Bounds on *R*-parity violating supersymmetric couplings from leptonic and semileptonic meson decays

H. K. Dreiner

Physikalisches Institut der Universität Bonn, Nußallee 12, 53115 Bonn, Germany

M. Krämer

Institut für Theoretische Physik E, RWTH Aachen, 52056 Aachen, Germany

Ben O'Leary

S.U.P.A., School of Physics, University of Edinburgh, Edinburgh EH9 3JZ, Scotland and Institut für Theoretische Physik E, RWTH Aachen, 52056 Aachen, Germany

(Received 6 February 2007; published 28 June 2007)

We present a comprehensive update of the bounds on R-parity violating supersymmetric couplings from lepton-flavor- and lepton-number-violating decay processes. We consider τ and μ decays as well as leptonic and semileptonic decays of mesons. We present several new bounds resulting from τ, η, and kaon decays and correct some results in the literature concerning B meson decays.

DOI: 10.1103/PhysRevD.75.114016 PACS numbers: 13.30.Ce, 12.60.Jv, 13.20.−v, 13.35.Dx

I. INTRODUCTION

When extending the symmetries of the standard model of particle physics (SM) [1,2] to include supersymmetry [3], the Yukawa couplings are fixed by the renormalizable superpotential [4,5]

$$W = W_{P_6} + W_{\not{P}_6}^{\not{L}} + W_{\not{P}_6}^{\not{B}}, \tag{1.1}$$

$$W_{P_6} = \epsilon_{ab}(h^E_{ij} L^a_i H^b_d \bar{E}_j + h^D_{ij} Q^a_i H^b_d \bar{D}_j + h^U_{ij} Q^a_i H^b_u \bar{U}_j + \mu H^a_d H^b_u), \tag{1.2}$$

$$W_{\not{P}_6}^{\not{L}} = \epsilon_{ab}(\tfrac{1}{2}\lambda_{ijk} L^a_i L^b_j \bar{E}_k + \lambda'_{ijk} L^a_i Q^b_j \bar{D}_k + \kappa_i L^a_i H^b_u), \tag{1.3}$$

$$W_{\not{P}_6}^{\not{B}} = \tfrac{1}{2}\epsilon_{rst}\lambda''_{ijk}\bar{U}^r_i \bar{D}^s_j \bar{D}^t_k. \tag{1.4}$$

Here, $i, j, k = 1, 2, 3$ are generation indices, $a, b = 1, 2$ are SU(2), and $r, s, t = 1, 2, 3$ are SU(3) indices. L, $\bar{E}$ denote the lepton doublet and singlet left-chiral superfields; Q, $\bar{U}$, $\bar{D}$ denote the quark doublet and singlet superfields, respectively. h^E, h^D, h^U, λ, λ', λ'' are dimensionless coupling constants and μ, κ are mass mixing parameters.

Together the operators in $W_{\not{P}_6}^{\not{L}}$ and $W_{\not{P}_6}^{\not{B}}$ lead to rapid proton decay in disagreement with the experimental lower bounds on the proton lifetime [6]. A possible solution to this problem is to introduce the discrete $\mathbf{Z}_6$ symmetry, proton hexality, $\mathbf{P}_6$ [7], which prohibits both $W_{\not{P}_6}^{\not{L}}$ and $W_{\not{P}_6}^{\not{B}}$, as well the dangerous dimension-5 proton decay operators [4,8]; this is the minimal supersymmetric standard model (MSSM) [9]. (Note that the widely used discrete $\mathbf{Z}_2$ symmetry R parity does not prohibit the dimension-5 proton decay operators.) However, in order to stabilize the proton it is sufficient to prohibit either the superpotential $W_{\not{P}_6}^{\not{L}}$ via baryon-triality [10,11] or the superpotential $W_{\not{P}_6}^{\not{B}}$ via lepton-parity [10]. Lepton parity is not discrete gauge anomaly free [12] and we thus disregard it in the following. Baryon parity has the further advantage of allowing for nonzero neutrino masses without the need for right-handed neutrinos. We thus consider here the total superpotential given by

$$W = W_{P_6} + W_{\not{P}_6}^{\not{L}}. \tag{1.5}$$

We shall focus exclusively on the trilinear couplings. At any given scale the bilinear terms $\kappa_i L_i H_2$ can be rotated away through a basis redefinition [13]. This is not true, when embedding the theory in a more unified model, e.g. supergravity [14,15]. However, at $M_{\rm Pl}$ the natural value is $\kappa_i = 0$ [15], which leads to $\kappa_i \ll M_W$ at low energy. Thus the bilinear terms are mainly relevant for neutrino masses, see for example [11,16], and we shall neglect them in the following. The trilinear operators in $W_{\not{P}_6}^{\not{L}}$, lead to novel supersymmetric collider signatures beyond those of the MSSM [17]. In particular, the operators in $W_{\not{P}_6}^{\not{L}}$ induce lepton flavor violation (LFV) as well as lepton number violation, neither of which has been observed [18].

There is extensive literature on the resulting bounds on the operators $W_{\not{P}_6}^{\not{L}}$ from indirect processes, see e.g. Refs. [13,19–30], including also several overviews [31–38]. However, due to the improved data, in particular, on B meson and τ decays, it is the purpose of this paper to present a systematic update of the bounds resulting from lepton decays as well as leptonic and semileptonic decays of mesons. In the process, we have found several new bounds resulting from τ, η, and kaon decays. We have also found a need to correct some results in the literature with respect to B meson decays.

Our paper is organized as follows. In Sec. II A we start from an effective Lagrangian, where the supersymmetric scalar fermions have been integrated out and then present the treatment of the QCD bound state in Sec. II B. General analytic expressions for the decay rates of the various lepton and meson decays are shown in Sec. II C. In Sec. III, we insert the present experimental results into the analytical expressions to obtain our new bounds. These are summarized in Tables II, III, IV, V, VI, VII, VIII, IX, X, XI, and XII. In Sec. IV, we discuss the implications of our results. Formulae for the meson decay constants and the general lepton and meson decay matrix elements are collected in the appendices.

II. THEORETICAL ANALYSIS

A. Effective Lagrangian

Because the sfermions are constrained to be heavy, $m_{\tilde{\nu},\tilde{q}} \gtrsim 100$ GeV $\gg M_B$ (this work does not consider the decays of particles heavier than B mesons), we approximate their propagators as static $1/m^2_{\tilde{f}}$. This is equivalent to integrating out the sfermionic degrees of freedom to obtain an effective interaction Lagrangian [44] and taking only the leading term in an expansion in inverse sfermion mass,

$$\mathcal{L}_{\rm eff} = \sum_{g=1}^{3}\Bigg\{\frac{1}{m^2_{\tilde{\nu}_{gL}}}\lambda_{gab}\lambda^*_{gcd}(\bar{l}_c P_R l_d)(\bar{l}_b P_L l_a) \tag{2.1}$$

$$+\left[\frac{1}{m^2_{\tilde{\nu}_{gL}}}\lambda_{gik}\lambda'^*_{gnm}(\bar{d}_n P_R d_m)(\bar{l}_k P_L l_i) + \text{H.c.}\right] \tag{2.2}$$

$$-\left[\frac{1}{2m^2_{\tilde{u}_{gL}}}\lambda'_{ign}\lambda'^*_{kgm}(\bar{d}_n\gamma^\mu P_R d_m)(\bar{l}_k\gamma_\mu P_L l_i) + \text{H.c.}\right] \tag{2.3}$$

$$+\left[\frac{1}{2m^2_{\tilde{d}_{gR}}}\lambda'_{img}\lambda'^*_{kng}(\bar{u}_n\gamma^\mu P_L u_m)(\bar{l}_k\gamma_\mu P_L l_i) + \text{H.c.}\right]\Bigg\}, \tag{2.4}$$

where (2.1) and (2.2) result from integrating out the sneutrino fields, and (2.3) and (2.4) result from integrating out the up-type and down-type squark fields, respectively, using some Fierz identities. The index g denotes the generation. There are additional terms in the effective Lagrangian which arise when integrating out the charged sleptons, which we do not consider here: For the product of two $LL\bar{E}$ or an $LL\bar{E}$ and an $LQ\bar{D}$ operator, these lead to neutrinos in the final state. Thus lepton flavor violation is not observable in the resulting lepton or meson decays; for the product of two $LQ\bar{D}$ operators, the resulting meson decays are purely hadronic.

In the following, we shall assume that the decay is dominated by the exchange of a single type of sfermion (up-type squark, down-type squark, or sneutrino) of a single generation, either because it is lighter than the others or because it has a larger product of couplings (the double coupling dominance convention). Subsequent expressions with an index g are thus implicitly for only one value of g, though one may always deduce the general result by replacing expressions like $|\lambda'_{gjk}\lambda'_{glm}/m^2_{\tilde{u}_{gL}}|^2$ with $|\sum_g \lambda'_{gjk}\lambda'_{glm}/m^2_{\tilde{u}_{gL}}|^2$, etc.

It is also assumed in this paper that the sneutrino-higgsino and squark mixing can be neglected. Such mixings just add to the notational burden. If one insists on accounting for mixing, one can make the replacement

TABLE I. Input parameters.

Pseudoscalar meson	Mass (in GeV)	f_P (in GeV)	Fundamental fermion	Mass (in GeV)
π^0	0.135	0.130	e	5.11×10^{-4}
K_S	0.498	0.160	μ	0.106
K_L	0.498	0.160	τ	1.777
η	0.548	0.130	u	3×10^{-3}
η'	0.958	0.172	d	6×10^{-3}
D_0	1.86	0.25	s	0.11
B_d	5.28	0.2	c	1.25
B_s	5.37	0.2	b	4.3
Vector meson	Mass (in GeV)	f_V (in GeV)		
ρ	0.776	0.22		
K^*	0.896	0.23		
ϕ	1.020	0.23		
J/ψ	3.10	0.41		

TABLE II. Coupling combinations which had no bounds previous to this work. The notation is explained in Sec. IV.

Coupling combination	Bound		Decay
$\lambda_{g21}\lambda'_{g22}$	2.1	$[\tilde{\nu}_{gL}]^2$	$\eta\to\mu\bar{e}+e\bar{\mu}$
$\lambda_{g12}\lambda'_{g22}$			
$\lambda_{g13}\lambda'_{g12}$	9.7×10^{-4}	$[\tilde{\nu}_{gL}]^2$	$\tau\to eK_S$
$\lambda_{g31}\lambda'_{g21}$			
$\lambda_{g23}\lambda'_{g12}$	1.0×10^{-3}	$[\tilde{\nu}_{gL}]^2$	$\tau\to\mu K_S$
$\lambda_{g32}\lambda'_{g21}$			
$\lambda'_{1g1}\lambda'_{3g2}$	2.3×10^{-3}	$[\tilde{u}_{gL}]^2$	$\tau\to eK_S$
$\lambda'_{1g2}\lambda'_{2g2}$	$1.5\times10^{+2}$	$[\tilde{u}_{gL}]^2$	$\eta\to\mu\bar{e}+e\bar{\mu}$
$\lambda'_{1g2}\lambda'_{3g2}$ †(−)	1.2×10^{-3}	$[\tilde{u}_{gL}]^2$	$\tau\to e\eta$
$\lambda'_{1g2}\lambda'_{3g2}$	3.4×10^{-3}	$[\tilde{u}_{gL}]^2$	$\tau\to e\phi$
$\lambda'_{2g1}\lambda'_{3g2}$	2.4×10^{-3}	$[\tilde{u}_{gL}]^2$	$\tau\to\mu K_S$
$\lambda'_{2g2}\lambda'_{3g2}$ †(−)	1.6×10^{-3}	$[\tilde{u}_{gL}]^2$	$\tau\to\mu\eta$
$\lambda'_{2g2}\lambda'_{3g2}$	3.4×10^{-3}	$[\tilde{u}_{gL}]^2$	$\tau\to\mu\phi$

TABLE III. Coupling combinations which have improved by a factor of 30 or more compared to those published before this work.

Coupling combination	From this work Bound		Decay	Previously published Bound		Decay	Key
$\lambda_{g13}\lambda'_{g22}$	4.6×10^{-4}	$[\tilde{\nu}_{gL}]^2$	$\tau\to e\eta$	1.6×10^{-2}	$[\tilde{\nu}_{gL}]^2$	$\tau\to e\eta$	Upd. [39]
$\lambda_{g31}\lambda'_{g22}$							
$\lambda_{g13}\lambda'_{g21}$	9.7×10^{-4}	$[\tilde{\nu}_{gL}]^2$	$\tau\to eK_S$	8.5×10^{-2}	$[\tilde{\nu}_{gL}]^2$	$\tau\to eK^0$	Upd. [39]
$\lambda_{g31}\lambda'_{g12}$							
$\lambda_{g23}\lambda'_{g21}$	1.0×10^{-3}	$[\tilde{\nu}_{gL}]^2$	$\tau\to\mu K_S$	7.6×10^{-2}	$[\tilde{\nu}_{gL}]^2$	$\tau\to\mu K^0$	Upd. [39]
$\lambda_{g32}\lambda'_{g12}$							
$\lambda_{g32}\lambda'_{g11}$	6.7×10^{-5}	$[\tilde{\nu}_{gL}]^2$	$\tau\to\mu\eta$	1.7×10^{-3}	$[\tilde{\nu}_{gL}]^2$	$\tau\to\mu\eta$	Upd. [39]
$\lambda_{g23}\lambda'_{g22}$	3.7×10^{-4}	$[\tilde{\nu}_{gL}]^2$	$\tau\to\mu\eta$	1.7×10^{-2}	$[\tilde{\nu}_{gL}]^2$	$\tau\to\mu\eta$	Upd. [39]
$\lambda_{g32}\lambda'_{g22}$							

TABLE IV. Coupling combinations where the combined bound is now better than the product of the individual bounds.

Coupling combination	From this work Bound		Decay	Previously published Bound		Decay	Key
$\lambda'_{11g}\lambda'_{31g}$	1.2×10^{-3}	$[\tilde{d}_{gR}]^2$	$\tau\to e\pi^0$	0.02 $\times0.12$	$[\tilde{d}_{gR}]$ $[\tilde{d}_{gR}]$	APV in Cs $\frac{\tau\to\pi^-\nu}{\pi^-\to\mu\bar{\nu}}$	Upd. [38], [38]
$\lambda'_{12g}\lambda'_{21g}$	9.0×10^{-3}	$[\tilde{d}_{gR}]^2$	$D^0\to\mu\bar{e}$	0.21 $\times5.9\times10^{-2}$	$[\tilde{d}_{gR}]$ $[\tilde{d}_{gR}]$	A^c_{FB} $\frac{\pi^-\to e\bar{\nu}}{\pi^-\to\mu\bar{\nu}}$	Upd. [38], [36]

TABLE V. Bounds on $(\lambda_{ijk}\lambda_{lmn})$: all but those from $\mu\to ee\bar{e}$ are updated from Ref. [40]. The presented $\mu\to ee\bar{e}$ bounds agree with those in Ref. [21].

