Differential and total cross sections for top pair and single top production

Nikolaos Kidonakis

(Kennesaw State University)

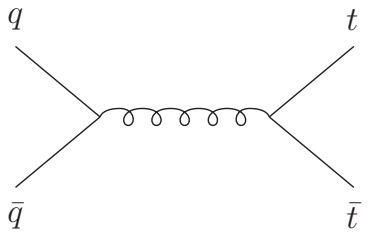
- $t\bar{t}$ **and single top production channels**
- **Higher-order two-loop corrections**
- $t\bar{t}$ **cross section at LHC and Tevatron**
- **Top** p_T **and rapidity distributions**
- t**-channel production**
- s**-channel production**
- **Associated production of a top with a** W^- **or** H^-

Partonic processes at LO

Top-antitop pair production

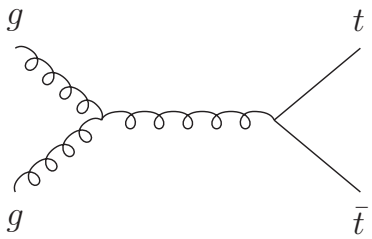
- $q\bar{q} \to t\bar{t}$

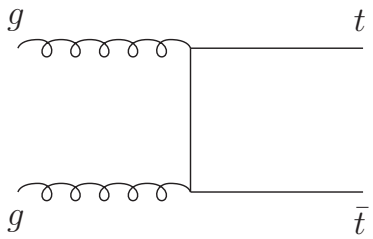
dominant at Tevatron

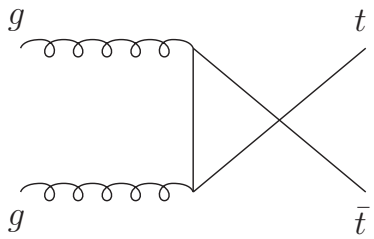


- $gg \to t\bar{t}$

dominant at LHC



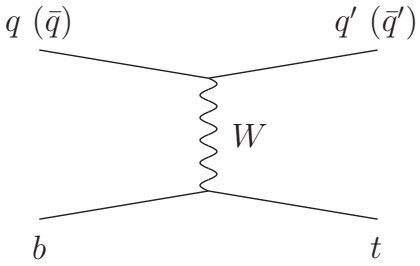




Single top quark production

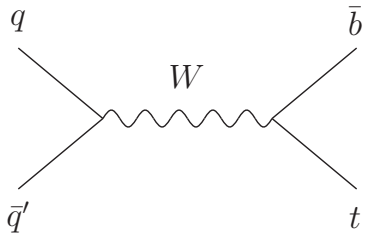
- **t channel: $qb \to q't$ and $\bar{q}b \to \bar{q}'t$**

dominant at Tevatron and LHC



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

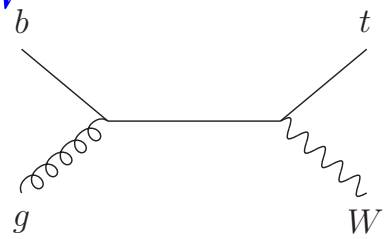
small at Tevatron and LHC

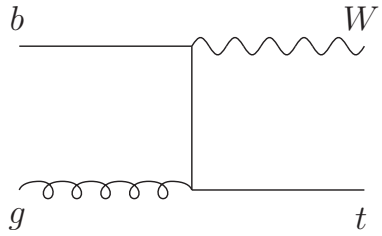


- **associated tW production: $bg \to tW^-$**

very small at Tevatron, significant at LHC

Related process: $bg \to tH^-$





Higher-order corrections

QCD corrections significant for top pair and single top quark production

Soft-gluon corrections from emission of soft (low-energy) gluons

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

Soft-gluon corrections are dominant near threshold

Resum these soft corrections - factorization and RGE

Complete results at NNLL–two-loop soft anomalous dimension

NK, PRD 82, 114030 (2010); PRD 84, 011504 (2011) ($t\bar{t}$)

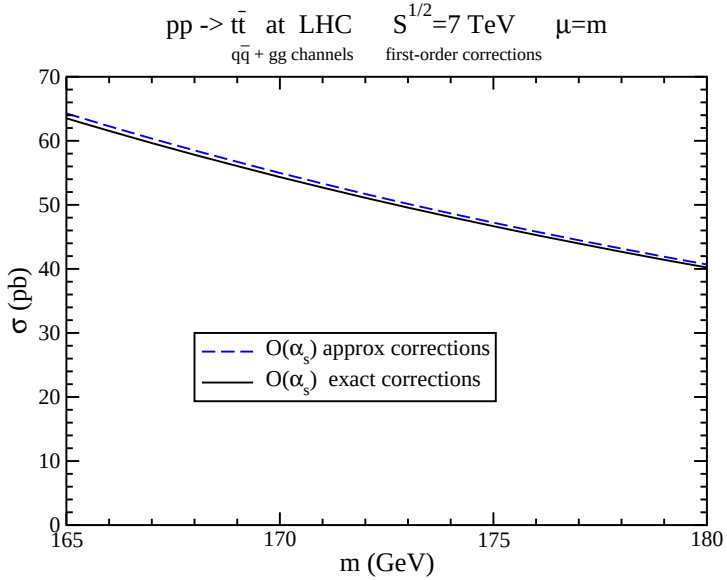
NK, PRD81, 054028 (2010); PRD 82, 054018 (2010); PRD 83,091503 (2011) (single top)

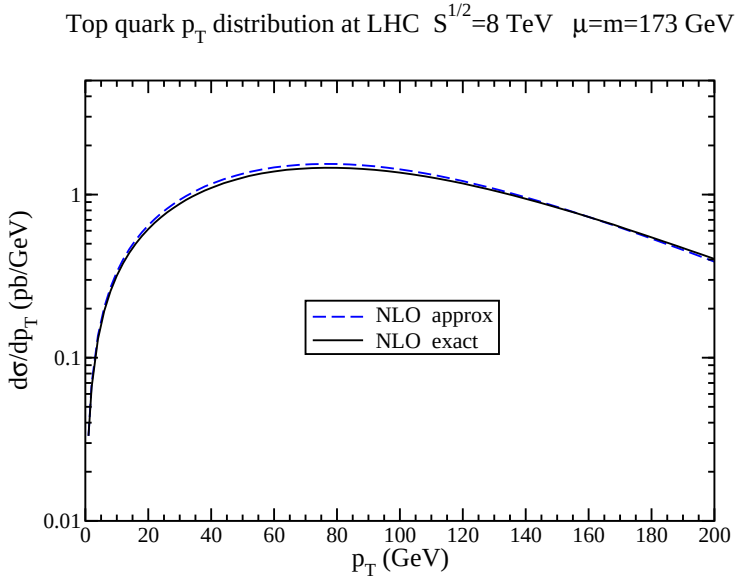
Approximate NNLO cross section from expansion of resummed cross section

This is the only calculation at the differential cross section level using the standard moment-space resummation in pQCD

Threshold approximation

Approximation works very well not only for Tevatron but also for LHC energies because partonic threshold is still important

