TWO TOPICS on TOP QUARKS

A. CHARGE ASYMMETRY in HADROPRODUCTION and AXIGLUONS

B. WEAK CORRECTIONS and SUDAKOV LOGARITHMS

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A. 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

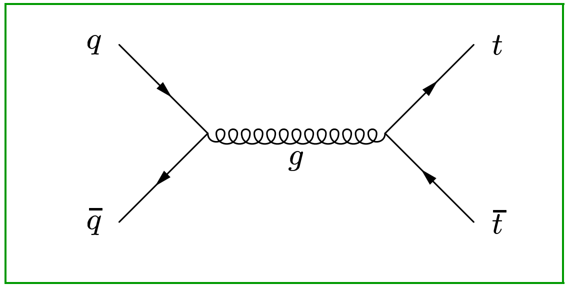
II. Results at Partonic Level

III. Asymmetries at Tevatron and LHC

IV. Limits on Axigluons

I MOTIVATION and MAIN IDEA

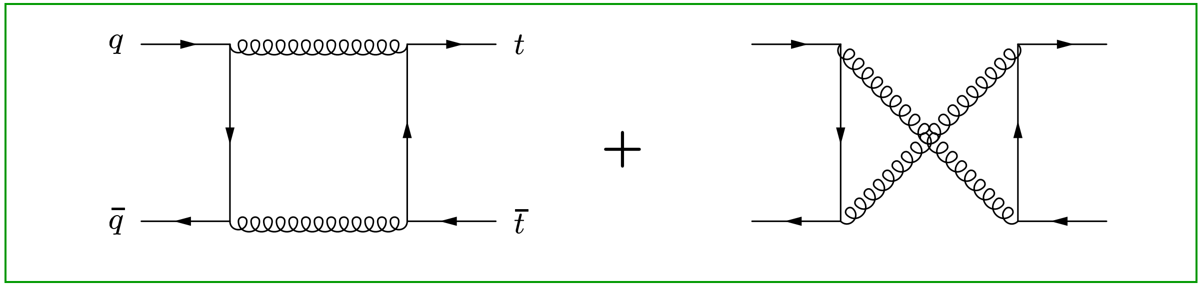
dominant process for
$t\bar{t}$ production . . .



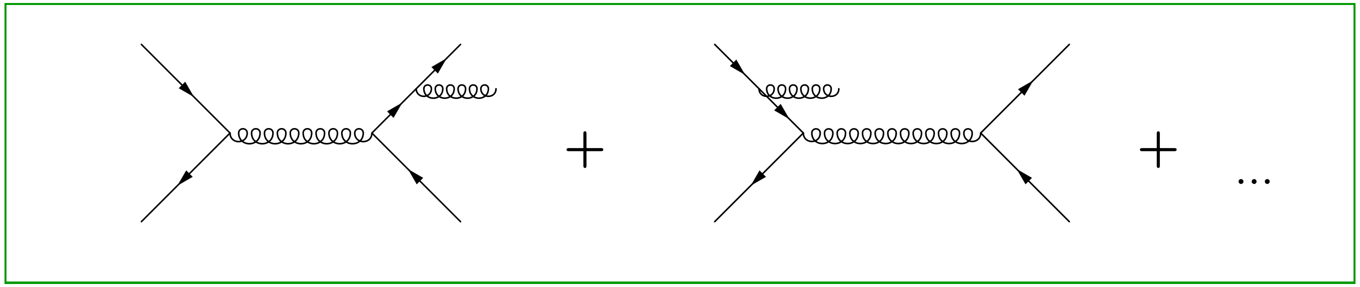
. . . is symmetric:

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

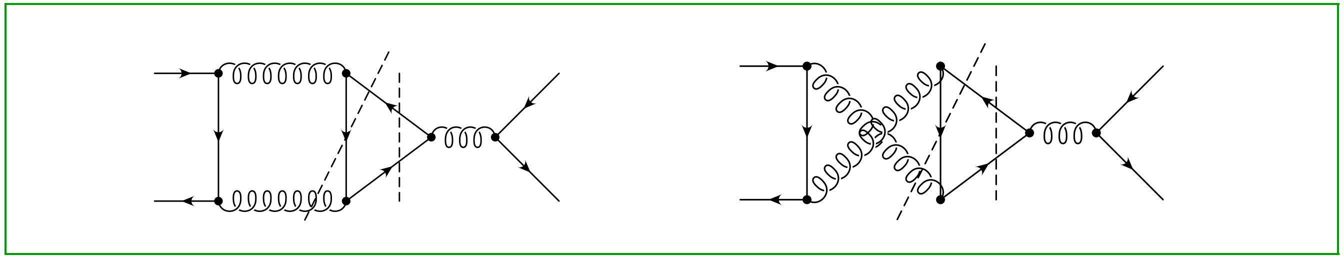
$\mathcal{O}(\alpha_s)$ corrections:
virtual gluons



real emission



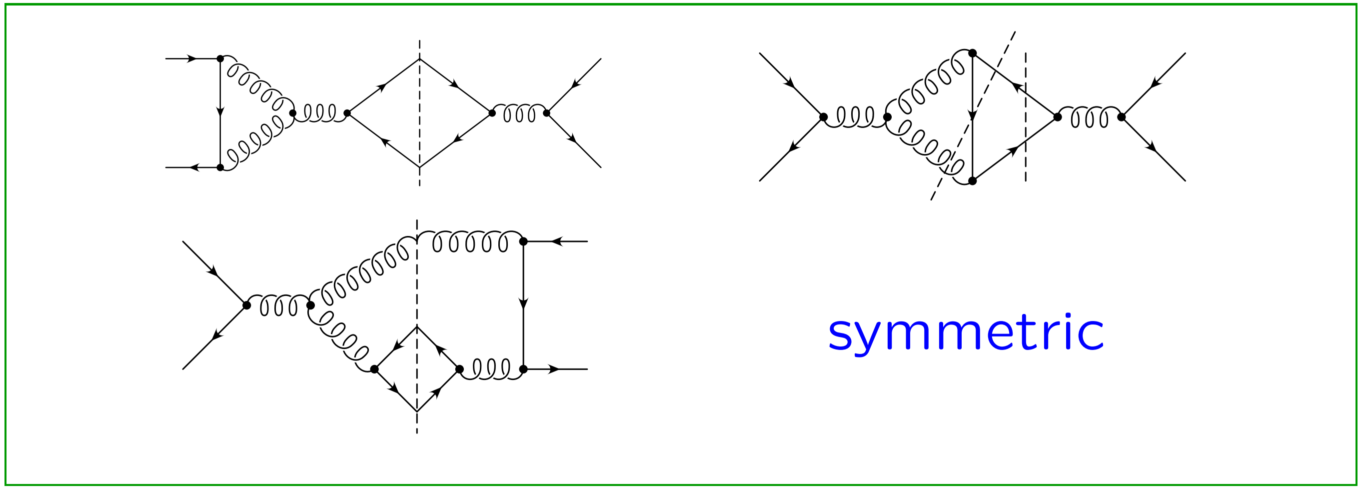
Interference between
$C = +1$ and $C = -1$
amplitudes



$\Rightarrow$ charge asymmetry
similar to QED!

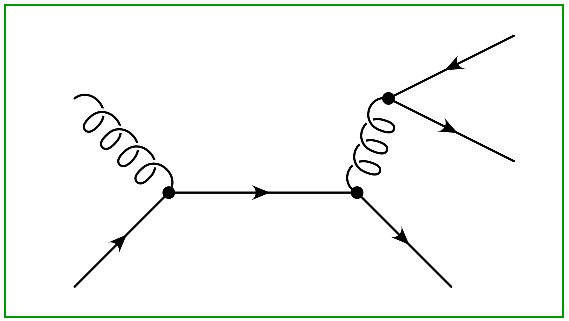
$$\boxed{\mathrm{d}\sigma(q\bar{q} \to QX) - \mathrm{d}\sigma(q\bar{q} \to \bar{Q}X) \neq 0}$$

Nonabelian terms:



similarly ("flavour excitation")
numerically unimportant

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



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

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

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

⇒ test of production mechanism

⇒ 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!

