NMSSM From Generalized Mirage Mediation

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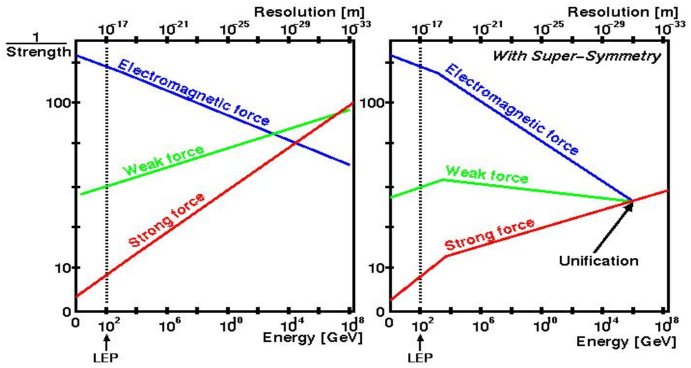
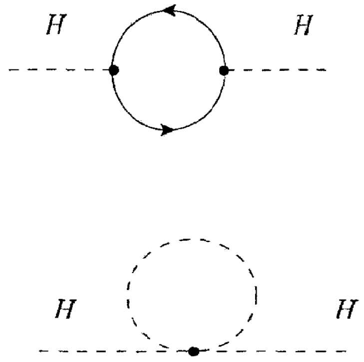
Why Supersymmetry



- Vacuum stability naturally in SUSY at tree-level.
- Possible dark matter candidate. Natural dark matter candidates, many possible baryogenesis mechanism.
- Radiative EW symmetry breaking-driven by RGE.
- Many good properties of SUSY–solve many strongly coupled system:

  Non-renormalization theorem, Seiberg duality, AdS/CFT...
- Predictive-the 125 GeV higgs lies in the '115-135' window favored by SUSY.
- Muon g-2 experiments favors new physics beyond the Standard Model.



超对称破缺的传递机制

软破缺项的来源：

$$\int d^4\theta \left(\frac{X^*X}{M_{\rm mess}^2} + \frac{X}{M_{\rm mess}} + \frac{X^*}{M_{\rm mess}} + V_A\right)\Phi^*\Phi$$

$$+ \quad \int d^2\theta \frac{X}{M_{\rm mess}}\left(\mathcal{W}^{a\alpha}\mathcal{W}^a_\alpha + \mu'\Phi^2 + y'\Phi^3\right) + {\rm c.c}$$

$$\mathcal{L}_{\rm SUSY} = \int d^2\theta d^2\bar{\theta}\left(Z_{\bar{I}J}\Phi_I^* e^{-V}\Phi_J + \ldots\right)$$

$$+ \left[\int d^2\theta \left(\frac{1}{4}f_a\mathcal{W}^{a\alpha}\mathcal{W}^a_\alpha + \frac{1}{2}\mu_{IJ}\Phi_I\Phi_J + \frac{1}{6}y_{IJK}\Phi_I\Phi_J\Phi_K + \ldots\right) + {\rm c.c}\right]$$

$$Z_{\bar{I}J} = \delta_{\bar{I}J} \quad \to \quad Z_{\bar{I}J}(X, X^*, V_A) = \delta_{\bar{I}J} + \frac{XX^*}{M_{\rm mess}^2} + \frac{X}{M_{\rm mess}} + \frac{X^*}{M_{\rm mess}} + V_A$$

$$f_a = \frac{1}{g_a^2} + i\frac{\theta_{\rm vac}}{8\pi^2} \quad \to \quad f_a(X) = \frac{1}{g_a^2} + i\frac{\theta_{\rm vac}}{8\pi^2} + \frac{X}{M_{\rm mess}}$$

$$\int d^4\theta(\delta_{\bar{I}J} - m^2_{\bar{I}J}\theta^2\bar{\theta}^2)\Phi^{I*}e^{-V}\Phi^J - \left(\int d^2\theta\,\frac{1}{4g_a^2}\left(1 - M_a\theta^2\right)\mathcal{W}^{a\alpha}\mathcal{W}^a_\alpha + {\rm c.c}\right)$$

$$+ \left(\int d^2\theta\,\frac{\mu_{IJ}}{2}(1 - B_{IJ}\theta^2)\Phi^I\Phi^J + \frac{y_{IJK}}{6}(1 - A_{IJK}\theta^2)\Phi^I\Phi^J\Phi^K + {\rm c.c}\right)$$

$$\Rightarrow \mathcal{L}_{\rm soft} = -m^2_{\bar{I}J}\phi^{I*}\phi^J - \left(\frac{1}{2}M_a\lambda^a\lambda^a + {\rm c.c}\right) - \left(\frac{1}{2}b_{IJ}\phi^I\phi^J + \frac{1}{6}a_{IJK}\phi^I\phi^J\phi^K + {\rm c.c}\right)$$

$$\left(b_{IJ} = \mu_{IJ}B_{IJ}, \quad a_{IJK} = y_{IJK}A_{IJK}\right)$$

偏转的反常传递超对称破缺机制

1.解决slepton负质量需要改变重整化群演化。

2. 最简单的就是引入重的threshold来偏转RGE的演化轨迹。

规避退耦定理？

超势中引入赝模场？

Kahler势中引入媒介场？

Generalized Deflected Anomaly Mediaiton Scenario

- Typical mixed gauge(Yukawa) and anomaly mediation scenario.
- Introduce messenger-matter interactions in AMSB.
- Many advantages:
  1. Solve the tachyonic slepton mass more easily.
  2. Large A-term because of new additional contributions.
  3. No Landau-pole problems with either sign of deflection parameters.
  4. Easily accommodate the 125 GeV higgs.
  5. Less EW fine-tuning.
- Several realization:

  1. The superpotential---messenger-matter interactions.

  [Fei Wang, PLB751,402 (2015),Fei Wang, Jin Min Yang,Yang Zhang, JHEP04(2016)177;
  Fei Wang, Wenyu Wang, Jin Min Yang, Phys. Rev. D 96, 075025 (2017) ;
  Xuyang Ning, Fei Wang,JHEP08(2017)089

  2. The Kahler potential--new types of mixing.

  [Xiaokang Du,Fei Wang, Euro.Phys.J.C 78:431(2018);
  Zhuang Li, Fei Wang, To appear]

NMSSM From Generalized dAMSB

- The simplest singlet extension of MSSM.

$$W_{\text{Higgs}} = (\mu + \lambda \widehat{S})\, \widehat{H}_u \cdot \widehat{H}_d + \xi_F \widehat{S} + \frac{1}{2}\mu' \widehat{S}^2 + \frac{\kappa}{3}\widehat{S}^3$$

