LHC Higgs Cross Section WG:

Progress for the (light) charged Higgs

Sven Heinemeyer, IFCA (CSIC, Santander)

BNL, 05/2011

co-contacts: Martin Flechl, Michael Krämer, Sami Lehti

1. What charged Higgs?
2. The light charged Higgs in the MSSM
3. New benchmarks?
4. Discussion points / future plans

1. What charged Higgs?

Models with charged Higgs bosons:

1. Two Higgs Doublet Model (THDM)
   $\rightarrow$ type I, II, III, IV, ...

2. Minimal Supersymmetric Standard Model (MSSM)
   $\rightarrow$ type II (+ loop corrections)

3. MSSM with extra singlet (NMSSM)
   $\rightarrow$ type II (+ loop corrections)

4. MSSM with more extra singlets
   $\rightarrow$ type II (+ loop corrections)

5. SM/MSSM with Higgs triplets
   $\rightarrow$ more options

6. ...

$\Rightarrow$ so far focus on type II: $g_{tbH^\pm} \sim m_t \cot\beta + m_b \tan\beta, \quad g_{\tau\nu H^\pm} \sim m_\tau \tan\beta$

Common and different features of Models with Charged Higgs Bosons

To my knowledge the following points have only partially been answered:

Common features:

- what are the common features of all (or most) models?
- how can the charged Higgs be discovered at the LHC?
  $\rightarrow$ only through $H^{\pm} \rightarrow \tau\nu_{\tau}$ (!?)
- which models would be missed?
- what can be done about them?

Different features:

- once we have discovered 'a' charged Higgs, how can we distinguish them?
- what are the relevant LHC capabilities?
- are we prepared for all possibilities?

$\Rightarrow$ very helpful: experts for the various models

$\Rightarrow$ so far focus on type II: $g_{tbH^\pm} \sim m_t \cot\beta + m_b \tan\beta, \quad g_{\tau\nu H^\pm} \sim m_\tau \tan\beta$

Light charged Higgs: $M_{H^\pm} < m_t$

Main production channel: $pp \to t\bar{t} \to t\, H^- \bar{b}$ or $H^+ b\, \bar{t}$

Heavy charged Higgs: $M_{H^\pm} > m_t$

Main production channel: $gb \to H^- t$ or $g\bar{b} \to H^+ \bar{t}$

Same relevant decay channel: $H^\pm \to \tau\nu_\tau$

$\Rightarrow$ in principle the same couplings are relevant for
light and heavy charged Higgs

$\Rightarrow$ so far focus on type II: $g_{tbH^\pm} \sim m_t \cot\beta + m_b \tan\beta, \quad g_{\tau\nu H^\pm} \sim m_\tau \tan\beta$

Light charged Higgs: $M_{H^\pm} < m_t$

Main production channel: $pp \to t\bar{t} \to t\, H^- \bar{b}$ or $H^+ b\, \bar{t}$

Heavy charged Higgs: $M_{H^\pm} > m_t$

Main production channel: $gb \to H^- t$ or $g\bar{b} \to H^+ \bar{t}$

Same relevant decay channel: $H^\pm \to \tau\nu_\tau$

$\Rightarrow$ in principle the same couplings are relevant for
light and heavy charged Higgs $\Rightarrow$ situation may change in other models

...

$\Rightarrow$ so far focus on type II: $g_{tbH^\pm} \sim m_t \cot\beta + m_b \tan\beta, \quad g_{\tau\nu H^\pm} \sim m_\tau \tan\beta$

Light charged Higgs: $M_{H^\pm} < m_t$

Main production channel: $pp \to t\bar{t} \to t\, H^- \bar{b}$ or $H^+ b\, \bar{t}$

Heavy charged Higgs: $M_{H^\pm} > m_t$

Main production channel: $gb \to H^- t$ or $g\bar{b} \to H^+ \bar{t}$

Same relevant decay channel: $H^\pm \to \tau\nu_\tau$

$\Rightarrow$ in principle the same couplings are relevant for
light and heavy charged Higgs $\Rightarrow$ situation may change in other models

...

