Restrictions on the heavy supersymmetry parameter space and simplified parametric scenarios in the effective field theory approach

Mikhail Dubinin

work with Elena Petrova

SINP MSU

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General remarks

Two approaches to precise calculations of the Higgs mass m_h and the Higgs mass spectrum

– fixed order (up to 3-loop) calculations of the complete diagram set in the "full"MSSM. Uses fixed-order evaluations of the renormalized self-energies in the Higgs propagator matrix.
Preferrable for low MSSM scale, where `logs` $\sim$ power terms.

– resummation in the effective theories (EFT). Uses resummation of certain classes of diagrams in the zero external momentum approximation. MSSM particles decouple at M_{SUSY} scale, are integrated out at the thresholds. Pole masses of scalars are evaluated for the two-doublet effective potential transformed to the mass basis.
Preferrable for high MSSM scales, where large `logs` should be resummed.

Evaluations in our case
– resummed effective one-loop two-doublet Higgs potential ($\overline{MS}$ scheme) in the generic mass basis
– moderate m_A scenario, rotation to the Higgs basis is not used for matching with the low-energy SM-like model at m_A scale, so not specifically corrections to m_h but full spectrum of m_h,m_H,m_A and $m_{H^\pm}$ defines the mass basis.

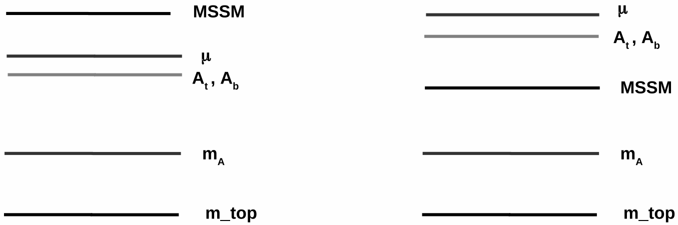
Mass scales

The lightest CP-even MSSM Higgs boson mass $m_h \sim 125$ ГэВ

Five MSSM Higgs bosons: $h,\ H, A, H^{\pm}$,

Calculation frameworks for m_h: effective potential decomposition in $1/M_{SUSY}$, $\overline{MS}$ scheme, RGEs [1]

Mass scales for the $\Delta\lambda^{\mathtt{wfr}}_{F,D}$ scenario under consideration



Low-energy effective field theory at the scale higher than m_{top} is THDM. Higgsinos, gluino and EW gauginos are very heavy and decouple. Main correctons are due to squarks.

Five-dimensional parameter space: $m_A, \tan\beta, M_{\mathrm{SUSY}}, A_t = A_b, \mu$

[1] Haber,Hempfling,PR D48 4280 (1993); Sasaki,Carena,Wagner, NP B381 66 (1992); Akhmetzyanova,Dolgopolov,M.D. PR D71 075008 (2005); Phys.Part.Nucl. 37, 677 (2006); Lee,Wagner, PR D92, 075032 (2015) Carena,Haber,Low,Shah,Wagner PR D91 035003 (2015)

THDM in the mass basis

Radiatively corrected Higgs sector of the MSSM is a THDM

$$\Phi_i = \left(\begin{array}{c} -i\omega_i^{\pm} \\ \frac{1}{\sqrt{2}}(v_i + \eta_i + i\chi_i) \end{array} \right), \qquad \langle \Phi_i \rangle = \frac{1}{\sqrt{2}} \left(\begin{array}{c} 0 \\ v_i \end{array} \right), \qquad i = 1, 2$$

$$\tan\beta = \frac{v_2}{v_1}, \qquad v = \sqrt{v_1^2 + v_2^2} = 246 \text{ GeV}$$

where $SU(2)$ states are related to mass states by means of two orthogonal rotations

$$\left(\begin{array}{c} \eta_1 \\ \eta_2 \end{array} \right) = \mathcal{O}_\alpha \left(\begin{array}{c} h \\ H \end{array} \right), \qquad \left(\begin{array}{c} \chi_1 \\ \chi_2 \end{array} \right) = \mathcal{O}_\beta \left(\begin{array}{c} G^0 \\ A \end{array} \right), \qquad \left(\begin{array}{c} \omega_1^{\pm} \\ \omega_2^{\pm} \end{array} \right) = \mathcal{O}_\beta \left(\begin{array}{c} G^{\pm} \\ H^{\pm} \end{array} \right)$$

where rotation matrix

$$\mathcal{O}_X = \left(\begin{array}{cc} \cos X & -\sin X \\ \sin X & \cos X \end{array} \right), \qquad X = \alpha, \beta. \tag{1}$$

THDM Higgs potential in a generic basis

$$U_{eff}(\Phi_1,\Phi_2) = -\mu_1^2(\Phi_1^\dagger\Phi_1) - \mu_2^2(\Phi_2^\dagger\Phi_2) - {\mu_{12}}^2(\Phi_1^\dagger\Phi_2) - ({\mu_{12}}^2)^*(\Phi_2^\dagger\Phi_1)$$
$$+\lambda_1(\Phi_1^\dagger\Phi_1)^2 + \lambda_2(\Phi_2^\dagger\Phi_2)^2 + \lambda_3(\Phi_1^\dagger\Phi_1)(\Phi_2^\dagger\Phi_2) + \lambda_4(\Phi_1^\dagger\Phi_2)(\Phi_2^\dagger\Phi_1)$$
$$+\frac{\lambda_5}{2}(\Phi_1^\dagger\Phi_2)^2 + \frac{{\lambda_5}^*}{2}(\Phi_2^\dagger\Phi_1)^2 + \lambda_6(\Phi_1^\dagger\Phi_1)(\Phi_1^\dagger\Phi_2) + {\lambda_6}^*(\Phi_1^\dagger\Phi_1)(\Phi_2^\dagger\Phi_1)$$
$$+\lambda_7(\Phi_2^\dagger\Phi_2)(\Phi_1^\dagger\Phi_2) + {\lambda_7}^*(\Phi_2^\dagger\Phi_2)(\Phi_2^\dagger\Phi_1)$$

can be reduced to the potential in the mass basis ($\lambda_{5,6,7}$ and μ_{12}^2 real)

$$U(h,H,A,H^\pm,G^0,G^\pm) = \frac{m_h^2}{2}h^2 + \frac{m_H^2}{2}H^2 + \frac{m_A^2}{2}A^2 + m_{H^\pm}^2 H^+H^- + I(3) + I(4)$$

by means of explicit symbolic transformation for $\lambda_1, ...\lambda_7$ in terms of mixing angles and pole masses[2]

