LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

UNIVERSIDAD
DE GRANADA

A bridge to new physics

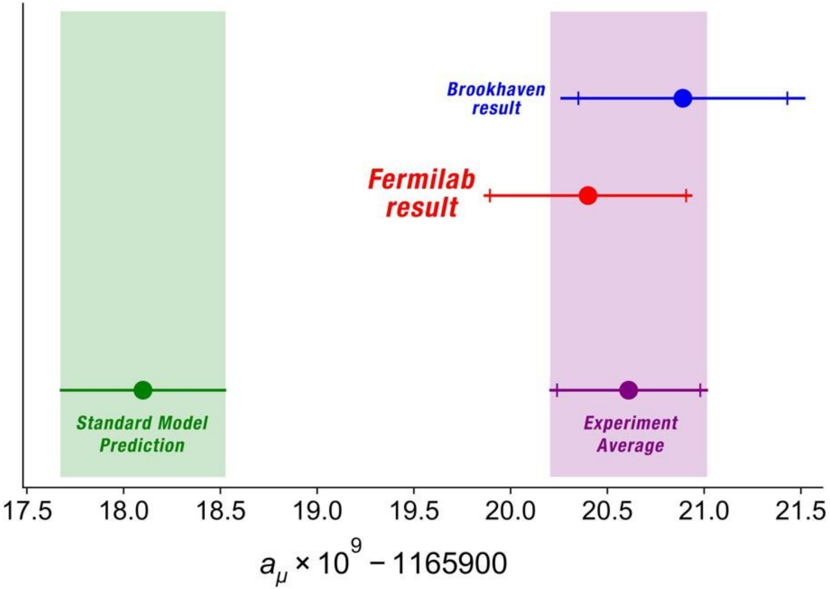
Explaining (g-2) and connecting it to other flavour anomalies

Guilherme Guedes, Pablo Olgoso

gguedes@lip.pt

The anomalous g-2

4.2σ



Big effort to explain this discrepancy in **SM extensions**

For a comprehensive review of the status of solutions, see:

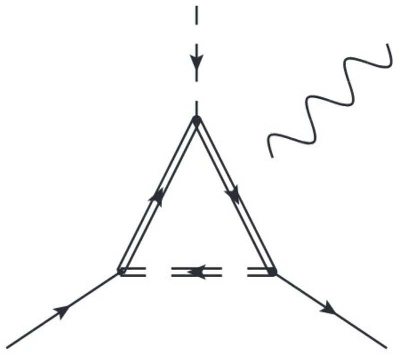
P. Athron, C. Balázs, D. Jacob, W. Kotlarski, D. Stöckinger, H. Stöckinger-Kim 2104.03691

$$\mathcal{O}_{eB} = (\bar{\ell}\sigma^{\mu\nu}e)HB_{\mu\nu} + \text{h.c.},$$
$$\mathcal{O}_{eW} = (\bar{\ell}\sigma^{\mu\nu}e)\sigma^I HW^I_{\mu\nu} + \text{h.c..}$$

Chirally enhanced solutions

$\mathcal{O}(\text{TeV})$ solutions need chirally enhanced contributions

NOT proportional to the muon's Yukawa



- **Chirality flip comes either from top Yukawa (S_1 leptoquark)**
- **Heavy fermion yukawa-like coupling (Vector like leptons)**

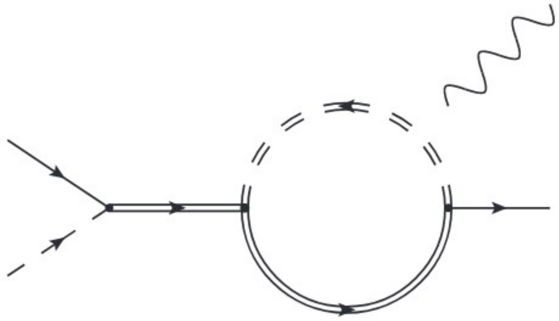
A. Crivellin and M. Hoferichter, 2104.03202

