$t\bar{t}H/b\bar{b}H$ PRODUCTION @ LHC

Michael Spira (PSI)

I $t\bar{t}H$ Production

II $b\bar{b}H$ Production

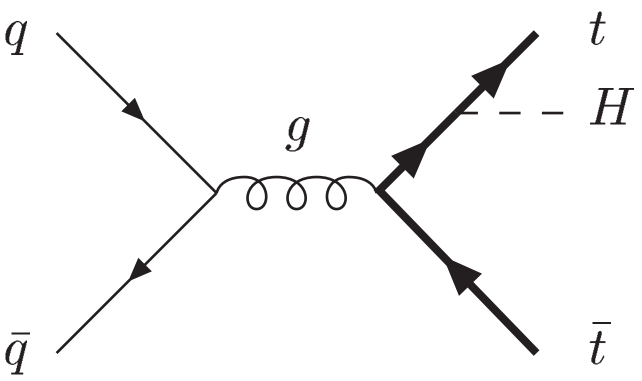
III Conclusions

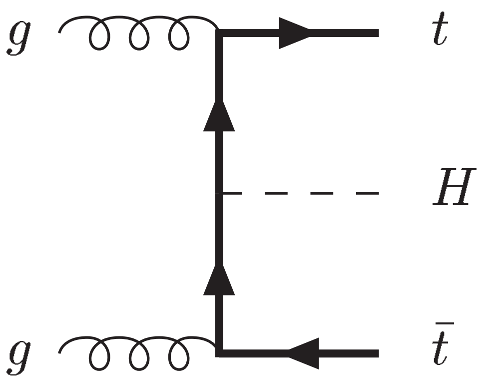
Phys. Rev. Lett. 87 (2001) 201805 [hep-ph/0107081]
Nucl. Phys. B653 (2003) 151 [hep-ph/0211352]

in collaboration with W. Beenakker, S. Dittmaier, M. Krämer, B. Plümper and P.M. Zerwas

I $t\bar{t}H$ PRODUCTION

• $gg, q\bar{q} \to t\bar{t}H$ important for $M_H \lesssim 130$ GeV F





• crucial for determination of top Yukawa coupling

• Equivalent Higgs Aproximation: $M_H^2 \ll m_t^2 \ll \hat{s}$

$\hat{\sigma}(t\bar{t}H) = (f_{H/t} + f_{H/\bar{t}}) \otimes \hat{\sigma}(t\bar{t})$ Dawson,Reina

valid within factor 2

QCD corrections $\sim 20\%$ [scale $= m_t + M_H/2$!]

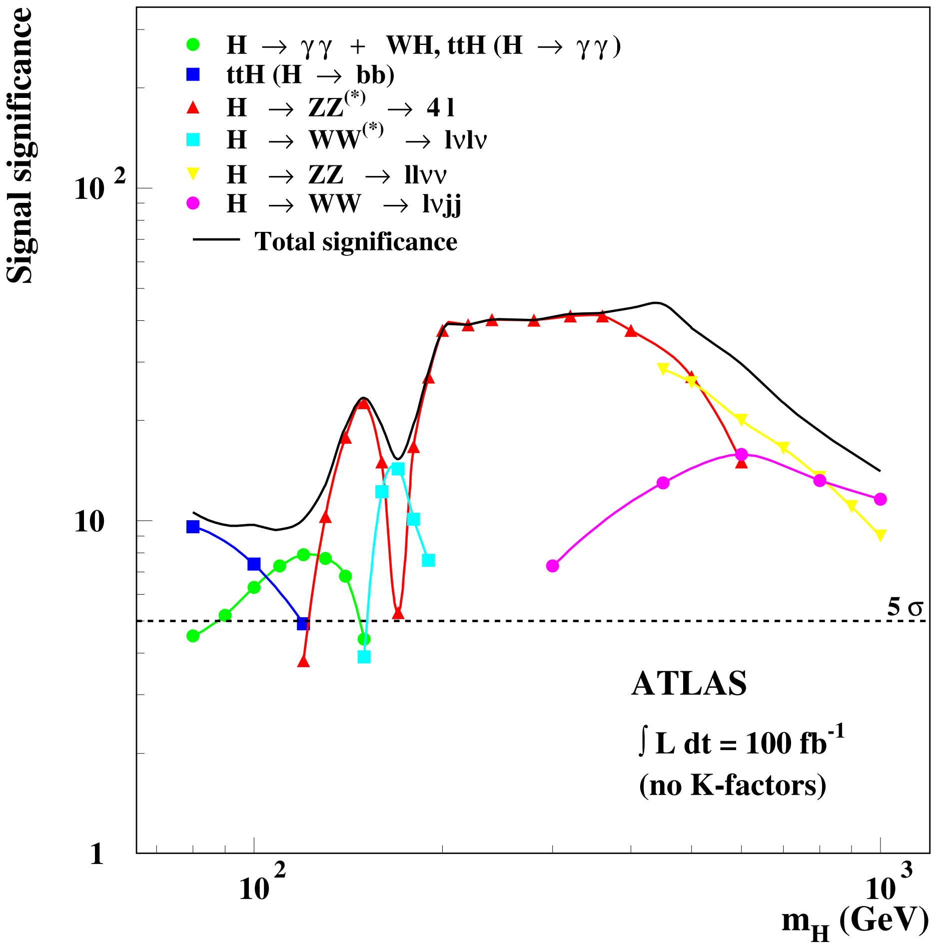
• full calculation: two groups

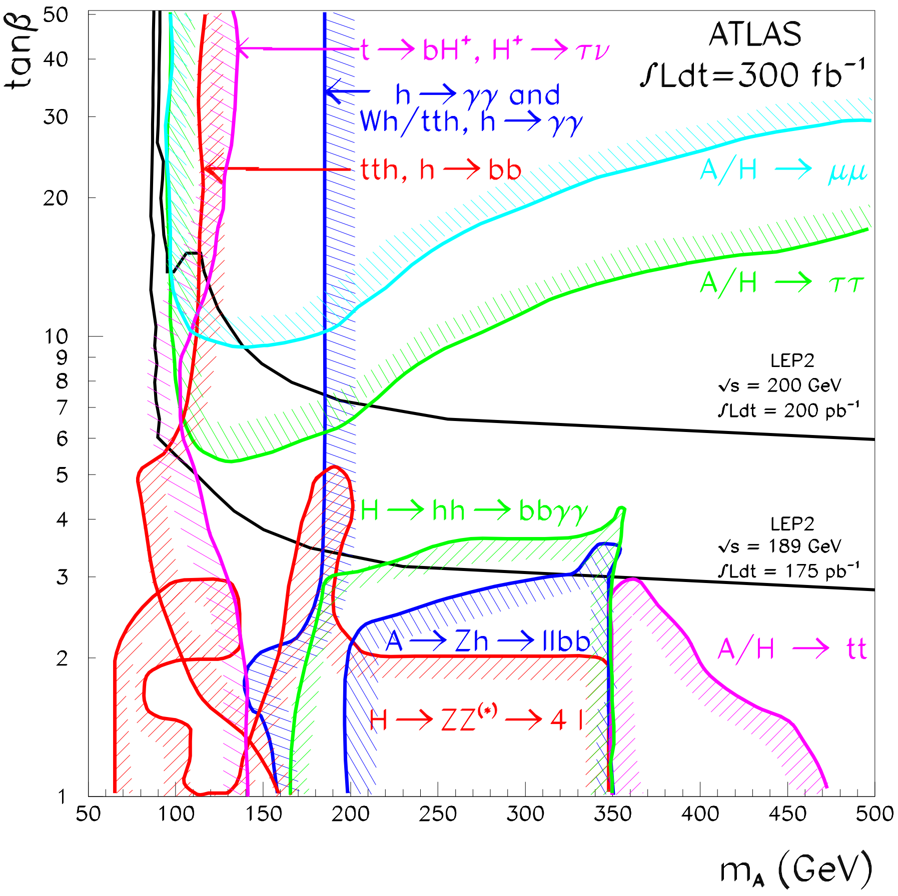
• Beenakker, Dittmaier, Krämer, Plümper, S., Zerwas

• Dawson, Jackson, Orr, Reina, Wackeroth

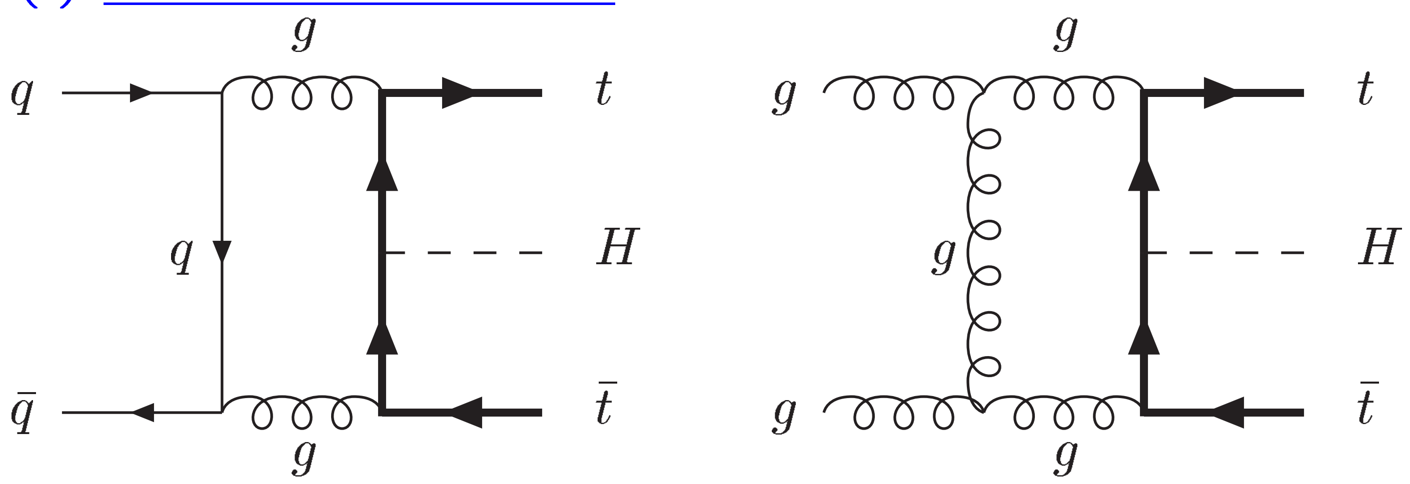
$\longrightarrow$ full agreement now for total cross sections

