Lepton flavor violating decays and soft leptogenesis in a supersymmetric SO(10) model

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We investigate lepton flavor violating decays in a supersymmetric (SUSY) SO(10) model with symmetric textures recently constructed by us. Unlike the models with lopsided textures which give rise to a large decay rate for $\mu \rightarrow e\gamma$, the decay rate we get is much suppressed and yet it is large enough to be accessible to the next generation of experiments. We have also investigated the possibility of baryogenesis resulting from soft leptogenesis. We find that with the soft-SUSY masses assuming their natural values, $B' \equiv \sqrt{BM_1} \sim 1.4$ TeV and $\mathrm{Im}(A) \sim 1$ TeV, the observed baryon asymmetry in the Universe can be accommodated in our model. We have also updated the predictions of our model for the masses, mixing angles, and CP violating measures in both charged fermion and neutrino sectors, using the most up-to-date experimental data as input.

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I. INTRODUCTION

After Neutrino 2004, the allowed region for the neutrino oscillation parameters has been reduced significantly, and their measurements have now entered the precision phase. There have been a few supersymmetric (SUSY) SO(10) models constructed aiming to accommodate the observed neutrino masses and mixing angles. (For a recent review on SO(10) models, see Ref. [1].) By far, the large mixing angle (LMA) solution is the most difficult to obtain. Most of the models in the literature assume "lopsided" mass matrices. In our model based on SUSY SO(10) $\times$ SU(2) [2] (referred to as "CM" herein), we consider *symmetric* mass matrices which result from the left-right symmetric breaking of SO(10) and the breaking of family symmetry SU(2). In view of the much improved experimental data on neutrino oscillation parameters as well as those in the quark mixing from B physics, we reanalyze our model and find that it can still accommodate all experimental data within 1σ. We investigate several lepton flavor violating (LFV) processes in our model, including the decay of the muon into an electron and a photon, which is the most stringently constrained LFV process. We also investigate in this paper the possibility of baryogenesis utilizing soft leptogenesis.

This paper is organized as follows: In Sec. II, we briefly describe our model and show its predictions for the masses, mixing angles, and CP violating phases in both charged fermion and neutrino sectors, using the most up-to-date experimental data as input. Various decay rates for lepton flavor violation processes are calculated in Sec. III. Section IV concerns soft leptogenesis in our model, while Sec. V concludes this paper.

II. THE MODEL

The details of our model based on $SO(10) \times SU(2)_F$ are contained in CM [2]. The following is an outline of its salient features. In order to specify the superpotential uniquely, we invoke $Z_2 \times Z_2 \times Z_2$ discrete symmetry. The matter fields are

$$\psi_a \sim (16, 2)^{-++} \quad (a = 1, 2), \qquad \psi_3 \sim (16, 1)^{+++},$$

where $a = 1, 2$ and the subscripts refer to family indices; the superscripts $+/-$ refer to $(Z_2)^3$ charges. The Higgs fields which break SO(10) and give rise to mass matrices upon acquiring vacuum expectation values (VEV)'s are

$$(10, 1)\colon T_1^{+++}, \quad T_2^{-+-}, \quad T_3^{--+}, \quad T_4^{---}, \quad T_5^{+--},$$
$$(\overline{126}, 1)\colon \overline{C}^{---}, \quad \overline{C}_1^{+++}, \quad \overline{C}_2^{++-}.$$

Higgs representations 10 and $\overline{126}$ give rise to Yukawa couplings to the matter fields which are symmetric under the interchange of family indices. SO(10) is broken through the left-right symmetry breaking chain, and symmetric mass matrices arise. The SU(2) family symmetry [3] is broken in two steps and the mass hierarchy is produced using the Froggatt-Nielsen mechanism: $SU(2) \xrightarrow{\epsilon M} U(1) \xrightarrow{\epsilon' M}$ nothing where M is the UV cutoff of the effective theory above which the family symmetry is exact, and ϵM and $\epsilon' M$ are the VEV's accompanying the flavon fields given by

$$\begin{aligned} &(1, 2)\colon \phi_{(1)}^{++-}, \quad \phi_{(2)}^{+-+}, \quad \Phi^{-+-}, \\ &(1, 3)\colon S_{(1)}^{+--}, \quad S_{(2)}^{---}, \quad \Sigma^{++-}. \end{aligned} \tag{1}$$

The various aspects of VEV's of Higgs and flavon fields are given in CM.

The superpotential of our model is

$$W = W_{\mathrm{Dirac}} + W_{\nu_{RR}}, \tag{2}$$

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$$W_{\rm Dirac} = \psi_3\psi_3 T_1 + \frac{1}{M}\psi_3\psi_a(T_2\phi_{(1)} + T_3\phi_{(2)}) + \frac{1}{M}\psi_a\psi_b(T_4+\overline{C})S_{(2)} + \frac{1}{M}\psi_a\psi_b T_5 S_{(1)}, \quad (3)$$
$$W_{\nu_{RR}} = \psi_3\psi_3\overline{C}_1 + \frac{1}{M}\psi_3\psi_a\Phi\overline{C}_2 + \frac{1}{M}\psi_a\psi_b\Sigma\overline{C}_2.$$

The mass matrices then can be read from the superpotential to be

$$M_{u,\nu_{LR}} = \begin{pmatrix} 0 & 0 & \langle 10_2^+\rangle\epsilon' \\ 0 & \langle 10_4^+\rangle\epsilon & \langle 10_3^+\rangle\epsilon \\ \langle 10_2^+\rangle\epsilon' & \langle 10_3^+\rangle\epsilon & \langle 10_1^+\rangle \end{pmatrix} = \begin{pmatrix} 0 & 0 & r_2\epsilon' \\ 0 & r_4\epsilon & \epsilon \\ r_2\epsilon' & \epsilon & 1 \end{pmatrix} M_U, \quad (4)$$

$$M_{d,e} = \begin{pmatrix} 0 & \langle 10_5^-\rangle\epsilon' & 0 \\ \langle 10_5^-\rangle\epsilon' & (1,-3)\langle\overline{126}^-\rangle\epsilon & 0 \\ 0 & 0 & \langle 10_1^-\rangle \end{pmatrix} = \begin{pmatrix} 0 & \epsilon' & 0 \\ \epsilon' & (1,-3)p\epsilon & 0 \\ 0 & 0 & 1 \end{pmatrix} M_D, \quad (5)$$

where $M_U \equiv \langle 10_1^+\rangle$, $M_D \equiv \langle 10_1^-\rangle$, $r_2 \equiv \langle 10_2^+\rangle/\langle 10_1^+\rangle$, $r_4 \equiv \langle 10_4^+\rangle/\langle 10_1^+\rangle$, and $p \equiv \langle\overline{1}26^-\rangle/\langle 10_1^-\rangle$. The right-handed (RH) neutrino mass matrix is

$$M_{\nu_{RR}} = \begin{pmatrix} 0 & 0 & \langle\overline{126}_2'^0\rangle\delta_1 \\ 0 & \langle\overline{126}_2'^0\rangle\delta_2 & \langle\overline{126}_2'^0\rangle\delta_3 \\ \langle\overline{126}_2'^0\rangle\delta_1 & \langle\overline{126}_2'^0\rangle\delta_3 & \langle\overline{126}_1'^0\rangle \end{pmatrix} = \begin{pmatrix} 0 & 0 & \delta_1 \\ 0 & \delta_2 & \delta_3 \\ \delta_1 & \delta_3 & 1 \end{pmatrix} M_R \quad (6)$$

with $M_R \equiv \langle\overline{126}_1'^0\rangle$. Here the superscripts $+/-/0$ refer to the sign of the hypercharge. It is to be noted that there is a factor of -3 difference between the (22) elements of mass matrices M_d and M_e. This is due to the Clebsch-Gordan coefficients associated with $\overline{126}$; as a consequence, we obtain the phenomenologically viable Georgi-Jarlskog relation. We then parametrize the Yukawa matrices as follows, after removing all the nonphysical phases by rephasing various matter fields:

$$Y_{u,\nu_{LR}} = \begin{pmatrix} 0 & 0 & a \\ 0 & be^{i\theta} & c \\ a & c & 1 \end{pmatrix} d, \quad (7)$$

$$Y_{d,e} = \begin{pmatrix} 0 & ee^{-i\xi} & 0 \\ ee^{i\xi} & (1,-3)f & 0 \\ 0 & 0 & 1 \end{pmatrix} h. \quad (8)$$

