





Unified Interpretation of Muon g-2 Anomaly, 95 GeV Excesses and Dark Matter in SUSY Models

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1/26 连经伟 HIST & HNU

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Outline • Motivation • DM, $(g - 2)_{\mu}$ and 95.4 GeV excesses General NMSSM • Sampling Strategy • Numerical results Conclusion

BSM New physics must exist

Motivation: > Dark matter and Dark energy > Matter-Antimatter asymmetry > Neutrino mass > Hierarchy problem > Strong CP problem > Unification of forces

Other important hints:

- muon g-2 anomaly
- Higgs searches

.





 $\Delta m_h^2 = -\frac{Y_f^2}{8\pi^2} [\Lambda^2 + ...],$



DM candidates

Some properties of DM are known we but the mass known poorly!

- > Primordial black holes
- > Super heavy particles
- > Asymmetric DM
- ➤ Hidden sector DM



Some properties of DM are known well, {e.g., abundance, weakly coupled, cold},



Muon anomalous magnetic moment

dipole moment $\overrightarrow{\mu}$ aligned with its spin \overrightarrow{s} :

$$\mu = (1+a)\frac{q\hbar}{2n}$$

QED







A charged elementary particle with half-integer intrinsic spin has a magnetic

Muon anomalous magnetic moment



95.4 GeV Excesses at colliders



CMS-PAS-HIG-20-002

Combined result: $\mu_{\gamma\gamma}^{exp} \equiv \mu_{\gamma\gamma}^{ATLAS+CMS} =$







C. Arcangeletti, LHC Seminar, 7th of June, 2023

$$= \frac{\sigma(pp \to \phi \to \gamma\gamma)}{\sigma_{\rm SM}(pp \to H_{\rm SM} \to \gamma\gamma)} = 0.24^{+0.09}_{-0.08} (3.1\sigma)$$

Phys.Rev.D 109 (2024) 3, 035005

95.4 GeV Excesses at colliders



Phys.Lett.B565:61-75,2003

LEP $e^+e^- \rightarrow Z\phi \rightarrow Z(b\bar{b})$: background-only, $\sqrt{s} = 189 \text{ GeV} - 209 \text{ GeV}$ $\mu_{b\bar{b}}^{exp} = 0.117 \pm 0.057 \ (2.3\sigma)$ at 98 GeV



The infamous 95 GeV $b\bar{b}$ excess at LEP: two b or not two b? P. Janot JHEP10(2024)223

Sadly, two background fluctuations in very different mass ranges do not make a new physics signal. It is therefore high time to stop using these fluctuations in support of any signal interpretation of the 3σ excess observed around 95 GeV by CMS in their diphoton mass distribution. Altogether, the 1999-2000 LEP data strongly disfavour the production of a new 95 GeV Higgs boson with a signal strength of 0.117, as well as any other new physics interpretation in the 95–100 GeV mass range of the 2.3σ excess observed in the 1998 data .





95.4 GeV Excesses at colliders





JHEP 07 (2023) 073 Eur. Phys. J. C 83 (2023) 1138

$$\mu_{\tau\bar{\tau}}^{\exp} = 1.38^{+0.69}_{-0.55}$$

For a CP-even scalar, expluded at 1σ level by ATLAS $t\bar{t} + \tau\bar{\tau}$ search Eur. Phys. J. C 82, 1053 (2022)

model-independently ruled out by $t\bar{t}\phi$ search Phys. Rev. D 108 (2023) 075011 Phys. Rev. D 110 (2024) 012013

0.010





Supersymmetry

超对称变换: Q| 玻色子 $\rangle = |$ 费米子 \rangle , Q|费米子 $\rangle = |$ 玻色子 \rangle

引入旋量生成元: Q_a^i 及其厄米共轭 $Q_a^{\dagger i}$, N=1构成超庞加莱代数

定义超势: $W = L^i d$

手征超场相互作用:

