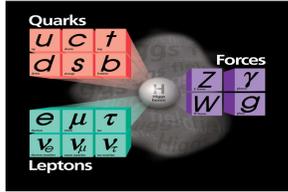


Standard Model and Higgs Boson



- Standard Model (SM) of particle Physics is so far well established experimentally
- Standard Model is described by the local gauge invariance of $SU(2)_L \times U(1)_Y \times SU(3)_C$
- SM describes the interaction between the 12 gauge bosons (force carriers) and the 12 fermions.
- But this leaves all the fundamental and mediator particles as massless
- **There must be some mechanism which generates the masses for these particles.**
- Higgs mechanism is one of solutions to this problem that gives mass to the EW gauge bosons in a gauge invariant way.

Triplet extended SSM

- The discovery of ~ 125 GeV Higgs pushed the required SUSY mass scale to $>$ few TeV for the most constrained scenarios.
- In pMSSM such solutions have one more alternative, corresponds to the possibility of one lighter stop. \Rightarrow Larger mass splitting between the stops: large $\tan\beta$ and $A_{t,b}$.
- In TESSM, the field content of the MSSM is enlarged by introducing an $SU(2)$ complex Higgs triplet with zero hypercharge which can be represented as a 2×2 matrix

$$\Sigma = \begin{pmatrix} \sqrt{\frac{1}{2}}\xi^0 & \xi_2^+ \\ \xi_1^- & -\sqrt{\frac{1}{2}}\xi^0 \end{pmatrix}. \quad (1)$$

Here ξ^0 is a complex neutral field, while ξ_1^- and ξ_2^+ are the charged Higgs fields. Note that $(\xi_1^-)^* \neq -\xi_2^+$.

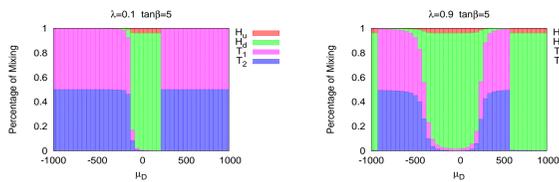
- The triplet field Σ only couples to the two Higgs doublets by a dimensionless coupling λ . The superpotential of the Higgs sector of the model is given by

$$W = \lambda H_d \cdot \Sigma H_u + \mu_D H_d \cdot H_u + \mu_T \text{Tr}(\Sigma^2), \quad (2)$$

where μ_D is the usual mixing parameter of the two MSSM Higgs doublets and μ_T is the mass parameter of the triplet.

Constrains from $\text{Br}(B_s \rightarrow X_s \gamma)$

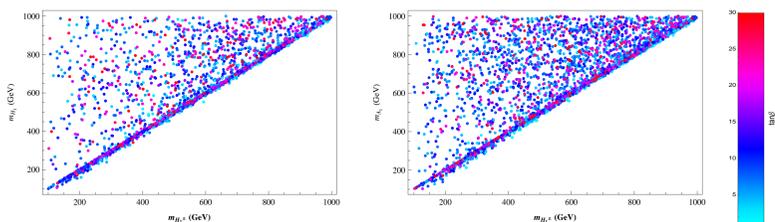
- The triplet component of the Higgs bosons do not couple to the fermions (see Eq. 2).
- This leads to the different $\Gamma(h^- \rightarrow gg)$ and $\Gamma(h^- \rightarrow \gamma\gamma)$ predictions for the neutral Higgses.
- In case of the charged Higgs bosons the triplet parts do not contribute to the flavour changing diagrams and so is for their superpartners [1].



- There are three charged Higgses and four charginos contributing to $B_s \rightarrow X_s \gamma$
- The change in doublet portions in both charged Higgses and charginos change the prediction for $\text{Br}(B_s \rightarrow X_s \gamma)$ as compared to MSSM.
- We for the first time calculated $\text{Br}(B_s \rightarrow X_s \gamma)$ in this model with NLO SUSY corrections [2].

Phenomenology of H^\pm

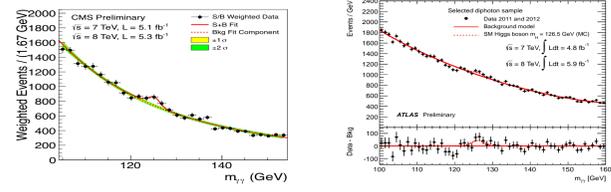
- If the light charged Higgs ($m_{H^\pm} \leq m_t$) is triplet type it cannot be produced through $pp \rightarrow t\bar{t}$ production via top decay.
- For $m_{H^\pm} \geq m_t$, the triplet component of the charged Higgs does not decay to tb but may decay to ZW
- These non-stared couplings can evade the recent ATLAS bound on the charged Higgses and leads to search for new final states.
- In the case of heavy neutral Higgs bosons, they couple to $H^\pm W^\mp$ irrespective of their doublet-triplet properties.
- For $m_{H_1/A_1} > (m_{H^\pm} + m_{W^\pm})$, heavy Higgses could be a source of the light triplet type charged Higgs boson.



