Search for Dark Matter in the mono-X* final states with ATLAS

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(on behalf of the ATLAS Collaboration)

Rencontres de Moriond (EW) 2018

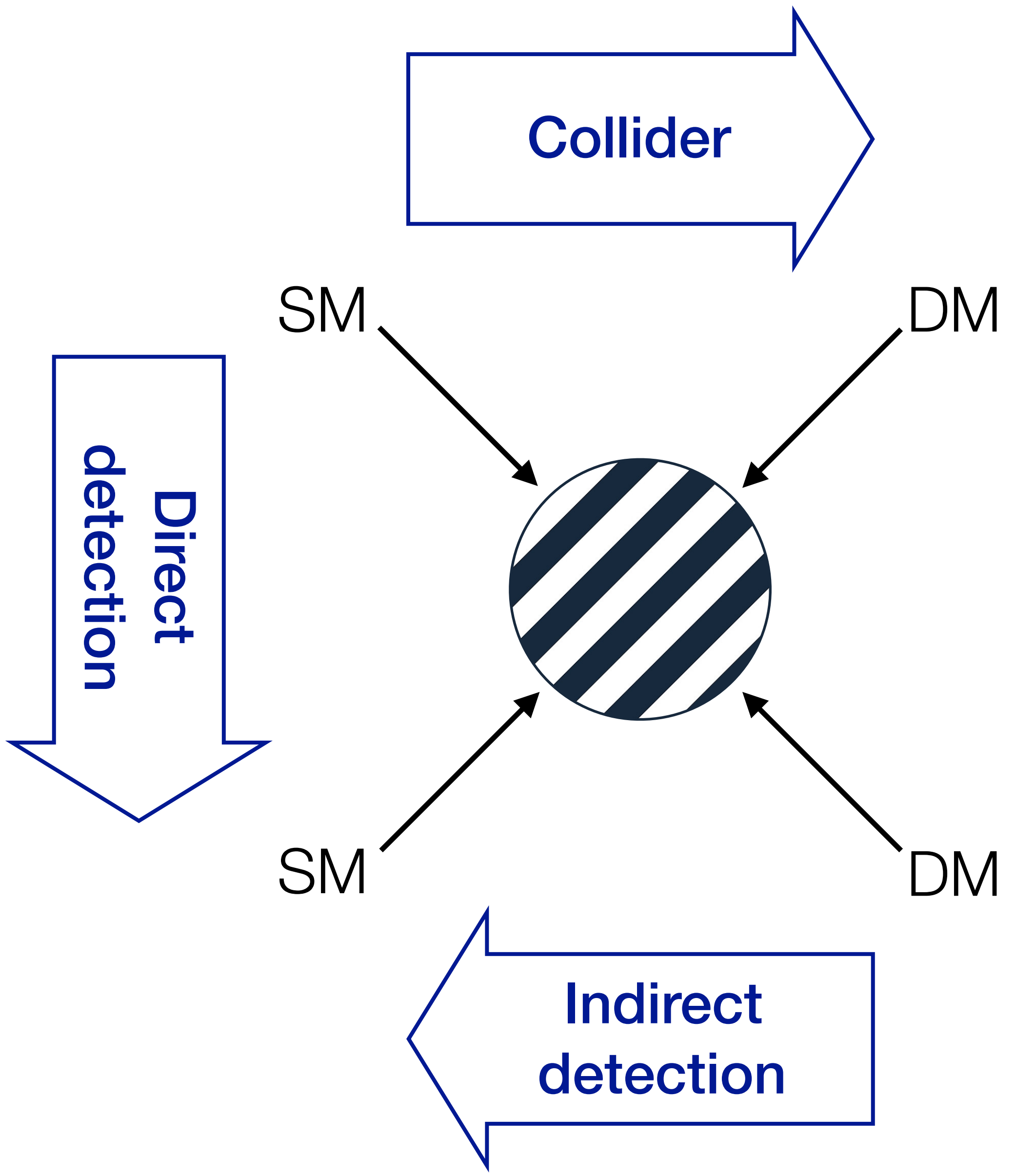
*: X = jet, Z, W, H

Probing Dark Matter (DM)

Underlying assumption: DM has also non-gravitational interactions with the Standard Model particles (SM)

- *Direct detection*: scattering of DM particles on nuclei
- *Indirect detection*: annihilation products out of WIMP collisions
- *Collider search*: produce WIMPs through collision of SM particles

DM is assumed to be a *weakly interacting massive particle* (WIMP)



The theoretical framework

A large number of DM models are out there, each with its own assumptions/observables/DM candidates

Completeness

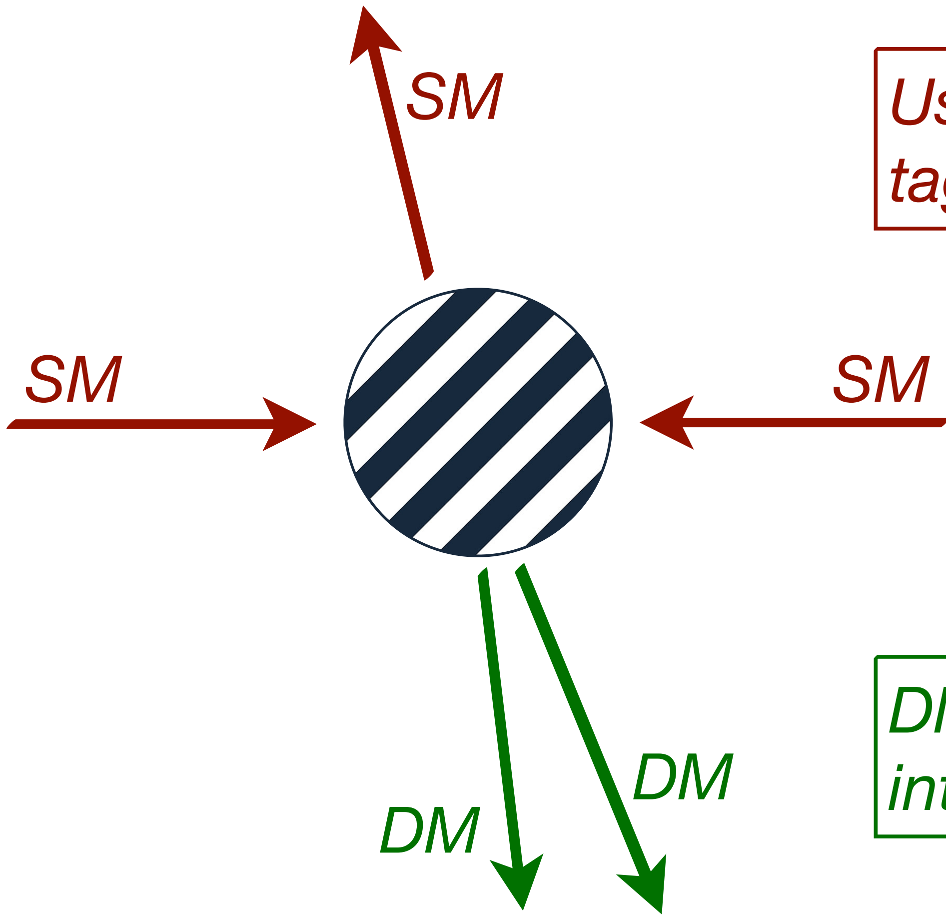
Effective Field Theory: just assume a massive mediator (M_{MED} >> momentum transfer), i.e. contact interaction only valid at low Q^2

Simplified Models:
- $M_{MED} \sim M_{DM}$
- more assumptions on the mediator (e.g. different spin hypotheses)
- DM is a Dirac fermion
- 4 parameters: M_{DM}, M_{MED}, mediator couplings to DM and SM

Complete Models: SUSY, extra-Dimensions, etc.

