Pre-SUSY 2021

Muon g-2

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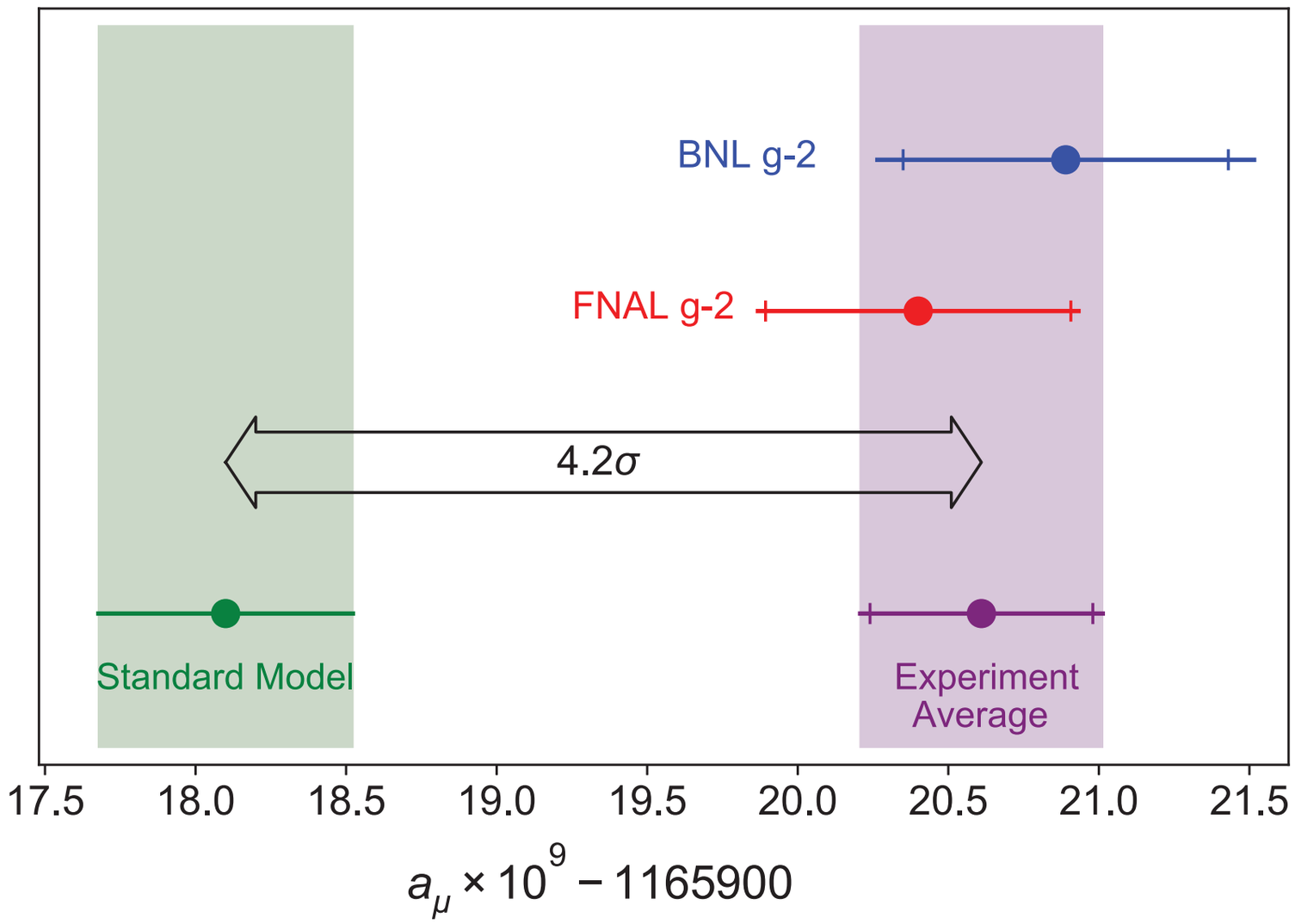
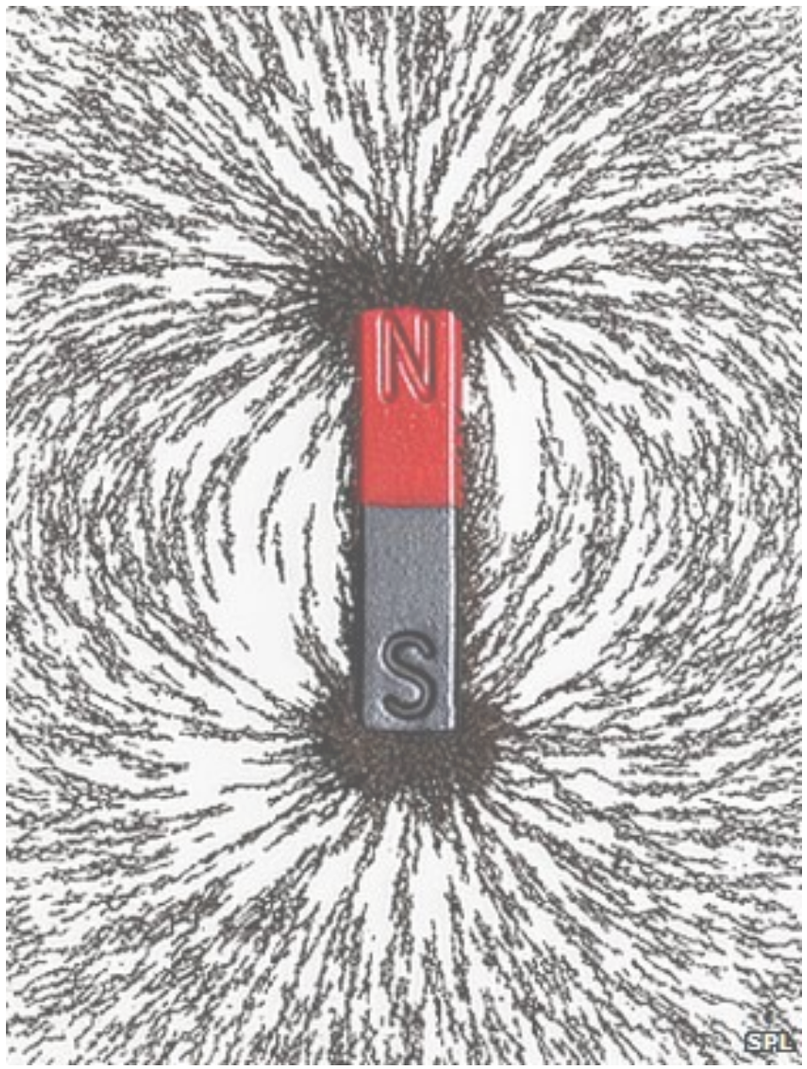
1. Why muon g-2?



Muon g-2 Phys.Rev.Lett. 126 (2021) 141801

Definition

Being charged spin 1/2 particles, leptons are tiny ***magnetic dipoles*** with the ***magnetic dipole moment*** aligned with the spin:



$$\vec{\mu} = g_\ell \left(\frac{q}{2m_\ell} \right) \vec{S}$$

electric charge (±*e*)

lepton mass

Dirac theory predicts $g_\ell = 2$

In quantum field theory, loop corrections give:

$$\boxed{a_\ell \equiv (g_\ell - 2)/2} \neq 0$$

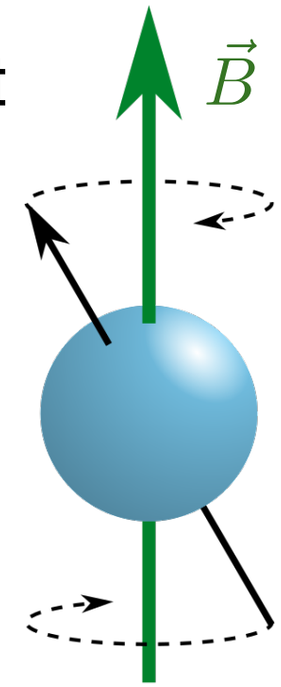
anomalous magnetic moment

How do we measure a_μ?

Our particles then interact with *external* magnetic fields such that

torque $\vec{N} = \vec{\mu} \times \vec{B}$

and this makes their spin *precess* about the field direction



Measuring the precession frequency allows to determine *g*

From now on, let's focus on muons:

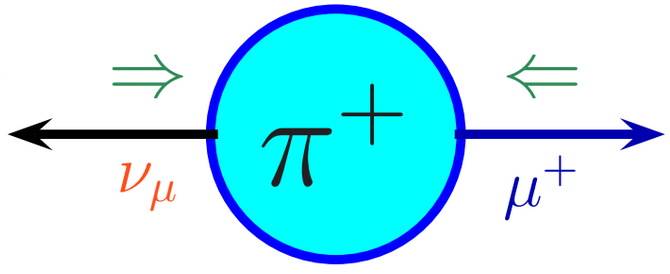
$m_\mu \approx 106\ \mathrm{MeV}$ *mass*

$\tau_\mu \approx 2.2\ \mu\mathrm{s}$ *lifetime*

$\mu^- \to e^- \bar{\nu}_e \nu_\mu \quad (\approx 100\%)$ *decay*

We can *produce* muons by protons hitting a target → pions → pion decays:

Neutrinos are only left-handed, pions have spin 0, muons must be left-handed too



highly polarised muon beam

How do we measure a_μ?

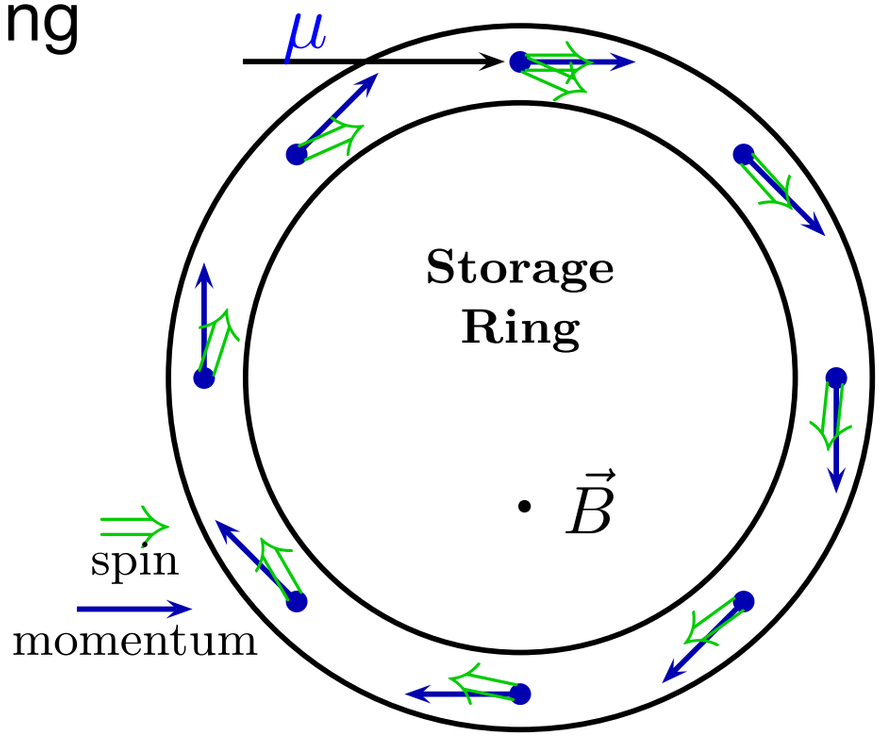
The muons are injected into a magnetic storage ring (field perpendicular to their velocity):

$$\vec{\omega}_c = -\frac{q\vec{B}}{m\gamma}, \qquad \vec{\omega}_s = -\frac{gq\vec{B}}{2m} - (1-\gamma)\frac{q\vec{B}}{\gamma m}$$

cyclotron frequency *precession frequency*

The difference is the *anomalous* precession ω

$$\vec{\omega}_a = \vec{\omega}_s - \vec{\omega}_c = -\left(\frac{g-2}{2}\right)\frac{q\vec{B}}{m} = -a_\mu \frac{q\vec{B}}{m}$$



In presence of an electric field too (e.g. for vertical focusing) the formula becomes

$$\vec{\omega}_a = -\frac{q}{m_\mu}\left[a_\mu \vec{B} - \left(a_\mu - \frac{1}{\gamma^2-1}\right)\vec{v}\times\vec{E}\right] \qquad \vec{v}\cdot\vec{B} = \vec{v}\cdot\vec{E} = 0, \quad c = 1$$

Vanishes for the "magic" momentum

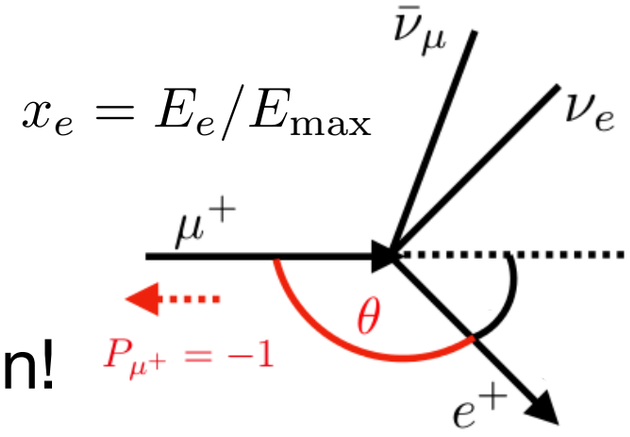
$$p_\mu = 3.094\ \text{GeV} \;\Rightarrow\; \gamma \equiv \frac{1}{\sqrt{1-v^2}} = 29.3$$

a_μ can be determined by precise measurements of ω_a and B only

How do we measure a_μ?

