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ATLAS DM summary plots

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the dijet, dijet+ISR, TLA, monojet, monophoton analysis teams

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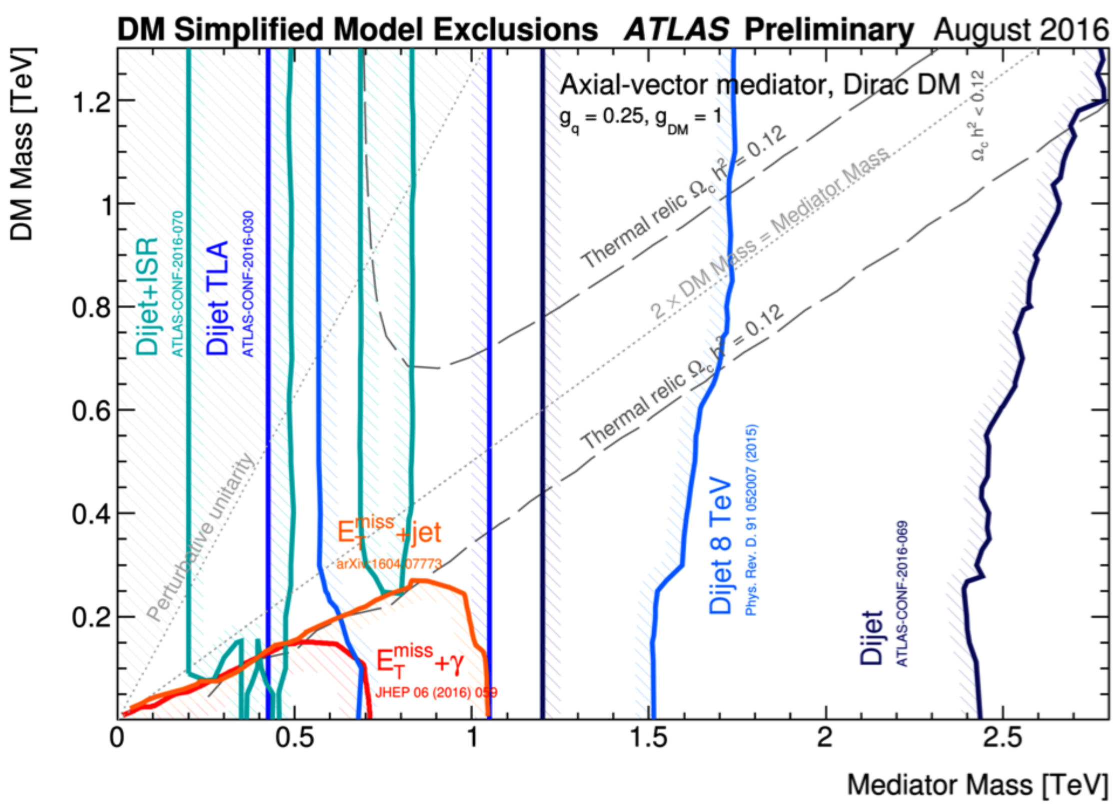
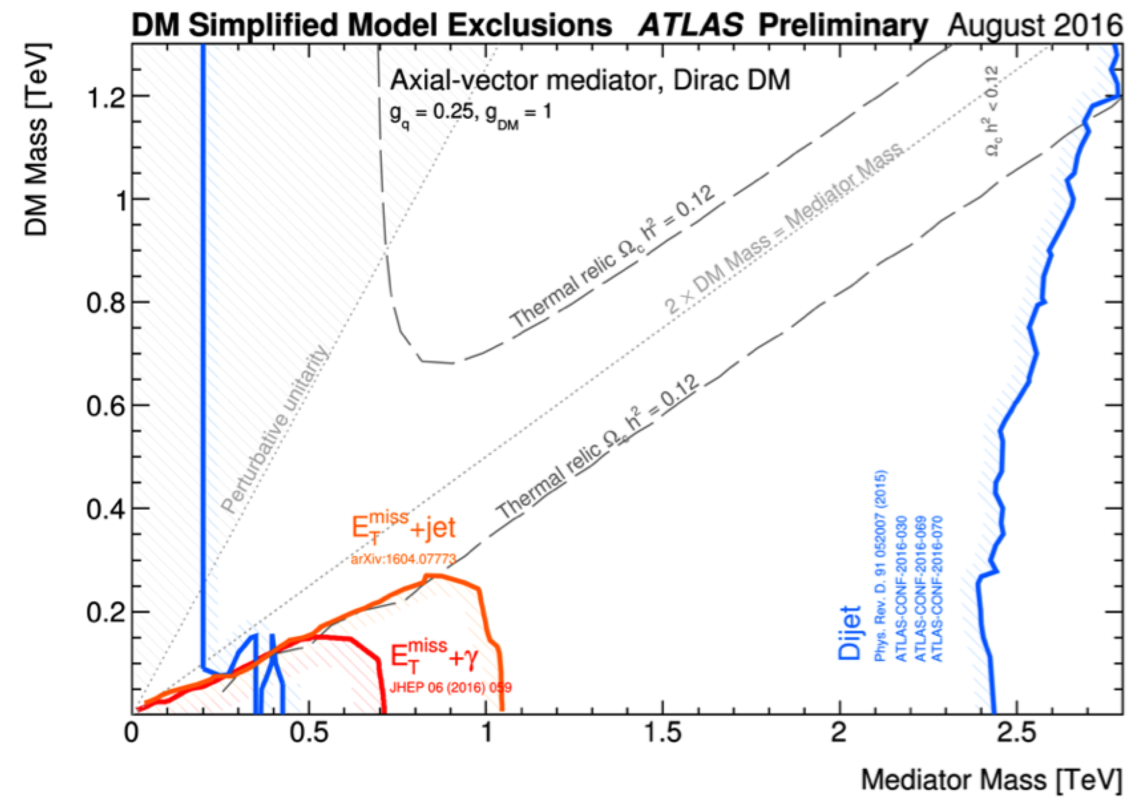
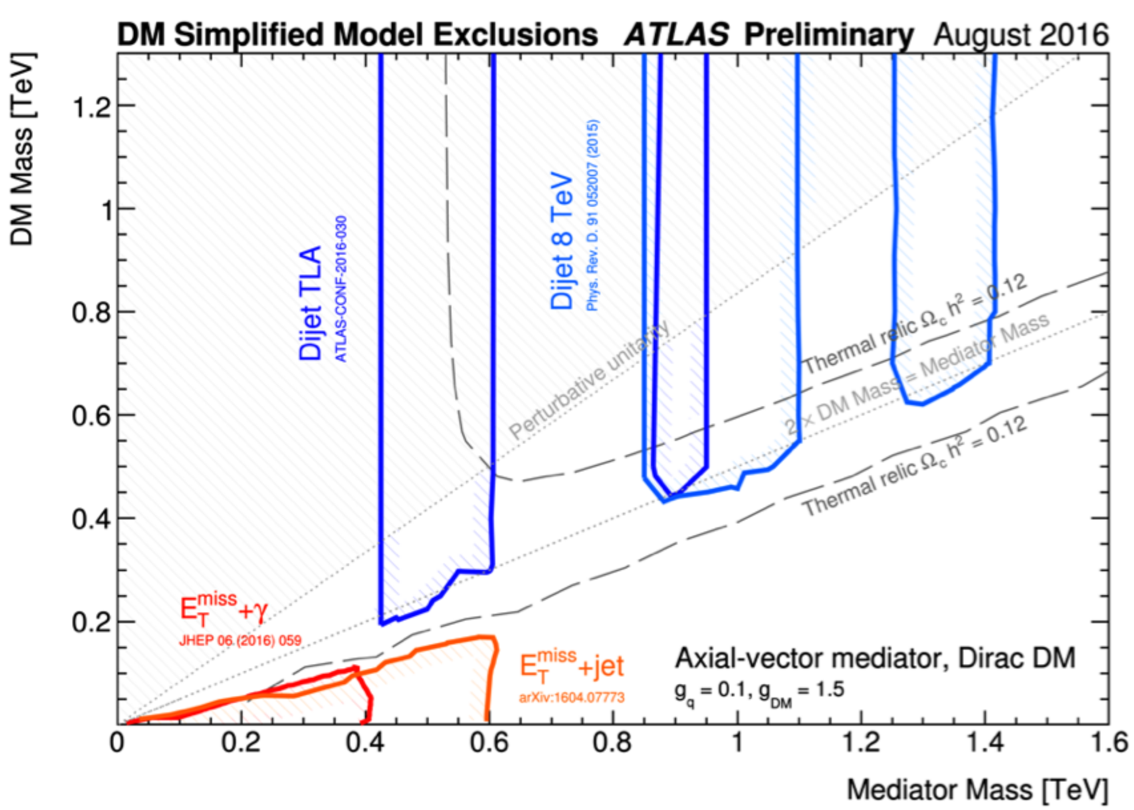
ATLAS summary plots

