Anomalous muon magnetic moment, supersymmetry, naturalness, LHC search limits and the landscape

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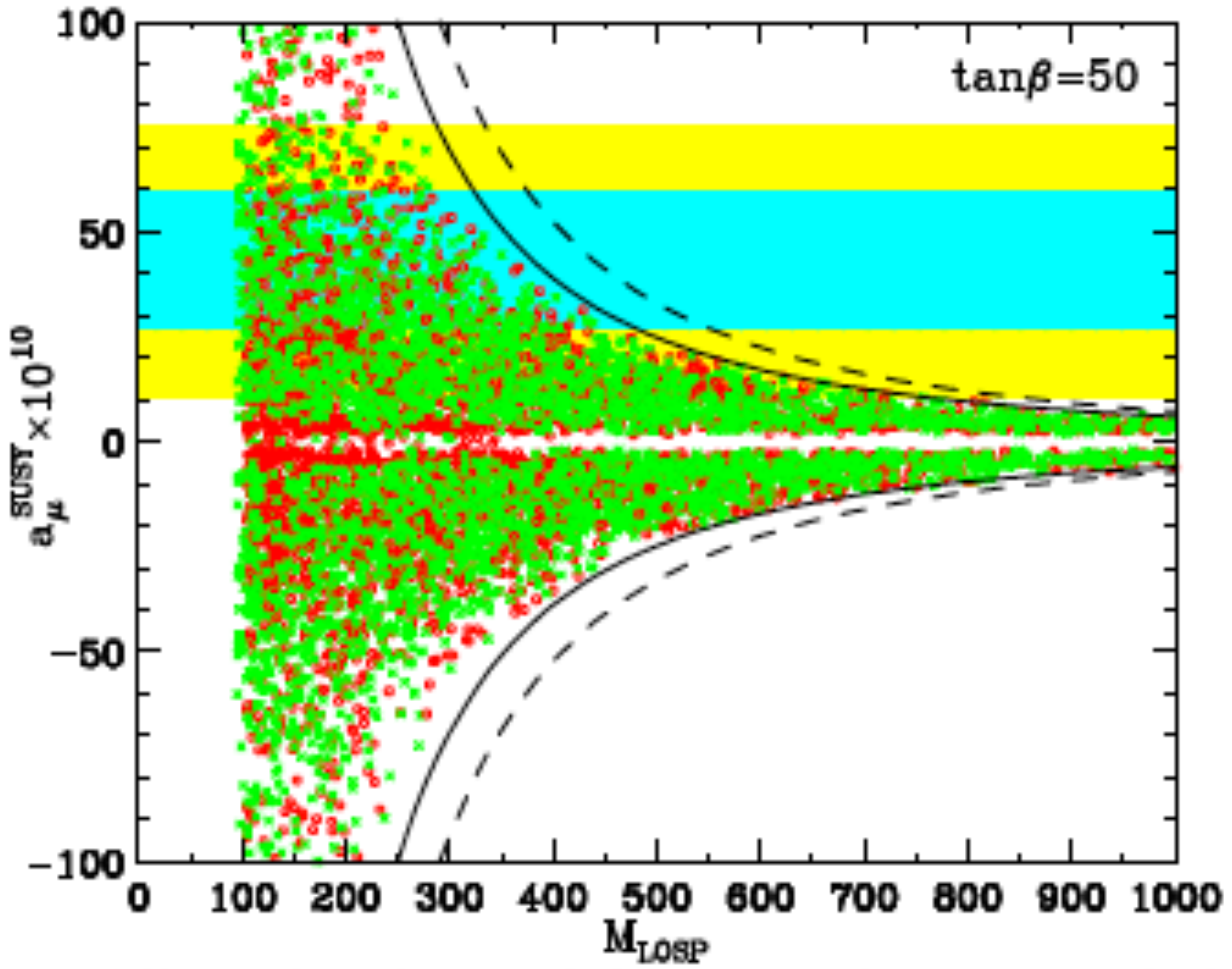
We know from complete 1-loop calculations from T.Moroi (1996) and general analysis of Feng and Matchev (2001) that SUSY with light smuons can explain any (g-2)_mu anomaly

