

Muon g-2: Ayar İletimli Süpersimetri Kırılması Modelleri

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1 Standart Model

2 SUSY

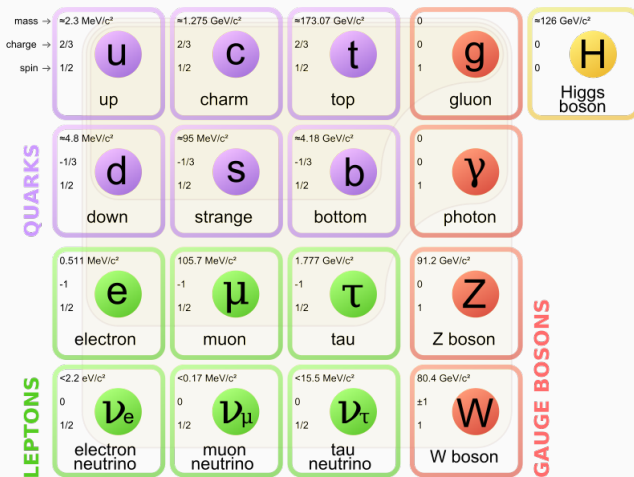
3 GMSB

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- Tarama Prosedürü ve Deneysel Kısıtlamalar
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Standart Model (SM)

$$SU(3) \times SU(2) \times U(1)$$



Süpersimetri (SUSY)

SUSY, fermiyonlar ve bosonlar arasında tanımlanan bir simetridir.

$$Q|Boson\rangle = |Fermion\rangle \quad Q|Fermion\rangle = |Boson\rangle$$

Parçacık Spektrumu

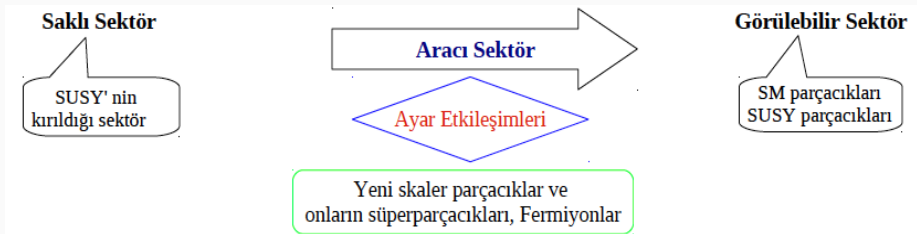
Names		spin 0	spin 1/2	$SU(3)_C, SU(2)_L, U(1)_Y$
squarks, quarks ($\times 3$ families)	Q	$(\tilde{u}_L \tilde{d}_L)$	$(u_L d_L)$	$(\mathbf{3}, \mathbf{2}, \frac{1}{6})$
	\bar{u}	\tilde{u}_R^*	u_R^\dagger	$(\bar{\mathbf{3}}, \mathbf{1}, -\frac{2}{3})$
	\bar{d}	\tilde{d}_R^*	d_R^\dagger	$(\bar{\mathbf{3}}, \mathbf{1}, \frac{1}{3})$
sleptons, leptons ($\times 3$ families)	L	$(\tilde{\nu} \tilde{e}_L)$	(νe_L)	$(\mathbf{1}, \mathbf{2}, -\frac{1}{2})$
	\bar{e}	\tilde{e}_R^*	e_R^\dagger	$(\mathbf{1}, \mathbf{1}, 1)$
Higgs, higgsinos	H_u	$(H_u^+ H_u^0)$	$(\tilde{H}_u^+ \tilde{H}_u^0)$	$(\mathbf{1}, \mathbf{2}, +\frac{1}{2})$
	H_d	$(H_d^0 H_d^-)$	$(\tilde{H}_d^0 \tilde{H}_d^-)$	$(\mathbf{1}, \mathbf{2}, -\frac{1}{2})$