[2] M.D.,Semenov, EJP C28, 223 (2003); Boudjema,Semenov, Phys.Rev. D66 095007 (2002), Gunion,Haber, PR D67 075019 (2003)

$$
\begin{aligned}
\lambda_1 &= \frac{1}{2v^2}[(\frac{s_\alpha}{c_\beta})^2 m_h^2 + (\frac{c_\alpha}{c_\beta})^2 m_H^2 - \frac{s_\beta}{c_\beta^3}\mu_{12}^2] + \frac{1}{4}(\lambda_7 \mathtt{tan}^3\beta - 3\lambda_6 \mathtt{tan}\beta), \\
\lambda_2 &= \frac{1}{2v^2}[(\frac{c_\alpha}{s_\beta})^2 m_h^2 + (\frac{s_\alpha}{s_\beta})^2 m_H^2 - \frac{c_\beta}{s_\beta^3}\mu_{12}^2] + \frac{1}{4}(\lambda_6 \mathtt{cot}^3\beta - 3\lambda_7 \mathtt{cot}\beta), \\
\lambda_3 &= \frac{1}{v^2}[2m_{H\pm}^2 - \frac{\mu_{12}^2}{s_\beta c_\beta} + \frac{s_{2\alpha}}{s_{2\beta}}(m_H^2 - m_h^2)] - \frac{1}{2}(\lambda_6 \mathtt{cot}\beta + \lambda_7 \mathtt{tan}\beta), \\
\lambda_4 &= \frac{1}{v^2}(\frac{\mu_{12}^2}{s_\beta c_\beta} + m_A^2 - 2m_{H\pm}^2) - \frac{1}{2}(\lambda_6 \mathtt{cot}\beta + \lambda_7 \mathtt{tan}\beta), \\
\lambda_5 &= \frac{1}{v^2}(\frac{\mu_{12}^2}{s_\beta c_\beta} - m_A^2) - \frac{1}{2}(\lambda_6 \mathtt{cot}\beta + \lambda_7 \mathtt{tan}\beta),
\end{aligned}
$$

massless goldstone G^0 is ensured by

$$
\mathtt{Re}\mu_{12}^2 = s_\beta c_\beta \left(m_A^2 + \frac{v^2}{2}(2\mathtt{Re}\lambda_5 + \mathtt{Re}\lambda_6 \cot\beta + \mathtt{Re}\lambda_7 \tan\beta) \right)
$$

Inverse transformation for pole masses in terms of λ_i

MSSM
$M_{\mathtt{SUSY}}$:
$m_{\mathtt{top}}$:

$$
\lambda_{1,2}^{\mathtt{SUSY}} = \frac{g_1^2 + g_2^2}{8}, \qquad \lambda_3^{\mathtt{SUSY}} = \frac{g_2^2 - g_1^2}{4}, \qquad \lambda_4^{\mathtt{SUSY}} = -\frac{g_2^2}{2}, \qquad \lambda_{5,6,7}^{\mathtt{SUSY}} = 0.
$$

$$
\lambda_i = \lambda_i^{\mathtt{SUSY}} - \Delta\lambda_i \qquad \Delta\lambda_i = \Delta\lambda_i^{\mathtt{thr}} + \Delta\lambda_k^{\mathtt{LL}} \; (i = 1,..,7, k = 1,..,4)
$$

in the mass basis

$$\begin{aligned}
m_h^2 &= s_{\alpha+\beta}^2 m_Z^2 + c_{\alpha-\beta}^2 m_A^2 - v^2(\Delta\lambda_1 s_\alpha^2 c_\beta^2 + \Delta\lambda_2 c_\alpha^2 s_\beta^2 \\
&- 2(\Delta\lambda_3 + \Delta\lambda_4) c_\alpha c_\beta s_\alpha s_\beta + \mathtt{Re}\Delta\lambda_5 (s_\alpha^2 s_\beta^2 + c_\alpha^2 c_\beta^2) \\
&- 2c_{\alpha+\beta}(\mathtt{Re}\Delta\lambda_6 s_\alpha c_\beta - \mathtt{Re}\Delta\lambda_7 c_\alpha s_\beta)), \\
m_H^2 &= c_{\alpha+\beta}^2 m_Z^2 + s_{\alpha-\beta}^2 m_A^2 - v^2(\Delta\lambda_1 c_\alpha^2 c_\beta^2 + \Delta\lambda_2 s_\alpha^2 s_\beta^2 \\
&+ 2(\Delta\lambda_3 + \Delta\lambda_4) c_\alpha c_\beta s_\alpha s_\beta + \mathtt{Re}\Delta\lambda_5 (c_\alpha^2 s_\beta^2 + s_\alpha^2 c_\beta^2) \\
&+ 2s_{\alpha+\beta}(\mathtt{Re}\Delta\lambda_6 c_\alpha c_\beta + \mathtt{Re}\Delta\lambda_7 s_\alpha s_\beta)), \\
\tan 2\alpha &= \frac{s_{2\beta}(m_A^2 + m_Z^2) + v^2((\Delta\lambda_3 + \Delta\lambda_4)s_{2\beta} + 2c_\beta^2 \mathtt{Re}\Delta\lambda_6 + 2s_\beta^2 \mathtt{Re}\Delta\lambda_7)}{c_{2\beta}(m_A^2 - m_Z^2) + v^2(\Delta\lambda_1 c_\beta^2 - \Delta\lambda_2 s_\beta^2 - \mathtt{Re}\Delta\lambda_5 c_{2\beta} + (\mathtt{Re}\Delta\lambda_6 - \mathtt{Re}\Delta\lambda_7)s_{2\beta})},
\end{aligned}$$

or equivalent equations in the basis of $SU(2)$ states[3]

$$\begin{aligned}
m_{H,h}^2 &= \frac{1}{2}(m_A^2 + m_Z^2 + \Delta\mathcal{M}_{11}^2 + \Delta\mathcal{M}_{22}^2 \pm \sqrt{m_A^4 + m_Z^4 - 2m_A^2 m_Z^2 c_{4\beta} + C}), \\
\tan 2\alpha &= \frac{2\Delta\mathcal{M}_{12}^2 - (m_Z^2 + m_A^2)s_{2\beta}}{(m_Z^2 - m_A^2)c_{2\beta} + \Delta\mathcal{M}_{11}^2 - \Delta\mathcal{M}_{22}^2},
\end{aligned}$$