ATLAS/CMS DM Forum: arxiv:1507.00966

Mono-X strategy



Use SM particles (or "objects") to select and tag the event

DM particles go through the detector without interacting with it

Mono-X: require a large amount of missing transverse momentum (due to DM) and a known object (X = jet, photon, W, Z, Higgs, …) recoiling against it

Also other strategies are used (e.g. resonance search), but they are not covered in this talk

Interesting reading:
B. Penning, "The pursuit of DM at Collider - an overview"
arxiv:1712.01391

Summary of ATLAS results in mono-X

mono-jet
36.1/fb $\sqrt{s}$ = 13 TeV
JHEP 01 (2018) 126
arxiv:1711.03301

mono-γ
36.1/fb $\sqrt{s}$ = 13 TeV
Eur. Phys. J. C 77 (2017) 393
arxiv:1704.03848

mono-V(had)
3.2/fb $\sqrt{s}$ = 13 TeV
Phys. Lett. B 763 (2016) 251
arxiv:1608.02372

mono-Z(lep)
36.1/fb $\sqrt{s}$ = 13 TeV
Phys. Lett. B 776 (2017) 318
arxiv:1708.09624

mono-H(bb)
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PRL 119, 181804 (2017)

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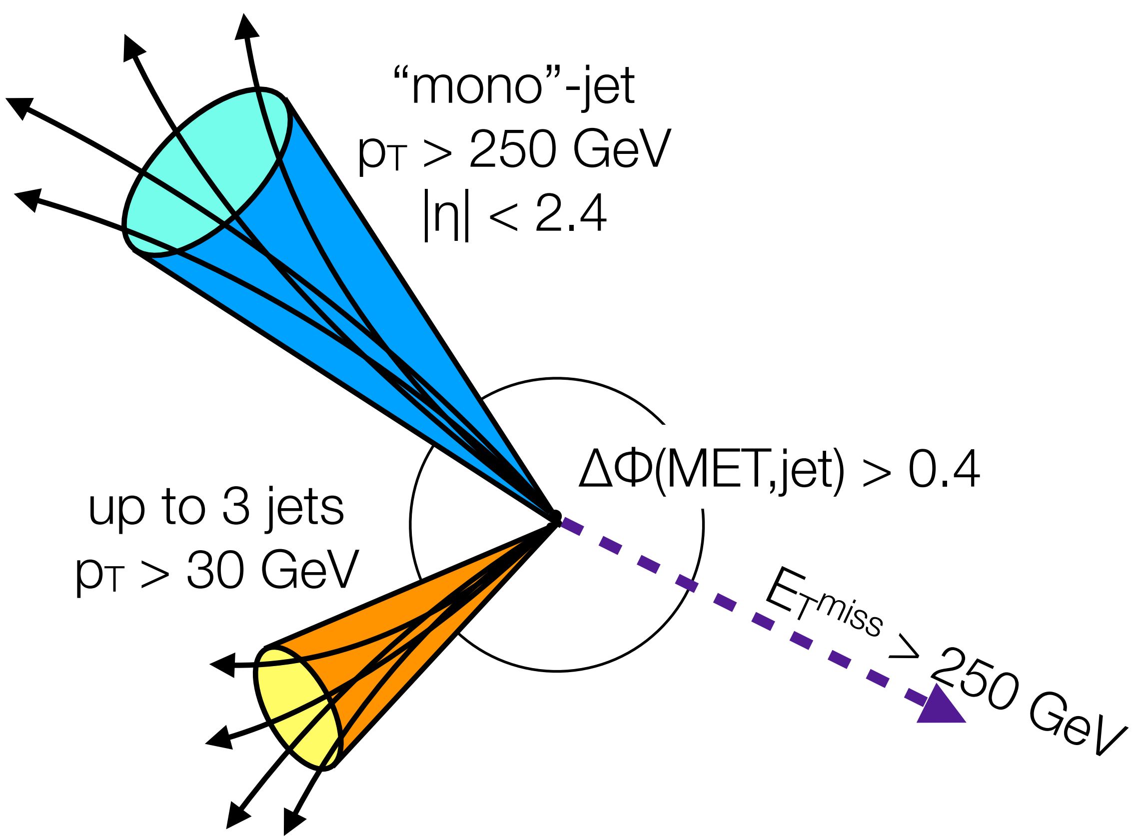
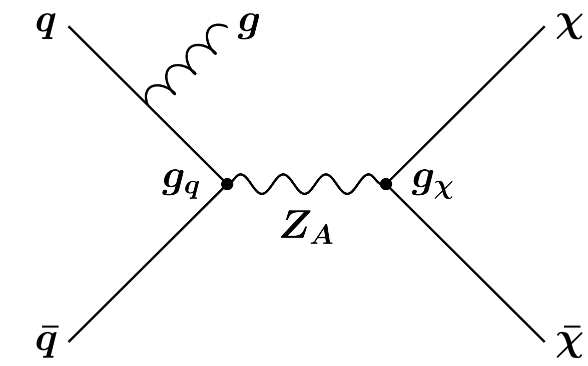
Mono-jet: analysis summary





