Testing IDM at the ILC.

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Plan

Introduction

- the standard model has brought great success in describing the nature of particles.
- there are still some phenomena which cannot be explained in this model, such as :
  dark matter
  neutrino oscillation
  baryon asymmetry of the universe

Introduction

- identify the Higgs sector
- In the SM, only one scalar isospin doublet field is introduced to break the electroweak gauge symmetry. This is just an assumption. There is a possibility for an extended Higgs sector with a specific multiplet structure.
- IDM ,2HDM ,MSSM , HSM

Brief review on IDM

- Similar to the THDMs, the Higgs sector of the IDM is composed of two doublet scalar fields ϕ_s and ϕ_D:

$$\phi_s = \begin{pmatrix} \phi_s^+ \\ \phi_s^0 \end{pmatrix} = \begin{pmatrix} \varphi_1 + i\varphi_2 \\ \varphi_3 + i\varphi_4 \end{pmatrix} \textit{and} \quad ; \quad \phi_D = \begin{pmatrix} \phi_D^+ \\ \phi_D^0 \end{pmatrix} = \begin{pmatrix} \varphi_5 + i\varphi_6 \\ \varphi_7 + i\varphi_8 \end{pmatrix} \tag{1}$$

- the Z_2 symmetry is assumed to be unbroken
- the VEV of ϕ_D must be taken to zero, and thus ϕ_D is called the inert doublet

Brief review on IDM

- The SM-like Higgs scenario
- stable scalar Dark Matter (DM)
- This model is in agreement with current data, both from accelerator and astrophysical experiments
- generates tiny neutrino masses
- solve the naturalness problem

Brief review on IDM

- The general Higgs potential under the exact Z_2 symmetry is written by:

$$V_{IDM}(\phi_S, \phi_D) = \mu_1^2|\phi_S|^2 + \mu_2^2|\phi_D|^2 + \frac{\lambda_1}{2}|\phi_S|^4 + \frac{\lambda_2}{2}|\phi_D|^4 + \lambda_3|\phi_S|^2|\phi_D|^2 + \lambda_4|\phi_S^+\phi_D|^2 + \frac{\lambda_5}{2}\{(\phi_S^+\phi_D)^2 + hc\} \tag{2}$$

All the parameters are taken to be real without loss of generality.

Brief review on IDM

- the choice of *vevs*:

$$\langle \phi_S \rangle_0 = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ \upsilon_S \end{pmatrix} \quad , \quad \langle \phi_D \rangle_0 = \frac{1}{\sqrt{2}} \begin{pmatrix} 0 \\ 0 \end{pmatrix}. \tag{3}$$

  Were $\upsilon_S = \upsilon = 246 GEV$
- We shall use the following parameterization of the two doublets :

$$\phi_S = \begin{pmatrix} G^{\pm} \\ (\upsilon_S + h + iG^0)/\sqrt{2} \end{pmatrix} \quad ; \quad \phi_D = \begin{pmatrix} H^{\pm} \\ (H + iA)/\sqrt{2} \end{pmatrix} \tag{4}$$

- $\Longrightarrow$ 8 degrees of freedom
- • 3 are absorbed to generate masses to the $W^{\pm}$ and Z^0 bosons.
- • 5 physical degrees of freedom: h^0, H^0, A^0 et $H^{\pm}$.

Brief review on IDM

Then one obtains the following expressions for the squared masses of the Higgs bosons :

$$m_h^2 = \lambda_1 \upsilon^2 \quad (5)$$

$$m_{H\pm}^2 = \mu_2^2 + \frac{\upsilon^2}{2}\lambda_3 \quad (6)$$

$$m_H^2 = \mu_2^2 + \frac{\upsilon^2}{2}(\lambda_3 + \lambda_4 + \lambda_5) \quad (7)$$

$$m_H^2 = \mu_2^2 + \frac{\upsilon^2}{2}(\lambda_3 + \lambda_4 - \lambda_5) \quad (8)$$

we are left with six independent parameters which we choose as follow :

$$\{\mu_2^2, \lambda_2, m_h, m^{\pm}, m_H, m_A\} \quad (9)$$

CONSTRAINTS

the theoretical constraints are :

- Vacuum stability

$$\lambda_1 > 0, \quad \lambda_2 > 0, \quad \lambda_3 + 2\sqrt{\lambda_1 \lambda_2} > 0, \quad \lambda_3 + \lambda_4 - |\lambda_5| > 2\sqrt{\lambda_1 \lambda_2} \tag{10}$$

- unitarity
  In the IHDM Model we requires that the tree-level unitarity is preserved in a variety of scattering processes: scalar - scalar, gauge boson - gauge boson and scalar - gauge boson.
- Perturbativity

$$|\lambda_i| \leq 8\pi \tag{11}$$

- Triviality

$$\lambda_i(\mu) \leq 4\pi \qquad for \qquad (m_Z \leq \mu \leq \Lambda_{cutoff}) \tag{12}$$

CONSTRAINTS

the experimental constraint are :

