Stefan Liebler
on behalf of the MSSM subgroup

Update of the MSSM neutral Higgs cross sections

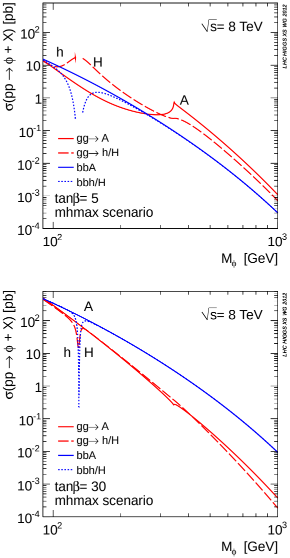
7th LHC Higgs Cross Section Workshop
CERN, Geneva

6. December 2012

Theoretische Teilchenphysik
Fachbereich C
Bergische Universität Wuppertal

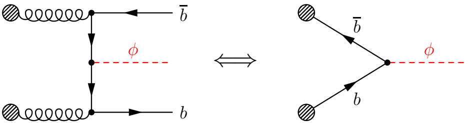
Outline

Neutral Higgs production in the MSSM:

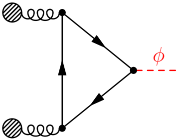


Production cross sections according to YR1 [arXiv:1101.0593]

Bottom-quark annihilation:



Gluon fusion:



The neutral components of the Higgs doublets $H_u = (H_u^+, H_u^0)^T$ and $H_d = (H_d^0, H_d^-)^T$ mix as follows

CP-even Higgs CP-odd Higgs

$$\begin{pmatrix} H_u^0 \\ H_d^0 \end{pmatrix} = \begin{pmatrix} v_u \\ v_d \end{pmatrix} + \frac{1}{\sqrt{2}} R_\alpha \begin{pmatrix} h \\ H \end{pmatrix} + \frac{i}{\sqrt{2}} R_\beta \begin{pmatrix} G \\ A \end{pmatrix} \quad .$$

The mixing matrix is expressed in terms of the "Higgs mixing angle α"

$$R_\alpha = \begin{pmatrix} \cos\alpha & \sin\alpha \\ -\sin\alpha & \cos\alpha \end{pmatrix} \quad .$$

The Higgs sector at LO is determined by fixing $\tan\beta = \frac{v_u}{v_d}$ and m_A^2:

$$m_{h,H} = \frac{1}{2}\left(m_A^2 + m_Z^2 \mp \sqrt{(m_A^2 - m_Z^2)^2 + 4 m_Z^2 m_A^2 \sin^2(2\beta)} \right)$$

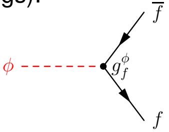
$$\tan(2\alpha) = \tan(2\beta) \frac{m_A^2 + m_Z^2}{m_A^2 - m_Z^2}$$

The lightest Higgs h mass obtains large corrections at higher orders:
`FeynHiggs` [Frank Degrassi Hahn Heinemeyer Hollik Rzehak Slavich Weiglein Williams]
3-loop [Martin '07; Kant Harlander Mihaila Steinhauser '08 '10].

In the MSSM, Higgs couplings to the b-quark can be enhanced by $\tan\beta$:
Relative strength of the Higgs boson couplings g_f^ϕ with $\phi \in \{h, H, A\}$ to the SM fermions (with respect to the SM Higgs boson couplings):

$$g_u^h = \frac{\cos\alpha}{\sin\beta} \qquad g_u^H = \frac{\sin\alpha}{\sin\beta} \qquad g_u^A = \frac{1}{\tan\beta}$$

$$g_d^h = -\frac{\sin\alpha}{\cos\beta} \qquad g_d^H = \frac{\cos\alpha}{\cos\beta} \qquad g_d^A = \tan\beta$$

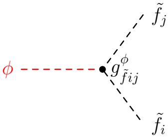


In addition, the superpartners of the quarks, the squarks, are relevant

$$\mathcal{L} \supset -(\tilde{q}_L^\dagger, \tilde{q}_R^\dagger)\mathcal{M}_{\tilde{q}}^2 \begin{pmatrix} \tilde{q}_L \\ \tilde{q}_R \end{pmatrix}$$

with the mass matrix:

$$\mathcal{M}_{\tilde{q}}^2 = \begin{pmatrix} M_{qL}^2 + m_q^2 + m_{E1}^2 & m_q(A_q - \mu\kappa) \\ m_q(A_q - \mu\kappa) & M_{qR}^2 + m_q^2 + m_{E2}^2 \end{pmatrix}$$



They form two mass eigenstates:

$$\begin{pmatrix} \tilde{q}_1 \\ \tilde{q}_2 \end{pmatrix} = \begin{pmatrix} \cos\theta_{\tilde{q}} & \sin\theta_{\tilde{q}} \\ -\sin\theta_{\tilde{q}} & \cos\theta_{\tilde{q}} \end{pmatrix} \begin{pmatrix} \tilde{q}_L \\ \tilde{q}_R \end{pmatrix}$$

