

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

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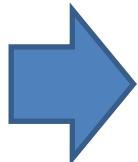
1, Introduction

◆ GUTs

Due to the decoupling theorem,
it is difficult to test GUTs at low energy scale.

GUT scale : $M_{GUT} \sim 10^{16}$ GeV
EW scale : $M_{EW} \sim 10^2$ GeV

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



Tests of GUTs rely on checking the relations
among the parameters of superparticles

◆ Supersymmetric grand unified theory with the Hosotani mechanism [Supersymmetric Grand Gauge-Higgs Unification (SGGHU)]

Doublet-triplet splitting is naturally realized

[*K. Kojima, K. Takenaga and T. Yamashita, PhysRevD.84.051701*]
[*T. Yamashita, Phys. Rev. D84 (2011) 115016*]

This model predicts the existence of the adjoint chiral supermultiplets

$O(8,1,0)$ color octet

$\Delta(1,3,0)$ SU(2) triplet

$S(1,1,0)$ singlet



The Higgs sector is extended

Investigating physics of the Higgs sector, we can test the GUT

2, Supersymmetric Grand Gauge-Higgs Unification

- **Higgs sector**

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



4 CP-even	h, H, S_R^0, Δ_R^0
3+1 CP-odd	$A, S_I^0, \Delta_I^0, G^0$
3+1 Charged	$H^\pm, \Delta^\pm, \bar{\Delta}^\pm, G^\pm$

Superpotential and soft SUSY term

$$W = \mu \widehat{H}_u \cdot \widehat{H}_d + \frac{\mu_s}{2} \widehat{S}^2 + \mu_\Delta \text{Tr}(\widehat{\Delta}^2) + \lambda_s \widehat{S} \widehat{H}_u \cdot \widehat{H}_d + \lambda_\Delta \widehat{H}_u \cdot \widehat{\Delta} \widehat{H}_d$$

$$\begin{aligned} V_{SOFT} = & \widetilde{m}_d^2 |H_d|^2 + \widetilde{m}_u^2 |H_u|^2 + 2\widetilde{m}_\Delta^2 \text{Tr}(\Delta^\dagger \Delta) + \widetilde{m}_s^2 |S|^2 \\ & + \left[B\mu H_u \cdot H_d + B_\Delta \mu_\Delta \text{Tr}(\Delta^2) + B_s \frac{\mu_s}{2} S^2 \right. \\ & \left. + A_\Delta \lambda_\Delta H_u \cdot \Delta H_d + A_S \lambda_s S H_u \cdot H_d + \eta S + H.C. \right] \end{aligned}$$

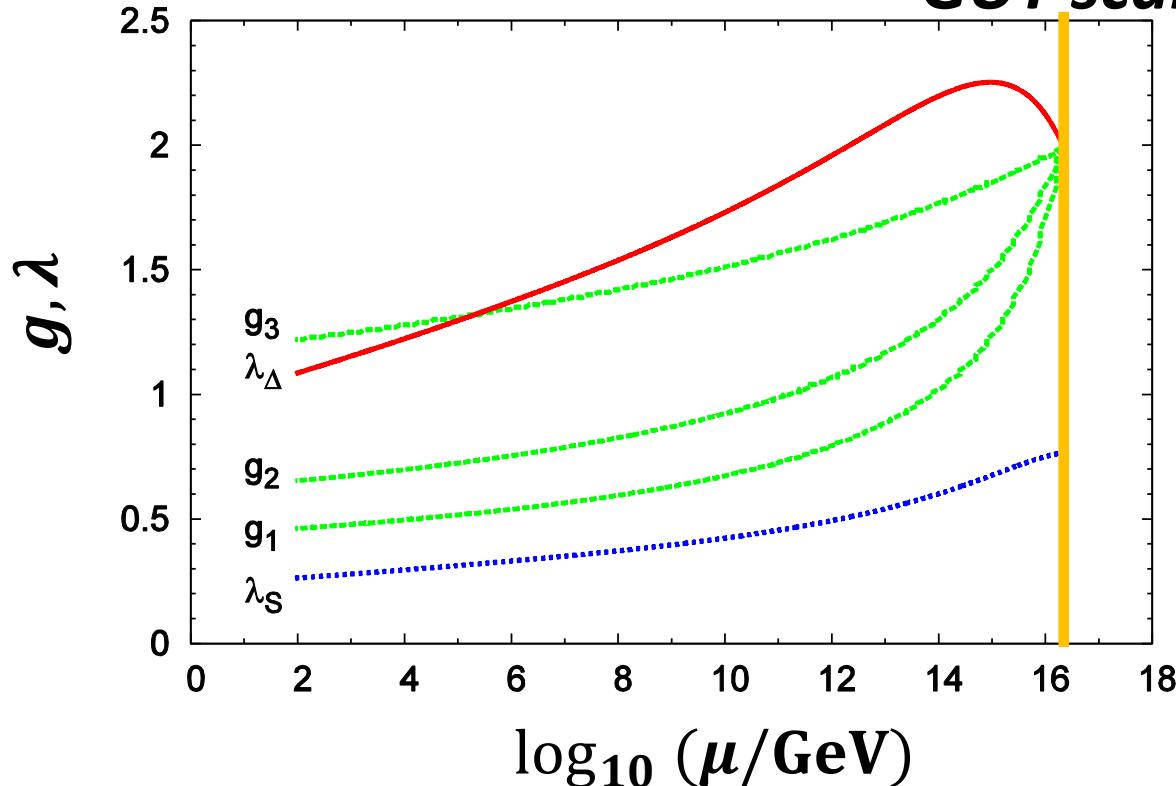
Features:

