I. Introduction

Although $m_h$ was found at the LHC, the structure of the Higgs sector is unknown. (No principle to require a minimal Higgs sector)

New physics beyond the SM Strong relation between NP and Higgs sector!

Higgs as a probe of NP!! By bottom up using experimental data, Higgs sector can be reconstructed.

Direction of new physics beyond SM can be determined!!

II. Our project

Theoretical predictions of $h$-couplings at loop level $\times$ Precision measurements of Higgs couplings $\Rightarrow$ Determination of Higgs sector

We calculate $h$-couplings with radiative corrections in extended Higgs sectors. (Higgs singlet model, Two Higgs doublet models, Higgs triplet model, Inert models...)

$h$-couplings can deviate from SM predictions by NP effects.

1. Mixing

The mixing factors depend on:
- representations of Higgs fields
- symmetries in the theory

A pattern of deviations indicate the structure. $h = \phi_1 \cos \theta + \phi_2 \sin \theta$

2. Loop effects

Directions and magnitudes of the deviations depend on:
- Spin
- Decoupling properties of New particle

By comparing future precision data, extract properties of Higgs sector.

III. Two Higgs doublet models

To avoid FCNCs, we introduce a $Z_2$ symmetry.

$\Phi_1 \to + \Phi_1$

$\Phi_2 \to - \Phi_2$


4 types of Yukawa interactions

1. Mass eigenstates $h$: SM-like Higgs $H$, $A$, $H^\pm$: Extra Higgs $G^0$, $G^\pm$

2. Parameters (8)

$\tan \beta \equiv v_2 / v_1$

$\nu \geq 246 \text{ GeV}$

$\delta M^2 \approx \lambda \nu^2 + M^2$

$Z_2$ charge

Type-I: $\ldots \ldots - \ldots + \ldots - \ldots$

Type-II: $\ldots \ldots - \ldots + \ldots$$+ \ldots$

Type-III: $\ldots \ldots - \ldots + \ldots$$- \ldots$

Type-IV: $\ldots \ldots + \ldots - \ldots$$- \ldots$

IV. Higgs couplings at the tree level

Gauge couplings ($hWW$, $hZZ$)

SM-like limit: $\lambda = \sin(\beta - \alpha) \to 1$

Yukawa couplings ($htt$, $hbh$, $hct$, $hh$, $hh$...)

$\tan \beta \equiv v_2 / v_1$

$\nu \geq 246 \text{ GeV}$

$\delta M^2 \approx \lambda \nu^2 + M^2$

$\sin(\beta - \alpha) = \sinh(\beta - \alpha) = 0.99$

V. Method (Renormalization)

- # of counter - terms: 5 (Gauge) + 3 x # of fermion (Yukawa) + 21 (Higgs)

- On-shell renormalization conditions

Ex) $\to$ Higgs sector

$$\delta \Phi^2 = \delta \Phi^2 = 0$$

Using the counter terms, we calculate Renormalized Higgs couplings.

VI. Radiative corrections to $h$-couplings

$$\Delta \Phi^x = \frac{1}{y_h \Phi^2} \frac{1}{M^2 - \Phi^2}$$

Decay rate of loop induce process

$\Gamma(\Phi \to \gamma \gamma) \equiv \frac{G_F^2 \Phi^4}{128 \pi^2} \left( \frac{1}{3} \left( 1 - \frac{M^2}{M^2} \right) + Q^2 \right)$

VII. Extractions of inner parameters

Set A

$\Delta \Phi^x = -1.0 \pm 0.4 \%$

$\Delta \Phi^x = +18 \pm 1.9 \%$

$\Delta \Phi^x = +18 \pm 0.9 \%$

VIII. Summary

- Structure of the Higgs sector
- Decoupling property
- Inner parameters

$\Rightarrow$ Determination of the Higgs sector!!

Direction of new physics!!