$m_{E1}^2 = m_z^2\cos(2\beta)(T_q^3 - Q_q\sin^2\theta_W)$; $m_{E2}^2 = m_Z^2\cos(2\beta)Q_q\sin^2\theta_W$; $\kappa = \tan\beta(d), \cot\beta(u)$

Gluon fusion at LO using $\tau_\phi = m_\phi^2/s$:

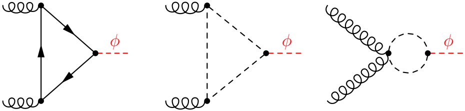
$$\sigma(pp \to \phi + X) = \sigma_0^\phi \tau_\phi \frac{d\mathcal{L}^{gg}}{d\tau_\phi}$$

Partonic $\to$ Hadronic XS:

$$\frac{d\mathcal{L}^{gg}}{d\tau} = \int_\tau^1 \frac{dx}{x} g(x) g(\tau/x)$$

LO partonic cross section (XS):

$$\sigma_0^\phi = \frac{G_F \alpha_s^2}{288\sqrt{2}\pi} |\mathcal{A}^\phi|^2$$



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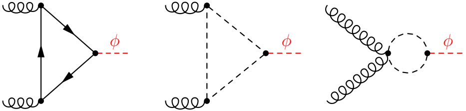


$$\mathcal{A}^\phi = \sum_{q \in \{t,b\}} \left(a_q^{\phi,(0)} + a_{\tilde{q}}^{\phi,(0)} \right)$$

with

$$a_q^{\phi,(0)} = g_q^\phi \frac{3\tau_q}{2}(1 + (1 - \tau_q^\phi) f(\tau_q^\phi))$$

Quark contributions

Squark contributions

$$\tilde{a}_q^{\phi,(0)} = -\frac{3\tau_q^\phi}{8} \sum_{i=1}^{2} g_{\tilde{q}ii}^\phi (1 - \tau_{\tilde{q}i}^\phi f(\tau_{\tilde{q}i}^\phi))$$

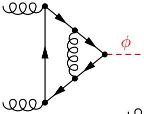
$$\tau_q^\phi = 4m_q^2/m_\phi^2, \quad \tau_{\tilde{q}i}^\phi = 4m_{\tilde{q}i}^2/m_\phi^2, \quad f(\tau) = \begin{cases} \arcsin^2 \frac{1}{\sqrt{\tau}} & \tau \geq 1 \\ -\frac{1}{4}\left(\log \frac{1+\sqrt{1-\tau}}{1-\sqrt{1-\tau}} - i\pi\right)^2 & \tau < 1 \end{cases}$$

Gluon fusion at NLO using $\tau_\phi = m_\phi^2/s$:

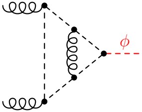
$$\sigma(pp \to \phi + X) = \sigma_0^\phi \tau_\phi \frac{d\mathcal{L}^{gg}}{d\tau_\phi}\left[1 + C^\phi \frac{\alpha_s}{\pi}\right] + \Delta\sigma_{gg}^\phi + \Delta\sigma_{gq}^\phi + \Delta\sigma_{q\bar{q}}^\phi$$

NLO amplitudes $a_q^{\phi,(1)}$ and $a_{\tilde{q}}^{\phi,(1)}, a_{\tilde{q}\tilde{g}}^{\phi,(1)}$ entering C^ϕ:

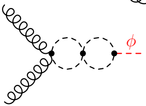
- ▷ gluon-quark: known analytically (higher orders)
  [Spira Djouadi Graudenz Zerwas '95; Harlander Kant '05; . . .]

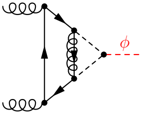


- ▷ gluon-squark: known analytically/numerically
  [Anastasiou Beerli Bucherer Daleo Kunszt '06;
  Aglietti Bonciani Degrassi Vicini '06; Mühlleitner Spira '06;
  Bonciani Degrassi Vicini '07]



- ▷ gluino-squark-quark contributions:
  semi-analytically known $\longrightarrow$ no public code
  [Anastasiou Beerli Daleo '08; Mühlleitner Spira Rzehak '10]

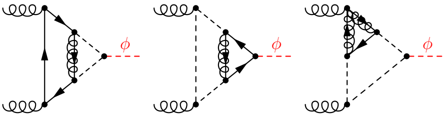




Problem with gluino-quark-squark contributions:
up to 5 different masses in the 2-loop integrals
$\longrightarrow$ think of reasonable approximations

Knowledge of NLO amplitudes $a_q^{\phi,(1)}$ (12 diag.) and $a_{\tilde{q}}^{\phi,(1)}, a_{\tilde{q}\tilde{g}}^{\phi,(1)}$ (59 diag.):
Five different masses in the diagram: $m_q, m_{\tilde{q}1}, m_{\tilde{q}2}, m_{\tilde{g}}, p^2 = m_\phi^2$