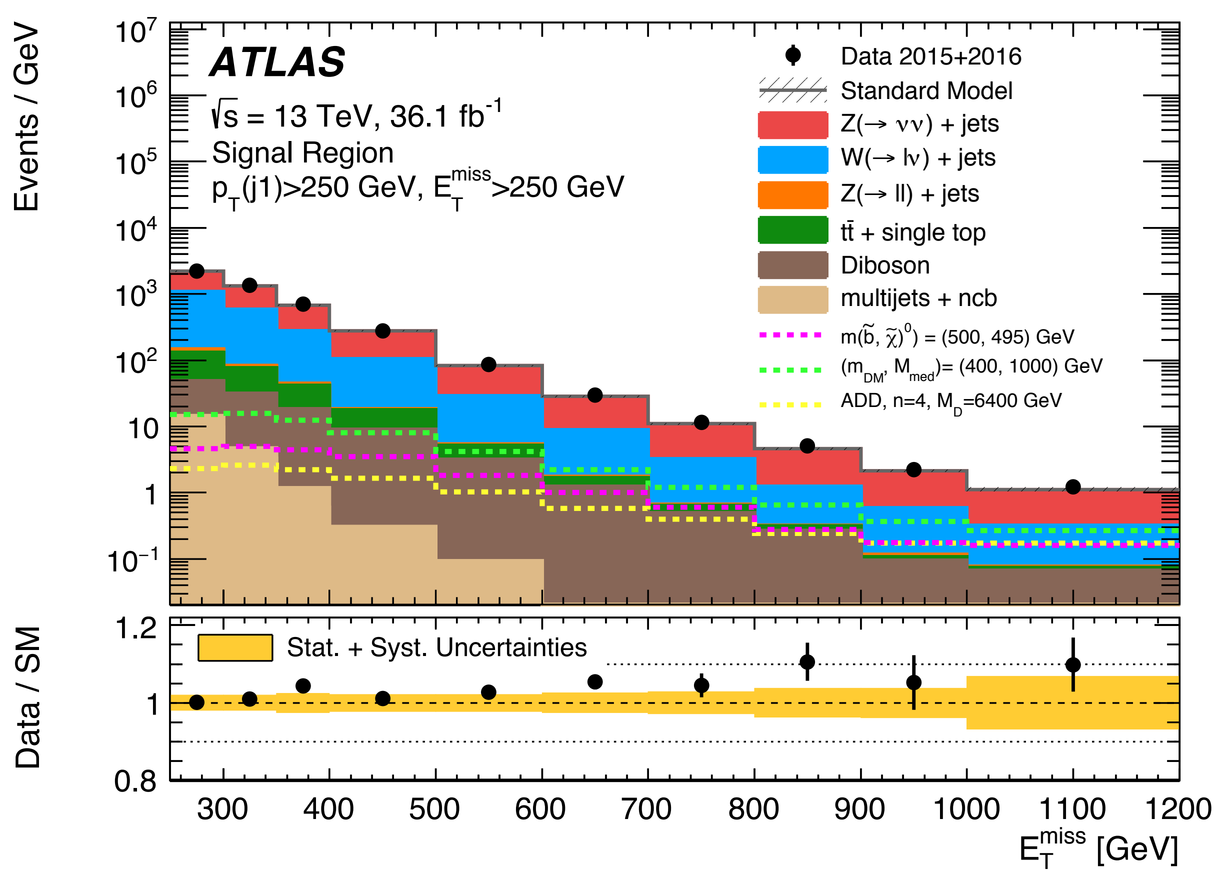
Dominant backgrounds are Z(→νν)+jets and W(→lν)+jets

constrained using dedicated control regions in which leptons are treated as invisible (e.g. Z→νν estimated from Z→μμ)

Simultaneous fit of the signal region (SR) and control regions (CR) using E_T^{miss} shape information

Main systematic uncertainties comes from E_T^{miss} and affect both signal (2-9%) and background (1-5%). Signal is also affected by ISR modelling (O(10%)).

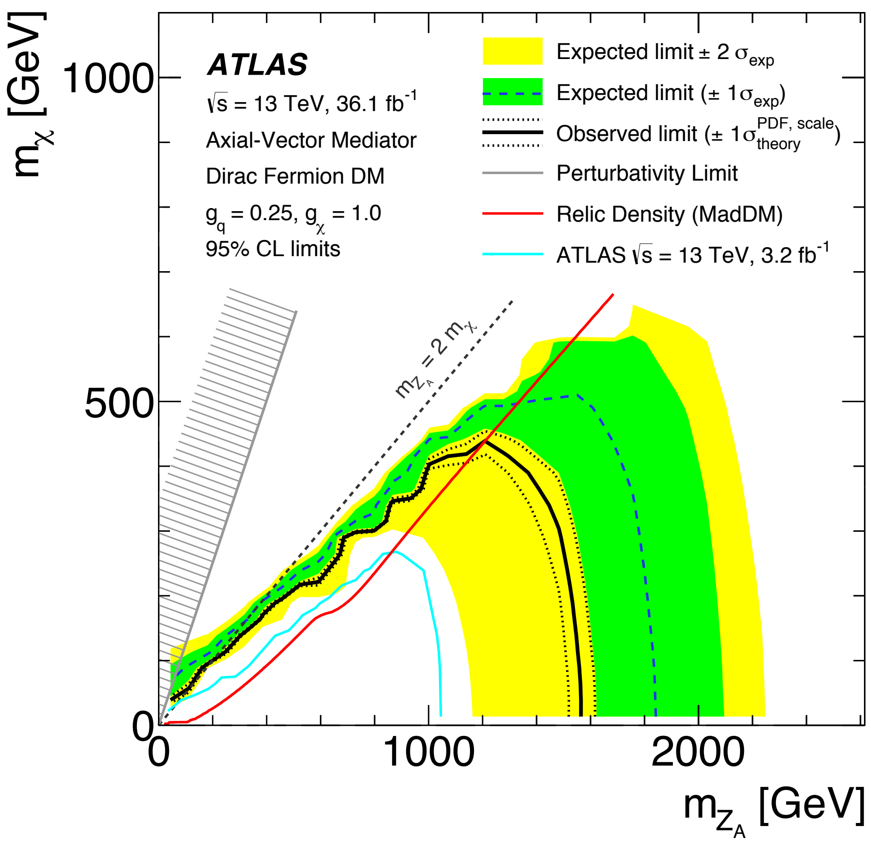
Signal is expected to arise as an excess of events in the E_T^{miss} distribution, E_T^{miss} spectrum is binned to enhance the sensitivity to several models



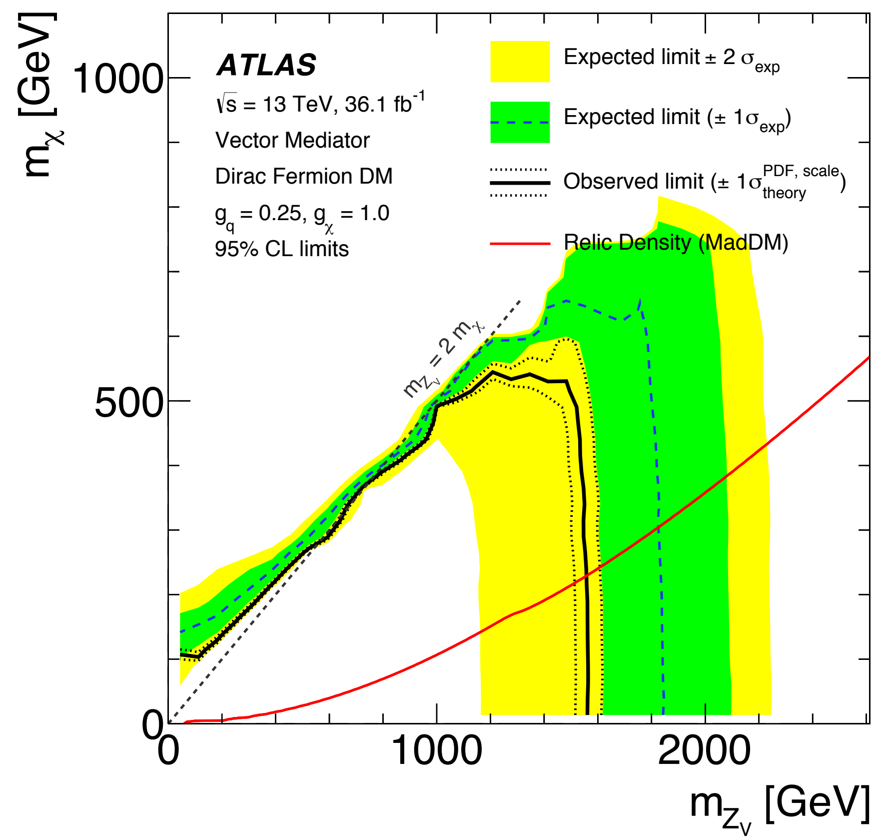
No significant excess is observed, limits are set on the relevant parameters of the model

