Physics Letters B 763 (2016) 164–168

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Muon anomalous magnetic moment in SUSY $B-L$ model with inverse seesaw

Shaaban Khalil [a], Cem Salih Ün [b,*]

[a] Center of Fundamental Physics, Zewail City of Science and Technology, 6 October City, Cairo, Egypt
[b] Department of Physics, Uludağ University, Bursa TR16059, Turkey

ARTICLE INFO

Article history:
Received 25 December 2015
Received in revised form 1 September 2016
Accepted 17 October 2016
Available online 20 October 2016
Editor: G.F. Giudice

ABSTRACT

Motivated by the tension between the Higgs mass and muon $g-2$ in minimal supersymmetric standard model (MSSM), we analyze the muon $g-2$ in supersymmetric $B-L$ extension of the standard model (BLSSM) with inverse seesaw mechanism. In this model, the Higgs mass receives extra important radiative corrections proportional to large neutrino Yukawa coupling. We point out that muon $g-2$ also gets significant contribution, due to the constructive interferences of light neutralino effects. The light neutralinos are typically the MSSM Bino like and the supersymmetric partner of $U(1)_{B-L}$ gauge boson ($\tilde{B}'$-ino). We show that with universal soft supersymmetry breaking terms, the muon $g-2$ resides within 2σ of the measured value, namely $\sim 20\times10^{-10}$, with Higgs mass equal to 125 GeV.

The Standard Model (SM) prediction for the anomalous magnetic moment of the muon, $a_\mu=(g-2)_\mu/2$ (hereafter muon $g-2$) has a discrepancy with the experimental results:

$$\Delta a_\mu \equiv a_\mu^{\rm exp}-a_\mu^{\rm SM}=(28.7\pm 8)\times 10^{-10}\,(1\sigma). \tag{1}$$

This discrepancy has survived after performing highly accurate theoretical calculations [1] within the SM framework and experimental analyses [2]; and hence, it can be resolved or ameliorated by contributions from new physics beyond the SM (BSM). If supersymmetry (SUSY), as one of the forefront candidates for the BSM physics, is a solution to the muon $g-2$, the SUSY particles, namely, smuon and weak gaugino (Bino or Wino) masses should be around a few hundred GeV, in order to utilize the supersymmetric contributions [3].

However, the observation of the Higgs boson of mass about 125 GeV requires rather heavy sparticle spectrum within the MSSM framework, and it results in a strong tension in simultaneous resolution for both the 125 GeV Higgs boson and the muon $g-2$ problem since SUSY contributions to muon $g-2$ is suppressed by the heavy spectrum. Non-universality in gaugino and/or scalar masses may remove this tension [4], nevertheless in this case SUSY models will have plenty of free parameters and will lose their productivity.

In this article we show that this tension can be alleviated in the $U(1)_{B-L}$ extended Supersymmetric Standard Model (BLSSM) based on the gauge group $SU(3)_C\times SU(2)_L\times U(1)_Y\times U(1)_{B-L}$. BLSSM is one of most elegant extensions of the supersymmetric models, since the SM has $B-L$ symmetry globally, and it is related to R-parity which is assumed to be protected in the MSSM to avoid rapid proton decay. When this symmetry is gauged, the model includes one more gauge boson associated with the $U(1)_{B-L}$ group. In addition, the anomaly cancellation can be achieved by simply adding three right-handed neutrino fields, and hence it is also well motivated by the established existence of non-zero neutrino masses [5]. It turns out that $B-L$ symmetry can be radiatively broken and related to the SUSY breaking scale [6]; therefore, a TeV scale Type-I or inverse seesaw mechanism can naturally be implemented in this class of models [7]. The radiative breaking of $U(1)_{B-L}$ requires two additional Higgs fields which are singlet under the MSSM gauge group, while they carry non-zero $B-L$ charges.

Despite the presence of the right-handed neutrinos, BLSSM contribution with Type-I seesaw is highly suppressed due to small neutrino Yukawa coupling ($Y_\nu\lesssim10^{-7}$) [8] which is restricted by infinitesimal neutrino masses [5]. Even though it still provides a richer phenomenology for the Higgs boson, BLSSM predicts a similar mass spectrum and muon $g-2$ results to those obtained in MSSM [9]. On the other hand, Y_ν does not have to be small if one implements inverse seesaw mechanism in which Y_ν can even be

* Corresponding author.
E-mail address: cemsalihun@uludag.edu.tr (C.S. Ün).

