

Status of electroweak corrections to top physics

Andreas Scharf



Tools for precision and discovery physics with top quarks

CERN July 17th 2012

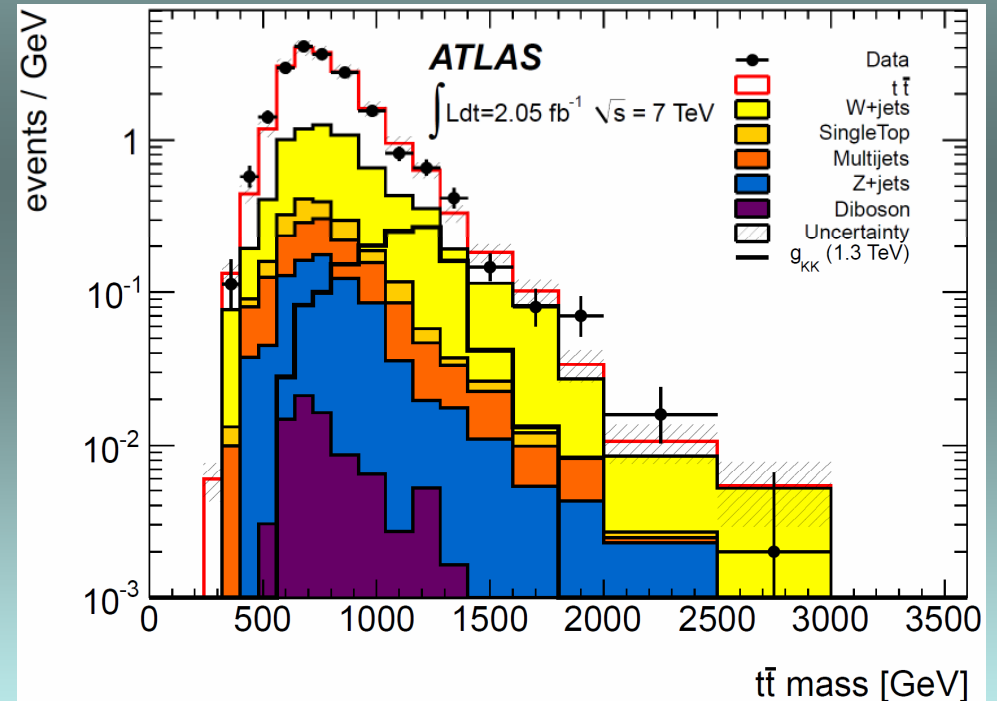
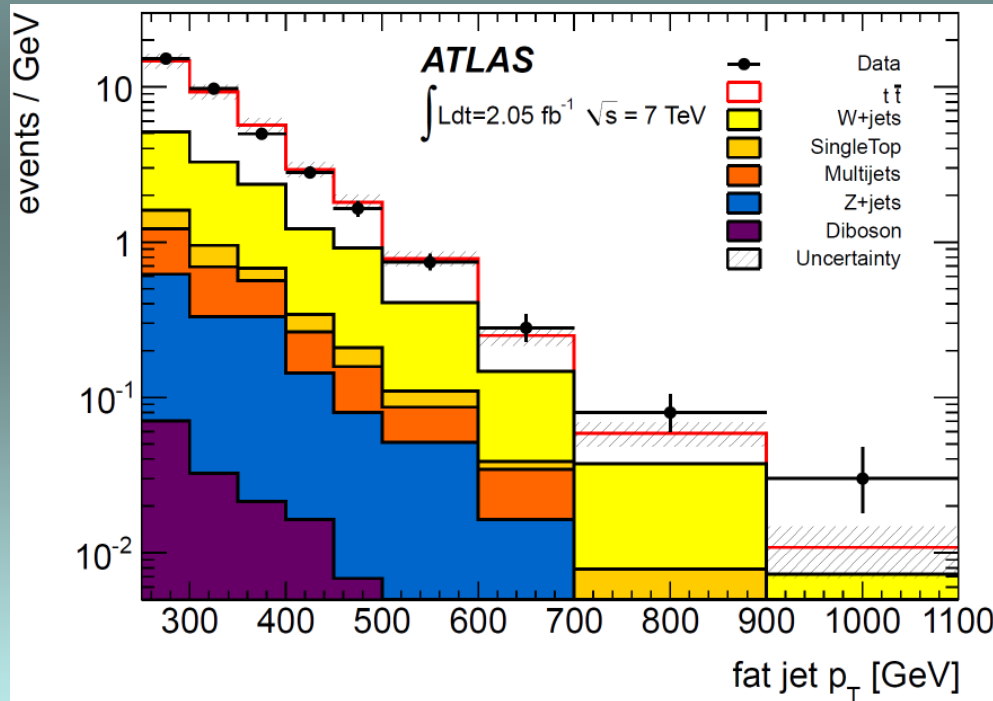
Recent results

Experimental results for boosted tops

ATLAS (2012)

Search for new resonances

Semi-leptonic channel: one fat jet required



Electroweak corrections provide Sudakov logarithms

$$-C^{ew} \frac{\alpha}{4\pi} \ln^2 \left(\frac{E_{cm}^2}{M_W^2} \right)$$

Electroweak corrections

□ Electroweak Sudakov logarithms:

Sudakov (1954)

Ciafaloni, Comelli (1999)

Kühn, Penin (1999)

Ciafaloni, Ciafaloni, Comelli (2000)

Beccaria, Ciafaloni, Comelli, Renard, Verzegnassi (2000)

Fadin, Lipatov, Martin, Melles (2000)

Kühn, Penin, Smirnov (2000)

Melles (2000)

Denner, Pozzorini (2001)

Beenakker, Werthenbach (2001)

Kühn, Moch, Penin, Smirnov (2001)

Jantzen, Kühn, Penin, Smirnov (2005)

Denner, Jantzen, Pozzorini (2006)

Chiu, Golf, Kelley, Manohar (2007)

Chiu, Golf, Kelley, Manohar (2008)

Denner, Jantzen, Pozzorini (2008)

Ciafaloni, Ciafaloni, Comelli (2009)

□ Electroweak corrections to $t\bar{t}$ production

Beenakker, Denner, Hollik, Mertig, Sack, Wackerroth (1994)

Kao, Ladinsky, Yuan (1994)

Bernreuther, Fücker, Si (2005)

Bernreuther, Fücker, Si (2006)

Kühn, AS, Uwer, (2005)

Kühn, AS, Uwer, (2006)

Moretti, Nolten, Ross (2006)

Baur (2006)

Hollik, Kollar (2007)

Bernreuther, Fücker, Si (2008)

Bernreuther, Si (2010)

Hollik, Pagani (2011)

Manohar, Trott (2012)

Weak corrections

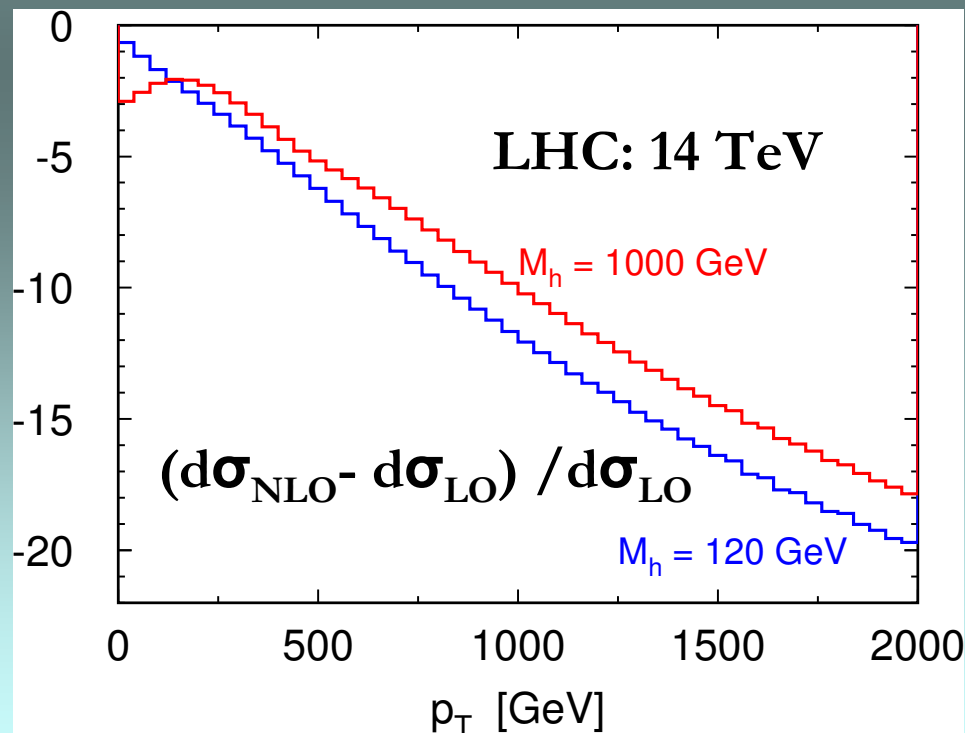
- Total cross-section (LHC @ 14 TeV)