- Naturally solve the mu-problem of MSSM.

$$\begin{aligned} -\mathcal{L}_{\text{soft}} \;=\;& m_{H_u}^2 |H_u|^2 + m_{H_d}^2 |H_d|^2 + m_S^2 |S|^2 + m_Q^2 |Q^2| + m_U^2 |U_R^2| \\ & + m_D^2 |D_R^2| + m_L^2 |L^2| + m_E^2 |E_R^2| \\ & + (h_u A_u\, Q \cdot H_u\, U_R^c - h_d A_d\, Q \cdot H_d\, D_R^c - h_e A_e\, L \cdot H_d\, E_R^c \\ & + \lambda A_\lambda\, H_u \cdot H_d\, S + \frac{1}{3}\kappa A_\kappa\, S^3 + m_3^2\, H_u \cdot H_d + \frac{1}{2} m_S'^2\, S^2 + \xi_S\, S + \text{h.c.})\,. \end{aligned}$$

- Easily accommodate 125 GeV higgs via additional tree-level contributions or by singlet-doublet mixing

$$M_Z^2 \left(\cos^2 2\beta + \frac{\lambda^2}{g^2} \sin^2 2\beta \right)$$

- Good DM candidates & EWBG.

Realistic NMSSM From Generalized DAMSB

Introduce the following superpotential involving M-M interactions

$$W = W_{Z_3 NMSSM} + \sum_i \left[\lambda_X X \bar{Q}_i Q_i + \sum_a \lambda_S S \mathbf{10}_a \bar{Q}_i \right] + W(X) \; .$$

$$W_{NMSSM} = W_{MSSM}|_{\mu=0} + \lambda S H_u H_d + \frac{\kappa}{3} S^3 \; ,$$

$$Q_i(\mathbf{10}) = TQ_i(3,2)_{1/3} \oplus TU_i(\bar{3},1)_{-4/3} \oplus TE_i(1,1)_2 \; ,$$
$$\bar{Q}_i(\overline{\mathbf{10}}) = \overline{TQ}_i(\bar{3},2)_{-1/3} \oplus \overline{TU}_i(3,1)_{4/3} \oplus \overline{TE}_i(1,1)_{-2} \; .$$

RGE

$$W_M = \sum_i \left[\lambda_X^Q X \overline{TQ}_i TQ_i + \lambda_X^U X \overline{TU}_i TU_i + \lambda_X^E X \overline{TE}_i TE_i + \lambda_{Q,a}^i S Q_{L,a} \overline{TQ}_i + \lambda_{U,a}^i S U_{L,a}^c \overline{TU}_i + \lambda_{E,a}^i S (E_{L,a}^c) \overline{TE}_i \right] + W(X).$$

Deflection Parameters: $$dF_\phi \equiv \frac{F_X}{X} - F_\phi \; .$$

Soft SUSY parameters: 1704.05079

NMSSM From Simplest dAMSB With Messenger-Matter Interactions

Singlet deflected dAMSB:

Du, Fei, arXiv: 1710.06105

Holomorphic terms in Kahler potential and superpotential involving messenger-matter interactions

$$K_h \supseteq \sum_{i=1}^{2} c_{S,i} T S_i + c_P \tilde{P} P + c_Q \tilde{Q} Q + \sum_{m=1}^{3} \left(c^P_{m,a} \tilde{P}_{m,a} P + c^Q_{m,a} \tilde{Q} Q_{m,a} \right),$$

$$W = W_M + \tilde{\lambda} S_1 H_u H_d + \frac{1}{3} \tilde{\kappa} S_1^3 + W_{\overline{MSSM}},$$

$$W_M = \sum_{a=1,2,3} \lambda_P S_1 \tilde{P}_{m,a} P + \lambda_Q S_1 \tilde{Q} Q_{m,a},$$

$$K \supseteq \frac{\phi^\dagger}{\phi} \left[T \left(\sum_{i=1,2} c_{S,i} S_i \right) \right.$$

$\phi = 1 + F_\phi \theta^2$

$$\mathcal{L} \supseteq -c_{S,i} |F_\phi|^2 T S_i + c_{S,i} F_\phi^\dagger \int d^2\theta T S_i + \cdots$$

$$(T,\ S_1^*,\ S_2^*) \begin{pmatrix} c_{S,1}^2 + c_{S,2}^2 & c_{S,1} & c_{S,2} \\ c_{S,1} & c_{S,1}^2 & c_{S,1} c_{S,2} \\ c_{S,2} & c_{S,1} c_{S,2} & c_{S,2}^2 \end{pmatrix} \begin{pmatrix} T^* \\ S_1 \\ S_2 \end{pmatrix}$$

$$\tilde{S}_0 \equiv \frac{1}{c_S} (c_{S,1} S_1 + c_{S,2} S_2), \quad \tilde{S}_1 \equiv \frac{1}{c_S} (-c_{S,2} S_1 + c_{S,1} S_2),$$

$$-(c_S^2 - c_S) F_\phi^2 \left| \frac{-T + \tilde{S}_0^*}{\sqrt{2}} \right|^2 - (c_S^2 + c_S) F_\phi^2 \left| \frac{T + \tilde{S}_0^*}{\sqrt{2}} \right|^2$$

$$
\begin{aligned}
W \supseteq\ & \tilde{\lambda} S_1 H_u H_d + \frac{1}{3}\tilde{\kappa} S_1^3 + \sum_{a=1,2,3}\left[\lambda_P S_1 \tilde{P}_{m,a} P + \lambda_Q S_1 \tilde{Q} Q_{m,a}\right] + y_{ij}^{\bar{\mathbf{5}}} \tilde{P}_{m,i} Q_{m,j} \bar{H}_{\bar{\mathbf{5}}} \\
& + y_{ij}^{\mathbf{5}} Q_{m,i} Q_{m,j} H_{\mathbf{5}} + \sqrt{c_P^2 + (c_{m,3}^P)^2}\,\bar{K}_1 P R + \sqrt{c_Q^2 + (c_{m,3}^Q)^2}\,\tilde{Q} K_1 R\ , \\
\supseteq\ & (\cos\theta \tilde{S}_0 + \sin\theta \tilde{S}_1)\tilde{\lambda} H_u H_d + \frac{\tilde{\kappa}}{3}(\cos\theta \tilde{S}_0 + \sin\theta \tilde{S}_1)^3 \\
& + \left[\lambda_P\left(\sin\psi_1 \bar{K}_1 + \cos\psi_1 \bar{K}_2\right) P + \lambda_Q \tilde{Q}\left(\sin\psi_2 K_1 + \cos\psi_2 K_2\right)\right](\cos\theta \tilde{S}_0 + \sin\theta \tilde{S}_1), \\
& + \sum_{a=1,2}\left(\lambda_P \tilde{P}_{m,a} P + \lambda_Q \tilde{Q} Q_{m,a}\right)(\cos\theta \tilde{S}_0 + \sin\theta \tilde{S}_1)\ . \qquad (2.1
\end{aligned}
$$

