Muon $g - 2$ in the MSSM and 2HDM

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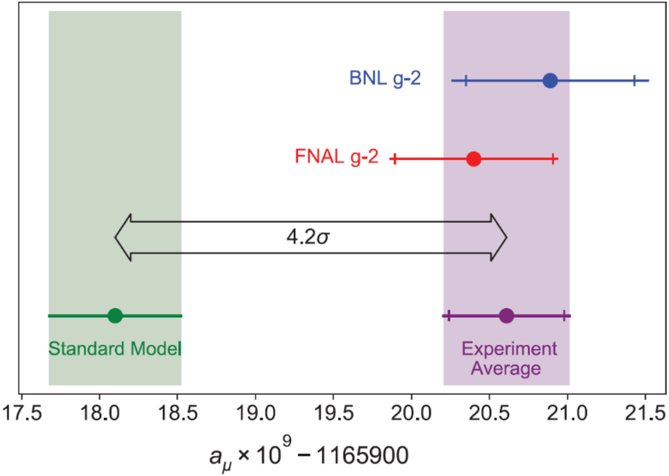
Collaborators: Peter Athron, Csaba Balasz, Douglas Jacob, Wojciech Kotlarski, Hyejung Stöckinger-Kim [2104.03691]

Finally: Fermilab Run 1 versus Theory Initiative SM value



Which models can(not) explain it?

Two important general points

SM prediction too low by $\approx (25 \pm 6) \times 10^{-10}$

discrepancy $\approx 2 \times a_\mu^{\text{SM,weak}}$

but: expect $a_\mu^{\text{NP}} \sim a_\mu^{\text{SM,weak}} \times \left(\frac{M_W}{M_{\text{NP}}}\right)^2 \times$ couplings

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loop-induced, CP- and Flavor-conserving, chirality-flipping ($\mu_L \leftrightarrow \mu_R$)

compare: EDMs, $b \to s\gamma$, $B \to \tau\nu$, $\mu \to e\gamma$, EWPO

Two promising directions

1. Dark sectors/dark matter
   - hard to see in detectors, but could couple to muons

2. Window to muon mass generation mechanism
   - $g-2$ and m_μ break "chiral" symmetry
   - and break EW gauge invariance
   - chiral enhancements possible with modified Higgs/Yukawa sector

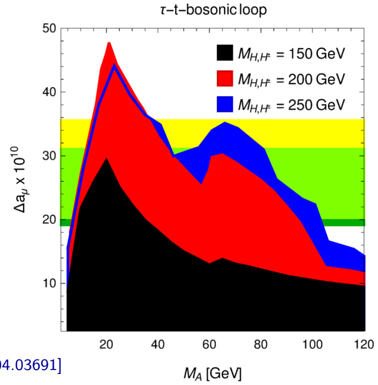
Outline

1. Examples of concrete models and constraints
   - 2HDM
   - MSSM and other SUSY models

Two-Higgs doublet model: $M_A < 100$ GeV

- Aligned 2-Higgs doublet model, rich new Higgs/Yukawa sectors

  [Type X extensively studied by E.J. Chun et al, Aligned (incl. full 2-loop) by Cherchiglia et al]



[2104.03691]

Details on Yukawa couplings:

Type X/lepton-specific: $Y_\ell \propto \tan\beta$ Type II: $Y_{\ell,d} \propto \tan\beta$ Aligned: $Y_\ell \propto \zeta_\ell$

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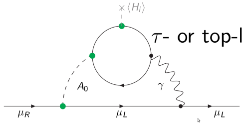
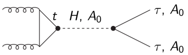
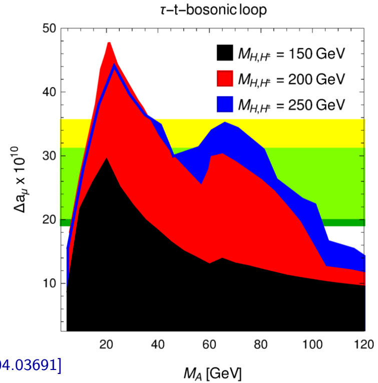


LHC constraints:



Also: τ-dec., $Z \to \tau\tau$, EWPO



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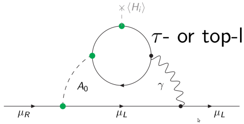

