TWO TOPICS on TOP QUARKS

A. WEAK CORRECTIONS and SUDAKOV LOGARITHMS

B. CHARGE ASYMMETRY in HADROPRODUCTION and AXIGLUONS

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A. WEAK CORRECTIONS TO TOP PRODUCTION

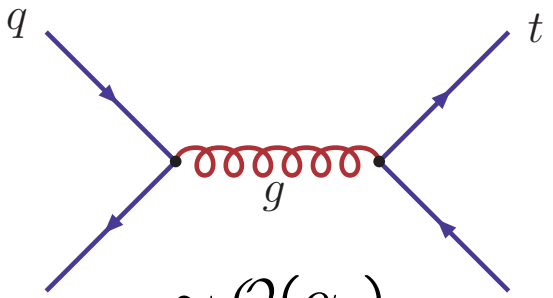
J.K., Scharf, Uwer: Eur. Phys. J. C45(2006) 139
Eur. Phys. J. C51(2007) 37

I. Results at Partonic Level

II. Tevatron and LHC

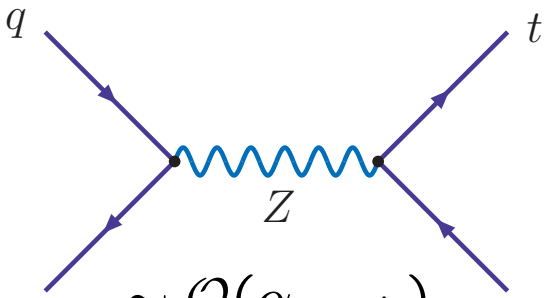
I. Results at Partonic Level

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



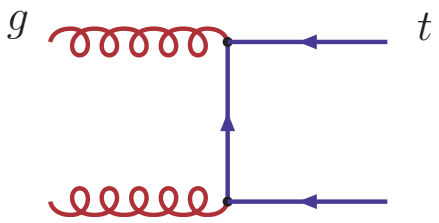
$\sim \mathcal{O}(\alpha_s)$

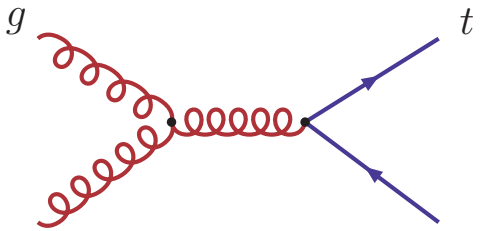
no interference with



$\sim \mathcal{O}(\alpha_{weak})$

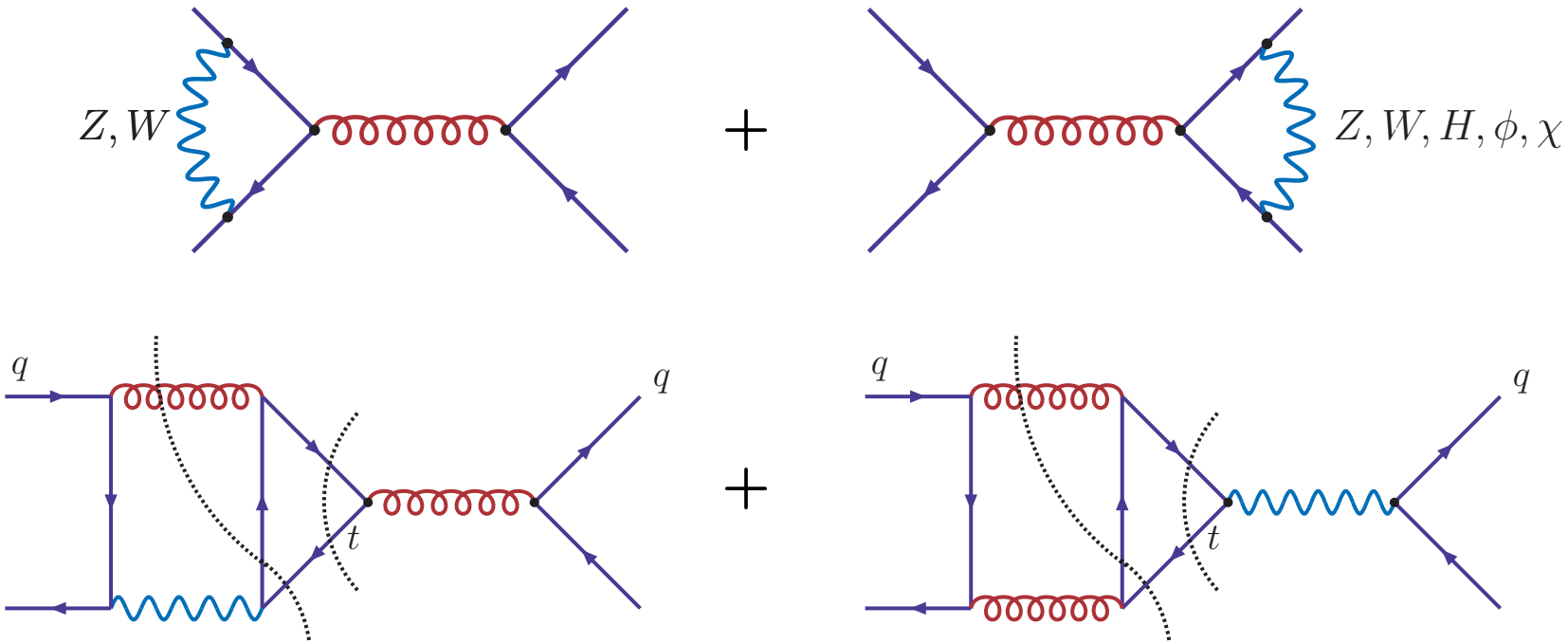
$g\,g \to t\,\bar{t}$:





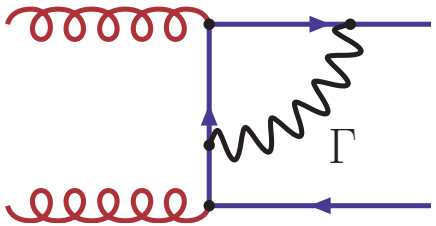
$\sim \mathcal{O}(\alpha_s)$

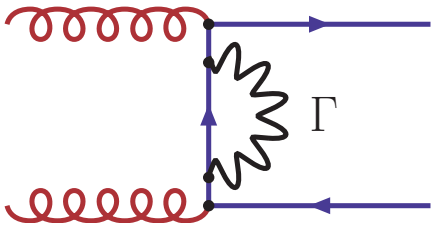
$\mathcal{O}(\alpha_s^2 \alpha_{\text{weak}})$ weak corrections $(q\,\bar{q} \to t\,\bar{t}\,)$

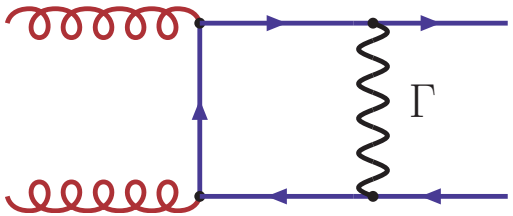


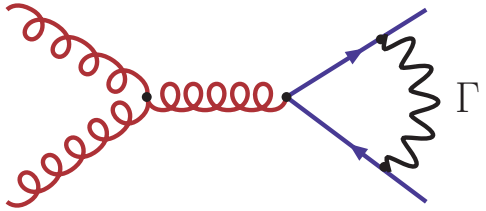
cuts of second group individually IR-divergent

$\mathcal{O}(\alpha_s^2 \alpha_{\text{weak}})$ weak corrections ($g\,g \to t\,\bar{t}$)

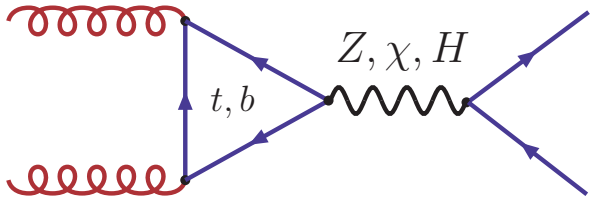








$\Gamma = W, Z, \chi, H$



Contribution also from virtual Z, no pole at $q^2 = m_Z^2$ (Yang theorem).

- analytical & numerical results available

- some disagreements with earlier partial results by Beenakker, Denner, Hollik, Mertig, Sack, Wackeroth 1994

- some discrepancies with Moretti, Nolten, Ross 2006

- in agreement with Bernreuther & Fücker 2005/06

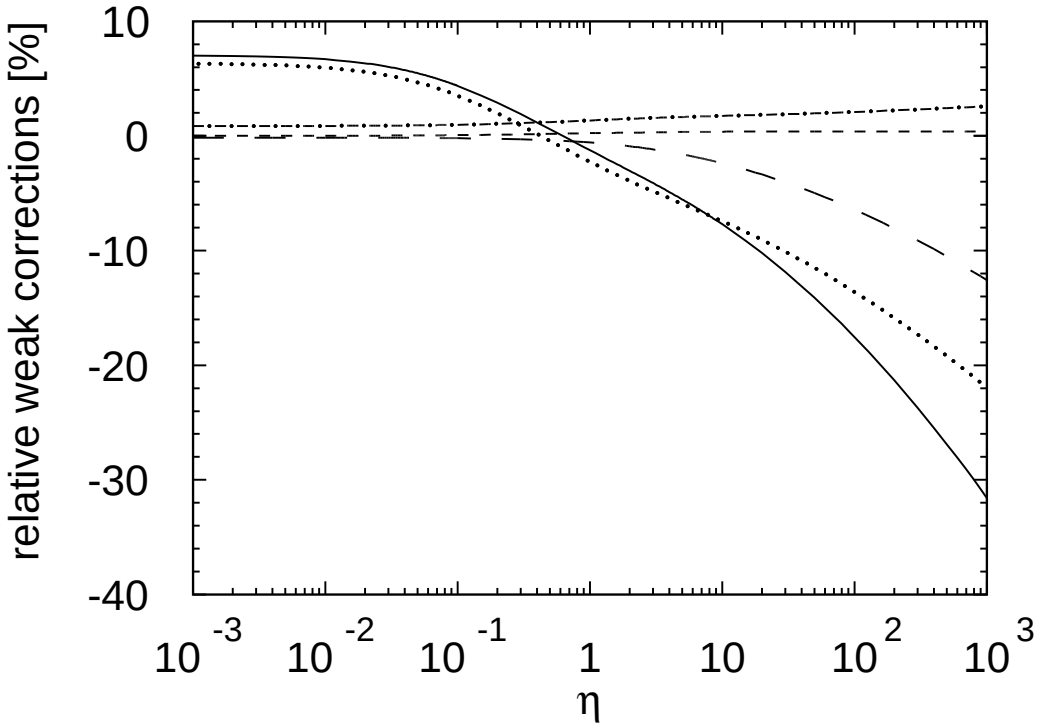
$\Rightarrow$ Partonic results

- (gZ)-box contribution to $q\bar{q} \to t\bar{t}$:
  proportional to I_q^3
  $\Rightarrow$ (box contribution)$_{\text{up-quark}}$ = -(box contribution)$_{\text{down-quark}}$
  $\Rightarrow$ suppression
  moderately $\hat{s}$-dependent

- strong increase of vertex and weak box contributions
  ("Sudakov-Logs")

