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# ATLAS H<sup>±</sup> Cross Sections: Current Status

LHC Charged Higgs Xsec Meeting  
February 2010

# H<sup>+</sup> Overview

- Three ingredients for H<sup>+</sup> cross sections:

- $\sigma(tt\bar{b})$

- ATLAS: Moch et al.

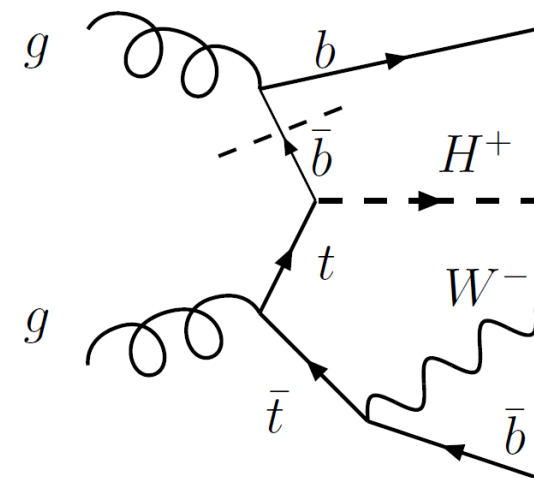
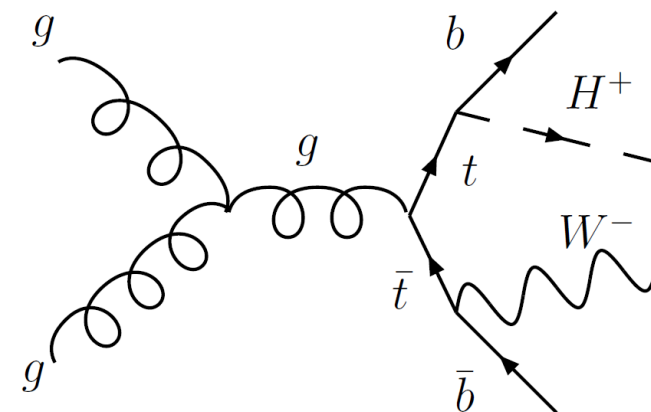
- $\sigma(gb \rightarrow tH^+)$