$(\lambda_{ijk}\lambda_{lmn})$ ijk	lmn	From this work Bound		Decay	Previously published Bound		Key
121	123	7.0×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu e\bar{\mu}$	2.1×10^{-3}	$[\tilde{\nu}_{1L}]^2$	Upd. [40]
121	131	6.8×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu e\bar{e}$	2.0×10^{-3}	$[\tilde{\nu}_{1L}]^2$	Upd. [40]
121	132	5.6×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu\mu\bar{e}$	1.9×10^{-3}	$[\tilde{\nu}_{1L}]^2$	Upd. [40]
122	123	6.8×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu\mu\bar{\mu}$	2.2×10^{-3}	$[\tilde{\nu}_{1L}]^2$	Upd. [40]
122	131	7.0×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu e\bar{\mu}$	2.1×10^{-3}	$[\tilde{\nu}_{1L}]^2$	Upd. [40]
122	132	6.8×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu\mu\bar{\mu}$	2.2×10^{-3}	$[\tilde{\nu}_{1L}]^2$	Upd. [40]
211	212	6.6×10^{-7}	$[\tilde{\nu}_{2L}]^2$	$\mu\to ee\bar{e}$	6.6×10^{-7}	$[\tilde{\nu}_{2L}]^2$	Agr. [21]
211	213	7.0×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$\tau\to ee\bar{e}$	2.7×10^{-3}	$[\tilde{\nu}_{2L}]^2$	Upd. [40]
211	231	7.0×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$\tau\to ee\bar{e}$	2.7×10^{-3}	$[\tilde{\nu}_{2L}]^2$	Upd. [40]
211	232	6.8×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$\tau\to\mu e\bar{e}$	2.0×10^{-3}	$[\tilde{\nu}_{2L}]^2$	Upd. [40]
212	213	6.8×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$\tau\to\mu e\bar{e}$	2.0×10^{-3}	$[\tilde{\nu}_{2L}]^2$	Upd. [40]
212	231	5.2×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$\tau\to ee\bar{\mu}$	1.9×10^{-3}	$[\tilde{\nu}_{2L}]^2$	Upd. [40]
212	232	7.0×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$\tau\to\mu e\bar{\mu}$	2.1×10^{-3}	$[\tilde{\nu}_{2L}]^2$	Upd. [40]
311	312	6.6×10^{-7}	$[\tilde{\nu}_{3L}]^2$	$\mu\to ee\bar{e}$	6.6×10^{-7}	$[\tilde{\nu}_{2L}]^2$	Agr. [21]
311	313	7.0×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$\tau\to ee\bar{e}$	2.7×10^{-3}	$[\tilde{\nu}_{3L}]^2$	Upd. [40]
311	321	6.6×10^{-7}	$[\tilde{\nu}_{3L}]^2$	$\mu\to ee\bar{e}$	6.6×10^{-7}	$[\tilde{\nu}_{2L}]^2$	Agr. [21]
311	323	6.8×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$\tau\to\mu e\bar{e}$	2.0×10^{-3}	$[\tilde{\nu}_{3L}]^2$	Upd. [40]
312	313	6.8×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$\tau\to\mu e\bar{e}$	2.0×10^{-3}	$[\tilde{\nu}_{3L}]^2$	Upd. [40]
312	323	5.6×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$\tau\to\mu\mu\bar{e}$	1.9×10^{-3}	$[\tilde{\nu}_{3L}]^2$	Upd. [40]
313	321	5.2×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$\tau\to ee\bar{\mu}$	1.9×10^{-3}	$[\tilde{\nu}_{3L}]^2$	Upd. [40]
313	322	7.0×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$\tau\to\mu e\bar{\mu}$	2.1×10^{-3}	$[\tilde{\nu}_{3L}]^2$	Upd. [40]
321	323	7.0×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$\tau\to\mu e\bar{\mu}$	2.1×10^{-3}	$[\tilde{\nu}_{3L}]^2$	Upd. [40]
322	323	6.8×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$\tau\to\mu\mu\bar{\mu}$	2.2×10^{-3}	$[\tilde{\nu}_{3L}]^2$	Upd. [40]

$|\lambda'_{gjk}\lambda'_{glm}/m^2_{\tilde{u}_{gL}}|^2 \to |\sum_{g,x,y}\lambda'_{xjk}U_{xg}U^\dagger_{gy}\lambda'_{ylm}/m^2_{\tilde{u}_{gL}}|^2$, etc. for squark mixing matrices U, with a similar expression for mixing between the sneutrinos and Higgses.

B. Meson decay constants

The decay constant f_V of a vector meson V with momentum p_V is defined as

$$\langle 0|\bar{q}_\alpha\gamma^\mu q_\beta|V(p_V)\rangle = H_V^{\alpha\beta} f_V m_V \epsilon_V^\mu, \tag{2.5}$$

where ϵ_V^μ is the polarization vector of V, m_V is the vector meson mass, and $H_V^{\alpha\beta}$ is the coefficient of $\bar{q}_\alpha q_\beta$ in the quark model wave function of the meson, e.g. $H_{\rho^0}^{uu} = 1/\sqrt{2}$, $H_{\rho^0}^{dd} = -1/\sqrt{2}$.

For a pseudoscalar meson P, we use the partially conserved axial current (PCAC) condition [45] and define the decay constant f_P through the axial vector matrix element

$$\langle 0|\bar{q}_\alpha\gamma^\mu\gamma^5 q_\beta|P(p_P)\rangle = iH_P^{\alpha\beta} f_P p_P^\mu, \tag{2.6}$$

where $H_P^{\alpha\beta}$ is the analogue of $H_V^{\alpha\beta}$. As described in Appendix A, the equation of motion for the quark fields can be used to derive the pseudoscalar matrix element from the axial vector matrix element (2.6). We find

$$\langle 0|\bar{q}_\alpha\gamma^5 q_\beta|P(p_P)\rangle = \frac{iH_P^{\alpha\beta} f_P m_P^2}{\mu_P^{\alpha\beta}}. \tag{2.7}$$

The factor $\mu_P^{\alpha\beta}$ is proportional to the sum of current quark masses m_α and m_β, e.g. $\mu_{\pi^0}^{uu} = -2m_u$ and $\mu_{\pi^0}^{dd} = 2m_d$. For the proper definition of $\mu_P^{\alpha\beta}$, a list of the coefficients $H_{P/V}^{\alpha\beta}$, and more details see Appendix A.

Since there are no QCD correlations between the initial and final states (if there is a meson in the initial state, the final state is purely leptonic, and vice versa), these definitions of the decay constants are taken to be accurate to order α, certainly for the processes with a mediating sneutrino, which is a color singlet. For processes mediated by a squark, there are QCD corrections, but since these must involve a gluon on the squark line (since all gluon

TABLE VI. Bounds on $(\lambda_{ijk}\lambda'_{lmn})$.

$(\lambda_{ijk}\lambda'_{lmn})$ ijk	lmn	From this work Bound		Decay	Previously published Bound		Decay	Key
121	111	1.2×10^{-2}	$[\tilde{\nu}_{1L}]^2$	$\pi^0\to e\bar{\mu}$	2.1×10^{-8}	$[\tilde{\nu}_{1L}]^2$	$\mu\to e$ in ^{48}Ti	Unimp. [41]
		0.39	$[\tilde{\nu}_{1L}]^2$	$\eta\to\mu\bar{e}+e\bar{\mu}$				
		0.41	$[\tilde{\nu}_{1L}]^2$	$\pi^0\to\mu\bar{e}$				
		16	$[\tilde{\nu}_{1L}]^2$	$\eta'\to\mu\bar{e}/e\bar{\mu}$				
121	112	6.7×10^{-9}	$[\tilde{\nu}_{1L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	6×10^{-9}	$[\tilde{\nu}_{1L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	†(−) Agr. [26]
121	113	1.3×10^{-5}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to\mu\bar{e}$	2.3×10^{-5}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to\mu\bar{e}$	Corr. (<) [27]
121	121	6.7×10^{-9}	$[\tilde{\nu}_{1L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	6×10^{-9}	$[\tilde{\nu}_{1L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	†(−) Agr. [26]
121	122	2.1	$[\tilde{\nu}_{1L}]^2$	$\eta\to\mu\bar{e}+e\bar{\mu}$	none		n/a	New
		$3.6\times10^{+4}$	$[\tilde{\nu}_{1L}]^2$	$\eta'\to\mu\bar{e}/e\bar{\mu}$				
121	123	7.6×10^{-5}	$[\tilde{\nu}_{1L}]^2$	$B_s^0\to\mu\bar{e}$	4.7×10^{-5}	$[\tilde{\nu}_{1L}]^2$	$B_s^0\to\mu\bar{e}$	Corr. (>) [27]
121	131	1.3×10^{-5}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to e\bar{\mu}$	2.3×10^{-5}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to e\bar{\mu}$	Corr. (<) [27]
121	132	7.6×10^{-5}	$[\tilde{\nu}_{1L}]^2$	$B_s^0\to e\bar{\mu}$	4.7×10^{-5}	$[\tilde{\nu}_{1L}]^2$	$B_s^0\to e\bar{\mu}$	Corr. (>) [27]
122	113	6.2×10^{-6}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to\mu\bar{\mu}$	1.5×10^{-5}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to\mu\bar{\mu}$	Corr. (<) [27]
122	123	1.2×10^{-5}	$[\tilde{\nu}_{1L}]^2$	$B_s^0\to\mu\bar{\mu}$	1.7×10^{-5}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to K^0\mu\bar{\mu}$	Upd. [30]
122	131	6.2×10^{-6}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to\mu\bar{\mu}$	1.5×10^{-5}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to\mu\bar{\mu}$	Corr. (<) [27]
122	132	1.2×10^{-5}	$[\tilde{\nu}_{1L}]^2$	$B_s^0\to\mu\bar{\mu}$	1.8×10^{-5}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to K^0\mu\bar{\mu}$	Upd. [30]
123	111	6.7×10^{-5}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu\eta$	1.7×10^{-3}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu\eta$	Upd. [39]
		1.0×10^{-3}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu\pi^0$				
123	112	1.0×10^{-3}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu K_S$	none		n/a	New
123	113	2.2×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to\mu\bar{\tau}$	6.2×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to\mu\bar{\tau}$	Corr. (<) [27]
123	121	1.0×10^{-3}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu K_S$	7.6×10^{-2}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu K^0$	Upd. [39]
123	122	3.7×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu\eta$	1.7×10^{-2}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu\eta$	Upd. [39]
123	131	2.2×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to\tau\bar{\mu}$	6.2×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to\mu\bar{\tau}$	Corr. (<) [27]
131	111	8.5×10^{-5}	$[\tilde{\nu}_{1L}]^2$	$\tau\to e\eta$	1.6×10^{-3}	$[\tilde{\nu}_{1L}]^2$	$\tau\to e\eta$	Upd. [39]
		7.1×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$\tau\to e\pi^0$				
131	112	9.7×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$\tau\to eK_S$	8.5×10^{-2}	$[\tilde{\nu}_{1L}]^2$	$\tau\to eK^0$	Upd. [39]
131	113	3.7×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to\tau\bar{e}$	4.9×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to\tau\bar{e}$	Corr. (<) [27]
131	121	9.7×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$\tau\to eK_S$	none		n/a	New
131	122	4.6×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$\tau\to e\eta$	1.6×10^{-2}	$[\tilde{\nu}_{1L}]^2$	$\tau\to e\eta$	Upd. [39]
131	131	3.7×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to e\bar{\tau}$	4.9×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to e\bar{\tau}$	Corr. (<) [27]

exchange between the quarks is accounted for by the decay constant), there is naively a suppression of the order of $(m_M/m_{\tilde{q}})^2$, where m_M is the meson mass and $m_{\tilde{q}}$ is the squark mass. Of course, there is the potential for large logarithms of this ratio, but since mesonic wave functions are not well understood, we can do little but assume that such effects can be absorbed into the renormalization of the RPV couplings and do not affect our above approximations.

C. Decay rates

The Feynman graphs and matrix elements for the various decays considered in this paper are given in Appendix B. Upon squaring the matrix elements, summing over the final spin states and averaging over the initial spin states, we arrive at the following expressions for the decay widths, assuming, as mentioned, that only one type of sfermion (sneutrino, up-type squark, or down-type squark), of one generation, dominates:

(i) For a heavy lepton a decaying into leptons b and c and an antilepton $\bar{d}$,

$$\Gamma_{a\to bc\bar{d}} = \frac{m_{l_a}^5}{6144\pi^3 m_{\tilde{\nu}_{gL}}^4}(\lambda_{gdc}^2\lambda_{gba}^2 + \lambda_{gcd}^2\lambda_{gab}^2 + \lambda_{gdb}^2\lambda_{gca}^2 + \lambda_{gbd}^2\lambda_{gac}^2), \quad (2.8)$$

where we approximate the final state (anti)leptons as massless.
When the leptons b and c are identical, $b = c$ and the phase space is halved,

$$\Gamma_{a\to bb\bar{d}} = \frac{m_{l_a}^5}{6144\pi^3 m_{\tilde{\nu}_{gL}}^4}(\lambda_{gdb}^2\lambda_{gba}^2 + \lambda_{gbd}^2\lambda_{gab}^2). \quad (2.9)$$

(ii) For a heavy lepton i decaying into a lepton k and a vector meson consisting of valence quark n and antiquark m, there are two cases: up-type squark-

TABLE VII. Bounds on $(\lambda_{ijk}\lambda'_{lmn})$ continued.