http://dx.doi.org/10.1016/j.physletb.2016.10.035

comparable to the top quark Yukawa coupling [10]. The Superpotential of this model is given by [11]

$$W = \mu \hat{H}_u \hat{H}_d - Y_d \hat{d} \hat{q} \hat{H}_d - Y_e \hat{e} \hat{l} \hat{H}_d + Y_u \hat{u} \hat{q} \hat{H}_u - \mu_\eta \hat{\chi}_1 \hat{\chi}_2 + Y_\nu \hat{\nu} \hat{l} \hat{H}_u + Y_s \hat{\nu} \hat{\chi}_1 \hat{s}_2 + \mu_S \hat{s}_2 \hat{s}_2 \tag{2}$$

where the first line is the terms of the MSSM superpotential, while the second line stands for the BLSSM contributions. The definition of the parameters in W, the corresponding soft SUSY breaking terms, and the details of the associate spectrum can be found in Refs. [11,12]. In sum, BLSSM with inverse seesaw extends the particle content with two SM singlet chiral Higgs superfields $\chi_{1,2}$, three sets of SM singlet chiral superfields ν_i, s_{1_i}, s_{2_i} and associated gauge superfield B' [12]. As seen from Eq. (2), the sneutrino fields interact with H_u like stops, and they provide extra contributions to the Higgs boson mass. Thus, the lower bound imposed by Higgs mass on the universal gaugino soft masses $m_{1/2}$ is reduced, which makes possible to find solutions with the light weak gauginos. Moreover, in BLSSM with inverse seesaw the $g-2$ may receive new contributions, in addition to the usual MSSM ones, due to the extension of the neutralino sector by SM singlet $(B-L)$ Higgsino and B'-ino and also due to the possibility that one of the right-handed sneutrinos is light (due to large mixing between right-handed sneutrinos and right-handed anti-sneutrinos).

Here, we will focus only on the particles involved in the $g-2$ loops, namely light neutralino, smuon and chargino, sneutrino.

Considering the additional SM singlet fields of BLSSM with inverse seesaw mentioned above the $B-L$ extension may modify only the neutral sectors of the MSSM only, and hence the chargino and slepton mass matrices remain intact. The 7×7 neutralino mass matrix, in the basis: $\left(\tilde{B}, \tilde{W}^0, \tilde{H}_d^0, \tilde{H}_u^0, \tilde{B}', \tilde{\chi}_1, \tilde{\chi}_2\right)$, can be found in Ref. [11]. One can easily show that depending on the ratio of the couplings g_1 and g_{BL}, the lightest neutralino could be B-ino $(\tilde{B})$ or B'-ino $(\tilde{B}')$ like. It is worth noting that in order to account for the Higgs mass, m_0 should be of order TeV. Now we turn to the sneutrino mass matrix. If we write $\tilde{\nu}_{L,R}$ and $\tilde{S}_2$ as $\tilde{\nu}_{L,R} = \frac{1}{\sqrt{2}}(\phi_{L,R} + i\sigma_{L,R})$ and $\tilde{S}_2 = \frac{1}{\sqrt{2}}(\phi_S + i\sigma_S)$, then we can get the CP-odd/even sneutrinos matrices as given in [11].

The supersymmetric contributions to a_μ in BLSSM can be split into neutralino and chargino parts as for the MSSM [3],

$$a_\mu^{\chi^0} = \frac{m_\mu}{16\pi^2} \sum_{m,i} \Bigg\{ -\frac{m_\mu}{6m^2_{\tilde{\mu}_m}(1-x_{mi})^4} \left(|N^L_{mi}|^2 + |N^R_{mi}|^2\right) \times \left(1 - 6x_{mi} + 3x^2_{mi} + 2x^3_{mi} - 6x^2_{mi}\ln x_{mi}\right) + \frac{m_{\chi^0_i}}{m^2_{\tilde{\mu}_m}(1-x_{mi})^3} N^L_{mi} N^R_{mi} (1 - x^2_{mi} + 2x_{mi}\ln x_{mi}) \Bigg\} \tag{3}$$

$$a_\mu^{\chi^\pm} = \frac{m_\mu}{16\pi^2} \sum_k \Bigg\{ \frac{m_\mu}{3m^2_{\tilde{\nu}}(1-x_k)^4} \left(|C^L_k|^2 + |C^R_k|^2\right) \times \left(1 + 1.5x_k + 0.5x^3_k - 3x^2_k + 3x_k \ln x_k\right) - \frac{3m_{\chi^\pm_k}}{m^2_{\tilde{\nu}}(1-x_k)^3} C^L_k C^R_k \left(1 - \frac{4x_k}{3} + \frac{x^2_k}{3} + \frac{2}{3}\ln x_k\right) \Bigg\} \tag{4}$$