dominant


Signal significance
H → γγ + WH, ttH (H → γγ)
ttH (H → bb)
H → ZZ(*) → 4 l
H → WW(*) → lνlν
H → ZZ → llνν
H → WW → lνjj
Total significance
5 σ
ATLAS
∫ L dt = 100 fb-1
(no K-factors)
m_H (GeV)


tanβ
ATLAS
∫Ldt=300 fb-1
t → bH+, H+ → τν
h → γγ and
Wh/tth, h → γγ
tth, h → bb
A/H → μμ
A/H → ττ
LEP2
√s = 200 GeV
∫Ldt = 200 pb-1
H → hh → bbγγ
LEP2
√s = 189 GeV
∫Ldt = 175 pb-1
A → Zh → llbb
A/H → tt
H → ZZ(*) → 4 l
m_A (GeV)

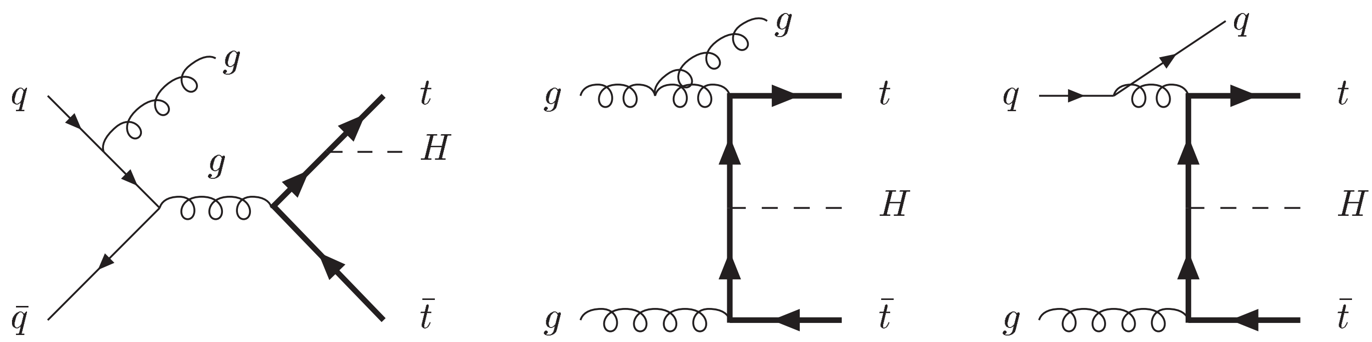
(i) Virtual Corrections



• most difficult part: Pentagon diagrams [infared and collinear divergent]