$$\Delta a_\mu^{\rm SUSY} \propto \frac{m_\mu^2 \mu M_i \tan\beta}{M_{\rm SUSY}^4}$$



$$a_\mu(Exp) - a_\mu(SM) = (25.1 \pm 5.9) \times 10^{-10}$$

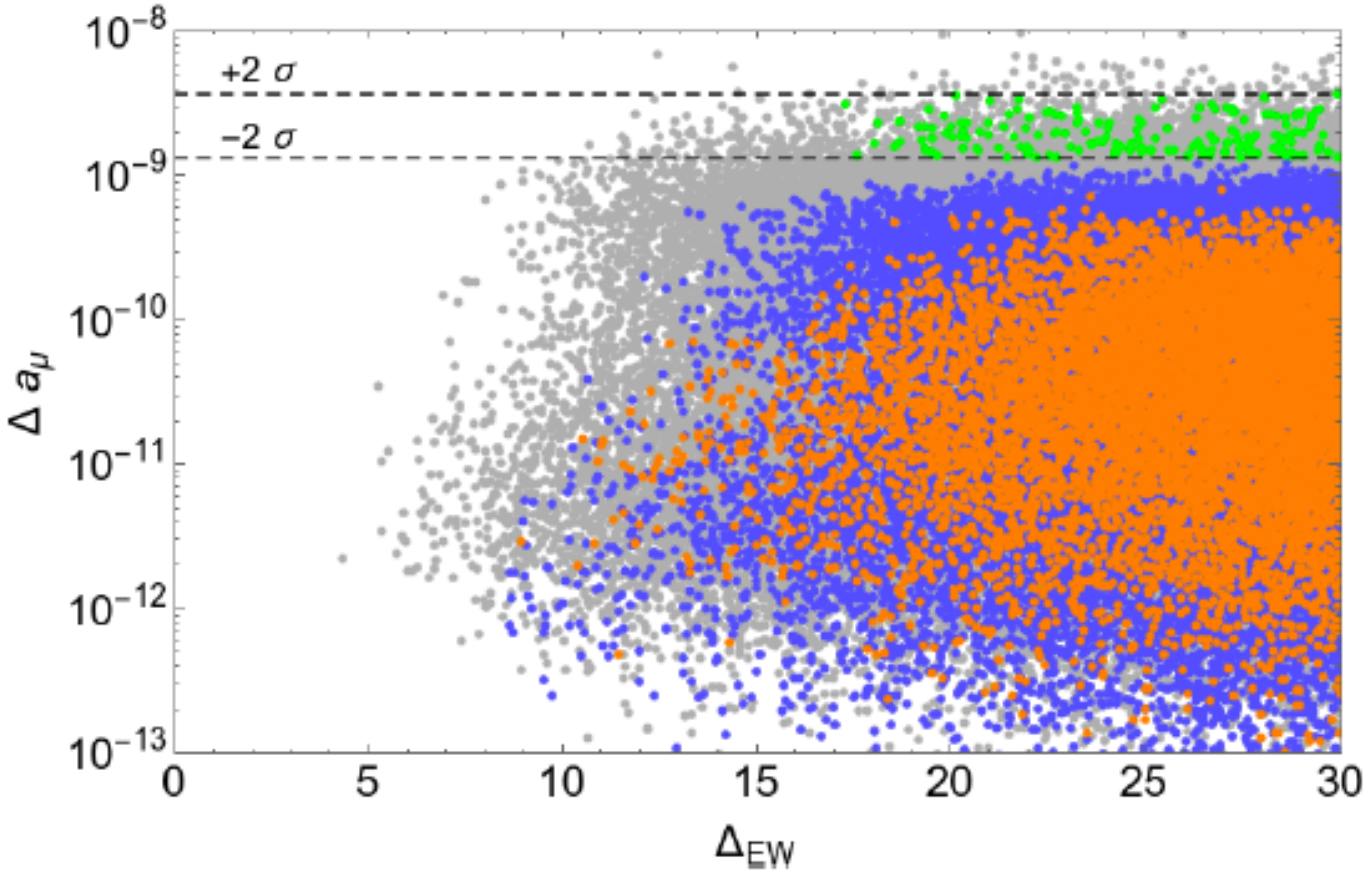
Current question: can SUSY
explain current (g-2)_mu anomaly
but keeping m(h)~125 GeV,
obey LHC constraints
(especially m(slepton)>~700 GeV in
simplified model analysis)
and be natural (i.e. be in accord with
m(W,Z,h)~100 GeV without unnatural finetuning)