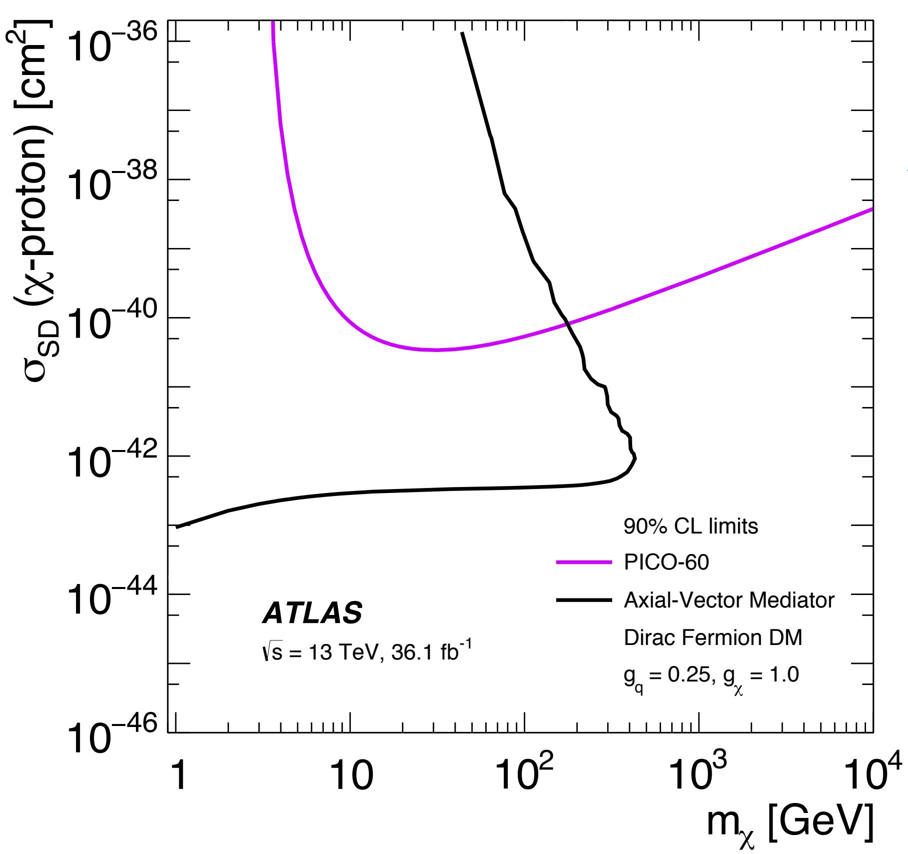
Mono-jet: results

Axial-vector mediator



Vector mediator





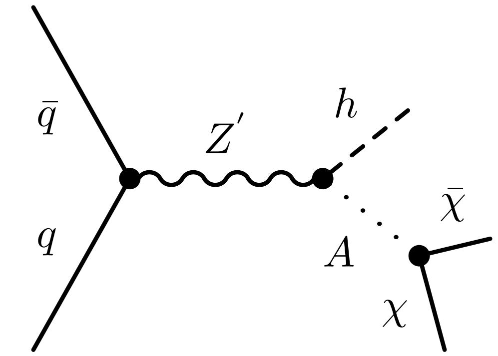
If ***strong*** assumptions are made, collider searches can play a role in the field of direct searches (here results from PICO-60 are shown)

Assume AV mediator and couplings (and DM composition) points in (xsec, m_χ) correspond to points in (M_{MED}, m_χ)

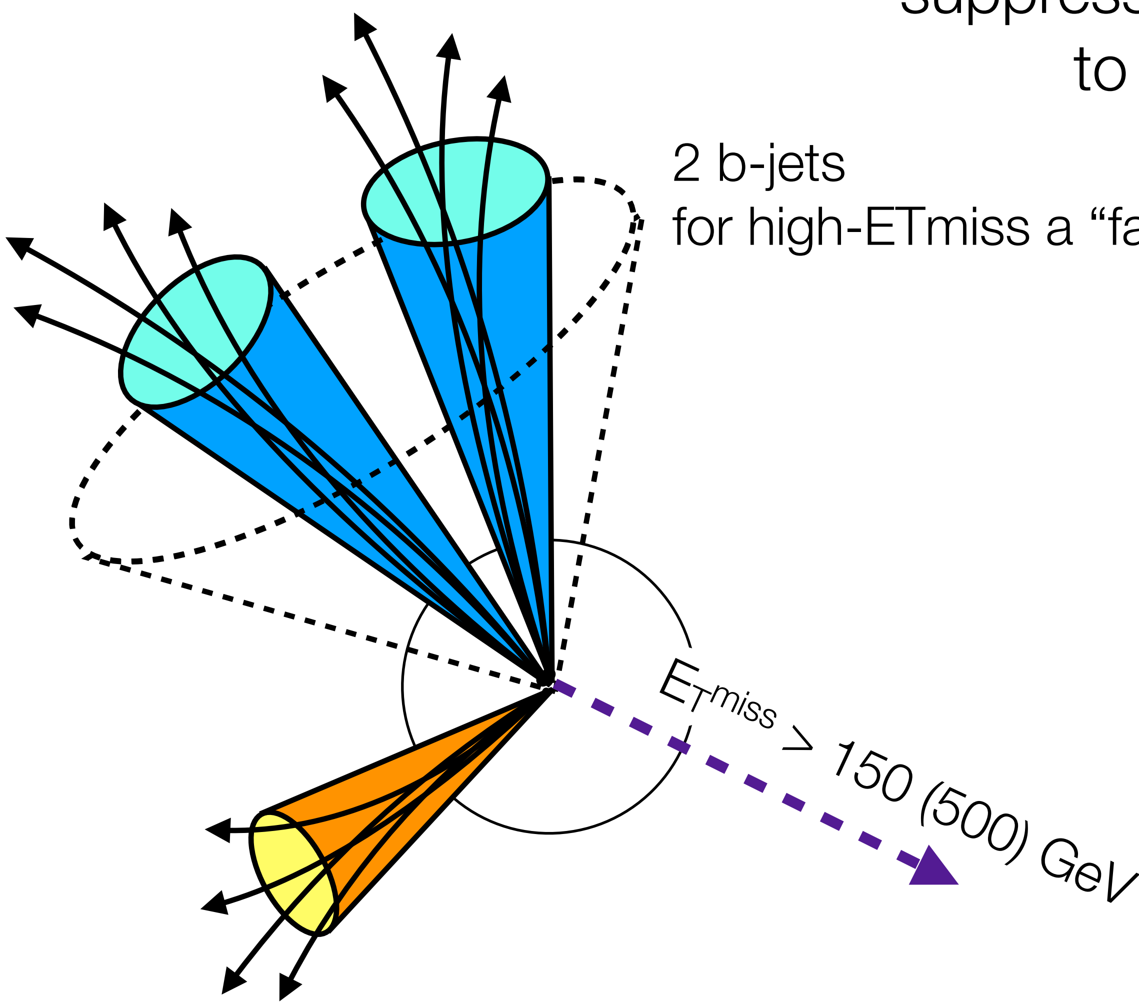
C. Amole et al., “DM search results from the PICO-60 C_3F_8 Bubble Chamber” arxiv:1702.07666

