CP Violation in B_s Mixing from Heavy Higgs Boson Exchange

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The anomalous dimuon charge asymmetry reported by the D0 Collaboration may be due to the tree-level exchange of some spin-0 particles that mediate *CP* violation in B_s-$\bar{B}_s$ meson mixing. We show that, for a range of couplings and masses, the heavy neutral states in a two-Higgs doublet model can generate a large charge asymmetry. This range is natural in "uplifted supersymmetry" and may enhance the $B^- \to \tau\nu$ and $B_s \to \mu^+\mu^-$ decay rates. However, we point out that on general grounds the reported central value of the charge asymmetry requires new physics not only in B_s-$\bar{B}_s$ mixing but also in $\Delta B = 1$ transitions or in B_d-$\bar{B}_d$ mixing.

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Introduction.—The standard model (SM) predicts that the violation of *CP* symmetry in B-$\bar{B}$ meson mixing is very small [1], and various measurements have so far confirmed this prediction in the B_d system. Experimental sensitivity to the properties of B_s mesons has improved within the past few years, with well-understood data sets from $p\bar{p}$ collisions at the Tevatron analyzed by the D0 and CDF Collaborations. The large ratio of the s and d quark masses and also the large $V_{\rm ts}/V_{\rm td}$ ratio make the B_s system more sensitive to new physics than the B_d system. We explore here the possibility that tree-level exchange of new particles induces a sizable *CP* violation in B_s-$\bar{B}_s$ mixing.

Recently [2], the D0 Collaboration has reported evidence for *CP* violation in final states involving two muons of the same charge, arising from semileptonic decays of b hadrons. The like-sign dimuon charge asymmetry, measured by D0 with 6.1 fb^{-1} of data, is defined by

$$A_{\rm sl}^b \equiv \frac{N_b^{++} - N_b^{--}}{N_b^{++} + N_b^{--}}, \tag{1}$$

where N_b^{++} is the number of events with two b hadrons decaying into $\mu^+ X$. The D0 result, $A_{\rm sl}^b = -[9.57 \pm 2.51({\rm stat.}) \pm 1.46({\rm syst.})] \times 10^{-3}$ is 3.2σ away from the SM prediction of -0.2×10^{-3}. The CDF [3] measurement of $A_{\rm sl}^b$, with 1.6 fb^{-1} of data, has a positive central value $A_{\rm sl}^b = (8.0 \pm 9.0 \pm 6.8) \times 10^{-3}$ but is compatible with the D0 measurement at the 1.5σ level because its uncertainties are 4 times larger than those of D0. Combining in quadrature (including the systematic errors) the D0 and CDF results for $A_{\rm sl}^b$, we find a 3σ deviation from the SM:

$$A_{\rm sl}^b \simeq -(8.5 \pm 2.8) \times 10^{-3}. \tag{2}$$

Another test of *CP* violation in B_s-$\bar{B}_s$ mixing is provided by the measurement of the "wrong-charge" asymmetry in semileptonic B_s decays,

$$a_{\rm sl}^s \equiv \frac{\Gamma(\bar{B}_s \to \mu^+ X) - \Gamma(B_s \to \mu^- X)}{\Gamma(\bar{B}_s \to \mu^+ X) + \Gamma(B_s \to \mu^- X)}. \tag{3}$$

The D0 measurement in this channel [4], $a_{\rm sl}^s = -(1.7 \pm 9.1^{+1.4}_{-1.5}) \times 10^{-3}$, is consistent with the SM. Assuming that the *CP* asymmetry in B_d-$\bar{B}_d$ mixing is negligible, the like-sign dimuon charge asymmetry is entirely due to B_s-$\bar{B}_s$ mixing and is related to $a_{\rm sl}^s$: $A_{\rm sl}^b = (0.494 \pm 0.043) a_{\rm sl}^s$, where the coefficient depends on the fraction of $\bar{b}$ antiquarks which hadronize into a B_s meson [2]. This allows the extraction of $a_{\rm sl}^s$ from Eq. (2), which then can be combined with the D0 measurement of $a_{\rm sl}^s$, resulting in

$$(a_{\rm sl}^s)_{\rm combined} \approx -(12.7 \pm 5.0) \times 10^{-3}. \tag{4}$$

