LHC Dark Matter WG public meeting
Sept 19-20 2006, CERN

Simplified Models of Dark Matter facing dileptons

B. Zaldivar, LAPTh

What if the mediator can couple to leptons?

- It is not minimal from LHC-interpretation point of view, but…
- I'm not aware of any UV-model with only quark couplings

Spin-0:

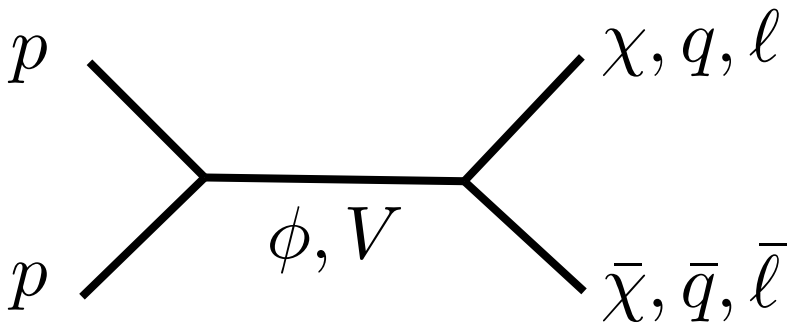
$$\mathcal{L}_{\text{fermion},\phi} \supset -g_\chi \phi \bar{\chi}\chi - \frac{\phi}{\sqrt{2}} \sum_i \left(g_u y_i^u \bar{u}_i u_i + g_d y_i^d \bar{d}_i d_i + g_\ell y_i^\ell \bar{\ell}_i \ell_i \right) ,$$

$$\mathcal{L}_{\text{fermion},a} \supset -i g_\chi a \bar{\chi}\gamma_5\chi - \frac{ia}{\sqrt{2}} \sum_i \left(g_u y_i^u \bar{u}_i \gamma_5 u_i + g_d y_i^d \bar{d}_i \gamma_5 d_i + g_\ell y_i^\ell \bar{\ell}_i \gamma_5 \ell_i \right)$$

1506.03116

Spin-1:

$$\mathcal{L}_{\text{fermion},V} \supset V_\mu \bar{\chi}\gamma^\mu (g_\chi^V - g_\chi^A \gamma_5)\chi + \sum_{f=q,\ell,\nu} V_\mu \bar{f}\gamma^\mu (g_f^V - g_f^A \gamma_5) f$$



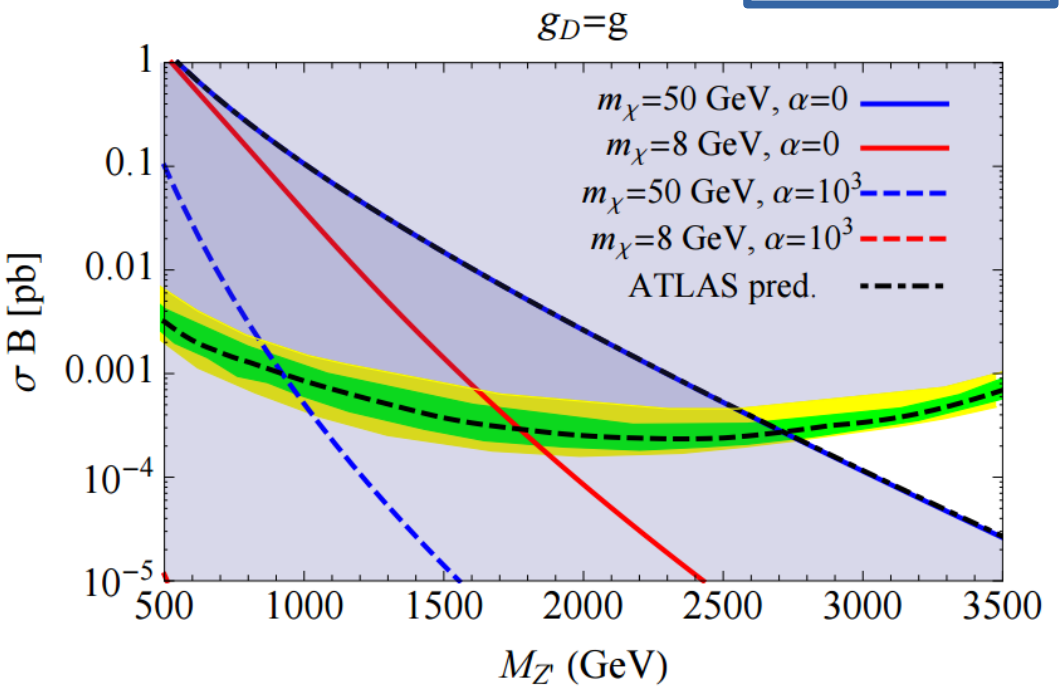
Existing example

G. Arcadi, Y. Mambrini, M. Tytgat and B.Z., 1401.0221

Model: *Sequential Z' with extra coupling to DM*

$$\Delta\mathcal{L} \supset \; g_D \bar{\chi}\gamma^\mu \left(V_D^\chi - A_D^\chi \gamma^5\right) \chi \; Z'_\mu + g_D \sum_f \bar{f}\gamma^\mu \left(V_D^f - A_D^f \gamma^5\right) f \; Z'_\mu$$

