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Enhanced Di-Higgs Production in Extended Higgs Models within Photonic Colliders

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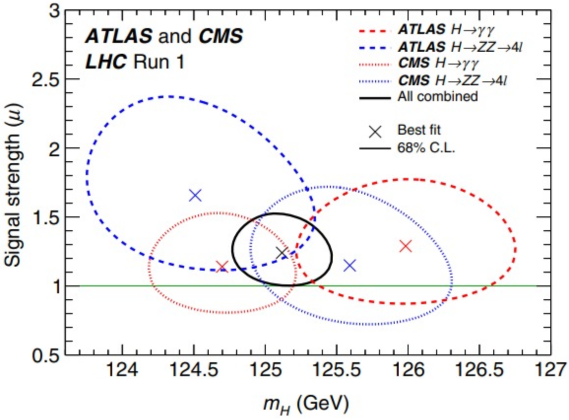
Outlines

Higgs Boson July 04, 2012 : Discovery BSM



Opening wide windows in this field for searching on the Higgs properties either on Standard model or Beyond.

I(1+2)HDM in a nutshell

- The I(1+2)HDM is an extension of the 2HDM, comprising the scalar doublets Φ_1 and Φ_2, by an inert scalar doublet η which can provide a stable dark matter candidate.
- The model exhibits a $\mathbb{Z}_2 \times \mathbb{Z}_2'$ symmetry, with the first factor being the inert-doublet $\mathbb{Z}_2$, where only the field η transforms as $\eta \to$ - η, while all other fields remain neutral.

$$\Phi_i = \left(\begin{array}{c} \phi_i^+ \\ (v_i + \eta_i + iz_i)/\sqrt{2} \end{array} \right), (i = 1, 2); \quad \eta = \left(\begin{array}{c} \chi^+ \\ (\chi + i\chi_a)/\sqrt{2} \end{array} \right) \tag{1}$$

- The most general scalar potential consistent with the gauge invariant and CP invariant is given by :

$$V(\Phi_1, \Phi_2, \eta) = V(\Phi_1, \Phi_2) + V(\eta) + V(\Phi_1, \Phi_2, \eta), \tag{2}$$

I(1+2)HDM in a nutshell

where

$$\begin{aligned} V(\Phi_1,\Phi_2) = &-\frac{1}{2}\left\{m_{11}^2\Phi_1^\dagger\Phi_1 + m_{22}^2\Phi_2^\dagger\Phi_2 + \left[m_{12}^2\Phi_1^\dagger\Phi_2 + \text{h.c.}\right]\right\} \\ &+ \frac{\rho_1}{2}(\Phi_1^\dagger\Phi_1)^2 + \frac{\rho_2}{2}(\Phi_2^\dagger\Phi_2)^2 + \rho_3(\Phi_1^\dagger\Phi_1)(\Phi_2^\dagger\Phi_2) \\ &+ \rho_4(\Phi_1^\dagger\Phi_2)(\Phi_2^\dagger\Phi_1) + \frac{1}{2}\left[\rho_5(\Phi_1^\dagger\Phi_2)^2 + \text{h.c.}\right], \end{aligned} \tag{3}$$

the potential of the inert sector is written as :

$$V(\eta) = m_\eta^2\eta^\dagger\eta + \frac{\rho_\eta}{2}(\eta^\dagger\eta)^2, \tag{4}$$

and the mixing terms are defined as follows :

$$\begin{aligned} V(\Phi_1,\Phi_2,\eta) = &\rho_{1133}(\Phi_1^\dagger\Phi_1)(\eta^\dagger\eta) + \rho_{2233}(\Phi_2^\dagger\Phi_2)(\eta^\dagger\eta) \\ &+ \rho_{1331}(\Phi_1^\dagger\eta)(\eta^\dagger\Phi_1) + \rho_{2332}(\Phi_2^\dagger\eta)(\eta^\dagger\Phi_2) \\ &+ \frac{1}{2}\left[\rho_{1313}(\Phi_1^\dagger\eta)^2 + \text{h.c.}\right] + \frac{1}{2}\left[\rho_{2323}(\Phi_2^\dagger\eta)^2 + \text{h.c.}\right]. \end{aligned} \tag{5}$$

