Muon $g-2$, M_W and related observables: BSM Overview

Dominik Stöckinger, TU Dresden

ALPS Conference, Obergurgl, 28th March 2023

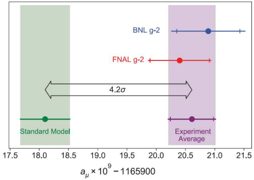
Two precise and important observables. . . a_μ and M_W

$a_\mu[10^{-10}]$

$$\text{EXP,2021} = (11\,659\,206.1\ \ (4.1))$$
$$\text{SM,2020WP} = (11\,659\,181.0\ \ (4.3))$$
$$\Delta a_\mu = (25.1 \pm 5.9) \times 10^{-10}$$

$M_W\,[\text{GeV}]$

$$\text{SM,OS} = 80.361(6)$$
$$\text{CDF 2022} = 80.434(9)$$
$$\text{ATLAS 2023} = 80.360(16)$$



But: BMW lattice result (intermediate window confirmed by other groups), CMD-3 result:

$$\Delta a_\mu \sim (10) \times 10^{-10}$$

Many additional discrepancies (KLOE/Babar, CMD-3/2/SND)

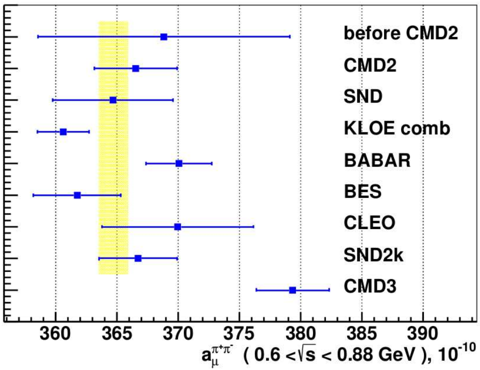
Two precise and important observables... a_μ and M_W

$a_\mu[10^{-10}]$

$$\text{EXP,2021} = (11\,659\,206.1\ \ (4.1))$$
$$\text{SM,2020WP} = (11\,659\,181.0\ \ (4.3))$$
$$\Delta a_\mu = (25.1 \pm 5.9) \times 10^{-10}$$

M_W[GeV]

$$\text{SM,OS} = 80.361(6)$$
$$\text{CDF 2022} = 80.434(9)$$
$$\text{ATLAS 2023} = 80.360(16)$$



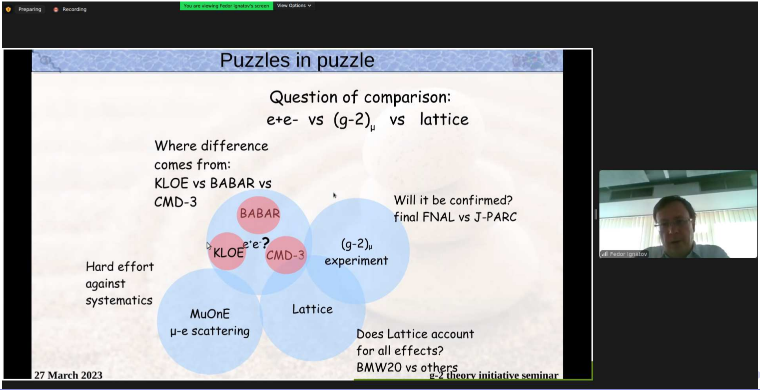
Two precise and important observables... a_μ and M_W

$a_\mu[10^{-10}]$

$$\text{EXP,2021} = (11\,659\,206.1\ (4.1))$$
$$\text{SM,2020WP} = (11\,659\,181.0\ (4.3))$$
$$\Delta a_\mu = (25.1 \pm 5.9) \times 10^{-10}$$

$M_W[\text{GeV}]$

$$\text{SM,OS} = 80.361(6)$$
$$\text{CDF 2022} = 80.434(9)$$
$$\text{ATLAS 2023} = 80.360(16)$$



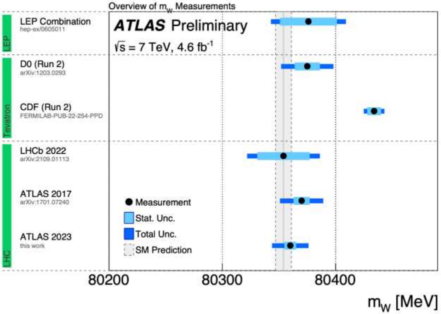
Two precise and important observables... a_μ and M_W

