The Higgs and EWPO in R-symmetric SUSY

[arXiv:1408.xxxx]

Philip Diessner, Jan Kalinowski, Wojciech Kotlarski, Dominik Stöckinger

TECHNISCHE UNIVERSITÄT DRESDEN

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R-Symmetry

- Symmetry allowed by SUSY algebra
- For (N=1)-SUSY: $U(1)_R$ symmetry
- Superfield components have different charges
- SM fields have $Q_{\mathrm{R}} = 0$ (R-parity is subgroup)
    - no rapid proton decay
    - forbids A-terms e.g. $Ay_u\tilde{Q}H_u\tilde{U}$
    - forbids Majorana masses and μ term

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Already excluded?

One way to fix it: Dirac masses (MRSSM; *Kribs et.al. arXiv:0712.2039*)

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Soft breaking

$$M_i\tilde{\lambda}_i\tilde{\lambda}_i \rightarrow M_i^D\tilde{\lambda}_i^a\psi_j^a;\ \{i,j\} \in \{\{G,O\},\{W,T\},\{B,S\}\};$$

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Additional fields

		$SU(3)_C$	$SU(2)_L$	$U(1)_Y$	$U(1)_{\mathrm{R}}$
Singlet	$\hat{S}$	1	1	0	0
Triplet	$\hat{T}$	1	3	0	0
Octet	$\hat{O}$	8	1	0	0
R-Higgses	$\hat{R}_u$	1	2	$-1/2$	2
	$\hat{R}_d$	1	2	$1/2$	2

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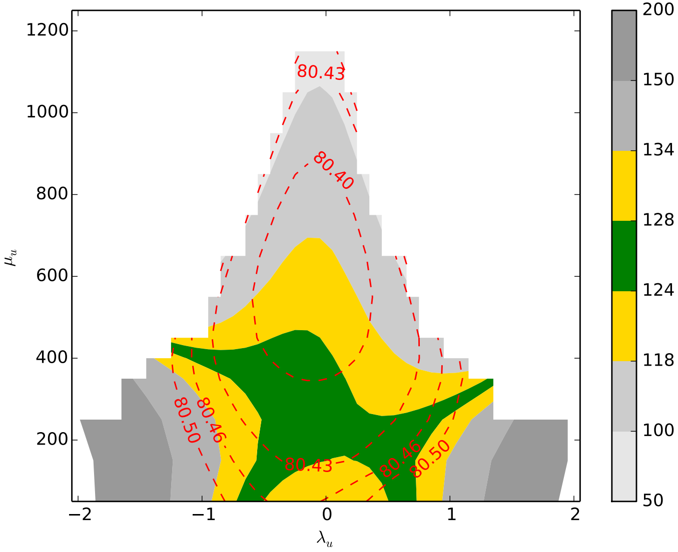
Superpotential

$$\begin{aligned}\mathcal{W} =& y_e\hat{H}_d\hat{L}\hat{E} + y_d\hat{H}_d\hat{Q}\hat{d} - y_u\hat{H}_u\hat{Q}\hat{U} + \\ & \mu_d\hat{H}_d\hat{R}_d + \mu_u\hat{H}_u\hat{R}_u + \\ & \lambda_d\hat{H}_d\hat{R}_d\hat{S} + \lambda_u\hat{H}_u\hat{R}_u\hat{S} + \Lambda_d\hat{H}_d\hat{T}\hat{R}_d + \Lambda_u\hat{H}_u\hat{T}\hat{R}_u\end{aligned}$$

Higgs mass vs. W mass (at one-loop)



Conclusions

- Introduction to R-symmetry for model building:
  $\rightarrow$ global $U(1)$ symmetry allowed by SUSY algebra
- Different μ than in the MSSM, different λ's than in the NMSSM
  $\rightarrow$ MRSSM with different phenomenology with complementary features
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Thanks for the attention!

References

MRSSM G. D. Kribs, E. Poppitz and N. Weiner, “Flavor in supersymmetry with an extended R-symmetry,” Phys. Rev. D **78** (2008) 055010 [arXiv:0712.2039 [hep-ph]].

