Flavour-Changing Neutral Currents and Leptophobic $Z'$ Gauge Bosons

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Abstract

Leptophobic $Z'$ gauge bosons can appear in models with an $E_6$ gauge symmetry. We show that flavour-changing neutral currents can be generated in some of these models due to the mixing of the ordinary $d_R$, $s_R$ and $b_R$ quark fields with the exotic $h_R$. Because the $Z'$ does not couple to charged leptons, the constraints on the flavour-changing couplings $U_{d_R}$ and $U_{s_R}$ are relatively weak. Indeed, $B_q^0$–$ar{B}_q^0$ mixing ($q = d, s$) can be dominated by $Z'$ exchange, which will affect CP-violating rate asymmetries in $B$ decays. Rare hadronic $B$ decays can also be affected, while decays involving charged leptons will be unchanged.
Many models of physics beyond the Standard Model (SM) predict the existence of exotic fermions with non-canonical $SU(2)_L \times U(1)_Y$ quantum numbers, i.e. left-handed $SU(2)_L$ singlets and/or right-handed $SU(2)_L$ doublets. The ordinary SM fermions can mix with these exotic fermions. It is well known that such mixing may induce flavour-changing neutral currents (FCNC’s) [1]: if two ordinary quarks mix with the same exotic quark, FCNC’s are generated between the ordinary quarks. This FCNC is second order in ordinary-exotic quark mixing.

This fact has been used to construct models with $Z$-mediated FCNC’s [2]. Here one introduces an additional vector-singlet charge $-1/3$ quark $h$, as is found in $E_6$ models, and allows it to mix with the ordinary down-type quarks $d, s$ and $b$. Since the weak isospin of the exotic quark is different from that of the ordinary quarks, $Z$-mediated FCNC’s among the ordinary down-type quarks are induced. Note that it is only the mixing between the left-handed components of the ordinary and exotic quarks which is responsible for the FCNC: since $d_R, s_R, b_R$ and $h_R$ all have the same $SU(2)_L \times U(1)_Y$ quantum numbers, their mixing cannot generate flavour-changing couplings of the $Z$.

The $Z$-mediated FCNC couplings $U^Z_{ds}, U^Z_{db}$ and $U^Z_{sb}$, which are in general complex, are constrained by a variety of processes. $U^Z_{ds}$ is bounded by the measurements of $\Delta M_K$ ($K^0-\bar{K}^0$ mixing), $|\epsilon|$ (CP violation in the kaon system) and $K_L \rightarrow \mu^+\mu^-$ [2], while the constraints on $U^Z_{db}$ and $U^Z_{sb}$ come principally from the experimental limit on $B(B \rightarrow \ell^+\ell^-X)$ [3, 1]. To the extent that the constraints on $U^Z_{db}$ and $U^Z_{sb}$ allow significant contributions to $B^0_\ell-\bar{B}^0_\ell$ mixing ($q = d, s$), CP asymmetries in $B$ decays may be affected by $Z$-mediated FCNC’s [2, 3].

In general, models of new physics which contain exotic fermions also predict the existence of additional neutral $Z'$ gauge bosons. The same ideas which lead to $Z$-mediated FCNC’s can be applied to the $Z'$. That is, mixing among particles which have different $Z'$ quantum numbers will induce FCNC’s due to $Z'$ exchange [3]. Surprisingly, these effects can be just as large as $Z$-mediated FCNC’s. Since the $U^Z_{pq}$ are generated by mixings which break weak isospin, they are expected to be at most $O(m/M)$, where $m$ ($M$) is a typical light (heavy) fermion mass. On the other hand, the $Z'$-mediated couplings $U^{Z'}_{pq}$ can be generated via mixings of particles with the same weak isospin, and so they suffer no such mass suppression. Therefore, even though processes with $Z'$ exchange are suppressed relative to those with $Z$ exchange
by $M_{Z'}^2/M_{Z}^2$, this is compensated by the fact that $U_{pq}^{Z'}/U_{pq}^Z \sim M/m$. Thus, the effects of $Z'$-mediated FCNC’s can be comparable to those of $Z$-mediated FCNC’s.