YR: production cross sections for light and heavy type II charged Higgs

$\Rightarrow$ so far focus on type II: $g_{tbH^\pm} \sim m_t \cot\beta + m_b \tan\beta, \quad g_{\tau\nu H^\pm} \sim m_\tau \tan\beta$

Light charged Higgs: $M_{H^\pm} < m_t$

Main production channel: $pp \to t\bar{t} \to t\, H^- \bar{b}$ or $H^+ b\, \bar{t}$

Heavy charged Higgs: $M_{H^\pm} > m_t$

Main production channel: $gb \to H^- t$ or $g\bar{b} \to H^+ \bar{t}$

Same relevant decay channel: $H^\pm \to \tau\nu_\tau$

$\Rightarrow$ in principle the same couplings are relevant for
light and heavy charged Higgs $\Rightarrow$ situation may change in other models

...

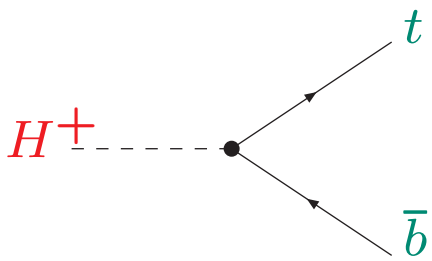
YR: production cross sections for light and heavy type II charged Higgs
$\Rightarrow$ new focus so far: light charged MSSM Higgs

2. The light charged MSSM Higgs

Work in progress:

- assessment of uncertainties in production and decay
- finer grid (incl. uncertainties)
- ...

Effects of Δ_b:



$$y_b \frac{\tan\beta}{1+\Delta_b}$$

$$\Delta_b = \frac{2\alpha_s}{3\pi} m_{\tilde{g}}\, \mu\, \tan\beta \times I(m_{\tilde{b}_1}, m_{\tilde{b}_2}, m_{\tilde{g}}) + \frac{\alpha_t}{4\pi} A_t\, \mu\, \tan\beta \times I(m_{\tilde{t}_1}, m_{\tilde{t}_2}, \mu) + \ldots$$

$\Rightarrow$ other parameters enter $\Rightarrow$ strong μ dependence

$$H^\pm : \frac{\tan^2\beta}{(1+\Delta_b)^2} \times \mathrm{BR}(H^\pm \to \tau\nu_\tau)$$

$$: \frac{\tan^2\beta}{(1+\Delta_b)^2} \times \frac{\Gamma(H^\pm \to \tau\nu_\tau)}{\Gamma^{\mathrm{THDM}}(H^\pm \to tb)/(1+\Delta_b)^2 + \Gamma(H^\pm \to \tau\nu_\tau) + \ldots}$$

$\Rightarrow$ no compensation of Δ_b effects for light charged Higgs
$\Rightarrow$ partial compensation for heavy charged Higgs

Sources of theory uncertainties:

1. PDF and α_s uncertainties on $\sigma(pp \to t\bar{t})$
2. experimental uncertainties on m_t, affecting $\sigma(pp \to t\bar{t})$
3. Uncertainties of Δ_b
4. Experimental uncertainties in SUSY masses entering Δ_b
5. Further missing higher order corrections in BR$(t \to H^+ b)$

– How large are the uncertainties?

– How large are the corresponding effects?

Size of theory uncertainties:

$\Rightarrow$ preliminary analysis exists for 14 TeV [*S.H., A. Nikitenko, G. Weiglein '08*]

$\Rightarrow$ careful reanalysis necessary! (at 7 TeV)