where $x_{mi} = m^2_{\chi^0_i}/m^2_{\tilde{\mu}_m}$, $x_k = m^2_{\chi^\pm_k}/m^2_{\tilde{\nu}}$, and

$$N^L_{aij} = -\frac{i}{2}\Big[\sqrt{2}(2g_1 + \tilde{g})N^*_{a1}(U^*_{\tilde{\mu}} Z^{\mu\dagger}_R)_{ij} + \sqrt{2}(2\tilde{g} + g_{BL})\, N^*_{a5}(U^*_{\tilde{\mu}} Z^{\mu\dagger}_R)_{ij} + 2N^*_{a3}(U_{\tilde{\mu}} Y^T_\mu Z^{\mu\dagger}_R)_{ij}\Big] \tag{5}$$

$$N^R_{aij} = \frac{i}{2}\Big[-2N_{a3}(Z^\mu_L Y^\dagger_\mu U^\dagger_{\tilde{\mu}})_{ij} + \sqrt{2}(g_1 + \tilde{g})N^*_{a1}(Z^\mu_L U^\dagger_{\tilde{\mu}})_{ij} + \sqrt{2}\, g_2 N^*_{a2}(Z^\mu_L U^\dagger_{\tilde{\mu}})_{ij} + \sqrt{2}(\tilde{g} + g_{BL})N^*_{a5}(Z^\mu_L U^\dagger_{\tilde{m u}})_{ij}\Big] \tag{6}$$

$$C^L_{bij} = \frac{-1}{\sqrt{2}}(U^*_{\tilde{\chi}^-})_{b2}(U^*_{\tilde{\nu}^i} Y^T_\mu Z^{\mu\dagger}_R)_{ij} + \frac{i}{2}(U^*_{\tilde{\chi}^-})_{b2}(U^*_{\tilde{\nu}^R} Y^T_\mu Z^{\mu\dagger}_R)_{ij} \tag{7}$$

$$C^R_{bij} = \frac{1}{\sqrt{2}}\Big[g_2(U_{\tilde{\chi}^+})_{b1}(Z^\mu_L U^\dagger_{\tilde{\nu}^i})_{ij} - (U_{\tilde{\chi}^+})_{b2}(Z^\mu_L Y^\dagger_\nu U^\dagger_{\tilde{\nu}^i})_{ij}\Big] - \frac{i}{\sqrt{2}}\Big[g_2(U_{\tilde{\chi}^+})_{b1}(Z^\mu_L U^\dagger_{\tilde{\nu}^R})_{ij} - (U_{\tilde{\chi}^+})_{b2}(Z^\mu_L Y^\dagger_\nu U^\dagger_{\tilde{\nu}^R})\Big] \tag{8}$$

where $Z^\mu_{L,R}$, $U_{\tilde{\mu}}$ are the rotation matrices which diagonalize the muon and smuon mass matrices respectively, while $U_{\tilde{\nu}^i}$ and $U_{\tilde{\nu}^R}$ diagonalize the CP-odd and CP-even sneutrino mass matrices. Note that one can neglect the mixing between slepton families, and consider the smuon mass matrix as 2×2 matrix separately from the first and third families. In addition, the mixing between two smuons is proportional to the Yukawa coupling associated with muon, which is of the order $\sim 10^{-4}$, and hence left- and right-handed smuons are approximately match with the mass eigenstates, and hence, the rotation matrix for the smuons, $U_{\tilde{\mu}}$ can be set to unity in a good approximation. A similar discussion holds for the muon mass matrix diagonalized by $Z^\mu_{L,R}$.

As seen from Eqs. (5), (6), the Bino contribution is in a similar form as obtained in the MSSM, but in BLSSM it is modified by the gauge mixing between $U(1)_Y$ and $U(1)_{B-L}$ characterized by the coupling $\tilde{g}$. It is worth emphasizing the contribution from B'-ino $(\tilde{B}')$. It contributes to a_μ through interactions with muon governed by $B-L$ gauge group and the gauge kinetic mixing. Moreover, since it is allowed to be as light as Bino, and even lighter, the lightest neutralino can be formed to be mostly $\tilde{B}'$ or $\tilde{B}$–$\tilde{B}'$ mixing. Thus, one can expect its contribution to be comparable with that from Bino in BLSSM; i.e. $N_{a1} \approx N_{a5}$ numerically. We also present the contribution from the Higgsino component of the Neutralino.