Names	spin 1/2	spin 1	$SU(3)_C, SU(2)_L, U(1)_Y$
gluino, gluon	\tilde{g}	g	$(\mathbf{8}, \mathbf{1}, 0)$
winos, W bosons	$\tilde{W}^\pm \tilde{W}^0$	$W^\pm W^0$	$(\mathbf{1}, \mathbf{3}, 0)$
bino, B boson	\tilde{B}^0	B^0	$(\mathbf{1}, \mathbf{1}, 0)$

İki Higgs doublet: $H_d, H_u \Rightarrow h, H, A, H^\pm$

- Hiyerarşi probleminin çözümü
- R parite
Karanlık madde adayı (sneutrino, neutralino, gravitino)
- Muon anomal manyetik moment (muon g-2) $a_\mu = \frac{1}{2}(g_\mu - 2)$
 $\Delta a_\mu = a_\mu^{exp} - a_\mu^{SM} = (24.5 \pm 4.9) \times 10^{-10}$
- Radyatif Elektrozayıf Simetri Kırılması (REWSB)
- Elektromanyetik, zayıf ve güçlü kuvvet birleşimi

Ayar İletimli Süpersimetri Kırılımı (GMSB)



$$\begin{aligned}\mathcal{L}_{\text{Soft}} = & -\frac{1}{2}(M_1\tilde{B}\tilde{B} + M_2\tilde{W}\tilde{W} + M_3\tilde{g}\tilde{g}) + \text{h.c.} \\ & -m_{H_u}^2 h_u^\dagger h_u - m_{H_d}^2 h_d^\dagger h_d - (b h_u h_d + \text{h.c.}) \\ & -m_Q^2 \tilde{q}^\dagger \tilde{q} - m_L^2 \tilde{l}^\dagger \tilde{l} - m_u^2 \tilde{u}_R^\dagger \tilde{u}_R - m_d^2 \tilde{d}_R^\dagger \tilde{d}_R - m_e^2 \tilde{e}_R^\dagger \tilde{e}_R \\ & -(A_u \tilde{u}_R \tilde{q} h_u + A_d \tilde{d}_R \tilde{q} h_d + A_e \tilde{e}_R \tilde{l} h_d) \\ & -(A'_u \tilde{u}_R \tilde{q} h_d + A'_d \tilde{d}_R \tilde{q} h_u + A'_e \tilde{e}_R \tilde{l} h_u) + \mu' \tilde{h}_u \tilde{h}_d\end{aligned}$$

SUSY Parçacıkları için Kütleler

$$W \supset (M_5 + \lambda_5 S)\Phi_5\Phi_{\bar{5}} + (M_3 + \lambda_3 S)Tr(\Sigma_3^2) + (M_8 + \lambda_8 S)Tr(\Sigma_8^2)$$

$$\Lambda_5 = \frac{\lambda_5 \langle F_S \rangle}{M_5} \quad \Lambda_3 = \frac{\lambda_3 \langle F_S \rangle}{M_3} \quad \Lambda_8 = \frac{\lambda_8 \langle F_S \rangle}{M_8}$$

$$M_1 \simeq \frac{g_1^2}{16\pi^2}(5\Lambda_5) \quad M_2 \simeq \frac{g_2^2}{16\pi^2}(2\Lambda_3 + 3\Lambda_5) \quad M_3 \simeq \frac{g_3^2}{16\pi^2}(3\Lambda_8 + 2\Lambda_5)$$

$$m_Q^2 \simeq \frac{2}{(16\pi^2)^2} \left[\frac{4}{3}g_3^4(3\Lambda_8^2 + 2\Lambda_5^2) + \frac{3}{4}g_2^4(2\Lambda_3^2 + 3\Lambda_5^2) + \frac{3}{5}g_1^4(5\Lambda_5^2)\frac{1}{6^2} \right]$$

$$m_{\bar{U}}^2 \simeq \frac{2}{(16\pi^2)^2} \left[\frac{4}{3}g_3^4(3\Lambda_8^2 + 2\Lambda_5^2) + \frac{3}{5}g_1^4(5\Lambda_5^2) \left(\frac{2}{3}\right)^2 \right]$$

$$m_{\bar{D}}^2 \simeq \frac{2}{(16\pi^2)^2} \left[\frac{4}{3}g_3^4(3\Lambda_8^2 + 2\Lambda_5^2) + \frac{3}{5}g_1^4(5\Lambda_5^2)\frac{2}{3^2} \right]$$