Even though the inclusion of the CDF dimuon asymmetry and the D0 semileptonic wrong-charge asymmetry reduces the deviation in $a_{\rm sl}^s$ derived from the D0 dimuon asymmetry, the above result is still about 2.5σ away from the SM value [5] of $(a_{\rm sl}^s)_{\rm SM} \approx 0.02 \times 10^{-3}$.

The D0 [6] and CDF [7] Collaborations have also reconstructed $B_s \to J/\psi\phi$ decays, measured angular distributions as a function of decay time, and reported some deviation consistent with *CP* violation in B_s-$\bar{B}_s$ oscillations (see [8] for a fit to earlier B_s data). The sign and size of this deviation are compatible with Eq. (4), further strengthening the case for physics beyond the SM.

Generic new physics.—The matrix element of some new physics Hamiltonian, $\mathcal{H}^{\rm NP}$, contributing to B_s-$\bar{B}_s$ mixing may be parameterized as [5,8,9]

$$\langle \bar{B}_s | \mathcal{H}^{\rm NP} | B_s \rangle = (C_{B_s} e^{-i\phi_s} - 1) 2 M_{B_s} (M_{12}^{\rm SM})^*, \tag{5}$$

where $C_{B_s} > 0$ and $-\pi \le \phi_s \le \pi$. The magnitude of the off-diagonal element of the B_s-$\bar{B}_s$ mass matrix due to SM box diagrams is $|M_{12}^{\rm SM}| \simeq (9.0 \pm 1.4)$ ps^{-1}, where we used the same inputs as in Ref. [5] except for the updated values of the B_s decay constant $f_{B_s} = (231 \pm 15)$ MeV and bag parameter $B = 0.86 \pm 0.04$ computed on the lattice with 2 + 1 flavors [10]. The phase of $M_{12}^{\rm SM}$ is negligible.

The measured mass difference of the B_s mass eigenstates depends linearly on C_{B_s}, $\Delta M_s = 2|M_{12}^{\rm SM}| C_{B_s}$. The combination [11] of the CDF and D0 measurements is $\Delta M_s = (17.78 \pm 0.12)$ ps^{-1}, so that we find

$$C_{B_s} = 0.98 \pm 0.15. \tag{6}$$

The semileptonic wrong-charge asymmetry is given by

$$a_{\rm sl}^s = \frac{2|\Gamma_{12}|}{\Delta M_s}\sin\phi_s, \qquad (7)$$

where Γ_{12} is the off-diagonal element of the B_s-$\bar{B}_s$ decay-width matrix. New physics contributing to $\Delta B = 1$ processes may affect Γ_{12}, but the effects are typically negligible compared to the SM $b \to c\bar{c}s$ transition due to tree-level W exchange, which is suppressed only by $V_{\rm cb}$. The SM prediction for $|\Gamma_{12}|$ is given by $|\Gamma_{12}^{\rm SM}| = (1/2)(0.090 \pm 0.024)$ ps^{-1}, where we again used the results of Ref. [5] with updated values for f_{B_s} and B (this is consistent with the result of Ref. [12]). Using the $a_{\rm sl}^s$ value from Eq. (4), we find that Eq. (7) gives

$$\sin\phi_s = -2.5 \pm 1.3. \qquad (8)$$

This is a somewhat troubling result: The central value is more than 1σ away from the physical region $|\sin\phi_s| \leq 1$. This tension arises because the absolute value of B_s-$\bar{B}_s$ mixing is constrained by the measured ΔM_s, not allowing enough room for an asymmetry as large as the central value of $a_{\rm sl}^s$ shown in Eq. (4). This suggests that the central value of $a_{\rm sl}^s$ will be reduced by a factor of more than 2 when the error bars become small enough.