 $\mathscr{L}_{int} = -$

C

H

Standard Model of Elementary Particles



$$\phi_i + \frac{1}{2}M^{ij}\phi_i\phi_j + \frac{1}{6}y^{ijk}\phi_i\phi_j\phi_k,$$

$$-\frac{1}{2}\frac{\delta^2 W}{\delta\phi_i\delta\phi_j}\psi_i\psi_j+\frac{\delta W}{\delta\phi_i}F_i+c.c,$$

$$\mathscr{L}_{s} = -\lambda_{s} |H|^{2} |S|^{2}$$
$$\delta m_{h}^{2}|_{s} = \frac{\lambda_{s}}{16\pi^{2}} [\Lambda^{2} + \dots]$$





Stringent constraints on WIMPs in $(\mathbb{Z}_3 - N)MSSM$

• **Bino-like DM:** LZ Experiments: Higgsino mass $\mu \gtrsim 380 \,\text{GeV}$, $LZ + LHC + a_{\mu}$: $\mu \gtrsim 500 \,\mathrm{GeV},$ A tuning of 1% in EWSB; • Singlino-like DM: $2|\kappa|/\lambda < 1,$ LZ Experiments: $\lambda < 0.1$, Bayesian evidence is heavily suppressed \rightarrow A fine-tuning theory!



General Next-to-Minimal Supersymmetric Standard Model (GNMSSM)

•	Chiral	Su	oerfie	ld
•	• ••	\sim -		

SF	Spin 0	Spin $\frac{1}{2}$	Generations	$ $ (U(1) \otimes SU(2) \otimes SU(3)
\hat{q}	ilde q	q	3	$\left(rac{1}{6}, 2, 3 ight)$
\hat{l}	$ $ \tilde{l}	l	3	$\left(-rac{1}{2}, 2, 1 ight)$
\hat{H}_d	H_d	$ ilde{H}_d$	1	$\left(-rac{1}{2}, 2, 1 ight)$
\hat{H}_u	H_u	$ ilde{H}_u$	1	$(\frac{1}{2}, 2, 1)$
\hat{d}	$ ilde{d}_R^*$	d_R^*	3	$\left(\frac{1}{3}, 1, \overline{3}\right)$
\hat{u}	$ ilde{u}_R^*$	u_R^*	3	$\left(-\frac{2}{3},1,\overline{3} ight)$
\hat{e}	$ ilde{e}_R^*$	e_R^*	3	(1, 1 , 1)
ŝ	S	$ ilde{S}$	1	(0, 1 , 1)

Superpotential — no ad hoc symmetry! $W = W_{Yukawa} + \lambda \hat{S}\hat{H}$

- Solve domain wall and tapole problem in \mathbb{Z}_3 NMSSM.
- \mathbb{Z}_3 -violating terms originate from unified theories with \mathbb{Z}_4^R .
- The $\xi \hat{S}$ term can be eliminated by field redefinitions.

$$\hat{H}_{u} \cdot \hat{H}_{d} + \frac{1}{3}\kappa\hat{s}^{3} + \mu\hat{H}_{u} \cdot \hat{H}_{d} + \frac{1}{2}\mu'\hat{s}^{2} + \xi\hat{S}$$



A Neutralino mass matrix in the base $\psi \equiv (\tilde{B}, \tilde{W}, \tilde{H}_d^0, \tilde{H}_u^0, \tilde{S})$

$$\mathcal{M} = \begin{pmatrix} M_1 & 0 & -m_Z \sin \theta_W \cos \theta_$$

with
$$\mu_{tot} \equiv \lambda v_s / \sqrt{2} + \mu$$
, $m_N \equiv \sqrt{2} \kappa v_s + \mu' \circ$

Diagonalizing \mathcal{M} gives five mass eigenstates:

$$\tilde{\chi}_i^0 = N_{i1}\psi_1^0 + N_{i2}\psi_2^0 + N_{i3}\psi_3^0 + N_{i4}\psi_4^0 + N_{$$