1. Trilinear terms S^3 and $S\Delta\Delta$ are absent
2. λ_s and λ_Δ are related to the gauge coupling at the GUT scale

2, Supersymmetric Grand Gauge-Higgs Unification

- Running of coupling constant

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



In order to unify the gauge couplings, we add vector like particles

$2 \times L(1,2,-1/2)$
 $+ U^C(\bar{3},1,-2/3)$
 $+ E^C(1,1,1)$
 @SUSY scale

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



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

3, Predictions

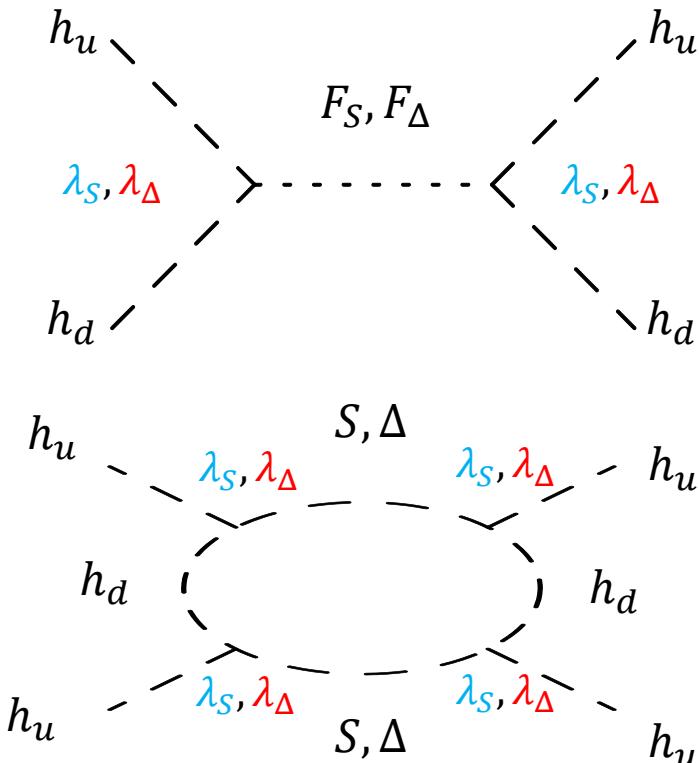
- Lightest CP-even Higgs boson mass

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

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

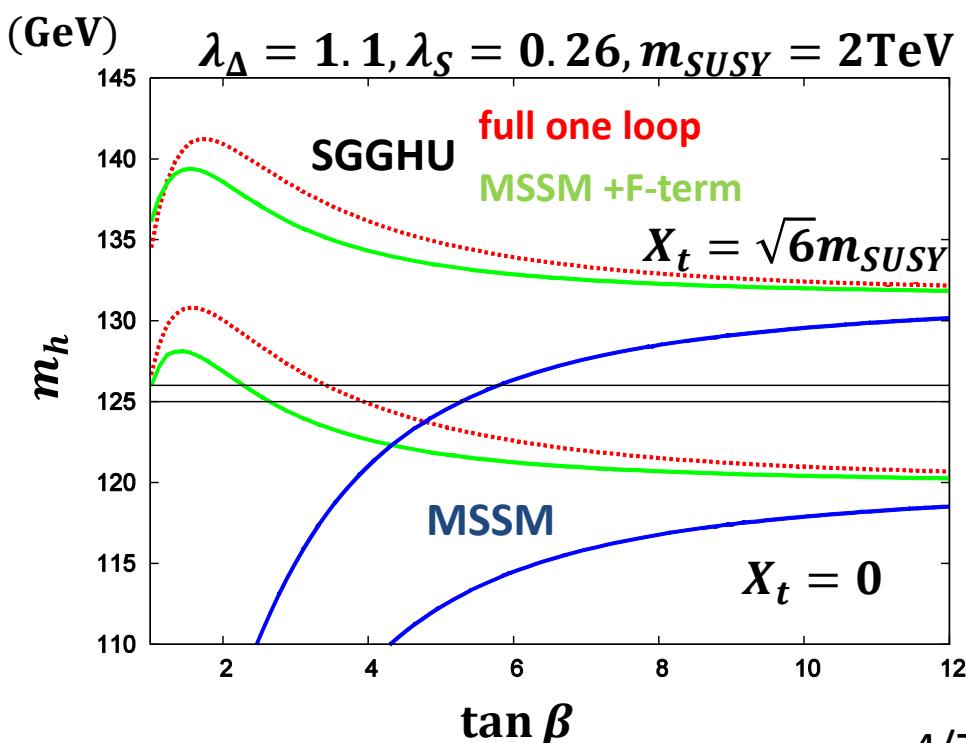
MSSM

Contributions from
singlet and triplet



m_h can be 126GeV

Heavy soft mass $\tilde{m}_S, \tilde{m}_\Delta$ scenario



3, Predictions

<Deviations from the MSSM>

- Charged Higgs boson mass

$$m_{H^\pm}^2 = m_{H^\pm}^2 \Big|_{MSSM} (1 + \delta_{H^\pm})^2$$

$$\sim \frac{m_A^2 + m_W^2}{MSSM} - \frac{1}{2} \lambda_S^2 v^2 + \frac{1}{8} \lambda_\Delta^2 v^2$$