We use the following as inputs at $M_Z = 91.187$ GeV [4,5]:

$$\begin{aligned} m_u &= 2.21\ \text{MeV}(2.33^{+0.42}_{-0.45}), \\ m_c &= 682\ \text{MeV}(677^{+56}_{-61}), \\ m_t &= 181\ \text{GeV}(181^{\pm}13), \\ m_e &= 0.486\ \text{MeV}(0.486847), \\ m_\mu &= 103\ \text{MeV}(102.75), \\ m_\tau &= 1.74\ \text{GeV}(1.7467), \\ |V_{us}| &= 0.225(0.221-0.227), \\ |V_{ub}| &= 0.003\,68(0.0029-0.0045), \\ |V_{cb}| &= 0.0392(0.039-0.044), \end{aligned}$$

where the values extrapolated from experimental data are given inside the parentheses. Note that the masses given above are defined in the modified minimal subtraction ($\overline{\rm MS}$) scheme and are evaluated at M_Z. These values correspond to the following set of input parameters at the grand unified theory (GUT) scale, $M_{\rm GUT} = 1.03 \times 10^{16}$ GeV:

$$\begin{gathered} a = 0.002\,50, \qquad b = 3.26\times 10^{-3}, \qquad c = 0.0346, \\ d = 0.650, \qquad \theta = 0.74, \qquad e = 4.036\times 10^{-3}, \\ f = 0.0195, \qquad h = 0.068\,78, \qquad \xi = -1.52, \\ g_1 = g_2 = g_3 = 0.746. \end{gathered} \quad (9)$$

The one-loop renormalization group equations (RGE's) for the minimal supersymmetric standard model (MSSM) spectrum with three right-handed neutrinos are solved numerically down to the effective right-handed neutrino mass scale, M_R. At M_R, the seesaw mechanism is implemented. With the constraints $|m_{\nu_3}| \gg |m_{\nu_2}|, |m_{\nu_1}|$ and maximal mixing in the atmospheric sector, the up-type mass texture leads us to choose the following effective neutrino mass matrix:

$$M_{\nu_{LL}} = \begin{pmatrix} 0 & 0 & t \\ 0 & 1 & 1+t^n \\ t & 1+t^n & 1 \end{pmatrix} \frac{d^2 v_u^2}{M_R} \quad (10)$$

with $n = 1.15$, and from the seesaw formula we obtain

$$\delta_1 = \frac{a^2}{r}, \quad (11)$$

$$\delta_2 = \frac{b^2 t e^{2i\theta}}{r}, \quad (12)$$

$$\delta_3 = \frac{-a[be^{i\theta}(1+t^{1.15}) - c] + bcte^{i\theta}}{r}, \quad (13)$$

where $r = [c^2 t + a^2 t^{0.15}(2 + t^{1.15}) - 2a(-1 + c + ct^{1.15})]$. We then solve the two-loop RGE's for the MSSM spectrum down to the SUSY breaking scale, taken to be $m_t(m_t) = 176.4$ GeV, and then the standard model (SM) RGE's from $m_t(m_t)$ to the weak scale, M_Z. We assume that $\tan\beta \equiv v_u/v_d = 10$, with $v_u^2 + v_d^2 = (246/\sqrt{2}\ \mathrm{GeV})^2$. At the weak scale M_Z, the predictions for $\alpha_i \equiv g_i^2/4\pi$ are

$$\alpha_1 = 0.016\,63, \qquad \alpha_2 = 0.033\,74, \qquad \alpha_3 = 0.1242.$$

These values compare very well with the values extrapolated to M_Z from the experimental data, $(\alpha_1, \alpha_2, \alpha_3) = (0.016\,96, 0.033\,71, 0.1214 \pm 0.0031)$. The predictions at the weak scale M_Z for the charged fermion masses, Cabibbo-Kobayashi-Maskawa (CKM) matrix elements and strengths of *CP* violation, are summarized in Table I. The predictions of our model in this *updated* fit are in good agreement with all experimental data within 1σ, including much improved measurements in B physics that give rise to precise values for the CKM matrix elements and for the unitarity triangle [6]. Note that we have taken the SUSY threshold correction to m_b to be -18% [7].

The allowed region for the neutrino oscillation parameters has been reduced significantly after Neutrino 2004. In the atmospheric sector, the global analysis including the most recent K2K result yields, at 90% C.L. [8],

$$\Delta m^2_{\mathrm{atm}} = 2.3^{+0.7}_{-0.4} \times 10^{-3}\ \mathrm{eV}^2, \tag{14}$$

$$\sin^2 2\theta_{\mathrm{atm}} > 0.9, \tag{15}$$

$$(\text{best fit value: } \sin^2 2\theta_{\mathrm{atm}} = 1.0). \tag{16}$$

In the solar sector, the global analysis with SNO and the most recent KamLAND data yields, at $1\sigma(3\sigma)$ [9],

$$\Delta m^2_{\odot} = 8.2^{+0.3}_{-0.3}\left({}^{+1.0}_{-0.8}\right) \times 10^{-5}\ \mathrm{eV}^2, \tag{17}$$

$$\tan^2\theta_{\odot} = 0.39^{+0.05}_{-0.04}\left({}^{+0.19}_{-0.11}\right). \tag{18}$$

TABLE I. The predictions for the charged fermion masses, the CKM matrix elements, and the *CP* violation measures.

	Experimental results extrapolated to M_Z	Predictions at M_z
m_s/m_d	17–25	25
m_s	$93.4^{+11.8}_{-13.0}$ MeV	86.0 MeV
m_b	3.00 ± 0.11 GeV	3.03 GeV
$\lvert V_{ud}\rvert$	0.9739–0.9751	0.974
$\lvert V_{cd}\rvert$	0.221–0.227	0.225
$\lvert V_{cs}\rvert$	0.9730–0.9744	0.973
$\lvert V_{td}\rvert$	0.0048–0.014	0.008 01
$\lvert V_{ts}\rvert$	0.037–0.043	0.0386
$\lvert V_{tb}\rvert$	0.9990–0.992	0.999
J^q_{CP}	$(2.88 \pm 0.33) \times 10^{-5}$	2.87×10^{-5}
$\sin 2\alpha$	-0.16 ± 0.26	-0.048
$\sin 2\beta$	0.736 ± 0.049	0.740
γ	$60° \pm 14°$	64°
$\bar{\rho}$	0.20 ± 0.09	0.173
$\bar{\eta}$	0.33 ± 0.05	0.366

Combining with the CHOOZ result, a global analysis shows that the angle θ_{13} is constrained to be [9]

$$\sin^2\theta_{13} < 0.015(0.048) \tag{19}$$

at 1σ (3σ). Using the mass square difference in the atmospheric sector $\Delta m^2_{\mathrm{atm}} = 2.33 \times 10^{-3}\ \mathrm{eV}^2$ and the mass square difference for the LMA solution $\Delta m^2_{\odot} = 8.14 \times 10^{-5}\ \mathrm{eV}^2$ as input parameters, we determine $t = 0.344$ and $M_R = 6.97 \times 10^{12}$ GeV, which yield $(\delta_1, \delta_2, \delta_3) = (0.001\,20, 0.000\,703e^{i(1.47)}, 0.0210e^{i(0.175)})$. We obtain the following predictions in the neutrino sector: The three mass eigenvalues are given by

$$(m_{\nu_1}, m_{\nu_2}, m_{\nu_3}) = (0.002\,62, 0.009\,39, 0.0492)\ \mathrm{eV}. \tag{20}$$