In this paper we apply these ideas to leptophobic $Z'$ gauge bosons, whose couplings to charged leptons vanish. Leptophobic $Z'$ bosons were introduced several years ago in the context of the $R_b$–$R_c$ puzzle [7], and as a possible explanation of anomalous high-$E_T$ jet events at CDF [8]. Although these experimental effects ultimately disappeared, thereby removing the original motivation for such new physics, models with a leptophobic $Z'$ still remain as viable candidates of physics beyond the SM, and it is therefore worthwhile exploring their phenomenology.

In Ref. [9] it was shown that a leptophobic $Z'$ can appear in $E_6$ models due to the mixing of the gauge boson kinetic terms. In such models, if the $d_R$, $s_R$ and $b_R$ have different $U(1)'$ quantum numbers than the $h_R$, then their mixing will induce $Z'$-mediated FCNC’s among the ordinary down-type quarks. However, since the $Z'$ is leptophobic, these FCNC couplings will not be constrained by limits on processes involving charged leptons, such as $K_L \rightarrow \mu^+\mu^-$ and $B \rightarrow \mu^+\mu^-X$. Thus, the constraints on such leptophobic $Z'$-mediated FCNC’s may be considerably weaker than those for $Z$-mediated FCNC’s and, as a consequence, there may be large effects in $B$ decays. These are the issues which we examine in this paper.

We begin with a brief review of models with a leptophobic $Z'$ gauge boson [10]. We assume that the low-energy gauge symmetry is $SU(2)_L \times U(1)_Y \times U(1)'$, in which the $U(1)'$ arises from the breaking chain

$$E_6 \rightarrow SO(10) \times U(1)_\psi \rightarrow SU(5) \times U(1)_\chi \times U(1)_\psi \rightarrow SU(2)_L \times U(1)_Y \times U(1)'.$$ (1)

Here, $U(1)'$ is a linear combination of $U(1)_\psi$ and $U(1)_\chi$, with $Q' = Q_\psi \cos \theta - Q_\chi \sin \theta$, where $\theta$ is the usual $E_6$ mixing angle. The fundamental representation of $E_6$ is a 27, which decomposes under $SO(10)$ as a $16 + 10 + 1$. The conventional embedding is to put all the ordinary SM particles, along with a right-handed neutrino, into the 16. Within this embedding, the quantum numbers of all particles are shown in Table [1].

It is straightforward to show that if the $Z'$ coupling to fermions is proportional to $Q'$, there is no value of $\theta$ which leads to leptophobia (i.e. $Q'(L) = Q'(e^c) = 0$). However, the most general $SU(2)_L \times U(1)_Y \times U(1)'$-invariant lagrangian includes a
| Particle | $SU(3)_c$ | $2\sqrt{6}Q_\psi$ | $2\sqrt{10}Q_\chi$ | $Y$ |
|----------|---------|----------------|----------------|-----|
| $Q = (u,d)^t$ | 3 | 1 | -1 | 1/6 |
| $L = (\nu,e)^T$ | 1 | 1 | 3 | -1/2 |
| $u^c$ | 3 | 1 | -1 | -2/3 |
| $d^c$ | $\bar{3}$ | 1 | 3 | 1/3 |
| $e^c$ | 1 | 1 | -1 | 1 |
| $\nu^c$ | 1 | 1 | -5 | 0 |
| $H = (N,E)^T$ | 1 | -2 | -2 | -1/2 |
| $H^c = (N^c,E^c)^T$ | 1 | -2 | 2 | 1/2 |
| $h$ | 3 | -2 | 2 | -1/3 |
| $h^c$ | $\bar{3}$ | -2 | -2 | 1/3 |
| $S^c$ | 1 | 4 | 0 | 0 |

Table 1: Quantum numbers of the particles contained in the 27 representation of $E_6$ within the standard embedding. All fields are taken to be left-handed.

