

Summary

- We evaluate full 1-loop corrected Higgs branching ratios in 4 types of two Higgs doublet models (2HDMs).
- We found that additional Higgs bosons loop can modify the $BR(h \rightarrow VV^*)$ to be about 2.5% (1.5%) for Type-II,Y (Type-I,X).
- Each type of 2HDMs can be discriminated by a pattern of deviations for Higgs branching ratios.

① Introduction

- Structure of the Higgs sector is still unknown.

Number, multiplets?

$\Phi_{SM} + S$ (Singlet),
 $\Phi_{SM} + \Phi$ (Doublet),
 $\Phi_{SM} + \Delta$ (Triplet), etc.

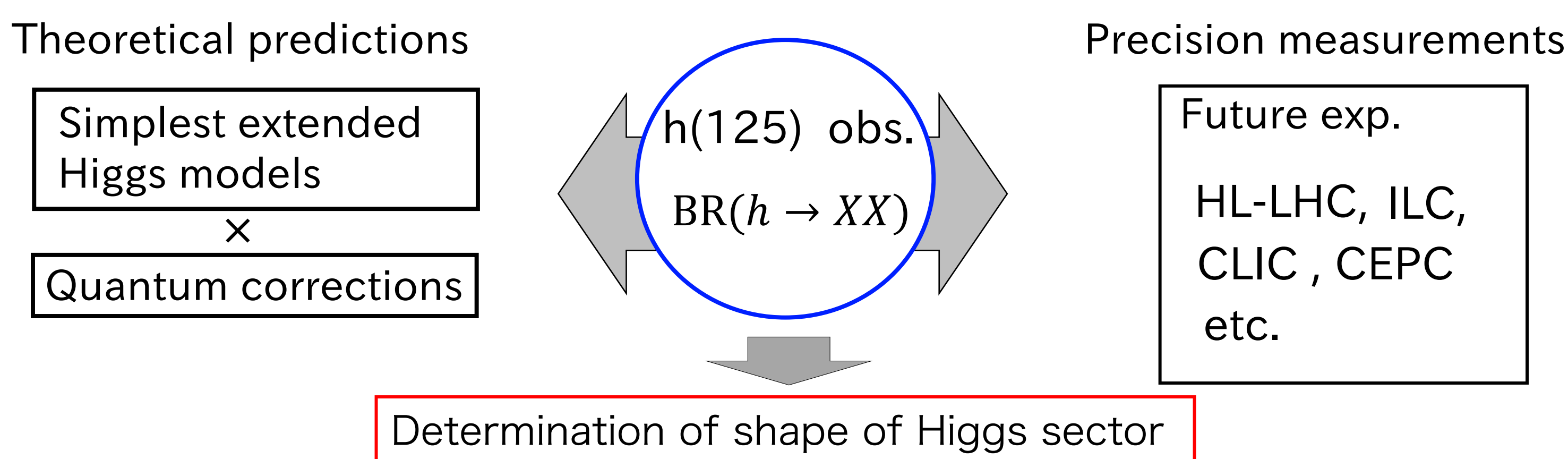
Symmetry?

Discrete sym.,
 Custodial sym.,
 etc.

- It rerates new physics beyond the SM.

→The determination is crucial to clarify the new physics.

Our approach:



② H-COUP project

- We have evaluated Higgs decay rates with NLO EW and NLO QCD corrections in various extended Higgs models [1].

• Higgs singlet model
 • Two Higgs doublet models (Type-I, Type-II, Type-X, Type-Y)
 • Inert doublet model

1-loop corrected
 $\Gamma(h \rightarrow ff), \Gamma(h \rightarrow Zff),$
 $\Gamma(h \rightarrow Wff'), \Gamma(h \rightarrow gg),$
 $\Gamma(h \rightarrow \gamma\gamma), \Gamma(h \rightarrow Z\gamma)$

- We have used improved on-shell scheme, in which gauge dependence for scalar mixing angles are removed by pinch technique [2].

- We have also got rid of infrared divergence by utilizing phase space slicing method [3].

- ➔ We compute full-1loop corrected Higgs branching ratios.

Our interest : Impact of additional Higgs loop for BRs.
 Pattern of deviations for BRs.