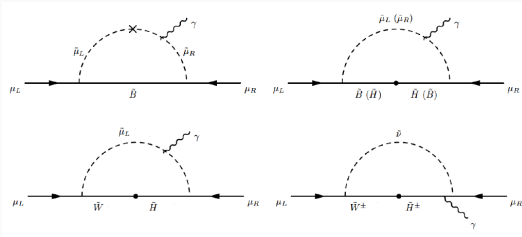
$$m_{\bar{L}}^2 \simeq \frac{2}{(16\pi^2)^2} \left[\frac{3}{4}g_2^4(2\Lambda_3^2 + 3\Lambda_5^2) + \frac{3}{5}g_1^4(5\Lambda_5^2)\frac{1}{2^2} \right] \quad m_{H_u}^2 = m_{H_d}^2 = m_{\bar{L}}^2$$

$$m_{\bar{E}}^2 \simeq \frac{2}{(16\pi^2)^2} \left[\frac{3}{5}g_1^4(5\Lambda_5^2) \right]$$

$$m_{3/2} \simeq \frac{\Lambda M_{mess}}{\sqrt{3}M_P}$$

Muon g-2

$$\Delta a_\mu = a_\mu^{\text{exp}} - a_\mu^{\text{SM}} = (24.5 \pm 4.9) \times 10^{-10}$$



$$\Delta a_\mu^{\tilde{B}\tilde{\mu}_L\tilde{\mu}_R} \simeq \frac{g_1^2}{16\pi^2} \frac{m_\mu^2 M_{\tilde{B}} (\mu \tan\beta - A_\mu)}{m_{\tilde{\mu}_L}^2 m_{\tilde{\mu}_R}^2} F_N \left(\frac{m_{\tilde{\mu}_L}^2}{M_{\tilde{B}}^2}, \frac{m_{\tilde{\mu}_R}^2}{M_{\tilde{B}}^2} \right)$$

$$\Delta a_\mu^{\tilde{B}\tilde{H}\tilde{\mu}} \simeq \frac{g_1^2}{16\pi^2} m_\mu^2 M_1 (\mu \tan\beta - A_\mu) \left[\frac{1}{m_{\tilde{\mu}_L}^4} F_N \left(\frac{M_1^2}{m_{\tilde{\mu}_L}^2}, \frac{\mu^2}{m_{\tilde{\mu}_L}^2} \right) - \frac{2}{m_{\tilde{\mu}_R}^4} F_N \left(\frac{M_1^2}{m_{\tilde{\mu}_R}^2}, \frac{\mu^2}{m_{\tilde{\mu}_R}^2} \right) \right]$$

$$\Delta a_\mu^{\tilde{W}\tilde{H}\tilde{\mu}} \simeq \frac{g_2^2}{16\pi^2} \frac{m_\mu^2 M_2 (\mu \tan\beta - A_\mu)}{m_{\tilde{\mu}_L}^4} F_N \left(\frac{M_2^2}{m_{\tilde{\mu}_L}^2}, \frac{\mu^2}{m_{\tilde{\mu}_L}^2} \right)$$

$$\Delta a_\mu^{\tilde{W}\tilde{H}\tilde{\nu}} \simeq \frac{g_2^2}{8\pi^2} \frac{m_\mu^2 M_2 (\mu \tan\beta - A_\mu)}{m_{\tilde{\nu}}^4} F_C \left(\frac{M_2^2}{m_{\tilde{\nu}}^2}, \frac{\mu^2}{m_{\tilde{\nu}}^2} \right)$$

