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Charged Higgs boson benchmarks from top quark polarization

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Table of contents

Introduction

Why the following benchmark points are important

- In a model-dependent context (2HDM in our case), they lead to totally different responses from top quark spin observables and still enjoy quite important rates.

  We used observables which are clean from systematic uncertainties

- The spin observables can be used in conjunction with multi-variate techniques in addition to traditional cut-based analyses to look for charged Higgs bosons (with the highest sensitivity being of these benchmark points). $\Longrightarrow$ As you go farther from these parameter points, the sensitivity decreases.
- They can be used for other models as well (2HDM-I is similar to e.g. Georgi-Machecek model in view of sensitivity of these observables). $\Longrightarrow$ Can be used in a model-independent analysis.

Motivation

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

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

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

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

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) $\Longrightarrow$ 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 $\Longrightarrow$ Top quark polarization is arbitrary and it's only controlled by $\tan\beta$ (in addition to charged Higgs boson mass.

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_{H^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 $m_{A^0} = m_{H^0}$.