$(\lambda_{ijk}\lambda'_{lmn})$ ijk	lmn	From this work Bound		Decay	Previously published Bound		Decay	Key
132	111	6.7×10^{-5}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu\eta$	1.7×10^{-3}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu\eta$	Upd. [39]
		1.0×10^{-3}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu\pi^0$				
132	112	1.0×10^{-3}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu K_S$	7.6×10^{-2}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu K^0$	Upd. [39]
132	113	2.2×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to\tau\bar{\mu}$	6.2×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to\mu\bar{\tau}$	Corr. (<) [27]
132	121	1.0×10^{-3}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu K_S$	none		n/a	New
132	122	3.7×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu\eta$	1.7×10^{-2}	$[\tilde{\nu}_{1L}]^2$	$\tau\to\mu\eta$	Upd. [39]
132	131	2.2×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to\mu\bar{\tau}$	6.2×10^{-4}	$[\tilde{\nu}_{1L}]^2$	$B_d^0\to\mu\bar{\tau}$	Corr. (<) [27]
211	213	4.1×10^{-5}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to e\bar{e}$	1.7×10^{-5}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to e\bar{e}$	Corr. (>) [27]
211	223	2.3×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$B_s^0\to e\bar{e}$	1.4×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to K^0e\bar{e}$	Unimp. [30]
211	231	4.1×10^{-5}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to e\bar{e}$	1.7×10^{-5}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to e\bar{e}$	Corr. (>) [27]
211	232	2.3×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$B_s^0\to e\bar{e}$	2.3×10^{-5}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to K^0e\bar{e}$	Unimp. [30]
212	211	1.2×10^{-2}	$[\tilde{\nu}_{2L}]^2$	$\pi^0\to e\bar{\mu}$	2.1×10^{-8}	$[\tilde{\nu}_{2L}]^2$	$\mu\to e$ in ^{48}Ti	Unimp. [41]
		0.38	$[\tilde{\nu}_{2L}]^2$	$\eta\to\mu\bar{e}+e\bar{\mu}$				
		0.41	$[\tilde{\nu}_{2L}]^2$	$\pi^0\to\mu\bar{e}$				
		16	$[\tilde{\nu}_{2L}]^2$	$\eta'\to\mu\bar{e}/e\bar{\mu}$				
212	212	6.7×10^{-9}	$[\tilde{\nu}_{2L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	6×10^{-9}	$[\tilde{\nu}_{2L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	$^{\dagger(-)}$ Agr. [26]
212	213	1.3×10^{-5}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to e\bar{\mu}$	2.3×10^{-5}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to e\bar{\mu}$	Corr. (>) [27]
212	221	6.7×10^{-9}	$[\tilde{\nu}_{2L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	6×10^{-9}	$[\tilde{\nu}_{2L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	$^{\dagger(-)}$ Agr. [26]
212	222	2.1	$[\tilde{\nu}_{2L}]^2$	$\eta\to\mu\bar{e}+e\bar{\mu}$	none		n/a	New
		$3.6\times10^{+4}$	$[\tilde{\nu}_{2L}]^2$	$\eta'\to\mu\bar{e}/e\bar{\mu}$				
212	223	7.6×10^{-5}	$[\tilde{\nu}_{2L}]^2$	$B_s^0\to e\bar{\mu}$	4.7×10^{-5}	$[\tilde{\nu}_{2L}]^2$	$B_s^0\to e\bar{\mu}$	Corr. (>) [27]
212	231	1.3×10^{-5}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to\mu\bar{e}$	2.3×10^{-5}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to\mu\bar{e}$	Corr. (<) [27]
212	232	7.6×10^{-5}	$[\tilde{\nu}_{2L}]^2$	$B_s^0\to\mu\bar{e}$	4.7×10^{-5}	$[\tilde{\nu}_{2L}]^2$	$B_s^0\to e\bar{\mu}$	Corr. (>) [27]
213	211	8.5×10^{-5}	$[\tilde{\nu}_{2L}]^2$	$\tau\to e\eta$	1.6×10^{-3}	$[\tilde{\nu}_{2L}]^2$	$\tau\to e\eta$	Upd. [39]
		7.1×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$\tau\to e\pi^0$				
213	212	9.7×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$\tau\to eK_S$	none		n/a	New
213	213	3.7×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to e\bar{\tau}$	4.9×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to e\bar{\tau}$	Corr. (<) [27]
213	221	9.7×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$\tau\to eK_S$	8.5×10^{-2}	$[\tilde{\nu}_{2L}]^2$	$\tau\to eK^0$	Upd. [39]
213	222	4.6×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$\tau\to e\eta$	1.6×10^{-2}	$[\tilde{\nu}_{2L}]^2$	$\tau\to e\eta$	Upd. [39]
213	231	3.7×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to\tau\bar{e}$	4.9×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to\tau\bar{e}$	Corr. (<) [27]

mediated:

$$\Gamma_{l_i\to l_k+V} = \left|\sum_{\text{d-type}}(\lambda'_{ign}\lambda'_{kgm})H_V^{mn}\right|^2\frac{(m_{l_i}^2-m_V^2)^2}{512\pi m_{\tilde{u}_{gL}}^4}\times\frac{|f_V|^2(m_{l_i}^2+2m_V^2)}{m_{l_i}^3}\left(1+\mathcal{O}\left(\frac{m_{l_k}}{m_{l_i}}\right)\right) \tag{2.10}$$

or down-type squark-mediated:

$$\Gamma_{l_i\to l_k+V} = \left|\sum_{\text{u-type}}(\lambda'_{img}\lambda'_{kng})H_V^{mn}\right|^2\frac{(m_{l_i}^2-m_V^2)^2}{512\pi m_{\tilde{d}_{gR}}^4}\times\frac{|f_V|^2(m_{l_i}^2+2m_V^2)}{m_{l_i}^3}\left(1+\mathcal{O}\left(\frac{m_{l_k}}{m_{l_i}}\right)\right), \tag{2.11}$$

where we have introduced the notation $\sum_{\text{d-type}}$ to mean only summing over the down-type quarks in the meson and $\sum_{\text{u-type}}$ to mean summing over the up-type quarks.

(iii) For a heavy lepton i decaying into a lepton k and a pseudoscalar meson consisting of valence quark n and antiquark m, there are three cases: up-type squark-mediated:

$$\Gamma_{l_i\to l_k+P} = \left|\sum_{\text{d-type}}(\lambda'_{ign}\lambda'_{kgm})H_P^{mn}\right|^2\frac{(m_{l_i}^2-m_P^2)^2}{512\pi m_{\tilde{u}_{gL}}^4}\times\frac{|f_P|^2}{m_{l_i}}\left(1+\mathcal{O}\left(\frac{m_{l_k}}{m_{l_i}}\right)\right), \tag{2.12}$$

down-type squark-mediated:

$$\Gamma_{l_i\to l_k+P} = \left|\sum_{\text{u-type}}(\lambda'_{img}\lambda'_{kng})H_P^{mn}\right|^2\frac{(m_{l_i}^2-m_P^2)^2}{512\pi m_{\tilde{d}_{gR}}^4}\times\frac{|f_P|^2}{m_{l_i}}\left(1+\mathcal{O}\left(\frac{m_{l_k}}{m_{l_i}}\right)\right), \tag{2.13}$$

TABLE VIII. Bounds on $(\lambda_{ijk}\lambda'_{lmn})$ continued.

$(\lambda_{ijk}\lambda'_{lmn})$ ijk	lmn	From this work Bound		Decay	Previously published Bound		Decay	Key
231	211	8.5×10^{-5}	$[\tilde{\nu}_{2L}]^2$	$\tau\to e\eta$	1.6×10^{-3}	$[\tilde{\nu}_{2L}]^2$	$\tau\to e\eta$	Upd. [39]
		7.1×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$\tau\to e\pi^0$				
231	212	9.7×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$\tau\to eK_S$	8.5×10^{-2}	$[\tilde{\nu}_{2L}]^2$	$\tau\to eK^0$	Upd. [39]
231	213	3.7×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to\tau\bar{e}$	4.9×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to\tau\bar{e}$	Corr. (<) [27]
231	221	9.7×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$\tau\to eK_S$	none		n/a	New
231	222	4.6×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$\tau\to e\eta$	1.6×10^{-2}	$[\tilde{\nu}_{2L}]^2$	$\tau\to e\eta$	Upd. [39]
231	231	3.7×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to e\bar{\tau}$	4.9×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to e\bar{\tau}$	Corr. (<) [27]
232	211	6.7×10^{-5}	$[\tilde{\nu}_{2L}]^2$	$\tau\to\mu\eta$	1.7×10^{-3}	$[\tilde{\nu}_{2L}]^2$	$\tau\to\mu\eta$	Upd. [39]
		1.0×10^{-3}	$[\tilde{\nu}_{2L}]^2$	$\tau\to\mu\pi^0$				
232	212	1.0×10^{-3}	$[\tilde{\nu}_{2L}]^2$	$\tau\to\mu K_S$	7.6×10^{-2}	$[\tilde{\nu}_{2L}]^2$	$\tau\to\mu K^0$	Upd. [39]
232	213	2.2×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to\tau\bar{\mu}$	6.2×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to\mu\bar{\tau}$	Corr. (<) [27]
232	221	1.0×10^{-3}	$[\tilde{\nu}_{2L}]^2$	$\tau\to\mu K_S$	none		n/a	New
232	222	3.7×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$\tau\to\mu\eta$	1.7×10^{-2}	$[\tilde{\nu}_{2L}]^2$	$\tau\to\mu\eta$	Upd. [39]
232	231	2.2×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to\mu\bar{\tau}$	6.2×10^{-4}	$[\tilde{\nu}_{2L}]^2$	$B_d^0\to\mu\bar{\tau}$	Corr. (<) [27]
311	313	4.1×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to e\bar{e}$	1.7×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to e\bar{e}$	Corr. (>) [27]
311	323	2.3×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$B_s^0\to e\bar{e}$	2.3×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to K^0e\bar{e}$	Unimp. [30]
311	331	4.1×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to e\bar{e}$	1.7×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to e\bar{e}$	Corr. (>) [27]
311	332	2.3×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$B_s^0\to e\bar{e}$	2.3×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to K^0e\bar{e}$	Unimp. [30]
312	311	1.2×10^{-2}	$[\tilde{\nu}_{3L}]^2$	$\pi^0\to e\bar{\mu}$	2.1×10^{-8}	$[\tilde{\nu}_{3L}]^2$	$\mu\to e$ in ^{48}Ti	Unimp. [41]
		0.38	$[\tilde{\nu}_{3L}]^2$	$\eta\to\mu\bar{e}+e\bar{\mu}$				
		0.41	$[\tilde{\nu}_{3L}]^2$	$\pi^0\to\mu\bar{e}$				
		16	$[\tilde{\nu}_{3L}]^2$	$\eta'\to\mu\bar{e}/e\bar{\mu}$				
312	312	6.7×10^{-9}	$[\tilde{\nu}_{3L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	6×10^{-9}	$[\tilde{\nu}_{3L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	$^{\dagger(-)}$ Agr. [26]
312	313	1.3×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to e\bar{\mu}$	2.3×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to e\bar{\mu}$	Corr. (<) [27]
312	321	6.7×10^{-9}	$[\tilde{\nu}_{3L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	6×10^{-9}	$[\tilde{\nu}_{3L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	$^{\dagger(-)}$ Agr. [26]
312	322	2.1	$[\tilde{\nu}_{3L}]^2$	$\eta\to\mu\bar{e}+e\bar{\mu}$	none		n/a	New
		$3.6\times10^{+4}$	$[\tilde{\nu}_{3L}]^2$	$\eta'\to\mu\bar{e}/e\bar{\mu}$				
312	323	7.6×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_s^0\to e\bar{\mu}$	4.7×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_s^0\to e\bar{\mu}$	Corr. (>) [27]
312	331	1.3×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to\mu\bar{e}$	2.3×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to\mu\bar{e}$	Corr. (<) [27]
312	332	7.6×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_s^0\to\mu\bar{e}$	4.7×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_s^0\to\mu\bar{e}$	Corr. (>) [27]

or sneutrino-mediated:

$$\Gamma_{l_i \to l_k + P} = \left(\left| \sum_{\text{d-type}} \lambda^*_{gki} \lambda'_{gmn} \frac{H_P^{mn*}}{\mu_P^{mn*}} \right|^2 + \left| \sum_{\text{d-type}} \lambda_{gik} \lambda'^*_{gnm} \frac{H_P^{mn*}}{\mu_P^{mn*}} \right|^2 \right) \frac{(m_{l_i}^2 - m_P^2)^2}{128 \pi m_{\tilde{\nu}_{gL}}^4} \frac{|f_P|^2 m_P^4}{m_{l_i}^3} \left(1 + \mathcal{O}\left(\frac{m_{l_k}}{m_{l_i}} \right) \right). \quad (2.14)$$

(iv) For a vector meson V decaying into a lepton of generation k' and an antilepton of generation i', there are again two cases: up-type squark-mediated:

$$\Gamma_{V \to l_{k'} + \bar{l}_{i'}} = \left| \sum_{\text{d-type}} (\lambda'_{k'gm'} \lambda'_{i'gn'}) H_V^{m'n'} \right|^2 \frac{(m_V^2 - m_{l_{i'}}^2)^2}{768 \pi m_{\tilde{u}_{gL}}^4} \frac{|f_V|^2 (2m_V^2 + m_{l_{i'}}^2)}{m_V^3} \left(1 + \mathcal{O}\left(\frac{m_{l_{k'}}}{m_V} \right) \right) \quad (2.15)$$

or down-type squark-mediated:

$$\Gamma_{V \to l_{k'} + \bar{l}_{i'}} = \left| \sum_{\text{u-type}} (\lambda'_{k'n'g} \lambda'_{i'm'g}) H_V^{m'n'} \right|^2 \frac{(m_V^2 - m_{l_{i'}}^2)^2}{768 \pi m_{\tilde{d}_{gR}}^4} \frac{|f_V|^2 (2m_V^2 + m_{l_{i'}}^2)}{m_V^3} \left(1 + \mathcal{O}\left(\frac{m_{l_{k'}}}{m_{l_{i'}}} \right) \right). \quad (2.16)$$

TABLE IX. Bounds on $(\lambda_{ijk}\lambda'_{lmn})$ continued.

