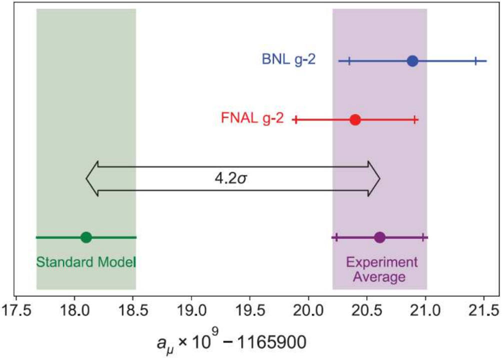
Muon $g-2$ and EDM theory motivation

Dominik Stöckinger, TU Dresden

Workshop: Potential Fermilab Muon Campus & Storage Ring Experiments, 24th May 2021

1. Overview and SM theory
2. $g-2$ and BSM — important general remarks
3. Comparisons a_μ and other dipole observables
4. General lessons and conclusions

Finally: Fermilab Run 1 versus Theory Initiative SM value

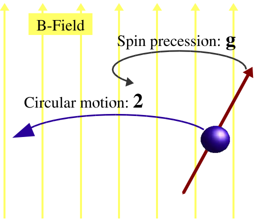


Limits on EDMs: $|d_e| < 8.7 \times 10^{-29} e\,\text{cm}$

$|d_\mu| < 1.5 \times 10^{-19} e\,\text{cm}$

Limit on $\mu \to e\gamma$: $BR(\mu \to e\gamma) < 4.2 \times 10^{-13}$

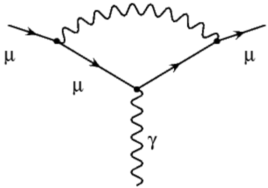
The landscape of dipole observables



$$H_{\text{eff}} = -2(1+a_\mu)\frac{e}{2m_\mu}\vec{B}\cdot\vec{S} - 2d_\mu \vec{E}\cdot\vec{S}$$

EDM is T, P, CP-violating!

QFT: $a_\mu = -2m_\mu \text{Re}(c)$, $d_\mu = -e\,\text{Im}(c)$, $BR_{(\mu\to e\gamma)} \approx\sim |c^{\mu e}|^2$



$$\sim \bar{u}(p')\left[\gamma_\mu F_1 + \frac{i}{2m}\sigma_{\mu\nu}q^\nu(\text{Re}(c) - i\gamma_5 \text{Im}(c))\right]u(p)$$

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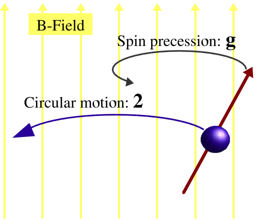

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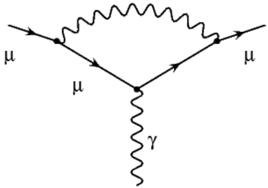

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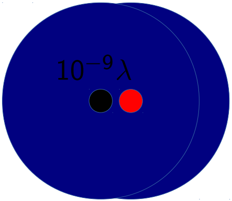
Note: $\mu \to e$ conversion and e.g. neutron-EDM are not only given by dipole operators but might be "dipole-dominated"

Units and first expectations: a_μ, d_μ and $\mu \to e\gamma$ are dipole observables

$$a_\mu = -2m_\mu \mathrm{Re}(c), \quad d_\mu = -e\,\mathrm{Im}(c), \quad BR_{(\mu\to e\gamma)} \approx\sim |c^{\mu e}|^2$$

- suppose $a_\mu \sim 10^{-9}$, and also $\mathrm{Im}(c)/\mathrm{Re}(c) = \tan\phi \sim 1$
- expect

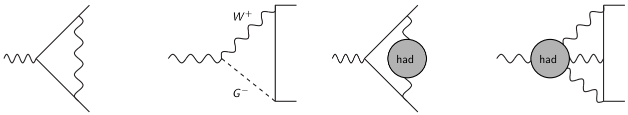


Compton wavelength λ

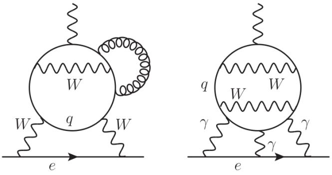
$$d_\mu \sim 10^{-9}\frac{e}{m_\mu} \sim 10^{-22} e\,cm$$

SM contributions

- All sectors of the SM contribute to a_μ:
  $a_\mu^{\text{QED}} \sim 10^{-3}$ $a_\mu^{\text{HVP}} \sim 10^{-7}$ $a_\mu^{\text{EW}} \sim 10^{-9}$



- Electron/muon EDM in SM needs quarks of all generations ($\rightsquigarrow \approx 0$)!