Kühn, AS, Uwer (2005,2006)

$$\delta\sigma_{t\bar{t}}^{\text{NLO}} = -8 \text{ pb}$$

Bernreuther, Fückler, Si (2005,2006)

- p_T distribution



Weak corrections

$$\delta\sigma_{t\bar{t}}^{\text{NLO}} = -8 \text{ pb}$$

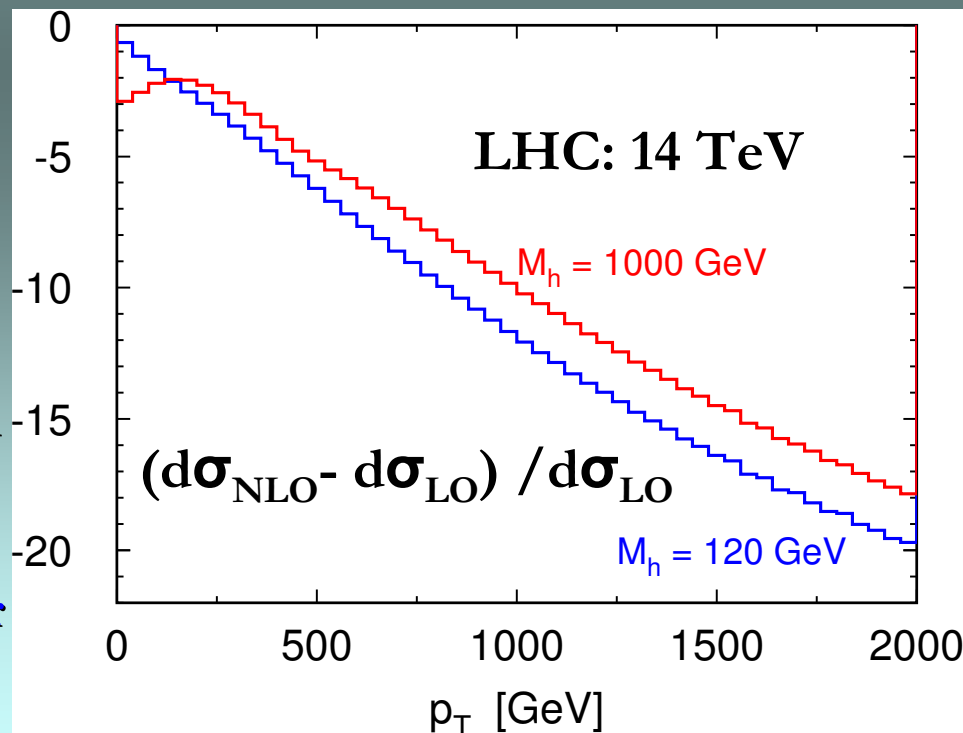


2006

- Small corrections
 - $\frac{\sigma_{t\bar{t}}^{\text{NLO}} - \sigma_{t\bar{t}}^{\text{LO}}}{\sigma_{t\bar{t}}^{\text{LO}}} \propto -2\%$
 - Sudakov behaviour
 - 10-20 % effects for distributions at high energies
 - Threshold behaviour
- Jezabek, Kühn (1993)



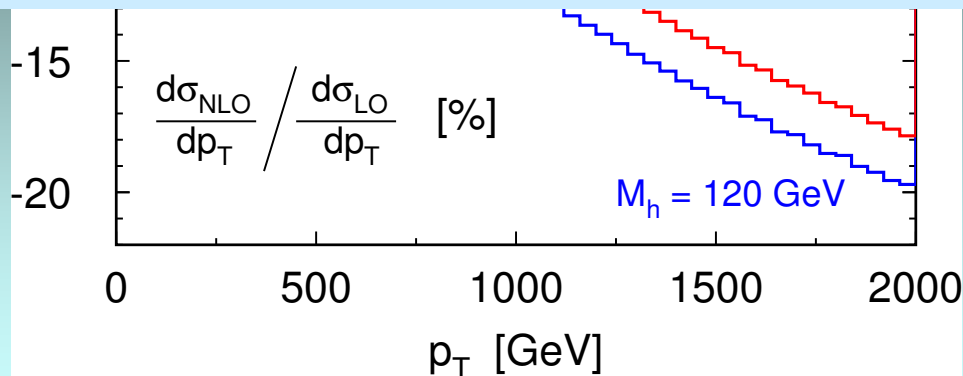
2012



- LHC @ 14 TeV
- No QED corrections
- No NLO QCD included

The remaining talk

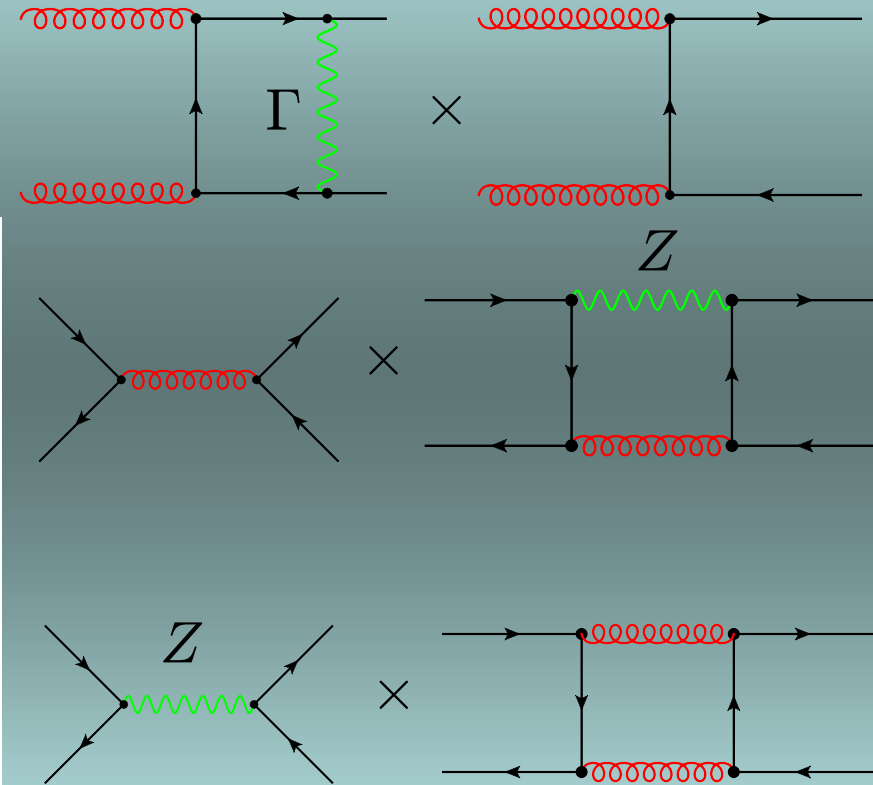
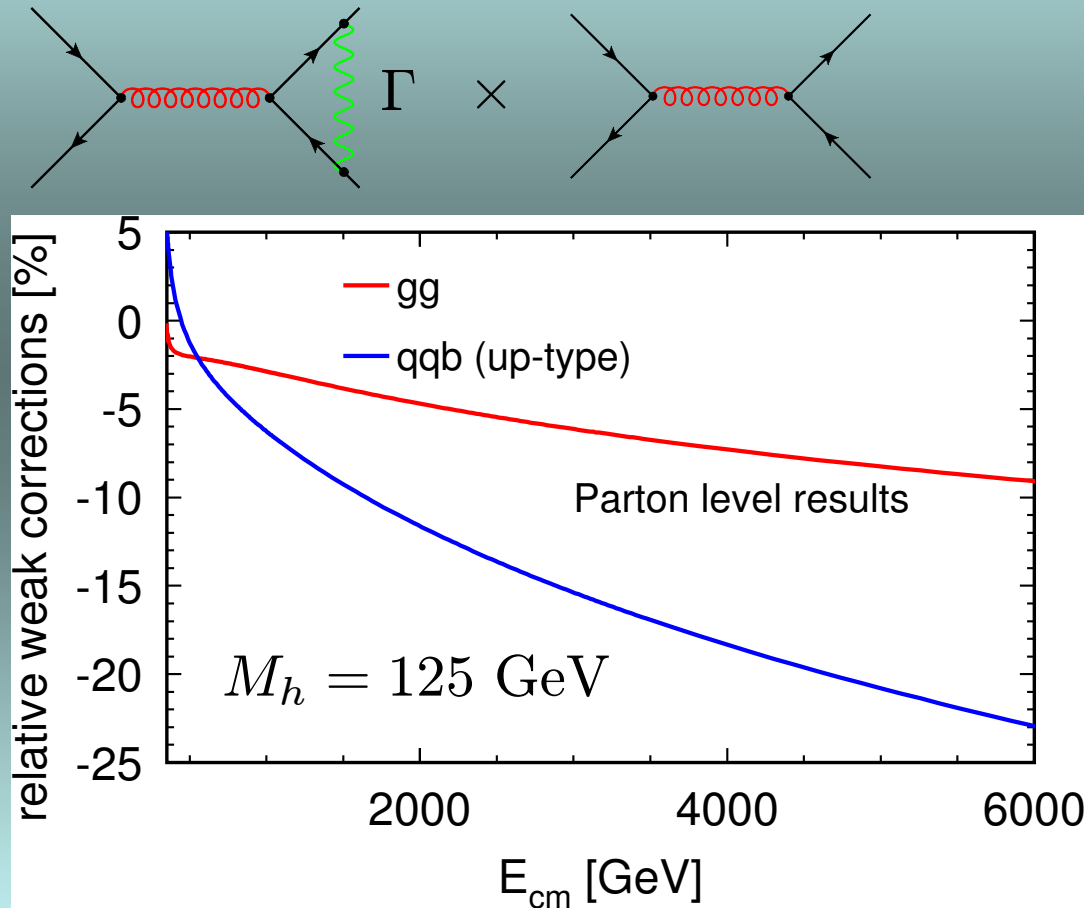
- ❑ LHC @ 7, 8 TeV
- ❑ Comparison with NLO QCD
- ❑ QED corrections
- ❑ Conclusions



