

LHC Higgs Cross Section Working Group 3

Charged Higgs boson benchmarks from top quark polarization

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October 24, 2018

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Introduction

- The two Higgs doublet model is one of the simplest extensions of the SM. The model contains (after EWSB) two CP-even scalars (h^0 and H^0), one CP-odd scalar (A^0) and a pair of charged scalars H^\pm .
- The presence of the new scalars can leave footprints in several channels and measurements (Higgs couplings, differential distributions. . .etc).
- We propose two benchmark points motivated by the sensitivity of top quark observables (based on 1807.11306) in charged Higgs production in association with a top quark at the LHC-HL.
- The observables were investigated are sensitive to the production mechanism of top quark (they show different behaviors for different processes)
⇒ Can be used for charged Higgs searches ?
- They have also the advantage of being resilient to matching of 4FS and 5FS and to NLO QCD corrections.

Motivation

- We start by remarking that $tH^- + c.c$ depends on $g_{\bar{t}bH^+}$ (in addition to the charged Higgs boson mass)

$$g_{\bar{t}bH^+} = i(C_L P_L + C_R P_R), \quad C_L = \frac{1}{\sqrt{2}v} m_t \kappa_u^A, \quad C_R = \frac{1}{\sqrt{2}v} m_b \kappa_d^A.$$

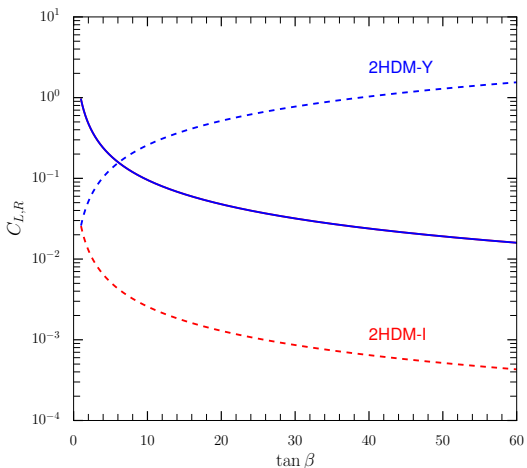
$$\kappa_u^A = 1 / \tan \beta \quad \text{for all the Yukawa type of 2HDM and}$$

$$\kappa_d^A = \tan \beta \quad (-1 / \tan \beta) \text{ for type-II and type-Y (type-I and type-X)}$$

What are the implications of this?

- In type-I (type-X), this coupling is always left-handed (with very small contribution from right-handed component) \implies **top quark is produced with negative polarisation in the helicity basis.**
- In type-II (type-Y), $g_{\bar{t}bH^+}$ can be L- dominated, R- dominated or purely scalar \implies **Top quark polarization is arbitrary and it's only controlled by $\tan \beta$ (in addition to charged Higgs boson mass.**

Motivation



blue color for the right-handed component while the red corresponds to the left-handed component of $\bar{t}bH^+$ coupling.

Benchmark points

We choose two benchmark points; one for type-I and the other one for type-Y which are maximally left-handed or right-handed. Which give

- $(C_L, C_R) = (0.94, -0.025)$ for 2HDM-I corresponding to $\tan \beta = 1$.
- $(C_L, C_R) = (0.019, 1.3)$ for 2HDM-Y corresponding to $\tan \beta = 50$.

| | $\tan \beta$ | m_{H^0} [GeV] | m_{H^\pm} [GeV] | m_{A^0} [GeV] | m_{12}^2 [GeV ²] |
|-----|--------------|-----------------|-------------------|-----------------|--------------------------------|
| BP1 | 1 | 125 | 300 | 400 | 1850 |
| BP2 | 50 | 125 | 500 | 700 | 9794 |

with $\sin(\beta - \alpha) \simeq 1$ and $m_{A^0} = m_{H^0}$.

Benchmark points

- The two benchmark points satisfy all the theoretical and experimental constraints which were checked using 2HDMC, HIGGSBOUNDS and HIGGSSIGNALS.
- The choice of CP-odd and CP-even masses is arbitrary and don't affect the phenomenology considered in our study. Other choices can be acceptable as long as decays such as $H^\pm \rightarrow H^0 W^\pm$ and $H^\pm \rightarrow A^0 W^\pm$ are kinematically forbidden.
- The choice of Charged Higgs boson masses is motivated to keep somehow decent rates. However, higher masses have higher sensitivities to top quark polarization (especially for type-I).

Some pheno

- In both benchmark scenarios, the branching ratio of $H^+ \rightarrow t\bar{b}$ is almost 100%.
- The cross section for the production in the lepton+jets final states is

$$0.367 \pm 10.2\%(\text{scale}) \pm 16.6\%(\text{PDF}) \text{ pb}$$

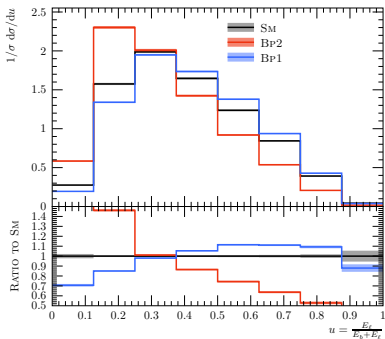
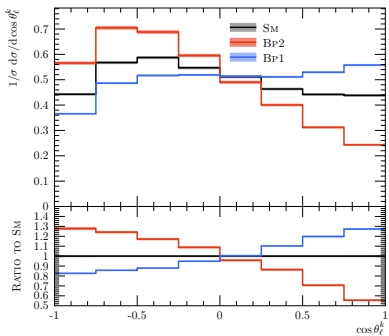
for BP1 and

$$0.162 \pm 9.5\%(\text{scale}) \pm 19.3\%(\text{PDF}) \text{ pb}$$

for BP2.

Estimation was performed at LO in perturbation theory in the 5FS. Matching the 4FS and 5FS reduces the total rate by 14% (15%) for BP1 (BP2).

Some pheno



Conclusion

- We have presented two benchmark points based on top quark polarization in the $H^- t + c.c.$ channel at the LHC-HL.
- The two benchmarks are only representative and there are other scenarios which yield almost the same sensitivity (provided that are dominated by either left-handed or right-handed components).
- There are multiple ways to quantify our findings in a fully-fledged selection by using multivariate methods and/or constructing forward backward asymmetries.
- These benchmarks can be generalised to any model containing the charged Higgs boson that decays predominantly to tb .