# Theoretical status of the top quark cross section

**Nikolaos Kidonakis**

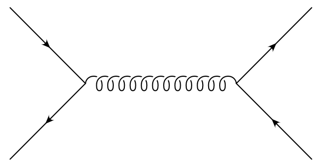
(Univ. of Cambridge and Kennesaw State Univ.)

- Top quark production near threshold
- NNLO threshold corrections
- Top pair production at the Tevatron and the LHC

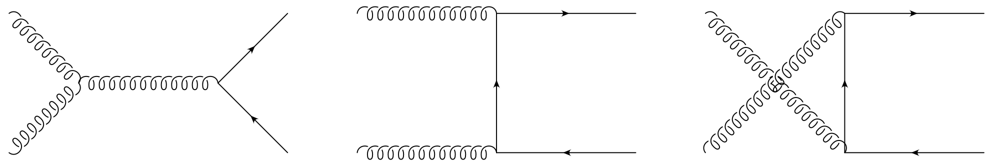
# Top quark production

## Born level

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



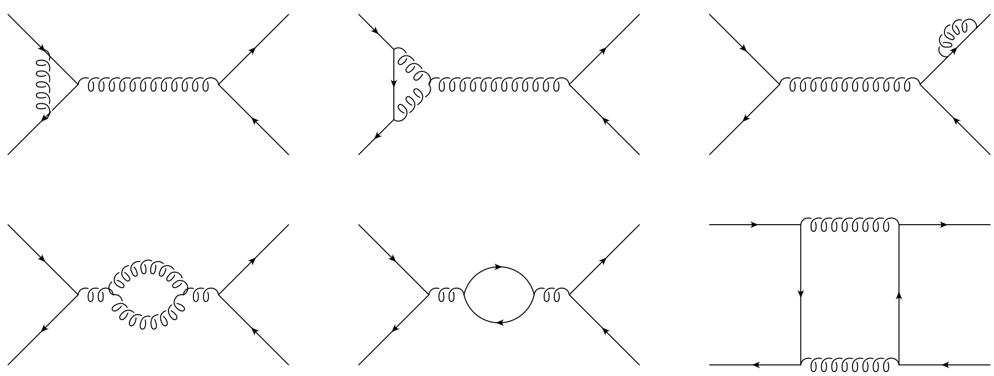
$gg \to t\bar{t}$



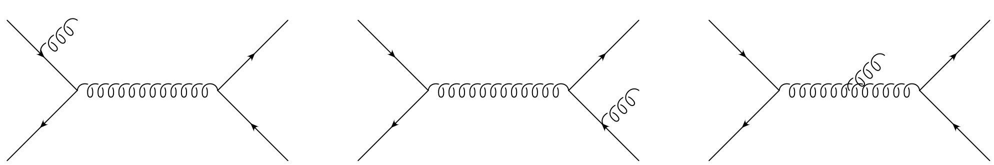
## NLO corrections – representative graphs

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

virtual



real



Similarly for $gg \to t\bar{t}$

At NLO also $qg \to t\bar{t}$ and $\bar{q}g \to t\bar{t}$ contribute

# Top quark production near threshold

## Kinematics: 1PI or PIM

## 1PI kinematics

$i(p_a) + j(p_b) \longrightarrow t(p_1) + X[\bar{t}](p_2)$ with $ij = q\bar{q}$ or $gg$

Define $s = (p_a + p_b)^2$, $t_1 = (p_b - p_1)^2 - m^2$, $u_1 = (p_a - p_1)^2 - m^2$ and $s_4 = s + t_1 + u_1$

At threshold $s_4 \to 0$

Soft corrections $\left[\frac{\ln^l(s_4/m^2)}{s_4}\right]_+$

Virtual corrections $\delta(s_4)$

## PIM kinematics

$i(p_a) + j(p_b) \longrightarrow t\bar{t}(p) + X(k)$

At threshold $z = M^2/s \to 1$

Soft corrections $\left[\frac{\ln^l(1-z)}{1-z}\right]_+$

Virtual corrections $\delta(1-z)$

Size of soft corrections depends on the kinematics

## Soft-gluon corrections

$$\mathcal{D}_l(x_{th}) \equiv \left[\frac{\ln^l(x_{th})}{x_{th}}\right]_+$$

For the order $\alpha_s^n$ corrections $l \le 2n-1$

At NLO, $\mathcal{D}_1(x_{th})$, $\mathcal{D}_0(x_{th})$, and $\delta(x_{th})$ terms

