Higgs phenomenology of the supersymmetric grand unified theory with the Hosotani mechanism

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1, Introduction

T. Appelquists Decoupling theorem

[T. Appelquist and J. Carazzone, Phys.Rev. D11 (1975) 2856]

→ Testing GUTs is difficult at the low energy.

- Conventional GUTs are tested only by probing relations among coupling constants and mass ratio
- If new TeV scale particles are predicted, we can probe GUTs at low energy experiments

➢ ***Supersymmetric grand unified theory with the Hosotani mechanism***

[K. Kojima, K. Takenaga and T. Yamashita, PhysRevD.84.051701]

[T. Yamashita, Phys. Rev. D84 (2011) 115016]

Doublet-Triplet splitting is naturally realized

New TeV-mass adjoint chiral supermultiplets, color octet, SU(2) triplet and singlet, are predicted

	$SU(3)$	$SU(2)$	$U(1)$	
$\hat{H}_d$	1	2	−1	MSSM doublet
$\hat{H}_u$	1	2	+1	MSSM doublet
$\hat{S}$	1	1	0	Singlet
$\hat{\Delta}$	1	3	0	Triplet

⇒

4 CP-even: h, H, S_R^0, Δ_R^0

3+1CP-odd : A, S_I^0, Δ_I^0, G

3+1Charged: $H^\pm, \Delta^\pm, \bar{\Delta}^\pm, G^\pm$

Investigating the Higgs sector, we can test this model

2, Model

➢ ***Superpotential and soft-SUSY term***

$$W = \mu \hat{H}_u \cdot \hat{H}_d + \eta \hat{S} + \frac{\mu_S}{2}\hat{S}^2 + \mu_\Delta \mathrm{Tr}(\hat{\Delta}^2) + \lambda_S \hat{S}\hat{H}_u \cdot \hat{H}_d + \lambda_\Delta \hat{H}_u \cdot \hat{\Delta}\hat{H}_d$$

These trilinear couplings contribute to the Higgs physics

$$V_{SOFT} = \tilde{m}_d^2|H_d|^2 + \tilde{m}_u^2|H_u|^2 + 2\tilde{m}_\Delta^2 Tr(\Delta^\dagger\Delta) + \tilde{m}_S^2|S|^2 + \left[B\mu\, H_u \cdot H_d + B_\Delta \mu_\Delta Tr(\Delta^2) + B_S \frac{\mu_S}{2} S^2 + A_\Delta \lambda_\Delta H_u \cdot \Delta H_d + A_S \lambda_S S H_u \cdot H_d + \bar{\eta} S + H.C.\right]$$

➢ ***Features***

- Trilinear coupling $S^3, S\Delta\Delta$ are absent
- $\lambda_S, \lambda_\Delta$ are related at the GUT scale

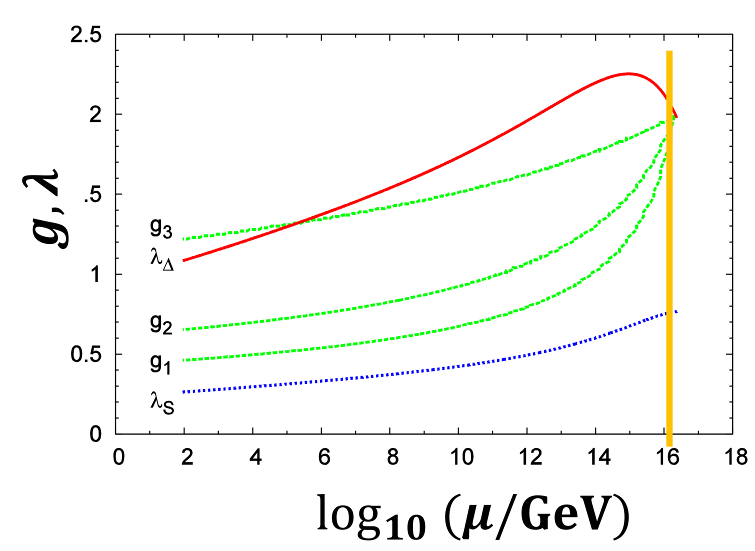
$\lambda_\Delta = 2\sqrt{5/3}\,\lambda_S = g_{GUT}$ @GUT scale