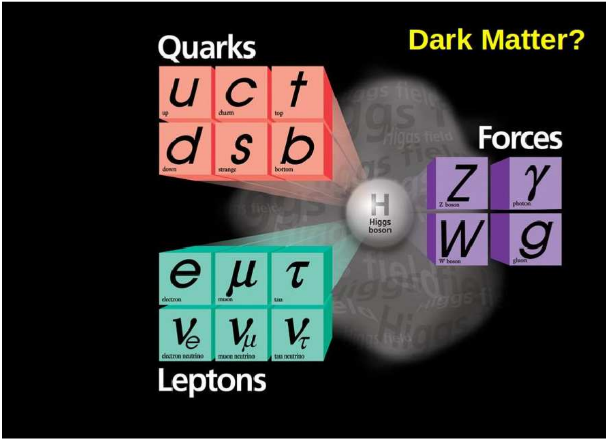


[Pospelov, Ritz '13]

4-, 5-loop diagrams
$d_e \sim 10^{-44} e\, cm$
($10^{-34} \times$ Compton!)

- Similarly: CLFV essentially zero in SM (even with neutrino masses) ($\mu \to e\gamma$, $\mu \to e$ conversion etc)

Open questions require Beyond the Standard Model (BSM) physics



Open questions!

- experimental clues needed! ⇝ $g-2$!

  not easy to explain!

- relevant and deep questions may be related to $g-2$
- Origin of baryon-antibaryon asymmetry?
  ⇝ EDMs!

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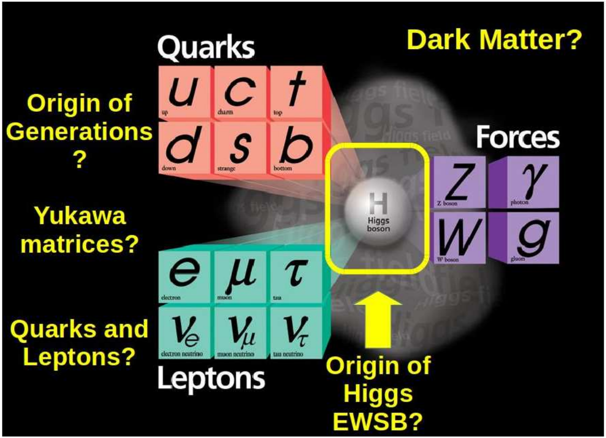

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Two important general points on a_μ

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

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

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

- Many experiments needed to investigate CPV and flavor structure of potential new physics

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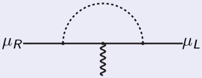
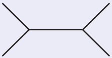
loop-induced, CP- and Flavor-conserving, chirality-flipping



compare: 

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

EWPO

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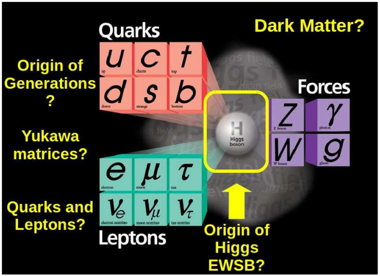
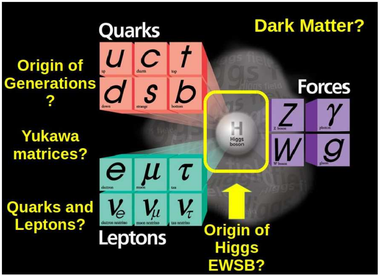


Window to muon mass generation mechanism?

Dark Matter? Hard to see in detectors

but could couple to muon ⇝ large effects possible!
many examples, but within simple models: need at least three new fields

generally: dark matter direct detection constraints important!



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allows significant chiral enhancements,

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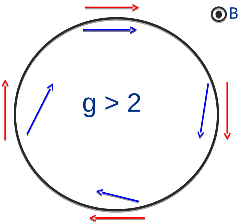
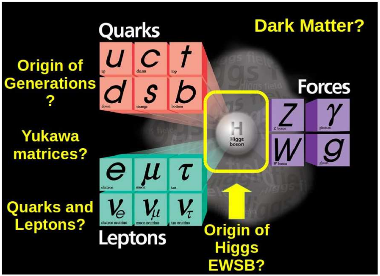
(continuous spin rotation requires rest mass!)





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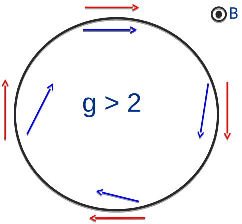
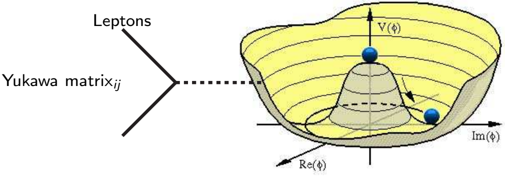
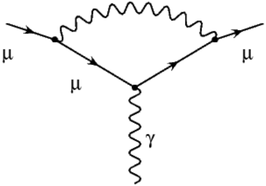




(changed by new physics?)