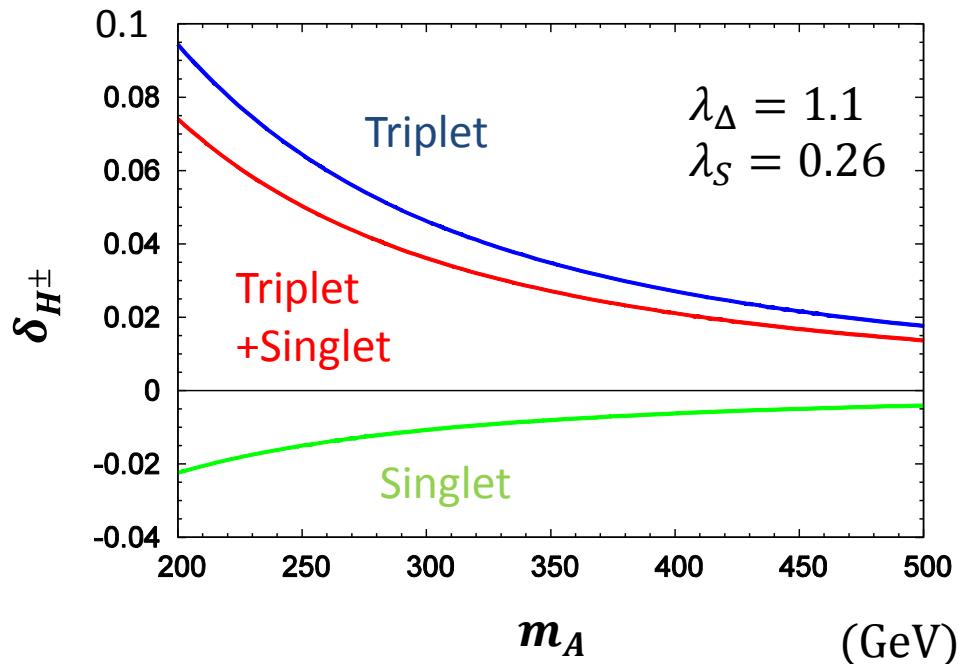
Deviation of mass: $O(1)\% - O(10)\%$

- Heavy CP-even Higgs boson mass

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

Deviation among masses is small $< O(1)\%$