--- Singlino-dominated DM

 $\begin{array}{ll} \cos\beta & m_Z \sin\theta_W \sin\beta & 0 \\ \sin\beta & -m_Z \cos\theta_W \sin\beta & 0 \end{array}$ $\begin{array}{ll} -\mu_{tot} & -\frac{1}{\sqrt{2}}\lambda v\sin\beta \\ 0 & -\frac{1}{\sqrt{2}}\lambda v\cos\beta \\ & m_N \end{array}$

 $N_{i5}\psi_5^0$

DM candidate: \tilde{S} -dominated $\tilde{\chi}_1^0$ LSP, $m_{\tilde{\chi}_1^0} \simeq m_N$ Relic abundance: $\tilde{\chi}_1^0 \tilde{\chi}_1^0 \rightarrow h_s A_s, h_s h_s, A_s A_s, \dots$ S - H coannihilation



$$\sigma_{\tilde{\chi}_{1}^{0}-N}^{\text{SI}} \simeq 5 \times 10^{-45} \text{cm}^{2} \times (\frac{V_{h}^{\text{SM}} C_{\tilde{\chi}_{1}^{0} \tilde{\chi}_{1}^{0} h} + V_{h_{s}}^{\text{SM}} C_{\tilde{\chi}_{1}^{0} \tilde{\chi}_{1}^{0} h_{s}}}{0.1})^{2}, \quad \sigma_{\tilde{\chi}_{1}^{0}-N}^{\text{SD}} \simeq 10^{-39} \text{cm}^{2} \times (\frac{C_{\tilde{\chi}_{1}^{0} \tilde{\chi}_{1}^{0} Z}}{0.1})^{2},$$

$$C_{\tilde{\chi}_{1}^{0}\tilde{\chi}_{1}^{0}h_{i}} \simeq \frac{\sqrt{2}\mu_{\text{tot}}}{\nu} \left(\frac{\lambda\nu}{\mu_{\text{tot}}}\right)^{2} \frac{V_{h_{i}}^{\text{SM}}(m_{\tilde{\chi}_{1}^{0}}/\mu_{\text{tot}} - \sin 2\beta)}{1 - (m_{\tilde{\chi}_{1}^{0}}/\mu_{\text{tot}})^{2}} + \dots, \quad C_{\tilde{\chi}_{1}^{0}\tilde{\chi}_{1}^{0}Z} \simeq \frac{m_{Z}}{\sqrt{2}\nu} \left(\frac{\lambda\nu}{\mu_{\text{tot}}}\right)^{2} \frac{\cos 2\beta}{1 - (m_{\tilde{\chi}_{1}^{0}}/\mu_{\text{tot}})^{2}}$$

DM properties are described by five independent parameters: $\tan\beta$, λ , κ , μ_{tot} , and $m_{\tilde{\chi}_1^0}$

Note that,

- Singlino-dominated DM

Different from \mathbb{Z}_3 -**NMSSM**, λ , κ , and $m_{\tilde{\chi}_1^0}$ are disentangled here!





$$-\mathscr{L}_{soft} = \left[\lambda A_{\lambda} S H_{u} \cdot H_{d} + \frac{1}{3} \kappa A_{\kappa} S^{3} + m_{3}^{2} H_{u} \cdot H_{d} + \frac{1}{2} m_{S}^{\prime 2} S^{2} + \xi^{\prime} S + h \cdot c \right]$$

 $+m_{H_u}^2 |H_u|^2 + m_{H_d}^2 |H_d|^2 + m_S^2 |S|^2$,



$$\mathcal{M}_{S,13}^2 = -\frac{m}{\sqrt{2}}(A_{\lambda} + m_N)\cos 2\beta, \quad \mathcal{M}_{S,22}^2 =$$

$$\mathscr{M}_{S,23}^2 = \frac{\lambda v}{\sqrt{2}} \left[2\mu_{tot} - (A_\lambda + m_N) \sin 2\beta \right], \quad \mathscr{M}$$