I(1+2)HDM in a nutshell

- The spectrum of the I(1+2)HDM containes 9 scalar particles : two CP-even, H and h which is the SM Higgs boson, a CP-odd A and a pair of charged scalars $H^{\pm}$, equivalent to pure 2HDM and for inert sector contains three scalars : χ, χ_a and $\chi^{\pm}$. Their masses are given by :

$$m^2_{\chi^{\pm}} = m^2_{\eta} + \frac{1}{2}\rho_a v^2, \tag{6}$$

$$m^2_{\chi} = m^2_{\chi^{\pm}} + \frac{1}{2}(\rho_b + \rho_c)v^2, \quad m^2_{\chi_a} = m^2_{\chi^{\pm}} + \frac{1}{2}(\rho_b - \rho_c)v^2. \tag{7}$$

wher

$$\rho_a \equiv \rho_{1133} = \rho_{2233}, \quad \rho_b \equiv \rho_{1331} = \rho_{2332}, \quad \rho_c \equiv \rho_{1313} = \rho_{2323}, \tag{8}$$

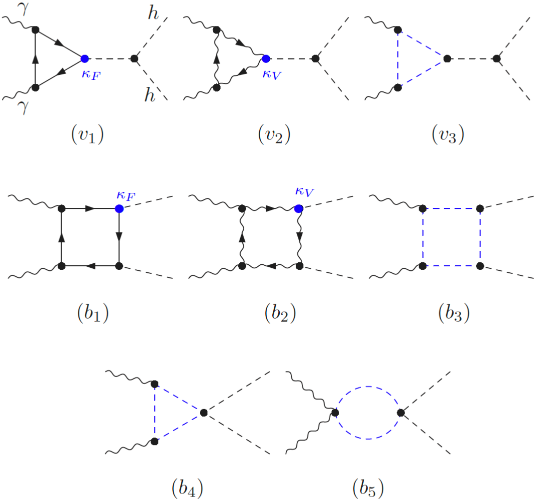
- The final independent parameters for the model are 12 which we choose as follows :

$$\Omega = \left\{ m_h, m_A, m_H, m_{H^{\pm}}, m^2_{12}, \beta, \alpha, m_{\chi}, m_{\chi_a}, m_{\chi^{\pm}}, m^2_{\eta}, \rho_{\eta} \right\}, \tag{9}$$

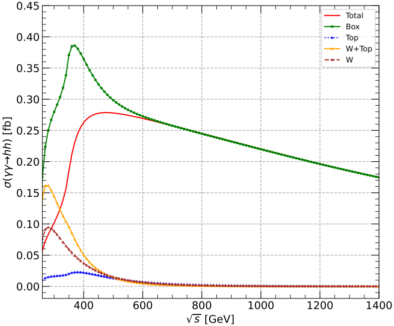
Theoretical and Experimental constraints

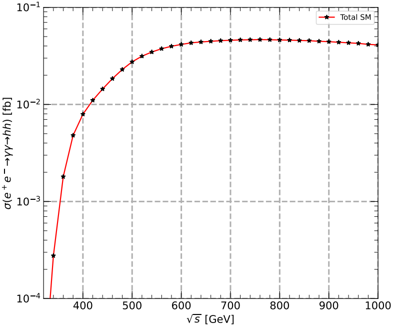
- **Theoretical constraints :** Perturbativity, Vacuum Stability, Charge-breaking minima, Unitarity..
- **Experimental constraints :**
  - * Contraints from Higgs data at LHC :
  - * Direct search from LEP :
    - $m_A, m_H > 80$ - $90 GeV$
    - $m_{H^\pm}, m_{\chi^\pm} > 80$ - 100 GeV
  - * electroweak precision through S, T, U .
  - * DM relic density, direct, indirect and collider searche.
  - * tools used : HiggsBounds-5.10.2, HiggsSignals-2.6.2, MicrOmegas-5.2.

Feynman diagram at one-loop



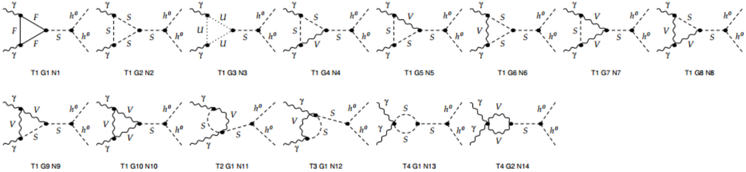
Total cross section for $\gamma\gamma \to hh$ and $e^+e^- \to \gamma\gamma \to hh$ as a function of the collision energy.