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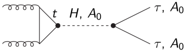

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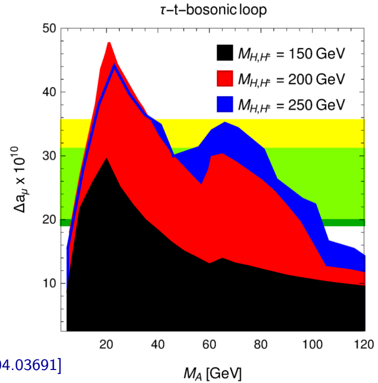

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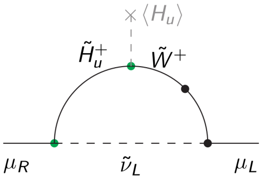
- can explain $g-2$
- need large new Yukawa couplings
- under pressure, testable at LHC, lepton colliders, B-physics

Analysis: a_μ in the MSSM

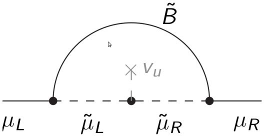
Typical SUSY contributions are chirally enhanced — Two interesting cases:

Wino–Higgsino–smuon or Bino–smuonL–smuonR(+heavy Higgsino)



$$a_\mu(WHL) \approx 21 \times 10^{-10} \left(\frac{500\ \text{GeV}}{M_{\text{SUSY}}}\right)^2 \frac{\tan\beta}{40}$$

$$a_\mu(BLR) \approx 2.4 \times 10^{-10} \left(\frac{500\ \text{GeV}}{M_{\text{SUSY}}}\right)^2 \frac{\tan\beta}{40} \frac{\mu}{500\ \text{GeV}}$$



$\propto \mu$ for $\mu \to \infty$

MSSM can explain $g-2$ and dark matter

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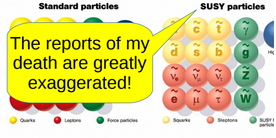
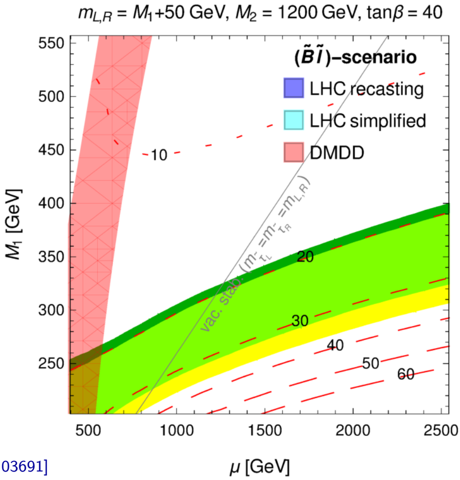
- Bino-LSP, close-by sleptons
- DM explained by stau/slepton-coannihilation
- explains $g-2$ in large region (expands for $\tan\beta \neq 40$) (both WHL and BLR important)
- this automatically evades (current) LHC limits





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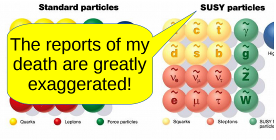
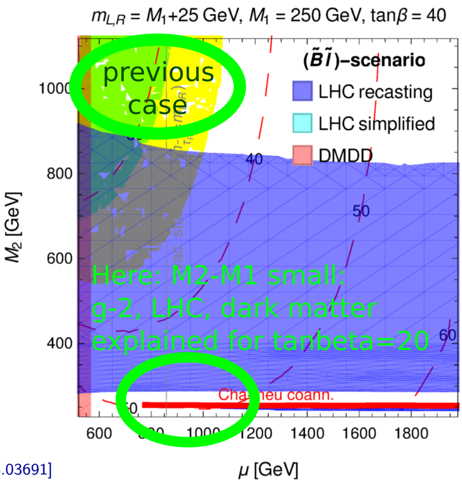
- Still Bino-LSP and close-by sleptons
- Now lower M_w: strong LHC limits
- DM also explained by Wino-coannihilation
- again evades (current) LHC limits