 $h_i = V_{h_i}^{\text{NSM}} H_{\text{NSM}} + V_{h_i}^{\text{SM}} H_{\text{SM}} + V_{h_i}^{\text{S}} \text{Re}[S]$



CP-even Squared Mass Matrix, in the base $(H_{\text{NSM}}, H_{\text{SM}}, \text{Re}[S])$: $\chi^2_{S,22} = m_Z^2 \cos^2 2\beta + \frac{1}{2}\lambda^2 v^2 \sin^2 2\beta,$

 $\mathscr{M}^2_{S,33} = m^2_B,$

3 CP-even Scalar: h_s , h, H; 2 CP-odd Scalar: A_S, A_H ; Charged Higgs: H^{\pm}







$$\gamma = \frac{1}{\sigma_{\rm SM}(pp \to h_s)} \times \frac{1}{{\rm Br}_{\rm SM}(h_s \to \gamma)}$$

Normalized *bb* signal strength

$$\mu_{b\bar{b}} = \frac{\sigma_{\rm SUSY}(e^+e^- \to Zh_s)}{\sigma_{\rm SM}(e^+e^- \to Zh_s)} \times \frac{{\rm Br}_{\rm SUSY}(h_s)}{{\rm Br}_{\rm SM}(h_s)}$$

-95.4 GeV CP-even Scalar

 $\mu_{\gamma\gamma} = \frac{\sigma_{\rm SUSY}(pp \to h_s)}{\sigma_{\rm SUSY}(np \to h_s)} \times \frac{{\rm Br}_{\rm SUSY}(h_s \to \gamma\gamma)}{{\rm Br}_{\rm SUSY}(h_s \to \gamma\gamma)} \simeq |C_{h_sgg}|^2 \times |C_{h_s\gamma\gamma}|^2 \times \frac{1}{{\rm R}_{\rm Width}},$

 $\frac{h_s \to bb}{\to b\bar{b}} \simeq \left| C_{h_s VV} \right|^2 \times \left| C_{h_s b\bar{b}} \right|^2 \times \frac{1}{R_{Width}},$

 $\mathbf{R}_{\text{Width}} \simeq 0.801 \times |C_{h_s b\bar{b}}|^2 + 0.083 \times |C_{h_s \tau \bar{\tau}}|^2 + 0.041 \times |C_{h_s c\bar{c}}|^2 + 0.067 \times |C_{h_s g\bar{g}}|^2 + \dots$



$$C_{h_{s}t\bar{t}} = V_{h_{s}}^{\text{SM}} + V_{h_{s}}^{\text{NSM}} \cot \beta \simeq V_{h_{s}}^{\text{SM}}, \quad C_{h_{s}b\bar{b}} = V_{h_{s}}^{\text{SM}} - V_{h_{s}}^{\text{NSM}} \tan \beta, \quad C_{h_{s}VV} = V_{h_{s}}^{\text{SM}},$$

$$C_{h_{s}c\bar{c}} = C_{h_{s}t\bar{t}}, \quad C_{h_{s}c\bar{\tau}} = C_{h_{s}b\bar{b}}, \quad C_{h_{s}gg} \simeq C_{h_{s}t\bar{t}}, \quad C_{h_{s}\gamma\gamma} \simeq V_{h_{s}}^{\text{SM}},$$
Considering loop mediated by quarks and squarks:
$$C_{h_{s}gg} \text{ and } C_{h_{s}\gamma\gamma} \text{ deviates from } C_{h_{s}t\bar{t}} \text{ by } 4\% \text{ and } 11\%;$$
Central values of $\mu_{\gamma\gamma}$ and $\mu_{b\bar{b}}$ corresponds to:
$$V^{\text{SM}} = 0.25 \quad (V^{\text{SM}} - V^{\text{NSM}} + v^{\text{CM}}) = 0.91 \times V^{\text{SM}} = 0.29$$

