1 Motivation

We have analysed the nMSSM where the singlet self-coupling κ of the NMSSM is set to 0. Following [1] we assumed that the Peccei-Quinn symmetry originating from $\kappa = 0$ and the usual NMSSM Z_3 symmetry are broken by additional singlet tadpole terms in the superpotential (ξ_F) and in the soft SUSY breaking potential (ξ_S). In addition we assumed non universality in the Higgs sector and used the minimisation equations to compute the Higgs soft masses. Hence we numerically scanned over the following 9 free parameters: m_0, $M_{1/2}$, A_0, A_λ, ξ_F, ξ_S (at the GUT scale), $\lambda, \mu_{\text{eff}}$ (at the SUSY scale), and $\tan\beta$ (at M_Z), looking for scenarios satisfying all available experimental constraints: Higgs measurements and flavor constraints as implemented in NMSSMTools, SUSY searches from LHC using SmodelS, dark matter relic density from Planck and (in)direct dark matter searches from Fermi-LAT and LUX.

2 Selection of benchmark points

We found an allowed region of parameter space where the lightest neutralino (mainly singlino) LSP has a very small mass ($m_{\text{LSP}} < 5$ GeV). The relic density can be compatible with the latest Planck measurements and the main annihilation process is via the lightest CP-odd a_1 resonance, where a_1 is mainly singlet and has a mass $m_{a_1} \sim 2m_{\text{LSP}}$.

The light singlino and CP-odd singlet are also accompanied by a light (mainly singlet) CP-even Higgs state h_1, with a mass varying between $\sim$ 30 and 90 GeV. Hence it is the second lightest CP-even state h_2 that has a mass close to 125 GeV (with an estimated 3 GeV theoretical error). The branching ratios for the exotic decays of h_2 into light Higgses can reach 8%($h_2 \to a_1 a_1$) and 10% ($h_2 \to h_1 h_1$) although only the former is always kinematically accessible.

Due to its small mass, a_1 decays mainly to a pair of neutralinos (if $m_{a_1} > 2m_{\text{LSP}}$) or a pair of τ leptons, while h_1 will decay mainly in a $b\bar{b}$ final state. Given these decay patterns, the interesting 4τ and $2b2\tau$ final states could be observed when a_1/h_1 originate from decays of the SM-like Higgs boson. The bba_1 associated production also leads to a $2b2\tau$ final state. Moreover, final states involving $\mu^+\mu^-$ pairs deserve investigation, although the branching ratios in this final state is depleted by a factor $\sim m_\mu^2/m_\tau^2$ with respect to the $\tau\tau$ one.

We therefore propose 2 benchmark points corresponding to the following configurations (although other configurations are also possible):

P1: $m_{a_1} > 2m_{\text{LSP}}$, $m_{h_2} > 2m_{h_1}$, maximising Br($h_2 \to a_1 a_1$)

P2: $m_{a_1} > 2m_{\text{LSP}}$, $m_{h_2} > 2m_{h_1}$, maximising Br($h_2 \to h_1 h_1$)

3 Prospects at LHC14

3.1 P1

This point presents a light CP-even Higgs, m_{h_1} =37 GeV and a CP-odd Higgs with mass $\sim$ 6.8 GeV. In this configuration the Br($h_2 \to a_1 a_1$) is maximum and reach the value of $\sim$ 8%, making it possible to produce the light CP odd scalar via exotics decay of the SM like Higgs boson h_2. For example the process $\sigma(gg \to h_2) \cdot Br(h_2 \to h_1 h_1)$ has a rate $\sim$ 3.4 pb with $\sqrt{s}$=13 TeV. The main decay modes of a_1 are into invisible final state, $\chi_1^0\chi_1^0$ ($\sim$ 73%) and $\tau\tau$ ($\sim$ 25%). Conversely the rate $h_2 \to h_1 h_1$ in this benchmark point is quite poor, and the light CP even scalar has to be produced directly, for example via gluon fusion. This cross

section is $\sim$ 12 pb at $\sqrt{s}$=13 TeV. The lightt CP-even scalar will decay predominantly into $b\bar{b}$ (85%) and $\tau\tau$ (7%) final states.

The remaining SUSY spectrum for this benchmark point is characterised by relatively light EWinos, sleptons and stops.

Given the standard decay modes of the EWinos, normal searches (with the simplified model assumption that χ_2^0 and $\chi_1^\pm$ decay directly to the χ_1^0 LSP and a SM boson) should be able to cover this region of parameter space. The main decay mode of the $\sim$ 650 GeV stop quark is into a $\chi^+ b$ final state ($\sim$ 50%), thus standard stop searches should be able to effectively test this benchmark point. Note that the decays of the stop via longer decay chains has a substantial rate as decays into $\chi_{2,3}^0$ can reach 15% and 22 % respectively. Finally the standard decay of the light sleptons in a lepton and the LSP is very suppressed,and sleptons will rather decay into heavier neutralinos leading to long decay chains, here $\tilde{l} \to l\chi_4^0, \chi_4^0 \to Z\chi_1^0$ or $\tilde{l} \to l\chi_4^0, \chi_4^0 \to h_1\chi_2^0$.

3.2 P2

In this point m_{h_1}=43 GeV and m_{a_1}=6.9 GeV. Exotic decays of the SM-like Higgs boson h_2 allow the production of the lighter CP even Higgs with a substantial rate, $\sim$ 4.3 pb, given the Br($h_2 \to h_1 h_1$)=9%. This state will mainly decay into $b\bar{b}$ (65%), $a_1 a_1$ (27%) and $\tau\tau$ (5%). Conversely the lightest CP odd Higgs can not be produced by h_2 decays but only via the aforementioned decay of h_1 or directly. It decays mainly into invisible (75%) and $\tau\tau$ (25%) final states. The remaining SUSY spectrum of this benchmark point present features similar to P1, both as concerns the spectrum and the decay modes.

References

[1] A. Dedes, C. Hugonie, S. Moretti and K. Tamvakis, Phys. Rev. D **63**, 055009 (2001) [hep-ph/0009125].