Challenging SO(10) SUSY GUTs with Family Symmetries through FCNC processes

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SUSY 2007
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Outline

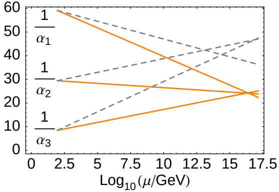
based on:

- M. Albrecht, WA, A. J. Buras, D. Guadagnoli and D. Straub
  in preparation
- R. Dermíšek and S. Raby hep-ph/0507045
  R. Dermíšek, M. Harada and S. Raby hep-ph/0606055

Supersymmetric Grand Unified Theories

Supersymmetry

- stabilizes the electro-weak scale
- has a Dark Matter candidate (LSP)
- achieves Gauge coupling unification



Minimal $SO(10)$ SUSY GUT

- Quarks and leptons of one family unified in a $\mathbf{16} = (Q, U, D, L, E, N)$
- Higgs doublets of the MSSM in one $\mathbf{10} \supset (H_u, H_d)$
- Yukawa unification for 3rd generation ($\tan\beta \approx 50$)

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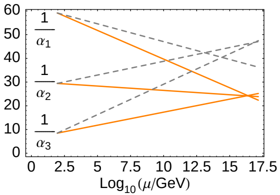

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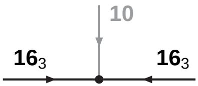
$\Rightarrow$ family symmetries

The Dermíšek-Raby Model (DR)

$SO(10)$ SUSY GUT with $D_3 \times U(1) \times Z_2 \times Z_3$ family symmetry

- only 3rd generation Yukawas allowed

$$\mathcal{W} = \mathbf{16}_3\ \mathbf{10}\ \mathbf{16}_3$$



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$\rightarrow$ Family symmetry is spontaneously broken by flavon vevs

$\rightarrow$ Integrating out FN states creates effective Yukawa operators

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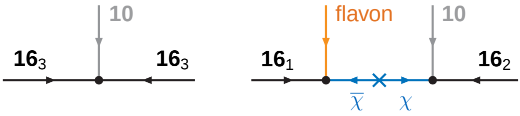

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→ Family symmetry is spontaneously broken by flavon vevs

→ Integrating out FN states creates effective Yukawa operators

$$\mathcal{W} = \mathbf{16}_3\ \mathbf{10}\ \mathbf{16}_3 + \frac{\langle \text{flavon} \rangle}{M_{FN}}\ \mathbf{16}_1\ \mathbf{10}\ \mathbf{16}_2 + \dots$$

$$Y_{u,d,e,\nu} = \begin{pmatrix} 0 & * & * \\ * & * & * \\ * & * & 1 \end{pmatrix} \lambda\,, \qquad * = \frac{\langle \text{flavon} \rangle}{M_{FN}}$$

Parameters of the DR model

- Yukawa matrices $\rightarrow$ 11 (including 4 phases)
- RH ν mass matrix: real, diagonal and hierarchical $\rightarrow$ 3
- gauge sector: M_G, α_G, ϵ_3 $\rightarrow$ 3
- soft SUSY breaking: $M_{1/2}$, m_{16}, A_0, m_{H_u}, m_{H_d} $\rightarrow$ 5
- μ and $\tan\beta \rightarrow$ 2

$\Rightarrow$ 24 parameters (less than in the SM!)

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- MSSM Lagrangian at the electro-weak scale completely determined by these parameters
- Mass insertions δ_{ij} created radiatively by Yukawa couplings
- no new phases besides the ones in CKM and PMNS matrices

$\Rightarrow$ Minimal Flavour Violation

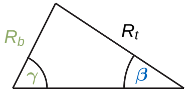
D'Ambrosio et al 02

Predictions at the low scale

- SUSY spectrum, Higgs spectrum
- Fermion masses (quarks, leptons and neutrinos)
- CKM and PMNS matrix

Predictions at the low scale

Unitarity Triangle



$R_b \propto |V_{ub}|$

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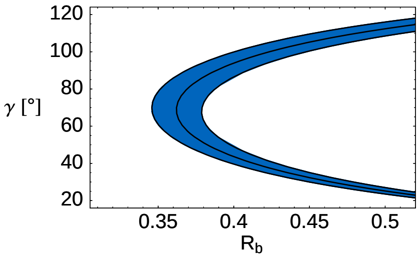
$$\sin(2\beta)_{\psi K_s} = 0.675 \pm 0.026$$



WA, Buras, Guadagnoli 07

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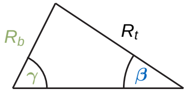