L. Allwicher, L. Luzio, M. Fedele, F. Mescia, M. Nardecchia, 2105.13981

Chirally enhanced solutions

$\mathcal{O}$(TeV) solutions need chirally enhanced contributions

NOT proportional to the muon's Yukawa



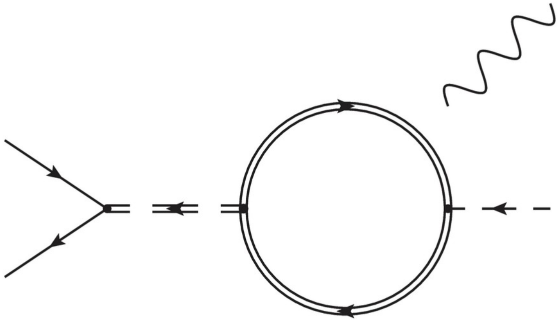
N. Arkani-Hamed and K. Harigaya, 2106.01373
L. Rose, B. Harling and A. Pomarol, 2201.10572

- **We will focus on the less studied bridge topology**

In this talk: Classification of the UV extensions which generate non-zero contribution to $(g$-$2)$ through bridge

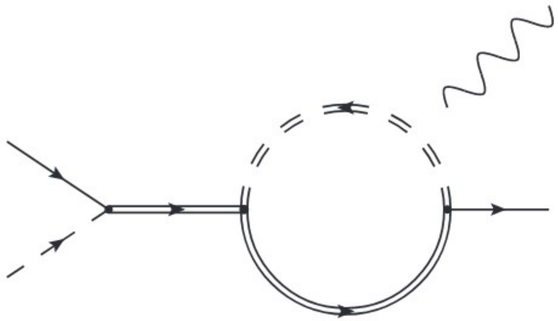
The bridge

The field running in the bridge can be fixed:



$$\Phi \sim (1, 2, 1/2)$$

No contribution



$$E \sim (1, 1, -1)$$
$$\Delta \sim (1, 2, -1/2)$$
$$\Sigma \sim (1, 3, -1)$$

General results

To see an example, let us focus on the doublet bridge:

$$\alpha_{e\gamma}^{2,2} = \frac{iN_c e}{4} y_M y_F y_b^R \sum_{IJ} T_{I2J} \left[\gamma_\Psi T_{I'I}^{\gamma,\Psi} T'_{2JI'} + \gamma_\Phi T_{JJ'}^{\gamma,\Phi} T'_{2IJ'} \right]$$

$$\gamma_\psi = \frac{-iM_\Psi}{(4\pi)^2 M_\Delta} \frac{M_\Psi^4 - 4M_\Psi^2 M_\Phi^2 + 3M_\Phi^4 + 2M_\Phi^4 \,\mathrm{Log}\left[M_\Psi^2/M_\Phi^2\right]}{(M_\Psi^2 - M_\Phi^2)^3}$$

$$\gamma_\Phi = -\frac{iM_\Psi}{(4\pi)^2 M_\Delta} \frac{M_\Psi^4 - M_\Phi^4 - 2M_\Psi^2 M_\Phi^2 \,\mathrm{Log}\left[M_\Psi^2/M_\Phi^2\right]}{(M_\Psi^2 - M_\Phi^2)^3}$$

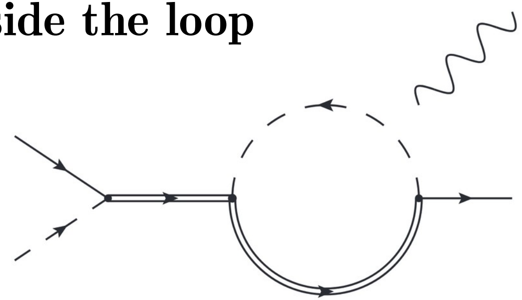
2-fermion extensions

Bridge	Other Fermion
$E \sim (1,1,-1)$	$\Delta \sim (1,2,-1/2)$
	$\Delta_3 \sim (1,2,-3/2)$
$\Delta \sim (1,2,-1/2)$	$E \sim (1,1,-1)$
	$\Sigma \sim (1,3,-1)$
	$N \sim (1,1,0)$
	$\Sigma_0 \sim (1,3,0)$
$\Sigma \sim (1,3,-1)$	$\Delta \sim (1,2,-1/2)$
	$\Delta_3 \sim (1,2,-3/2)$

Discussed in:

A. Freitas, J. Lykken, S. Kell, S. Westhoff 1402.7065

SM Higgs as the scalar inside the loop

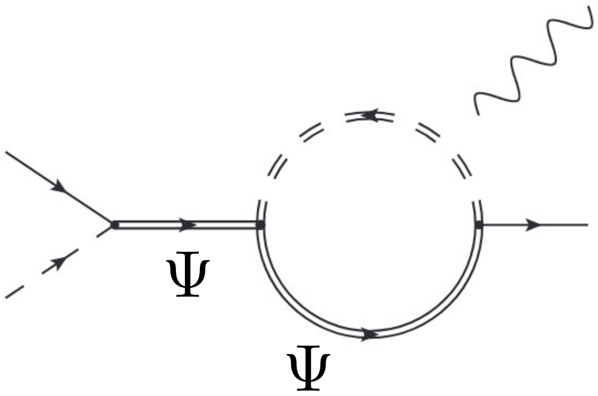


N. Arkani-Hamed and K. Harigaya, 2106.01373

N. Craig, I. Garcia, A. Vainshtein, Z. Zhang 2112.05770

L. Rose, B. Harling and A. Pomarol, 2201.10572

2-field fermion & scalar extensions



Fermion	Scalar
$E \sim (1,1,-1)$	$\mathcal{S}_0 \sim (1,1,0)$
	$\mathcal{S}_2 \sim (1,1,-2)$
	$\mathcal{S}_0 \sim (1,1,0)$
$\Delta \sim (1,2,-1/2)$	$\mathcal{S}_1 \sim (1,1,-1)$
	$\Xi_0 \sim (1,3,0)$
	$\Xi_1 \sim (1,3,-1)$
$\Sigma \sim (1,3,-1)$	$\Xi_0 \sim (1,3,0)$
	$\Xi_2 \sim (1,3,-2)$

Excluded in the literature

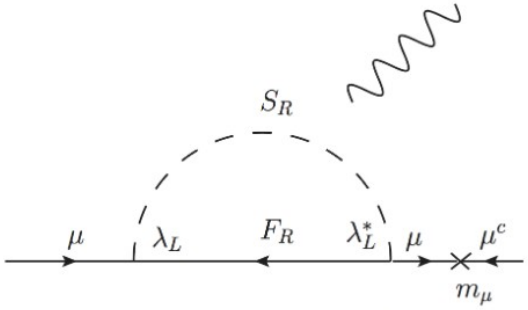
but

only Yukawa suppressed terms

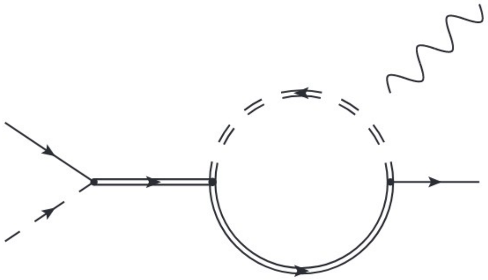
2-field fermion & scalar extensions

P. Athron, C. Balázs, D. Jacob, W. Kotlarski, D. Stöckinger, H. Stöckinger-Kim 2104.03691

$(\mathbf{1}, \mathbf{3}, 0)_0$ and $(\mathbf{1}, \mathbf{2}, -1/2)_{1/2} \Longrightarrow$ $\Delta a_\mu < 0$ irrespective of $\mathbb{Z}_2$