Connection to chirality flip, and structure of BSM

But:



$$\mathcal{L}_{\text{eff}} = \frac{Qe}{2} c \times \bar{\psi}_L \sigma_{\mu\nu} \psi_R F^{\mu\nu} + h.c.$$

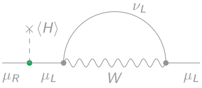
EW gauge invariant a_μ-operator: $\bar{L}\sigma_{\mu\nu}\mu_R F^{\mu\nu}\langle H\rangle$

$$a_\mu \sim m_\mu \times \underbrace{(\text{some VEV}) \times (\mu_{L\leftrightarrow R}\text{-flipping param.})}_{\text{potential enhancement! Often } \propto m_\mu} \times \frac{(\text{other couplings})}{M^2_{\text{typical}}}$$

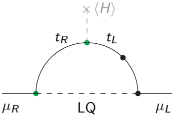
$m_\mu(\text{SM}) \sim$ (SM Higgs-VEV) $\times$ (muon Yukawa coupling)

Typical behaviour: $\sim$ chirality flip ($\rightsquigarrow$ Higgs!) and masses

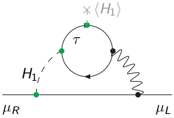
- EWSM: $\alpha \frac{m_\mu^2}{M_W^2}$



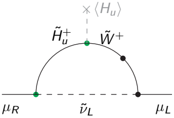
- LQ: $g_L g_R \frac{m_\mu m_t}{M_{\text{LQ}}^2}$

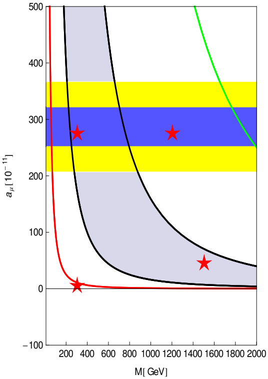


- 2HDM: $\alpha^2 \tan^2\beta \frac{m_\mu{}^2}{M_H^2}$



- SUSY: $\alpha \frac{m_\mu^2 \tan\beta}{M_{\text{SUSY}}^2} \frac{\mu}{M_{\text{SUSY}}}$





Details: see backup slides
[Athron,Balazs,Jacob,Kotlarski, DS,Stöckinger-Kim, 2104.03691]

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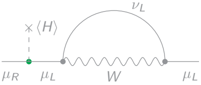
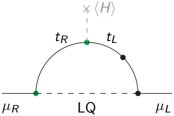
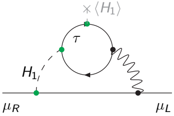


- LQ: $g_L g_R \frac{m_\mu m_t}{M_{\rm LQ}^2}$



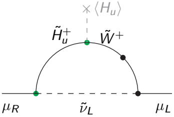
Couplings $\sim$ new flavor structure, formally $\propto m_\mu m_t$

- 2HDM: $\alpha^2 \tan^2\beta \frac{m_\mu{}^2}{M_H^2}$

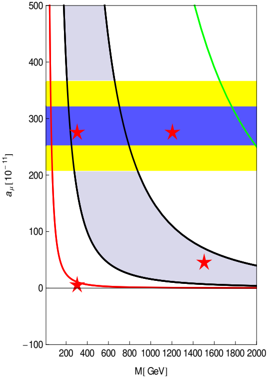


Couplings $\sim$ new flavor structure or "minimal flavor violating"

- SUSY: $\alpha \frac{m_\mu^2 \tan\beta}{M_{\rm SUSY}^2} \frac{\mu}{M_{\rm SUSY}}$



New flavor-independent and new flavor-dependent contributions



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Relations and estimates

also: [Giudice, Paradisi, Passera 2012] [Crivellin, Hoferichter, Schmidt-Wellenburg 2018]

Can unify description of MDM, EDM, CLFV: generalize $\mathcal{L}_{\text{eff}} \sim c^{ij}$ to leptons i, j with coefficients c^{ij}, $c^{ij} \propto$ VEV $\times$ chir.-flip:

$$
\begin{aligned}
a_\mu &= -2m_\mu \mathrm{Re}(c^{\mu\mu}) \\
a_\ell &= -2m_\ell \mathrm{Re}(c^{\ell\ell}) \\
d_\ell &= -e\,\mathrm{Im}(c^{\ell\ell}) \\
BR(\mu \to e\gamma) &= \frac{e^2 m_\mu^3}{\pi \Gamma_\mu}(|c^{\mu e}|^2 + |c^{e\mu}|^2)
\end{aligned}
$$

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$$d_\mu \approx \left(\frac{\Delta a_\mu}{3 \times 10^{-9}}\right) 2 \times 10^{-22} e\,\text{cm} \times \tan\phi_\mu\,,$$

$$d_e \approx \left(\frac{\Delta a_e}{7 \times 10^{-14}}\right) 10^{-24} e\,\text{cm} \times \tan\phi_e\,,$$

