Gluino, wino and Higgsino-like particles without supersymmetry

Tirtha Sankar Ray

Work done in collaboration with
Carlos A. Savoy and Hiroshi de Sandes

Institut de Physique Théorique
CEA-Saclay, France.

Basic Premise

- The SM fermion mass hierarchies and mixing are experimentally well established but still an unanswered mystery.

- An elegant resolution of this problem can be achieved within the framework of Froggatt-Nielsen mechanism.

- In the simplest form, this entails the prediction of an additional $U(1)_X$ flavor symmetry group, under which the SM fermions are charged. The flavor group is spontaneously broken by the vev of a flavon field due to some high scale dynamics.

- Hierarchies are generated in the low energy effective theory through clever distribution of the $U(1)_X$ charges:
  This is because the coefficient of an SM operator $(\hat{O})$ is suppressed by a factor $\epsilon^{|\Delta X|}$, where ΔX is the $U(1)_X$ charge of the operator $(\hat{O})$ and $\epsilon = \langle\phi\rangle/\Lambda$, where $\langle\phi\rangle$ is the flavon vev and Λ is the cut-off.

Motivation for Exotic fields from flavor theories

- Easy to see that within the SM the $U(1)_X$ group is anomalous. Precisely one can define the following anomalies: $\mathcal{A}_{C^2X}$, $\mathcal{A}_{Q^2X} - 4/3\mathcal{A}_{C^2X}$, $\mathcal{A}_{W^2X}$ and $\mathcal{A}_{YX^2}$.

- It is generally assumed that such anomaly cancellation takes place at the string scale through the Green-Schwarz mechanism.

- A pragmatic approach is to consider that real fermionic degrees of freedom contribute to the anomaly expressions and balance them.

- They can have masses if they either come in vector like pairs in some representation of the SM gauge group or are in the real representation of the SM gauge group. Typically, $m_f \sim \epsilon^{|\chi_f|}\Lambda$.

- The anomaly relations are so badly violated within the SM that these exotic fermions get large $U(1)_X$ charges and hence large suppression $\Rightarrow$ Mass in the LHC RANGE.

The Minimal and Next to Minimal Models

- Minimal Model: SM + FN flavon +
  exotic fermions $\tilde{g}(8,1,0)$ (Gluino), $\tilde{w}(1,3,0)$ (Wino) and $\tilde{h}_d(1,2,-\frac{1}{2})$, $\tilde{h}_u(1,2,+\frac{1}{2})$(Higgsinos).

- We expand the scalar sector to include a second Higgs doublet: Field content exactly mirrors that of the Split SUSY models.

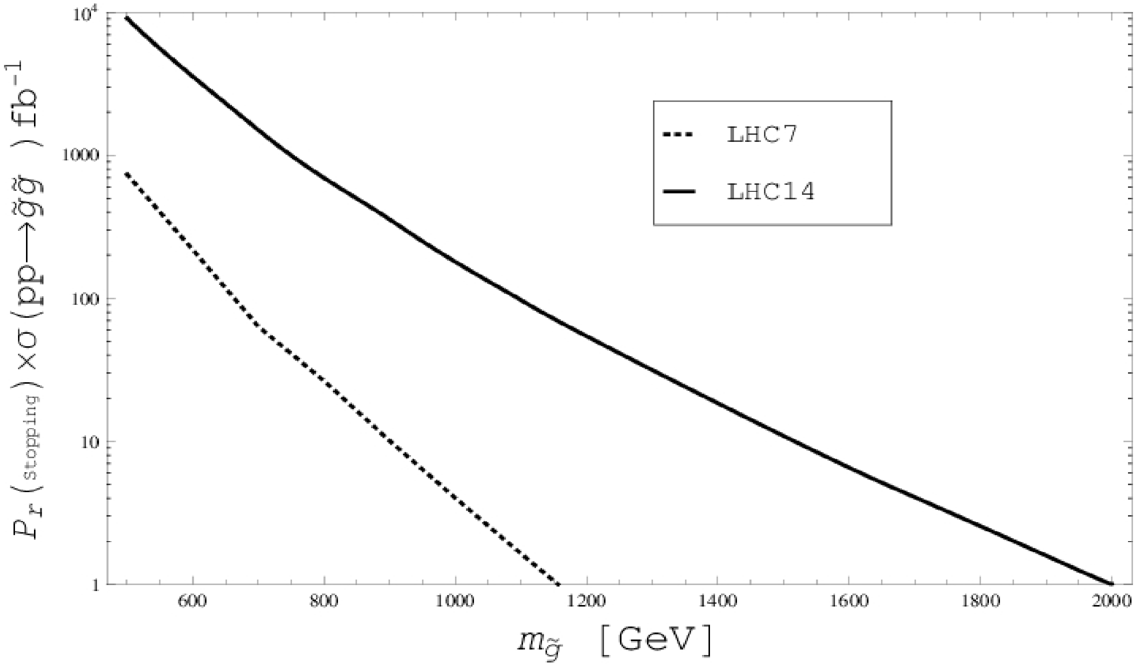
- In our next to minimal model, an exotic lepton (E) (Right Handed Neutrino) is added. This allows the possibility of driving gauge coupling unification around the usual GUT scale.