- sizable M_h-dependence,
  large effect close to threshold

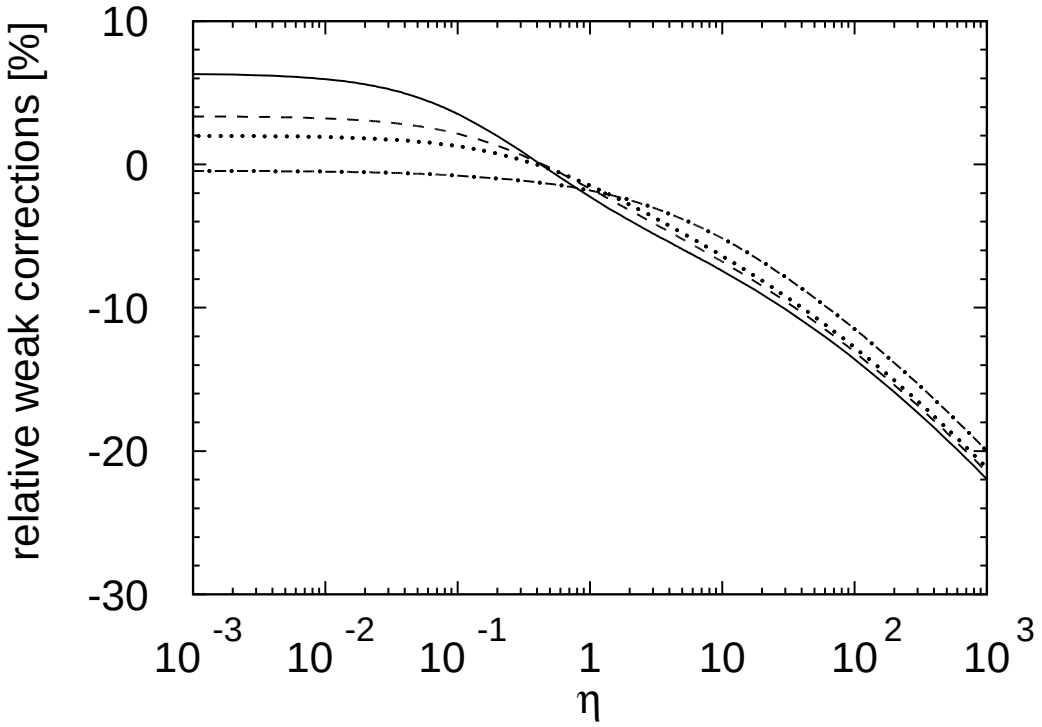
$$u\bar{u} \to t\bar{t}$$



$$\eta = \frac{s}{4m_t^2} - 1$$

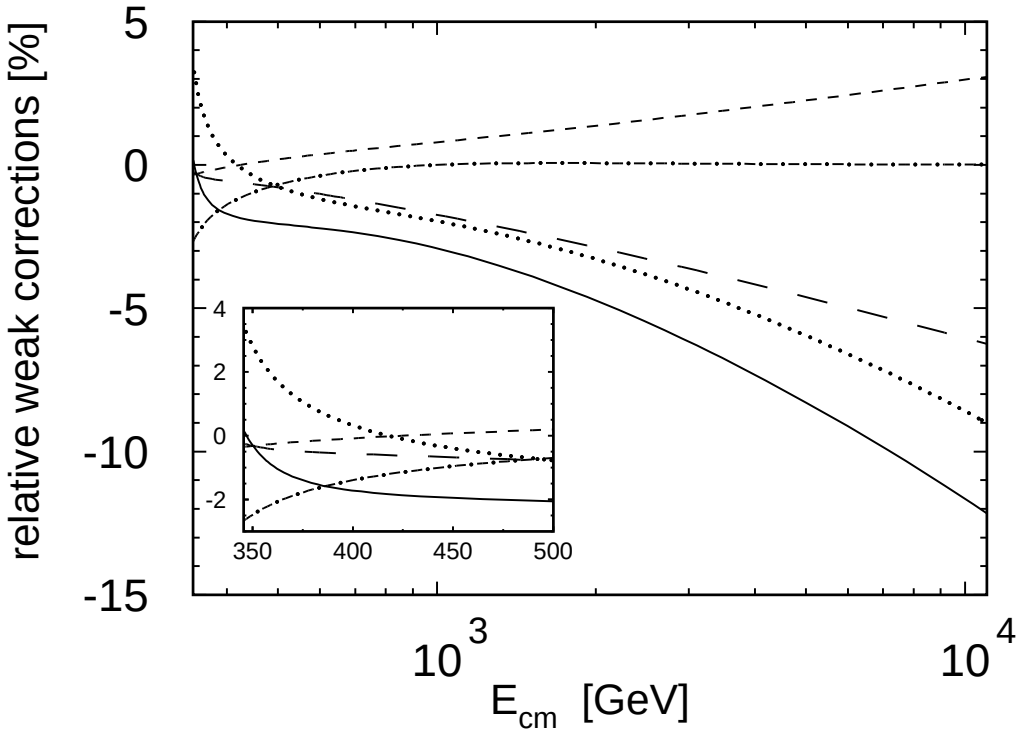
Different contributions to the electroweak corrections for incoming up-quarks: Initial vertices (long-dashed), final vertices (dotted), EW-box (dash-dotted), QCD-box (dashed). The sum is shown as a full line.

Higgs Mass Dependence of $q\bar{q} \to t\bar{t}$



Relative change of the cross section from corrections to the final vertex for different Higgs masses $m_H = 120$ GeV (full line), $m_H = 180$ GeV (dashed), $m_H = 240$ GeV (dotted), $m_H = 1000$ GeV (dashed-dotted).

$$g\bar{g} \to t\bar{t}$$

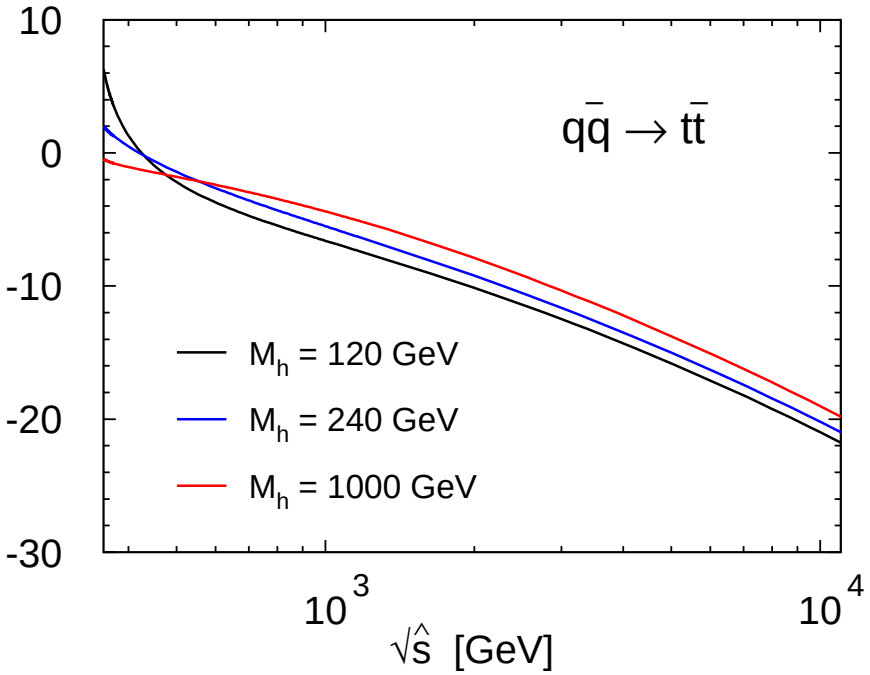


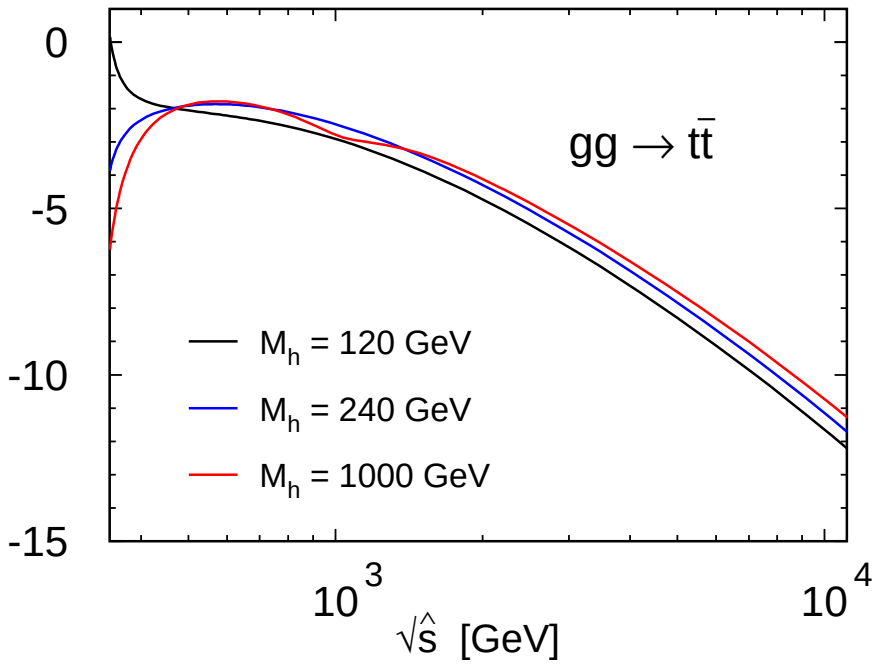
Different contributions to the weak corrections: vertices (long-dashed), self-energies (dashed), boxes (dotted), triangles (dash-dotted). The sum is shown as the full line.