Because weak interactions *violate parity* ($W^\pm$ only couple to LH fermions) the muon decay is not isotropic. In the muon rest frame:

$$\frac{d^2\Gamma^\pm}{dx_e\, d\cos\theta} = \frac{G_\mu^2 m_\mu^5}{192\pi^3}\, x_e^2\, \left(3 - 2x_e \pm P_\mu\, \cos\theta\, (2x_e - 1)\right)$$

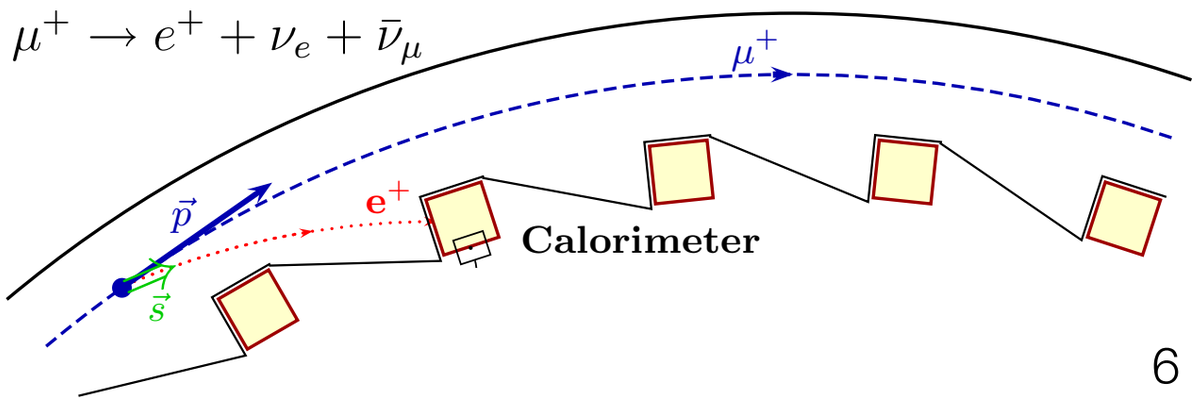


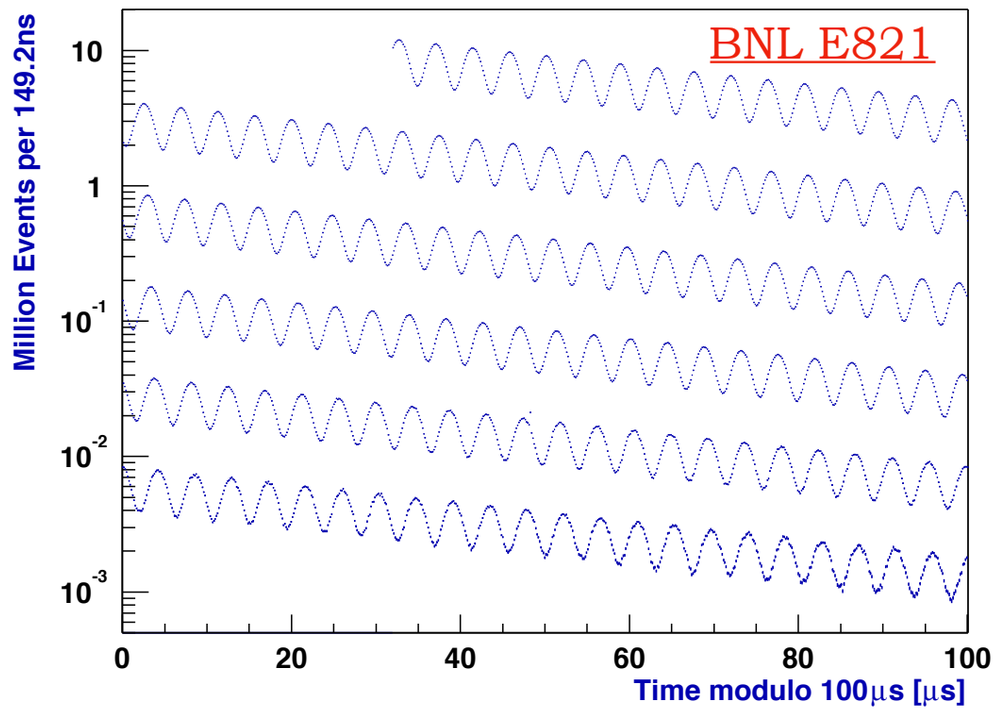
The direction of the positron is correlated to the muon spin!

In the lab frame: $E_{\rm lab} \approx \gamma E(1 + \cos\theta)$ → depends on θ

⇒ the number of positrons above a certain threshold energy *E* is modulated at frequency ω_a, which we can then measure:

$$N(t) = N_0(E)\, \exp\left(\frac{-t}{\gamma\tau_\mu}\right)\, [1 + A(E)\, \sin(\omega_a t + \phi(E))]$$





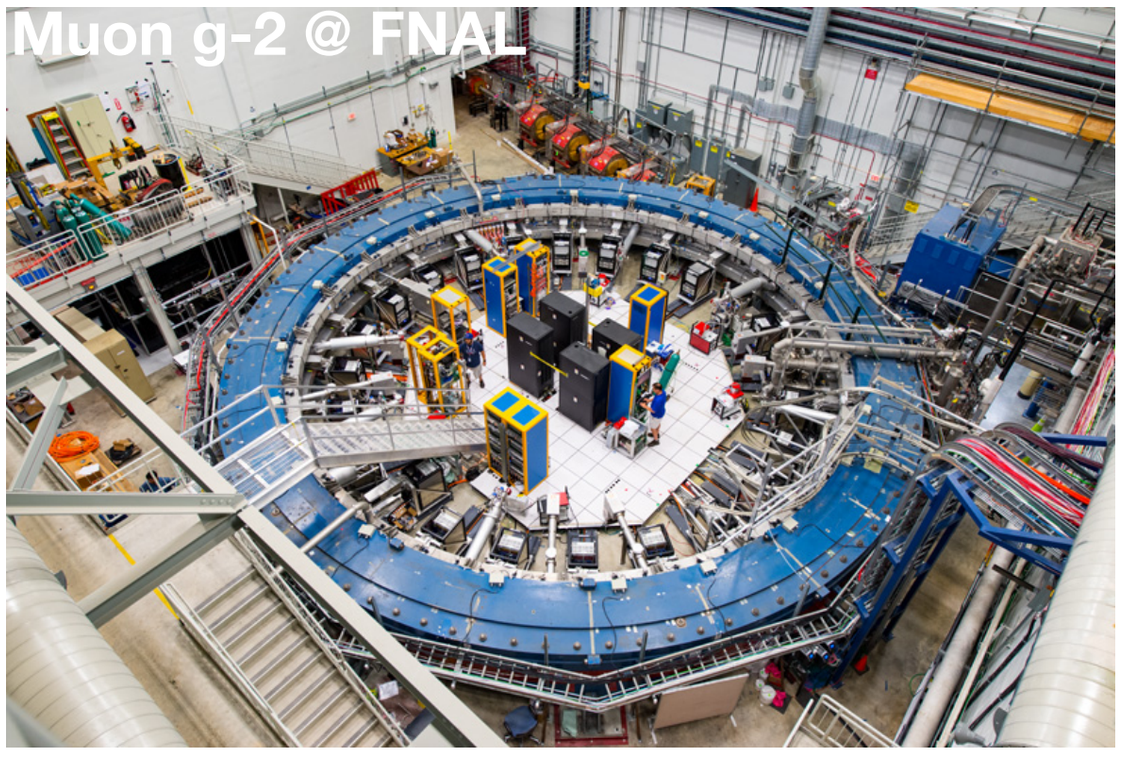
Experimental results and prospect

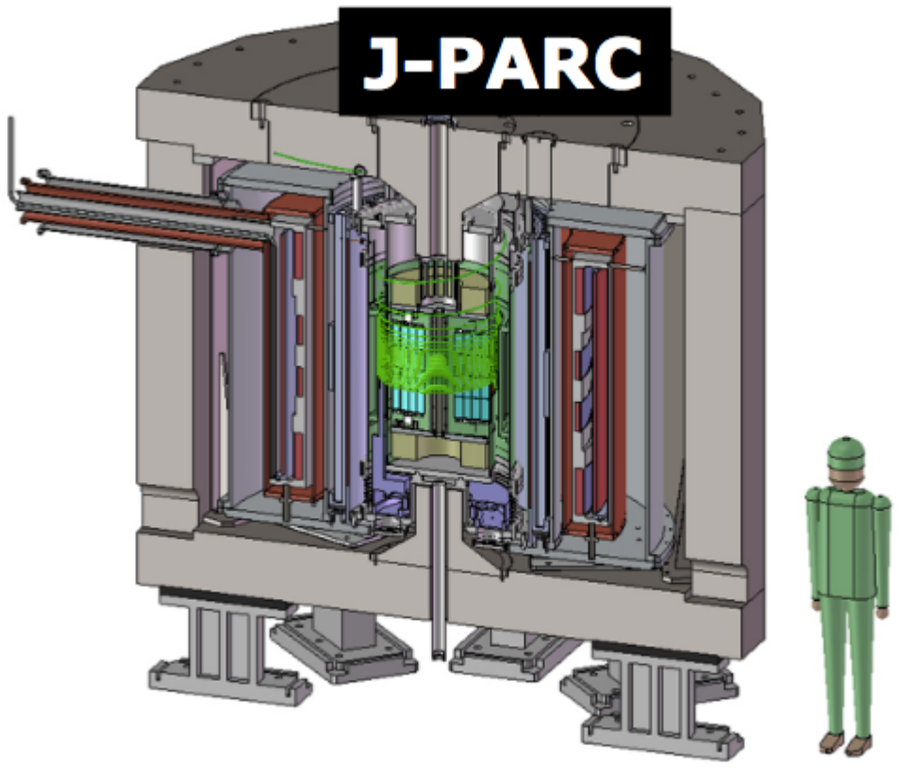
Using the above technique experiments at Brookhaven and Fermilab measured:

$$a_\mu\ (\mathrm{BNL\ '06}) = (116\,592\,089 \pm 63) \times 10^{-11} \quad (0.54\mathrm{ppm}) \qquad \text{BNL E821}$$

$$a_\mu\ (\mathrm{FNAL\ '21}) = (116\,592\,040 \pm 54) \times 10^{-11} \quad (0.46\mathrm{ppm}) \qquad \text{FNAL Muon g-2}$$

The final expected sensitivity of the FNAL experiment is 0.1ppm. A sensitivity ~BNL will be also achieved by another experiment under construction at J-PARC, using a *completely different concept* (lower-momentum muons, no electric field)

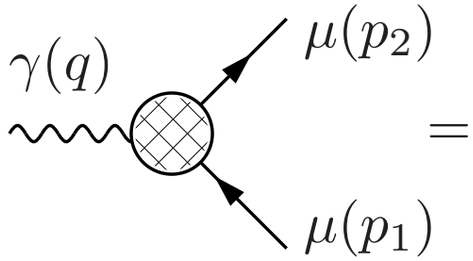




Theoretical prediction

What does the Standard Model predict for the value of a_μ?

We are interested in how muons interact with a magnetic field, that is, in the zero-momentum-transfer limit of the muon-muon-photon vertex function:

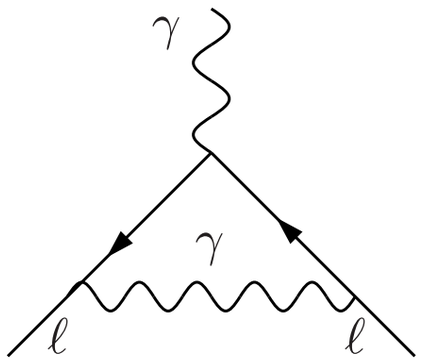


$$= (-\mathrm{i}e)\,\bar{u}(p_2)\left[\gamma^\mu F_\mathrm{E}(q^2) + \mathrm{i}\frac{\sigma^{\mu\nu}q_\nu}{2m_\mu}F_\mathrm{M}(q^2)\right]u(p_1) \quad \Rightarrow \quad F_\mathrm{M}(0) = a_\mu$$

Any field that can correct this vertex at loop level will contribute to a_μ

Leading-order QED:

Schwinger '48



$$\Rightarrow \quad a_\ell = \frac{\alpha}{2\pi} \approx 0.00116141$$

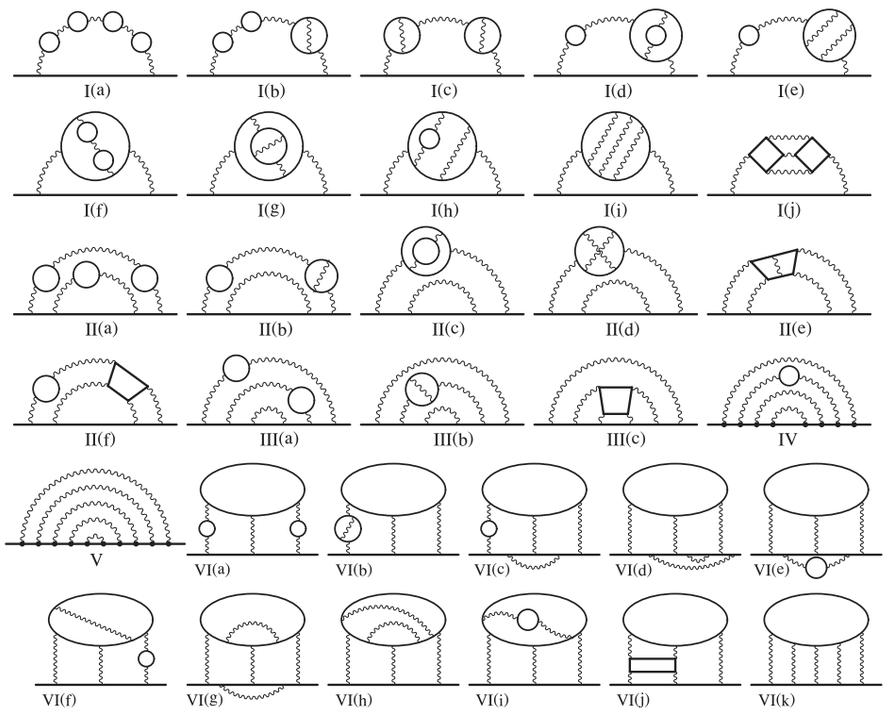
Historically one of the first triumphs of QED!

Theoretical prediction

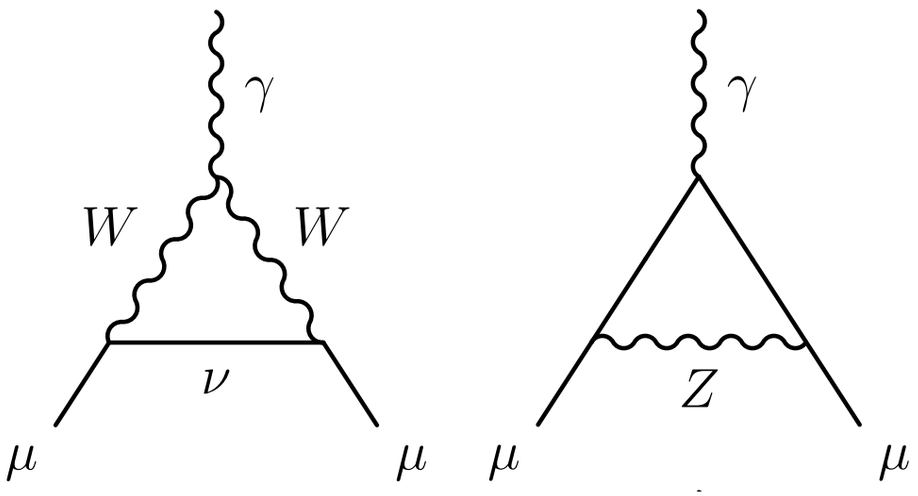
The QED calculation has been completed up to order $(\alpha/\pi)^5$ (12672 diagrams!) :

$$a_\mu^{\mathrm{QED}}(\alpha(a_e)) = 116\,584\,718.842(7)(17)(6)(100)(28)[106] \times 10^{-11}$$

"White paper" (WP) arXiv:2006.04822



Uncertainties two orders of magnitude smaller than the experimental one!