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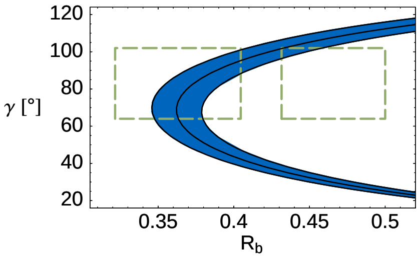
$$\gamma^{\text{tree}} = 83^\circ \pm 19^\circ$$

$$|V_{ub}|^{\text{incl}} = (4.49 \pm 0.33) \times 10^{-3}$$
$$|V_{ub}|^{\text{excl}} = (3.50 \pm 0.40) \times 10^{-3}$$



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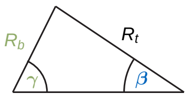

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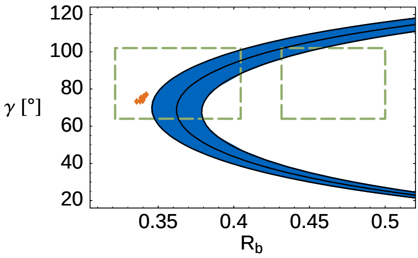
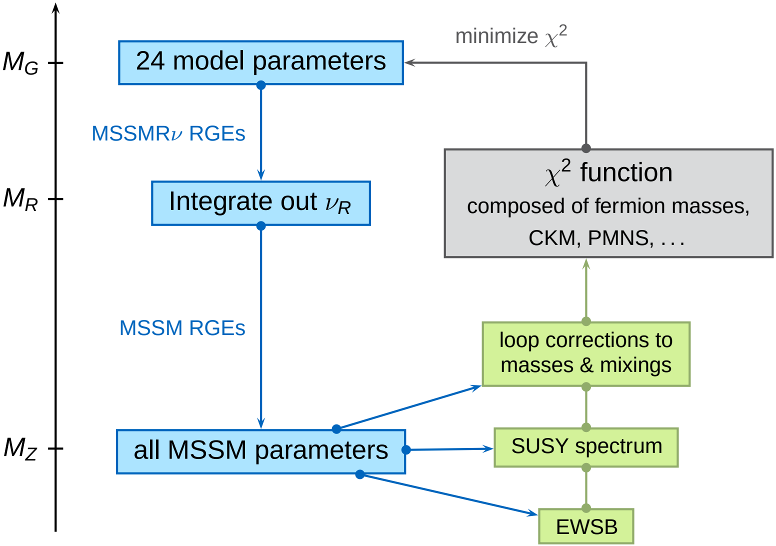


$$\gamma^{\text{DR}} \approx 75^\circ$$
$$|V_{ub}|^{\text{DR}} \approx 3.2 \times 10^{-3}$$

WA, Buras, Guadagnoli 07

Basic procedure of our analysis



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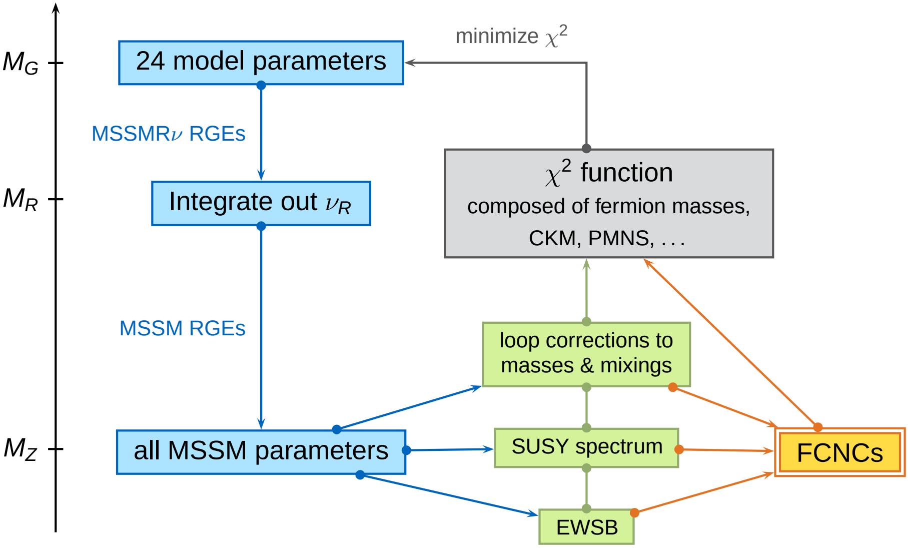
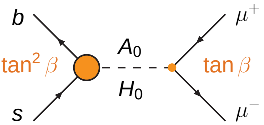