$a_\mu [10^{-10}]$

$$\text{EXP,2021} = (11\,659\,206.1\ \ (4.1))$$
$$\text{SM,2020WP} = (11\,659\,181.0\ \ (4.3))$$
$$\Delta a_\mu = (25.1 \pm 5.9) \times 10^{-10}$$

$M_W [\text{GeV}]$

$$\text{SM,OS} = 80.361(6)$$
$$\text{CDF 2022} = 80.434(9)$$
$$\text{ATLAS 2023} = 80.360(16)$$



[ATLAS, 23rd March 2023]
But: discrepancy CDF 2022 – ATLAS and SM!

⇝ Workshop MWDays2023 at CERN, 25th April

a_μ and M_W are sensitive to all interactions and BSM!

$M_W^{\mathrm{exp}} = 80.4??(9\dots16)$ GeV 0.02%

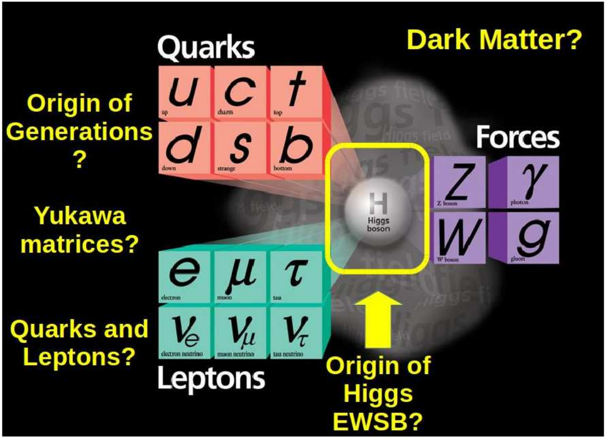
SM	had-VP effects	$> 200\sigma$
	1L top-effects	$> 200\sigma$
	1L Higgs, $\geq$ 2L	10σ
SUSY	loop effects	$\mathcal{O}(0\dots10\sigma)$

a_μ and M_W are sensitive to all interactions and BSM!

$$a_\mu^{\rm exp} = 11\,659\,206.1(4.1)\ \times 10^{-10}$$ 0.4ppm

SM	QED $\geq$ 2L	7000σ
	had	150σ
	weak	4σ
SUSY	loop effects	$\mathcal{O}(0\ldots\pm 20\sigma)$

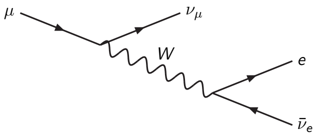
Open questions require Beyond the Standard Model (BSM) physics



BSM can be constrained (discovered?) by a_μ, M_W

Outline

M_W theory prediction and Muon decay

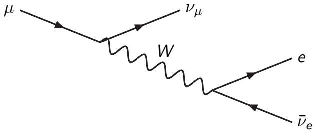


$$G_F = \frac{\pi\alpha}{\sqrt{2}M_W^2\left(1-\frac{M_W^2}{M_Z^2}\right)}(1+\Delta r)$$

$\Longrightarrow$ predict M_W as function of G_F, α, M_Z (and further parameters)

[More general EWPO and EW fit $\rightarrow$ Martin Hoferichter's talk]

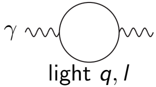
M_W theory prediction and Muon decay

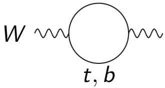


$$G_F = \frac{\pi\alpha}{\sqrt{2}M_W^2\left(1 - \frac{M_W^2}{M_Z^2}\right)}(1 + \Delta r)$$

$\Longrightarrow$ predict M_W as function of G_F, α, M_Z (and further parameters)

- Leading corrections from finite renormalizations:





$$\alpha \to \alpha(1 + \Delta\alpha) \quad , \quad \frac{1}{s_W^2} \to \frac{1}{s_W^2}\left(1 - \frac{c_W^2}{s_W^2}\Delta\rho\right)$$

Here, we will focus on $\Delta\rho$
often, leading corrections in (B)SM $\rightsquigarrow$ custodial symmetry!