理论的特征是出现rescaled couplings-predictive

$$\lambda = \tilde{\lambda}\sin\theta,\ \ \kappa = \tilde{\kappa}\sin^3\theta,\ \ y_{b,\tau} = y_{33}^{D,L}\cos\psi_1\cos\psi_2,\ \ y_t = y_{33}^{U}\cos^2\psi_2$$

Spurion to determine the deflection parameters

$$W = \int d^2\theta \left(c_D R\tilde{P}P + c_Q R\tilde{Q}Q + c_T RST\right),$$ with $$R \equiv M_R + \theta^2 F_R = F_\phi(1 - \theta^2 F_\phi)\ ,$$

$$d \equiv \frac{F_R}{M_R F_\phi} - 1 = -2.$$ Most general type involving both Kahler and Superpotential deflection.

Mirage Mediation SUSY Breaking

From KKLT compacification. The resulting effective N=1 SUGRA description after integrating out heavy moduli

$$S_{N=1} = \int d^4x\sqrt{g^C}\left[\int d^4\theta\, CC^*\left(-3\exp\left(-\frac{K_{\rm eff}}{3}\right)\right) + \right.$$
$$\left. + \left\{\int d^2\theta\left(\frac{1}{4}f_a W^{a\alpha}W^a_\alpha + C^3 W_{\rm eff}\right) + {\rm h.c.}\right\}\right],$$

$$S_{\rm lift} = -\int d^4x\sqrt{g^C}\int d^4\theta\, C^2 C^{2*}\theta^2\bar\theta^2\,\mathcal{P}_{\rm lift}(T,T^*),$$

$$\mathcal{P}_{\rm lift} = D(T+T^*)^{n_P}$$

where

$$K_{\rm eff} = K_0(T+T^*) + Z_i(T+T^*)Q_i^* Q_i\,,$$
$$W_{\rm eff} = W_0(T) + \frac{1}{6}\lambda_{ijk}Q_iQ_jQ_k\,.$$

KKLT v.s. Generalization:

$$K_0 = -3\ln(T+T^*)\,,$$
$$W_0 = w_0 - Ae^{-aT}\,,$$

$$K_0 = -n_0\ln(T+T^*)\,,$$
$$W_0 = w_0 - A_1e^{-a_1T} + A_2e^{-a_2T} \qquad (a_1 \le a_2)\,,$$
$$\mathcal{P}_{\rm lift} = D\,(T+T^*)^{n_P}\,,$$

$$\alpha = \frac{\xi}{1-3n_P/2n_0}\,, \qquad V_{\rm lift} = e^{2K_0/3}\mathcal{P}_{\rm lift} = \frac{D}{(T+T^*)^{\frac{2}{3}n_0-n_P}}\,.$$

Mixed Modulus-Anomaly Mediation Scenario

Stabilize the Kahler moduli gives:

$$\begin{aligned} \langle a\,\mathrm{Re}\,T\rangle &\simeq \ln(M_{st}/m_{3/2}) = \mathcal{O}(4\pi^2), \\ m_{3/2} &= \langle M_{Pl} e^{K} W_0 \rangle \simeq \frac{M_{Pl} w_0}{(2\mathrm{Re}\,T)^{3/2}}, \\ \langle V_{N=1}\rangle &= -3 m_{3/2}^2 M_{Pl}^2 , \end{aligned}$$

$$m_T \sim 4\pi^2 m_{3/2} \text{ and } m_{3/2} \sim 4\pi^2 m_{soft},$$

The soft SUSY parameters:

$$\begin{aligned} M_a &= l_a \frac{F^T}{(T+T^*)} + \frac{b_a g_a^2}{2}\left(\frac{F^C}{4\pi^2 C_0}\right), \\ A_{ijk} &= (3 - n_i - n_j - n_k)\frac{F^T}{(T+T^*)} - \frac{1}{4}(\gamma_i + \gamma_j + \gamma_k)\left(\frac{F^C}{4\pi^2 C_0}\right), \\ m_i^2 &= (1-n_i)\left|\frac{F^T}{(T+T^*)}\right|^2 - \frac{1}{32\pi^2}\frac{d\gamma_i}{d\ln\mu}\left|\frac{F^C}{C_0}\right|^2 \\ &\quad + \left(\frac{1}{8}\sum_{jk}(3-n_i-n_j-n_k)|y_{ijk}|^2 - \frac{1}{2}\sum_a l_a T_a(Q_i) g_a^2\right) \\ &\quad \times \left(\frac{F^T}{(T+T^*)}\left(\frac{F^{*C}}{4\pi^2 C_0^*}\right) + \frac{F^{*T}}{(T+T^*)}\left(\frac{F^C}{4\pi^2 C_0}\right)\right). \end{aligned}$$

Mirage Mediation v.s. Mirage Scale

The parameter $\alpha \equiv \frac{m_{3/2}}{M_0 \ln(M_{Pl}/m_{3/2})}$ $M_0 = F^T/(T+T^*)$

$$M_a(M_{\rm GUT}^{(-)}) = M_0 \left(1 + \frac{\ln(M_{Pl}/m_{3/2})}{8\pi^2} \alpha b_a g_{\rm GUT}^2\right), \quad M_a(\mu) = M_0 \left[1 - \frac{1}{4\pi^2} b_a g_a^2(\mu) \ln\left(\frac{M_{\rm GUT}}{(M_{Pl}/m_{3/2})^{\alpha/2}\mu}\right)\right].$$

Pure modulus mediation form at the mirage scale. $M_a(M_{\rm mir}) = M_0.$

$$A_{ijk}(\mu) = M_0 \left[a_{ijk} + \frac{1}{8\pi^2}(\gamma_i(\mu) + \gamma_j(\mu) + \gamma_k(\mu)) \ln\left(\frac{M_{\rm GUT}}{(M_{Pl}/m_{3/2})^{\alpha/2}\mu}\right)\right],$$

$$m_i^2(\mu) = |M_0|^2 \left[c_i + \frac{1}{4\pi^2}\left\{\gamma_i(\mu) - \frac{1}{2}\frac{d\gamma_i(\mu)}{d\ln\mu} \ln\left(\frac{M_{\rm GUT}}{(M_{Pl}/m_{3/2})^{\alpha/2}\mu}\right)\right\} \times \right.$$
$$\left. \times \ln\left(\frac{M_{\rm GUT}}{(M_{Pl}/m_{3/2})^{\alpha/2}\mu}\right) - \frac{1}{8\pi^2} Y_i \left(\sum_j c_j Y_j\right) g_Y^2(\mu) \ln\left(\frac{M_{\rm GUT}}{\mu}\right)\right],$$