The off-diagonal coupling of the $\tilde{B}$ and $\tilde{Z}'$ can be removed by making the non-unitarity transformation

$$\tilde{B}_\mu = B_\mu - \tan \chi Z'_\mu$$

$$\tilde{Z}'_\mu = \frac{Z'_\mu}{\cos \chi}.$$  

(3)

With this transformation, the couplings of the physical gauge bosons to fermions can be written as

$$\mathcal{L}_{\text{int}} = -\bar{\psi} \gamma^\mu [g T^a W_\mu^a + g' Y_{\text{SM}} B_\mu + g_{Q'} (Q' + \sqrt{\frac{3}{5}} \delta Y_{\text{SM}}) Z'_\mu] \psi,$$

(4)

where $Q_{em} = T_{3L} + Y_{\text{SM}}$ and $\delta \equiv -\tilde{g}_v \sin \chi / \tilde{g}_{Q'}$ ($\tilde{g}_v$ and $\tilde{g}_{Q'}$ are, respectively, the $U(1)_Y$ and $U(1)'$ coupling constants). Assuming the couplings to be “GUT” normalized, the $Z'$-fermion interaction term can be written

$$\mathcal{L}(Z')_{\text{int}} = -\frac{g}{\cos \theta_W} \sqrt{\frac{5}{3} x_w} \bar{\psi} \gamma^\mu (Q' + \sqrt{\frac{3}{5}} \delta Y_{\text{SM}}) \psi Z'_\mu,$$

(5)
where \( x_w \equiv \sin^2 \theta_w = e^2/g^2 \) and \( \lambda = g_{Q'}/g_Y \). The key point here is that, due to kinetic mixing, the \( Z' \) coupling to fermions is no longer proportional to \( Q' \). It is this feature which leads to the possibility of leptophobia.

The \( Z' \)-fermion coupling involves two unknown parameters: \( \theta \) and \( \delta \). Since leptophobia requires two couplings to vanish (the \( Z' \) coupling to \( e^- \) and \( e^+ \)), obviously this can be satisfied for some choice of the two parameters. For example, for the conventional embedding of Table 1, one obtains a leptophobic \( Z' \) for \( \tan \theta = \sqrt{3}/5 \) and \( \delta = -1/3 \).

However, other embeddings are possible. First, since \( L \) and \( H \) have the same \( SU(2)_L \times U(1)_Y \) quantum numbers, it is always possible to switch the quantum numbers of \( L \) and \( H \) in Table 1. (This also holds for \( d^c \) and \( h^c \).) Second, there are three states which are singlets under both \( SU(3)_c \) and \( SU(2)_L \) – the \( e^c \) field can be assigned to any one of these three. Of course, since not all three states have the same electric charge, these three embeddings correspond to different definitions of the charge generator. Thus, in addition to changing the \( e^c \) assignment, one also has to change the assignment of the \( u^c \) field. (Note that there are three states which are \( SU(2)_L \) singlets and \( 3 \)'s under \( SU(3)_c \). The three \( e^c \) embeddings are equivalent to assigning the \( u^c \) to each of these states.) There are thus a total of six choices for possible embeddings of the charged leptons in the \( 27 \) representation of \( E_6 \). A leptophobic \( Z' \) can be produced for any of these.

We summarize the six embeddings, along with the corresponding values of \( \tan \theta \) and \( \delta \) which produce leptophobia, in Table 2. Note that the first four models have been discussed in Ref. [10], while the last two are new possibilities.