At NNLO, $\mathcal{D}_3(x_{th})$, $\mathcal{D}_2(x_{th})$, $\mathcal{D}_1(x_{th})$, $\mathcal{D}_0(x_{th})$, and $\delta(x_{th})$ terms
LL, NLL, NNLL, NNNLL

We can formally resum these logarithms to all orders in $\alpha_s$

A unified approach and a master formula for calculating these distributions at NNLO for any process

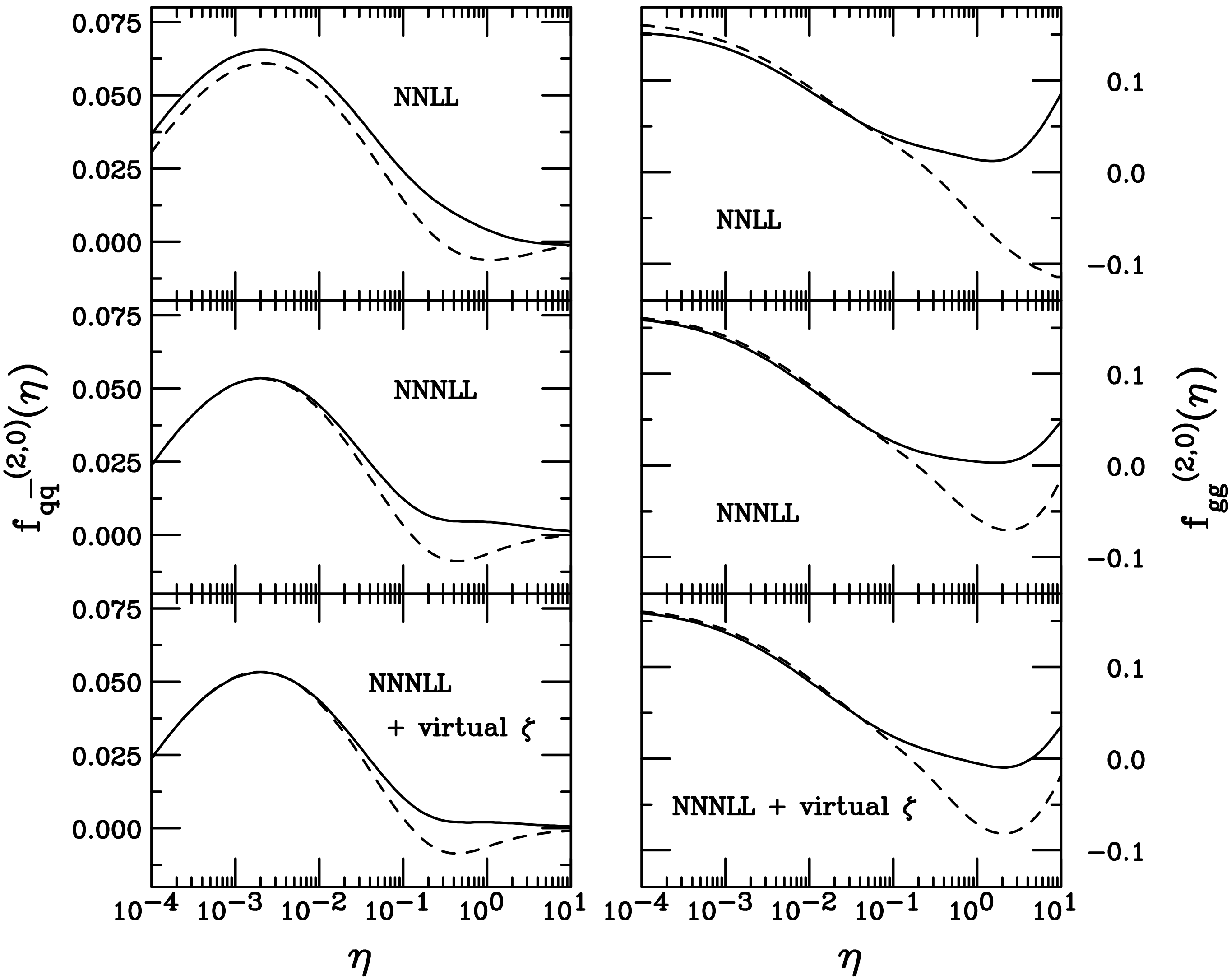
N. Kidonakis, Int. J. Mod. Phys. A 19, 1793 (2004)