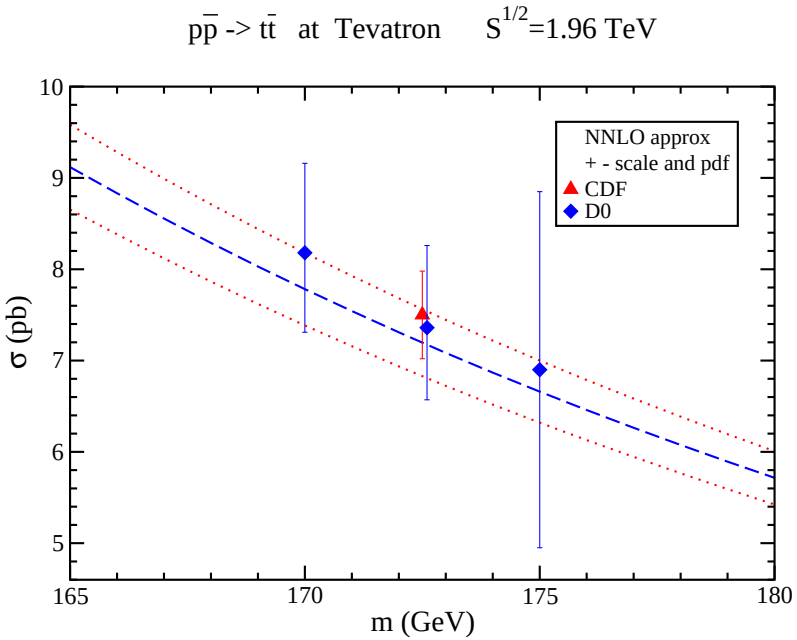


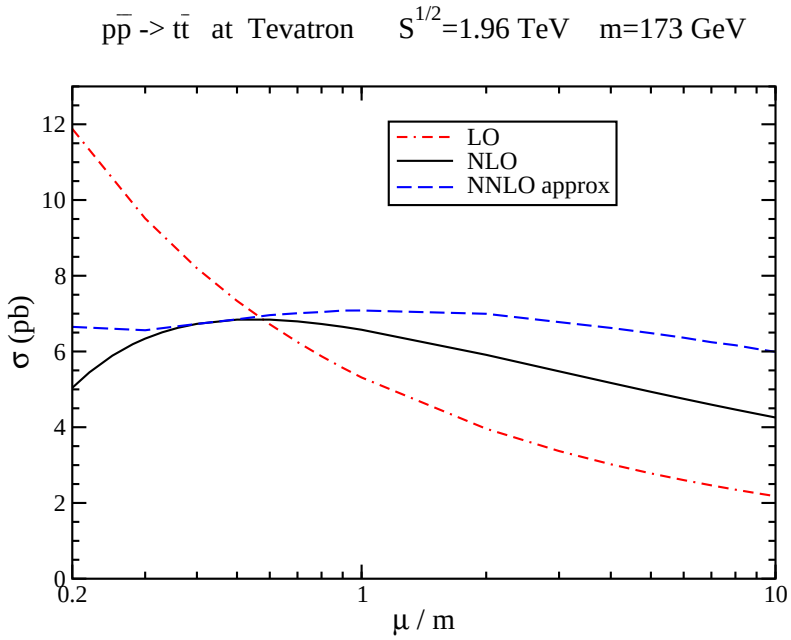


only 1% difference between first-order approximate and exact corrections
→ less than 1% difference between NLO approximate and exact cross sections
Also true for differential distributions

For best prediction add NNLO approximate corrections to exact NLO cross section

$t\bar{t}$ cross section at the Tevatron





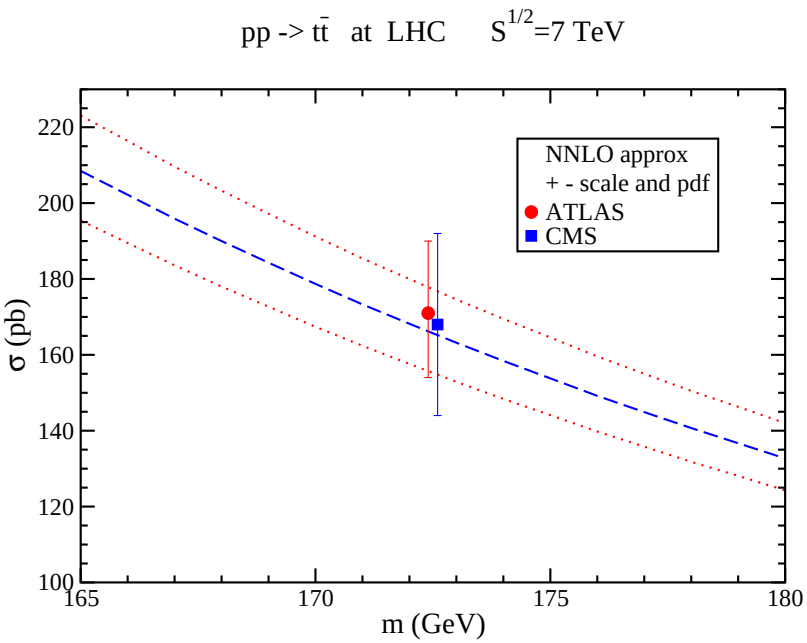
$$\sigma_{t\bar{t}}^{\rm NNLOapprox}(m_t = 173\,{\rm GeV},\, 1.96\,{\rm TeV}) \quad = \quad 7.08^{+0.00\,+0.36}_{-0.24\,-0.27}\ {\rm pb}$$

