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Electroweak Supersymmetry around the Electroweak Scale

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Abstract

Inspired by the phenomenological constraints, LHC supersymmetry and Higgs searches, dark matter search as well as string model building, we propose the electroweak supersymmetry around the electroweak scale: the squarks and/or gluinos are around a few TeV while the sleptons, sneutrinos, bino and winos are within one TeV. The Higgsinos can be either heavy or light. We consider bino as the dominant component of dark matter candidate, and the observed dark matter relic density is achieved via the neutralino-stau coannihilations. Considering the Generalized Minimal Supergravity (GmSUGRA), we show explicitly that the electroweak supersymmetry can be realized, and the gauge coupling unification can be preserved. With two Scenarios, we study the viable parameter spaces that satisfy all the current phenomenological constraints, and we present the concrete benchmark points. Furthermore, we comment on the fine-tuning problem and LHC searches.

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I. INTRODUCTION

Supersymmetry (SUSY) provides the most natural solution to the gauge hierarchy problem in the Standard Model (SM). In supersymmetric SMs (SSMs) with R parity, the gauge couplings for $SU(3)_C$, $SU(2)_L$ and $U(1)_Y$ gauge symmetries are unified at about 2×10^{16} GeV [1], the lightest supersymmetric particle (LSP) like neutralino can be cold dark matter candidate [2, 3], and the electroweak precision constraints can be evaded, etc. Especially, gauge coupling unification [1] strongly suggests Grand Unified Theories (GUTs), which can explain the quantum numbers of the SM fermions and charge quantization elegantly. Thus, the SSMs are the most promising new physics beyond the SM. However, the recent LHC searches for supersymmetry [4–6] and Higgs boson [7, 8] have considerably shrinken the viable parameter spaces. Thus, to explore the phenomenologically inspired SSMs, we briefly review the phenomenological constraints in the following:

- In the $\sqrt{s} = 7$ TeV proton-proton collisions at the LHC with a total integrated luminosity of 4.7 fb^{-1}, the gluinos masses below 860 GeV and squarks masses below 1320 GeV are excluded at the 95% Confidence Level (C.L.) in simplified models with the first two generation squarks, gluino, and a massless neutralino, for squark or gluino masses below 2 TeV, respectively [4]. Also, squarks and gluinos with equal masses below 1410 GeV are excluded [4]. In the Minimal Supergravity (mSUGRA) or Constrained Minimal SSM (CMSSM), the squarks and glunios with equal masses up to about 1350 GeV [4, 5], the gluino with mass up to 800 GeV [5], and stop and sbottom masses up to 400 GeV [5] are ruled out as well. Moreover, in the $\sqrt{s} = 8$ TeV proton-proton collisions at the LHC with a total integrated luminosity of 5.8 fb^{-1}, gluino masses below 1100 GeV are excluded in the simplified models, and squarks and gluinos of equal mass are excluded for masses below 1500 GeV in the mSUGRA/CMSSM [6].

- The ATLAS and CMS Collaborations have discovered the SM-like Higgs boson. Their combined Higgs boson mass measurements are $m_{h^0} = 125.2 \pm 0.3(\text{stat}) \pm 0.6(\text{syst})$ GeV and $m_{h^0} = 125.8 \pm 0.4(\text{stat}) \pm 0.4(\text{syst})$ GeV, respectively [7, 8]. Moreover, the Higgs boson mass around 125.5 GeV gives very strong constraints on the viable supersymmetry parameter space, which have been studied extensively recently [9–26]. Especially, the squark and/or gluino masses will be about a few TeV in general in the Minimal

Supersymmetric Standard Model (MSSM) and the Next to the MSSM (NMSSM) with simple supersymmetry mediation mechanisms.

- The cold dark matter relic density is 0.112 ± 0.0056 from the seven-year WMAP measurements [27].

- The spin-independent elastic dark matter-nucleon scattering cross-sections are smaller than about 2×10^{-45} cm^2 for the dark matter mass around 55 GeV at 90% CL [28].

- The experimental limit on the Flavor Changing Neutral Current (FCNC) process, $b \to s\gamma$. The results from the Heavy Flavor Averaging Group (HFAG) [29], in addition to the BABAR, Belle, and CLEO results, are: $\mathrm{BR}(b \to s\gamma) = (355 \pm 24^{+9}_{-10} \pm 3) \times 10^{-6}$. There is also a theoretical estimate in the SM [30] of $\mathrm{BR}(b \to s\gamma) = (3.15 \pm 0.23) \times 10^{-4}$. The limits, where the experimental and theoretical errors are added in quadrature, are $2.86 \times 10^{-4} \leq \mathrm{BR}(b \to s\gamma) \leq 4.18 \times 10^{-4}$.

- The anomalous magnetic moment of the muon $(g_\mu - 2)/2$. The experimental value of the muon $(g_\mu - 2)/2$ deviates from the SM prediction by about 3.3σ, *i.e.*, $\Delta a_\mu = a_\mu^{\mathrm{exp}} - a_\mu^{\mathrm{SM}} = (26.1 \pm 8.0) \times 10^{-10}$ [31].

- The process $B_s \to \mu^+\mu^-$. The branching fraction of $\mathrm{BR}(B_s^0 \to \mu^+\mu^-)$ is $3.2^{+1.5}_{-1.2} \times 10^{-9}$ from the LHCb Collaboration [32].

- The experimental limit on the process $B_u \to \tau\bar{\nu}_\tau$ is $0.85 \leq \mathrm{BR}(B_u \to \tau\bar{\nu}_\tau)/\mathrm{SM} \leq 1.65$ [33].

In addition, from the theoretical point of view, we usually have the family universal squark and slepton soft masses in the string model building, for example, the heterotic $E_8 \times E_8$ string theory with Calabi-Yau compactifications [34, 35], the intersecting D-brane model building [36–44], and the F-theory model building [45–52], etc. Therefore, based on the above phenomenological constraints and theoretical considerations, we propose the electroweak supersymmetry around the electroweak scale: *the squarks and/or gluinos are around a few TeV while the sleptons, sneutrinos, bino and winos are within one TeV.* The Higgsinos (or say the Higgs bilinear μ term) can be either heavy or light. We emphasize that gluinos can be within one TeV because squarks are heavy. Therefore, the constraints from the current ATLAS and CMS supersymmetry and Higgs searches and the $b \to s\gamma$,

$B_s^0 \to \mu^+\mu^-$, and $B_u \to \tau\bar{\nu}_\tau$ processes can be satisfied automatically due to the heavy squarks. Also, the dimension-five proton decays in supersymmetric GUTs can be relaxed as well. Moreover, the $(g_\mu - 2)/2$ experimental result can be explained due to the light sleptons. Also, we will assume that the dominant component of the LSP neutralino is bino. Interestingly, the observed dark matter relic density can be realized via the LSP neutralino and light stau coannihilations, and the XENON experiment [28] will not give any constraint on such viable parameter spaces due to the heavy squarks. For simplicity, we will call the *electroweak supersymmetry around the electroweak scale* as the *electroweak supersymmetry*. We emphasize that the electroweak supersymmetry is different from the traditional mSUGRA/CMSSM, gauge mediation, and anomaly mediation [53]. In particular, the ratios between the squark masses and slepton masses in the electroweak supersymmetry are larger than those in the traditional mSUGRA/CMSSM, gauge mediation, and anomaly mediation [53]. Also, the ratios between the gluino mass and the bino/wino masses might be larger as well.