- Semi-public code from Tilman Plehn

- $\text{BR}(t \rightarrow bH^+)$ ,  $\text{BR}(H^+ \rightarrow \dots)$

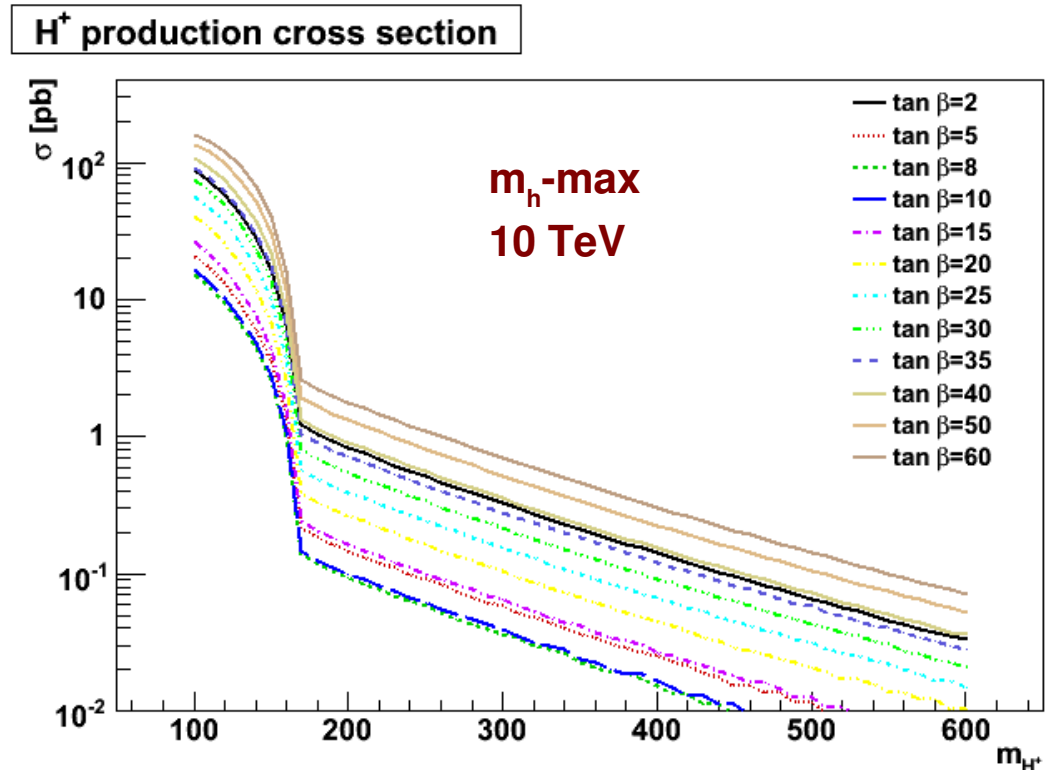
- FeynHiggs 2.6.5

- All done for 7, 10, and 14 TeV

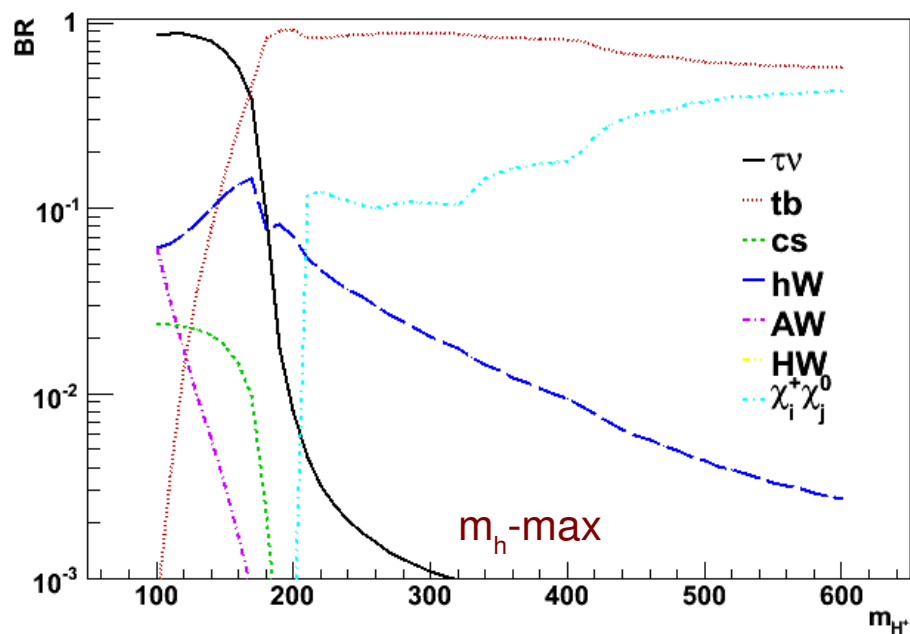
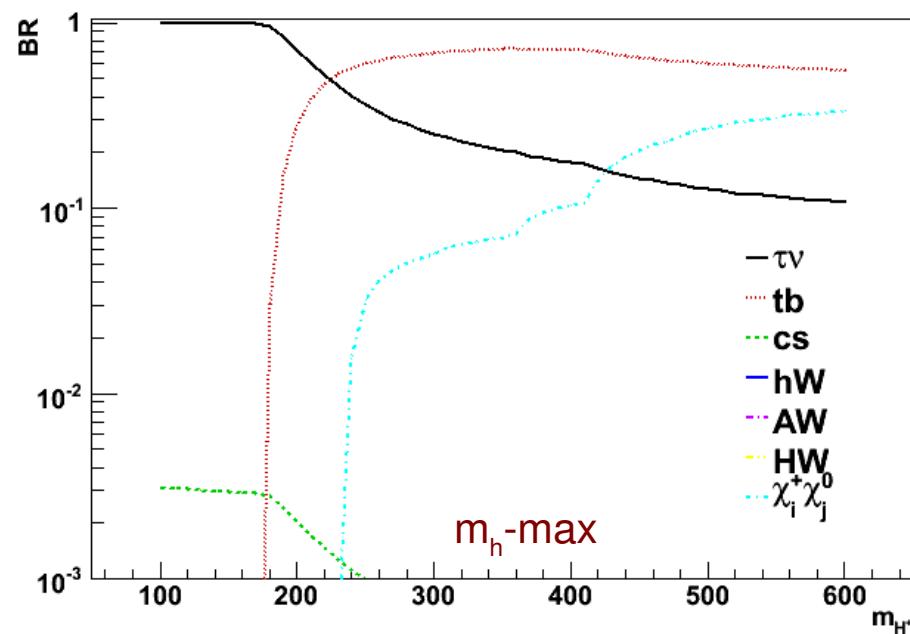