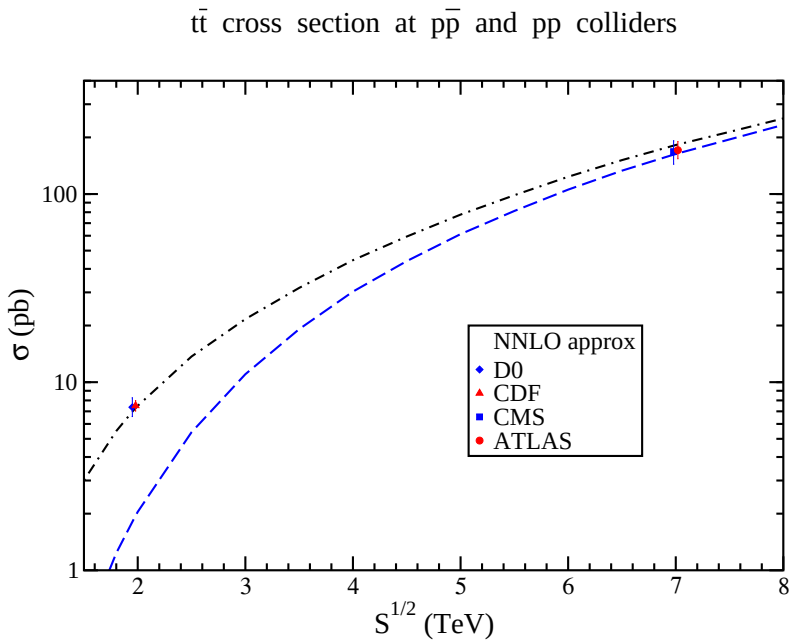
scale pdf

NNLO approx: 7.8% enhancement over NLO
scale dependence greatly reduced

used MSTW 2008 NNLO pdf

$t\bar{t}$ cross section at the LHC





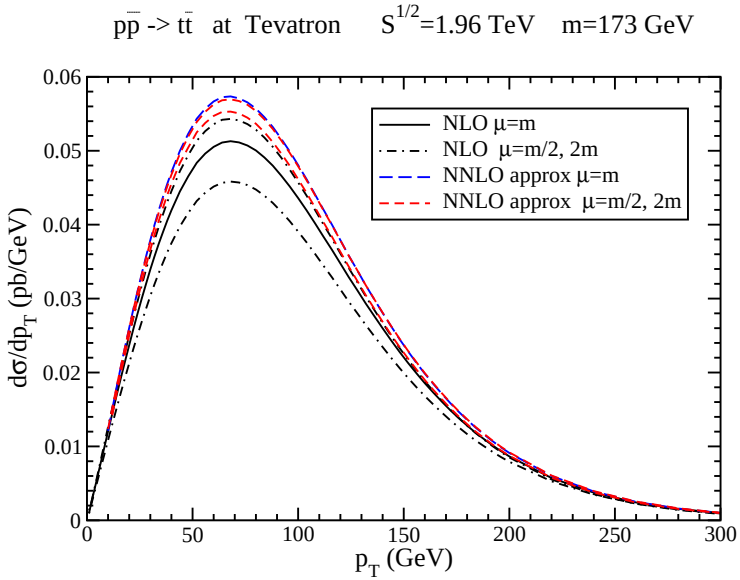
$$\sigma_{t\bar{t}}^{\rm NNLOapprox}(m_t = 173\,{\rm GeV},\, 7\,{\rm TeV}) \;=\; 163^{+7}_{-5} \pm 9\ {\rm pb}$$

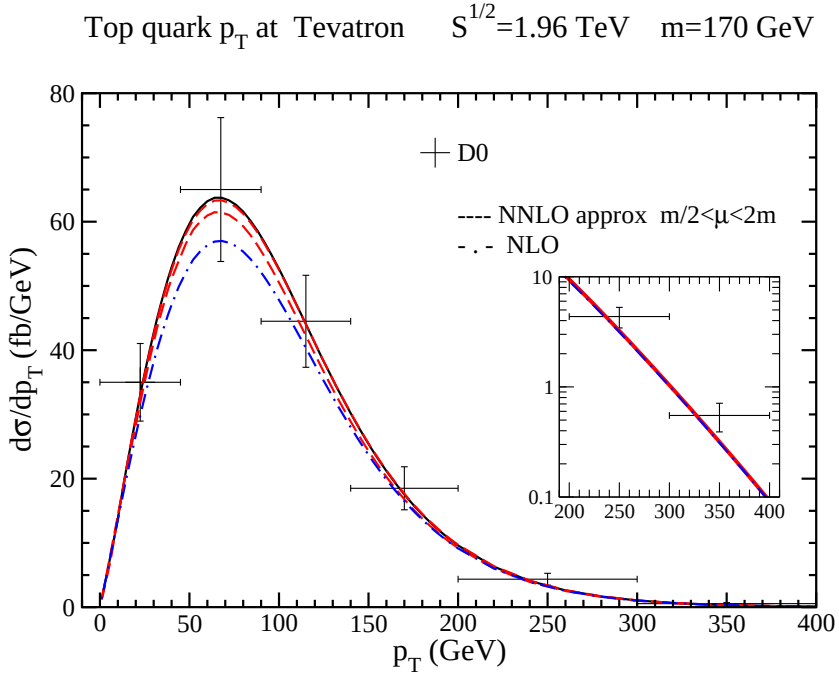
$$\sigma_{t\bar{t}}^{\rm NNLOapprox}(m_t = 173\,{\rm GeV},\, 8\,{\rm TeV}) \;=\; 234^{+10}_{-7} \pm 12\ {\rm pb}$$

$$\sigma_{t\bar{t}}^{\rm NNLOapprox}(m_t = 173\,{\rm GeV},\, 14\,{\rm TeV}) \;=\; 920^{+50\,+33}_{-39\,-35}\ {\rm pb}$$

NNLO approx: enhancement over NLO (same pdf) is 7.6% at 7 TeV; 7.8% at 8 TeV; 8.0% at 14 TeV

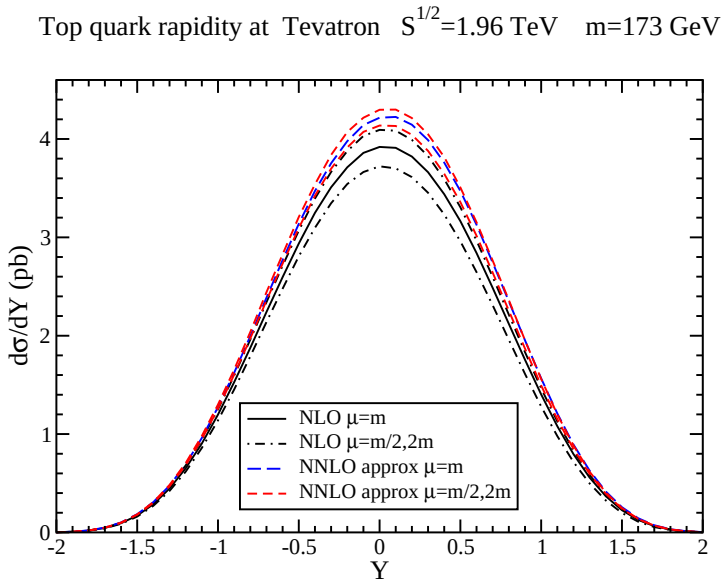
Top quark p_T distribution at Tevatron





Excellent agreement of NNLO approx results with D0 data

Top quark rapidity distribution at Tevatron



Top Forward-backward asymmetry

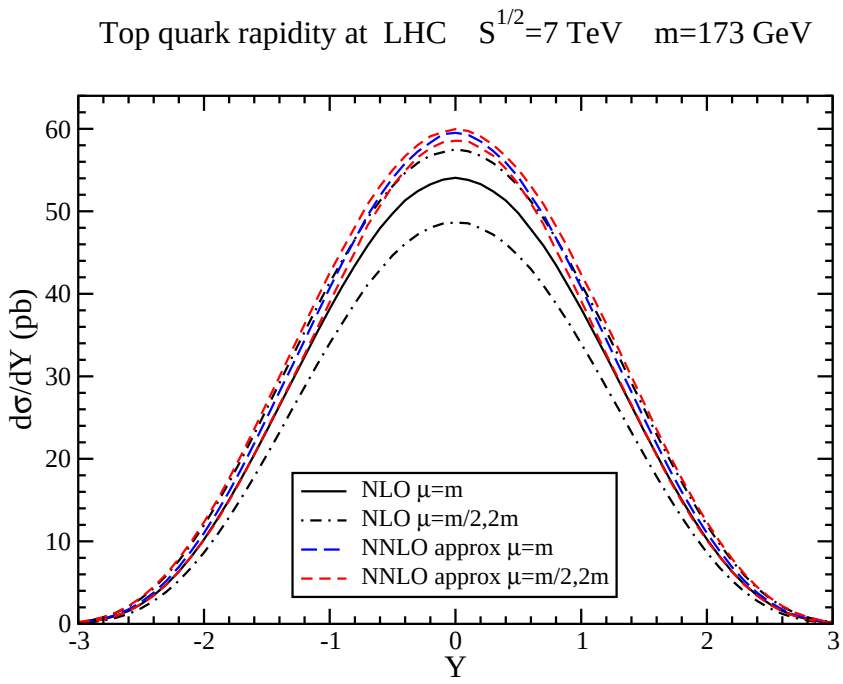
$$A_{\rm FB} = \frac{\sigma(Y>0) - \sigma(Y<0)}{\sigma(Y>0) + \sigma(Y<0)}$$