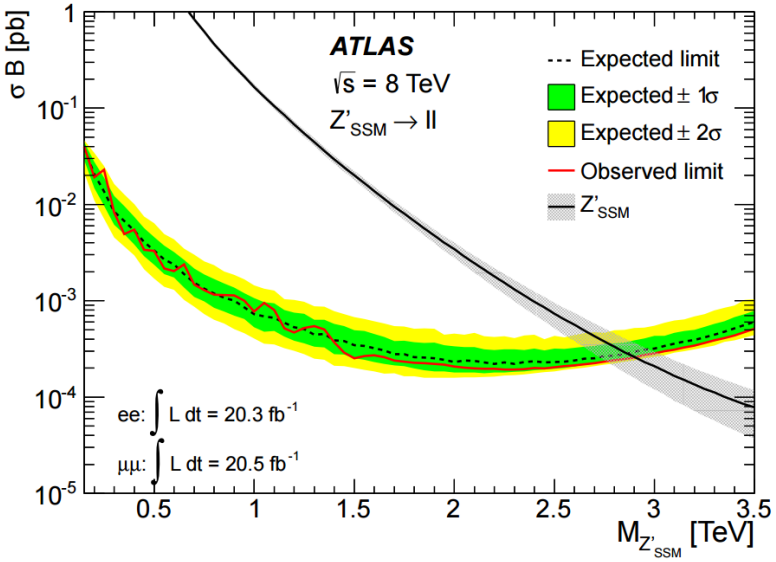
$$\alpha \equiv A_D^\chi / V_D^\chi$$



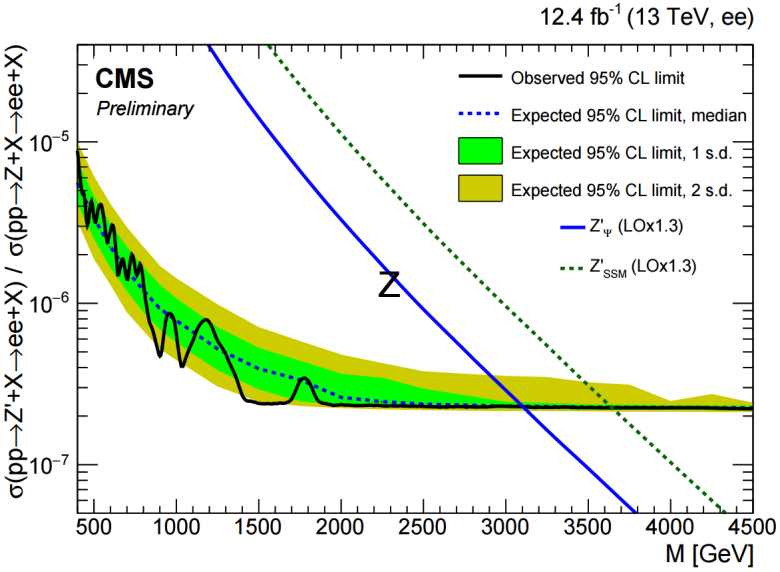
based on:
- ATLAS, 1209.2535, 7TeV, ~5/fb
- LUX, 1310.8214

Since then….

- ATLAS, 1405.4123, 8TeV, 20.5/fb



- CMS-EXO-16-031, 13TeV, 12.4/fb



Perturbative unitarity and gauge invariance

F. Kahlhoefer, K. Schmidt-Hoberg, T. Schwetz, S. Vog, 1510.02110

$$k^\mu \bar{v}(p_2)\left(g^V_{\rm DM}\gamma_\mu + g^A_{\rm DM}\gamma_\mu\gamma^5\right)u(p_1) = \bar{v}(p_2)\left[g^V_{\rm DM}(\not{p}_2 + \not{p}_1) + g^A_{\rm DM}(\not{p}_2\gamma^5 - \gamma^5\not{p}_1)\right]u(p_1)$$
$$= -2\, g^A_{\rm DM}\, m_{\rm DM}\, \bar{v}(p_2)\gamma^5 u(p_1)\ .$$