⇒ positive asymmetry for
inclusive cross section

$t\bar{t}g$

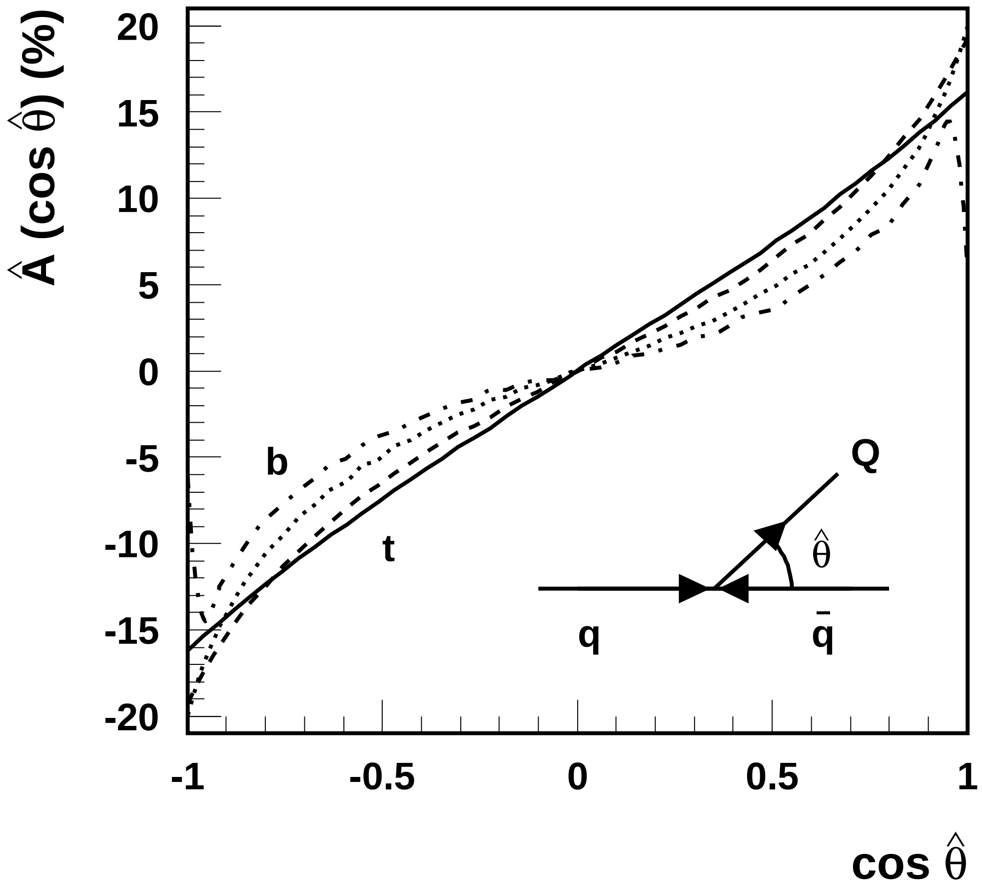
propability for gluon emission enhanced
if t and q in opposite direction

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

II PARTONIC LEVEL

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

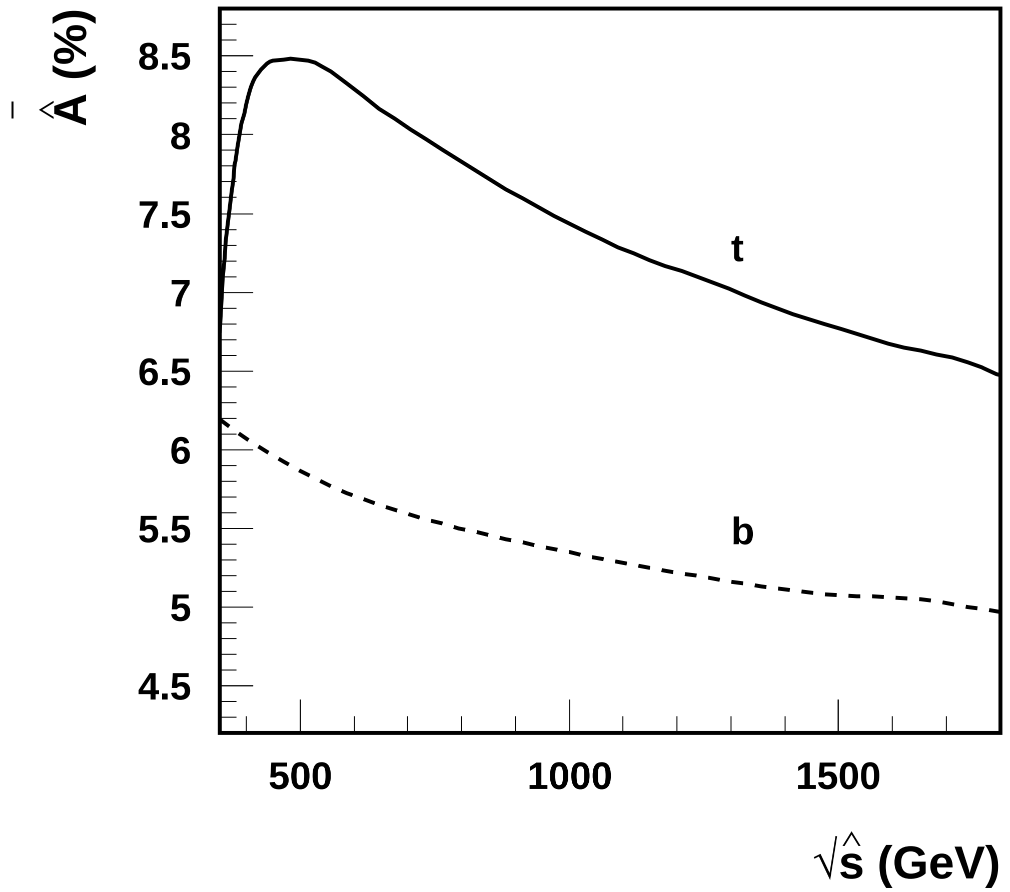
$$\hat{A}(\cos\hat{\Theta}) = \frac{N_t(\cos\hat{\Theta}) - N_{\bar{t}}(\cos\hat{\Theta})}{N_t(\cos\hat{\Theta}) + N_{\bar{t}}(\cos\hat{\Theta})} = \frac{N_t(\cos\hat{\Theta}) - N_{\bar{t}}(-\cos\hat{\Theta})}{N_t(\cos\hat{\Theta}) + N_{\bar{t}}(-\cos\hat{\Theta})}$$



integrated asymmetry
(parton level)

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

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



III HADRONIC COLLISIONS

$p\bar{p}$ – 1.96 TeV

dominantly central production:

$$q\bar{q} \longrightarrow t\bar{t}$$

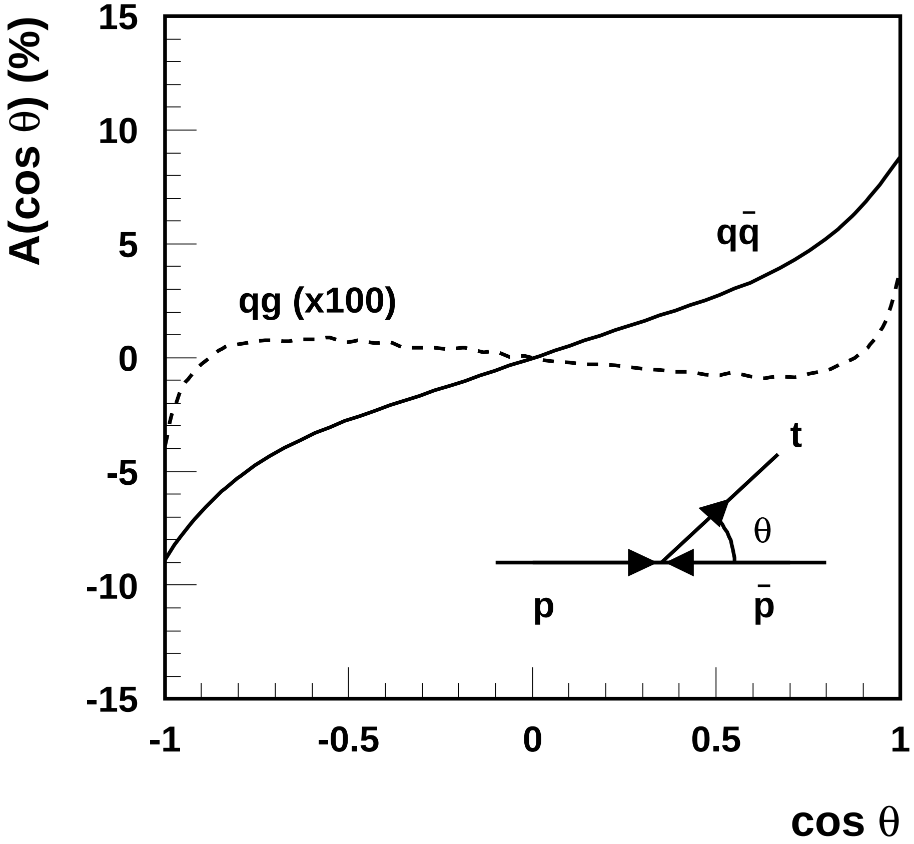
partonic asymmetry

$\Downarrow$

hadronic asymmetry

$\Rightarrow$ Integrated asymmetry

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



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

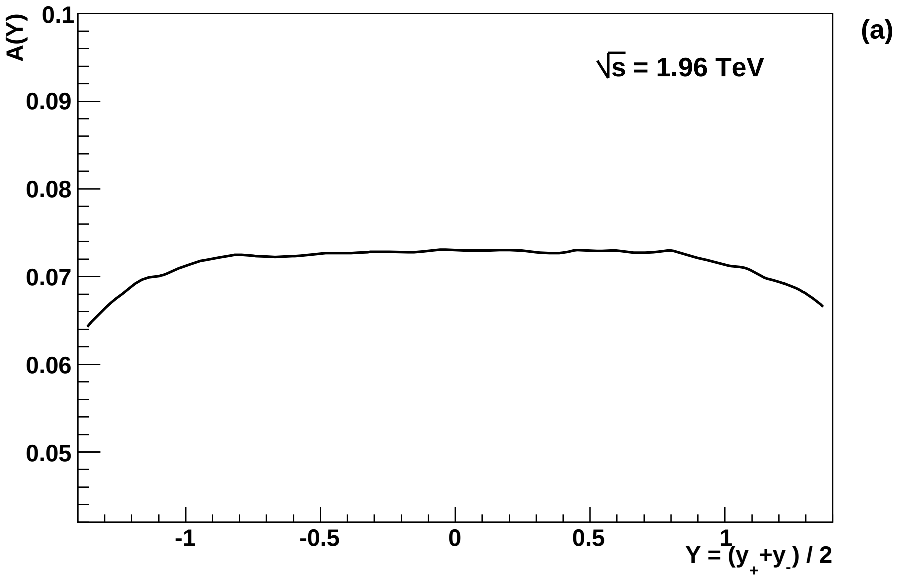
top rapidity y_+ and anti-top rapidity y_- are known (in one event)

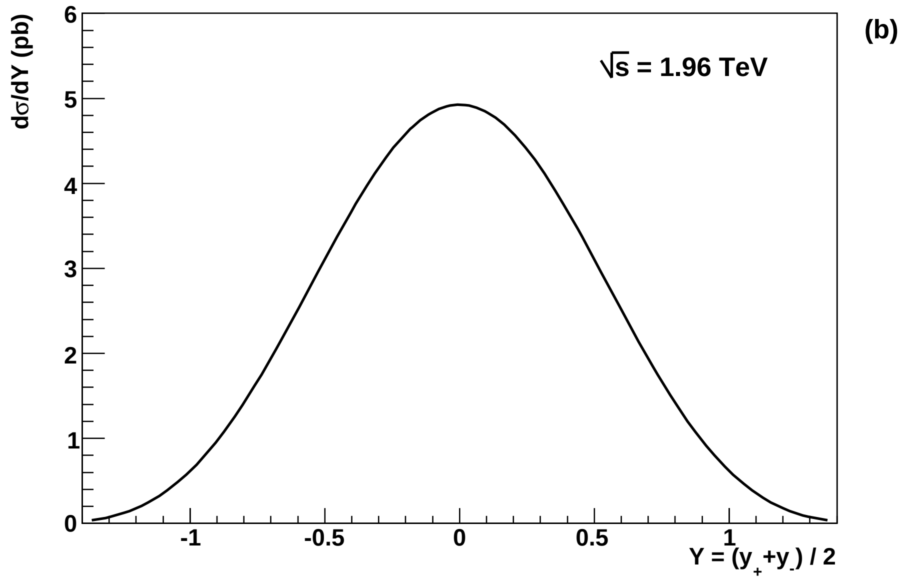
Average: $Y \equiv \frac{1}{2}(y_+ + y_-)$

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

nearly equivalent to partonic asymmetry

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





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

preliminary Tevatron results:

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

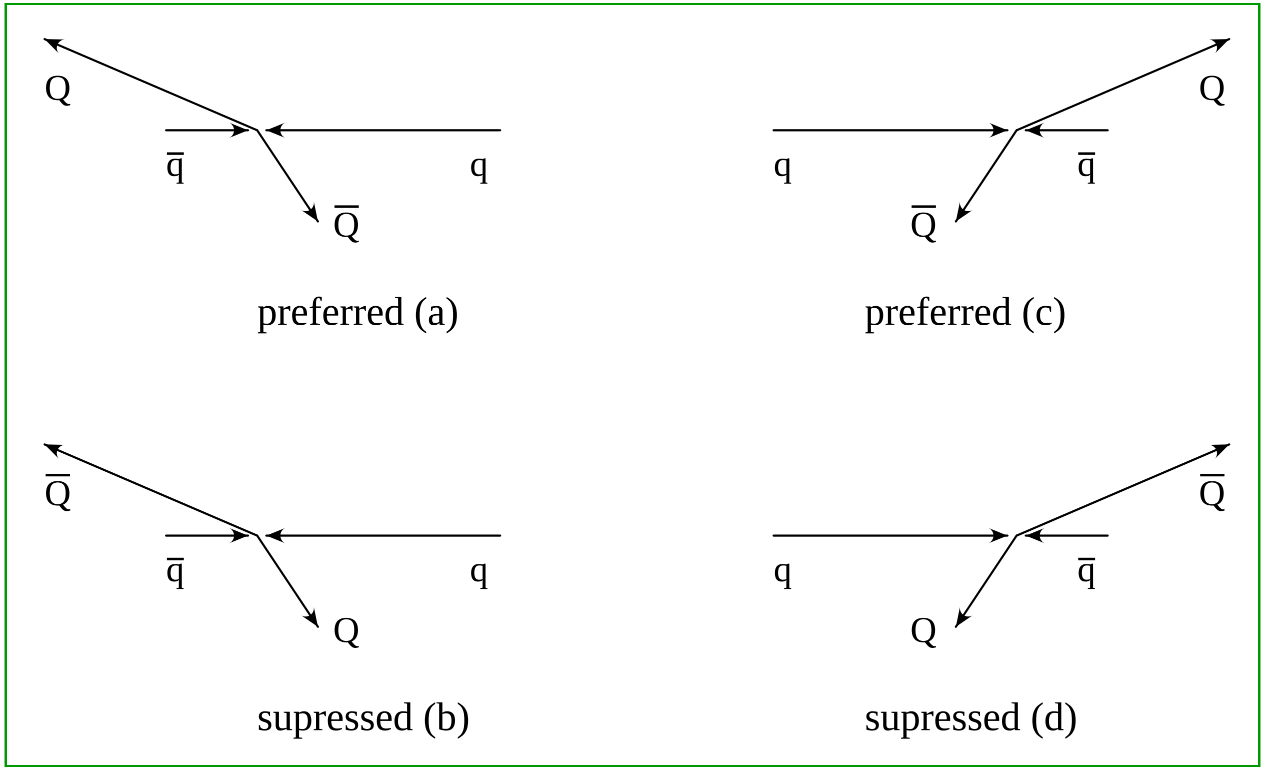
Comments

- 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

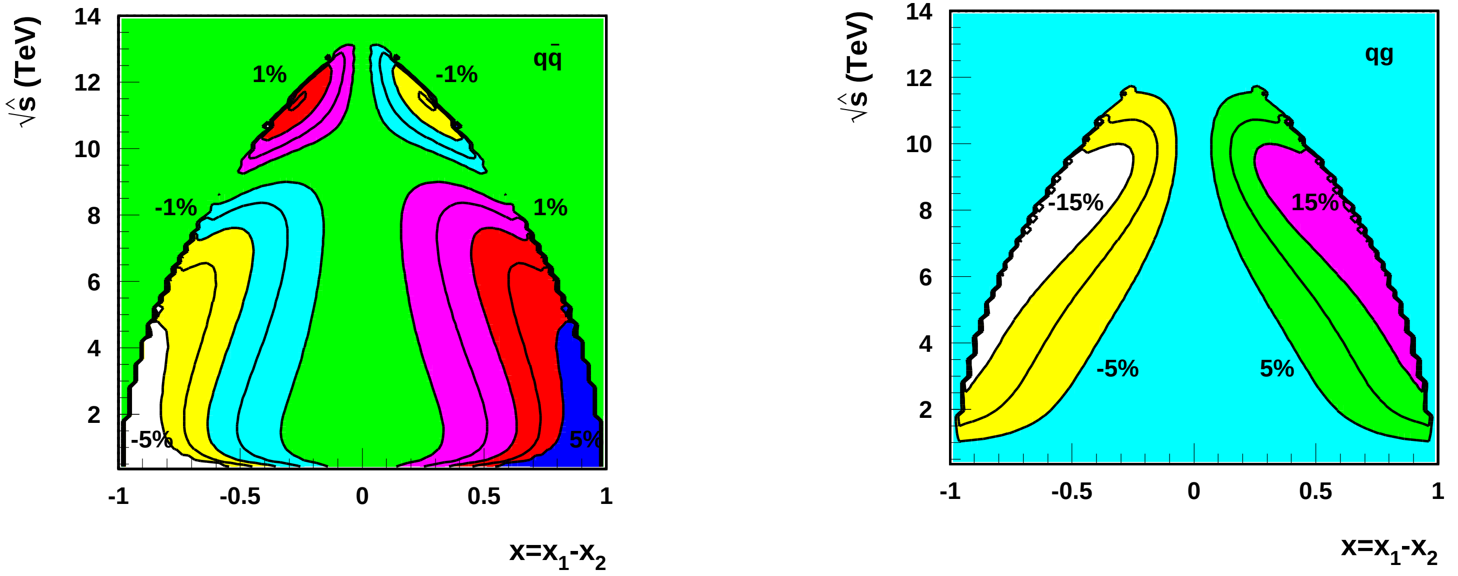
- no forward backward asymmetry
- slight difference between rapidity distributions of Q and $\bar{Q}$ from (small) admixture of $q\bar{q}$ processes



⇒ more t at large rapidity

⇒ more $\bar{t}$ at small rapidity

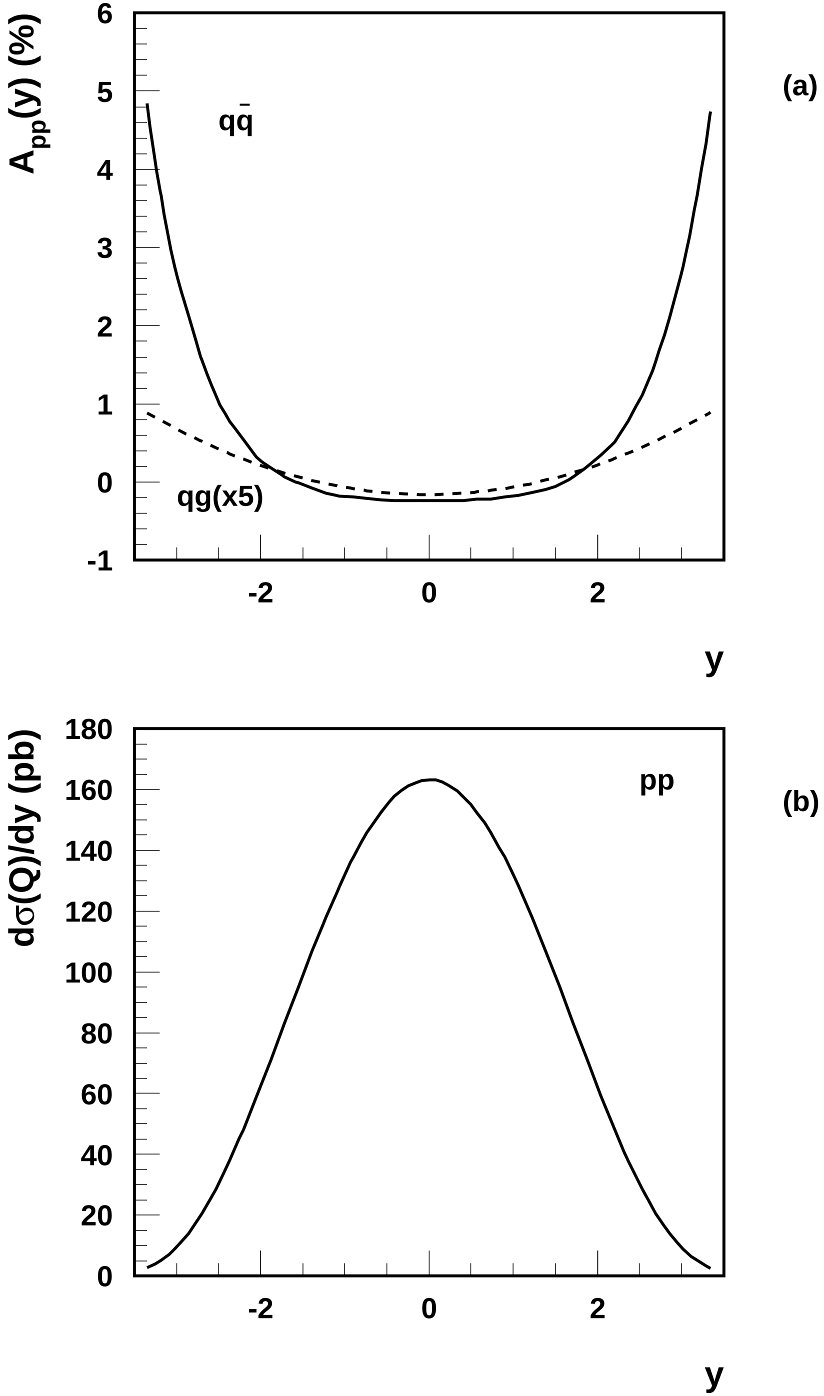
main effect in regions of small cross section



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

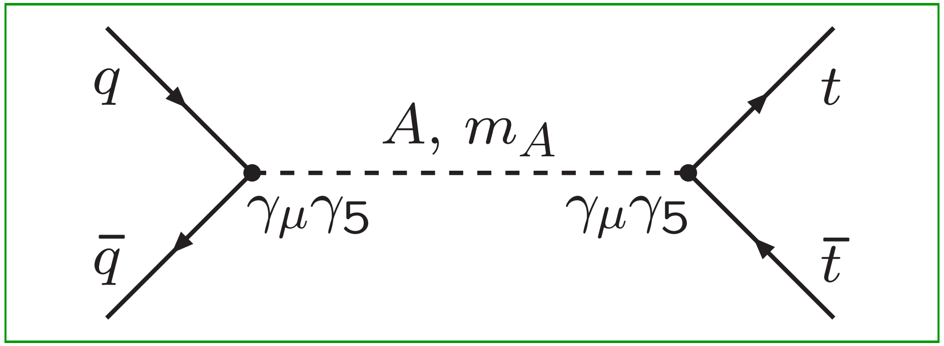
- Select the invariant mass of the $t\bar{t}(+g)$ system and its longitudinal momentum.
  - For some extreme kinematic regions, large x and/or large $\hat{s}$ (in practice $\hat{s} < 2$TeV), sizable asymmetry