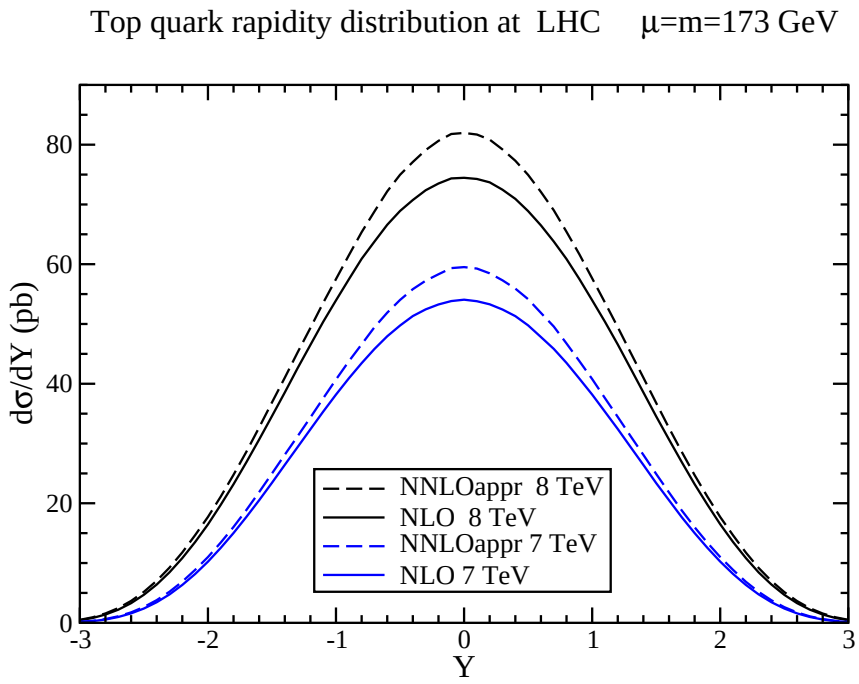
Asymmetry significant at the Tevatron

Theoretical result at Tevatron: $A_{\rm FB} = 0.052^{+0.000}_{-0.006}$

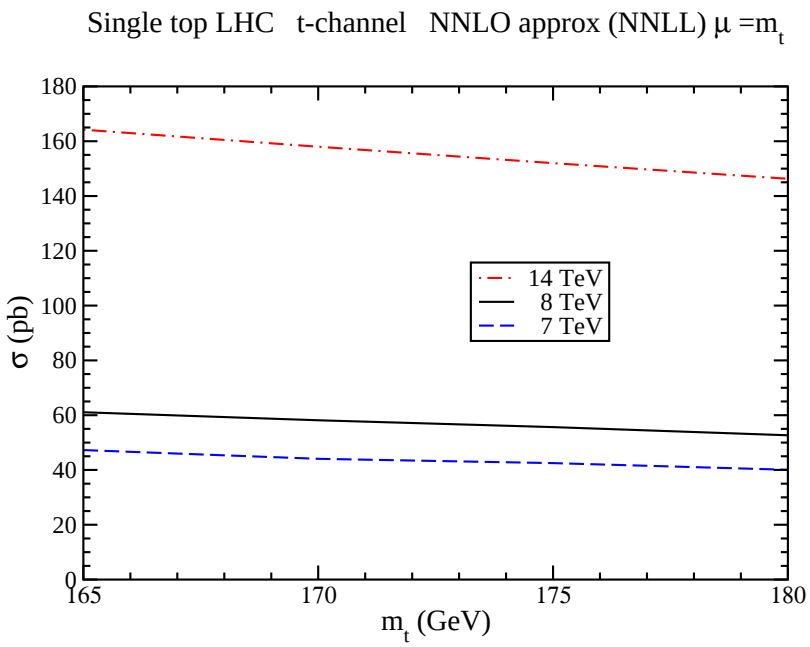
smaller than observed values

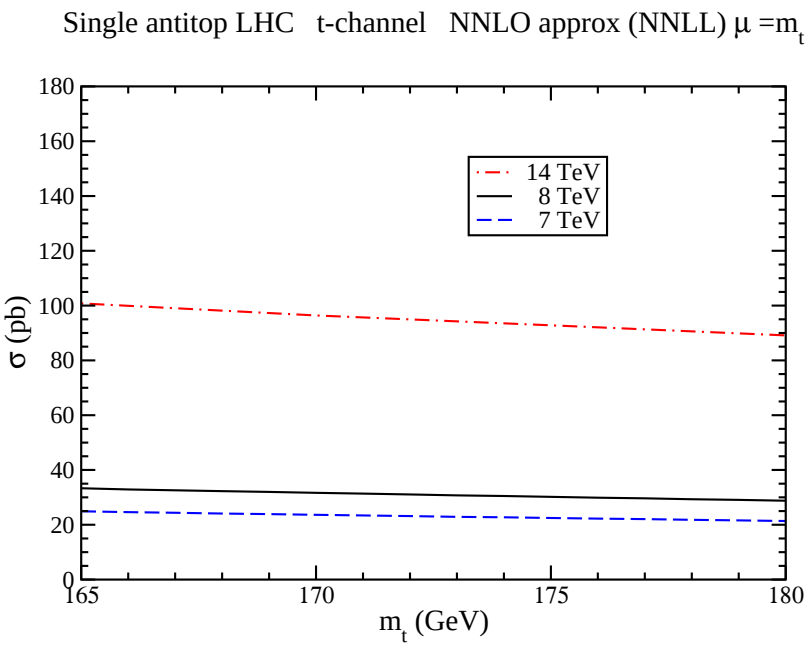
Top quark rapidity distribution at LHC





t-channel cross sections at LHC

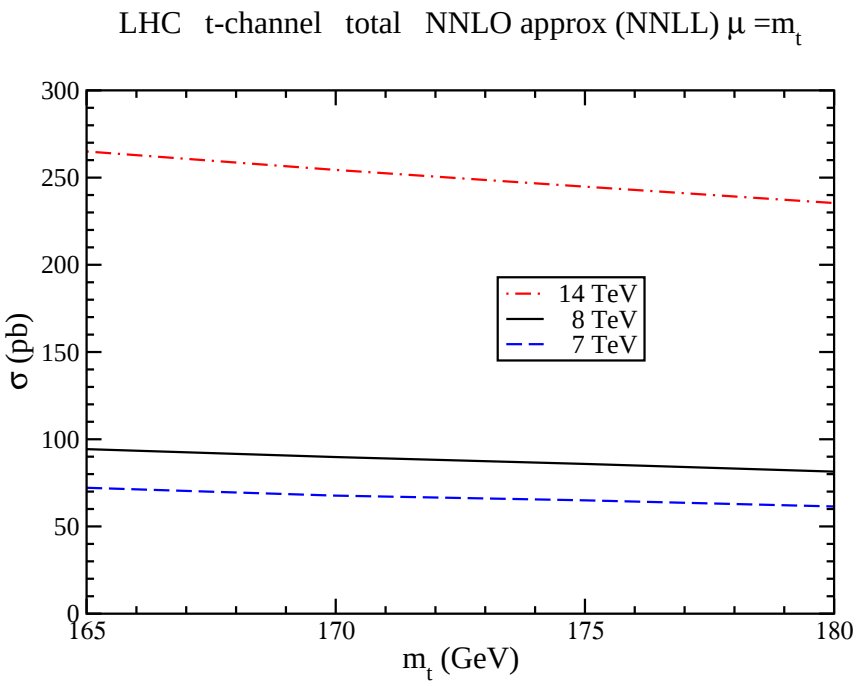


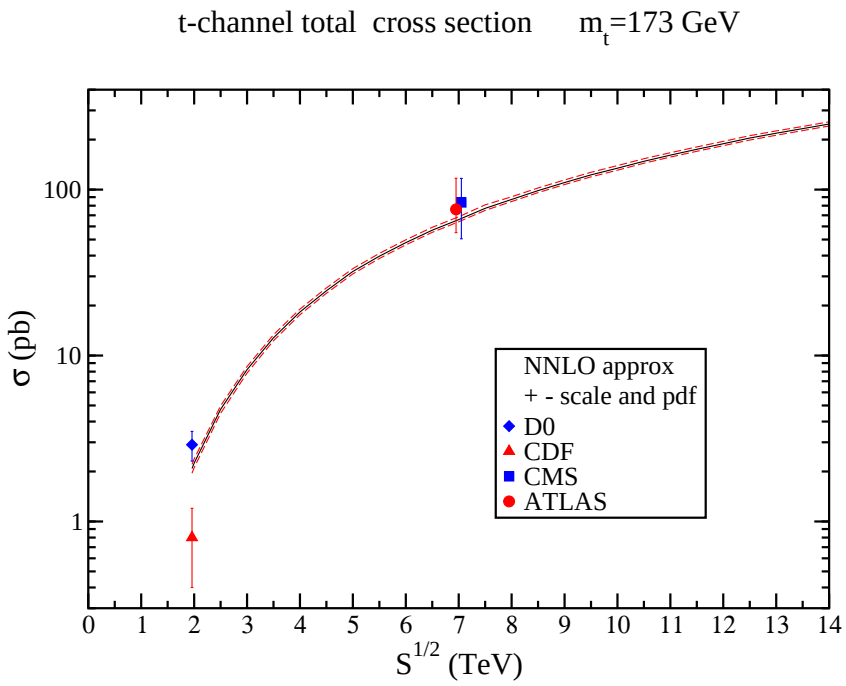


For $m_t = 173$ GeV

LHC	t	$\bar{t}$
7 TeV	$43.0^{+1.6}_{-0.2} \pm 0.8$	$22.9 \pm 0.5^{+0.7}_{-0.9}$