 $V_{h_s}^{\text{SIM}} \simeq 0.35, \ (V_{h_s}^{\text{SIM}} - V_{h_s}^{\text{INSIM}} \tan \beta) \simeq 0.81 \times V_{h_s}^{\text{SIM}} \simeq 0.28$

 $Br_{SUSY}(h_s \rightarrow \gamma \gamma) \simeq 1.77 \times Br_{SM}(h_s \rightarrow \gamma)$

 $Br_{SUSY}(h_s \rightarrow b\bar{b}) \simeq 0.95 \times Br_{SM}(h_s \rightarrow b\bar{b})$

GNMSSM — 95.4 GeV CP-even Scalar

$$(\gamma\gamma) \simeq 2.5 \times 10^{-3}$$

$$b\bar{b}) \simeq 76.1\%$$





Using eigenstate equation, one can obatain:

$$V_{h_s}^{\text{NSM}} \simeq \frac{V_{h_s}^S}{\sqrt{2}} \times \frac{\lambda v \bar{A}_\lambda \cos 2\beta}{m_A^2}, \quad \lambda \left(\mu_{tot} - \bar{A}_\lambda \sin \beta \cos \beta\right) \simeq \frac{V_{h_s}^{\text{SM}} V_{h_s}^S}{\sqrt{2}} \times \frac{m_{h_s}^2 - m_h^2}{v},$$
$$m_B^2 \simeq m_{h_s}^2 |V_{h_s}^S|^2 + m_h^2 |V_{h_s}^{\text{SM}}|^2, \quad \mathcal{M}_{S,22}^2 \simeq m_h^2 |V_{h_s}^S|^2 + m_{h_s}^2 |V_{h_s}^{\text{SM}}|^2,$$

with $A_{\lambda} \equiv A_{\lambda} + m_N$. This implies that $\lambda \simeq 0.06 \times \left(\frac{V_{h_s}^{\text{SM}}}{0.35}\right) \times \left(\frac{\mu_{tot} - \bar{A}_{\lambda} \sin\beta\cos\beta}{100 \text{ Gev}}\right)^{-1},$ $\lambda \gtrsim 0.017 \times \frac{1}{|\cos 2\beta|} \times \left(\frac{\tan \beta}{50}\right)^{-1} \times \left(\frac{\bar{A}_{\lambda}}{2 \text{ TeV}}\right)^{-1} \times \left(\frac{m_A}{2 \text{ TeV}}\right)^2,$

-95.4 GeV CP-even Scalar



$$\begin{aligned} a_{\mu,\text{WHL}}^{\text{SUSY}} &= \frac{\alpha_2}{8\pi} \frac{m_{\mu}^2 M_2 \mu \tan \beta}{m_{\tilde{\nu}_{\mu}}^4} \left\{ 2f_C \left(\frac{M_2^2}{m_{\tilde{\nu}_{\mu}}^2}, \frac{\mu^2}{m_{\tilde{\nu}_{\mu}}^2} \right) \right. \\ a_{\mu,\text{BHL}}^{\text{SUSY}} &= \frac{\alpha_Y}{8\pi} \frac{m_{\mu}^2 M_1 \mu \tan \beta}{M_{\tilde{\mu}_L}^4} f_N \left(\frac{M_1^2}{M_{\tilde{\mu}_L}^2}, \frac{\mu^2}{M_{\tilde{\mu}_L}^2} \right) \\ a_{\mu,\text{BHR}}^{\text{SUSY}} &= -\frac{\alpha_Y}{4\pi} \frac{m_{\mu}^2 M_1 \mu \tan \beta}{M_{\tilde{\mu}_R}^4} f_N \left(\frac{M_1^2}{M_{\tilde{\mu}_R}^2}, \frac{\mu^2}{M_{\tilde{\mu}_R}^2} \right) \\ a_{\mu,\text{BLR}}^{\text{SUSY}} &= \frac{\alpha_Y}{4\pi} \frac{m_{\mu}^2 M_1 \mu \tan \beta}{M_1^4} f_N \left(\frac{M_{\mu}^2}{M_1^2}, \frac{M_{\mu}^2}{M_1^2} \right) \end{aligned}$$