[3] Djouadi,Maiani,Polosa,Quevillon,Riquer, EPJ C73 2650 (2013), JHEP 1506 168 (2015)

where, using the notation of Djouadi et al.

$$\mathcal{M}_Y^2 = \begin{pmatrix} \mathcal{M}_{11}^2 & \mathcal{M}_{12}^2 \\ \mathcal{M}_{21}^2 & \mathcal{M}_{22}^2 \end{pmatrix}, \qquad \mathcal{M}_{ij}^2 = \frac{\partial^2 U}{\partial Y_i \partial Y_j}, \qquad Y = \eta, \chi, \omega^\pm, \qquad i, j = 1, 2$$

$$\mathcal{M}_\eta^2 = \begin{pmatrix} \mathcal{M}_{11}^2 & \mathcal{M}_{12}^2 \\ \mathcal{M}_{12}^2 & \mathcal{M}_{22}^2 \end{pmatrix} + \begin{pmatrix} \Delta\mathcal{M}_{11}^2 & \Delta\mathcal{M}_{12}^2 \\ \Delta\mathcal{M}_{12}^2 & \Delta\mathcal{M}_{22}^2 \end{pmatrix},$$

$$\mathcal{M}_{11}^2 = m_A^2 s_\beta^2 + m_Z^2 c_\beta^2, \qquad \mathcal{M}_{22}^2 = m_A^2 c_\beta^2 + m_Z^2 s_\beta^2, \qquad \mathcal{M}_{12}^2 = -s_\beta c_\beta (m_A^2 + m_Z^2),$$

$$\begin{aligned} \Delta\mathcal{M}_{11}^2 &= -v^2(\Delta\lambda_1 c_\beta^2 + \mathrm{Re}\Delta\lambda_5 s_\beta^2 + \mathrm{Re}\Delta\lambda_6 s_{2\beta}), \\ \Delta\mathcal{M}_{22}^2 &= -v^2(\Delta\lambda_2 s_\beta^2 + \mathrm{Re}\Delta\lambda_5 c_\beta^2 + \mathrm{Re}\Delta\lambda_7 s_{2\beta}), \\ \Delta\mathcal{M}_{12}^2 &= -v^2(\Delta\lambda_{34} s_\beta c_\beta + \mathrm{Re}\Delta\lambda_6 c_\beta^2 + \mathrm{Re}\Delta\lambda_7 s_\beta^2), \end{aligned}$$

$$C = 4\Delta\mathcal{M}_{12}^4 + (\Delta\mathcal{M}_{11}^2 - \Delta\mathcal{M}_{22}^2)^2 - 2(m_A^2 - m_Z^2)(\Delta\mathcal{M}_{11}^2 - \Delta\mathcal{M}_{22}^2)c_{2\beta} - 4(m_A^2 + m_Z^2)\Delta\mathcal{M}_{12}^2 s_{2\beta}$$

Simplified representation for heavy CP-even Higgs boson mass if $\Delta\mathcal{M}_{12}^2 = 0$

$$m_H^2 = m_A^2 + m_Z^2 - m_h^2 + \Delta\mathcal{M}_{11}^2 + \Delta\mathcal{M}_{22}^2 \tag{2}$$

Post-Higgs MSSM scenarios

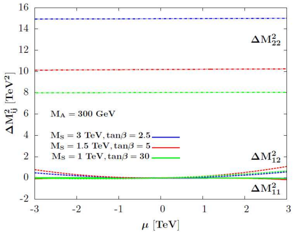
1. hMSSM scenario, uses simplified mixing matrix[4]
$\Delta\lambda_i$: 1-loop (ϵ-approximation); 1,2-loop (leading logarithms)

$$\Delta\mathcal{M}_{11} \sim 0, \qquad \Delta\mathcal{M}_{12} \sim 0, \qquad \Delta\mathcal{M}_{22} \neq 0$$

$$\Delta\mathcal{M}^2_{22} = \frac{m_h^2(m_A^2 + m_Z^2 - m_h^2) - m_A^2 m_Z^2 c^2_{2\beta}}{m_Z^2 c_\beta^2 + m_A^2 s_\beta^2 - m_h^2},$$

$$m_H^2 = \frac{(m_A^2 + m_Z^2 - m_h^2)(m_Z^2 c_\beta^2 + m_A^2 s_\beta^2) - m_A^2 m_Z^2 c^2_{2\beta}}{m_Z^2 c_\beta^2 + m_A^2 s_\beta^2 - m_h^2},$$

$$\alpha = -\arctan\left(\frac{(m_Z^2 + m_A^2) s_\beta c_\beta}{m_Z^2 c_\beta^2 + m_A^2 s_\beta^2 - m_h^2}\right)$$



$m_h = 123 - 129$ ГэВ

Free parameters: m_A, $\tan\beta$
ϵ-approximation does not respect $\lambda_i(\alpha, \beta, m_{h,H,H^\pm})$ transformation to the mass basis.

[4] Djouadi,Maiani,Polosa,Quevillon,Riquer, EPJ C73 2650 (2013), JHEP 1506 168 (2015); Maiani,Polosa,Riquer, PL B274 274 (2013)

2. Low-tb-high scenario[5] (FeynHiggs) $0.5 \leq \tan\beta \leq 10$, 150 ГэВ $\leq m_A \leq 500$ ГэВ

1) all fermionic superpartner masses $\sim M_{\rm SUSY}$;
2) $M_{\rm SUSY}$ variation range from several TeV for large m_A $(\tan\beta)$ up to 100 TeV for moderate m_A $(\tan\beta)$ with imposed constraints

$$\begin{aligned} \tan\beta \leq 2 \quad &: \quad X_t/M_{\rm SUSY} = 2, \qquad X_t = A_t - \mu/\tan\beta, \\ 2 < \tan\beta \leq 8.6 \quad &: \quad X_t/M_{\rm SUSY} = 0.0375\tan^2\beta - 0.7\tan\beta + 3.25, \\ 8.6 < \tan\beta \quad &: \quad X_t/M_{\rm SUSY} = 0; \end{aligned}$$

3) $A_t = 2$ TэB, $\mu = 1.5$ TeV, gaugino mass $M_2 = 2$ TeV.