References

- [1] P. Bandyopadhyay, K. Huitu and A. Sabanci, JHEP **1310** (2013) 091 [arXiv:1306.4530 [hep-ph]].
- [2] P. Bandyopadhyay, S. Chiara, K. Huitu and A. Sabanci, *Fit of $Y = 0$ triplet extended supersymmetric model with the Higgs results and $B_s \rightarrow X_s \gamma$, To appear soon*
- [3] P. Bandyopadhyay, K. Huitu and A. Sabanci, *Multilepton signatures probing $Y = 0$ TESSM at the LHC, To be appeared soon*

Higgs discovery and Supersymmetry



- Finally, on 4th of July 2012, we get evidence of a even-integer-spin particle similar to Higgs boson at the LHC with mass around 125.5 GeV.
- LHC data strongly favor the spin 0 possibility and exclude the spin 2 hypothesis with a confidence level above 99.9%.
- Though the recent experimental observation in different decay modes are compatible with SM, still there is room for theories beyond SM.
- Supersymmetric extension of SM was well motivated as it rescues the SM Higgs mass from the hierarchy problem and it also provide the much needed dark matter candidate for the evolution of the universe.

Status of ~ 125 GeV Higgs in TESSM

- TESSM has three neutral CP-even Higgses (h, H_1, H_2), two CP-odd Higgses (A_1, A_2) and three charged Higgs bosons ($H_{1,2,3}^\pm$).
- At tree-level the light Higgs mass gets an additional contribution from the λ term Eq. 2

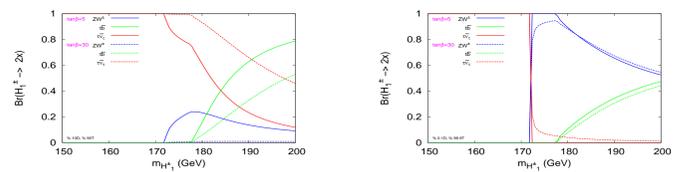
$$m_h^2 \leq M_Z^2 (\cos 2\beta + \frac{2\lambda^2}{g_2^2 + g_1^2} \sin 2\beta) \quad (3)$$

\Rightarrow Low $\tan\beta$ increases the tree-level Higgs mass.

- We calculated the one-loop neutral Higgs masses via Coleman-Weinberg effective potential approach [1].
- The Higgs bosons in TESSM could be a mixture of doublets and triplets.
- The merit of TESSM depends on the status of the discovered light Higgs boson as well as the bounds for the heavy Higgs bosons at the LHC which is studied in details [2].

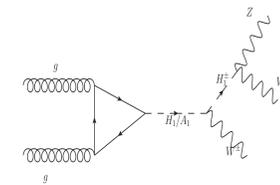
Charged Higgses in TESSM

- $Y = 0$ Triplet extension leads to new vertex of the triplet charged Higgs boson: $H_T^\pm - Z - W^\mp$.
- This vertex leads to an interesting phenomenology for the as the triplet charged Higgs boson could decay to ZW .
- From the coupling we can see that $\Gamma(H^\pm \rightarrow ZW^\pm)$ gets a tough competition from $\Gamma(H^\pm \rightarrow tb)$ [3].



- $\Gamma(H^\pm \rightarrow tb) \simeq 0$ when H^\pm is completely triplet type.
- Thus measuring the triplet type charged Higgs could be a very good indicator of this model.

Triplet H^\pm at the LHC



- We propose to explore $pp \rightarrow H_i/A_i \rightarrow H_i^\pm W^\mp$ as a production mode for the light charged Higgs boson (H_1^\pm).
- We zeroed in to the parameter space allowed by the experimental data to have $H_1/A_1 \rightarrow H_1^\pm W^\mp$ decay kinematically possible.
- The H^\pm then decays to gauge bosons and leads to $3\ell + 2j + \cancel{p}_T$ and $4\ell + \cancel{p}_T$ final states.

$$pp \rightarrow A_1/H_1 \rightarrow H_1^\pm W^\mp \rightarrow Z + W^\pm + W^\mp \rightarrow 3\ell + 2j + \cancel{p}_T, \quad 4\ell + \cancel{p}_T$$

- The above final states which probe the triplet type charged Higgs boson prefers low $\tan\beta$
- A PYTHIA + FASTJET level simulation considering dominant SM backgrounds shows a 5σ signal significance over backgrounds requires 3000 fb^{-1} of data at the LHC with $E_{cm} = 14 \text{ TeV}$ [3].