Corrections for $q\bar{q}$ larger:
Weak charge of $q\bar{q}$ and $t\bar{t}$ vs gg and $t\bar{t}$.

large corrections for large $\sqrt{\hat{s}}$

sizable M_h-dependence



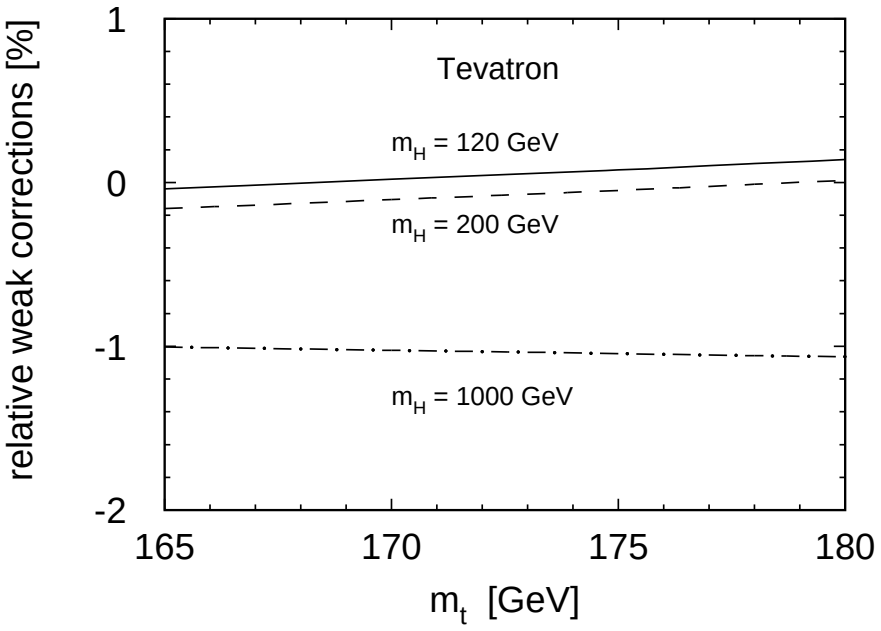


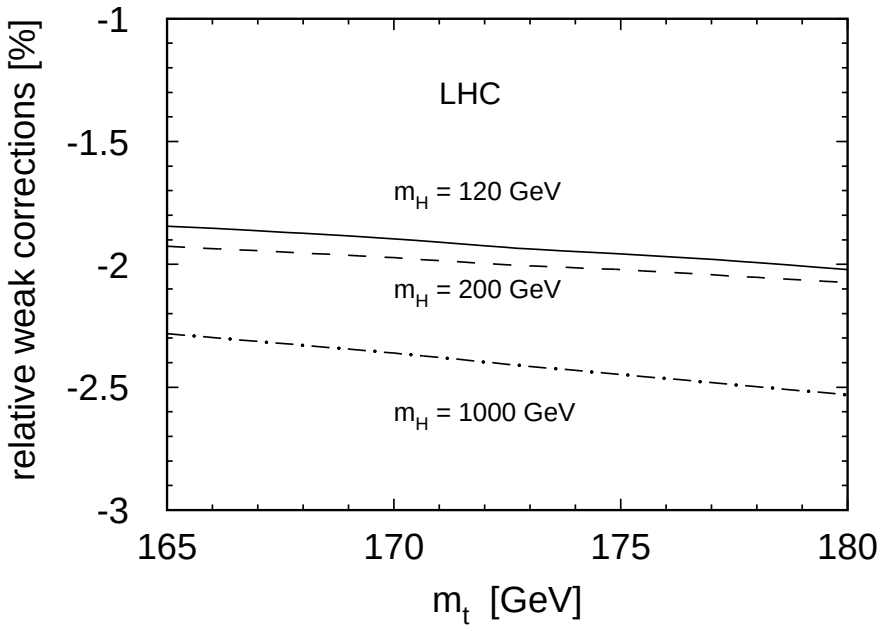
(relative weak corrections [%])

II. Tevatron and LHC

Small effects for total cross section

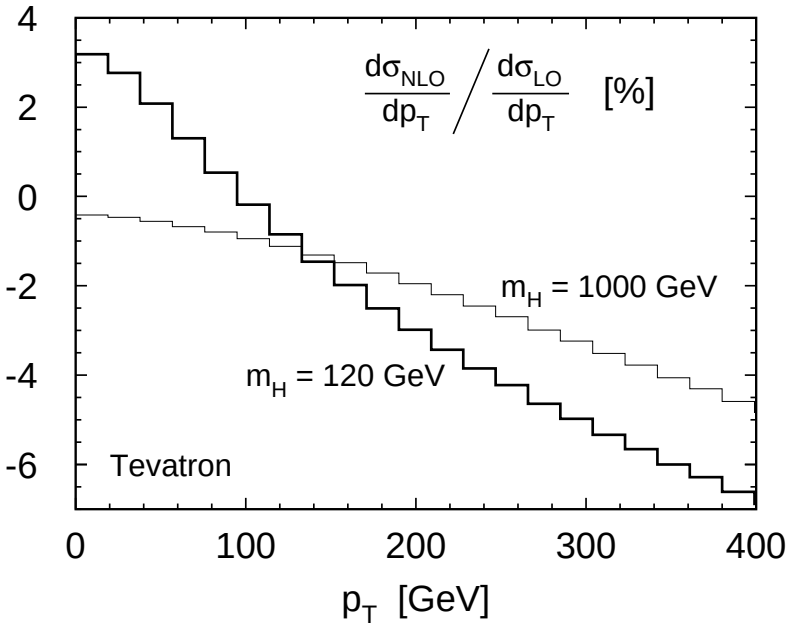
(dominated by $\sqrt{\hat{s}} \sim$ 360-380 GeV)

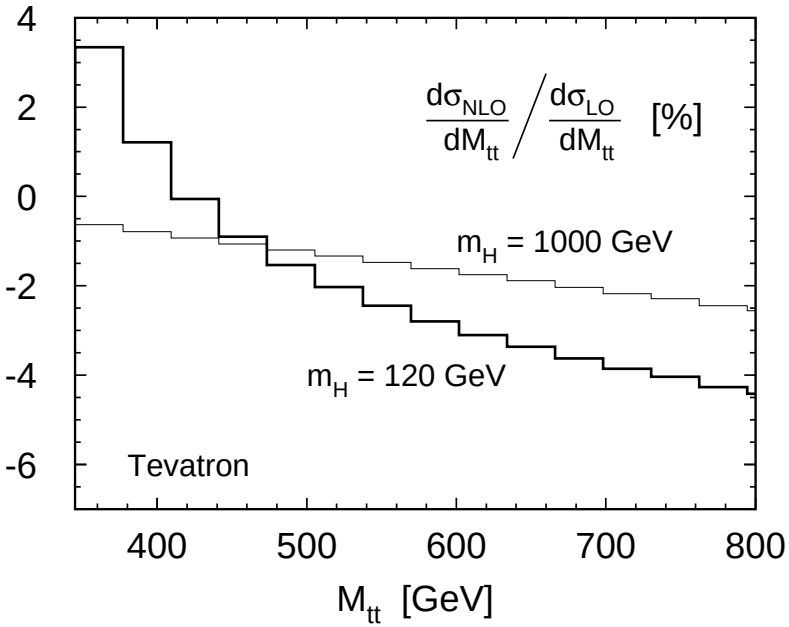




Sizeable effects for differential distribution

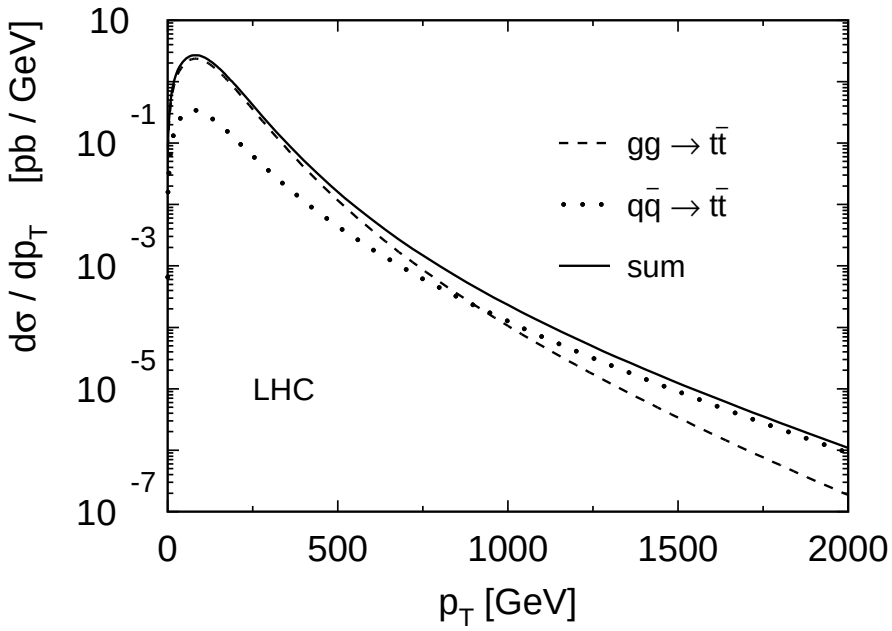
TEVATRON

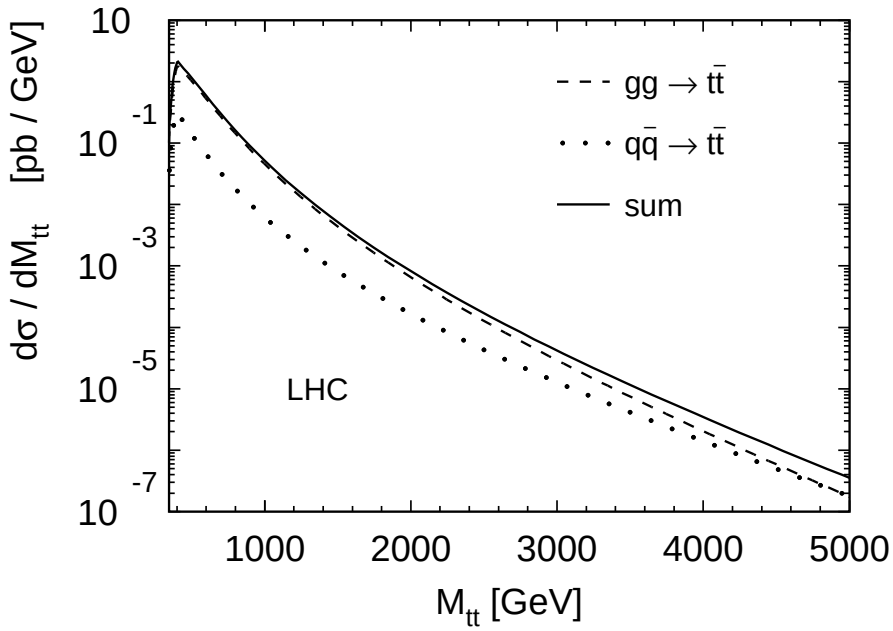




LHC

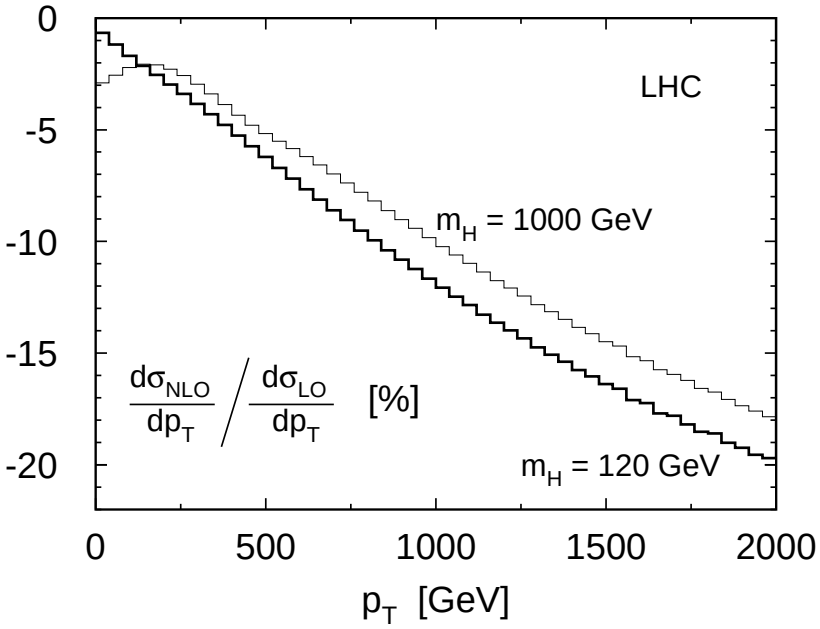
Relative composition of $q\bar{q}$ vs gg induced reactions