$(\lambda_{ijk}\lambda'_{lmn})$		From this work			Previously published			
ijk	lmn	Bound		Decay	Bound		Decay	Key
313	311	8.5×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$\tau\to e\eta$	1.6×10^{-3}	$[\tilde{\nu}_{3L}]^2$	$\tau\to e\eta$	Upd. [39]
		7.1×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$\tau\to e\pi^0$				
313	312	9.7×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$\tau\to eK_S$	none		n/a	New
313	313	3.7×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to e\bar{\tau}$	4.9×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to e\bar{\tau}$	Corr. (<) [27]
313	321	9.7×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$\tau\to eK_S$	8.5×10^{-2}	$[\tilde{\nu}_{3L}]^2$	$\tau\to eK^0$	Upd. [39]
313	322	4.6×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$\tau\to e\eta$	1.6×10^{-2}	$[\tilde{\nu}_{3L}]^2$	$\tau\to e\eta$	Upd. [39]
313	331	3.7×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to\tau\bar{e}$	4.9×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to\tau\bar{e}$	Corr. (<) [27]
321	311	1.2×10^{-2}	$[\tilde{\nu}_{3L}]^2$	$\pi^0\to e\bar{\mu}$	2.1×10^{-8}	$[\tilde{\nu}_{3L}]^2$	$\mu\to e$ in ^{48}Ti	Unimp. [41]
		0.38	$[\tilde{\nu}_{3L}]^2$	$\eta\to\mu\bar{e}+e\bar{\mu}$				
		0.41	$[\tilde{\nu}_{3L}]^2$	$\pi^0\to\mu\bar{e}$				
		16	$[\tilde{\nu}_{3L}]^2$	$\eta'\to\mu\bar{e}/e\bar{\mu}$				
321	312	6.7×10^{-9}	$[\tilde{\nu}_{3L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	6×10^{-9}	$[\tilde{\nu}_{3L}]^3$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	†(−) Agr. [26]
321	313	1.3×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to\mu\bar{e}$	2.3×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to\mu\bar{e}$	Corr. (<) [27]
321	321	6.7×10^{-9}	$[\tilde{\nu}_{3L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	6×10^{-9}	$[\tilde{\nu}_{3L}]^3$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	†(−) Agr. [26]
321	322	2.1	$[\tilde{\nu}_{3L}]^2$	$\eta\to\mu\bar{e}+e\bar{\mu}$	none		n/a	New
		$3.6\times10^{+4}$	$[\tilde{\nu}_{3L}]^2$	$\eta'\to\mu\bar{e}/e\bar{\mu}$				
321	323	7.6×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_s^0\to\mu\bar{e}$	4.7×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_s^0\to\mu\bar{e}$	Corr. (>) [27]
321	331	1.3×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to e\bar{\mu}$	2.3×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to e\bar{\mu}$	Corr. (<) [27]
321	332	7.6×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_s^0\to e\bar{\mu}$	4.7×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_s^0\to e\bar{\mu}$	Corr. (>) [27]
322	313	6.2×10^{-6}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to\mu\bar{\mu}$	1.5×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to\mu\bar{\mu}$	Corr. (<) [27]
322	323	1.2×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_s^0\to\mu\bar{\mu}$	1.7×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to K^0\mu\bar{\mu}$	Upd. [30]
322	331	6.2×10^{-6}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to\mu\bar{\mu}$	1.5×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to\mu\bar{\mu}$	Corr. (<) [27]
322	332	1.2×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$B_s^0\to\mu\bar{\mu}$	1.8×10^{-5}	$[\tilde{\nu}_{3L}]^3$	$B_d^0\to K^0\mu\bar{\mu}$	Upd. [30]
323	311	6.7×10^{-5}	$[\tilde{\nu}_{3L}]^2$	$\tau\to\mu\eta$	1.7×10^{-3}	$[\tilde{\nu}_{3L}]^2$	$\tau\to\mu\eta$	Upd. [39]
		1.0×10^{-3}	$[\tilde{\nu}_{3L}]^2$	$\tau\to\mu\pi^0$				
323	312	1.0×10^{-3}	$[\tilde{\nu}_{3L}]^2$	$\tau\to\mu K_S$	none		n/a	New
323	313	2.2×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to\mu\bar{\tau}$	6.2×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to\mu\bar{\tau}$	Corr. (<) [27]
323	321	1.0×10^{-3}	$[\tilde{\nu}_{3L}]^2$	$\tau\to\mu K_S$	7.6×10^{-2}	$[\tilde{\nu}_{3L}]^2$	$\tau\to\mu K^0$	Upd. [39]
323	322	3.7×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$\tau\to\mu\eta$	1.7×10^{-2}	$[\tilde{\nu}_{3L}]^2$	$\tau\to\mu\eta$	Upd. [39]
323	331	2.2×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to\tau\bar{\mu}$	6.2×10^{-4}	$[\tilde{\nu}_{3L}]^2$	$B_d^0\to\mu\bar{\tau}$	Corr. (<) [27]

(v) For a pseudoscalar meson P decaying into a lepton of generation k' and an antilepton of generation i', there are again three cases: up-type squark-mediated:

$$\Gamma_{P\to l_{k'}+\bar{l}_{i'}} = \Big|\sum_{\text{d-type}} (\lambda'_{k'gm'}\lambda'_{i'gn'}) H_P^{m'n'}\Big|^2 \frac{(m_P^2 - m_{l_{i'}}^2)^2}{256\pi m_{\tilde{u}_{gL}}^4} \frac{|f_P|^2 m_{l_{i'}}^2}{m_P^3}\left(1 + \mathcal{O}\left(\frac{m_{l_{k'}}}{m_P}\right)\right), \tag{2.17}$$

down-type squark-mediated:

$$\Gamma_{P\to l_{k'}+\bar{l}_{i'}} = \Big|\sum_{\text{u-type}} (\lambda'_{k'n'g}\lambda'_{i'm'g}) H_P^{m'n'}\Big|^2 \frac{(m_P^2 - m_{l_{i'}}^2)^2}{256\pi m_{\tilde{d}_{gR}}^4} \frac{|f_P|^2 m_{l_{i'}}^2}{m_P^3}\left(1 + \mathcal{O}\left(\frac{m_{l_{k'}}}{m_P}\right)\right), \tag{2.18}$$

or sneutrino-mediated:

$$\Gamma_{P\to l_{k'}+\bar{l}_{i'}} = \left(\Big|\sum_{\text{d-type}} \lambda^*_{gi'k'}\lambda'_{gn'm'}\frac{H_P^{m'n'}}{\mu_P^{m'n'*}}\Big|^2 + \Big|\sum_{\text{d-type}} \lambda_{gk'i'}\lambda'^*_{gm'n'}\frac{H_P^{m'n'}}{\mu_P^{m'n'*}}\Big|^2\right)\frac{(m_P^2 - m_{l_{i'}}^2)^2}{64\pi m_{\tilde{\nu}_{gL}}^4}|f_P|^2 m_P\left(1 + \mathcal{O}\left(\frac{m_{l_{k'}}}{m_P}\right)\right). \tag{2.19}$$

TABLE X. Bounds on $(\lambda'_{ijk}\lambda'_{lmn})$.

$(\lambda'_{ijk}\lambda'_{lmn})$ ijk	lmn	From this work Bound		Decay	Previously published Bound		Decay	Key
111	113	2.6×10^{-2}	$[\tilde{u}_{1L}]^2$	$B_d^0\to e\bar{e}$	0.03	$[\tilde{u}_{1L}]$	APV in Cs	Unimp. [38],
					$\times 0.18$	$[\tilde{u}_{1L}]$	A_{FB}^b	[38]
111	211	0.36	$[\tilde{d}_{1R}]^2$	$\pi^0\to e\bar{\mu}$	4.5×10^{-8}	$[\tilde{d}_{1R}]^2$	$\mu\to e$ in ^{48}Ti	Unimp. [41]
		11	$[\tilde{d}_{1R}]^2$	$\pi^0\to \mu\bar{e}$				
		$1.5\times 10^{+2}$	$[\tilde{d}_{1R}]^2$	$\eta\to\mu\bar{e}+e\bar{\mu}$				
		$1.9\times 10^{+4}$	$[\tilde{d}_{1R}]^2$	$\eta'\to\mu\bar{e}/e\bar{\mu}$				
111	211	0.36	$[\tilde{u}_{1L}]^2$	$\pi^0\to e\bar{\mu}$	4.3×10^{-8}	$[\tilde{u}_{1L}]^2$	$\mu\to e$ in ^{48}Ti	Unimp. [41]
		11	$[\tilde{u}_{1L}]^2$	$\pi^0\to \mu\bar{e}$				
		$1.5\times 10^{+2}$	$[\tilde{u}_{1L}]^2$	$\eta\to\mu\bar{e}+e\bar{\mu}$				
		$1.9\times 10^{+4}$	$[\tilde{u}_{1L}]^2$	$\eta'\to\mu\bar{e}$				
111	212	2.7×10^{-7}	$[\tilde{u}_{1L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	3×10^{-7}	$[\tilde{u}_{1L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	†(−) Agr. [26]
111	213	1.6×10^{-3}	$[\tilde{u}_{1L}]^2$	$B_d^0\to e\bar{\mu}$	4.7×10^{-3}	$[\tilde{u}_{1L}]^2$	$B_d^0\to e\bar{\mu}$	Upd. [27]
111	221	2.8×10^{-2}	$[\tilde{d}_{1R}]^2$	$D^0\to e\bar{\mu}$	0.02	$[\tilde{d}_{1R}]$	APV in Cs	Unimp. [38],
					$\times 0.21$	$[\tilde{d}_{1R}]$	$\frac{\tau\to\pi^-\nu}{\pi^-\to\mu\bar{\nu}}$	[42]
111	311	1.2×10^{-3}	$[\tilde{d}_{1R}]^2$	$\tau\to e\pi^0$	0.02	$[\tilde{d}_{1R}]$	APV in Cs	Upd. [38],
		2.0×10^{-3}	$[\tilde{d}_{1R}]^2$	$\tau\to e\eta$	$\times 0.12$	$[\tilde{d}_{1R}]$	$\frac{\tau\to\pi^-\nu}{\pi^-\to\mu\bar{\nu}}$	[38]
		2.4×10^{-3}	$[\tilde{d}_{1R}]^2$	$\tau\to e\rho^0$				
111	311	1.2×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau\to e\pi^0$	2.4×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau\to e\rho^0$	Upd. [39] †(−)
		2.0×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau\to e\eta$				
		2.4×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau\to e\rho^0$				
111	312	2.3×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau\to eK_S$	none		n/a	New
		3.6×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau\to e\bar{K}^{*0}$				
111	313	2.7×10^{-3}	$[\tilde{u}_{1L}]^2$	$B_d^0\to e\bar{\tau}$	5.9×10^{-3}	$[\tilde{u}_{1L}]^2$	$B_d^0\to e\bar{\tau}$	Upd. [27]
112	113	9.3	$[\tilde{u}_{1L}]^2$	$B_s^0\to e\bar{e}$	4.3×10^{-4}	$[\tilde{u}_{1L}]^2$	$b\to se\bar{e}$	Unimp. [28]
112	211	2.7×10^{-7}	$[\tilde{u}_{1L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	3×10^{-7}	$[\tilde{u}_{1L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	†(−) Agr. [26]
112	212	0.36	$[\tilde{d}_{2R}]^2$	$\pi^0\to e\bar{\mu}$	4.5×10^{-8}	$[\tilde{d}_{2R}]^2$	$\mu\to e$ in ^{48}Ti	Unimp. [41]
		1.1	$[\tilde{d}_{2R}]^2$	$\pi^0\to\mu\bar{e}$				
		$1.6\times 10^{+2}$	$[\tilde{d}_{2R}]^2$	$\eta\to\mu\bar{e}+e\bar{\mu}$				
		$1.9\times 10^{+4}$	$[\tilde{d}_{2R}]^2$	$\eta'\to\mu\bar{e}/e\bar{\mu}$				

III. NUMERICAL RESULTS

We assume for simplicity the *double coupling dominance hypothesis*, that the bounds from any one experimental result are applied to only one product of couplings.

The input values for the various fermion and meson masses and decay constants are listed in Table I. All the f_P values and masses were taken from the 2006 edition of *Review of Particle Physics* by the Particle Data Group (PDG) [18]. The f_V values were calculated from $V \to e^+e^-$ according to

$$\Gamma(V \to e^+e^-) = \frac{4\pi}{3}\frac{\alpha^2}{m_V} f_V^2 c_V, \tag{3.1}$$

where c_V are factors determined by the electric charge of the meson's valence quarks [46]. The experimental results on lifetimes, decay widths, and branching fractions are also taken from the 2006 review of the PDG [18].

In Tables II, III, and IV we present what may be considered the most interesting results of our analysis. The coupling combinations which had no bounds previously are collected in Table II. Those combinations which have improved by a factor of 30 or more are presented in Table III, and the cases where the new combined bound is better than the previously published product of individual bounds are presented in Table IV. Here and in the following, the symbol $[\tilde{f}]$ denotes $m_{\tilde{f}}/(100\text{ GeV})$, i.e. the sfermion mass in units of 100 GeV. This also indicates the mediating sfermion for the decay. The superscript $^{\dagger(-)}$ in Table II indicates that this bound comes from a decay which involves a difference of couplings, so there could be a cancellation which would lead to the double coupling dominance hypothesis giving an excessively tight bound. While we also include very loose bounds in our listings, we note that couplings $\lambda \gtrsim \mathcal{O}(2\pi)$ would imply a breakdown of our perturbative analysis.

In Tables V, VI, VII, VIII, IX, X, XI, XII, XIII, XIV, and XV we collect all our bounds on the products of couplings $\lambda_{ijk}^{(\prime)}\lambda_{lmn}^{(\prime)}$. The results have been arranged so that the number made from reading off the indices of the couplings to make a six-digit number $ijklmn$ ascends.

In the rightmost columns of Tables V, VI, VII, VIII, IX, X, XI, XII, XIII, XIV, and XV, "New" indicates a previously unpublished result (see also Table II), "Upd." indicates that the bound has been updated and tightened in this paper, "Agr." indicates that the bound has not changed and we agree with the previously published result [47], and "Unimp." indicates that our bound from decay data is less strong than the previously published result, which in these cases is from a different experimental source (e.g. the nonobservation of $\mu \to e$ in ^{48}Ti gives a better bound on

TABLE XI. Bounds on $(\lambda'_{ijk}\lambda'_{lmn})$ continued.