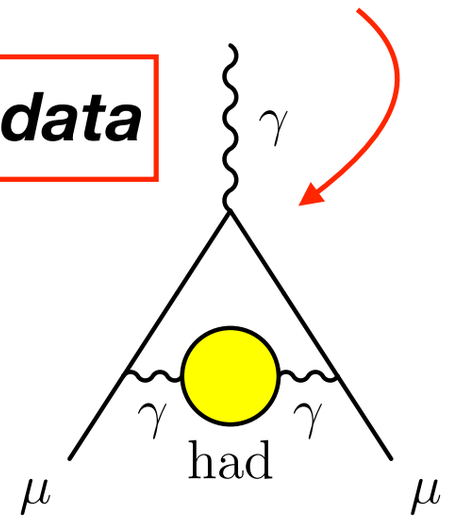
The electroweak contributions are relatively small and the uncertainties also under control, 1-loop + 2-loop + leading 3- and 4-loop give:

$$a_\mu^{\mathrm{EW}} = 153.6(1.0) \times 10^{-11}$$ WP '20

Larger uncertainties stem from the *hadronic* contributions

Theoretical prediction

We can not use perturbative theory in QCD to calculate something like this



One approach is to extract the hadronic vacuum polarisation ***from data***

Analyticity and unitarity (in particular, the *optical theorem* relating the imaginary part of the amplitude to the cross section e^+e^- into hadrons) allows to write the leading hadronic contribution as

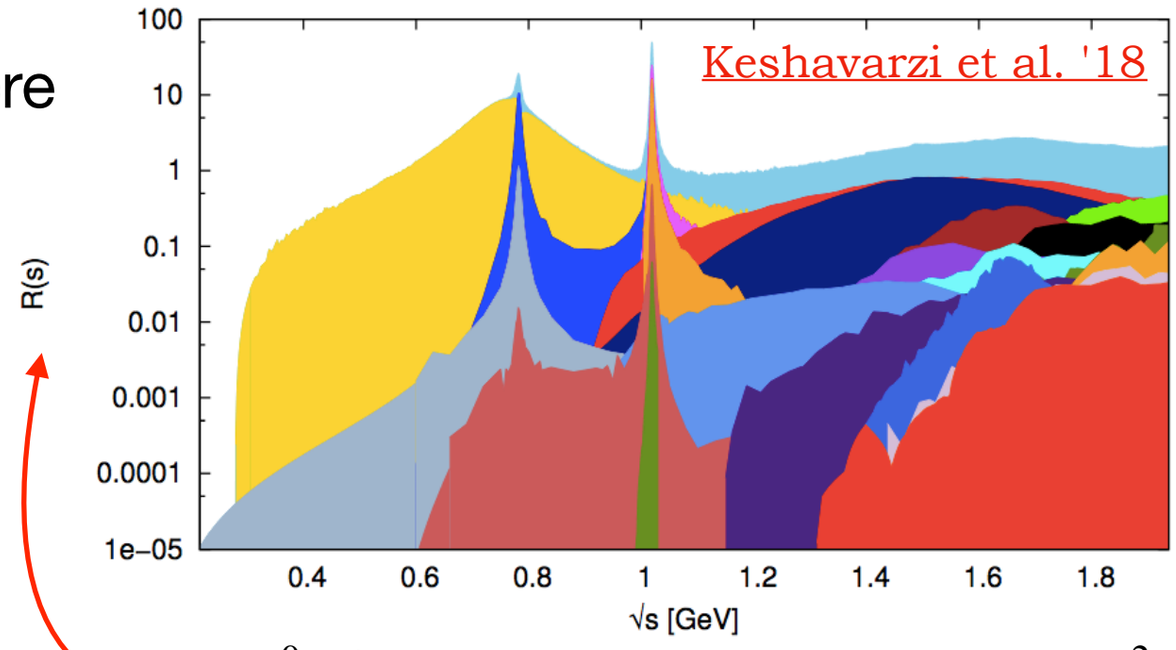
$$a_\mu^{\mathrm{HVP,\,LO}} = \frac{1}{4\pi^3}\int_{m_\pi^2}^{\infty} ds\, K(s)\,\sigma^0(e^+e^- \to \text{hadrons}) \qquad K(s) = \int_0^1 dx \frac{x^2(1-x)}{x^2 + (1-x)(s/m_\mu^2)}$$

Low-energy data (i.e. pion modes) weight more

$$\Rightarrow a_\mu^{\mathrm{HVP,\,LO}} = 6931(40) \times 10^{-11}$$ WP '20

uncertainty comparable to the exp one

NLO and other hadronic contributions have smaller errors



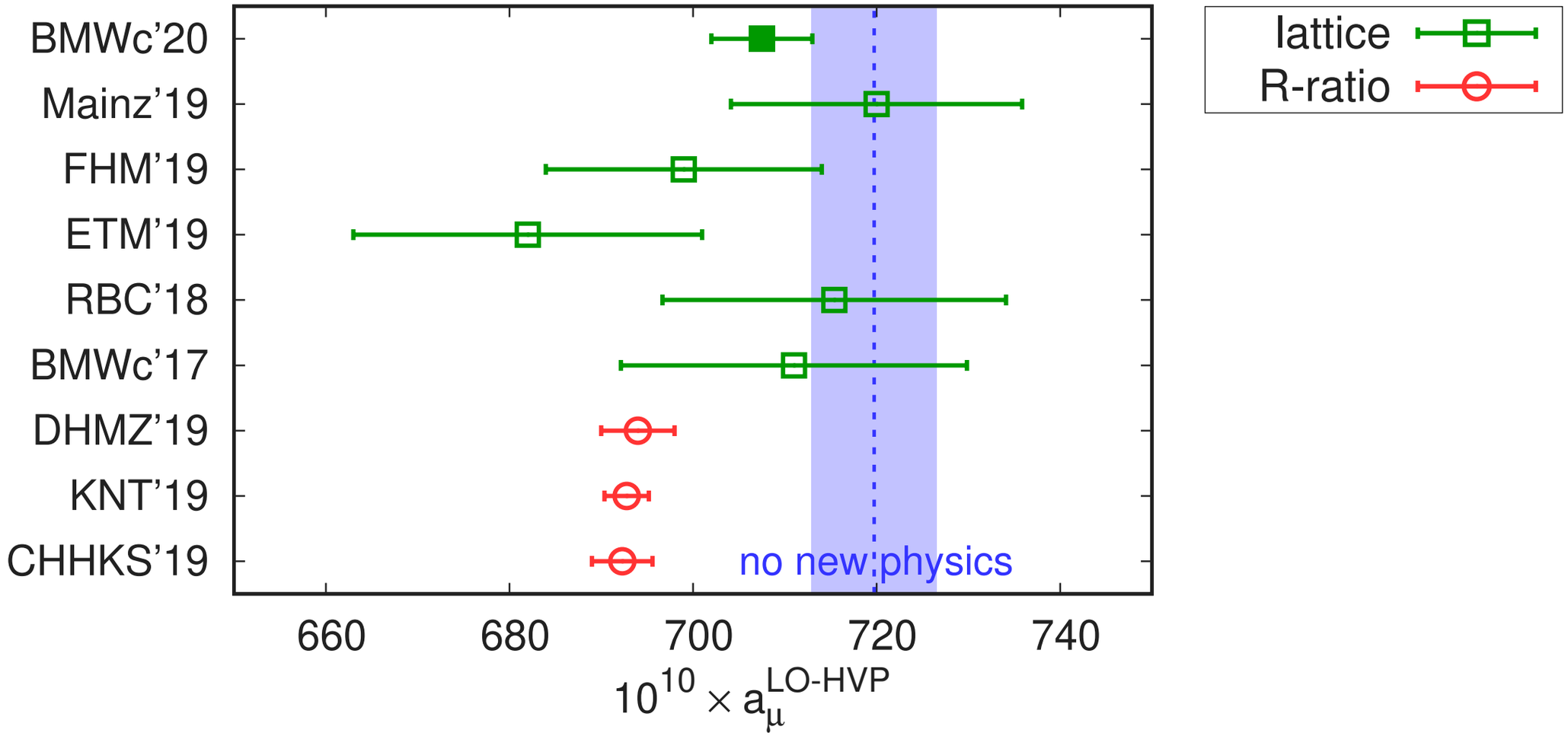
$$R(s) = \frac{\sigma^0(e^+e^- \to \text{hadrons}(+\gamma))}{\sigma_{\mathrm{pt}}}, \qquad \sigma_{\mathrm{pt}} = \frac{4\pi\alpha^2}{3s}$$

Theoretical prediction

One can also perform first-principle calculations within ***lattice QCD***.
The latest result of the BMW collaboration reached high precision:

$$\Rightarrow a_\mu^{\mathrm{HVP,\,LO}} = 7075(55) \times 10^{-11}$$

BMW Nature '21



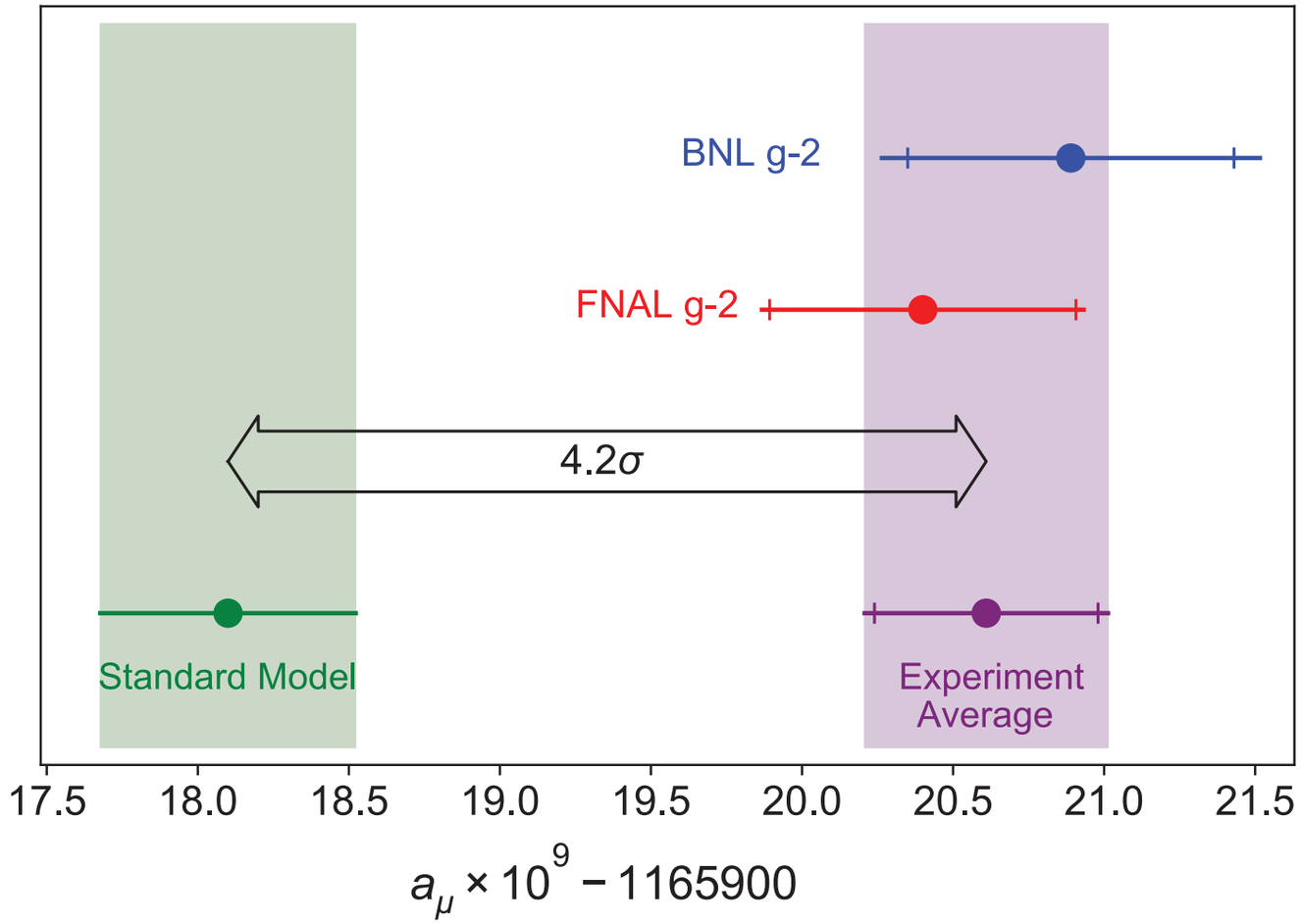
This result and those based on e^+e^- data are somewhat in tension (~2σ)

The famous discrepancy

Putting everything together, the SM prediction (using data-driven HVP) is

$$a_\mu\,(\mathrm{SM}) = (116\,591\,810 \pm 43) \times 10^{-11}$$ WP '20

Exp. comb. : $$a_\mu\,(\mathrm{BNL{+}FNAL}) = (116\,592\,061 \pm 41) \times 10^{-11}$$ FNAL Muon g-2



$$\Delta a_\mu \equiv a_\mu^{\mathrm{exp}} - a_\mu^{\mathrm{SM}} = 251(59) \times 10^{-11} \qquad (4.2\sigma)$$

2. Muon g-2 and New Physics (NP)

The FNAL result caused a sensation, as it *excluded* the most mundane explanations of the discrepancy (that has been there for ~20 years, since early BNL data), i.e.

- ~~a statistical fluctuations (*very* unlikely now)~~
- ~~unknown systematics affecting the BNL measurement~~

Now ***only two possibilities are left***:

- underestimated hadronic contributions
  (as the tension with the lattice calculation *may* suggest)
- contributions from additional fields in the loops, i.e. *new physics*!

How could NP solve the problem?

From now on, let's assume we indeed need new particles/interactions.
The NP contribution should be ***positive*** and quite large, *of the order of the EW one*:

$$a_\mu^{\rm EW}(\text{1-loop}) \simeq \frac{5}{3}\frac{G_F m_\mu^2}{8\sqrt{2}\pi^2} = \frac{5\, m_\mu^2}{192\pi^2}\frac{g^2}{M_W^2} \simeq 1.95\times 10^{-9}$$

Does this imply that the scale of NP (if weakly-coupled) should be ~100 GeV?