Alternatively, the assumptions about new physics employed here may be relaxed. For example, the wrong-charge asymmetry in semileptonic B_d decays, $a_{\rm sl}^d$, may be non-negligible. Its value given by measurements at B factories is $(-4.7 \pm 4.6) \times 10^{-3}$ [11], so including it would change the relation between $A_{\rm sl}^b$ and $a_{\rm sl}^s$ as discussed in Ref. [2].

Another possibility is that there are sizable new contributions to Γ_{12}. This is problematic because the SM tree-level contribution is Cabibbo-Kobayashi-Maskawa–favored, while new particles that induce $\Delta B = 1$ effects are constrained by various limits on flavor-changing neutral currents (e.g., $b \to s\gamma$ or K-$\bar{K}$ mixing). Nevertheless, examples of relatively large shifts in Γ_{12} can be found [12,13]. Consider, for example, two operators $(\bar{b}_R\gamma^\mu c_R) \times (\bar{u}_R\gamma^\mu s_R)$ and $(\bar{b}_R\gamma^\mu u_R)(\bar{c}_R\gamma^\mu s_R)$, which may be induced by W' exchanges. The main effect of these $\Delta B = 1$ operators is to enhance the rate for $B_d \to DK$ decays. Given that these dominant decay modes of B_d involve a form factor which is not known precisely, these operators may account for a significant fraction of the measured decay width. If the scale of the new operators is 0.9 TeV, then Γ_{12} is enhanced by 30%. In what follows we will focus on $\Delta B = 2$ transitions [see Eq. (5)], ignoring new contributions to $|\Gamma_{12}|$.

New physics models for B_s-$\bar{B}_s$ mixing.—Although more experimental studies are required before concluding that physics beyond the SM contributes to B_s-$\bar{B}_s$ mixing, it is useful to analyze what kind of new physics could induce CP-violating effects as large as $\sin\phi_s \approx -1$. Given that the SM B_s-$\bar{B}_s$ mixing is a 1-loop effect, it is often assumed that new physics contributes also at one loop, for example, via gluino-squark box diagrams in the minimal supersymmetric standard model (MSSM) [14]. However, the large effect indicated by the data is more likely to be due to tree-level exchange of new particles which induce $\bar{b}s\bar{b}s$ operators. These particles must be bosons (with spin 0, 1, or 2 being the more likely possibilities) carrying baryon number 0 or $\pm 2/3$. In the first case they must be electrically neutral and color singlets or octets. The bosons of baryon number $\pm 2/3$ are diquarks of electric charge $\mp 2/3$ and transform under $SU(3)_c$ as $\bar{3}$ or 6 (3 or $\bar{6}$ for charge $+2/3$).

The new bosons may be related to electroweak symmetry breaking, as in the case of the heavy Higgs states in two-Higgs doublet models. We concentrate in what follows on a spin-0 boson $H_d^0 = (H^0 + iA^0)/\sqrt{2}$, which is electrically neutral and a color singlet (and part of a weak doublet). The Yukawa couplings of H_d^0 to b and s quarks in the mass eigenstate basis are given by

$$-H_d^0(y_{bs}\bar{b}_R s_L + y_{sb}\bar{s}_R b_L) + \text{H.c.} \qquad (9)$$

Let us assume for simplicity that the vacuum expectation value (VEV) of H^0 is negligible at tree level (the coupling to quarks induces a small VEV at one loop), so that H^0 and A^0 have the same mass M_A. Examples of theories with these features are the MSSM in the uplifted region [15], as discussed later, and composite Higgs models [16].