3. EFT approach, Lee,Wagner, PR D92, 075032 (2015); Carena, Haber, Low, Shah, Wagner PR D91 035003 (2015). Uses SM→THDM matching at m_A scale in the Higgs basis or effective THDM potential in a generic basis.

We use the approach which in the following is denominated as '$\Delta\lambda^{\tt wfr}_{F,D}$ scenario'[6] Has beeen used for the case of explicit CP violaton (Workshop on CP Studies and Non-Standard Higgs Physics, CERN Report 2006-009).

[5] S. Heinemeyer, LHC-HXSWG-3, E. Bagnashi *et al.*, LHCHXSWG-INT-2015-004; J.R. Espinosa and R. J. Zhang, JHEP, **0003**, 26 (2000).

[6] Akhmetzyanova,Dolgopolov, M.D., PR D71, 075008 (2005)

$\Delta\lambda^{\texttt{wfr}}_{F,D}$ scenario

Set of corrections:

– 1-loop resummed threshold, wave-function renormalization
– non-leading D-terms
– 2-loop electroweak and QCD[7]
– Yukawa

For instance,

$$\begin{aligned}\lambda_1 \quad = \quad & \frac{g_2^2+g_1^2}{8} + \frac{3}{32\pi^2}\left[h_b^4\frac{|A_b|^2}{M^2_{\rm SUSY}}\left(2-\frac{|A_b|^2}{6M^2_{\rm SUSY}}\right) - h_t^4\frac{|\,\mu|^4}{6M^4_{\rm SUSY}}\right. + \\ & + 2h_b^4 l + \left.\frac{g_2^2+g_1^2}{4\,M^2_{\rm SUSY}}(h_t^2|\,\mu|^2 - h_b^2|A_b|^2)\right] + \Delta\,\lambda_1^{\rm wfr} + \\ & + \frac{1}{768\pi^2}\,\left(11g_1^4+9g_2^4-36\,(g_1^2+g_2^2)\,h_b^2\right) l \,-\, \Delta\lambda_1[2-\texttt{loop}],\end{aligned}$$

where $l = log(M^2_{SUSY}/\sigma^2)$ and $\Delta\,\lambda_1^{\rm wfr}$, $\Delta\lambda_1[2-\texttt{loop}]$ are

[7] Haber,Hempfling,Hoang, ZP C75 539 (1997); Carena,Espinosa,Quiros,Wagner PL B355 209 (1995); Heinemeyer,Hollik,Weiglein, EPJC C9 343 (1999); Pilaftsis,Wagner, NP B553 3 (1999)

`wfr` terms

$$\Delta\,\lambda_1^{\rm wfr} = \frac{1}{2}(g_1^2+g_2^2)A'_{11}, \qquad \Delta\,\lambda_2^{\rm wfr} = \frac{1}{2}(g_1^2+g_2^2)A'_{22},$$

$$\Delta\,\lambda_3^{\rm wfr} = -\,\frac{1}{4}(g_1^2-g_2^2)(A'_{11}+A'_{22}), \quad \Delta\,\lambda_4^{\rm wfr} = -\,\frac{1}{2}g_2^2(A'_{11}+A'_{22}), \quad \Delta\,\lambda_5^{\rm field} = 0,$$

$$\Delta\,\lambda_6^{\rm wfr} = \frac{1}{8}(g_1^2+g_2^2)(A'_{12}-{A'_{21}}^*) = 0, \quad \Delta\,\lambda_7^{\rm wfr} = \frac{1}{8}(g_1^2+g_2^2)(A'_{21}-{A'_{12}}^*) = 0,$$

where A'

$$A'_{ij} = -\,\frac{3}{96\,\pi^2\,M_{SUSY}^{\,2}}\left(h_t^2\left[\begin{array}{cc} |\mu|^2 & -\mu^* A_t^* \\ -\mu A_t & |A_t|^2 \end{array}\right] + \, h_b^2\left[\begin{array}{cc} |A_b|^2 & -\mu^* A_b^* \\ -\mu A_b & |\mu|^2 \end{array}\right]\right) \times$$

$$\times \left(1 - \,\frac{1}{2}\,l\right)\,.$$

two-loop terms

$$\Delta\lambda_1[2-\texttt{loop}] = -\frac{3}{16\pi^2}h_b^4\frac{1}{16\pi^2}(\frac{3}{2}h_b^2+\frac{1}{2}h_t^2-8g_{\rm S}^2)(X_b l + l^2)+$$

$$+\frac{3}{192\pi^2}h_t^4\frac{1}{16\pi^2}\frac{|\mu|^4}{M_{\rm SUSY}^4}(9h_t^2-5h_b^2-16g_{\rm S}^2)l$$

Benchmark parameter sets

4. $m_h^{\rm alt}$ ($m_h^{\rm mod+}$)[8] $A/M_{\rm SUSY} = 2.45(1.5)$

5. Small μ scenario

...

Input parameter set in the following evaluations is in most cases identical to Bagnaschi et al, 'Benchmark scenarios', LHCHXSWG-INT-2015-004 unless otherwise specified.

[8] ATLAS, CMS

Simplified mixing matrix (hMSSM)

.

MSSM parameter sets

$(i;j)$	j, $M_{\rm SUSY}$ [ТэВ]			
$i, \tan\beta$	1	1.5	3	3.5
1	2 3.5	6 3.1	5 8.3	10 8
2.5	2 6.5	4 6.5	5.5 14	10 8.5
5	2.2 $(7;10)$	3 $(-5;5)$	5 $(-5;5)$	5 $(-5;5)$
30	1.4 $(-2;2)$	1.7 $(-3;3)$	0 $(-9;9)$	0.5 $(-11;11$

Таблица : Parameter sets $(i;j) \equiv (\tan\beta, M_{\rm SUSY}, A, \mu)_{ij}$, where $i,j = 1,\dots,4$, $m_h = 123-128$ GeV, $m_A = 300$ GeV, in [TeV]. The sets (2;3),(3;2),(4;1) correspond to Djouadi et al, 2013.

