Is the Higgs our first supersymmetric particle?

If it looks like a Higgs
spins like a Higgs
couples like a Higgs
it must be a ~~Higgs~~ sneutrino

Carla Biggio [1], **Jeff Asaf Dror** [2], Wee Hao Ng[2], and Yuval Grossman[2]

[1]Università di Genova

[2]Cornell University

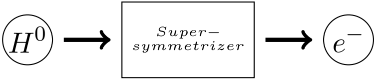
What do we know about our new scalar?

- New boson
  - is spin 0 (scalar)
  - is neutral
  - couples to fermions and gauge bosons
  - has Particle Data Group entry:

H^0 $J = 0$

Mass $m = 125.7 \pm 0.4$ GeV

- **Can be Higgs, but maybe $\tilde{\nu}_e$?**



- **Our goal:** study new bounds on such models

- R_P isn't enough, need R symmetry
- Most general assignment of $U(1)_R \rightarrow$
- If arbitrarily L and B

$$W = y_d^{ij} H Q_i D_j + y_e^{ab} H L_a E_b$$

↳ Has e_L^- ⟵

- $m_{u,c,t} = 0$ & $m_e = 0$ & $m_\nu = 0$
- $\tau_{proton} = 0$
- ~~$U(1)_R$~~ due to gravity is inevitable
  - Parametrized by $m_{3/2} \ll$ TeV

	$U(1)_R$
$Q_{1,2,3}$	$1+B$
$U_{1,2,3}$	$1-B$
$D_{1,2,3}$	$1-B$
$L_{1,2}$	$1-L$
$E_{1,2}$	$1+L$
$\mathbf{H \equiv L_3}$	0
E_3	2
$\tilde{\lambda}, \psi_\lambda$	$1, -1$

- $m_{u,c,t} \neq 0$ with introducing H_u, R_d:

$$\int d^2\theta H_u Q U$$

  - Alternative: low cut-off, $\Lambda \lesssim 4\pi$TeV
- m_e^- given by higher order terms, e.g.,

$$\int \frac{d^4\theta}{M^2} X^\dagger H_u^\dagger H E_3$$

- e_L^- is naturally light

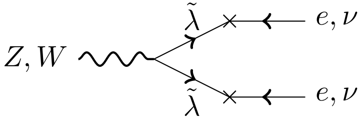
- Mixing between e^-, ν_e and $\tilde{\lambda}$:

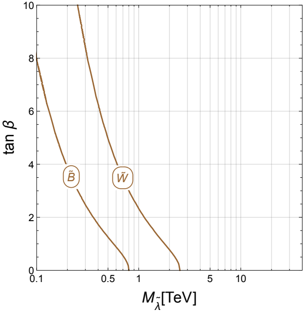
$$\int d^4\theta H^\dagger e^V H = g h e_L^- \tilde{W}^+ + g h \nu_e \tilde{W}^0 + g' h \nu_e \tilde{B}^0$$

- $e, \nu_e \rightarrow$ *electroweakinos*

$$\Rightarrow \chi_e^- \sim e^- + \epsilon\, \psi_{\tilde{\lambda}}, \epsilon \equiv v_h / M_{\tilde{\lambda}}$$

- Known bound-universality(LEP):
  $\delta g_{eeZ} \sim \epsilon^2 \lesssim 0.1\%$
  $\delta g_{e\nu W} \sim \epsilon^2 \lesssim 1\%$

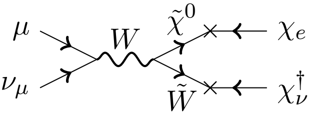


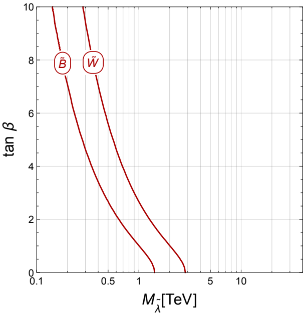


Non-standard neutrino interactions

- Model produces new operators,

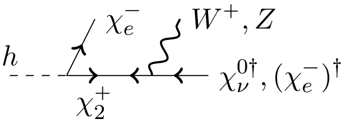
$$\Delta\mathcal{L} = -2\sqrt{2}G_F\epsilon^{\alpha\beta}_{\gamma\delta}\left[\ell^\dagger_\alpha\bar{\sigma}^\mu\ell_\beta\right]\left[\nu^\dagger_\gamma\bar{\sigma}_\mu\nu_\delta\right] \quad , \epsilon_{e\mu}, \epsilon_{e\tau} = -\frac{1}{2}\epsilon^2$$



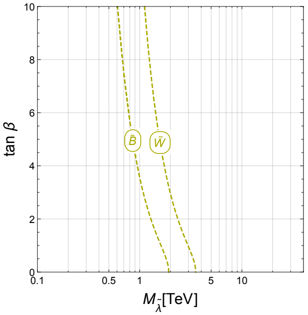


- Operator probed through,
  - Muon decay
  - Heavy flavor decays
- ν mixing to heavy states $\rightarrow$ vanishing neutrinos
  - Probed by short base-line expt