• α_s: $\overline{\text{MS}}$ scheme [5 flavours], m_t: on-shell

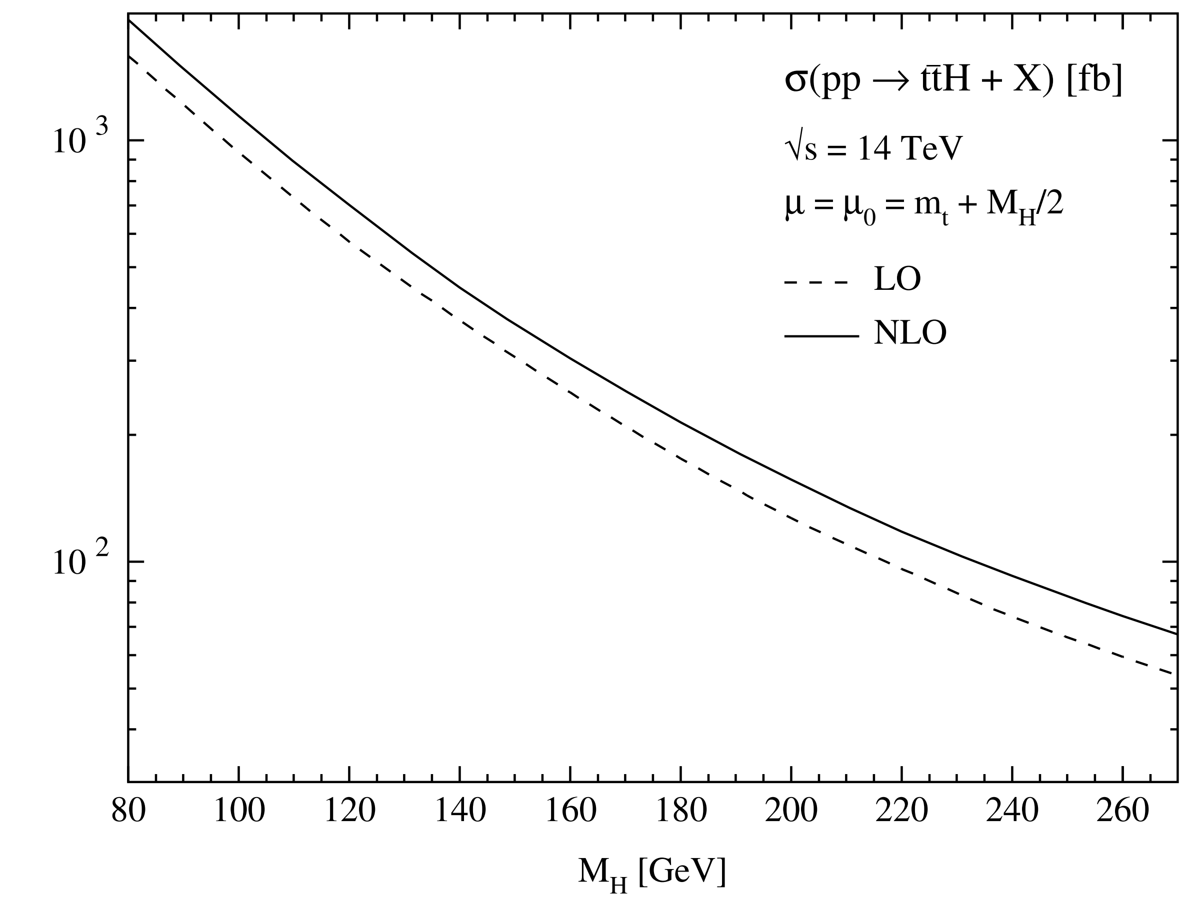
(ii) Real Corrections

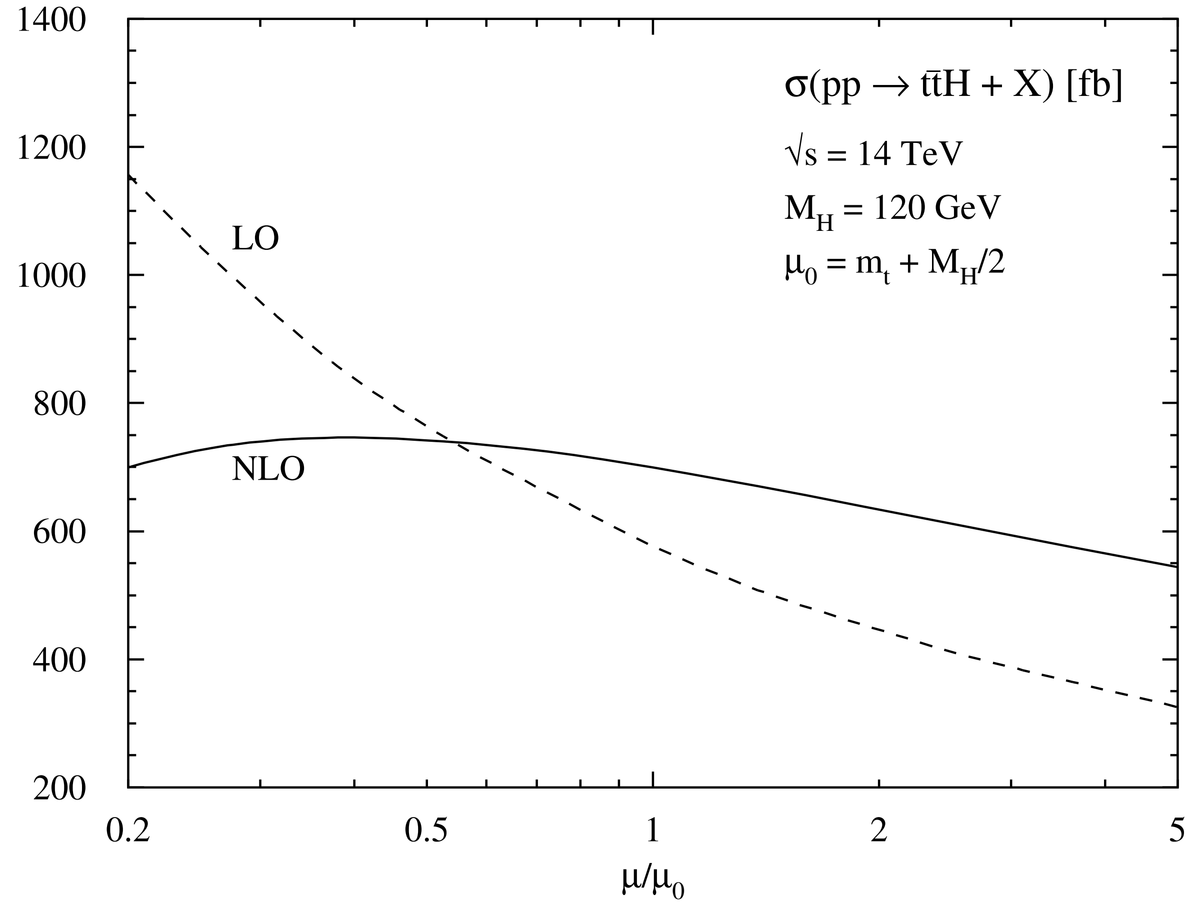


• complex matrix elements

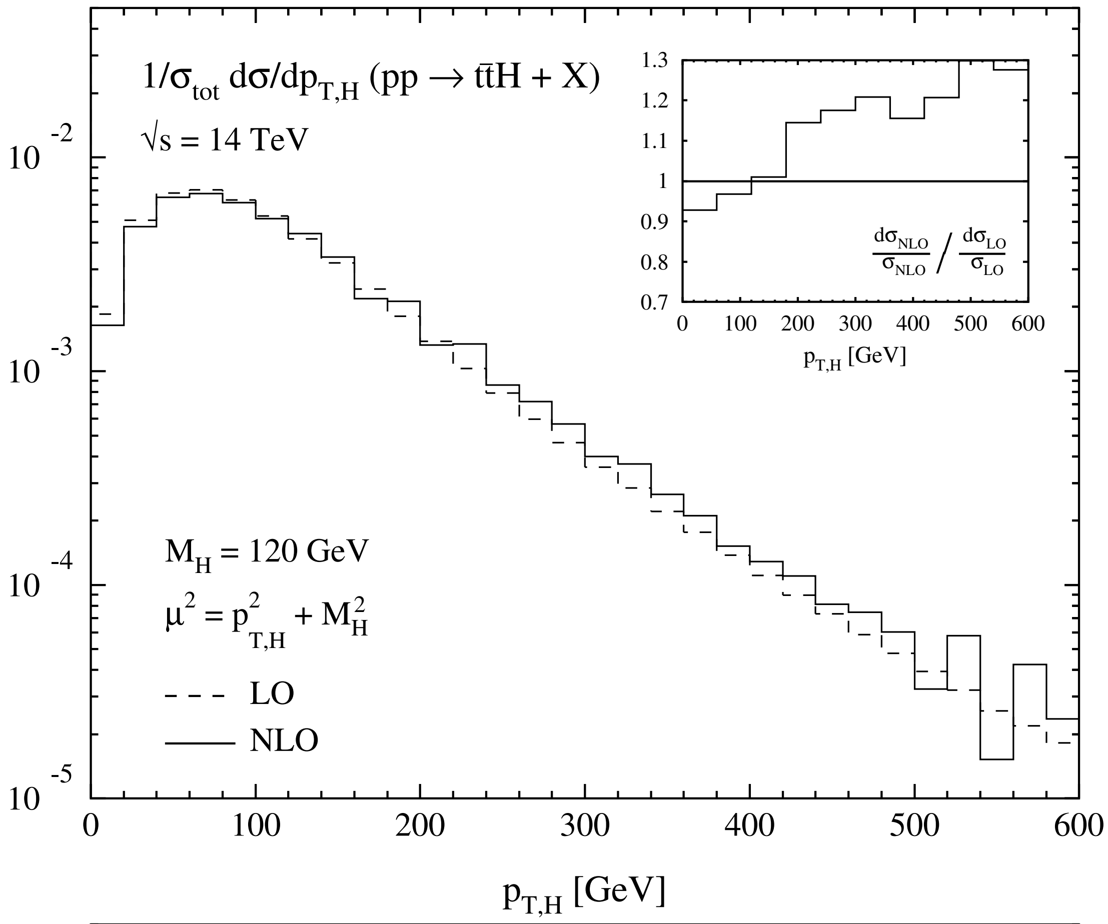
• infrared and collinear singularities cancel against virtual corrections and counter terms of PDFs [mass factorization]

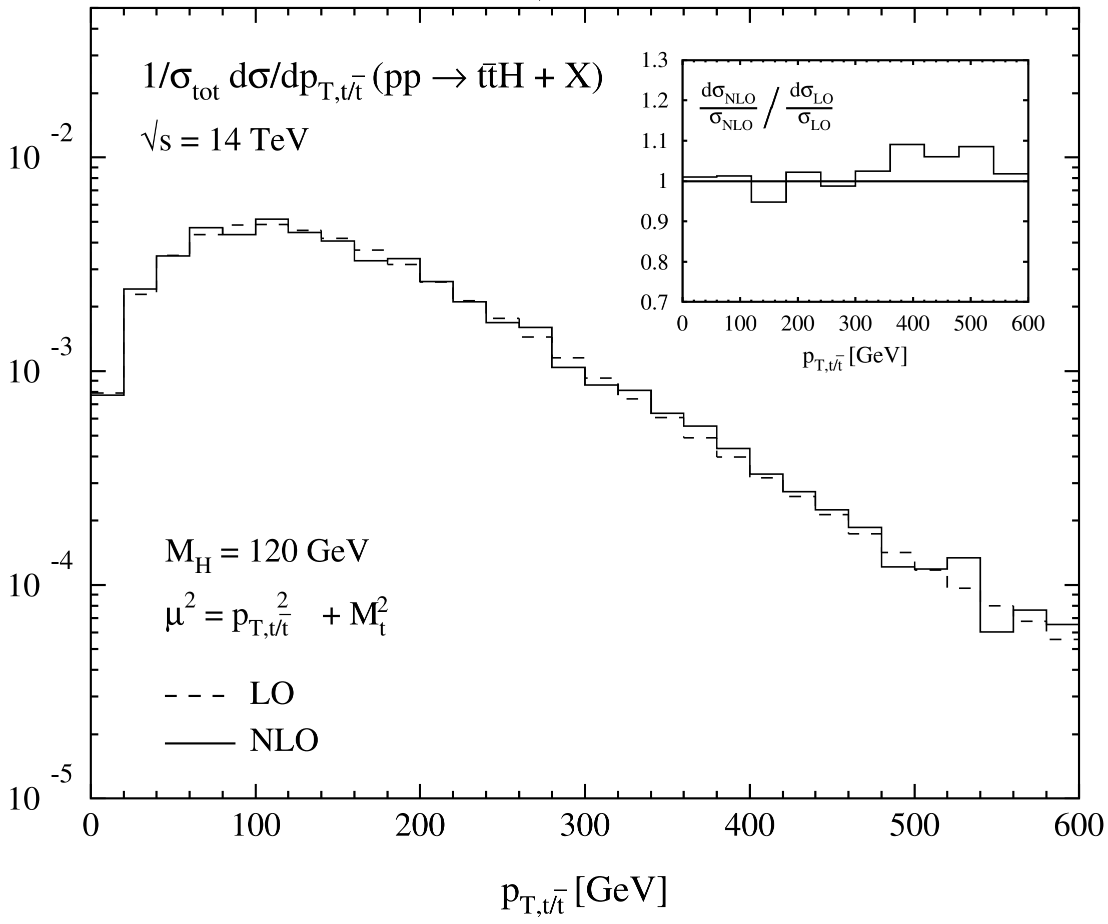
• PDF: $\overline{\text{MS}}$ scheme [5 flavours]