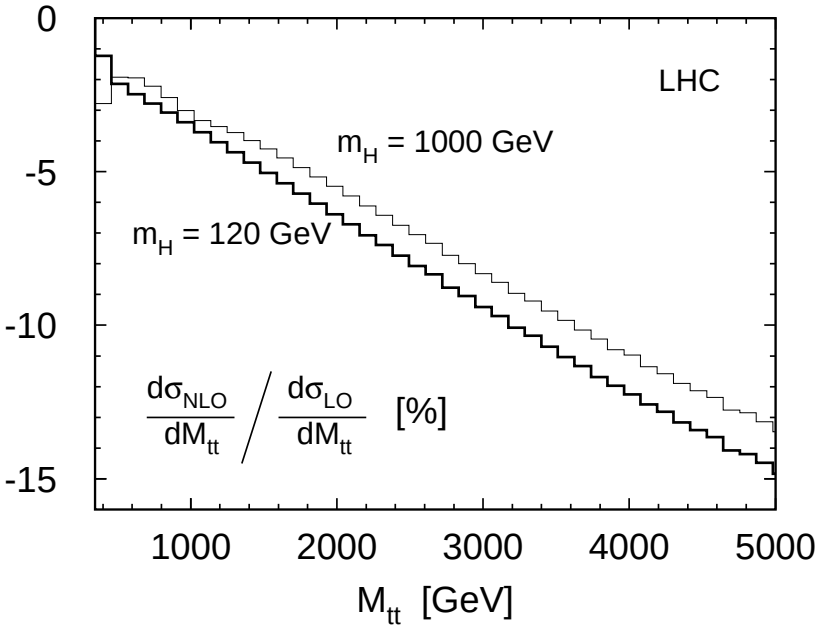




Leading-order differential cross section for the LHC as a function of p_T and $M_{t\bar{t}}$. Shown is the sum (full) and the contributions from gluon fusion (dashed) and quark–antiquark annihilation (dotted).

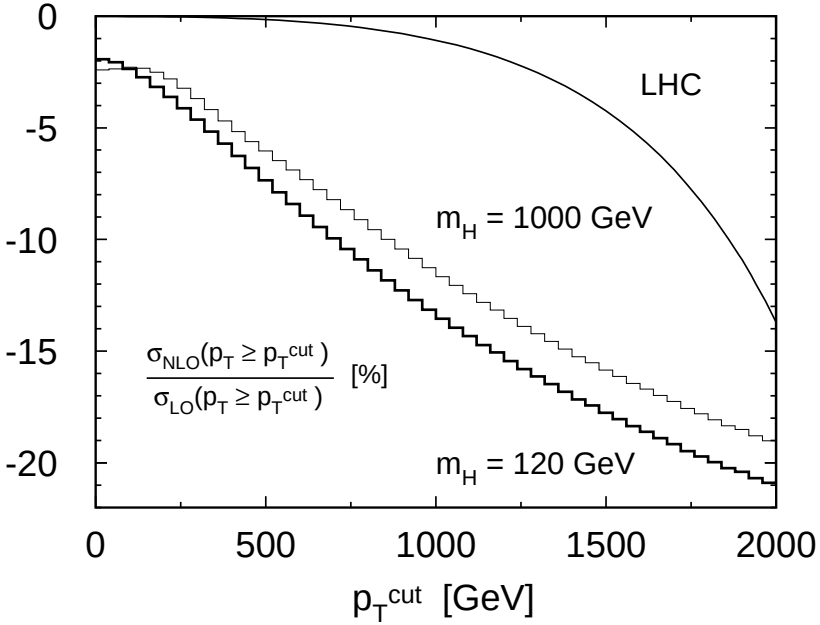
LHC

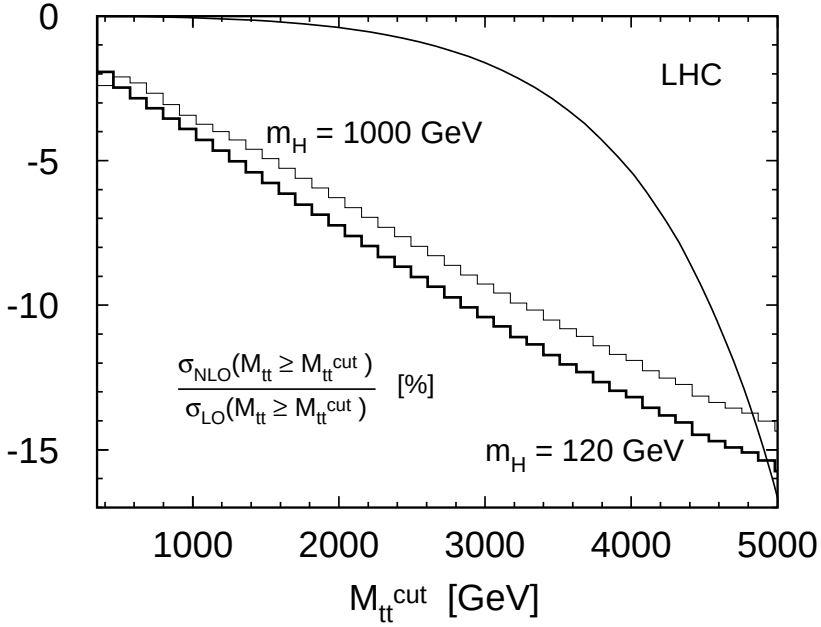




The relative corrections to the p_T and $M_{t\bar{t}}$ distribution for the LHC for $m_H = 120$ GeV (bold histogram) and $m_H = 1000$ GeV (thin histogram).