If $\Lambda_{\rm NP} \gg m_\mu$ NP effects can be encoded in the (dimension-6) dipole operator

model-dependent coefficient

chirality flip of the muon field

$$\mathcal{L} \supset \frac{e v}{8\pi^2}\frac{C}{\Lambda_{\rm NP}^2}(\bar\mu_L \sigma_{\mu\nu}\mu_R)\, F^{\mu\nu} + \text{h.c.} \quad \Rightarrow \quad a_\mu^{\rm NP} = \frac{m_\mu v}{2\pi^2}\frac{\text{Re}(C)}{\Lambda_{\rm NP}^2}$$

EW-symmetry breaking vev (for gauge invariance)

loop factors, couplings, mixing angles…

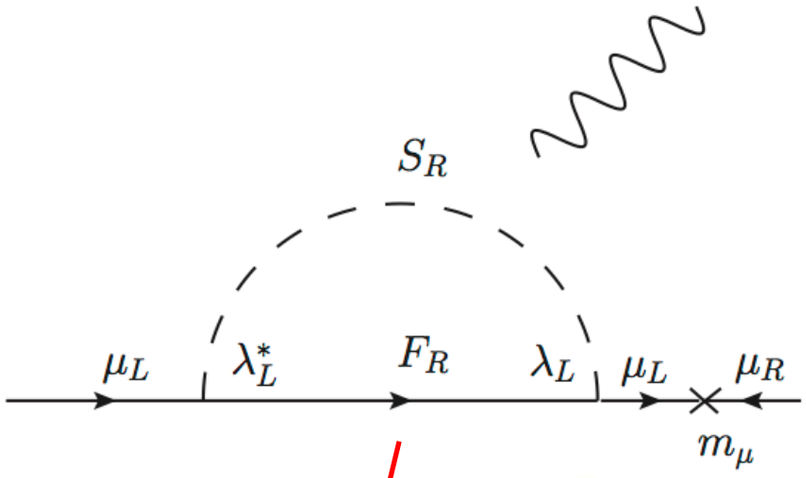
Requiring $a_\mu^{\rm NP} = \Delta a_\mu \quad \Rightarrow \quad \frac{\text{Re}(C)}{\Lambda_{\rm NP}^2} \approx [1.5,\, 2.4]\times 10^{-9}\ \ \text{GeV}^{-2} \qquad (1\sigma)$

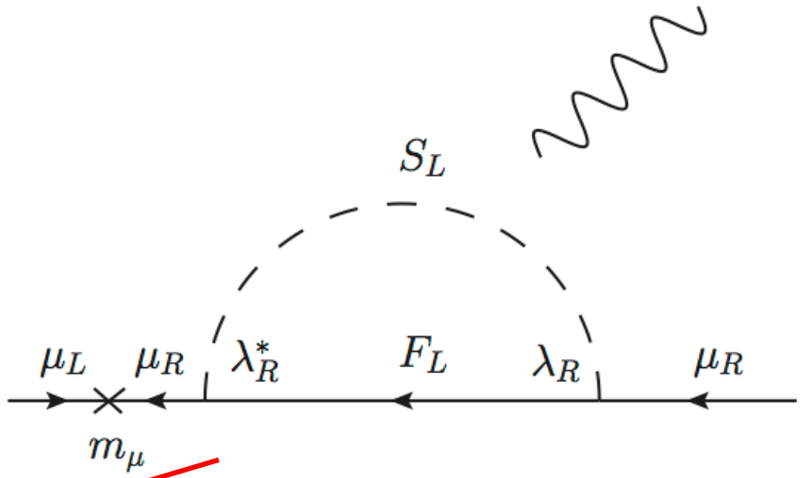
A simplified example

Let us consider a simple model with new fermions (*F*) and new scalars (*S*) coupling to muons with interactions of the kind $\lambda_{L(R)}\, \bar{F}\, S\, \mu_{L(R)}$

As we have seen, the goal is generating the dipole operator, proportional to an EW-breaking vev to provide a gauge invariant chirality flip → we need a Higgs insertion:

(i) Higgs insertion on the external line → *suppression* from the (small) muon Yukawa coupling, and *sign* of the contribution determined by the EM charges





$$x = M_F^2/M_S^2$$

$$a_\mu^{\rm NP} = -\frac{m_\mu^2}{8\pi^2 M_S^2} \sum_{F,S} \left(|\lambda_L|^2 + |\lambda_R|^2\right) \left[Q_F f_{LL}^F(x) + Q_S f_{LL}^S(x)\right] \qquad \left(f_{LL}^{F,S}(x) > 0, \quad f_{LR}^{F,S}(x) > 0\right)$$

EM charges $Q_F = Q_S - 1$

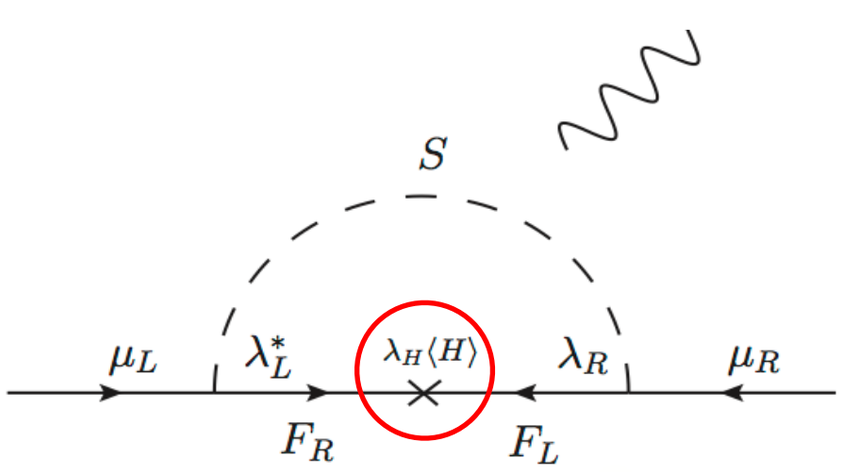
see e.g. LC Ziegler Zupan '18

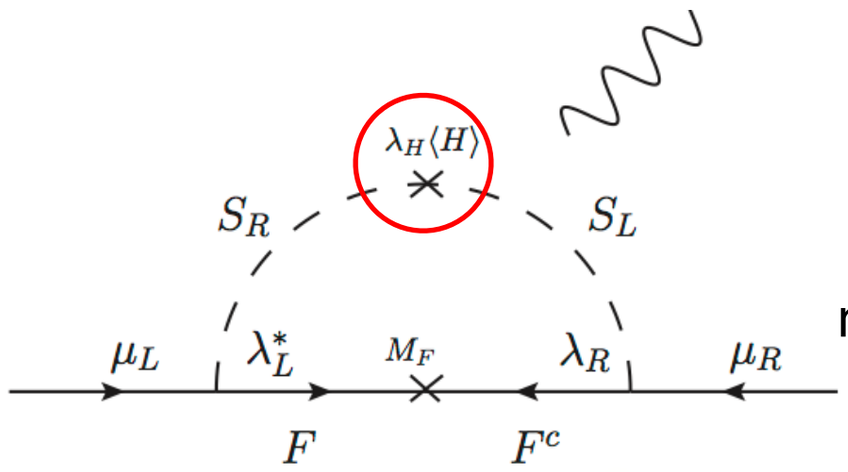
A simplified example

Let us consider a simple model with new fermions (F) and new scalars (S) coupling to muons with interactions of the kind $\lambda_{L(R)}\,\bar{F}\,S\,\mu_{L(R)}$

As we have seen, the goal is generating the dipole operator, proportional to an EW-breaking vev to provide a gauge invariant chirality flip → we need a Higgs insertion:

(ii) Higgs insertion inside the loop: we need another field that mixes with our scalar or fermion via a Higgs vev → no ~y_μ suppression (*chiral enhancement)*





muon Yukawa coupling

$$a_\mu^{\rm NP} = -\frac{m_\mu M_F}{8\pi^2 M_S^2}\sum_{F,S}{\rm Re}\,(\lambda_R^*\lambda_L)\,[Q_F f_{LR}^F(x) + Q_S f_{LR}^S(x)]$$

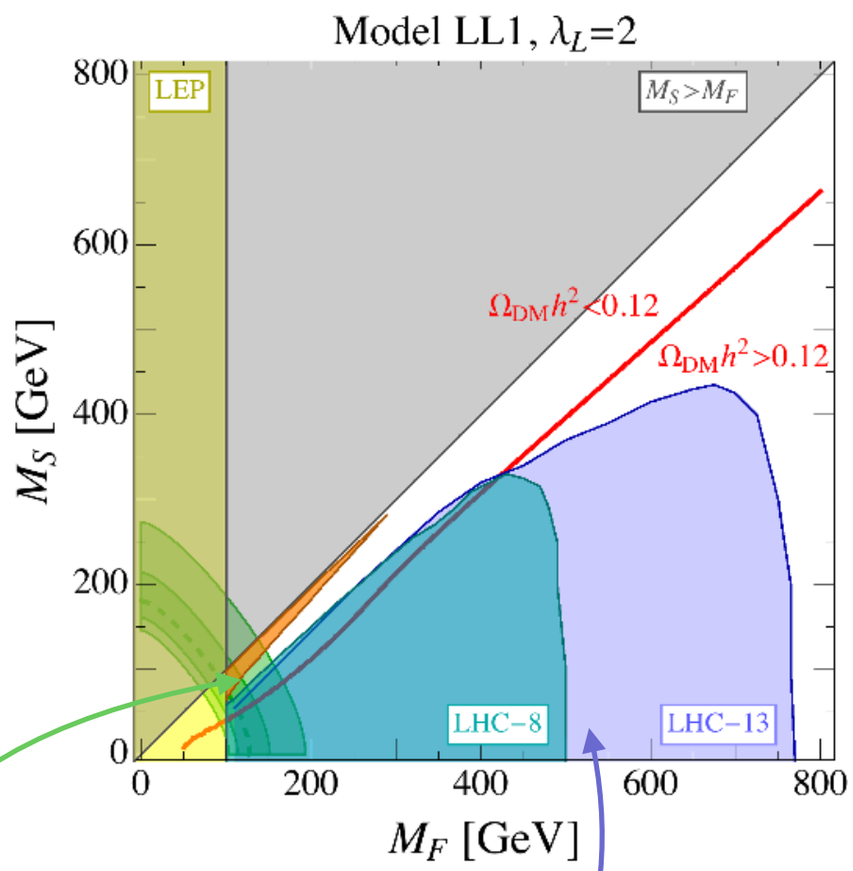
$$\propto \frac{\lambda_H v}{M_{F(S)}} \quad \text{(mixing)}$$

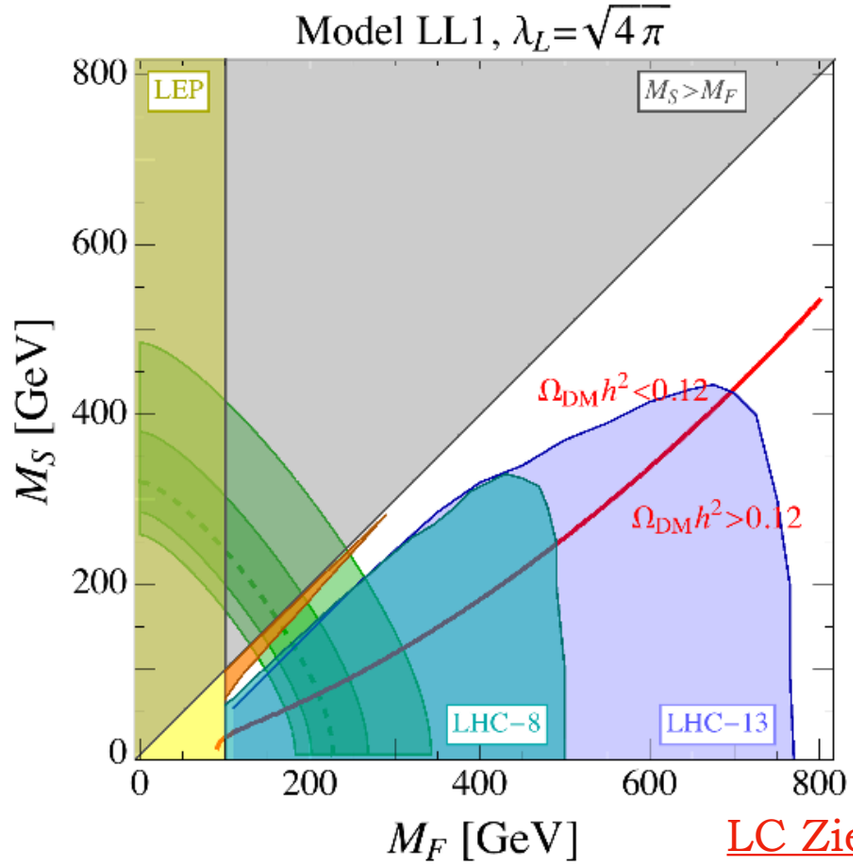
$$\lambda_H/y_\mu \quad \textit{enhancement} \quad (\mathcal{O}(10^3) \text{ for } \lambda_H \sim 1)$$

see e.g. LC Ziegler Zupan '18

A simplified example

Due to the suppression it is difficult to explain the anomaly in models of type (i):





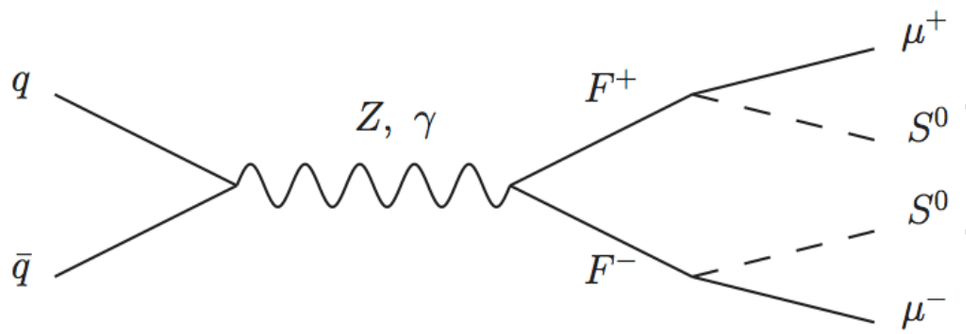
LC Ziegler Zupan '18

see also Athron et al. '21

region compatible with the discrepancy:

$$a_\mu^{\rm NP} = \Delta a_\mu$$

region excluded by LHC searches:



S could be dark matter

Models of type (ii) can instead explain the discrepancy with $M_{F,S} \sim \text{few} \times \text{TeV}$

Another minimal solution

In the above example we had to introduce at least 2 new fields, but in some models, it is possible to explain the g-2 discrepancy *with one new field only*

reviews in Biggio et al. ’14 & ’16, Lindner et al. '16, Athron et al. '21

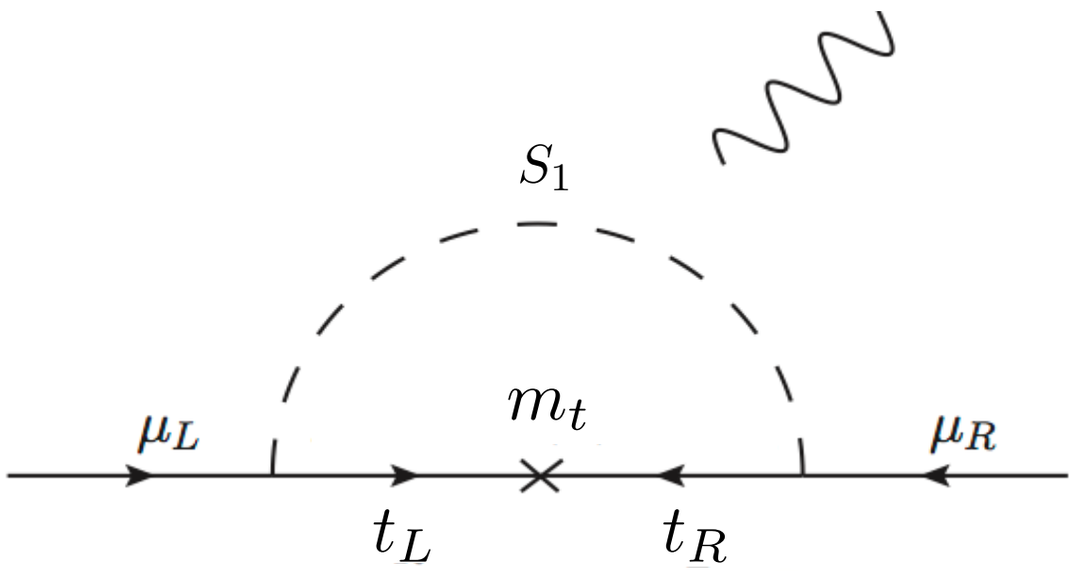
A possibility is *leptoquarks*, fields that couple to both leptons and quarks, e.g.:

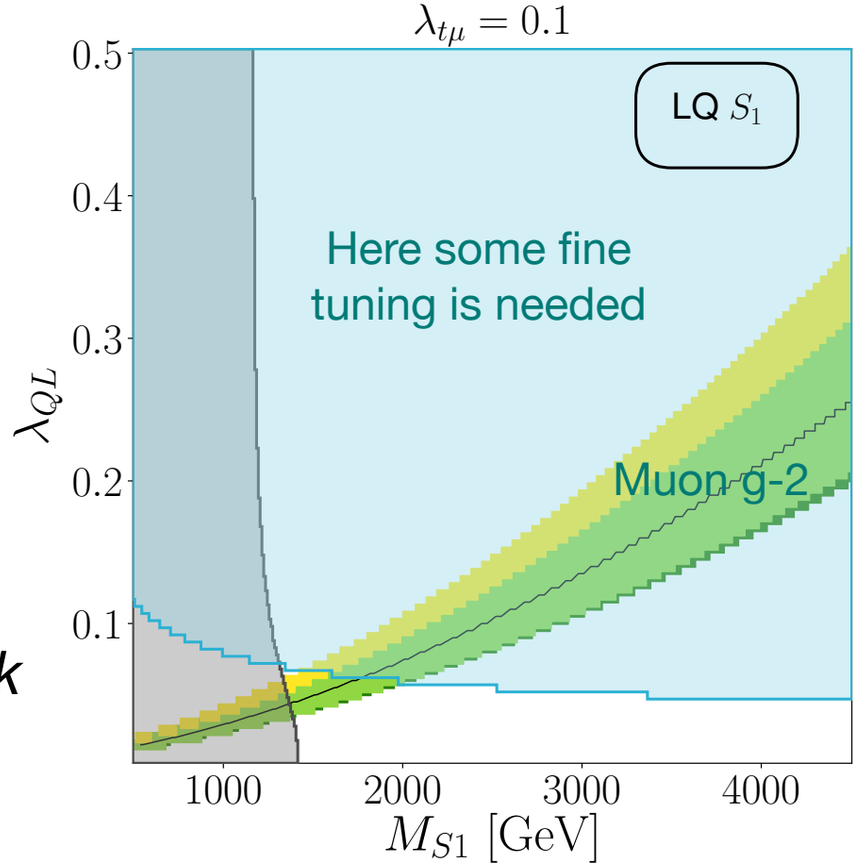
$S_1 \ (\overline{\mathbf{3}}, \mathbf{1}, 1/3)$

$SU(3)_c,\, SU(2)_L,\, U(1)_Y$

$$\mathcal{L}_{S_1} = -\left(\lambda_{QL} Q_3 \cdot L_2 S_1 + \lambda_{t\mu} t \mu S_1^* + h.c.\right)$$

Chakraverty et al. '01





Similar to the previous model, with *F* being the *top quark*

The leptoquark couples to both LH and RH muons, the chirality flip is due to the (large) top mass!

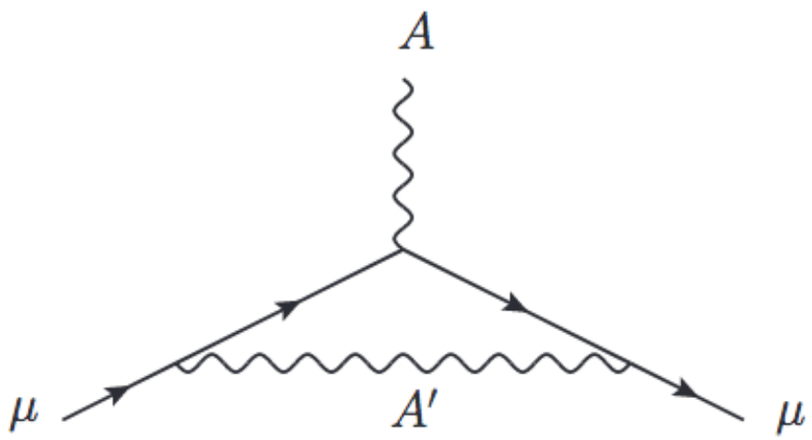
Athron et al. '21

A light possibility

The g-2 anomaly could also be caused by ***light***, ***very weakly-interacting*** particles, such as axion-like particles and light gauge bosons of new local symmetries

Example: *A'* from *gauged* $U(1)_{L_\mu - L_\tau}$ (one of the combinations of the global symmetries of the SM that are anomaly-free)

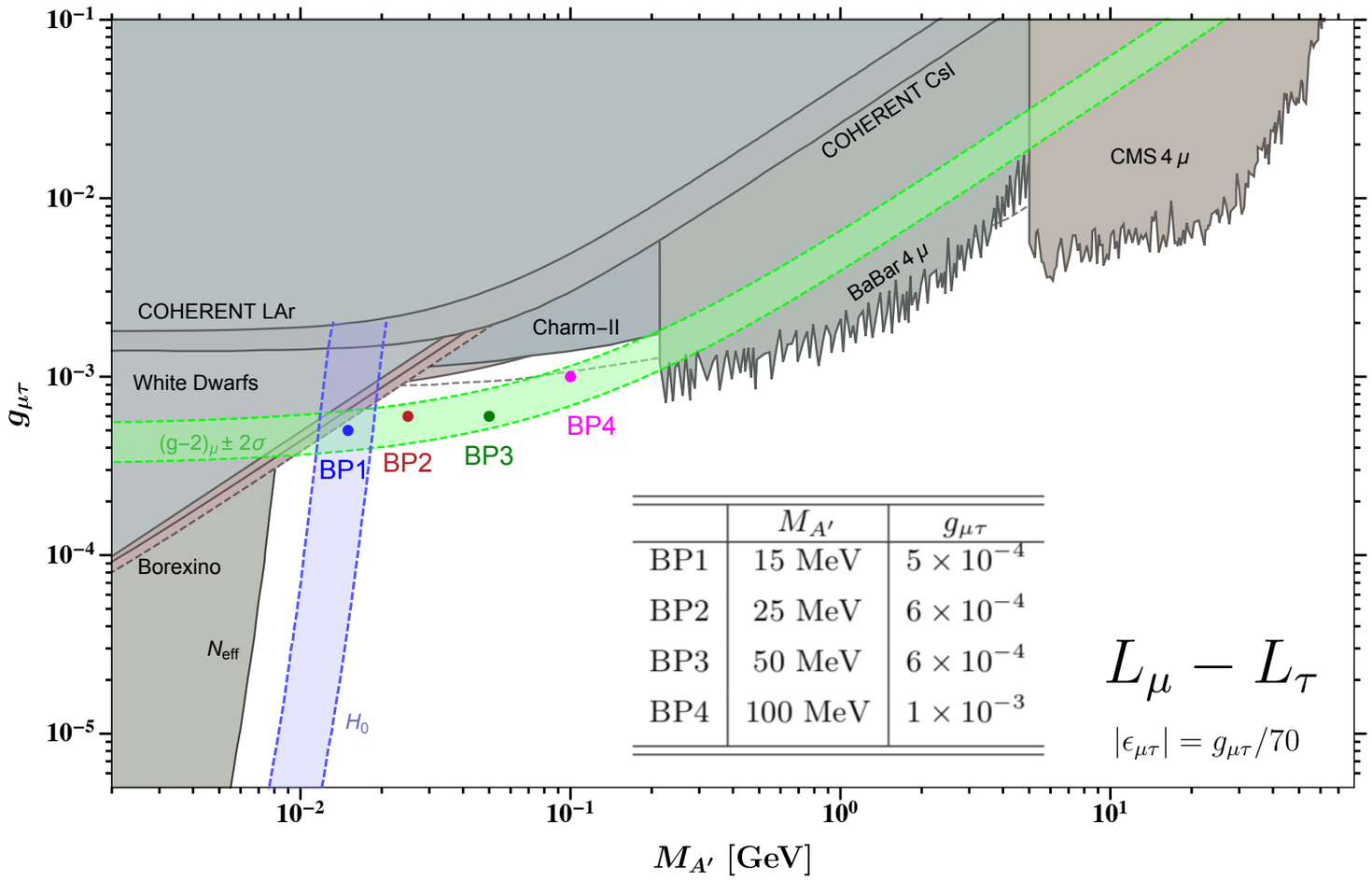
Xiao-Gang He et al. '91



$$\Delta a_\mu = Q_\mu^{x^2} \frac{\alpha_x}{\pi} \int_0^1 \mathrm{d}u \, \frac{u^2(1-u)}{u^2 + \frac{(1-u)}{x_\mu^2}}$$

$$\alpha_x = g_x^2/4\pi$$

$$x_\mu = m_\mu/M_{A'}$$



	$M_{A'}$	$g_{\mu\tau}$
BP1	15 MeV	5×10^{-4}
BP2	25 MeV	6×10^{-4}
BP3	50 MeV	6×10^{-4}
BP4	100 MeV	1×10^{-3}

Amaral et al. '21

What about SUSY?

In R-parity conserving SUSY models, the only SUSY particles that contribute to the g-2 are smuons (including $\tilde{\nu}_\mu$), charginos and neutralinos. The relevant parameters are:

$M_1,\ M_2,\ \mu$	$\tan\beta = \frac{v_u}{v_d}$	$m_L,\ m_R,\ [A_\mu]$
Bino, Wino, Higgsino mass parameters		LH/RH smuon mass terms, [trilinear coupling]

Mass matrices:

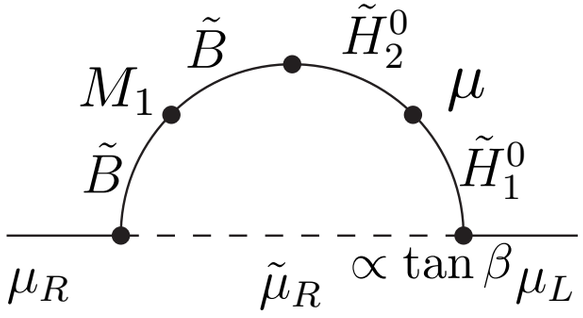
$$M_{\chi^\pm} = \begin{pmatrix} M_2 & M_W\sqrt{2}\sin\beta \\ M_W\sqrt{2}\cos\beta & \mu \end{pmatrix}$$ charginos

$$M_{\chi^0} = \begin{pmatrix} M_1 & 0 & -M_Z s_W \cos\beta & M_Z s_W \sin\beta \\ 0 & M_2 & M_Z c_W \cos\beta & -M_Z c_W \sin\beta \\ -M_Z s_W \cos\beta & M_Z c_W \cos\beta & 0 & -\mu \\ M_Z s_W \sin\beta & -M_Z c_W \sin\beta & -\mu & 0 \end{pmatrix}$$ neutralinos

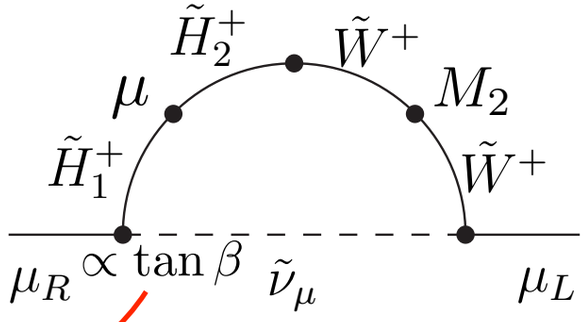
$$M^2_{\tilde{\mu}} = \begin{pmatrix} m_\mu^2 + m_L^2 + M_Z^2\cos 2\beta\,(-\frac{1}{2} + s_W^2) & m_\mu(-\mu\tan\beta + A_\mu^*) \\ m_\mu(-\mu^*\tan\beta + A_\mu) & m_\mu^2 + m_R^2 + M_Z^2\cos 2\beta\,(-s_W^2) \end{pmatrix}$$ smuons

What about SUSY?

A substantial contribution to the g-2 requires that either the neutralinos/charginos or the smuons are *substantially mixed* (e.g. if the lightest neutralino is ~Bino —i.e. M_2, $\mu \gg M_1$—and the smuons are not mixed, its contributions are *negative*)



The leading contributions then are:



$$a_\mu^{\mathrm{WHL}} = \frac{g_2^2}{8\pi^2}\frac{m_\mu^2 M_2}{m_{\mathrm{L}}^4}\,\mu\tan\beta\,F_a\left(\frac{M_2^2}{m_{\mathrm{L}}^2},\frac{\mu^2}{m_{\mathrm{L}}^2}\right) - \frac{g_2^2}{16\pi^2}\frac{m_\mu^2 M_2}{m_{\mathrm{L}}^4}\,\mu\tan\beta\,F_b\left(\frac{M_2^2}{m_{\mathrm{L}}^2},\frac{\mu^2}{m_{\mathrm{L}}^2}\right),$$

Wino-Higgsino-LH smuon/sneutrino

$$a_\mu^{\mathrm{BHL}} = \frac{g_1^2}{16\pi^2}\frac{m_\mu^2 M_1}{m_{\mathrm{L}}^4}\,\mu\tan\beta\,F_b\left(\frac{M_1^2}{m_{\mathrm{L}}^2},\frac{\mu^2}{m_{\mathrm{L}}^2}\right),$$

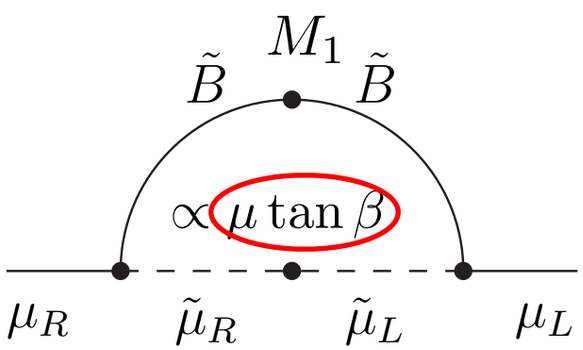
Bino-Higgsino-LH smuon

$$a_\mu^{\mathrm{BHR}} = -\frac{g_1^2}{8\pi^2}\frac{m_\mu^2 M_1}{m_{\mathrm{R}}^4}\,\mu\tan\beta\,F_b\left(\frac{M_1^2}{m_{\mathrm{R}}^2},\frac{\mu^2}{m_{\mathrm{R}}^2}\right),$$

Bino-Higgsino-RH smuon

$$a_\mu^{\mathrm{BLR}} = \frac{g_1^2}{8\pi^2}\frac{m_\mu^2}{M_1^3}\,\mu\tan\beta\,F_b\left(\frac{m_{\mathrm{L}}^2}{M_1^2},\frac{m_{\mathrm{R}}^2}{M_1^2}\right).$$

LH-RH smuon-Bino



Moroi '95

for reviews see Stöckinger '06, Athron et al. '21

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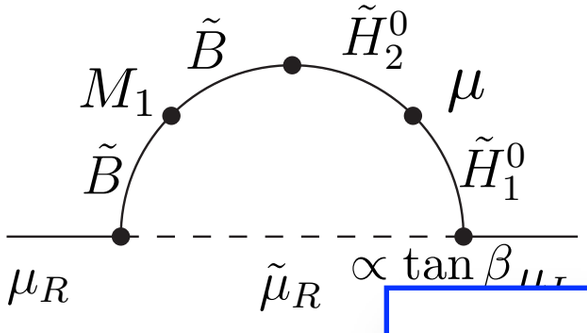