# Cross Section, mh-max

- $\sigma(pp \rightarrow tt \rightarrow bH + bW)$   
for  $m_{H^+} \ll m_{top}$   
 $= 2 * \sigma(tt) * BR(t \rightarrow bH^+) * (1 - BR(t \rightarrow bH^+))$
- $\sigma(gb \rightarrow tH^+)$  [w/o intermediate tt]  
for  $m_{H^+} \gg m_{top}$
- (incoherent) sum of both  
for  $m_{H^+} \approx m_{top}$
- Ingredients:
  - $\sigma(tt)$ : Moch et al. (401.6 pb)
  - $BR(t \rightarrow bH^+)$ : FeynHiggs 2.6.5
  - $\sigma(gb \rightarrow tH^+)$ : Code from Tilman Plehn, CTEQ6.6M



# BR, $m_h$ -max

 BR( $H^+ \rightarrow \dots$ ),  $\tan \beta=2$ 

 BR( $H^+ \rightarrow \dots$ ),  $\tan \beta=35$ 


- BR( $H^+ \rightarrow \dots$ ): FeynHiggs 2.6.5
- $\tan \beta$ : 1...70
- $m_{H^+}$ : 100...600 GeV



# Scenarios A & B

- Below: 10 TeV
- Cross Section ( $gb \rightarrow tH^+$ ):

- A1: 0.0087 pb
- A2: 0.014 pb
- B1: 0.0085 pb
- B2: 0.013 pb

Designed for  $H^+ \rightarrow \chi_i^+ \chi_j^0 \rightarrow 3 \text{ leptons} + X$  study

$M_A=390 \text{ GeV}$	$M_{\text{SUSY}}=1000 \text{ GeV}$
$A_t=A_b=2000 \text{ GeV}$	$M_3=800 \text{ GeV}$
$M_{\text{stau}}(L,R)=250 \text{ GeV}$	$M_{\text{slepton}}(L,R)=150 \text{ GeV}$
$A_{\text{tau}}=A_l=0$	