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- SM: $\tan\phi \ll 1$, $\theta_{\mu e} \ll 1$.
- Current EDM, MEG limits: $\tan\phi_\mu \lesssim 1000$, ($\tan\phi_e \ll 1$ or $\Delta a_e \ll 10^{-14}$), $\theta_{\mu e} \lesssim 10^{-5}$
- New physics strongly restricted in $\theta_{\mu e}$ and $\tan\phi_e$ but not in $\tan\phi_\mu$ $\rightsquigarrow$ improve!
- Naive scaling $c^{\ell\ell} = m_\ell \times$ const.:
  $\Delta a_e : \Delta a_\mu = m_e^2 : m_\mu^2, \quad d_e : d_\mu = m_e : m_\mu \quad \overset{\text{Exp.}}{\Rightarrow} \quad |d_\mu^{\text{naive sc.}}| \lesssim 10^{-27}$
- New physics possibilities: new flavor structures (LQ, sleptons, 2HDM-Yukawas), new flavor-independent parameters (complex Higgsino mass, gaugino masses)
- Note: neutron EDM and $\mu \to e$ conversion sensitive to non-dipole operators!
  Note 2: naive scaling is different from writing $a_\mu = C_{\text{BSM}} \frac{m_\mu^2}{M_{\text{BSM}}^2} \quad \rightsquigarrow \quad c^{\mu\mu} \sim m_\mu \times C_{\text{BSM}}^{\text{dimensionless BSM-couplings}}$

Summary of main points

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

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

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

Which models can still accommodate large deviation?

Many (but not all) models! $\rightsquigarrow$ Connection to dark matter? Window to muon mass generation?

but always: experimental constraints!

Questions for a_μ versus d_μ (and a_e and $\mu \to e(\gamma)$):

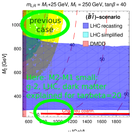
- Is there new physics in a_μ? Dark matter/new Yukawas/Higgs?
- Is there more flavor structure beyond SM Yukawas? (LQ, SUSY, 2HDM, ...)
- Is CPV connected to flavor/generations? (SUSY Higgsino/gaugino masses vs new Yukawas)
- Are there $\mathcal{O}(1)$ sources of CPV (in the muon sector)? $d_\mu^{\Delta a_\mu, \mathcal{O}(1)} \sim 10^{-22}\, e\,{\rm cm}$
- Does naive scaling hold (exactly/approximately) for a_ℓ or for d_ℓ? $d_\mu^{\text{naive sc.}} \lesssim 10^{-27}\, e\,{\rm cm}$

Looking forward to experimental programme. . . very promising future!

There are many more examples. . .

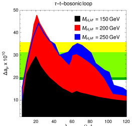
SUSY: MSSM, MRSSM

- MSugra. . . many other generic scenarios
- Bino-dark matter+some coannihil.+mass splittings
- Wino-LSP+specific mass patterns



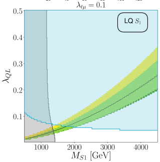
Two-Higgs doublet model

- Type I, II, Y, Type X(lepton-specific), flavour-aligned



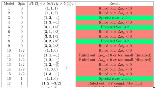
Lepto-quarks, vector-like leptons

- scenarios with muon-specific couplings to μ_L and μ_R



Simple models (one or two new fields)

- Mostly excluded
- light N.P. (ALPs, Dark Photon, Light $L_\mu - L_\tau$)



Model	Spin	$SU(3)_C \times SU(2)_L \times U(1)_Y$	Result
1	0	$(\mathbf{1},\mathbf{1},1)$	Ruled out: $\Delta a_\mu < 0$
2	0	$(\mathbf{1},\mathbf{1},2)$	Ruled out: $\Delta a_\mu < 0$
3	0	$(\mathbf{1},\mathbf{2},-\frac{1}{2})$	Special cases viable
4	0	$(\mathbf{1},\mathbf{3},-1)$	Ruled out: $\Delta a_\mu < 0$
5	0	$(\mathbf{3},\mathbf{1},1/3)$	Updated Sec. 3.2.
6	0	$(\bar{\mathbf{3}},\mathbf{1},4/3)$	Ruled out: $\Delta a_\mu < 0$
7	0	$(\bar{\mathbf{3}},\mathbf{3},1/3)$	Ruled out: $\Delta a_\mu < 0$
8	0	$(\mathbf{3},\mathbf{2},7/6)$	Updated Sec. 3.2.
9	0	$(\mathbf{3},\mathbf{2},2/3)$	Ruled out: $\Delta a_\mu < 0$
10	1/2	$(\mathbf{1},\mathbf{1},0)$	Ruled out: $\Delta a_\mu < 0$
11	1/2	$(\mathbf{1},\mathbf{1},-1)$	Ruled out: $\Delta a_\mu < 0$ or too small (disputed)
12	1/2	$(\mathbf{1},\mathbf{2},-\frac{1}{2})$	Ruled out: $\Delta a_\mu < 0$ or too small (disputed)
13	1/2	$(\mathbf{1},\mathbf{2},-\frac{3}{2})$	Ruled out: $\Delta a_\mu < 0$
14	1/2	$(\mathbf{1},\mathbf{3},0)$	Ruled out: $\Delta a_\mu < 0$
15	1/2	$(\mathbf{1},\mathbf{3},-1)$	Ruled out: $\Delta a_\mu < 0$
16	1	$(\mathbf{1},\mathbf{1},0)$	Special cases viable
17	1	$(\mathbf{1},\mathbf{2},-3/2)$	Ruled out: UV compl. $M_{Z'}$ limit