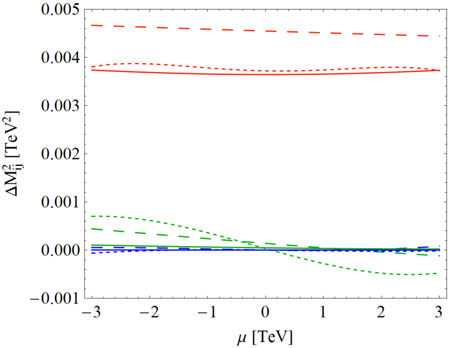
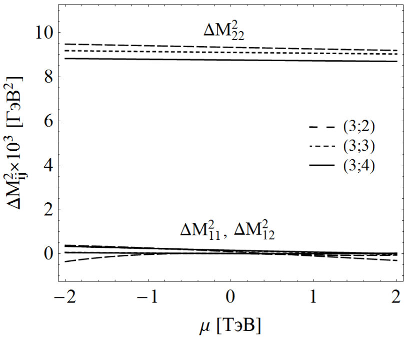


Рис. : $\Delta\mathcal{M}^2_{11}$ - green, $\Delta\mathcal{M}^2_{12}$ - blue, $\Delta\mathcal{M}^2_{22}$ - red, (3;3) - long-dashed line, (4;2) - dashed line, (4;4) - solid line.

For $\tan\beta$ >5 and M_{SUSY} >1 TeV mixing is weakly dependent on μ at some fixed A respecting m_h =125 GeV, so $\Delta\mathcal{M}^2_{11,12}$ =0 is a satisfatory approximation. For the full 5-dim parameter space m_A, $\tan\beta$, μ, $A_{t,b} = A$, M_S such approximation is not always valid. Best agreement is reached at M_{SUSY} ≥3.5 TeV and $\tan\beta$ ∼30.

Mixing matrix elements for $\tan\beta$ >5 and M_{SUSY} >1 TeV, $\Delta\lambda^{\mathtt{wfr}}_{F,D}$ scenario



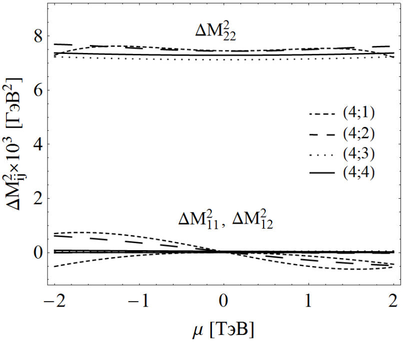


Рис. : (i,j)=(column,line number) denotes the parameter set as indicated in the Table. μ in TeV, ΔM_{ij} in GeV.

2. Comparison of hMSSM (dashed) and $\Delta\lambda^{\mathtt{wfr}}_{F,D}$ (solid) scenarios

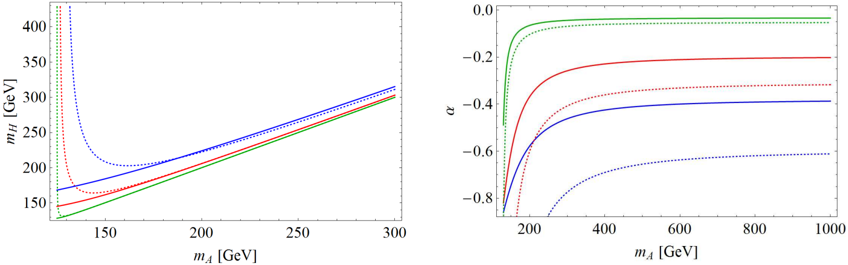


Рис. : (2;4) - blue, (3;4) - red, (4;4) - green.

Max departure of α value is 0.047 (37%) at large $\tan\beta = 30$ and 0.312 (50%) at small $\tan\beta = 2.5$. For heavy CP-even scalar H departure is 0.004 GeV (0.1%) at $\tan\beta = 30$ and 4.009 GeV (1.3%) at $\tan\beta = 2.5$.