Answer: yes, but for a rather peculiar
SUSY spectrum: normal scalar
mass hierarchy (NSMH) where
m0(1,2)<<m0(3)

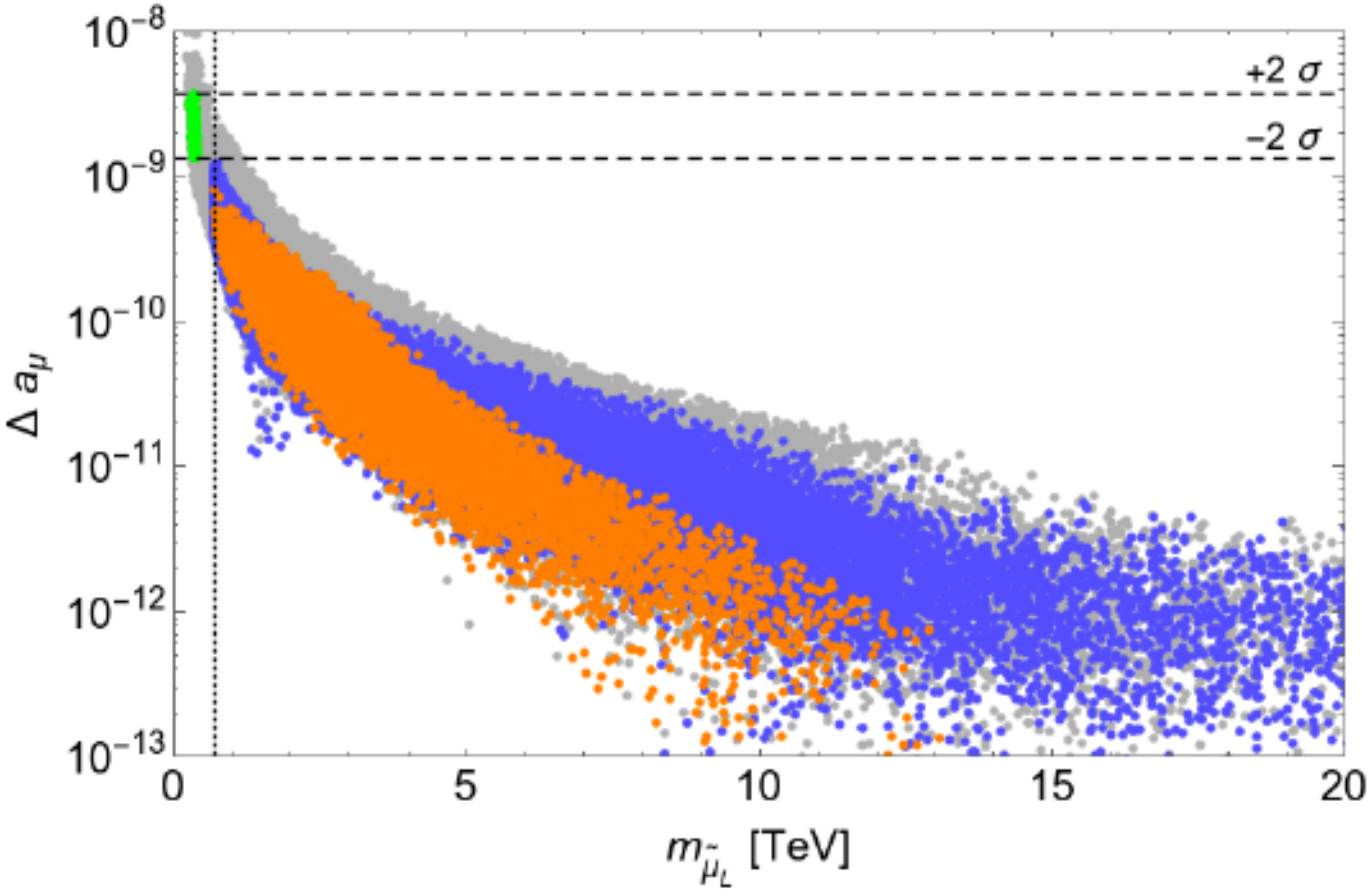
Must go to NUHM3 model:

$$
\begin{aligned}
m_0 &: \quad 0-13\ \text{TeV} \\
m_{1/2} &: \quad 0-3\ \text{TeV}, \\
-A_0 &: \quad 0-20\ \text{TeV}, \\
m_A &: \quad 0-10\ \text{TeV}, \\
\mu &: \quad 100-360\ \text{GeV} \\
\tan\beta &: \quad 3-60.
\end{aligned}
$$

$$\text{n on } m_0(1,2) : \ 0-55\ \text{TeV}.$$



Green points obey mh, LHC constraint, naturalness (DEW<30), and (g-2)_mu



Green points allowed even though m(smuon)<700 GeV

parameter	$NUHM3$
$m_0(1,2)$	368
$m_0(3)$	2955
$m_{1/2}$	1055
A_0	-4370
$\tan\beta$	26
μ	230
m_A	5365
$m_{\tilde{g}}$	2341.6
$m_{\tilde{u}_L}$	2148.8
$m_{\tilde{u}_R}$	1848.6
$m_{\tilde{e}_R}$	1117.7
$m_{\tilde{e}_L}$	376.0
$m_{\tilde{\nu}_L}$	249.8
$m_{\tilde{t}_1}$	1347.5
$m_{\tilde{t}_2}$	2613.0
$m_{\tilde{b}_1}$	2647.6
$m_{\tilde{b}_2}$	3192.0
$m_{\tilde{\tau}_1}$	2648.3
$m_{\tilde{\tau}_2}$	2704.0
$m_{\tilde{\nu}_\tau}$	2695.6
$m_{\tilde{\chi}_2^\pm}$	-864.7
$m_{\tilde{\chi}_1^\pm}$	-240.0
$m_{\tilde{\chi}_4^0}$	-875.4
$m_{\tilde{\chi}_3^0}$	-460.7
$m_{\tilde{\chi}_2^0}$	239.7
$m_{\tilde{\chi}_1^0}$	-227.1
m_h	124.1
$\Delta a_\mu^{\rm SUSY}$	20.3×10^{-10}
$BF(b\to s\gamma)\times10^4$	2.8
$BF(B_s\to\mu^+\mu^-)\times10^9$	3.8
$\Omega^{std}_{\tilde{\chi}_1^0}h^2$	0.015
$\sigma^{SI}(\tilde{\chi}_1^0,p)$ (pb)	2.7×10^{-9}
$\sigma^{SD}(\tilde{\chi}_1^0 p)$ (pb)	5.2×10^{-5}
$\langle\sigma v\rangle\|_{v\to0}$ (cm^3/sec)	1.6×10^{-25}
$\Delta_{\rm EW}$	29.4