Heavy soft mass $\tilde{m}_S, \tilde{m}_\Delta$ scenario



We can test the deviation
at the LHC

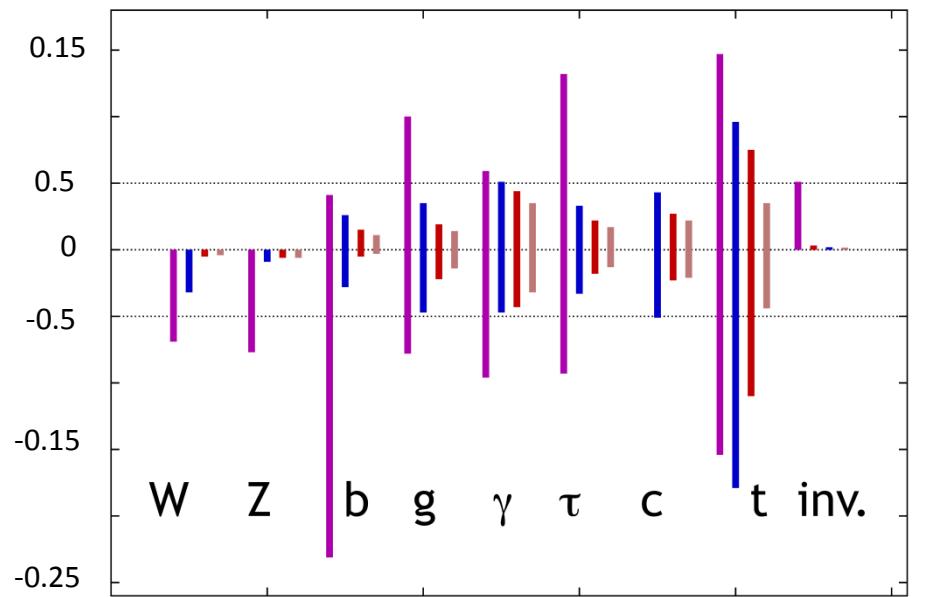
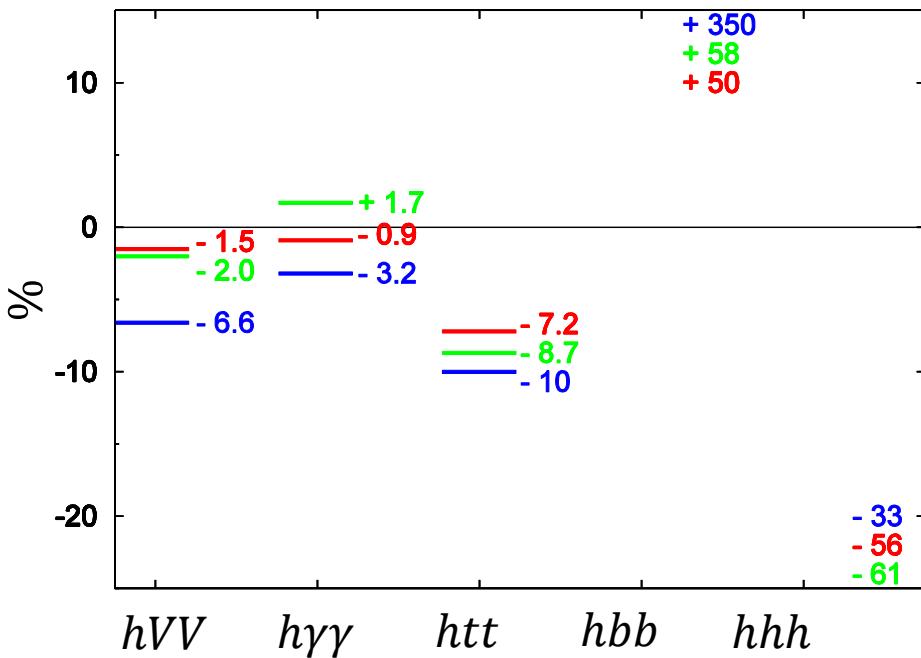
3, Predictions