Custodial Symmetry: One of the SM Miracles

If we use nothing but the symmetry pattern

$$\mathrm{SU}(2)_L \times \mathrm{U}(1)_Y \to \mathrm{U}(1)_{Q=T^3+Y}$$

the gauge boson mass matrix must look like

$$\mathcal{M}^2_{ab} = \langle\phi\rangle^\dagger\{T^a, T^b\}\langle\phi\rangle = \begin{pmatrix} g_2^2 v^2 & & & \\ & g_2^2 v^2 & & \\ & & g_2^2 u^2 & -g_1 g_2 u^2 \\ & & -g_1 g_2 u^2 & g_1^2 u^2 \end{pmatrix}$$

and therefore

$$\rho = \frac{M_W^2}{M_Z^2 \cos^2\theta_W} = \frac{v^2}{u^2} = \text{arbitrary!}$$

In the SM at tree-level, $u = v$ and $\rho = 1$ — an additional O(3) or SU(2) custodial symmetry of the SM vacuum!

Custodial Symmetry: One of the SM Miracles

If we use nothing but the symmetry pattern

$$\mathrm{SU}(2)_L \times \mathrm{U}(1)_Y \to \mathrm{U}(1)_{Q=T^3+Y}$$

the gauge boson mass matrix must look like

$$\mathcal{M}^2_{ab} = \langle\phi\rangle^\dagger \{T^a, T^b\} \langle\phi\rangle = \begin{pmatrix} g_2^2 v^2 & & & \\ & g_2^2 v^2 & & \\ & & g_2^2 u^2 & -g_1 g_2 u^2 \\ & & -g_1 g_2 u^2 & g_1^2 u^2 \end{pmatrix}$$

and therefore

$$\rho = \frac{M_W^2}{M_Z^2 \cos^2\theta_W} = \frac{v^2}{u^2} = \text{arbitrary!}$$

In the SM at tree-level, $u = v$ and $\rho = 1$ — an additional O(3) or SU(2) custodial symmetry of the SM vacuum!

Custodial Symmetry in SM

to see it, rewrite SM Higgs doublet as

$$\phi = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix} \longrightarrow \Phi = \begin{pmatrix} \phi^{0*} & \phi^+ \\ -\phi^- & \phi^0 \end{pmatrix}$$

Custodial Symmetry in SM

to see it, rewrite SM Higgs doublet as

$$\phi = \begin{pmatrix} \phi^+ \\ \phi^0 \end{pmatrix} \longrightarrow \Phi = \begin{pmatrix} \phi^{0*} & \phi^+ \\ -\phi^- & \phi^0 \end{pmatrix}$$

The Higgs potential only depends on $\mathrm{Tr}(\Phi^\dagger\Phi)$ and is invariant under

$$\mathrm{SU}(2)_L \times \mathrm{SU}(2)_R,\ \Phi \to L\Phi R^\dagger$$

vacuum is invariant under $\mathrm{SU}(2)_{L=R}$

$$\langle\Phi\rangle_{\mathrm{vac}} = \begin{pmatrix} v & 0 \\ 0 & v \end{pmatrix}$$

Violations of Custodial Symmetry — BSM

- SM Yukawa couplings: for $y_t = y_b$?

$$\mathcal{L}_{\text{Yukawa}} = y \left[(\bar{t}_L \ \bar{b}_L) \Phi \begin{pmatrix} t_R \\ b_R \end{pmatrix} \right]$$

They break custodial symmetry via $y_t \neq y_b$
$\Longrightarrow$ dominant m_t^2-correction to M_W (and other EWPOs): 3% effect!

Violations of Custodial Symmetry — BSM

- SM Yukawa couplings: for $y_t = y_b$?

$$\mathcal{L}_{\text{Yukawa}} = y \left[(\bar{t}_L \ \bar{b}_L) \Phi \begin{pmatrix} t_R \\ b_R \end{pmatrix} \right]$$

  They break custodial symmetry via $y_t \neq y_b$
  $\Longrightarrow$ dominant m_t^2-correction to M_W (and other EWPOs): 3% effect!

- Higgs triplet VEV: $\langle\Phi\rangle = \begin{pmatrix} 0 \\ 0 \\ v \end{pmatrix}$, no remnant SU(2) or O(3) $\Rightarrow$

$$\mathcal{M}^2_{ab} = \langle\phi\rangle^\dagger \{T^a, T^b\} \langle\phi\rangle = \begin{pmatrix} g_2^2 v^2 & & & \\ & g_2^2 v^2 & & \\ & & 0 & 0 \\ & & 0 & 0 \end{pmatrix}$$

Violations of Custodial Symmetry — BSM

- SM Yukawa couplings: for $y_t = y_b$?

$$\mathcal{L}_{\rm Yukawa} = y\left[(\bar{t}_L\ \bar{b}_L)\Phi\begin{pmatrix} t_R \\ b_R \end{pmatrix}\right]$$

  They break custodial symmetry via $y_t \neq y_b$
  $\Longrightarrow$ dominant m_t^2-correction to M_W (and other EWPOs): 3% effect!