3. Comparison of hMSSM with $\Delta\lambda^{\mathtt{wfr}}_{F,D}$ without additional constraints, M_{SUSY} =500 GeV.

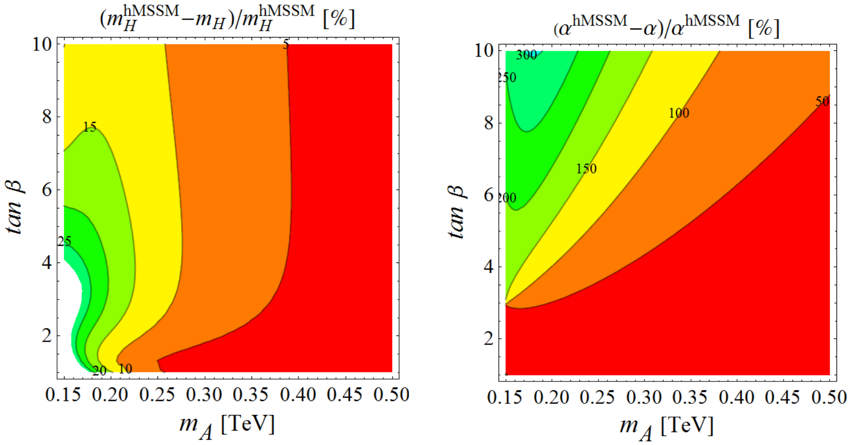


Рис. : Relative differences of m_H and α. $m_h = 125$ GeV, μ =1.5 TeV, A =2 TeV

3. Comparison of hMSSM with $\Delta\lambda^{\mathtt{wfr}}_{F,D}$ using the constraint of 'low-tb-high' scenario

$M_{SUSY} = (0.0375\tan^2\beta - 0.7\tan\beta + 3.25)/X_t$

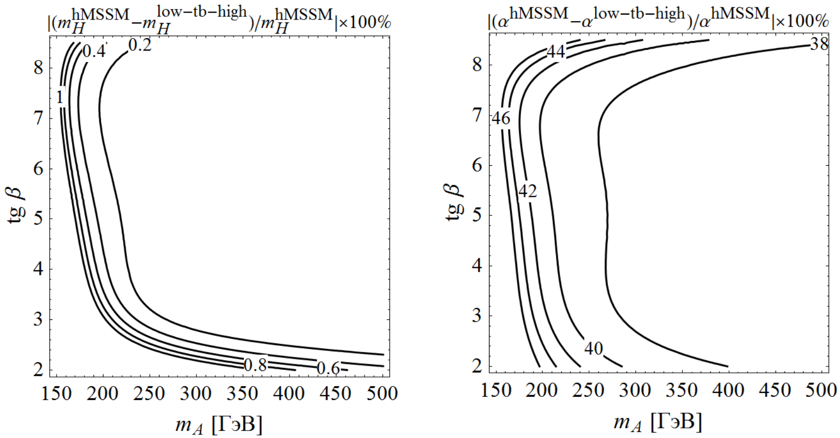
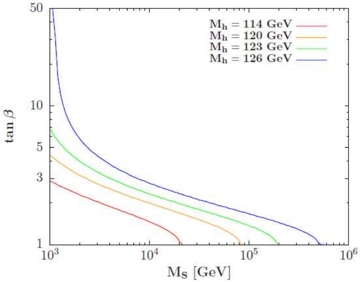
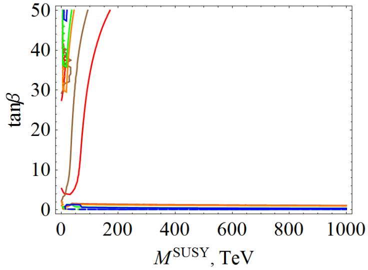
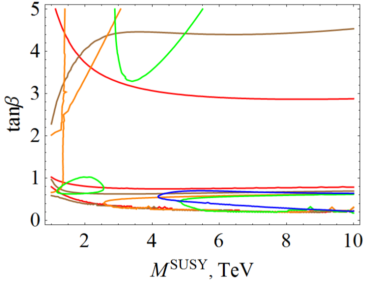


Рис. : Relative differences of m_H and α. $m_h = 125$ GeV, μ =1.5 TeV, A =2 TeV

Comparison of Orsay+Rome evaluation (HXSWG meeting, March 1995) based on hMSSM with $\Delta\lambda^{\mathtt{wfr}}_{F,D}$ scenario







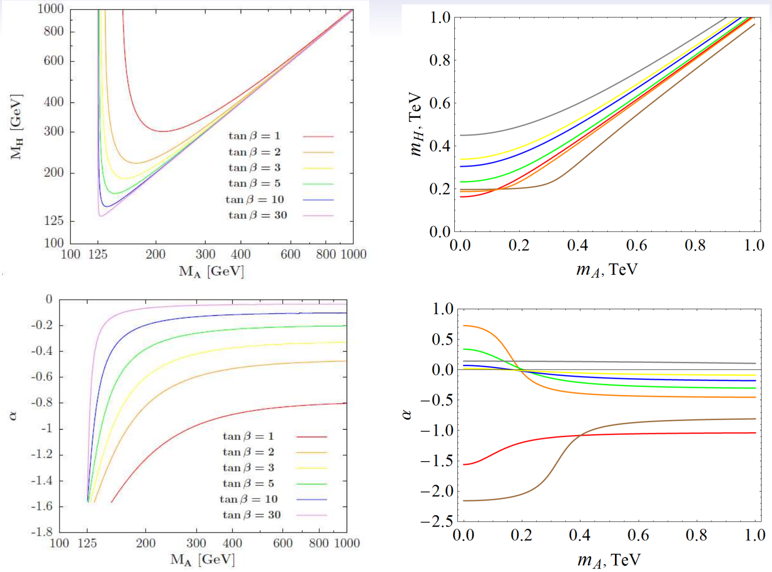

M_H [GeV]
M_A [GeV]
tan β = 1
tan β = 2
tan β = 3
tan β = 5
tan β = 10
tan β = 30
m_H, TeV
m_A, TeV
α
M_A [GeV]
α
m_A, TeV

Рис. :

m_h dependence on $A = A_{t,b}$ in $\Delta\lambda^{\texttt{wfr}}_{F,D}$ scenario.

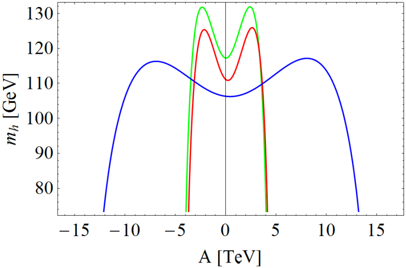


Рис. : m_h dependence on $A = A_{t,b}$ at m_A =300 GeV, μ =1 TeV for the tree sets (1) M_{SUSY} =3 TeV, $\tan\beta$ =2.5 (blue); (2) M_{SUSY} =1.5 TeV, $\tan\beta$ =5 (red); (3) M_{SUSY} =1 TeV, $\tan\beta$ =30 (green). With a limited set of $\Delta\lambda_i^a$ corrections curves have the same shape, but are 5-10 GeV lower.

3D surfaces of m_h =125 GeV at low and high $\tan\beta$ in M^{SUSY},μ,A space for m_A =0.3 TeV and m_A =1 TeV. $\Delta\lambda^{\texttt{wfr}}_{F,D}$ scenario.

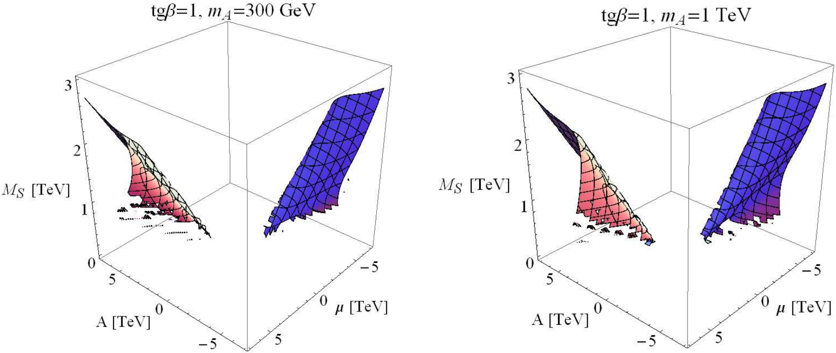


Рис. : Surface of $m_h = 125$ GeV, $\tan\beta$ =1, m_A =300 GeV (left) and 1 TeV (right)