$(\lambda'_{ijk}\lambda'_{lmn})$ ijk	lmn	From this work Bound		Decay	Previously published Bound		Decay	Key
112	212	76	$[\tilde{u}_{1L}]^2$	$\eta \to \mu\bar{e} + e\bar{\mu}$	none		n/a	New
		$1.1 \times 10^{+5}$	$[\tilde{u}_{1L}]^2$	$\eta' \to \mu\bar{e}$				
112	213	9.4×10^{-3}	$[\tilde{u}_{1L}]^2$	$B_s^0 \to e\bar{\mu}$	2.7×10^{-4}	$[\tilde{u}_{1L}]^2$	$b \to se\bar{\mu}$	Unimp. [28]
112	222	2.8×10^{-2}	$[\tilde{d}_{2R}]^2$	$D^0 \to e\bar{\mu}$	0.02	$[\tilde{d}_{2R}]$	APV in Cs	Unimp. [38],
					$\times 0.21$	$[\tilde{d}_{2R}]$	$\frac{\tau\to\pi^-\nu}{\pi^-\to\mu\bar{\nu}}$	[42]
112	311	2.3×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau \to eK_S$	2.7×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau \to eK^{0*}$	Upd. [39]
		2.9×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau \to eK^{*0}$				
112	312	1.2×10^{-3}	$[\tilde{d}_{2R}]^2$	$\tau \to e\pi^0$	0.02	$[\tilde{d}_{2R}]$	APV in Cs	Upd. [38],
		2.0×10^{-3}	$[\tilde{d}_{2R}]^2$	$\tau \to e\eta$	$\times 0.12$	$[\tilde{d}_{2R}]$	$\frac{\tau\to\pi^-\nu}{\pi^-\to\mu\bar{\nu}}$	[38]
		2.4×10^{-3}	$[\tilde{d}_{2R}]^2$	$\tau \to e\rho^0$				
112	312	1.2×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau \to e\eta$	none		n/a	$^{\dagger(-)}$ New
		3.4×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau \to e\phi$				
113	211	1.6×10^{-3}	$[\tilde{u}_{1L}]^2$	$B_d^0 \to \mu\bar{e}$	4.7×10^{-3}	$[\tilde{u}_{1L}]^2$	$B_d^0 \to \mu\bar{e}$	Upd. [27]
113	212	9.4×10^{-3}	$[\tilde{u}_{1L}]^2$	$B_s^0 \to \mu\bar{e}$	2.7×10^{-4}	$[\tilde{u}_{1L}]^2$	$b \to s\mu\bar{e}$	Unimp. [28]
113	213	0.36	$[\tilde{d}_{3R}]^2$	$\pi^0 \to e\bar{\mu}$	4.5×10^{-8}	$[\tilde{d}_{3R}]^2$	$\mu \to e$ in ^{48}Ti	Unimp. [41]
		11	$[\tilde{d}_{3R}]^2$	$\pi^0 \to \mu\bar{e}$				
		$1.5 \times 10^{+2}$	$[\tilde{d}_{3R}]^2$	$\eta \to \mu\bar{e} + e\bar{\mu}$				
		$1.9 \times 10^{+4}$	$[\tilde{d}_{3R}]^2$	$\eta' \to \mu\bar{e}/e\bar{\mu}$				
113	223	2.8×10^{-2}	$[\tilde{d}_{3R}]^2$	$D^0 \to e\bar{\mu}$	0.02	$[\tilde{d}_{3R}]$	APV in Cs	Unimp. [38],
					$\times 0.21$	$[\tilde{d}_{3R}]$	$\frac{\tau\to\pi^-\nu}{\pi^-\to\mu\bar{\nu}}$	[42]
113	311	2.7×10^{-3}	$[\tilde{u}_{1L}]^2$	$B_d^0 \to \tau\bar{e}$	5.9×10^{-3}	$[\tilde{u}_{1L}]^2$	$B_d^0 \to \tau\bar{e}$	Upd. [27]
113	313	1.2×10^{-3}	$[\tilde{d}_{3R}]^2$	$\tau \to e\pi^0$	0.02	$[\tilde{d}_{3R}]$	APV in Cs	Upd. [38],
		2.0×10^{-3}	$[\tilde{d}_{3R}]^2$	$\tau \to e\eta$	$\times 0.12$	$[\tilde{d}_{3R}]$	$\frac{\tau\to\pi^-\nu}{\pi^-\to\mu\bar{\nu}}$	[38]
		2.4×10^{-3}	$[\tilde{d}_{3R}]^2$	$\tau \to e\rho^0$				

TABLE XII. Bounds on $(\lambda'_{ijk}\lambda'_{lmn})$ continued.

$(\lambda'_{ijk}\lambda'_{lmn})$		From this work			Previously published			
ijk	lmn	Bound		Decay	Bound		Decay	Key
121	123	2.6×10^{-2}	$[\tilde{u}_{2L}]^2$	$B_d^0\to e\bar{e}$	0.03	$[\tilde{u}_{2L}]$	APV in Cs	Unimp. [38],
					$\times0.18$	$[\tilde{u}_{2L}]$	A_{FB}^b	[38]
121	211	9.0×10^{-3}	$[\tilde{d}_{1R}]^2$	$D^0\to\mu\bar{e}$	0.21	$[\tilde{d}_{1R}]$	A_{FB}^c	Upd. [38],
					$\times5.9\times10^{-2}$	$[\tilde{d}_{1R}]$	$\frac{\pi^-\to e\bar{\nu}}{\pi^-\to\mu\bar{\nu}}$	[36]
121	221	1.6	$[\tilde{d}_{1R}]^2$	$J/\psi\to\mu\bar{e}/e\bar{\mu}$	0.21	$[\tilde{d}_{1R}]$	A_{FB}^c	Unimp. [38],
					$\times0.21$	$[\tilde{d}_{1R}]$	$\frac{D^0\to\nu\bar{\mu}K^-}{D^0\to\nu\bar{e}K^-}$	[42]
121	221	0.36	$[\tilde{u}_{2L}]^2$	$\pi^0\to e\bar{\mu}$	4.3×10^{-8}	$[\tilde{u}_{2L}]^2$	$\mu\to e$ in ^{48}Ti	Unimp. [41]
		11	$[\tilde{u}_{2L}]^2$	$\pi^0\to\mu\bar{e}$				
		$1.5\times10^{+2}$	$[\tilde{u}_{2L}]^2$	$\eta\to\mu\bar{e}+e\bar{\mu}$				
		$1.9\times10^{+4}$	$[\tilde{u}_{2L}]^2$	$\eta'\to\mu\bar{e}$				
121	222	2.7×10^{-7}	$[\tilde{u}_{2L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	3×10^{-7}	$[\tilde{u}_{2L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	†(−) Agr. [26]
121	223	1.6×10^{-3}	$[\tilde{u}_{2L}]^2$	$B_d^0\to e\bar{\mu}$	4.7×10^{-3}	$[\tilde{u}_{2L}]^2$	$B_d^0\to e\bar{\mu}$	Upd. [27]
121	321	5.9	$[\tilde{d}_{1R}]^2$	$J/\psi\to\tau\bar{e}/e\bar{\tau}$	0.21	$[\tilde{d}_{1R}]$	A_{FB}^c	Unimp. [38],
					$\times0.52$	$[\tilde{d}_{1R}]$	$\frac{D_s^-\to\tau\bar{\nu}}{D_s^-\to\mu\bar{\nu}}$	[43]
121	321	1.2×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau\to e\pi^0$	2.4×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau\to e\rho^0$	Upd. [39] †(−)
		2.0×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau\to e\eta$				
		2.4×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau\to e\rho^0$				
121	322	2.3×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau\to eK_S$	none		n/a	New
		3.6×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau\to e\bar{K}^{*0}$				
121	323	2.7×10^{-3}	$[\tilde{u}_{2L}]^2$	$B_d^0\to e\bar{\tau}$	5.9×10^{-3}	$[\tilde{u}_{2L}]^2$	$B_d^0\to e\bar{\tau}$	Upd. [27]
122	123	4.1	$[\tilde{u}_{2L}]^2$	$B_s^0\to e\bar{e}$	4.3×10^{-4}	$[\tilde{u}_{2L}]^2$	$b\to se\bar{e}$	Unimp. [28]
122	212	9.0×10^{-3}	$[\tilde{d}_{2R}]^2$	$D^0\to\mu\bar{e}$	0.21	$[\tilde{d}_{2R}]$	A_{FB}^c	Upd. [38],
					$\times5.9\times10^{-2}$	$[\tilde{d}_{2R}]$	$\frac{\pi^-\to e\bar{\nu}}{\pi^-\to\mu\bar{\nu}}$	[36]
122	221	2.7×10^{-7}	$[\tilde{u}_{2L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	3×10^{-7}	$[\tilde{u}_{2L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	†(−) Agr. [26]
122	222	1.6	$[\tilde{d}_{2R}]^2$	$J/\psi\to\mu\bar{e}/e\bar{\mu}$	0.21	$[\tilde{d}_{1R}]$	A_{FB}^c	Unimp. [38],
					$\times0.21$	$[\tilde{d}_{1R}]$	$\frac{D^0\to\nu\bar{\mu}K^-}{D^0\to\nu\bar{e}K^-}$	[42]
122	222	76	$[\tilde{u}_{2L}]^2$	$\eta\to\mu\bar{e}+e\bar{\mu}$	none		n/a	New
		$1.1\times10^{+5}$	$[\tilde{u}_{2L}]^2$	$\eta'\to\mu\bar{e}$				

$\lambda_{121}\lambda'_{111}\tilde{\nu}_{1L}^2$ than that of $\pi^0\to e\bar{\mu}$). "Corr." indicates that we disagree with the previously published result [48], "Corr.($<$)" indicates that our result is stronger than the incorrect previous bound, and "Corr.($>$)" indicates that our result is less strong. The reference in this column gives the previous published bound. Where two references are given, the comparison is between our bound on a product of two couplings and the product of the bounds on individual couplings.

Note that the $B\to l\bar{l}$ decays can proceed through standard model interactions [49]. However, the SM contribution is suppressed by a small Cabibbo-Kobayashi-Maskawa (CKM) matrix element and by the decay only arising at one-loop level and has thus been neglected in our analysis.

IV. DISCUSSION

The bounds presented here generally update those presented in the literature, with the noted disagreement with some of the bounds coming from the B meson data. Many bounds have been improved, some through tighter experimental decay bounds like those from τ decays, others through using $\tau\to K_S l^-$ instead of $\tau\to K^0 l^-$, which also leads to some previously unpublished bounds. The η decay data was also previously unpublished, but does not seem particularly useful, with bounds of order $10^2\tilde{f}^2$. The decay $\tau\to\eta l^-$ seems to give previously unpublished bounds too, which are more stringent. The decay $\tau\to\phi l^-$ leads to bounds which are less strong than those from $\tau\to\eta l^-$. Note, however, that $\tau\to\phi l^-$ is free from potential interference effects induced by the coupling of the mediating squark to both down and strange quarks.

Assuming that the sfermion masses are of order 100 GeV and taking the square root of the bound on a coupling product to be a rough guide to the bound on each coupling gives an estimate of the couplings λ being of order 0.01, apart from the very tight bounds from the nonobservation of $\mu\to ee\bar{e}$. The bounds on the couplings λ' vary considerably, though those involving a third gen-

TABLE XIII. Bounds on $(\lambda'_{ijk}\lambda'_{lmn})$ continued.

$(\lambda'_{ijk}\lambda'_{lmn})$		From this work			Previously published			
ijk	lmn	Bound		Decay	Bound		Decay	Key
122	223	9.4×10^{-3}	$[\tilde{u}_{2L}]^2$	$B_s^0\to e\bar{\mu}$	2.7×10^{-4}	$[\tilde{u}_{2L}]^2$	$b\to se\bar{\mu}$	Unimp. [28]
122	321	2.3×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau\to eK_S$	2.7×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau\to eK^{0*}$	Upd. [39]
		2.9×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau\to eK^{*0}$				
122	322	5.9	$[\tilde{d}_{2R}]^2$	$J/\psi\to\tau\bar{e}/e\bar{\tau}$	0.21	$[\tilde{d}_{2R}]$	A_{FB}^c	Unimp. [38],
					$\times0.52$	$[\tilde{d}_{2R}]$	$\frac{D_s^-\to\tau\bar{\nu}}{D_s^-\to\mu\bar{\nu}}$	[43]
122	322	1.2×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau\to e\eta$	none		n/a	†(−) New
		3.4×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau\to e\phi$				
123	213	9.0×10^{-3}	$[\tilde{d}_{3R}]^2$	$D^0\to\mu\bar{e}$	0.21	$[\tilde{d}_{3R}]$	A_{FB}^c	Upd. [38],
					$\times5.9\times10^{-2}$	$[\tilde{d}_{3R}]$	$\frac{\pi^-\to e\bar{\nu}}{\pi^-\to\mu\bar{\nu}}$	[36]
123	221	1.6×10^{-3}	$[\tilde{u}_{2L}]^2$	$B_d^0\to\mu\bar{e}$	4.7×10^{-3}	$[\tilde{u}_{2L}]^2$	$B_d^0\to\mu\bar{e}$	Upd. [27]
123	222	9.4×10^{-3}	$[\tilde{u}_{2L}]^2$	$B_s^0\to\mu\bar{e}$	2.7×10^{-4}	$[\tilde{u}_{2L}]^2$	$b\to s\mu\bar{e}$	Unimp. [28]
123	223	1.6	$[\tilde{d}_{3R}]^2$	$J/\psi\to\mu\bar{e}/e\bar{\mu}$	0.21	$[\tilde{d}_{3R}]$	A_{FB}^c	Unimp. [38],
					$\times0.21$	$[\tilde{d}_{1R}]$	$\frac{D^0\to\nu\bar{\mu}K^-}{D^0\to\nu\bar{e}K^-}$	[42]
123	321	2.7×10^{-3}	$[\tilde{u}_{2L}]^2$	$B_d^0\to\tau\bar{e}$	5.9×10^{-3}	$[\tilde{u}_{2L}]^2$	$B_d^0\to\tau\bar{e}$	Upd. [27]
123	323	5.9	$[\tilde{d}_{3R}]^2$	$J/\psi\to\tau\bar{e}/e\bar{\tau}$	0.21	$[\tilde{d}_{3R}]$	A_{FB}^c	Unimp. [38],
					$\times0.52$	$[\tilde{d}_{3R}]$	$\frac{D_s^-\to\tau\bar{\nu}}{D_s^-\to\mu\bar{\nu}}$	[43]
131	133	2.6×10^{-2}	$[\tilde{u}_{3L}]^2$	$B_d^0\to e\bar{e}$	0.03	$[\tilde{u}_{3L}]$	APV in Cs	Unimp. [38],
					$\times0.18$	$[\tilde{u}_{3L}]$	A_{FB}^b	[38]
131	231	0.36	$[\tilde{u}_{3L}]^2$	$\pi^0\to e\bar{\mu}$	4.3×10^{-8}	$[\tilde{u}_{3L}]^2$	$\mu\to e$ in ^{48}Ti	Unimp. [41]
		11	$[\tilde{u}_{3L}]^2$	$\pi^0\to\mu\bar{e}$				
		$1.5\times10^{+2}$	$[\tilde{u}_{3L}]^2$	$\eta\to\mu\bar{e}+e\bar{\mu}$				
		$1.9\times10^{+4}$	$[\tilde{u}_{3L}]^2$	$\eta'\to\mu\bar{e}$				
131	232	2.7×10^{-7}	$[\tilde{u}_{3L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	3×10^{-7}	$[\tilde{u}_{3L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	†(−) Agr. [26]
131	233	1.6×10^{-3}	$[\tilde{u}_{3L}]^2$	$B_d^0\to e\bar{\mu}$	4.7×10^{-3}	$[\tilde{u}_{3L}]^2$	$B_d^0\to e\bar{\mu}$	Upd. [27]
131	331	1.2×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau\to e\pi^0$	2.4×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau\to e\rho^0$	Upd. [39] †(−)
		2.0×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau\to e\eta$				
		2.4×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau\to e\rho^0$				
131	332	2.3×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau\to eK_S$	none		n/a	New
		3.6×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau\to e\bar{K}^{*0}$				
131	333	2.7×10^{-3}	$[\tilde{u}_{3L}]^2$	$B_d^0\to e\bar{\tau}$	5.9×10^{-3}	$[\tilde{u}_{3L}]^2$	$B_d^0\to e\bar{\tau}$	Upd. [27]
132	133	4.1	$[\tilde{u}_{3L}]^2$	$B_s^0\to e\bar{e}$	4.3×10^{-4}	$[\tilde{u}_{3L}]^2$	$b\to se\bar{e}$	Unimp. [28]

eration quark are consistently of order 0.01. Since these come from B meson decays, they are likely to become even tighter with more data from B factories.