Now, what interests us is the possibility of \( Z' \)-mediated FCNC’s. This can occur if the \( d, s \) and \( b \) quarks mix with the \( h \) quark. However, as discussed earlier, mixing of the \( d_L, s_L \) and \( b_L \) fields with \( h_L \) will lead to \( Z \)-mediated FCNC’s among the ordinary fermions. These \( Z \)-mediated FCNC’s will always dominate over any \( Z' \)-mediated FCNC’s induced by the mixing of the left-handed fermions. On the other hand, if only the right-handed fields mix, then no \( Z \)-mediated FCNC’s will be generated, while \( Z' \)-mediated FCNC’s will appear if the \( d_R, s_R \) and \( b_R \) fields have different \( Z' \) quantum numbers than the \( h_R \). The question then is the following: of the six leptophobic models, are there any in which \( Q'(d^c) \neq Q'(h^c) \)?

In order to answer this question, for each of the six models of Table 2, we calculate
Table 2: $Q_\psi$ and $Q_\chi$ quantum numbers of $L$ and $e^c$ for the six embeddings of charged leptons in the 27 representation of $E_6$, along with the values of $\theta$ and $\delta$ which produce a leptophobic $Z'$ gauge boson.

| Model | $2\sqrt{6}Q_\psi$ | $2\sqrt{10}Q_\chi$ | $2\sqrt{6}Q_\psi$ | $2\sqrt{10}Q_\chi$ | $\tan\theta$ | $\delta$ |
|-------|---------------------|---------------------|---------------------|---------------------|-------------|---------|
| 1     | $L$: 1 3 $e^c$: 1 -1 | $\sqrt{3/5}$ | -1/3 |
| 2     | $L$: -2 -2 $e^c$: 1 -1 | $\sqrt{3/5}$ | -1/3 |
| 3     | $L$: 1 3 $e^c$: 1 -5 | $\sqrt{15}$ | -1/3 |
| 4     | $L$: -2 -2 $e^c$: 1 -5 | $\sqrt{5/27}$ | -1/3 |
| 5     | $L$: 1 3 $e^c$: 4 0 | $\sqrt{5/3}$ | -1/3 |
| 6     | $L$: -2 -2 $e^c$: 4 0 | $\sqrt{5/3}$ | -1/3 |

Table 3: $U(1)'$ quantum numbers of $d^c$ and $h^c$ for each of the six models given in Table 2, calculated using $Q' = Q_\psi \cos \theta - Q_\chi \sin \theta$.

| Model | $2\sqrt{6}Q_\psi$ | $2\sqrt{10}Q_\chi$ | $Q'$ | $2\sqrt{6}Q_\psi$ | $2\sqrt{10}Q_\chi$ | $Q'$ |
|-------|---------------------|---------------------|-----|---------------------|---------------------|-----|
| 1     | $d^c$: 1 3 | -1/2$\sqrt{15}$ | $h^c$: -2 | -2 | -1/2$\sqrt{15}$ |
| 2     | $d^c$: 1 3 | -1/2$\sqrt{15}$ | $h^c$: -2 | -2 | -1/2$\sqrt{15}$ |
| 3     | $d^c$: 1 -1 | 1/2$\sqrt{6}$ | $h^c$: -2 | -2 | 1/2$\sqrt{6}$ |
| 4     | $d^c$: 1 -1 | 1/4 | $h^c$: -2 | -2 | -1/4 |
| 5     | $d^c$: 1 -1 | 1/4 | $h^c$: 1 | 3 | -1/4 |
| 6     | $d^c$: 1 -1 | 1/2$\sqrt{6}$ | $h^c$: 1 | 3 | 1/2$\sqrt{6}$ |

In order to examine the constraints on such $Z'$-mediated FCNC couplings, we parametrize them as

\[ \mathcal{L}_{\text{FCNC}}^{Z'} = -\frac{g}{2\cos\theta_W} U_{q p}^{Z'} \bar{q}_{q R} \gamma^\mu d_{p R} Z'_{\mu} \]  \hspace{1cm} (6)

