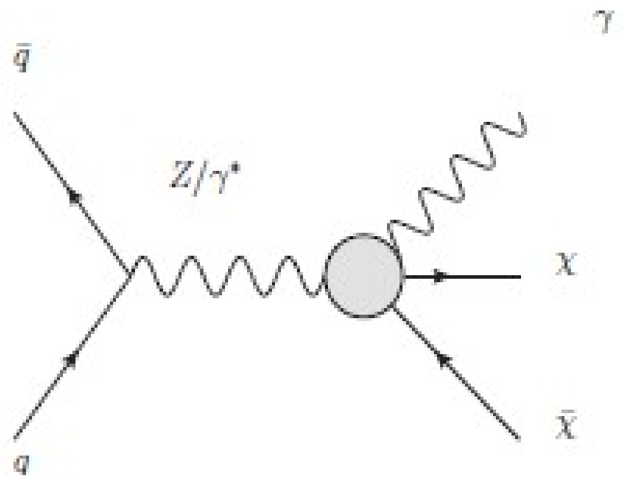
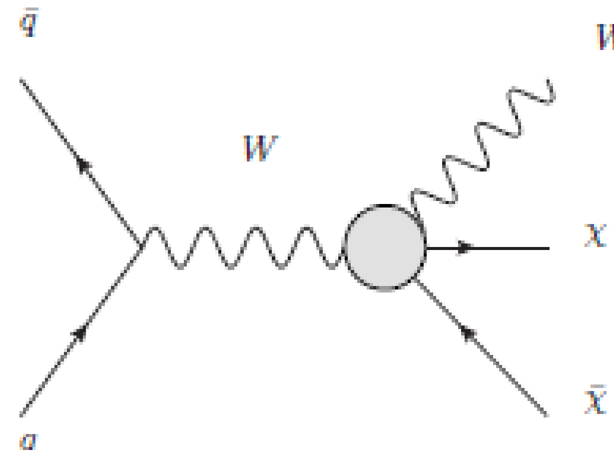
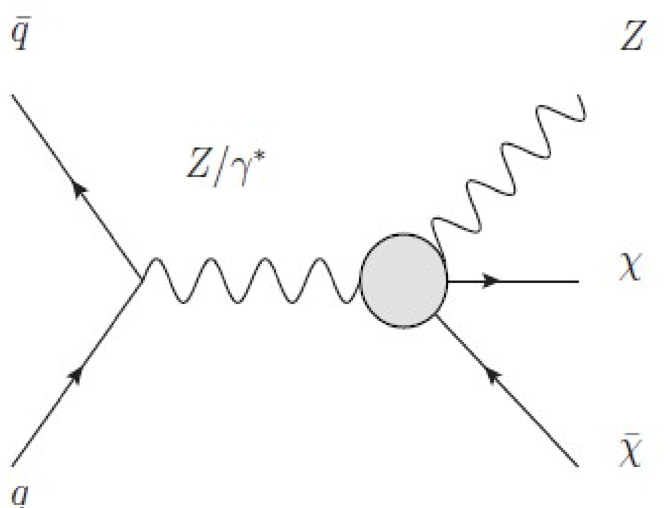
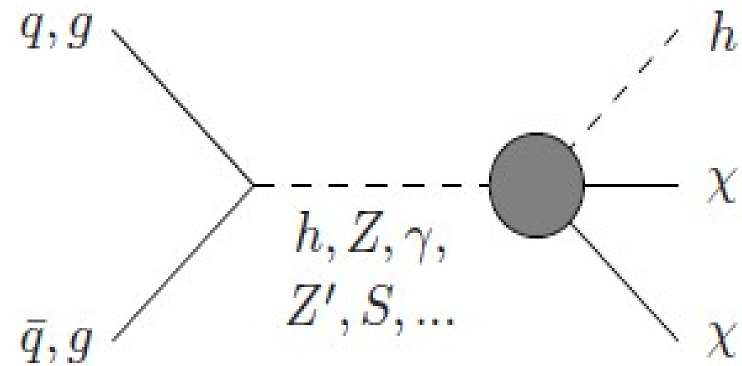
Mono-Higgs & EW Gauge Boson









arXiv:1212.3352 arXiv:1307.5064 arXiv:1403.6734

Why?