<Deviations from the SM>

● Couplings of Higgs boson

$$g(hXX)/g(hXX)_{SM} - 1$$

Heavy soft mass $\tilde{m}_S, \tilde{m}_\Delta$ scenario



[M. E. Peskin, arXiv:1207.2516v3]

	MSSM
	NMSSM
	SGGHU

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

We can distinguish each model at the ILC

Summary

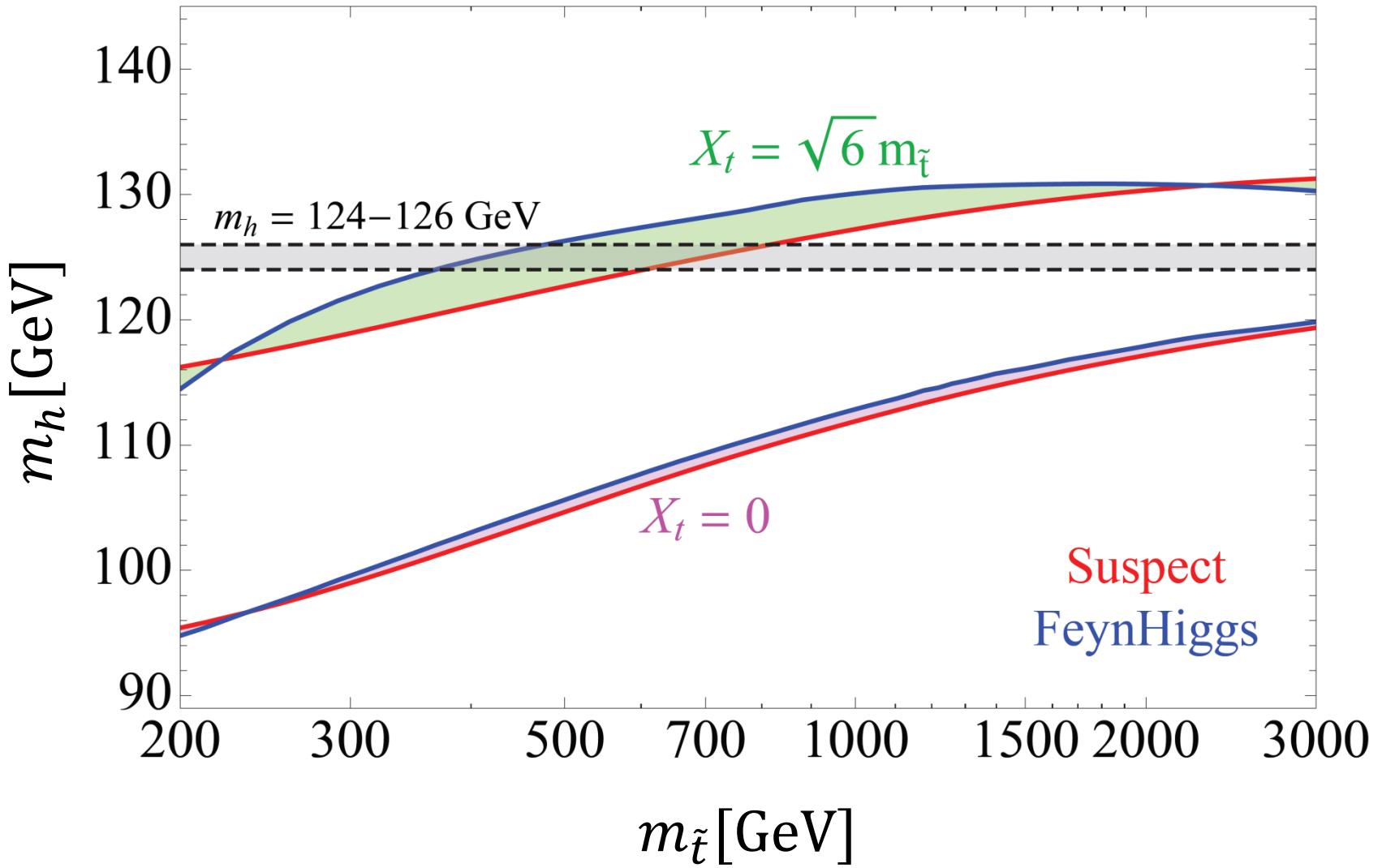
We investigate the Higgs sector of the SGGHU