Beenakker, Dittmaier, Krämer, Plümper, S., Zerwas





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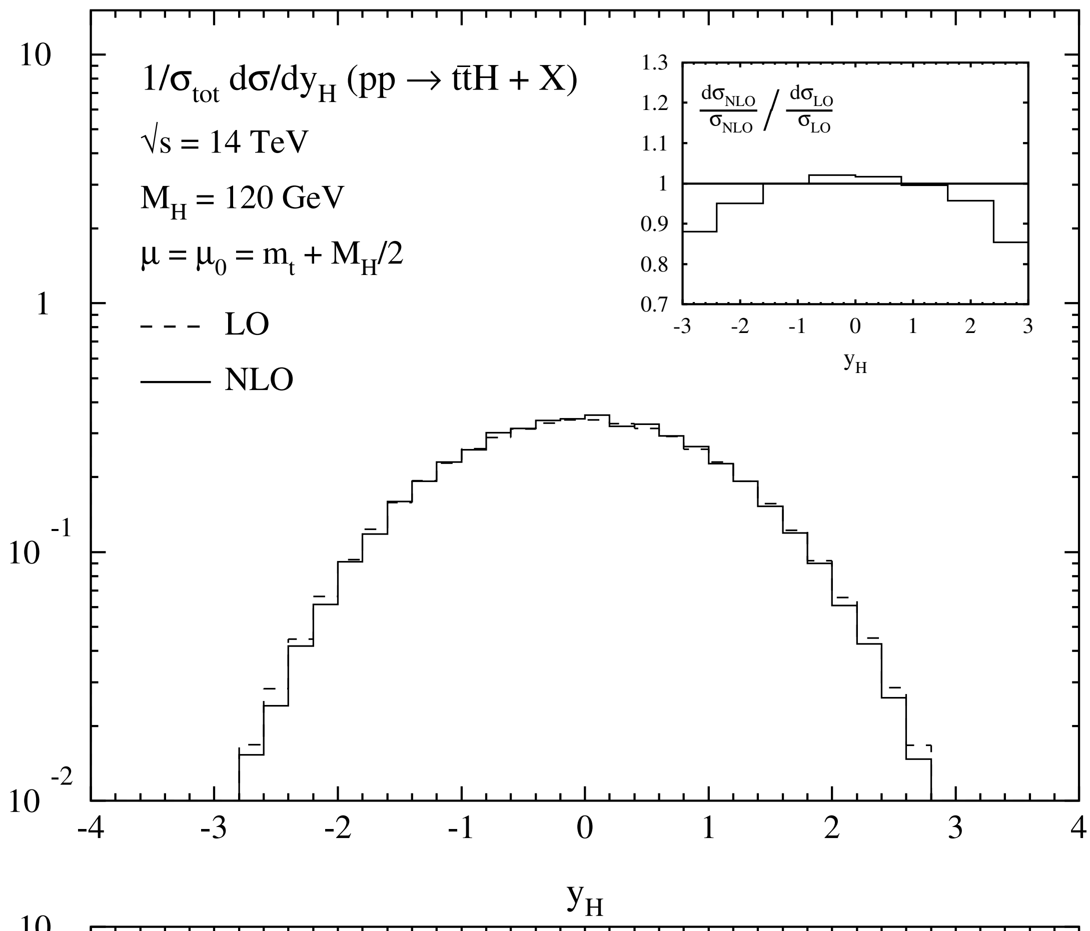
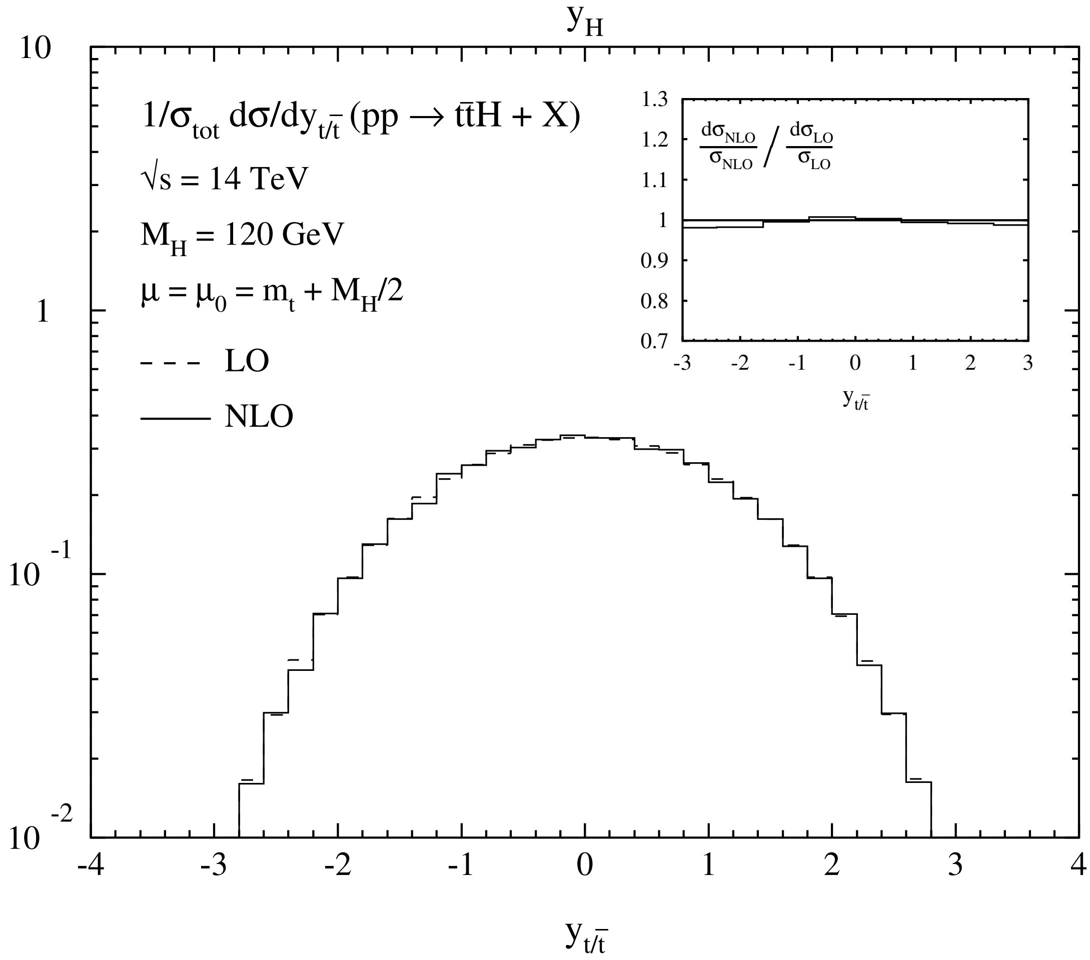
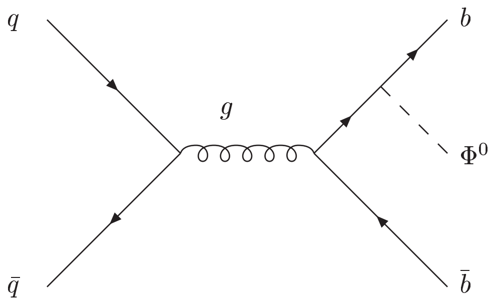




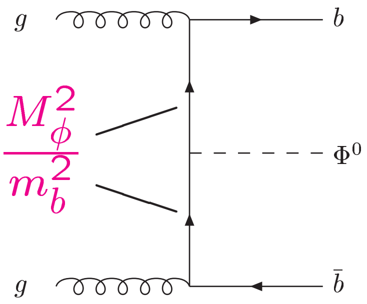
Beenakker, Dittmaier, Krämer, Plümper, S., Zerwas

II $b\bar{b}H$ PRODUCTION

- $b\bar{b} + H/A$ dominant for large tgβ



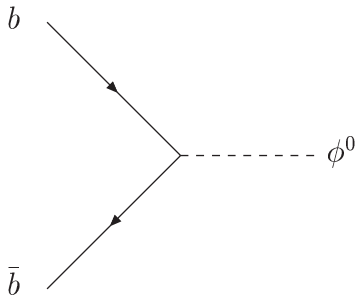
$\log \frac{M_\phi^2}{m_b^2}$



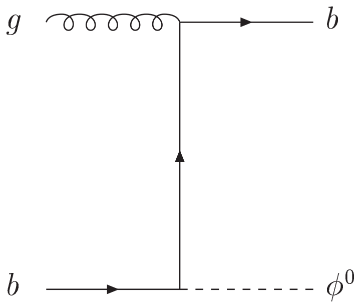
dominant

large logs from phase space integration
$\longrightarrow$ absorbed in bottom PDF
resummation $\equiv$ DGLAP evolution

- new processes:



NNLO



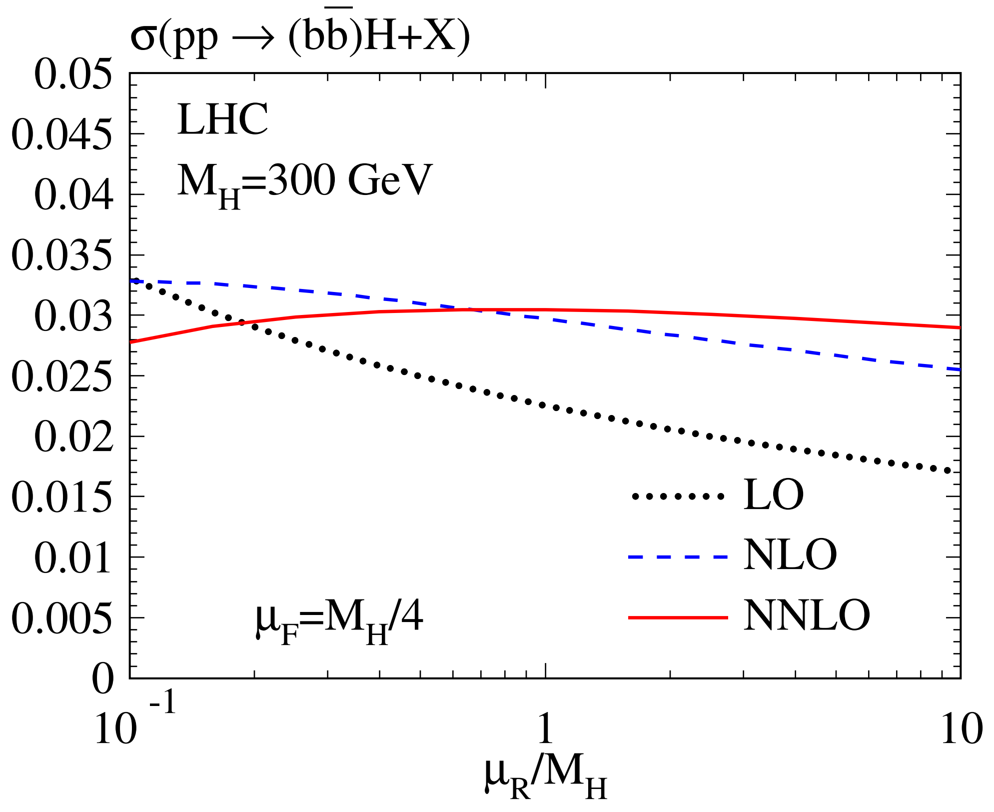
NLO

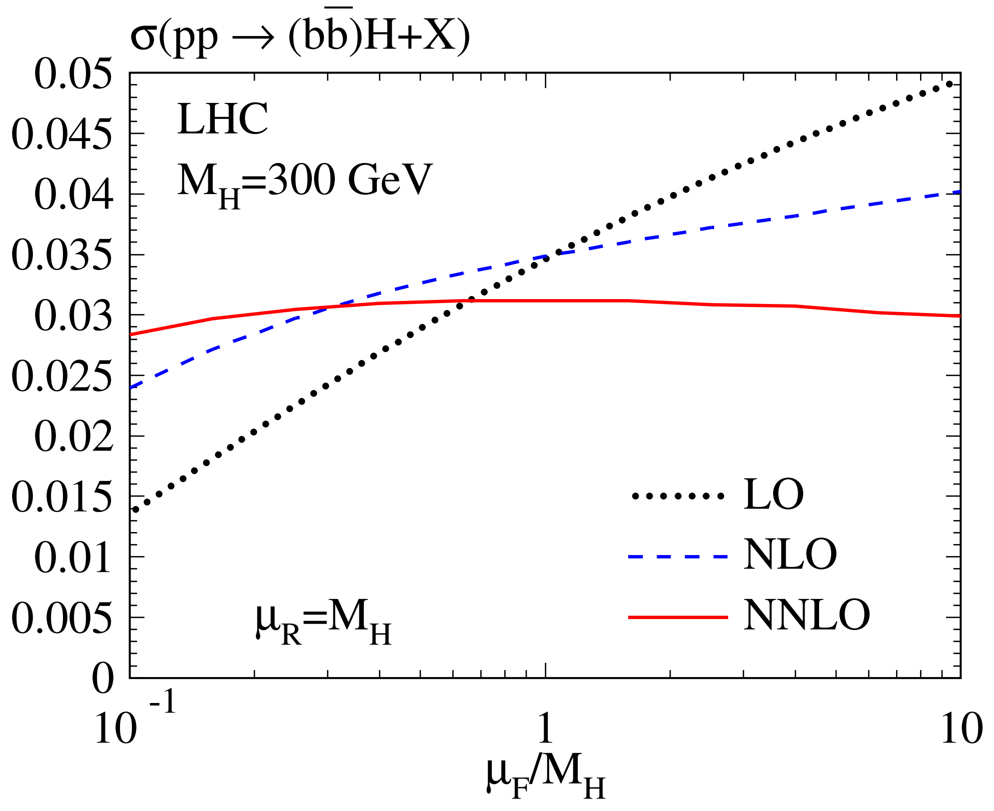
Dicus,Willenbrock
Stelzer, . . .
Balazs,. . .
Campbell,. . .

Harlander, Kilgore

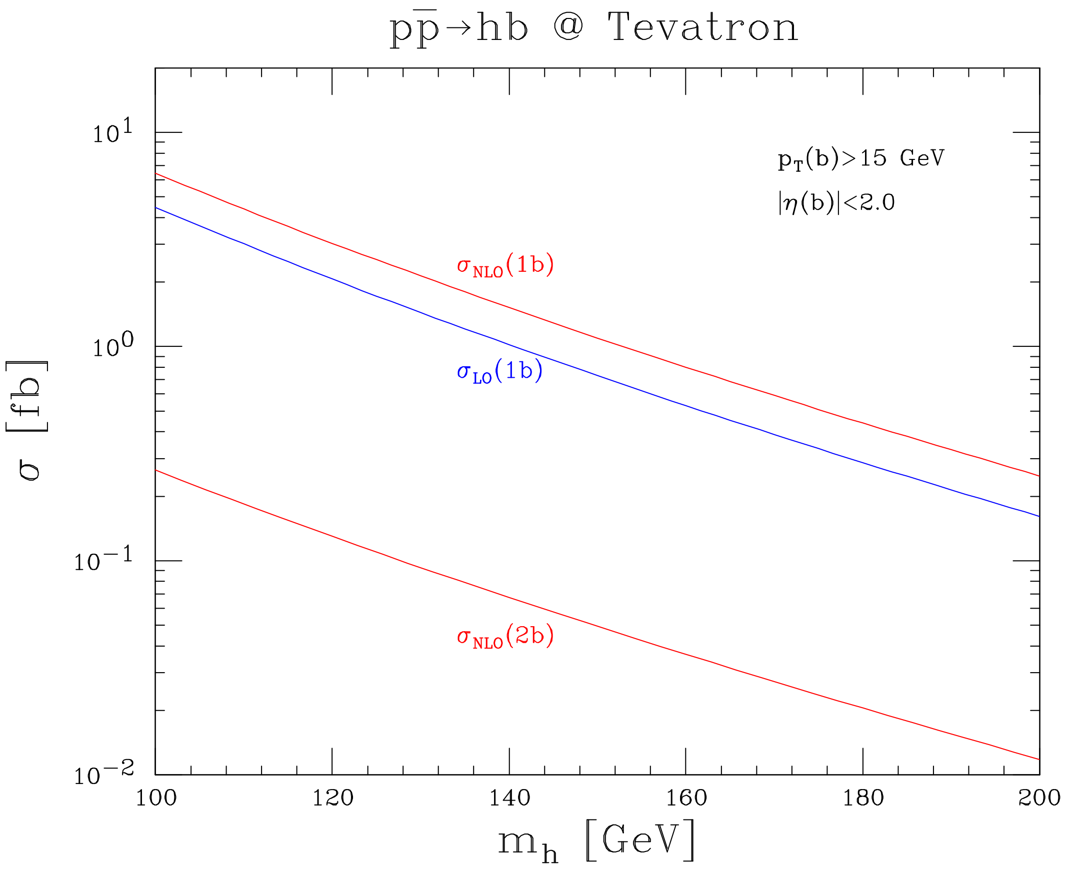
$$b(x, \mu^2) \longrightarrow b(x, \mu^2) - \frac{\alpha_s}{2\pi} P_{qg} \otimes g(x, \mu^2) \log \frac{\mu^2}{m_b^2}$$

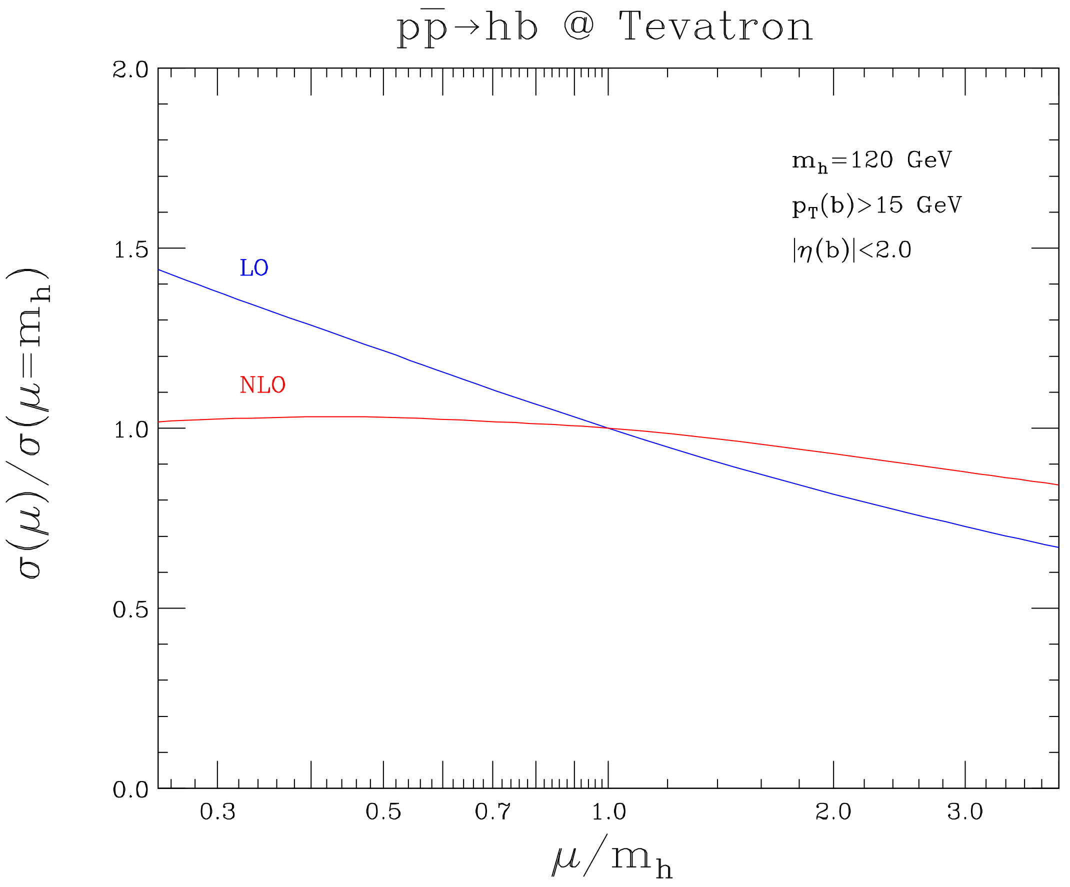
$$\mu \sim M_\phi \Rightarrow \sigma_{tot}$$