- ▷ Taylor expansion in external momentum/Higgs mass:
  $m_\phi \ll m_q, m_{\tilde{q}1}, m_{\tilde{q}2}, m_{\tilde{g}}$
  $\longrightarrow$ top-stop-gluino contribution using $m_\phi \ll m_t, m_{\tilde{t}1}, m_{\tilde{t}2}, m_{\tilde{g}}$
  [Harlander Steinhauser ’03 ’04 + Hofmann ’05; Degrassi Slavich ’08]
- ▷ Expansion in SUSY masses: $m_\phi, m_q \ll m_{\tilde{q}_1}, m_{\tilde{q}_2}, m_{\tilde{g}}$
  $\longrightarrow$ bottom-sbottom-gluino for $m_{\tilde{q}_1} = m_{\tilde{q}_2} = m_{\tilde{g}}$ [Harlander Hofmann Mantler ’10]
  $\longrightarrow$ quark-squark-gluino [Degrassi Slavich ’10 + Di Vita ’11 ’12]



3-loop top-stop-gluino contributions known for $m_\phi \ll m_t, m_{\tilde{t}1}, m_{\tilde{t}2}, m_{\tilde{g}}$
[Pak Steinhauser Zerf ’10 ’12]

Outline

Current calculation of MSSM Higgs cross sections (YR1):

SM: ggh@nnlo

SM: Higlu

$$\sigma(pp \to \phi + X) = (g_t^\phi)^2 \left(\sigma_{\text{NLO}}^{t,\text{SM}} + \Delta\sigma_{\text{NNLO}}^{t,\text{SM}}\right) + (g_b^\phi)^2 \sigma_{\text{NLO}}^{b,\text{SM}} + (g_t^\phi)(g_b^\phi)\sigma_{\text{NLO}}^{tb,\text{SM}}$$

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Couplings including resummation from FeynHiggs, e.g.:

$$g_t^h = \frac{\cos\alpha}{\sin\beta} \qquad g_b^h = -\frac{\sin\alpha}{\cos\beta}\frac{1}{1+\Delta_b}\left(1 - \frac{\Delta_b}{\tan\alpha\tan\beta}\right)$$

Resummation of sbottom effects for large $\tan\beta$:

$$\Delta_b = \frac{2\alpha_s}{3\pi} m_{\tilde{g}}\mu\tan\beta I(m_{\tilde{b}1}^2, m_{\tilde{b}2}^2, m_{\tilde{g}}^2) + \ldots$$

- ✗ No squark contributions (except from Δ_b)
- ✗ No electroweak contributions

YR1: "...we will have to include the full SUSY QCD and SUSY EW corrections..."

Goals: Add squark and electroweak effects to $\sigma(pp \to \phi + X)$!

Two computer codes:

- ▷ Bagnaschi, Degrassi, Slavich, Vicini
- ▷ Harlander, Mantler, Liebler: `SusHi` ("Supersymmetric Higgs")

Our road map: Status "Higgs Days" Santander **10/2012** - Talk by P. Slavich

- ✓ Compare the computer codes at NLO
- ✓ Explore different options for renormalization schemes
- ✗ Determine best way to include the NNLO and electroweak effects
- ✗ Produce new numbers and compare with "official" LHCHXSWG root files

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Our road map: Current status **12/2012**

- ✓ Compare the computer codes at NLO
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What do we take into account?

0. Take Higgs and squark sector and Δ_b (with EW contr.) from `FeynHiggs`

1. Calculate XS with quark contributions using full resummation Δ_b ($\sim$ LHCHXSWG):

$$g_b^h \to g_b^h \frac{1 - \Delta_b \frac{\cot\alpha}{\tan\beta}}{1+\Delta_b} \qquad g_b^H \to g_b^H \frac{1 + \Delta_b \frac{\tan\alpha}{\tan\beta}}{1+\Delta_b} \qquad g_b^A \to g_b^A \frac{1 - \Delta_b \frac{1}{\tan^2\beta}}{1+\Delta_b}$$

2. Add squark contributions of third generation:
   - top-stop-gluino contributions:
     Expansion in $m_\phi \ll m_t, m_{\tilde{t}1}, m_{\tilde{t}2}, m_{\tilde{g}}$ for $\phi = h$
     Expansion in SUSY masses $m_\phi, m_t \ll m_{\tilde{t}1}, m_{\tilde{t}2}, m_{\tilde{g}}$ for $\phi \in \{H, A\}$
   - sbottom-bottom-gluino contributions
     in SUSY masses expansion $m_b < m_\phi \ll m_{\tilde{b}1}, m_{\tilde{b}2}, m_{\tilde{g}}$

3. Add NNLO top effects and electroweak contributions:

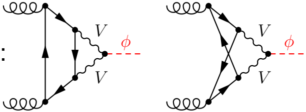
$$\sigma(pp \to \phi + X) = \sigma_{\text{NLO}}^{\text{MSSM}}(1 + \delta_{\text{EW}}^{lq}) + (g_t^\phi)^2 \left(\sigma_{\text{NNLO}}^{t,\text{SM},0} - \sigma_{\text{NLO}}^{t,\text{SM},0}\right)$$