$A_{ijk}(M_{\rm mir}) = (c_i + c_j + c_k) M_0,$ $m_i^2(M_{\rm mir}) = c_i M_0^2,$ for $a_{ijk} = c_i + c_j + c_k = 1,$

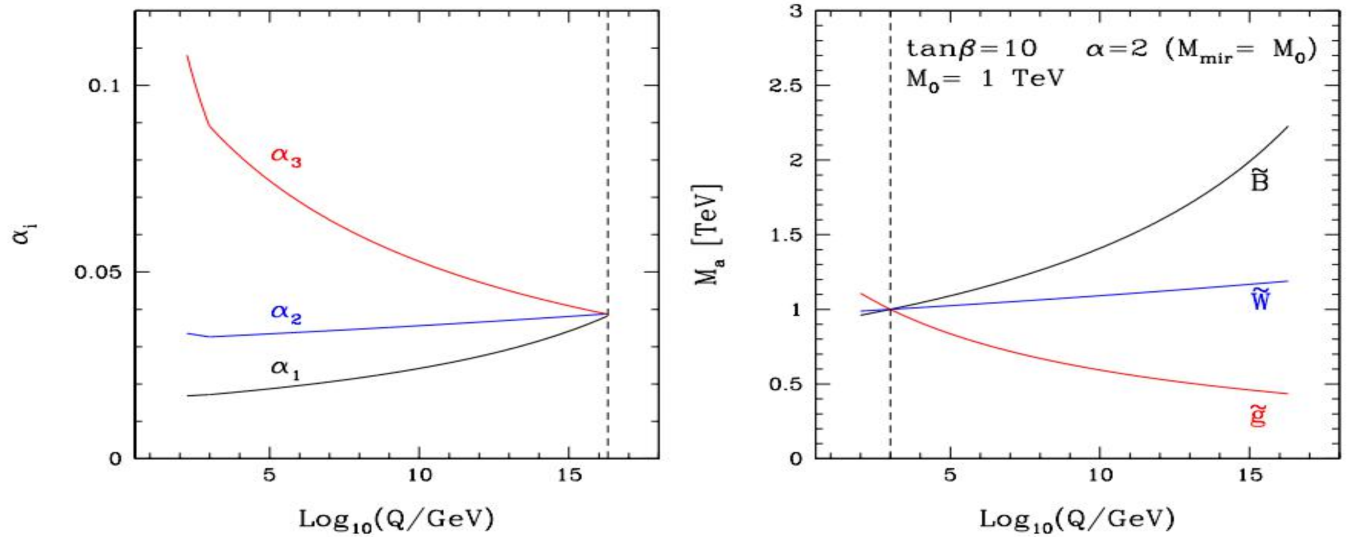
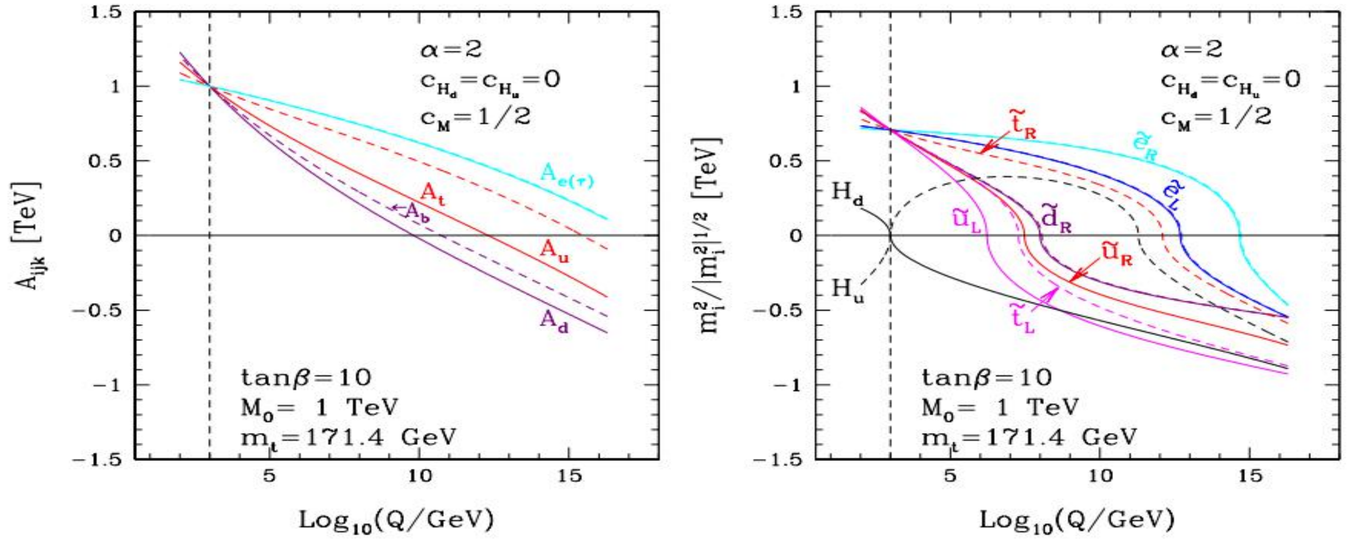


FIG. 1: Running of gauge couplings and gaugino masses in TeV scale mirage mediatior



Deflected Mirage Mediation

- modulous mediation + deflected AMSB

$$m_{\rm soft}^{(\rm modulus)} \sim \frac{F^T}{T+\overline{T}}, \qquad m_{\rm soft}^{(\rm anomaly)} \sim \frac{1}{16\pi^2}\frac{F^C}{C}, \qquad m_{\rm soft}^{(\rm gauge)} \sim \frac{1}{16\pi^2}\frac{F^X}{X}.$$

comparable contributions.