Mono-H(bb)

Higgs radiation from the initial state is Yukawa-suppressed, mono-H signatures are sensitive to different (more complex) DM models



2 b-jets
for high-ETmiss a “fat” jet with two bs inside



other soft jets allowed

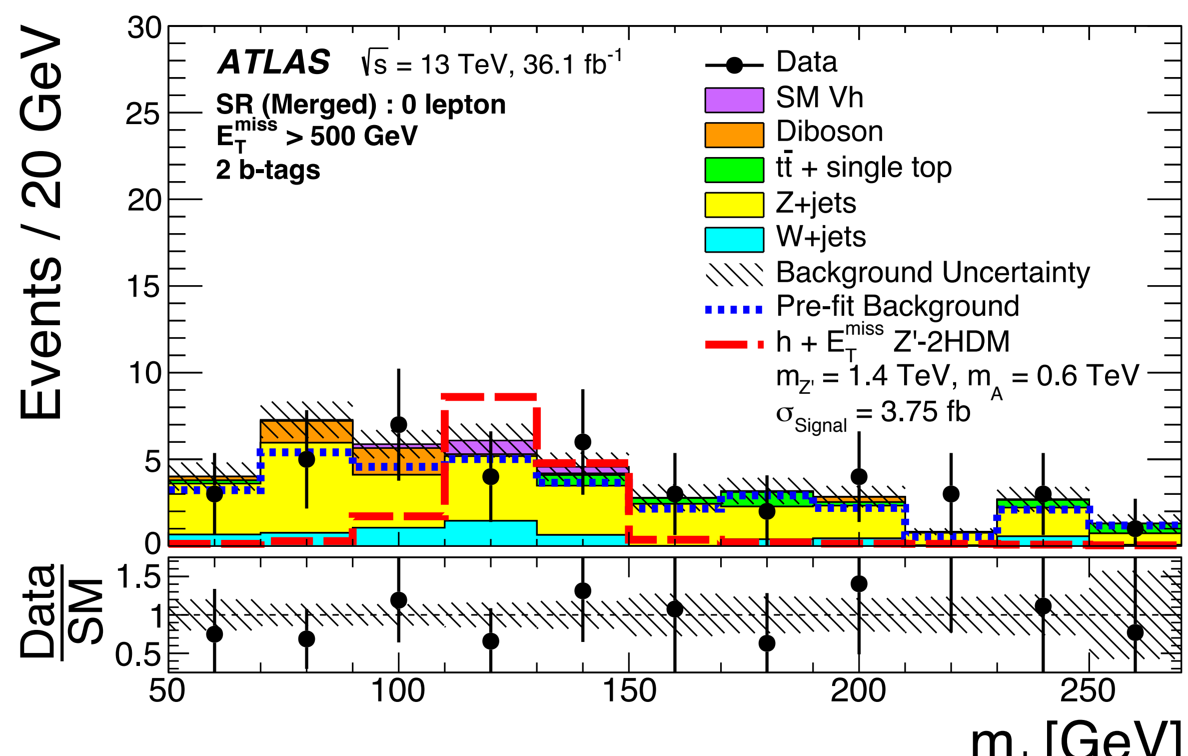
Background contamination varies as a function of the kinematic range: top quark production at low p_T, Z+jets at high p_T

backgrounds are constrained in CRs defined using leptons

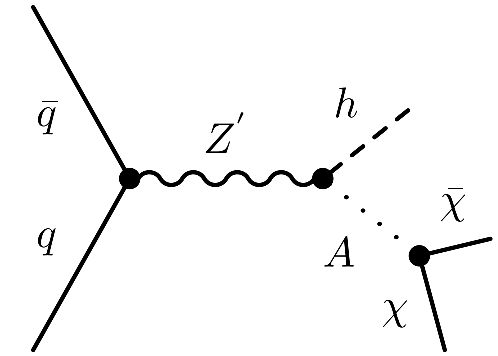
Several signal regions defined depending on the E_T^{miss} and the number of b-tagged jets

Main systematic uncertainties come from the modelling of background processes

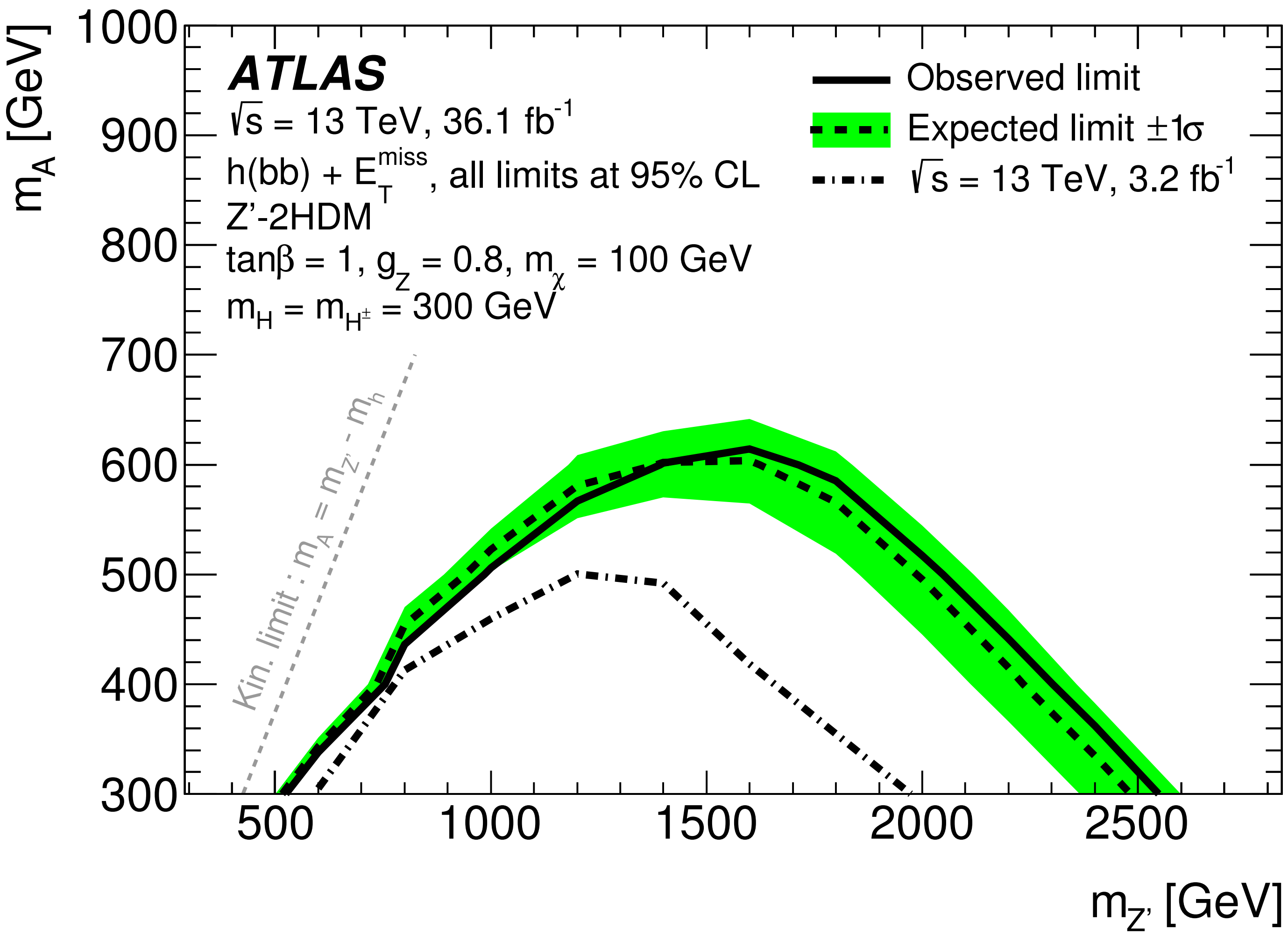
Since no SM Higgs is expected in the final state, here we look for the presence of the Higgs boson itself, which would appear in this topology thanks to DM signatures