• Stable tops

Weak corrections

□ Parton level results $\Gamma = Z, W, \chi, \phi, H$



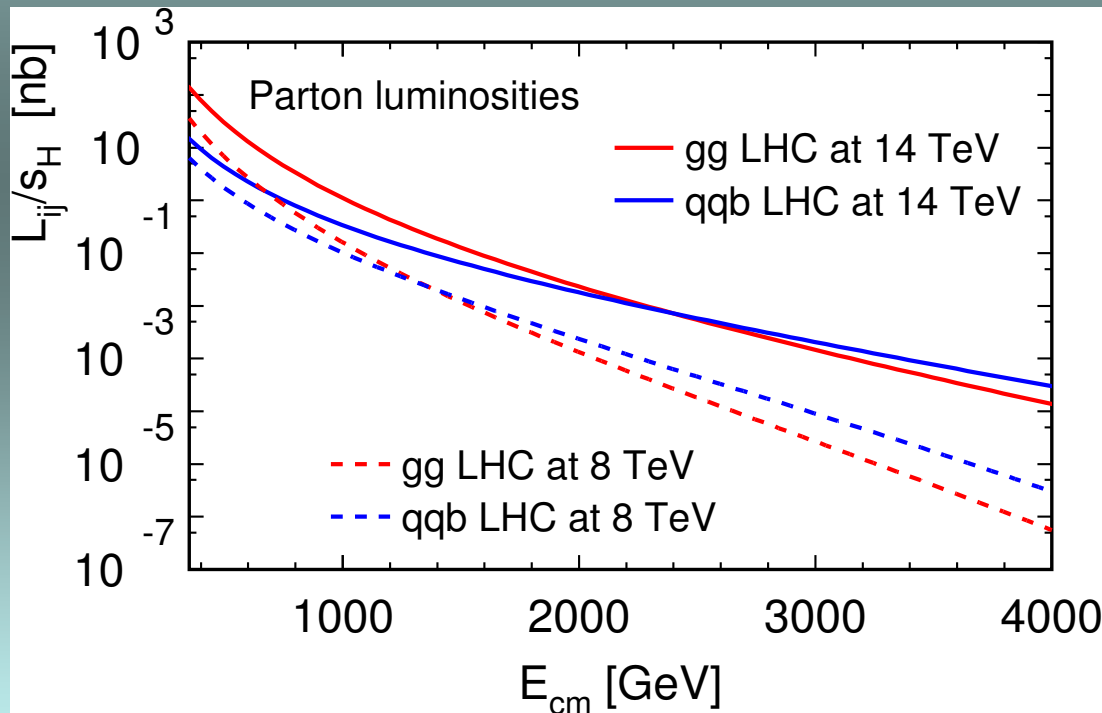
□ $q\bar{q}$ channel receives larger corrections

Weak corrections

□ Parton luminosities: MSTW 2008 LO

Martin, Stirling, Thorne, Watt (2008)

$$L_{ij}(\tau, \mu_F) = \int_{\tau}^1 \frac{1}{x_1} f_{i,H_1}(x_1, \mu_F^2) f_{j,H_2}\left(\frac{\tau}{x_1}, \mu_F^2\right) dx_1$$



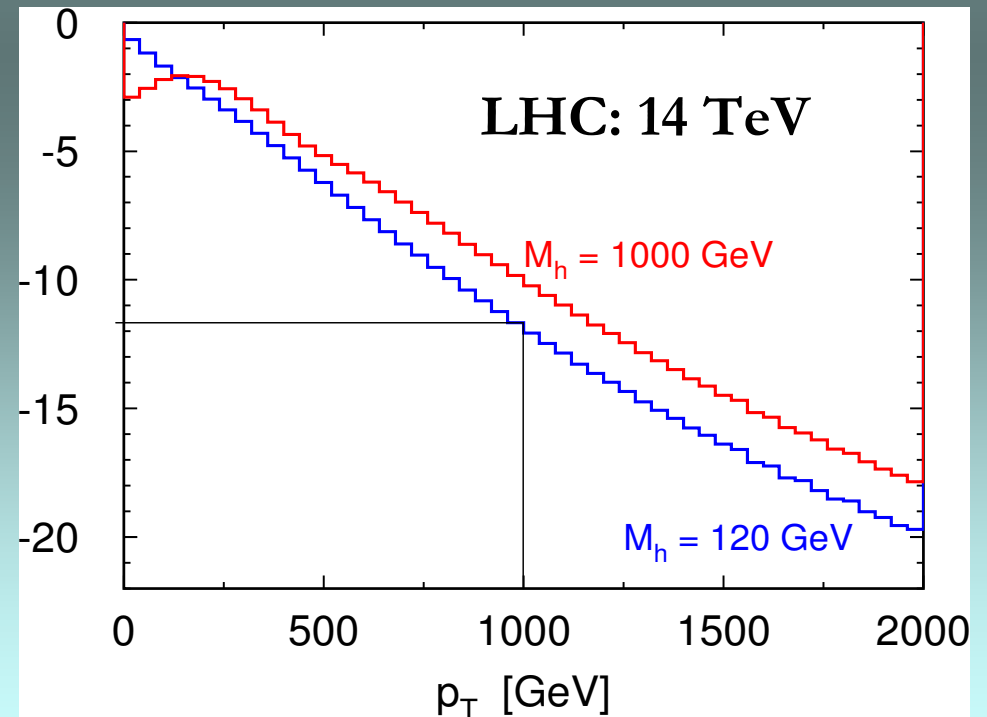
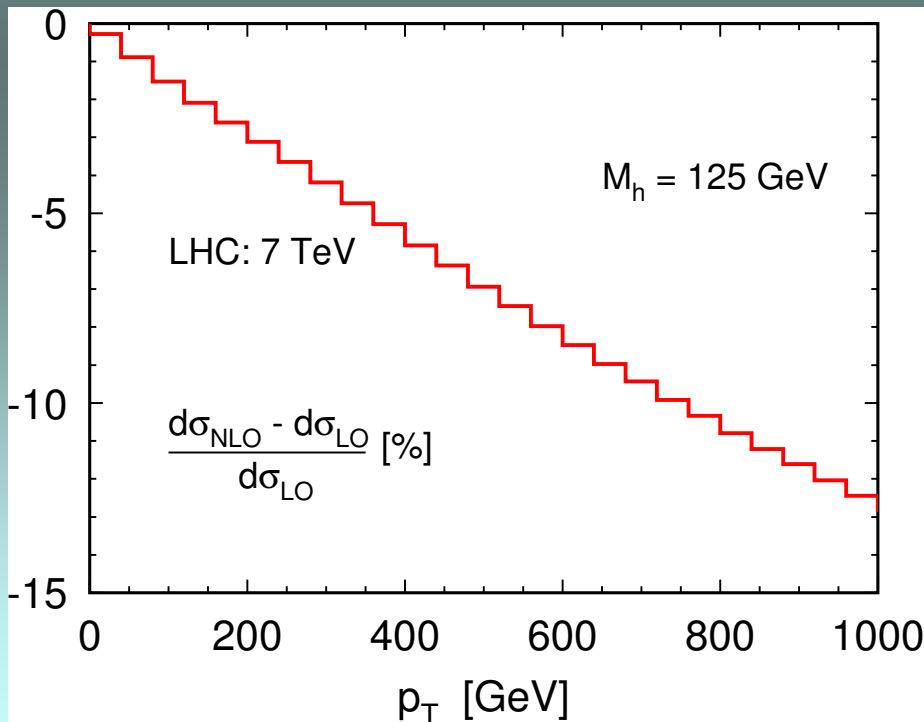
□ $q\bar{q}$ becomes more important for LHC @ 8(7) TeV