The prediction for the Maki-Nakagawa-Sakata (MNS) matrix is

$$|U_{\mathrm{MNS}}| = \begin{pmatrix} 0.852 & 0.511 & 0.116 \\ 0.427 & 0.560 & 0.710 \\ 0.304 & 0.652 & 0.695 \end{pmatrix}, \tag{21}$$

which translates into the mixing angles in the atmospheric, solar, and reactor sectors,

$$\sin^2 2\theta_{\mathrm{atm}} \equiv \frac{4|U_{\mu\nu_3}|^2|U_{\tau\nu_3}|^2}{(1 - |U_{e\nu_3}|^2)^2} = 1.00, \tag{22}$$

$$\tan^2\theta_{\odot} \equiv \frac{|U_{e\nu_2}|^2}{|U_{e\nu_1}|^2} = 0.36, \tag{23}$$

$$\sin^2\theta_{13} = |U_{e\nu_3}|^2 = 0.0134. \tag{24}$$

The prediction of our model for the strengths of *CP* violation in the lepton sector are

$$J^l_{CP} \equiv \mathrm{Im}\{U_{11}U^*_{12}U^*_{21}U_{22}\} = -0.009\,41, \tag{25}$$

$$(\alpha_{31}, \alpha_{21}) = (0.934, -1.49). \tag{26}$$

Using the predictions for the neutrino masses, mixing angles, and the two Majorana phases, α_{31} and α_{21}, the matrix element for the neutrinoless double β decay can be calculated and given by $|\langle m \rangle| = 3.1 \times 10^{-3}$ eV, with the present experimental upper bound being 0.35 eV [4]. Masses of the heavy right-handed neutrinos are

$$M_1 = 1.09 \times 10^7\ \mathrm{GeV}, \tag{27}$$

$$M_2 = 4.53 \times 10^9\ \mathrm{GeV}, \tag{28}$$

$$M_3 = 6.97 \times 10^{12}\ \mathrm{GeV}. \tag{29}$$

The prediction for the $\sin^2\theta_{13}$ value is 0.0134, in agreement with the current bound 0.015 at 1σ. Because our prediction for $\sin^2\theta_{13}$ is very close to the present sensitivity of the experiment, the validity of our model can be tested in the foreseeable future [10].

III. LEPTON FLAVOR VIOLATING DECAYS

In light of the neutrino oscillation, extensive searches for lepton flavor violation processes, such as $\ell_i \rightarrow \ell_j \gamma$, $\ell_i^- \rightarrow \ell_j^- \ell_j^+ \ell_j^-$, and muon-electron conversion, are underway. In the SM, as the lepton number is conserved, there is no lepton flavor violation. Nonzero neutrino masses imply lepton number violation. If neutrino masses are induced by the seesaw mechanism, new Yukawa coupling involving the RH neutrinos can induce flavor violation [11], similar to its quark counterpart. In the nonsupersymmetric case, the decay amplitudes for these processes are inversely proportional to the RH neutrino mass, M_R^2, which is typically much higher than the electroweak scale. As a consequence, in nonsupersymmetric models, these processes are highly suppressed to the level that are unobservable.

Significant enhancement in the decay rate can be obtained in supersymmetric models, as the characteristic scale in this case is the SUSY scale, which is expected to be not too far from the electroweak scale. Thus the amplitudes for these decay processes scale as an inverse square of the SUSY breaking scale, rather than $1/M_R^2$. The relevant interactions that give rise to lepton flavor violating decays come from the soft-SUSY breaking Lagrangian,

$$\begin{aligned} -\mathcal{L}_{\text{soft}} = {} & (m_{\tilde{L}}^2)_{ij} \tilde{\ell}_{L_i}^\dagger \tilde{\ell}_{L_j} + (m_{\tilde{e}}^2)_{ij} \tilde{e}_{R_i}^\dagger \tilde{e}_{R_j} + (m_{\tilde{\nu}}^2)_{ij} \tilde{\ell}_{R_i}^\dagger \tilde{\ell}_{R_j} \\ & + (\tilde{m}_{h_d}^2) \tilde{H}_d^\dagger \tilde{H}_d + (\tilde{m}_{h_2}^2) \tilde{H}_u^\dagger \tilde{H}_u + [A_\nu^{ij} \tilde{H}_u \tilde{\nu}_{R_i}^* \tilde{\nu}_{L_j} \\ & + A_e^{ij} H_d \tilde{e}_{R_i}^* \tilde{e}_{L_j} + \tfrac{1}{2} B_\nu^{ij} \tilde{\nu}_{R_i} \tilde{\nu}_{R_j} + B_h H_d H_u \\ & + \text{H.c.}], \end{aligned} \tag{30}$$

where $\tilde{\ell}_L$, $\tilde{e}_R$, and $\tilde{\nu}_R$ are the left-handed (LH) slepton doublets, RH charged sleptons, and RH sneutrinos, respectively; H_u ($\tilde{H}_u$) and H_d ($\tilde{H}_d$) are the two Higgs (Higgsino) doublets in MSSM. Assuming mSUGRA boundary conditions at the GUT scale,

$$(m_{\tilde{L}}^2)_{ij} = (m_{\tilde{e}}^2)_{ij} = (m_{\tilde{\nu}}^2)_{ij} = m_0 \delta_{ij}, \tag{31}$$

$$\tilde{m}_{H_d}^2 = \tilde{m}_{H_u}^2 = m_0^2, \tag{32}$$

$$A_\nu^{ij} = (Y_\nu)_{ij} A_0, \qquad A_e^{ij} = (Y_e)_{ij} A_0, \tag{33}$$

$$B_\nu^{ij} = M_{\nu_{RR}} B_0, \qquad B_h = \mu B_0, \tag{34}$$

where Y_ν and Y_e are the Yukawa couplings of the neutrinos and charged leptons, and $M_{\nu_{RR}}$ is the Majorana mass matrix of the RH neutrinos. As the slepton mass matrix $(m_{\tilde{L}}^2)_{ij}$ is flavor blind at the GUT scale, there is no flavor violation at M_{GUT}. However, as $(m_{\tilde{L}}^2)_{ij}$ evolves from M_{GUT} to the RH neutrino mass scale, M_R, according to the renormalization group equation,

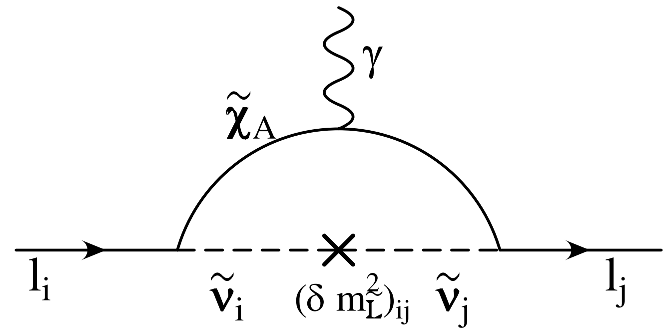

FIG. 1. The dominant diagram that contributes to the decay $\ell_i \rightarrow \ell_j \gamma$ at one loop, mediated by the neutralino $\tilde{\chi}_A$ and the sneutrinos $\tilde{\nu}$. The inserted mass term $(\delta m_{\tilde{L}}^2)_{ij}$ is induced by the renormalization group evolution from the GUT scale to the RH neutrino mass scales.