- Higgs triplet VEV: $\langle\Phi\rangle = \begin{pmatrix} 0 \\ 0 \\ v \end{pmatrix}$, no remnant SU(2) or O(3) $\Rightarrow$

$$\mathcal{M}^2_{ab} = \langle\phi\rangle^\dagger\{T^a, T^b\}\langle\phi\rangle = \begin{pmatrix} g_2^2 v^2 & & & \\ & g_2^2 v^2 & & \\ & & 0 & 0 \\ & & 0 & 0 \end{pmatrix}$$

- BSM custodial sym. violations will lead to shift (often dominant)

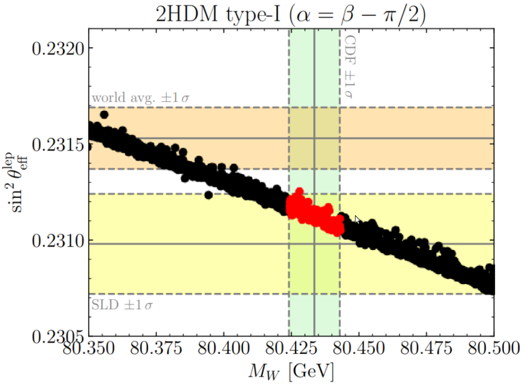
$$\Delta M_W \approx \frac{M_W}{2}\frac{c_W^2}{c_W^2 - s_W^2}\Delta\rho^{\rm BSM}$$

Side remark: correlation M_W and $\sin\theta^{\text{eff}}$ via $\Delta\rho$

[slide from J. Braathen]

Results: M_W vs $\sin^2\theta_{\text{eff}}^{\text{lep}}$

[Bahl, JB, Weiglein 2204.05269]

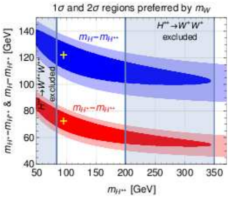


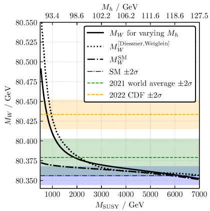
- **2HDM can explain the discrepancy in M_W!**
- Light tension with world average for $\sin^2\theta_{\text{eff}}^{\text{lep}}$ but good agreement with SLD result
- ***World average***: using both LEP result (based on forward-backward asymmetry of bottom quarks) + SLD result (based on left-right asymmetry) which show a *3σ discrepancy* between each other
- ***SLD***: most precise *single* measurement of $\sin^2\theta_{\text{eff}}^{\text{lep}}$ and only depends on leptonic couplings

Example models for M_W

Higgs triplet VEV $\mathcal{O}(1\text{ GeV})$

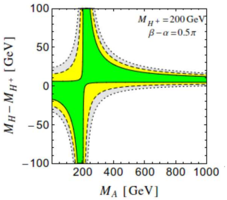
- e.g. neutrino seesaw [Heeck'22] or within MRSSM [Athron,etal'22]

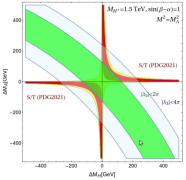




2HDM

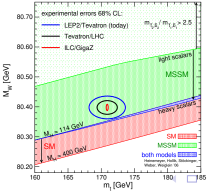
- Splitting $M_{A,H,H^\pm}$ breaks custodial sym. [Broggio,Chun,etal'14]
- Easy to accomm. a_μ, M_W^{CDF} [Lee,Cheung,etal'22]

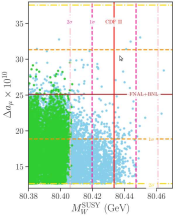




MSSM

- Splitting within $\tilde{t}, \tilde{b}$ sector breaks custodial sym. [Heinemeyer,Hollik,DS,etal'06]
- Now strongly constrained by LHC mass limits and M_h [Yang,Zhang'22]