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CombinedSummaryPlots/EXOTICS/index.html

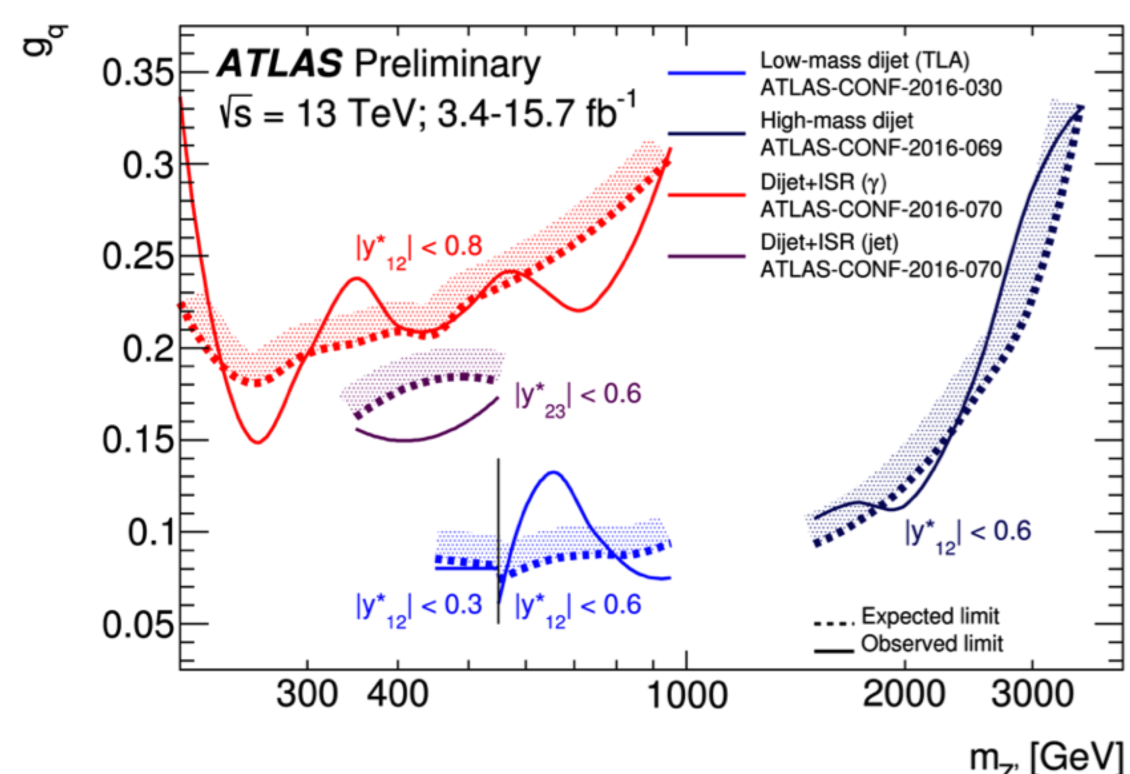
DM mass - Mediator mass, fixed couplings
Mono-jet/photon and dijet searches