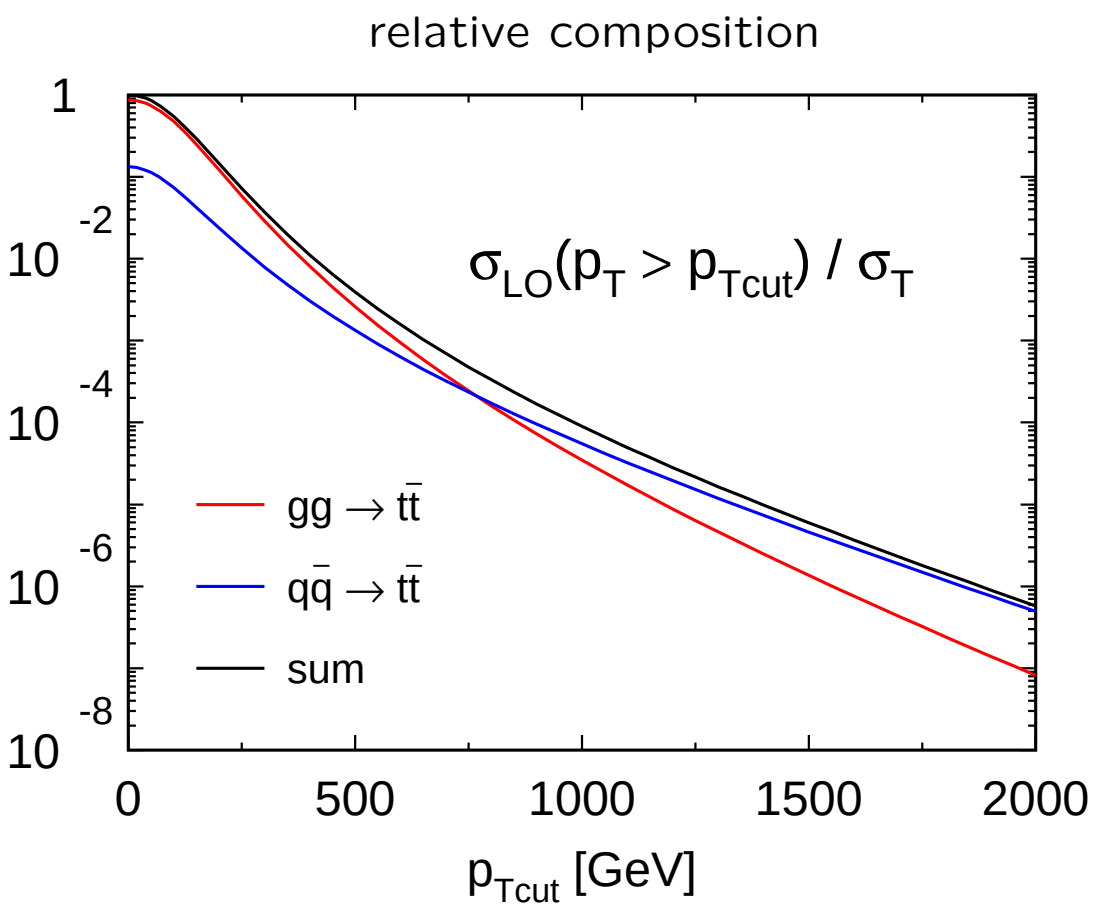
LHC

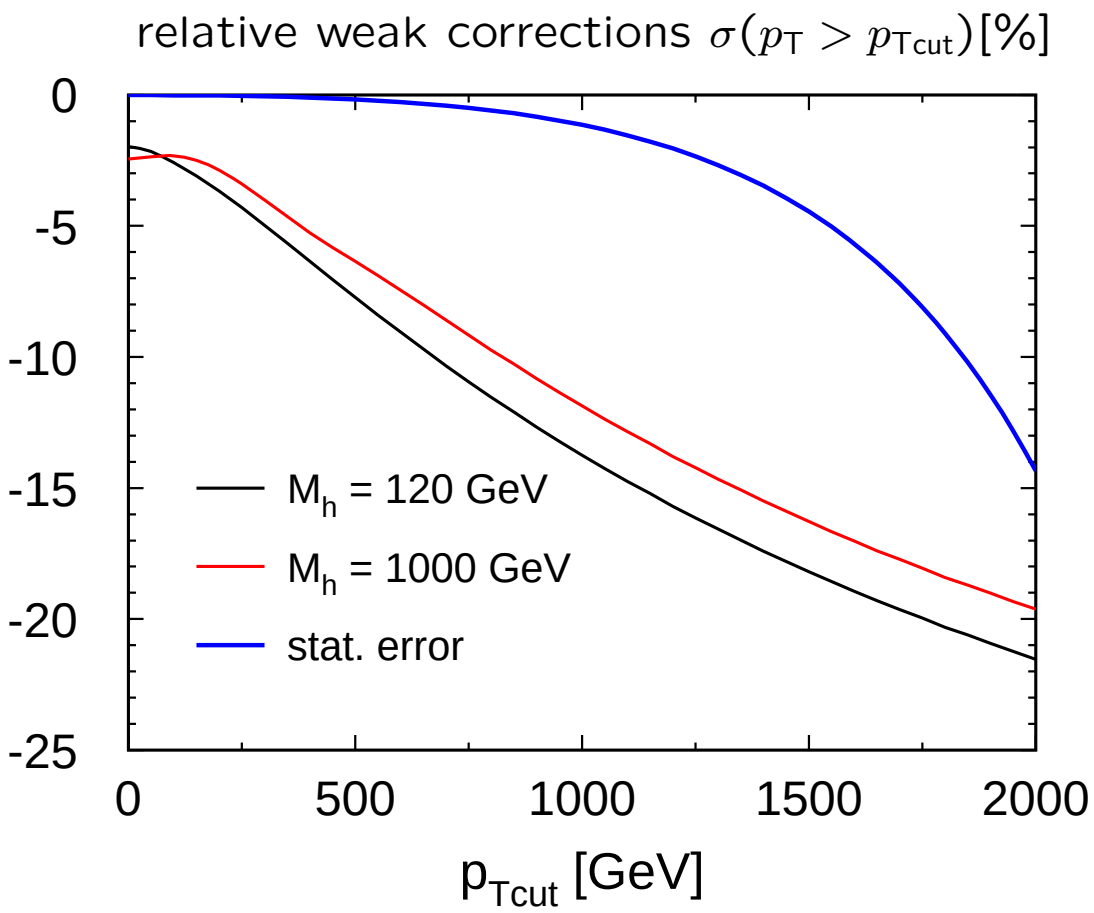




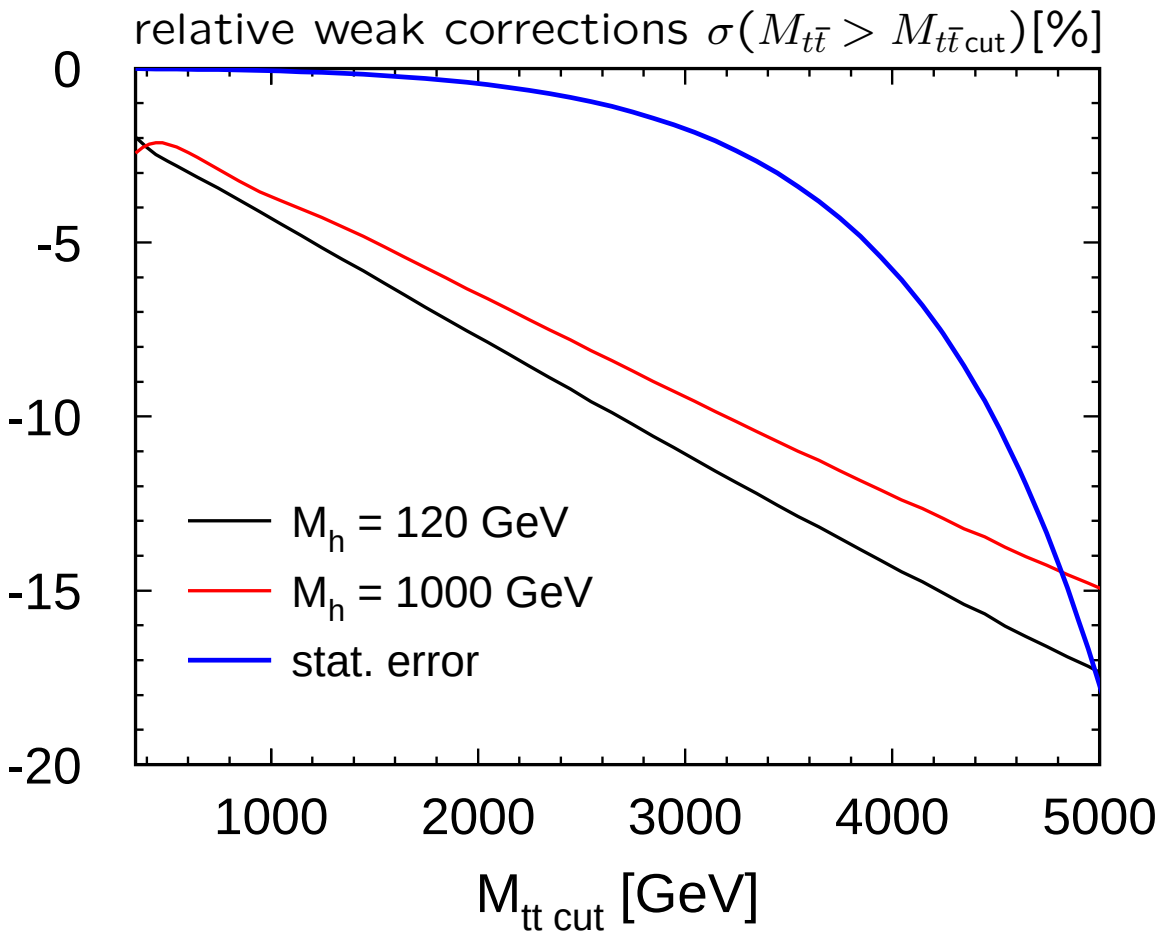
The relative corrections to the p_T and $M_{t\bar{t}}$ distributions, integrated from a lower value in p_T and $M_{t\bar{t}}$ to the kinematic limit, for the LHC and two Higgs masses ($m_H = 120$ GeV (bold histogram), $m_H = 1000$ GeV (thin histogram)). The smooth curve gives an estimate of the corresponding statistical uncertainty for an integrated luminosity of 200 fb^{-1}.

Transverse momentum dependence (LHC)





$M_{t\bar{t}}$ -dependence (LHC)



IV. Conclusions on weak corrections

- LHC will explore the TeV-region: $\hat{s}/M_W^2 \gg 1$
- electroweak corrections amount to $\mathcal{O}(10\% - 20\%)$ in the interesting kinematic region
- top-quark distributions at large $\hat{s}$ are strongly modified
- sizable M_{h}-dependence for small p_{T}

B. CHARGE ASYMMETRY in HADROPRODUCTION and AXIGLUONS

J.K., G. Rodrigo: PRL 81, 49 (1998)
PRD 59, 054017 (1999)
O. Antuñano, J.K., G. Rodrigo: PRD 77, 014003 (2008)

I. Motivation and Main Idea

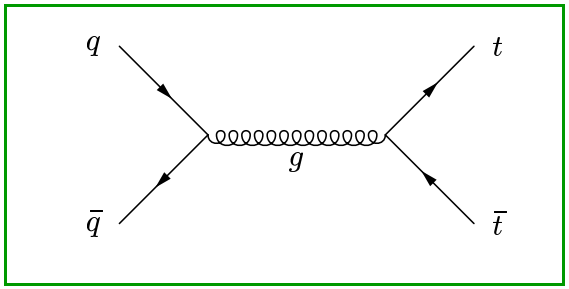
II. Results at Partonic Level

III. Asymmetries at Tevatron and LHC

IV. Limits on Axigluons

I MOTIVATION and MAIN IDEA

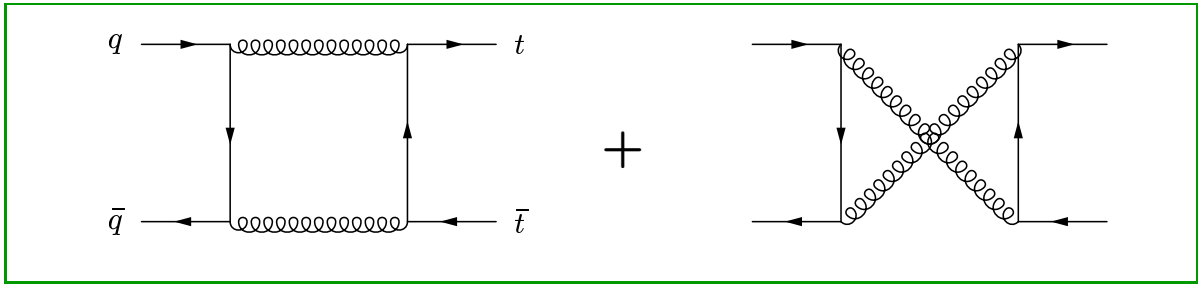
dominant process for $t\bar{t}$ production ...



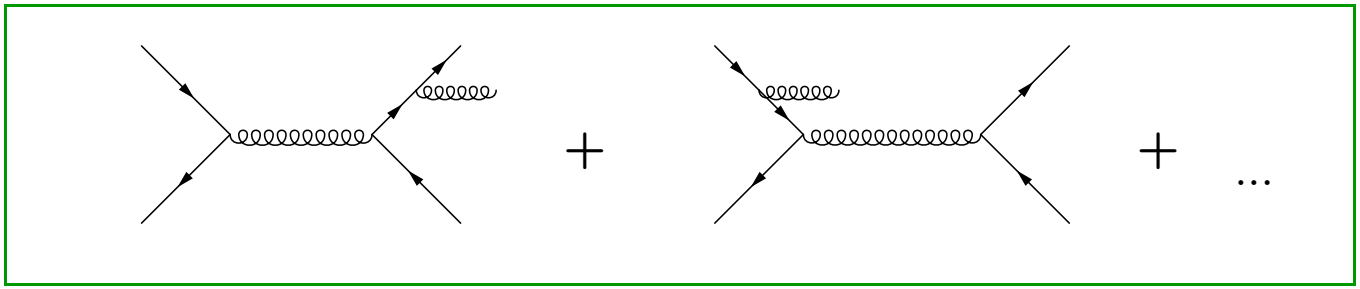
... is symmetric:

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\cos\hat{\Theta}} \propto \left(1+\frac{4m^2}{Q^2}\right) + \left(1-\frac{4m^2}{Q^2}\right)\cos^2\hat{\Theta}$$

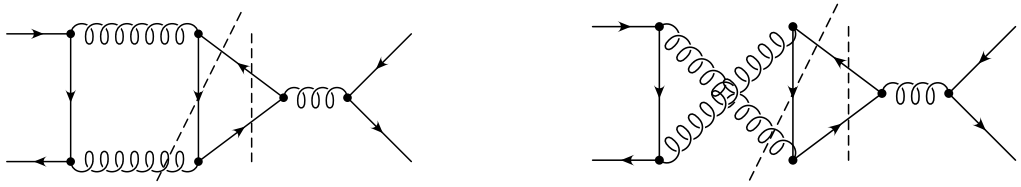
$\mathcal{O}(\alpha_s)$ corrections: virtual gluons



real emission



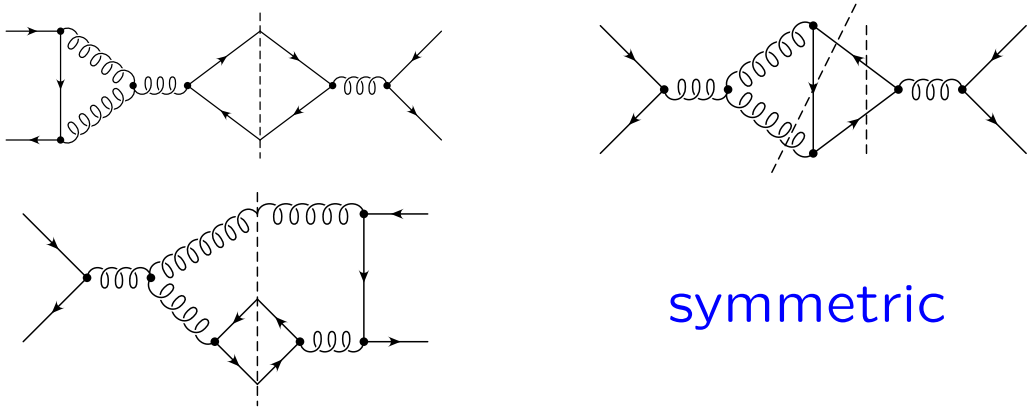
Interference between $C = +1$ and $C = -1$ amplitudes



$\Rightarrow$ charge asymmetry
similar to QED!