APPENDIX A: MESON DECAY CONSTANTS

We have defined the decay constants of vector and pseudoscalar mesons through

$$\langle 0|\bar{q}_\alpha\gamma^\mu q_\beta|V(p_V)\rangle \equiv H_V^{\alpha\beta} f_V m_V \epsilon_V^\mu \tag{A1}$$

and

$$\langle 0|\bar{q}_\alpha\gamma^\mu\gamma^5 q_\beta|P(p_P)\rangle \equiv iH_P^{\alpha\beta} f_P p_P^\mu, \tag{A2}$$

where $H_{V/P}^{\alpha\beta}$ is the coefficient of $\bar{q}_\alpha q_\beta$ in the quark model wave function of the meson. As $H_{V/P}^{\alpha\beta}$ is not standard notation we shall describe it in some detail. First, it is only of relevance to the light mesons composed of u, d, s quarks, as it is assumed that the charmed and bottom meson wave functions consist entirely of one quark bilinear, e.g. D^0 is entirely $\bar{d}c$, so $H_{D^0}^{dc}=1$ and all other $H_{D^0}^{\alpha\beta}=0$. Hence for mesons which are not part of the light $SU(3)_{uds}$ octet or singlet, $H_{V/P}^{\alpha\beta}=1$ for the relevant α and β. Similarly for the charged light mesons, e.g. K^+ is entirely $\bar{s}u$, hence $H_{K^+}^{su}=1$. For the neutral light mesons, we obtain $H_P^{\alpha\beta}$ from the standard PDG [18] definition of the pseudoscalar decay constant

$$\sqrt{2}\langle 0|\bar{q}\gamma^\mu\gamma^5\frac{\lambda^a}{2}q|P^b(p)\rangle = i\delta^{ab}f_P p^\mu, \tag{A3}$$

where q is the vector $q=(u,d,s)^T$, and a, b are SU(3)-flavor indices. $P^b(p)=\bar{q}\lambda^b q$ denotes a basis vector of the eight-dimensional representation of flavor SU(3), and λ^a are the Gell-Mann matrices (normalized such that

TABLE XIV. Bounds on $(\lambda'_{ijk}\lambda'_{lmn})$ continued.

$(\lambda'_{ijk}\lambda'_{lmn})$		From this work			Previously published			
ijk	lmn	Bound		Decay	Bound		Decay	Key
132	231	2.7×10^{-7}	$[\tilde{u}_{3L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	3×10^{-7}	$[\tilde{u}_{3L}]^2$	$K_L^0\to\mu\bar{e}/e\bar{\mu}$	$^{\dagger(-)}$ Agr. [26]
132	232	76	$[\tilde{u}_{3L}]^2$	$\eta\to\mu\bar{e}+e\bar{\mu}$	none		n/a	New
		$1.1\times10^{+5}$	$[\tilde{u}_{3L}]^2$	$\eta'\to\mu\bar{e}$				
132	233	9.4×10^{-3}	$[\tilde{u}_{3L}]^2$	$B_s^0\to e\bar{\mu}$	2.7×10^{-4}	$[\tilde{u}_{3L}]^2$	$b\to se\bar{\mu}$	Unimp. [28]
132	331	2.3×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau\to eK_S$	2.7×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau\to eK^{0*}$	Upd. [39]
		$2.9\times10^{-3}[\tilde{u}_{3L}]^2$	$[\tilde{u}_{3L}]^2$	$\tau\to eK^{*0}$				
132	332	1.2×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau\to e\eta$	none		n/a	$^{\dagger(-)}$ New
		3.4×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau\to e\phi$				
133	231	1.6×10^{-3}	$[\tilde{u}_{3L}]^2$	$B_d^0\to\mu\bar{e}$	4.7×10^{-3}	$[\tilde{u}_{3L}]^2$	$B_d^0\to\mu\bar{e}$	Upd. [27]
133	232	9.4×10^{-3}	$[\tilde{u}_{3L}]^2$	$B_s^0\to\mu\bar{e}$	2.7×10^{-4}	$[\tilde{u}_{3L}]^2$	$b\to s\mu\bar{e}$	Unimp. [28]
133	331	2.7×10^{-3}	$[\tilde{u}_{3L}]^2$	$B_d^0\to\tau\bar{e}$	5.9×10^{-3}	$[\tilde{u}_{3L}]^2$	$B_d^0\to\tau\bar{e}$	Upd. [27]
211	213	5.4×10^{-4}	$[\tilde{u}_{1L}]^2$	$B_d^0\to\mu\bar{\mu}$	2.1×10^{-3}	$[\tilde{u}_{1L}]^2$	$B_d^0\to\mu\bar{\mu}$	Upd. [27]
211	311	1.6×10^{-3}	$[\tilde{d}_{1R}]^2$	$\tau\to\mu\eta$	4.4×10^{-3}	$[\tilde{d}_{1R}]^2$	$\tau\to\mu\rho^0$	Upd. [39]
		1.8×10^{-3}	$[\tilde{d}_{1R}]^2$	$\tau\to\mu\pi^0$				
		4.3×10^{-3}	$[\tilde{d}_{1R}]^2$	$\tau\to\mu\rho^0$				
211	311	1.6×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau\to\mu\eta$	4.4×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau\to\mu\rho^0$	$^{\dagger(-)}$ Upd. [39]
		1.8×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau\to\mu\pi^0$				
		4.3×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau\to\mu\rho^0$				
211	312	2.4×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau\to\mu K_S$	none		n/a	New
		3.6×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau\to\mu\bar{K}^{*0}$				
211	313	1.6×10^{-3}	$[\tilde{u}_{1L}]^2$	$B_d^0\to\mu\bar{\tau}$	7.3×10^{-3}	$[\tilde{u}_{1L}]^2$	$B_d^0\to\mu\bar{\tau}$	Upd. [27]
212	213	1.0×10^{-3}	$[\tilde{u}_{1L}]^2$	$B_s^0\to\mu\bar{\mu}$	4.6×10^{-5}	$[\tilde{u}_{1L}]^2$	$B_d^0\to K^0\mu\bar{\mu}$	Unimp. [30]
212	311	2.4×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau\to\mu K_S$	3.4×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau\to\mu K^{0*}$	Upd. [39]
		3.6×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau\to\mu K^{*0}$				
212	312	1.6×10^{-3}	$[\tilde{d}_{2R}]^2$	$\tau\to\mu\eta$	4.4×10^{-3}	$[\tilde{d}_{2R}]^2$	$\tau\to\mu\rho^0$	Upd. [39]
		1.8×10^{-3}	$[\tilde{d}_{2R}]^2$	$\tau\to\mu\pi^0$				
		4.3×10^{-3}	$[\tilde{d}_{2R}]^2$	$\tau\to\mu\rho^0$				
212	312	9.2×10^{-4}	$[\tilde{u}_{1L}]^2$	$\tau\to\mu\eta$	none		n/a	$^{\dagger(-)}$ New
		3.4×10^{-3}	$[\tilde{u}_{1L}]^2$	$\tau\to\mu\phi$				
213	311	1.6×10^{-3}	$[\tilde{u}_{1L}]^2$	$B_d^0\to\tau\bar{\mu}$	7.3×10^{-3}	$[\tilde{u}_{1L}]^2$	$B_d^0\to\tau\bar{\mu}$	Upd. [27]
213	313	1.6×10^{-3}	$[\tilde{d}_{3R}]^2$	$\tau\to\mu\eta$	4.4×10^{-3}	$[\tilde{d}_{3R}]^2$	$\tau\to\mu\rho^0$	Upd. [39]
		1.8×10^{-3}	$[\tilde{d}_{3R}]^2$	$\tau\to\mu\pi^0$				
		4.3×10^{-3}	$[\tilde{d}_{3R}]^2$	$\tau\to\mu\rho^0$				

$\mathrm{tr}(\lambda^a\lambda^b)=2\delta^{ab}$; also here λ^0 is defined as $\sqrt{2/3}$ times the three-by-three identity matrix). To relate (A2) and (A3) we note that the quark bilinears $\bar{q}_\alpha q_\beta$ can be written as linear combinations of $\bar{q}\lambda^a q$, so that

$$\langle 0|\bar{q}_\alpha\gamma^\mu\gamma^5 q_\beta|P^b(p)\rangle=\sum_a C^a_{\alpha\beta}\langle 0|\bar{q}\gamma^\mu\gamma^5\frac{\lambda^a}{2}q|P^b(p)\rangle = C^b_{\alpha\beta}\frac{i}{\sqrt{2}}f_P p_\mu. \quad (A4)$$

Expressing the physical meson states $|P\rangle$ in terms of the basis states $|P^b\rangle$, we arrive at the generic equation (A2), where the coefficients $H^{\alpha\beta}_{P^a}$ are given as $C^a_{\alpha\beta}/\sqrt{2}$.

Let us consider a specific example and determine $\langle 0|\bar{u}\gamma^\mu\gamma^5 u|\pi^0\rangle$. We find

$$\langle 0|\bar{u}\gamma^\mu\gamma^5 u|\pi^0(p)\rangle=\langle 0|\bar{q}\left(\sqrt{\frac{2}{3}}\frac{\lambda^0}{2}+\frac{\lambda^3}{2}+\frac{\sqrt{2}}{\sqrt{3}}\frac{\lambda^8}{2}\right)q|P^3(p)\rangle = \frac{i}{\sqrt{2}}f_\pi p_\mu \quad (A5)$$

and hence $H^{uu}_{\pi^0}=1/\sqrt{2}$. Note that with our definition (A3) $f_\pi=130$ MeV.

In our numerical analysis we take into account η^0-η^8 mixing, so η and η' are not exactly $(\bar{u}u+\bar{d}d-2\bar{s}s)/\sqrt{6}$ and $(\bar{u}u+\bar{d}d+\bar{s}s)/\sqrt{3}$, but mixtures with a mixing angle $\theta_\eta=-11.5°=0.052$ radians [18], e.g. $\langle 0|\bar{s}\gamma^5\gamma^\mu s|\eta(p)\rangle=i[\cos(\theta_\eta)H^{ss}_{\eta_8}f_{\eta_8}-\sin(\theta_\eta)H^{ss}_{\eta_0}f_{\eta_0}]p^\mu$. For ϕ and ω we assume ideal mixing, so that $\phi=\bar{s}s$ and $\omega=(\bar{u}u+\bar{d}d)/\sqrt{2}$. The nontrivial coefficients $H^{\alpha\beta}_P$ can be read off the quark bilinear coefficients listed in

TABLE XV. Bounds on $(\lambda'_{ijk}\lambda'_{lmn})$ continued.