In this paper, we consider the simple Generalized Minimal Supergravity (GmSUGRA) [54, 55] (For previous studies on non-universal gaugino masses in the supersymmetric GUTs, see Refs. [56–67].). We show explicitly that the electroweak supersymmetry can be realized naturally, and gauge coupling unification can be preserved. To be concrete, we consider two Scenarios for the gaugino mass ratios: Scenario I has $M_1 : M_2 : M_3 = 1 : (-1) : 4$ and Scenario II has $M_1 : M_2 : M_3 = \frac{5}{3} : 1 : \frac{8}{3}$, where M_1, M_2 and M_3 are bino mass, wino mass, and gluino mass, respectively. We discuss two cases for the supersymmetry breaking scalar masses and trilinear soft A terms: (A) The universal scalar mass m_0, and universal/non-universal trilinear A terms. This case is similar to the mSUGRA/CMSSM; (B) The universal squark and slepton mass m_0, universal/non-universal trilinear A terms, and especially non-universal Higgs scalar masses. This case is similar to the NUHM2. Choosing the universal squark and slepton mass, the fixed trilinear A terms and a moderate $\tan\beta = 13$ for simplicity where $\tan\beta$ is the ratio of the Higgs vacuum expectation values (VEVs) in the SSMs, we scan the viable parameter spaces which satisfy all the current phenomenological constraints. Also, we present the concrete benchmark points where the squarks, gluinos and Higgsinos are about a few TeV while the sleptons, bino and winos are several hundreds of GeV. For the universal trilinear soft A term, we can fit all the experimental constraints very well except the $(g_\mu - 2)/2$. And the deviations of $(g_\mu - 2)/2$ from the central value is about

2.6σ. Interestingly, with non-universal trilinear soft A terms, we can fit all the experimental constraints very well, especially, the deviations of $(g_\mu - 2)/2$ from the central value is within 1 or 2σ. We would like to point out that comparing to the traditional mSUGRA/CMSSM, gauge mediation, and anomaly mediation [53], the ratios between the squark masses and slepton masses and ratios between the gluino mass and the bino/wino masses in our models are larger. Moreover, we comment on the fine-tuning problem as well as the LHC searches.

II. ELECTROWEAK SUPERSYMMETRY FROM THE GMSUGRA

First, we explain our conventions. In SSMs, we denote the left-handed quark doublets, right-handed up-type quarks, right-handed down-type quarks, left-handed lepton doublets, right-handed neutrinos, and right-handed charged leptons as Q_i, U_i^c, D_i^c, L_i, N_i^c, and E_i^c, respectively. Also, we denote one pair of Higgs doublets as H_u and H_d, which give masses to the up-type quarks/neutrinos and the down-type quarks/charged leptons, respectively.

We consider the simple GmSUGRA where the GUT gauge group is $SU(5)$ and the Higgs field Φ for the GUT symmetry breaking is in the $SU(5)$ adjoint representation [54, 55]. Because Φ can coulpe to the gauge field kinetic terms via high-dimensional operators, the gauge coupling relation and gaugino mass relation at the GUT scale will be modified after Φ acquires a VEV [54, 56]. Similarly, the scalar masses and trilinear soft terms will be modified as well due to the relevant high-dimensional operators [55]. The gauge coupling relation and gaugino mass relation at the GUT scale are the following [54, 56]

$$\frac{1}{\alpha_2} - \frac{1}{\alpha_3} \;=\; k\left(\frac{1}{\alpha_1} - \frac{1}{\alpha_3}\right) \;, \tag{1}$$

$$\frac{M_2}{\alpha_2} - \frac{M_3}{\alpha_3} \;=\; k\left(\frac{M_1}{\alpha_1} - \frac{M_3}{\alpha_3}\right) \;, \tag{2}$$

where k is the index of these relations and is equal to 5/3 [54] in our simple GmSUGRA. Such gauge coupling relation and gaugino mass relation at the GUT scale can be realized in the F-theory $SU(5)$ models where the gauge symmetry is broken down to the SM gauge symmetry by turning on the $U(1)_Y$ flux, and the F-theory $SO(10)$ models where the gauge symmetry is broken down to the $SU(3)_C \times SU(2)_L \times SU(2)_R \times U(1)_{B-L}$ gauge symmetry by turning on the $U(1)_{B-L}$ flux [65]. The point is that the $U(1)_Y$ and $U(1)_{B-L}$ fluxes can give the extra contributions to the gauge kinetic terms of the SM gauge fields.

At the GUT scale, we assume $\alpha_1 \simeq \alpha_2 \simeq \alpha_3$ for simplicity, and then the gaugino mass relation becomes

$$M_2 - M_3 = \frac{5}{3}(M_1 - M_3) \ . \tag{3}$$

So there are two free parameters in gaugino masses. To realize the electroweak supersymmetry, we require that M_3 be larger than M_1 and M_2. In the next Section, we shall consider the following two simple Scenarios for gaugino masses at the GUT scale

$$\text{Scenario I}: \quad M_1 = M_{1/2} \ , \quad M_2 = -M_{1/2} \ , \quad M_3 = 4M_{1/2} \ , \tag{4}$$

$$\text{Scenario II}: \quad M_1 = \frac{5}{3}M_{1/2} \ , \quad M_2 = M_{1/2} \ , \quad M_3 = \frac{8}{3}M_{1/2} \ , \tag{5}$$

where $M_{1/2}$ is the normalized gaugino mass scale. Thus, the gluino mass will be much larger than the bino and wino masses at low energy. The reasons why we choose such two Scenarios are the following: (1) In this paper, we consider the universal squark and slepton mass, which can not be large in the electroweak supersymmetry. Thus, to have the heavier squarks, we need to choose larger M_3 comparing to M_2 and M_1 at the GUT scale. (2) We consider the universal bino and wino mass in Scenario I, and the non-universal bino and wino masses in Scenario II.

In addition, the supersymmetry breaking scalar masses at the GUT scale are [55]

$$m^2_{\widetilde{Q}_i} = (m_0^U)^2 + \sqrt{\frac{3}{5}}\beta'_{\mathbf{10}}\frac{1}{6}(m_0^N)^2 \ , \tag{6}$$

$$m^2_{\widetilde{U}^c_i} = (m_0^U)^2 - \sqrt{\frac{3}{5}}\beta'_{\mathbf{10}}\frac{2}{3}(m_0^N)^2 \ , \tag{7}$$

$$m^2_{\widetilde{E}^c_i} = (m_0^U)^2 + \sqrt{\frac{3}{5}}\beta'_{\mathbf{10}}(m_0^N)^2 \ , \tag{8}$$

$$m^2_{\widetilde{D}^c_i} = (m_0^U)^2 + \sqrt{\frac{3}{5}}\beta'_{\bar{\mathbf{5}}}\frac{1}{3}(m_0^N)^2 \ , \tag{9}$$

$$m^2_{\widetilde{L}_i} = (m_0^U)^2 - \sqrt{\frac{3}{5}}\beta'_{\bar{\mathbf{5}}}\frac{1}{2}(m_0^N)^2 \ , \tag{10}$$

$$m^2_{\widetilde{H}_u} = (m_0^U)^2 + \sqrt{\frac{3}{5}}\beta'_{Hu}\frac{1}{2}(m_0^N)^2 \ , \tag{11}$$

$$m^2_{\widetilde{H}_d} = (m_0^U)^2 - \sqrt{\frac{3}{5}}\beta'_{Hd}\frac{1}{2}(m_0^N)^2 \ , \tag{12}$$

where i is generation index, $\beta'_{\mathbf{10}}$, $\beta'_{\bar{\mathbf{5}}}$, β'_{Hu} and β'_{Hd} are coupling constants, and m_0^U and m_0^N are the scalar masses related to the universal and non-universal parts, respectively. Especially, the squark masses can be much larger than the slepton masses since the cancellations between the two terms in the slepton masses $m^2_{\widetilde{E}^c_i}$ and $m^2_{\widetilde{L}^c_i}$ can be realized by fine-tuning respectively $\beta'_{\mathbf{10}}$ and $\beta'_{\bar{\mathbf{5}}}$ a little bit. Also, the supersymmetry breaking soft masses $m^2_{\widetilde{H}_u}$ and $m^2_{\widetilde{H}_d}$ can be free parameters as well.

Interestingly, we can derive the scalar mass relations at the GUT scale

$$3m^2_{\widetilde{D}^c_i} + 2m^2_{\widetilde{L}_i} = 4m^2_{\widetilde{Q}_i} + m^2_{\widetilde{U}^c_i} = 6m^2_{\widetilde{Q}_i} - m^2_{\widetilde{E}^c_i} = 2m^2_{\widetilde{E}^c_i} + 3m^2_{\widetilde{U}^c_i} ~. \tag{13}$$

Choosing slepton masses as input parameters, we can parametrize the squark masses as follows

$$m^2_{\widetilde{Q}_i} ~=~ \frac{5}{6}(m_0^U)^2 + \frac{1}{6}m^2_{\widetilde{E}^c_i} ~, \tag{14}$$

$$m^2_{\widetilde{U}^c_i} ~=~ \frac{5}{3}(m_0^U)^2 - \frac{2}{3}m^2_{\widetilde{E}_i} ~, \tag{15}$$

$$m^2_{\widetilde{D}^c_i} ~=~ \frac{5}{3}(m_0^U)^2 - \frac{2}{3}m^2_{\widetilde{L}_i} ~. \tag{16}$$

In short, the squark masses can be parametrized by the slepton masses and the universal scalar mass. If the slepton masses are much smaller than the universal scalar mass, we obtain $2m^2_{\widetilde{Q}_i} \sim m^2_{\widetilde{U}^c_i} \sim m^2_{\widetilde{D}^c_i}$.