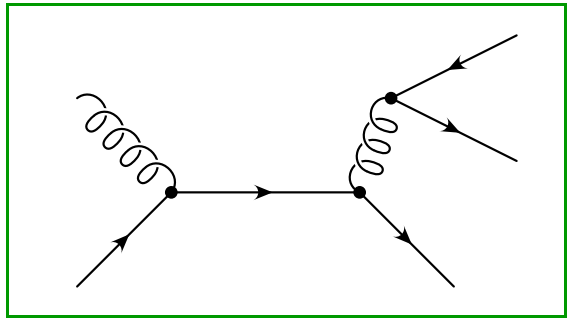
$$\mathrm{d}\sigma(q\bar{q} \to QX) - \mathrm{d}\sigma(q\bar{q} \to \bar{Q}X) \neq 0$$

Nonabelian terms:



similarly ("flavour excitation")
numerically unimportant

$$\mathrm{d}\sigma(qg \to QX) - \mathrm{d}\sigma(qg \to \bar{Q}X) \neq 0$$



real and virtual corrections must be combined to obtain sensible (=IR–finite) result

$\Rightarrow$ forward–backward asymmetry of top quarks in $p\bar{p}$ collisions (TEVATRON)

$\Rightarrow$ difference in rapidity distributions between t and $\bar{t}$ in pp collisions (LHC)

$\Rightarrow$ test of production mechanism

$\Rightarrow$ potential confusion with asymmetry from weak production avoided

Intuitive picture

inclusive cross section

top and light quark in same direction
preferred coherence with gluon field!

$\Rightarrow$ positive asymmetry for
inclusive cross section

$t\bar{t}g$

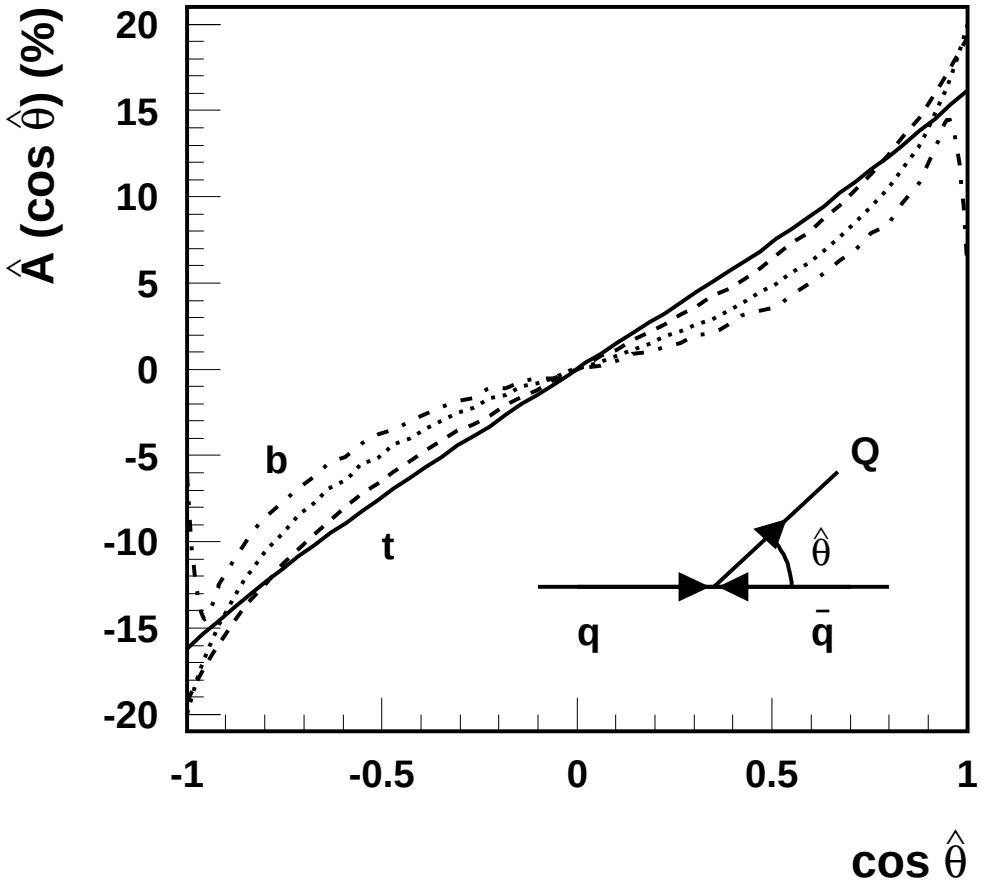
propability for gluon emission enhanced
if t and q in opposite direction

$\Rightarrow$ negative asymmetry for $t\bar{t}g$
(tagged events)

II PARTONIC LEVEL

differential asymmetry
($q\bar{q}$ induced)

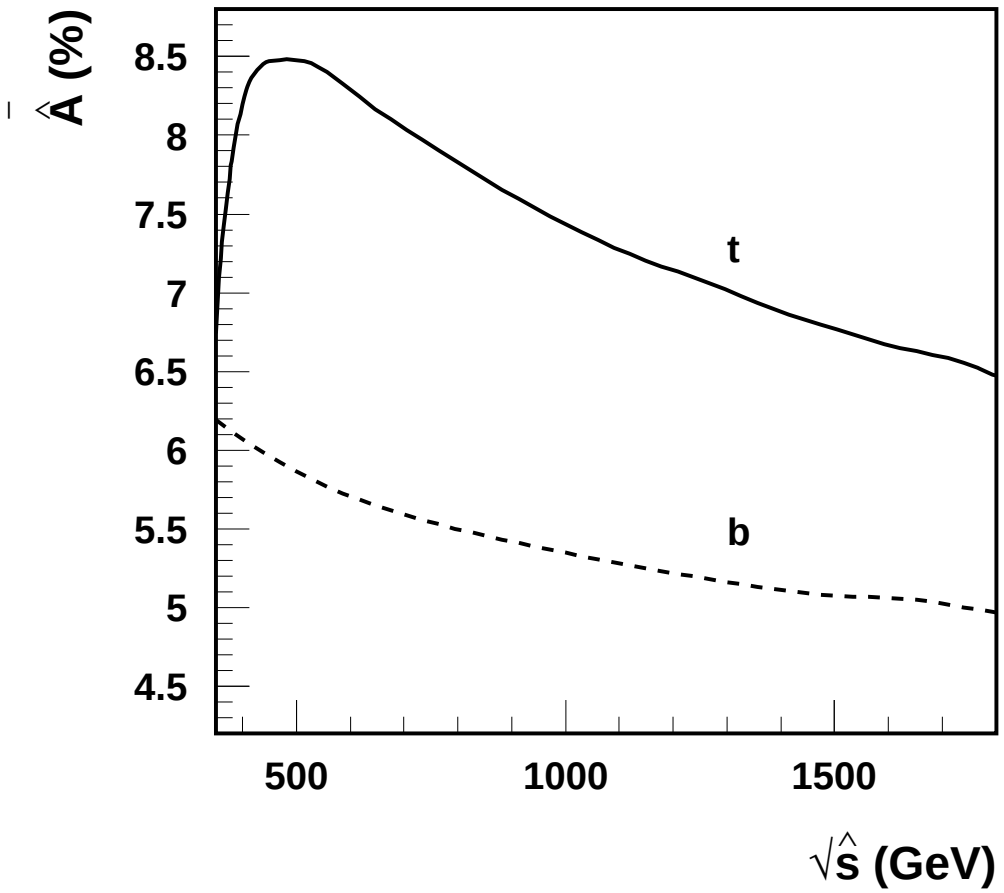
$$\hat{A}(\cos\hat{\Theta}) = \frac{N_t(\cos\hat{\Theta}) - N_{\bar{t}}(\cos\hat{\Theta})}{N_t(\cos\hat{\Theta}) + N_{\bar{t}}(\cos\hat{\Theta})} = \frac{N_t(\cos\hat{\Theta}) - N_{\bar{t}}(-\cos\hat{\Theta})}{N_t(\cos\hat{\Theta}) + N_{\bar{t}}(-\cos\hat{\Theta})}$$



integrated asymmetry
(parton level)

as function of $\sqrt{\hat{s}}$:

$$\hat{A}(\cos\hat{\Theta}) = \frac{N_t(\cos\hat{\Theta} \geq 0) - N_{\bar{t}}(\cos\hat{\Theta} \geq 0)}{N_t(\cos\hat{\Theta} \geq 0) + N_{\bar{t}}(\cos\hat{\Theta} \geq 0)} = \frac{N_t(\cos\hat{\Theta} \geq 0) - N_t(\cos\hat{\Theta} \leq 0)}{N_t(\cos\hat{\Theta} \geq 0) + N_t(\cos\hat{\Theta} \leq 0)}$$



III HADRONIC COLLISIONS

$p\bar{p}$ – 1.96 TeV

dominantly central production:

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

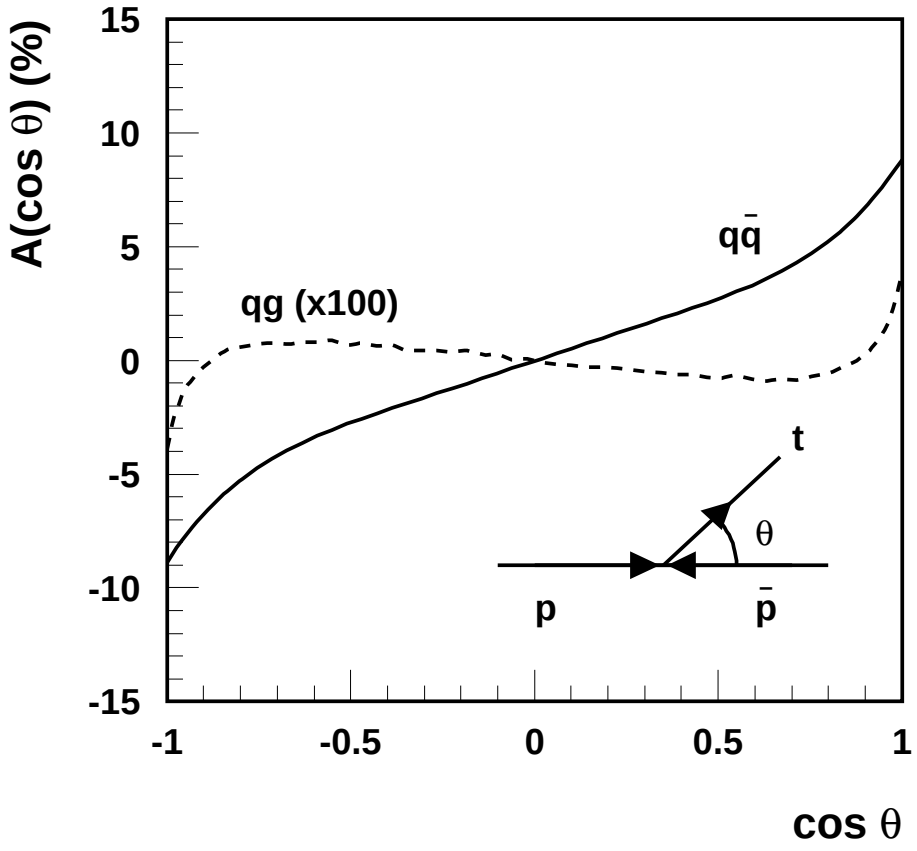
partonic asymmetry

$\Downarrow$

hadronic asymmetry

$\Rightarrow$ Integrated asymmetry

$\bar{A}_{\rm fb} = 4.5 - 5.7\ \%$ (1.96 TeV)