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



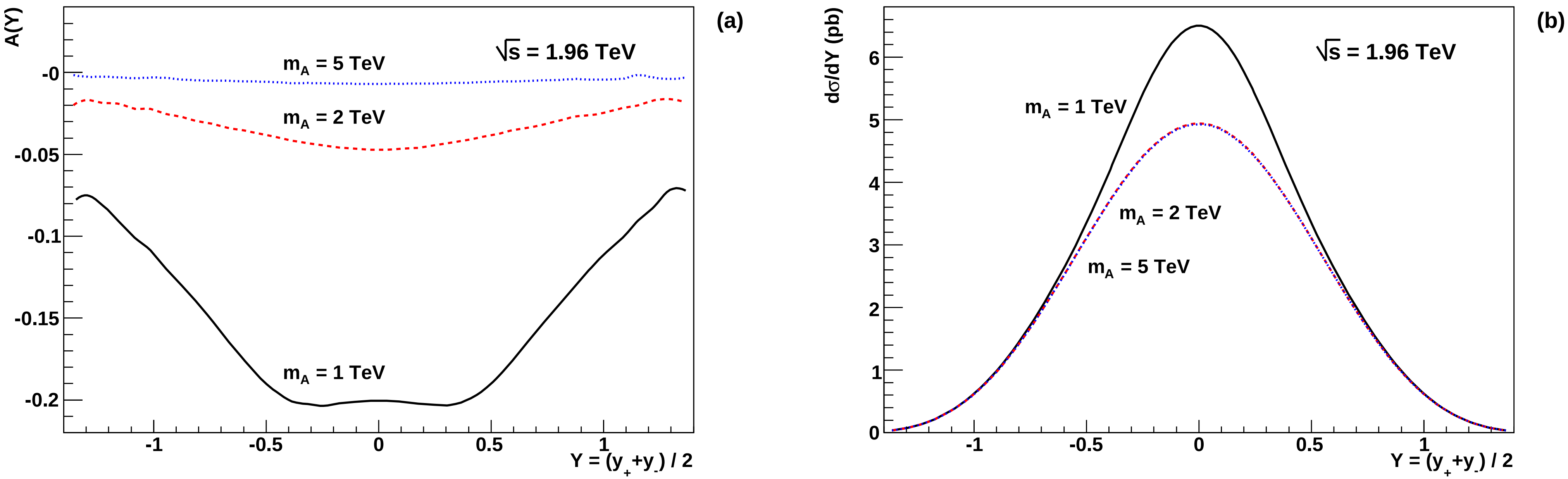
Leading order!

IV Limits on Axigluons



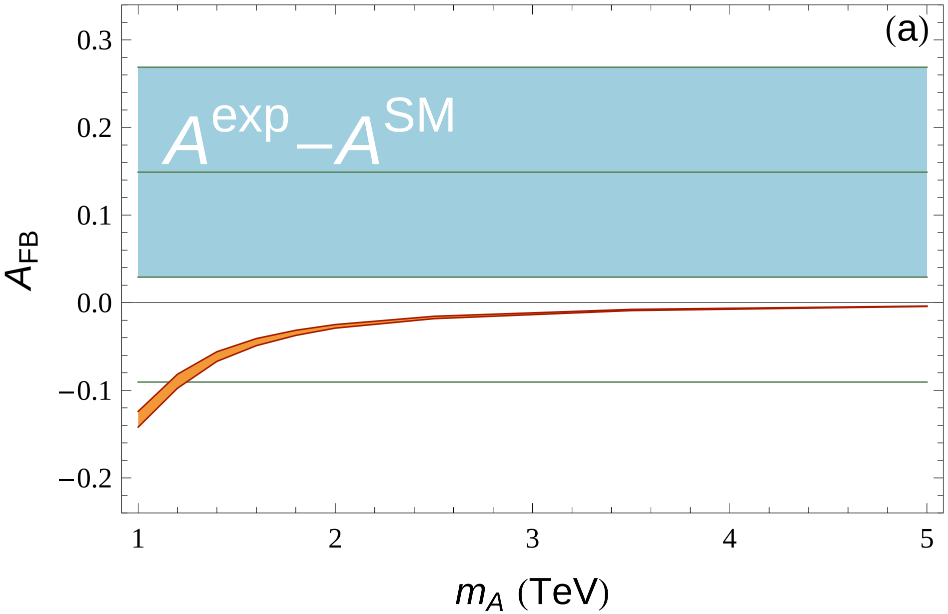
$\Rightarrow$ modified $t\bar{t}$ production
(resonance for $m(t\bar{t}) = m_A$)

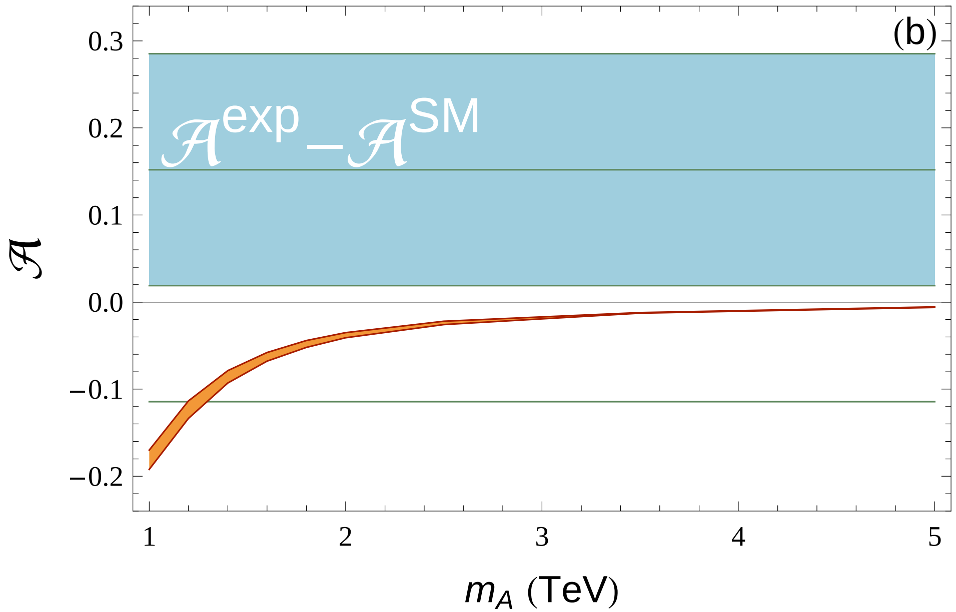
$\Rightarrow$ interference with gluon
$\longrightarrow$ forward backward asymmetry



	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

B. WEAK CORRECTIONS TO TOP PRODUCTION

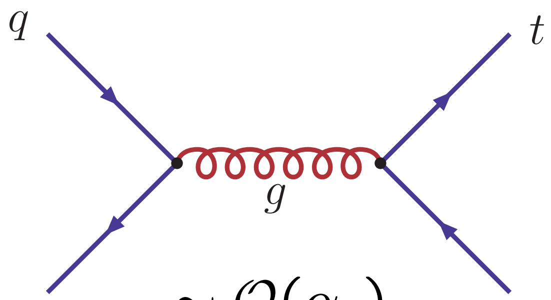
J.K., Scharf, Uwer: Eur. Phys. J. C45(2006) 139
Eur. Phys. J. C51(2007) 37

