Coupling Scaling for Direct Detection Reinterpretation of LHC Limits

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LHC DMWG Meeting

20 June 2017

The Ohio State University

ATLAS EXPERIMENT

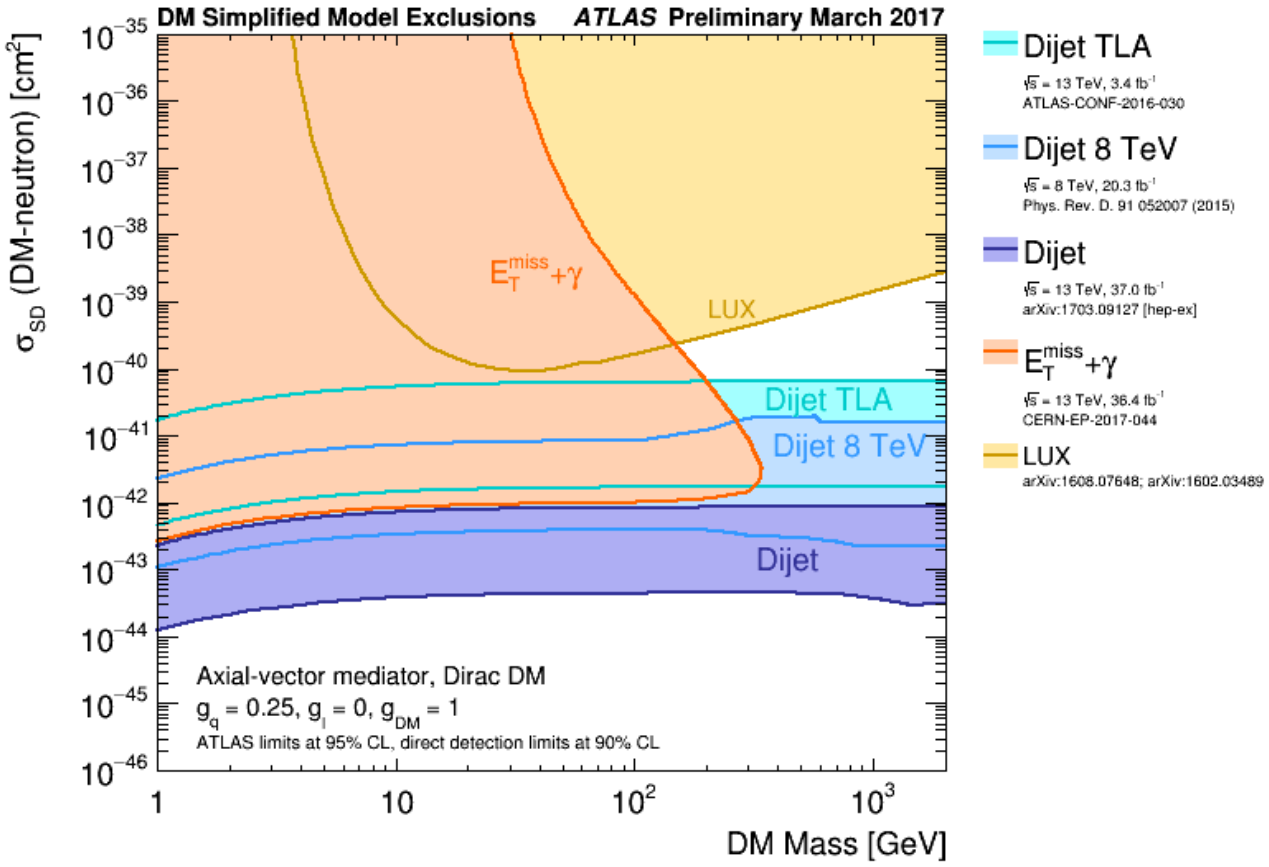
DM-Nucleon Scattering

- Direct detection (DD) of DM
  - DD experiments set a limit on the rate of interactions between local DM halo and atomic nuclei
- Translate simplified model collider limits into limits on DM-nucleon effective vertex
  - Constraints on DM & mediator production constrain DM-nucleon scattering
- ATLAS currently following DMWG recommendations from arXiv:1603.04156v1:

$$\sigma_{\mathrm{SI}} \simeq 6.9 \cdot 10^{-41}\ \mathrm{cm}^2 \left(\frac{g_q g_{\mathrm{DM}}}{0.25}\right)^2 \left(\frac{1\,\mathrm{TeV}}{M_{\mathrm{med}}}\right)^4 \left(\frac{\mu_{n\chi}}{1\,\mathrm{GeV}}\right)^2$$

Use equations to numerically convert (M_{med},m_{DM}) contours into (m_{DM},σ) contours