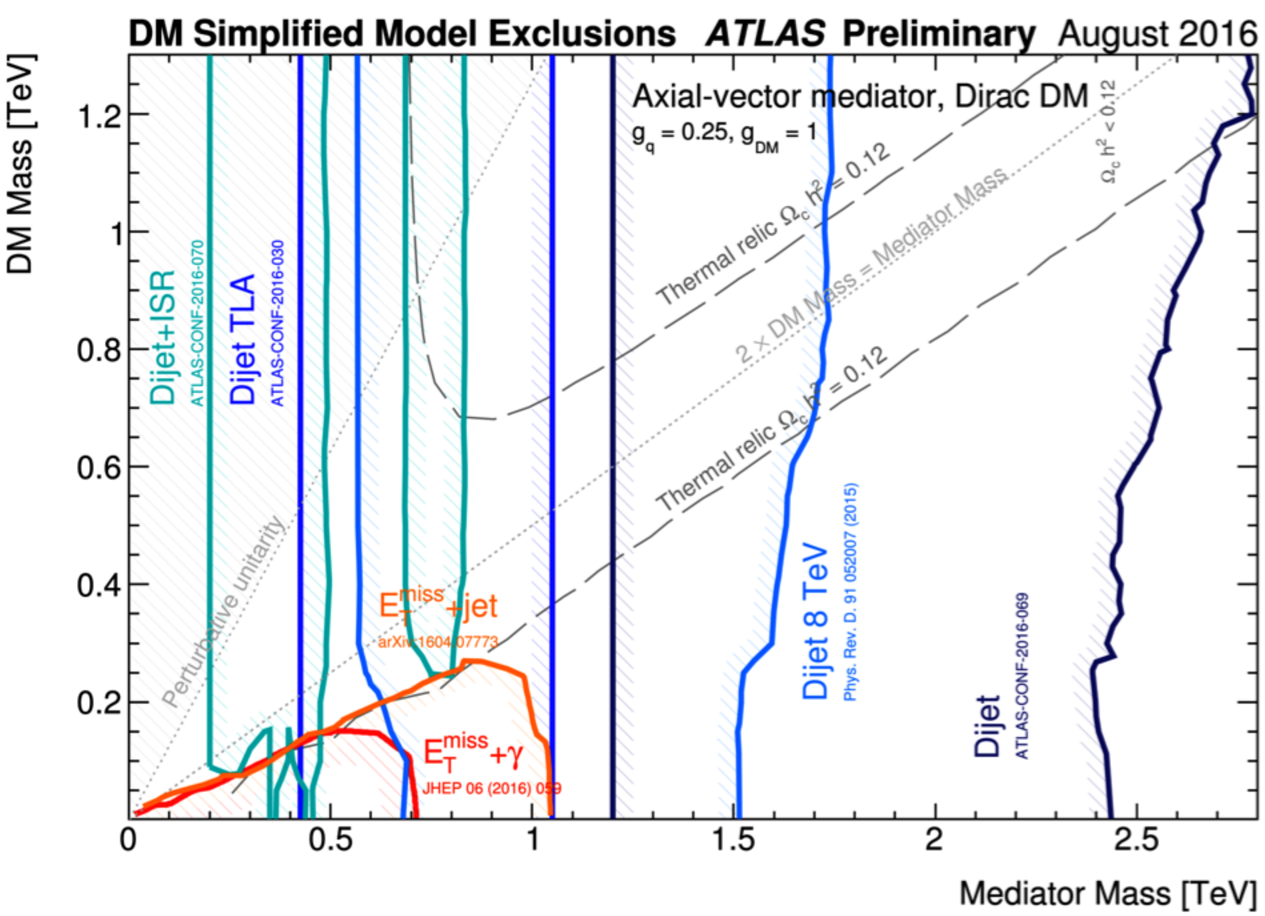


SM coupling - Mediator mass
Fixed DM mass (off-shell), dijet searches only



How is the mass-mass plot made?

DM mass - Mediator mass
Fixed SM and DM couplings
Mono-jet/photon and dijet searches



Dijet-like searches:
Reinterpretation using Gaussian limits, following the procedure of Phys. Rev. D91 052007 (2015), see next slides

Monojet/monophoton:
Use result in mass-mass plane
Result can be rescaled to other couplings, after checking that acceptance does not vary

Relic density: MadDM calculation (2.0.5 so far - check tomorrow's talk by P. Tunney)

Perturbativity line:

$$m_{\rm DM} = \sqrt{\pi/2}\, M_{\rm med}\ (g_{\rm DM})^{-1}$$

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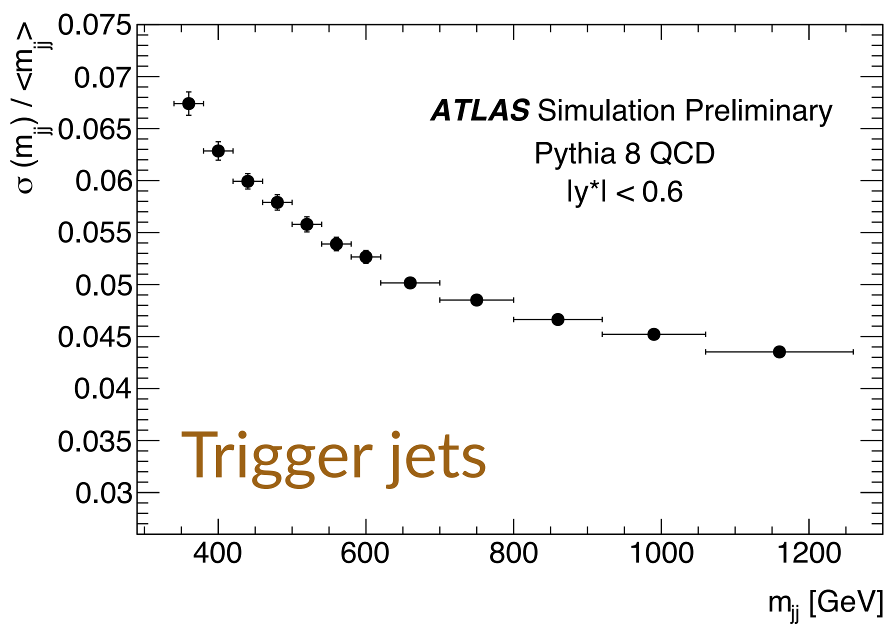
1. Create signal templates

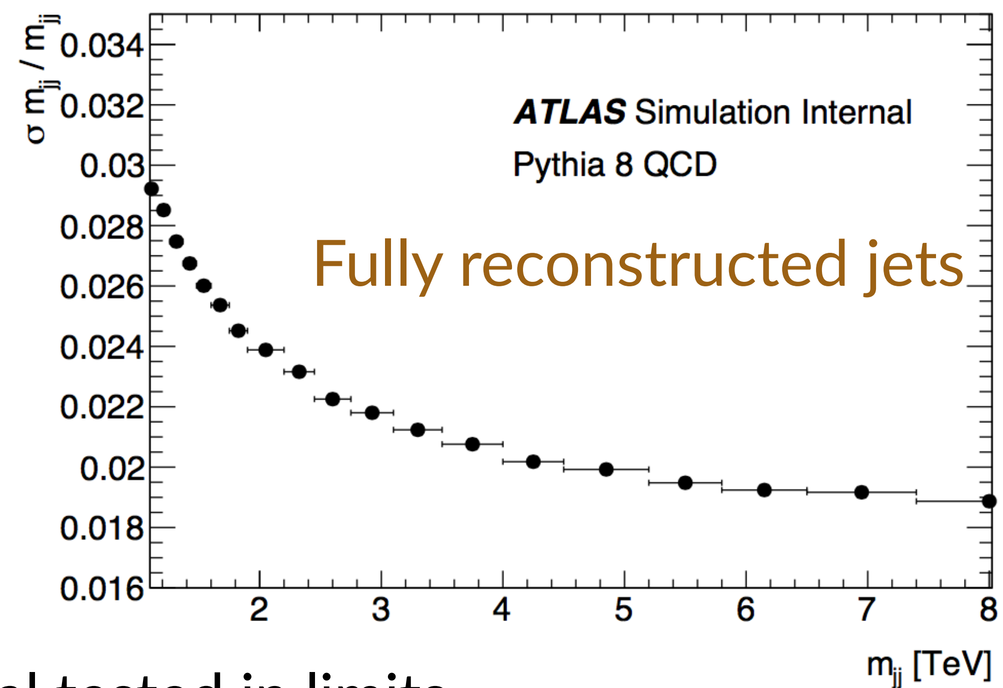
- Use MadGraph DMSimp package to generate axial vector mediator
  - Generate axial vector mediator **with b-quarks**:
    - `generate p p > xi, xi > j j`
    - `add process p p > xi, xi > b b~`
    - Some early samples had light quarks only:
      - template shape with and without b-quarks unchanged to inclusive dijet analysis
        - a b-jet is a jet is a jet is a jet, account for fragmentation changes in JES uncertainties
      - for these samples, multiply light quark theory xsec*BR by 1.25
  - Recalculate and apply minimal width with all six quark flavours
    - This ensures production side contains (little) top but there is no BR enhancement on the decay side (limit on sigma*A*BR)
    - This effectively makes the analysis insensitive to top quarks but keeps the right width: conservative
      - Dedicated analyses would be better off for t-tbar decays of the mediator