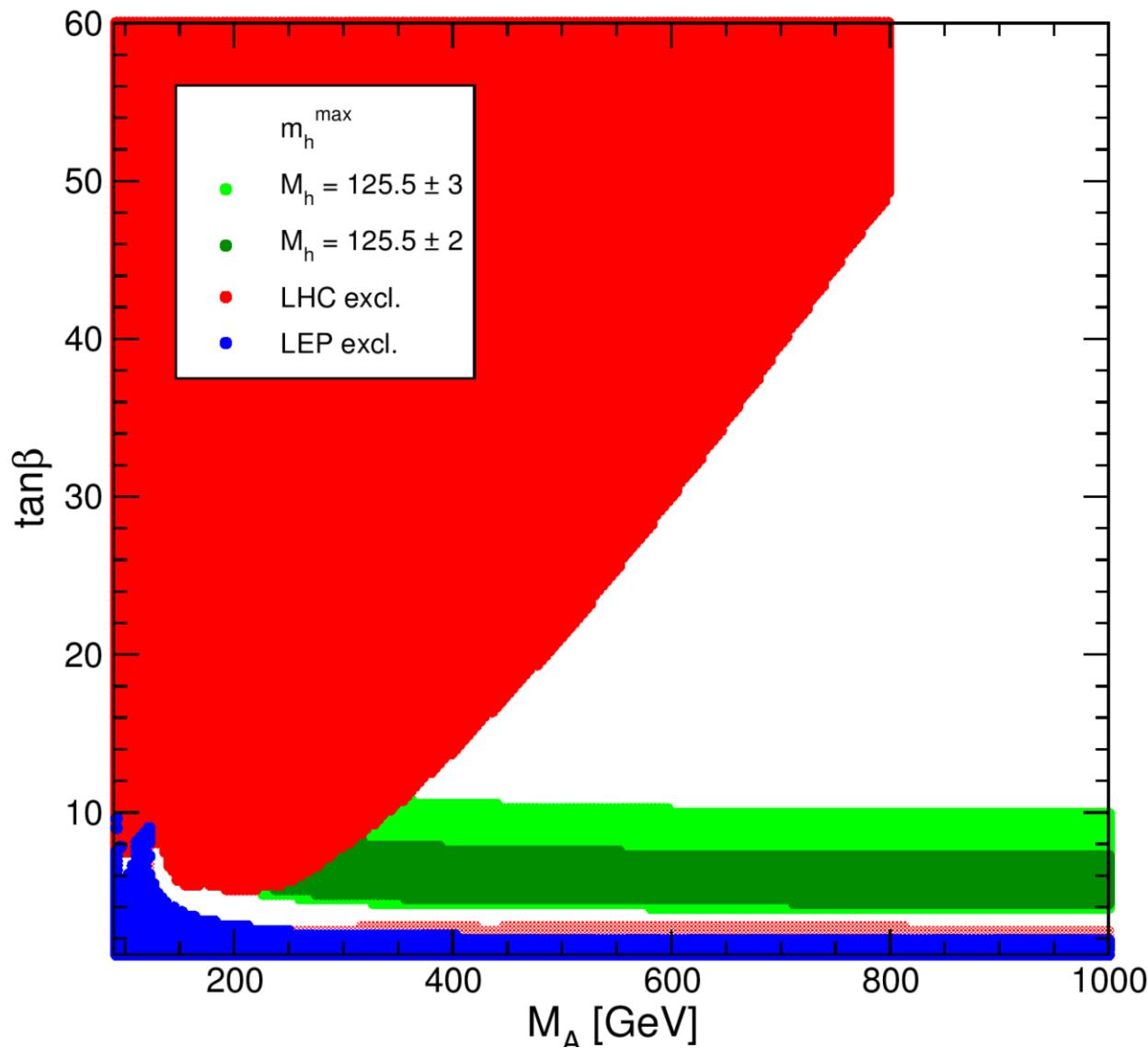
- Deviation of m_{H^\pm} from the MSSM value is $O(1)\% - O(10)\%$
We can investigate this deviation at the LHC
- Measuring the Higgs boson couplings,
we can distinguish each model at the ILC