- Superpotential involving the messenger sector

$$W = W_0 + W_1(X) + \lambda X \Psi \overline{\Psi} + W_{\rm MSSM},$$

$W_1(X) = \frac{1}{2}m(X - X_0)^2,$	SUSY thresholds, F_X negligible
$W_1(X) = 0.$	Radiative potenital, d=-1
$W_1(X) = \frac{X^n}{\Lambda^{n-3}},$	General deflection parameters

Mu and Bmu Term in Mirage Mediation

Introduce Higgs bilinear in the Kahler and superpotential

$$\Delta K_{\rm eff} = \frac{H_1 H_1^*}{(T+T^*)^{n_{H_1}}} + \frac{H_2 H_2^*}{(T+T^*)^{n_{H_2}}} + \left(\frac{\kappa H_1 H_2}{(T+T^*)^h} + {\rm h.c.}\right),$$

$$\Delta W_{\rm eff} = \tilde{A} e^{-aT} H_1 H_2 \,,$$

$\mu = \mu_W + \mu_K \,,$ with $$\mu_W = \frac{\tilde{A} e^{-aT}}{(T+T^*)^{l_W}}, \quad \mu_K = \frac{\kappa}{(T+T^*)^{l_K}} \left(\frac{F^C}{C_0} + (1-h)\frac{F^T}{(T+T^*)}\right)^*$$

$$B\mu = -\left[m_{3/2} - a(T+T^*)M_0 + \mathcal{O}(M_0)\right]\mu_W + \left[m_{3/2} + \mathcal{O}(M_0)\right]\mu_K$$

Desirable way by promoting to NMSSM

$$\Delta W_{\rm eff} = \lambda_1 N H_1 H_2 + \frac{\lambda_2}{3} N^3 .$$

$$\mu = \frac{e^{K_0/2}\lambda_1 \langle N \rangle}{\sqrt{Z_{H_1} Z_{H_2}}} \,,$$

$$B = A_{N H_1 H_2} + \frac{e^{K_0/2}\lambda_2^* \langle N \rangle}{Z_N} \,,$$

NMSSM From Typical dMirage Mediation

$$e^{-1}\mathcal{L} = \int d^4\theta \left[\phi^\dagger\phi\left(-3e^{-K/3}\right) - (\phi^\dagger\phi)^2\bar{\theta}^2\theta^2\mathcal{P}_{lift}\right] + \int d^2\theta\phi^3 W + \int d^2\theta \frac{f_i}{4} W_i^a W_i^a$$

$$K = -3\ln(T+T^\dagger) + Z_X(T^\dagger,T)X^\dagger X + Z_\Phi(T^\dagger,T)\Phi^\dagger\Phi + \sum_i Z_{P_i,\bar{P}_i}(T^\dagger,T)\left[P_i^\dagger P_i + \bar{P}_i^\dagger \bar{P}_i\right] .$$

$$Z_X(T^\dagger,T) = \frac{1}{(T^\dagger+T)^{n_X}} , \quad Z_\Phi(T^\dagger,T) = \frac{1}{(T^\dagger+T)^{n_\Phi}} ,$$

$$f_i(T)_i = T^{l_i} , \quad Z_{P_m}(T^\dagger,T) = \frac{1}{(T^\dagger+T)^{n_P}} ,$$

$$W = \left(\omega_0 - Ae^{-aT}\right) + W_M + W_{\overline{NMSSM}} .$$

The Z_3 symmetric NMSSM superpotential reads

$$W_{\overline{NMSSM}} = \lambda S H_u H_d + \frac{1}{3}\kappa S^3 + W_{MSSM} ,$$

and the messenger terms

$$W_M = \sum_m \left[\lambda_X^T X \tilde{X}_m X_m + \lambda_X^D X \tilde{Y}_m Y_m + \lambda_P^T S \tilde{X}_1 X_2 + \lambda_P^D S \tilde{Y}_1 Y_2\right] + W(X).$$

The $2m$ family of messengers can be fitted in terms of $'5, \bar{5}'$ representation of $SU(5)$ GUT group

Based on 1804.07335 by

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Wenyu Wang,
Jin Min Yang,
Yang Zhang

$$A_{ijk} = y_{ijk}/\sqrt{e^{-K_0} Z_i Z_j Z_k}\ . \qquad A_0^{ijk} \equiv \frac{A_{ijk}}{y_{ijk}} = \sum \left(F^T \frac{\partial}{\partial T} - \frac{F_\phi}{2} \frac{\partial}{\partial \ln \mu} + dF_\phi \frac{\partial}{\partial \ln X} \right) \ln \left[e^{-K_0/3} Z_i(\mu, X, T) \right]$$

$$M_i(M_P) = g_i^2 \left(F^T \frac{\partial}{\partial T} - \frac{F_\phi}{2} \frac{\partial}{\partial \ln \mu} + dF_\phi \frac{\partial}{\partial \ln X} \right) \frac{1}{g_i^2}(\mu, X, T)\ ,$$

$$\begin{aligned} m_{soft}^2 &= - \left| F_T \frac{\partial}{\partial T} - \frac{F_\phi}{2} \frac{\partial}{\partial \ln \mu} + dF_\phi \frac{\partial}{\partial \ln X} \right|^2 \ln \left[e^{-K_0/3} Z_i(\mu, X, T) \right]\ , \\ &= - \left(F_T^2 \frac{\partial^2}{\partial T \partial T^*} + \frac{F_\phi^2}{4} \frac{\partial^2}{\partial (\ln \mu)^2} + \frac{d^2 F_\phi^2}{4} \frac{\partial}{\partial (\ln |X|)^2} - F_T F_\phi \frac{\partial^2}{\partial T \partial \ln \mu} \right. \\ &\quad \left. + dF_T F_\phi \frac{\partial^2}{\partial T \partial \ln |X|} - \frac{dF_\phi^2}{2} \frac{\partial^2}{\partial \ln |X| \partial \ln \mu} \right) \ln \left[e^{-K_0/3} Z_i(\mu, X, T) \right], \end{aligned}$$

Coherently Summation

$$\begin{aligned} \frac{\partial^2}{\partial T \partial \ln \mu} Z_i^{-} &= \frac{\partial}{\partial T} G_i^{-}(Z_a, g_m)\ , \\ &= \left[\frac{\partial Z_a}{\partial T} \frac{\partial}{\partial Z_a} + \frac{\partial g_m}{\partial T} \frac{\partial}{\partial g_m} \right] G_i^{-}(Z_a, g_m) \end{aligned}$$

$$\begin{aligned} \frac{\partial^2}{\partial T \partial \ln X} Z_i^{-} &= \frac{\partial}{\partial T} \frac{\Delta G_i(Z_a, g_m)}{2}\ , \\ &= \frac{1}{2} \left[\frac{\partial Z_a}{\partial T} \frac{\partial}{\partial Z_a} + \frac{\partial g_m}{\partial T} \frac{\partial}{\partial g_m} \right] \Delta G_i(Z_a, g_m) \end{aligned}$$