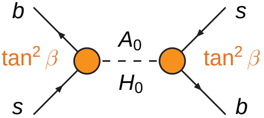
$B_s \to \mu^+\mu^-$ and ΔM_s



$$\mathcal{BR}[B_s \to \mu^+\mu^-] \propto \frac{\tan^6\beta}{M_A^4}$$

$$\mathcal{BR}[B_s \to \mu^+\mu^-]^{\text{exp.}} < 5.8 \times 10^{-8} \text{ [CDF+DØ]}$$

$$\mathcal{BR}[B_s \to \mu^+\mu^-]^{\text{SM}} = (3.35 \pm 0.32) \times 10^{-9}$$



$$\Delta M_s^{\text{DP}} \propto -\frac{\tan^4\beta}{M_A^2}$$

$$\Delta M_s^{\text{exp.}} = (17.77 \pm 0.12) ps^{-1} \text{ [HFAG]}$$

$$\Delta M_s^{\text{SM}} = (18.6 \pm 2.3) ps^{-1} \text{ [UTfit]}$$

Buras, Chankowski, Rosiek, Slawianowska 02

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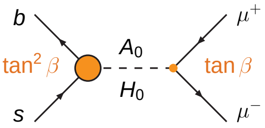

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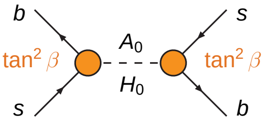

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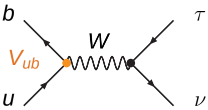
$\Rightarrow$ lower bound on M_A



$$\mathcal{BR}[B^+ \to \tau^+\nu]^{\text{exp.}} = (1.31 \pm 0.48) \times 10^{-4}$$

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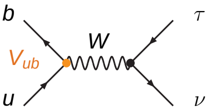

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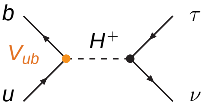

$$\frac{\mathcal{BR}[B^+ \to \tau^+\nu]^{\text{MSSM}}}{\mathcal{BR}[B^+ \to \tau^+\nu]^{\text{SM}}} = \left(1 - \frac{M_{B^+}^2}{M_{H^+}^2} \frac{\tan^2\beta}{1+\epsilon_0 \tan\beta}\right)^2$$

Isidori, Paradisi 06

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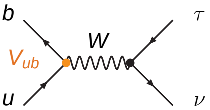

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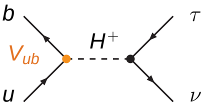

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Isidori, Paradisi 06

$$\mathcal{BR}[B^+ \to \tau^+ \nu]_{\text{DR}} \lesssim 0.6 \times 10^{-4}$$

$$\mathcal{BR}[B \to X_s\gamma]^{\text{exp.}} = (3.55 \pm 0.27) \times 10^{-4} \text{ [HFAG]}$$

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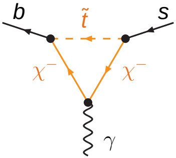

- Heavy Higgses $\Rightarrow$ dominant correction from chargino stop loop

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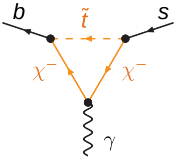

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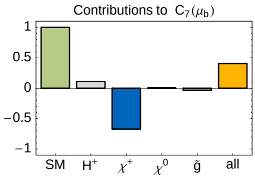

$$\mathcal{BR}[B \to X_s \gamma] = 1.3 \times 10^{-4}$$

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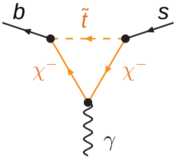

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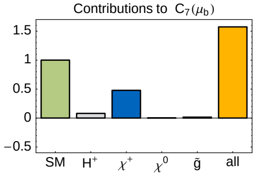

$$\mathcal{BR}[B \to X_s\gamma] = 6.5 \times 10^{-4}$$

$\mathcal{BR}[B \to X_s\gamma]^{\text{exp.}} = (3.55 \pm 0.27) \times 10^{-4}$ [HFAG]

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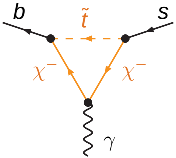

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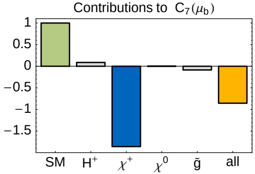


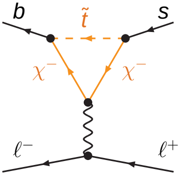
possible solution $C_7 = -C_7^{\text{SM}}$?

$\mathcal{BR}[B \to X_s\gamma] = 3.5 \times 10^{-4}$?