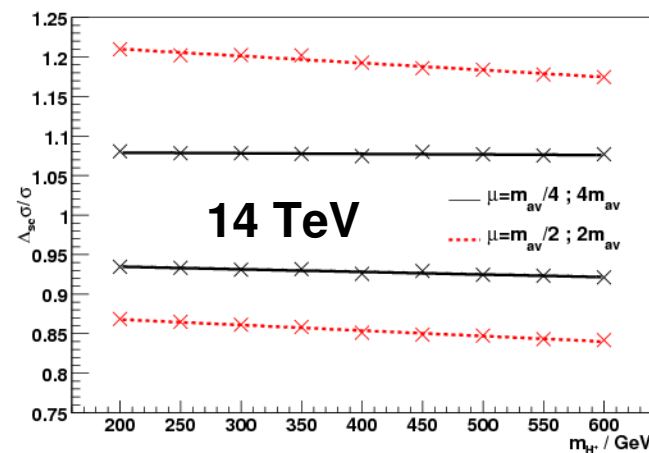
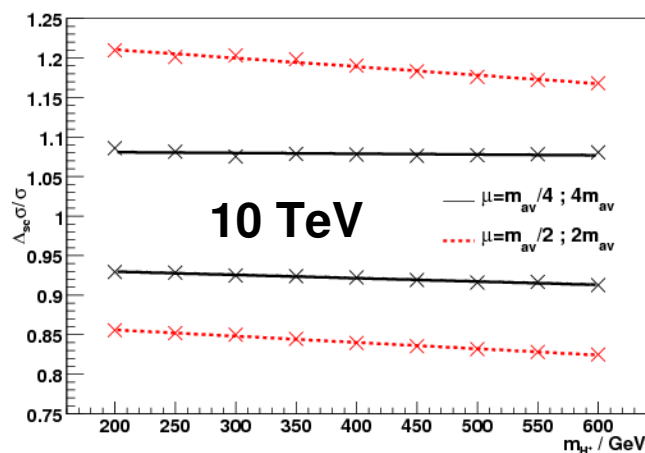
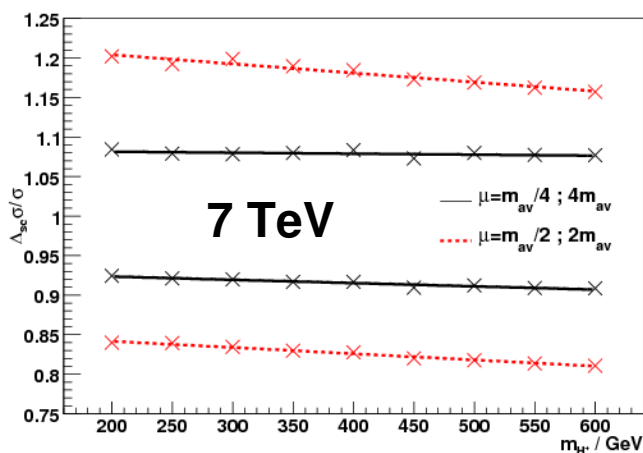
**Scenario A:**  $\mu=135 \text{ GeV}$ ,  $M_2=210 \text{ GeV}$ ;  $\tan \beta=7$  and  $15$

**Scenario B:**  $\mu=200 \text{ GeV}$ ,  $M_2=310 \text{ GeV}$ ;  $\tan \beta=7$  and  $15$

- $BR(H^+ \rightarrow \chi_i^+ \chi_j^0)$ :
  - A1: 0.73
  - A2: 0.56
  - B1: 0.35
  - B2: 0.19

# Scale Uncertainties

- $\sigma$ : Scale Uncertainties ( $\mu_F, \mu_R$ )
  - low mass: uncertainties due to  $t\bar{t}$  cross section: 3% [Moch09]
  - high mass:  $< 20\%$  at 14 TeV [Plehn03]. Have reinvestigated for all  $E_{CM}$ :
  - Uncertainties are almost identical: about  $+20\%$  /  $-15\%$ , small dependence on  $m_{H^+}$  [when varying the scale  $m_{av}/4 < \mu < 4 m_{av}$ ]
  - [Berger05]: when varying over a very large range ( $m_{av}/10 < \mu < 10 m_{av}$ ),  $\mu_F, \mu_R$  should be varied independently and uncertainties can be huge. Still, they advocate a 20% total scale uncertainty.





