DM simplified model coupling scans

Snowmass EF10

September 2, 2021

Andreas Albert,
on behalf of the LOI authors

BOSTON UNIVERSITY

Snowmass LOI: Displaying dark matter constraints from colliders with varying simplified model parameters

Andreas Albert,[1] Antonio Boveia,[2] Oleg Brandt,[3,*] Eric Corrigan,[4] Zeynep Demiragli,[1] Caterina Doglioni,[4] Boyu Gao,[2] Ulrich Haisch,[5,*] Philip Harris,[6,*] Jeffrey Krupa,[6] Greg Landsberg,[7] Alexander Moreno,[7] Katherine Pachal,[9] Priscilla Pani,[10,*] Tim M. P. Tait,[11,*] David Yu,[7] Felix Yu,[12] Lian-Tao Wang[13]

Starting situation

DM interpretations often formulated
in simplified models. Parameter space:
mediator spin, coupling type, m_{med}, m_{dm}, g_q, g_χ, g_l

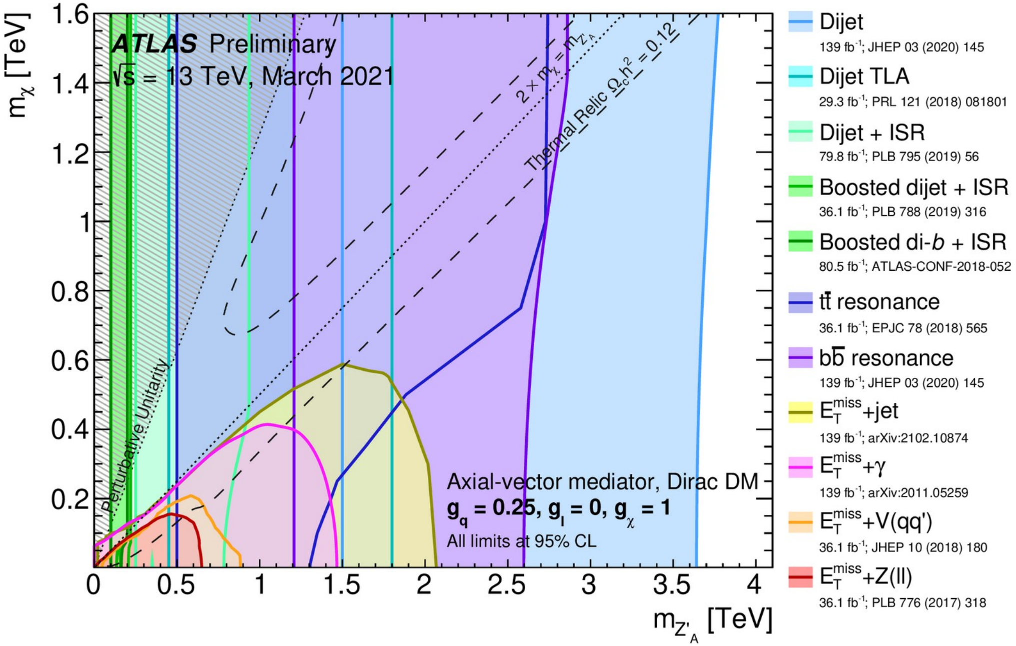
+ minimal width assumption

Steps for a typical result plot
1. Pick a mediator spin/type, e.g. axial-vector
2. Pick fixed couplings (g_q, g_χ, g_l)
3. Draw exclusion in m_{med}-m_{dm} plane

→ Focus on mass dimensions made sense in historical context of early Run-2: new √s=13 TeV, large gains in mass, etc