Weak corrections

□ LHC @ 7 TeV (preliminary results)

□ Total cross section: $(\sigma_{\text{NLO}} - \sigma_{\text{LO}})/\sigma_{\text{LO}} \simeq -2\%$

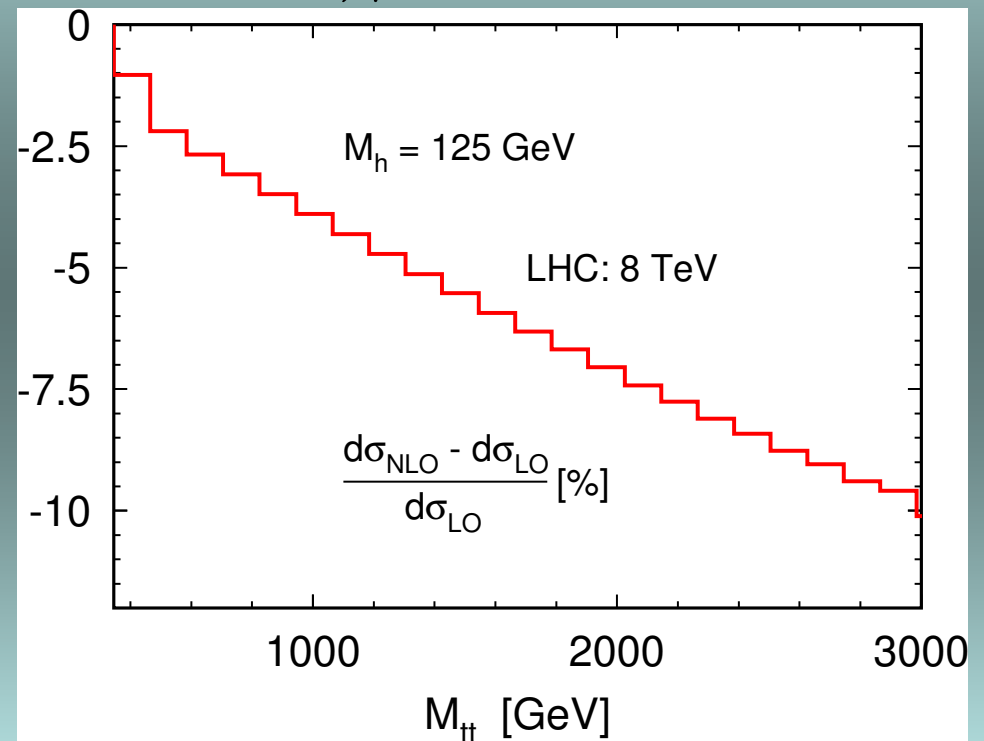
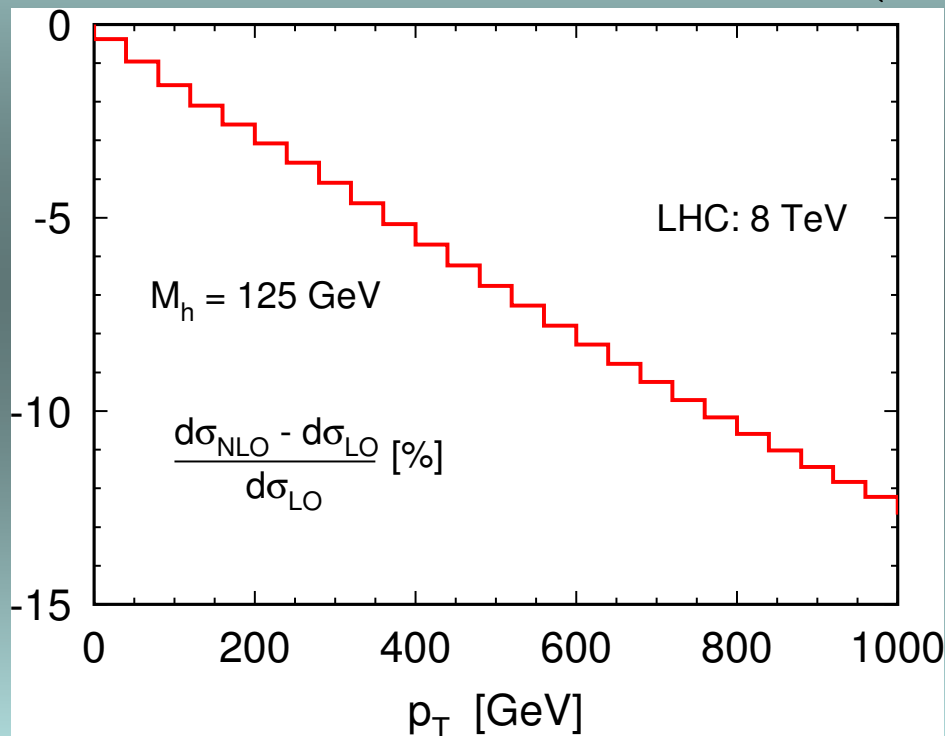
□ Compared to LHC @ 14 TeV corrections become slightly larger



Weak corrections

□ LHC @ 8 TeV (preliminary results)

□ Total cross section: $(\sigma_{\text{NLO}} - \sigma_{\text{LO}})/\sigma_{\text{LO}} \simeq -2\%$



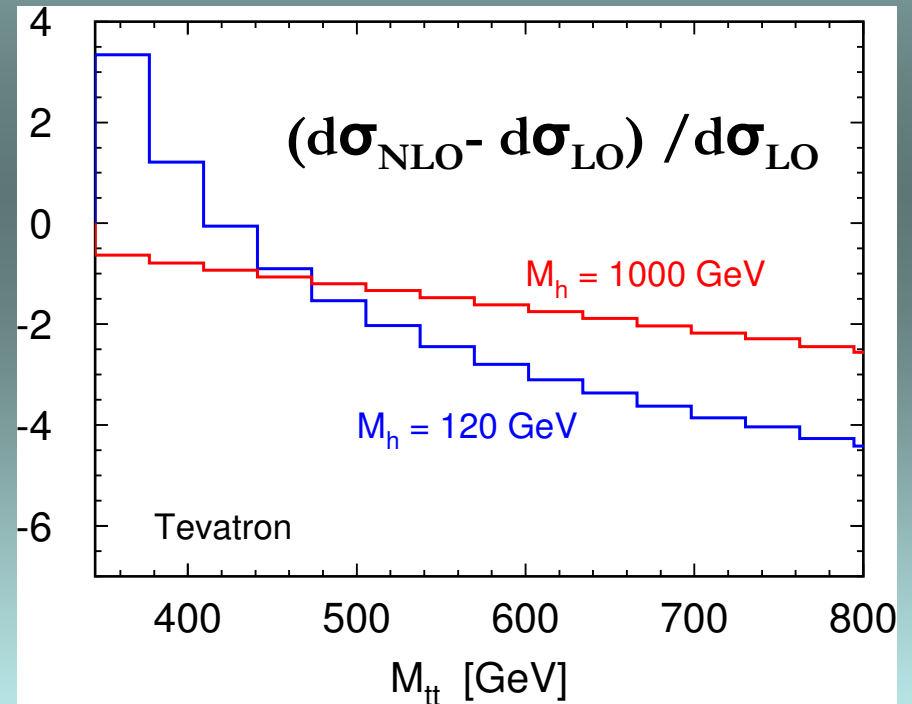
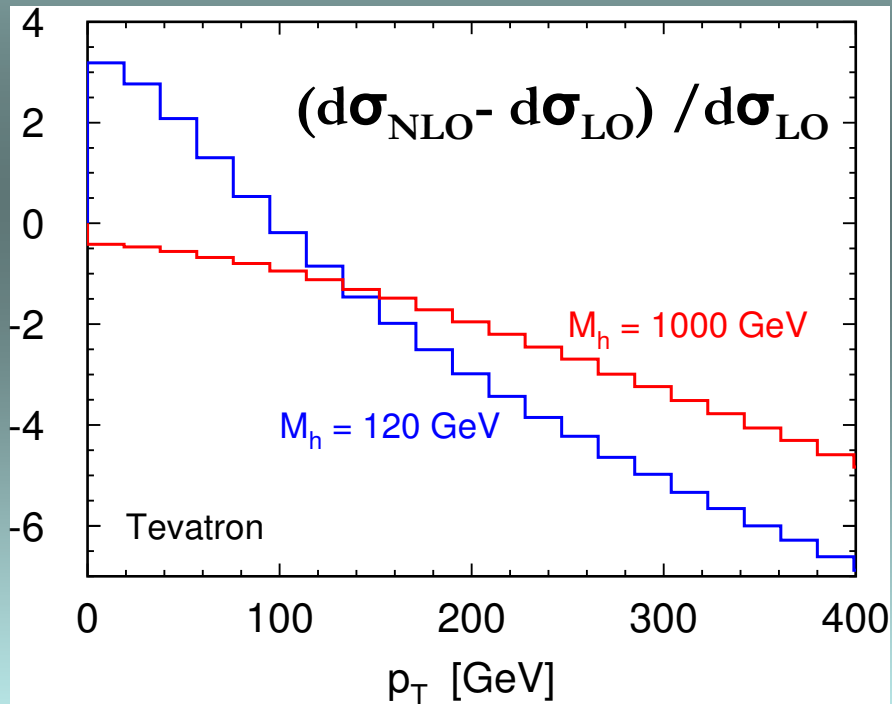
□ Weak boson emission: Partial cancellation for inclusive observables