Outline

Discrepancy

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

or $\approx 10 \times 10^{-10}$? — conclusions $\approx$ unchanged

Two important general points

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

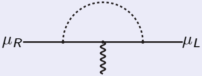
but: expect $a_\mu^{\mathrm{NP}} \sim a_\mu^{\mathrm{SM,weak}} \times \left(\frac{M_W}{M_{\mathrm{NP}}}\right)^2 \times$ couplings

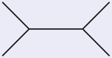
Two important general points

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

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

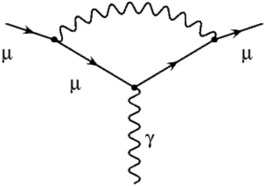


compare: 

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

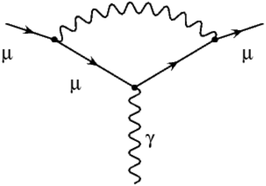
EWPO

Connection to chirality flip, and structure of BSM



$$\mathcal{L}_{\text{eff}} = -\frac{Qe}{4m_\mu} a_\mu \times \bar{\psi}_L \sigma_{\mu\nu} \psi_R F^{\mu\nu}$$

Connection to chirality flip, and structure of BSM



$$\mathcal{L}_{\text{eff}} = -\frac{Qe}{4m_\mu} a_\mu \times \bar{\psi}_L \sigma_{\mu\nu} \psi_R F^{\mu\nu}$$

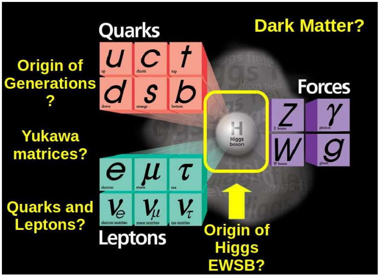
But:

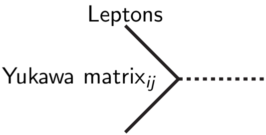
EW gauge invariant a_μ-operator: $\bar{L}\sigma_{\mu\nu}\mu_R F^{\mu\nu}\langle H\rangle$

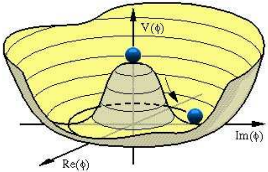
$$a_\mu \sim m_\mu \times \underbrace{(\text{some VEV}) \times (\mu_{L\leftrightarrow R}\text{-flipping param.})}_{\text{related to muon mass generation, potential enhancement!}} \times \frac{(\text{other couplings})}{M^2_{\text{typical}}}$$

In SM: $= m_\mu^{\text{tree}}$

Window to the muon mass generation mechanism (Higgs/Yukawa sectors)







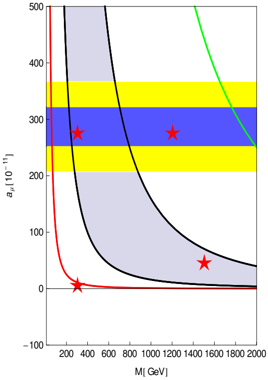
(changed by new physics?)

Second connection of a_μ: Dark Matter, (light?) dark sectors? Hard to see in detectors but could couple to muon $\rightsquigarrow$ large effects possible!

many concrete examples of both kinds of connections

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

$$a_\mu \sim \frac{m_\mu \times (\text{some VEV}) \times (\mu_{L\leftrightarrow R}\text{-flipping parameter})}{M^2_{\text{typical}}} \times (\text{other couplings})$$

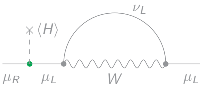


Typical behaviour: $\sim$ chirality flip ($\rightsquigarrow$ Higgs!) and masses

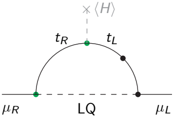
$$a_\mu \sim \frac{m_\mu \times (\text{some VEV}) \times (\mu_{L\leftrightarrow R}\text{-flipping parameter})}{M^2_{\text{typical}}} \times (\text{other couplings})$$