For next iteration: should ATLAS and CMS agree on a parameter card?

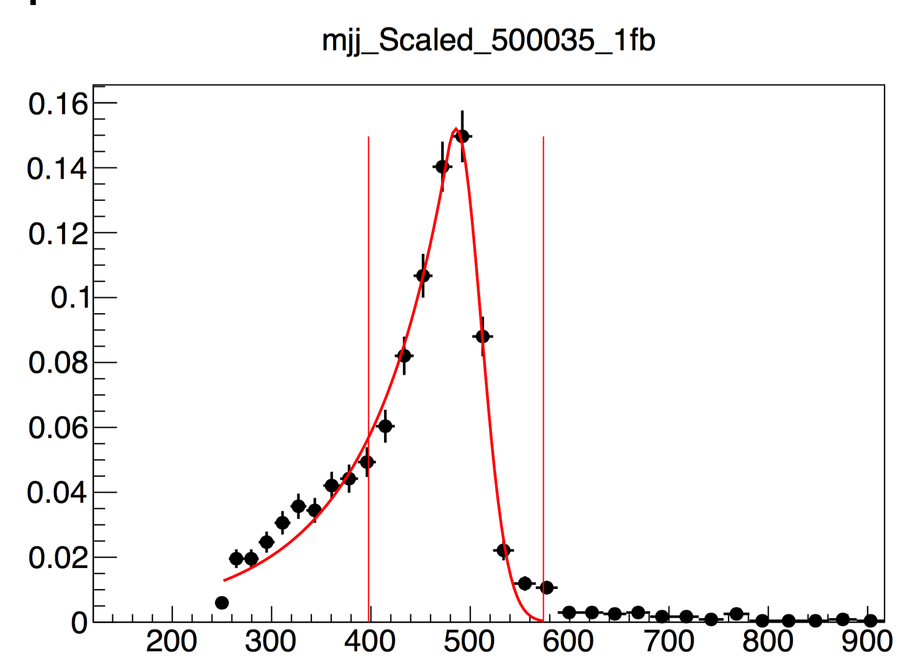
2. smear templates, take Gaussian acceptance

- Apply dijet resolution smearing to mass template
  - Relevant for low-mass mediators with trigger-level jets (worse resolution wrt offline analysis)





- Comparing to Gaussian templates: no tails in signal tested in limits
- Following procedure in Phys. Rev. D91 052007 (2015) and arXiv:1306.2629, truncate tails after a Crystal Ball fit and derive an acceptance correction