Moreover, we can calculate the supersymmetry breaking trilinear soft A terms A_U, A_D, and A_E respectively for the SM fermion Yukawa superpotential terms of the up-type quarks, down-type quarks, and charged leptons at the GUT scale [55]

$$A_U ~=~ A_0^U + (2\gamma_U + \gamma'_U)A_0^N ~, \tag{17}$$

$$A_D ~=~ A_0^U + \frac{1}{6}\gamma_D A_0^N ~, \tag{18}$$

$$A_E ~=~ A_0^U + \gamma_D A_0^N ~, \tag{19}$$

where γ_U, γ'_U and γ_D are coupling constants, and A_0^U and A_0^N are the corresponding trilinear soft A terms related to the universal and non-universal parts, respectively. Therefore, A_U, A_D and A_E can be free parameters in general in the GmSUGRA.

In short, we can parametrize the generic supersymmetry breaking soft mass terms at the GUT scale in our simple GmSUGRA as following: two parameters in the gaugino masses, three parameters for the squark and slepton soft masses, three parameters in the trilinear soft A terms, and two parameters for the Higgs soft masses. The μ and its soft term B_μ are determined by the M_Z and $\tan\beta$ from electroweak symmetry breaking. Thus, including $\tan\beta$ we have eleven parameters in the most general case.

We propose the electroweak supersymmetry: *the squarks and/or glunios are heavy around a few TeV while the sleptons, bino and winos are light and within one TeV*. The Higgsinos (or μ term) can be either heavy or light. Thus, both the gaugino masses M_1 and M_2 and the slepton/sneutrino soft masses are smaller than one TeV. Also, there are three cases for the gaugino mass M_3 and squark soft masses: (1) M_3 is about a few TeV while the squark soft masses are small; (2) M_3 is small while the squark soft masses are about a few TeV; (3) Both M_3 and squark soft masses are heavy. In this paper, for simplicity, we only consider the first case. The comprehensive study will be presented elsewhere. We would like to emphasize that our electroweak supersymmetry is different from the mSUGRA/CMSSM, gauge mediation, and anomaly mediation. In particular, the ratios between the squark masses and slepton masses in the electroweak supersymmetry are larger than those in the traditional mSUGRA/CMSSM, gauge mediation, and anomaly mediation [53]. Also, the ratios between the gluino mass and the bino/wino masses might be larger as well.

Interestingly, we can show that the gauge coupling unification can be preserved in the electroweak supersymmetry even if the squarks and/or gluinos are about one or two orders heavier than the sleptons, bino and winos. The point is that the gauge coupling relation at the GUT scale is given by Eq. (1). The worst case is that the Higgsinos are light while the gluinos are heavy. So we discuss it as an example. For simplicity, we assume that the masses for the sleptons, bino, winos and Higgsinos are universersal, and the masses for the squarks and gluinos are universal. To prove the gauge coupling unification, we only need to calculate the one-loop beta functions for the renormalization scale from the slepton mass to the squark mass. The one-loop beta functions b_1, b_2, and b_3 respectively for $U(1)_Y$, $SU(2)_L$ and $SU(3)_C$ are $b_1 = 27/5$, $b_2 = -4/3$, $b_3 = -7$. Because $b_1 - b_2 = 101/15$ is larger than $b_2 - b_3 = 17/3$, the gauge coupling relation at the GUT scale in Eq. (1) can be realized properly. Especially, the discrepancies among the SM gauge couplings at the GUT scale are less than a few percents [68].

Let us briefly comment on the fine-tuning problem on electroweak gauge symmetry breaking in the SSMs. The radiative electroweak gauge symmetry breaking gives the minimization condition at tree level

$$\frac{1}{2}M_Z^2 \ = \ -\mu^2 + \frac{m_{H_d}^2 - m_{H_u}^2 \tan^2\beta}{\tan^2\beta - 1} \ , \tag{20}$$

where M_Z is the Z boson mass. For the moderate and large values of $\tan\beta$, this condition can be simplified to

$$\frac{1}{2}M_Z^2 \simeq -\mu^2 - m_{H_u}^2 ~. \tag{21}$$

The electroweak-scale $m_{H_u}^2$ depends on the GUT-scale supersymmetry breaking soft terms such as gaugino masses, scalar masses, and trilinear soft A terms, etc, via the renormalization group equation (RGE) running. Thus, if the squarks/gluinos are heavy and A terms are large, the low energy $m_{H_u}^2$ will be large as well. And then we need to fine-tune the large μ term to realize the correct electroweak gauge symmetry breaking. Such fine-tuning problem does exist in electroweak supersymmetry, and one of the solution is to employ the idea of focus point/hyperbolic branch supersymmetry [69–71], which will be studied elsewhere.

III. LOW ENERGY SUPERSYMMETRY PHENOMENOLOGY

We study two Scenarios for gaugino masses, as given in Eqs. (4) and (5). For simplicity, we will consider two cases for the scalar masses and trilinear soft A terms: (A) The unversal scalar mass m_0 and universal/non-universal trilinear soft A terms. This case is similar to the mSUGRA. (B) The universal squark and slepton soft mass m_0 and universal/non-universal trilinear soft A terms while the non-universal Higgs soft masses. This case is similar to the NUHM2, and then we will have larger viable parameter spaces. In both cases, the point why we consider the non-universal soft A terms is that we want to have the viable parameter spaces with better values for $(g_\mu - 2)/2$. Therefore, we will study four kinds of Scenarios: Scenario IA, Scenario IB, Scenario IIA, and Scenario IIB. To reduce the input papameters in the scan, we shall choose the universal squark and slepton mass, fix the trilinear soft terms and $\tan\beta$. Note that there is only one input parameter for gaugino mass in Scenarios I and II, we reduce 7 parameters in total. In the Scenarios IA and IIA, we have two input paramters $M_{1/2}$ and m_0. Also, in the Scenarios IB and IIB, we have four input paramters $M_{1/2}$, m_0, m_{H_u} and m_{H_d}.

In our numerical study, we will use the `SuSpect` program [72] to calculate the supersymmetric particle spectra, and use the `MicrOMEGAs` program [73, 74] to calculate the phenomenological constraints, the LSP neutralino relic density, and the direct detection cross-sections. We will focus on the lightest CP-even Higgs boson mass from 123 GeV to 127 GeV in the numerical results, and choose the benchmark points with Higgs boson mass only from

125.0 GeV to 126.0 GeV. The current top quark mass m_t is 173.2 ± 0.9 GeV [75]. Because the lightest CP-even Higgs boson mass is sensitive to the top quark mass, we take the upper bound $m_t = 174.1$ GeV in our numerical study. We emphasize that the viable parameter spaces with Higgs boson mass larger than 127 GeV but less than about 130 GeV in the following discussions are still fine due to the following two reasons: (1) If we choose the top quark mass central value 173.2 GeV and low bound 172.3 GeV, we can low the Higgs boson mass by 1 GeV and 2 GeV, respectively. (2) There exist the uncertainties about 2 GeV in the theoretical calculations [76].

In addition, we employ the following experimental constraints: (1) The cold dark matter relic density is $0.05 \leq \Omega_{\chi_1^0} h^2 \leq 0.135$; (2) The $b \to s\gamma$ branch ratio is $2.77 \times 10^{-4} \leq Br(b \to s\gamma) \leq 4.27 \times 10^{-4}$; (3) The 3σ $(g_\mu - 2)/2$ constraint is $2.1 \times 10^{-10} < \Delta a_\mu < 40.1 \times 10^{-10}$; (4) The branching fraction of $\text{BR}(B_s^0 \to \mu^+\mu^-)$ is $3.2^{+1.5}_{-1.2} \times 10^{-9}$. (5) The experimental limit on the process $B_u \to \tau\bar{\nu}_\tau$ is $0.85 \leq \text{BR}(B_u \to \tau\bar{\nu}_\tau)/\text{SM} \leq 1.65$. In our electroweak supersymmetry, the dominant component of the LSP neutralino will be bino. Thus, the constaints from the XENON100 experiment [28] can be evaded automatically due to the heavy squarks.