Benchmark point

Left-smuons turn out lightest
with right-smuons much heavier

$$\frac{dm_{L_3}^2}{dt} = \frac{2}{16\pi^2}\left(-\frac{3}{5}g_1^2M_1^2 - 3g_2^2M_2^2 - \frac{3}{10}g_1^2S + f_\tau^2X_\tau\right),$$
$$\frac{dm_{\tilde{\tau}_R}^2}{dt} = \frac{2}{16\pi^2}\left(-\frac{12}{5}g_1^2M_1^2 + \frac{3}{5}g_1^2S + 2f_\tau^2X_\tau\right),$$
$$\frac{dm_{H_d}^2}{dt} = \frac{2}{16\pi^2}\left(-\frac{3}{5}g_1^2M_1^2 - 3g_2^2M_2^2 - \frac{3}{10}g_1^2S + 3f_b^2X_b + f_\tau^2X_\tau\right),$$
$$\frac{dm_{H_u}^2}{dt} = \frac{2}{16\pi^2}\left(-\frac{3}{5}g_1^2M_1^2 - 3g_2^2M_2^2 + \frac{3}{10}g_1^2S + 3f_t^2X_t\right),$$

$$X_t = m_{Q_3}^2 + m_{\tilde{t}_R}^2 + m_{H_u}^2 + A_t^2,$$
$$X_b = m_{Q_3}^2 + m_{\tilde{b}_R}^2 + m_{H_d}^2 + A_b^2,$$
$$X_\tau = m_{L_3}^2 + m_{\tilde{\tau}_R}^2 + m_{H_d}^2 + A_\tau^2, \text{ and}$$

$$S = m_{H_u}^2 - m_{H_d}^2 + Tr\left[\mathbf{m}_Q^2 - \mathbf{m}_L^2 - 2\mathbf{m}_U^2 + \mathbf{m}_D^2 + \mathbf{m}_E^2\right]$$

large S term due to soft Higgs splitting (needed for naturalness) drive left smuons low while right smuons larger

$$m_{\tilde{e}_L}^2 = m_{L_1}^2 + m_e^2 + M_Z^2\cos 2\beta\left(-\frac{1}{2} + \sin^2\theta_W\right)$$
$$m_{\tilde{\nu}_e}^2 = m_{L_1}^2 + M_Z^2\cos 2\beta\left(\frac{1}{2}\right)$$
$$m_{\tilde{e}_R}^2 = m_E^2 + m_e^2 + M_Z^2\cos 2\beta\left(-\sin^2\theta_W\right),$$

Then negative EW D-term makes smuon lightest visible slepton decay products become soft enough so as to evade the bounds. Furthermore, the dominant decay mode is actually to invisibles: $\tilde{\nu}_{\mu L} \to \nu_\mu \widetilde{\chi}_1^0$. The left smuon lies precisely on the edge of the LHC slepton excluded region. However, its dominant decay mode is [57] $\tilde{\mu}_L \to W^- \tilde{\nu}_{\mu L} \to q\bar{q}' \nu_\mu \widetilde{\chi}_1^0$ which is radically different from the assumed simplified models from the ATLAS/CMS exclusion plots. Thus, the point should at present be allowed by LHC slepton searches.

Mu-sneutrino mainly decays to invisibles
while left-smuon decays to W+invisibles
so that simplified model analysis
does not apply

However, new LHC slepton
search channels open up, motivated
by (g-2)_mu anomaly, mh~125,
naturalness and LHC constraints

Slepton BFs

Table 1

NUML	-->	Z1SS	NUM	8.2171E-04	7.53E-01
NUML	-->	Z2SS	NUM	3.1923E-05	2.9253E-02
NUML	-->	W1SS+	MU-	2.3761E-04	2.1775E-01

Table 1-1

MUL-	-->	Z1SS	MU-	1.7825E-04	6.6238E-05
MUL-	-->	Z2SS	MU-	3.1079E-04	1.1549E-04
MUL-	-->	W1SS-	NUM	2.2863E-03	8.4958E-04
MUL-	-->	W-	NUML	2.6883E+00	9.9897E-01

Table 1-2

MUR-	-->	Z1SS	MU-	8.9802E-02	2.2782E-02
MUR-	-->	Z2SS	MU-	9.0086E-03	2.2854E-03
MUR-	-->	Z3SS	MU-	3.8428E+00	9.749E-01
MUR-	-->	Z4SS	MU-	1.3257E-04	3.3632E-05