Applied to top production in

N. Kidonakis and R. Vogt, Phys. Rev. D 68, 114014

NNLO-NNNLL+$\zeta$

# Top quark production

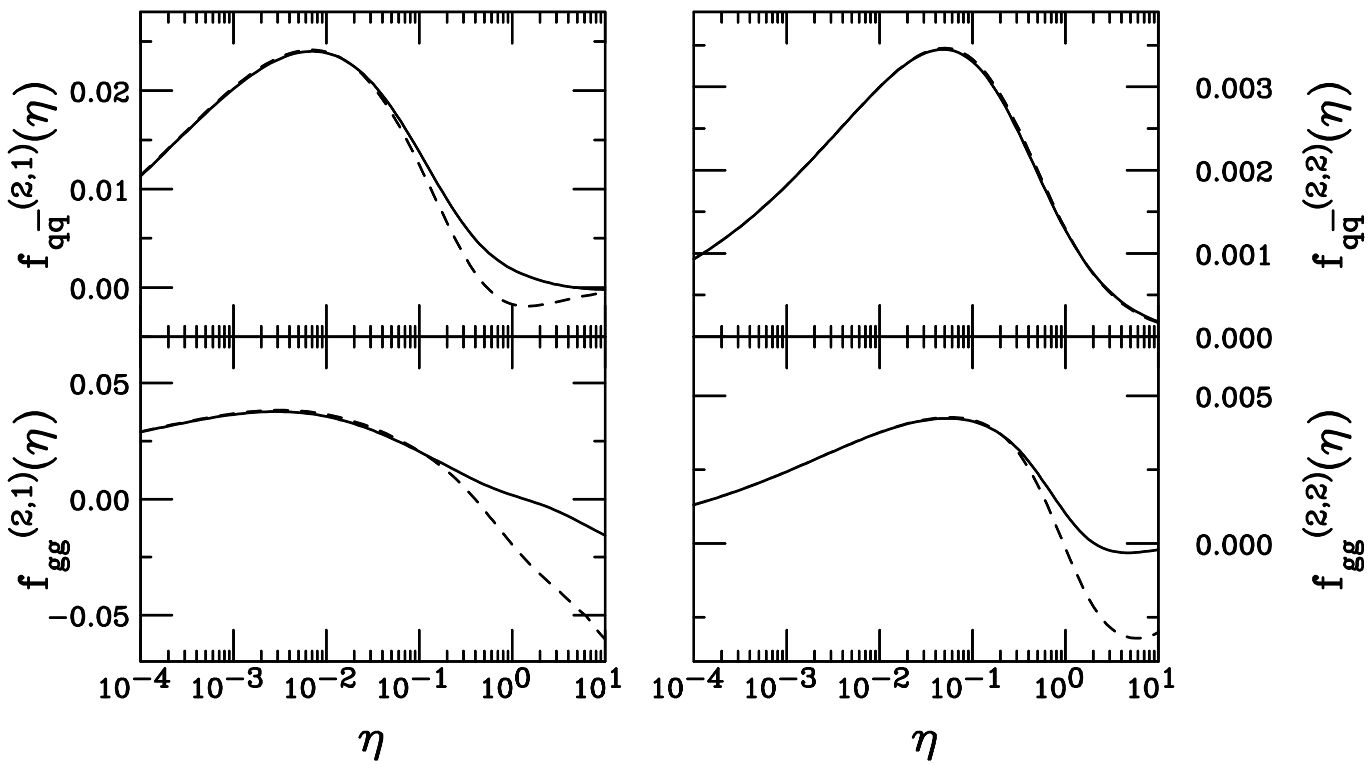



Scaling functions vs $\eta = s/4m^2 - 1$

(solid: 1PI kinematics; dashed: PIM kinematics)

$$\sigma_{ij}(s, m^2, \mu^2) = \frac{\alpha_s^2(\mu)}{m^2} \sum_{k=0}^{\infty} (4\pi\alpha_s(\mu))^k \sum_{r=0}^{k} f_{ij}^{(k,r)}(\eta) \ln^r \left(\frac{\mu^2}{m^2}\right)$$