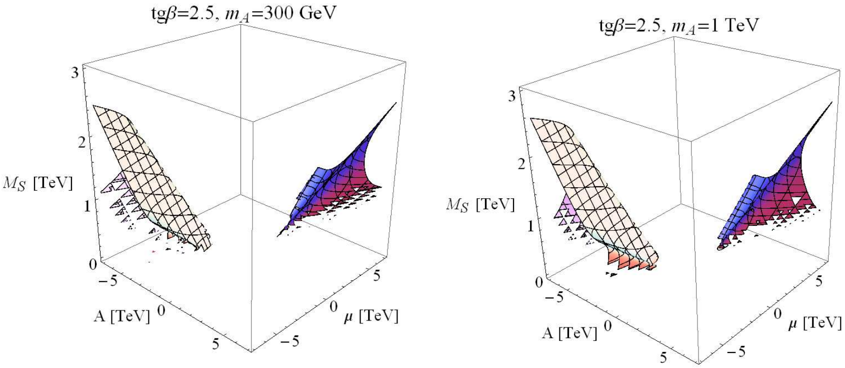


Рис. : Surface of $m_h = 125$ GeV, $\tan\beta$ =2.5, m_A =300 GeV (left) and 1 TeV (right)

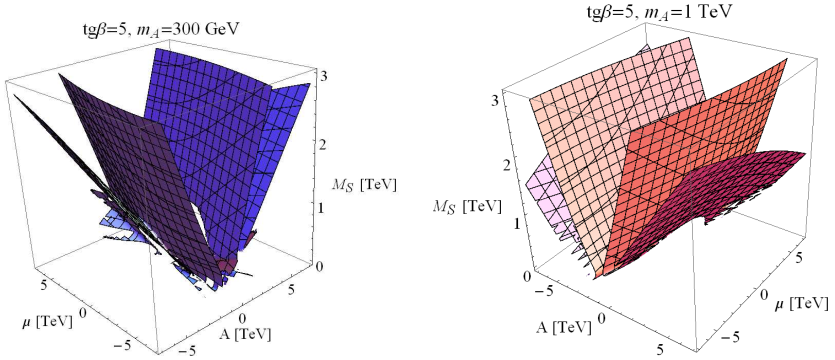


Рис. : Surface of $m_h = 125$ GeV, $\tan\beta$ =5, m_A =300 GeV (left) and 1 TeV (right). Right 3D plot is rotated 90 degrees.

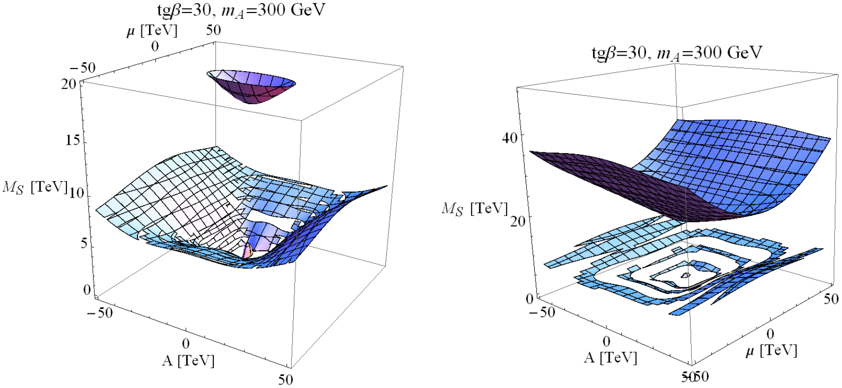
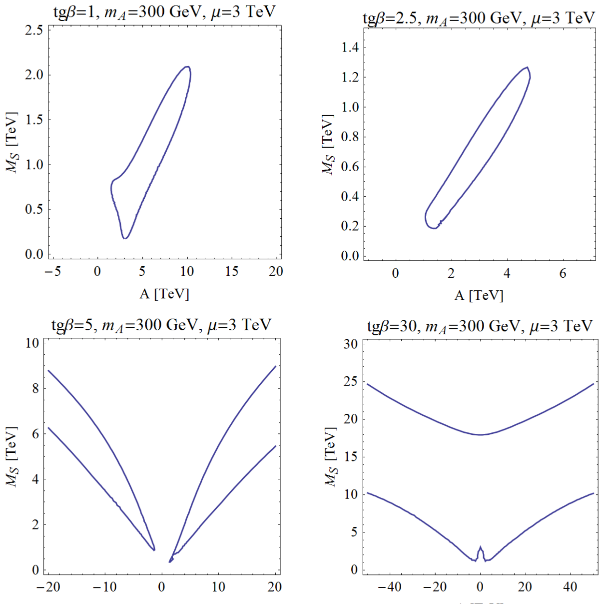
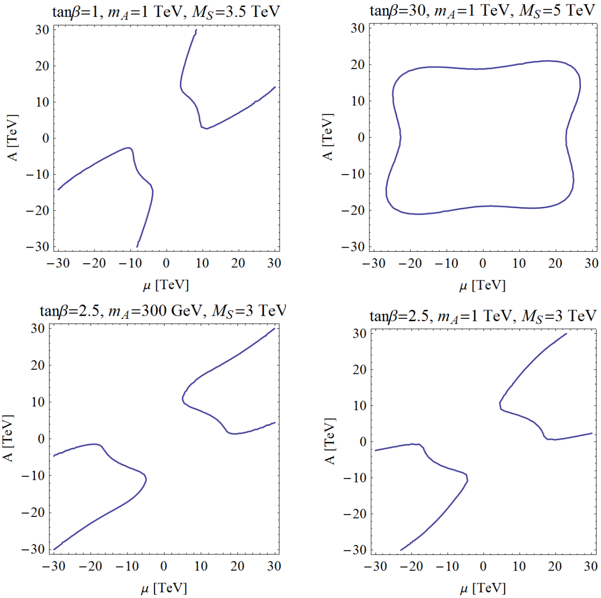


Рис. : Surface of $m_h = 125$ GeV, $\tan\beta$ =30, m_A =300 GeV (left), A, μ formally extended beyond a perturbative calculation framework

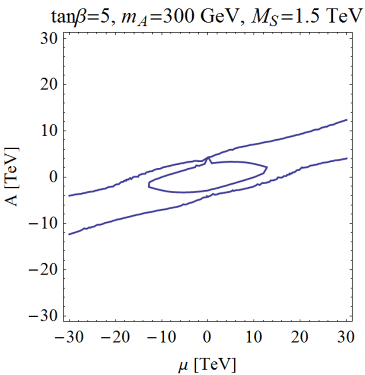
Contours of m_h =125 GeV at low and high $\tan\beta$ in M^{SUSY}, A plane for m_A =0.3 TeV and m_A =1 TeV. $\Delta\lambda^{\mathtt{wfr}}_{F,D}$ scenario.