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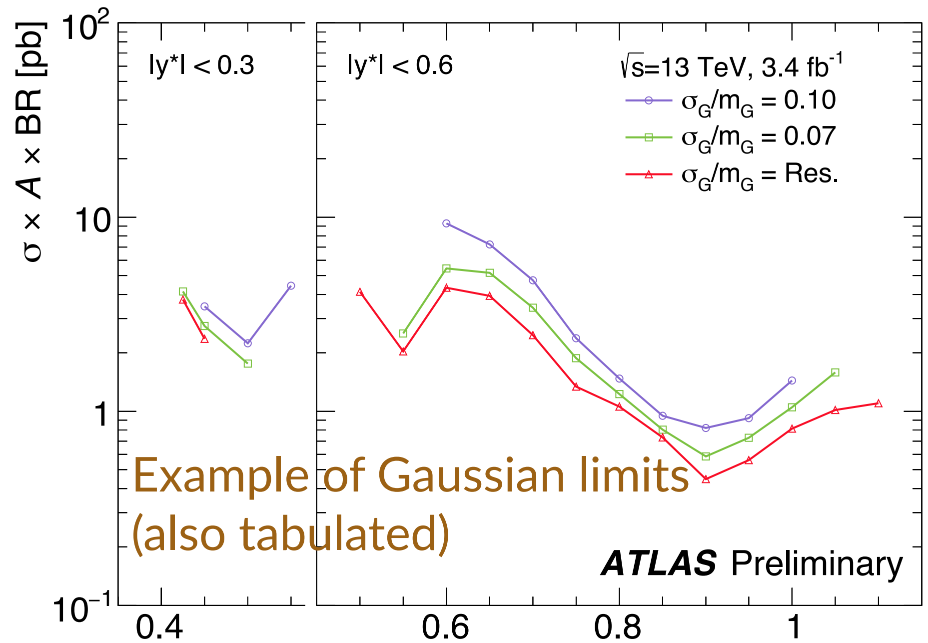
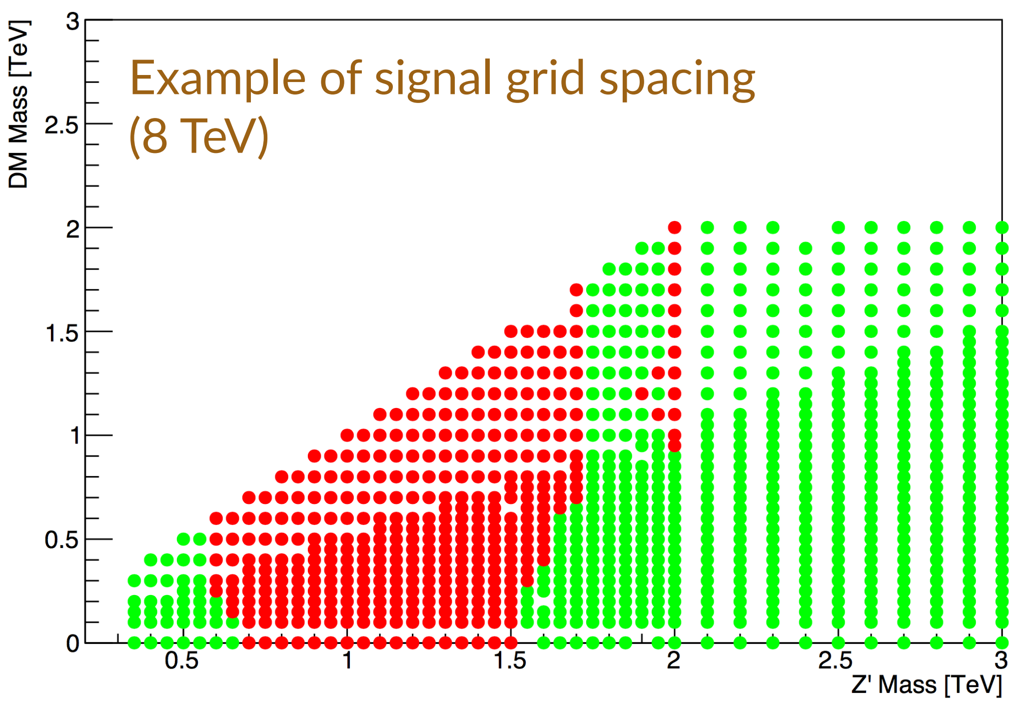
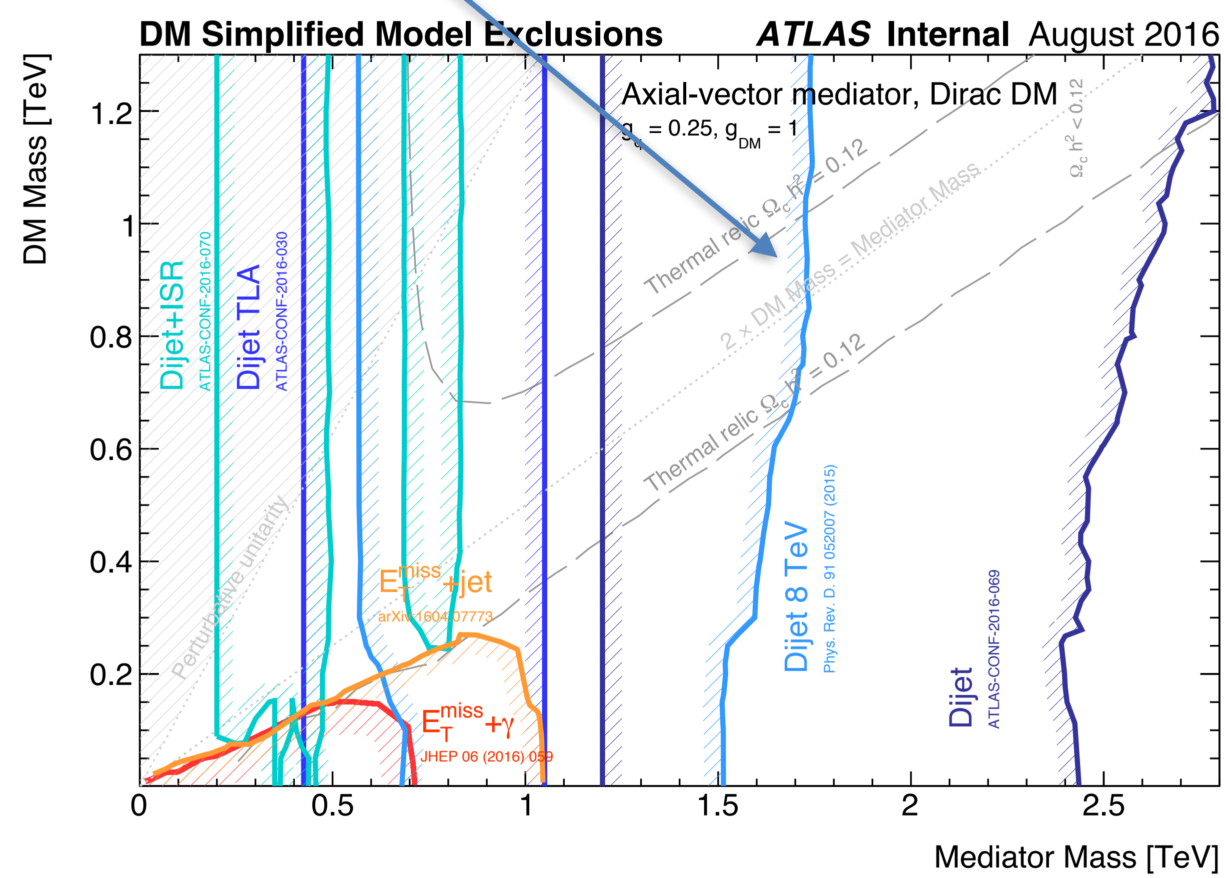
3. compare observed/theory (σ x A x BR)

- Comparison of observed 95% CL limit vs theory on σ x A x BR of Gaussian shapes





Off-shell wiggles convey size of extrapolation effects



- Fine grid spacing, still some finite grid effects
- Morphing would be better, but it does not take too long to generate + smear (order 1-2 days)
- This is not a plot intended for reinterpretation