Similarly Eqs. (7), (8) reveal the contribution from the chargino expressed in terms of CP-odd and CP-even sneutrino sectors separately. Note that Eqs. (7), (8) hold approximately, and one can combine these two sectors in the case of strong mixing between them by summing over $j = 1, \ldots, 9$. The contribution denoted by C^L_{bij} are mostly suppressed because of Y_μ. On the other hand, C^R_{bij} is expected to dominate in the chargino contribution to a_μ. It arises from the interactions between muon and sneutrinos through SU(2) interactions as shown in the first and third terms in Eq. (8). The remaining terms are from the Yukawa interactions, and they cannot be neglected, since Y_ν is allowed to be of the order $\mathcal{O}(1)$ when one employs the inverse seesaw mechanism in BLSSM.

The terms with $N^L N^R$ and $C^L C^R$ in Eqs. (3), (4) correspond to the diagrams with the chirality flip between the internal fermions running through the loop, and such terms dominate in SUSY contributions to muon $g-2$ when $\tan\beta$ is large. When the universal boundary conditions at $M_{\rm GUT}$ are imposed in MSSM, the low scale mass spectrum is rather required to be heavy due to the Higgs boson of mass about 125 GeV; hence, the SUSY contributions are highly suppressed. On the other hand, as mentioned above, in BLSSM with inverse seesaw, the right-handed sneutrinos can significantly contribute to the Higgs boson mass that results in solutions with low $M_{1/2}$ even in the case with universal boundary conditions. In this sense, BLSSM with inverse seesaw improves the MSSM contributions to muon $g-2$. Note that, the gauge coupling of $U(1)_Y$ is modified as $g_1 \to g_1 + \frac{1}{2}\tilde{g}$, where $\tilde{g}$ stands for the gauge kinetic mixing. In addition to the MSSM contributions, BLSSM provides new ones to muon $g-2$ represented with the diagrams given in Fig. 1. The approximate contributions are given in

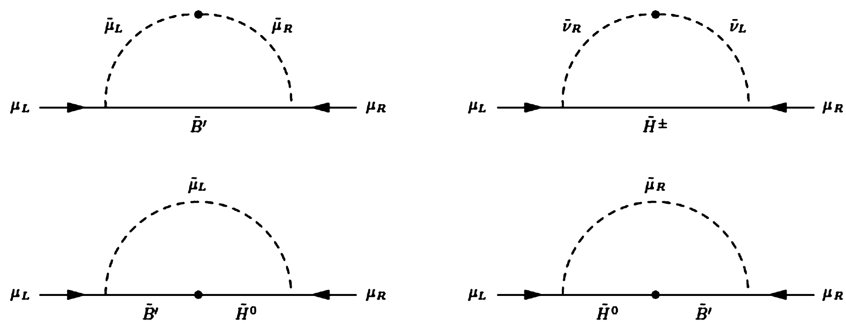

Fig. 1. Contributions to muon $g-2$ from $B-L$ sector.

Eqs. (9)–(12) so that the $\tan\beta$ dependence can be understood easily.

$$(\Delta a_\mu)_{N1} \approx \frac{(g_{BL}+2\tilde{g})^2 m_\mu^2 M_{\tilde{B}'}\mu\tan\beta}{m_{\tilde{\mu}_R}^2 - m_{\tilde{\mu}_L}^2} \times \left[\frac{f_\chi(M_{\tilde{B}'}^2/m_{\tilde{\mu}_R}^2)}{m_{\tilde{\mu}_R}^2} - \frac{f_\chi(M_{\tilde{B}'}^2/m_{\tilde{\mu}_L}^2)}{m_{\tilde{\mu}_L}^2}\right] \tag{9}$$

$$(\Delta a_\mu)_{N2} \approx \frac{m_\mu^2\mu\cot\beta}{m_{\tilde{\nu}_R}^2 - m_{\tilde{\nu}_L}^2}\left[\frac{f_\chi(\mu^2/m_{\tilde{\nu}_R}^2)}{m_{\tilde{\nu}_R}^2} - \frac{f_\chi(\mu^2/m_{\tilde{\nu}_L}^2)}{m_{\tilde{\nu}_L}^2}\right] \tag{10}$$

$$(\Delta a_\mu)_{N3} \approx \frac{(g_{BL}+2\tilde{g})\tilde{g} m_\mu^2 M_{\tilde{B}'}\mu\tan\beta}{m_{\tilde{\mu}_L}^2} \times \left[\frac{f_\chi(M_{\tilde{B}'}^2/m_{\tilde{\mu}_R}^2) - f_\chi(\mu^2/m_{\tilde{\mu}_R}^2)}{M_{\tilde{B}'}^2 - \mu^2}\right] \tag{11}$$

$$(\Delta a_\mu)_{N4} \approx \frac{(g_{BL}+2\tilde{g})\tilde{g} m_\mu^2 M_{\tilde{B}'}\mu\tan\beta}{m_{\tilde{\mu}_R}^2} \times \left[\frac{f_\chi(M_{\tilde{B}'}^2/m_{\tilde{\mu}_R}^2) - f_\chi(\mu^2/m_{\tilde{\mu}_R}^2)}{M_{\tilde{B}'}^2 - \mu^2}\right] \tag{12}$$