• $a_u^{\text{SUSY}} \propto m_u^2 \tan \beta / M_{\text{SUSY}}^2$, favor a larger $\tan \beta$ and low SUSY scale

- $a_{\mu,\text{WHL}}^{\text{SUSY}}$ dominates when $\mu \lesssim 1$ TeV and $\tilde{\mu}_L$ is not much heavier than $\tilde{\mu}_R$





• $a_{\mu,\text{BLR}}^{\text{SUSY}}$ linearly relies on μ , especially, $\mu \gtrsim 30$ TeV is capable of predicting Δa_{μ}

Sampling Strategy

$$\mathscr{L}_{\Delta a_{\mu}} = \exp\left[-\frac{1}{2}\left(\frac{a_{\mu}^{\mathrm{SUSY}} - 2.49 \times 10^{-9}}{4.8 \times 10^{-10}}\right)^{2}\right], \quad \mathscr{L}_{\gamma\gamma+b\bar{b}} = \exp\left[-\frac{1}{2}\left(\frac{\mu_{\gamma\gamma} - 0.24}{0.08}\right)^{2} - \frac{1}{2}\left(\frac{\mu_{b\bar{b}} - 0.117}{0.057}\right)^{2}\right]_{m_{h_{s}} \simeq 9566}$$

- ✓ Masses of Higgs bosons: m_{h_s} ~ 95.4 GeV
 ✓ Higgs data fit using *HiggsSignals-2.6.2* ✓ Extra Higgs searches using *HiggsBounds* ✓ DM relic density: 20% uncertainties of Ω
 ✓ LZ SI and SD DM-nucleon scattering cross
 ✓ B physics observables: B_s → μ⁺μ⁻ and B
- Vacuum stability using *Vevacious*++

$jeV, m_h \sim 125 \text{ GeV}$			
· 11	Parameter	Prior	Range
5.2	λ	Flat	$0.001 \sim 0.03$
. –	aneta	Flat	$5\sim 60$
inds-5.10.2	$\mu_{ m tot}/{ m TeV}$	Flat	$0.4 \sim 1.0$
	$A_t/{ m TeV}$	Flat	$1.0\sim 3.0$
- 12 - 120	$M_1/{ m TeV}$	Flat	$-1.0 \sim -0.2$
$DI \Omega 2n^{-} = 0.120$	$M_{ ilde{\mu}_L}/{ m TeV}$	Flat	$0.2\sim 1.0$
	κ	Flat	$-0.2\sim 0.2$
cross sections	$m_B/{ m GeV}$	Flat	$90 \sim 120$
)	$m_N/{ m TeV}$	Flat	$-1.0 \sim 1.0$
$\mathbf{A} \mathbf{D} \to \mathbf{V} \mathbf{u}$	$A_{\lambda}/{ m TeV}$	Flat	$1.0\sim 3.0$
$\Pi D \to \Lambda_{S} \gamma$	$M_2/{ m TeV}$	Flat	$0.3 \sim 1.0$
	$M_{ ilde{\mu}_R}/{ m TeV}$	Flat	$0.2 \sim 1.0$





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- Scan yields > 92000 points,
- about 50000 samples explains the anomalies at 2σ .
- Bayesian evidence:

 \tilde{S} -like $\tilde{\chi}_1^0$, coannihilating with \tilde{H} , 74% \tilde{B} -like $\tilde{\chi}_1^0$, coannihilating with \tilde{W} , 26%

• Best points:

$$\chi^2_{\gamma\gamma+b\bar{b}} + \chi^2_{\Delta a_{\mu}} = 0.20$$
 for \tilde{B} case

$$\chi^2_{\gamma\gamma+b\bar{b}} + \chi^2_{\Delta a_{\mu}} = 0.04$$
 for \tilde{S} case.