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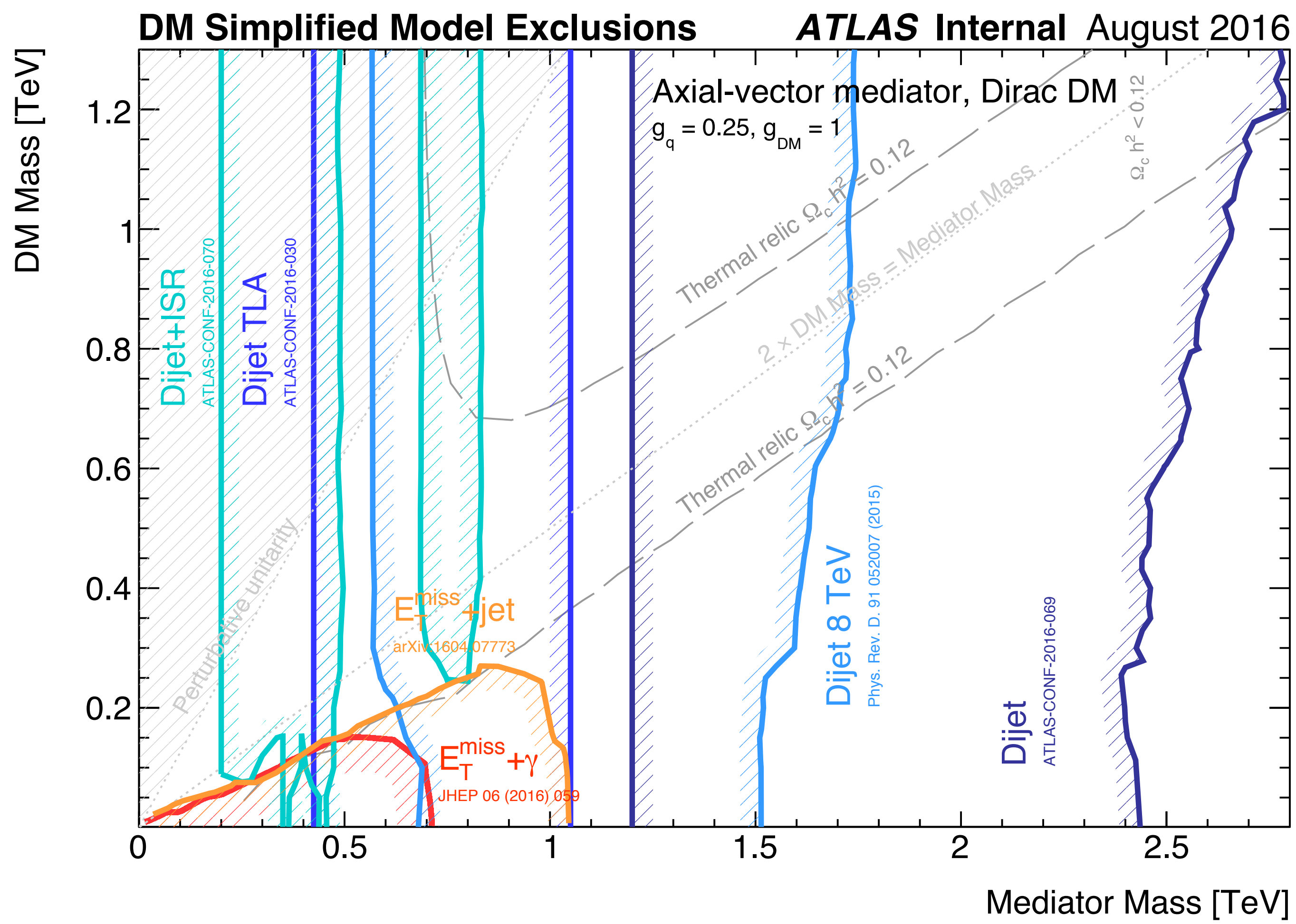
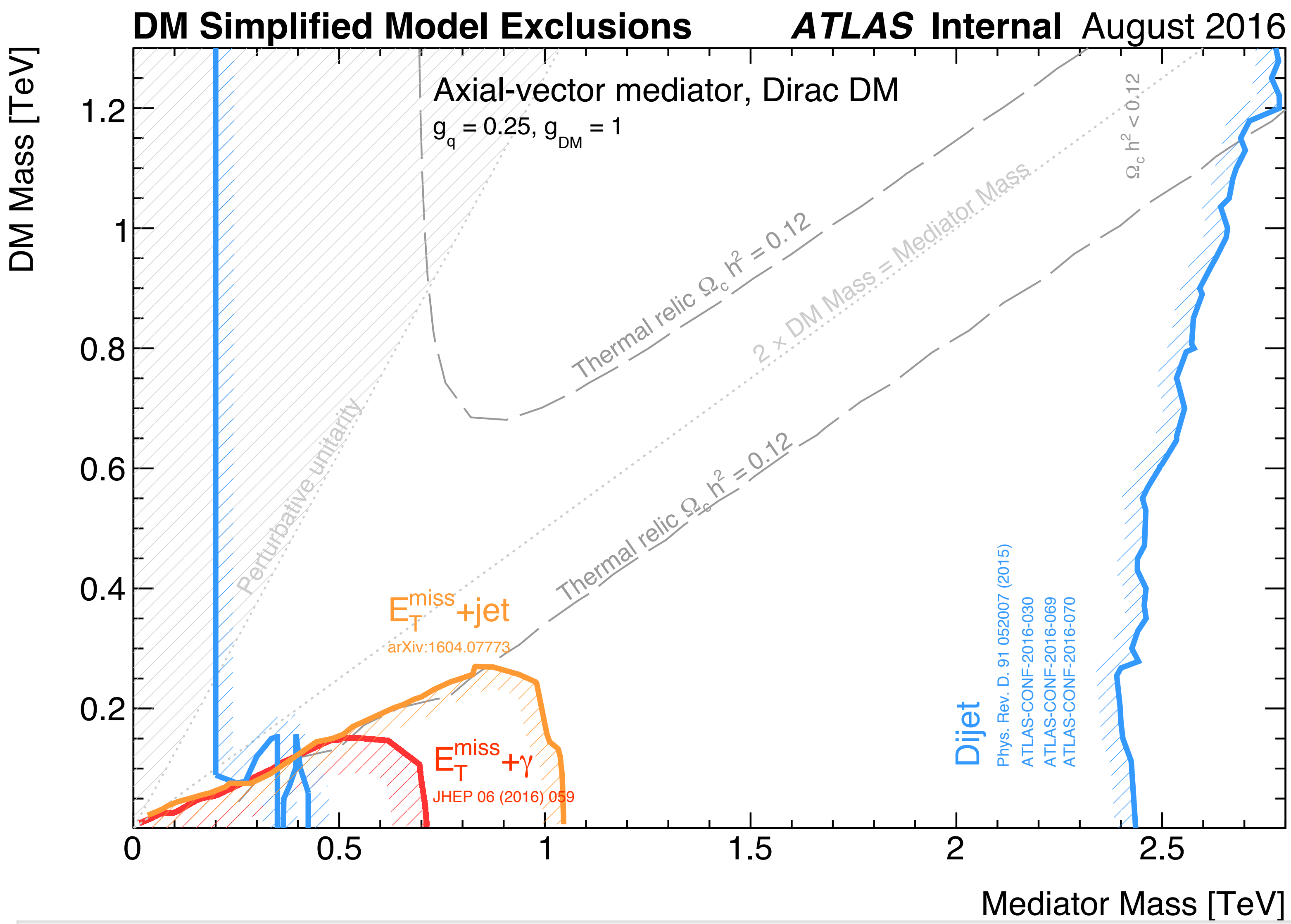
gSM=0.25, gDM=1.0