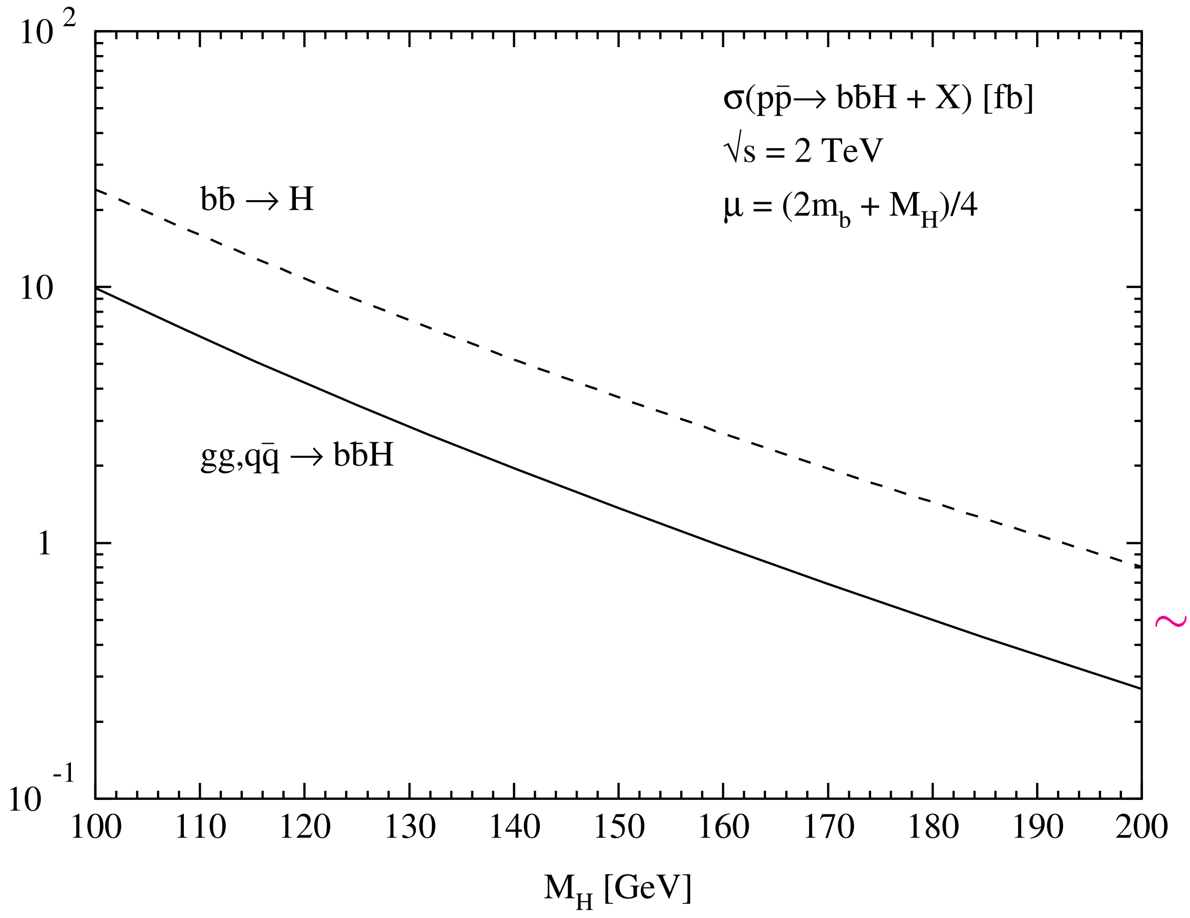


Harlander, Kilgore

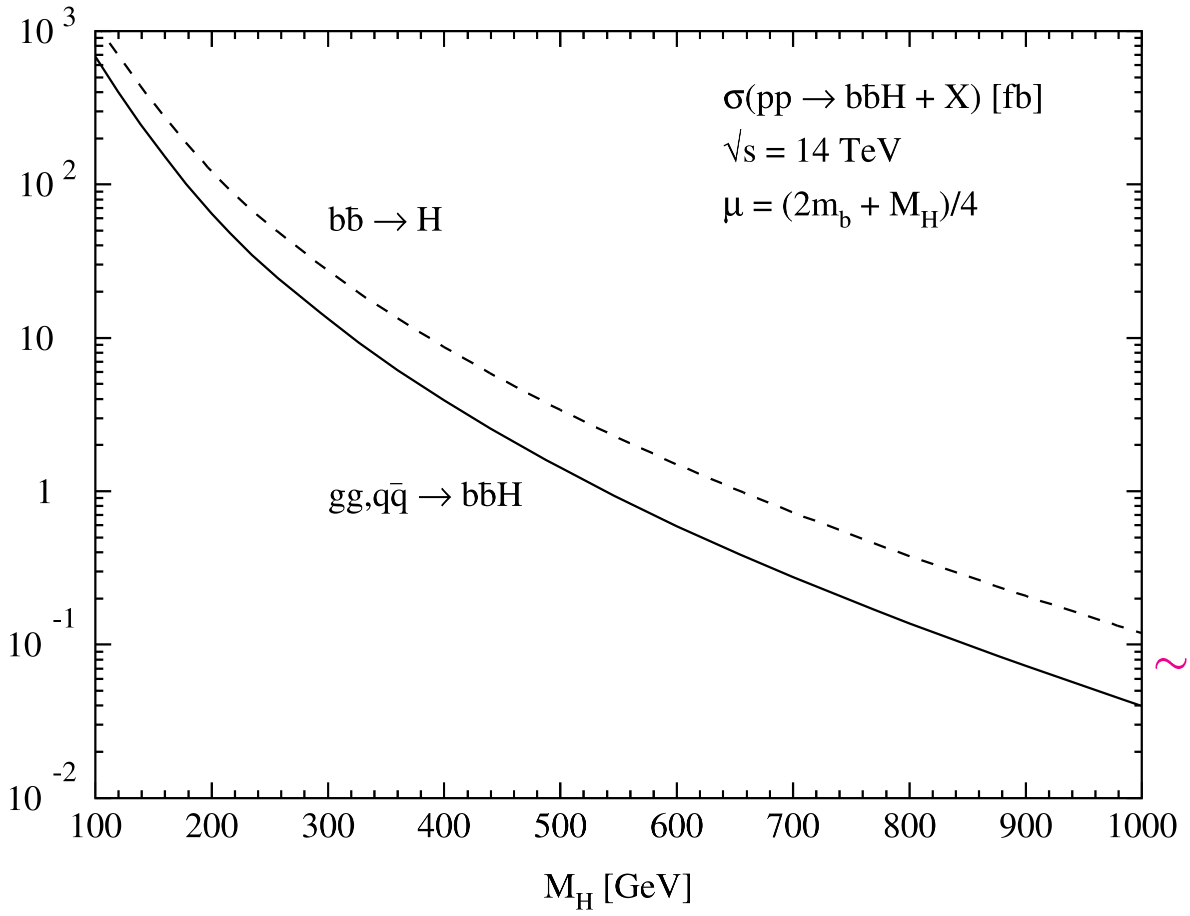




Campbell, Ellis, Maltoni, Willenbrock



~ factor 3



~ factor 3

• factorization in high-energy limit: $[M_{Tb} = \sqrt{p_{Tb}^2 + m_b^2}]$

$$\frac{d\sigma^{(2\to 3)}}{dM_{Tb}^2} = \frac{1}{M_{Tb}^2} \left\{ \frac{\alpha_s}{2\pi} \Delta_{qg} \otimes g \otimes g \otimes \hat{\sigma}_{\bar{b}g} \right\}_{M_{Tb}=m_b\to 0} + \cdots$$

$$\Delta_{qg}(x) = P_{qg}(x) + \frac{m_b^2}{M_{Tb}^2} x(1-x)$$

• total cross section:

$$\sigma = \underbrace{\int_{m_b^2}^{\mu_F^2} \frac{dM_{Tb}^2}{M_{Tb}^2}}_{\log \frac{\mu_F^2}{m_b^2}} \left\{ \frac{\alpha_s}{2\pi} P_{qg} \otimes g \otimes g \otimes \hat{\sigma}_{\bar{b}g} \right\}_{M_{Tb}=m_b\to 0} + \cdots$$