First, let us discuss the Scenario I. To scan the viable parameter spaces in the $M_{1/2} - m_0$ plane, we consider the universal trilinear soft A term A_0, and we choose $\tan\beta = 13$ and $A_0 = -4000$ GeV. We present the viable parameter space in Scenarios IA and IB respectively in Fig. 1 and Fig. 2. We emphasize again that the viable parameter spaces with Higgs boson mass larger than 127 GeV in all the figures are still fine because we can choose the smaller value for top quark mass within its uncertainty. It is easy to understand that Scenario IB has larger viable parameter spaces since the Higgs scalar masses are hidden variables in Fig. 2. Interestingly, in Scenario IA, we find the narrow viable range for m_0, which is about from 410 GeV to 440 GeV. This narrow m_0 range is obtained in the electroweak supersymmetry since the observed dark matter relic density is realized from the LSP neutralino-stau coannihilations. Moreover, we present the benchmark points in Tables I and II for Scenarios IA and IB, respectively. In these benchmark points, the squarks, gluinos, and Higgsinos are heavy while the sleptons, bino and winos are light. Thus, the electroweak supersymmetry is realized. Similar results are held for all the following benchmark points in this paper. In particular, the LSP neutralino has 99.99% bino component due to the heavy Higgsinos. However, the deviations of $(g_\mu - 2)/2$ from the central value are about 2.88σ and 2.63σ for the benchmark points respectively in Tables I and II. To be concrete, we would like to compare the particle spectra in the electroweak supersymmetry and the traditional mSUGRA/CMSSM, gauge mediation, and anomaly mediation [53]. In the traditional mSUGRA/CMSSM, gauge mediation, and anomaly mediation [53], the ratios between the squark masses and slepton masses in the first two generations are usually about 3 or smaller, and the mass relation among the bino $\widetilde{B}$, wino $(\widetilde{W})$ and gluino $\tilde{g}$ at low energy is $m_{\widetilde{B}} : m_{\widetilde{W}} : m_{\tilde{g}} \simeq 1 : 2 : 6$. In the benchmark points for Scenario IA and IB, the ratios between the squark masses and slepton masses are respectively about 5 and 6, and the gaugino mass relation is $m_{\widetilde{B}} : m_{\widetilde{W}} : m_{\tilde{g}} \simeq 1 : 2.3 : 21$. Therefore, the ratios between the squark masses and slepton masses and the ratios between the gluino mass and the bino/wino masses in electroweak supersymmetry are larger than those in the traditional mSUGRA/CMSSM, gauge mediation, and anomaly mediation [53].

$\widetilde{\chi}_1^0$	114	$\widetilde{\chi}_1^{\pm}$	262	$\widetilde{e}_R/\widetilde{\mu}_R$	426	$\widetilde{t}_1$	1161	$\widetilde{u}_R/\widetilde{c}_R$	2150	h^0	125.0
$\widetilde{\chi}_2^0$	262	$\widetilde{\chi}_2^{\pm}$	2166	$\widetilde{e}_L/\widetilde{\mu}_L$	447	$\widetilde{t}_2$	1755	$\widetilde{u}_L/\widetilde{c}_L$	2150	A^0/H^0	2132
$\widetilde{\chi}_3^0$	2165	$\widetilde{\nu}_{e/\mu}$	440	$\widetilde{\tau}_1$	129	$\widetilde{b}_1$	1730	$\widetilde{d}_R/\widetilde{s}_R$	2152	$H^{\pm}$	2134
$\widetilde{\chi}_4^0$	2165	$\widetilde{\nu}_{\tau}$	353	$\widetilde{\tau}_2$	395	$\widetilde{b}_2$	2097	$\widetilde{d}_L/\widetilde{s}_L$	2152	$\widetilde{g}$	2436

TABLE I: Supersymmetric particle and Higgs boson mass spectrum (in GeV) for a benchmark point in Scenario IA with $\tan\beta = 13$, $M_{1/2} = 280$ GeV, $m_0 = 411$ GeV and $A_0 = -4000$ GeV. In this benchmark point, we have $\Omega_{\chi_1^0} h^2 = 0.0942$, $\mathrm{BR}(b \to s\gamma) = 3.22 \times 10^{-4}$, $\Delta a_\mu = 3.07 \times 10^{-10}$, $\mathrm{BR}(B_s^0 \to \mu^+\mu^-) = 3.15 \times 10^{-9}$, and $\mathrm{BR}(B_u \to \tau\bar{\nu})/\mathrm{SM} = 0.998$. Moreover, the LSP neutralino is 99.99% bino. The LSP neutralino-proton spin independent and dependent cross sections are respectively 5.1×10^{-12} pb and 3.9×10^{-12} pb, and the LSP neutralino-neutron spin independent and dependent cross sections are respectively 5.2×10^{-12} pb and 2.4×10^{-9} pb.

In order to have the viable parameter spaces with better values for $(g_\mu - 2)/2$, we need to decrease the smuon masses. Thus, we consider the non-universal trilinear soft A terms. We

$\widetilde{\chi}_1^0$	164	$\widetilde{\chi}_1^\pm$	375	$\widetilde{e}_R/\widetilde{\mu}_R$	488	$\widetilde{t}_1$	2043	$\widetilde{u}_R/\widetilde{c}_R$	2937	h^0	125.2
$\widetilde{\chi}_2^0$	375	$\widetilde{\chi}_2^\pm$	2598	$\widetilde{e}_L/\widetilde{\mu}_L$	411	$\widetilde{t}_2$	2558	$\widetilde{u}_L/\widetilde{c}_L$	2949	A^0/H^0	2792
$\widetilde{\chi}_3^0$	2597	$\widetilde{\nu}_{e/\mu}$	403	$\widetilde{\tau}_1$	182	$\widetilde{b}_1$	2543	$\widetilde{d}_R/\widetilde{s}_R$	2952	$H^\pm$	2794
$\widetilde{\chi}_4^0$	2597	$\widetilde{\nu}_\tau$	302	$\widetilde{\tau}_2$	397	$\widetilde{b}_2$	2899	$\widetilde{d}_L/\widetilde{s}_L$	2950	$\widetilde{g}$	3394

TABLE II: Supersymmetric particle and Higgs boson mass spectrum (in GeV) for a benchmark point in Scenario IB with $\tan\beta = 13$, $M_{1/2} = 400$ GeV, $m_0 = 380$ GeV, $A_0 = -4000$ GeV, $m_{H_u} = 1200$ GeV, and $m_{H_d} = 0.0$ GeV. In this benchmark point, we have $\Omega_{\chi_1^0} h^2 = 0.111$, $\text{BR}(b \to s\gamma) = 3.26 \times 10^{-4}$, $\Delta a_\mu = 5.06 \times 10^{-10}$, $\text{BR}(B_s^0 \to \mu^+\mu^-) = 3.13 \times 10^{-9}$, and $\text{BR}(B_u \to \tau\bar{\nu})/\text{SM} = 0.999$. Moreover, the LSP neutralino is 99.99% bino. The LSP neutralino-proton spin independent and dependent cross sections are respectively 3.4×10^{-12} pb and 2.2×10^{-10} pb, and the LSP neutralino-neutron spin independent and dependent cross sections are respectively 3.5×10^{-12} pb and 1.5×10^{-9} pb.