Regions in a dark matter mass–mediator mass plane excluded at 95% CL by a selection of ATLAS dark matter searches, for one possible interaction between the Standard Model and dark matter, the lepto-phobic axial-vector mediator described in arXiv:1507.00966. The exclusions are computed for a dark matter coupling g_{DM} = 1.0 and a quark coupling g_q = 0.25 universal to all flavors. The results use 13 TeV data from 2015 except for Phys. Rev. D91 052007 (2015). The exclusions from the ATLAS dijet searches are derived from the limits provided on Gaussian-shaped resonances following the procedure recommended by ATLAS in Appendix A of Phys. Rev. D91 052007 (2015). The search for new resonances in a dijet system accompanied by a photon or jet Initial-State Radiation (ISR) (ATLAS-CONF-2016-070) excludes mediator masses starting from 200 GeV. Results from the Trigger-object Level Analysis (ATLAS-CONF-2016-030) and the dijet resonance searches at 8 (Phys. Rev. D91 052007 (2015)) and 13 TeV (ATLAS-CONF-2016-069) constrain the parameter space starting from 425 GeV up to 2.5-2.8 TeV depending on the value of the dark matter mass. Dashed curves labeled "thermal relic" indicate combinations of dark matter and mediator mass that are consistent with a dark matter density of Ω_c = 0.12 h^{-2} and a standard thermal history, as computed in MadDM. Between the two curves, annihilation processes described by the simplified model deplete Ω_c below 0.12 h^{-2}. A dotted curve indicates the kinematic threshold where the mediator can decay on-shell into dark matter. Points in the plane where the model is in tension with the perturbative unitary considerations of JHEP 02 016 (2016) are indicated by the shaded triangle at the upper left. The exclusion regions, relic density contours, and unitarity curve are not applicable to other choices of coupling values or model.

gSM=0.25, gDM=1.0, simple version



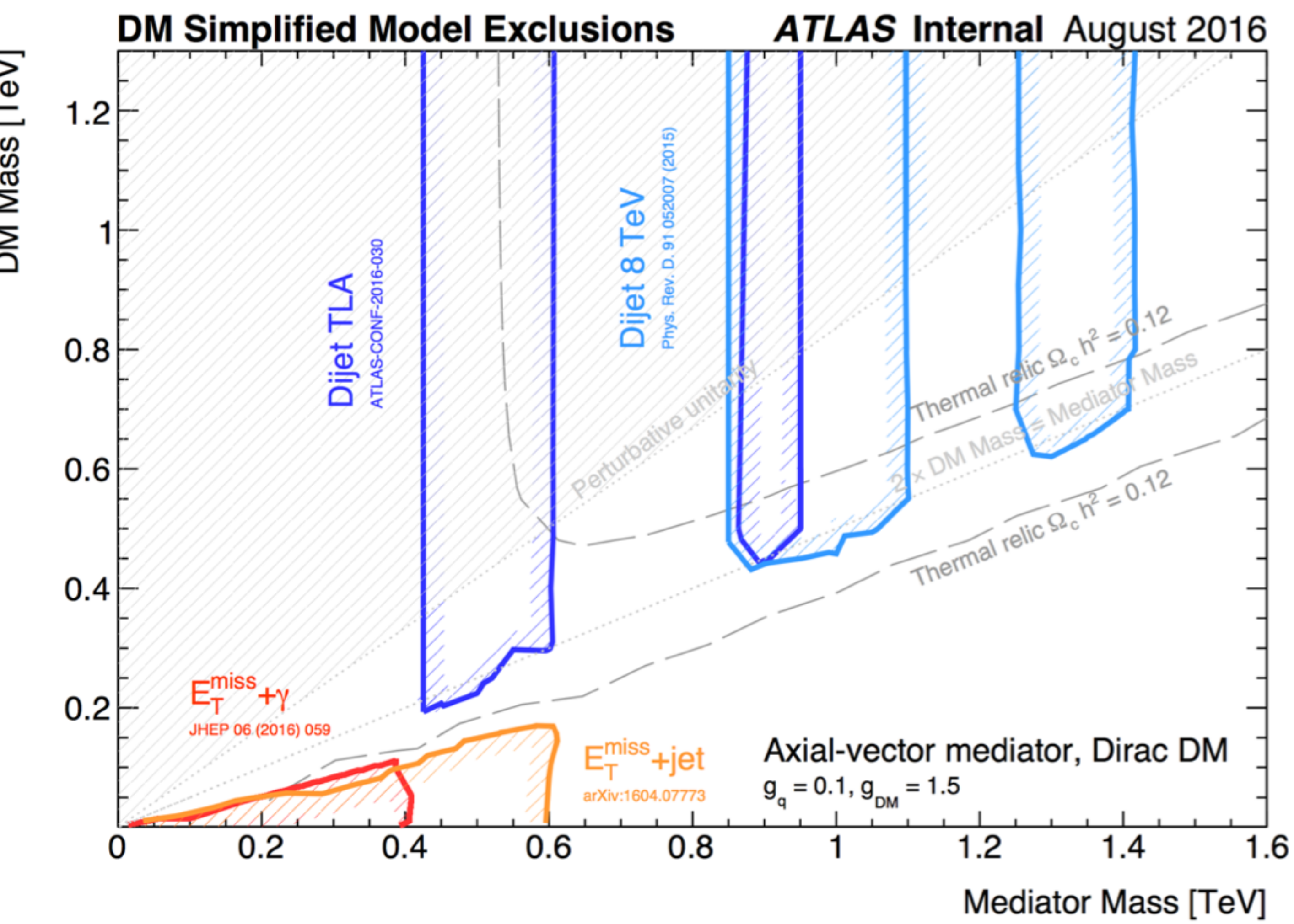
An alternate version of the figure, with all dijet results combined to form a single exclusion.

Need to be careful
with message from this plot

We should **not** convey that:
- dijets dominate over monojet
- there is not much more to do in terms of DM@LHC

Other couplings: gSM=0.1, gDM=1.5

Aim: find a benchmark point highlighting complementarity of monojet, rather than dijet domination



Exclusions are computed for a dark matter coupling g_{DM} = 1.5 and a quark coupling g_q = 0.1 universal to all flavors. With this choice of couplings, the Z' decays to quarks are suppressed in favour of a higher branching ratio to dark matter particles, reducing the sensitivity of dijet searches to this scenario. The mono-jet and mono-photon exclusion regions are obtained by rescaling, using acceptance and cross-section information from samples simulated at truth-level, the exclusion contours published in the corresponding papers. The exclusion regions, relic density contours, and unitarity curve are not applicable to other choices of coupling values or model.

Couplings chosen so that perturbativity limits are not too stringent (would happen for larger gDM)

For discussion: does this have a bearing on current DMF recommendations?

