Higgs in Susy Seesaw and difference from MSSM

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Introduction

Supersymmetric seesaw model is well motivated because MSSM may not explain the neutrino oscillation experiments while seesaw model may give a natural explanation of neutrino mass. Study of sneutrino spectrum and its impact on higgs mass spectrum (through neutrinos and sneutrinos loop) may be important.

$$\begin{pmatrix} \overline{\nu_L} & \overline{(N_R)^C} \end{pmatrix} \begin{pmatrix} 0 & y\langle H\rangle \\ y\langle H\rangle & M_R \end{pmatrix} \begin{pmatrix} (\nu_L)^C \\ N_R \end{pmatrix}$$

Members of Super fields:
lepton doublet ($\hat{L}, Y = -1$), Higgs ($\hat{H}_2, Y = 1$, $\hat{H}_1, Y = -1$) ,righthanded ($\hat{N}$) neutrino-sneutrinos
Super Symmetric seesaw
Neutrino (ν_L, ν_R) (2 weyl) and sneutrino ($\tilde{\nu}_L, \tilde{\nu}_R$) (2 complex scalar) mass matrices:

$$M_F = \begin{pmatrix} 0 & y\langle H\rangle \\ y\langle H\rangle & M_R \end{pmatrix}$$

$$\begin{aligned} {M_B}^2 &= {M_F}^\dagger M_F = \begin{pmatrix} 0 & y\langle H\rangle \\ y\langle H\rangle & M_R \end{pmatrix} \begin{pmatrix} 0 & y\langle H\rangle \\ y\langle H\rangle & M_R \end{pmatrix} \\ &= \begin{pmatrix} m_D^2 & m_D M_R \\ m_D M_R & M_R^2 + m_D^2 \end{pmatrix} \end{aligned} \tag{1}$$

with $y\langle H\rangle = m_D, M_R = M$. Without soft susy breaking term neutrino and sneutrino sector have the same mass spectrum. (one light and one heavy neutrino (sneutrino)).

$$det({M_B}^2 - \lambda) = 0$$

and

$$det({M_F}^\dagger M_F - \lambda) = 0$$

They have the same eigenvalues

$$\lambda_\pm = \frac{\sqrt{2m_D^2 + M^2}}{2} \pm \sqrt{\left(\frac{2m_D^2 + M^2}{2}\right)^2 - m_D^4}$$

With seesaw condition $m_D \ll M$ The approximate eigenvalues are

$$\lambda_+ = M^2, \quad \lambda_- = \frac{m_D^4}{M^2}$$

Superpotential of Susy seesaw is given as,

$$W = y\hat{L}\hat{H}_2\hat{N} + \frac{M}{2}\hat{N}\hat{N} + \mu\hat{H}_1\hat{H}_2$$

We introduce soft breaking terms: $(A, B, m^2_{\tilde{l}}, m^2_{\tilde{N}})$ and decompose the original complex fields into CP even and odd parts. In total there are four real scalars.

If CP is not violated mass matrix for real scalars 4×4 is block diagonalized into to 2×2 No $\tilde{\nu}_1 \leftrightarrow \tilde{\nu}_2$ mixings.

$$\begin{aligned} \tilde{\nu}_L &= \frac{\tilde{\nu}_{1L} + i\tilde{\nu}_{2L}}{\sqrt{2}} \\ \tilde{\nu}_R &= \frac{\tilde{\nu}_{1R} + i\tilde{\nu}_{2R}}{\sqrt{2}} \end{aligned}$$

Mass matrix for CP even part $\tilde{\nu}_{1LR}$

$$M_+^2 = \begin{pmatrix} m_D^2 + m_{\tilde{l}}^2 & -m_D(M + A + \mu\frac{v_1}{v_2}) \\ -m_D(M + A + \mu\frac{v_1}{v_2}) & m_D^2 + m_{\tilde{N}}^2 + M^2 + 2MB \end{pmatrix} \tag{2}$$