Baur (2006)

Weak corrections

□ Tevatron

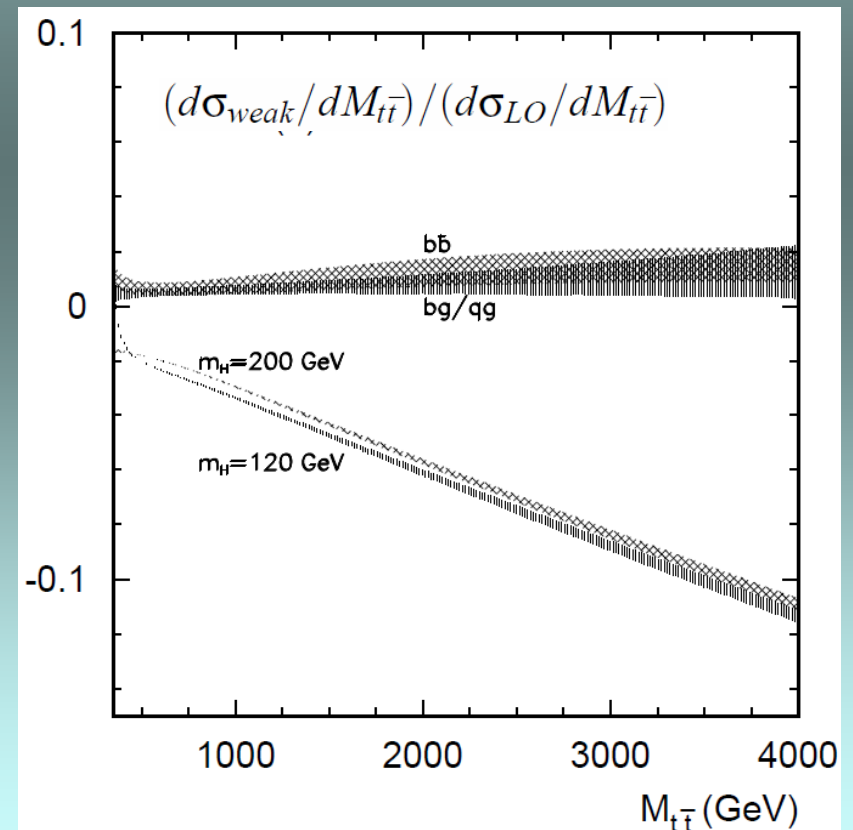
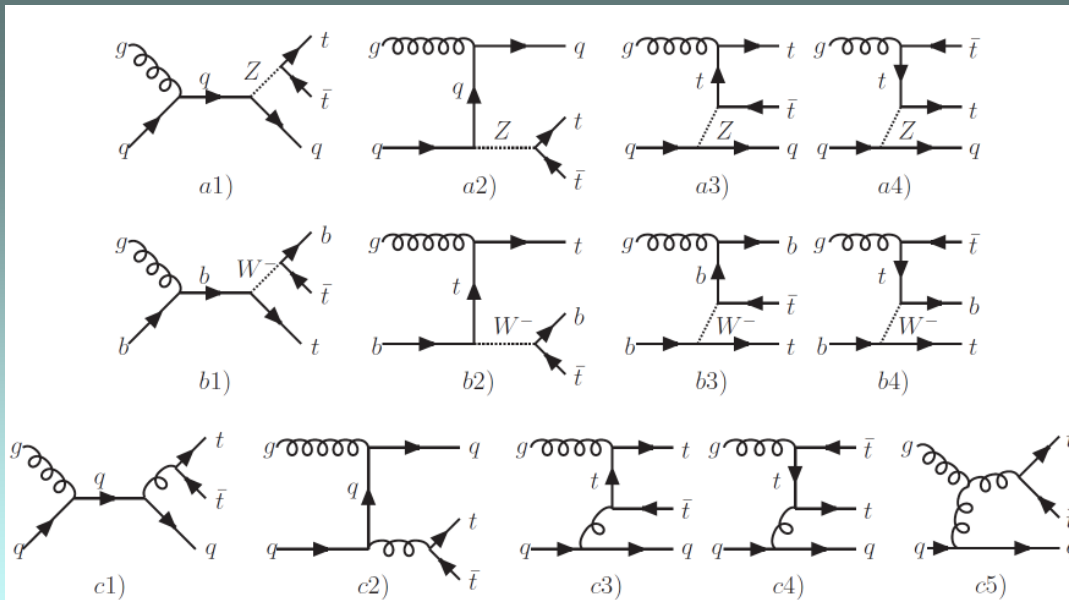
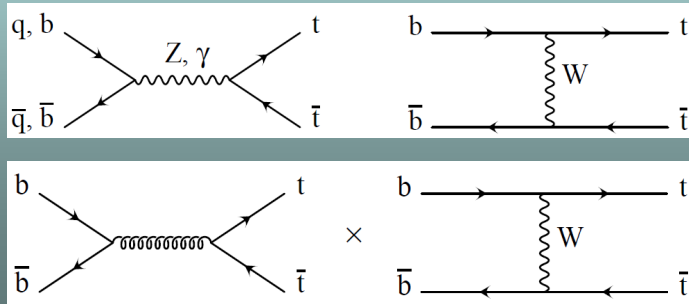
□ Total cross section: $(\sigma_{\text{NLO}} - \sigma_{\text{LO}}) / \sigma_{\text{LO}} < 0.5\%$



Weak LO & interferences

□ Results from: Phys.Rev. D78 (2008) 017503

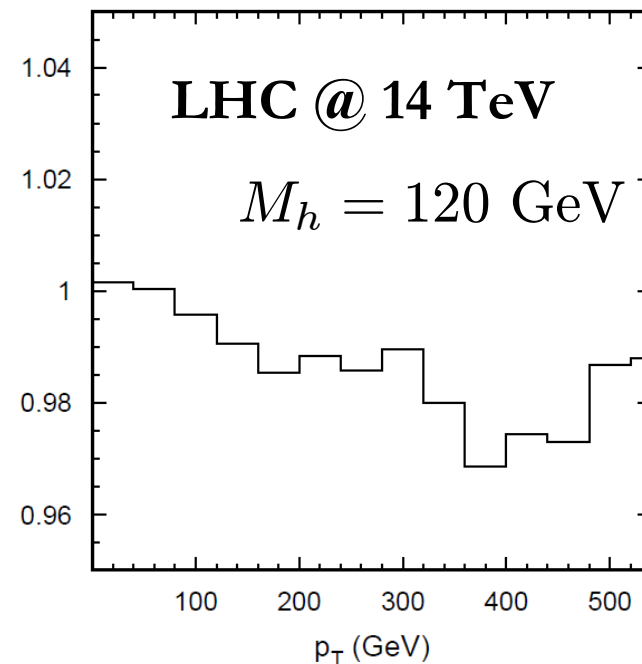
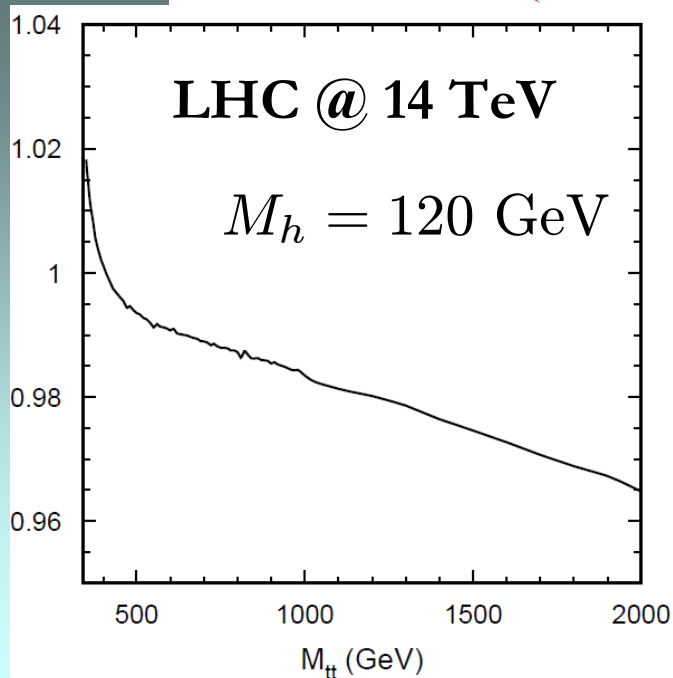
Bernreuther, Fückler, Si (2005, 2006, 2008)