modulus-anomaly interference term

modulus-gauge interference term

广义Mirage传递的软破缺质量形式

$$M_i = l_i M_0 + F_\phi \frac{\alpha_i}{4\pi}(b_i - d\Delta b_i) \ ,$$

$$\alpha = \frac{F_\phi}{(16\pi^2)M_0}.$$

$$(b_1\ , b_2\ ,\ b_3) = (\frac{33}{5},\ 1, -3)\ ,$$

$$\Delta(b_1\ , b_2\ ,\ b_3) = (\ 2,\ 2,\ 2).$$

$$A_t = (m_{Q_{L,3}} + m_{H_u} + m_{t^c_L})M_0 + \frac{F_\phi}{16\pi^2}\left[6y_t^2 + y_b^2 + \lambda^2 - (\frac{16}{3}g_3^2 + 3g_2^2 + \frac{13}{15}g_1^2)\right] \ ,$$

$$A_b = (m_{Q_{L,3}} + m_{H_d} + m_{b^c_L})M_0 + \frac{F_\phi}{16\pi^2}\left[y_t^2 + 6y_b^2 + \lambda^2 - (\frac{16}{3}g_3^2 + 3g_2^2 + \frac{7}{15}g_1^2)\right] \ ,$$

$$A_\tau = (m_{L_{L,3}} + m_{H_d} + m_{\tau^c_L})M_0 + \frac{F_\phi}{16\pi^2}\left[3y_b^2 + \lambda^2 - (3g_2^2 + \frac{9}{5}g_1^2)\right] \ ,$$

$$A_\lambda = (m_S + m_{H_d} + m_{H_u})M_0 + \frac{F_\phi}{16\pi^2}\left[4\lambda^2 + 2\kappa^2 + 3y_t^2 + 3y_b^2 - (3g_2^2 + \frac{3}{5}g_1^2)\right] + \Delta A_\lambda$$

$$A_\kappa = 3m_S M_0 + \frac{F_\phi}{16\pi^2}\left[6\lambda^2 + 6\kappa^2\right] + \Delta A_\kappa \ ,$$

$$\Delta A_\lambda = -d\frac{F_\phi}{16\pi^2}\left[3(\lambda_P^T)^2 + 2(\lambda_P^D)^2\right] \ ,$$

$$\Delta A_\kappa = -3d\frac{F_\phi}{16\pi^2}\left[3(\lambda_P^T)^2 + 2(\lambda_P^D)^2\right] \ .$$

$$m^2_{soft} = \delta_m + \delta_d + \delta_I \ ,$$

每种sfermion软破缺质量为六项相加

理论的自由参数和取值范围

- A deflection parameter d of either sign with $m_{(L_L)^{1,2,3}} = m_{(E_L^c)^{1,2,3}} = 1/2$.
- Modular weights for other matter and messenger fields are given by

$$
\begin{aligned}
m_{H_u} &= m_S = m_{Q_L^3} = m_{t_L^c} = m_{b_L^c} = 0, \\
m_a &= \frac{1}{2}, \quad (a = Q_L^{1,2}, (U_L^c)^{1,2}, (D_L^c)^{1,2}) \ , \\
m_{H_d} &= m_X = m_{\tilde{X}} = m_Y = m_{\tilde{Y}} = 1.
\end{aligned}
$$

$d, \alpha, M_{mess}, M_0, \lambda, \kappa, \lambda_P^D, \lambda_P^T, \lambda_X^D, \lambda_X^T$

$F_\phi/(16\pi^2) \approx \alpha M_0$

$\lambda_P^D = \lambda_P^T = \lambda_X^D = \lambda_X^T = \lambda_0$

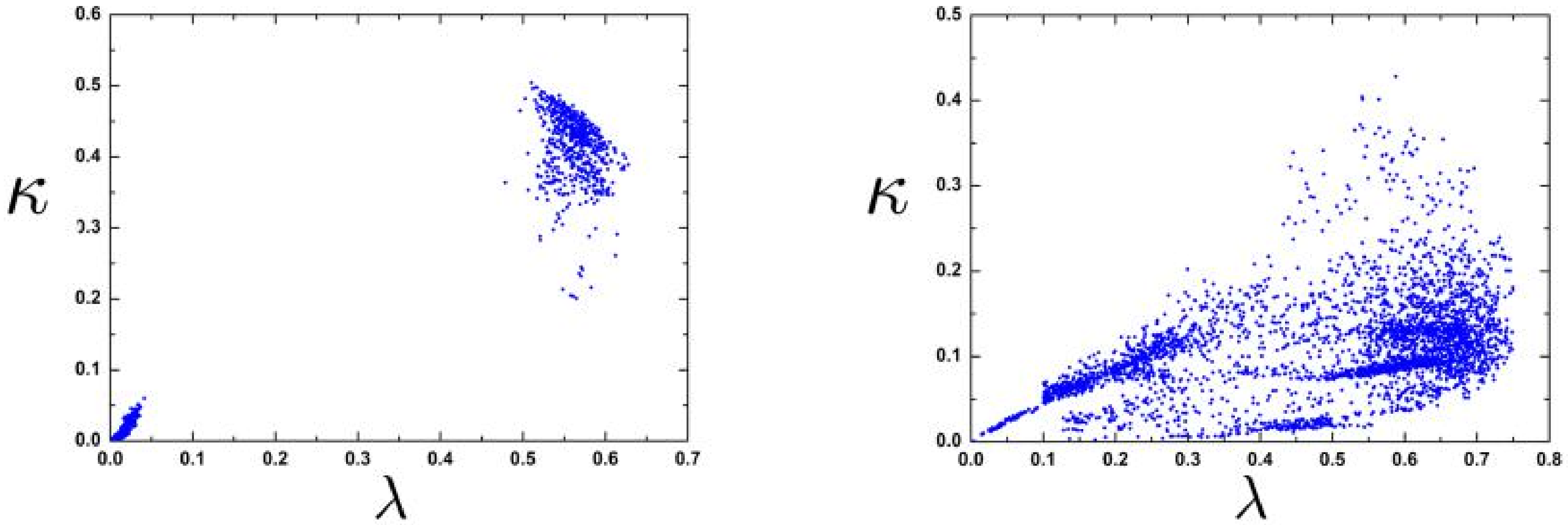
$$
\begin{aligned}
&10^{15}\text{GeV} > M_{mess} > 10^5\text{GeV} \ , \quad 100\text{TeV} > M_0 > 0.1\text{TeV} \ , \\
&16 > \alpha > 0 \ , \quad 4 > d > -4 \ , \quad 0.7 > \lambda, \kappa > 0 \ , \ \sqrt{4\pi} > \lambda_0 > 0
\end{aligned}
$$