Mono-H(bb): results



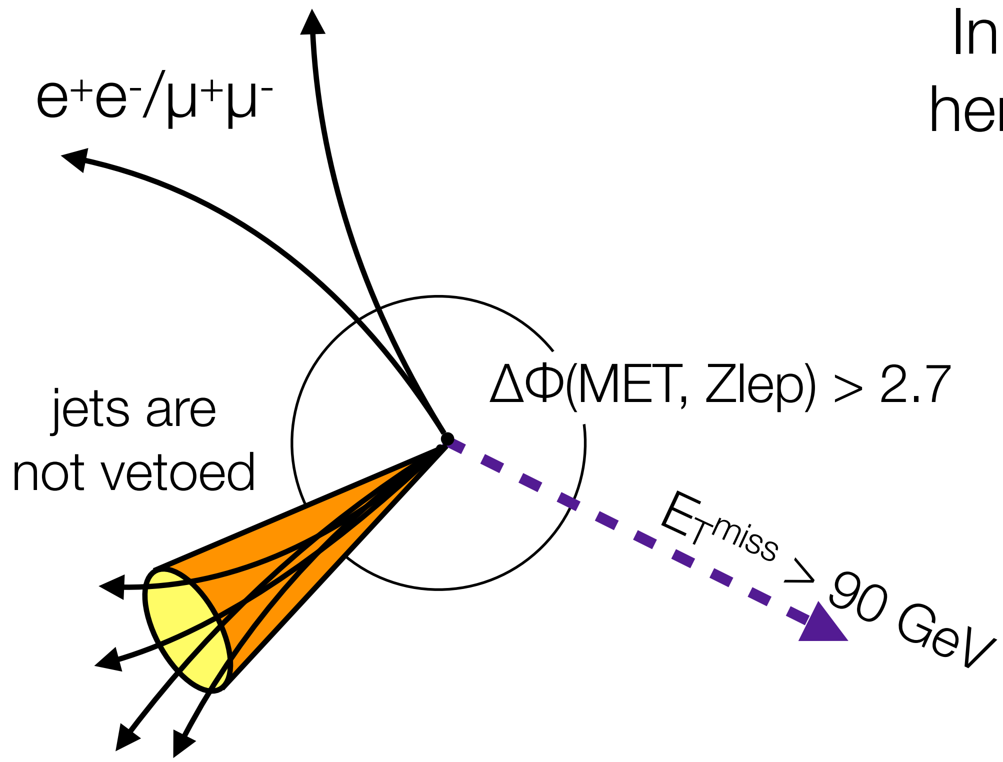
In this search, limits are set on the parameters of this specific Z'-2HDM model: scan ($m_{Z'}$, m_A) for fixed values of the other parameters



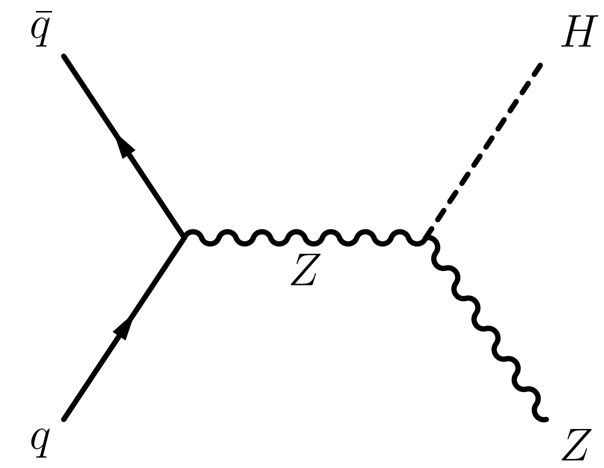
Not to be confused with the (m_{MED}, m_{DM}) plane from other mono-X searches

Z'-2HDM: a Two Higgs Doublet Model (which foresees h, H, H± and A) with an additional Z'

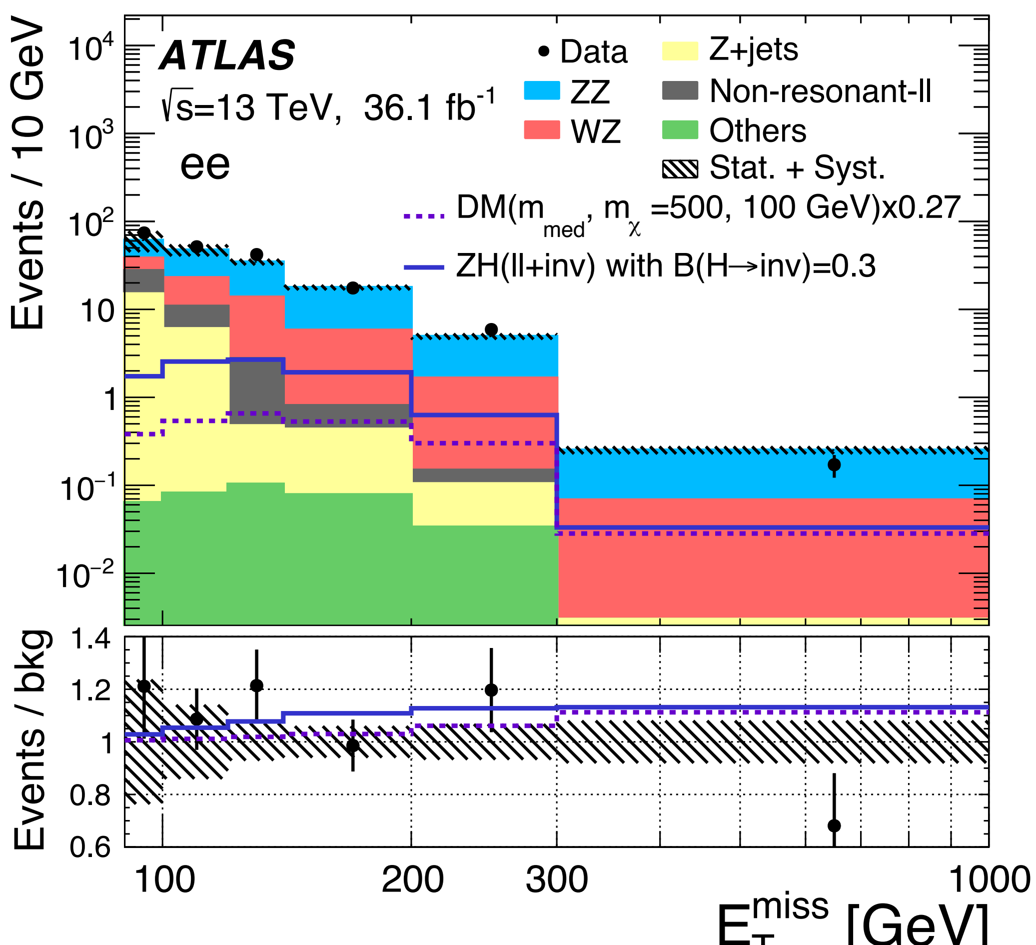
Mono-Z(lep)



