On the Double Radiative Decays of B_s-meson $B_s \to \gamma\gamma$.

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It is obvious that new physics is conducted now and willcontinue in rare processes in a foreseen future.Prior to their direct detection on colliders, supersymmetry effects may manifest themselves implicitly in rare processes. Supersymmetry gives elegant solutions to the problems of the standard model and predicts (minimal supersymmetry) the masses of supersymmetry particles in the range $100Gev - O(1)TeV$ (with the exception of the lightest supersymmetry particle). In the present paper we consider the B^0-meson's rare double-photon radiative decays $B^0 \to \gamma\gamma$ in the framework of the minimal supersymmetric standard model(MSSM). The process $B_s \to \gamma\gamma$ is similar to the decay $K^0 \to \gamma\gamma$. However in the former process long-distance effects does not play an important role and short-distance contributions are the leading one. It should be mentioned that the two photons in the final state can be both in CP-odd and CP-even configuration. This possibility could become as a nontraditional source for the search for CP-violating effects in B-physics.

The investigation of the B-meson's rare decays is of great interest in order to test the standard model and beyond standard model physics. It seems that experimental investigation of beauty physics will be one of the major topics at the world facilities. The L3 collaboration(CERN) established that[1]

$$Br(B_s \to \gamma\gamma) < 14,8 \cdot 10^{-5}$$

$$Br(B_d \to \gamma\gamma) < 3,95 \cdot 10^{-5} \tag{1}$$

The experimental interest stimulates theoretical investigations [2-5]. All group of the authors have obtained (in the frame of the standard model) the same values for the branching ratios in the leading order $1/M_W^2$:

$$Br(B_s \to \gamma\gamma) = (3.0 \pm 1.0) \cdot 10^{-7}$$

$$Br(B_d \to \gamma\gamma) = (1.2 \pm 1.1) \cdot 10^{-8} \tag{2}$$

In the framework of supersymmetric extension of the standard model one has following set of diagrams which contribute into decays $B \to \gamma\gamma$ (the diagrams are classified by particles which appear in the loops): a) charged gauge fermions (chargino) and up scalar quarks, b) charged Higgs particles and up quarks, c) neutral gauge fermions (neutralino) and down scalar quarks, d) gluino and down scalar quarks. The Lagranjian of interaction down quarks witth supersymmetric particles has the following form[6]:

$$L_{d\tilde{\chi}^*\tilde{u}} = -\frac{ig}{2}[V_{j1}(1+\gamma_5) - \frac{m_d V_{j2}^*}{\sqrt{2}M_W \cos\beta}(1-\gamma_5)]C\Gamma^L_{ab}\bar{d}_a\tilde{\chi}^*\tilde{u}_{Lb}+$$

$$\frac{igm_u V_{j2}}{2\sqrt{2}M_W \sin\beta}(1-\gamma_5)C\Gamma^R_{ab}\bar{d}_a\tilde{\chi}^*\tilde{u}_{Rb},$$

$$L_{dHu} = \frac{ig}{2\sqrt{2}M_W}[m_d \tan\beta(1-\gamma_5) + m_u \cot\beta(1+\gamma_5)]O_{ab}\bar{d}_a H u_b$$

$$L_{d\tilde{\chi}^0\tilde{u}} = -\frac{i}{\sqrt{2}}\{\frac{gm_d}{2M_W\cos\beta}N^*_{j3}(1-\gamma_5) + [eQ_d N_{j1} -$$

$$\frac{g}{\cos\theta_W}(\frac{1}{2} + Q_d \sin^2\theta_W)N_{j2}](1+\gamma_5)\}F^L_{ab}\bar{d}_a\tilde{\chi}^0\tilde{u}_{Lb} -$$

$$\frac{i}{\sqrt{2}}\{\frac{gm_d}{2M_W\cos\beta}N_{j3}(1+\gamma_5) - [eQ_d N^*_{j1} - N^*_{j2}\frac{gQ_d\sin^2\theta_W}{\cos\theta_W}](1-\gamma_5)\}F^R_{ab}\bar{d}_a\tilde{\chi}^0\tilde{u}_{Rb}$$

$$L_{d\tilde{g}\tilde{d}} = -\sqrt{2}g_s\frac{\lambda^a_{ij}}{2}F^L_{ij}\frac{1+\gamma_5}{2}\bar{d}_i\tilde{g}_a\tilde{d}_{Lj} + \sqrt{2}g_s\frac{\lambda^a_{ij}}{2}F^R_{ij}\frac{1-\gamma_5}{2}\bar{d}_i\tilde{g}\tilde{d}_{Rj}, \tag{3}$$

where $g = e\sin\theta_W$, V and U are charged gauge fermions' mixing matrices, C is charge conjugtion matrix, Γ^L, Γ^R are up skalar quarks mixing matrices, $tg\beta = v_2/v_1$, $v_{1,2}$ are are scalar Higgs fields' vacuum expectation[6], O is Kabibo-Kobayashi-Maskava matrix, N is neutral gauge fermins mixing matrix [6], $Q_d = -1/3$, F^L, F^R are down scalar quarks mixing matrices, g_s is strong interaction coupling constant, λ^a are Gell-Mann matrices.

