Effects of Inverse Seesaw Mechanism on the Sparticle Sprectrum

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Outline

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Motivation

- In low scale supersymmetry, a Higgs boson mass of around 125 GeV requires either a relatively large value, $\mathcal{O}(\text{few} - 10)$ TeV, for the geometric mean of top squark masses, or a large SSB trilinear A_t-term.
- In order to be able to reduce the sparticle masses to more accessible values in models with universal sfermion and gaugino masses, we require additional contributions from new physics.
- The inverse seesaw mechanism (ISS) can impact the lightest CP-even Higgs boson mass through radiative corrections and increase it by 2-3 GeV when the additional new fields are SM singlets.

Model Description

We supplement the MSSM field content with three pairs of MSSM singlet chiral superfields $(N_i^c + N_i)$, $i = 1, 2, 3$, and a singlet chiral superfield S which develops a vacuum expectation value (VEV) comparable to or less than the electroweak scale.

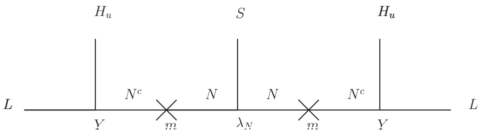
$$W \supset Y_{N_{ij}} N_i^c H_u L_j + \lambda_{N_{ij}} S N_i N_j + m_{ij} N_i^c N_j .$$

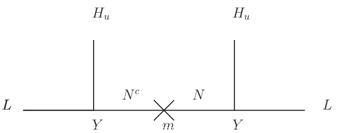
A non-zero VEV for the scalar component of S generates the lepton-number-violating term $\mu_s N_i N_j \equiv \lambda_{N_{ij}} < S > N_i N_j$.

Model Description

After integrating out the $(N_i^c + N_i)$ fields, the neutrino mass arises from the effective dimension six operator:

$$\frac{LLH_uH_uS}{M_6^2}$$





Model Description

Following the electroweak symmetry breaking, the neutrino Majorana mass matrix is generated:

$$m_\nu = \frac{(Y_N^T Y_N) {v_u}^2}{M_6} \times \frac{\lambda_N \langle S \rangle}{M_6}.$$

This implies that even if $Y_N \sim \mathcal{O}(1)$ and $M_6 \sim 1$ TeV, the correct mass scale for the light neutrinos can be reproduced by suitably adjusting $\lambda_N \langle S \rangle$.

Model Description

Keeping $Y_N \sim \mathcal{O}(1)$ will provide sizable contribution to the lightest CP-even Higgs mass, which is given by

$$\left[m_h^2\right]_N = n \times \left[-M_Z^2 \cos^2 2\beta \left(\frac{1}{8\pi^2} Y_N^2 t_N\right) + \frac{1}{4\pi^2} Y_N^4 v^2 \sin^2\beta \left(\frac{1}{2}\widetilde{X}_{Y_N} + t_N\right)\right]$$

where

$$t_N = \log\left(\frac{M_S^2 + M_6^2}{M_6^2}\right), \quad \widetilde{X}_{Y_N} = \frac{4\widetilde{A}_{Y_N}^2\left(3M_S^2 + 2M_6^2\right) - \widetilde{A}_{Y_N}^4 - 8M_S^2 M_6^2 - 10M_S^4}{6\left(M_S^2 + M_6^2\right)^2},$$

and

$$\widetilde{A}_{Y_N} = A_{Y_N} - Y_N\langle S\rangle \cot\beta$$

Scanning Procedure

We employ the ISAJET 7.84 package to generate sparticle spectrum over the fundamental parameter space in CMSSM and NUHM2. We set $\lambda_N = 0.7$ to maximize the impact of ISS on the sparticle spectrum.

$$
\begin{aligned}
0 \leq m_0 &\leq 10\,\mathrm{TeV} \\
0 \leq m_{1/2} &\leq 5\,\mathrm{TeV} \\
-3 \leq A_0/m_0 &\leq 3 \\
3 \leq \tan\beta &\leq 60 \\
\mu &> 0 \\
(0 \leq m_{H_u} &\leq 10\,\mathrm{TeV}, \\
0 \leq m_{H_d} &\leq 10\,\mathrm{TeV})
\end{aligned}
$$

Scanning Procedure

Phenomenological constraints:

$$\begin{aligned} m_h &= 123 - 127 \text{ GeV} \\ 0.8 \times 10^{-9} \leq \mathrm{BR}(B_s \to \mu^+\mu^-) &\leq 6.2 \times 10^{-9}\ (2\sigma) \\ 2.99 \times 10^{-4} \leq \mathrm{BR}(b \to s\gamma) &\leq 3.87 \times 10^{-4}\ (2\sigma) \\ 0.15 \leq \frac{\mathrm{BR}(B_u \to \tau\nu_\tau)_{\mathrm{MSSM}}}{\mathrm{BR}(B_u \to \tau\nu_\tau)_{\mathrm{SM}}} &\leq 2.41\ (3\sigma) \end{aligned}$$

Bounds on the sparticle masses

$$m_{\tilde{g}} \gtrsim 1.5\,\mathrm{TeV}\ (\text{for } m_{\tilde{g}} \sim m_{\tilde{q}}) \quad \text{and} \quad m_{\tilde{g}} \gtrsim 0.9\,\mathrm{TeV}\ (\text{for } m_{\tilde{g}} \ll m_{\tilde{q}})$$

Results

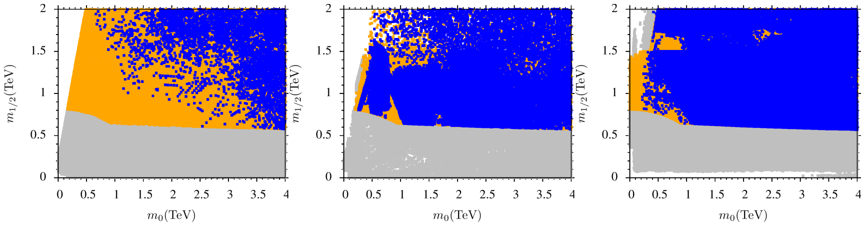


Figure: Plots in $m_0 - m_{1/2}$ plane for CMSSM, CMSSM-ISS and NUHM2-ISS. Grey points satisfy REWSB and LSP neutralino conditions. Orange point solutions satisfy mass bounds and B-physics bounds. Points in blue are a subset of orange points and satisfy $123\,\mathrm{GeV} \lesssim m_h \lesssim 127\,\mathrm{GeV}$.