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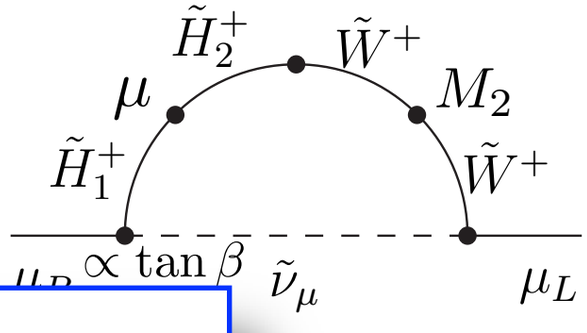


If $M_1 \sim M_2 \sim \mu \sim M_{\rm SUSY}$:

$$a_\mu^{\rm WHL} \approx 21 \times 10^{-10} {\rm sign}(\mu M_2) \left(\frac{500\ {\rm GeV}}{M_{\rm SUSY}}\right)^2 \frac{\tan\beta}{40},$$

$$a_\mu^{\rm BHL} \approx 1.2 \times 10^{-10} {\rm sign}(\mu M_1) \left(\frac{500\ {\rm GeV}}{M_{\rm SUSY}}\right)^2 \frac{\tan\beta}{40},$$

$$a_\mu^{\rm BHR} \approx -2.4 \times 10^{-10} {\rm sign}(\mu M_1) \left(\frac{500\ {\rm GeV}}{M_{\rm SUSY}}\right)^2 \frac{\tan\beta}{40},$$

$$a_\mu^{\rm BLR} \approx 2.4 \times 10^{-10} {\rm sign}(\mu M_1) \left(\frac{500\ {\rm GeV}}{M_{\rm SUSY}}\right)^2 \frac{\tan\beta}{40} \frac{\mu}{500\ {\rm GeV}}.$$

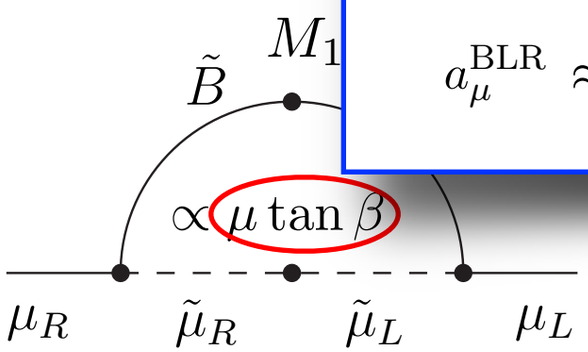
Moroi '95

o-Higgsino-
uon/sneutrino

o-Higgsino-
H smuon

o-Higgsino-
H smuon

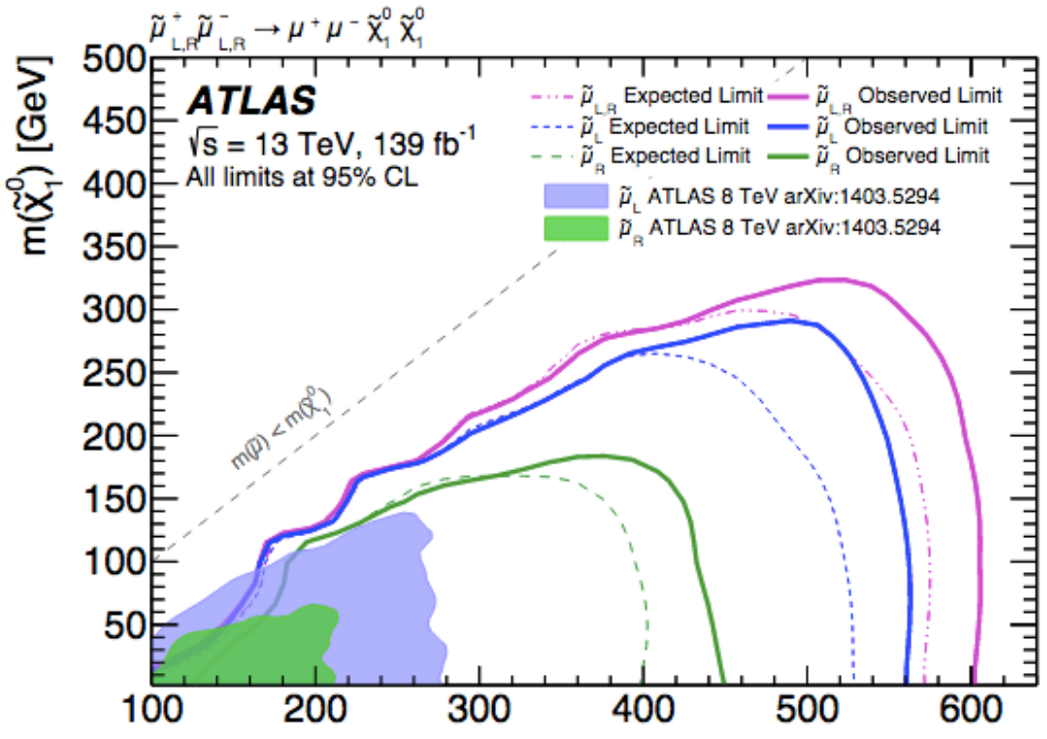
RH smuon-
Bino



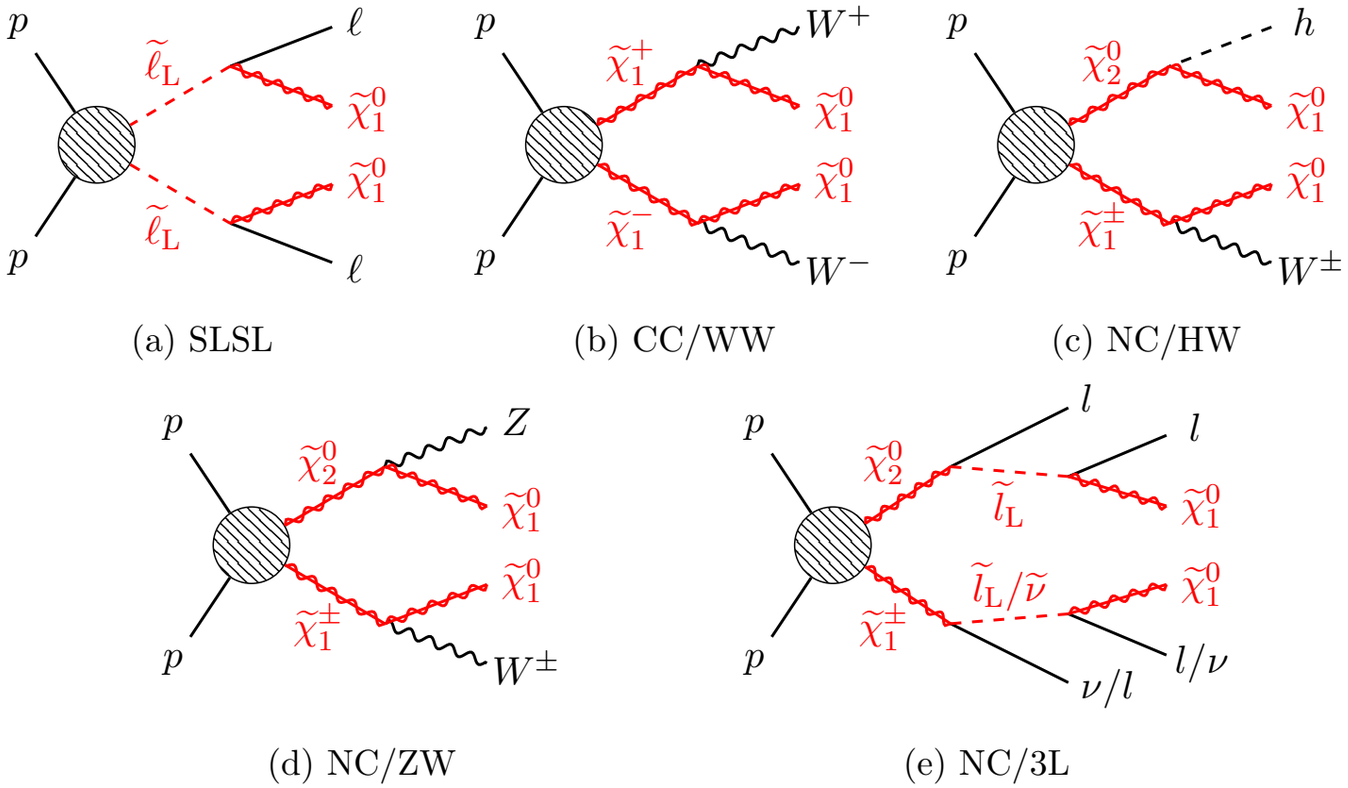
for reviews see Stöckinger '06, Athron et al. '21

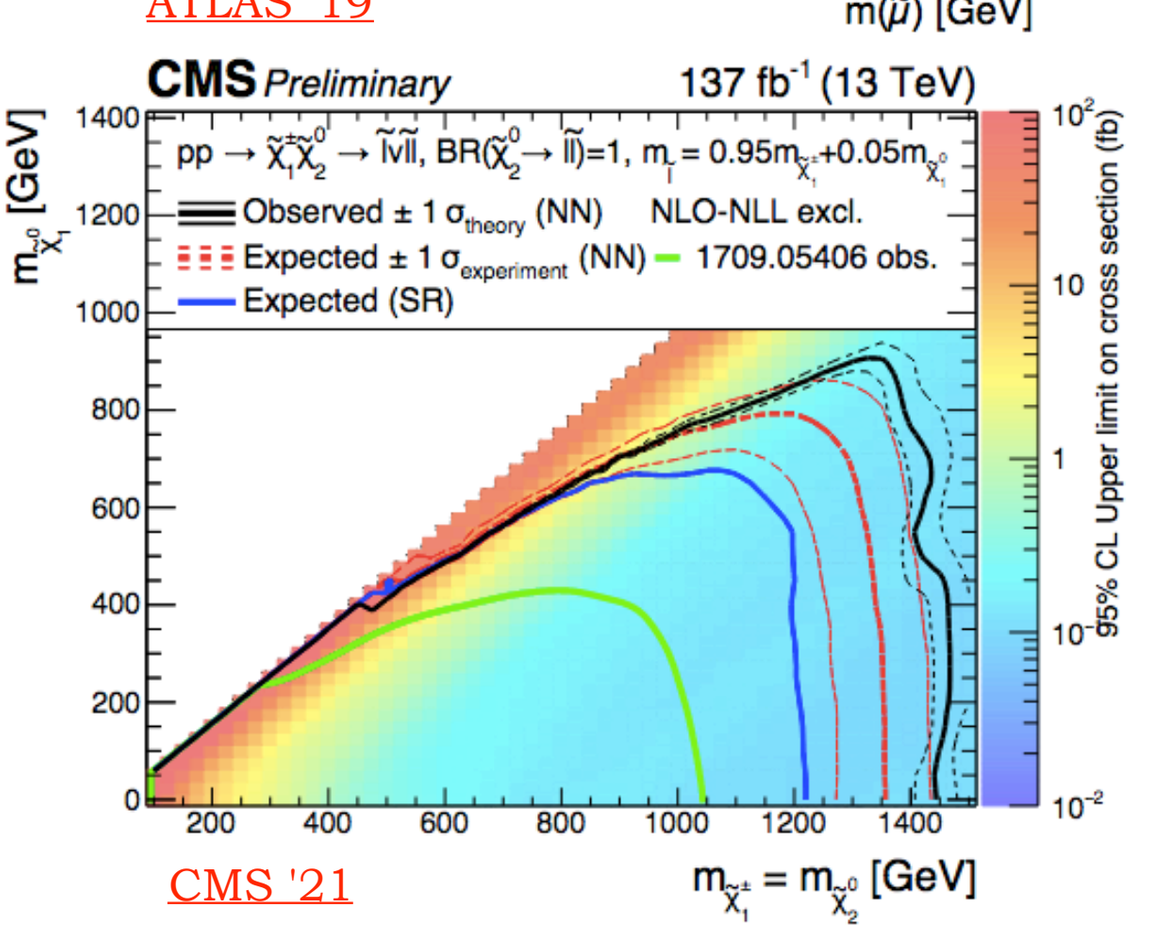
What about LHC searches for SUSY?

Extensive searches have been performed by ATLAS and CMS for the electro-weak production of SUSY sleptons/charginos/ neutralinos, that can exclude SUSY masses even above ~1 TeV (barring the cases with "*compressed spectrum*")



