NMHDECAY_SLHA: A Fortran Code for the Higgs Masses, Couplings and Decay Widths in the NMSSM

U. Ellwanger, J. Gunion, C. Hugonie

Motivation:

– The NMSSM is the simplest solution to the μ problem of the MSSM:
replace $\mu H_u H_d \to \lambda S H_u H_d + \frac{\kappa}{3} S^3$

– The NMSSM is the simplest SUSY extension of the SM such that
  – all SUSY interactions are scale invariant (involving dimensionless couplings only)
  – the electroweak scale originates from the SUSY breaking scale only

– The MSSM re-appears in the limit λ, $\kappa \ll 1$ of the NMSSM
$\to$ the parameter space of the NMSSM includes the physics of the MSSM and more!

– The NMSSM renders the "little fine tuning problem" due to the non-observation of a Higgs at LEP less severe

→ The Physics of the NMSSM merits to be studied as thoroughly as the one of the MSSM

S: one new gauge singlet superfield in the Higgs sector (beyond the MSSM)

⟶ One more neutral scalar: 3 instead of 2
⟶ One more neutral pseudosc.: 2 instead of 1
⟶ One more neutralino: 5 instead of 4

⟶ New physics (beyond the MSSM) in the Higgs sector: more states, more mixing angles

But: The detection of at least one Higgs boson at the LHC is not necessarily easier than in the MSSM!

NMHDECAY: A tool to compute masses, couplings and branching ratios of all Higgs states (3 neutral scalars, 2 neutral pseudoscalars, 1 charged Higgs) for arbitrary parameters at the EW scale

Bare parameters:
2 Yukawa couplings λ, κ
2 trilinear soft terms $\lambda A_\lambda S H_u H_d + \frac{\kappa}{3} A_\kappa S^3$
3 soft mass terms $m_u^2 H_u^2 + m_d^2 H_d^2 + m_s^2 S^2$

Use the 3 minimization equations of the effective potential w.r.t. H_u, H_d and S, and $M_Z^2 = \frac{g_1^2+g_2^2}{2}(\langle H_u \rangle^2 + \langle H_d \rangle^2)$

$\longrightarrow$ 6 parameters:

$$\lambda,\ \kappa,\ A_\lambda,\ A_\kappa,\ tan\beta = \frac{\langle H_u \rangle}{\langle H_d \rangle},\ \mu_{eff} = \lambda \langle S \rangle$$

(Recall: MSSM: 2 parameters $tan\beta$, M_A)

For a given set of these 6 parameters NMHDECAY computes

1) The Higgs masses and mixing angles from the effective potential including radiative corrections

a) to V_{eff} from:

- top/bottom quark/squark effects exactly to one loop,
  $+$ leading double-logs $\sim h_t^6$, $h_t^4 \alpha_s$
- one loop electroweak corrections (leading logs $\sim ln(M_{sq}^2/M_Z^2),\ ln(M_{Higgs}^2/M_Z^2),\ ln(M_\chi^2/M_Z^2)$)

b) to Z_{eff} (propagators) from top/bottom quarks to one loop (leading logs $\sim ln(M_{sq}^2/M_Z^2),\ ln(M_{Higgs}^2/M_Z^2)$)

2) All decay widths $H \to 2\ particle\ final\ states$: gluons/quarks/leptons/$\gamma\gamma$/WW/ZZ/Z$\gamma$/ HH/HZ/HW (as in HDECAY; WW/ZZ: single off-shell option only)

3) Masses and mixing angles of charginos and neutralinos, and all decay widths $H \to$ charginos/neutralinos

(Not yet: $H \to$ squarks/sleptons)

Theoretical Tests on the Parameter Space:

– No Landau pole for the Yukawa couplings λ, κ, h_t, h_b below M_{GUT}
– No deeper minimum of V_{eff} for $\langle H_u \rangle = 0$ or $\langle H_d \rangle = 0$

Experimental Tests on the Parameter Space:

– $m_{H^+} > 78,6$ GeV
– $m_{\chi_1^+} > 103,5$ GeV
– $\Gamma(Z \to \chi_1^0 \chi_1^0) < 1,76$ MeV
– $\sigma(e^+e^- \to \chi_1^0 \chi_i^0) < 10^{-2}$ pb
(i > 1, $if\ m_{\chi_1^0} + m_{\chi_i^0} < 209$ GeV)
– $\sigma(e^+e^- \to \chi_i^0 \chi_j^0) < 10^{-1}$ pb
(i, j > 1, $if\ m_{\chi_i^0} + m_{\chi_j^0} < 209$ GeV)
– LEP constraints on $e^+e^- \to$ hZ:
$h \to b\bar{b}$, $\tau^+\tau^-$, jj, $\gamma\gamma$, invisible
recoil mass in $e^+e^- \to$ ZX
$e^+e^- \to\ ha \to\ 4b/4\tau/aaa \to\ 6b/4b + 2j$

(Very important for certain regions of the NMSSM parameter space where $h_1 \to aa$ dominant)

If any of these tests fails the parameter set is not dropped, but the user is warned

Input file slhainp.dat:
need to specify $\alpha_s(M_Z)$, $m_b(m_b)$ (running mass), m_{top} (pole mass), one set of NMSSM parameters and soft terms in the squark/gaugino sectors

Two output files:
– spectr.dat: input parameters, results of theoret./exp. tests, Higgs masses and mixing angles, neutralino/chargino masses and mixing angles
– decay.dat: widths and branching ratios of all 6 Higgs states