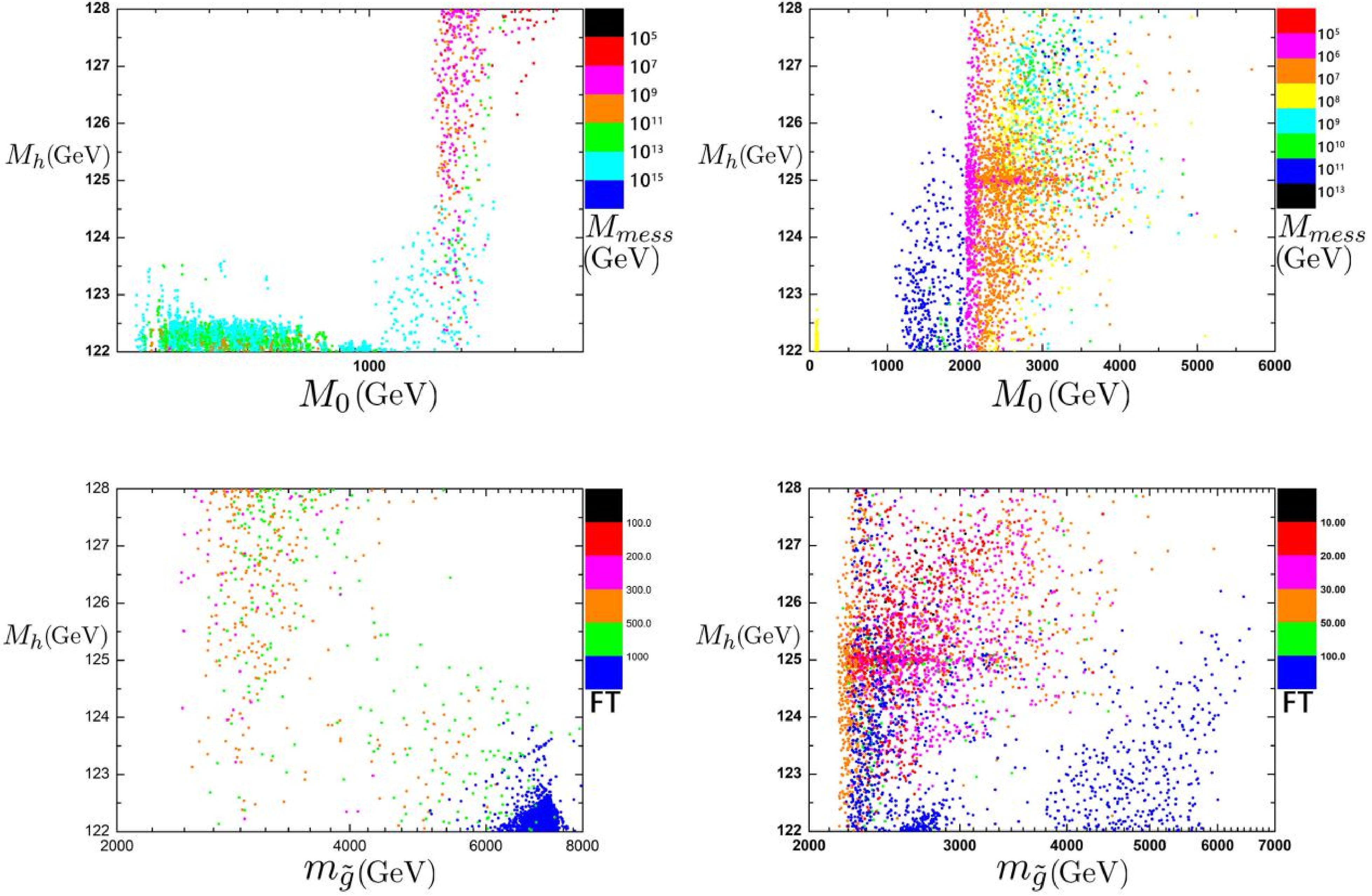
EWSB conditions and 125 GeV Higgs

$$|\mu_{eff}|^2 = -\frac{M_Z^2}{2} - m_{H_u}^2 + \frac{1}{\tan^2\beta}(m_{H_d}^2 - m_{H_u}^2) + \mathcal{O}(1/\tan^4\beta) ,$$

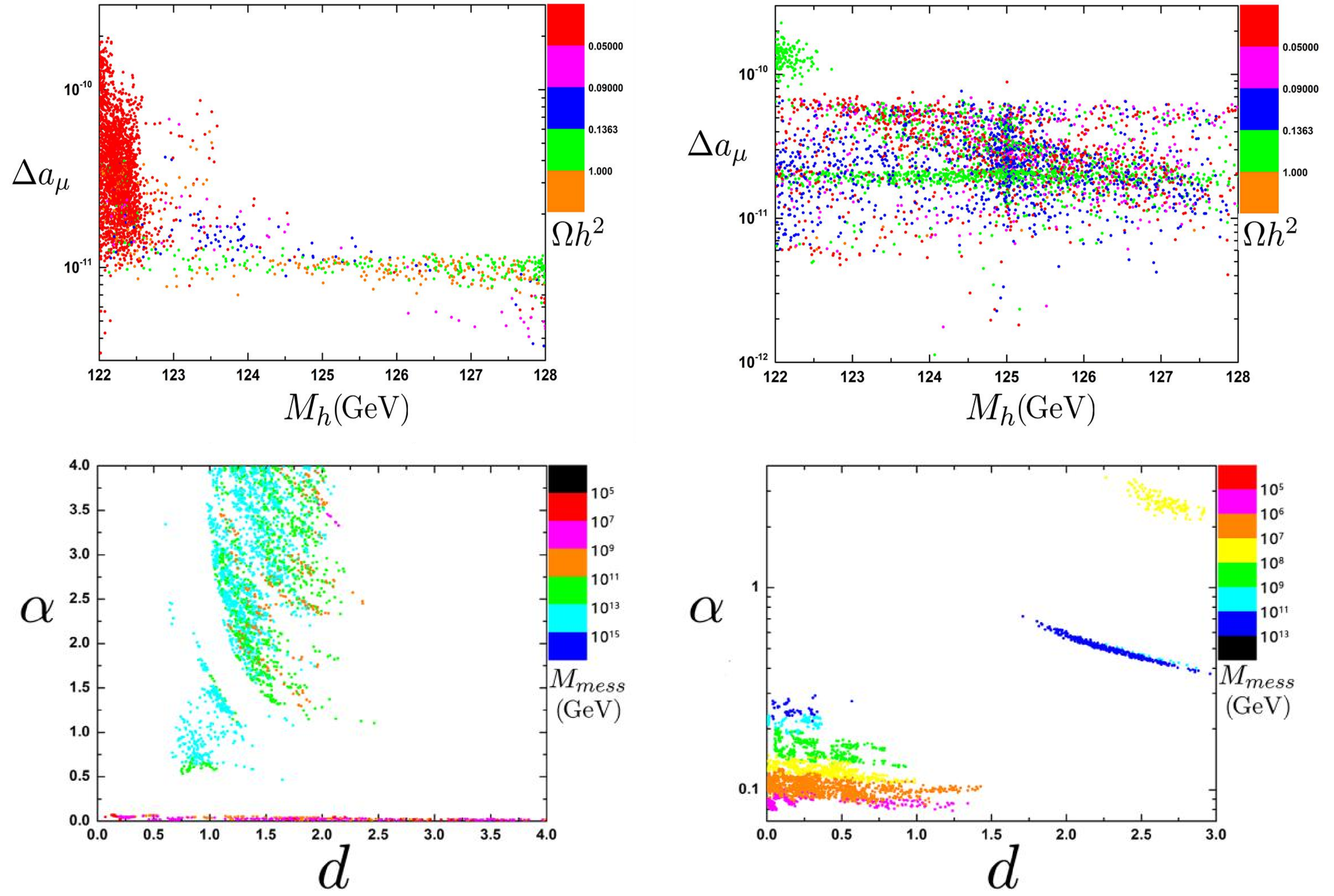
$$\sin 2\beta = \frac{2B_{eff}\mu_{eff}}{m_{H_u}^2 + m_{H_d}^2 + 2|\mu_{eff}|^2 + \lambda^2 v^2} ,$$