As is the case for $Z$-mediated FCNC’s, the coupling $U_{d s}^{Z'}$ is strongly constrained by
measurements of $\Delta M_K$ and $|\epsilon|$ in the kaon system \[2\]:

\[
\left| \text{Re} \left( U_{\bar{d}s}^{z'} \right)^2 \frac{M^2}{M_{Z'}^2} \right| \leq 4.1 \times 10^{-7} \quad (\Delta M_K),
\]

\[
\left| \text{Im} \left( U_{\bar{d}s}^{z'} \right)^2 \frac{M^2}{M_{Z'}^2} \right| \leq 2.6 \times 10^{-9} \quad (|\epsilon|).
\] (7)

Note that, unlike the flavour-changing couplings of the $Z$, there are no constraints on $U_{\bar{d}s}^{z'}$ from $K_L \to \mu^+\mu^-$ since the leptophobic $Z'$ does not couple to charged leptons. Similarly, the couplings $U_{\bar{d}b}^{z'}$ and $U_{\bar{s}b}^{z'}$ are unconstrained by the experimental limit on $B(B \to \mu^+\mu^-X)$, which is the main constraint on the flavour-changing couplings of the $Z$ to the $b$ quark. On the other hand, $Z'$-mediated FCNC's do contribute to the process $b \to s\nu\bar{\nu}$ \[11\], for which ALEPH has an experimental limit \[12\]:

\[
B(b \to s\nu\bar{\nu}) \leq 6.4 \times 10^{-4} .
\] (8)

In order to compute the contribution of the $U_{\bar{s}b}^{z'}$ coupling to this process, we need the coupling of the $Z'$ to $\nu\bar{\nu}$. Since the $Z'$ is leptophobic, it does not couple to $L_L$, which includes both $e_\ell^-$ and $\nu_{\ell L}$. However, it does couple to the right-handed neutrino, and this must be taken into account.

In $E_6$, there are two candidates for the right-handed neutrino: the fields labelled $\nu^c$ and $S^c$ in Table \[1\]. In Table \[4\] we present the $U(1)'$ charges of these two fields. (Note that, as before for $L/H$ and $d^c/h^c$, one can always exchange the fields $\nu^c \leftrightarrow S^c$, so that the labels are arbitrary.) From this table we see that the leptophobic $Z'$ does indeed couple to the right-handed neutrino, and so it can contribute to $b \to s\nu\bar{\nu}$\[1\].

| Model | $2\sqrt{6}Q_\psi$ | $2\sqrt{10}Q_\chi$ | $Q'$ | $2\sqrt{6}Q_\psi$ | $2\sqrt{10}Q_\chi$ | $Q'$ |
|-------|-------------------|-------------------|------|-------------------|-------------------|------|
| 4     | $\nu^c$: 1        | -1                | $1/4$ | $S^c$: 4          | 0                 | $3/4$ |
| 5     | $\nu^c$: 1        | -1                | $1/4$ | $S^c$: 1          | -5                | $3/4$ |

Table 4: $U(1)'$ quantum numbers of $\nu^c$ and $S^c$ for models 4 and 5 of Table \[2\], calculated using $Q' = Q_\psi \cos \theta - Q_\chi \sin \theta$.

Taking $Q'(\nu^c) = 1/4$, the coupling of the $Z'$ to the right-handed neutrino can be written as

\[
- \frac{g}{2 \cos \theta_W} Q_{\nu R}^{z'} \bar{\nu}_R \gamma^\mu \nu_R Z'_{\mu} ,
\] (9)