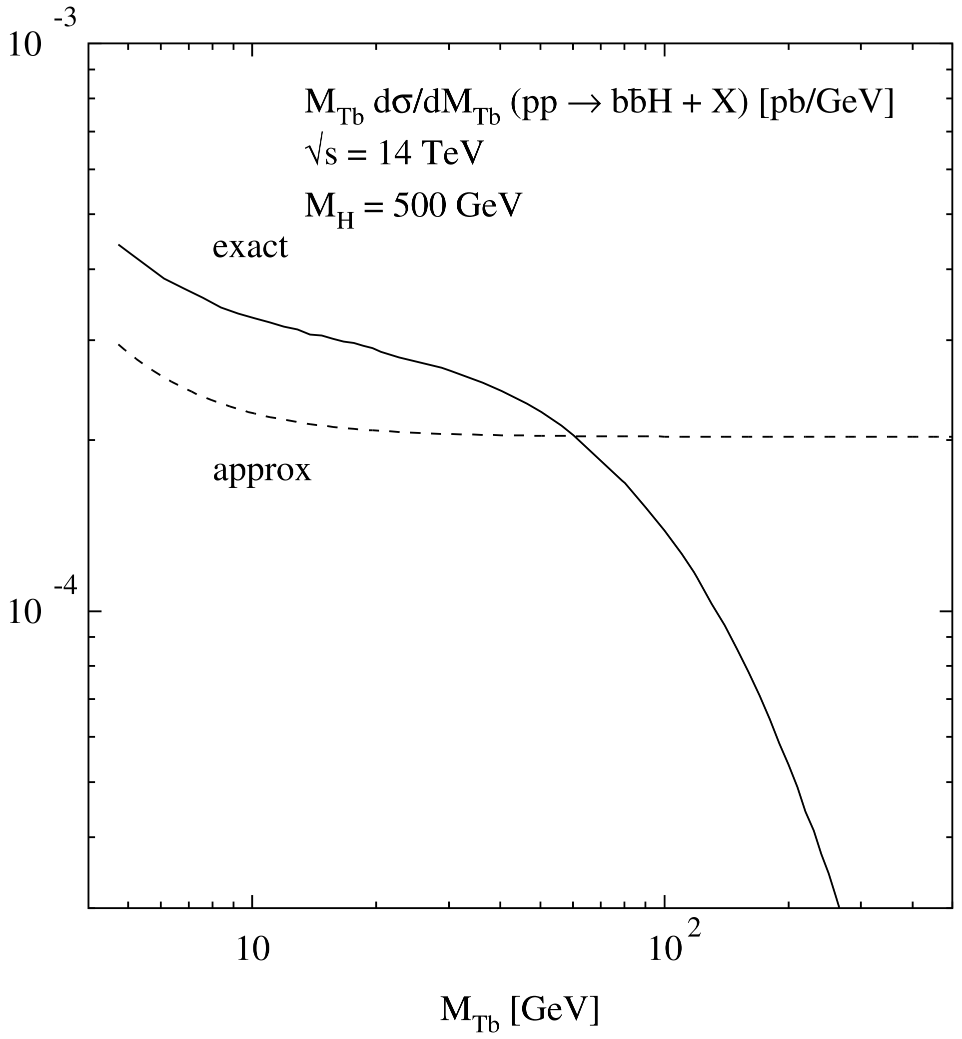
$\Rightarrow$ crucial condition: F

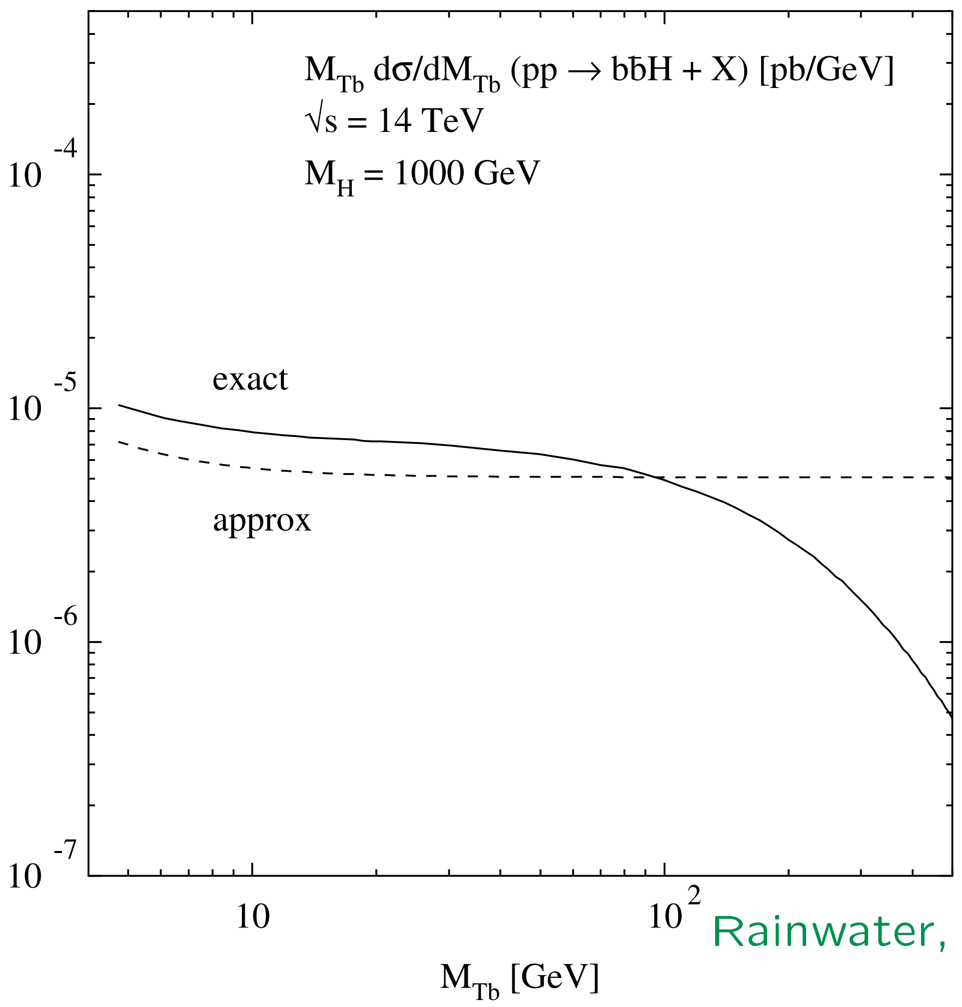
$$\frac{d\sigma^{(2\to 3)}}{dM_{Tb}} \propto \frac{1}{M_{Tb}} \quad \text{up to } M_{Tb} \sim \mu_F$$

• $p_T > p_{Tmin}$: $\log \frac{\mu_F^2}{m_b^2} \to \log \frac{\mu_F^2}{M_{Tmin}^2}$

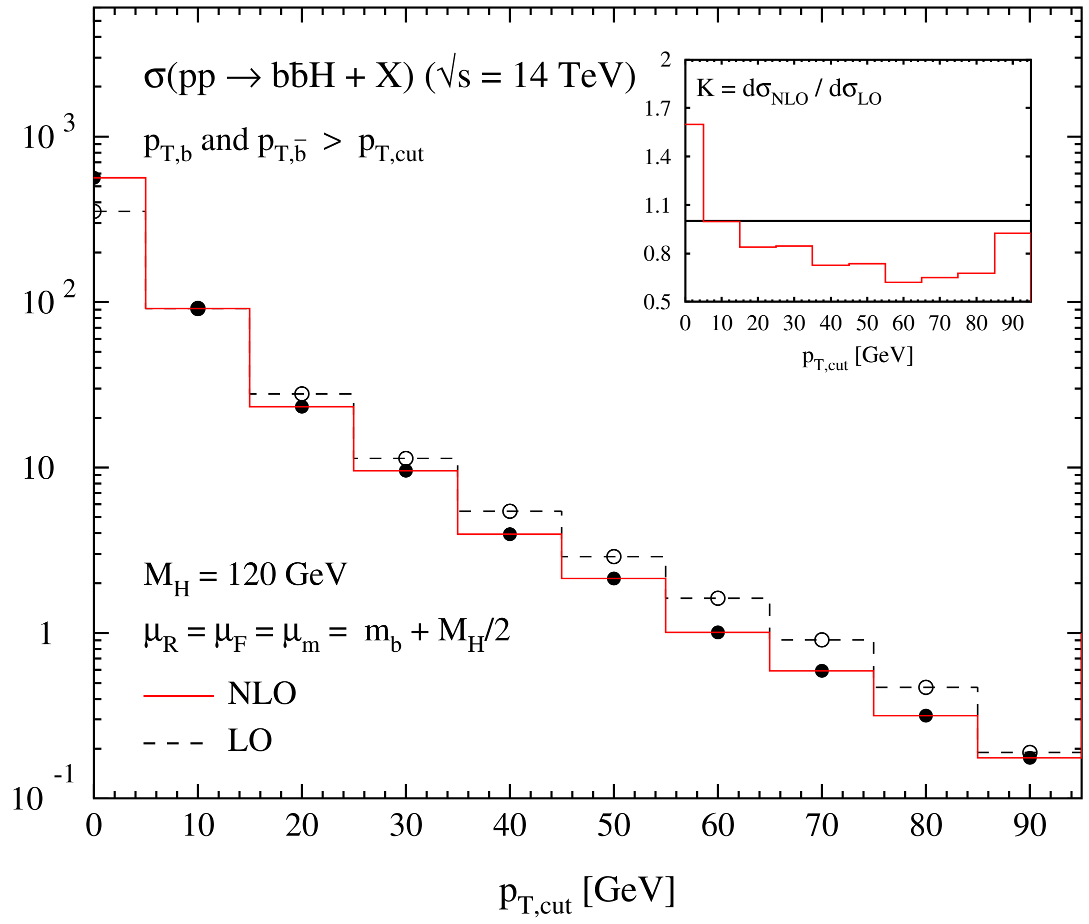
$\Rightarrow$ unintegrated PDFs. . .