In addition to the ISR of a Z boson, here one can probe the presence of H→χχ direct coupling



SM Higgs has an invisible BR of ~10^{-3} (via $H\to ZZ^*\to \nu\nu\nu\nu$) a direct coupling to DM would enhance this BR

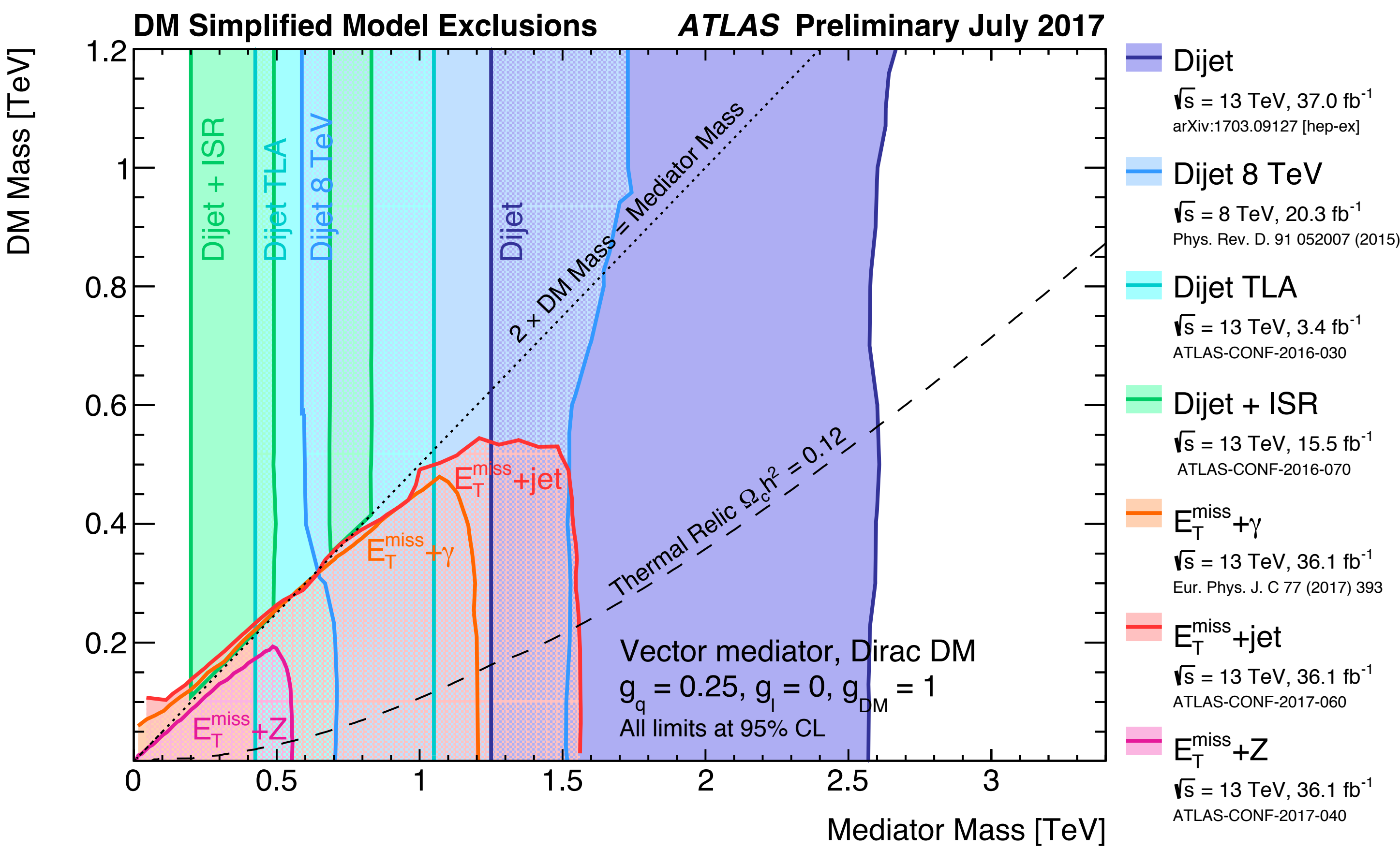


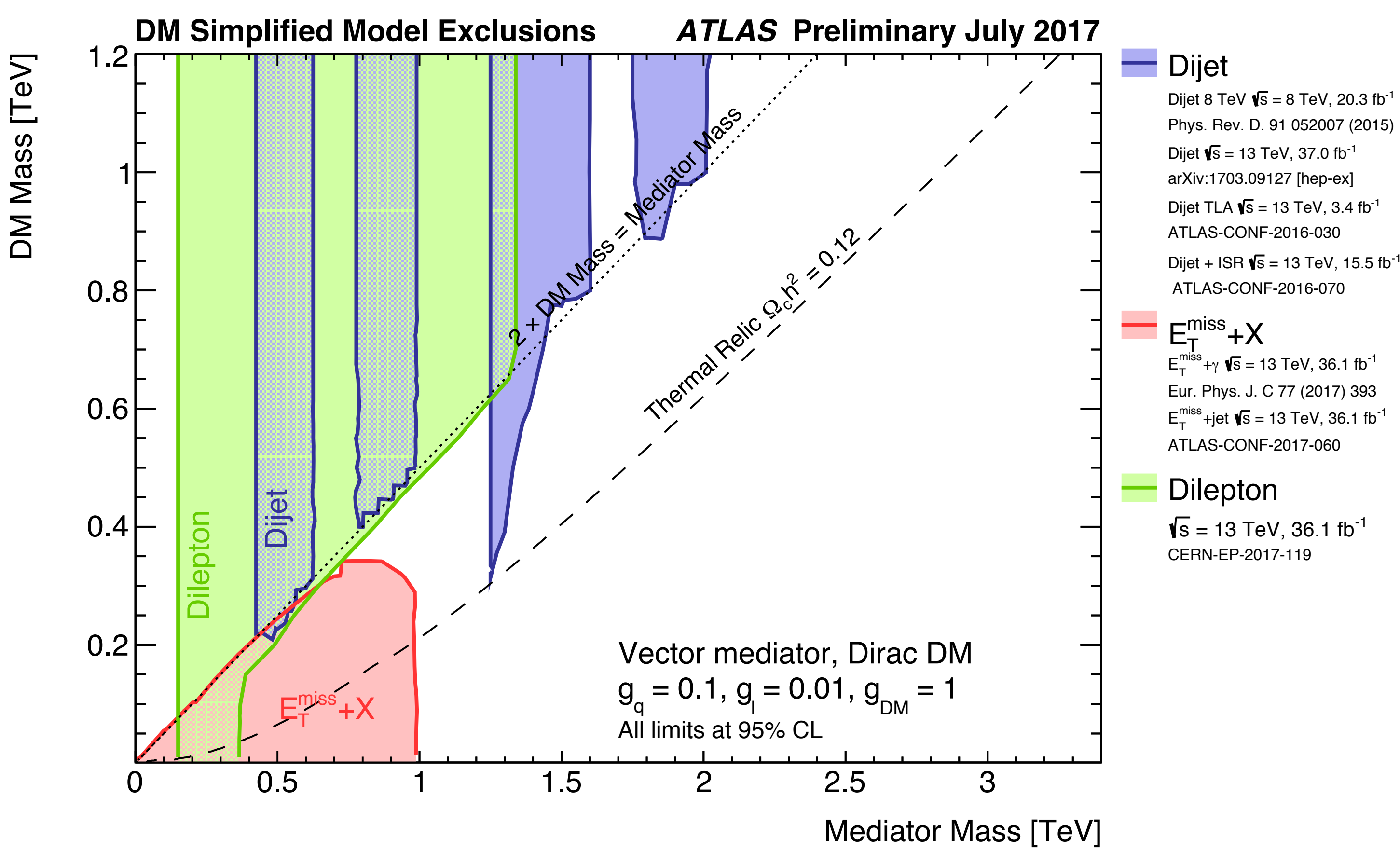
Main systematic uncertainties come from signal theory and jet/E_T^{miss} scale and resolution

Fitting the E_T^{miss} spectrum allows to set upper limits on the BR(H→inv.)