$(\lambda'_{ijk}\lambda'_{lmn})$		From this work			Previously published			
ijk	lmn	Bound		Decay	Bound		Decay	Key
221	223	5.4×10^{-4}	$[\tilde{u}_{2L}]^2$	$B_d^0 \to \mu\bar{\mu}$	2.1×10^{-3}	$[\tilde{u}_{2L}]^2$	$B_d^0 \to \mu\bar{\mu}$	Upd. [27]
221	321	2.9	$[\tilde{d}_{1R}]^2$	$J/\psi \to \tau\bar{\mu}/\mu\bar{\tau}$	0.21	$[\tilde{d}_{1R}]$	$\frac{D^0\to\nu\bar{\mu}K^-}{D^0\to\nu\bar{e}K^-}$	Unimp. [42],
					$\times 0.52$	$[\tilde{d}_{1R}]$	$\frac{D_s^-\to\tau\bar{\nu}}{D_s^-\to\mu\bar{\nu}}$	[43]
221	321	1.6×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau \to \mu\eta$	4.4×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau \to \mu\rho^0$	$\dagger(-)$ Upd. [39]
		1.8×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau \to \mu\pi^0$				
		4.3×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau \to \mu\rho^0$				
221	322	2.4×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau \to \mu K_S$	none		n/a	New
		3.6×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau \to \mu\bar{K}^{*0}$				
221	323	1.6×10^{-3}	$[\tilde{u}_{2L}]^2$	$B_d^0 \to \mu\bar{\tau}$	7.3×10^{-3}	$[\tilde{u}_{2L}]^2$	$B_d^0 \to \mu\bar{\tau}$	Upd. [27]
222	223	1.0×10^{-3}	$[\tilde{u}_{2L}]^2$	$B_s^0 \to \mu\bar{\mu}$	4.6×10^{-5}	$[\tilde{u}_{2L}]^2$	$B_d^0 \to K^0\mu\bar{\mu}$	Unimp. [30]
222	321	2.4×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau \to \mu K_S$	3.4×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau \to \mu K^{0*}$	Upd. [39]
		3.6×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau \to \mu K^{*0}$				
222	322	2.9	$[\tilde{d}_{2R}]^2$	$J/\psi \to \tau\bar{\mu}/\mu\bar{\tau}$	0.21	$[\tilde{d}_{2R}]$	$\frac{D^0\to\nu\bar{\mu}K^-}{D^0\to\nu\bar{e}K^-}$	Unimp. [42],
					$\times 0.52$	$[\tilde{d}_{2R}]$	$\frac{D_s^-\to\tau\bar{\nu}}{D_s^-\to\mu\bar{\nu}}$	[43]
222	322	9.2×10^{-4}	$[\tilde{u}_{2L}]^2$	$\tau \to \mu\eta$	none		n/a	$\dagger(-)$ New
		3.4×10^{-3}	$[\tilde{u}_{2L}]^2$	$\tau \to \mu\phi$				
223	321	1.6×10^{-3}	$[\tilde{u}_{2L}]^2$	$B_d^0 \to \tau\bar{\mu}$	7.3×10^{-3}	$[\tilde{u}_{2L}]^2$	$B_d^0 \to \tau\bar{\mu}$	Upd. [27]
223	323	2.9	$[\tilde{d}_{3R}]^2$	$J/\psi \to \tau\bar{\mu}/\mu\bar{\tau}$	0.21	$[\tilde{d}_{3R}]$	$\frac{D^0\to\nu\bar{\mu}K^-}{D^0\to\nu\bar{e}K^-}$	Unimp. [42],
					$\times 0.52$	$[\tilde{d}_{3R}]$	$\frac{D_s^-\to\tau\bar{\nu}}{D_s^-\to\mu\bar{\nu}}$	[43]
231	233	5.4×10^{-4}	$[\tilde{u}_{3L}]^2$	$B_d^0 \to \mu\bar{\mu}$	2.1×10^{-3}	$[\tilde{u}_{3L}]^2$	$B_d^0 \to \mu\bar{\mu}$	Upd. [27]
231	331	1.6×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau \to \mu\eta$	4.4×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau \to \mu\rho^0$	$\dagger(-)$ Upd. [39]
		1.8×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau \to \mu\pi^0$				
		4.3×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau \to \mu\rho^0$				
231	332	2.4×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau \to \mu K_S$	none		n/a	New
		3.6×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau \to \mu\bar{K}^{*0}$				
231	333	1.6×10^{-3}	$[\tilde{u}_{3L}]^2$	$B_d^0 \to \mu\bar{\tau}$	7.3×10^{-3}	$[\tilde{u}_{3L}]^2$	$B_d^0 \to \mu\bar{\tau}$	Upd. [27]
232	233	1.0×10^{-3}	$[\tilde{u}_{3L}]^2$	$B_s^0 \to \mu\bar{\mu}$	4.6×10^{-5}	$[\tilde{u}_{3L}]^2$	$B_d^0 \to K^0\mu\bar{\mu}$	Unimp. [30]
232	331	2.4×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau \to \mu K_S$	3.4×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau \to \mu K^{0*}$	Upd. [39]
		3.6×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau \to \mu K^{*0}$				
232	332	9.2×10^{-4}	$[\tilde{u}_{3L}]^2$	$\tau \to \mu\eta$	none		n/a	$\dagger(-)$ New
		3.4×10^{-3}	$[\tilde{u}_{3L}]^2$	$\tau \to \mu\phi$				
233	331	1.6×10^{-3}	$[\tilde{u}_{3L}]^2$	$B_d^0 \to \tau\bar{\mu}$	7.3×10^{-3}	$[\tilde{u}_{3L}]^2$	$B_d^0 \to \tau\bar{\mu}$	Upd. [27]

Table XVI. The $H_V^{\alpha\beta}$ are defined to be the same as the $H_P^{\alpha\beta}$ for their pseudoscalar counterparts.

Let us now discuss the derivation of the pseudoscalar matrix element from the axial vector matrix element (A2) in its general form

$$\sqrt{2}\langle 0|A_\mu^a(x)|P^b(p)\rangle = i\delta^{ab} f_P p_\mu \exp(-ip\cdot x), \tag{A6}$$

with $A_\mu^a = \bar{q}\gamma_\mu\gamma^5\frac{1}{2}\lambda^a q$. Applying ∂^μ to both sides leads to

$$\sqrt{2}\langle 0|\partial^\mu A_\mu^a|P^b(p)\rangle = \delta^{ab} f_P m_P^2 \exp(-ip\cdot x). \tag{A7}$$

Now

$$\partial^\mu A_\mu^a = \partial^\mu\left(\bar{q}\gamma_\mu\gamma^5\frac{1}{2}\lambda^a q\right) = \left(\bar{q}\overleftarrow{\not\partial}\gamma^5\frac{1}{2}\lambda^a q + \bar{q}\not\partial\gamma^5\frac{1}{2}\lambda^a q\right) = \bar{q}\gamma^5\frac{i}{2}\{\lambda^a, M\}q \tag{A8}$$

TABLE XVI. Nontrivial quark bilinear coefficients.

π^0	$\frac{1}{\sqrt{2}}(\bar{u}u - \bar{d}d)$
K_S	$\frac{1}{\sqrt{2}}(\bar{s}d + \bar{d}s)$
K_L	$\frac{1}{\sqrt{2}}(\bar{s}d - \bar{d}s)$
η	$0.515(\bar{u}u + \bar{d}d) - 0.685\bar{s}s$
η'	$0.484(\bar{u}u + \bar{d}d) + 0.729\bar{s}s$
ϕ	$\bar{s}s$

assuming that the quark fields satisfy the Dirac equation, and M here is defined as

$$M = \begin{pmatrix} m_u & 0 & 0 \\ 0 & m_d & 0 \\ 0 & 0 & m_s \end{pmatrix}. \qquad \text{(A9)}$$

Combining this result with Eq. (A7) at $x = 0$ leads to

$$\langle 0|\bar{q}\gamma^5 \frac{1}{2}\{\lambda^a, M\}q|P^b(p)\rangle = \frac{-i}{\sqrt{2}}\delta^{ab} f_P m_P^2. \qquad \text{(A10)}$$

Since

$$\langle 0|\bar{q}_\alpha\gamma^5(m_{q_\alpha} + m_{q_\beta})q_\beta|P^b(p)\rangle = \sum_a C^a_{\alpha\beta}\langle 0|\bar{q}\gamma^5\frac{1}{2}\{\lambda^a, M\}q|P^b(p)\rangle = C^b_{\alpha\beta}\frac{-i}{\sqrt{2}} f_P m_P^2, \qquad \text{(A11)}$$

where $C^a_{\alpha\beta}$ is defined such that $\bar{q}_\alpha q_\beta = C^a_{\alpha\beta}\bar{q}\frac{\lambda^a}{2}q$, we arrive at

$$\langle 0|\bar{q}_\alpha\gamma^5 q_\beta|P^b(p)\rangle = \frac{C^b_{\alpha\beta}}{(m_{q_\alpha} + m_{q_\beta})}\frac{-i}{\sqrt{2}} f_P p^2. \qquad \text{(A12)}$$

By comparison with Eq. (2.7), $\mu_P^{\alpha\beta}$ is identified as

$$\mu_P^{\alpha\beta} \equiv \frac{-H_P^{\alpha\beta}\sqrt{2}(m_{q_\alpha} + m_{q_\beta})}{C^b_{\alpha\beta}}. \qquad \text{(A13)}$$

Take the neutral pion as an example:

$$\begin{aligned} 2m_u\langle 0|\bar{u}\gamma^5 u|\pi^0(p)\rangle &= \langle 0|\bar{q}\gamma^5\left\{\left(\sqrt{\frac{2}{3}}\frac{\lambda^0}{2} + \frac{\lambda^3}{2} + \frac{1}{\sqrt{3}}\frac{\lambda^8}{2}\right), M\right\}q|P^3(p)\rangle \\ &= \frac{-i}{\sqrt{2}} f_\pi m_\pi^2, \end{aligned} \qquad \text{(A14)}$$

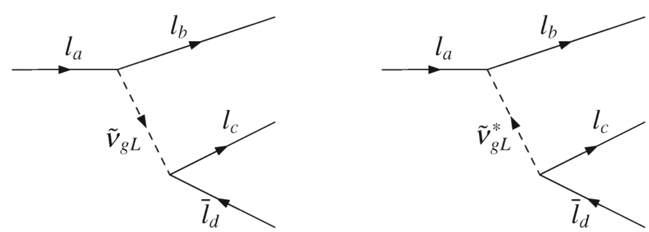
so that $\mu^{uu}_{\pi^0} = -2m_u$ and analogously $\mu^{dd}_{\pi^0} = 2m_d$. We note that this result is in disagreement with [50].

APPENDIX B: FEYNMAN GRAPHS AND MATRIX ELEMENTS

In this appendix we present the Feynman graphs and matrix elements of the various decays.

1. Charged lepton decaying into two charged leptons and one charged antilepton

This process proceeds through the exchange of a sneutrino $\tilde{\nu}_{gL}$ in the t and u channels:



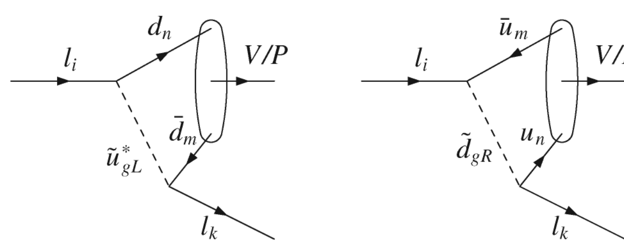
The matrix element for this decay is given by

$$\begin{aligned} i\mathcal{M}_{a\to bc\bar{d}} &= \langle l_b(p_{l_b}), l_c(p_{l_c}), \bar{l}_d(p_{\bar{l}_d})|[\bar{l}_k i\lambda_{jik}P_L l_i\tilde{\nu}_{jL}][\bar{l}_l i\lambda^*_{mln}P_R l_n\tilde{\nu}^*_{mL}]|l_a(p_{l_a})\rangle \\ &= \frac{i}{m^2_{\tilde{\nu}_{gL}}}([\bar{u}(p_{l_b})\lambda^*_{gba}P_R u(p_{l_a})][\bar{u}(p_{l_c})\lambda_{gdc}P_L v(p_{\bar{l}_d})] - [\bar{u}(p_{l_b})\lambda_{gdb}P_L v(p_{\bar{l}_d})][\bar{u}(p_{l_c})\lambda^*_{gca}P_R u(p_{l_a})] \\ &\quad - [\bar{u}(p_{l_c})\lambda_{gac}P_L u(p_{l_a})][\bar{u}(p_{l_b})\lambda^*_{gbd}P_R v(p_{\bar{l}_d})] + [\bar{u}(p_{l_b})\lambda_{gab}P_L u(p_{l_a})][\bar{u}(p_{l_c})\lambda^*_{gcd}P_R v(p_{\bar{l}_d})]). \end{aligned} \qquad \text{(B1)}$$

For the case where the final-state leptons are identical, the matrix element is the same, with $b = c$, but the phase space picks up a factor of $\frac{1}{2}$ to avoid overcounting identical phase-space configurations.

2. Charged lepton decays into a charged lepton and a neutral vector meson

Charged leptons can decay into a vector meson and a charged lepton through the exchange of a left-handed up-type squark or a right-handed down-type squark:



The matrix element for this process is given by

$$i\mathcal{M}_{l_i\to l_k+V} = \langle \text{out states}|([-i\lambda'_{ijn}\bar{d}_{nR}l_{iL}\tilde{u}_{jL}] \times [-i\lambda'^{*}_{ktm}\bar{l}_{kL}d_{mR}\tilde{u}^{*}_{tL}] + [-i\lambda'_{imj}l_{iL}u_{mL}\tilde{d}_{jR}] \times [-i\lambda'^{*}_{knt}\bar{u}_{nL}\bar{l}_{kL}\tilde{d}^{*}_{tR}])|\text{in states}\rangle. \quad \text{(B2)}$$

After some use of Fierz identities we find

$$i\mathcal{M}_{l_i\to l_k+V} = \langle \text{out states}|\tfrac{1}{4}[\lambda'_{ijn}\lambda'^{*}_{ktm}\tilde{u}_{jL}\tilde{u}^{*}_{tL}\bar{d}_n(\gamma^\mu+\gamma^\mu\gamma^5)d_m - \lambda'_{imj}\lambda'^{*}_{knt}\tilde{d}_{jR}\tilde{d}^{*}_{tR}\bar{u}_n(\gamma^\mu-\gamma^\mu\gamma^5)u_m] \times [\bar{l}_kP_R\gamma_\mu l_i]|\text{in states}\rangle. \quad \text{(B3)}$$

Contracting the meson state with the quark bilinear results in

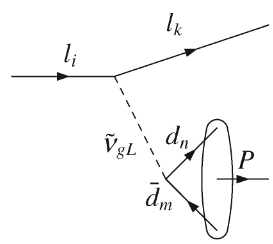
$$\begin{aligned} i\mathcal{M}_{l_i\to l_k+V} &= \langle \text{leptons out}|\frac{1}{4}\bigg[\sum_{\text{d-type}}\lambda'_{ijn}\lambda'^{*}_{ktm}H_V^{mn*}\tilde{u}_{jL}\tilde{u}^{*}_{tL} - \sum_{\text{u-type}}\lambda'_{imj}\lambda'^{*}_{knt}H_V^{mn*}\tilde{d}_{jR}\tilde{d}^{*}_{tR}\bigg][\bar{l}_kP_R\gamma_\mu l_i]|\text{leptons in}\rangle f_V^* m_V\epsilon_V^{\mu*} \\ &= \frac{1}{4}\bigg[\sum_{\text{d-type}}\lambda'_{ign}\lambda'^{*}_{kgm}H_V^{mn*}\bigg(\frac{-i}{m^2_{\tilde{u}_{gL}}}\bigg) - \sum_{\text{u-type}}\lambda'_{img}\lambda'^{*}_{kng}H_V^{mn*}\bigg(\frac{-i}{m^2_{\tilde{d}_{gR}}}\bigg)\bigg][\bar{u}(p_{l_k})P_R\gamma^\mu u(p_{l_i})]f_V^* m_V\epsilon^*_{V\mu}, \end{aligned} \quad \text{(B4)}$$

where we have introduced the notation $\sum_{\text{d-type}}$ to mean only summing over the down-type quarks in the meson and $\sum_{\text{u-type}}$ to mean summing over the up-type quarks. The m and n in H_V^{mn} are the generation indices of the appropriate quarks and can be used in standard summation convention with the m and n appearing in the coupling indices. For example, for the decay $\tau\to e\rho^0$, we have

