Signals of Supersymmetry in Flavor Physics

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Abstract

In this talk I give a short summary of possible signals of Supersymmetry in flavor physics, concentrating on low energy observables that play an important role at LHCb. Characteristic SUSY effects in the rare B decays $B_{s,d} \to \mu^+\mu^-$ and $B \to K^*\mu^+\mu^-$, in CP violation in $D^0 - \overline{D}^0$ mixing as well as in the B_s mixing phase are discussed within several SUSY frameworks.

1 Introduction

Supersymmetric (SUSY) extension of the Standard Model (SM) can have a very rich flavor sector and often predict non-standard effects in many low energy flavor observables [1]. This talk briefly outlines possible SUSY signals in observables that play an important role at LHCb and that can be regarded as "discovery channels", because they are strongly suppressed in the SM. In particular we discuss the branching ratios of the rare $B_{s,d} \to \mu^+\mu^-$ decays, angular observables in the $B \to K^*\mu^+\mu^-$ decay, CP violation in $D^0 - \overline{D}^0$ mixing as well as the B_s mixing phase.

2 The $B_s \to \mu^+\mu^-$ and $B_d \to \mu^+\mu^-$ Decays

The rare $B_{s,d} \to \mu^+\mu^-$ decays are strongly helicity suppressed in the SM by the small muon mass. The SM predictions of the branching ratio of $B_s \to \mu^+\mu^-$ [2] is still a factor of 3 below the combined experimental bound from CMS and LHCb [3]

$$\mathrm{BR}(B_s \to \mu^+\mu^-)_{\mathrm{exp}} < 1.1 \cdot 10^{-8} \ , \quad \mathrm{BR}(B_s \to \mu^+\mu^-)_{\mathrm{SM}} = (3.0 \pm 0.2) \cdot 10^{-9} \ . \qquad (1)$$

In the Minimal Supersymmetric Standard Model (MSSM), the helicity suppression can be lifted. Higgs penguin contributions to the decay amplitude scale as $\tan^3\beta/M_A^2$ and can strongly enhance the branching ratio in the large $\tan\beta$ regime [4]. Even in models with Minimal Flavor Violation (MFV), where the CKM matrix is the only source of flavor violation, the experimental bound can easily be reached.

The measurement of both $\mathrm{BR}(B_s \to \mu^+\mu^-)$ and $\mathrm{BR}(B_d \to \mu^+\mu^-)$ offers a clean test of the MFV hypothesis. In the MSSM with MFV the ratio of the branching ratios is determined by the ratio of the CKM elements $|V_{ts}|^2/|V_{td}|^2$. We find

$$\mathrm{BR}(B_s \to \mu^+\mu^-)/\mathrm{BR}(B_d \to \mu^+\mu^-) = 31.9 \pm 3.9 \ . \tag{2}$$

Significant deviation from (2) would be a clear signal for additional sources of flavor violation beyond the CKM matrix.

3 The $B \to K^*\mu^+\mu^-$ Decay

The angular analysis of the $B \to K^*(\to K\pi)\mu^+\mu^-$ decay gives access to many observables that are sensitive to New Physics effects [5]. Using the angular coefficients I_i and $\overline{I}_i$ of the full angular decay distributions of the $\overline{B}^0 \to \overline{K}^{*0}(\to K^-\pi^+)\mu^+\mu^-$ decay and its CP conjugate mode $B^0 \to K^{*0}(\to K^+\pi^-)\mu^+\mu^-$ allows to systematically define CP averaged angular coefficients S_i and CP asymmetries A_i

$$S_i = (I_i + \overline{I}_i)\Big/\frac{d(\Gamma + \overline{\Gamma})}{dq^2} \ , \quad A_i = (I_i - \overline{I}_i)\Big/\frac{d(\Gamma + \overline{\Gamma})}{dq^2} \ . \tag{3}$$

Of particular interest are the observables S_3 and A_9 that probe the presence of CP conserving and CP violating right-handed (RH) currents, and that can be extracted from a one-dim angular analysis. First results on these observables have recently been obtained at CDF [6]. SUSY models that contain sources of RH bottom $\to$ strange squark transitions generate S_3 and A_9 through RH magnetic penguin operators and can easily accommodate values as large as the model independent bounds of $\pm 15\%$ [2].

Important observables that probe CP violation in left-handed (LH) currents are the CP asymmetries A_7 and A_8. In many SUSY models, for example in models with (effective) MFV that allow for additional sources of CP violation [7], they are dominantly generated through LH magnetic penguin operators and can be as large as $\pm 35\%$ and $\pm 20\%$ respectively [2]. Measurements of A_7 and A_8 are crucial to probe CP violating SUSY effects in the LH operators.

4 CP Violation in $D^0 - \overline{D}^0$ Mixing

In the SM, CPV in $D^0 - \overline{D}^0$ mixing is strongly suppressed and experimental evidence above the per mill level would be a clear indication for NP. Even though NP frameworks with MFV can in principle lead to testable CP signals in $D^0 - \overline{D}^0$ mixing [8], CPV in $D^0 - \overline{D}^0$ mixing remains SM-like in the MSSM with MFV.

In so-called SUSY alignment models [9] on the other hand, large SUSY effects in $D^0 - \overline{D}^0$ mixing arise generically. While present data on $D^0 - \overline{D}^0$ mixing already strongly constrains such models [10], they generically predict that CPV in $D^0 - \overline{D}^0$ mixing should be close to the current bounds. As shown in [11], a second characteristic signal of SUSY alignment models are electric dipole moments (EDMs) of hadronic systems, like the neutron or the mercury EDM, not far below current constraints.

5 The B_s Mixing Phase

Experimental data from Tevatron seemed to indicate an O(1) B_s mixing phase, 2-3σ above its tiny SM prediction [12]. Recent measurements from LHCb on the other hand are fully consistent with the SM and only allow for a NP phase of approximately $|\phi_s^{\rm NP}| < 0.3$ [13]. SUSY models that contain non-MFV mixing between bottom and strange squarks can easily account for NP phases in B_s mixing as large as the bounds from LHCb. Among such models are SUSY flavor models [1, 14], SUSY GUTs [15] and also models with flavor violating trilinear couplings [16]. Interestingly, in the MSSM with MFV on the other hand, the B_s mixing phase remains essentially SM like. However, if the Higgs sector of the MSSM is extend by higher dimensional operators, also a MFV soft sector is sufficient to generate non-standard CP effects in B_s mixing that will be probed in the future by LHCb [17].

6 Summary and Outlook

Low energy flavor observables provide complementary probes of SUSY degrees of freedom that are searched for at the LHC. Many such observables that are highly suppressed in the SM model can be strongly enhanced up to the current experimental bounds in SUSY models. The experimental prospects for measuring the discussed observables at LHCb are excellent [18] and, since the PLHC conference in June 2011, many experimental results in B and charm physics were already published. More improved measurements are expected in the near future and they will test the flavor structure of any NP that might be expected at the TeV scale.

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