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TOP QUARK RARE RADIATIVE DECAY IN UNIVERSAL EXTRA DIMENSION MODEL

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Abstract: *We have estimated additional to the standard model (SM) contributions to the top quark FCNC decays in the framework of the model with one extra dimension. The estimates of performed calculations show that extra dimension models with only one additional spatial dimension cannot raise branching ratios for top FCNC decays.*
Key words: Top quark, Standard Model, Extra dimension.

Exited times become for fundamental physics after discovery of neutral Higgs particle. Many people in scientific society await new discovery, namely new physics (NP) beyond the standard model (SM) at the scale around 1TeV. These new discoveries could be supersymmetric particles or technycolor or something more radical, like extra additional space dimension. Success of the SM do not weaken theoretical arguments in favour of NP, which is anticipated at the TeV scale. The task to find and identify NP seems to us to be as a most important challenge for High Energy Physics. In spite of successes of SM of particle physics and SM of cosmology (based on traditional theory of General Relativity), there are profound experimental and theoretical reasons to suppose that both of them are incomplete. From the experimental point of view to this opinion hint, for example, the small but non vanishing neutrino masses and small but non vanishing value for cosmological constant, the presence of dark matter, dark energy and baryon asymmetry of the Universe. Theoretical problems include hierarchy problem, supersymmetry breaking, replication of fermion generations and highly hierarchical structure of fermion mass matrixes, *CP* - conservation in QCD etc.

Very important is the question on how to identify the manifestation of NP and how to give the preference to some special kind of SM expansion. As a most promising extensions of the SM are considered SUSY extensions, based on the idea of supersymmetry [1,2,3,4] and approaches with large extra dimensions [5-9], though there are also more radical ways beyond SM.

In the framework of extra dimensional models with the fundamental gravity scale around ~TeV the NP is expected to manifest itself around this scale. As soon as indicated scale will be tested, for example at LHC energies, NP must manifest itself. The question is only in which form it manifests itself. The most direct way to manifest and analyze experimental patterns of NP could consist in the direct production of the new particles like supersymmetric or Kaluza-Klein (KK) resonances. Another possibility consists in the indirect manifestation of the effects beyond SM. Before showing in the direct production processes, beyond SM effects could manifest themselves in the rare decays induced by flavor changing neutral current (FCNC) transitions. The importance of such a possibility is hard to be overestimated. To differ various NP scenarios, we are in need to investigate their influence on the aromatodynamics.

FCNC processes are strongly suppressed in the SM. In the quark sector FCNC processes first arise on the one loop level and are suppressed by Glashow-Iliopoulos-Maiani (GIM) mechanism [10]. Some, of such processes ($B^0 \leftrightarrow \overline{B}^0$, $K^0 \leftrightarrow \overline{K}^0$, $B \to K^* \gamma$) are experimentally observed and are in quite good agreement with SM predictions. As for top quark sector, the FCNC processes in it are also very small in the SM with following rates [11]:

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$$Br(t \to c\gamma) \approx 5 \cdot 10^{-13}, \quad Br(t \to cg) \approx 5 \cdot 10^{-11},$$
$$Br(t \to cZ) \approx 1.3 \cdot 10^{-11}, \quad Br(t \to cH) \approx 10^{-13} \qquad (1)$$

So, even single experimental observation for any top rare processes could be breakthrough beyond the SM physics. In some extensions of the SM there could be several mechanisms for enhancements of FCNC processes, including top quark FCNC phenomena. One of such mechanism could be arisen in case when GIM suppression changes its quadratic nature by linear one. This happens when particles running in the loops have comparable masses. Such a situation is realized in the universal extra dimension (UED) models [8].