Number Constraints	$DM(\Omega h^2 + LZ)$	$DM + \mu_{95}$	$DM + \mu_{95} + ($
Scenario	Grey	Green	Dark Gr
Bino-DM	17368	14416	8408
Singlino-DM	59038	38731	20851







23/26 连经伟 HIST & HNU

- $|C_{h_sgg}|, |C_{h_s\gamma\gamma}| > |C_{h_st\bar{t}}|,$
- $|C_{h,b\bar{b}}|$ suppressed
- $Br_{SUSY}(h_s \to \gamma\gamma), Br_{SUSY}(h_s \to b\bar{b})$ strongly correlate
- $|C_{h,b\bar{b}}|, |C_{h,t\bar{t}}|$ loosely correlate Bino-DM case:

 $|C_{h,t\bar{t}}| \simeq |C_{h,VV}| \simeq 0.37, |C_{h,b\bar{b}}| \simeq 0.33, |C_{h,gg}| \simeq 0.38,$ $|C_{h_s\gamma\gamma}| \simeq 0.41, \operatorname{Br}_{SUSY}(h_s \to \gamma\gamma) \simeq 0.25\%,$ $Br_{SUSY}(h_s \to b\bar{b}) \simeq 81 \%, \mu_{\gamma\gamma} = 0.22, \mu_{b\bar{b}} = 0.13$ Singlino-DM case: $|C_{h,t\bar{t}}| \simeq |C_{h,VV}| \simeq 0.35, |C_{h,b\bar{b}}| \simeq 0.29, |C_{h,gg}| \simeq 0.37,$ $|C_{h_s\gamma\gamma}| \simeq 0.39, \operatorname{Br}_{\operatorname{SUSY}}(h_s \to \gamma\gamma) \simeq 0.28\%,$ $Br_{SUSY}(h_s \to b\bar{b}) \simeq 79\%, \mu_{\gamma\gamma} = 0.24, \mu_{b\bar{b}} = 0.12$









- $|C_{hb\bar{b}}|, |C_{h_s\gamma\gamma}| > |C_{h_st\bar{t}}|,$
- $Br_{SUSY}(h \to \gamma\gamma), Br_{SUSY}(h \to b\bar{b})$ loosely correlate
- $Br_{SUSY}(h \rightarrow b\bar{b}): 55.8\%-59.5\% \text{ (SM } 57.7 \pm 1.8\%)$
- $Br_{SUSY}(h \to \gamma \gamma)$: 2.95 × 10⁻³ 3.13 × 10⁻³, $(SM (2.28 \pm 0.11) \times 10^{-3})$, because $C_{hgg} < 1$









Conclusion

- searches SUSY particles.

- Future colliders experiments, e.g. HL-LHC, CEPC, are worth looking forward to.

• The GNMSSM can simultaneously account for the $(g - 2)_{\mu}$ anomaly and the $\gamma\gamma$ and bb excesses at a 1σ level, without conflicting with constraints from Higgs data fit, B-physics, the Planck and LZ experiments, the vacuum stability considerations, as well as the LHC's

• DM physics significantly influences the unified explanation through the crucial parameter μ_{tot} . \tilde{B} -case and \tilde{S} -case co-annihilate with \tilde{W} and \tilde{H} respectively, contributing to 26% and 74% of the total Bayesian evidence, featuring $\mu_{tot} \gtrsim 600$ GeV and $\mu_{tot} \gtrsim 400$ GeV.

• The explanation of the 95 GeV excesses favor moderately large $V_{h_s}^{\text{SM}}$ and suppressed $C_{h_s b \bar{b}}$.

• Further work involving cosmological phase transition and stochastic GW are carrying out.