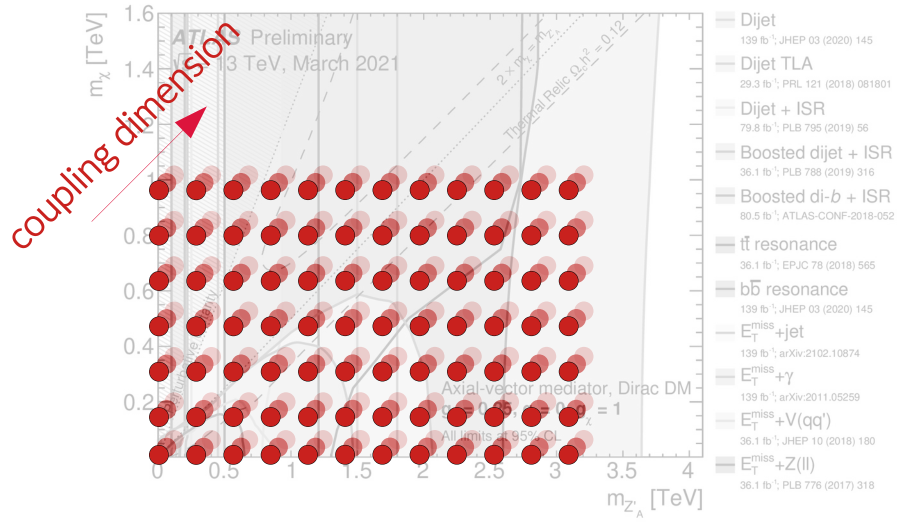
Information is lost here: What happens if the couplings change?
Absolute exclusions & channel interplay change
low-mass analysis improvements (systematics) can be exposed

→ Must explore coupling dimension systematically



Practical implications

Naive approach to cover parameter space:
Multi dimensional sample production



Complexity grows quickly in both computing and human effort :(

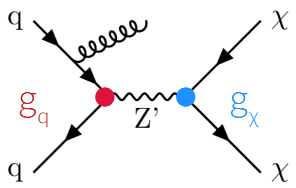
If not done in experiments, recasting effort comes on top

Alternative approach: rescaling of existing limits
→ If we know μ(gq=0.25), can we e.g. obtain μ(gq=0.2) ?

Two parts to the equation:

Signal cross section vs kinematics

Simple example: Monojet



Total on-shell cross section × branching:

$$\sigma \times B \sim g_q^{\,2} \times \Gamma_{med \to \chi\chi}(g_q, g_\chi) \,/\, \Gamma_{med \to anything}(g_q, g_\chi)$$

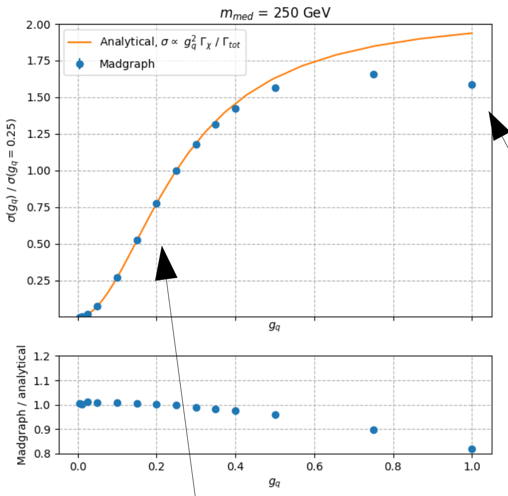
Signal strength limit:

$$\mu \sim 1/(\sigma \times B)$$

→ If you know μ for one point in (gq, gχ) space,
can rescale completely analytically to different points

Approach works well if width effects are small
→ low couplings, sufficiently on shell ($m_{DM} < 2 \times m_{med}$)

Comparison of anaytical scaling with actual XS from MG:



%-level agreement for gq < 0.4 or so
approach starts to fail above

That's fine! Interesting phase space is @ g_q<0.25
→ the limitation does not matter much in practice

Method already in use e.g. here

Scope & status

Scope:

1. Describe rescaling methods and evaluate their performance and limitations
   - Provide ready-to-use formulas, validate against Madgraph, specify regions of validity
   - Explore (semi-analytical) refinements: propagator & PDF reweighting can capture some width dependence

2. Cover different topologies: mono-X, dijet, dilepton)

3. Provide the code to do all of it

→ Goal is to lower the barrier of entry for the reader
Can I achieve my goal with rescaling?
What level of refinement do I need?

Format: short DMWG whitepaper + python package

Status:

Initial work exists: paper draft, partial validation data / plots
Work largely dormant during snowmass shutdown
Now regrouping

Backup