③ Two Higgs doublet models

- Higgs potential

$$V = \sum_{i=1}^2 (m_i^2 |\Phi_i|^2 + \frac{\lambda_i}{2} |\Phi_i|^4) - m_3^2 (\Phi_1^\dagger \Phi_2 + \text{h.c.}) + \lambda_3 |\Phi_1|^2 |\Phi_2|^2 + \lambda_4 |\Phi_1^\dagger \Phi_2|^2 + \frac{1}{2} \lambda_5 [(\Phi_1^\dagger \Phi_2)^2 + \text{h.c.}]$$

$$\Phi_i = \begin{pmatrix} \omega_i^+ \\ \frac{1}{\sqrt{2}}(v_i + h_i + iz_i) \end{pmatrix} \quad (i=1,2)$$

Input parameters

$m_H, m_A, m_{H^\pm}, \alpha, \beta, M^2$

$$\begin{pmatrix} h_1 \\ h_2 \end{pmatrix} = R(\alpha) \begin{pmatrix} H \\ h \end{pmatrix}, \quad \begin{pmatrix} z_1 \\ z_2 \end{pmatrix} = R(\beta) \begin{pmatrix} z \\ A \end{pmatrix}, \quad \begin{pmatrix} w_1^+ \\ w_2^+ \end{pmatrix} = R(\beta) \begin{pmatrix} H^+ \\ H^\pm \end{pmatrix}$$

h : SM-like Higgs H, A, H^\pm : Additional Higgs

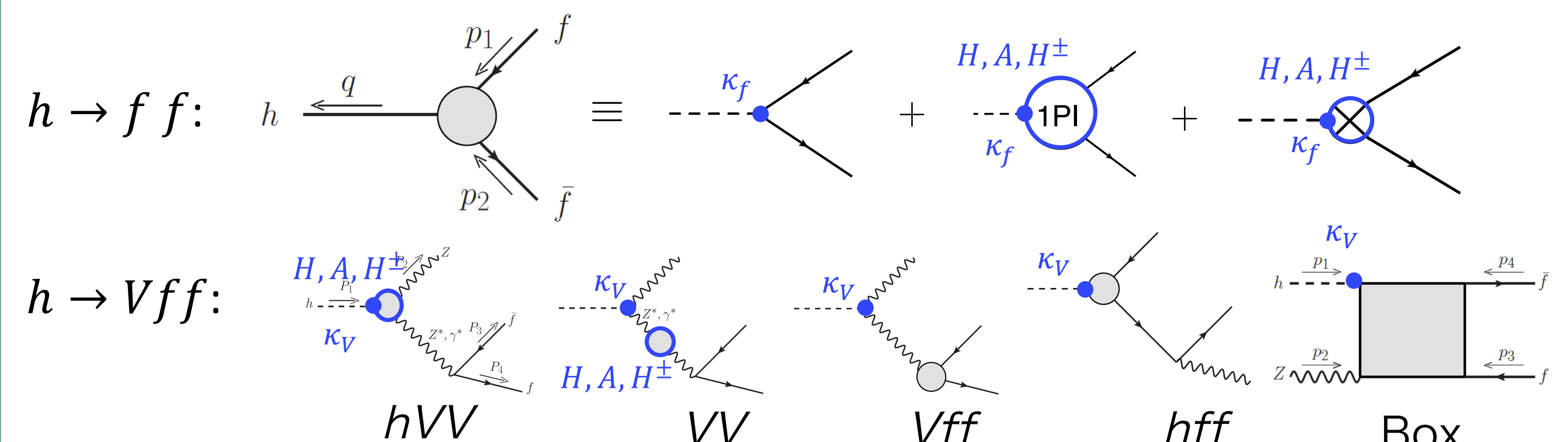
- Higgs couplings $\kappa_X = g_{hXX}^{2HDM} / g_{hXX}^{SM}$

$$\kappa_V = \sin(\beta - \alpha),$$

$$\kappa_f = \sin(\beta - \alpha) - \xi_f \cos(\beta - \alpha)$$

	ξ_u	ξ_d	ξ_e
Type-I	$\cot \beta$	$\cot \beta$	$\cot \beta$
Type-II	$\cot \beta$	$-\tan \beta$	$-\tan \beta$
Type-X	$\cot \beta$	$\cot \beta$	$-\tan \beta$
Type-Y	$\cot \beta$	$-\tan \beta$	$\cot \beta$