# Top quark production

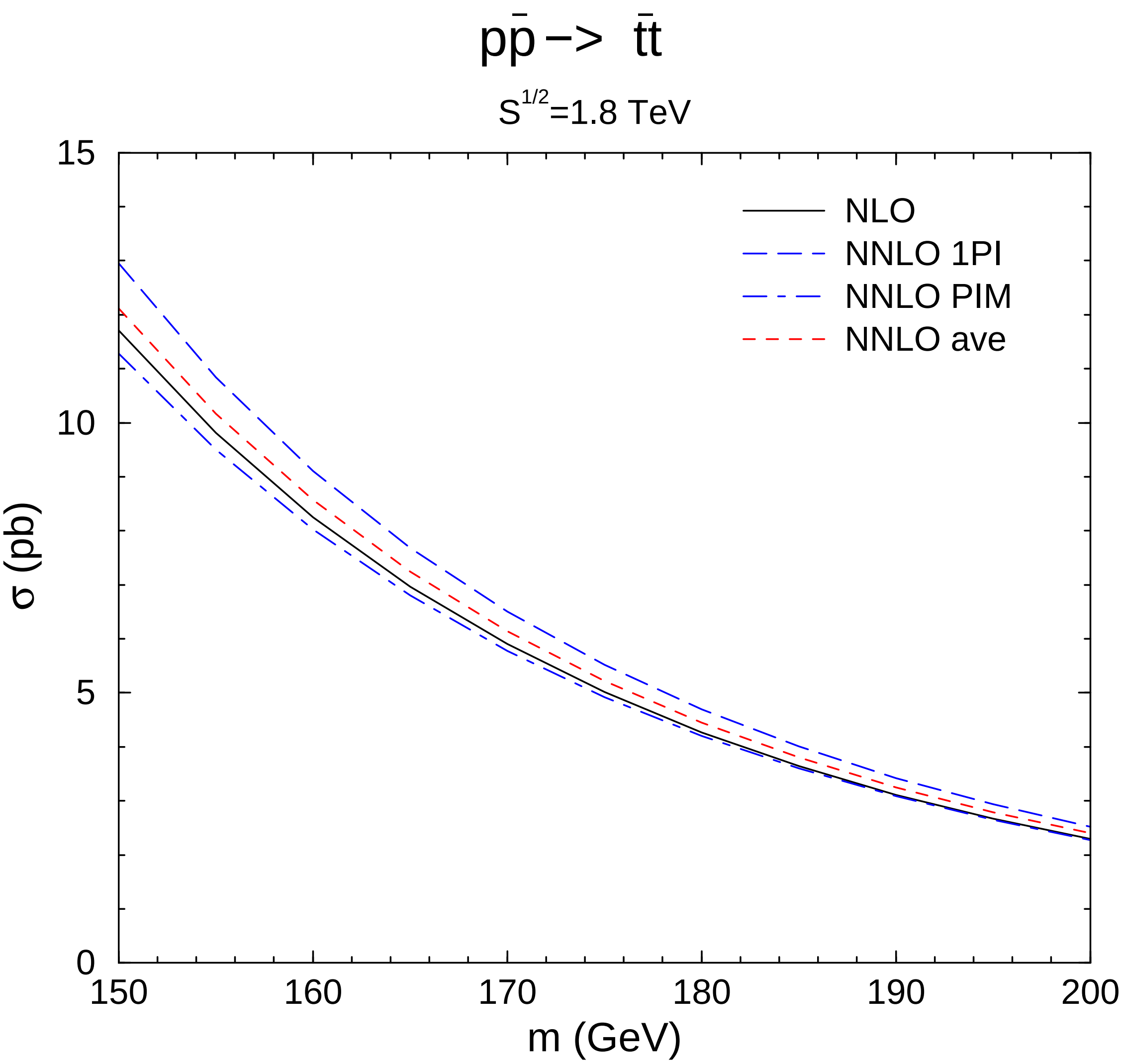



Scaling functions vs $\eta = s/4m^2 - 1$

(solid: 1PI kinematics; dashed: PIM kinematics)