Backup

SUSY and R-Symmetry

usual: $\{Q, Q\} = \{\bar{Q}, \bar{Q}\} = 0$
in "Haag-Łopuszański-Sohnius-Theorem": $\{Q^L_\alpha, Q^M_\beta\} = \epsilon_{\alpha\beta} \sum_l (a^l)^{LM} R^l$
$[R, Q] = -Q, \quad [R, \bar{Q}] = \bar{Q},$
$\rightarrow$ in $\mathcal{N} = 1$ is $U(1)_R$

R-Symmetry

- additional symmetry allowed by SUSY algebra described in "Haag-Łopuszański-Sohnius-Theorem"
- For $N = 1$ SUSY it is a global $U(1)_{\mathrm{R}}$ symmetry
  $\rightarrow$ charged Spinor coordinates:
  $Q_{\mathrm{R}}(\theta) = 1,\ Q_{\mathrm{R}}(\bar{\theta}) = -1; \quad (\theta \rightarrow e^{i\alpha}\theta, \theta \rightarrow e^{-i\alpha}\theta)$
- Lagrangian has to be invariant:
  - terms in superpotential have $Q_{\mathrm{R}} = 2$; $\mathcal{L}_{\mathcal{W}} = \int \mathrm{d}^2\theta\mathcal{W}$
  - softbreaking terms have $Q_{\mathrm{R}} = 0$
- SM fields have $Q_{\mathrm{R}} = 0$

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R charges of component fields

	Q_R	scalar	vector	fermionic
vector superfield	0	-	0	1
chiral superfield	Q	Q	-	$Q - 1$

$\rightarrow$ Higgs superfield: $Q_\mathrm{R} = 0$; lepton and quark superfields: $Q_\mathrm{R} = 1$

Dirac masses for soft breaking

$$\mathcal{L}_{\text{dirac}} = \int d\theta^2 \hat{S} \hat{W}'^{\alpha} \hat{W}_{B\alpha} = -M^D \tilde{\lambda}_B \psi_S^a + \sqrt{2} M^D D_B^a \phi_S^a$$

using Spurion: $\hat{W}'^{\alpha} = \sqrt{2} M^D \theta^{\alpha}$

Lightest Higgs mass - Tree level

EWSB

- Separating h_u, h_d, s, t in vevs, scalar and pseudo-scalar part
- Forming mass eigenstates with (4×4) mass matrices

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For $v_S, v_T \ll v$ and $(M^D)^2 \ll m^2_{\text{soft}}$
($\lambda_u = -\lambda_d = \lambda$, $\Lambda_u = \Lambda_d = \Lambda$, $\mu_u = \mu_d = \mu$):

$$m^2_{h,\text{tree}} = \left(m_Z^2 - v^2 \left(\frac{\left(g_1 M_B^D + \sqrt{2}\lambda\mu\right)^2}{8(M_B^D)^2 + 2m_S^2} + \frac{\left(g_2 M_W^D + \Lambda\mu\right)^2}{8(M_W^D)^2 + 2m_T^2} \right) \right) \cos(2\beta)$$

No enhancement from singlet like in the NMSSM, additional states lower lightest mass on tree level $\rightarrow$ one loop even more important

Lightest Higgs mass - One Loop I

Analytical approximation from the effective potential:

$$(\Delta m_h^2)_{1L} = \frac{3v^2}{16\pi^2}\Bigg[\frac{4\lambda^4 + 4\lambda^2\Lambda^2 + 5\Lambda^4}{8}\log\left(\frac{m_{R_u}^2}{Q^2}\right)$$
$$+ \left(\frac{\lambda^4}{2} - \frac{\lambda^2\Lambda^2}{2}\frac{m_S^2}{m_T^2 - m_S^2}\right)\log\left(\frac{m_S^2}{Q^2}\right)$$
$$+ \left(\frac{5}{8}\Lambda^4 + \frac{\lambda^2\Lambda^2}{2}\frac{m_T^2}{m_T^2 - m_S^2}\right)\log\left(\frac{m_T^2}{Q^2}\right)$$
$$- \left(\frac{5}{4}\Lambda^4 - \lambda^2\Lambda^2\frac{(M_W^D)^2}{(M_B^D)^2 - (M_W^D)^2}\right)\log\left(\frac{(M_W^D)^2}{Q^2}\right)$$
$$- \left(\lambda^4 + \lambda^2\Lambda^2\frac{(M_B^D)^2}{(M_B^D)^2 - (M_W^D)^2}\right)\log\left(\frac{(M_B^D)^2}{Q^2}\right)$$
$$+ \frac{\Lambda^2\lambda^2}{2}\Bigg] + \text{stop contrb.}$$

λ or/and Λ can give sizeable contribution, reducing the need for large stop