$$\begin{aligned} \frac{d}{d \ln \mu} (m_{\tilde{L}}^2)_{ij} = {} & \frac{1}{16\pi^2} \{ m_{\tilde{L}}^2 (Y_\nu^\dagger Y_\nu)_{ij} + 2[(Y_\nu^\dagger m_{\tilde{\nu}}^2 Y_\nu)_{ij} \\ & + m_{\tilde{h}}^2 (Y_\nu^\dagger Y_\nu)_{ij} + (A_\nu^\dagger A_\nu)_{ij}]\}, \quad \text{for } i \neq j, \end{aligned} \tag{35}$$

the off-diagonal elements in the slepton mass matrix $m_{\tilde{L}}^2$ can be generated at low energies due to the RG corrections [12],

$$\begin{aligned} \delta(m_{\tilde{L}}^2)_{ij} = {} & -\frac{1}{8\pi} (3m_0^2 + A_0^2) \sum_{k=1,2,3} (\mathcal{Y}_\nu^\dagger)_{ik} (\mathcal{Y}_\nu)_{kj} \\ & \times \ln\left(\frac{M_{\text{GUT}}}{M_{R_k}} \right), \end{aligned} \tag{36}$$

for $i \neq j$. Here $\mathcal{Y}_\nu$ is the Yukawa couplings for the neutrinos in the basis where both charged lepton Yukawa matrix and the Majorana mass matrix for the RH neutrinos are diagonal; M_{R_k} are the masses of the heavy neutrinos. The Yukawa coupling $\mathcal{Y}_\nu$ in the new basis is related to Y_ν in the original basis by

$$\mathcal{Y}_\nu = P_R O_R Y_\nu O_{e_L}^\dagger. \tag{37}$$

Here O_{L_e} is the diagonalization matrix for

$$\mathcal{M}_e^{\text{diag}} = O_{e_R} M_e O_{e_L}^\dagger, \tag{38}$$

and the diagonal phase matrix P_R and the orthogonal matrix O_R are defined by

$$\mathcal{M}_{\nu_{RR}}^{\text{diag}} = \text{diag}(M_1, M_2, M_3) = P_R O_R M_{\nu_{RR}} O_R^T P_R, \tag{39}$$

where $M_{1,2,3}$ are real and positive, and their numerical values are given in Eqs. (27)–(29). In our model, the Yukawa matrix $\mathcal{Y}_\nu$ is

$$\mathcal{Y}_\nu = \begin{pmatrix} 2.69\times 10^{-6}e^{-(0.695)i} & 5.92\times 10^{-5}e^{-(2.75)i} & 6.54\times 10^{-4}e^{-(1.68)i} \\ 1.44\times 10^{-4}e^{(1.54)i} & 1.73\times 10^{-3}e^{-(0.176)i} & 8.91\times 10^{-3}e^{-(1.32)i} \\ 2.18\times 10^{-3}e^{(0.737)i} & 0.0213e^{(0.0064)i} & 0.618 \end{pmatrix}. \tag{40}$$

The nonvanishing off-diagonal matrix elements in $(\delta m^2_{\tilde{L}})_{ij}$ induce lepton flavor violating processes mediated by the superpartners of the neutrinos through the one-loop diagram shown in Fig. 1.

In Table II we summarize the current status and future proposals of the experimental searches for lepton flavor violating decays. In the following subsections, we discuss each LFV process individually.

A. $\mu \to e\gamma$, $\tau \to \mu\gamma$, and $\tau \to e\gamma$

The branching ratio for the decay of $\ell_i \to \ell_j + \gamma$ induced by the renormalization group effects described above is given by [12]

$$\mathrm{Br}(\ell_i \to \ell_j\gamma) = \frac{\alpha^3}{G_F^2 m_S^8}\left|\frac{-1}{8\pi}(3m_0^2 + A_0^2)\right|^2 \tan^2\beta \left|\sum_{k=1,2,3}(\mathcal{Y}_\nu^\dagger)_{ik}(\mathcal{Y}_\nu)_{kj}\ln\left(\frac{M_{\mathrm{GUT}}}{M_{R_k}}\right)\right|^2. \tag{41}$$

Here α is the fine structure constant, G_F is the Fermi constant, and m_S is the typical SUSY scalar mass which is given by, to a very good approximation [20],

$$m_S^8 = \tfrac{1}{2}m_0^2 M_{1/2}^2(m_0^2 + 0.6M_{1/2}^2)^2, \tag{42}$$

where $M_{1/2}$ is the universal gaugino mass. In our model, $|\delta(m^2_{\tilde{L}})_{ij}|$ is given by

$$|\delta(m^2_{\tilde{L}})_{ij}| = \left|\frac{1}{8\pi}(3m_0^2 + A_0^2)\right| \times \begin{pmatrix} * & 3.41\times 10^{-4} & 0.0098 \\ 3.41\times 10^{-4} & * & 0.0962 \\ 0.0098 & 0.0962 & * \end{pmatrix}, \tag{43}$$

for $i \neq j$. Thus the following relation is predicted:

$$\mathrm{B\,r}(\mu \to e\gamma) < \mathrm{Br}(\tau \to e\gamma) < \mathrm{Br}(\tau \to \mu\gamma). \tag{44}$$

A similar relation was observed in Ref. [21] in which symmetric mass matrices with four texture zeros are utilized. We also note that the value for $\tan\beta$ is 10; thus there is no $\tan\beta$ enhancement in our predictions.

Currently the most stringent experimental bound on the lepton flavor violating processes is on the decay $\mu \to e\gamma$. The prediction of our model for $\mathrm{Br}(\mu \to e\gamma)$ is well below the most stringent bound up-to-date from MEGA at LANL [13]. In Fig. 2, the branching ratio of the decay $\mu \to e\gamma$ as a function of the universal gaugino mass $M_{1/2}$ is shown for various scalar masses A_0 and m_0. For large A_0 and low m_0 and $M_{1/2}$, there is a large soft-SUSY parameter space that gives rise to predictions which can be probed by MEG at PSI and/or at J-PARC. In Fig. 3, the branching ratio of the decay $\tau \to \mu\gamma$ as a function of the universal gaugino mass $M_{1/2}$ is shown for various scalar masses A_0 and m_0. For $A_0 \sim \mathcal{O}(1\ \mathrm{TeV})$ and m_0 and $M_{1/2}$ both of order $\mathcal{O}(100\ \mathrm{GeV})$, the prediction of our model on $\tau \to \mu\gamma$ may be tested at BELLE in the future. In Fig. 4, the branching ratio of the decay $\tau \to e\gamma$ as a function of the universal gaugino mass $M_{1/2}$ is shown for various scalar masses A_0 and m_0. For the SUSY parameter space we consider, the prediction for $\mathrm{Br}(\tau \to e\gamma)$ is at least 4 orders of magnitude below the current experimental upper bound.

We comment that, in models with lopsided textures [22], the maximal mixing angle observed in the atmospheric neutrino sector is due to a large (23) mixing in the charged lepton sector. As a result, the off-diagonal elements in the (23) sector of O_{e_L} are of order $\mathcal{O}(1)$, which in turn gives rise to an enhancement in the decay branching ratios. In order to satisfy the current experimental upper bound, some new mechanism must be in place to suppress the decay rate of $\mu \to e\gamma$ in models with lopsided textures [23]. In our model which utilizes symmetric textures, as large leptonic mixing in our model is a result of the seesaw

TABLE II. Summary of current status and future proposals of the experimental searches for lepton flavor violating decays.