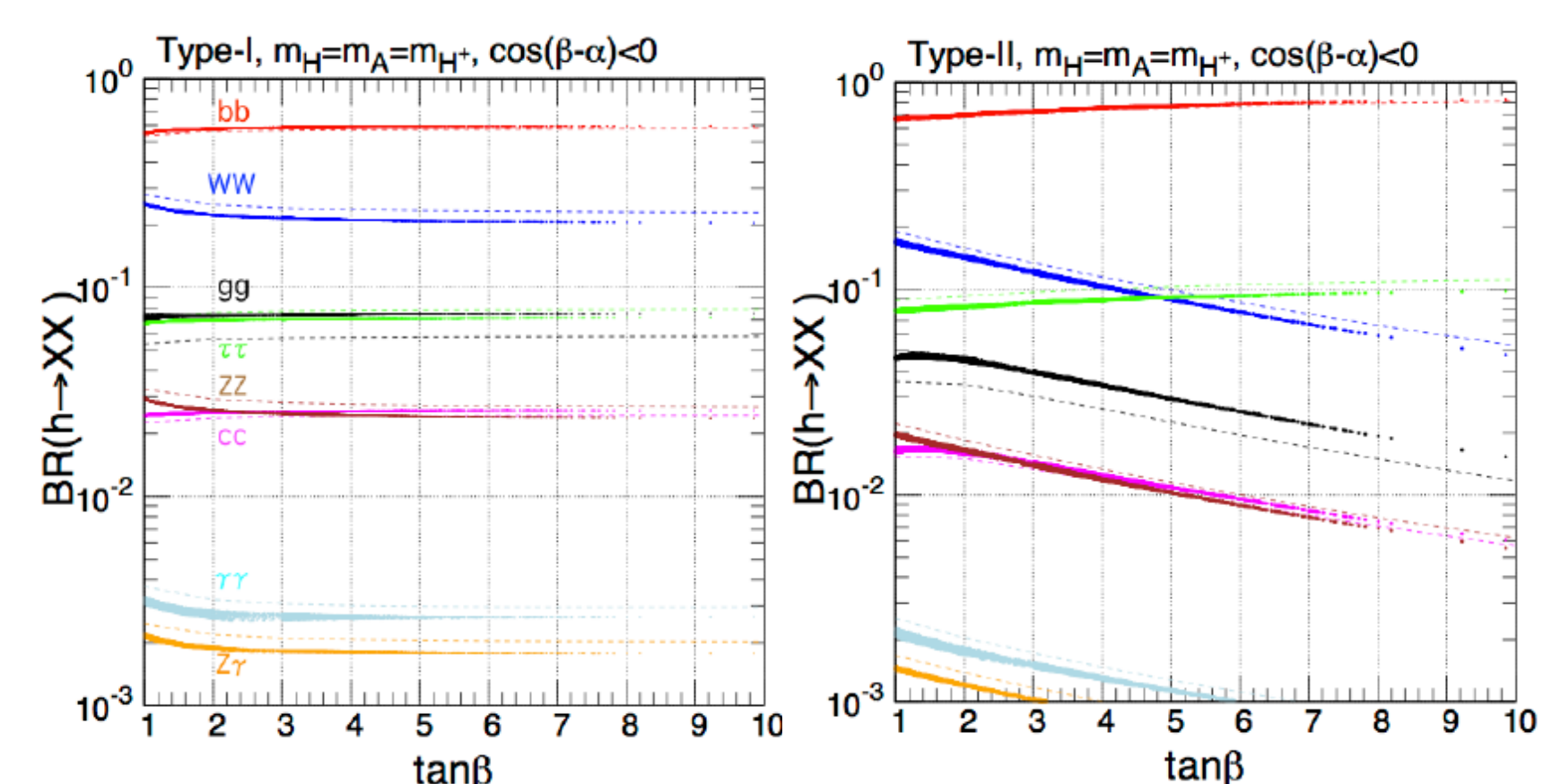
④ Calculations of Higgs BRs at 1-loop



- Higgs branching ratios has been study at the tree level [4].

- We evaluated it at the 1-loop by utilizing H-COUP ver1.0 [5].