- oblique parameter from S, T and U
  Under $U = 0$

$$S = 0.05 \pm 0.09, \qquad T = 0.08 \pm 0.07 \tag{13}$$

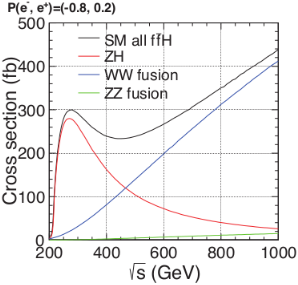
  $m_h = 125$ GEV ,$m_t = 173$ GEV and $\rho_{ST} = +0.89$
  we defined the quantity ΔS and ΔU as a sign of a New physics as follow :

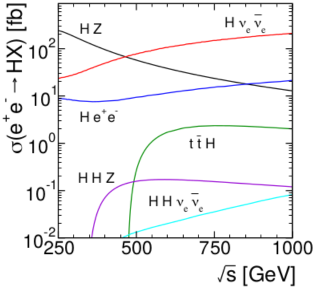
$$\Delta S = S^{IDM} - S^{SM}, \qquad \Delta U = U^{IDM} - U^{SM} \tag{14}$$

- Direct search colliders
  LEP, Tevatron, and the LHC-Run2 13 and 14 Gev

Higgs production at the ILC

- Higgsstrahlung process $e^+e^- \longrightarrow ZH$
- the weak boson fusion processes $e^+e^- \longrightarrow W^{+*}W^{-*}\nu\bar{\nu} \longrightarrow h\nu\bar{\nu}$ and $e^+e^- \longrightarrow Z^*Z^*e^+e^- \longrightarrow he^+e^-$
- $e^+e^- \longrightarrow t\bar{t}H$
- double Higgs production $e^+e^- \longrightarrow Zhh$ and $e^+e^- \longrightarrow \nu\bar{\nu}hh$





Results and Discussions

- $e^+e^- \longrightarrow Zh$ then $h \longrightarrow f\bar{f}$, VV , $\gamma\gamma$, $Z\gamma$, gg
- To parameterize the quantum corrections, we define the following one loop ratios:

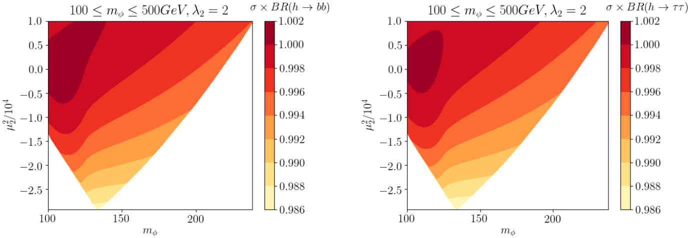
$$\sigma = \frac{\sigma^{IDM}(e^+e^- \longrightarrow Zh)^{NLO}}{\sigma^{SM}(e^+e^- \longrightarrow Zh)^{NLO}} \tag{15}$$

And

$$BR(h \longrightarrow XX) = \frac{BR^{IDM}(h \longrightarrow XX)^{NLO}}{BR^{SM}(h \longrightarrow XX)^{NLO}} \tag{16}$$

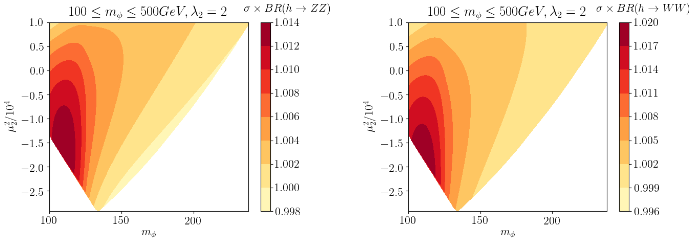
$$\sigma \times BR(h \longrightarrow XX) = \frac{\sigma^{IDM}(e^+e^- \longrightarrow Zh)^{NLO}}{\sigma^{SM}(e^+e^- \longrightarrow Zh)^{NLO}} \times \frac{BR^{IDM}(h \longrightarrow XX)^{NLO}}{BR^{SM}(h \longrightarrow XX)^{NLO}} \tag{17}$$

Results and Discussions



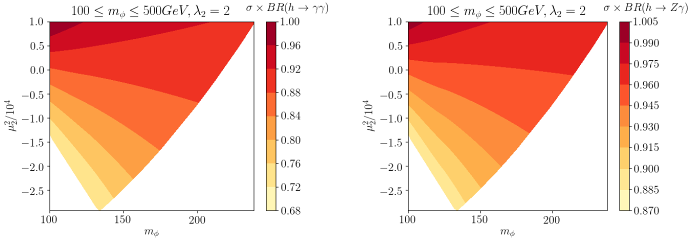
- we present the allowed area in the (μ_2^2, m_ϕ) plan
- the left plot show -0.002% to 0.02% for $b\bar{b}$ and $\tau\tau$

Results and Discussions



- we show here the scan as before and the deviation may attend -0.01% to 0.001% for both ZZ and WW channels

Results and Discussions



- IN the $\gamma\gamma$ and γZ channel, the deviation still very larg and can reach -0.32% for $\gamma\gamma$ while -0.13% to 0.005% for $Z\gamma$

Conclusion

- the deviation still large in the $\gamma\gamma$ and $Z\gamma$ channel at $\sqrt{s} = 250$ GEV
- The e^+e^- machine may help to understand the nature of higgs sector.

THANK YOU