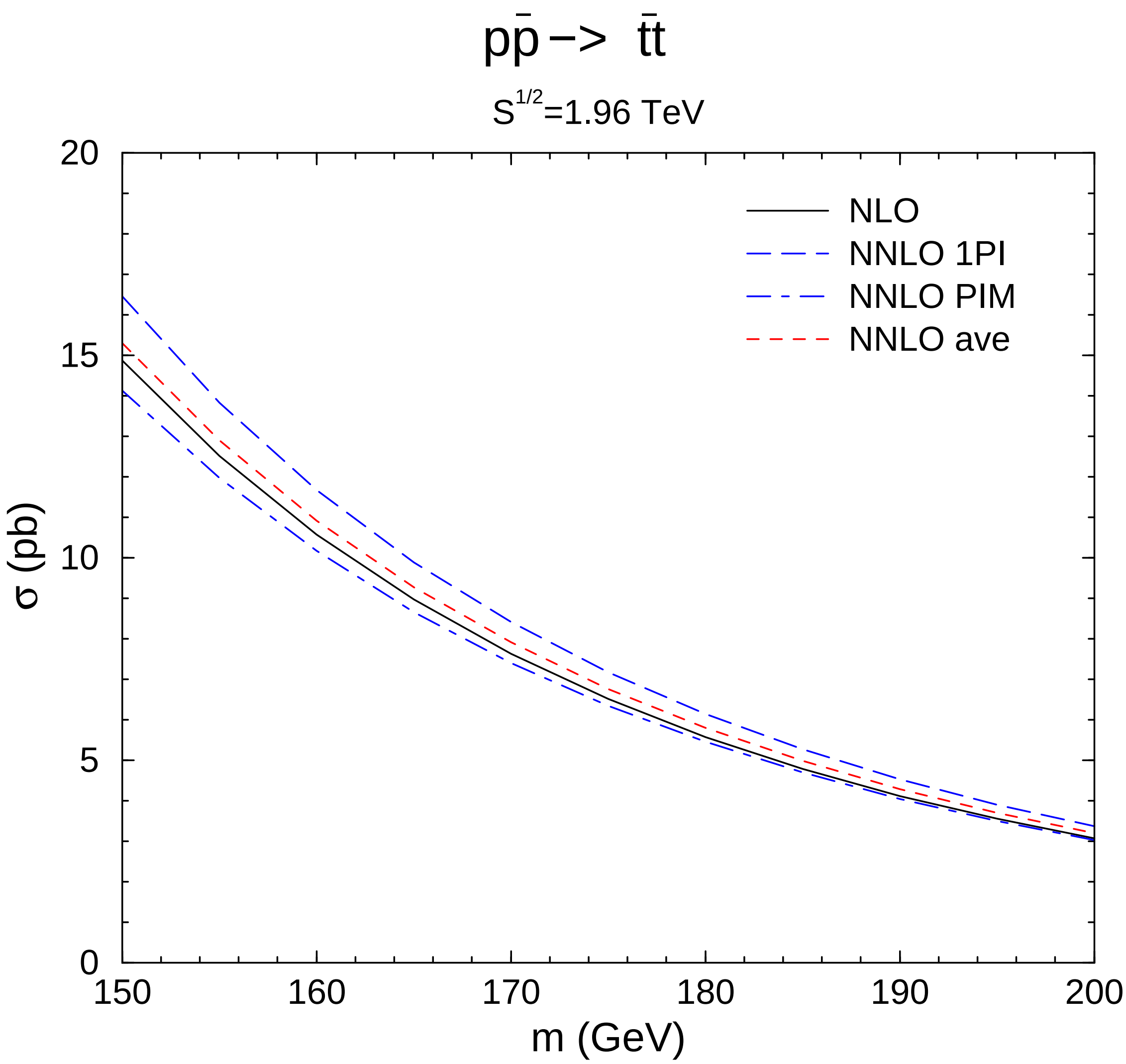
$$\sigma_{ij}(s, m^2, \mu^2) = \frac{\alpha_s^2(\mu)}{m^2} \sum_{k=0}^{\infty} (4\pi\alpha_s(\mu))^k \sum_{r=0}^{k} f_{ij}^{(k,r)}(\eta) \ \ln^r \left(\frac{\mu^2}{m^2}\right)$$