Another program: 2HDECAY [6]



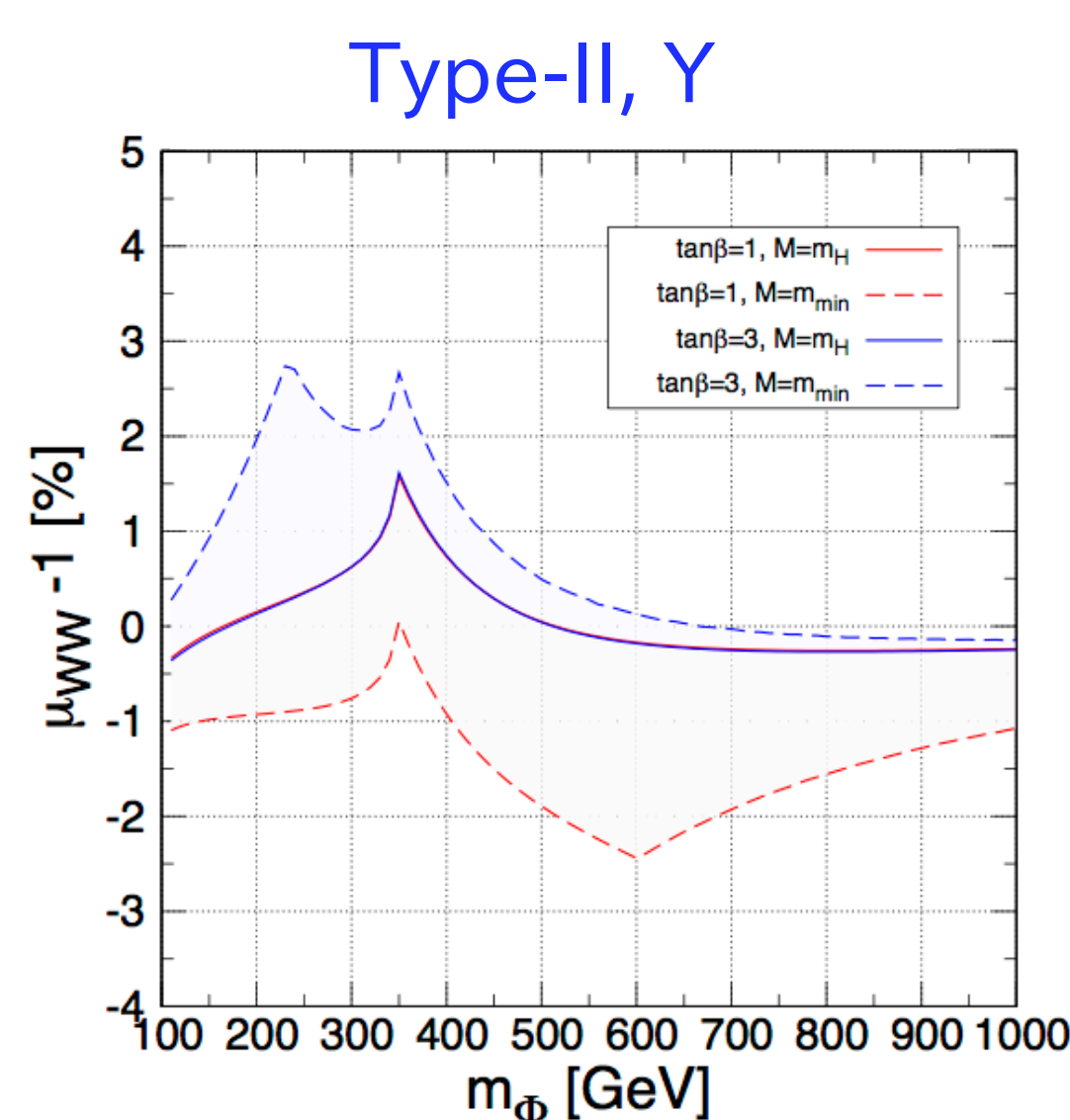