Non-trivial



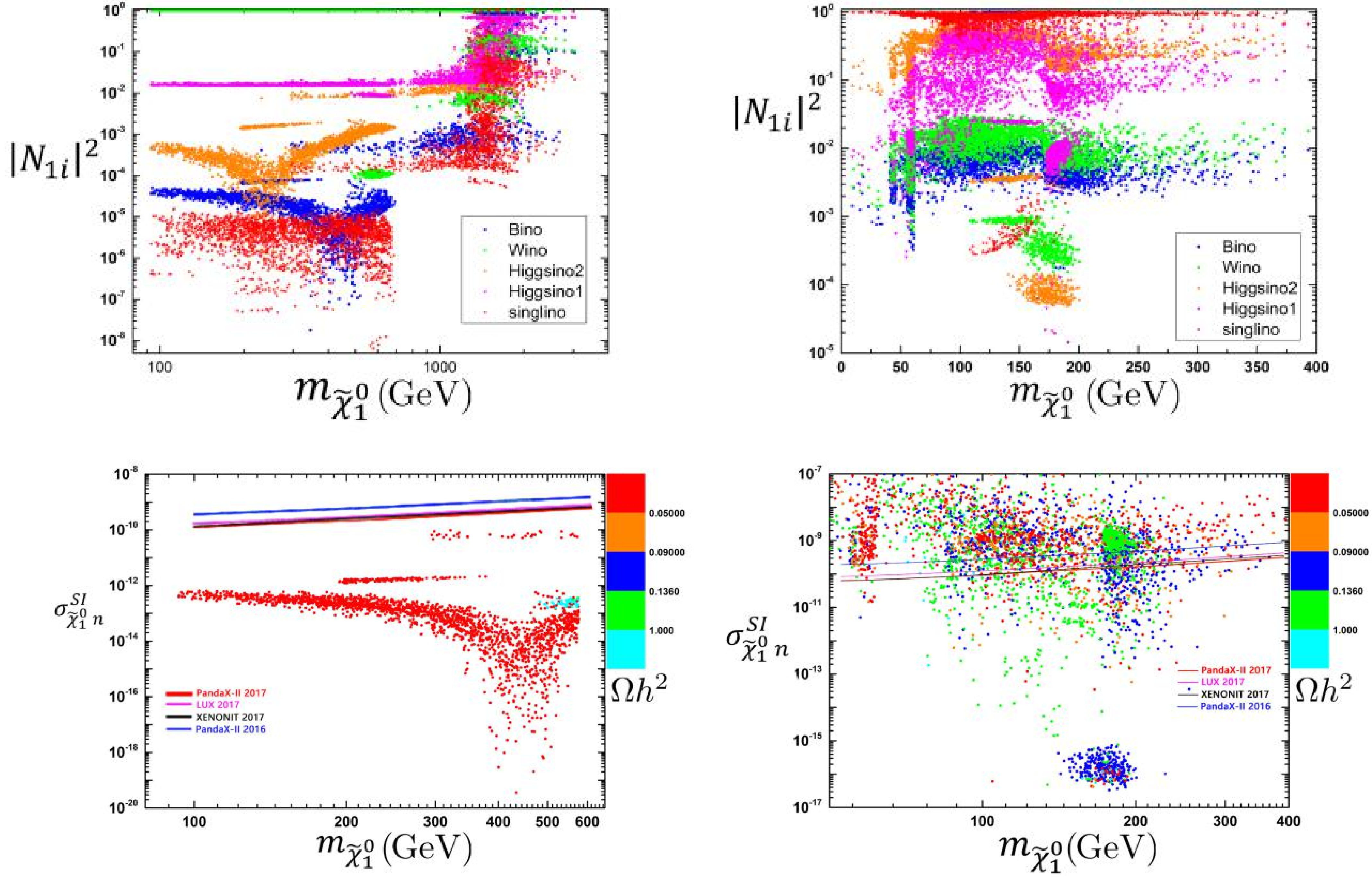


M_h(GeV)
M_0(GeV)
M_{mess} (GeV)
10^5 10^7 10^9 10^{11} 10^{13} 10^{15}
10^5 10^6 10^7 10^8 10^9 10^{10} 10^{11} 10^{13}
$m_{\tilde{g}}$(GeV)
FT
100.0 200.0 300.0 500.0 1000
10.00 20.00 30.00 50.00 100.0



Gaugino ratio at SUSY scale:

$$M_3 : M_2 : M_1 \approx 6 \cdot [\frac{1}{g_3^2} + \alpha(-3 - 2d)] : 2 \cdot [\frac{1}{g_2^2} + \alpha(1 - 2d)] : [\frac{1}{g_1^2} + \alpha(6.6 - 2d)],$$



$|N_{1i}|^2$
$m_{\tilde{\chi}_1^0}$ (GeV)
Bino
Wino
Higgsino2
Higgsino1
singlino
$\sigma^{SI}_{\tilde{\chi}_1^0 n}$
PandaX-II 2017
LUX 2017
XENON1T 2017
PandaX-II 2016
0.05000
0.09000
0.1360
1.000
Ωh^2

谢谢大家