Results

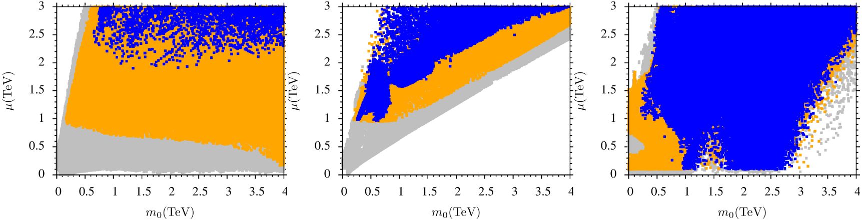


Figure: Plots in $m_0 - \mu$ plane for CMSSM, CMSSM-ISS and NUHM2-ISS. Grey points satisfy REWSB and LSP neutralino conditions. Orange point solutions satisfy mass bounds and B-physics bounds. Points in blue are a subset of orange points and satisfy $123\,\mathrm{GeV} \lesssim m_h \lesssim 127\,\mathrm{GeV}$.

Results

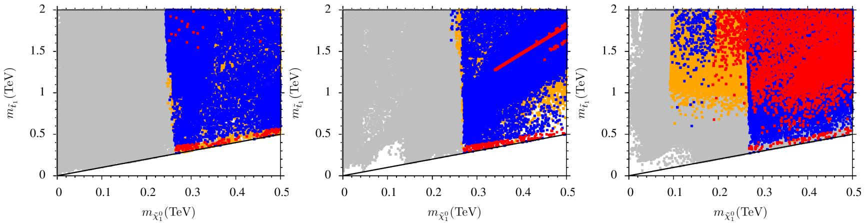


Figure: Plots in $m_{\tilde{\chi}_1^0} - m_{\tilde{t}_1}$ plane for CMSSM, CMSSM-ISS and NUHM2-ISS. Grey points satisfy REWSB and LSP neutralino conditions. Orange point solutions satisfy mass bounds and B-physics bounds given in Section 2. Points in blue are a subset of orange points and satisfy $123\,\mathrm{GeV} \lesssim m_h \lesssim 127\,\mathrm{GeV}$. Red points are a subset of blue point solutions and also satisfy bounds for relic abundance, $0.001 \leq \Omega h^2 \leq 1$.

Results

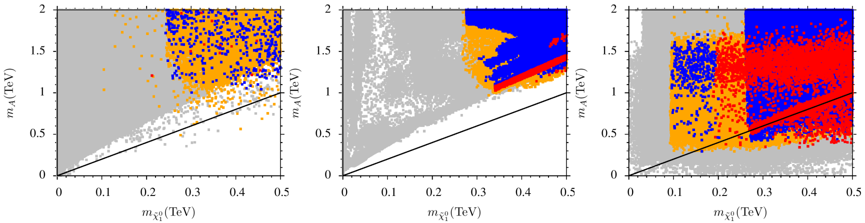


Figure: Plots in $m_{\tilde{\chi}_1^0} - m_A$ plane for CMSSM, CMSSM-ISS and NUHM2-ISS. Grey points satisfy REWSB and LSP neutralino conditions. Orange point solutions satisfy mass bounds and B-physics bounds. Points in blue are a subset of orange points and satisfy $123\,\mathrm{GeV} \lesssim m_h \lesssim 127\,\mathrm{GeV}$. Red points are a subset of blue point solutions and also satisfy bounds for relic abundance, $0.001 \leq \Omega h^2 \leq 1$.

Results

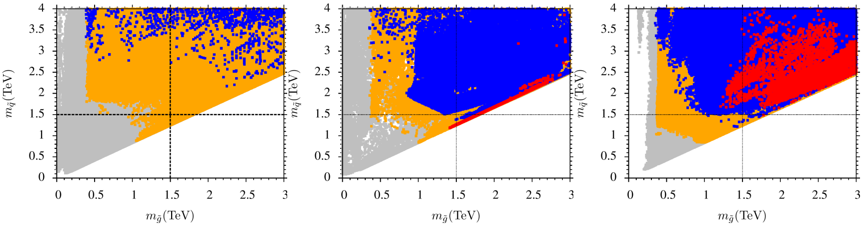


Figure: Plots in $m_{\tilde{g}} - m_{\tilde{q}}$ plane for CMSSM, CMSSM-ISS and NUHM2-ISS. Grey points satisfy REWSB and LSP neutralino conditions. Orange point solutions satisfy mass bounds and B-physics bounds. Points in blue are a subset of orange points and satisfy $123\,\text{GeV} \lesssim m_h \lesssim 127\,\text{GeV}$. Red points are a subset of blue point solutions and also satisfy bounds for relic abundance, $0.001 \leq \Omega h^2 \leq 1$.

Conclusion

- The Inverse Seesaw mechanism allows an increase of m_h by a few GeV, while simultaneously generating mass for neutrinos via dimension six operators.
- This effect allows one to have lighter colored sparticles in CMSSM and NUHM2 scenarios which can be tested at LHC14.