Axial couplings in the high-energy limit: $2g^A_{\rm DM}m_{\rm DM}/m_{Z'}$

Bounded by perturbative unitarity

A more complete model includes:

$$\mathcal{L}'_{\rm SM} = \left[(D^\mu H)^\dagger(-i\, g'\, q_H\, Z'_\mu\, H) + \text{h.c.}\right] + g'^2\, q_H^2\, Z'^\mu Z'_\mu\, H^\dagger H$$
$$- \sum_{f=q,\ell,\nu} g'\, Z'^\mu \left[q_{f_L}\, \bar{f}_L\gamma_\mu f_L + q_{f_R}\, \bar{f}_R\gamma_\mu f_R\right]\ ,$$

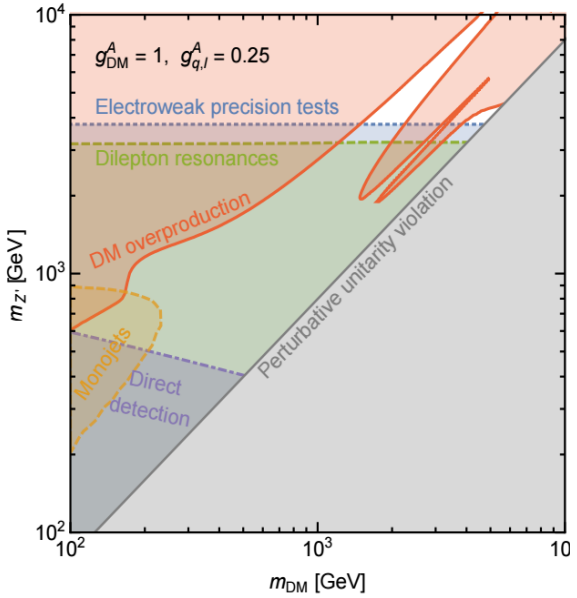
$$q_H = q_{q_L} - q_{u_R} = q_{d_R} - q_{q_L}, q_{e_R} - q_{\ell_L}$$

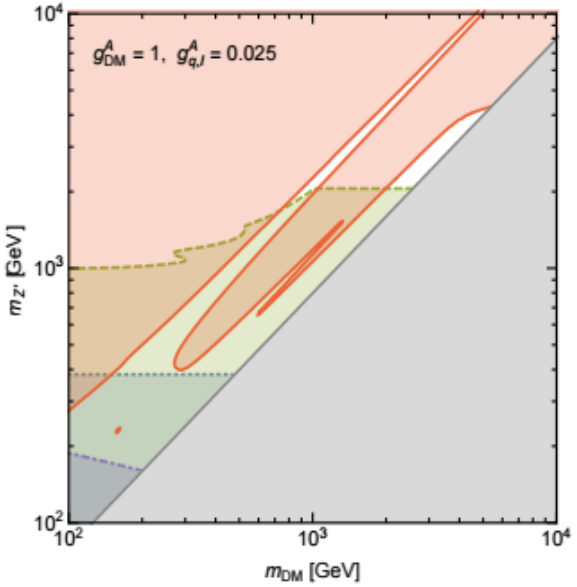
Non-zero axial couplings to quarks → non-zero axial couplings to leptons
[gauge invariance]

Perturbative unitarity and gauge invariance

F. Kahlhoefer, K. Schmidt-Hoberg, T. Schwetz, S. Vog, 1510.02110

Axial SM – Axial DM

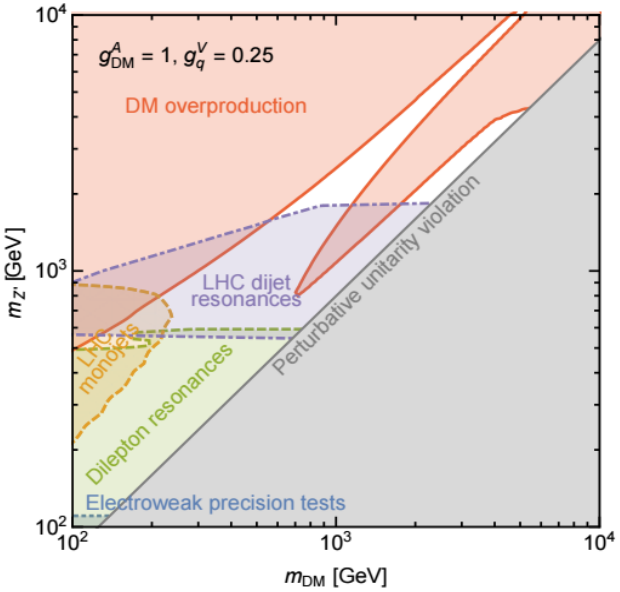




EW precision tests:
-Strongest for sizeable SM couplings

Dilepton searches
- Push relic abundance to be on the resonance (unless unitarity is ensured)

Vector SM – Axial DM



Kinetic mixing generated at loop level

Dilepton searches:
- weaker but complementary to dijet searches

Other setups:
- Vector DM, largely excluded by Direct Detection
- SM Higgs – dark Higgs mixing (no dilepton bounds)

Discussion

- Include dilepton bounds on axial model?