Tree-level H_d^0 exchange gives rise to a single term in the Lagrangian which contributes to B_s-$\bar{B}_s$ mixing:

$$\frac{y_{bs}y_{sb}^*}{M_A^2}(\bar{b}_R s_L)(\bar{b}_L s_R), \qquad (10)$$

where the quark fields are taken in the mass eigenstate basis. If the VEV of H^0 is taken into account, then additional operators contribute [17], most importantly $(\bar{b}_R s_L)^2$; we will ignore these contributions in what follows. The matrix element of operator (10) is

$$\langle\bar{B}_s|\mathcal{H}^{\rm NP}|B_s\rangle = -\frac{y_{bs}y_{sb}^*\eta}{M_A^2}\frac{M_{B_s}^4 f_{B_s}^2 B_4}{2(m_b + m_s)^2}. \qquad (11)$$

The bag parameter for operator (10) has been estimated by using the quenched approximation on the lattice [18], $B_4 \approx 1.16$. The parameter $\eta \approx 4$ takes into account the running of operator (10) between the M_A and M_{B_s} scales [19]. For the sum of quark masses we use $m_b + m_s \approx 4.3$ GeV. Comparing Eqs. (5) and (11) we find

$$\frac{M_A}{\sqrt{|y_{bs}y_{sb}|\eta}} = \frac{(147 \pm 15)\ \text{TeV}}{(C_{B_s}^2 + 1 - 2C_{B_s}\cos\phi_s)^{1/4}},$$
$$\arg(y_{bs}y_{sb}^*) = \tan^{-1}\left(\frac{C_{B_s}\sin\phi_s}{1 - C_{B_s}\cos\phi_s}\right). \qquad (12)$$

The off-diagonal coupling y_{bs} is expected to be suppressed by $V_{\rm ts}$ compared to the diagonal y_b Yukawa coupling of H_d^0 to $\bar{b}_R b_L$, while y_{sb} is suppressed by an additional factor of m_s/m_b, so that we take $|y_{bs}| \lesssim 10^{-2}$ and $|y_{sb}| \lesssim 2 \times 10^{-4}$. When y_{bs} and y_{sb} saturate these upper bounds, the experimental constraint Eq. (6) on C_{B_s} gives $M_A \approx (0.65 \pm 0.07)$ TeV and $\arg(y_{bs}y_{sb}^*) = -1.3 \pm 0.3$ for a phase

$\phi_s = -\pi/6$. Figure 1 shows the range of $M_A/\sqrt{|y_{bs}y_{sb}|}$ as a function of ϕ_s.

The H_d^0 exchange that induces *CP* violation in B_s-$\bar{B}_s$ mixing contributes to the $B_s \to \mu^+\mu^-$ branching fraction, provided the coupling of H_d^0 to muons is not negligible. The coupling $y_\mu H_d^0 \bar{\mu}_R \mu_L$ leads to

$$\mathcal{B}(B_s \to \mu^+\mu^-) = (|y_{bs}|^2 + |y_{sb}|^2)\frac{|y_\mu|^2}{M_A^4}\frac{\eta_b^2 \tau_{B_s} M_{B_s}^5 f_{B_s}^2}{64\pi(m_b + m_s)^2} \approx 1.3 \times 10^{-8}\left(\frac{|y_{bs}|}{10^{-2}}\right)^2\left(\frac{|y_\mu|}{0.02}\right)^2\left(\frac{1\ \text{TeV}}{M_A}\right)^4. \tag{13}$$

QCD corrections are taken into account by $\eta_b \approx 1.5$ [20]. The experimental limit $\mathcal{B}(B_s \to \mu^+\mu^-) < 4.3 \times 10^{-8}$ [21] imposes $|y_\mu| < 0.018$ for $M_A = 0.7$ TeV. Given this constraint, the impact on $B \to K\mu^+\mu^-$ observables is relatively small [22].