$\tilde{\chi}_1^0$	160	$\tilde{\chi}_1^\pm$	365	$\tilde{e}_R/\tilde{\mu}_R$	268	$\tilde{t}_1$	1967	$\tilde{u}_R/\tilde{c}_R$	2862	h^0	125.4
$\tilde{\chi}_2^0$	365	$\tilde{\chi}_2^\pm$	2548	$\tilde{e}_L/\tilde{\mu}_L$	332	$\tilde{t}_2$	2475	$\tilde{u}_L/\tilde{c}_L$	2863	A^0/H^0	2507
$\tilde{\chi}_3^0$	2547	$\tilde{\nu}_{e/\mu}$	322	$\tilde{\tau}_1$	176	$\tilde{b}_1$	2459	$\tilde{d}_R/\tilde{s}_R$	2864	$H^\pm$	2508
$\tilde{\chi}_4^0$	2547	$\tilde{\nu}_\tau$	321	$\tilde{\tau}_2$	385	$\tilde{b}_2$	2813	$\tilde{d}_L/\tilde{s}_L$	2864	$\tilde{g}$	3311

TABLE III: Supersymmetric particle and Higgs boson mass spectrum (in GeV) for a benchmark point in Scenario IA with $\tan\beta = 13$, $M_{1/2} = 390$ GeV, $m_0 = 225$ GeV, $A_Q = -4000$ GeV and $A_E = -400$ GeV. In this benchmark point, we have $\Omega_{\chi_1^0} h^2 = 0.1105$, $\text{BR}(b \to s\gamma) = 3.227 \times 10^{-4}$, $\Delta a_\mu = 19.3 \times 10^{-10}$, $\text{BR}(B_s^0 \to \mu^+\mu^-) = 3.13 \times 10^{-9}$, and $\text{BR}(B_u \to \tau\bar{\nu})/\text{SM} = 0.999$. Moreover, the LSP neutralino is 99.98% bino. The LSP neutralino-proton spin independent and dependent cross sections are respectively 3.6×10^{-12} pb and 2.2×10^{-10} pb, and the LSP neutralino-neutron spin independent and dependent cross sections are respectively 3.7×10^{-12} pb and 1.6×10^{-9} pb.

assume that $A_U = A_D \equiv A_Q$ is much larger than A_E. To scan the viable parameter spaces in the $M_{1/2} - m_0$ plane, we choose $\tan\beta = 13$, $A_Q = -4000$ GeV, and $A_E = -400$ GeV. We present the viable parameter space in Scenarios IA and IB respectively in Fig. 3 and Fig. 4. Moreover, we present the benchmark points in Tables III and IV for Scenarios IA and IB, respectively. Similar to the above, the LSP neutralinos have 99.98% and 99.99%

$\widetilde{\chi}_1^0$	121.7	$\widetilde{\chi}_1^{\pm}$	279.4	$\widetilde{e}_R/\widetilde{\mu}_R$	269.2	$\widetilde{t}_1$	1279.2	$\widetilde{u}_R/\widetilde{c}_R$	2256.4	h^0	125.2
$\widetilde{\chi}_2^0$	279.4	$\widetilde{\chi}_2^{\pm}$	2188.0	$\widetilde{e}_L/\widetilde{\mu}_L$	270.0	$\widetilde{t}_2$	1862.4	$\widetilde{u}_L/\widetilde{c}_L$	2259.5	A^0/H^0	2272
$\widetilde{\chi}_3^0$	2186.9	$\widetilde{\nu}_{e/\mu}$	258.6	$\widetilde{\tau}_1$	140.6	$\widetilde{b}_1$	1839.0	$\widetilde{d}_R/\widetilde{s}_R$	2261.3	$H^{\pm}$	2274
$\widetilde{\chi}_4^0$	2187.2	$\widetilde{\nu}_{\tau}$	252.1	$\widetilde{\tau}_2$	340.0	$\widetilde{b}_2$	2207	$\widetilde{d}_L/\widetilde{s}_L$	2260.9	$\widetilde{g}$	2593.7

TABLE IV: Supersymmetric particle and Higgs boson mass spectrum (in GeV) for a benchmark point in Scenario IB with $\tan\beta = 13$, $M_{1/2} = 300$ GeV, $m_0 = 210$ GeV, $A_Q = -4000$ GeV, $A_E = -400$ GeV, $m_{H_u} = 600$ GeV and $m_{H_d} = 800$ GeV. In this benchmark point, we have $\Omega_{\chi_1^0} h^2 = 0.114$, $\text{BR}(b \to s\gamma) = 3.32 \times 10^{-4}$, $\Delta a_\mu = 26.4 \times 10^{-10}$, $\text{BR}(B_s^0 \to \mu^+\mu^-) = 3.14 \times 10^{-9}$, and $\text{BR}(B_u \to \tau\bar{\nu})/\text{SM} = 0.998$. Moreover, the LSP neutralino is 99.99% bino. The LSP neutralino-proton spin independent and dependent cross sections are respectively 5.2×10^{-12} pb and 6.28×10^{-11} pb, and the LSP neutralino-neutron spin independent and dependent cross sections are respectively 5.3×10^{-12} pb and 2.46×10^{-9} pb.

$\tilde{\chi}_1^0$	299	$\tilde{\chi}_1^{\pm}$	341	$\tilde{e}_R/\tilde{\mu}_R$	537	$\tilde{t}_1$	1076	$\tilde{u}_R/\tilde{c}_R$	2180	h^0	125.2
$\tilde{\chi}_2^0$	341	$\tilde{\chi}_2^{\pm}$	2245	$\tilde{e}_L/\tilde{\mu}_L$	549	$\tilde{t}_2$	1747	$\tilde{u}_L/\tilde{c}_L$	2181	A^0/H^0	2223
$\tilde{\chi}_3^0$	2244	$\tilde{\nu}_{e/\mu}$	543	$\tilde{\tau}_1$	308	$\tilde{b}_1$	1724	$\tilde{d}_R/\tilde{s}_R$	2178	$H^{\pm}$	2225
$\tilde{\chi}_4^0$	2245	$\tilde{\nu}_{\tau}$	461	$\tilde{\tau}_2$	495	$\tilde{b}_2$	2118	$\tilde{d}_L/\tilde{s}_L$	2182	$\tilde{g}$	2453

TABLE V: Supersymmetric particle and Higgs boson mass spectrum (in GeV) for a benchmark point in Scenario IIA with $\tan\beta = 13$, $M_{1/2} = 424$ GeV, $m_0 = 468$ GeV and $A_0 = -4000$ GeV. In this benchmark point, we have $\Omega_{\chi_1^0} h^2 = 0.1110$, $\text{BR}(b \to s\gamma) = 3.16 \times 10^{-4}$, $\Delta a_\mu = 5.67 \times 10^{-10}$, $\text{BR}(B_s^0 \to \mu^+\mu^-) = 3.15 \times 10^{-9}$, and $\text{BR}(B_u \to \tau\bar{\nu})/\text{SM} = 0.998$. Moreover, the LSP neutralino is 99.97% bino. The LSP neutralino-proton spin independent and dependent cross sections are respectively 9.7×10^{-12} pb and 7.9×10^{-12} pb, and the LSP neutralino-neutron spin independent and dependent cross sections are respectively 9.9×10^{-12} pb and 2.4×10^{-9} pb.

bino components respectively in Tables III and IV. Especially, the deviations of $(g_\mu - 2)/2$ from the central value are within 1σ in both benchmark points.

Second, we discuss the Scenario II. To scan the viable parameter spaces in the $M_{1/2} - m_0$ plane, we consider the universal trilinear soft A term A_0, and we choose $\tan\beta = 13$ and $A_0 = -4000$ GeV. We present the viable parameter spaces in Scenarios IIA and IIB respectively

$\widetilde{\chi}_1^0$	310.0	$\widetilde{\chi}_1^{\pm}$	353.0	$\widetilde{e}_R/\widetilde{\mu}_R$	657.0	$\widetilde{t}_1$	1120.1	$\widetilde{u}_R/\widetilde{c}_R$	2229.5	h^0	125.5
$\widetilde{\chi}_2^0$	353.0	$\widetilde{\chi}_2^{\pm}$	2251.9	$\widetilde{e}_L/\widetilde{\mu}_L$	473.8	$\widetilde{t}_2$	1818.7	$\widetilde{u}_L/\widetilde{c}_L$	2257.3	A^0/H^0	2798
$\widetilde{\chi}_3^0$	2250.4	$\widetilde{\nu}_{e/\mu}$	467.4	$\widetilde{\tau}_1$	320.1	$\widetilde{b}_1$	1795.6	$\widetilde{d}_R/\widetilde{s}_R$	2260.1	$H^{\pm}$	2798
$\widetilde{\chi}_4^0$	2251.5	$\widetilde{\nu}_{\tau}$	348.4	$\widetilde{\tau}_2$	511.0	$\widetilde{b}_2$	2195	$\widetilde{d}_L/\widetilde{s}_L$	2258.6	$\widetilde{g}$	2539.0

TABLE VI: Supersymmetric particle and Higgs boson mass spectrum (in GeV) for a benchmark point in Scenario IIB with $\tan\beta = 13$, $M_{1/2} = 440$ GeV, $m_0 = 460$ GeV, $A_0 = -4000$ GeV, $m_{H_u} = 600$ GeV and $m_{H_d} = 1800$ GeV. In this benchmark point, we have $\Omega_{\chi_1^0} h^2 = 0.12$, BR$(b \to s\gamma) = 3.16 \times 10^{-4}$, $\Delta a_\mu = 5.58 \times 10^{-10}$, BR$(B_s^0 \to \mu^+\mu^-) = 3.14 \times 10^{-9}$, and BR$(B_u \to \tau\bar{\nu})$/SM $=$ 0.999. Moreover, the LSP neutralino is 99.99% bino. The LSP neutralino-proton spin independent and dependent cross sections are respectively 9.23×10^{-12} pb and 2.92×10^{-11} pb, and the LSP neutralino-neutron spin independent and dependent cross sections are respectively 9.40×10^{-12} pb and 2.41×10^{-9} pb.