Contours of m_h =125 GeV at low and high $\tan\beta$ in μ,A plane for m_A =0.3 TeV and m_A =1 TeV. $\Delta\lambda^{\mathtt{wfr}}_{F,D}$ scenario.



Contours of m_h =125 GeV at low and high $\tan\beta$ in μ, A plane for m_A =0.3 TeV and m_A =1 TeV. $\Delta\lambda^{\mathtt{wfr}}_{F,D}$ scenario.



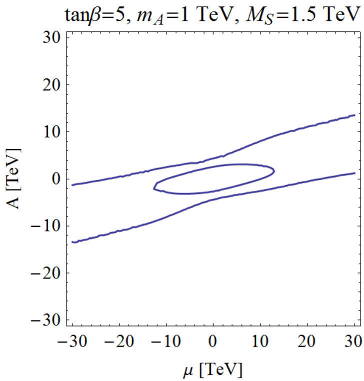
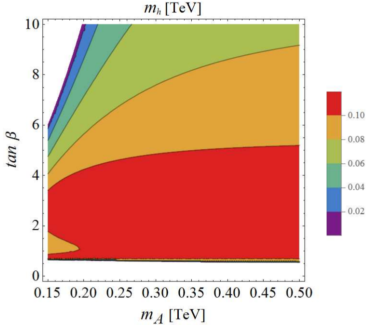


Рис. : Contours of $m_h = 125$ GeV, m_A =300 GeV (left) and m_A =1 TeV (right)

Domains of m_h in the μ, A plane for $A_{t,b}$ =2 TeV and μ =1.5 TeV. $\Delta\lambda^{\mathtt{wfr}}_{F,D}$ scenario.



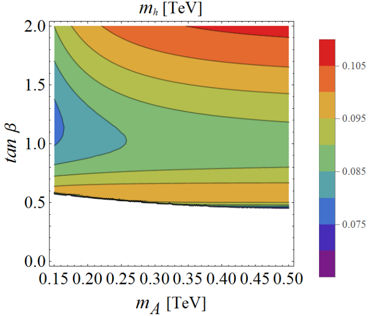


Рис. : M_{SUSY} =500 GeV (left) and 750 GeV (right).

Domains of m_h in the μ,A plane for $A_{t,b}$ =2 TeV and μ =1.5 TeV. $\Delta\lambda^{\mathtt{wfr}}_{F,D}$ scenario.

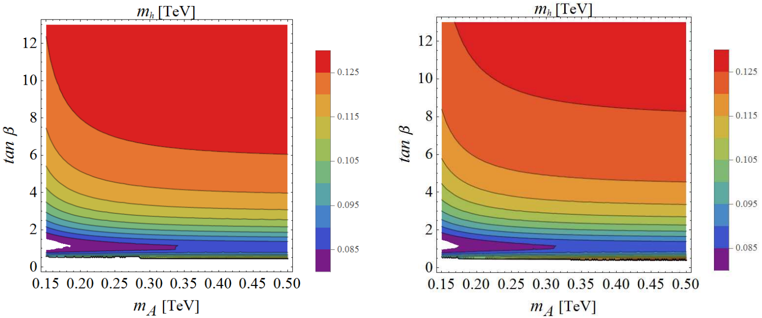


Рис. : M_{SUSY} =1 TeV (left) and 1.25 TeV (right).

4. Heavy CP-even H branchng ratios for $m_h^{\rm alt}$ and $m_h^{\rm mod+}$ parameter sets

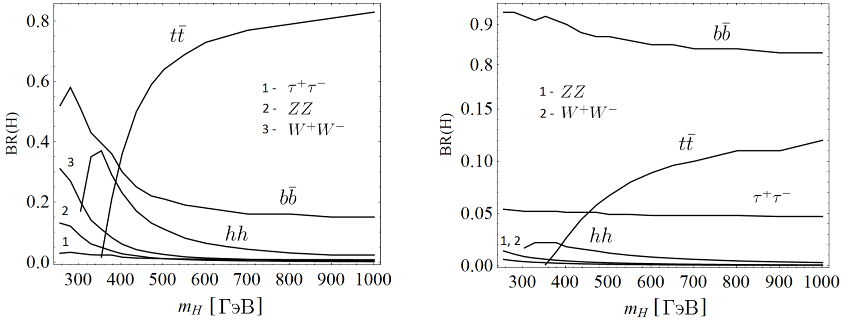


Рис. : $m_h = 124 - 126$ GeV, $M_{\rm SUSY} = 1.5$ TeV and $\mu = 200$ GeV or 1 TeV. Left panels: $\tan\beta = 4$, $A = 2.45 M_{\rm SUSY}$ ($m_h^{\rm alt}$ scenario); right panels $\tan\beta = 10$, $A = 1.5 M_{\rm SUSY}$ ($m_h^{\rm mod+}$ scenario). Results are stable with respect to higgs superfield parameter μ variation.

Summary

- Sensitivity of all results to radiative corrections is as a rule high. Reduction of multidimensinal MSSM parameter space, although very attractive for qualitative interpretations, should be carefully performed if possible in some restricted regions only
- For low $\tan\beta \leq$3 parameter sets M_{SUSY} top value is restricted at the level of a few (3–4) TeV.
- For high $\tan\beta \geq$30 an ambiguity of M_{SUSY} is observed, both heavy (TeV) and extremely heavy (20–30 TeV) scales are possible. However, with this observation one should not get involved by high $\tan\beta$ in the range $m_{H^\pm} \leq$400 GeV because of specific $t\bar{t} \to H^\pm \to$ 6 jets which are not observed.
- Some 'tuning' of results for comparisons could be useful. Deviations are significant. Direct comparisons of two-doublet effective potentials (e.g. evaluation of $\lambda_1, ...\lambda_7$ for a given set of input parameters) are not obvious since they are defined for different bases (in particular generic (v_1, v_2) basis and Higgs basis $(0, v)$), so different potential forms can give identical mass spectrum and couplings.