NEW PHYSICS SEARCH IN B MESON DECAYS

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We discuss new physics search within the minimal supergravity model by using a possible large direct CP asymmetry in $B^\pm \to K^\pm \phi, K^0 \pi^\pm$ decays and B meson rare decays.

1 Introduction

$B$ factories at KEK and SLAC are taking data to probe the origin of CP violation which is one of main issue in current high energy physics. In the standard model(SM) the CP violation is originated by a physical phase of the Cabibbo-Kobayashi-Maskawa(CKM) matrix $\theta$. A new source of CP violation can appear in models beyond the SM. If there is new physics beyond SM, we expect to see its effects in CP violating B meson decays.

The most important task for new physics search is to identify decay modes where one can find a large deviations from standard model expectations, and also experimentally accessible in near future. It is really good chance to probe the new physics effects in B-meson decays through indirect ($B^0 - \bar{B}^0$ mixing) and direct CP-violating processes at B factories.

In this talk we discuss a possible new physics impact on B-meson rare decays and the direct CP violating phenomena through the magnetic penguin contributions in $B^\pm \to K^\pm \phi, K^0 \pi^\pm$ decays.

2 New physics Effects in mSUGRA Model

We investigate the new physics effects in rare B decays: $B \to X_s \gamma$ and $B \to X_s \ell^+ \ell^-$ and in direct CP violating modes: $B^\pm \to \phi K^\pm, K^0 \pi^\pm$ within the minimal Supergravity model(mSUGRA). In the mSUGRA, there are four new CP violating phases, i.e. phases of the gaugino mass, the higgsino mass parameter, the SUSY breaking Higgs boson mass, and the trilinear scalar coupling constant, of which two combinations are physically independent. When we impose the universal condition at GUT scale, two physical phases at GUT scale comes from, if we take a phase convention, the trilinear coupling constant and higgsino mass parameter, $\phi_A$ and $\phi_\mu$, respectively. These phases induce the neutron and electron electric dipole moments (EDMs). When we require the
universal of SUSY breaking term at GUT scale and explicitly solve the renormalization group equations (RGEs) to determine the masses and the mixings of SUSY particles and also require the condition for the radiative electroweak breaking, the phase $\phi_\mu$ is strongly constrained by EDMs and the phase $\phi_A$ is not constrained at GUT scale, however, in low energy scale, the phase of $A$-term for top squarks is strongly supressed, becuse the phase of $A$-term for top squarks is reduced due to the large top Yukawa coupling constant and aligned to that of the gaugino mass $\mu$.

When we investigate the effect of the SUSY CP violating parameter on rare B decays, $B \to X_s \gamma$ and $B \to X_s \ell^+ \ell^-$, in the mSUGRA, we find some interesting results [4] with following SUSY parameters: $0 < m_0 < 1$ TeV, $120 < M_0 < 500$ GeV, $|A_0| < 5m_0$, and the bound of EDM $|d_e| \leq 4.0 \times 10^{-27} e \cdot cm$, $|d_\mu| \leq 0.97 \times 10^{-27} e \cdot cm$, in addition, the branching ratio of $B \to X_s \gamma$ [4]: $2.0 \times 10^{-4} < B(B \to X_s \gamma) < 4.5 \times 10^{-4}$ ; (i) $\phi_\mu < 10^{-2}$ and $0 < \phi_A < 2\pi$, (ii) As in the case of no SUSY CP violating phase, $C_7$ and $C_8$ have large SUSY contributions, however, those to $C_9$ and $C_{10}$ are small. (iii) CP asymmetry of $B \to X_s \gamma : A_{CP}(B \to X_s \gamma) \leq 2\%$ with EDM constraints, however when we consider EDM cancellation in one loop level, it can be reached up to 7%. (iv) In $B \to X_s \ell^+ \ell^-$ decay, for small $\tan\beta$ value, $\text{Im}(C_7/C_7^m) \approx 0$ since $\text{Im}(A_0)$ becomes small, however, for large $\tan\beta$ value, since chargino and stop loop effect becomes dominated in $C_7$, $C_7 \approx \pm C_7^m$. So branching ratio of $B \to X_s \ell^+ \ell^-$ can be enhanced when $C_7 \approx -C_7^m$. (v) The allowed domain of $C_8/C_8^m$ can be extracted from the $B \to X_s g \gamma$ contribution into $B \to X_s \gamma$, shown in Figure 1.