Electroweak contributions by light quarks

`ggh@nnlo`

Electroweak contributions by light quarks: [Aglietti Bonciani Degrassi Vicini '04 '10]

Relevant diagrams with $V \in \{W, Z\}$:



Definition of SUSY electroweak correction factor:

$$\delta_{\rm EW}^{lq} = \frac{\alpha_{\rm EW}}{\pi} 2\text{Re}(\mathcal{A}^{\phi}\mathcal{A}^{\phi,\rm EW})/|\mathcal{A}^{\phi}|^2$$

$$\mathcal{A}^{\phi,\rm EW} = -\frac{3}{8}\frac{x_W}{s_W^2}\left[\frac{2}{c_W^2}\left(\tfrac{5}{4} - \tfrac{7}{3}s_W^2 + \tfrac{22}{9}s_W^4\right)A[x_Z] + 4A[x_W]\right] g_V^{\phi}$$

Complex mass scheme: $x_V = (m_V - i\frac{\Gamma_V}{2})^2/m_\phi^2$

Supersymmetry enters g_V^{ϕ}:
$g_V^h = \sin(\beta-\alpha), \quad g_V^A = 0, \quad g_V^H = \cos(\beta-\alpha)$

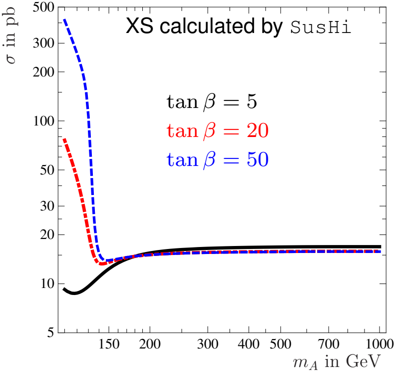
For moderate masses of SM-like Higgs results in similiar correction as SM electroweak correction factor [Actis Passarino Sturm Uccirati '08].

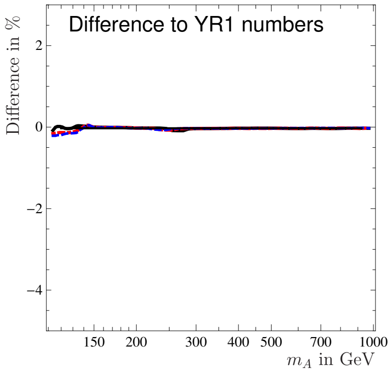
Outline

m_h^{max} scenario with $\mu = 200$ GeV, $\sqrt{s} = 8$ TeV
Variation of m_A and $\tan\beta$
PDF sets: MSTW2008, FH 2.8.6

Difference to Root files obtained with FH 2.8.6

Light Higgs h: only quark contributions





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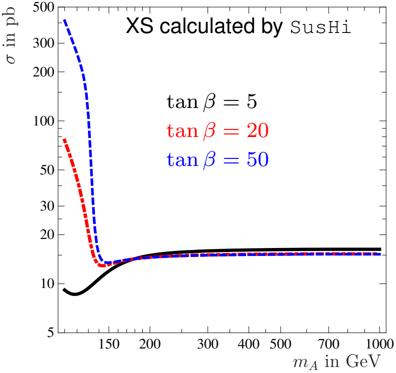
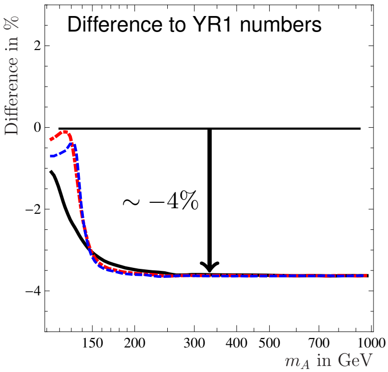
Light Higgs h: quark+squark contributions





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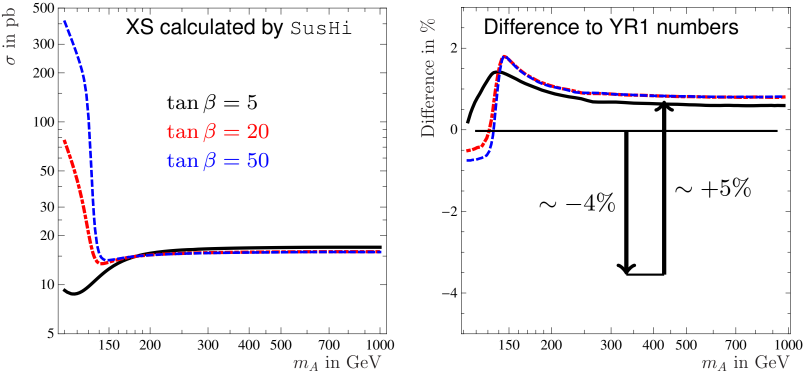
Light Higgs h: quark+squark contributions + electroweak contributions