\[^3\]Of course, it could be that the light right-handed neutrino is that linear combination of $\nu^c$ and $S^c$ whose coupling to the $Z'$ vanishes, in which case there are no $Z'$ contributions to $b \to s\nu\bar{\nu}$. Although logically possible, we do not consider this fine-tuned solution here.
with [see Eq. (3)]
\[ Q_{\nu R}^{Z'} = \frac{1}{2} \lambda \sqrt{\frac{5 \sin^2 \theta_W}{3}} = 0.31 , \tag{10} \]
where we have taken \( \lambda = 1 \) (its precise value depends on the details of unification). The contribution of \( Z' \)-mediated FCNC’s to \( b \to s \nu \bar{\nu} \) is then given by
\[ \frac{B(B \to X_s \nu \bar{\nu})}{B(B \to \mu \nu X)} = \frac{\left( Q_{\nu R}^{Z'} \right)^2 |U_{sb}^{Z'}|^2}{|V_{ub}|^2 + F_{ps} |V_{cb}|^2} \left( \frac{M_Z^2}{M_{Z'}^2} \right)^2 , \tag{11} \]
where \( F_{ps} \simeq 0.5 \) is a phase-space factor. This yields the constraint
\[ \left| U_{sb}^{Z'} \right| \frac{M_Z^2}{M_{Z'}^2} \leq 7.1 \times 10^{-3} . \tag{12} \]
This can be turned into a bound on \( U_{sb}^{Z'} \) if one assumes a value for \( M_{Z'} \). The only experimental constraint on leptophobic \( Z' \) gauge bosons comes from the D0 experiment \[13\], which excludes the mass range \( 365 \text{ GeV} \leq M_{Z'} \leq 615 \text{ GeV} \) for a \( Z' \) with quark couplings equal to those of the \( Z \). (Interestingly, light leptophobic \( Z' \) bosons are not ruled out.)

There are two points to be stressed here. First, the constraints on \( Z' \)-mediated \( b \to s \) transitions are quite a bit weaker than those on the corresponding \( Z \)-mediated FCNC’s. The most recent result from BELLE gives \[3\]
\[ B(B \to X_s e^+ e^-) \leq 1.01 \times 10^{-5} , \tag{13} \]
which leads to the constraint
\[ |U_{sb}^{Z'}| \leq 7.6 \times 10^{-4} . \tag{14} \]
This is about an order of magnitude more stringent than the corresponding \( Z' \) FCNC constraint of Eq. (12). Thus, effects due to leptophobic \( Z' \)-mediated FCNC’s in \( b \to s \) processes may be larger than those due to \( Z \)-mediated FCNC’s.

Second, unlike \( Z \)-mediated FCNC’s, there are no constraints on \( b \to d \) transitions from \( B \) decays. Thus, here too the effects of \( Z' \)-mediated FCNC’s can be considerably larger than those due to \( Z \) exchange.

Of course, \( Z' \)-mediated FCNC’s will contribute to \( B_{q}^{0} \to B_{q}^{0} \) mixing (\( q = d, s \)):
\[ M_{12}^{Z'}(B_q) = \frac{\sqrt{2} G_F M_{B_q} \eta_{B_q}}{12} \frac{M_Z^2}{M_{Z'}^2} \frac{f_{B_q}^2 B_{B_q}}{f_{B_q}^2 B_{B_q}} (U_{qB}^*)^2 . \tag{15} \]
These contributions can be compared with those of the SM:

\[
\frac{\Delta M_{q'}^z}{\Delta M_{q'}^w} = \frac{\sqrt{2}\pi^2}{G_F M_w^2} \frac{1}{x_l f_2(x_l)} \frac{M_{q'}^2}{M_{Z'}^2} \frac{|U_{q'b}|^2}{|V_{tb}|^2} \frac{M_{Z'}^2}{M_{Z'}^2} \frac{|U_{q'b}|^2}{|V_{tb}|^2},
\]

(16)

where we have taken \(|V_{tb}| = 1\) and \(m_t = 170\) GeV.