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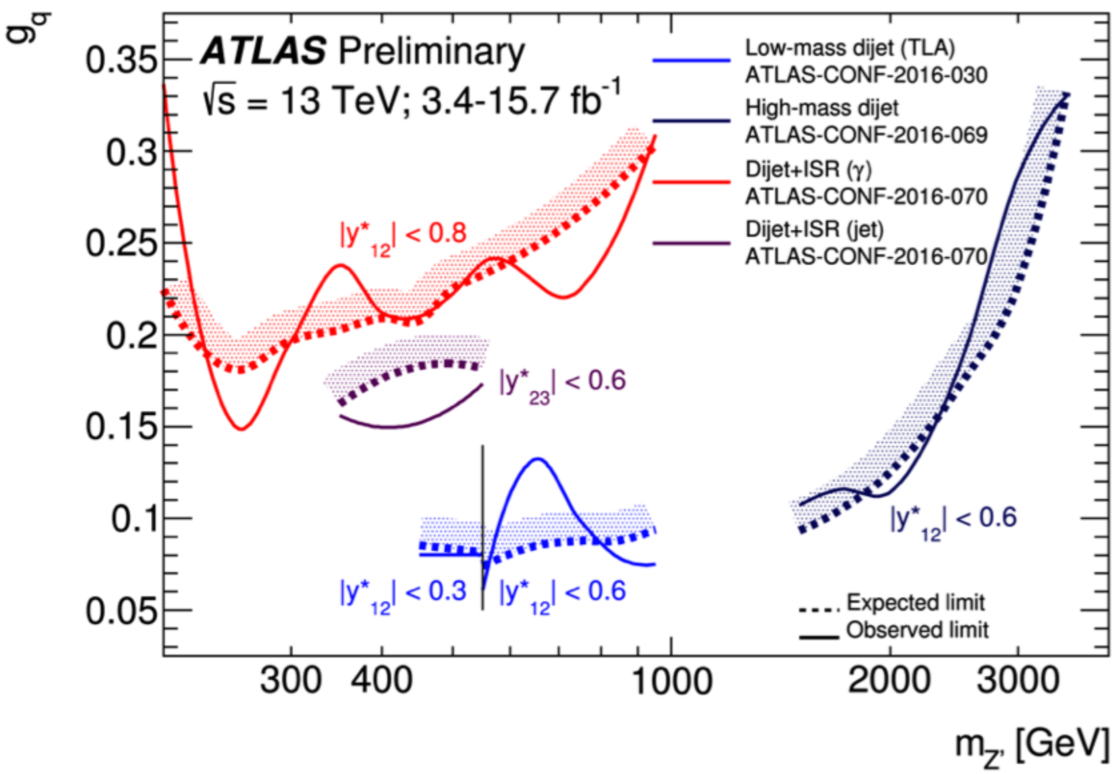
How is the coupling-mass plot made?

SM coupling - Mediator mass
Fixed DM mass (off-shell)
Dijet searches only



All searches displayed here use Z' as benchmark
this is the reason why no 8 TeV limits are displayed

Input: xsec_limit / xsec_theory from each search, from full simulation

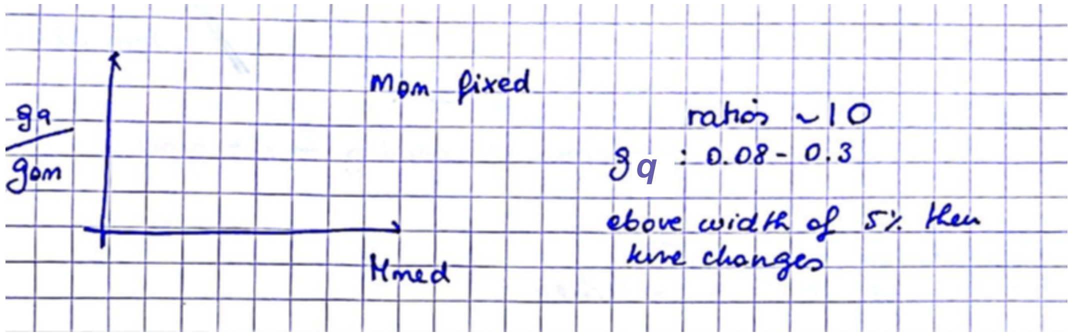
Lines shown on plot where xsec_limit = xsec_theory, using interpolation:
- **scaling** by gq^2 on y axis
- **'C'** interpolation option by ROOT on mZ' axis

Summary plot of ATLAS bounds in the Dark matter mass-coupling plane from dijet searches using 2015 data. Caption: The 95% CL upper limits obtained from three ATLAS searches using 2015 data on coupling g_q as a function of the resonance mass m_Z' for the leptophobic Z' model described in arXiv:1507.00966. The expected limits from each search are indicated by dotted curves. The darker blue curves show the results from a "high-mass" search using the traditional triggering strategy for dijet resonances, employing the lowest-transverse-momentum-threshold single-jet trigger without prescales (ATLAS-CONF-2016-069). The red curves show the results from a search triggering on events containing a photon, such as those radiated from the initial state partons that would produce the resonance (ATLAS-CONF-2016-070). The lighter blue curves show the results from a Trigger-object Level Analysis (TLA) of events triggered with much lower jet tranverse momenta than the high-mass result (ATLAS-CONF-2016-030). The selections in the rapidity difference ($y^{*} = \frac{1}{2}of the two jet used to reconstruct the invariant mass (y_i - y_j)$) are also shown, for the three searches. Coupling values above the solid curves are excluded, as long as the signals are narrow enough to be detected using these searches (10% signal width / mass for dijet+ISR and TLA, 15% for high-mass dijets).

Discussion

- Alternative coupling values: worth recommending? One or more values?

- Alternative summary plot proposals:
  - vary one, not both couplings, or
    use coupling ratio as y axis and fix DM mass
    - 1d or 2d plot? which axes?
    - how to show relic density lines?
    - more intensive simulation work for mono-X: doable?
  - see also talk from Jacques, Nordstrom, Gramling at the last DMWG meeting



- Dedicated discussion on lepton couplings coming next

- Minor: do we trust this Gaussian reinterpretation (or any observed limit) to better than 10%?
  Main differences:
    - tail truncation
    - full simulation vs smearing of mass peak using dijet mass resolution
  Agreement with full model-dependent limits ranging from 10% to 35%

- Minor for this plot: RGE evolution: see Francesco D'Eramo's talk at the last DMWG meeting
  - Limits for axial vector mediator change when evolved to DD scale
  - This plot is consistent, but mention in caption this is taken at LHC CoM scale?

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