$B \to X_s \ell^+ \ell^-$ and the sign of C_7

$$\mathcal{BR}[B \to X_s \ell^+ \ell^-]^{\text{exp.}} = (1.60 \pm 0.51) \times 10^{-6}$$

$$\mathcal{BR}[B \to X_s \ell^+ \ell^-]^{\text{SM}} = (1.59 \pm 0.11) \times 10^{-6}$$ [Huber et al 06]

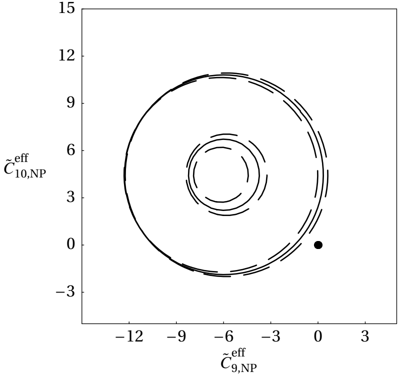


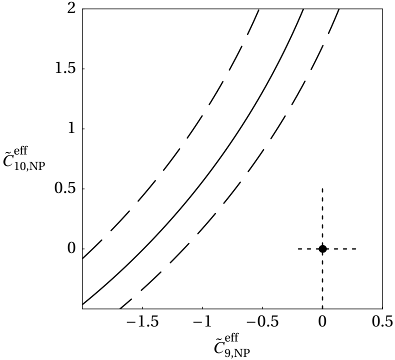
- Differential decay width and forward-backward Asymmetry are sensitive to sign(C_7)

$$\frac{\mathrm{d}\Gamma}{\mathrm{d}\hat{s}} \supset \mathrm{Re}(C_7 C_9^*) \quad ; \qquad A_{FB} \supset \mathrm{Re}(C_7 C_{10}^*)$$

- Wilson coefficients C_9 and C_{10} SM-like
- SUSY contributions enter dominantly through C_7
- no zero in A_{FB} for $\mathrm{sign}(C_7) = -\mathrm{sign}(C_7^{\mathrm{SM}})$

Testing the "wrong sign" of C_7





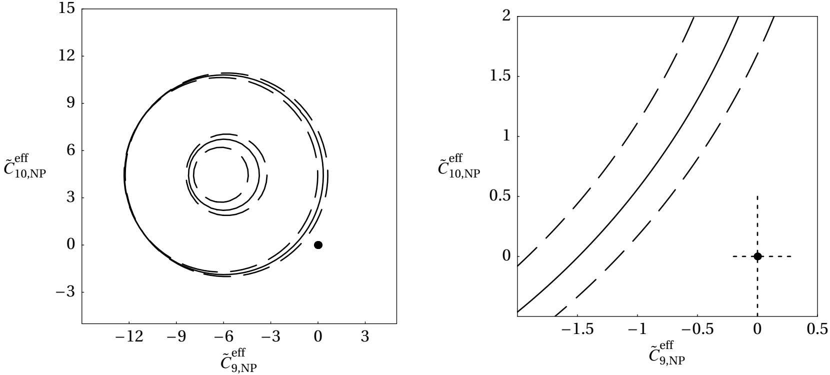
Gambino, Haisch, Misiak 04

Ali, Lunghi, Greub, Hiller 02

Lunghi, Porod, Vives 06

$B \to X_s \ell^+ \ell^-$ and the sign of C_7

Testing the "wrong sign" of C_7



Gambino, Haisch, Misiak 04

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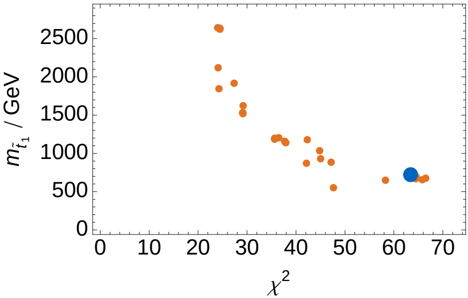
"wrong sign" for C_7 is excluded

Results of the global fit



To be in agreement with the experimental data on $B \to X_s \gamma$, the SUSY spectrum has to be made very heavy.