⇓

$\lambda_\Delta = 1.1\,, \lambda_S = 0.26$ @EW scale

- High predictability

GUT scale: $O(10^{16})GeV$



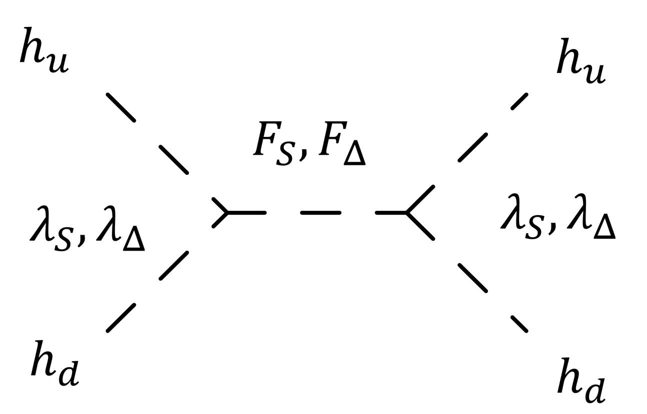
3, Phenomenology of the Higgs sector of Our model

a) Light CP-even Higgs boson mass

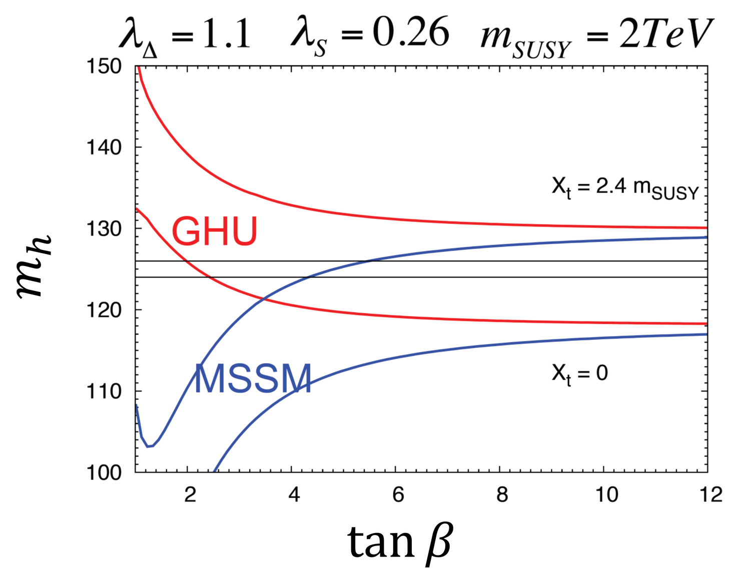
$X_t = A_t - \mu \cot\beta$

$$m_h^2 \sim m_Z^2 c_{2\beta}^2 + \frac{3m_t^4}{2\pi^2 v^2}\left(\log\frac{m_{\tilde{t}}^2}{m_t^2} + \frac{X_t^2}{m_{\tilde{t}}^2}\left(1 - \frac{X_t^2}{12 m_{\tilde{t}}^2}\right)\right) + \frac{1}{2}\lambda_S^2 v^2 s_{2\beta}^2 + \frac{1}{8}\lambda_\Delta^2 v^2 s_{2\beta}^2$$

contribution from MSSM ***contribution from singlet and triplet***



Large $\tilde{m}_S, \tilde{m}_\Delta$ scenario



Light CP-even mass reaches a 126GeV

b) Deviation from the MSSM

- **Charged Higgs boson**

$$m_{H^\pm}^2 = m_{H^\pm}^2\Big|_{MSSM}(1 + \delta_{H^\pm})^2 \sim m_A^2 + m_W^2 - \frac{1}{2}\lambda_S^2 v^2 + \frac{1}{8}\lambda_\Delta^2 v^2$$