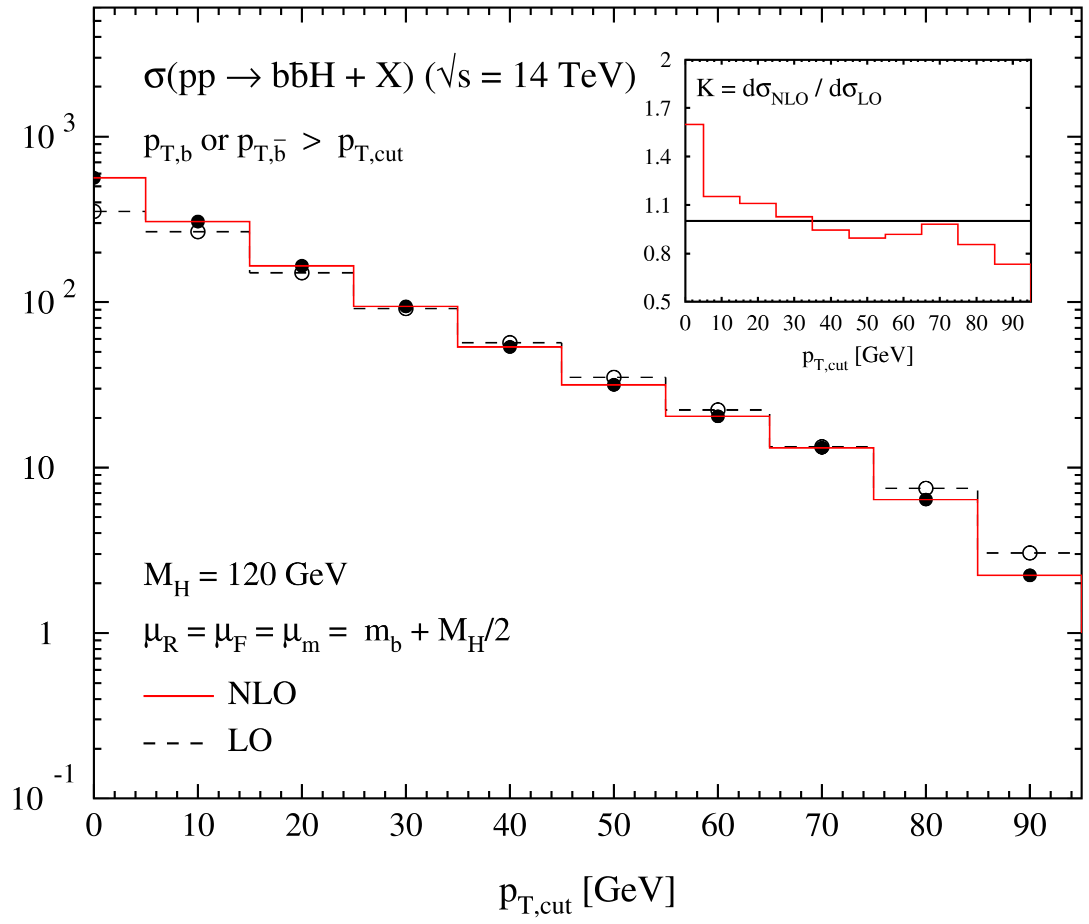
• large corrections to $gg \to b\bar{b}H$?



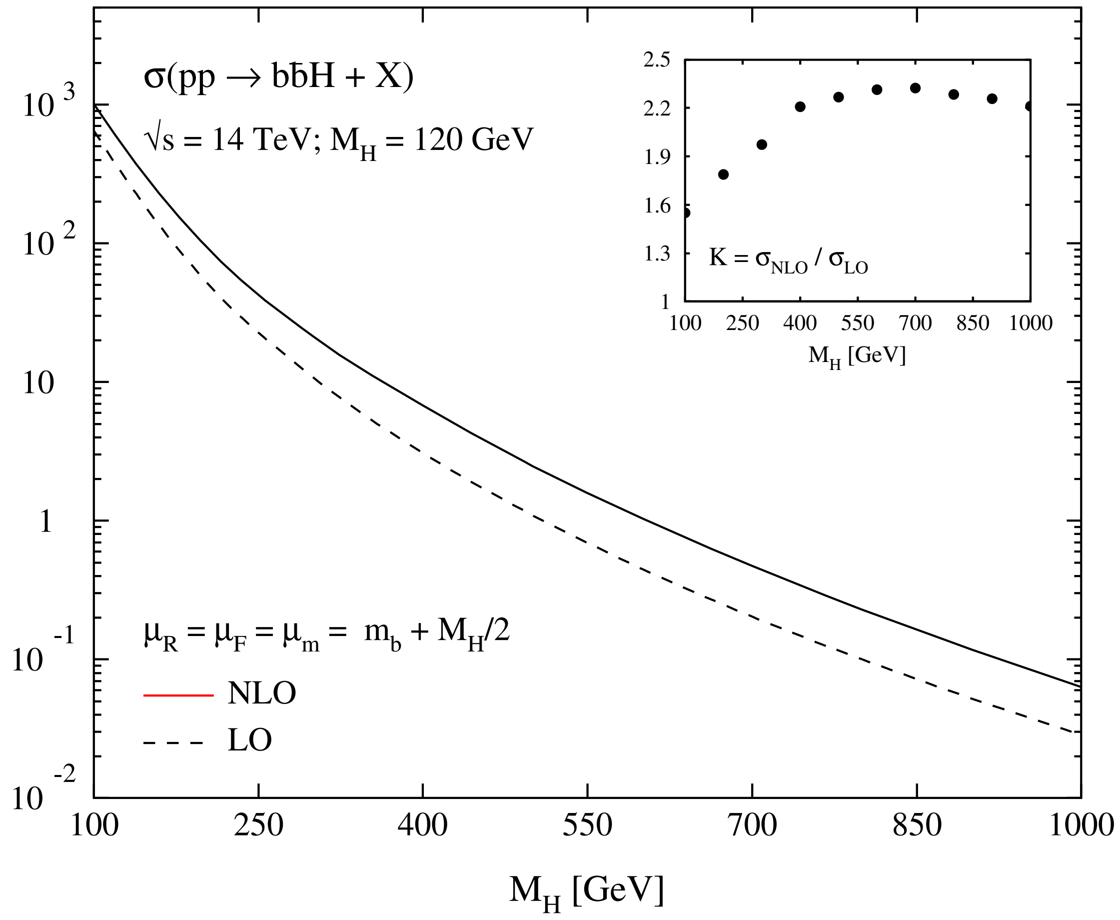


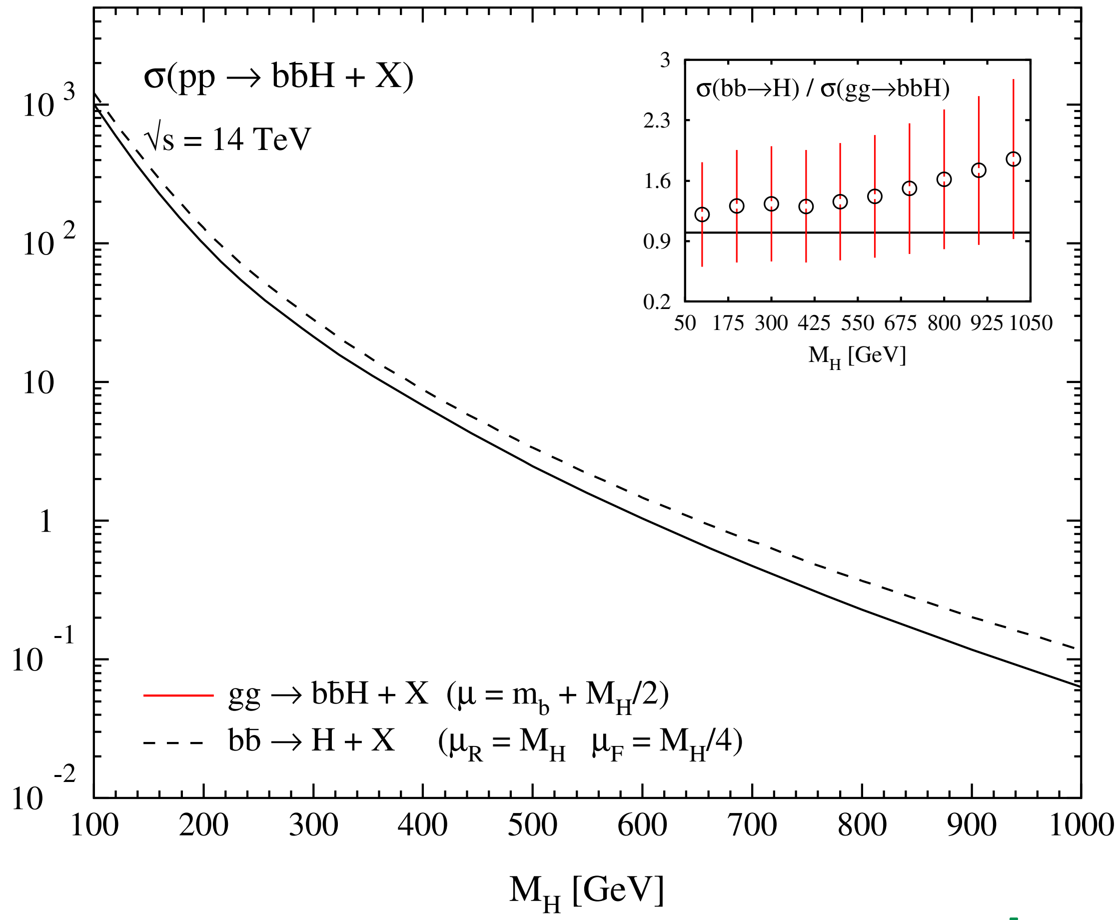
Rainwater, S., Zeppenfeld





Dittmaier, Krämer, S. [preliminary]





Dittmaier, Krämer, S. [preliminary]

[compared to Maltoni, Sullivan, Willenbrock]

III *CONCLUSIONS*

(i) $t\bar{t}H$

- QCD corrections: $\sim (20 - 40)\%$ @ LHC

- strong reduction of scale dependence:
  $\Delta \lesssim 10 - 15\%$

- shape of Higgs p_T distribution changed by 10% [scale = transverse mass]

- shape of (anti)top p_T distribution hardly affected [scale = transverse mass]

- shape of rapidity distributions hardly modified

(ii) $b\bar{b}H$

- QCD corrections: (50–120)% for total cxn
  $\mathcal{O}$(20–40)% with 2 b jets

- reasonable agreement with $b\bar{b} \to H$ [$\mu_F = M_H/4$]

- reliability of bottom PDFs still not clear [scale choice, approximate kinematics, etc.]
  $\Rightarrow$ more [conceptual] work required