FCNC processes are intensively investigated in large extra dimension scenarios. As these studies show in case when theoretical approaches are not enriched other way than simply adding extra dimension to the SM, there is hard to get theoretical predictions close to experimental bounds [12-16]. It is expected from common theoretical sense that FCNC processes would be possibly enhanced in case when particles running in the appropriate loops have close masses [17]. Loop amplitudes with comparable masses of inter mediate particles running in the loop seem to be quite large because the generic quadratic suppression factor is changed to a linear one. Such a situation with comparable masses in principle is realizable in the models with extra dimensions. It is not obvious without specific calculations how would be changed the SM estimate of the above processes in the models with extra dimensions. Some details of the models can enhance suitable amplitudes and others can cause suppression. On general grounds, one expects an enhancement of the amplitudes, but this expectation is not fulfilled because of the almost degeneracy of the massive towers modes from different generations. This is not necessarily the last word, though; the black hole can inspire FV processes and enhance them [18-22]. On the other hand it is not obvious without specific calculations how would be changed the SM estimate of the above processes in the models with extra dimensions (ED). Some details of the models can enhance suitable amplitudes and others can cause suppression. It is impossible to estimate summary effects of this interplay without specific calculations. We have calculated the relevant contributions to $t \to c\gamma$ via intermediate black hole.

We accept the conjecture that black holes violate global symmetries [21, 22] including family number. So, black holes could manifest themselves in FCNC processes as intermediate states and enhance them. We assume that black holes with mass lighter than effective Planck mass have a zero charges (electric, color) and zero angular moment in the classical case and this feature is adopted by quantum gravity too. So, one can write the effective Lagrangian describing interactions between quarks and black hole in the following way [21, 22]

$$L = g_{ij}\bar{q}_{Li}q_{Rj}\Phi + h.c. \qquad (1)$$

where g_{ij} are dimensionless effective coupling constants. Virtual black hole can induce FV process $t \to c\gamma$ at the one loop level (Fig.1).

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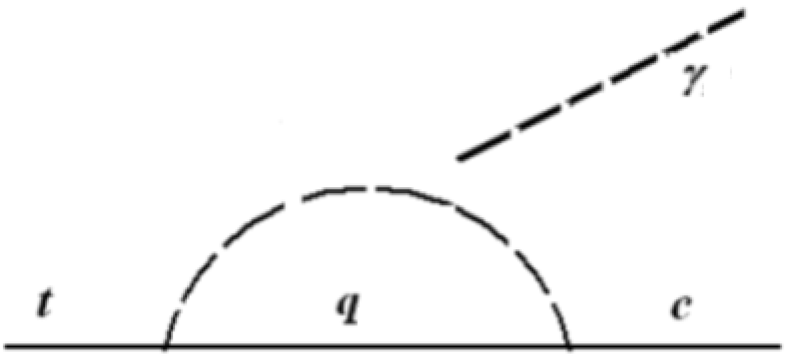

Fig.1. Top quark radiative decay $t \to c\gamma$ via intermediate black hole (dashed line).

Through direct calculation we get following expression for the decay width

$$\Gamma(t \to c\gamma) = \frac{\alpha m_t^5}{(4\pi)^4 M^4}\left(g_{ti} g_{cj}^* f(x_i)\right)^2 \qquad (2)$$

where M is mass of the intermediate black hole and we have introduced following notation

$$f(x) = \frac{2 + 3x - 6x^2 + x^3 + 6x \ln x}{36(1-x)^4}, \qquad x = m^2(q_i)/M^2 \qquad (3)$$

For the total decay width of the top quark we have used $\Gamma = 1.55 GeV$. Using formulae (2), (3) one get

$$Br(t \to c\gamma) = 4.4 \cdot 10^{-8}\left(g_{ti} g_{cj}^* f(x_i)\right)^2 \qquad (4)$$

As numerical analyses show the branching ratio does not increases significantly (all necessary numerical data were taken from [23]). One can consider LHC as a top quark factory, though observation of top quark decays with branching ratios less than 10^{-5} is impossible in foreseen future.

Conclusion

Experimental success of SM is very expressive in the last decades after its acknowledgment. At least we know only experimental derivation from “standard thinking” due to discovery of small finite (but nonzero) neutrino masses in the various neutrino oscillation experiments. Therefore it is important to know how numerous and at which confidence level will be realized intervention of any kind of new physics (NP) beyond SM in all sectors of the knowledge of high energy physics. We have discussed one of the ways on the theoretical road for manifestation of NP in the top quark sector, particularly, in the top FCNC decays. As our analyses show the ED models with only one additional spatial dimension cannot raise branching ratios for top FCNC decays. Experimental observation of a few events with these decays opens the possibility for NP intervention different from the ED.

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