1. Uncertainties on $\sigma(pp \to t\bar{t})$ (for $M_{H^\pm} < m_t$)
   $\to \sim 10\%$ (now, or in the near future)

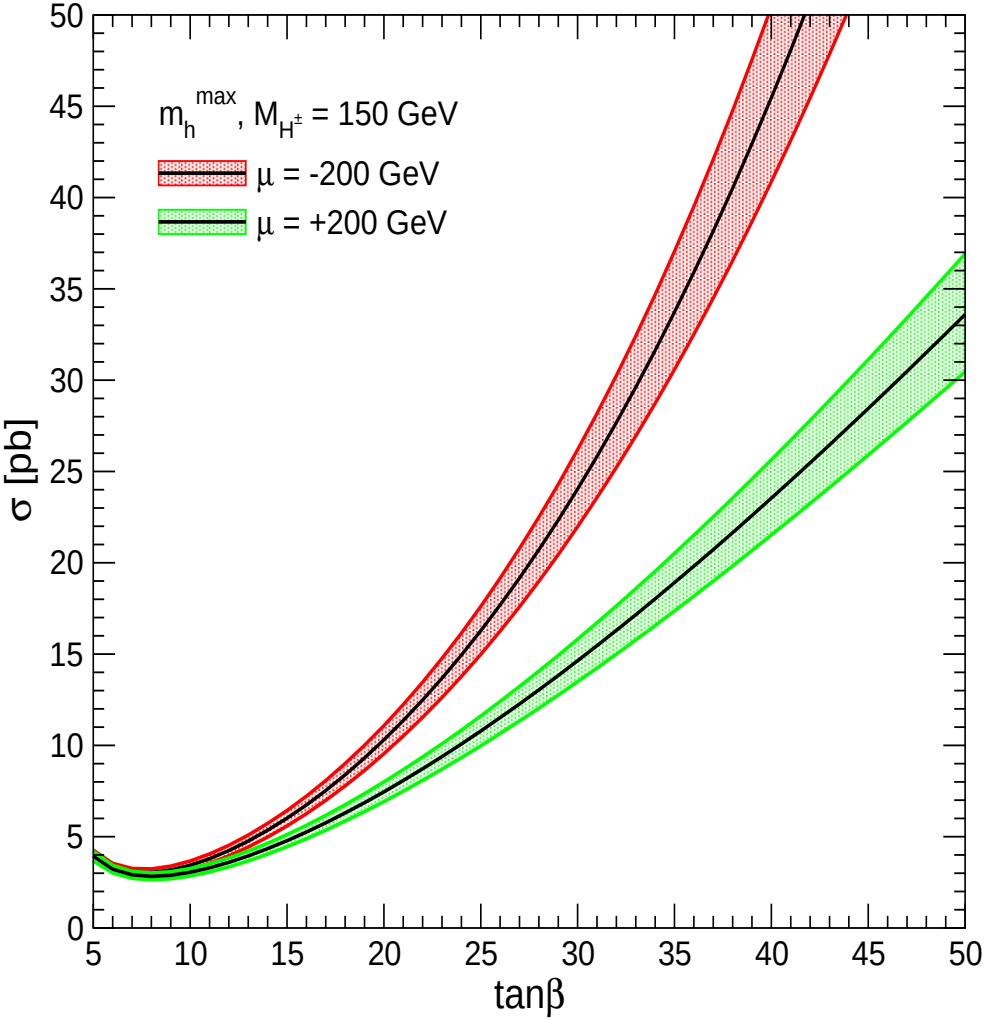
2. experimental uncertainties on m_t, affecting $\sigma(pp \to t\bar{t})$
   $\to \Delta\sigma/\sigma \approx 5\Delta m_t^{\rm exp}/m_t$
   combined error on σ: $\sim 11\%$

3. Uncertainties beyond $\Delta_b (\sim \alpha_s \ldots + \alpha_t \ldots)$
   $\Rightarrow$ scale variation of $\alpha_s(Q)$ $\Rightarrow$ effect on Δ_b $\lesssim 20\%$
   ($\Rightarrow$ smaller effects for $\mu \propto \Delta_b > 0$, larger effects for $\mu \propto \Delta_b < 0$)
   $\Rightarrow$ improvement with two-loop corrections on Δ_b

