$b \to s\gamma$ DECAY IN SUPERSYMMETRIC THEORIES

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Recent advances in the calculation of the $b \to s\gamma$ decay branching ratio are presented in the context of supersymmetric theories. Theoretical accuracy increased by inclusion of the next-to-leading order QCD corrections makes it possible to significantly decrease scale dependence of the result. Comparison with the latest CLEO experimental results then allows to limit supersymmetric loop contributions to the process and consequently constrain the parameter space of supersymmetric extensions of the Standard Model. We discuss these constraints both in the minimal supergravity inspired model (SUGRA) and in the simplest gauge-mediated supersymmetry breaking model (GMSB) both of which are interesting from the point of view of the searches for supersymmetry at present and future colliders. Our analysis also includes the interesting region of large $\tan\beta$ relevant for models with Yukawa coupling unification.

An important experimental check of SUSY models is provided by the measurement of the $b \to s\gamma$ decay rate. Weak scale SUSY particles contribute to the one loop decay amplitude and their presence can significantly modify the Standard Model (SM) result.

The best experimental value available for the inclusive $B \to X_s\gamma$ branching ratio as measured by the CLEO collaboration $B(B \to X_s\gamma) = (2.32 \pm 0.57 \pm 0.35) \times 10^{-4}$ has to be compared to the next-to-leading order Standard Model prediction including non-perturbative corrections $B(B \to X_s)\gamma = (3.38 \pm 0.33) \times 10^{-4}$, see[1]. SUSY contributions can correct the theoretical value in both directions and a requirement that the branching ratio remain restricted within the experimental 95% confidence level band $1 \times 10^{-4} < B(B \to X_s\gamma) < 4.2 \times 10^{-4}$ translates into constraints on the supersymmetric parameter space. All the next-to-leading order calculation ingredients for SUSY models are already available with the exception of the exact two-loop matching conditions between the full theory and the effective theory, which have been evaluated only for the SM contribution, the charged Higgs contribution and for some special cases of the chargino contribution . Here we adopt an approximate procedure effectively decoupling the heavy particles in the loop at different scales for the dominating SUSY contributions to approximate the exact matching conditions[2].

In the minimal supersymmetric extension of the SM, the SUSY contribution involves the charged Higgs-top quark loop, chargino-squark loops, gluino-squark loops and neutralino-squark loops[3]. The first two are most impor-
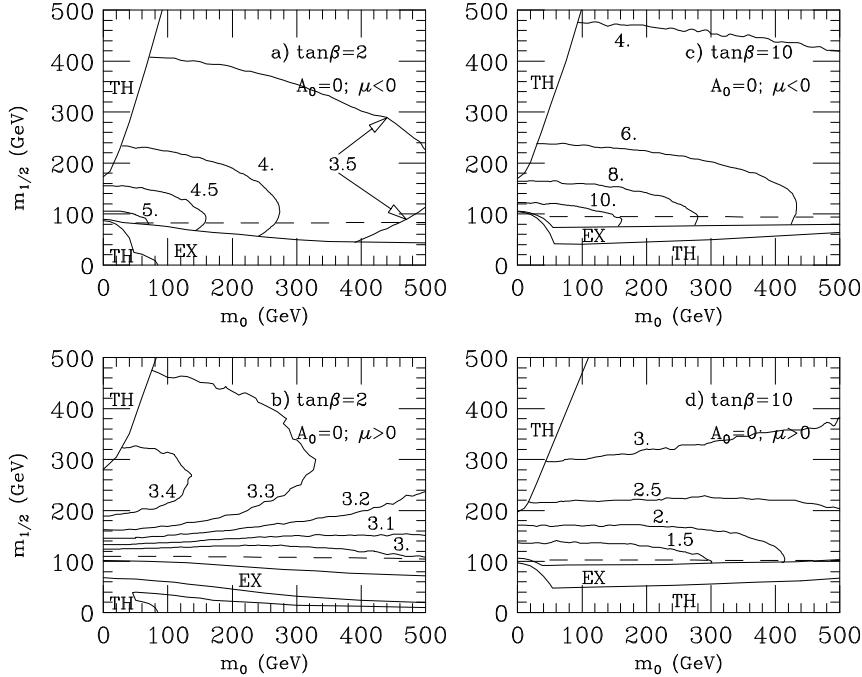
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Figure 1: Plot of contours of constant branching ratio $B(b \to s\gamma)$ in the m_0 vs. $m_{1/2}$ plane, where $A_0 = 0$ and $m_t = 175$ GeV. Each contour should be multiplied by 10^{-4}. The regions labelled by TH (EX) are excluded by theoretical (experimental) considerations. The dashed contour corresponds to $m_{\widetilde{W}_1} > 80$ GeV for a gaugino-like chargino.

tant while the gluino and neutralino loops can be safely neglected within the two major classes of SUSY models, namely the supergravity (SUGRA) inspired models and models with gauge mediated SUSY breaking (GMSB). The charged Higgs loop contribution is always of the same sign as the SM contribution and adds constructively with the SM loop. The chargino-squark loops, on the other hand, can interfere with the SM contribution either constructively or destructively depending on the sign of μ. This feature together with the fact that the magnitude of the total chargino-squark contribution grows with $\tan\beta$ characterizes constraints imposed on the minimal SUGRA parameter space by $b \to s\gamma$.