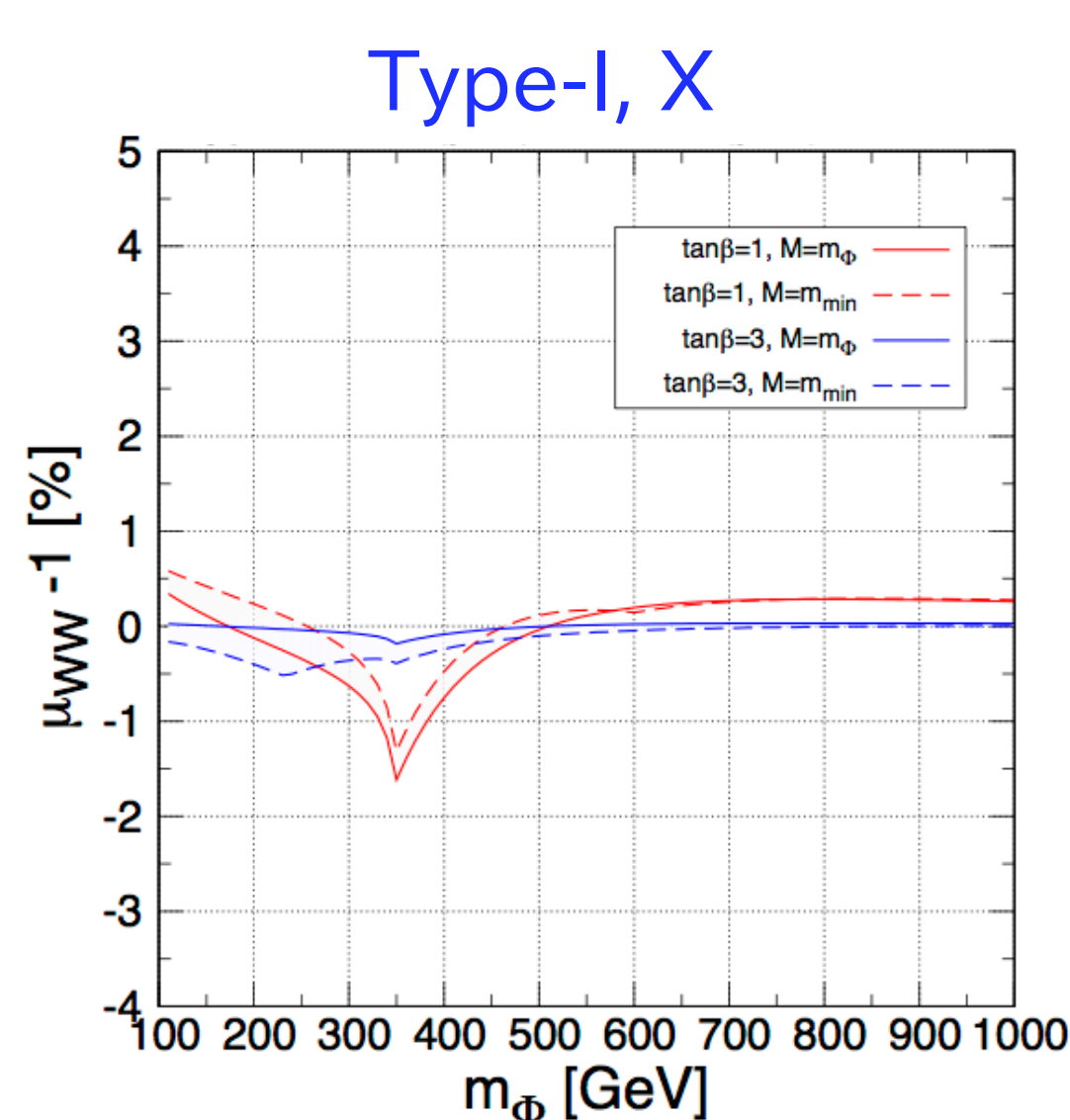
⑤ Impact of additional Higgs loop