ATLAS '19

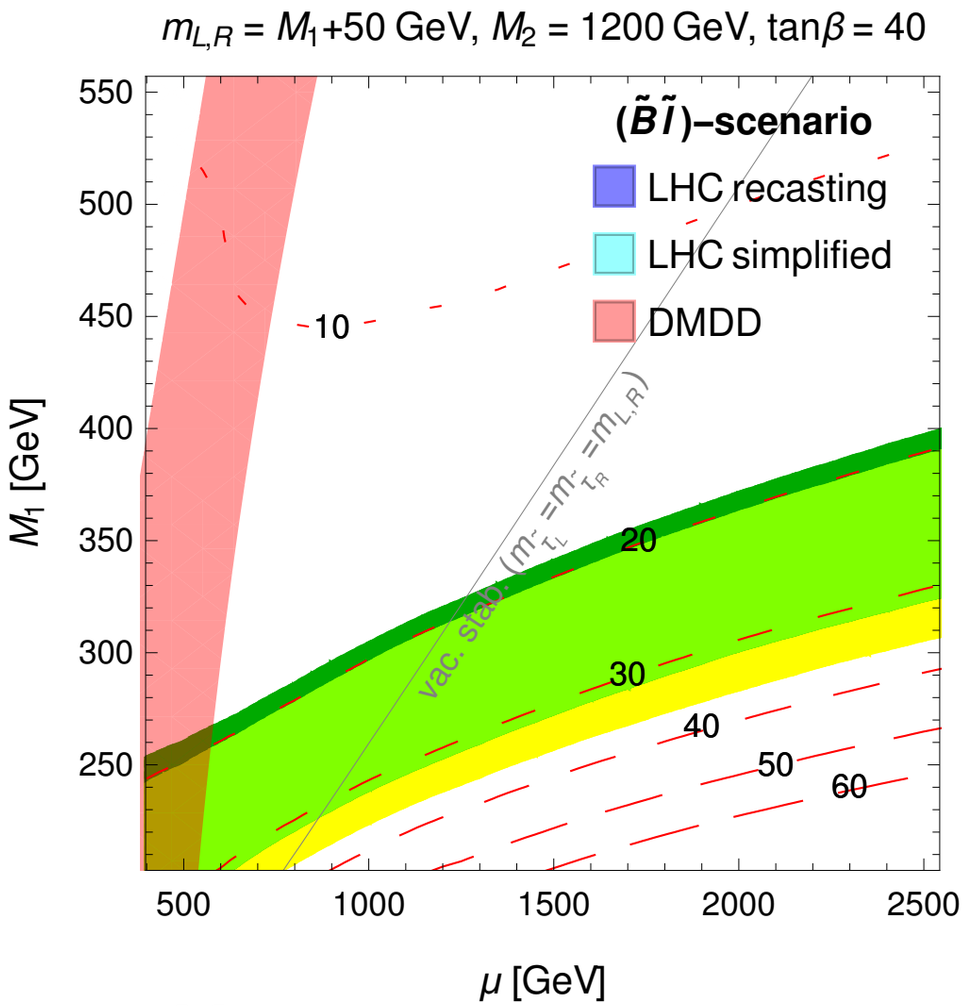


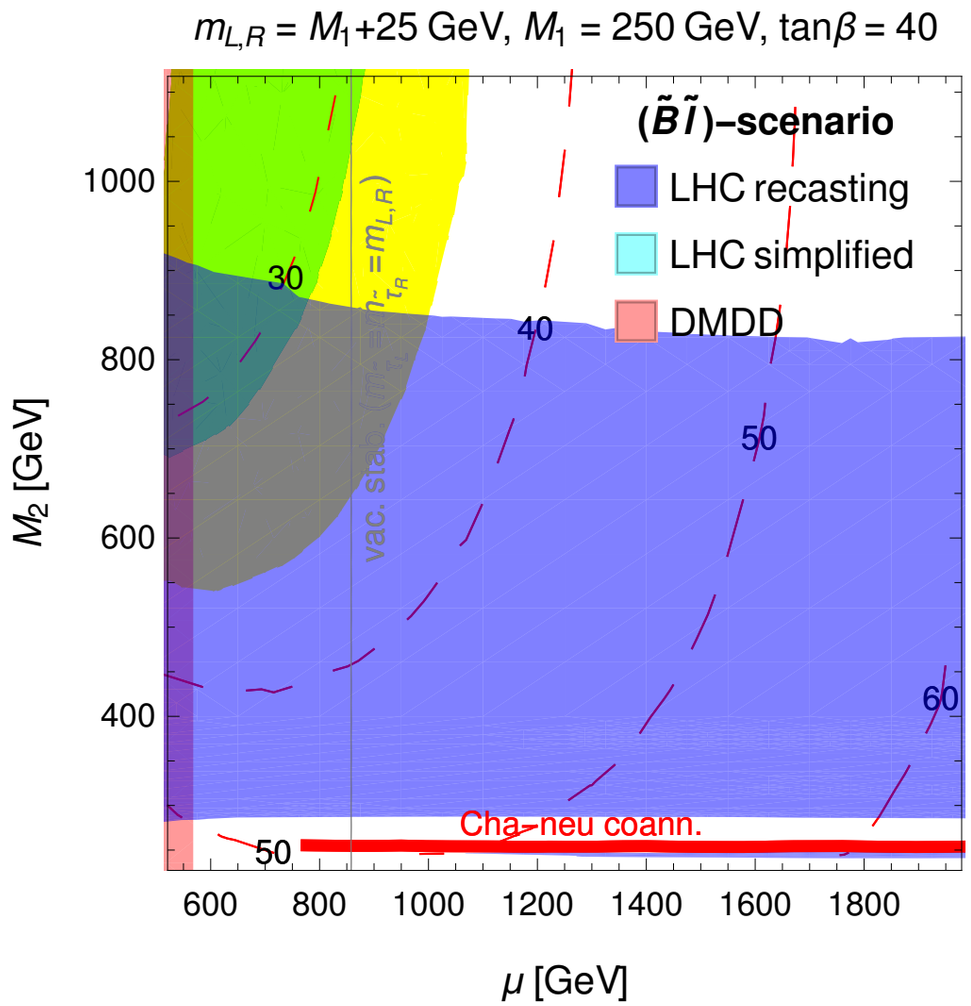


CMS '21

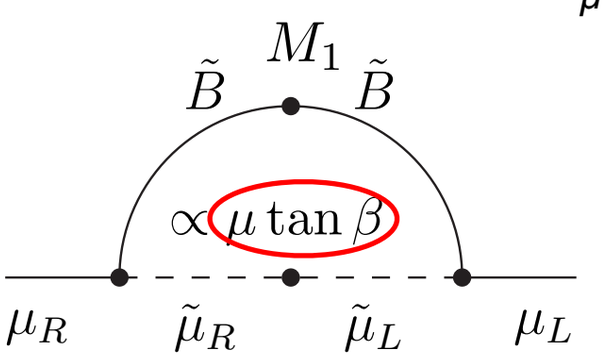
What about LHC searches for SUSY?

LHC searches can already probe substantial portion of the parameter space favoured by the g-2 anomaly





Athron et al. '21



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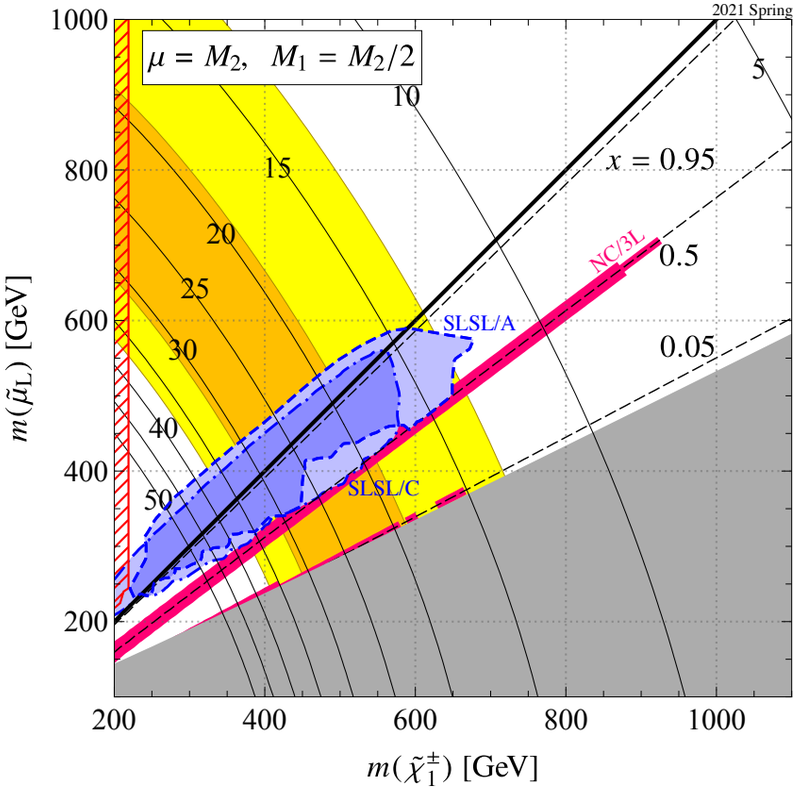
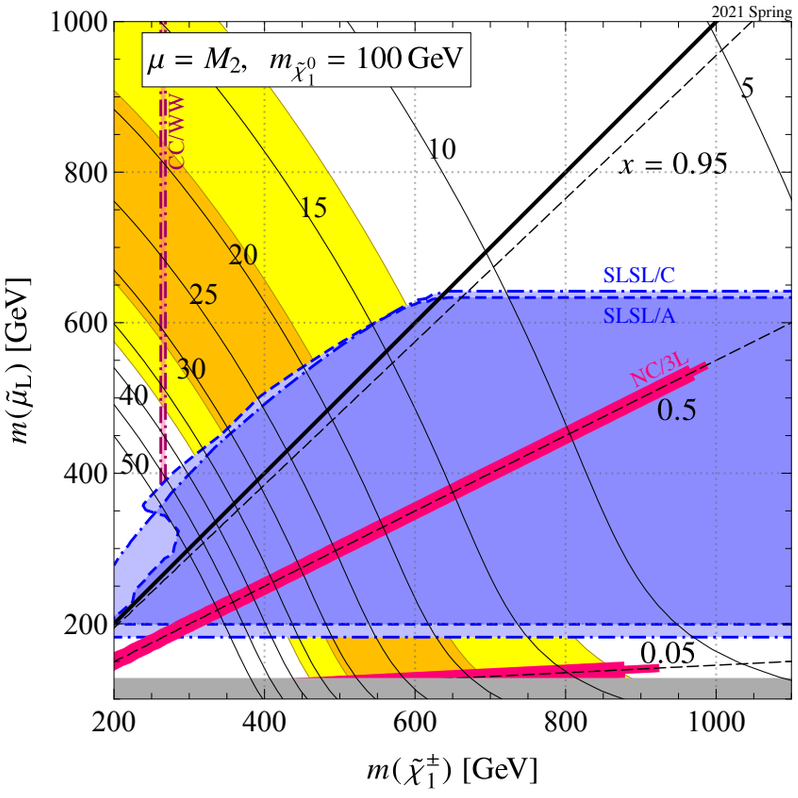
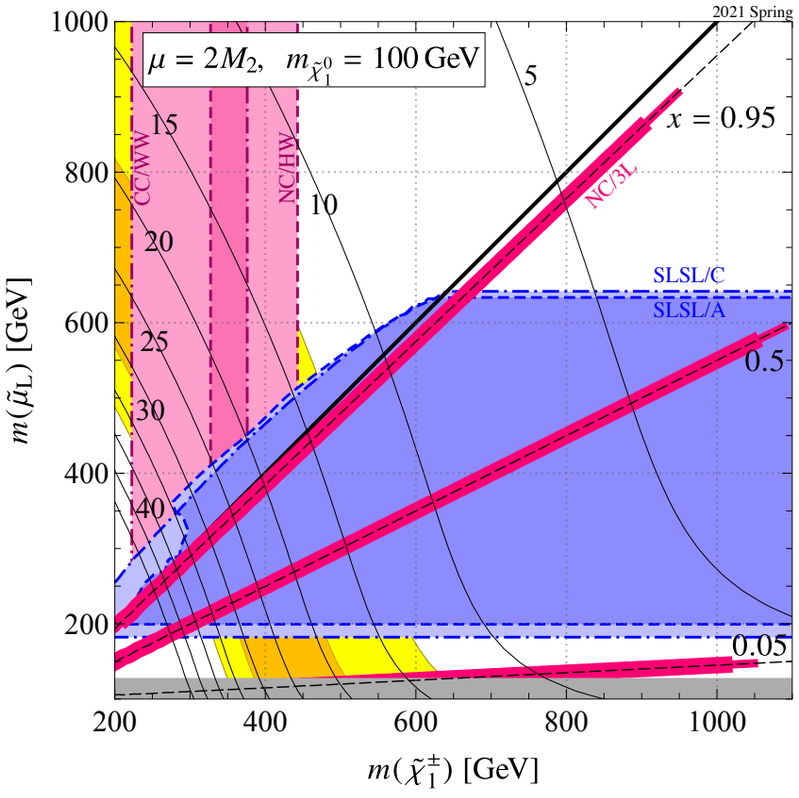


(A) $\mu = M_2,\ M_1 = M_2/2$



(C) $\mu = M_2,\ m_{\tilde{\chi}_1^0} = 100\,\mathrm{GeV}$



(D) $\mu = 2M_2,\ m_{\tilde{\chi}_1^0} = 100\,\mathrm{GeV}$

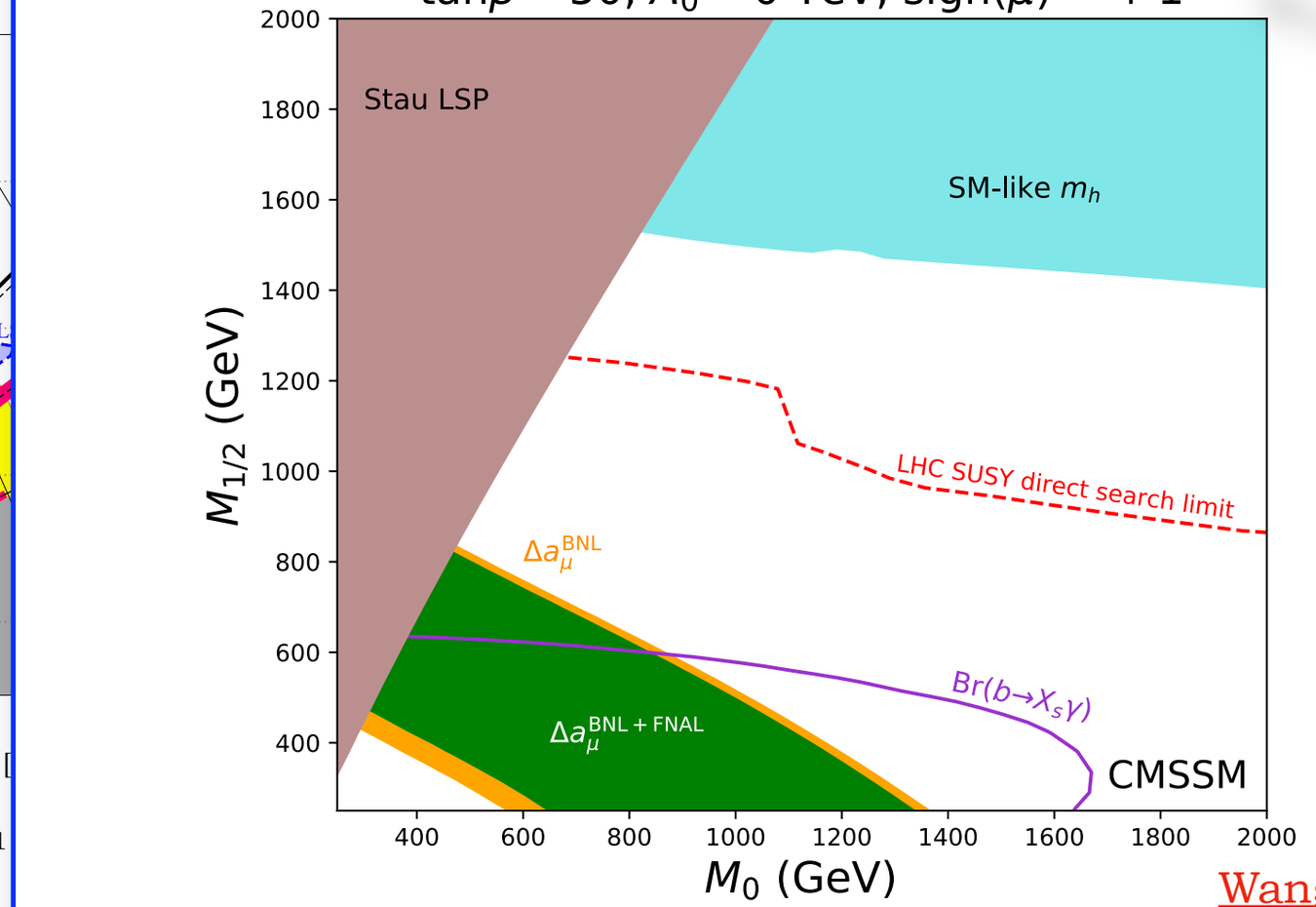
Endo et al. '21

There is still room for a supersymmetric explanation of the discrepancy, but LHC constraints are increasingly tight (and challenge UV-complete SUSY-breaking scenarios)

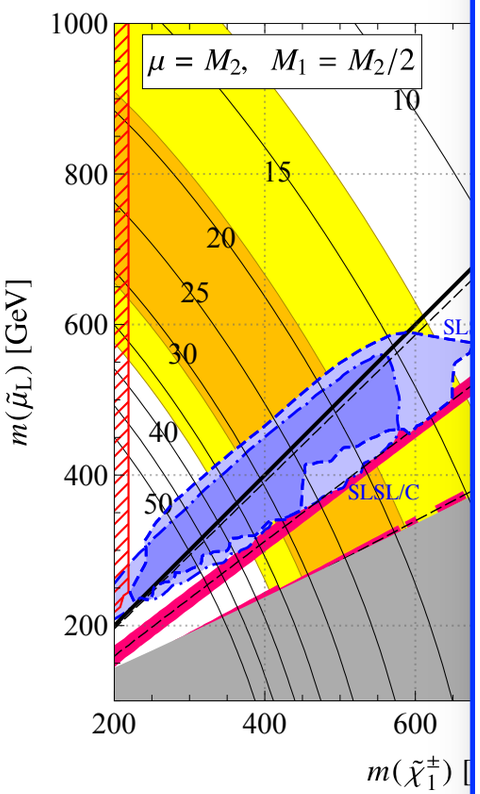
What about LHC searches for SUSY?

