LABORATÓRIO DE INSTRUMENTAÇÃO
E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

UNIVERSIDAD DE GRANADA

Extending the SMEFT

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A global approach to physics BSM

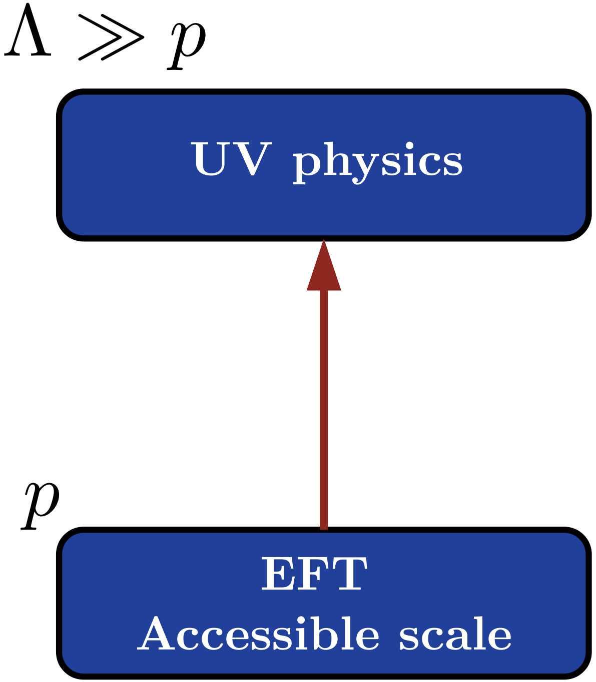
1. **Model-driven approach to search for specific signatures**

   Dedicated search for vector-like leptons with an exotic decay channel
   Complementarity between collider and DM probes

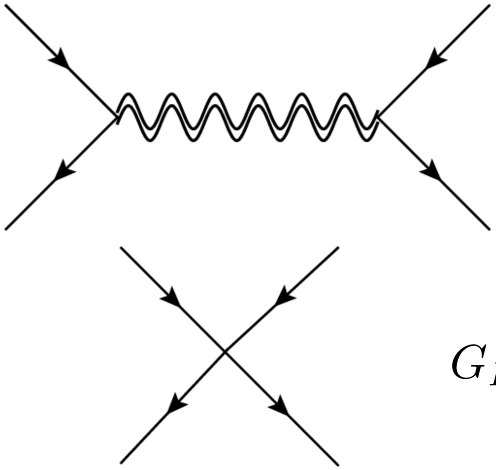
   G. G. and J. Santiago 2107.03429

2. **Model-independent approach – extending the SMEFT**

The EFT approach



e.g. **Fermi theory**



$$G_F \sim \frac{g_\omega^2}{m_W^2}$$

$$\mathcal{L}_{\text{EFT}} = G_F(\overline{\psi}\gamma_\mu\psi)^2$$

Why extend the SMEFT?

$$\mathcal{L}_{\text{SMEFT}} = \mathcal{L}_{\text{SM}} + \frac{\mathcal{L}_{5+s}}{\Lambda} + \frac{\mathcal{L}_6}{\Lambda^2} + \frac{\mathcal{L}_8}{\Lambda^4} + \cdots$$

- **Extra light degrees of freedom**

  Large motivation for light (pseudo)scalars (ALPs). Extend the SMEFT with an ALP @ dimension-5

  M. Chala, G.G., M. Ramos, J. Santiago 2012.09017

- **One-loop matching at dimension-6**

  Consistent treatment at one-loop requires knowledge of these matching contributions

  G. G. and P. Olgoso 2205.04480

- **Dimension-8 effects**

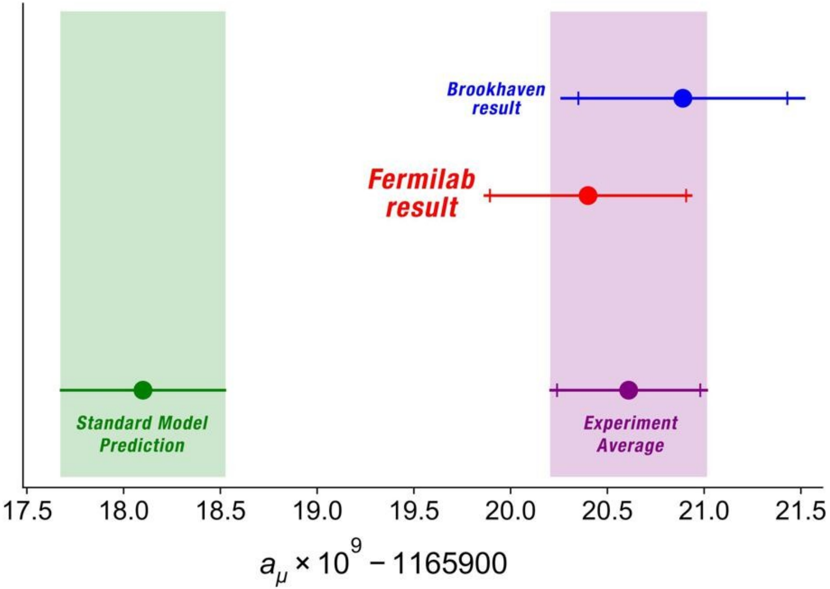
  Contributions to certain observales arises only at this order