I. Results at Partonic Level

II. Tevatron and LHC

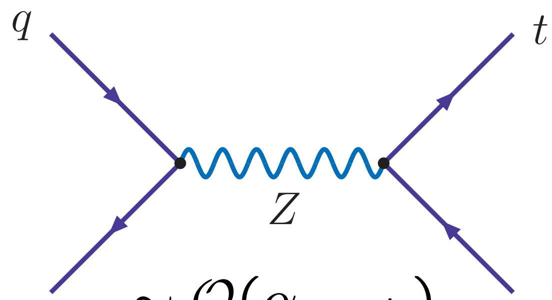
I. Results at Partonic Level

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



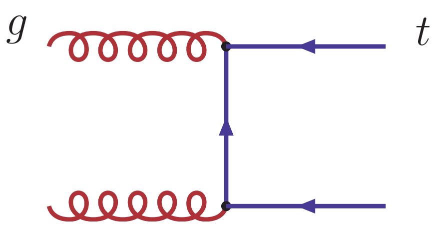
$\sim \mathcal{O}(\alpha_{\mathrm{s}})$

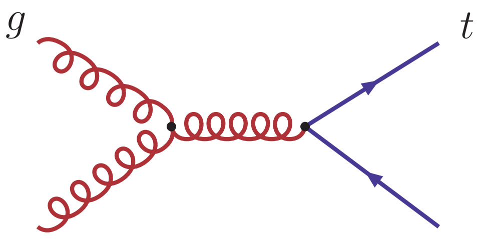
no
interference
with



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

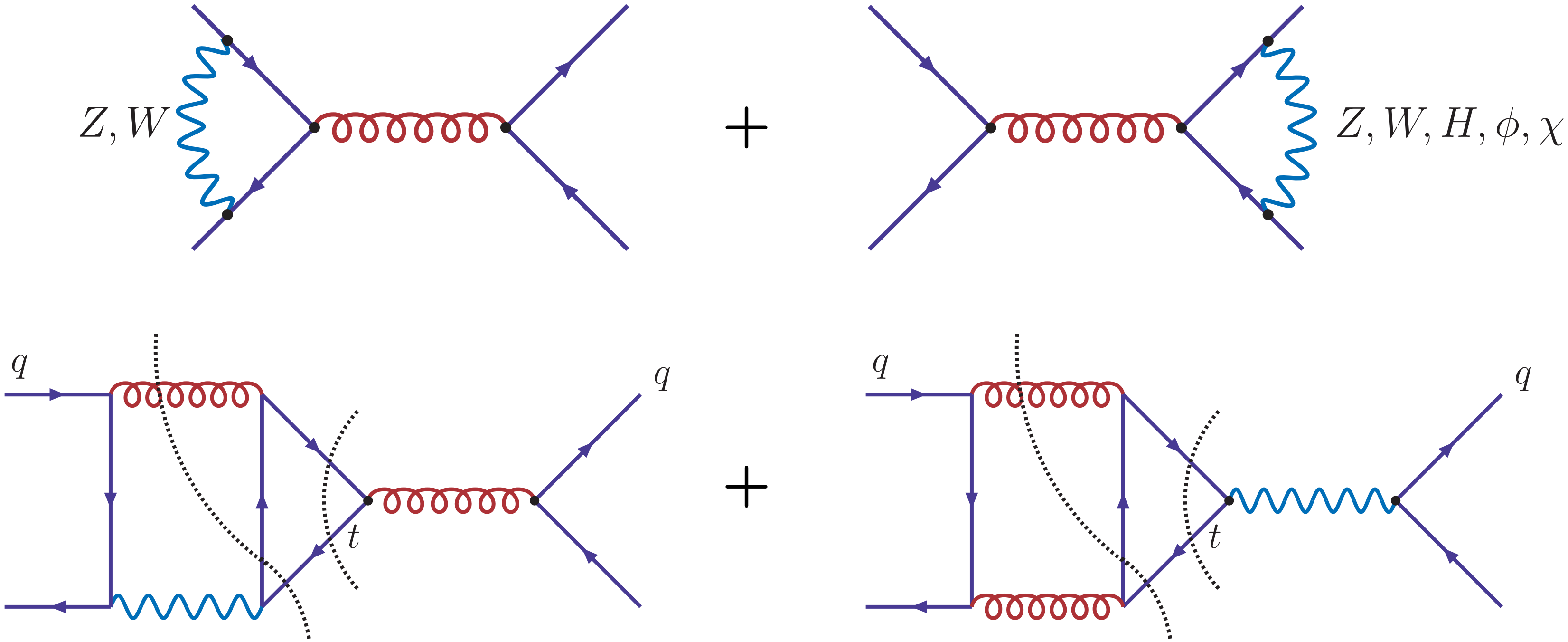
$g\,g \longrightarrow t\,\bar{t}$:





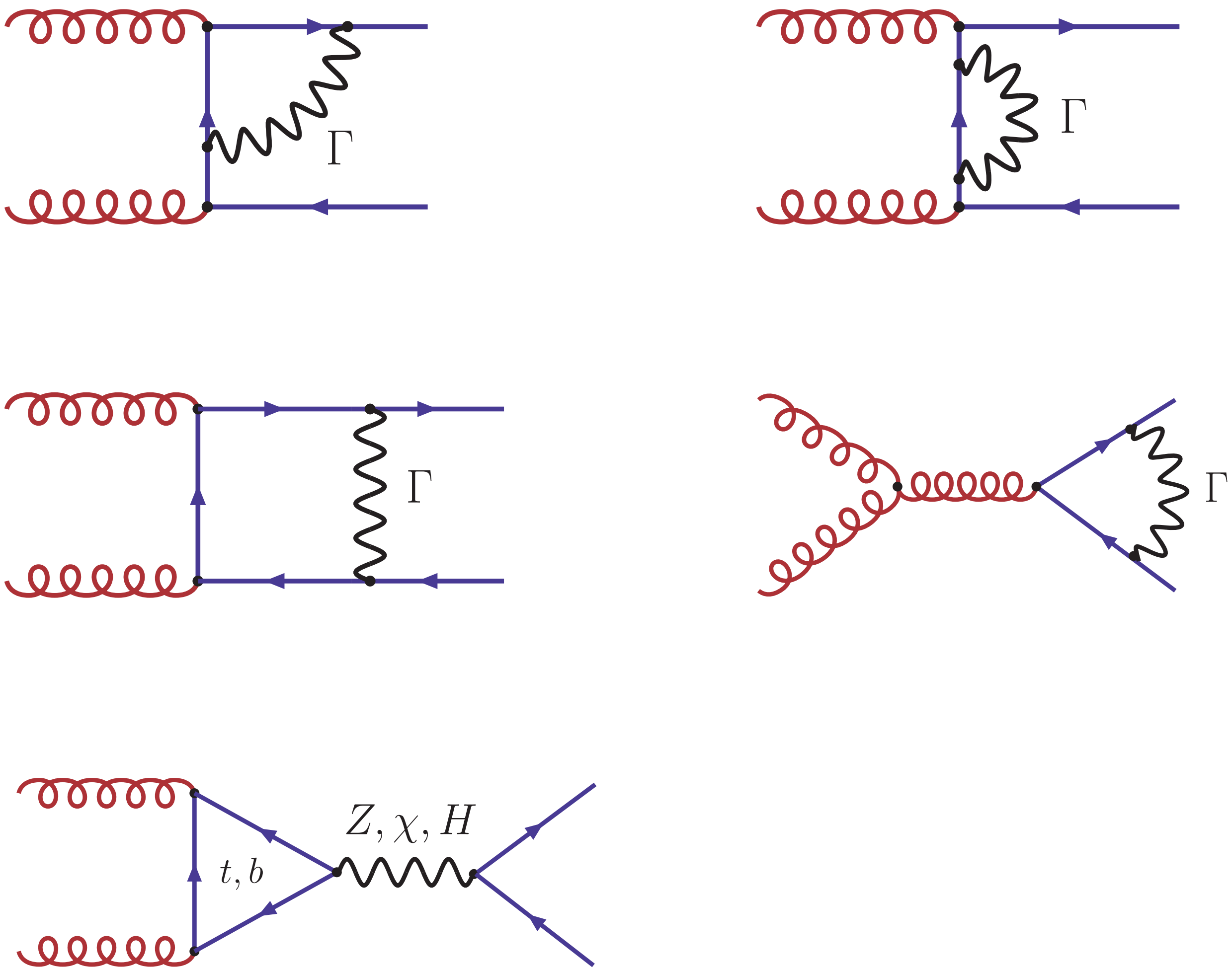
$\sim \mathcal{O}(\alpha_{\mathrm{s}})$

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



cuts of second group individually IR-divergent

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



- analytical & numerical results available
  (earlier partial results by Beenakker *et al.*, some disagreements)
  independent evaluation by Bernreuther & Fücker

- $(\text{box contribution})_{\text{up-quark}} = -(\text{box contribution})_{\text{down-quark}}$
  $\Rightarrow$ suppression

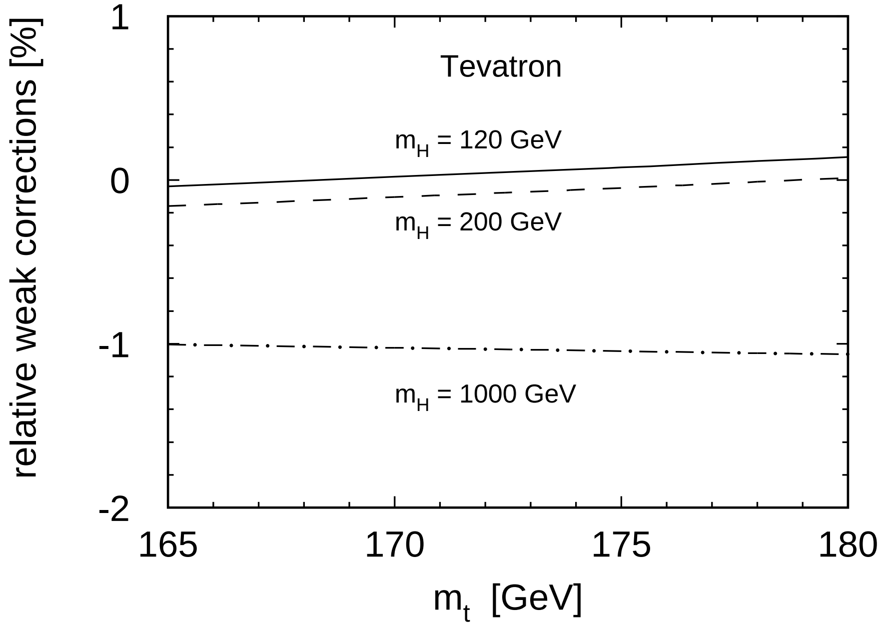
- box contribution moderately $\hat{s}$-dependent