Decay	Current bound on the branching ratio	Reach of future experiment
$\mu \to e\gamma$	$<1.2\times 10^{-11}$ (MEGA, 1999)[13]	10^{-14} (PSI)[14] 10^{-15} (J-PARC)
$\mu \to 3e$	$<1.0\times 10^{-12}$ (SINDRUM, 1988)[15]	
$\mu \to e$ in ${}^{48}_{22}\mathrm{Ti}$	$<6.1\times 10^{-13}$ (SINDRUM II, 1998)[16]	2.0×10^{-17} (MECO)[17] 10^{-18} (J-PARC)
$\tau \to \mu\gamma$	$<3.1\times 10^{-7}$ (BELLE, 2003) [18]	10^{-9} (BELLE)[18]
$\tau \to e\gamma$	$<3.6\times 10^{-7}$ (BELLE, 2003) [19]	

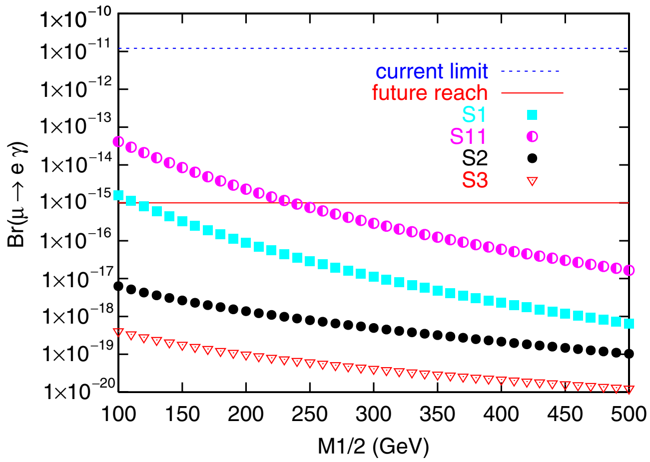

FIG. 2 (color online). The branching ratio of the decay $\mu \to e\gamma$ as a function of the universal gaugino mass $M_{1/2}$ for various scalar masses A_0 and m_0. (S1): $m_0 = A_0 = 100$ GeV; (S11): $m_0 = 100$ GeV, $A_0 = 1$ TeV; (S2): $m_0 = A_0 = 500$ GeV; (S3): $m_0 = A_0 = 1$ TeV. The dashed line corresponds to the current experimental limit 1.2×10^{-11} from MEGA, while the solid line indicates the reach of a future experiment at J-PARC, 10^{-15}. The value of $\tan\beta$ in our model is $\tan\beta = 10$.

mechanism, all off-diagonal matrix elements in Y_ν, O_{e_L}, and O_R are much smaller than unity, leading to a much smaller branching ratio for $\mu \to e\gamma$ than that predicted in models with lopsided textures. Yet our prediction is large enough to be probed by the next generation of experiments within a few years.

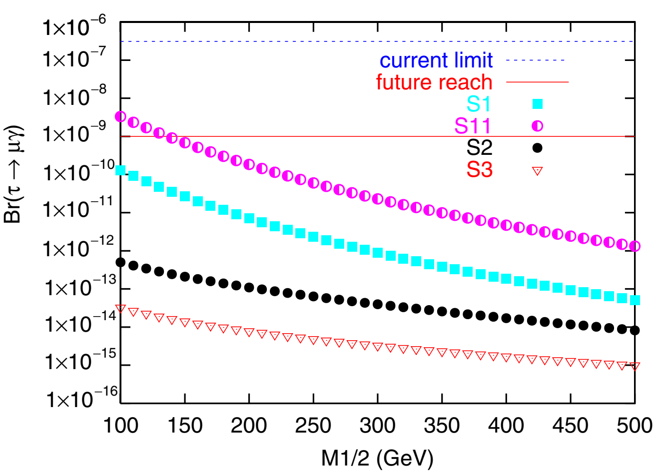

FIG. 3 (color online). The branching ratio of the decay $\tau \to \mu\gamma$ as a function of the universal gaugino mass $M_{1/2}$ for various scalar masses A_0 and m_0. (S1): $m_0 = A_0 = 100$ GeV; (S11): $m_0 = 100$ GeV, $A_0 = 1$ TeV; (S2): $m_0 = A_0 = 500$ GeV; (S3): $m_0 = A_0 = 1$ TeV. The dashed line corresponds to the current experimental limit 3.1×10^{-7} from BELLE, while the solid line indicates the reach of a future experiment at BELLE, 10^{-9}. The value of $\tan\beta$ in our model is $\tan\beta = 10$.

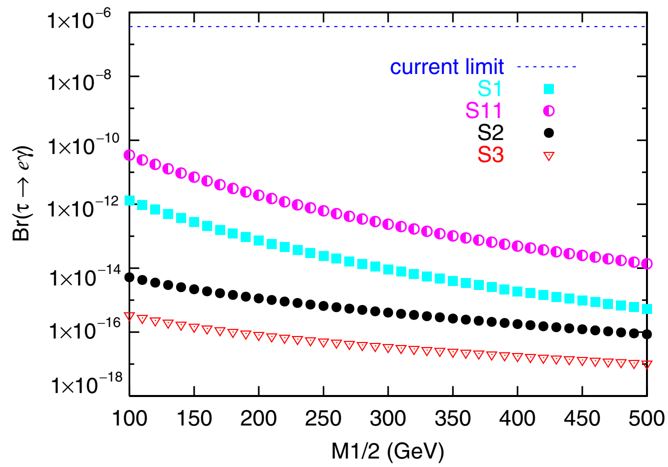

FIG. 4 (color online). The branching ratio of the decay $\tau \to e\gamma$ as a function of the universal gaugino mass $M_{1/2}$ for various scalar masses A_0 and m_0. (S1): $m_0 = A_0 = 100$ GeV; (S11): $m_0 = 100$ GeV, $A_0 = 1$ TeV; (S2): $m_0 = A_0 = 500$ GeV; (S3): $m_0 = A_0 = 1$ TeV. The dashed line corresponds to the current upper bound, 3.6×10^{-7}, from BELLE. The value of $\tan\beta$ in our model is $\tan\beta = 10$.

B. $\mu \to 3e$

For the process $\mu \to 3e$, as penguin diagrams are the dominant contributions, the branching ratio of the decay $\ell_i^- \to \ell_j^- \ell_j^+ \ell_j^-$ has a similar structure as that of the decay $\ell_i^- \to \ell_j^- \gamma$. To a very good approximation, the relation between these two processes reads [12],

$$\frac{\mathrm{Br}(\ell_i^- \to \ell_j^- \ell_j^+ \ell_j^-)}{\mathrm{Br}(\ell_i^- \to \ell_j^- \gamma)} \simeq \frac{\alpha}{8\pi}\left[\frac{16}{3}\ln\left(\frac{m_{\ell_i}}{2m_{\ell_j}}\right) - \frac{14}{9}\right], \tag{45}$$

where m_{ℓ_i} is the ith generation lepton mass. For the decay $\mu \to 3e$, we thus have

$$\mathrm{B\,r}(\mu \to 3e) \simeq 7 \times 10^{-3}\mathrm{Br}(\mu \to e\gamma). \tag{46}$$

In Fig. 5, the branching ratio of the decay $\mu \to 3e$ as a function of the universal gaugino mass $M_{1/2}$ is shown for various scalar masses A_0 and m_0. As the current experimental upper bound and the reach of the next phase of experiment at BELLE are still quite high, the prediction for $\mu \to 3e$ in our model cannot be tested, even with a high value of the scalar mass, $A_0 = 1$ TeV.