We examined magnitude of additional Higgs boson loop contributions for Higgs branching ratios in 2HDMs.

$$\text{Deviations: } \mu_{XX} = BR(h \rightarrow XX)^{2HDM} / BR(h \rightarrow XX)^{SM}$$

$$\text{Inputs: } \sin(\beta - \alpha) = 1, \quad m_\Phi = m_H = m_A = m_{H^\pm}$$

Constraints : Perturbative unitarity, Vacuum stability,

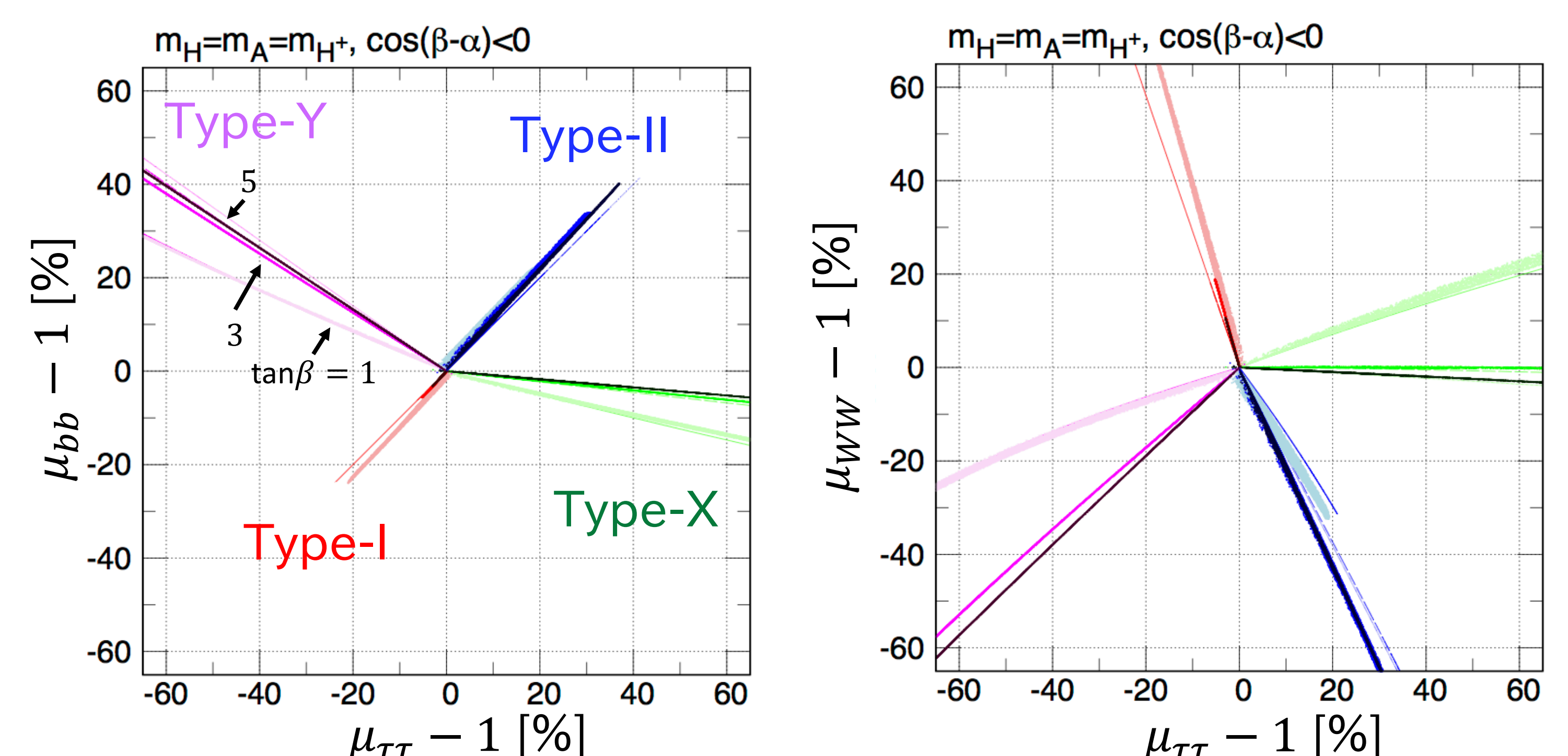


For Type-I,X, $|\mu_{WW}|_{max} \sim 1.5\%$.

For Type-II, Y, $|\mu_{WW}|_{max} \sim 2.5\%$.

⑥ Deviations in the BRs of Higgs boson

We also examined whether 4 types of 2HDMs can be distinguished by the deviations from the SM in 1-loop corrected Higgs branching ratios or not.



4 types of 2HDMs can be discriminated by μ_{WW} vs $\mu_{\tau\tau}$ or μ_{bb} vs $\mu_{\tau\tau}$.