[Athron,Balazs,Jacob,Kotlarski,DS,Stöckinger-Kim, 2104.03691]

Example BSM idea

- fundamental new QFT symmetry
- predicts Higgs potential/mass
- dark matter candidate
- chirality flip enhancement $\rightsquigarrow g-2$
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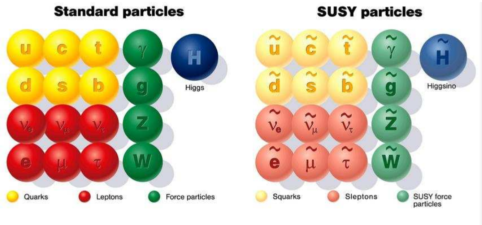
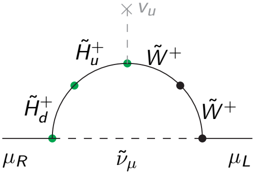
- chirality flip enhancement $\rightsquigarrow g-2$
- viable (LHC)?



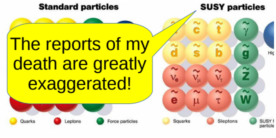
Superpartners and SUSY Higgs sector $\rightsquigarrow \tan\beta = \frac{v_u}{v_d}$, Higgsino mass μ

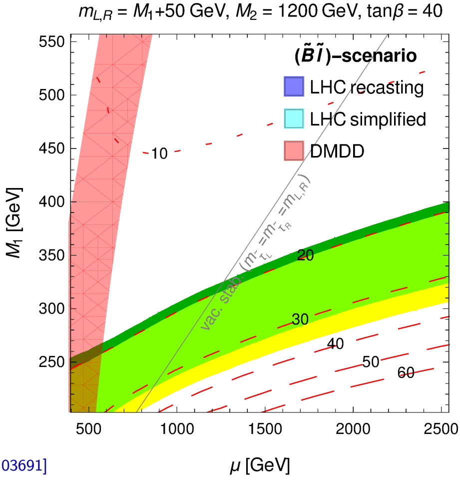
MSSM can explain $g-2$ and dark matter



$$a_\mu^{\mathrm{SUSY}} \approx 25 \times 10^{-10} \, \frac{\tan\beta}{50} \, \frac{\mu}{M_{\mathrm{SUSY}}} \left(\frac{500\mathrm{GeV}}{M_{\mathrm{SUSY}}}\right)^2$$

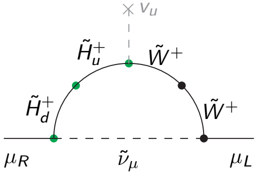
- "Dark matter mass" versus μ
- explains $g-2$ in large region (expands for $\tan\beta \neq 40$)
- DM explained by stau/slepton-coannihilation
- this automatically evades (current) LHC limits





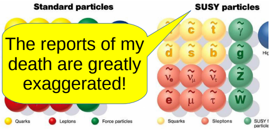
[2104.03691]

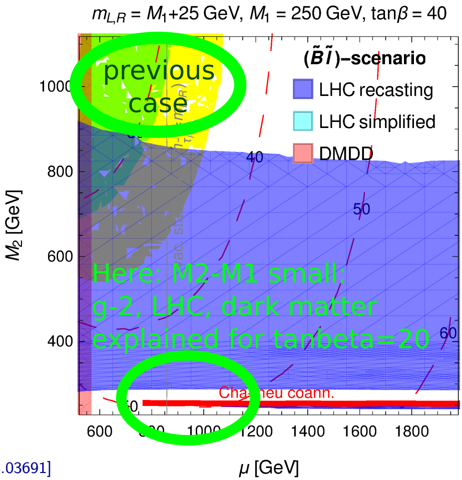
MSSM can explain $g-2$ and dark matter



$$a_\mu^{\text{SUSY}} \approx 25\times 10^{-10}\ \frac{\tan\beta}{50}\ \frac{\mu}{M_{\text{SUSY}}}\left(\frac{500\text{GeV}}{M_{\text{SUSY}}}\right)^2$$

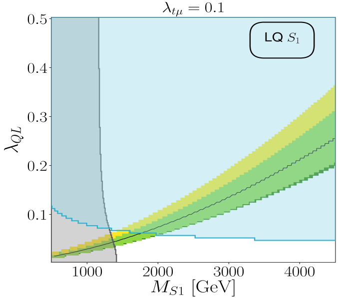
- Strong LHC limits on M_2
- DM also explained by Wino-coannihilation
- again evades (current) LHC limits

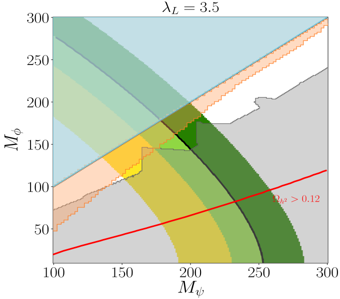




[2104.03691]

