Non-decoupling of charged scalar from Higgs to diphoton decay

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♣ Work in progress in collaboration with G. Bhattacharyya

- LHC Higgs data suggests that the new boson posses SM-like properties.
- SM scalar sector extensions which promise an *alignment limit* where a SM-like neutral scalar is recovered, may thus hold the upper hand in the future survival race.
- In this alignment limit, we expect every observable involving SM particles to reach its corresponding SM values. NP contributions can only show up in the loops. But these loop contributions are expected to die out as the masses of the non-standard particles entering the loops becomes heavy.
- The agreement of the experimental numbers with corresponding SM predictions with increasing precision thus pushes the NP mass scales higher but never really rules it out.
- Most the BSM models rely on an extension of the SM scalar sector and, almost invariably, they predict the existence of new charged scalars. Here we shall focus on certain doublet extensions of the SM scalar sector where the charged scalar do not decouple from the Higgs to diphoton decay width. Therefore, it is possible to completely rule out these extensions if the diphoton signal strength agrees to the SM prediction with certain amount of accuracy.

The quantity which actually controls the charge scalar ($H_i^{\pm}$) loop contribution in diphoton or Z-photon decay is

$$\kappa_i = \frac{g_{hH_i^+H_i^-}\, v}{2m_{i+}^2}$$

$$\mu_{\gamma\gamma} = \frac{\Gamma(h \to \gamma\gamma)}{\Gamma^{\rm SM}(h \to \gamma\gamma)} = \frac{\left| \cancelto{7}{F_W} + \frac{4}{3}\cancelto{-\frac{4}{3}}{F_t} + \sum_i \kappa_i \cancelto{\frac{1}{3}}{F_{i+}} \right|^2}{\left| F_W + \frac{4}{3} F_t \right|^2}$$

Model		Expression for κ_i	value of $\mu_{\gamma\gamma}$	value of $\mu_{Z\gamma}$	Decoupling?
2HDM	Softly broken Z_2	$-\left(1 + \frac{m_h^2}{2m_{1+}^2} - \frac{\lambda_5 v^2}{2m_{1+}^2}\right)$	Depends on λ_5	Depends on λ_5	No
	Z_2	$-\left(1 + \frac{m_h^2}{2m_{1+}^2}\right)$	≤ 0.9	≤ 0.96	No
	Softly broken $U(1)$	$-\left(1 + \frac{m_h^2}{2m_{1+}^2} - \frac{m_A^2}{m_{1+}^2}\right)$	Depends on m_A	Depends on m_A	Yes
3HDM	S_3	$-\left(1 + \frac{m_h^2}{2m_{i+}^2}\right)$ for $i = 1, 2$	≤ 0.8	≤ 0.93	No
	A_4	$-\left(1 + \frac{m_h^2}{2m_{i+}^2}\right)$ for $i = 1, 2$	≤ 0.8	≤ 0.93	No

Amount of suppression $\propto$ no. of extra doublets with exact discrete symmetries ? Possible to restrict no. of extra doublets with discrete symmetries?