$\tilde{\chi}_1^0$	318	$\tilde{\chi}_1^{\pm}$	362	$\tilde{e}_R/\tilde{\mu}_R$	396	$\tilde{t}_1$	1210	$\tilde{u}_R/\tilde{c}_R$	2275	h^0	125.7
$\tilde{\chi}_2^0$	362	$\tilde{\chi}_2^{\pm}$	2312	$\tilde{e}_L/\tilde{\mu}_L$	416	$\tilde{t}_2$	1849	$\tilde{u}_L/\tilde{c}_L$	2276	A^0/H^0	2281
$\tilde{\chi}_3^0$	2311	$\tilde{\nu}_{e/\mu}$	408	$\tilde{\tau}_1$	327	$\tilde{b}_1$	1827	$\tilde{d}_R/\tilde{s}_R$	2272	$H^{\pm}$	2284
$\tilde{\chi}_4^0$	2312	$\tilde{\nu}_{\tau}$	405	$\tilde{\tau}_2$	463	$\tilde{b}_2$	2213	$\tilde{d}_L/\tilde{s}_L$	2277	$\tilde{g}$	2597

TABLE VII: Supersymmetric particle and Higgs boson mass spectrum (in GeV) for a benchmark point in Scenario IIA with $\tan\beta = 13$, $M_{1/2} = 452$ GeV, $m_0 = 280$ GeV, $A_Q = -4000$ GeV and $A_E = -400$ GeV. In this benchmark point, we have $\Omega_{\chi_1^0} h^2 = 0.1125$, BR$(b \to s\gamma) = 3.18 \times 10^{-4}$, $\Delta a_\mu = 10.6 \times 10^{-10}$, BR$(B_s^0 \to \mu^+\mu^-) = 3.15 \times 10^{-9}$, and BR$(B_u \to \tau\bar{\nu})$/SM $= 0.998$. Moreover, the LSP neutralino is 99.97% bino. The LSP neutralino-proton spin independent and dependent cross sections are respectively 9.2×10^{-12} pb and 2.0×10^{-11} pb, and the LSP neutralino-neutron spin independent and dependent cross sections are respectively 9.39×10^{-12} pb and 2.2×10^{-9} pb.

in Fig. 5 and Fig. 6. Moreover, we present the benchmark points in Tables V and VI for Scenarios IIA and IIB, respectively. In particular, the LSP neutralinos have 99.97% and 99.99% bino components due to the heavy Higgsinos respectively in Tables V and VI. However, the deviations of $(g_\mu - 2)/2$ from the central value are about 2.6σ for both benchmark points.

$\widetilde{\chi}_1^0$	309.1	$\widetilde{\chi}_1^\pm$	351.8	$\widetilde{e}_R/\widetilde{\mu}_R$	449.7	$\widetilde{t}_1$	1045.5	$\widetilde{u}_R/\widetilde{c}_R$	2214.8	h^0	125.0
$\widetilde{\chi}_2^0$	351.8	$\widetilde{\chi}_2^\pm$	2144.9	$\widetilde{e}_L/\widetilde{\mu}_L$	376.2	$\widetilde{t}_2$	1765.9	$\widetilde{u}_L/\widetilde{c}_L$	2224.8	A^0/H^0	2498
$\widetilde{\chi}_3^0$	2143.3	$\widetilde{\nu}_{e/\mu}$	368.2	$\widetilde{\tau}_1$	315.8	$\widetilde{b}_1$	1742.6	$\widetilde{d}_R/\widetilde{s}_R$	2223.6	$H^\pm$	2499
$\widetilde{\chi}_4^0$	2144.5	$\widetilde{\nu}_\tau$	352.2	$\widetilde{\tau}_2$	457.6	$\widetilde{b}_2$	2159.4	$\widetilde{d}_L/\widetilde{s}_L$	2226.1	$\widetilde{g}$	2533.7

TABLE VIII: Supersymmetric particle and Higgs boson mass spectrum (in GeV) for a benchmark point in Scenario IIB with $\tan\beta = 13$, $M_{1/2} = 440$ GeV, $m_0 = 280$ GeV, $A_Q = -4000$ GeV, $A_E = -400$ GeV, $m_{H_u} = 1000$ GeV, and $m_{H_d} = 1400$ GeV. In this benchmark point, we have $\Omega_{\chi_1^0} h^2 = 0.09$, $\mathrm{BR}(b \to s\gamma) = 3.14 \times 10^{-4}$, $\Delta a_\mu = 10.3 \times 10^{-10}$, $\mathrm{BR}(B_s^0 \to \mu^+\mu^-) = 3.15 \times 10^{-9}$, and $\mathrm{BR}(B_u \to \tau\bar{\nu})/\mathrm{SM} = 0.999$. Moreover, the LSP neutralino is 99.99% bino. The LSP neutralino-proton spin independent and dependent cross sections are respectively 1.11×10^{-11} pb and 1.82×10^{-10} pb, and the LSP neutralino-neutron spin independent and dependent cross sections are respectively 1.14×10^{-11} pb and 3.25×10^{-9} pb.

Moreover, we consider the non-universal trilinear soft A terms. To scan the viable parameter spaces in the $M_{1/2} - m_0$ plane, we choose $\tan\beta = 13$, $A_Q = -4000$ GeV, and $A_E = -400$ GeV. We present the viable parameter spaces in Scenarios IIA and IIB respectively in Fig. 7 and Fig. 8. Moreover, we present the benchmark points in Tables VII and VIII for Scenarios IIA and IIB, respectively. Similar to the above, the LSP neutralinos respectively have 99.97% and 99.99% bino components respectively in Tables VII and VIII. Especially, the deviations of $(g_\mu - 2)/2$ from the central value are within 2σ in both benchmark points.

In the electroweak supersymmetry, we can automatically avoid the LHC supersymmetry search constraints since the squarks are very heavy and gluino may be very heavy as well. It is easy to check that all our benchmark points satisfy the current LHC supersymmetry search constraints [4–6]. Thus, the LHC searches for electroweak supersymmetry are to look for the productions and decays of the light chargino, neutralinos, and sleptons. For example, the trilepton plus missing transverse energy signals arise from the first chargino χ_1^+ and second neutralino χ_2^0 pair productions and decays. The LHC searches for the electroweak supersymmetry will be presented elsewhere.

IV. CONCLUSION

We proposed the electroweak supersymmetry around the electroweak scale: the squarks and/or gluinos are around a few TeV while the sleptons, sneutrinos, bino and winos are within one TeV. The Higgsinos can be either heavy or light. Thus, the constraints from the ATLAS and CMS supersymmetry and Higgs searches and the $b \to s\gamma$, $B_s \to \mu^+\mu^-$, and $B_u \to \tau\bar{\nu}_\tau$ processes can be satisfied automatically due to the heavy squarks. Also, the dimension-five proton decays in the supersymmetric GUTs can be relaxed as well. In addition, the $(g_\mu - 2)/2$ experimental result can be explained due to the light sleptons. With bino as the dominant component of the LSP neutralino, we obtained the observed dark matter relic density via the neutralino-stau coannihilations, and the XENON experimental constraint can be evaded due to the heavy squarks as well. Considering the GmSUGRA, we showed explicitly that the electroweak supersymmetry can be realized, and the gauge coupling unification can be preserved. With two Scenarios, we presented the viable parameter spaces that satisfy all the current phenomenological constraints. Furthermore, we commented on the fine-tuning problem and LHC searches.