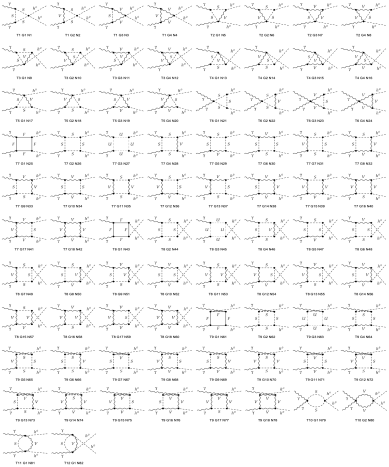


the box loop contributions almost entirely dominate the triangle ones for the partonic cross-section.

Vertex type diagrams contribution at one-loop

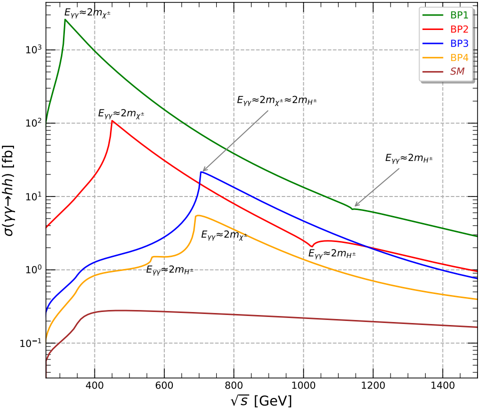


Box type diagrams contribution at one-loop



It can be clearly seen that box contribution has either the quartic vertex $hh\chi^+\chi^-$ and/or hhH^+H^- or twice the triple vertex hH^+H^- and/or $h\chi^+\chi^-$.

total cross section $\sigma(e^+e^- \to \gamma\gamma \to hh)$



- The threshold effect is observed for each BPs when $E_{\gamma\gamma} \approx 2m_{\chi^\pm}(2m_{H^\pm})$, corresponding to the opening of the inert charged Higgs/chagred Higgs pair channel, $\gamma\gamma \to \chi^+\chi^-; H^+H^-$.

total cross section $\sigma(e^+e^- \to \gamma\gamma \to hh)$

- The cross-section is enhanced significantly for small $m_{\chi^\pm}$ when $m_{\chi^\pm} < m_{H^\pm}$, and the production channel $\gamma\gamma \to \chi^+\chi^-$ opened firstly, wihle for the BP4 when $m_{H^\pm} < m_{\chi^\pm}$ the cross-section decreases compared to the other BPs and the production channel $\gamma\gamma \to \chi^+\chi^-$ opened secondly.
- The total cross-section is now principally determined by the contributions of the boxes, both at low and high center-of-mass energy. This is because the triple couplings $h\chi^+\chi^-$, hH^+H^- and quartic couplings $hh\chi^+\chi^-$, hhH^+H^-, which contribute to the boxes, are relatively large.

BPs	BP1	BP2	BP3	BP4
$\lambda_{hhh}^{\rm I(1+2)HDM}/\lambda_{hhh}^{\rm SM} \approx$	0.024	1.55	0.89	1.03
$\lambda_{Hhh}^{\rm I(1+2)HDM}/\lambda_{hhh}^{\rm SM} \approx$	0.63	-0.15	0.48	-0.12
$\lambda_{hH^+H^-}^{\rm I(1+2)HDM}/\lambda_{hhh}^{\rm SM} \approx$	10.25	11.03	4.43	3.22
$\lambda_{HH^+H^-}^{\rm I(1+2)HDM}/\lambda_{hhh}^{\rm SM} \approx$	8.94	9.18	5.33	2.45
$\lambda_{h\chi^+\chi^-}^{\rm I(1+2)HDM}/\lambda_{hhh}^{\rm SM} \approx$	12.84	10.52	14.54	10.17
$\lambda_{H\chi^+\chi^-}^{\rm I(1+2)HDM}/\lambda_{hhh}^{\rm SM} \approx$	8.12	4.68	6.36	3.31
$\lambda_{H^+H^-hh}^{\rm I(1+2)HDM}/\lambda_{hhhh}^{\rm SM} \approx$	9.62	10.35	5.76	2.98
$\lambda_{\chi^+\chi^-hh}^{\rm I(1+2)HDM}/\lambda_{hhhh}^{\rm SM} \approx$	15.49	11.73	16.18	10.90

The trilpe and quartic Higgs couplings in I(1+2)HDM normalized by SM

Conclusion

The cross section for production of Di-Higgs boson via photon- fusion at photonic collider within the framework of I(1+2)HDM can be enhanced more than the corresponding SM after all constraints.

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Thank you

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