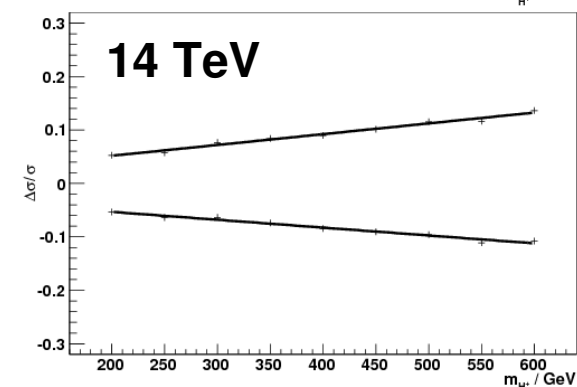
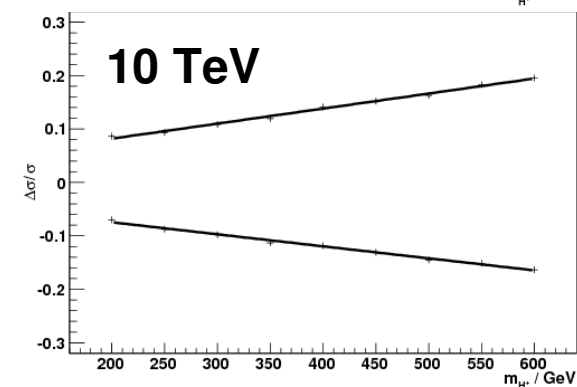
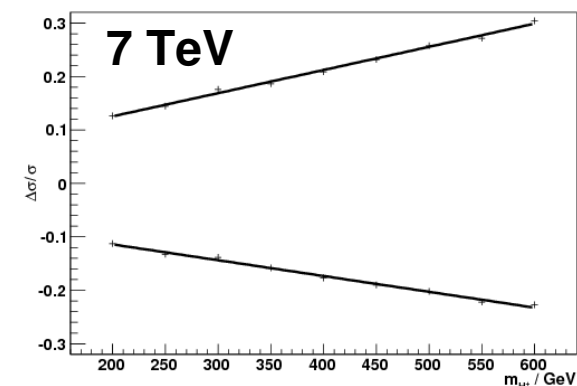
# Other Systematic Uncertainties

- $\sigma$ : SUSY loop corrections
  - Leading corrections taken into account ( $\Delta b$ ), rest negligible [Plehn03]
- BR: Loop corrections to  $tbH^+$  vertex, running of  $c$  and  $s$  masses:  
(communication with Sven Heinemeyer)
  - $\Delta BR(t \rightarrow bH^+)/BR < 10\%$
  - $\Delta BR(H^+ \rightarrow \tau\nu)/BR < 5\%$
  - $\Delta BR(H^+ \rightarrow tb, cs)/BR < 10\%$



# PDF Uncertainties

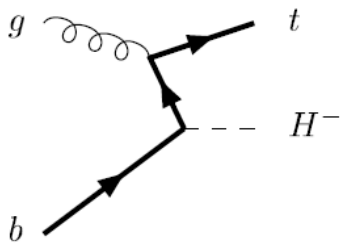
- CTEQ 6.6M, 44 error PDFs
- Results – PDF Uncertainties:
  - 7 TeV: 11-30%
  - 10 TeV: 7-20%
  - 14 TeV: 5-14%
- Do not depend on  $\tan \beta$ ; increase with  $m_{H^+}$ ; decrease with  $E_{cm}$





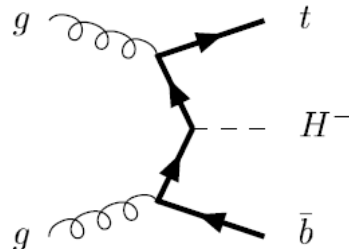
# 4FS vs 5FS

- 5FS (Plehn03) vs 4FS (Dittmaier/Krämer/Spira/Walser09)



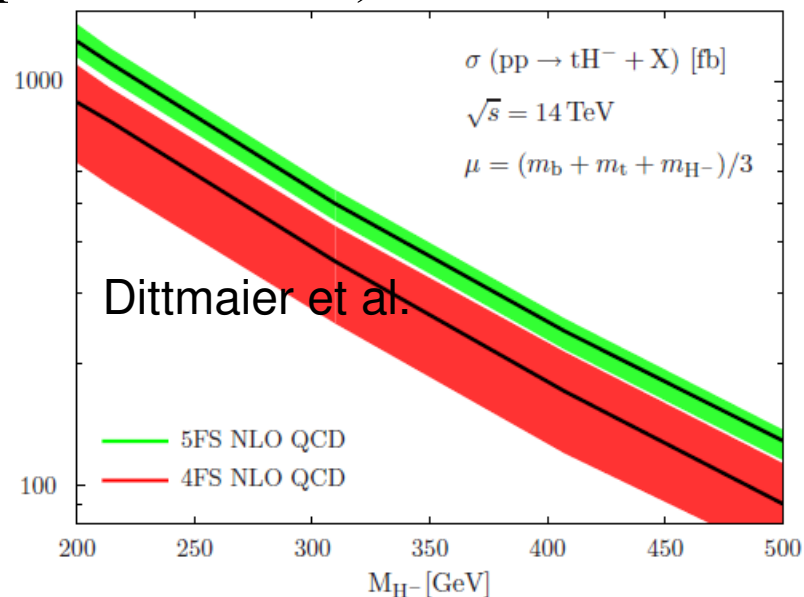
Resummation of  
 $\log(m_{hp}^2/m_b^2)$   
=>introduces b PDFs