Uplifted supersymmetry.—Let us describe a renormalizable gauge-invariant theory that includes the interactions of Eq. (9) without violating current limits on flavor processes. The MSSM parameter space contains a region where the down-type fermion masses are induced at one loop by the VEV of the up-type Higgs doublet H_u. In this so-called uplifted Higgs region [15,23,24] the ratio of H_u and H_d VEVs is very large, $v_u/v_d \equiv \tan\beta \gtrsim 100$, but all Yukawa couplings remain perturbative. The physical states of this uplifted two-Higgs doublet model include a SM-like Higgs boson h^0, which is entirely part of H_u in the $\tan\beta \to \infty$ limit, the two neutral states H^0 and A^0 of mass M_A, and a charged Higgs boson $H^\pm$ of mass $M_{H^+} = (M_A^2 + M_W^2)^{1/2} \approx M_A$. The heavy states H^0, A^0, and $H^\pm$ are almost entirely part of H_d.

The Yukawa terms in the superpotential give rise to H_d couplings to down-type fermions in the Lagrangian:

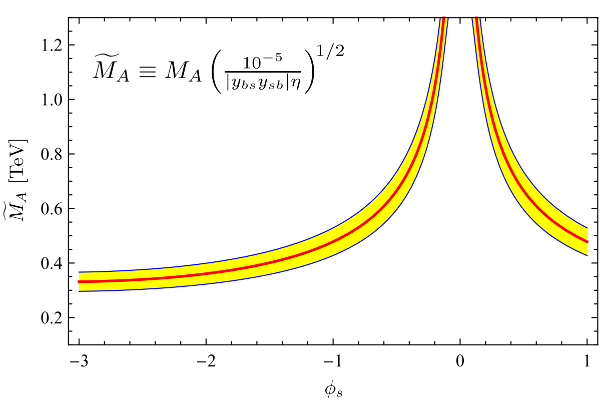

FIG. 1 (color online). Range for M_A compatible with a *CP* asymmetry in B_s-$\bar{B}_s$ mixing described by the ϕ_s angle. The vertical size of the shaded band accounts for the 1σ experimental uncertainty in ΔM_s and for the theoretical uncertainties in f_{B_s} and $|M_{12}^{\rm SM}|$. The off-diagonal Yukawa couplings are expected to satisfy $|y_{bs}| \lesssim 10^{-2}$ and $|y_{sb}| \lesssim 2 \times 10^{-4}$. The running between M_A and M_{B_s} is parametrized by $\eta \approx 4$.

$$- H_d(d^c \hat{y}_d Q + e^c \hat{y}_\ell L) + \text{H.c.}, \tag{14}$$

where the quark and leptons shown here are gauge eigenstates and their generation index is implicit. The $\hat{y}_d$ and $\hat{y}_\ell$ couplings are 3×3 matrices in flavor space. Various 1-loop diagrams involving superpartners generate couplings of $H_u^\dagger$ to down-type fermions,

$$- H_u^\dagger(d^c \hat{y}_d' Q + e^c \hat{y}_\ell' L) + \text{H.c.}, \tag{15}$$

inducing masses for down-type quarks and charged leptons. The dominant contributions, from gluino and wino loops, to the effective quark Yukawa matrix are

$$(\hat{y}_d')_{ij} \approx -\frac{\alpha_s}{4\pi} e^{-i\theta_\mu}(\hat{y}_d)_{ij} f_{ij}. \tag{16}$$

The complex coefficients f_{ij} have magnitude of order 1:

$$f_{ij} \approx \frac{8|\mu|e^{i\theta_{\tilde{g}}}}{3M_{\tilde{d}_i}} F\left(\frac{M_{\tilde{g}}}{M_{\tilde{Q}_j}}, \frac{M_{\tilde{d}_i}}{M_{\tilde{Q}_j}}\right) - \frac{3\alpha e^{i\theta_{\tilde{W}}}}{2s_W^2 \alpha_s} F\left(\frac{M_{\tilde{W}}}{M_{\tilde{Q}_j}}, \frac{|\mu|}{M_{\tilde{Q}_j}}\right), \tag{17}$$

where $0 < F(x, y) < 1$ is a function given in Eq. (3.2) of Ref. [15]. The phases of the gluino and wino masses are explicitly displayed here, so that $M_{\tilde{g}}, M_{\tilde{W}} > 0$.