Backup **Bino DM** (same as MSSM and Z_3 -NMSSM) $\hat{\chi}_1^0$ 与核子的自旋无关(SI)和自旋相关(SD)散射截面:

$$\sigma_{\tilde{\chi}_{1}^{0}-N}^{\text{SI}} \simeq 5 \times 10^{-45} \text{cm}^{2} \left(\frac{C_{\tilde{\chi}_{1}^{0} \tilde{\chi}_{1}^{0}h}}{0.1}\right)^{2} \left(\frac{m_{h}}{125 \text{GeV}}\right)^{2}, \qquad \sigma_{\tilde{\chi}_{1}^{0}-N}^{\text{SD}} \simeq C_{N} \times \left(\frac{C_{\tilde{\chi}_{1}^{0} \tilde{\chi}_{1}^{0}Z}}{0.1}\right)^{2}, \quad C_{N} \simeq 2.3 \times 10^{-41} \text{cm}^{2}$$

$$C_{\tilde{\chi}_{1}^{0} \tilde{\chi}_{1}^{0}h} \simeq e \tan \theta_{W} \frac{m_{Z}}{\mu_{\text{tot}}(1 - m_{\tilde{\chi}_{1}^{0}}^{2}/\mu_{\text{tot}}^{2})} \left(\sin 2\beta + \frac{m_{\tilde{\chi}_{1}^{0}}}{\mu_{\text{tot}}}\right), \qquad C_{\tilde{\chi}_{1}^{0} \tilde{\chi}_{1}^{0}Z} \simeq \frac{e \tan \theta_{W} \cos 2\beta}{2} \frac{m_{Z}^{2}}{\mu_{\text{tot}}^{2} - m_{\tilde{\chi}_{1}^{0}}^{2}},$$

• Conservative bounds on Higgsino mass: LZ Experiment: $\mu \gtrsim 380$ GeV, $LZ + LHC + a_{\mu}$: $\mu \gtrsim 500$ GeV. • Higgsino mass is related with electroweak symmetry breaking! $m_Z^2 = 2(m_{H_d}^2 - m_{H_u}^2 \tan^2 \beta) / (\tan^2 \beta - 1) - 2\mu^2.$



A tuning of about 1%

Backup

Parameter space scanned by *MultiNest*:



$$\mathscr{L}_{\Delta a_{\mu}} = \exp$$

Likelihood function:

 $\mathscr{L}_{\gamma\gamma+b\bar{b}} = \exp$

$$\mathscr{L} \equiv \mathscr{L}_{\Delta a_{\mu}}$$

	р.				
	Prior	Range	Parameter	Prior	Range
	Flat	$0.001 \sim 0.03$	κ	Flat	$-0.2\sim 0.2$
	Flat	$5\sim 60$	$m_B/{ m GeV}$	Flat	$90 \sim 120$
	Flat	$0.4 \sim 1.0$	$m_N/{ m TeV}$	Flat	$-1.0 \sim 1.0$
	Flat	$1.0\sim 3.0$	$A_\lambda/{ m TeV}$	Flat	$1.0\sim 3.0$
	Flat	$-1.0\sim-0.2$	$M_2/{ m TeV}$	Flat	$0.3 \sim 1.0$
•	Flat	$0.2 \sim 1.0$	$M_{ ilde{\mu}_R}/{ m TeV}$	Flat	$0.2 \sim 1.0$

$$\begin{bmatrix} -\frac{\chi_{\Delta a_{\mu}}^{2}}{2} \end{bmatrix} = \exp\left[-\frac{1}{2}\left(\frac{a_{\mu}^{\text{SUSY}} - 2.49 \times 10^{-9}}{4.8 \times 10^{-10}}\right)^{2}\right]$$
$$\begin{bmatrix} -\frac{\chi_{\gamma\gamma+b\bar{b}}^{2}}{2} \end{bmatrix} = \exp\left[-\frac{1}{2}\left(\frac{\mu_{\gamma\gamma} - 0.24}{0.08}\right)^{2} - \frac{1}{2}\left(\frac{\mu_{b\bar{b}} - 0.117}{0.057}\right)^{2}\right]_{m_{h_{s}}^{2}}$$

 $_{a_{\mu}} \times \mathscr{L}_{\gamma\gamma+b\bar{b}} \times \mathscr{L}_{\text{Res}}$



≥95GeV