works only for low- $p_T$  b;  
b massless and on-shell



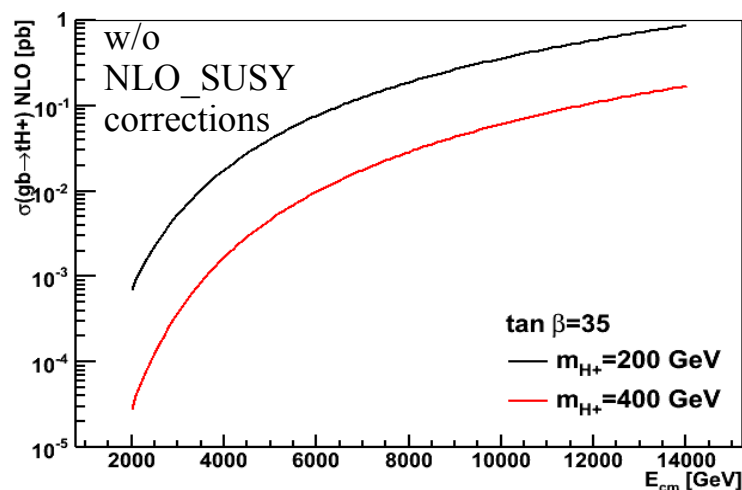
b massive, can be off-shell  
can reproduce distributions  
of the outgoing b

- 4FS  $\approx 0.7 \cdot 5FS$ ; Barely within each others scale uncertainties;
- Possible explanations:
  - PDF uncertainties not included in the comparison;
  - scale choice not optimal for 5FS [Plehn03]  $\rightarrow$  shifts green band 5-10%
  - b PDF uncertainties underestimated?

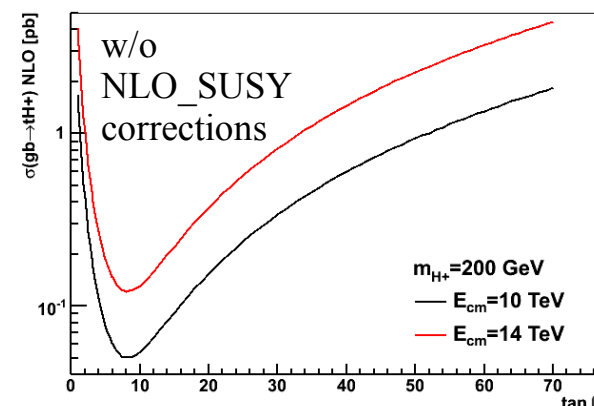


# $gb \rightarrow tH^+$ as $f(E_{CM})$

- Tilman's code –  $\sigma(E_{CM})$ :

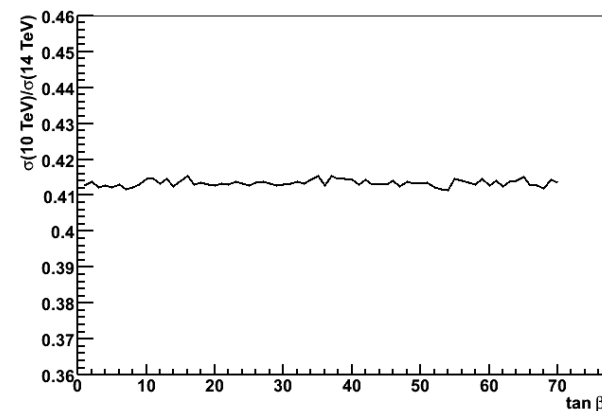


10 vs 14 TeV,  $f(\tan \beta)$



The ratio  $\sigma(10 \text{ TeV})/\sigma(14 \text{ TeV})$  is constant wrt  $\tan \beta$ .  
All results for 10 TeV can easily be scaled to any other  
 $E_{cm} \rightarrow$  scale factor is only  $f(m_{H^+})$ .