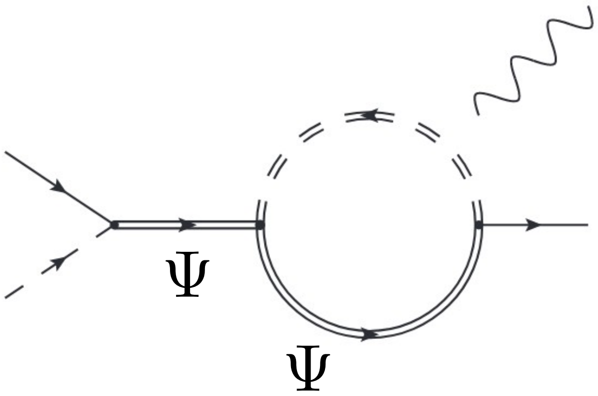
Yukawa-suppressed: < 0



Bridge-like: no definite sign

$$\alpha_{e\gamma} = y_b y_M y_F f(M_\Delta, M_\Xi)$$

2-field fermion & scalar extensions



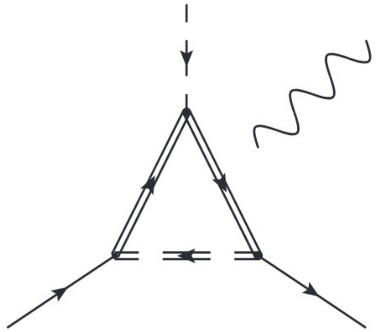
Fermion	Scalar
$E \sim (1, 1, -1)$	$\mathcal{S}_0 \sim (1, 1, 0)$
	$\mathcal{S}_2 \sim (1, 1, -2)$
$\Delta \sim (1, 2, -1/2)$	$\mathcal{S}_0 \sim (1, 1, 0)$
	$\mathcal{S}_1 \sim (1, 1, -1)$
	$\Xi_0 \sim (1, 3, 0)$
	$\Xi_1 \sim (1, 3, -1)$
$\Sigma \sim (1, 3, -1)$	$\Xi_0 \sim (1, 3, 0)$
	$\Xi_2 \sim (1, 3, -2)$

3-field extensions

A. Crivellin and M. Hoferichter, 2104.03202
L. Allwicher, L. Luzio, M. Fedele, F. Mescia, M. Nardecchia, 2105.13981

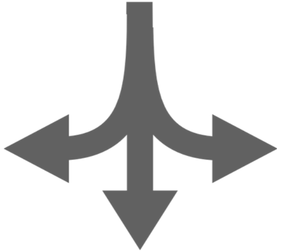
Bridge	$(SU(2)_\Psi\,, SU(2)_\Phi)$
$E \sim (1,1,-1)$	(1,1)
	(2,2)
	(3,3)
$\Delta \sim (1,2,-1/2)$	(2,1)
	(2,3)
$\Sigma \sim (1,3,-1)$	(2,2)
	(3,3)

Not the same as those contributing through



New class of 3-field extensions

Connecting trees and bridges



Neutral B-anomalies

Cabibbo angle anomaly

$(g\text{-}2)$

The triple triplet model

$S_3 \sim (3, 3, -1/3)$ as an explanation to $R_K^{(*)}$

The triple triplet model

- 🌳 $S_3 \sim (3, 3, -1/3)$ as an explanation to $R_K^{(*)}$
- 🌳 $\Sigma \sim (1, 3, -1)$ as an explanation for C.A.A.

A. Crivellin, M. Hoferichter 2002.07184

$$R(V_{us}) = 1 - \left(\frac{V_{ud}}{V_{us}}\right)^2 v^2 \left[C_{H\ell}^{(3)}\right]_{22}$$

$$R(V_{us}) \equiv \frac{V_{us}^{K\mu 2}}{V_{us}^{\beta}} \equiv \frac{V_{us}^{K\mu 2}}{\sqrt{1 - |V_{ud}^{\beta}|^2 - |V_{ub}|^2}}$$

Tension with EWPD (worsened by CDF measurement)

M. Kirk, 2008.03261

A. Crivellin, F. Kirk, C. A. Manzari, M. Montull, 2008.01113

The triple triplet model

- $S_3 \sim (3, 3, -1/3)$ as an explanation to $R_K^{(*)}$
- $\Sigma \sim (1, 3, -1)$ as an explanation for C.A.A.
- $\Psi \sim (3, 3, -4/3)$ to construct the bridge of $(g-2)$

