Rare Decays of K and B Mesons at T31 in 2002

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1. Introduction

The flavour changing neutral current (FCNC) processes play an important role in the tests of the short distance structure of the Standard model (SM) and of its extensions like supersymmetric models and models with extra space dimensions. The Standard Model is consistent with all presently available data on FCNC processes. On the other hand the increased precision on the available data and the observation of new decay channels in K and B meson decays to be expected in this decade at B–factories, Tevatron, LHC and K–physics dedicated experiments, calls for more precise theoretical predictions within the SM and for estimates of branching ratios in its extensions. The activities of T31 in 2002 as in previous years were centered around these two goals.

2. $B \to X_s\gamma$ Decay

The $B \to X_s\gamma$ decay proceeding through the so-called photon-magnetic penguins is subject to large strong interaction (QCD) corrections. The calculations of these corrections are very involved and their completion required the efforts of several groups over the last six years. Our group was the first and the only one until now that completed all necessary steps in this project. The final piece has been presented in [1] and the summary of this full effort has been given in [2]. We find

$$BR(B \to X_s\gamma)_{\rm TH} = (3.60 \pm 0.30) \cdot 10^{-4}$$

to be compared with the experimental world average from CLEO, ALEPH, Babar and Belle

$$BR(B \to X_s\gamma)_{\rm EXP} = (3.30 \pm 0.40) \cdot 10^{-4}.$$

The agreement is good but in order to put better constraints on possible new physics contributions, the precision of theory and experiment have to be further improved.

3. Unitarity Triangle

The studies of the unitarity Triangle (UT), a geometrical representation of the Cabibbo–Kobayashi–Maskawa (CKM) matrix, that have been central for the activities of T31 in the last ten years, have been continued [3] also in 2002 in view of new data from BaBar and Belle from which a precise value of the angle β in the UT could be recently obtained. This allowed a rather precise determination of the UT within the SM and in a restricted class of its extensions that is known under the name of models with minimal flavour violation (MFV). In these models the CKM matrix remains to be the only source of flavour and CP violation and moreover the effective low energy operators responsible for the K and B decays are the same as in the SM. The analysis in [3] demonstrates that it will not be easy to distinguish the expectations for the UT in the SM from the corresponding expectations within the MFV models. This will require improved theoretical calculations of $B^0_{d,s}$–$\overline{B^0_{d,s}}$ mixing and of the CP violation in $K \to \pi\pi$ decays parameterized by ϵ_K.

In this respect new strategies for the determination of the UT should be useful. A detailed numerical analysis in [3] has shown that the most efficient strategies to find the UT are the ones that determine the angles β and γ simultaneously. Such strategies should be at work soon in view of the forthcoming data.

4. The Impact of Extra Dimensions on Rare Decays

The simplest extension of the SM is to increase the number of space–time dimensions from four to five and to allow all SM fields to propagate in the fifth dimension. From the point of view of effective four dimensional low energy theory the model consists of all SM fields and the corresponding Kaluza–Klein (KK) modes with masses larger than 250 GeV. The attractive feature of this model is the presence of only a single new parameter ($1/R$), the compactification scale, that parameterizes the KK mass spectrum and the interactions of these modes with the SM particles and among themselves. In [4] a detailed analysis of the $B^0_{d,s}$–$\overline{B^0_{d,s}}$ mixing, ϵ_K, UT and of rare decays $K \to \pi\nu\bar\nu, B_{s,d} \to \mu^+\mu^-, B \to X_{s,d}\nu\bar\nu$ and $K_L \to \mu^+\mu^-$ in such a model has been done for the first time. For the lowest compactification scale (250 GeV) that is allowed by the electroweak precision data the impact of the KK modes on $B^0_{d,s}$–$\overline{B^0_{d,s}}$ mixing and ϵ_K is small, typically below 10%. It can be substantially larger for rare decays, in particular $B_s \to \mu^+\mu^-$ where the branching ratio is enhanced by 50% relative to the SM expectation. Of interest is also the 20% enhancement of $K^+ \to \pi^+\nu\bar\nu$ that could be welcome in view of Brookhaven data that are above the SM prediction.

5. $B_s \to \mu^+\mu^-$, ΔM_s in Supersymmetry

Much larger effects of new physics are expected in supersymmetric models with large $\tan\beta = v_2/v_1$, where v_i are the vacuum expectation values of the relevant Higgs fields. As shown in [5,6], the branching ratio for $B_{s,d} \to \mu^+\mu^-$ can be enhanced by three orders of magnitude, reaching $2 \cdot 10^{-6}$ and $1 \cdot 10^{-7}$ for $B_s \to \mu^+\mu^-$ and $B_d \to \mu^+\mu^-$, respectively. Consequently these decays could soon be measured at Tevatron, if indeed the relevant SUSY contributions are as high as found in these papers. However, as pointed out in [6], the enhancement of $B_{s,d} \to \mu^+\mu^-$ is correlated in these models with the suppression of ΔM_s, the difference of the masses of the mass eigenstates in the B^0_s–$\overline{B^0_s}$ system. The future data for $B_{s,d} \to \mu^+\mu^-$ and ΔM_s should confirm or disprove this correlation and the predicted enhancements and suppressions.

References

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