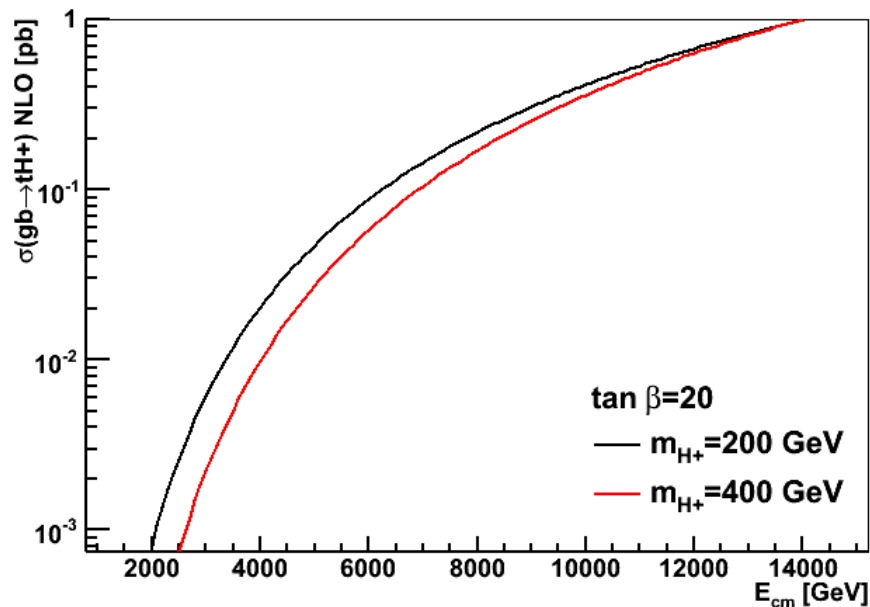
$\Delta b$  corrections can be applied afterwards (very fast)



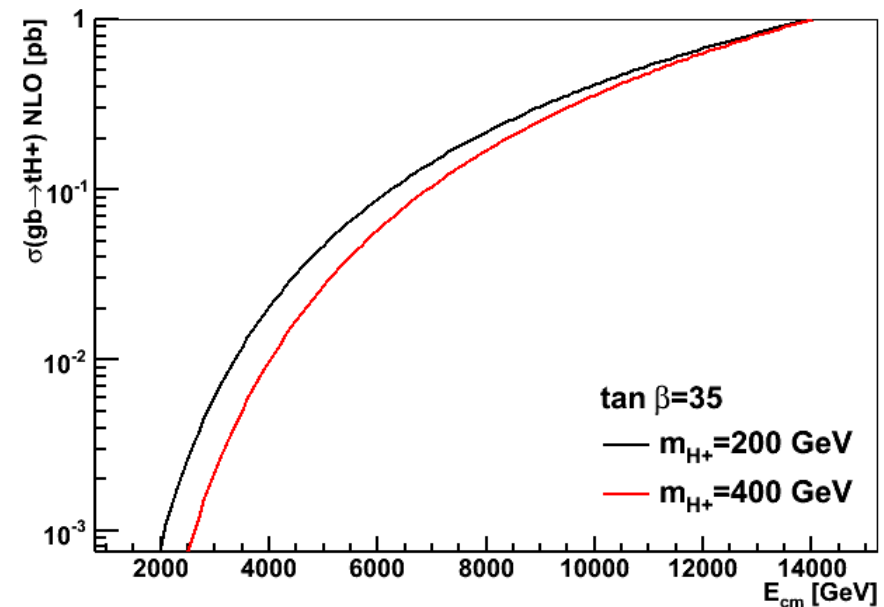
# $gb \rightarrow tH^+$ : Scaling with $E_{cm}$

- Scale factors for different  $E_{cm}$  (wrt the 14 TeV-cross section)

Graph



Graph



- Depend on  $m_{H^+}$ , but not on tan  $\beta$  (as expected)