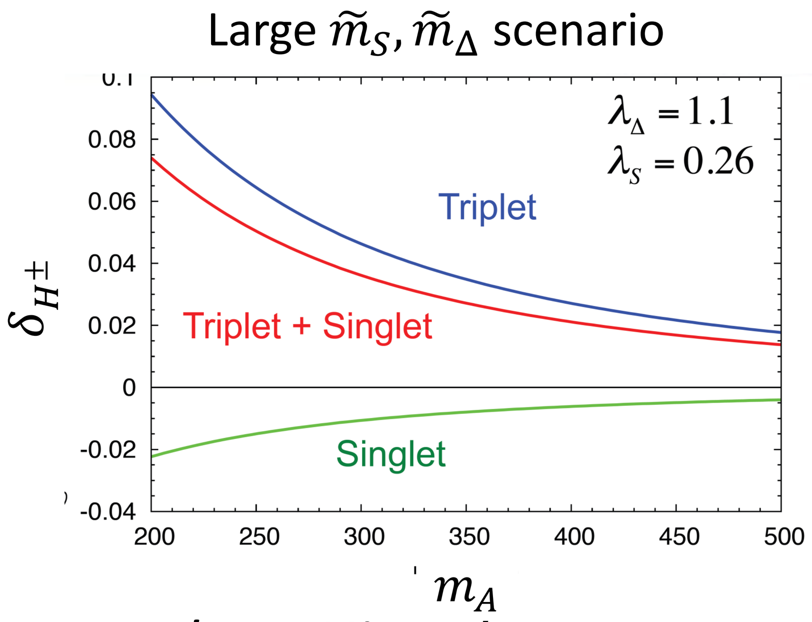
Mass shifts: $O(1)\% - O(10)\%$

- **Heavy CP-even Higgs boson**

$$m_H \cong m_H\Big|_{MSSM} \cong m_H\Big|_{NMSSM}$$

Mass shifts is very small <O(1)%

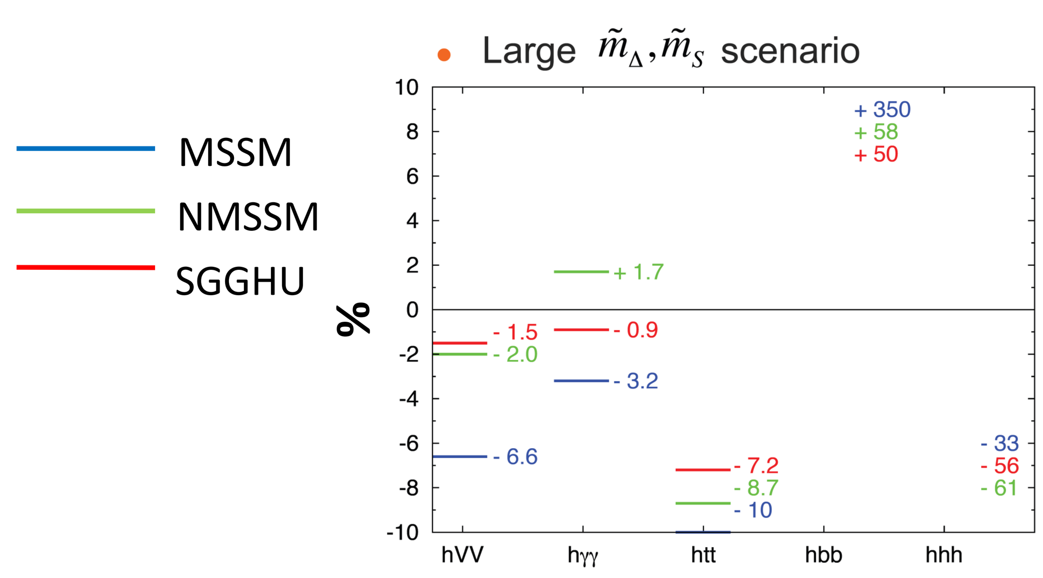
Large $\tilde{m}_S, \tilde{m}_\Delta$ scenario