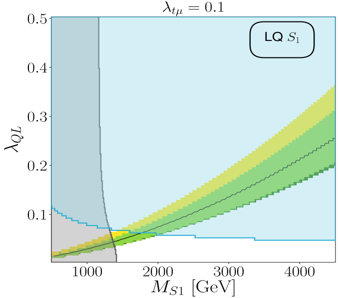
Leptoquarks and Model L with 2 fields

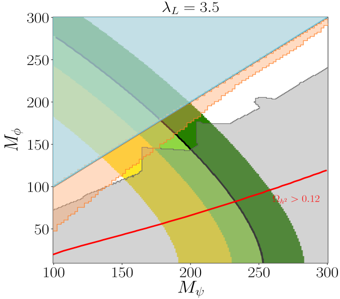




[Athron,Balazs,Jacob,Kotlarski,DS,Stöckinger-Kim, 2104.03691]

Leptoquarks and Model L with 2 fields

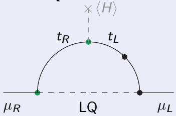




[Athron,Balazs,Jacob,Kotlarski,DS,Stöckinger-Kim, 2104.03691]

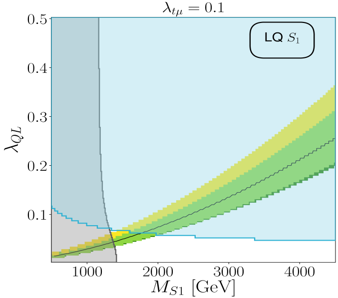
a_μ from LQ (or VLL) $\mathcal{L}_{S_1} = -\left(\lambda_{QL} Q_3 \cdot L_2 S_1 + \lambda_{t\mu} t \mu S_1^*\right)$

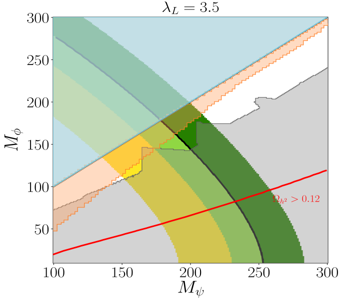
Specific LQ that works:



- Chiral enhancement $\sim y_{\text{top}}, y_{\text{VLL}}$ versus y_μ
- LHC: lower mass limits
- Flavour constraints $\rightsquigarrow$ assume only couplings to muons
- Viable window above LHC (without m_μ-finetuning)

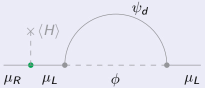
Leptoquarks and Model L with 2 fields





[Athron,Balazs,Jacob,Kotlarski,DS,Stöckinger-Kim, 2104.03691]

a_μ from 2-field model L

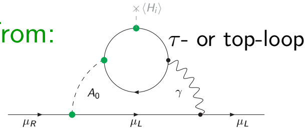


- No chiral enhancement, need very large couplings
- LHC: lower mass limits
- Dark matter candidate, but
  incompatible with large a_μ
  General result: a_μ and DM require at least three new fields!

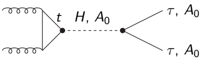
BSM with smaller masses, hidden from colliders?

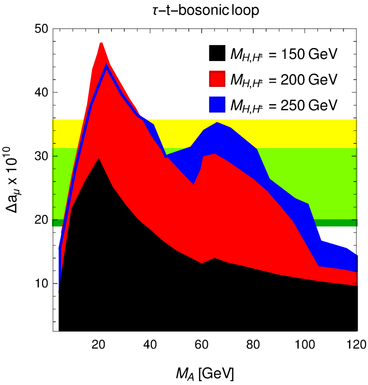
- Aligned 2-Higgs doublet model, rich new Higgs/Yukawa sectors

a_μ from:



LHC constraints:





[2104.03691]

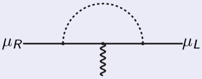
- can explain $g-2$
- need large new Yukawa couplings
- under pressure, testable at LHC, lepton colliders, B-physics

Two important general points

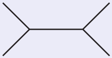
discrepancy $\approx 2 \times a_\mu^{\text{SM,weak}}$

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

loop-induced, CP- and Flavor-conserving, chirality-flipping



compare:



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

EWPO

Questions: Which models can(not) explain it?

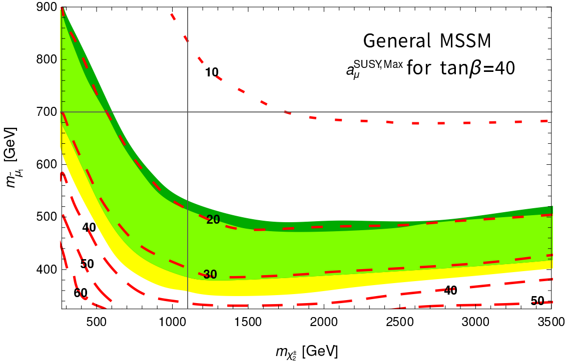
Why is a single number so interesting?