Differential asymmetry: $\mathcal{A}(Y)$

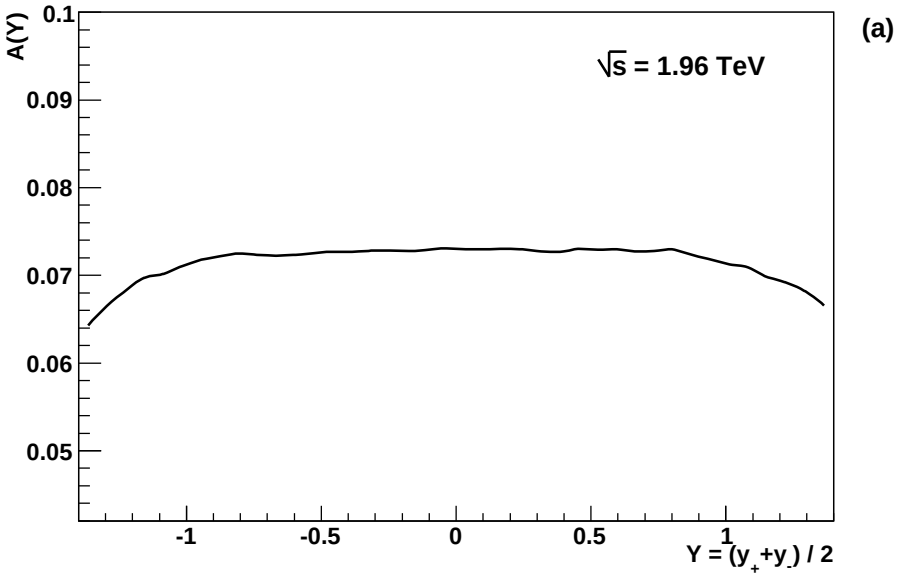
top rapidity y_+ and anti-top rapidity y_- are known (in one event)

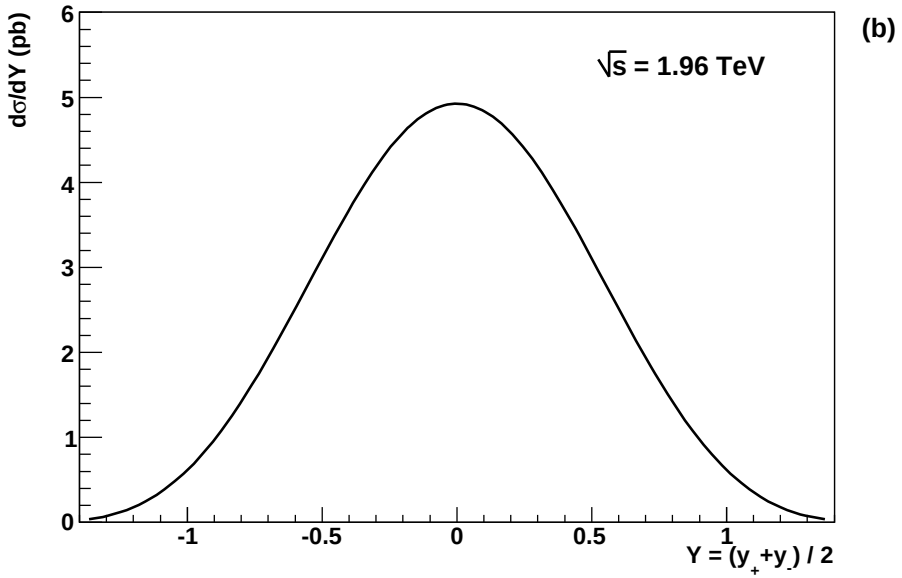
Average: $Y \equiv \frac{1}{2}(y_+ + y_-)$

$$\mathcal{A}(Y) = \frac{N_{ev}(y_+ > y_-) - N_{ev}(y_+ < y_-)}{N_{ev}(y_+ > y_-) + N_{ev}(y_+ < y_-)}$$

nearly equivalent to partonic asymmetry

$Y \widehat{=}$ partonic rest frame!





$$\mathcal{A}_{total} \equiv \frac{N_{ev}(y_+ > y_-) - N_{ev}(y_+ < y_-)}{N_{ev}}$$

preliminary Tevatron results:

$$A_{FB} = 0.20 \pm 0.11 \pm 0.05$$
$$\mathcal{A}_{total} = 0.23 \pm 0.12 \pm 0.06$$

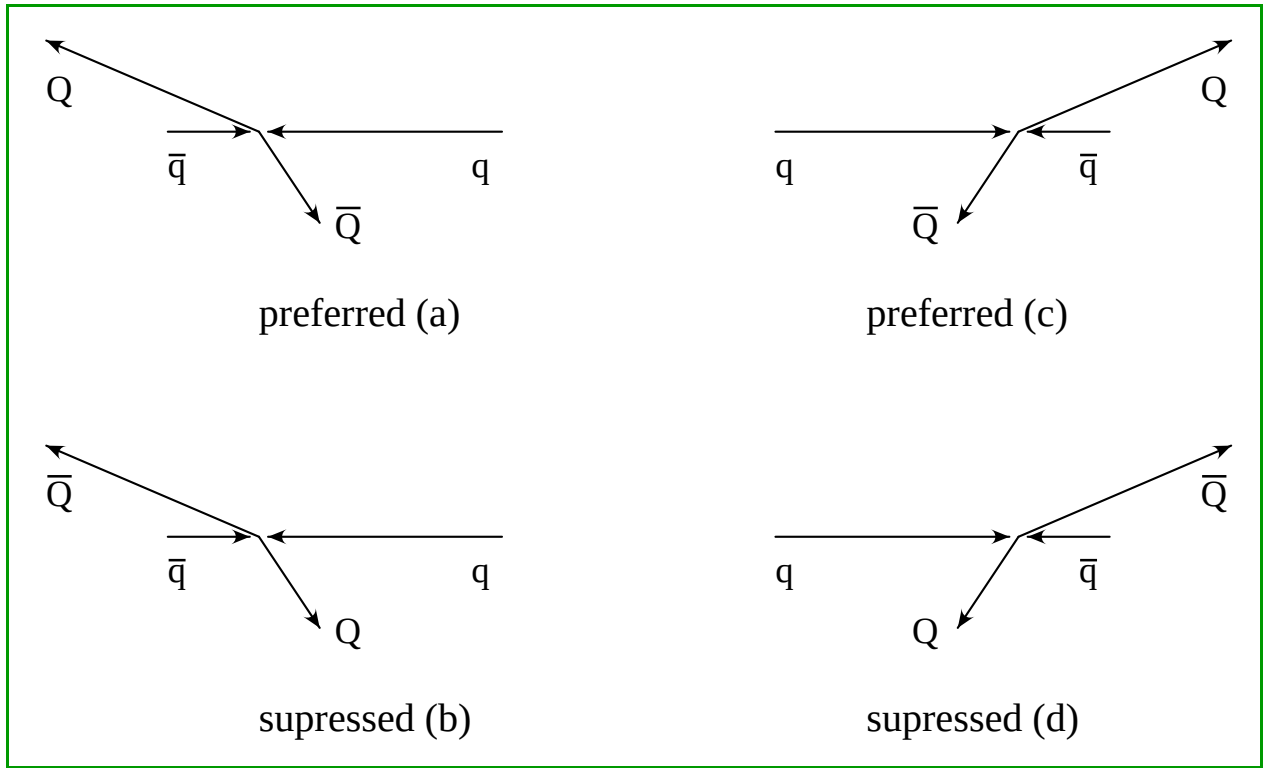
Comments

- inclusive asymmetry hardly affected by radiative corrections (Almeida, Sterman, Vogelsang)

- $t\bar{t}g$ asymmetry strongly affected by radiative corrections, sensitive to cuts (Dittmaier, Uwer, Weinzierl)

pp – 14 TeV

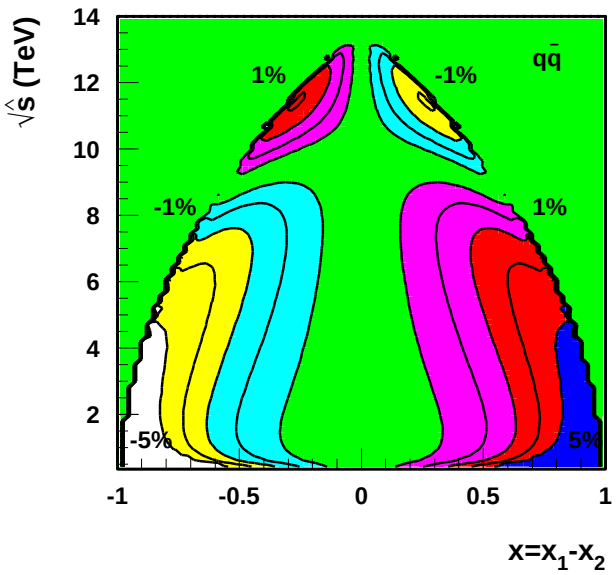
- no forward backward asymmetry
- slight difference between rapidity distributions of Q and $\bar{Q}$ from (small) admixture of $q\bar{q}$ processes