Examples:
$m_{16} = 4\text{TeV}$, $\mu = 236\text{GeV}$

$\mathcal{BR}[B \to X_s \gamma]$	$5.0\ \sigma$	too low
$\mathcal{BR}[B \to X_s \ell^+ \ell^-]$	$0.3\ \sigma$	too high
$\mathcal{BR}[B^+ \to \tau^+ \nu]$	$2.1\ \sigma$	too low

$$m_{\tilde{t}_1} = 697\text{GeV}$$
$$M_{\chi_1^+} = 202\text{GeV}$$
$$M_A = 458\text{GeV}$$

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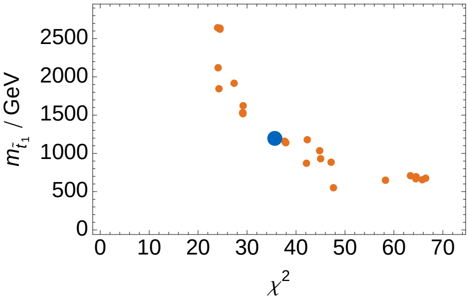

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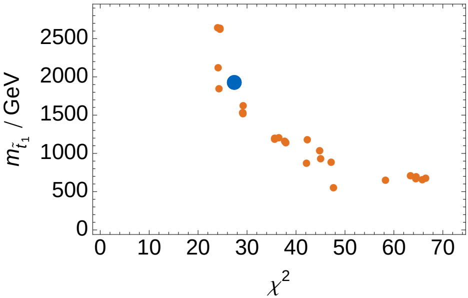
Examples:
$m_{16} = 6\text{TeV}$, $\mu = 953\text{GeV}$

$\mathcal{BR}[B \to X_s\gamma]$	$2.3\,\sigma$	too low
$\mathcal{BR}[B \to X_s\ell^+\ell^-]$	perfect agreement	
$\mathcal{BR}[B^+ \to \tau^+\nu]$	$1.8\,\sigma$	too low

$$m_{\tilde{t}_1} = 1.17\text{TeV}$$
$$M_{\chi_1^+} = 119\text{GeV}$$
$$M_A = 559\text{GeV}$$

Results of the global fit



To be in agreement with the experimental data on $B \to X_s\gamma$, the SUSY spectrum has to be made very heavy.

Examples:

$m_{16} = 10$TeV, $\mu = 1.2$TeV

$\mathcal{BR}[B \to X_s\gamma]$	1.3 σ	too low
$\mathcal{BR}[B \to X_s\ell^+\ell^-]$	perfect agreement	
$\mathcal{BR}[B^+ \to \tau^+\nu]$	1.7 σ	too low

$$m_{\tilde{t}_1} = 1.9\text{TeV}$$
$$M_{\chi_1^+} = 120\text{GeV}$$
$$M_A = 842\text{GeV}$$

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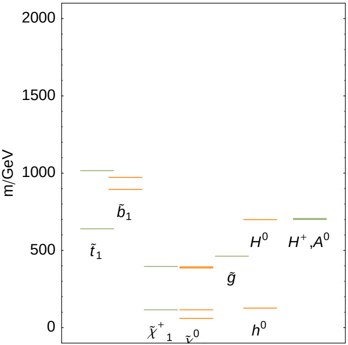
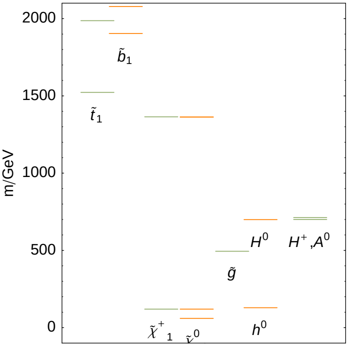
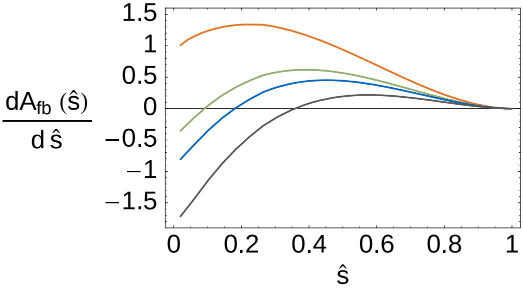
Main Message

- To test the validity of models for fermion masses and mixings, it is essential to check flavour changing processes
- not only one at a time but all of them simultaneously

Example SUSY spectra







$C_7 = -C_7^{SM}$

$C_7 = 0.5 \times C_7^{SM}$

$C_7 = C_7^{SM}$

$C_7 = 2 \times C_7^{SM}$

no zero in the forward backward asymmetry if $C_7 = -C_7^{SM}$

$a_\mu^{\text{exp}} = 11\,659\,\mathbf{2080}(63) \times 10^{-11}$ [Muon (g-2) collaboration]

$a_\mu^{\text{SM}} = 11\,659\,\mathbf{1785}(61) \times 10^{-11}$ [Miller, de Rafael, Roberts 07]

$\Rightarrow$ 3.4σ discrepancy

In the DR model, $|\Delta a_\mu|$ is less than $\approx 80 \times 10^{-11}$

no explanation of the discrepancy