The upper diagrams in Fig. 1 place the chirality flip on smuon and sneutrino respectively. The diagram with smuons exhibits $\tan\beta$ enhancement, while the contribution from sneutrinos is suppressed with $\tan\beta$. Note that this suppression can be compensated when the left-handed sneutrinos are degenerate with the right-handed sneutrinos, which is unlikely since the RGEs for these sparticles yield a sizable mass splitting between them during the run from the GUT scale to the low scale. The bottom diagrams shows the contributions from the mixing between $\tilde{H}$ of MSSM and $\tilde{B}'$ of BLSSM. Note that this mixing is induced at tree level since the gauge covariant derivative takes a non-canonical form in the presence of the gauge kinetic mixing [13]. If one assumes zero or negligible gauge kinetic mixing, the bottom diagrams disappear in $B-L$ contributions to the muon $g-2$. BLSSM's singlet Higgsino does not contribute to muon $g-2$, since it does not interact with the SM particles. Before concluding, one can count the non-SUSY contributions to muon $g-2$, since BLSSM extends the SM as well. In this work we focus only on the SUSY contributions, the detailed calculations for the non-SUSY contribution can be seen in Ref. [14].

In an approach from the low scale, it is possible to fit the relevant parameters to resolve the muon $g-2$ problem. On the other hand, especially when one imposes the universal boundary conditions at $M_{\rm GUT}$, the MSSM predictions for muon $g-2$ are only as good as the SM. In this study, we consider BLSSM with some extra particles in the low scale content associated with $U(1)_{B-L}$ gauge group and its radiative breaking to investigate how much improvement can be obtained in muon $g-2$ predictions. In order to focus on the extra sector, we keep the universal boundary conditions at $M_{\rm GUT}$.

In scanning the parameter space, we have employed the Metropolis–Hastings algorithm as described in [15], and used SARAH [16] and SPheno [17] for the numerical results. The data points collected all satisfy the requirement of radiative electroweak symmetry breaking. After collecting the data, we impose the mass bounds on all the particles [18]. We have employed the Higgs mass bound as 123 GeV $\leq m_h \leq$ 127 GeV [19,20], where we take into account about 2 GeV uncertainty in Higgs boson mass due to the theoretical uncertainties in calculation of the minimum of the scalar potential, and the experimental uncertainties in m_t and α_s. We also employ the gluino mass bound: $m_{\tilde{g}} \geq 1$ TeV [21] and the neutral gauge boson Z' mass bound: $M_{Z'} \geq 2.5$ TeV [22].

Even though the mass spectrum is mostly effective, the couplings are also important in determining the sign of the contributions to muon $g-2$. We display the correlation between Δa_μ and $\tan\beta$, g_{BL}, and $\tilde{g}$ in Fig. 2. All points are consistent with radiative electroweak symmetry breaking. Green points are consistent with the mass bounds on the Higgs boson and sparticles. The dashed lines indicate the 1σ uncertainty in Δa_μ measurements. As expected, muon $g-2$ solutions are obtained when $\tan\beta$ is large, and it gets the best result for $\tan\beta \approx 57$ as seen from the Δa_μ–$\tan\beta$ plane. g_{BL} is found in the range $\sim 0.47-0.55$, while the gauge kinetic mixing, $\tilde{g}$, is always negative at the low scale. The last panel of Fig. 2 represents the total effects of g_{BL} and $\tilde{g}$. As seen, their total effect mostly give positive sign, while there is a small portion in which $\tilde{g}$ dominates over g_{BL} and changes the sign to negative. In this region, the contributions given in Eqs. (11), (12) becomes negative. The plots, on the other hand, shows that it is possible to compensate the effects from these couplings with lighter spectrum; hence, the region of the best solutions for muon $g-2$ (green) remains almost flat.

Fig. 3 displays the correlation of Δa_μ with $m_{\tilde{\chi}_1^0}$ and $m_{\tilde{\chi}_1^\pm}$. The color coding is the same as Fig. 2. The lightest neutralino should be lighter than about 400 GeV in order for contributions which result in muon $g-2$ within 2σ. The largest contributions to muon $g-2$ restrict the neutralino mass $\lesssim 300$ GeV. The chargino mass is found slightly heavier (~ 600 GeV) within the 2σ band, and the region with the chargino mass less than about 300 GeV is excluded by the mass bounds on the sparticles and Higgs boson. The mass scales obtained for the neutralino and chargino are also very favorable for significant contributions to muon $g-2$ even if the $B-L$ sector does not involve. Hence, one can expect an improvement in the MSSM contributions.