## $p\bar{p} \to t\bar{t}$ at the Tevatron Run I



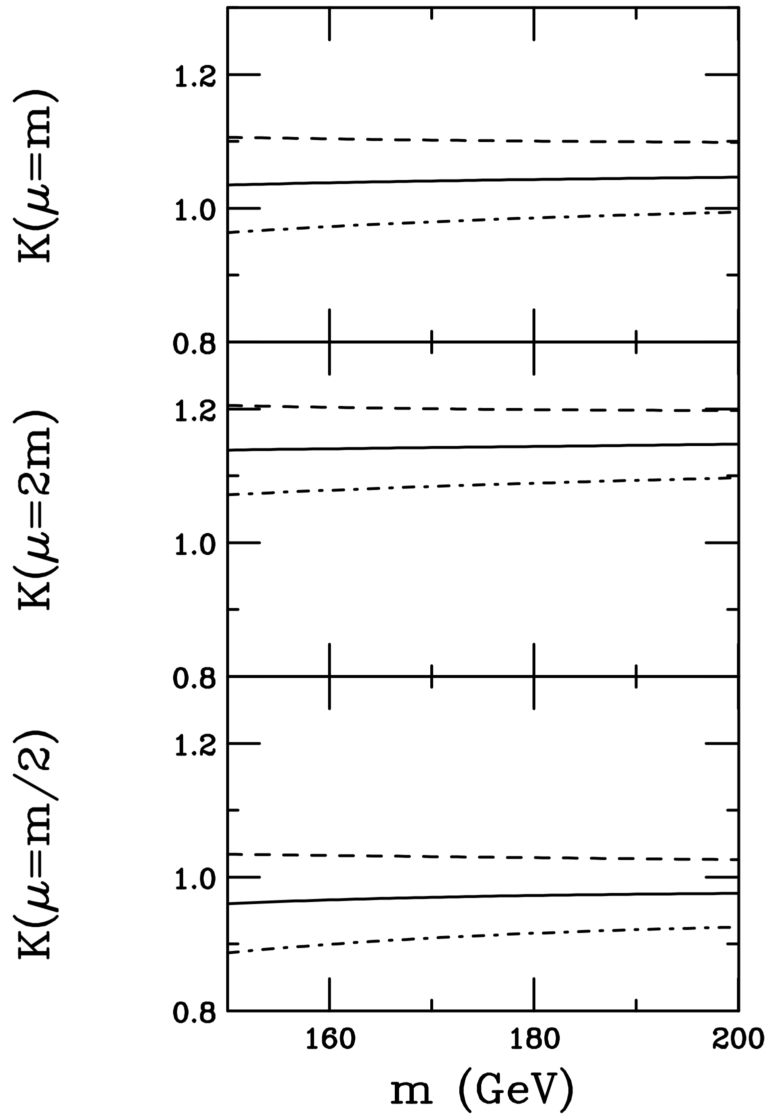

$\sigma(m = 175 \text{ GeV}) = 5.24 \pm 0.31$ pb

## $p\bar{p} \to t\bar{t}$ at the Tevatron Run II




$\sigma(m = 175$ GeV$)$=$6.77 \pm 0.42$ pb

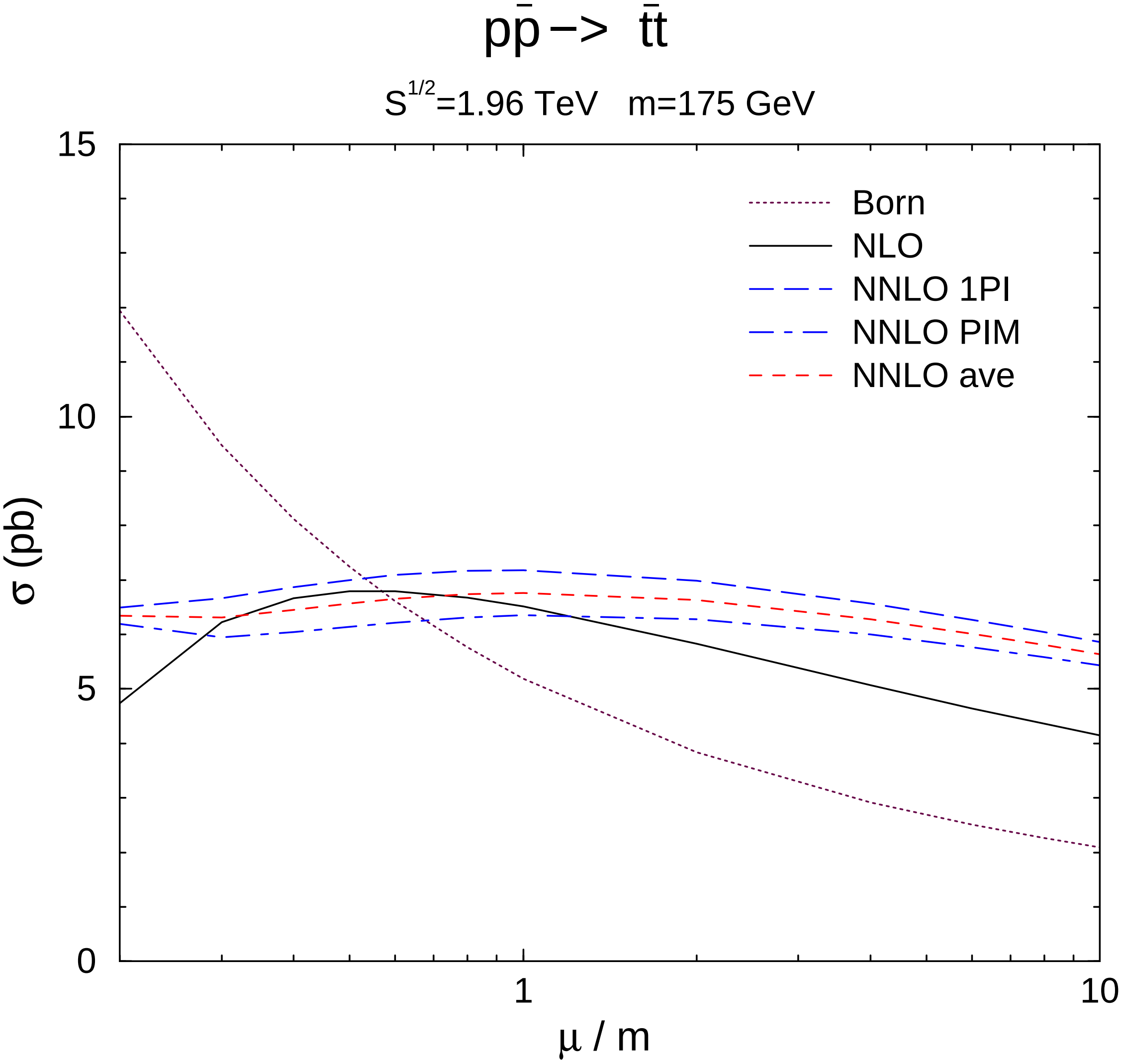
# K-factors for $p\bar{p} \to t\bar{t}$ at the Tevatron Run I