C. μ-e conversion

Similar to the case of $\mu \to 3e$, the branching ratio for muon-electron conversion is also related to the branching ratio of the decay $\mu \to e\gamma$ as long as $\tan\beta$ is not too small. In the region $\tan\beta > 1$, the relation between these two processes is given by, to a very good approximation [12],

$$\frac{\mathrm{Br}(\mu \to e)}{\mathrm{Br}(\mu \to e\gamma)} \simeq 16\alpha^4 Z_{\mathrm{eff}}^4 Z|F(q^2)|^2, \tag{47}$$

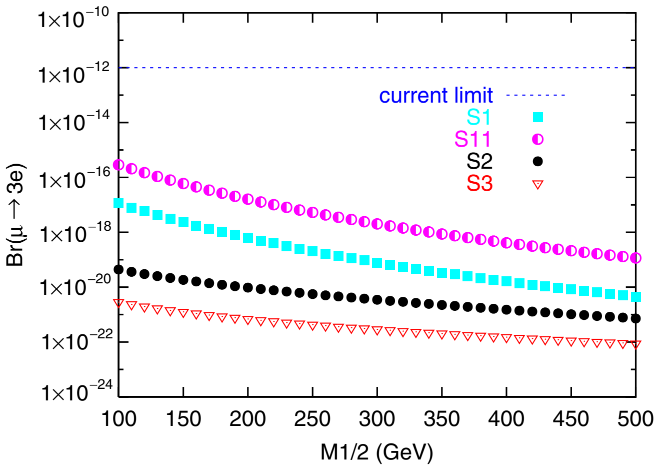

FIG. 5 (color online). The branching ratio of the decay $\mu^- \rightarrow e^- e^+ e^-$ as a function of the universal gaugino mass $M_{1/2}$ for various scalar masses A_0 and m_0. (S1): $m_0 = A_0 = 100$ GeV; (S11): $m_0 = 100$ GeV, $A_0 = 1$ TeV; (S2): $m_0 = A_0 = 500$ GeV; (S3): $m_0 = A_0 = 1$ TeV. The dashed line corresponds to the current experimental limit 1.0×10^{-12} from SINDRUM. The value of $\tan\beta$ in our model is $\tan\beta = 10$.

where Z_{eff} is the effective charge of the nucleon, Z is the proton number, and $F(q^2)$ is the nuclear form factor at momentum transfer q. For ${}^{48}_{22}\mathrm{Ti}$, the conversion rate is

$$\mathrm{B\,r}(\mu \rightarrow e; {}^{48}_{22}\mathrm{Ti}) \simeq 6 \times 10^{-3} \mathrm{Br}(\mu \rightarrow e\gamma), \tag{48}$$

where $Z_{\mathrm{eff}} = 17.6$ and $F(q^2 = -m_\mu^2) = 0.54$ have been used. In Fig. 6, the branching ratio of the decay $\mu \rightarrow e$ in

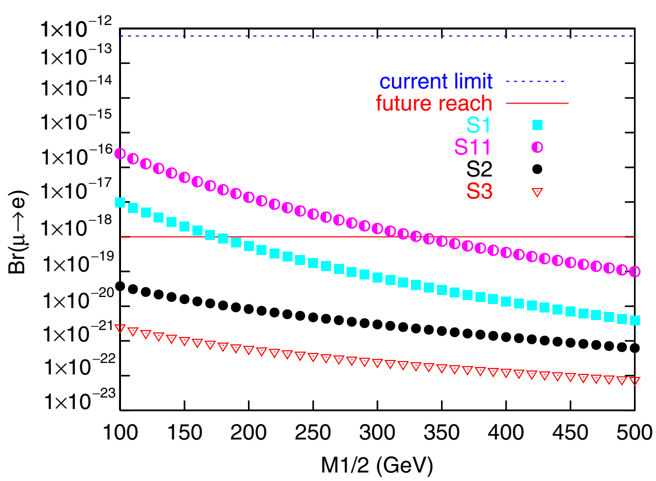

FIG. 6 (color online). The branching ratio of the decay $\mu^- \rightarrow e^-$ in ${}^{48}_{22}\mathrm{Ti}$ as a function of the universal gaugino mass $M_{1/2}$ for various scalar masses A_0 and m_0. (S1): $m_0 = A_0 = 100$ GeV; (S11): $m_0 = 100$ GeV, $A_0 = 1$ TeV; (S2): $m_0 = A_0 = 500$ GeV; (S3): $m_0 = A_0 = 1$ TeV. The dashed line corresponds to the current experimental limit 6.1×10^{-13} from SINDRUM II, while the solid line indicates the reach of a future experiment at J-PARC, 10^{-18}. The value of $\tan\beta$ in our model is $\tan\beta = 10$.

${}^{48}_{22}\mathrm{Ti}$ as a function of the universal gaugino mass $M_{1/2}$ is shown for various scalar masses A_0 and m_0. For low values of m_0 and $M_{1/2}$, there is a very large soft-SUSY parameter space that gives rise to a prediction for the μ-e conversion rate that is sensitive to MECO [17] at BNL and the proposal at J-PARC.

IV. BARYOGENESIS À *LA* SOFT LEPTOGENESIS

It is well known that the *CP* violation in the quark sector is too small to explain the observed baryon asymmetry of the Universe (BAU), expressed in terms of the ratio of the baryon number to entropy [24],

$$\frac{n_b}{s} = (0.87 \pm 0.04) \times 10^{-10}, \tag{49}$$

derived from cosmic microwave background and nucleosynthesis measurements. In leptogenesis, leptonic *CP* violating phases are used to produce asymmetry in leptonic number which then is converted into baryon asymmetry by the electroweak nonperturbative effects due to sphalerons. There are two ways of producing lepton number asymmetry: (i) standard leptogenesis (STDL) [25] and (ii) soft leptogenesis (SFTL) [26–28].

In the STDL scenario, the primordial leptonic asymmetry is generated by the decay of the heavy right-handed Majorana neutrinos and their scalar partners, mediated by the Yukawa interactions in the superpotential. In our model, the large hierarchy among the three heavy neutrinos leads to a very small *CP* asymmetry, which is of the order of $\mathcal{O}(10^{-9})$. In addition, the low value for the mass of the lightest RH neutrino, $M_1 = 1.09 \times 10^7$ GeV, leads to an extremely large washout effect. Because of these reasons, the prediction in our model for the baryonic asymmetry utilizing the standard leptogenesis is of the order of $\mathcal{O}(10^{-15})$, which is 4 orders of magnitude below the value derived from experimental observations.

SFTL utilizes the soft-SUSY breaking sector, and the asymmetry in the lepton number is generated in the decay of the superpartner of the RH neutrinos [26,27], as opposed to the lightest RH neutrino in the case of STDL. Unlike in STDL where the Yukawa sector is responsible for the required *CP* violation and lepton number violation, in the scenario of SFTL, the *CP* violation and lepton number violation trace their origins to SUSY breaking. As a result, it allows a much lower bound on the mass of the lightest RH neutrino, M_1, compared to that in STDL. In fact, it has been shown very recently that in contrast to the STDL scenario in which $M_1 > 10^9$ GeV is typically required to have sufficient baryonic asymmetry [29], SFTL can work only in the region where $M_1 < 10^9$ GeV [30]. As a result, the problem of the gravitino overproduction [31] may be avoided.