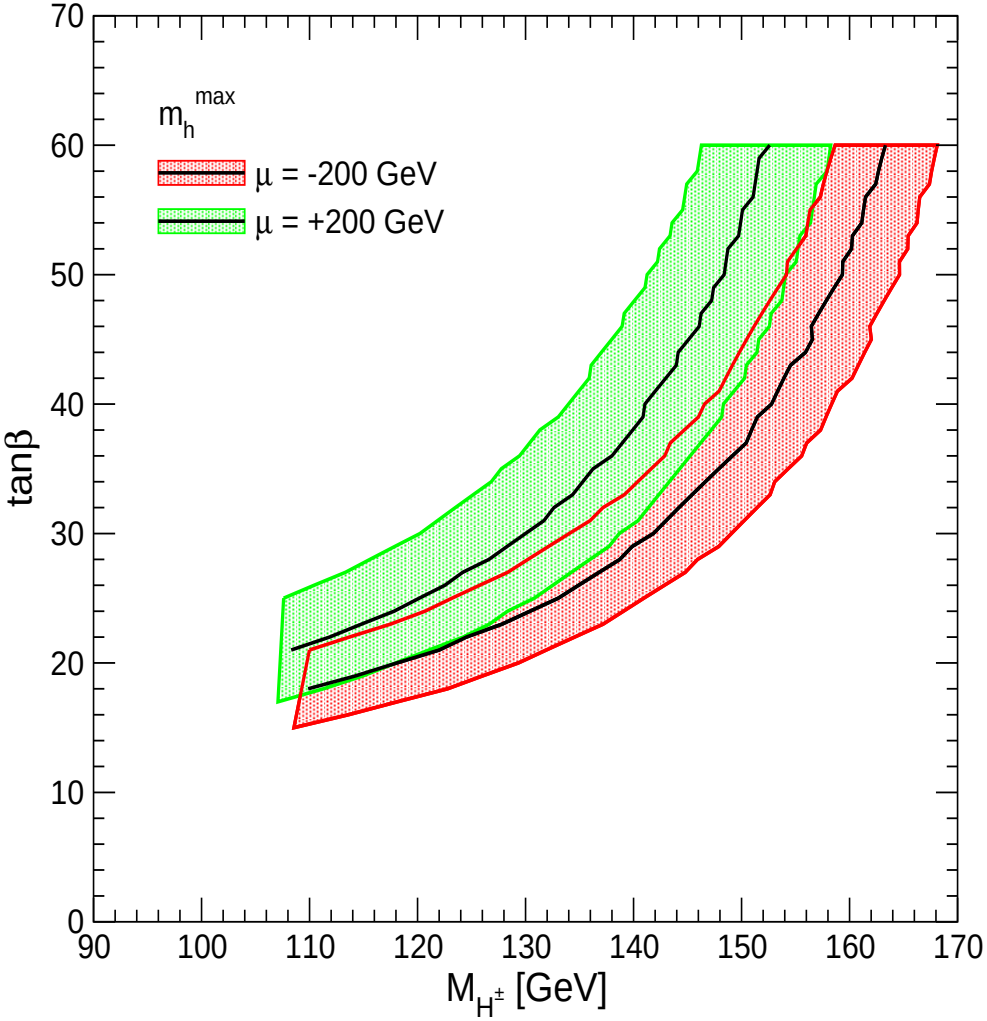
4. Uncertainties on SUSY masses very difficult
   $\Rightarrow$ at least a few test points ...

Theory uncertainties for the light charged MSSM Higgs:

cross section



$5\,\sigma$ discovery contours



⇒ uncertainties have to be reduced to get reliable prediction

From the ATLAS top group:

- Measurement of $\sigma(pp \to t\bar{t})$ at 7 TeV:

$$\sigma = 180 \pm 9\,(\text{stat.}) \pm 15\,(\text{syst.}) \pm 6\,(\text{lumi})\ \text{pb}$$

  Uncertainty will go down with more data.

- Replace calculated cross section by measured cross section with higher precision?

3. New benchmarks?

Same problem as in the (other) MSSM groups:

- general set-up that can handle all input
- no "final results" as in the SM possible due to too involved parameter dependence
- numerical values so far only in the m_h^{max} scenario

Are other scenarios desirable?

- Scenario with large BR($H^\pm \to$ SUSY) ? – new signatures?
- suppressed BR($H^\pm \to \tau\nu$)

Any further suggestions/ideas?

4. Discussion points / future plans

- Short term: focus on light charged Higgs
  Medium term: same for heavy charged Higgs
  4FS vs. 5FS ...

- Re-evaluate theory uncertainties for $\sigma \times$ BR
  with current estimates and for 7 TeV

- Re-evalution of finer grid, including the theory uncertainties

- Distributions ...

- Uncertainty of $\sigma(pp \to t\bar{t})$ from experiment?

- New benchmark?
  What would be interesting/desirable?