Limits on spin-dependent (SD) DM-neutron scattering

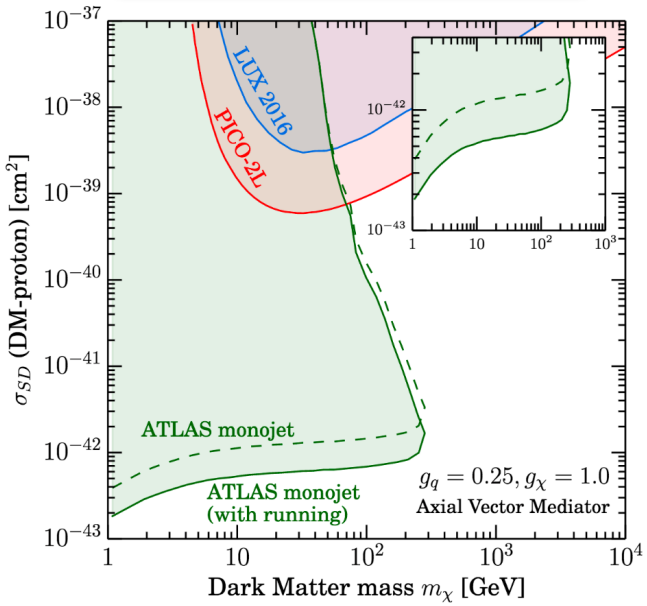


Evolving the Couplings

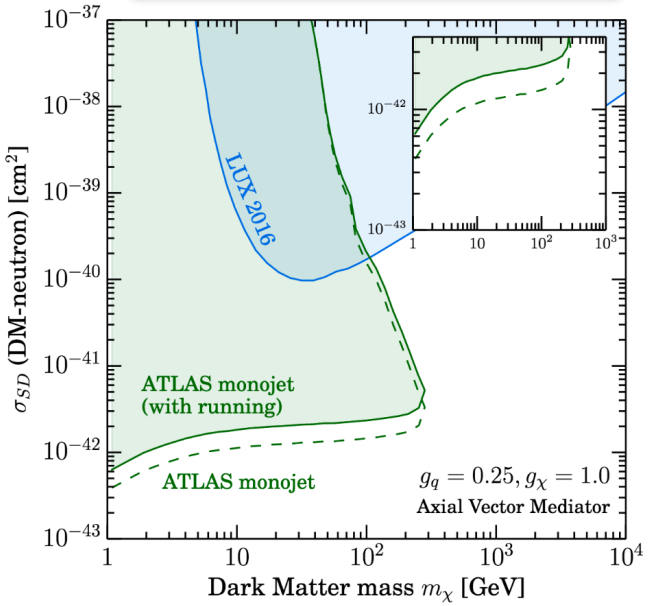
- DMWG recommendation does not account for the evolution of the couplings
  - Should in principle evolve down to the nuclear energy scale
- Work by Francesco D'Eramo, Bradley Kavanagh, and Paolo Panci
  - Previous talk at DMWG meeting: https://indico.cern.ch/event/543112/contributions/2213994/attachments/1296558/1933481/2016-06-22_DMWG.pdf
- The Renormalization Group (RG) equations to evolve the couplings derived in:
  - https://arxiv.org/abs/1402.1173
  - https://arxiv.org/abs/1411.3342
- The impact on the axial-vector mediator model studied in:
  - https://arxiv.org/abs/1605.04917
- Public code to automatically incorporate these effects:
  - https://github.com/bradkav/runDM/

Figure from arXiv:1605.04917v2

DM-proton scattering



DM-neutron scattering



Effective couplings change interpretation!
=> Different limits for proton vs neutron scattering

Output of RunDM

Start with axial-vector coupling "A1 scenario" coupling to all quarks at 500 GeV:

Universal AV coupling to quarks with $g_q = 0.25$

```
c_q1 = -0.25
c_u = 0.25
c_d = 0.25
c_q2 = -0.25
c_c = 0.25
c_s = 0.25
c_q3 = -0.25
c_t = 0.25
c_b = 0.25
```

No couplings to other SM particles

```
c_l1 = 0.0
c_e = 0.0
c_l2 = 0.0
c_mu = 0.0
c_l3 = 0.0
c_tau = 0.0
c_H = 0.0
```

Use RunDM to evolve couplings to 1 GeV:

Effective AV couplings with non-universal quark couplings and nonzero lepton couplings

```
c_A^u   = ~0.236
c_A^d   = ~0.263
c_A^c   = ~0.236
c_A^s   = ~0.263
c_A^b   = ~0.261
c_A^e   = ~0.0137
c_A^mu  = ~0.0137
c_A^tau= ~0.0137
```

… also results in effective V couplings

```
c_V^u   =  0.0050
c_V^d   = -0.0093
c_V^c   =  0.0050
c_V^s   = -0.0093
c_V^b   = -0.0070
c_V^e   = -0.0006
c_V^mu  = -0.0006
c_V^tau= -0.0006
```

- Can run couplings, but not clear how to calculate full interpretation
- What to do with mixed AV & V couplings? Non-universal quark couplings? Etc
- Feedback welcome!