Tarama Prosedürü ve Deneysel Kısıtlamalar

$$\begin{aligned} 10^{-7} &\leq \Lambda_{3,5,8} \leq 10^7 \text{ GeV} \\ 10^{11} &\leq M_{mess} \leq 10^{16} \text{ GeV} \\ 1.2 &\leq \tan \beta \leq 60 \end{aligned}$$

$$\begin{aligned} m_{\tilde{e}} &\geq 99 \text{ GeV} \\ m_{\tilde{\tau}} &\geq 105 \text{ GeV} \\ m_{\tilde{\chi}} &\geq 175 \text{ GeV} \\ m_{\tilde{b}} &\geq 222 \text{ GeV} \\ m_{\tilde{\chi}_1^\pm} &\geq 103.5 \text{ GeV} \end{aligned}$$

$$\begin{aligned} 123 &\leq m_h \leq 127 \text{ GeV} \\ 2.9 \times 10^{-4} &\leq BR(b \rightarrow s\gamma) \leq 3.87 \times 10^{-4} \quad (2\sigma) \\ 1.95 \times 10^{-9} &\leq BR(B_s \rightarrow \mu^+ \mu^-) \leq 3.43 \times 10^{-9} \quad (2\sigma) \end{aligned}$$

$$0.114 \leq \Omega h^2 \leq 0.126 \quad (\text{Planck } 5\sigma)$$

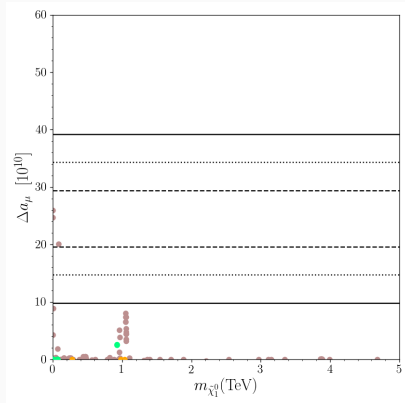
$$0. \leq \Omega h^2 \leq 0.114$$

$$\Delta a_\mu = a_\mu^{\text{MSSM}} - a_\mu^{\text{SM}} = (24.5 \pm 4.9) \times 10^{-10}$$

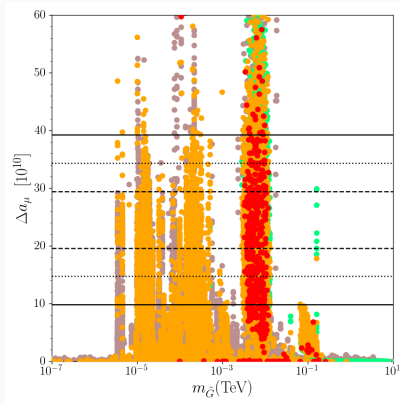
- **Yeşil noktalar**, yukarıda listelediğimiz kütle ve B-mezon bozunum ölçümlerini sağlamaktadır.
- **Mavi noktalar**, yeşil noktaların alt kümesi olup, muon g-2 çözümlerini sağlamaktadır.
- **Kırmızı noktalar**, mavi noktaların alt kümesi olup, Planck uydularından gelen karanlık madde ölçümlerini sağlamaktadır.
- **Turuncu noktalar**, mavi noktaların alt kümesi olup, düşük karanlık madde ölçümlerini sağlamaktadır.