For SFTL, the relevant soft-SUSY Lagrangian that involves the lightest RH sneutrinos $\tilde{\nu}_{R_1}$ is the following:

$$-\mathcal{L}_{\rm soft} = (\tfrac{1}{2}BM_1\tilde{\nu}_{R_1}\tilde{\nu}_{R_1} + A\mathcal{Y}_{1i}\tilde{L}_i\tilde{\nu}_{R_1}H_u + \text{H.c.}) + \tilde{m}^2\tilde{\nu}_{R_1}^\dagger\tilde{\nu}_{R_1}. \tag{50}$$

This soft-SUSY Lagrangian and the superpotential that involves the lightest RH neutrino, N_1,

$$W = M_1N_1N_1 + \mathcal{Y}_{1i}L_iN_1H_u \tag{51}$$

give rise to the following interactions:

$$-\mathcal{L}_{\mathscr{A}} = \tilde{\nu}_{R_1}(M_1Y_{1i}^*\tilde{\ell}_i^*H_u^* + \mathcal{Y}_{1i}\overline{\tilde{H}}_u\ell_L^i + A\mathcal{Y}_{1i}\tilde{\ell}_iH_u) + \text{H.c.}, \tag{52}$$

and mass terms (to leading order in soft-SUSY breaking terms),

$$-\mathcal{L}_{\mathscr{M}} = (M_1^2\tilde{\nu}_{R_1}^\dagger\tilde{\nu}_{R_1} + \tfrac{1}{2}BM_1\tilde{\nu}_{R_1}\tilde{\nu}_{R_1}) + \text{H.c.} \tag{53}$$

Diagonalization of the mass matrix $\mathcal{M}$ with the two states $\tilde{\nu}_{R_1}$ and $\tilde{\nu}_{R_1}^\dagger$ leads to eigenstates $\tilde{N}_+$ and $\tilde{N}_-$ with masses,

$$M_\pm \simeq M_1\left(1 \pm \frac{|B|}{2M_1}\right), \tag{54}$$

where the leading order term M_1 is the F-term contribution from the superpotential (RH neutrino mass term) and the mass difference between the two mass eigenstates $\tilde{N}_+$ and $\tilde{N}_-$ is induced by the SUSY breaking B term. The time evolution of the $\tilde{\nu}_{R_1}$-$\tilde{\nu}_{R_1}^\dagger$ system is governed by the Schrödinger equation,

$$\frac{d}{dt}\begin{pmatrix}\tilde{\nu}_{R_1}\\ \tilde{\nu}_{R_1}^\dagger\end{pmatrix} = \mathcal{H}\begin{pmatrix}\tilde{\nu}_{R_1}\\ \tilde{\nu}_{R_1}^\dagger\end{pmatrix}, \tag{55}$$

where the Hamiltonian $\mathcal{H}$ is given by [26,27],

$$\mathcal{H} = \mathcal{M} - \frac{i}{2}\mathscr{A}, \tag{56}$$

$$\mathcal{M} = \begin{pmatrix}1 & \frac{B^*}{2M_1}\\ \frac{B}{2M_1} & 1\end{pmatrix}M_1, \tag{57}$$

$$\mathscr{A} = \begin{pmatrix}1 & \frac{A^*}{M_1}\\ \frac{A}{M_1} & 1\end{pmatrix}\Gamma_1. \tag{58}$$

For the decay of the lightest RH sneutrino, $\tilde{\nu}_{R_1}$, the total decay width Γ_1 is given by, in the basis defined in Eq. (37) where both the charged lepton mass matrix and the RH neutrino mass matrix are diagonal,

$$\Gamma_1 = \frac{1}{4\pi}(\mathcal{Y}_\nu\mathcal{Y}_\nu^\dagger)_{11}M_1 = 0.374\ \text{GeV}. \tag{59}$$

The eigenstates of the Hamiltonian $\mathcal{H}$ are $\tilde{N}'_\pm = p\tilde{N} \pm q\tilde{N}^\dagger$, where $|p|^2 + |q|^2 = 1$. The ratio q/p is given in terms of $\mathcal{M}$ and Γ as

$$\left(\frac{q}{p}\right)^2 = \frac{2\mathcal{M}_{12}^* - i\mathscr{A}_{12}^*}{2\mathcal{M}_{12} - i\mathscr{A}_{12}} \simeq 1 + \text{Im}\left(\frac{2\Gamma_1A}{BM_1}\right), \tag{60}$$

in the limit $\mathscr{A}_{12} \ll \mathcal{M}_{12}$. Similar to the $K^0 - \overline{K}^0$ system, the source of CP violation in the lepton number asymmetry considered here is due to the CP violation in the mixing which occurs when the two neutral mass eigenstates ($\tilde{N}_+$, $\tilde{N}_-$) are different from the interaction eigenstates ($\tilde{N}'_+$, $\tilde{N}'_-$). Therefore CP violation in mixing is present as long as the quantity $|q/p| \neq 1$, which requires

$$\text{Im}\left(\frac{A\Gamma_1}{M_1B}\right) \neq 0. \tag{61}$$

For this to occur, SUSY breaking, i.e., nonvanishing *A and* B, is required. As the relative phase between the parameters A and B can be rotated away by an $\text{U}(1)_R$ rotation, without loss of generality we assume from now on that the physical phase that remains is solely coming from the trilinear coupling A.

The total lepton number asymmetry integrated over time, ϵ, is defined as the ratio of difference to the sum of the decay widths Γ for $\tilde{\nu}_{R_1}$ and $\tilde{\nu}_{R_1}^\dagger$ into final states of the slepton doublet $\tilde{L}$ and the Higgs doublet H, or the lepton doublet L and the Higgsino $\tilde{H}$ or their conjugates,

$$\epsilon = \frac{\sum_f\int_0^\infty[\Gamma(\tilde{\nu}_{R_1}, \tilde{\nu}_{R_1}^\dagger \to f) - \Gamma(\tilde{\nu}_{R_1}, \tilde{\nu}_{R_1}^\dagger \to \overline{f})]}{\sum_f\int_0^\infty[\Gamma(\tilde{\nu}_{R_1}, \tilde{\nu}_{R_1}^\dagger \to f) + \Gamma(\tilde{\nu}_{R_1}, \tilde{\nu}_{R_1}^\dagger \to \overline{f})]}, \tag{62}$$

where final states $f = (\tilde{L}H), (L\tilde{H})$ have the lepton number $+1$, and $\overline{f}$ denotes their conjugate, $(\tilde{L}^\dagger H^\dagger), (\overline{L}\,\overline{\tilde{H}})$, which have the lepton number -1. After carrying out the time integration, the total CP asymmetry is [26,27]

$$\epsilon = \left(\frac{4\Gamma_1B}{\Gamma_1^2 + 4B^2}\right)\frac{\text{Im}(A)}{M_1}\delta_{B-F}, \tag{63}$$

where the additional factor δ_{B-F} takes into account the thermal effects due to the difference between the occupation numbers of bosons and fermions [32]. The final result for the baryon asymmetry is [26,27]

$$\frac{n_B}{s} \simeq -cd_{\tilde{\nu}_R}\epsilon\kappa \simeq -1.48\times10^{-3}\epsilon\kappa \simeq -(1.48\times10^{-3})\left(\frac{\text{Im}(A)}{M_1}\right)R\delta_{B-F}\kappa, \tag{64}$$

where $d_{\tilde{N}}$ in the first line is the density of the lightest sneutrino in equilibrium in units of entropy density, and is given by $d_{\tilde{\nu}_R} = 45\zeta(3)/(\pi^4g_*)$; the factor $c = (8N_F + 4N_H)/(22N_F + 13N_H)$ characterizes the amount of $B - L$ asymmetry being converted into the baryon asymmetry Y_B, with N_F and N_H being the number of families and the SU(2) Higgs doublets, respectively. For the MSSM particle spectrum, $(N_F, N_H) = (3, 2)$. The parameter κ is the dilution factor which characterizes the washout effects due to the inverse decays and lepton number violating scattering processes together with the time evolution of the system. It is obtained by solving the Boltzmann equations for the system. An approximation is given by [33]

$$10^6 \le r\colon\ \kappa = (0.1r)^{1/2} e^{-(4/3)(0.1r)^{1/4}}, \tag{65}$$

$$10 \le r \le 10^6\colon\ \kappa = 0.3/(r(\ln r)^{0.6}), \tag{66}$$

$$0 \le r \le 10\colon\ \kappa = 1/(2\sqrt{r^2+9}), \tag{67}$$

where r is defined as

$$r \equiv \frac{M_{pl}}{(1.7)(32\pi)\sqrt{g_*}} \frac{(\mathcal{Y}_\nu \mathcal{Y}_\nu^\dagger)_{11}}{M_1} \tag{68}$$