As mentioned above, BLSSM does not involve in the charged sector; hence, the contributions from chargino can be illustrated in the same way as done in MSSM. On the other hand, the neutralino structure is enriched with the extra neutral particles. Fig. 4 represents our results for the mass spectrum with plots in the $M_{\tilde{B}'}$–$M_{\tilde{B}}$ and $M_{\tilde{W}}$–μ planes. The color coding is the same as Fig. 2. In ad-

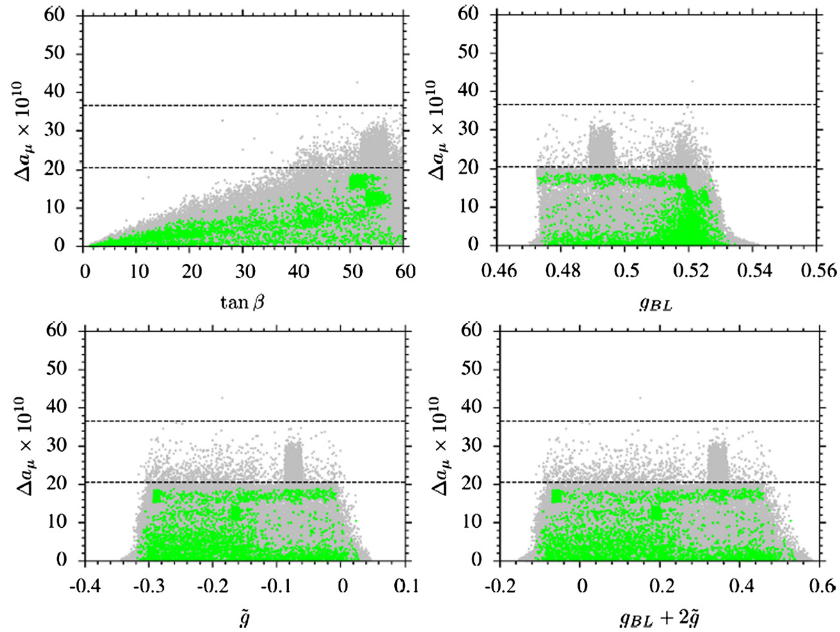

Fig. 2. Correlations between Δa_μ and $\tan\beta$, g_{BL}, and $\tilde{g}$. All points are consistent with radiative electroweak symmetry breaking. Green points are consistent with the mass bounds on the Higgs boson and sparticles. The dashed lines indicate the 1σ uncertainty in Δa_μ measurements. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

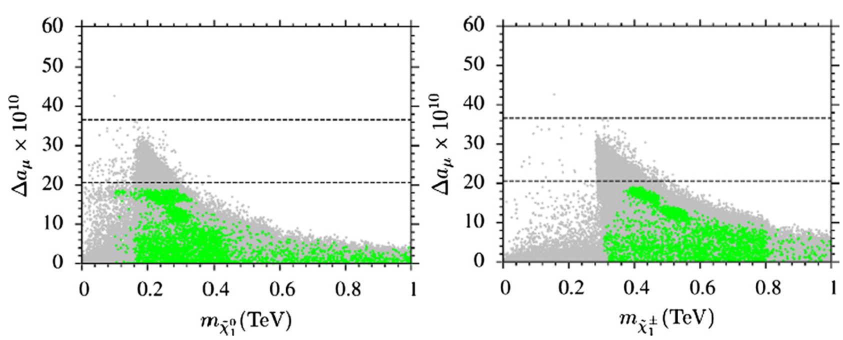

Fig. 3. Correlations of Δa_μ with $m_{\tilde{\chi}_1^0}$ and $m_{\tilde{\chi}_1^\pm}$. The color coding is the same as Fig. 2. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