One can write down the amplitude for the decays $B \to \gamma\gamma$ in the following form, which is correct after gauge fixing for final photons:

$$T(B \to \gamma\gamma) = \epsilon_1^\mu(k_1)\epsilon_2^\nu(k_2)[Ag_{\mu\nu} + iB\epsilon_{\mu\nu\alpha\beta}k_1^\alpha k_2^\beta] \tag{4}$$

where $\epsilon_1^\mu(k_1)$ and $\epsilon_2^\nu(k_2)$ are the polarization vectors of final photons with momenta k_1 and k_2 respectively.

Let us mention that our calculations are performed in the frame of Feynman-t'Hooft gauge and we use dimension regularization technique for divergent Feynmann diagrams. Only one particle reducible diagrams contain divergent parts. The divergent parts mutually cancel in the sum of amplitudes and due to the GIM mechanism[7].

Ccontribution of the diagrams with charged gauge fermions into amplitudes A and B have the following forms:

$$A = i\frac{\sqrt{2}m_b}{16\pi^2 m_s}G_F f_B(eQ_D)^2 M_B^2 \sum \lambda_l\{\frac{\sqrt{2}M_W}{M(\tilde{\chi}_j^*)\cos\beta}(V_{j1}U_{j2} - \frac{m_s}{m_b}V_{j1}^* U_{j2}^*)f_1(x_l) +$$

$$(\mid V_{j1}\mid^2 - \frac{m_s m_b \mid U_{j2}\mid^2}{2M_W^2\cos^2\beta})\frac{M_W^2}{M^2(\tilde{\chi}_j^*)}f_2(x_l)\},$$

$$B = i\frac{\sqrt{2}m_b}{8\pi^2 m_s}G_F f_B(eQ_D)^2 \sum \lambda_l\{\frac{\sqrt{2}M_W}{M(\tilde{\chi}_j^*)\cos\beta}(V_{j1}U_{j2} + \frac{m_s}{m_b}V_{j1}^* U_{j2}^*)f_1(x_l) +$$

$$(\mid V_{j1}\mid^2 + \frac{m_s m_b \mid U_{j2}\mid^2}{2M_W^2\cos^2\beta})\frac{M_W^2}{M^2(\tilde{\chi}_j^*)}f_2(x_l)\}, \tag{5}$$

where

$$x_l = \frac{m^2(\tilde{u}_{Ll})}{M^2(\tilde{\chi}_j^*)}, \qquad f_1(x) = \frac{5 - 12x + 7x^2 + (4x - 6x^2)\ell nx}{2(1-x)^3},$$

$$f_2(x) = \frac{29 - 96x + 111x^2 - 44x^3 + 6x(4 - 9x + 6x^2)\ell nx}{6(1-x)^4}. \tag{6}$$

The higgs particles contribution into A and B have the following forms (contributions of other supersymmetric particles are significantly small):

$$A = i\frac{\sqrt{2}m_b}{16\pi^2 m_l}G_F f_B(eQ_D)^2 M_B^2 \sum O_{bi}O_{si}^*\{f_1(x_i)$$

$$+\cot^2\beta f_2(x_i) - \tan^2\beta \frac{m_l m_b}{M^2(H)}\frac{1}{x_i} f_2(x_i)\},$$

$$B = i\frac{\sqrt{2}m_b}{8\pi^2 m_l} G_F f_B (eQ_D)^2 \sum O_{bi}O^*_{si}\{f_1(x_i) + \cot^2\beta f_2(x_i)$$

$$+\tan^2\beta \frac{m_l m_b}{M^2(H)}\frac{1}{x_i} f_2(x_i)\}, \tag{7}$$

where f_B is the B-meson decay constant, O_{ij} being elements of Cabbibo-Kobayashi-Maskawa matrix, $l = s, d$, $Q_d = -1/3$ is charge of down quarks, $M_{B_s} \approx m_b + m_s$, $\tan\beta = v_2/v_1$, ($v_{1,2}$ being vacuum expectation of the Higgs bosons)[6] and we have introduced following notation:

$$x_i = \frac{m^2(u_i)}{M^2(H)}, \qquad f_1(x) = \frac{-3x + 8x^2 - 5x^3 + (6x^2 - 4x)\ell n x}{2(1-x)^3},$$

$$f_2(x) = \frac{31x - 84x^2 + 69x^3 - 16x^4 + 6x(x^2 - 6x + 4)\ell n x}{12(1-x)^4}, \tag{8}$$

