The decay $H \rightarrow Wb\bar{c}$ as a proof for the flavor changing neutral coupling $Htc$

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Abstract. It is analyzed if the flavor changing neutral coupling (FCNC) $Htc$ can give place to a significant deviation from the Standard Model predictions in the decay channel $H \rightarrow W^+b\bar{c}$, the effect of this coupling in the three $W^+$ polarization states is studied. The FCNC comes from an effective Lagrangian with dimension six operators which give rise to an extended Yukawa sector non diagonal in the mass fermionic eigenstates.

Keywords: Flavor changing neutral coupling, Polarization.

INTRODUCTION

The couplings between the Higgs boson and the fermion fields are diagonal in the mass base within the Standard Model Lagrangian, therefore at tree level the Flavor Changing Neutral Coupling FCNC $Htc$ is not allowed and remains highly suppressed when it appears in radiative corrections [2]. Nevertheless in different standard model extensions some processes involving Top-quark FCNCs can be enhanced by several orders of magnitude because of the presence of new fields such as a second Higgs doublet or new fermionic degrees of freedom. That is the case of the decay $t \rightarrow cH$: in the standard model it has a branching ratio between $10^{-13}$ and $10^{-14}$, however in the Two Higgs Doublet Models II and III the results are $10^{-4}$ and $10^{-3}$ respectively, in the MSSM its value is $10^{-4}$ and in models with extra quarks a branching ratio of $10^{-5}$ is obtained [2]. In this work the effect of the $Htc$ coupling in the decay channel $H \rightarrow W^+b\bar{c}$ is studied making a comparison between the standard model process $H \rightarrow W^+W^* \rightarrow W^+b\bar{c}$ (SM) and the flavor changing channel $H \rightarrow t\bar{c} \rightarrow W^+b\bar{c}$ (FC). The FCNC $Htc$ is introduced following a model independent approach through the effective coupling[1]

$$\mathcal{L} = \frac{g}{2 \sqrt{2}} \left( h_{tcH} + i \tilde{h}_{tcH} \gamma_5 \right) H c + h.c. \tag{1}$$

which comes from an extended Yukawa sector with dimension six operators. Here the equality $\tilde{h}_{tcH} = 0$ will be taken in order to avoid CP violation effects, the remaining coupling constant will be written as $C_a$. The bounds for $C_a$ derived from the experimental information available are very loose hence its value was fixed using the Cheng and Sher Ansatz $C_a = g \frac{m_t}{2m_W} = 0.060$. 

**STUDY OF THE CHANNELS** $H \rightarrow W^+W^{*-} \rightarrow W^+b\bar{c}$ AND $H \rightarrow t\bar{c} \rightarrow W^+b\bar{c}$ BY $W^+$’S POLARIZATION STATE

The Feynman diagrams for the purely Standard Model (SM) and Flavor Changing (FC) decay channels are given in figure 1. In order to evaluate the effect of the FCNC $Htc$ in the process $H \rightarrow W^+b\bar{c}$, the energy distributions $\frac{d\Gamma_{SM}}{dE_W}$ and $\frac{d\Gamma_{SM+FC}}{dE_W}$ were constructed and compared. Here $\Gamma_{SM}$ and $\Gamma_{SM+FC}$ are the decay widths for the Higgs particle into the products $W^+b\bar{c}$: the first one was estimated regarding just the SM process, the second width was obtained combining the SM and FC channels. The calculations were made taking into account the separate contribution of the following $W^+(\pm)$-polarization vectors to the Higgs decay width:

$$
\epsilon^{(\pm)} = -\frac{\epsilon(1)+i\epsilon(2)}{\sqrt{2}}, \quad \epsilon^{(-)} = \frac{\epsilon(1)-i\epsilon(2)}{\sqrt{2}}
$$

and $\epsilon^{(l)}$. The symbols $\epsilon(1)$ and $\epsilon(2)$ represent transverse polarization states and $\epsilon^{(l)}$ refers to the longitudinal polarization vector associated with a spin 1 massive particle. The figure 2 shows the energy distributions $\frac{d\Gamma}{dE_W}$ by $W^+$ polarization state assuming a Higgs mass of $m_H = 154.4 \text{ GeV}$, this value falls inside the recent experimental bounds and is almost the energy necessary to produce two real $W$ bosons.

**FIGURE 1.** Left Standard Model Channel decay $H \rightarrow W^+W^{*-} \rightarrow W^+b\bar{c}$ (SM) and right with flavor changing effect $H \rightarrow t\bar{c} \rightarrow W^+b\bar{c}$.

Finally the ratio $r^{(j)} = \frac{\Gamma^{(j)}(H \rightarrow W^+b\bar{c})}{\Gamma(H \rightarrow W^+b\bar{c})} = \int \frac{d\Gamma^{(j)}_{SM+FC}}{dE_W} dE_W \int \frac{d\Gamma^{(j)}_{SM+FC}}{dE_W} dE_W$ was evaluated, where $\frac{d\Gamma_{SM+FC}}{dE_W} = \sum_j \frac{d\Gamma^{(j)}_{SM+FC}}{dE_W}$ with $j = +,-,l$ (more details about the calculations can be found in [3]).
FIGURE 2. Solid curve $\frac{d\Gamma_{SM} + FC}{dE_W}$, dashed curve $\frac{d\Gamma_{SM}}{dE_W}$ and dotted curve $\frac{d\Gamma_{FC}}{dE_W}$ (logarithmic scale).

FIGURE 3. Solid curve $r(l)$, dashed curve $r(\cdot \cdot \cdot)$ and dotted curve $r(\cdot \cdot \cdot)$ (logarithmic scale).

CONCLUSIONS

The decay channel $H \rightarrow W^+b\bar{c}$ is enhanced in one order of magnitude due to the FCNC $Htc$ (see figure 2). As the $C_a$ coupling constant is increased the $W(\cdot \cdot \cdot)$ longitudinal polarization contribution to the Higgs decay width grows from 51.6% to nearly 56.0%, the $\epsilon(\cdot \cdot \cdot)$ contribution goes from 24.2% to around 35.0%, and the $\epsilon(\cdot \cdot \cdot)$ contribution value is always lower than 24.2% (see figure 3).

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REFERENCES