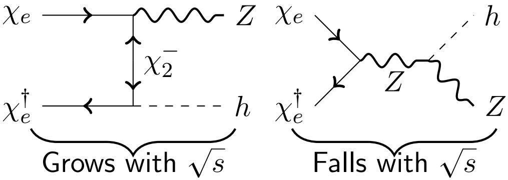
- New higgs decays:



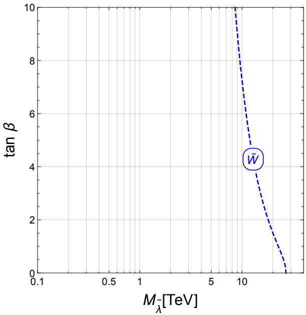
- For $\delta\Gamma(h \to W^* W) \sim 0.1\%$ (at higgs factory) get limit on right
- Could improved using cuts
- Exist similar contributions to $h \to ZZ^*$
- LHC might probe this at $\mathcal{O}(1\%)$ which would probe $\mathcal{O}(m_{\tilde{\lambda}} \lesssim \text{TeV})$



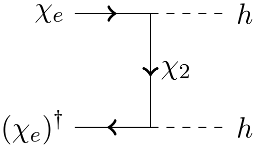
- Higgs production at an e^+e^- collider has exciting consequences



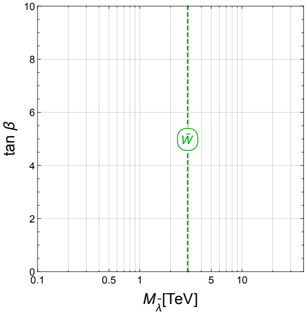
- For e^+e^- collider assuming
  - $\sqrt{s} = 1$TeV
  - signal detectable if $\delta\sigma/\sigma_{SM} < 1\%$.



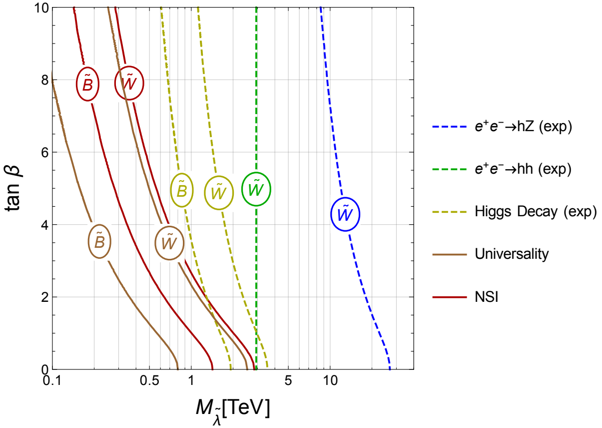
- SM: $e^+e^- \to hh$ is **loop suppressed**
- $\ell_e - \tilde{\lambda}$ mixing gives new production channel



- Assuming
  - $\sqrt{s} =$ TeV
  - Detectable if 10 events @ $\mathcal{L} = 300 fb^{-1}$
- **Independent of v_h**



- Combining all the limits:

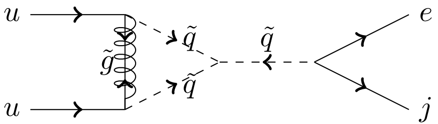


- Generic L in 2HDM the neutrino mass matrix is,

$$m_\nu \sim \begin{array}{c} \\ \nu_e \\ \nu_\mu \\ \nu_\tau \end{array} \begin{array}{c} \begin{array}{ccc} \nu_e & \nu_\mu & \nu_\tau \end{array} \\ \left[\begin{array}{ccc} a & b & c \\ b & 0 & 0 \\ c & 0 & 0 \end{array} \right] \end{array} \times \epsilon^2 m_{3/2} \qquad (1)$$

- Terms are consequence of the rotation between $\tilde{W}, \tilde{H}_u, \nu_e$
- Massless eigenvector, $\vec{v}_0 \equiv \left(0, b/\sqrt{b^2+c^2}, c/\sqrt{b^2+c^2}\right)$
- If identify $\vec{v}_0$ as $\nu_3 \rightarrow$ inverted mass hierarchy with $\theta_{13} = 0$
- If $a \sim b \sim c$ then we get **tribimaximal mixing**.
- For $\theta_{13} \neq 0$ **need to fill 0's**
  - $\Rightarrow$ low cutoff $\Lambda \sim$ **few TeV**.
- Same physics that gives mass to up-type quarks?

- Model has large $\not{L}$, ~~$U(1)_R$~~ **induces** $\not{B}$
- Proton decay though,



$$\rightarrow \frac{m_{3/2}^2}{16\pi^2 m_{\tilde{q}}^4} y_e(uued)$$

- $\Rightarrow$ $m_{3/2} \lesssim$ **keV**
- To get $m_\nu \sim 0.1$eV with correct PMNS requires $m_{3/2} \gtrsim 10$**eV**.
- $\Rightarrow m_{3/2}$ bounded within 2 orders of magnitude

- H^0 might be superpartner of e_L^-
- We've introduce variety of new bounds
  - NSI
  - Higgs decays
  - $e^+e^- \to hZ$
  - $e^+e^- \to hh$
- $\not{U}(1)_R$ has important effects
  - Prediction of small θ_{13} and inverted mass spectrum
  - Proton decay restricts allowed values of $m_{3/2}$
- Framework is still in its early stages and needs to be studied further