When we investigate the new physics effect through magnetic gluon penguin contributions in the exclusive B meson decays, we find that a possible large direct CP violation can be observed in pure penguin modes, specially $B^\pm \to \phi K^\pm$ and $K^0 \pi^\pm$.

The CP asymmetry is defined as :

$$A_{CP} = \frac{\Gamma(B^- \to f) - \Gamma(B^+ \to \bar{f})}{\Gamma(B^- \to f) + \Gamma(B^+ \to \bar{f})}$$

For instance, the amplitude of $B^+ \to \phi K^+$ decay is :

$$A(B^+ \to \phi K^+) = -\frac{G_F}{\sqrt{2}} V_{tb} V_{ts}^* \left[ a_3 + a_4 + a_5 - \frac{1}{2} (a_7 + a_9 + a_{10}) + a_{8G} \right] M^{(BK,\phi)}$$

$$M^{(BK,\phi)} = < \phi | (\bar{s}s)_{V-A} | 0 > < K | (\bar{b}s)_{V-A} | B > = 2 f_{\phi} m_{\phi} \left( \epsilon \cdot P_B \right) F^{BK}_{1}(m_{\phi}^2)$$

where

$$a_{8G} = \frac{\alpha_s}{4\pi} \frac{m_{t}^2}{q^2} C_{SG} \frac{N_c^2 - 1}{N_c} S_{\phi K} \cdot e^{i\sigma}$$

$$F^{BK}_{1}(m_{\phi}^2) = \frac{1}{2} \left( 1 - \frac{m_{\phi}^2}{m_K^2} \right)$$
\[ C_{8G} = C_{8G}^{new} + C_{8G}^{sm} = C_{8G}^{sm} \cdot R \cdot e^{i\theta} \]

where \( S_{8K} = -0.49 \), \( \sigma \) is the strong phase difference between \( O_{8G} \) and \( O_{1-10} \), \( \theta = \delta_{new} - \delta_{sm} \) is the electroweak phase difference between new physics and SM, and \( R = |C_{8G}/C_{8G}^{sm}| \). In our analysis we use the factorization approach including non-factorizable contributions into \( N_{c}^{eff} \) and strong phases via Bander-Silverman-Soni mechanism. We use \( (N_{c}^{eff})_{LL} = 2.0 \) for \( O_{1,2,3,4,9,10} \) and \( (N_{c}^{eff})_{LR} = 6.0 \) for \( O_{5,6,7,8} \) as like as H.Y. Cheng et al. As shown in Figure 2, we have large direct CP asymmetries which is induced by new physics contributions: in \( B^{\pm} \to \phi K^{\pm} \) decay, we have \( 0.1 \times 10^{-5} \leq B(B^{\pm} \to \phi K^{\pm}) \leq 0.75 \times 10^{-5} \) and \( |A_{CP}| \leq 15\% \) with EDM constrained condition, however, without EDM constraints, \( |A_{CP}| \leq 30\% \). For \( B^{\pm} \to K^{0}\pi^{\pm} \) decay, we get the branching ratio upto \( 22.5 \times 10^{-6} \) which is well agreed with present experimental data. \[ B(B^{\pm} \to K^{0}\pi^{\pm}) = (18.2^{+4.6}_{-4.0} \pm 1.6) \times 10^{-6} \] and \( |A_{CP}| \leq 20\% \).

In conclusion we have given example of decay modes which can allow an early detection of new physics effects in the minimal supergravity model.

Acknowledgments

The author wishes to thank T. Goto, T.Nihei, Y. Okada and Y.Shimizu for collaboration on some of the work presented here. Y.Y.K. would like to thank M. Kobayashi and H.Y Cheng for their hospitality.

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Figure 1: The allowed region of $C_S/C_S^{em}$ at the bottom mass scale with $\tan\beta = 30$.

Figure 2: CP asymmetry at four different points: (a) prediction of the Standard Model, (b) the point with pure imaginary of $C_S$, (c) the point with maximum distance from origin, (d) an example point without EDM constraint.