8 TeV	$56.4^{+2.1}_{-0.3} \pm 1.1$	$30.7 \pm 0.7^{+0.9}_{-1.1}$
14 TeV	$154^{+4}_{-1} \pm 3$	$94^{+2\,+2}_{-1\,-3}$

t-channel total cross section at LHC





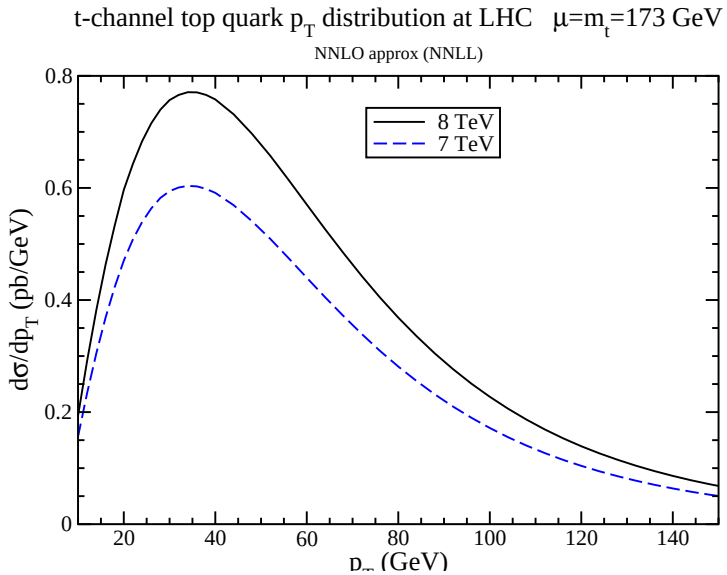
$$\sigma^{\rm NNLOapprox,\,total}_{t-{\rm channel}}(m_t = 173\,{\rm GeV},\,7\,{\rm TeV}) = 65.9^{+2.1\,+1.5}_{-0.7\,-1.7}\ {\rm pb}$$

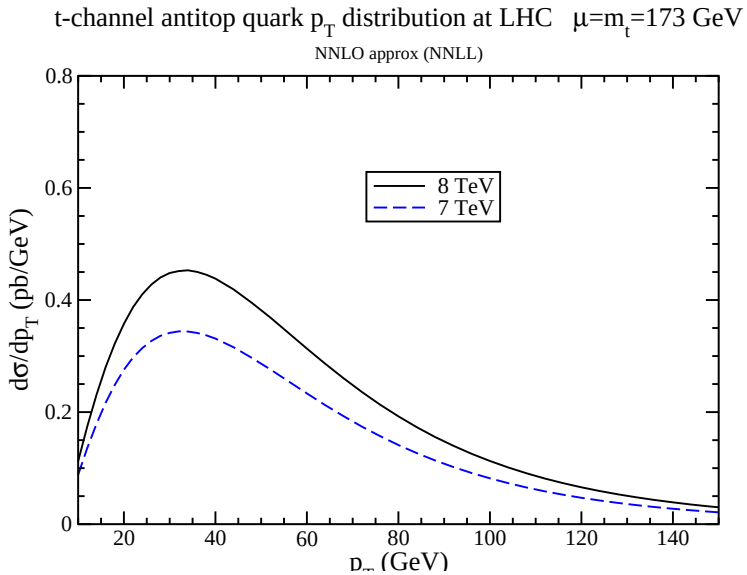
$$\sigma^{\rm NNLOapprox,\,total}_{t-{\rm channel}}(m_t = 173\,{\rm GeV},\,8\,{\rm TeV}) = 87.2^{+2.8\,+2.0}_{-1.0\,-2.2}\ {\rm pb}$$