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

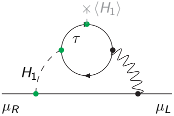
  Similar in Z', Dark Z_d models

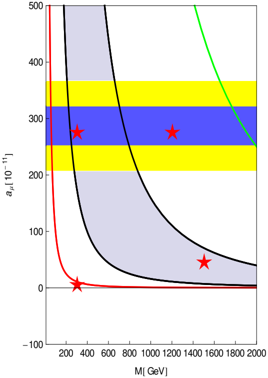


- LQ: $g_L g_R \frac{m_\mu m_t}{M_{\text{LQ}}^2}$



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

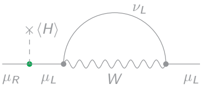




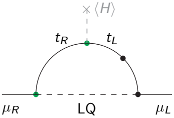
Typical behaviour: $\sim$ chirality flip ($\rightsquigarrow$ Higgs!) and masses

$$a_\mu \sim \frac{m_\mu \times (\text{some VEV}) \times (\mu_{L\leftrightarrow R}\text{-flipping parameter})}{M^2_{\text{typical}}} \times (\text{other couplings})$$

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



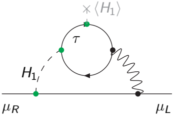
- LQ: $g_L g_R \frac{m_\mu m_t}{M_{LQ}^2}$



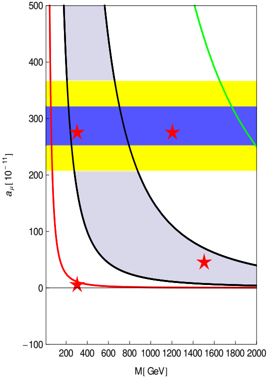
Can also involve Higgs couplings to b, c or new particles.

Beware: $\Delta m_\mu / m_\mu \sim g_L g_R m_t / m_\mu$ restricts couplings

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



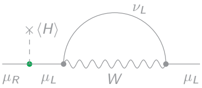
Well motivated; many variants; many constraints



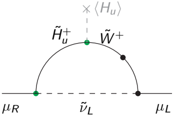
Typical behaviour: $\sim$ chirality flip ($\rightsquigarrow$ Higgs!) and masses

$$a_\mu \sim \frac{m_\mu \times (\text{some VEV}) \times (\mu_{L\leftrightarrow R}\text{-flipping parameter})}{M^2_{\text{typical}}} \times (\text{other couplings})$$

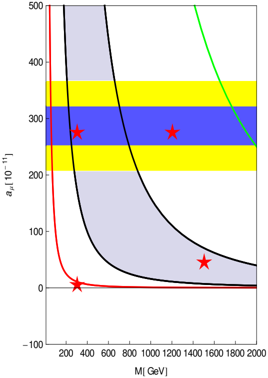
- EWSM: $\propto \frac{m_\mu^2}{M_W^2}$



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



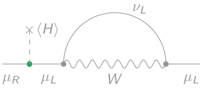
- rad. m_μ $\sim \frac{m_\mu^2}{M^2_{\text{NP}}}$



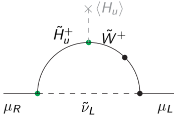
Typical behaviour: $\sim$ chirality flip ($\rightsquigarrow$ Higgs!) and masses

$$a_\mu \sim \frac{m_\mu \times (\text{some VEV}) \times (\mu_{L\leftrightarrow R}\text{-flipping parameter})}{M^2_{\text{typical}}} \times (\text{other couplings})$$

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



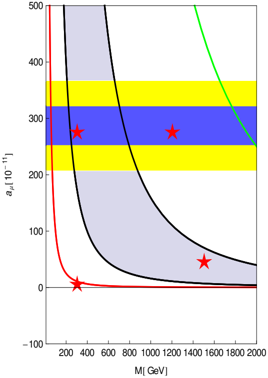
- SUSY: $\alpha \frac{m_\mu^2 \tan\beta}{M^2_{\text{SUSY}}} \frac{\mu}{M_{\text{SUSY}}}$



Well-motivated theory. Many other advantages

- rad. m_μ $\sim \frac{m_\mu^2}{M^2_{\text{NP}}}$

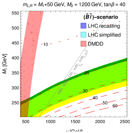
E.g. MSSM for $\tan\beta \to \infty$ [Bach,Park,DS,Stöckinger-Kim'15]



Example models for a_μ — strong experimental constraints

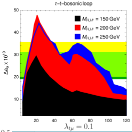
SUSY: MSSM, MRSSM

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



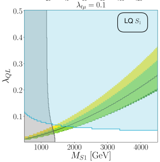
Two-Higgs doublet model

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



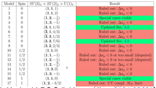
Lepto-quarks, vector-like leptons

- 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]