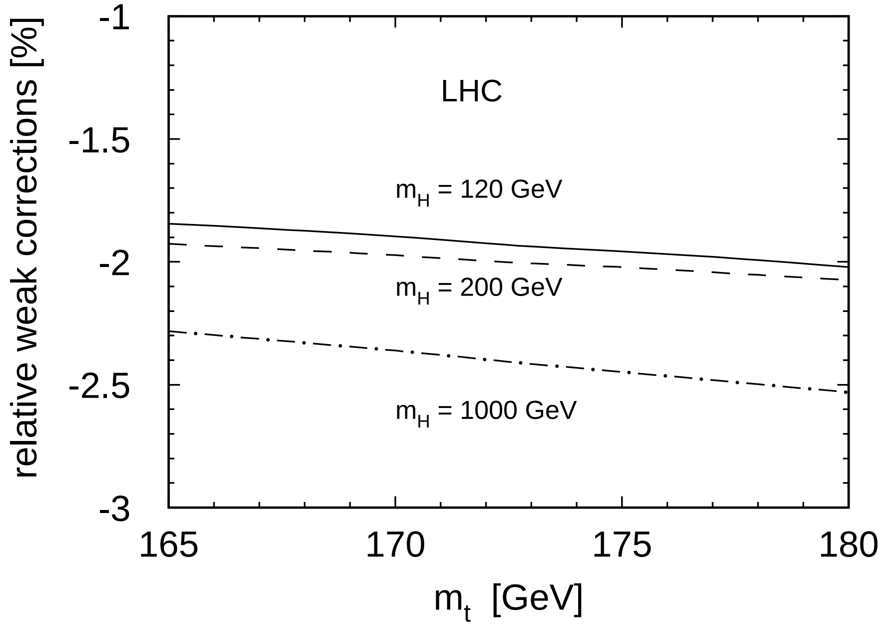
- strong increase with $\hat{s}$

- sizable M_{h}-dependence, large effect close to threshold

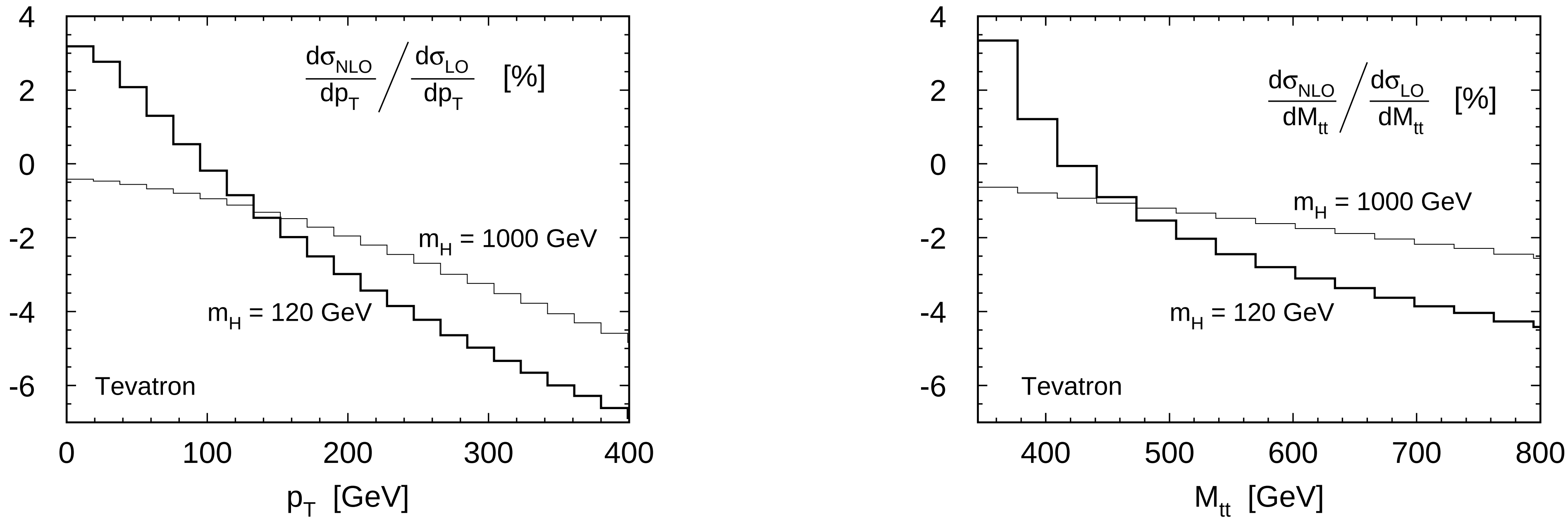
II. Tevatron and LHC

Small effects for total cross section
(dominated by $\sqrt{\hat{s}} \sim$ 360-380 GeV)



