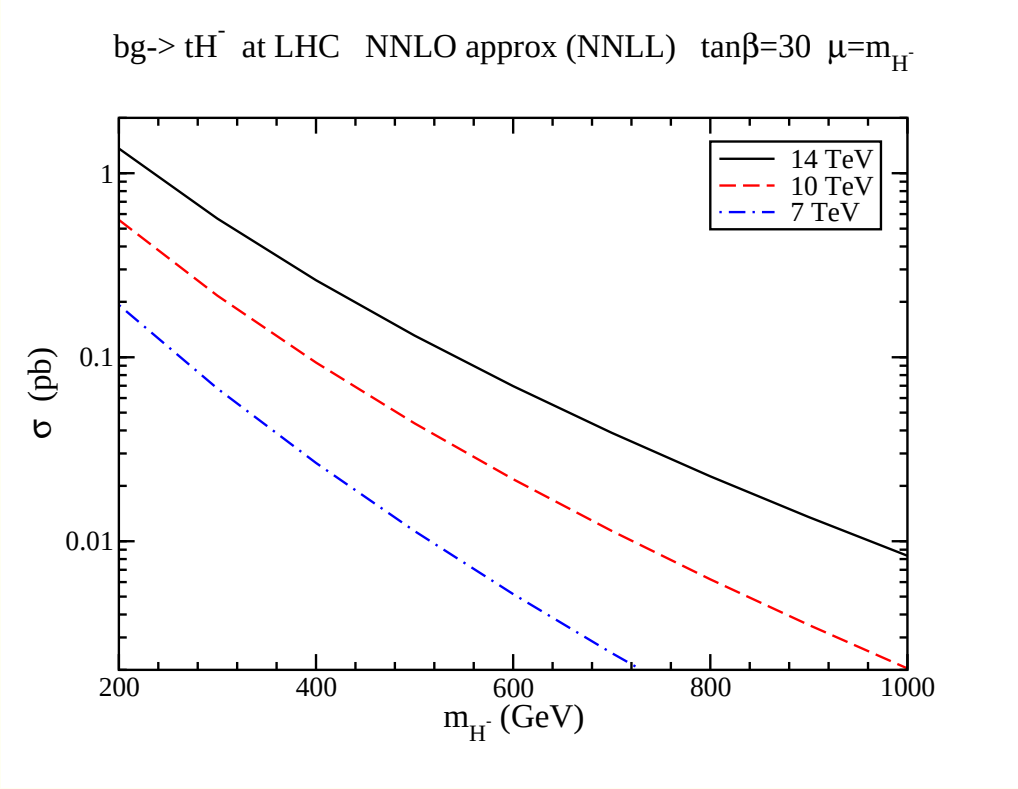
$$\sigma_{tW}^{\rm NNLOapprox}(m_t = 173\,{\rm GeV}, 10\,{\rm TeV}) = 19.4^{+1.0}_{-1.1}\ {\rm pb}$$

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

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

- **Single top production - Tevatron data consistent with theory**
- **Theoretical progress in higher-order QCD corrections at NNLL**
- **NNLO approx corrections for s-channel production are significant at Tevatron and LHC**
- **NNLO approx for $bg \longrightarrow tW^-$ at LHC: relatively large cross section**
- **NNLO approx for $bg \longrightarrow tH^-$ at LHC: large corrections**