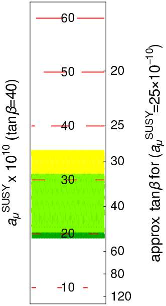
"Why are you happy about a discrepancy?"

$\Rightarrow$ we might make significant progress!

Full MSSM overview in 7 plots

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





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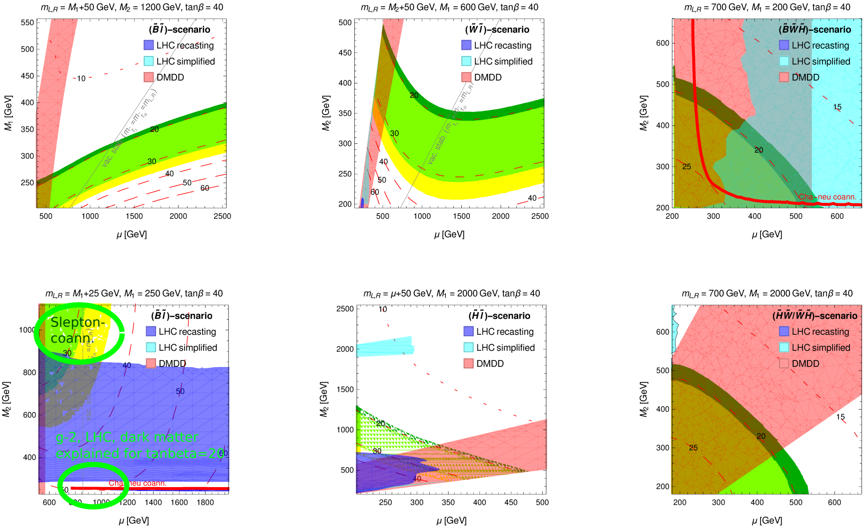
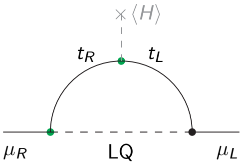
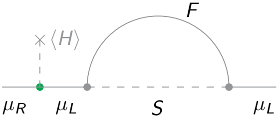


Summary: Bino-LSP: a_μ and DM. Wino-/Higgsino-LSP: a_μ. Both cha<slepton: ≈disfavoured.

DM+LHC⇒mass patterns! Coannihilation regions help! Specific cases excluded, e.g. Constrained MSSM

One-field, two-field models (renormalizable, spin $0, 1/2$)





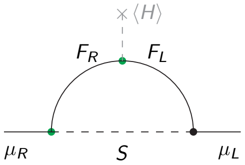
- many models: excluded
- very special models: chiral enhancement
  specific leptoquarks, specific 2HDM versions
- however, no dark matter

Model	Spin	$SU(3)_C \times SU(2)_L \times U(1)_Y$	Result
1	0	$(\mathbf{1}, \mathbf{1}, 1)$	Ruled out: $\Delta a_\mu < 0$
2	0	$(\mathbf{1}, \mathbf{1}, 2)$	Ruled out: $\Delta a_\mu < 0$
3	0	$(\mathbf{1}, \mathbf{2}, -\frac{1}{2})$	Special cases viable
4	0	$(\mathbf{1}, \mathbf{3}, -1)$	Ruled out: $\Delta a_\mu < 0$
5	0	$(\mathbf{3}, \mathbf{1}, 1/3)$	Updated Sec. 3.2.
6	0	$(\bar{\mathbf{3}}, \mathbf{1}, 4/3)$	Ruled out: $\Delta a_\mu < 0$
7	0	$(\bar{\mathbf{3}}, \mathbf{3}, 1/3)$	Ruled out: $\Delta a_\mu < 0$
8	0	$(\mathbf{3}, \mathbf{2}, 7/6)$	Updated Sec. 3.2.
9	0	$(\mathbf{3}, \mathbf{2}, 2/3)$	Ruled out: $\Delta a_\mu < 0$
10	1/2	$(\mathbf{1}, \mathbf{1}, 0)$	Ruled out: $\Delta a_\mu < 0$
11	1/2	$(\mathbf{1}, \mathbf{1}, -1)$	Ruled out: $\Delta a_\mu < 0$ or too small (disputed)
12	1/2	$(\mathbf{1}, \mathbf{2}, -\frac{1}{2})$	Ruled out: $\Delta a_\mu < 0$ or too small (disputed)
13	1/2	$(\mathbf{1}, \mathbf{2}, -\frac{3}{2})$	Ruled out: $\Delta a_\mu < 0$
14	1/2	$(\mathbf{1}, \mathbf{3}, 0)$	Ruled out: $\Delta a_\mu < 0$
15	1/2	$(\mathbf{1}, \mathbf{3}, -1)$	Ruled out: $\Delta a_\mu < 0$
16	1	$(\mathbf{1}, \mathbf{1}, 0)$	Special cases viable
17	1	$(\mathbf{1}, \mathbf{2}, -3/2)$	Ruled out: UV compl. $M_{Z'}$ limit

- even more models: excluded
- no chirality flip
- few models: either a_μ^{BNL} or dark matter