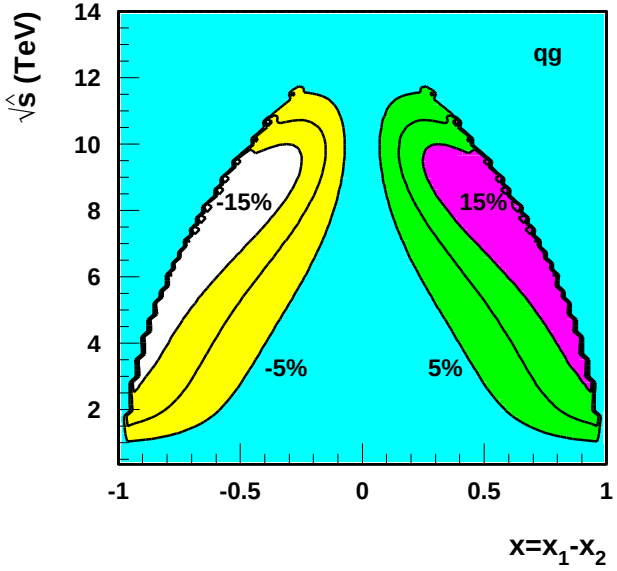


$\Rightarrow$ more t at large rapidity

$\Rightarrow$ more $\bar{t}$ at small rapidity

main effect in regions of small cross section

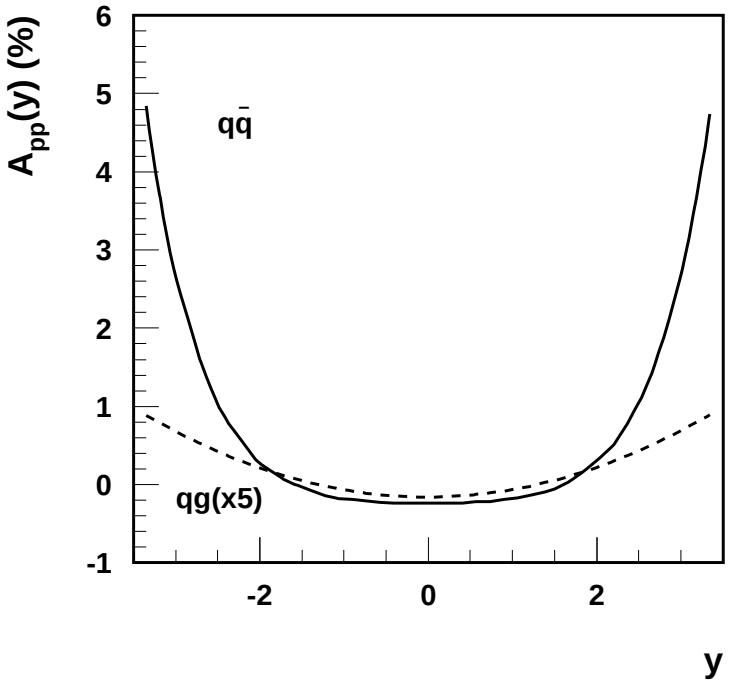




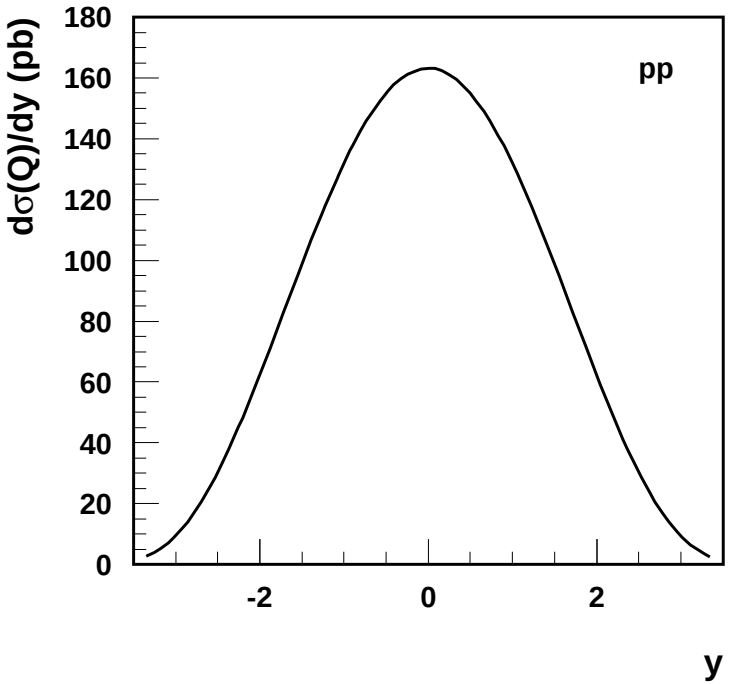
$t\bar{t}$ production in proton-proton collisions (LHC) is forward-backward symmetric in the laboratory frame.

- Select the invariant mass of the $t\bar{t}(+g)$ system and its longitudinal momentum.
  - For some extreme kinematic regions, large x and/or large $\hat{s}$ (in practice $\hat{s} < 2$TeV), sizable asymmetry

reconstruction of the $t\bar{t}(+g)$ rest frame required!!!



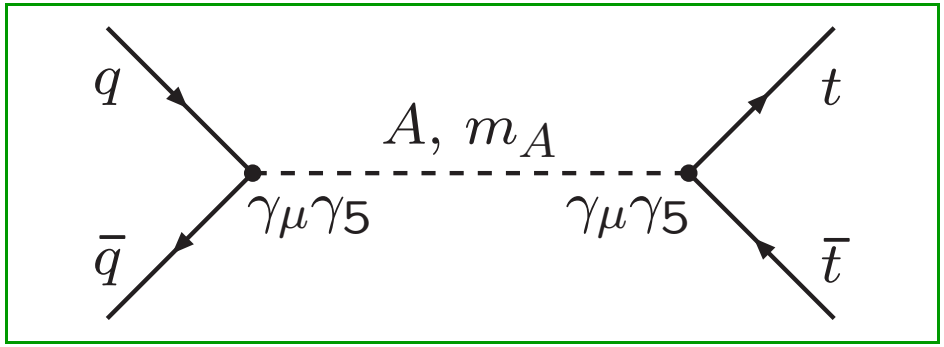
(a)



(b)

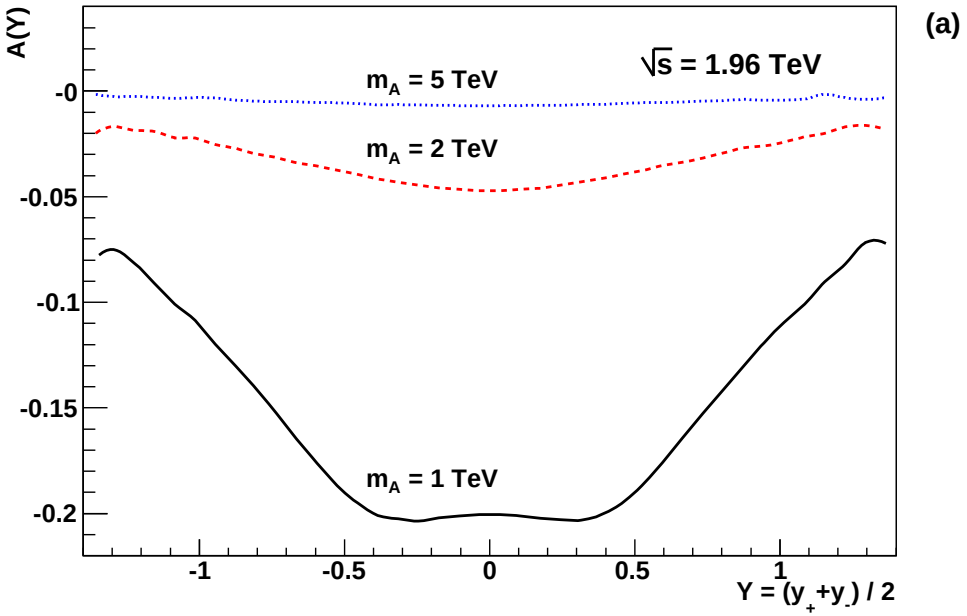
Leading order!

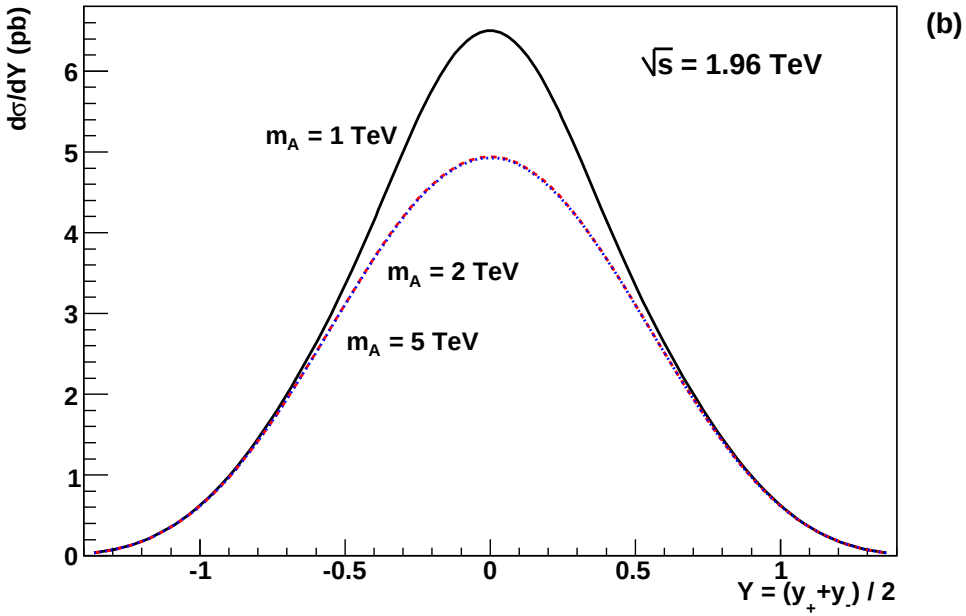
IV Limits on Axigluons



$\Rightarrow$ modified $t\bar{t}$ production
(resonance for $m(t\bar{t}) = m_A$)

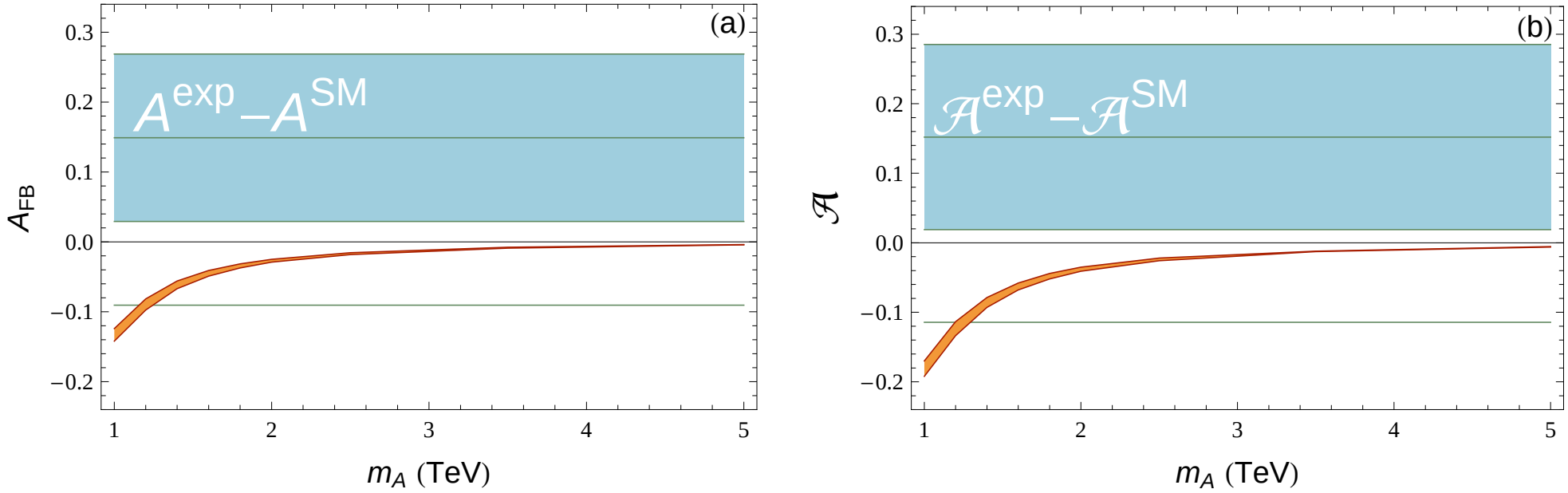
$\Rightarrow$ interference with gluon
$\longrightarrow$ forward backward asymmetry





	QCD	$m_A = 1$ TeV	$m_A = 2$ TeV	$m_A = 5$ TeV
A_{FB}	0.051(6)	$-0.133(9)$	$-0.027(2)$	$-0.0041(3)$
$\mathcal{A}$	0.078(9)	$-0.181(11)$	$-0.038(3)$	$-0.0058(4)$

Preliminary Tevatron results



$m_A > 1.2$ TeV at 2σ

Summary

- ⋆ forward backward asymmetry for t production at TEVATRON $\sim 7\%$
- ⋆ important test of production mechanism
- ⋆ unique possibility for $p\bar{p}$ collider
- ⋆ differences between t and $\bar{t}$ distributions at LHC mainly in regions of small cross section (large rapidity!)
- ⋆ access to "new physics" signal for axigluons