$$\begin{aligned} i\mathcal{M}_{\tau\to e\rho^0} &= \frac{1}{4}\bigg[\sum_{\text{d-type}}\lambda'_{3gn}\lambda'^{*}_{1gm}H_{\rho^0}^{mn*}\bigg(\frac{-i}{m^2_{\tilde{u}_{gL}}}\bigg) - \sum_{\text{u-type}}\lambda'_{3mg}\lambda'^{*}_{1ng}H_{\rho^0}^{mn*}\bigg(\frac{-i}{m^2_{\tilde{d}_{gR}}}\bigg)\bigg][\bar{u}(p_e)P_R\gamma^\mu u(p_\tau)]f^*_{\rho^0}m_{\rho^0}\epsilon^*_{\rho^0\mu} \\ &= \frac{-1}{4}\bigg[(\lambda'_{3g1}\lambda'^{*}_{1g1}H_{\rho^0}^{dd*} + \lambda'_{3g1}\lambda'^{*}_{1g2}H_{\rho^0}^{ds*} + \lambda'_{3g1}\lambda'^{*}_{1g3}H_{\rho^0}^{db*} + \lambda'_{3g2}\lambda'^{*}_{1g1}H_{\rho^0}^{sd*} + \ldots)\frac{i}{m^2_{\tilde{u}_{gL}}} \\ &\quad - (\lambda'_{31g}\lambda'^{*}_{11g}H_{\rho^0}^{uu*} + \lambda'_{31g}\lambda'^{*}_{12g}H_{\rho^0}^{uc*} + \ldots)\frac{i}{m^2_{\tilde{d}_{gR}}}\bigg][\bar{u}(p_e)P_R\gamma^\mu u(p_\tau)]f^*_{\rho^0}m_{\rho^0}\epsilon^*_{\rho^0\mu} \\ &= \frac{-1}{4}\bigg[\bigg(\lambda'_{3g1}\lambda'^{*}_{1g1}\times\frac{-1}{\sqrt{2}} + \lambda'_{3g1}\lambda'^{*}_{1g2}\times 0 + \lambda'_{3g1}\lambda'^{*}_{1g3}\times 0 + \lambda'_{3g2}\lambda'^{*}_{1g1}\times 0 + \ldots\bigg)\frac{i}{m^2_{\tilde{u}_{gL}}} \\ &\quad - \bigg(\lambda'_{31g}\lambda'^{*}_{11g}\times\frac{1}{\sqrt{2}} + \lambda'_{31g}\lambda'^{*}_{12g}\times 0 + \ldots\bigg)\frac{i}{m^2_{\tilde{d}_{gR}}}\bigg][\bar{u}(p_e)P_R\gamma^\mu u(p_\tau)]f^*_{\rho^0}m_{\rho^0}\epsilon^*_{\rho^0\mu}. \end{aligned} \quad \text{(B5)}$$

3. Charged lepton decays into a charged lepton and a neutral pseudoscalar meson

In addition to the two diagrams above, which can lead to pseudoscalar mesons as well as vector mesons, there is a further diagram for the decay into pseudoscalar mesons that is mediated by a sneutrino:



The contribution from the squark-mediated diagrams is given by

$$i\mathcal{M}^{\tilde{q}}_{l_i\to l_k+P} = \langle \text{out states}|\tfrac{1}{4}[\lambda'_{ijn}\lambda'^{*}_{ktm}\tilde{u}_{jL}\tilde{u}^{*}_{tL}\bar{d}_n(\gamma^\mu+\gamma^\mu\gamma_5)d_m - \lambda'_{imj}\lambda'^{*}_{knt}\tilde{d}_{jR}\tilde{d}^{*}_{tR}\bar{u}_n(\gamma^\mu-\gamma^\mu\gamma_5)u_m][\bar{l}_kP_R\gamma_\mu l_i]|\text{in states}\rangle. \quad \text{(B6)}$$

Contracting the meson state with the quark bilinear one finds

$$i\mathcal{M}^{\tilde{q}}_{l_i\to l_k+P} = \langle\text{lepton out states}|\frac{1}{4}\Bigg[\sum_{\text{d-type}}\lambda'_{ijn}\lambda'^{*}_{ktm}H_P^{mn*}\tilde{u}_{jL}\tilde{u}^{*}_{tL} - \sum_{\text{u-type}}\lambda'_{imj}\lambda'^{*}_{knt}H_P^{mn*}\tilde{d}_{jR}\tilde{d}^{*}_{tR}\Bigg] \times [\bar{l}_k P_R\gamma_\mu l_i]|\text{lepton in states}\rangle f_P^{*}p_P^{\mu}$$
$$= \frac{1}{4}\Bigg[\sum_{\text{d-type}}\lambda'_{ign}\lambda'^{*}_{kgm}H_P^{mn*}\bigg(\frac{-i}{m^2_{\tilde{u}_{gL}}}\bigg) - \sum_{\text{u-type}}\lambda'_{img}\lambda'^{*}_{kng}H_P^{mn*}\bigg(\frac{-i}{m^2_{\tilde{d}_{gR}}}\bigg)\Bigg][\bar{u}(p_{l_k})P_R\gamma_\mu u(p_{l_i})]f_P^{*}p_P^{\mu}. \quad \text{(B7)}$$

The contribution from the sneutrino-mediated diagrams is given by

$$i\mathcal{M}^{\tilde{\nu}}_{l_i\to l_k+P} = \langle\text{out states}|[\bar{l}_k i(\lambda_{jik}P_L\tilde{\nu}_{jL} + \lambda^{*}_{jki}\tilde{\nu}^{j*}P_R)l_i][\bar{d}_n i(\lambda'_{tmn}P_L^{\tilde{\nu}^t} + \lambda'^{*}_{tnm}P_R\tilde{\nu}^{t*})d_m]|\text{in states}\rangle$$
$$= \frac{-i}{2m^2_{\tilde{\nu}_{gL}}}\sum_{\text{d-type}}[\bar{u}(p_{l_k})\lambda_{gik}P_L u(p_{l_i})\lambda'^{*}_{gnm} - \bar{u}(p_{l_k})\lambda^{*}_{gki}P_R u(p_{l_i})\lambda'_{gmn}]\bigg[\frac{H_P^{mn}f_P m_P^2}{\mu_P^{mn}}\bigg]^{*} \quad \text{(B8)}$$

noting that the sneutrino does not couple to up-type quarks.

For the case of a meson decaying into a lepton and an antilepton, the matrix elements are identical up to making the appropriate index substitutions in the couplings.

[1] S. L. Glashow, Nucl. Phys. **22**, 579 (1961).
[2] S. Weinberg, Phys. Rev. Lett. **19**, 1264 (1967).
[3] J. Wess and B. Zumino, Nucl. Phys. **B70**, 39 (1974).
[4] N. Sakai and T. Yanagida, Nucl. Phys. **B197**, 533 (1982).
[5] S. Weinberg, Phys. Rev. D **26**, 287 (1982).
[6] M. Shiozawa *et al.* (Super-Kamiokande Collaboration), Phys. Rev. Lett. **81**, 3319 (1998).
[7] H. K. Dreiner, C. Luhn, and M. Thormeier, Phys. Rev. D **73**, 075007 (2006).
[8] S. Dimopoulos, S. Raby, and F. Wilczek, Phys. Lett. B **112**, 133 (1982).
[9] For an introduction, see e.g.: S. P. Martin, arXiv:hep-ph/9709356; I. J. R. Aitchison, arXiv:hep-ph/0505105; M. Drees, arXiv:hep-ph/9611409.
[10] L. E. Ibanez and G. G. Ross, Nucl. Phys. **B368**, 3 (1992).
[11] H. K. Dreiner, C. Luhn, H. Murayama, and M. Thormeier, arXiv:hep-ph/0610026.
[12] L. M. Krauss and F. Wilczek, Phys. Rev. Lett. **62**, 1221 (1989); L. E. Ibanez and G. G. Ross, Phys. Lett. B **260**, 291 (1991).
[13] L. J. Hall and M. Suzuki, Nucl. Phys. **B231**, 419 (1984).
[14] E. Nardi, Phys. Rev. D **55**, 5772 (1997).
[15] B. C. Allanach, A. Dedes, and H. K. Dreiner, Phys. Rev. D **69**, 115002 (2004); **72**, 079902(E) (2005).
[16] M. Hirsch, M. A. Diaz, W. Porod, J. C. Romao, and J. W. F. Valle, Phys. Rev. D **62**, 113008 (2000); **65**, 119901(E) (2002); A. Abada, G. Bhattacharyya, and M. Losada, Phys. Rev. D **66**, 071701 (2002); E. J. Chun, D. W. Jung, and J. D. Park, Phys. Lett. B **557**, 233 (2003); D. E. Kaplan and A. E. Nelson, J. High Energy Phys. 01 (2000) 033; R. Hempfling, Nucl. Phys. **B478**, 3 (1996).
[17] S. Dimopoulos, R. Esmailzadeh, L. J. Hall, and G. D. Starkman, Phys. Rev. D **41**, 2099 (1990); H. K. Dreiner and G. G. Ross, Nucl. Phys. **B365**, 597 (1991).
[18] W. M. Yao *et al.* (Particle Data Group), J. Phys. G **33**, 1 (2006).
[19] G. Bhattacharyya, J. R. Ellis, and K. Sridhar, Mod. Phys. Lett. A **10**, 1583 (1995).
[20] K. Agashe and M. Graesser, Phys. Rev. D **54**, 4445 (1996).
[21] D. Choudhury and P. Roy, Phys. Lett. B **378**, 153 (1996).
[22] J. H. Jang, J. K. Kim, and J. S. Lee, Phys. Rev. D **55**, 7296 (1997).
[23] J. E. Kim, P. Ko, and D. G. Lee, Phys. Rev. D **56**, 100 (1997).
[24] G. Bhattacharyya and A. Raychaudhuri, Phys. Rev. D **57**, R3837 (1998).
[25] O. Lebedev, W. Loinaz, and T. Takeuchi, Phys. Rev. D **61**, 115005 (2000); **62**, 015003 (2000); S. A. Abel, A. Dedes, and H. K. Dreiner, J. High Energy Phys. 05 (2000) 013.
[26] H. K. Dreiner, G. Polesello, and M. Thormeier, Phys. Rev. D **65**, 115006 (2002).
[27] J. P. Saha and A. Kundu, Phys. Rev. D **66**, 054021 (2002).
[28] J. H. Jang, Y. G. Kim, and J. S. Lee, Phys. Rev. D **58**, 035006 (1998).
[29] H. Dreiner, G. Polesello, and M. Thormeier, arXiv:hep-ph/0207160.
[30] Y. G. Xu, R. M. Wang, and Y. D. Yang, Phys. Rev. D **74**, 114019 (2006).
[31] V. D. Barger, G. F. Giudice, and T. Han, Phys. Rev. D **40**, 2987 (1989).
[32] S. Davidson, D. C. Bailey, and B. A. Campbell, Z. Phys. C **61**, 613 (1994).
[33] H. K. Dreiner, arXiv:hep-ph/9707435.
[34] G. Bhattacharyya, arXiv:hep-ph/9709395.
[35] B. C. Allanach, A. Dedes, and H. K. Dreiner, Phys. Rev. D **60**, 075014 (1999).
[36] M. Herz, Diploma Thesis, arXiv:hep-ph/0301079.
[37] M. Chemtob, Prog. Part. Nucl. Phys. **54**, 71 (2005).
[38] R. Barbier *et al.*, Phys. Rep. **420**, 1 (2005).

[39] [38] updating bounds given in [23] with data published by the Particle Data Group [52] in 2002.
[40] [38] updating bounds given in [21] with data published by the Particle Data Group [52] in 2002.
[41] [38] updating bounds given in [23] with data from P. Wintz (SINDRUM II Collaboration), *14th International Conference on Particles and Nuclei (PANIC), Williamsburg, Virginia, 1996*, edited by C. E. Carlson and J. J. Domingo (World Scientific, Singapore, 1997), p. 458.
[42] G. Altarelli, G. F. Giudice, and M. L. Mangano, Nucl. Phys. **B506**, 29 (1997); updated by [38] with data published by the Particle Data Group [52] in 2002.
[43] F. Ledroit and G. Sajot, Rapport GDR-Supersymétrie, ISN, Grenoble, GDR-S-008, 1998; updated by [38] with data published by the Particle Data Group [52] in 2002.
[44] Our effective Lagrangian is to be compared with those in [21–23,27,31] (noting that both [22,31] use the convention where there is *no* factor of $\frac{1}{2}$ before the λ terms). We disagree with the form of the effective Lagrangians in [21,27], and agree with those in [22,23,31]. We note, however, that through projection onto vector or pseudoscalar quark bilinears the difference with [27] reduces to a simple overall sign error of the matrix element, which is then eliminated by squaring. Accordingly, this has no ill effects in the quadratic coupling dominance convention. Also, in the case of [21] we note that it is merely that the wrong coupling in the second term of their Eq. (7) has the $*$ denoting complex conjugation.
[45] See for example T. P. Cheng and L. F. Li, *Gauge Theory of Elementary Particle Physics*, Oxford Science Publications (Clarendon, Oxford, 1984), p. 536.
[46] M. Neubert and B. Stech, Adv. Ser. Dir. High Energy Phys. **15**, 294 (1998).
[47] In all these cases, it turns out we are agreeing with [26], though [26] only gives the bounds to the first significant figure, and we assume that the differences (6.7×10^{-9} compared to 6×10^{-9} and 2.7×10^{-7} compared to 3×10^{-7}) arise from rounding errors.
[48] We do not agree with the bounds presented in [38], which are just those taken from [27]. We believe that [27] presented incorrect bounds, and that this arises from their Eq. (13) for the decay width $\Gamma(B_{q_i} \to l_l^- l_m^+)$. We find that the ratio of the decay width (13) in [27] over our decay width (2.19) is $4(m_b + m_{q_i})^2/M^2_{B_{q_i}}$. While $m_b + m_{q_i} \approx M_{B_{q_i}}$ for heavy mesons, we believe that Eq. (13) in [27] misses a factor $\frac{1}{4}$ which results in too tight bounds. However, as the experimental bounds for many of the rare B decay branching ratios have improved, we still obtain bounds for the couplings associated with these decays tighter than in [27]. Note that we agree with the corresponding Eq. (8) in [22] (taking into account that [22] defines the couplings λ such that the superpotential does *not* have the factor of $\frac{1}{2}$ before the trilinear lepton term) and with the generic result in [51].
[49] See e.g. A. J. Buras, arXiv:hep-ph/0101336.
[50] D. Black, T. Han, H. J. He, and M. Sher, Phys. Rev. D **66**, 053002 (2002).
[51] W. Skiba and J. Kalinowski, Nucl. Phys. **B404**, 3 (1993).
[52] K. Hagiwara *et al.* (Particle Data Group), Phys. Rev. D **66**, 010001 (2002).