$(\mathbf{1},\mathbf{1},0)_0 - (\mathbf{1},\mathbf{1},-1)_{1/2}$	No	Projected LHC 14 TeV exclusion, not confirmed
	Yes	Updated Sec. 4.2
$(\mathbf{1},\mathbf{1},-1)_0 - (\mathbf{1},\mathbf{1},0)_{1/2}$	Both	Excluded: $\Delta a_\mu < 0$
$(\mathbf{1},\mathbf{2},-1/2)_0 - (\mathbf{1},\mathbf{1},0)_{1/2}$	Both	Excluded: $\Delta a_\mu < 0$
$(\mathbf{1},\mathbf{1},0)_0 - (\mathbf{1},\mathbf{2},-1/2)_{1/2}$	No	Excluded: LHC searches
	Yes	Updated Sec. 4.2
$(\mathbf{1},\mathbf{1},0)_0 - (\mathbf{1},\mathbf{1},-1)_{1/2}$	No	Excluded: LEP contact interactions
	Yes	Viable with under abundant DM
$(\mathbf{1},\mathbf{1},-1)_0 - (\mathbf{1},\mathbf{2},-1/2)_{1/2}$	Both	Excluded: $\Delta a_\mu < 0$
$(\mathbf{1},\mathbf{2},-1/2)_0 - (\mathbf{1},\mathbf{2},-1/2)_{1/2}$	Both	Excluded: LEP search
$(\mathbf{1},\mathbf{1},0)_0 - (\mathbf{1},\mathbf{1},-1)_{1/2}$	No	Excluded: LHC searches
	Yes	Viable with under abundant DM
$(\mathbf{1},\mathbf{1},0)_0 - (\mathbf{1},\mathbf{1},-1)_{1/2}$	No	Excluded: LHC searches + LEP contact interactions
	Yes	Viable with under abundant DM
$(\mathbf{1},\mathbf{3},0)_0 - (\mathbf{1},\mathbf{2},-1/2)_{1/2}$	Both	Excluded: $\Delta a_\mu < 0$
$(\mathbf{1},\mathbf{1},0)_0 - (\mathbf{1},\mathbf{1},-1)_{1/2}$	No	Excluded: LHC searches
	Yes	Viable with under abundant DM
$(\mathbf{1},\mathbf{3},-1)_0 - (\mathbf{1},\mathbf{2},-1/2)_{1/2}$	Both	Excluded: $\Delta a_\mu < 0$
$(\mathbf{1},\mathbf{3},-1)_0 - (\mathbf{1},\mathbf{3},0)_{1/2}$	Both	Excluded: $\Delta a_\mu < 0$
$(\mathbf{1},\mathbf{1},-1)_{1/2} - (\mathbf{1},\mathbf{1},0)_1$	No	Excluded: $\Delta a_\mu < 0$
$(\mathbf{1},\mathbf{2},-1/2)_{1/2} - (\mathbf{1},\mathbf{1},0)_1$	No	Excluded: $\Delta a_\mu < 0$
$(\mathbf{1},\mathbf{2},-1/2)_{1/2} - (\mathbf{1},\mathbf{3},0)_1$	No	Excluded: LHC searches + LEP contact interactions
$(\mathbf{1},\mathbf{1},0)_{1/2} - (\mathbf{1},\mathbf{1},1)_1$	No	Excluded: LHC searches + LEP contact interactions
$(\mathbf{1},\mathbf{2},-1/2)_{1/2} - (\mathbf{1},\mathbf{1},-1)_1$	No	Excluded: LHC searches + LEP contact interactions

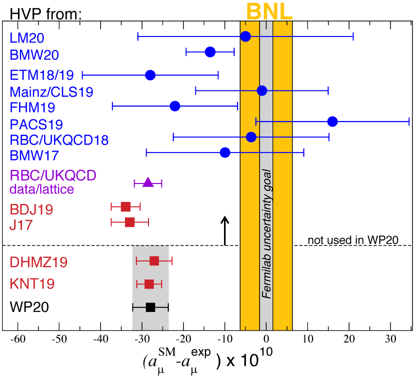
Three-field models



- many models: viable, large chirality enhancements
- can explain a_μ^{BNL} and LHC and dark matter

Details on hadronic vacuum polarization

a_μ^{HVP} : Status of Hadronic Vacuum Polarisation contributions



Lattice QCD + QED

- impressive progress, but…
- large spread between results
- tensions when looking at `Euclidean time window' comparisons
- large systematic uncertainties (e.g. from non-trivial extrapolation to continuum limit, finite size)

Dispersive/lattice hybrid (`window' method)

For WP20: Dispersive data-driven from DHMZ and KNT

TI White Paper 2020 value:

a_μ^{HVP} = 6845 (40) × 10^{-11}

- TI WP2020 prediction uses dispersive data-driven evaluations with **minimal model dependence**
- **a_μ^{HVP} value and error** obtained **by merging** procedure ➠ accounts for tensions in input data and differences in data treatment & combination (going beyond usual χ^2_{min} inflation)