Consider first \(B^0_s - \bar{B}^0_s\) mixing. As a figure of merit, we assume that \(|V_{tb}| = 1\) and \(M_{Z'} = 750\) GeV, which satisfy the bound of Eq. (12). Taking \(|V_{ts}| = |V_{cb}| = 0.04\), this yields

\[
\frac{\Delta M_{Z'}^s}{\Delta M_{Z'}^w} = 7.2.
\]

(17)

Thus, \(B^0_s - \bar{B}^0_s\) mixing can be completely dominated by the exchange of a leptophobic \(Z'\). This is in stark contrast to \(Z\)-mediated FCNC's. With the constraint of Eq. (14), we have

\[
\frac{\Delta M_{Z}^s}{\Delta M_{Z}^w} \leq 0.029.
\]

(18)

The contribution of \(Z\)-mediated FCNC's to \(B^0_s - \bar{B}^0_s\) mixing is therefore negligible compared to that of the SM.

Turning to \(B^0_d - \bar{B}^0_d\) mixing, since there are no constraints on \(U_{qb}^z\) from \(B\) decays, it is clear that this mixing can also be dominated by \(Z'\)-mediated FCNC's. (Note that it was shown in Ref. [5] that \(B^0_d - \bar{B}^0_d\) mixing could be dominated by \(Z\)-mediated FCNC's. Since the bounds on \(U_{db}^z\) have not changed, this still holds true. Even if it is assumed that the bound of Eq. (13) also applies to \(b \to d e^+ e^-\), in which case \(|U_{db}^z| < 7.6 \times 10^{-4}\), the contributions of \(Z\)-mediated FCNC's to \(B^0_d - \bar{B}^0_d\) mixing can still be important.)

From the above, we have seen that both \(B^0_d - \bar{B}^0_d\) and \(B^0_s - \bar{B}^0_s\) mixing can be dominated by \(Z'\)-mediated FCNC's. Since the couplings \(U_{qb}^z\) \((q = d, s)\) can be complex, there may be large effects on CP-violating rate asymmetries in \(B\) decays. Furthermore, if \(B^0_q - \bar{B}^0_q\) mixing is significantly affected by this type of new physics, one expects that rare \(B\) decays will also be affected [5]. What distinguishes leptophobic \(Z'\)-mediated FCNC's from other models of new physics is that its effects will only show up in rare hadronic \(B\) decays; leptonic decays such as \(b \to q \ell^+ \ell^-\) and \(B_q^0 \to \ell^+ \ell^-\) will be unaffected. This provides a rather unique “smoking-gun” signal for this type of new physics.

To sum up: leptophobic \(Z'\) gauge bosons can appear in models with an \(E_6\) gauge symmetry due to mixing of the gauge-boson kinetic terms. There are a total of six
fermion embeddings in the 27 of $E_6$ which can produce leptophobia. Of these, we have shown that flavour-changing neutral currents (FCNC’s) can be generated in two of these models. This is due to the mixing of the right-handed components of the ordinary $d$, $s$ and $b$ quarks with the exotic $h$ quark. Since all of these particles have the same weak isospin, this mixing can be quite large.

The flavour-changing coupling $U'_{ds}$ is strongly constrained by measurements of $\Delta M_K$ and $|\epsilon|$ in the kaon system. However, because the $Z'$ does not couple to charged leptons, the constraints on $U'_{db}$ and $U'_{sb}$ are relatively weak – they are bounded only by the experimental limit on $B(b \to s\nu\bar{\nu})$. (This is in contrast to $Z$-mediated FCNC’s. For these, the constraints on the $U'_{q\tilde{q}}$ ($q = d, s$) from $B(B \to X\ell^+\ell^-)$ are quite stringent.) The result is that both $B^0_d-\bar{B}^0_d$ and $B^0_s-\bar{B}^0_s$ mixing can be dominated by $Z'$-mediated FCNC’s. If there are significant new-physics effects due to $Z'$ exchange in $B^0_q-\bar{B}^0_q$ mixing, this will affect CP-violating rate asymmetries in $B$ decays. In addition, one expects that rare hadronic $B$ decays will also be affected. The fact that only hadronic decays are affected, and not leptonic decays such as $b \to q\ell^+\ell^-$ and $B^0_q \to \ell^+\ell^-$, provides a unique signal for leptophobic $Z'$-mediated FCNC’s.

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