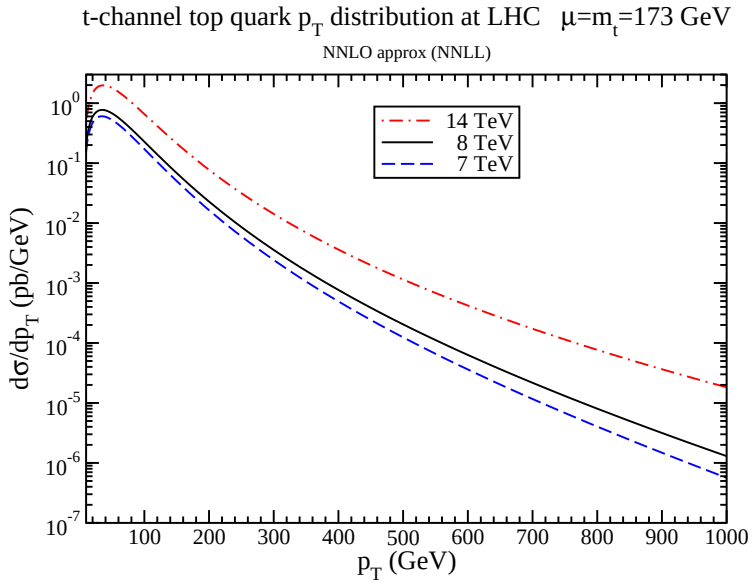
$$\sigma^{\rm NNLOapprox,\,total}_{t-{\rm channel}}(m_t = 173\,{\rm GeV},\,14\,{\rm TeV}) = 248^{+6\,+5}_{-2\,-6}\ {\rm pb}$$

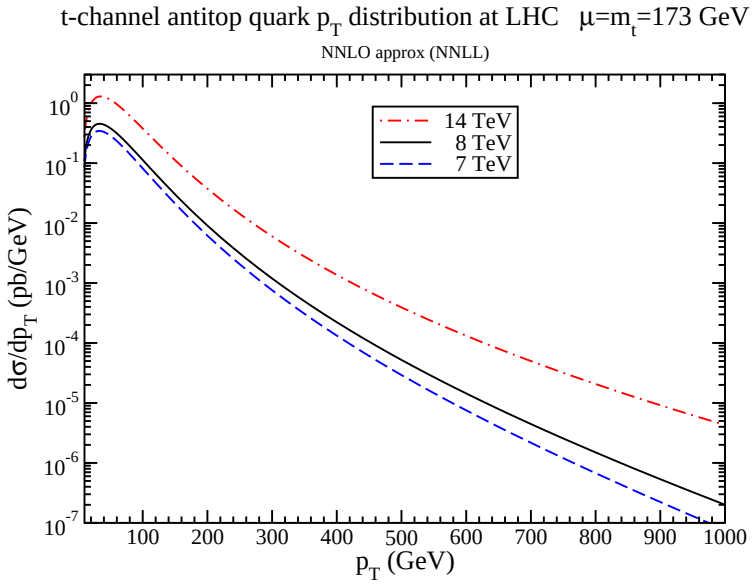
Small $\mathcal{O}(1\%)$ corrections over NLO