Neutralino vs Gravitino

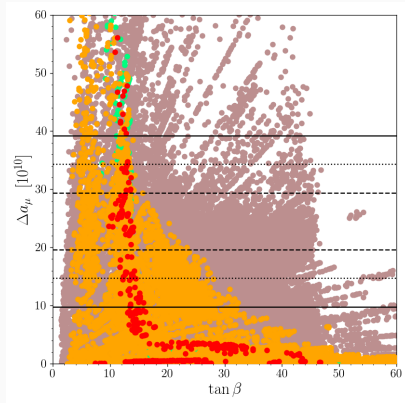
LSP $\tilde{\chi}_1^0$



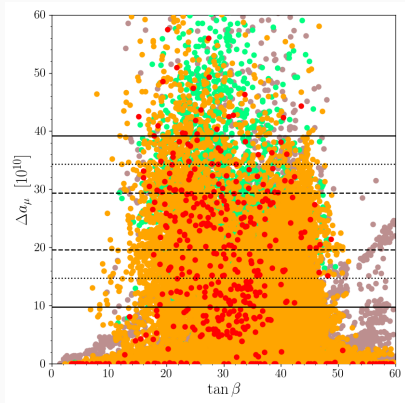
LSP \tilde{G}



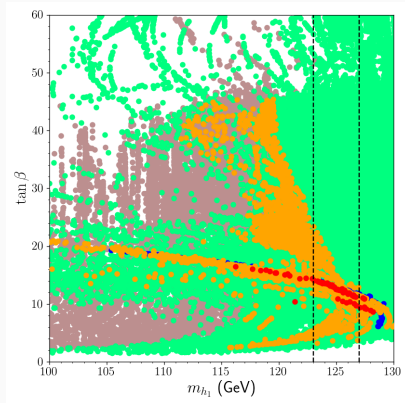
Holomorphic



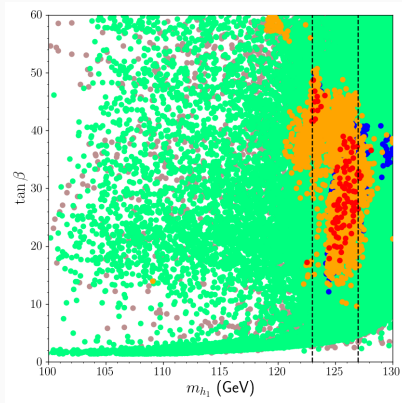
Non-holomorphic



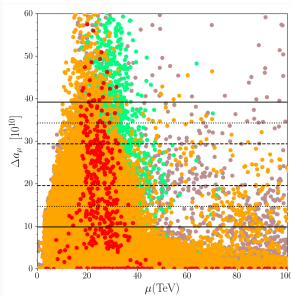
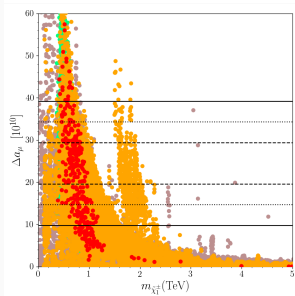
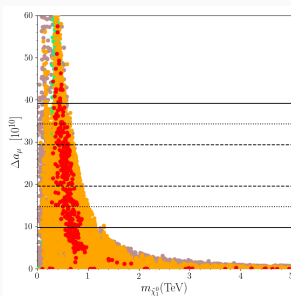
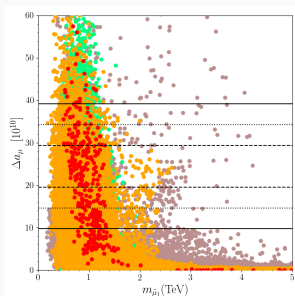
Holomorphic



Non-holomorphic



Kütle Spektrumu



- Adjoint mesajlı GMSB
- Muon g-2
 - ▶ Holomorphic, Higgs kütlesi problemi
 - ▶ Non-holomorphic, A'
- $m_{\tilde{\mu}_1} \lesssim 1.5 \text{ TeV}$
 $m_{\tilde{\chi}_1^0} \lesssim 1 \text{ TeV}, \quad m_{\tilde{\chi}_1^\pm} \lesssim 1 \text{ TeV}$
- Higgs ve muon g-2
- Daha yüksek $\tan \beta \gtrsim 50$