LHC searches can already probe substantial portion of the

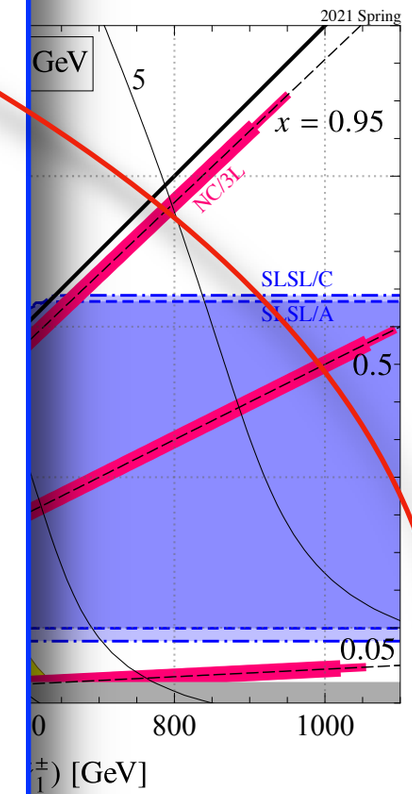
For instance, for minimal SUGRA/CMSSM:



Wang et al. '21



(A) $\mu = M_2$, M_1



$\tilde{\chi}_1^0 = 100\,\mathrm{GeV}$

Endo et al. '21

There is still room for a supersymmetric explanation of the discrepancy, but LHC constraints are increasingly tight (and challenge UV-complete SUSY-breaking scenarios)

Correlated observables

What about the ***electron*** g-2? It is one of the best-measured quantities in physics!

$$a_e^{\rm exp} = 11\,596\,521\,807.3(2.8) \times 10^{-13} \quad [0.24\,{\rm ppb}]$$!! Hanneke Fogwell Gabrielse '08

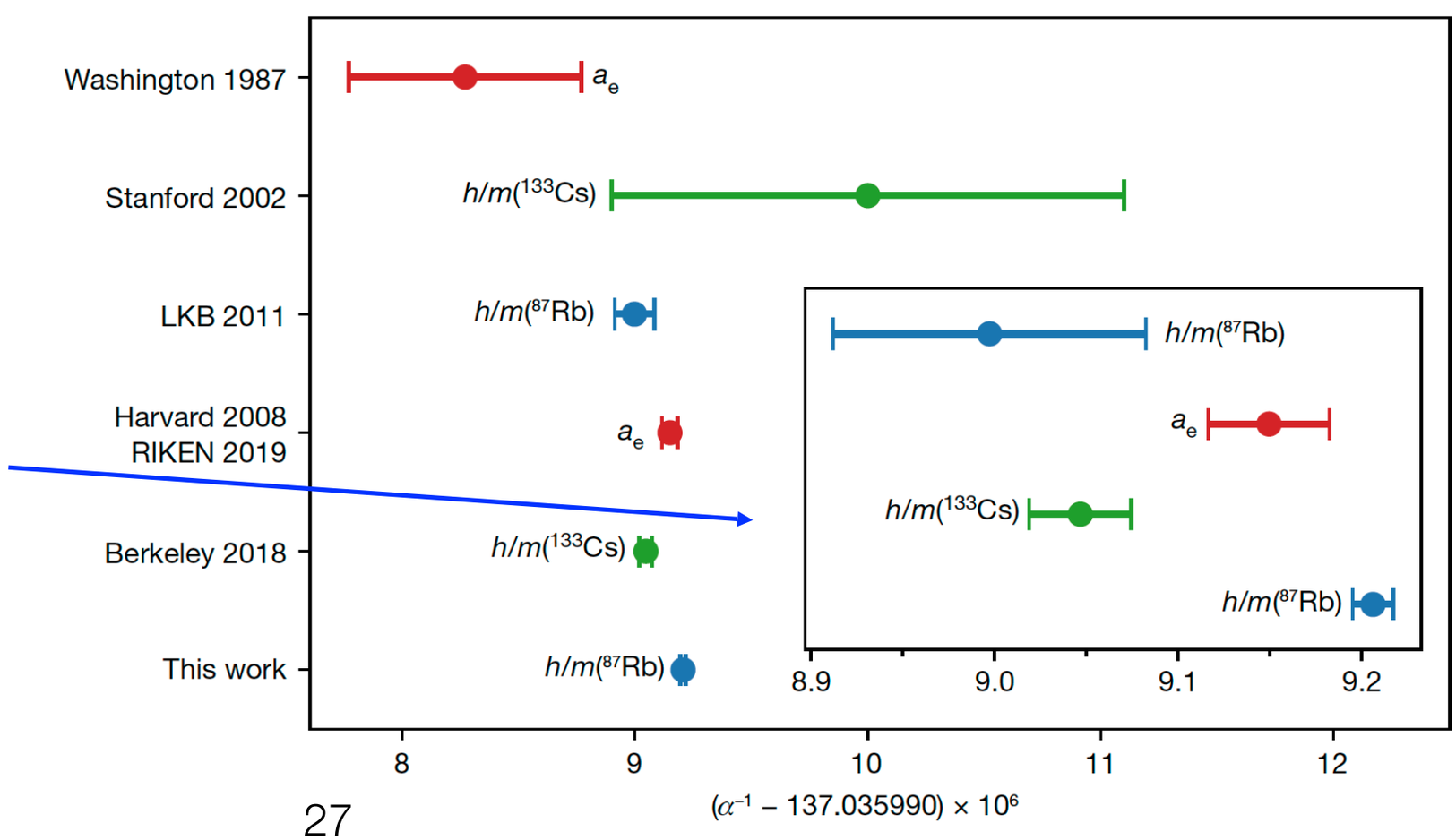
Also the theoretical prediction is very precise (QED dominated, QCD contributions less important) until few years ago it was used as a way to *measure* $\alpha_{\rm em}$

in order to use it as a test for new physics, we need an alternative, precise, determination of $\alpha_{\rm em}$ Giudice Passera Paradisi '12

In recent years, it became possible thanks to atomic interferometry

The two best measurements are somewhat in tension

Parker et al. '18 Morel et al. '20



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Depending on which one you adopt, you get

$$\Delta a_{\rm e}^{\rm Cs} \equiv a_{\rm e}^{\rm exp} - a_{\rm e}^{\rm SM,Cs} = -(8.8 \pm 3.6) \times 10^{-13},$$
$$\Delta a_{\rm e}^{\rm Rb} \equiv a_{\rm e}^{\rm exp} - a_{\rm e}^{\rm SM,Rb} = (4.8 \pm 3.0) \times 10^{-13}.$$

Passera Paradisi '12

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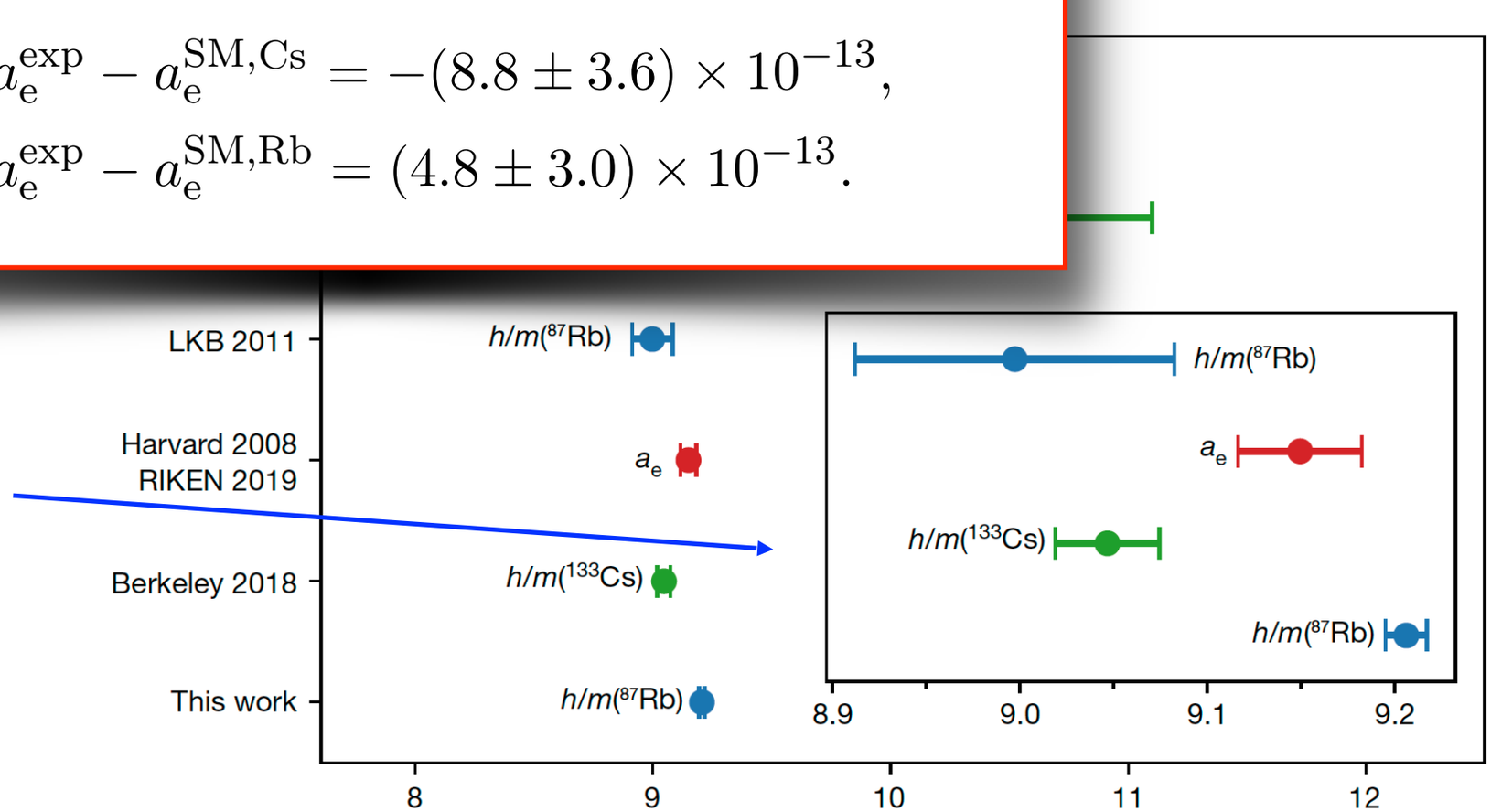
Parker et al. '18 Morel et al. '20



Correlated observables

The electron g-2 can be used to test models that explain the muon g-2 tension (some predict $a_e^{\rm NP}/a_\mu^{\rm NP} \sim (m_e/m_\mu)^2$ or (m_e/m_μ))

In general, there is no reason why NP should not have a generic flavour structure:

$$\mathcal{L} \supset \frac{e\,v}{8\,\pi^2}\,C_{\ell\ell'}\left(\bar{\ell}\sigma_{\mu\nu}P_R\ell'\right)\,F^{\mu\nu} + \text{h.c.} \qquad \ell,\ell' = \text{e},\mu,\tau$$

NP models with non-trivial flavour structures could exhibit *correlations* among the g-2 of different flavours, but also the lepton EDMs, and lepton flavour violating (LFV) observables:

$$\Delta a_\ell = \frac{m_\ell v}{2\pi^2}\,\text{Re}(C_{\ell\ell}) \qquad d_\ell = \frac{ev}{4\pi^2}\,\text{Im}(C_{\ell\ell}) \qquad \frac{\text{BR}(\ell\to\ell'\gamma)}{\text{BR}(\ell\to\ell'\nu\bar{\nu}')} = \frac{3\alpha}{\sqrt{2}\pi\,G_F^3\,m_\ell^2}\left(|C_{\ell\ell'}|^2+|C_{\ell'\ell}|^2\right)$$

Some model-independent bounds:

g-2 $\quad \text{Re}(C_{\mu\mu}) \approx [1.5,\,2.4]\times10^{-9}\ \text{GeV}^{-2} \quad -1.9\times10^{-11}\ \text{GeV}^{-2} \lesssim \text{Re}(C_{ee}) \lesssim 1.7\times10^{-10}\ \text{GeV}^{-2}$

EDM $\quad d_e < 1.1\times10^{-29}\,e\,\text{cm}$, $d_\mu < 1.9\times10^{-19}\,e\,\text{cm}$ ➡ $|\text{Im}(C_{ee})| \lesssim 9.0\times10^{-17}\ \text{GeV}^{-2}$, $|\text{Im}(C_{\mu\mu})| \lesssim 1.2\times10^{-6}\ \text{GeV}^{-2}$

LFV $\quad \mu\to e\gamma$, $\tau\to\mu\gamma$ ➡ $|C_{e\mu}|,\ |C_{\mu e}| \lesssim 3.9\times10^{-14}\ \text{GeV}^{-2}$ $\quad |C_{\tau\mu}|,\ |C_{\mu\tau}| \lesssim 5.0\times10^{-10}\ \text{GeV}^{-2}$

see e.g. LC Ibáñez-López Melis Vives '21

3. Take-home messages

- After the FNAL experiment confirmed the previous BNL result, the g-2 puzzle can only be solved by (i) hadronic vacuum polarisation (ii) new physics

Either way, interesting (even exciting) times await us!

- Plenty of NP models can explain the discrepancy, but constraints (e.g. from collider searches) are becoming increasingly tighter

- New particles models featuring *chiral enhancement* can address the g-2 with masses in the multi-TeV range, thus evading the bounds more easily

- In general, if NP is there, one can expect deviations induced by correlated dipole operators (flavour-conserving and flavour-violating)

Upcoming years could bring us other exciting discoveries!

4. Bibliography

Excellent reviews on the muon g-2 are available online, for instance

M. Passera, J.Phys.G 2004 → SM calculation

D. Stöckinger, J.Phys.G 2006 → SUSY

F. Jegerlehner, A. Nyffeler, Physics Reports 2009 → basics, experiments, SM

M. Lindner, M. Platscher, F. S. Queiroz, Physics Reports 2018 → NP (including simplified models)

P. Athron *et al.*, arXiv:2104.03691 → NP (simplified models), SUSY

Also to check out:

The White Paper on the SM prediction: Aoyama *et al.*, Physics Reports 2020

The latest lattice QCD result: Borsanyi *et al.,* Nature 2021

The experimental papers: Bennett *et al.*, PRD 2006 (BNL); Abi *et al.*, PRL 2021 (FNAL)