t-channel top and antitop p_T distributions at LHC

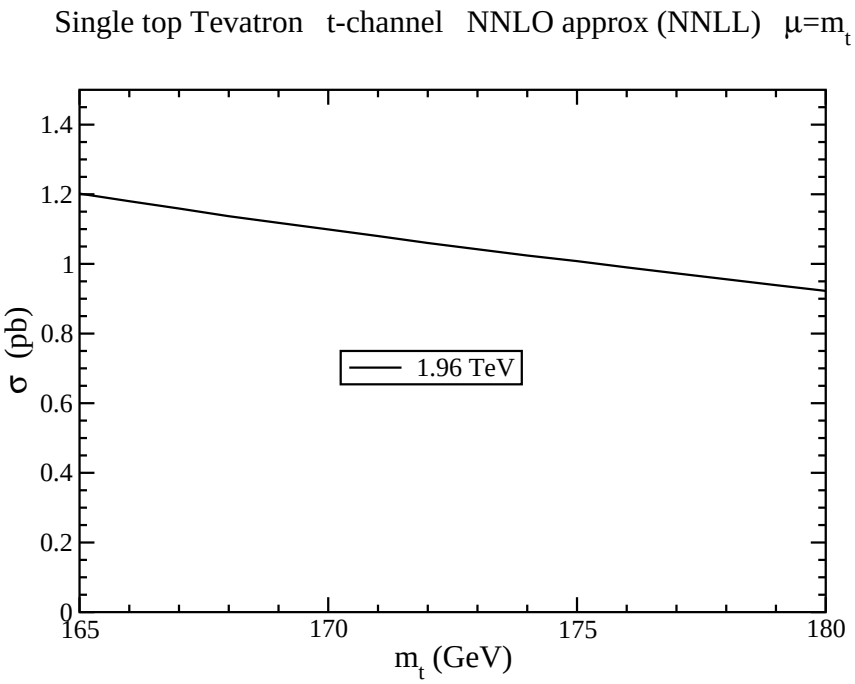


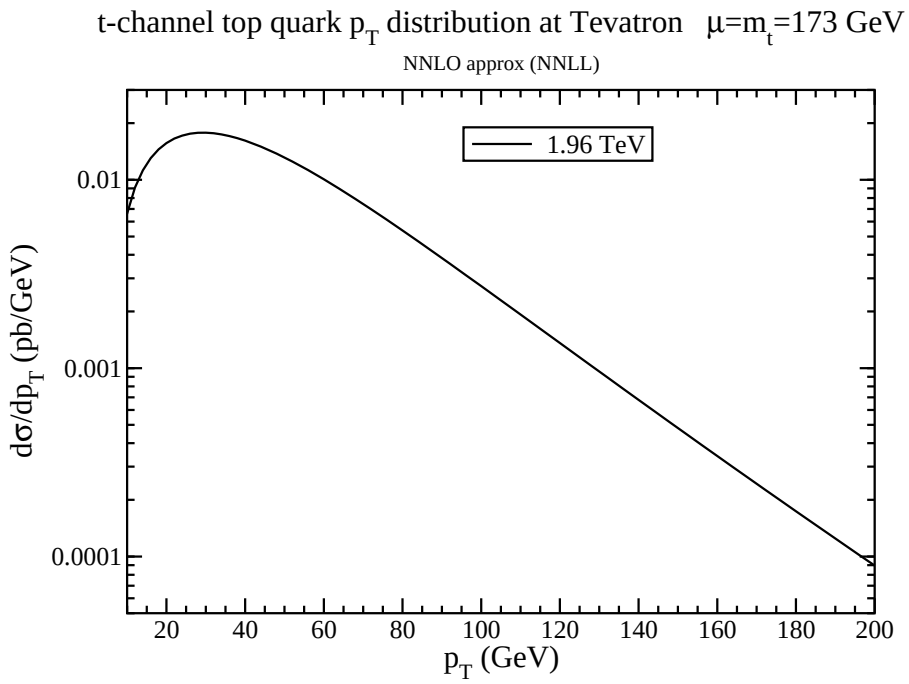






t-channel top quark production at Tevatron

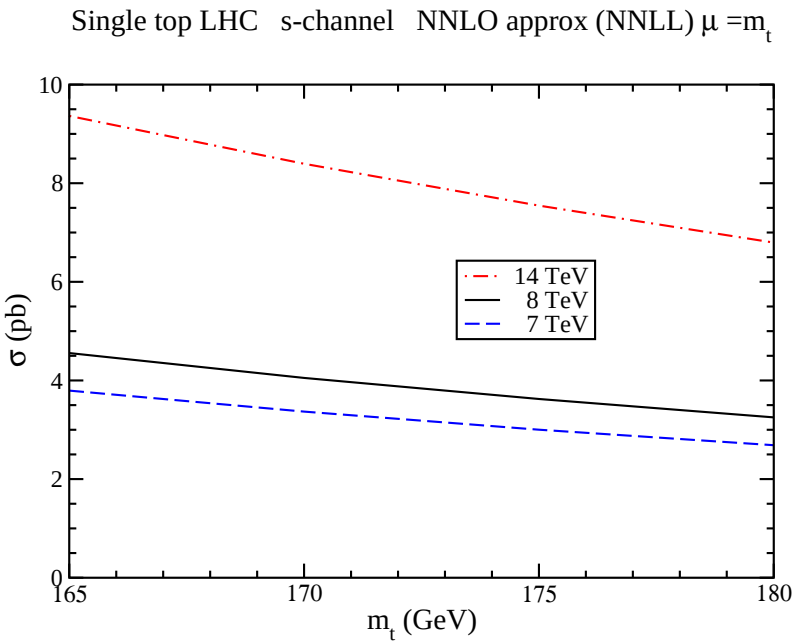


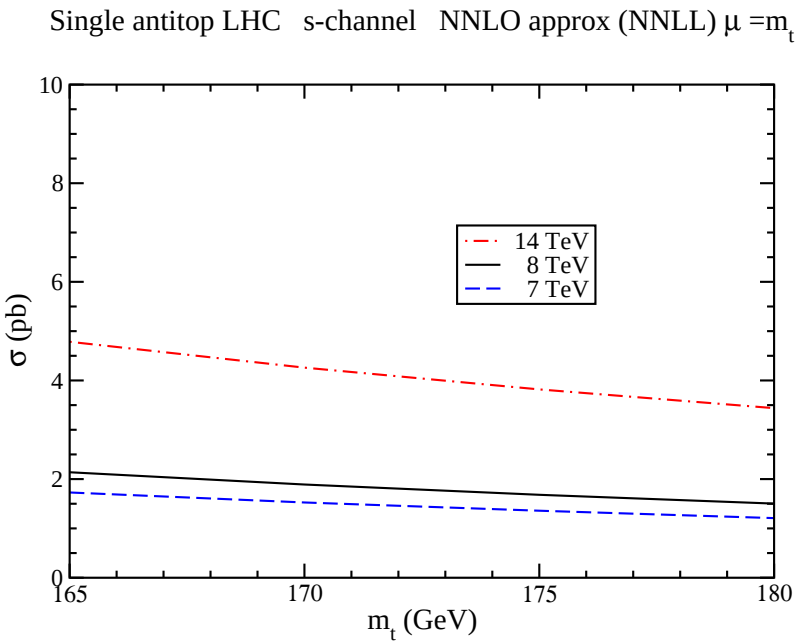


$$\sigma^{\mathrm{NNLOapprox,\,top}}_{t-\mathrm{channel}}(m_t = 173\,\mathrm{GeV},\, 1.96\,\mathrm{TeV}) \quad = \quad 1.04^{+0.00}_{-0.02} \pm 0.06\ \mathrm{pb}$$

Cross section for antitop t-channel production at Tevatron is identical

s-channel cross sections



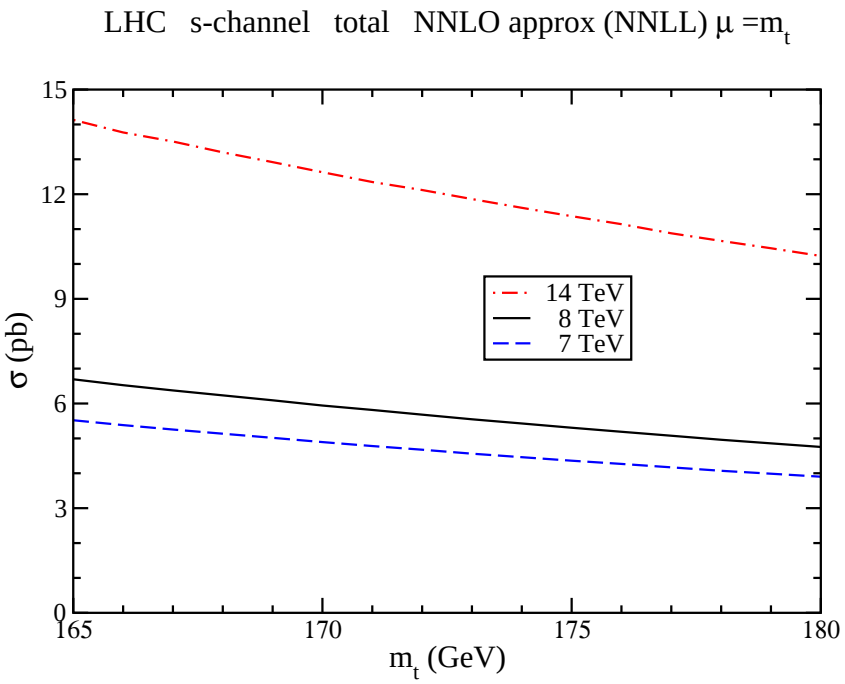


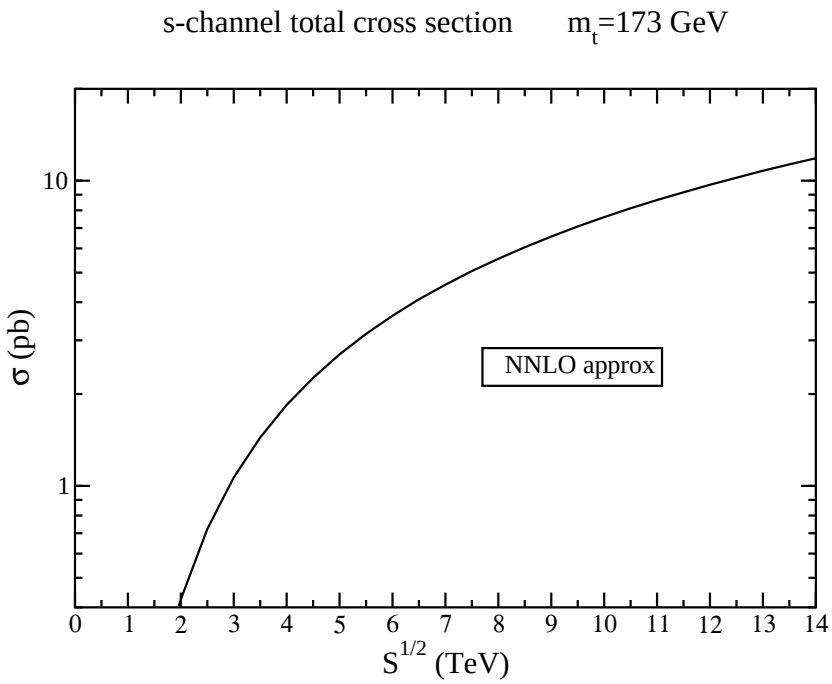
For $m_t = 173$ GeV

LHC	t	$\bar{t}$
7 TeV	$3.14 \pm 0.06^{+0.12}_{-0.10}$	$1.42 \pm 0.01^{+0.06}_{-0.07}$
8 TeV	$3.79 \pm 0.07 \pm 0.13$	$1.76 \pm 0.01 \pm 0.08$
14 TeV	$7.87 \pm 0.14^{+0.31}_{-0.28}$	$3.99 \pm 0.05^{+0.14}_{-0.21}$