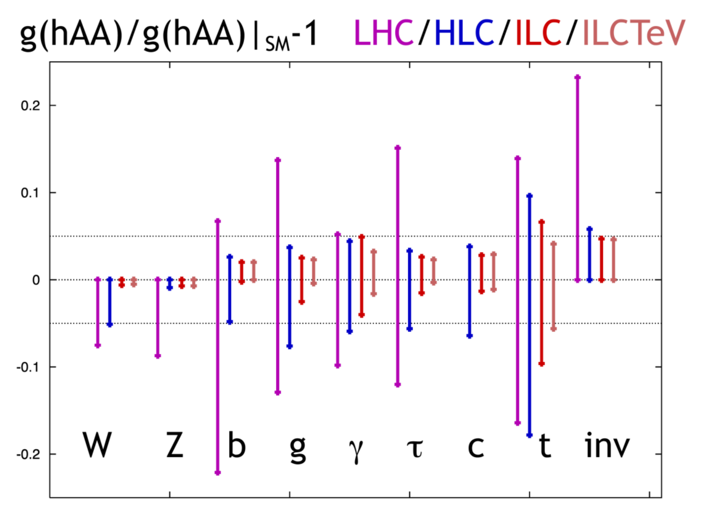


These Higgs bosons are testable at the LHC

c) Coupling of light Higgs boson

$$\frac{g(hAA)}{g(hAA)_{SM}} - 1$$





$\lambda_\Delta = 1.1, \lambda_S = 0.26, \lambda_{S,NMSSM} = 0.6$
$\tan\beta_{MSSM} = 10, \tan\beta_{SGGHU,NMSSM} = 3$
$m_h = 126GeV, mA = \mu_{\rm eff} = 150GeV, m_{SUSY} = 2TeV$

[Peskin, arXive:1207.2516]

We can distinguish models using precision measurement at the ILC

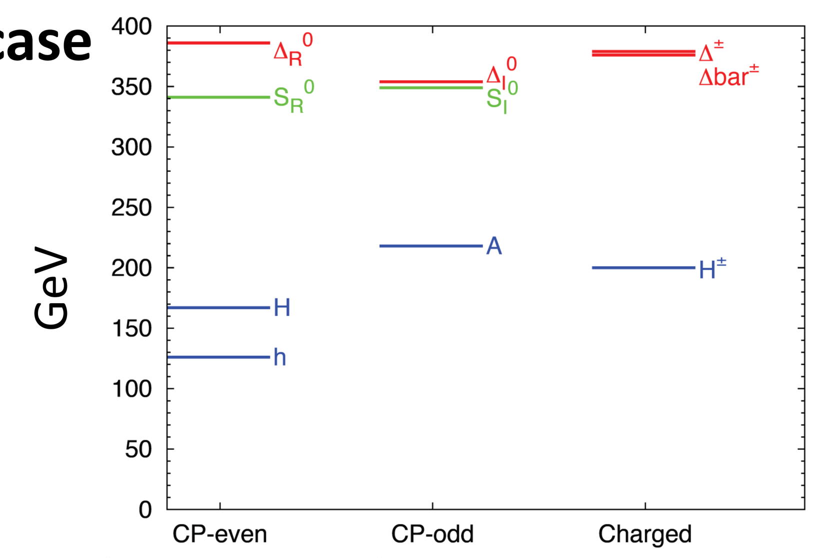
d) Masses of the Higgs bosons for light S, Δ scenario

- **Small soft triplet and singlet mass case**

In this case, we can directly produce additional Higgs bosons at the ILC

ex) $e^+e^- \to \Delta^+\Delta^- \to tbtb$

via large mixing $H^\pm - \Delta^\pm$



$\lambda_\Delta = 1.1, \lambda_S = 0.26, \tan\beta = 3$
$\mu_{\rm eff} = 180GeV, \mu_\Delta = 330GeV, \mu_S = 150GeV$
$\tilde{m}_\Delta = 100GeV, \tilde{m}_S = 300GeV, m_{SUSY} = 2TeV$

4, Conclusion

The predicted values of the Higgs sector deviates from the MSSM and the SM by $O(1) - O(10)\%$

We can test the SGGHU with two steps at the collider experiment. First, we will test charged Higgs at the LHC. Then, we will test the coupling constants of light CP-even Higgs at the ILC

Supersymmetric grand unified theory with the Hosotani mechanism is a good example of a GUT verifiable at colliders