1. Introduction

In July 2012 the Higgs boson, the last missing piece of the Standard Model (SM), was discovered at the Large Hadron Collider (LHC) at CERN. Still, the SM faces several theoretical problems it cannot explain satisfactorily:

- The Higgs hierarchy problem and the radiative stability
- Hierarchical structure of the Yukawa couplings (flavor puzzle)
- Cosmological constant problem
- String CP problem

A promising possibility to solve the Higgs hierarchy problem and the flavor puzzle is offered by Randall-Sundrum (RS) models [1], in which the SM is embedded in a slice of anti-de Sitter space while the flavor puzzle is offered by Randall-Sundrum (RS) models [1], in addition to a tower of KK modes. In this work, we investigate the flavor-changing neutral current (FCNC) transition $b \to s\gamma$ in the minimal RS model with a brane-localized Higgs sector. The transition is interesting in order to search for new physics since the SM and the dipole Wilson coefficients are Cabibbo-Kobayashi-Maskawa (CKM) and loop-suppressed.

In order to include the effects of the RS model we implement an effective Lagrangian, in which the heavy Kaluza-Klein (KK) quarks and bosons are integrated out. The most important operators are the electromagnetic dipole operators

$$Q_{\gamma b} = \frac{e}{2} \frac{1}{v^4} \int d^4x \sqrt{g} F_{\mu \nu} F^{\mu \nu} b, \\
Q_{\gamma b} = \frac{e}{2} \frac{1}{v^4} \int d^4x \sqrt{g} \frac{2}{3} F_{\mu \nu} F^{\mu \nu} b,$$

with $\sigma_{\mu \nu} = G_{\mu \nu} - \frac{1}{3} \epsilon_{\mu \nu \rho \sigma} G^{\rho \sigma}$ and the projection operators $P_{\pm} = (1 \pm \gamma^5)/2$. Due to operator mixing we also have to consider the chargino-dipole operators

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where $L_a$ are the generators of SU(3).

4. FCNC transition $b \to s\gamma$

Like in the SM, the leading-order contributions to the $b \to s\gamma$ dipole Wilson coefficients in the RS model are loop suppressed. However, contributions from the RS sector are present and can be enhanced. In particular, corrections to the SM transition vertices

- new FCNC couplings of the Higgs and the Z-boson
- and heavy KK excitations of the bosons and quarks. Below are shown all relevant Feynman diagrams contributing in a general RS model with branes labeled by $A, G, W, Z$ the contributions from the scalar component of the 5D gauge bosons and from the corresponding Goldstone bosons for $W$ and $Z$ in the Higgs sector

The Wilson coefficients $C_{\gamma b}$ and $C_{\gamma b}$ are defined via the general parametrization of the transition amplitude

$$A_{\gamma b} = \int \frac{d^4x}{16\pi^2} \bar{L}_a \gamma_{\mu} \left[ C_{\gamma b} \gamma_{\mu} \bar{L}_b + C_{\gamma b} \gamma_{\mu} \bar{L}_b \right],$$

where $C_{\gamma b}$ is the Fermi constant and $C_{\gamma b}$ are defined analogously.

Discussions of the Wilson coefficients for $s \to b\gamma$ in the literature:

- [7-9]: Using naive dimension arguments (NDA) the authors claim that the Wilson coefficient for a heavy Higgs boson is logarithmically sensitive to the UV cutoff.
- [10]: The authors perform a 4D calculation treating Yukawa interactions as perturbations finding finite Wilson coefficients.
- [11]: The authors perform a 4D calculation, where they focused on the (dominant) diagrams exchanging the first level of KK fermions with intermediate ghost and Goldstone bosons.
- [12]: The authors perform a 4D calculation focusing on the diagrams with scalars and KK fermions and claim a non-decoupling effect of the heavy KK Higgs.

7. Summary

- We calculated the radiative Wilson coefficients $C_{\gamma b}$ and $C_{\gamma b}$ in the context of the minimal RS model with a Higgs sector localized on the IR brane using the 5D approach, where the coefficients are expressed in terms of integrals of 5D propagators. Since we kept the full dependence on the Yukawa matrices, the integral expressions are formally valid up to all orders in $m_t^2/M_{\text{KK}}^2$.
- In addition, we related our results to the expressions obtained in the Kaluza-Klein decomposed theory and showed the consistency in both pictures analytically and numerically, which presents a non-trivial cross-check.
- We investigated the finiteness of the dipole Wilson coefficients.
- The dominant KK corrections in RS are given by scalar penguin diagrams with a chirality flip on the internal KK quark line. The exchange of KK gluons and photons turns out to be subleading, due to an approximate flavor alignment.
- The dipole Wilson coefficients for the scalar penguin diagrams are “model-dependent”. For a brane-localized Higgs sector and the Z-boson contributions cancel to good approximation.
- Corrections to $C_{\gamma b}$ and $C_{\gamma b}$ with respect to the SM is then in the weak $T^2$ region for (anarchy Yukawa matrices) $C_{\gamma b} < 0.5$ transitions to brane-localized Wilson coefficients are larger since they are not suppressed by $m_b/m_t$ as it is the case in the SM.

8. References