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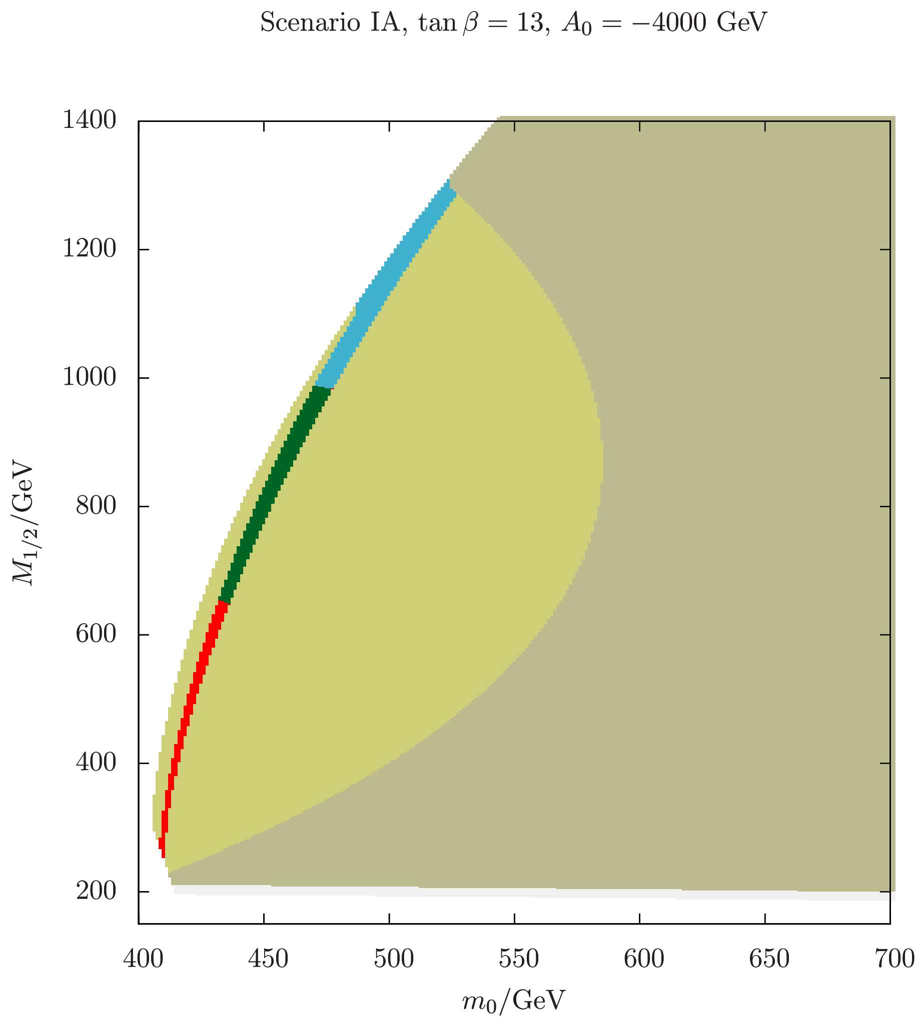
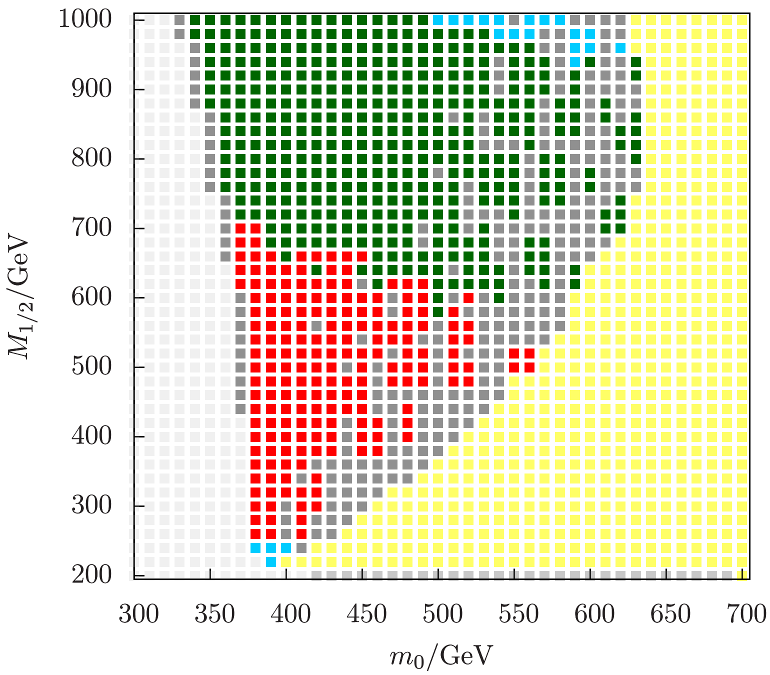
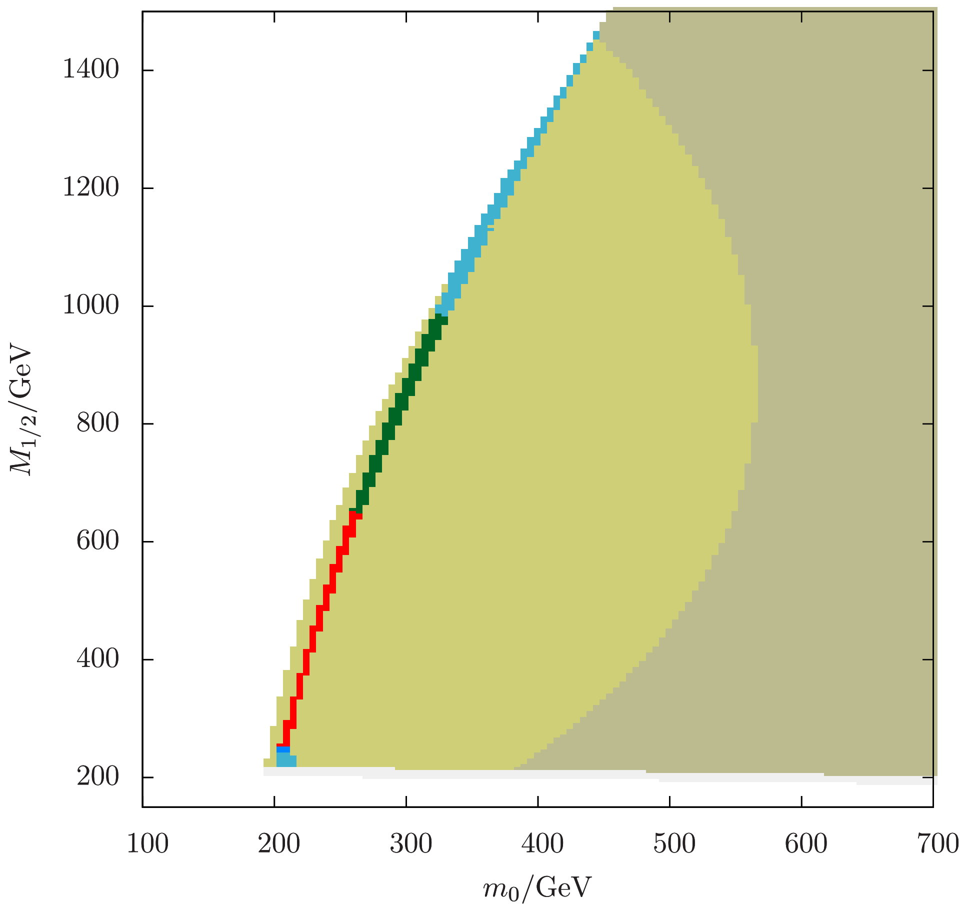

Scenario IA, $\tan\beta = 13$, $A_0 = -4000$ GeV
1400
1200
1000
800
600
400
200
$M_{1/2}$/GeV
400
450
500
550
600
650
700
m_0/GeV