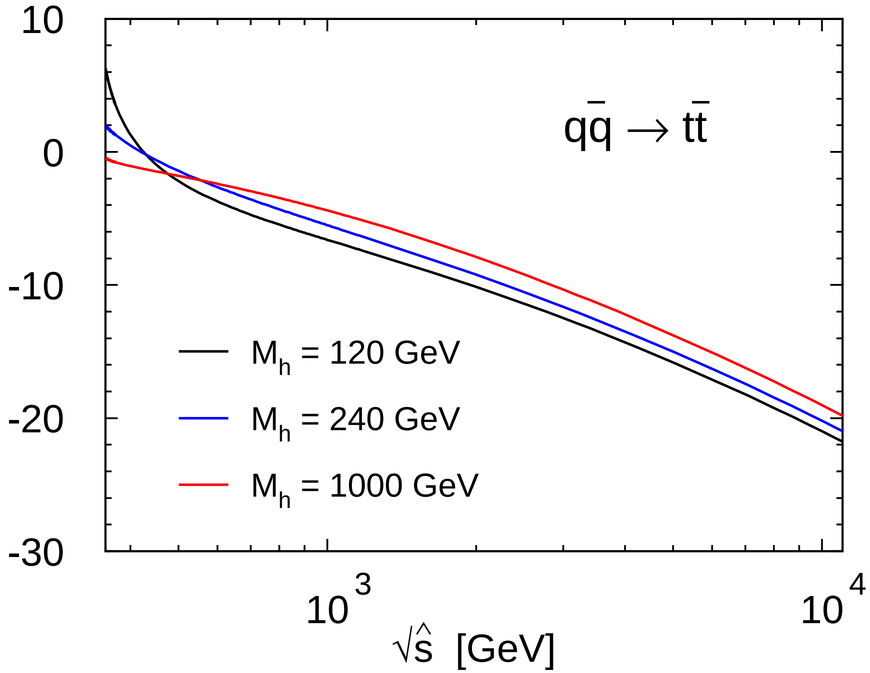


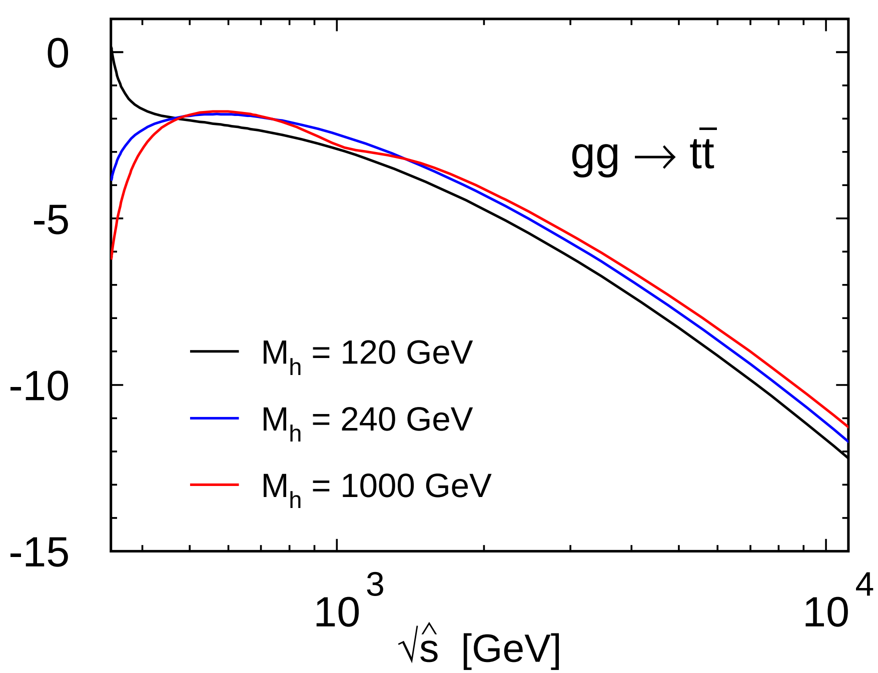
Sizeable effects for differential distribution



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

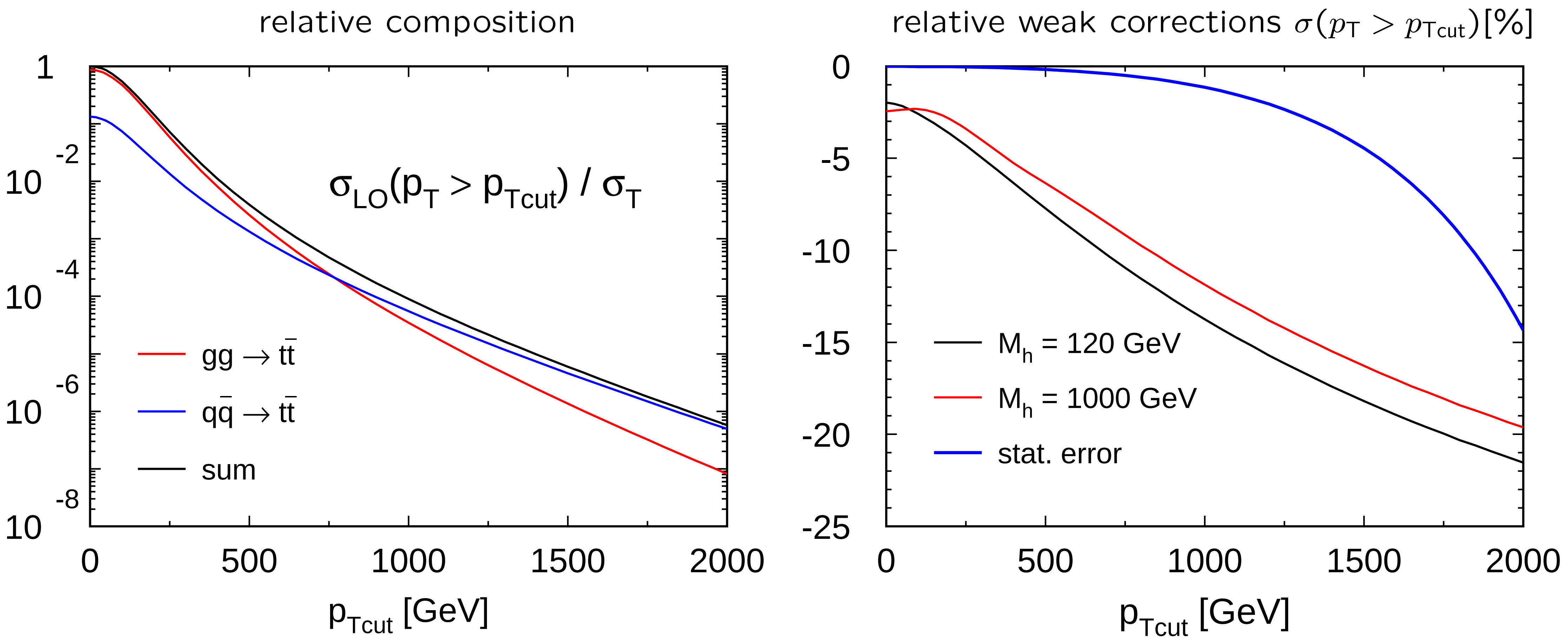
sizable M_h-dependence



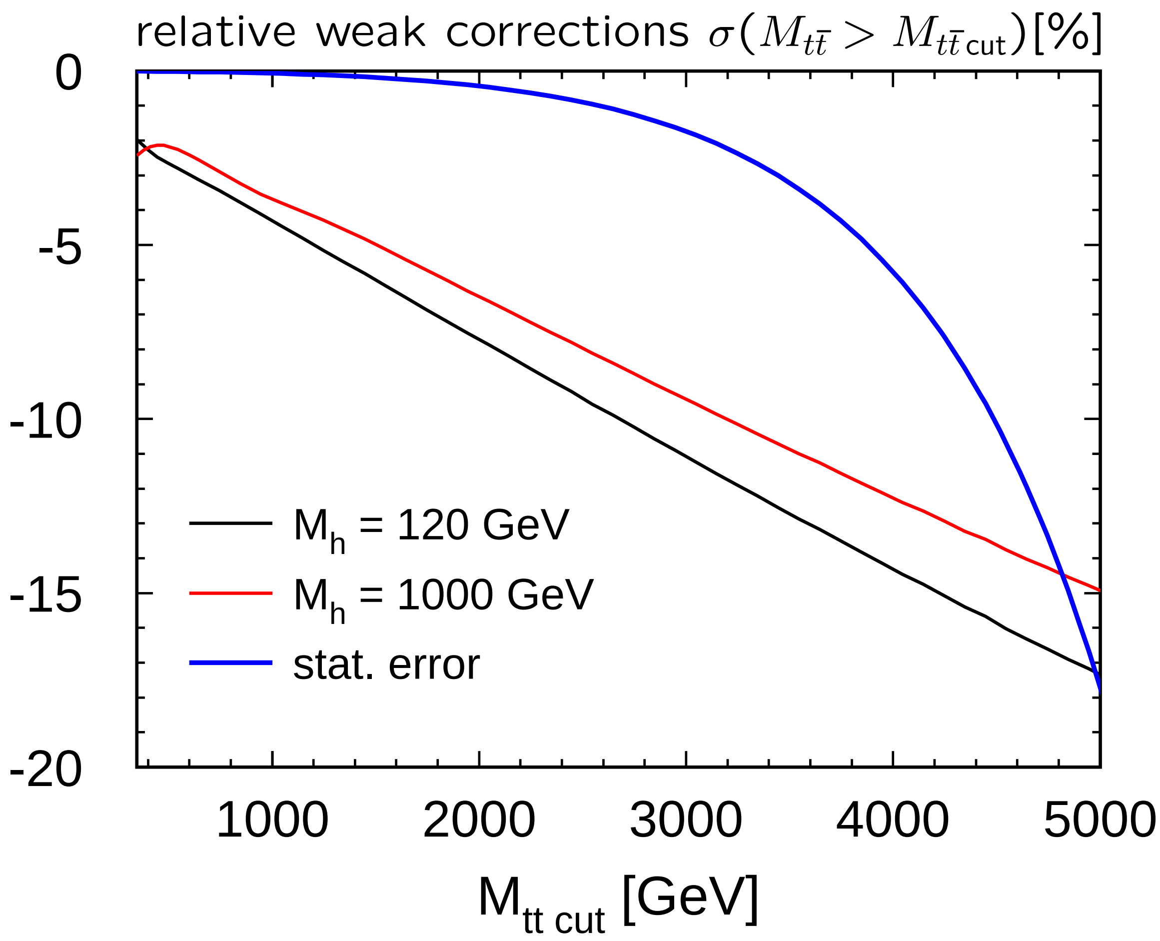


(relative weak corrections [%])

Transverse momentum dependence (LHC)



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



IV. Conclusions on weak corrections

- LHC will explore the TeV-region: $\hat{s}\Big/M_W^2 \gg 1$

- 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