Recent Improvements of NMHDECAY

U. Ellwanger, LPT Orsay

The NMSSM:

Recall the problems of the MSSM:

a) μ-problem: Why is μ (so precisely) of the order of the weak scale $\sim\ M_{Susy}$?

b) little fine-tuning problem: Why has no Higgs been observed at the LHC?

$\longrightarrow$ Add a Singlet S:

In the superpotential: $\mu H_u H_d \to \lambda S H_u H_d + \frac{\kappa}{3} S^3$

New soft terms: $\lambda A_\lambda S H_u H_d + \frac{\kappa}{3} A_\kappa S^3 + m_S^2 S^2$

$\longrightarrow$ $\langle S \rangle \sim M_{Susy}$ naturally, generates $\mu_{eff} = \lambda \langle S \rangle \sim M_{Susy}$ (See the first Susy/Sugra extensions of the SM by Fayet, Nilles, Srednicki, Wyler,...)

$\longrightarrow$ The μ-problem is solved, the NMSSM is the simplest Susy extension of the standard model where the weak scale originates from M_{Susy} only (scale invariant superpotential)

Parameter space:

MSSM: $m_{H_u}^2 + \mu^2,\ m_{H_d}^2 + \mu^2,\ B \longrightarrow M_Z,\ tan\beta,\ \mu$ (or M_A)
(+ soft terms in the squark/slepton/gaugino sectors)

NMSSM: $m_{H_u}^2,\ m_{H_d}^2,\ m_S^2,\ \lambda,\ \kappa,\ A_\lambda,\ A_\kappa \longrightarrow$
$M_Z,\ tan\beta,\ \mu_{eff},\ \lambda,\ \kappa,\ A_\lambda,\ A_\kappa$
(+ soft terms in the squark/slepton/gaugino sectors)

Physical Higgs states:

3 CP even neutral scalars (instead of h, H in the MSSM)

2 CP odd neutral scalars (instead of A in the MSSM)

1 charged complex scalar (as in the MSSM)

$\longrightarrow$ The computation of Higgs masses, couplings and branching ratios is (even) more complex than in the MSSM

e.g.: Unconventional Higgs $\longrightarrow$ Higgs decays as $h \to AA$ are possible, compatible with LEPII constraints for $M_h \lesssim 90$ GeV!

($\to$ less fine tuning in this region of parameter space)

The computation of Higgs masses, couplings and branching ratios as functions of

$tan\beta$, μ_{eff}, λ, κ, A_λ, A_κ

(+ soft terms in the squark/slepton/gaugino sectors) is performed in the public code

NMHDECAY

(U.E., J. Gunion, C. Hugonie)

+ check for theoretical constraints:

– absolute minimum of the scalar potential?

– Landau singularity below M_{GUT} for λ, κ, h_t?

+ experimental constraints:

– from Higgs searches at LEPII (incl. unconventional channels specific to the NMSSM)

– on sparticle masses/couplings

Present precision in the lightest Higgs mass ($\sim g^2 v^2$ at tree level):

Included radiative corrections are of the orders

$h_{t/b}^4$ (exact), $h_{t/b}^6$ (LLA), $\alpha_s h_{t/b}^4$ (LLA), $g^2 h_{t/b}^2$ (exact)*, g^4, $g^2\lambda^2$*, $g^2\kappa^2$*, λ^4*, κ^4*, $\lambda^2\kappa^2$*(all LLA)

*: New in version 2.0

Additional new features in the version 2.0 of NMHDECAY:

– all squark, slepton and gaugino masses and mixings (incl. rad. corrs. $\sim \alpha_s$ to pole masses, with thanks to S. Kraml)

– branching ratios $H \to$ squarks, sleptons for all 6 Higgs states (+ squark/slepton loop contributions to $H \to$ gg/$\gamma\gamma$)

– LEP/Tevatron constraints on all squark/slepton/gaugino masses

– $BR(b \to s\gamma)$ to lowest order

– Link to a NMSSM version of MicrOMEGAs (if desired) $\longrightarrow$ Dark matter relic density Ω

Still: NMHDECAY is fast ($\sim 10^3$ pts. in parameter space/sec without Ω, but only ~ 10 pts./sec with Ω)

$\longrightarrow$ Large scans are feasable

Also:

– Input/output in SLHA format possible

– For $\lambda \sim \kappa \sim 10^{-6}$: application to the MSSM (incl. exp. constraints!)

To come:

- integrate RGEs for all soft terms up to M_{GUT} (computation of the NMSSM specific threshold corrections under way)
- better precision of $BR(b \to s\gamma)$ (required for large $\tan\beta$)
- constraints from myon anomalous magnetic moment
- more rad. corrs. in V_{eff}(Higgs)

Conclusions:

Why the NMSSM should be studied as thoroughly as the MSSM:

⟶ The Susy extension of the SM via the NMSSM is theoretically at least as attractive as the MSSM:
— less finetuning required
— μ-problem solved

⟶ All the "goodies" of the MSSM are maintained:
— gauge coupling unification
— dark matter relic density from the lightest neutralino (→ G. Belanger et al.)
— $m_{h_u}^2(M_{Weak}) < 0$ naturally from large h_t
— agreement with all present constraints on "physics beyond the SM" is possible

⟶ New Physics beyond the MSSM: Higgs detection at the LHC may be (but not necessarily) difficult (U.E., J. Gunion, C. Hugonie, JHEP 0507:041,2005):
— $\sim 300\ fb^{-1}$ may be required
— if h decays dominantly into $a_1 a_1$:
Possibly no Higgs signal at the LHC!!!

⟶ If a Higgs (+ sparticles?) is found at the LHC: still a LC is required in order to disentangle the MSSM from the NMSSM!

⟶ NMHDECAY is a useful tool for such studies...