Outline

Relations and estimates

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

Can unify description of MDM, EDM, CLFV: dipole coefficients c^{ij} to leptons i, j

$c^{ij} \propto$ VEV $\times$ chir.-flip:

$$\Delta a_e \sim \Delta a_\mu \times \left\{ \left(\frac{m_e^2}{m_\mu^2}\right)^{\text{naive scaling}}, \left(\frac{m_e}{m_\mu}\right)^{\text{flavour-indep.}}_{\text{new chiral. flips}}, \left(\frac{m_e^4}{m_\mu^4}\right)^{\text{2HDM low } M_H} \right\}$$

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

$$BR(\mu \to e\gamma) \approx \left(\frac{\Delta a_\mu}{3 \times 10^{-9}}\right)^2 2 \times 10^{-13} \left(\frac{\theta_{\mu e}}{10^{-5}}\right)^2,$$

Relations and estimates

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

Can unify description of MDM, EDM, CLFV: dipole coefficients c^{ij} to leptons i, j

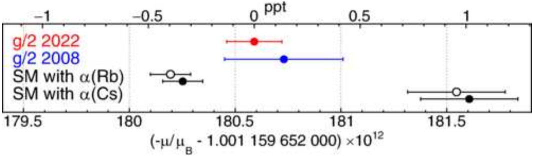
$c^{ij} \propto$ VEV $\times$ chir.-flip:

$$\Delta a_e \sim \Delta a_\mu \times \left\{ \left(\frac{m_e^2}{m_\mu^2}\right)^{\text{naive scaling}}, \left(\frac{m_e}{m_\mu}\right)^{\text{flavour-indep.}}_{\text{new chiral. flips}}, \left(\frac{m_e^4}{m_\mu^4}\right)^{\text{2HDM low } M_H} \right\}$$

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

$$BR(\mu \to e\gamma) \approx \left(\frac{\Delta a_\mu}{3 \times 10^{-9}}\right)^2 2 \times 10^{-13} \left(\frac{\theta_{\mu e}}{10^{-5}}\right)^2,$$

- If Δa_μ is nonzero $\Rightarrow$ constraints on LFV/CPV parameters, particularly from d_e, $\mu \to e\gamma$
- a_e can become sensitive to BSM with non-naive scaling, BUT:



a_e measurement Fan etal '23

$\alpha(Rb)$ measurement Morel etal (Sorbonne) '20

$\alpha(Cs)$ measurement Parker etal (Berkeley) '18

- a_τ: motivated to measure at the order of EW corrections $\sim 10^{-6}$

Outline

Questions for Anomalies workshop 2021/now:

- Is there a common link between anomalies?
- Are we leaving any stone unturned?
- What's the interplay between $g-2$ and B-physics, τ-physics, dark sector physics and high-energy (TeV-scale) physics? M_W, a_e?

Some thoughts (updated):

- $g-2$, M_W can be well connected to high-energy physics (with chiral enhancements/custodial sym.viol.)
- or to dark sectors
- it can be explained in many models (even simultaneously) (though in each model we have to go to special parameter regions)
- It is not easy to explain simultaneously with B-anomalies (see e.g. Z'? Leptoquarks?) easier without $R(K^{(*)})$
- Hence:
  1. explanations of $g-2$ typically contain potential flavour (violating) parameters, which are strongly constrained
  2. if all "anomalies" are real, then very special models needed $\rightsquigarrow$ progress!

Summary of main points

many longstanding and new "anomalies"

- discrepancies Exp/Exp Exp/SM SM/SM
- Exciting time for BSM: many potential explanations but also strong constraints (LHC, dark matter, flavour)
- Intriguing directions (dark sector, origin of mass/flavour/EWSB...)
- Progress from further LHC+dark matter data

BUT: inconcistencies everywhere

- a_μ: HVP lattice vs KLOE/Babar/CMD-2 etc vs CMD-3
- M_W: CDF 2022 vs ATLAS 2023 vs LEP/M_W vs $\sin^2\theta^{\text{lep,eff,SLD<LEP}}$
- a_e: $\alpha(Cs)$ vs $\alpha(Rb)$
- BSM physics might explain the mismatch in $\sin^2\theta^{\text{lep,eff,SLD<LEP}}$; a_μ HVP is hard to explain via BSM [Masiero,Paradisi,Passera'21]

Important measurements: $e^+e^- \to \pi^+\pi^-$ (Belle-2), M_W (LHC Run-2,3)