Comparison with NLO QCD

- Results from: Nucl.Phys. B837 (2010) 90-121 Bernreuther, Si (2010)
 - NLO QCD corrections $\mathcal{O}(\alpha_S^3)$ Dawson, Nason, Ellis (1987)
Beenakker, Kuijf, Neerven, Smith (1988)
Mangano, Nason, Ridolfi (1991)
 - NLO weak corrections $\mathcal{O}(\alpha\alpha_S^2)$ Bernreuther, Brandenburg, Si, Uwer (2001, 2004)
 - Including: $\mathcal{O}(\alpha^2), \mathcal{O}(\alpha\alpha_S), \mathcal{O}(\alpha^2\alpha_S)$ Bernreuther, Fückler, Si (2005, 2006, 2008)

Ratio: NLO (weak + QCD) / NLO (QCD)



Including top decays

□ Results from: Nucl.Phys. B837 (2010) 90-121

Bernreuther, Si (2010)

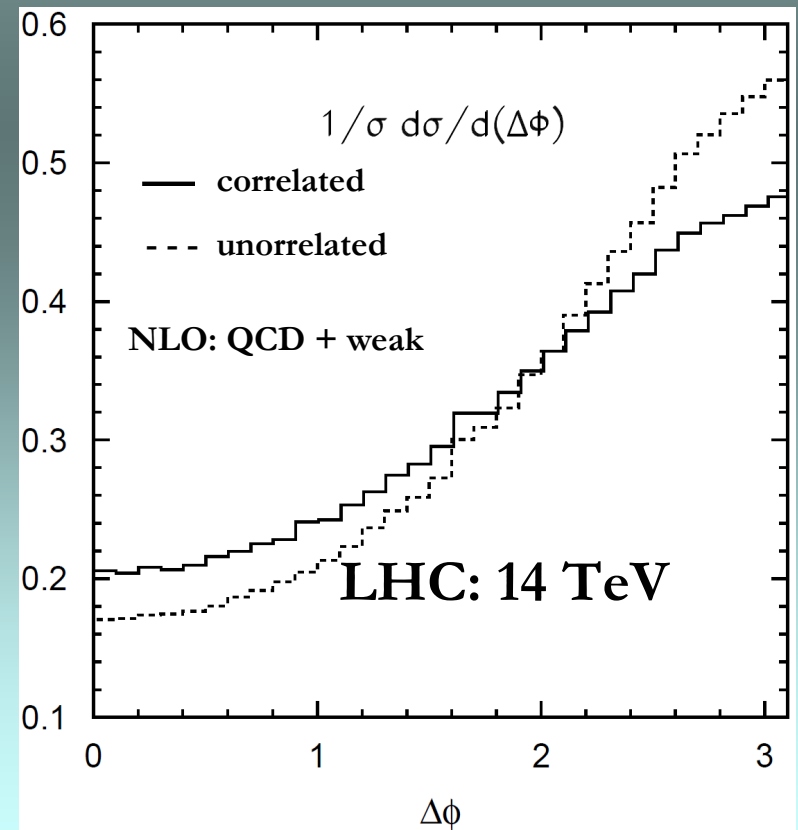
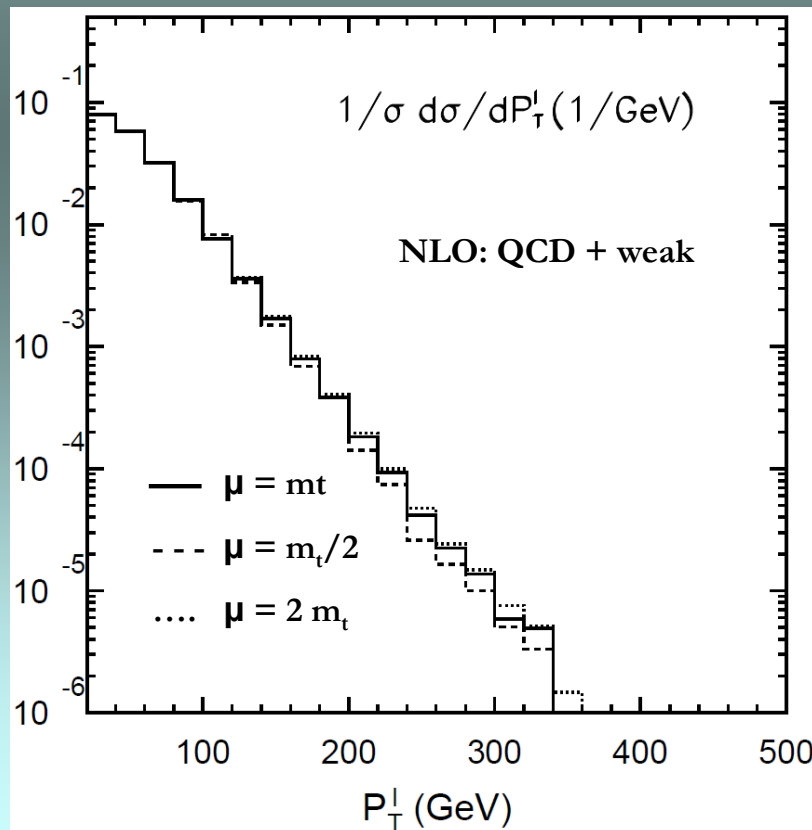
□ Including top decays at NLO QCD

Melnikov, Schulze (2009)

Bredenstein, Denner, Dittmaier, Pozzorini (2009)

Bevilacqua, Czakon, Papadopoulos, Pittau, Worek (2009)

Di-lepton channel



Charge asymmetry

Kühn, Rodrigo (1998,2011)

□ Results from: Nucl.Phys. B837 (2010) 90-121

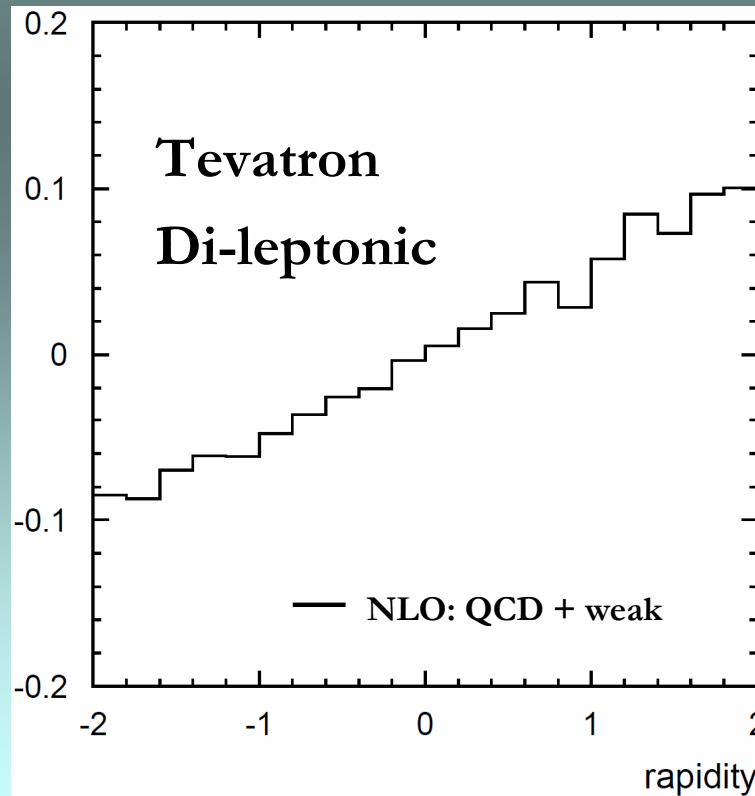
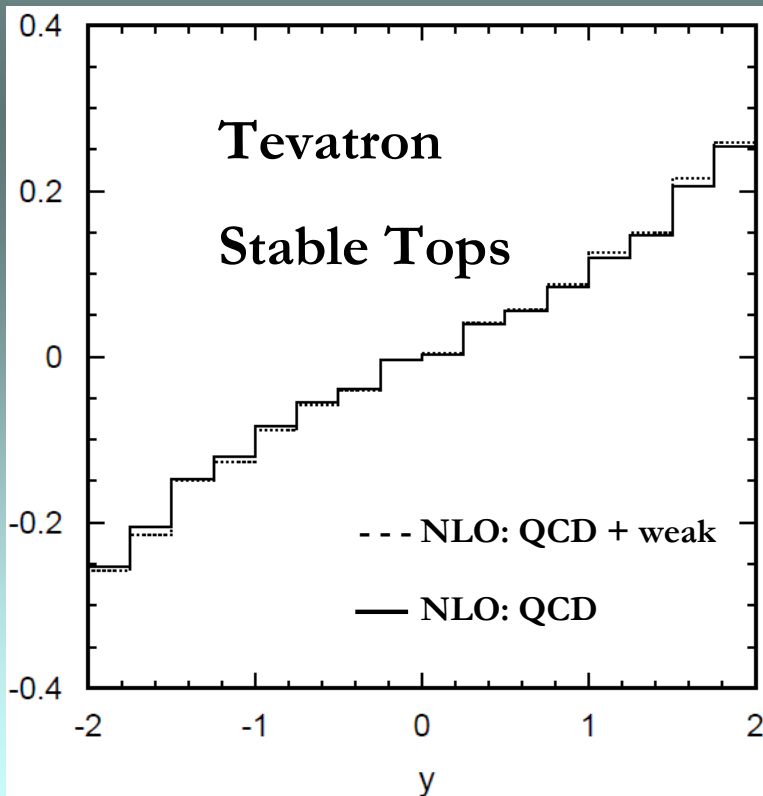
Bernreuther, Si (2010)