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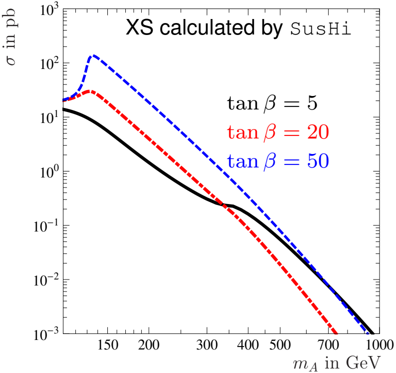
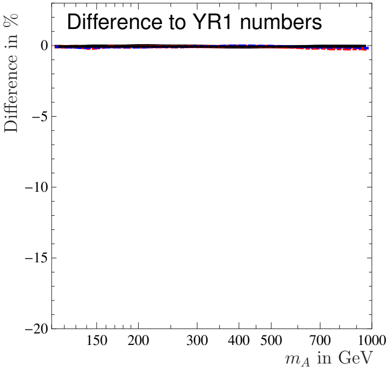
Heavy Higgs H: only quark contributions





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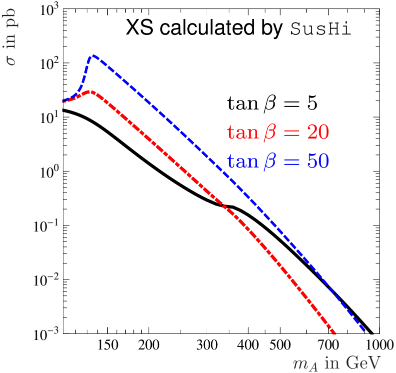

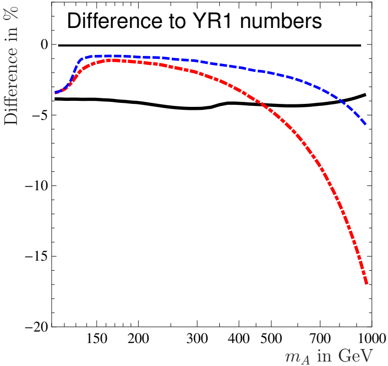

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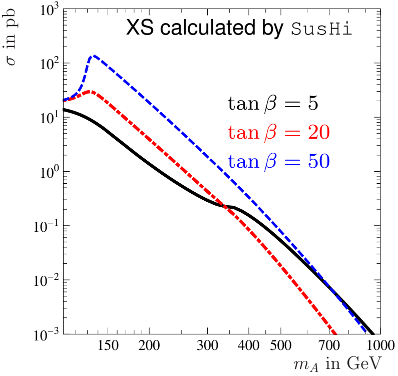
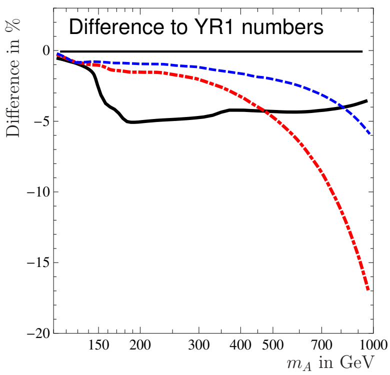
Heavy Higgs H: quark+squark contributions + electroweak contributions





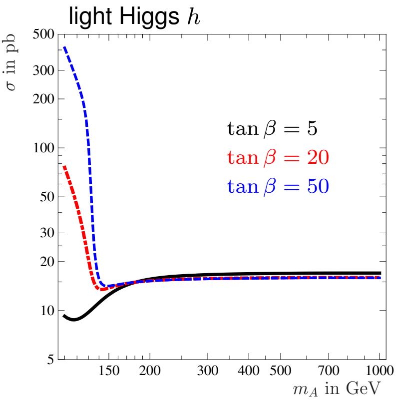
Impact on the "best-fit" MSSM point: [Bechtle Heinemeyer Stål Stefaniak Weiglein Zeune '12]

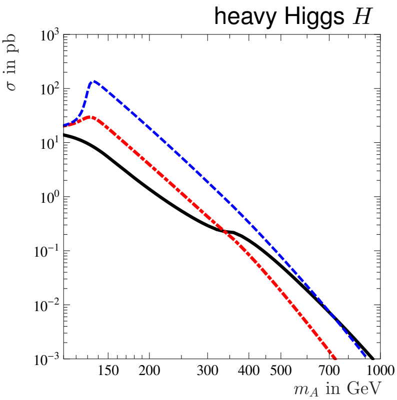
Parameter	Light Higgs case	Best fit		Heavy Higgs case	Best fit	
M_A [GeV]	300	669	860	120.5	124.2	128.0
$\tan\beta$	15	16.5	26	9.7	9.8	10.8
μ [GeV]	1900	2640	(3000)	1899	2120	2350
$M_{\tilde{q}_3}$ [GeV]	450	1100	(1500)	580	670	740
$M_{\tilde{l}_3}$ [GeV]	250	285	(1500)	(200)	323	(1500)
A_f [GeV]	1100	2569	3600	1450	1668	1840
M_2 [GeV]	(200)	201	450	(200)	304	370
M_h [GeV]	122.2	126.1	127.1	63.0	65.3	72.0
M_H [GeV]	280	665	860	123.9	125.8	126.4
$M_{H^\pm}$ [GeV]	310	673	860	136.5	138.8	141.5