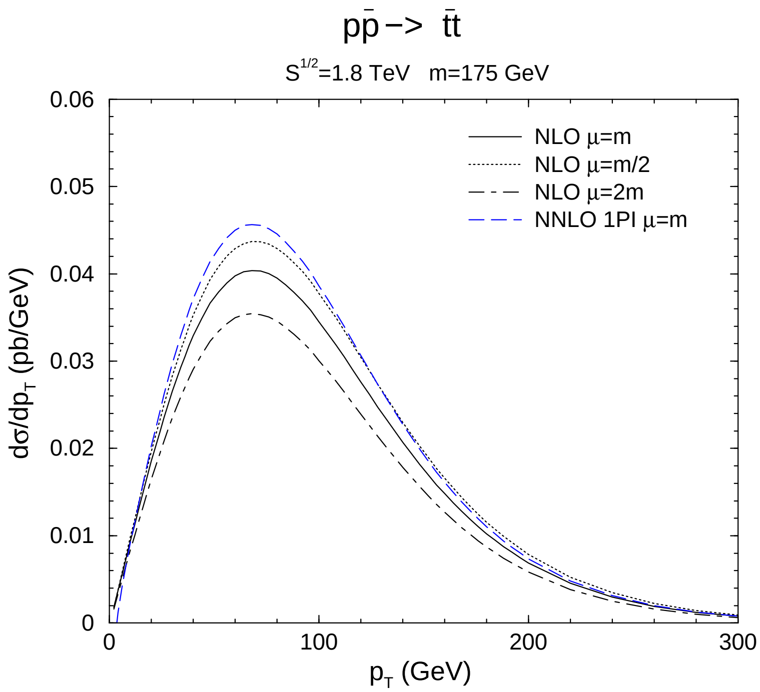

K = NNLO-NNNLL+$\zeta$ / NNLO

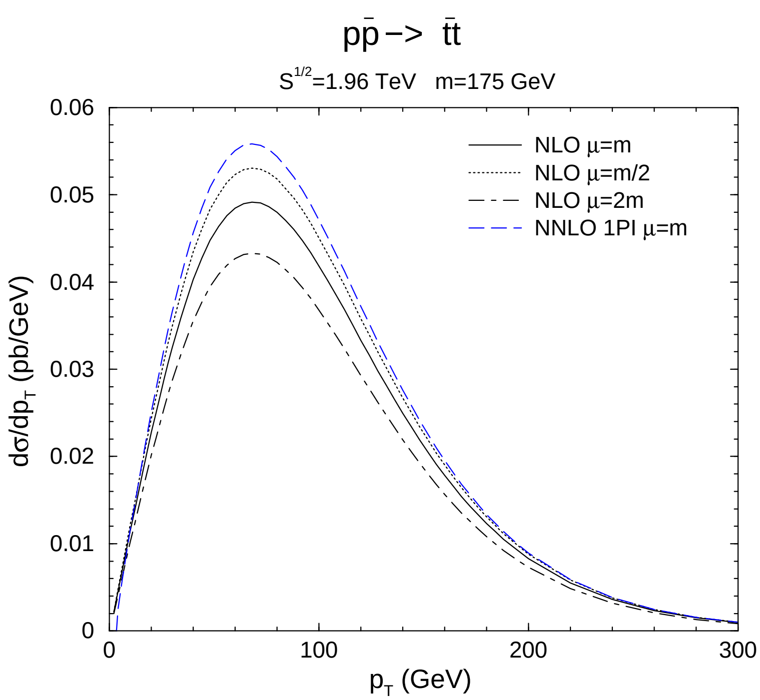
1PI (dashed), PIM (dot-dashed), and average (solid)