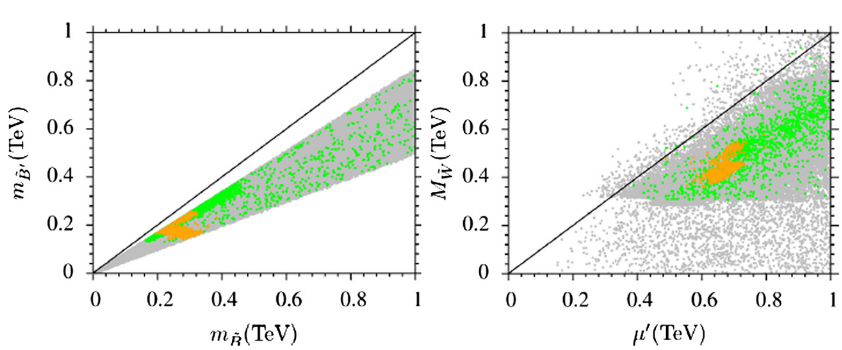

Fig. 4. Plots in the $M_{\tilde{B}'}$–$M_{\tilde{B}}$ and $M_{\tilde{W}}$–μ planes. The color coding is the same as Fig. 2. In addition, the orange region is a subset of green and it represents the solutions for muon $g-2$ within 2σ. The diagonal line indicates the mass degeneracy. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

dition, the orange region is a subset of green and it represents the solutions for muon $g-2$ within 2σ. The diagonal line indicates the mass degeneracy. The $M_{\tilde{B}'}$–$M_{\tilde{B}}$ plane shows that the lightest neutralino is mostly formed by $\tilde{B}'$, as expected. In this context, $\tilde{B}$-ino forms the second lightest neutralino of mass $\gtrsim 250$ GeV; and hence it still provides significant contribution to muon $g-2$. We can also see from the $M_{\tilde{W}}$–μ plane that the lightest chargino is always Wino-like of mass about 400 GeV, while one can also count on the heavier chargino of mass about 600 GeV in muon $g-2$ results.

In conclusion, we have found that the supersymmetric contribution to muon $g-2$ in BLSSM with inverse seesaw mostly relies on the light Bino with $M_1 \gtrsim 250$ GeV, and even lighter $\tilde{B}'$ of mass about 180 GeV. In this case the lightest neutralino mass eigenstate is either mostly $\tilde{B}'$ or a linear superposition of $\tilde{B}'$ and $\tilde{B}$. When such a light neutralino solution combines with the chirality flip of smuons, one can expect the contribution to muon $g-2$ to be dominant over the other diagrams. The $\tan\beta$ dependence of Δa_μ is also represented, and we have found that $\tan\beta$ needs to be $\gtrsim 45$ in order to raise the supersymmetric contribution such that muon $g-2$ results satisfy the measurement within 2σ. Besides, we found that the lightest chargino is mostly Wino-like of mass about 400 GeV, while the second chargino of mass about 600 GeV can also be counted in the muon $g-2$ results. In this context, BLSSM improves the MSSM contributions despite the universal boundary conditions imposed at $M_{\rm GUT}$, which yield a TeV scale smuons and sneutrinos. In addition, even though it is always negative at the low scale, the kinetic gauge mixing coupling $\tilde{g}$ enhances the SUSY contributions to muon $g-2$ by allowing the mixing between the MSSM Higgsinos and $\tilde{B}'$-ino. These contributions become negative only in a small portion of the parameter space where $\tilde{g}$ dominates over g_{BL}. As a result of our scan over the BLSSM parameter space with universal boundary conditions in the presence of inverse seesaw the best solution is found with $\Delta a_\mu \approx 20 \times 10^{-10}$, which is much larger than those found in MSSM.

Acknowledgements

We would like to thank Waleed Abdallah for useful discussions about the gauge kinetic mixing. The work of SK is partially supported by the ICTP grant AC-80 and the STDF project 13858. The work of CSÜ is supported in part by the Scientific and Technological Research Council of Turkey (TUBITAK) Grant no. MFAG-114F461. This work used the Extreme Science and Engineering Discovery Environment (XSEDE), which is supported by the National Science Foundation grant number OCI-1053575.

References

[1] M. Davier, A. Hoecker, B. Malaescu, Z. Zhang, Eur. Phys. J. C 71 (2011) 1515, Eur. Phys. J. C 72 (2012) 1874, arXiv:1010.4180 [hep-ph];
K. Hagiwara, R. Liao, A.D. Martin, D. Nomura, T. Teubner, J. Phys. G 38 (2011) 085003, arXiv:1105.3149 [hep-ph].

[2] G.W. Bennett, et al., Muon g-2 Collaboration, Phys. Rev. D 73 (2006) 072003, arXiv:hep-ex/0602035;
G.W. Bennett, et al., Muon (g-2) Collaboration, Phys. Rev. D 80 (2009) 052008, arXiv:0811.1207 [hep-ex].

[3] T. Moroi, Phys. Rev. D 53 (1996) 6565, Phys. Rev. D 56 (1997) 4424, arXiv:hep-ph/9512396;
S.P. Martin, J.D. Wells, Phys. Rev. D 64 (2001) 035003, arXiv:hep-ph/0103067;
G.F. Giudice, P. Paradisi, A. Strumia, A. Strumia, J. High Energy Phys. 1210 (2012) 186, arXiv:1207.6393 [hep-ph].

