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

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- $t\bar{t}$ 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

- $q\bar{q} \rightarrow t\bar{t}$
  dominant at Tevatron
- $gg \rightarrow t\bar{t}$
  dominant at LHC

Single top quark production

- **t channel**: $qb \rightarrow q't$ and $\bar{q}b \rightarrow \bar{q}'t$
  dominant at Tevatron and LHC
- **s channel**: $q\bar{q}' \rightarrow \bar{b}t$
  small at Tevatron and LHC

- associated $tW$ production: $bg \rightarrow tW^-$
  very small at Tevatron, significant at LHC

Related process: $bg \rightarrow tH^-$
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

\[ \ln^k \left( \frac{s_4}{m^2} \right) \left( \frac{s_4}{4} \right)^{2n-1} \]

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


This allows NNLL resummation
**$t\bar{t}$ cross section at Tevatron and LHC**

\[ p\,\bar{p} \rightarrow t\bar{t} \text{ at Tevatron } \quad S^{1/2} = 1.96 \text{ TeV} \quad \mu = m \]

\[ p\,p \rightarrow t\bar{t} \text{ at LHC } \quad S^{1/2} = 7 \text{ TeV} \quad \mu = m \]

\[ \sigma_{t\bar{t}}^{\text{NNLO approx}} (m_t = 173 \text{ GeV}, 1.96 \text{ TeV}) = 7.08^{+0.00+0.36}_{-0.32-0.27} \text{ pb} \]

\[ \sigma_{t\bar{t}}^{\text{NNLO approx}} (m_t = 173 \text{ GeV}, 7 \text{ TeV}) = 163^{+4+9}_{-8-9} \text{ pb} \]

\[ \sigma_{t\bar{t}}^{\text{NNLO approx}} (m_t = 173 \text{ GeV}, 10 \text{ TeV}) = 415^{+17+18}_{-21-19} \text{ pb} \]

\[ \sigma_{t\bar{t}}^{\text{NNLO approx}} (m_t = 173 \text{ GeV}, 14 \text{ TeV}) = 920^{+50+33}_{-45-35} \text{ pb} \]
Top quark $p_T$ distribution at Tevatron and LHC

The figure shows the differential cross-section $d\sigma/dp_T$ for the processes $p\bar{p} \rightarrow t\bar{t}$ at Tevatron with $S^{1/2} = 1.96$ TeV, $m = 173$ GeV, and $\mu = m_T$, and $pp \rightarrow t\bar{t}$ at LHC with $S^{1/2} = 7$ TeV, $m = 173$ GeV, and $\mu = m_T$. The graphs compare the NNLO approximation with NLO results.
Single top quark production - $s$ channel

Two-loop eikonal diagrams

N. Kidonakis, ICHEP 2010, Paris, France, July 2010
\[ \sigma_{\text{s-channel}}^{\text{NNLO approx, top}}(m_t = 173 \text{ GeV}) = 0.523^{+0.001+0.030}_{-0.005-0.028} \text{ pb} \]

Cross section for anti-top production is identical

Single top production at the LHC - s channel

\[ \sigma_{s-channel}^{NNLO\,approx,\,top} (m_t = 173 \,\text{GeV}, 7 \,\text{TeV}) = 3.17 \pm 0.06^{+0.13}_{-0.10} \,\text{pb} \]

\[ \sigma_{s-channel}^{NNLO\,approx,\,top} (m_t = 173 \,\text{GeV}, 10 \,\text{TeV}) = 5.16 \pm 0.09^{+0.20}_{-0.14} \,\text{pb} \]

\[ \sigma_{s-channel}^{NNLO\,approx,\,top} (m_t = 173 \,\text{GeV}, 14 \,\text{TeV}) = 7.93 \pm 0.14^{+0.31}_{-0.28} \,\text{pb} \]
Single antitop production at the LHC - s channel

\[ \sigma_{s\text{-channel}}^{\text{NNLOapprox, antitop}} \left( m_t = 173 \text{ GeV}, \ 7 \text{ TeV} \right) = 1.42 \pm 0.01^{+0.06}_{-0.07} \text{ pb} \]

\[ \sigma_{s\text{-channel}}^{\text{NNLOapprox, antitop}} \left( m_t = 173 \text{ GeV}, \ 10 \text{ TeV} \right) = 2.48 \pm 0.02^{+0.09}_{-0.13} \text{ pb} \]

\[ \sigma_{s\text{-channel}}^{\text{NNLOapprox, antitop}} \left( m_t = 173 \text{ GeV}, \ 14 \text{ TeV} \right) = 3.99 \pm 0.05^{+0.14}_{-0.21} \text{ pb} \]
Associated production of a top quark with a $W^-$

Two-loop eikonal diagrams

+ top quark self-energy graphs
Cross section for $tW^-$ production

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

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

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

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

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

N. Kidonakis, ICHEP 2010, Paris, France, July 2010
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
- $bg \rightarrow tW^-$ and $bg \rightarrow tH^-$ at LHC
- NNLO approx corrections for top pair and single top production are significant at Tevatron and LHC