Alignment limit in 2HDM effective field theory

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2HDM effective field theory

- Extended scalar sectors address issues like dark matter, neutrino mass, vacuum metastability etc.
- Two-Higgs-doublet models often stem from more complicated UV-complete theories. (like SUSY, some composite Higgs models)
- 2HDM with different UV-completions $\equiv$ 2HDM + $(1/\Lambda^{d-4})\sum_{d>4,i} c_i\,\mathcal{O}_i^{(d)}(\varphi_1, \varphi_2,$ SM bosons and fermions). ($\Lambda \sim$ NP Scale beyond 2HDM)
- Using EoMs, 129 operators upto $d = 6$, with B, L, CP-conservation. (*SK, S.Rakshit, JHEP 1710 (2017) 048*)

Alignment limit in 2HDM

- The physical degrees of freedom in a 2HDM: 2 neutral CP-even physical scalars (h, H), one neutral pseudoscalar (A), one charged scalar ($H^{\pm}$).
- To mass diagonalise, charged/pseudoscalar sector is rotated by angle β and the neutral scalars by angle α.
- $g_{hVV} = \sin(\beta - \alpha)\, g_{hVV}^{SM}$, $g_{HVV} = \cos(\beta - \alpha)\, g_{hVV}^{SM}$. $(V = W, Z)$
- If $h \equiv h(125$ GeV), $\cos(\beta - \alpha) \to 0$.
- Exotic scalar masses can be much below $\sim$ TeV $\to$ alignment without decoupling, interesting from collider perspective.

• *Question:* If the effect of such operators on br. ratios and production cross sections are substantial, can they mask the true alignment limit?

• Let us consider a few $\varphi^4 D^2$ operators,

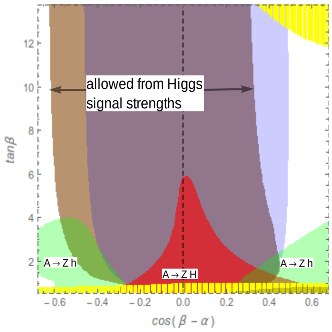
$O_{H1} = (\partial_\mu|\varphi_1|^2)^2$, $O_{H2} = (\partial_\mu|\varphi_2|^2)^2$, $O_{H12} = (\partial_\mu(\varphi_1^\dagger\varphi_2 + h.c.))^2$, $O_{H1H2} = \partial_\mu|\varphi_1|^2\partial^\mu|\varphi_2|^2$, $O_{H1H12} = \partial_\mu|\varphi_1|^2\partial^\mu(\varphi_1^\dagger\varphi_2 + h.c.)$, $O_{H2H12} = \partial_\mu|\varphi_2|^2\partial^\mu(\varphi_1^\dagger\varphi_2 + h.c.)$.

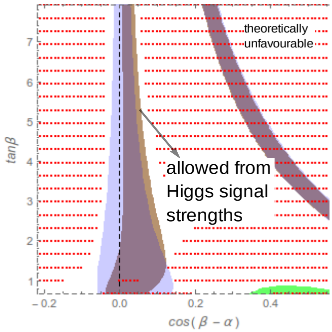
which change the coupling multipliers by field redefinition,

$$\kappa'_{hXX} = (1-x_1)\kappa_{hXX} + y\kappa_{HXX},$$
$$\kappa'_{HXX} = (1-x_2)\kappa_{HXX} + y\kappa_{hXX}.$$

$x_1, x_2, y = f(\text{Wilson coefficients}, \beta, \alpha)$
$\rightarrow 0$ if $\Lambda \rightarrow \infty$

Alignment limit in 2HDMEFT, benchmarks





- **BP1** (Type-I) $c_{H1} = c_{H2} = c_{H12} = 1$, $c_{H1H2} = c_{H1H12} = c_{H2H12} = 0$, $\Lambda \sim 1.5$ TeV, $m_H \sim 150$ GeV, $m_A \sim m_{H\pm} \sim 400$ GeV. $\sim 89\%$ change from tree-level at $\tan\beta \sim 10$.
- **BP2** (Type-II) $c_{H1} = c_{H2} = 1$, $c_{H1H12} = -c_{H2H12} = 1$, $c_{H1H2} = c_{H12} = 0$, $\Lambda \sim 1.5$ TeV, $m_H \sim 415$ GeV, $m_A \sim m_{H\pm} \sim 485$ GeV. Possible to deviate from exact alignment.

(SK and S. Rakshit, 1802.03366)

Conclusions

- 6-dim operators in 2HDMEFT can be important in cases of ‘alignment without decoupling’.
- Possible that higher dim. operators are masking the tree-level alignment limit.

Thank You