The minimal version of SUGRA models is parametrized in terms of the common scalar mass m_0, common gaugino mass $m_{1/2}$ and the universal trilinear parameter A_0, which are all evaluated at the unification scale. Furthermore,
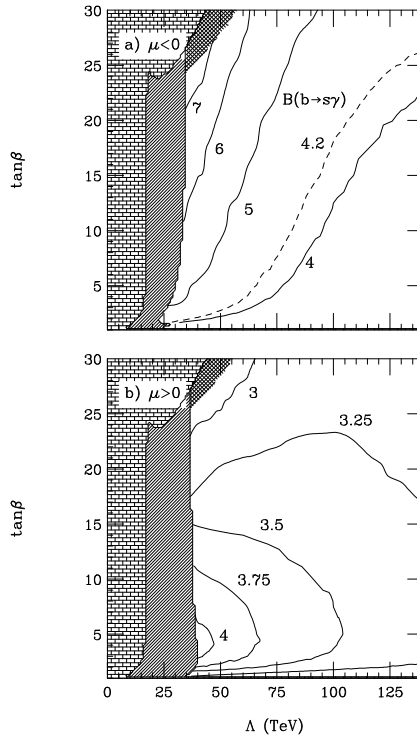
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Figure 2: Contours of constant branching ratio $B(b \to s\gamma)$ in the Λ $vs.$ $\tan\beta$ plane, for $M_{mes} = 500\text{TeV}$. Each contour should be multiplied by 10^{-4}. The bricked (shaded) regions are excluded by theoretical (experimental) considerations. The cross hatched region is where $\tilde{\tau}_1$ is the NLSP.

the value of the ratio of the two Higgs VEV's $\tan\beta$ and the sign of the supersymmetric Higgs parameter have to be specified. In the minimal SUGRA models with $\tan\beta \lesssim 5$ the chargino squark contribution is small enough to permit large allowed regions for both signs of μ yielding larger branching ratios for the case of $\mu < 0$. With $\tan\beta$ increasing, the allowed region in the $\mu < 0$ case narrows down requiring heavy charginos to suppress $\tan\beta$ enhancement in the chargino-squark loops while in the $\mu > 0$ case cancellation between the chargino loops and and the charged Higgs loop makes it possible to obtain branching ratios in some cases very close to the CLEO mean value and certainly consistent with the experimental limits over the whole range of parameters. As an example, Fig.1 displays contours of constant branching ratio

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$B(b \to s\gamma)$ in the m_0 vs $m_{1/2}$ plane for $\tan\beta = 2$ and 10, and both signs of μ.

In the large $\tan\beta$ parameter region with $\tan\beta \gtrsim 35$, the $\mu > 0$ branch of the parameter set is also constarined by $b \to s\gamma$ since a very large chargino-squark contribution drives the branching ratio below the lower experimental value of 1×10^{-4}. The $\mu < 0$ case requires extremely heavy superpartners ($m_{\tilde{g}} \gtrsim 1500$ GeV, $m_{\tilde{q}} \gtrsim 1600$ GeV) in order to satisfy experimental constraints on $B(b \to s\gamma)$ and thus imposes severe constraints on models with Yukawa coupling unification[4].

Additional dependence on A_0 does not change the general picture as determined by the value of $\tan\beta$ and the sign of μ but needs to be considered for a detailed analysis of minimal SUGRA models since it can change the branching ratio by up to several tens of percent in either direction.

In the simplest GMSB model with a single set of messengers in a $5 + \bar{5}$ representation of SU(5) SUSY is broken at the messenger scale M_{mes} and both scalar and gaugino masses are proportional to their corresponding quantum numbers and a single scale Λ. Here also the value of $\tan\beta$ and the sign of μ determine the way in which the chargino-squark contribution is added to the SM and Higgs contributions. Generally, the squarks tend to be significantly heavier than the charginos in this type of models, which correspondingly suppresses the magnitude of the chargino contribution. As a result, for $\mu > 0$ the effects from chargino and charged Higgs loops more or less cancel each other as they interfere destructively ans $b \to s\gamma$ imposes no constraints over much of the parameter space as can be seen in Fig.2. In the $\mu < 0$ case, the $b \to s\gamma$ constraint becomes increasingly restrictive with growing $\tan\beta$ since the $\tan\beta$ enhancement of the chargino contribution pushes the value of the $b \to s\gamma$ branching ratio over the CLEO experimental limit[5].

References

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