# Scale-dependence for $p\bar{p} \to t\bar{t}$ at the Tevatron Run II

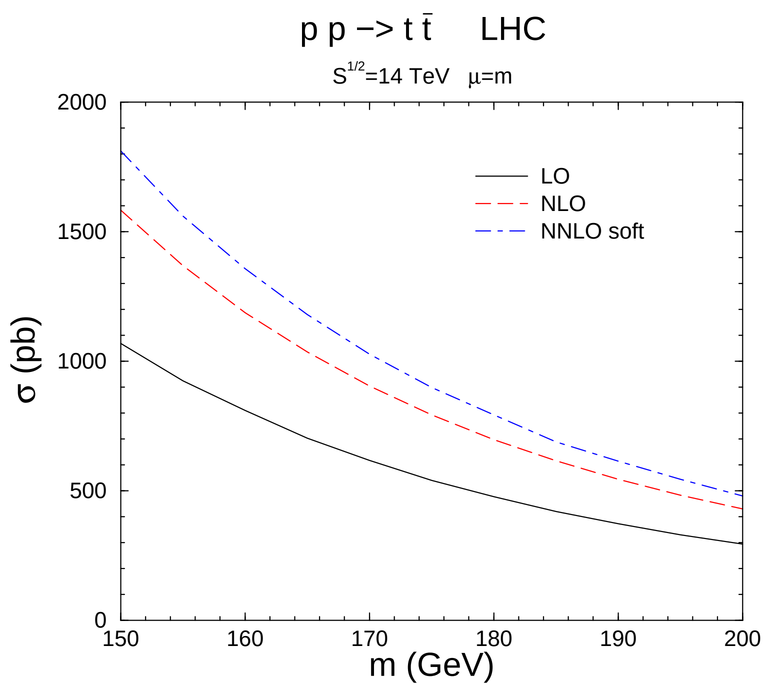


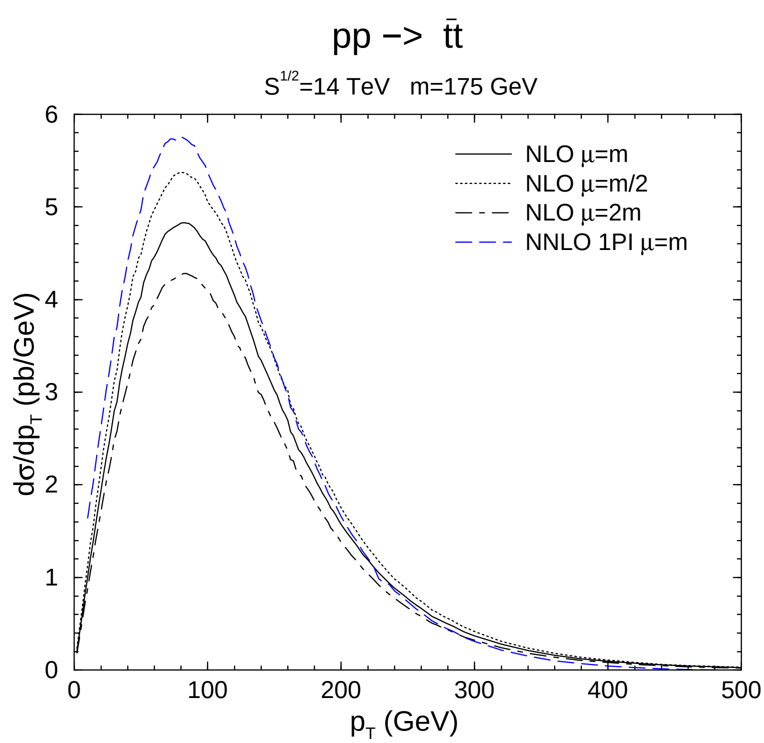
# Top quark tranverse momentum distributions at the Tevatron Run I and II



# Top cross section and tranverse momentum distributions at the LHC




$\sigma(m = 175\ \text{GeV}) = 873\ \text{pb}$

# Summary

- Top production in $p\bar{p}$ and $pp$ collisions
- soft-gluon threshold corrections are important
- NNLO threshold corrections
- reduced scale dependence
- sizable K-factors