  Theoretical bounds can be placed on dim-8 coefficients

  M. Chala, G.G., M. Ramos, J. Santiago 2106.05291
  M.Chala, A. Carmona, G.G 2112.12724
  S. Bakshi, M. Chala, A. Carmona, G.G. 2205.03301

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:

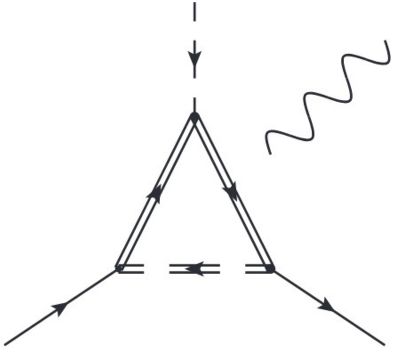
P. Athron, C. Balázs, D. Jacob, W. Kotlarski, D. Stöckinger, H. Stöckinger-Kim 2104.03691

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

Chirally enhanced solutions

$\mathcal{O}$(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

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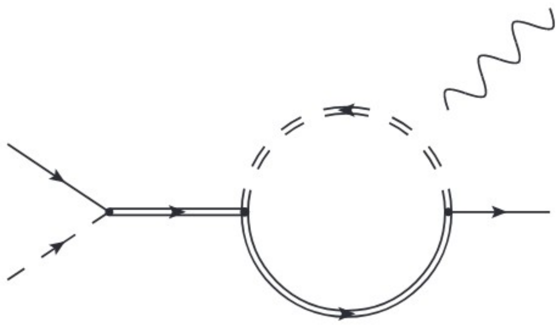


N. Arkani-Hamed and K. Harigaya, 2106.01373
L. Rose, B. Harling and A. Pomarol, 2201.10572

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

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

General results

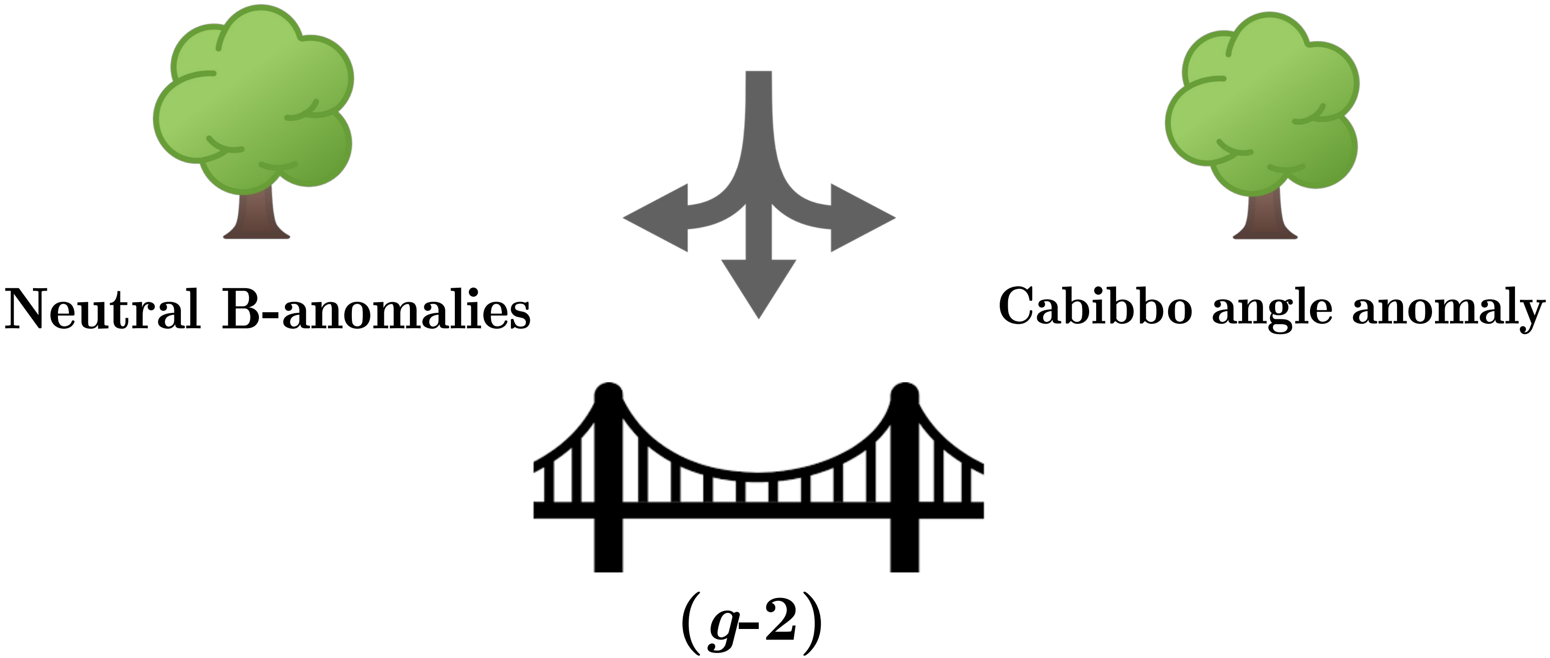
To see an example, let us focus on the doublet bridge:

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

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

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

Connecting trees and bridges



The triple triplet model

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

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- $S_3 \sim (3, 3, -1/3)$ 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

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

&

smelli

Fit to observables

P. Stangl 2012.12211

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

Best-fit point

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

$M_{S_3} = 2$ TeV

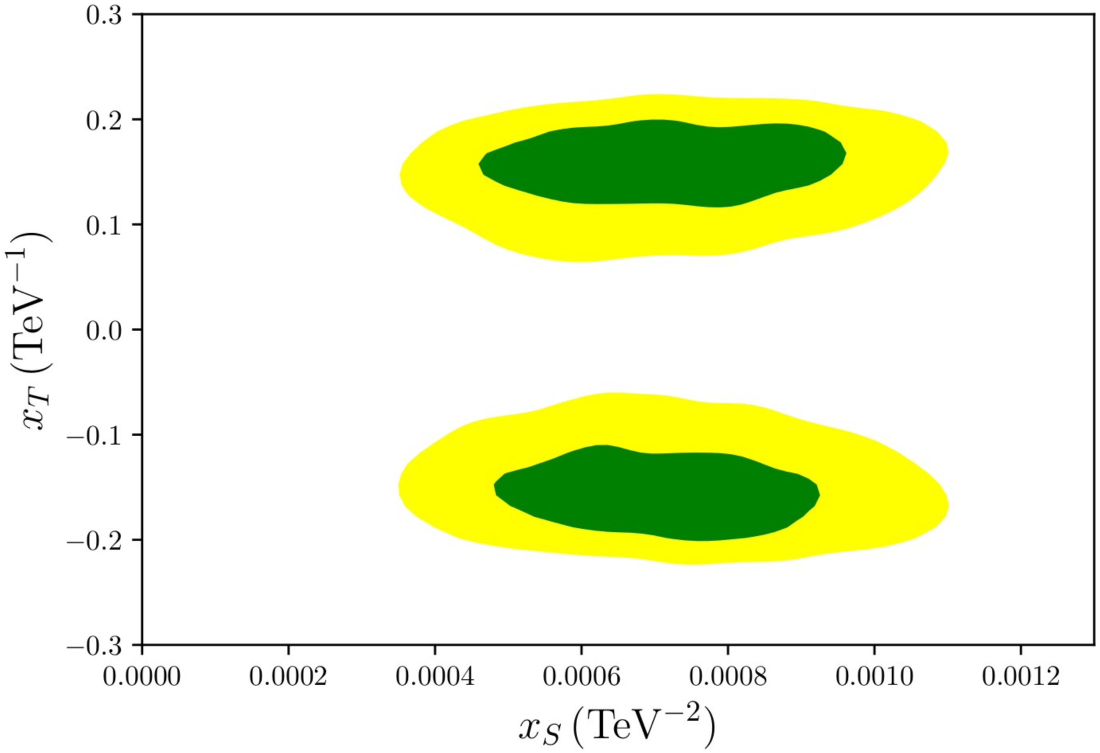
$M_\Sigma = 3.4$ TeV

$M_{\Psi_Q} = 4.6$ 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

Thanks

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