Contributions	$\sigma(gg \to h + X)$		Contributions	$\sigma(gg \to H + X)$	
$t + b$	17.12 pb	$\Delta(t+b)$	$t + b$	18.56 pb	$\Delta(t+b)$
$t + b + \tilde{t}$	16.42 pb	-4.1%	$t + b + \tilde{t}$	16.11 pb	-13.2%
$t + b + \tilde{t} + \tilde{b}$	16.43 pb	-4.0%	$t + b + \tilde{t} + \tilde{b}$	16.13 pb	-13.1%
+EW	17.14 pb	$+0.1\%$	+EW	16.79 pb	-9.5%

Remaining question: How do we estimate the uncertainty?
Renormalization and factorization scale dependence $\mu = \mu_R = \mu_F$
Scale variation between $\mu \in [m_\phi/2, 2m_\phi]$:

Reminder: XS obtained by `SusHi`





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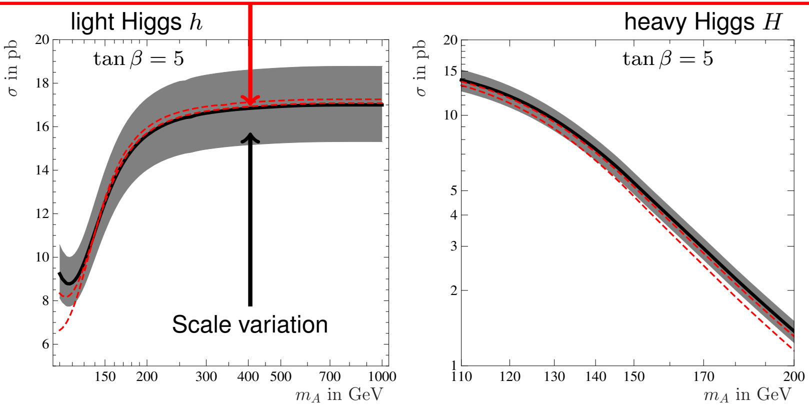
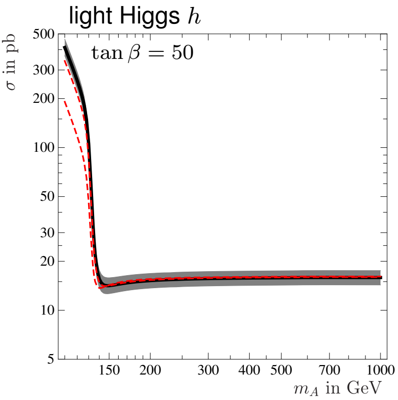
Different renormalization scheme for bottom Yukawa: $m_b = m_b^{\overline{\text{MS}}}(m_b), m_b^{\overline{\text{MS}}}(m_\phi)$

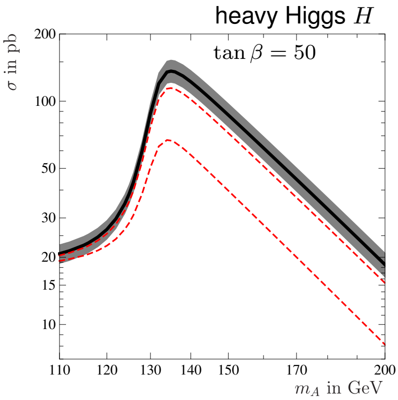


Remaining question: How do we estimate the uncertainty?

Renormalization and factorization scale dependence $\mu = \mu_R = \mu_F$

Scale variation between $\mu \in [m_\phi/2, 2m_\phi]$:





Outline

We provide an update of the cross sections for light Higgs h, heavy Higgs H and pseudoscalar A in the MSSM via gluon fusion taking into account

- quark contributions at NLO QCD (top up to NNLO QCD) including resummation of $\tan\beta$-enhanced sbottom effects ($\sim$ YR1).
- squark contributions at NLO (SUSY-) QCD.
- electroweak contributions by light quarks (approx.).

The impact of the squark and electroweak contributions for moderate Higgs masses $m_\phi < 200$ GeV is $\mathcal{O}(5\%)$ for a SUSY spectrum at the TeV scale.

Thank you for your attention!