At Tevatron $\sqrt{S} = 1.96$ TeV: $0.523^{+0.001\,+0.030}_{-0.005\,-0.028}$ pb for top; same for antitop

s-channel total cross section at LHC





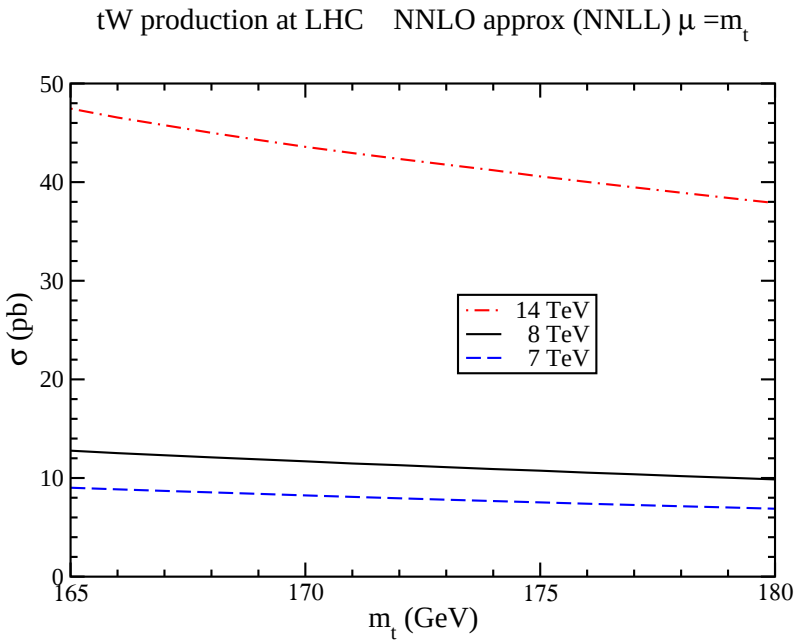
$$\sigma^{\rm NNLOapprox,\,total}_{s-{\rm channel}}(m_t = 173\,{\rm GeV},\,7\,{\rm TeV}) = 4.56 \pm 0.07^{+0.18}_{-0.17}\ {\rm pb}$$

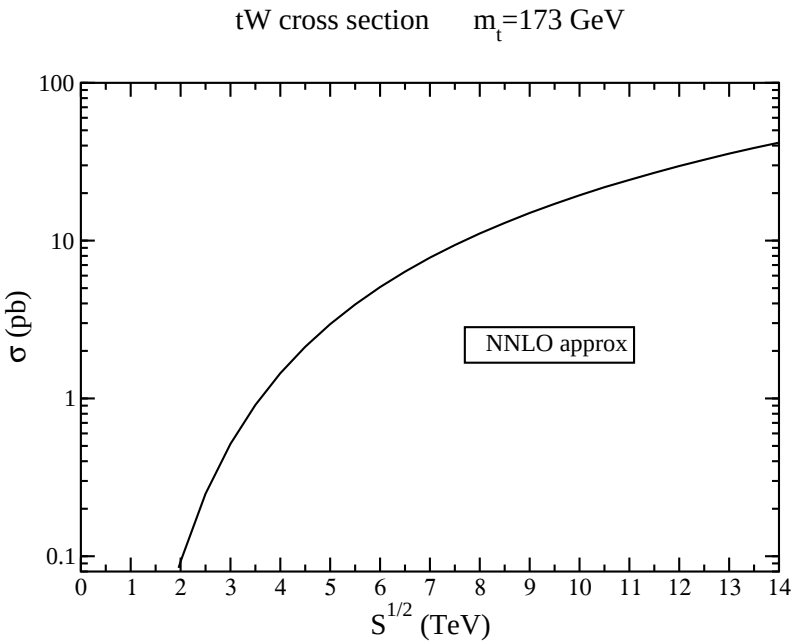
$$\sigma^{\rm NNLOapprox,\,total}_{s-{\rm channel}}(m_t = 173\,{\rm GeV},\,8\,{\rm TeV}) = 5.55 \pm 0.08 \pm 0.21\ {\rm pb}$$

$$\sigma^{\rm NNLOapprox,\,total}_{s-{\rm channel}}(m_t = 173\,{\rm GeV},\,14\,{\rm TeV}) = 11.86 \pm 0.19^{+0.45}_{-0.49}\ {\rm pb}$$

NNLO approx: enhancement over NLO is $\sim 10\%$

Associated tW^- production at the LHC





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

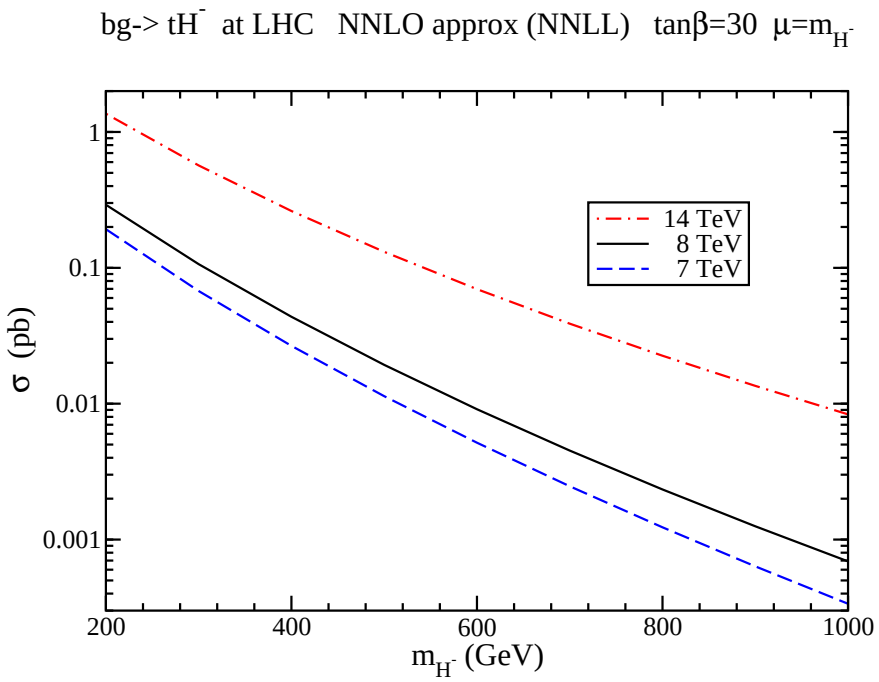
$$\sigma_{tW}^{\rm NNLOapprox}(m_t = 173\,{\rm GeV},\, 8\,{\rm TeV}) \;=\; 11.1 \pm 0.3 \pm 0.7\ {\rm pb}$$

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

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 ~ 15 to $\sim 20\%$

Summary

- **NNLL resummation for top quark pair and single top production**
- **$t\bar{t}$ production cross section**
- **top quark p_T and rapidity distributions**
- **single top cross sections and p_T distributions**
- **NNLO approx corrections for top pair and single top production are significant at Tevatron and LHC**
- **good agreement with LHC and Tevatron data**