We assume that the communication of supersymmetry breaking to squarks is flavor-blind. In the absence of renormalization group effects of the Yukawa couplings, the squark mass matrices at the weak scale are proportional to the 3×3 unit matrix, so that the $\hat{y}_d'$ matrix is given by $\hat{y}_d$ times a complex number. However, the large t, b, and τ Yukawa couplings have substantial renormalization group effects, driving $M_{\tilde{Q}_3} < M_{\tilde{Q}_1} = M_{\tilde{Q}_2}$ and $M_{\tilde{d}_3} < M_{\tilde{d}_1} = M_{\tilde{d}_2}$, which breaks the alignment between $\hat{y}_d'$ and $\hat{y}_d$ in the $3j$ and $j3$ elements. After diagonalization of the down-type quark masses (i.e., of $\hat{y}_d'$), the neutral component of H_d acquires off-diagonal couplings as in Eq. (9). Assuming that the unitary matrix which transforms between the gauge and mass eigenstate bases of right-handed down-type quarks is approximately the unit matrix, we find

$$\begin{aligned} y_{bs} &= y_0(a_{33} - a_{31})(V_L^d)_{33}(V_L^d)_{23}^*, \\ y_{sb} &= y_0 \frac{m_s}{m_b} a_{13}(V_L^d)_{23}(V_L^d)_{33}^*, \\ y_b &= y_0[1 + a_{31} + (a_{33} - a_{31})|(V_L^d)_{33}|^2], \end{aligned} \tag{18}$$

where $a_{ij} \equiv f_{11}/f_{ij} - 1$ and $y_0 \equiv -e^{i\theta_\mu} 4\pi m_b/(\alpha_s v_h f_{11})$, with $v_h \approx 174$ GeV. The unitary matrix V_L^d transforms the $d_{\rm Li}$ quarks from gauge to mass eigenstates.

For $y_b = O(1)$ and $V_L^d \simeq (V_{\rm CKM})^\dagger$, we obtain $|y_{bs}| \approx 10^{-2}$, $|y_{sb}| = O(y_{bs} m_s/m_b)$, confirming the bounds used after Eq. (12). The combination of couplings that control K-$\bar{K}$ and B_d-$\bar{B}_d$ mixing,

$$\begin{aligned} |y_{sd}y_{ds}| &= |y_{bs}y_{sb}| \frac{m_d|V_{\rm td}^2 a_{13}|}{m_b|a_{33} - a_{31}|} \lesssim O(10^{-13}), \\ |y_{bd}y_{db}| &= |y_{bs}y_{sb}| \frac{m_d|V_{\rm td}|^2}{m_s|V_{\rm ts}|^2} \lesssim 2 \times 10^{-9}, \end{aligned} \tag{19}$$

are small enough to satisfy the limits from ε_K and $a^d_{\rm sl}$ for $M_A > 100$ GeV.

In the uplifted Higgs region, the τ Yukawa coupling to H_d (at the weak scale) must be large, $|y_\tau| \approx 1.3$, in order for the observed m_τ to be generated by wino and bino diagrams [15]. The small m_μ leaves more room for its possible origin and, consequently, a wider range of values for y_μ. If m_μ is generated entirely by the Yukawa coupling to H_d, then $|y_\mu| \approx |y_\tau| m_\mu / m_\tau \approx 0.08$, which is compatible with the current limit on $\mathcal{B}(B_s \to \mu^+\mu^-)$ provided $M_A \gtrsim 1.5$ TeV. Such a large mass would imply $\phi_s \approx 0.1$, which is too small to accommodate a significant charge asymmetry. On the other hand, m_μ may be due to loop-induced couplings of the muon to $H_u^\dagger$ which exist even for $y_\mu \to 0$. For example, in models of gauge mediate supersymmetry breaking [25], which fit well the requirements of uplifted supersymmetry, there is a vectorlike chiral superfield d_m with the quantum numbers of weak-singlet down-type squarks. The scalar components of this messenger superfield $\tilde{d}_m$ and $\tilde{d}^c_m$ may couple to the SM fermions $\kappa \tilde{d}_m \bar{\mu}^c_L t_L$ and $\kappa' \tilde{d}^c_m \bar{t}^c_R \mu_R$, which at 1-loop give