□ Differential asymmetries

$$A(y) = \frac{N_t(y) - N_{\bar{t}}(y)}{N_t(y) + N_{\bar{t}}(y)}$$

$$N(y) = d\sigma_{t\bar{t}}/dy$$

$$A^\ell(y) = \frac{N_{\ell^+}(y) - N_{\ell^-}(y)}{N_{\ell^+}(y) + N_{\ell^-}(y)}$$



**Integrated charge
asymmetry**

$$R_{\text{weak}} = \frac{A_{\text{weak}}}{A_{\text{QCD}}} \simeq 0.04$$

**Charge asymmetry
(option two)**

$$A_{FB}^{t\bar{t}} = \frac{\sigma(\Delta y > 0) - \sigma(\Delta y < 0)}{\sigma(\Delta y > 0) + \sigma(\Delta y < 0)}$$

$$R_{\text{weak}}^{t\bar{t}} = \frac{A_{\text{weak}}^{t\bar{t}}}{A_{\text{QCD}}^{t\bar{t}}} \simeq 0.05$$

Charge asymmetry

Kühn, Rodrigo (1998,2011)

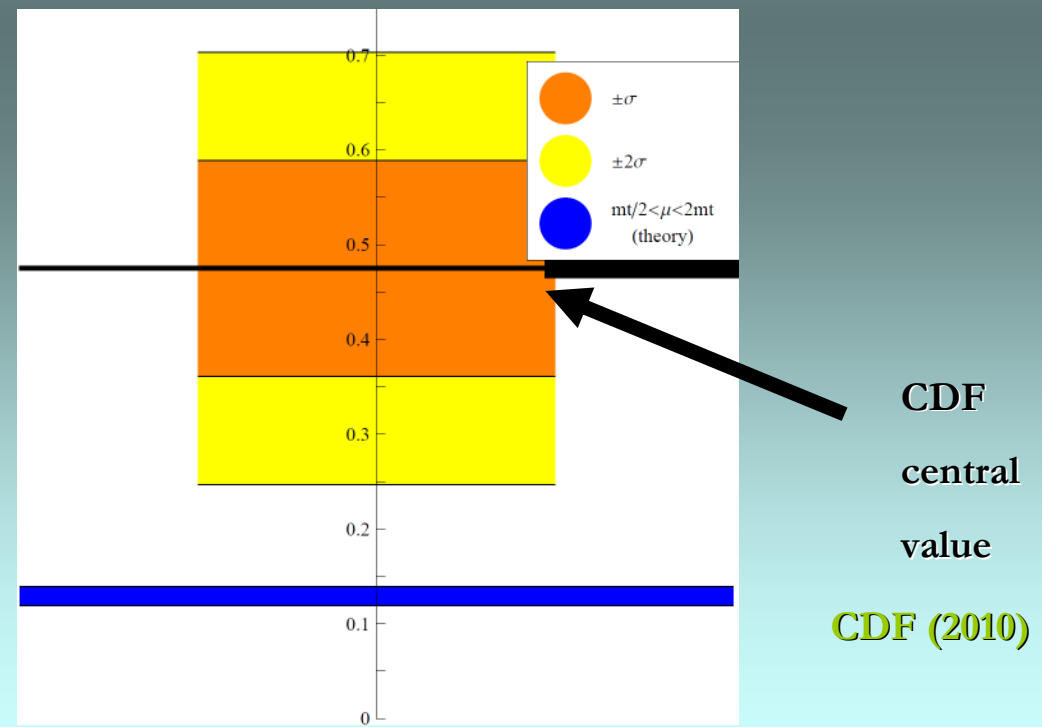
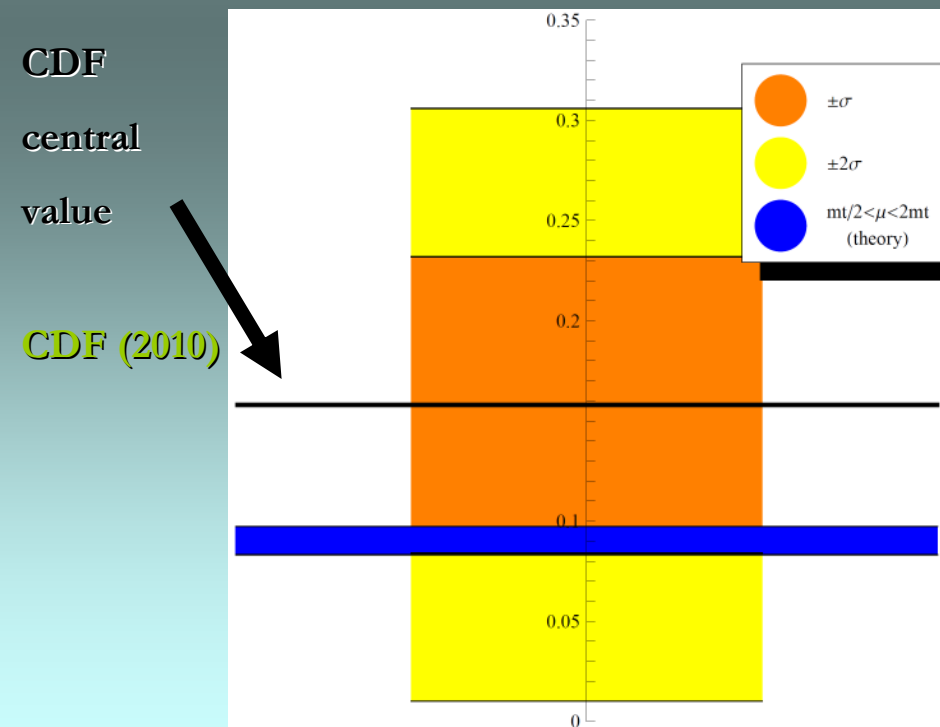
□ Results from: Phys.Rev. D84 (2011) 093003 Hollik, Pagani (2011)