with M_{Pl} being the Planck scale taken to be 1.2×10^{19} GeV. We have $r = 183$ and correspondingly $\kappa = 0.000\,61$ in our model. The parameter R is defined as the ratio,

$$R \equiv \frac{4\Gamma_1 B}{\Gamma_1^2 + 4B^2}, \tag{69}$$

which gives a value equal to 1 when the resonance condition, $\Gamma_1 = 2|B|$, is satisfied, leading to maximal CP asymmetry. As Γ_1 is of the order of $\mathcal{O}(0.1-1)$ GeV, to satisfy the resonance condition, a small value for $B \ll \tilde{m}$ is thus needed. Such a small value of B can be generated by some dynamical relaxation mechanisms [34] in which B vanishes in the leading order. A small value of $B \sim \tilde{m}^2/M_1$ is then generated by an operator $\int d^4\theta Z Z^\dagger N_1^2/M_{pl}^2$ in the Kähler potential, where Z is the SUSY breaking spurion field, $Z = \theta^2 \tilde{m} M_{pl}$ [27]. In our model, with the parameter $B' \equiv \sqrt{BM_1}$ having the size of the natural SUSY breaking

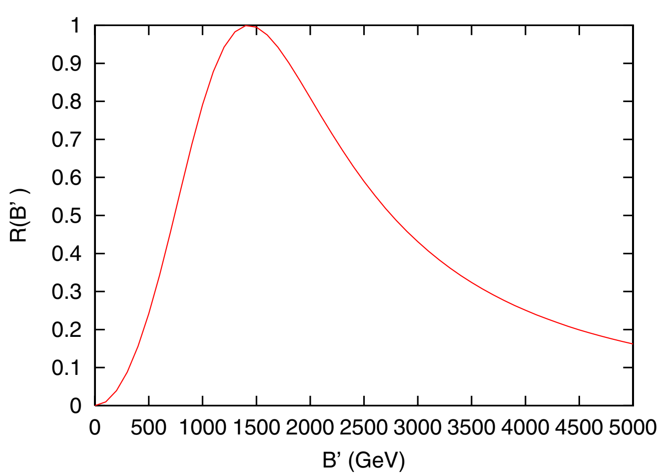

FIG. 7 (color online). The ratio R as a function of B'. The resonance occurs at around $B' \sim 1.4$ TeV.

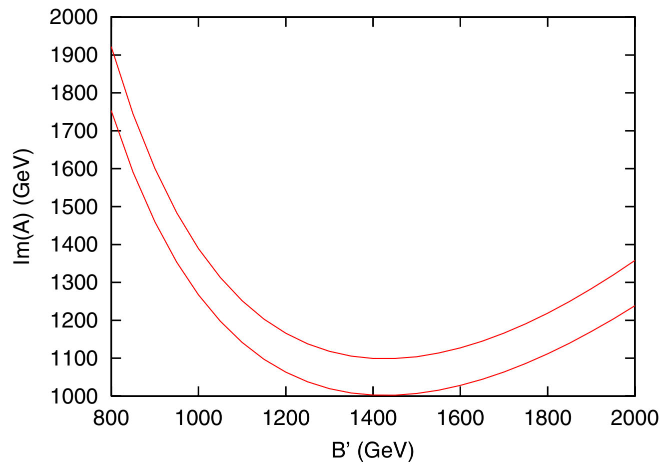

FIG. 8 (color online). The parameter space on the Im(A) versus B' plane that gives rise to an amount of baryon asymmetry consistent with the value derived from observations, $n_B/s = (0.87 \pm 0.04) \times 10^{-10}$, is the region bounded by these two curves. The upper curve corresponds to the upper bound from observation, $n_B/s = 0.91 \times 10^{-10}$, while the lower curve corresponds to the lower bound, $n_B/s = 0.83 \times 10^{-10}$.

scale $\sqrt{\tilde{m}^2} \sim \mathcal{O}(1\ \text{TeV})$, a small value for B required by the resonance condition $B \sim \Gamma_1 \sim \mathcal{O}(0.1\ \text{GeV})$ can thus be obtained.

Figure 7 shows the ratio R as a function of B'. For the specific value of the decay width Γ_1 predicted in our model, the resonance occurs at around $B' \sim 1.4$ TeV. In Fig. 8, the region on the Im(A) versus B' plane that gives rise to an amount of baryon asymmetry consistent with the value derived from observation, $n_B/s = (0.87 \pm 0.04) \times 10^{-10}$, is shown. The required value for B' near the resonance is around 800 GeV–2 TeV, and the required value for $|\text{Im}(A)|$ is around (1–2) TeV. At the resonance B', the

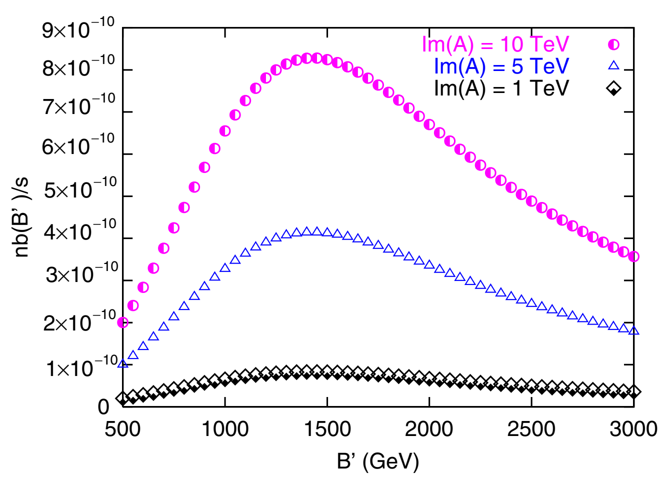

FIG. 9 (color online). The prediction for n_B/s as a function of B' for $|\text{Im}(A)| = 10$ TeV (circles), 5 TeV (triangles), and 1 TeV (squares).

value for $|\mathrm{Im}(A)|$ can be as low as 1 TeV to generate a sufficient amount of baryon asymmetry. In Fig. 9, we show the predictions for the asymmetry, n_B/s, as a function of B' for different values of $\mathrm{Im}(A)$. In the numerical analyses presented in Figs. 8 and 9, we assume $\delta_{B-F} = 1$. We note that even if an additional suppression $\delta_{B-F} \sim 0.1$ is present, with a value of $\mathrm{Im}(A) \simeq 10$ TeV at the resonance our model can still account for the observed BAU.

V. CONCLUSION

We have shown in this paper that, in contrast to the predictions of models with lopsided textures, the predictions for LFV decays are well below the current experimental bounds. This is demonstrated in a model based on SUSY SO(10) with symmetric mass textures which give rise to predictions for all fermion masses and mixing angles, including those in the neutrino sector, that are in good agreement with experimental data within 1σ. The predictions of our model for LFV processes, $\ell_i \rightarrow \ell_j \gamma$, $\mu - e$ conversion as well as $\mu \rightarrow 3e$, are well below the most stringent bounds up to date. Our predictions for many processes are within the reach of the next generation of LFV searches. This is especially true for μ-e conversion and $\mu \rightarrow e\gamma$. We have also investigated the possibility of baryogenesis resulting from soft leptogenesis. Our model predicts $M_1 < 10^9$ GeV which is the required condition for this mechanism to work. With the soft-SUSY masses assuming their natural values, $B' \sim 1.4$ TeV and $\mathrm{Im}(A) \sim 1$ TeV, we find that our model can indeed accommodate the observed baryon asymmetry of the Universe.

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