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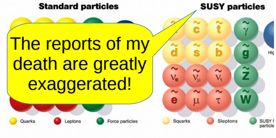
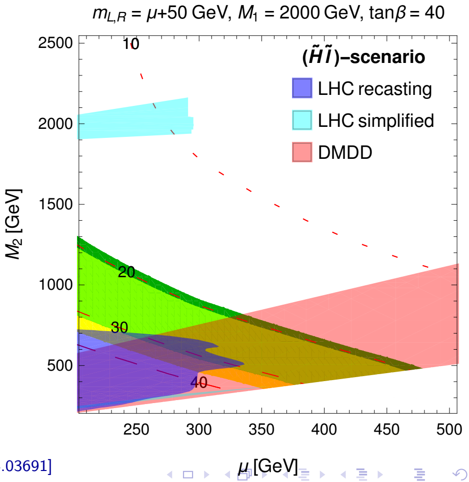
- Higgsino-LSP and ≈ light sleptons
- DMRD too small
- significant LHC limits on M_2
- ⇒ attractive, generic scenario





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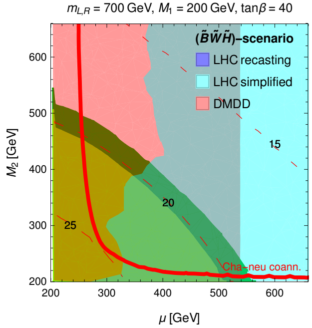
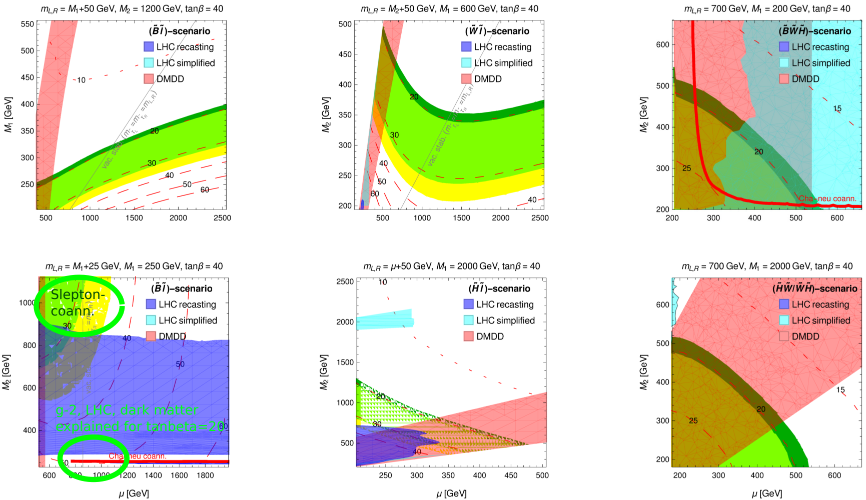
Further case: Bino-LSP < charginos < sleptons



- Bino-LSP <Wino,Higgsino<sleptons: stau-coann. essentially excluded because of LHC limits on cha-decays into staus and by DMDD constraints
  Hagiwara,Ma,Mukhopadhyay: more details on stau recasting
- This entire scenario might be excluded by further $g-2$, DM, LHC constraints
- The case with Wino-coann. is viable

MSSM overview:

[Peter Athron, Csaba Balasz, Douglas Jacob, Wojciech Kotlarski, DS, Hyejung Stöckinger-Kim, 2104.03691]



- Bino-LSP: DM via slepton- or Wino-coannihilation Interesting/challenges: $M_1 < M_2/2$ preferred; super-large μ helps
- Higgsino- or Wino-LSP: promising if we accept some other DM candidate
- Both charginos < sleptons: disfavoured, may be excluded(?)

Summary of main points

discrepancy $\approx 2 \times a_\mu^{\text{SM,weak}}$

but: expect $a_\mu^{\text{NP}} \sim a_\mu^{\text{SM,weak}} \times \left(\frac{M_W}{M_{\text{NP}}}\right)^2 \times$ couplings

a_μ is loop-induced, CP- and flavor-conserving and chirality-flipping

rather light, neutral (?) particles $\rightsquigarrow$ Connection to dark matter?

Chirality flip enhancement $\rightsquigarrow$ Window to muon mass generation? EWSB/generations?

Which models can still accommodate large deviation?

Many (but not all) models!

but always: experimental constraints!

MSSM and 2HDM:

- 2HDM still "just about possible", many constraints
- General MSSM very promising: Bino-LSP+coannihilation; Wino-/Higgsino-LSP.
- But "non-traditional" parameter regions particularly favourable