One can obtain contributions other supersymmetric particles from formulae (5) by following way:
Charged gauge fermions and right handed up scalar quarks:

$$V_{j1} \to 0, \qquad \frac{\mid U_{j2}\mid^2}{\cos^2\beta} \to \frac{m^2(\tilde{u}_{Rl})}{m_b m_s}\frac{\mid V_{j2}\mid^2}{\sin^2\beta},$$

$$m(\tilde{u_{Ll}}) \to m(\tilde{u}_{Rl}), \qquad \Gamma^L_{li} \to \Gamma^R_{li}, \tag{9}$$

$$M(\tilde{u}_{Ll}) \to M(H), \qquad M(\tilde{\chi}^*_j) \to m(u_l), \tag{10}$$

Neutral gauge fermions and left handed down scalar quarks:

$$V_{j1} \to 2[\sin\theta_W N_{j1} - \frac{1}{\cos\theta_W}(\frac{1}{2} + Q_d \sin^2\theta_W)N_{j2}] \equiv t_{Lj},$$

$$U_{j2} \to -N_{j3}, \qquad Q_u \to 0, \qquad M(\tilde{\chi}^*_j) \to M(\tilde{\chi}^0_j),$$

$$m(\tilde{u}_{Ll}) \to m(\tilde{d}_{Ll}), \qquad \Gamma^L_{li} \to F^L_{li}, \tag{11}$$

One can obtain expressions for the diagrams with neutral gauge fermions and righ handed down scalar quarks from the contribution of neutral gauge fermions and left handed down scalar quarks by following way:

$$t_{Lj} \to \frac{m_s}{\sqrt{2}M_W \cos\beta} N_{j3}, \qquad t^*_{Lj} \to \frac{m_b}{\sqrt{2}M_W \cos\beta} N^*_{j3},$$

$$\frac{m_s}{\sqrt{2}M_W \cos\beta} N^*_{j3} \to -\sqrt{2}(\sin\theta_W Q_d N^*_{j1} - Q_d \frac{\sin^2\theta_W}{\cos\theta_W} N^*_{j2}) \equiv t^*_{Rj},$$

$$\frac{m_b}{\sqrt{2}M_W \cos\beta} N_{j3} \to t_{Rj}, \qquad m(\tilde{d}_{Ll}) \to m(\tilde{d}_{Rl}), \qquad \Gamma^L_{li} \to F^R_{li}, \qquad (12)$$

One can obtain expressions for the diagrams with gluino from the contributions of the neutral gauge fermions by following way:

$$N_{j3} \to 0, \quad g \to \frac{4}{3} g_s, \quad t_{Lj} \to \sqrt{2}, \quad \tilde{\chi}^0_j \to \tilde{g}$$

$$N_{j3} \to 0, \quad g \to \frac{4}{3} g_s, \quad t_{Rj} \to -\sqrt{2}, \quad \tilde{\chi}^0_j \to \tilde{g}. \qquad (13)$$

Using equation (4) we find that the branching ratio of the decays $B \to \gamma\gamma$ can be represented as

$$Br(B \to \gamma\gamma) = \frac{1}{32\pi M_B \Gamma_{tot}} [4 \mid A \mid^2 + \frac{1}{2} M^4_B \mid B \mid^2]. \qquad (14)$$

With the aid of equation (4) we can find the relative fraction of CP-odd state of two final photons is given by

$$\delta = \frac{4A^2}{4A^2 + (1/2)M^4_B B^2} \qquad (15)$$

Using formulae (4)-(15) one can estimate the branching ratio and parameter δ of the decay $B_s \to \gamma\gamma$, We have used the following set of parameters: $\Gamma_{tot}(B_s) = 5 \cdot 10^{-4} eV$, $m_t = 174 GeV$, $m_b = 4,8 GeV$, $m_s = 0,5 GeV$, $f_{B_s} = 200 MeB$ [8]. For small value of the Higgs particles masses ($M(H) \approx 100 GeV$) and large $\tan\beta$ the supersymmetric contribution into branching ratio of the deacay $B_s \to \gamma\gamma$ are significant large than standard model estimate ($Br_{susy}(B_s \to \gamma\gamma) \sim 10^{-6} > Br_{SM}(B_s \to \gamma\gamma) \sim 10^{-7}$). In the wide range of supersymmetric parameters ($1 < tan\beta < 50, \quad 100 GeV < M(H) < 350 GeV$) the supersymmetric contribution on the same level or more as standard model estimate ($Br_{SM}(B_s \to \gamma\gamma) \sim 10^{-7}$).

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