CP odd part $\tilde{\nu}_{2LR}$

$$M_-^2 = \begin{pmatrix} m_D^2 + m_{\tilde{l}}^2 & -m_D(-M + A + \mu\frac{v_1}{v_2}) \\ -m_D(-M + A + \mu\frac{v_1}{v_2}) & m_D^2 + m_{\tilde{N}}^2 + M^2 - 2MB \end{pmatrix} \tag{3}$$

Here we consider by keeping a soft breaking part term $m_{\tilde{N}}^2$

$$
\begin{aligned}
M^2_{++} = M^2_{-+} &= m^2_D \frac{m^2_{\tilde{N}} + m^2_D}{M^2} \\
M^2_{+-} = M^2_{--} &= M^2 + m^2_{\tilde{N}}
\end{aligned}
$$

In two mass eigenvalues $m^2_{\tilde{N}}$ and $m^2_D \frac{m^2_{\tilde{N}}}{M^2}$ plays role of soft breaking If we switched off the soft breaking term as $m_{\tilde{N}} \to 0$ We may recover the fermionic sector of the mass spectrum as

$$
\begin{aligned}
M^2_{++} = M^2_{-+} &\to \frac{m^4_D}{M^2} \\
M^2_{+-} = M^2_{--} &\to M^2
\end{aligned} \tag{4}
$$

The mixing angles of sneutrino sector and neutrino sector differ
Fermionic sector
$\nu_L \leftrightarrow \nu_R^c$

$$\tan 2\theta = -\frac{2m_D}{M} \quad (5)$$

$$(6)$$

$$\begin{aligned} \tan 2\theta_1 &= \frac{2m_D M}{M^2 + m_{\tilde{N}}^2} \\ \theta_2 &= -\theta_1 \end{aligned}$$

Soft breaking of the mixing angles:

$$\theta_1 \simeq \theta(1 - \frac{m_{\tilde{N}}^2}{M^2})$$

Conclusions and Discussions

(1)We workout the mass eigenvalues and mixings of seesaw model with one generation.

(2) Coupling of neutrino and sneutrinos to Higgs fields are determined.

(3) The relations (soft breaking of mass and angles) are important to show the various divergence will be cancelled in the limit of vanishing soft breaking.

(4) Remember Okada , Yamaguch ,Yanagida
compute top-stop loop corrections to V_{eff}(effective potential to Higgs)

$$e^{-iV_{eff}} = \int dt d\tilde{t} e^{iS}$$

$$S = \int d^4 x \mathcal{L}$$

$$\mathcal{L} = \partial\widetilde{t_R}^*\partial\widetilde{t_R} + \widetilde{t_L}^*\partial\widetilde{t_L} - {M_s}^2\widetilde{t_R}^*\widetilde{t_R} - {M_s}^2\widetilde{t_L}^*\widetilde{t_L} + \bar{t}i\partial\!\!\!/ t - \bar{t}m_t t$$
$$-y_t\overline{t_R}t_L{H_2}^0 - {y_t}^*\overline{t_L}t_R{H_2}^{0*}$$
$$- \mid y_t \mid^2\mid \widetilde{t_R} \mid^2\mid {H_2}^0 \mid^2 - \mid y_t \mid^2\mid \widetilde{t_L} \mid^2\mid {H_2}^0 \mid^2$$

$$V^{nad} = \frac{N_c}{16\pi^2} \mid y_t{H_2}^0 \mid^4 (ln\frac{M^2}{\mid y{H_2}^0 \mid^2} + \frac{3}{2})\cdots$$

They show the increase of the lightest higgs $> m_Z^2$. While recently, Junjie Cao and Jin Ming Yang (PRD 71,11701 (R)), shows that in susy seesaw a few tens of GEV reductions of the lightest Higgs mass is possible.

(5) We are examinng their results and will extend to more realistic case with flavor mixings and CP violation which will be useful for higgs phenomenology.