- Beside the universal gauge interactions, the exotic fields have only effective four fermion couplings to the standard model.
  A discrete symmetry proton hexality $(B-2L)/6$ is imposed to prevent proton decay.

Once we have the Masses and the Interactions we have a well defined phenomenology for these models.

Example I

SM fields	*Exotic fields*	*Lightest particle*	r	*Decay width*
$x_{\bar{u}} = (6,4,2),\ x_q = (2,0,-2)$ $x_{\bar{d}} = (7,7,7),\ x_{\bar{e}} = (-9,3,-1)$ $x_t = 0,\ x_H = -2$ $x_l = 4,\ z'(\tilde{h}_d) = -\frac{3}{18}$	$\chi_{\tilde{g}} = -11$ $\chi_{\tilde{w}} = -1$ $\chi_{\tilde{h}} = -7$	$m_{\tilde{g}} \sim 1.5\ TeV$	0.33	$C\tau(\tilde{g}_1) \sim 5.6 \times 10^{12}\ km$



Decay Modes: $\tilde{g} \to \bar{l} q \bar{u}_R,\quad \bar{l} d_R \bar{q},\quad \bar{e}_R \bar{u}_R d_R$ (+h.c.) Metastable

Example II

$SM\ \ fields$	$Exotic\ fields$	$Lightest\ particle$	r	$Decay\ width$
$x_q = (6,4,2)$ $x_{\bar{u}} = (2,0,-2)$ $x_{\bar{d}} = (-3,-3,-3)$ $x_t = 2,\ \ x_H = 2$ $x_l = -4,\ \ z'(\tilde{h}_d) = -\frac{3}{18}$ $x_{\bar{e}} = (-3,5,3)$	$\chi_{\tilde{g}} = -5$ $\chi_{\tilde{w}} = -9$ $\chi_{\tilde{h}} = -5$ $\chi_E = 4$	$m_{\tilde{w}} \sim 1.5\ TeV$	0.09 Unification	$\tilde{w}$ in unstable
$x_q = (4,2,0)$ $x_{\bar{u}} = (4,2,0)$ $x_{\bar{d}} = (1,1,1)$ $x_t = 2,\ \ x_H = 0$ $x_l = 4,\ \ z'(\tilde{h}_d) = -\frac{3}{18}$ $x_{\bar{e}} = (-9,-1,-3)$	$\chi_{\tilde{g}} = -7$ $\chi_{\tilde{w}} = -10$ $\chi_{\tilde{h}} = -9$ $\chi_E = 1$	$m_{\tilde{w}} \sim 1.6\ TeV$	0.05 Unification	$\tilde{w}$ is a DM candidate

$\chi_{\tilde{w}}$ Odd

Decay Modes:

$\tilde{w} \to \bar{l} q \bar{u}_R,\quad \bar{l} d_R \bar{q},\quad \bar{l} \bar{l} d_R,\quad \bar{l} \bar{H}_u (+\text{h.c.})$

Neutrino mass generated through the last operator:

$m_\nu \sim \left(\epsilon^{|2x_l - 1|} + \epsilon^{|2x_l - 1 + \chi_{\tilde{w}}| - |\chi_{\tilde{w}}|}\right) \frac{v^2}{\Lambda}.$

$\chi_{\tilde{w}}$ Even

The Wino is a stable Minimal Dark Matter (MDM) candidate.
For mass around $\sim 2.7\ TeV$, it satisfies the 7 year WMAP constraints.
However the nuclear cross-sections of these species get an unavoidable Sommerfeld enhancement, putting them in imminent danger of being ruled out by indirect searches.

Conclusion

- We have studied a class of models with exotic fields at the TeV scale, motivated by flavor theories.
- These particles have distinctive phenomenology and are identifiable at LHC.
- The choice of the exotic field content is not unique within this framework.
- Indeed SM and Supersymmetric versions with exotic fields below the TeV scale in the fundamental representation have also been studied recently.

THANK YOU