One-loop phenomenology

Matchmakereft

Full one loop matching onto the Warsaw basis

&

smelli

Fit to observables

A. Carmona, A. Lazopoulos, P. Olgoso, J. Santiago 2112.10787

P. Stangl 2012.12211

Only take as *non*-zero the BSM couplings needed to account for the anomalies

Best-fit point

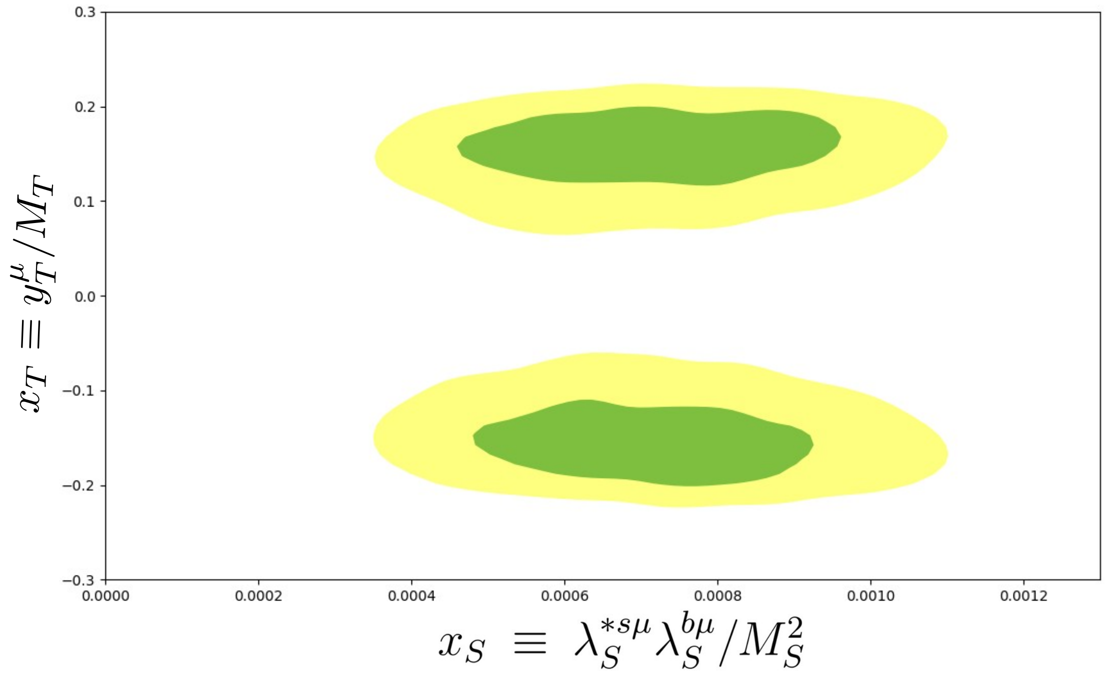
$$\mathcal{L} \supset y_T^i \bar{\ell}_{Li} \phi \sigma^I \Sigma_R^I + y_Q^i \overline{\Psi}_{QL}^I S_3^I \ell_{Ri} + y_b^L \epsilon^{IJK} \overline{\Sigma}_R^I \Psi_{Q,L}^J S_3^{K\dagger}$$
$$+ y_b^R \epsilon^{IJK} \overline{\Sigma}_L^I \Psi_{Q,R}^J S_3^{K\dagger} + \lambda_S^{ij} \overline{Q}_{Li}^c i\sigma^2 \sigma^I \ell_{Lj} S_3^{I\dagger} + \text{h.c.}$$

$$M_{S_3} = 2 \text{ TeV}$$
$$M_\Sigma = 3.4 \text{ TeV}$$
$$M_{\Psi_Q} = 4.6 \text{ TeV}$$

$x_F = 0.2 \ \text{TeV}^{-1}$	$x_S = 0.00078 \ \text{TeV}^{-2}$
$x_T = 0.17 \ \text{TeV}^{-1}$	$\lambda_S^{b\mu} = 0.07$
$y_b^L = 0.10$	$y_b^R = 0.13$

defining $x_S \equiv \lambda_S^{*s\mu} \lambda_S^{b\mu} / M_S^2$ $\quad x_T \equiv y_T^\mu / M_T$ $\quad x_F \equiv y_Q^\mu / M_F$

Best-fit point



Results as expected from the tree-level explanations

Introduces some tension with EWPD, especially with W mass

Conclusions

- We classified all possible extensions which can generate a chirally enhanced contribution to g-2 through the bridge
- Further pheno studies would be needed
- A complete classification of one-loop solutions to anomalies is helpful in connecting tree-level explanations

Thanks

ggedes@lip.pt

Supported by research grant: SFRH/BD/144244/2019

FCT, COMPETE2020-Portugal2020, FEDER, POCI-01-0145-FEDER-007334