Cancellation of logs - Bottom 2-loop contributions: [Degrassi Slavich, arXiv:1007.3465]

$$G_b^{2\ell} = C_F\, G_b^{(g,C_F)} + C_A\, G_b^{(g,C_A)}$$

$$2\, m_b^2\, G_b^{(g,C_F)} = \mathcal{F}_{1/2}^{(2\ell,a)}(\tau_b) + \mathcal{F}_{1/2}^{(2\ell,b)}(\tau_b)\left(\ln\frac{m_b^2}{Q^2} - \frac{1}{3}\right)$$

$$2\, m_b^2\, G_b^{(g,C_A)} = \mathcal{G}_{1/2}^{(2\ell,C_A)}(\tau_b)$$

In the limit $\tau_b = 4m_b^2/m_\phi^2 \ll 1$ the above expressions reduce to:

$$\mathcal{F}_{1/2}^{(2\ell,a)}(\tau) = -\tau\left[9 + \frac{9}{5}\zeta_2^2 - \zeta_3 - (1+\zeta_2+4\,\zeta_3)\ln(\frac{-4}{\tau}) - (1-\zeta_2)\ln^2(\frac{-4}{\tau}) + \frac{1}{4}\ln^3(\frac{-4}{\tau}) + \frac{1}{48}\ln^4(\frac{-4}{\tau})\right] + \mathcal{O}(\tau^2)$$

$$\mathcal{F}_{1/2}^{(2\ell,b)}(\tau) = 3\,\tau\left[1 + \frac{1}{2}\ln(\frac{-4}{\tau}) - \frac{1}{4}\ln^2(\frac{-4}{\tau})\right] + \mathcal{O}(\tau^2)$$

$$\mathcal{G}_{1/2}^{(2\ell,C_A)}(\tau) = -\tau\left[3 - \frac{8}{5}\zeta_2^2 - 3\,\zeta_3 + 3\,\zeta_3\ln(\frac{-4}{\tau}) - \frac{1}{4}(1+2\,\zeta_2)\ln^2(\frac{-4}{\tau}) - \frac{1}{48}\ln^4(\frac{-4}{\tau})\right] + \mathcal{O}(\tau^2)$$

For $Q = m_b$ the various logarithms accidentally cancel in case of gluon fusion.

Renormalization of the stop and the sbottom sector

Typically in the stop sector $m_t, m_{\tilde{t}1}, m_{\tilde{t}2}, \theta_{\tilde{t}}$ are taken to be on-shell parameters and A_t is derived from

$$\sin(2\theta_t) = \frac{2m_t(A_t - \mu/\tan\beta)}{{m_{\tilde{t}1}}^2 - {m_{\tilde{t}2}}^2} \quad .$$

However in the sbottom sector a similar procedure induces large corrections:

$$\delta A_b \propto \alpha_s \mu^2 \tan^2\beta / m_{\tilde{g}}$$

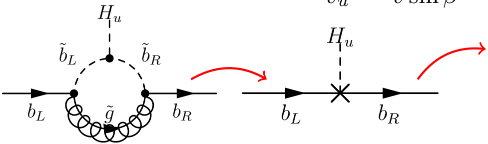
Alternative scheme: [Brignole et al. '02; Rzehak et al. '04 '10; Degrassi Slavich '10]
Define A_b from $\tilde{b}_1\tilde{b}_2 A$ vertex and use $A_b, m_{\tilde{b}1}, m_{\tilde{b}2}, \theta_{\tilde{b}}$ as on-shell parameters. $\Rightarrow$ m_b^{sbot} is a derived quantity.

Resummation of large $\tan\beta$-enhanced terms in the MSSM

$$\mathcal{L} \supset -Y_t H_u Q t_R + Y_b H_d Q b_R$$

Using $\langle H_u \rangle = v_u$, $\langle H_d \rangle = v_d$ and $v_d^2 + v_u^2 = v^2$, $\tan\beta = v_u / v_d$ we define

$$Y_t = \frac{m_t}{v_u} = \frac{m_t}{v \sin\beta}, \qquad Y_b = \frac{m_b}{v_d} = \frac{m_b}{v \cos\beta}$$



$$\mathcal{L}^{\text{eff}} \supset Y_b H_d Q b_R - \tilde{Y}_b H_u^* Q b_R$$

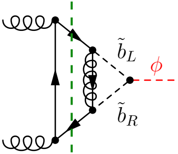
$$\Delta_b = \frac{\tilde{Y}_b v_u}{Y_b v_d} =: \epsilon \tan\beta$$

The effective Lagrangian motivates:

$$m_b = Y_b v_d + \tilde{Y}_b v_u = Y_b v_d (1 + \epsilon \tan\beta)$$

$$\Rightarrow \quad Y_b = \frac{m_b}{v_d (1 + \Delta_b)}$$

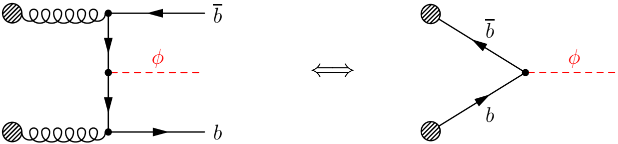
This replacement implies a resummation of large $\tan\beta$-enhanced terms:



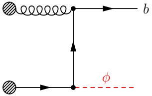
Bottom-quark annihilation:
$pp \to (b\bar{b})\phi + X$ for enhanced couplings to b-quarks relevant $\to$ MSSM!

