Effects of Inverse Seesaw Mechanism on the Sparticle Spectrum

Bin He

Bartol Research Institute
Department of Physics and Astronomy
University of Delaware

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in collaboration with Ilia Gogoladze, Azar Mustafayev, Shabbar Raza and Qaisar Shafi.
Outline

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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.
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.

\[
W \supset Y_{N_{ij}} N_i^c H_u L_j + \lambda_{N_{ij}} SN_i N_j + m_{ij} N_i^c N_j.
\]

A non-zero VEV for the scalar component of \(S\) generates the lepton-number-violating term \(\mu_s N_i N_j \equiv \lambda_{N_{ij}} < S > N_i N_j\).
After integrating out the \((N^c_i + N_i)\) fields, the neutrino mass arises from the effective dimension six operator:

\[
\frac{LLH_u H_u S}{M_6^2}
\]
Model Description

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

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

This implies that even if \( Y_N \sim \mathcal{O}(1) \) and \( M_6 \sim 1 \text{ TeV} \), the correct mass scale for the light neutrinos can be reproduced by suitably adjusting \( \lambda_N \langle S \rangle \).
Keeping $Y_N \sim \mathcal{O}(1)$ will provide sizable contribution to the lightest CP-even Higgs mass, which is given by

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

where

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

and

$$
\tilde{A}_{Y_N} = A_{Y_N} - Y_N \langle S \rangle \cot \beta
$$
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{align*}
0 \leq m_0 &\leq 10 \text{ TeV} \\
0 \leq m_{1/2} &\leq 5 \text{ TeV} \\
-3 \leq A_0/m_0 &\leq 3 \\
3 \leq \tan \beta &\leq 60 \\
\mu &> 0 \\
(0 \leq m_{H_u} &\leq 10 \text{ TeV}, \quad 0 \leq m_{H_d} \leq 10 \text{ TeV})
\end{align*}
Phenomenological constraints:

\[ m_h = 123 - 127 \text{ GeV} \]

\[ 0.8 \times 10^{-9} \leq \text{BR}(B_s \to \mu^+ \mu^-) \leq 6.2 \times 10^{-9} \ (2\sigma) \]

\[ 2.99 \times 10^{-4} \leq \text{BR}(b \to s\gamma) \leq 3.87 \times 10^{-4} \ (2\sigma) \]

\[ 0.15 \leq \frac{\text{BR}(B_u \to \tau\nu_\tau)_{\text{MSSM}}}{\text{BR}(B_u \to \tau\nu_\tau)_{\text{SM}}} \leq 2.41 \ (3\sigma) \]

Bounds on the sparticle masses

\[ m_{\tilde{g}} \gtrsim 1.5 \text{ TeV} \ (\text{for } m_{\tilde{g}} \sim m_{\tilde{q}}) \quad \text{and} \quad m_{\tilde{g}} \gtrsim 0.9 \text{ TeV} \ (\text{for } m_{\tilde{g}} \ll m_{\tilde{q}}) \]
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 $123 \text{ GeV} \lesssim m_h \lesssim 127 \text{ GeV}$. 
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 $123 \text{ GeV} \lesssim m_h \lesssim 127 \text{ GeV}$. 
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 $123 \text{ GeV} \lesssim m_h \lesssim 127 \text{ GeV}$. Red points are a subset of blue point solutions and also satisfy bounds for relic abundance, $0.001 \leq \Omega h^2 \leq 1$. 
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 $123 \text{ GeV} \lesssim m_h \lesssim 127 \text{ GeV}$. Red points are a subset of blue point solutions and also satisfy bounds for relic abundance, $0.001 \leq \Omega h^2 \leq 1$. 

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, $0.001 \leq \Omega h^2 \leq 1$. 

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Results
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.