**SGGHU is a good example of a GUT
testable at collider experiments**

Back up

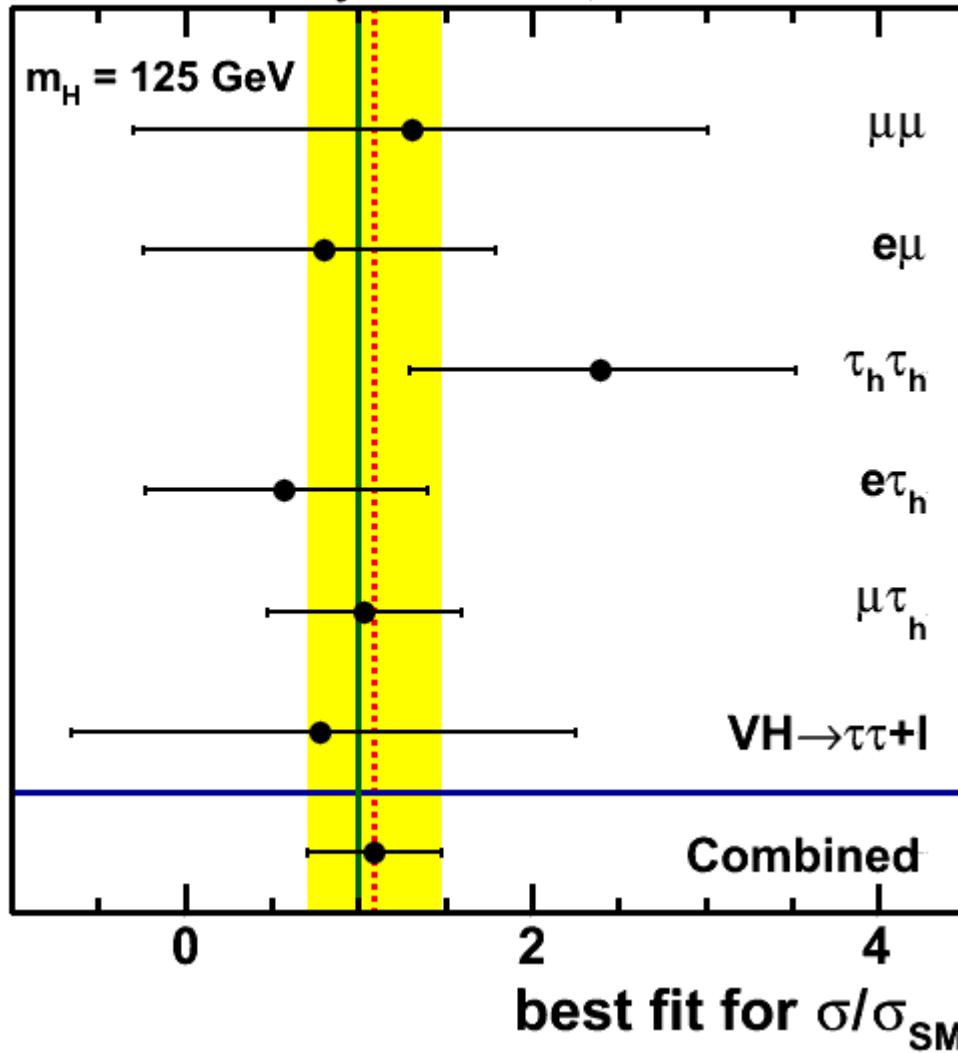
MSSM Higgs Mass





[*M. Carena, S. Heinemeyer, O. Stal, C. E. M. Wagner and G. Weiglein,
arXiv:1302.7033*]

CMS Preliminary, $\sqrt{s}=7\text{-}8 \text{ TeV}$, $L=24.3 \text{ fb}^{-1}$, $H \rightarrow \tau\tau$



[<https://twiki.cern.ch/twiki/bin/view/CMSPublic/Hig13004TWiki>]