4 flavour scheme (4FS)
Collinear logarithms $\propto \log(m_b/m_\phi)$

5 flavour scheme (5FS)
Resummmation of logarithms
b quarks as partons

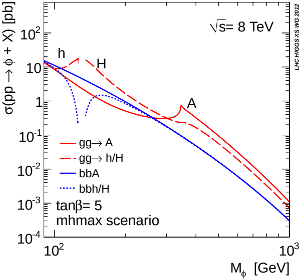


Calculation of inclusive cross section at NNLO in the 5FS:
`bbh@nnlo` [Harlander Kilgore '03]



Distributions for Higgs+jet(s) production in the 5FS [Harlander Ozeren Wiesemann '10]

Enhancement of g_b^ϕ for large $\tan\beta$ in MSSM



Idea: Use results from 5FS and reweight accordingly with resummed MSSM couplings [Guasch Häfliger Spira '03]:

$$g_b^A = g_b^A \frac{1}{1+\Delta_b}\left(1 - \frac{1}{\tan^2\beta}\Delta_b\right)$$

$$g_b^h = g_b^h \frac{1}{1+\Delta_b}\left(1 - \frac{1}{\tan\beta\tan\alpha}\Delta_b\right)$$

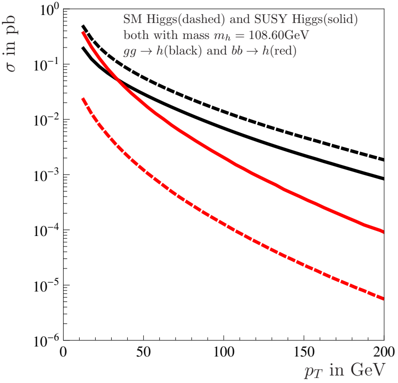
$$g_b^H = g_b^H \frac{1}{1+\Delta_b}\left(1 + \frac{\tan\alpha}{\tan\beta}\Delta_b\right)$$

$$\left.\begin{array}{l}\Delta_{Ab} = -\frac{C_F}{2\pi}\alpha_s(\mu_r)m_{\tilde{g}}A_b I(m_{\tilde{b}1}^2, m_{\tilde{b}2}^2, m_{\tilde{g}}^2)\\ \Delta_b = \frac{C_F}{2\pi}\alpha_s(\mu_r)m_{\tilde{g}}\mu\tan\beta I(m_{\tilde{b}1}^2, m_{\tilde{b}2}^2, m_{\tilde{g}}^2)\end{array}\right\} \Delta_b \to \Delta_b \frac{1}{1+\Delta_{Ab}}$$

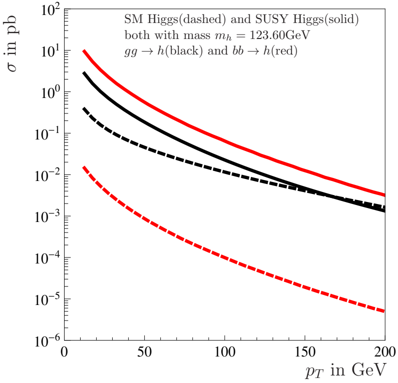
Differential cross section $gg/bb \to \phi$ in transverse momentum p_T

mhmax: $M_{\tilde{q}_{L,R}} = 750\text{GeV}, A_q = 2\text{TeV}, m_{\tilde{g}} = 800\text{GeV}, \mu = 500\text{GeV}, m_A = 150\text{GeV}$

$\tan\beta = 5$



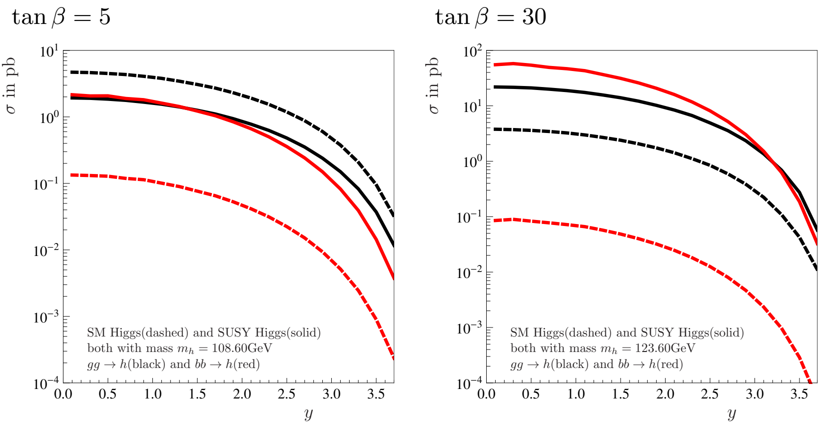
$\tan\beta = 30$



$bb \to \phi$ can dominate $gg \to \phi$ in SUSY showing a different slope!

Differential cross section $gg/bb \to \phi$ in rapidity y

mhmax: $M_{\tilde{q}_{L,R}} = 750$GeV, $A_q = 2$TeV, $m_{\tilde{g}} = 800$GeV, $\mu = 500$GeV, $m_A = 150$GeV



$bb \to \phi$ can dominate $gg \to \phi$ in SUSY showing a different slope!