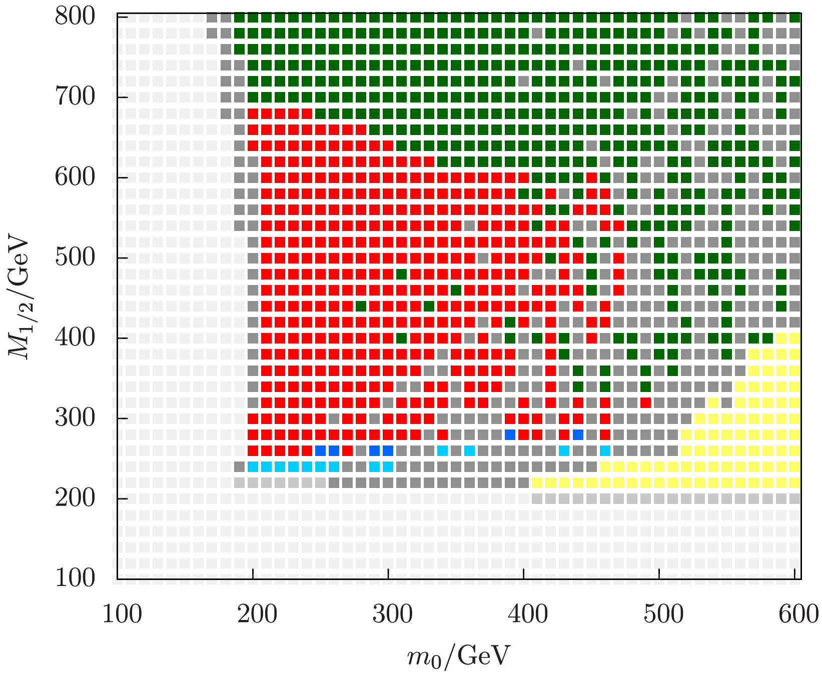
Scenario IB, $\tan\beta = 13,\ A_0 = -4000$ GeV



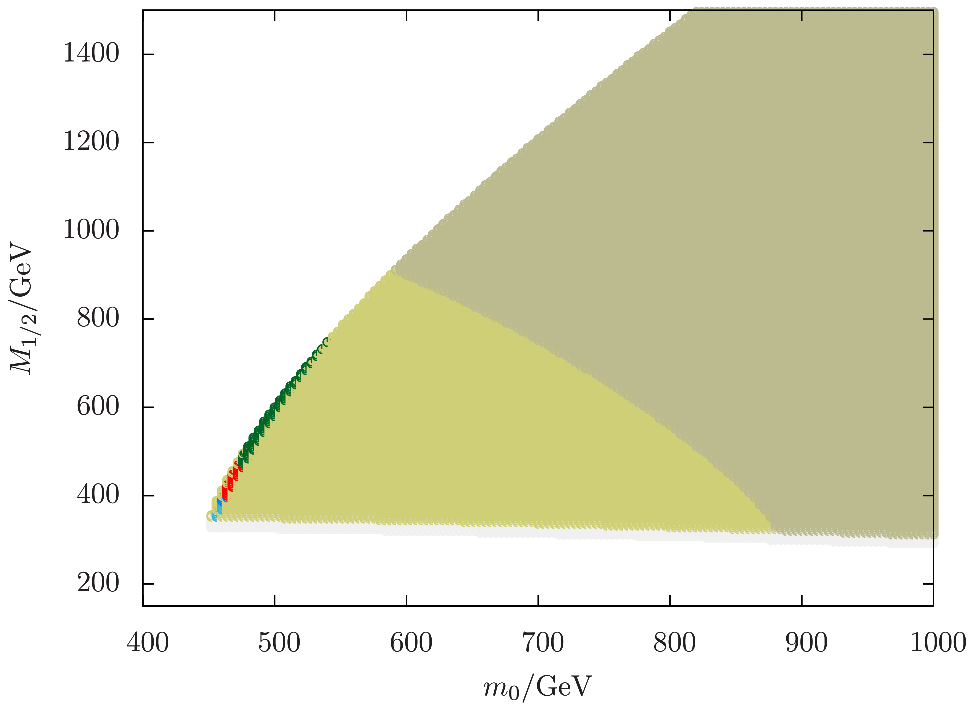
Scenario IA, $\tan\beta = 13$, $A_Q = 10A_E = -4000$ GeV



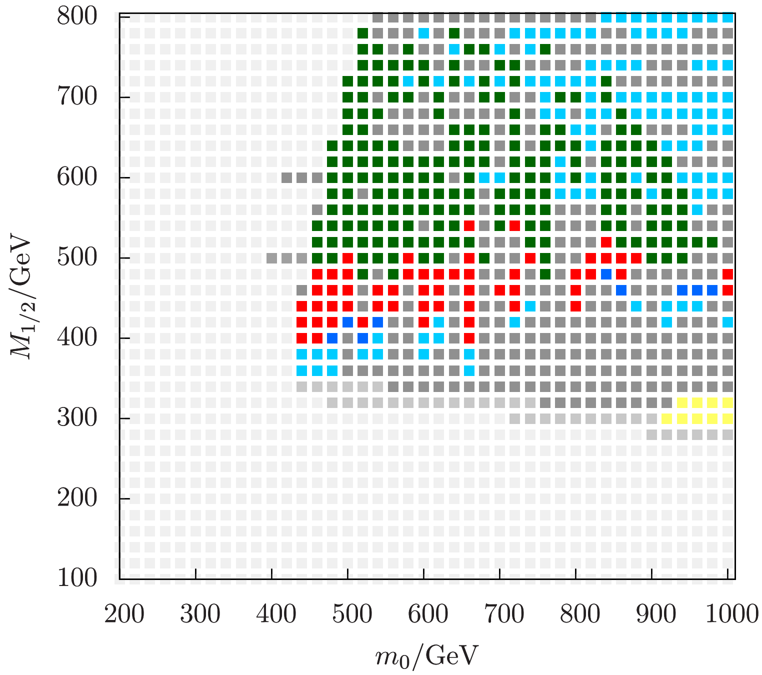
Scenario IB, $\tan\beta = 13$, $A_Q = 10A_E = -4000$ GeV



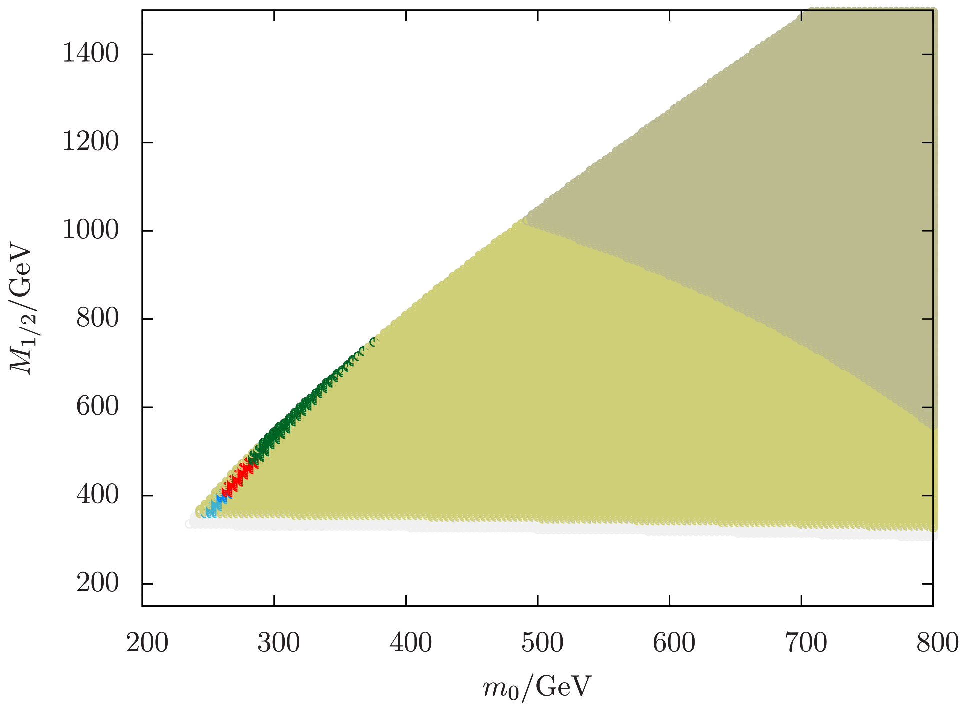
Scenario IIA, $\tan\beta = 13$, $A_0 = -4000$ GeV



Scenario IIB, $\tan\beta = 13$, $A_0 = -4000$ GeV



Scenario IIA, $\tan\beta = 13$, $A_Q = 10A_E = -4000$ GeV



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