□ Including weak and QED contributions to the integrated asymmetry

$$A_{FB}^{t\bar{t}} = \frac{\sigma(\Delta y > 0) - \sigma(\Delta y < 0)}{\sigma(\Delta y > 0) + \sigma(\Delta y < 0)}$$

$$R_{EW}^{t\bar{t}} = (0.19, 0.22, 0.254)$$

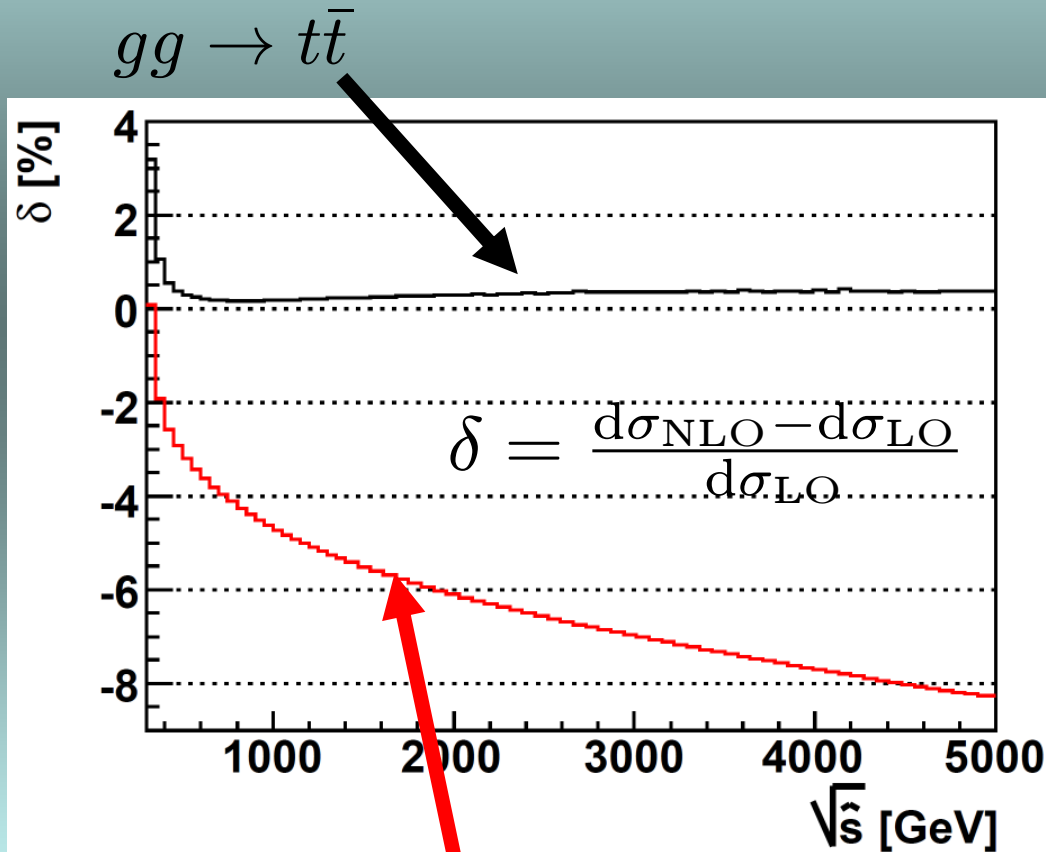
$$R_{EW}^{t\bar{t}}(M_{t\bar{t}} > 450 \text{ GeV}) = (0.2, 0.232, 0.266)$$



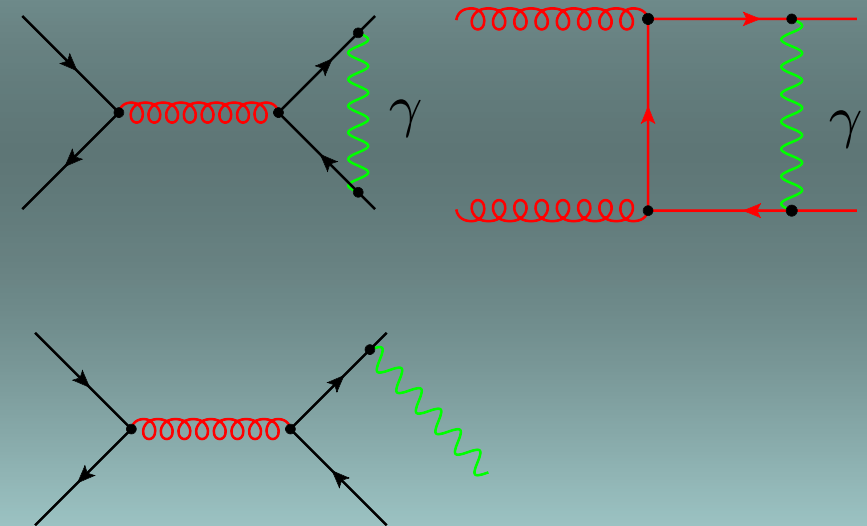
QED corrections

□ Results from: Phys.Rev. D77 (2008) 014008

Hollik, Kollar (2007)



$q\bar{q} \rightarrow t\bar{t}$



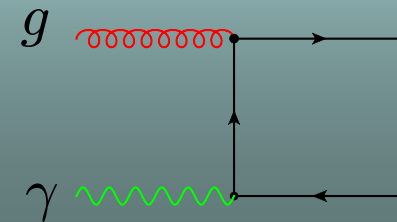
QED corrections

□ Results from: Phys.Rev. D77 (2008) 014008

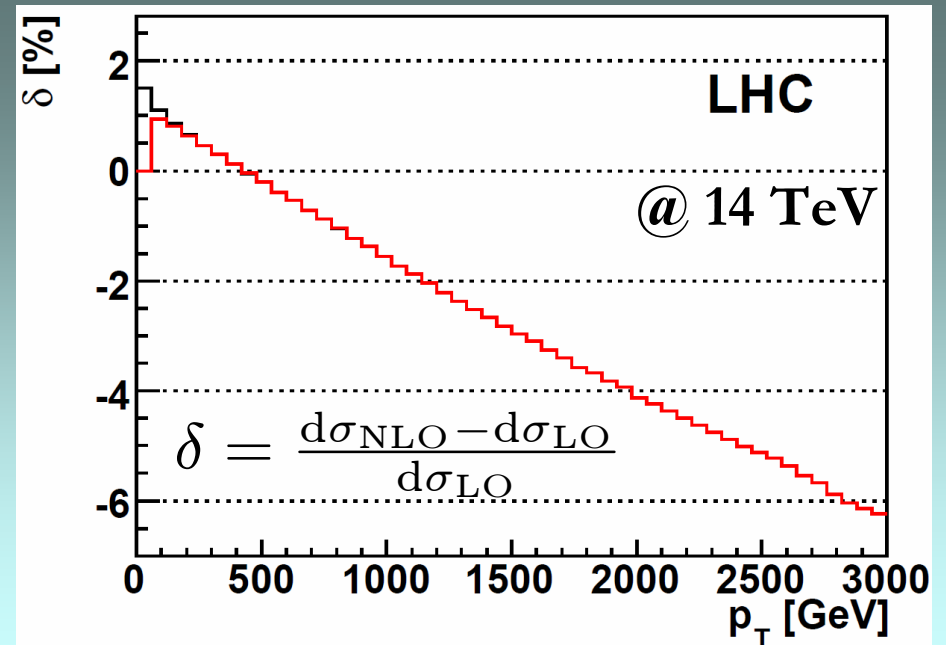
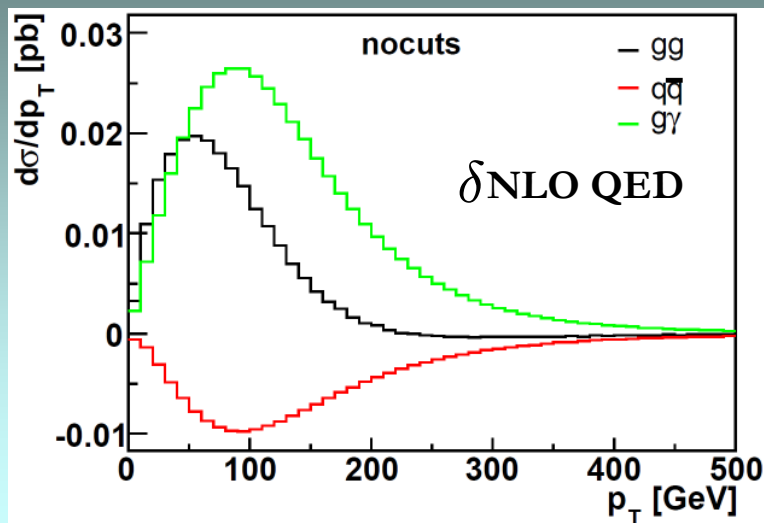
Hollik, Kollar (2007)

□ Effect from initial state photons is relatively large

| Process | σ_{tot} without cuts [pb] | |
|------------|---|------------|
| | Born | correction |
| $u\bar{u}$ | 34.25 | -1.41 |
| $d\bar{d}$ | 21.61 | -0.228 |
| $s\bar{s}$ | 4.682 | -0.0410 |
| $c\bar{c}$ | 2.075 | -0.0762 |
| gg | 407.8 | 2.08 |
| $g\gamma$ | 470.4 | 4.45 |
| pp | 470.4 | 4.78 |



Relative corrections LHC @ 14 TeV



Conclusions

- ❑ Electroweak corrections are known up to NLO for $t\bar{t}b$ production
- ❑ Tevatron: 20 % correction on QCD induced charge asymmetry
- ❑ Results for LHC @ $\sqrt{s}=7,8$ TeV not yet available
- ❑ Small corrections to the total cross section
- ❑ Few % effects for differential distributions