[4] M.A. Ajaib, I. Gogoladze, Q. Shafi, C.S. Ün, J. High Energy Phys. 1405 (2014) 079, arXiv:1402.4918 [hep-ph];
I. Gogoladze, F. Nasir, Q. Shafi, C.S. Un, Phys. Rev. D 90 (3) (2014) 035008, arXiv:1403.2337 [hep-ph].

[5] R. Wendell, et al., Super-Kamiokande Collaboration, Phys. Rev. D 81 (2010) 092004, arXiv:1002.3471 [hep-ex].

[6] S. Khalil, A. Masiero, Phys. Lett. B 665 (2008) 374, arXiv:0710.3525 [hep-ph].

[7] S. Khalil, Phys. Rev. D 82 (2010) 077702, arXiv:1004.0013 [hep-ph].

[8] M. Abbas, S. Khalil, J. High Energy Phys. 0804 (2008) 056, http://dx.doi.org/10.1088/1126-6708/2008/04/056, arXiv:0707.0841 [hep-ph].

[9] C.S. Un, O. Ozdal, Phys. Rev. D 93 (2016) 055024, http://dx.doi.org/10.1103/PhysRevD.93.055024, arXiv:1601.02494 [hep-ph].

[10] R.N. Mohapatra, J.W.F. Valle, Phys. Rev. D 34 (1986) 1642, http://dx.doi.org/10.1103/PhysRevD.34.1642;
M.C. Gonzalez-Garcia, J.W.F. Valle, Phys. Lett. B 216 (1989) 360, http://dx.doi.org/10.1016/0370-2693(89)91131-3;
S. Khalil, Phys. Rev. D 82 (2010) 077702, http://dx.doi.org/10.1103/PhysRevD.82.077702, arXiv:1004.0013 [hep-ph].

[11] F. Staub, Comput. Phys. Commun. 185 (2014) 1773, arXiv:1309.7223 [hep-ph].

[12] S. Khalil, S. Moretti, arXiv:1503.08162 [hep-ph].

[13] B. O'Leary, W. Porod, F. Staub, J. High Energy Phys. 1205 (2012) 042, http://dx.doi.org/10.1007/JHEP05(2012)042, arXiv:1112.4600 [hep-ph].

[14] W. Abdallah, A. Awad, S. Khalil, H. Okada, Eur. Phys. J. C 72 (2012) 2108, http://dx.doi.org/10.1140/epjc/s10052-012-2108-9, arXiv:1105.1047 [hep-ph].

[15] G. Belanger, F. Boudjema, A. Pukhov, R.K. Singh, J. High Energy Phys. 0911 (2009) 026, arXiv:0906.5048 [hep-ph];
H. Baer, S. Kraml, S. Sekmen, H. Summy, J. High Energy Phys. 0803 (2008) 056, arXiv:0801.1831 [hep-ph].

[16] F. Staub, Comput. Phys. Commun. 184 (2013) 1792, Comput. Phys. Commun. 184 (2013) 1792, arXiv:1207.0906 [hep-ph].

[17] W. Porod, Comput. Phys. Commun. 153 (2003) 275, arXiv:hep-ph/0301101;
W. Porod, F. Staub, Comput. Phys. Commun. 183 (2012) 2458, arXiv:1104.1573 [hep-ph].

[18] K.A. Olive, et al., Particle Data Group Collaboration, Chin. Phys. C 38 (2014) 090001.

[19] G. Aad, et al., ATLAS Collaboration, Phys. Lett. B 716 (2012) 1, arXiv:1207.7214 [hep-ex].

[20] S. Chatrchyan, et al., CMS Collaboration, Phys. Lett. B 716 (2012) 30, arXiv:1207.7235 [hep-ex].

[21] G. Aad, et al., ATLAS Collaboration, J. High Energy Phys. 1410 (2014) 24, arXiv:1407.0600 [hep-ex];
ATLAS Collaboration, ATLAS-CONF-2013-062, ATLAS-COM-CONF-2013-039;
G. Aad, et al., ATLAS Collaboration, J. High Energy Phys. 1409 (2014) 103, arXiv:1407.0603 [hep-ex];
S. Chatrchyan, et al., CMS Collaboration, J. High Energy Phys. 1210 (2012) 018, arXiv:1207.1798 [hep-ex].

[22] ATLAS Collaboration, ATLAS-CONF-2013–017, ATLAS-COM-CONF-2013-010;
CMS Collaboration, CMS-PAS-EXO-12-061.