- Low Background
- Explore Interesting Portals
- Complimentary Indirect Experiments looking for annihilation (e.g. line searches)
- Many of these type of couplings hard for Direct Detection, leaving room for collider discovery

Dimension 6 and 7 Operators

$$\mathcal{L} = \frac{1}{\Lambda^3_{C1,2}} \bar{\chi}\chi \sum_i k_i F^{\mu\nu}_i F^i_{\mu\nu} + \frac{1}{\Lambda^3_{C3,4}} \bar{\chi}\chi \sum_i k_i F^{\mu\nu}_i \tilde{F^i_{\mu\nu}}$$

Fermionic DM

$$\mathcal{L} = \frac{1}{\Lambda^3_{C5,6}} \bar{\chi}\gamma^5\chi \sum_i k_i F^{\mu\nu}_i F^i_{\mu\nu} + \frac{1}{\Lambda^3_{C7,8}} \bar{\chi}\gamma^5\chi \sum_i k_i F^{\mu\nu}_i \tilde{F^i_{\mu\nu}},$$

Fermionic DM, pseudoscalar current

$$\mathcal{L} = \frac{1}{\Lambda^2_{B1,2}} \bar{\phi}\phi \sum_i k_i F^{\mu\nu}_i F^i_{\mu\nu} + \frac{1}{\Lambda^2_{B3,4}} \bar{\phi}\phi \sum_i k_i F^{\mu\nu}_i \tilde{F^i_{\mu\nu}}$$

Scalar DM

Mono-Higgs A Menagerie of Models

$$\lambda |H|^2 \chi^2$$

Dimenion 4

$$\frac{1}{\Lambda}|H|^2\bar{\chi}\chi\,, \quad \frac{1}{\Lambda}|H|^2\bar{\chi}i\gamma_5\chi$$

Dimenion 5

$$\frac{1}{\Lambda^2}\chi^\dagger i\overleftrightarrow{\partial^\mu}\chi H^\dagger iD_\mu H$$

$$\frac{1}{\Lambda^2}\bar{\chi}\gamma^\mu\chi H^\dagger iD_\mu H\,, \quad \frac{1}{\Lambda^2}\bar{\chi}\gamma^\mu\gamma_5\chi H^\dagger iD_\mu H\,.$$

Dimenion 6

$$\frac{1}{\Lambda^4}\bar{\chi}\gamma^\mu\chi B_{\mu\nu}H^\dagger D^\nu H\,, \quad \frac{1}{\Lambda^4}\bar{\chi}\gamma^\mu\chi W^a_{\mu\nu}H^\dagger t^a D^\nu H$$

$$\frac{1}{\Lambda^4}\bar{\chi}\sigma^{\mu\nu}\chi B_{\mu\nu}H^\dagger H\,, \quad \frac{1}{\Lambda^4}\bar{\chi}\sigma^{\mu\nu}\chi W^a_{\mu\nu}H^\dagger t^a H$$

Dimenion 8

10 operators
And 4 higgs final state
Event topologies

Extra Slides

Operators of Effective Dim 5

$$\frac{1}{\Lambda_5^3}\,\bar{\chi}\chi\,(D_\mu H)^\dagger D^\mu H$$

Inserting Higgs vevs and expanding the covariant derivative yields

$$\frac{m_W^2}{\Lambda_5^3}\,\bar{\chi}\chi\,W^{+\mu}W_\mu^- + \frac{m_Z^2}{2\Lambda_5^3}\,\bar{\chi}\chi\,Z^\mu Z_\mu$$

Notice a single parameter determines ratio of DM couplings to W's and Z's. γγ a γZ couplings genrated at higher at loop order.

A Note on Gauge Invariance

The general gauge invariant operators are given by

$$L = \frac{1}{\Lambda_7^3}\,\bar{\chi}\chi\,\sum_i k_i F_i^{\mu\nu} F^i_{\mu\nu}$$

3 independent couplings for 3 SM gauge groups

$$g_{gg} = \frac{k_3}{\Lambda_7^3}$$

One independent coupling for SU(3)

$$g_{WW} = \frac{2k_2}{s_w^2 \Lambda_7^3}$$

$$g_{ZZ} = \frac{1}{4 s_w^2 \Lambda_7^3} \left(\frac{k_1 s_w^2}{c_w^2} + \frac{k_2 c_w^2}{s_w^2} \right)$$

$$g_{\gamma\gamma} = \frac{1}{4 c_w^2} \frac{k_1 + k_2}{\Lambda_7^3}$$

$$g_{Z\gamma} = \frac{1}{2 s_w c_w \Lambda_7^3} \left(\frac{k_2}{s_w^2} - \frac{k_1}{c_w^2} \right)$$

Related by Gauge invariance, determined by 2 coefficients