$$m_\mu \simeq m_t \frac{3\kappa\kappa'}{32\pi^2} \frac{\Delta M^2_{\tilde{d}_m}}{M^2_{d_m}}. \qquad (20)$$

A typical splitting between the messenger scalar squared masses is $\Delta M^2_{\tilde{d}_m} \approx 0.2 M^2_{d_m}$, where $M_{d_m} \sim O(100)$ TeV is the messenger fermion mass. The muon mass may be generated entirely through this mechanism if $\kappa\kappa' \approx 0.3$. A similar mechanism is used in Ref. [26]. Thus, the y_μ coupling, which determines the heavy Higgs boson contribution to $\mathcal{B}(B_s \to \mu^+\mu^-)$, is sensitive to physics at the 100 TeV scale and can be significantly smaller than 0.08.

The dominant contributions to $(g-2)_\mu$, due to wino-slepton diagrams, tend in the uplifted region to enhance the discrepancy between the SM and experiment [23]. We point out, though, that the wino-slepton diagrams become small if the slepton doublet of the second generation is sufficiently heavier than $M_{\tilde{W}}$, while the bino-slepton diagrams can explain the discrepancy if $y_\mu \gtrsim 10^{-2}$.

Flavor-changing charged currents due to $H^\pm$ exchange are important independent of renormalization group effects. The couplings

$$\frac{m_b V_{ub} y_b}{y_b v_d + y'_b v_u} H^- \bar{b}_R u_L + \frac{m_\tau y_\tau}{y_\tau v_d + y'_\tau v_u} H^- \bar{\tau}_R \nu_L \qquad (21)$$

(y'_b and y'_τ are the 33 eigenvalues of $\hat{y}'_d$ and $\hat{y}'_e$) may significantly affect the rate for the $B^\pm \to \tau^\pm \nu$ decay:

$$\frac{\mathcal{B}(B^- \to \tau\nu)}{\mathcal{B}(B^- \to \tau\nu)_{\rm SM}} = \left| 1 - y^*_b y_\tau \frac{v_h^2}{m_b m_\tau} \frac{M^2_{B^+}}{M^2_{H^+}} \right|^2. \qquad (22)$$

Unlike the usual MSSM where $\mathcal{B}(B^- \to \tau\nu)$ is smaller than in the SM, the uplifted region allows an enhancement compared to the SM [23], depending on the phase of $y^*_b y_\tau$. Interestingly, the measurement of this branching fraction is larger than the SM prediction by a factor of 2, a $\sim 2\sigma$ discrepancy [27]. For $y^*_b y_\tau = -1$ and $M_{H^+} = 1$ TeV, $\mathcal{B}(B^- \to \tau\nu)$ increases by 24% compared to the SM prediction.

Conclusions.—We have shown that the evidence for CP violation reported by the D0 Collaboration may be explained in part by the exchange of the neutral states of a two-Higgs doublet model contributing to B_s-$\bar{B}_s$ mixing. In particular, in the uplifted Higgs region of the MSSM [15], a large CP-violating effect in B_s-$\bar{B}_s$ mixing implies that the $B_s \to \mu^+\mu^-$ decay could be discovered in the near future and that, unlike in the usual MSSM, the rate for $B^- \to \tau\nu$ may be enhanced compared to the SM prediction. Independent of the new physics interpretation, however, the reported central value of the charge asymmetry requires new physics beyond B_s-$\bar{B}_s$ mixing, for example, in $\Delta B = 1$ transitions or in B_d-$\bar{B}_d$ mixing.

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