	Obs. $B_{H\to\text{inv}}$ Limit	Exp. $B_{H\to\text{inv}}$ Limit $\pm1\sigma\pm2\sigma$
ee	59%	$(51\ ^{+21}_{-15}\ ^{+49}_{-24})$ %
$\mu\mu$	97%	$(48\ ^{+20}_{-14}\ ^{+46}_{-22})$ %
$ee+\mu\mu$	67%	$(39\ ^{+17}_{-11}\ ^{+38}_{-18})$ %

Where do mono-X analyses contribute?





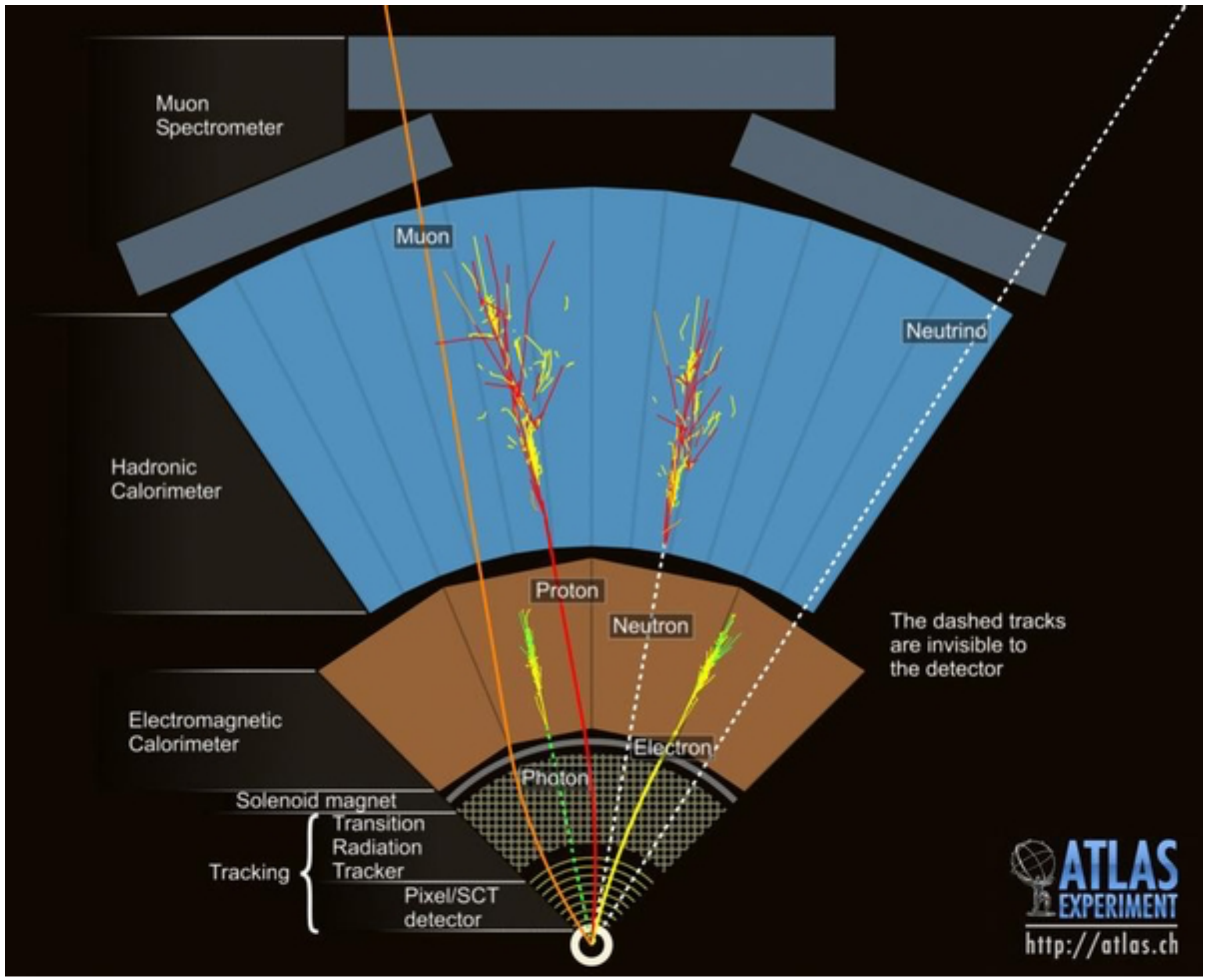
Varying the couplings (even with the same hypotheses on the mediator) the reach and the importance of the different signatures varies wildly

Summary

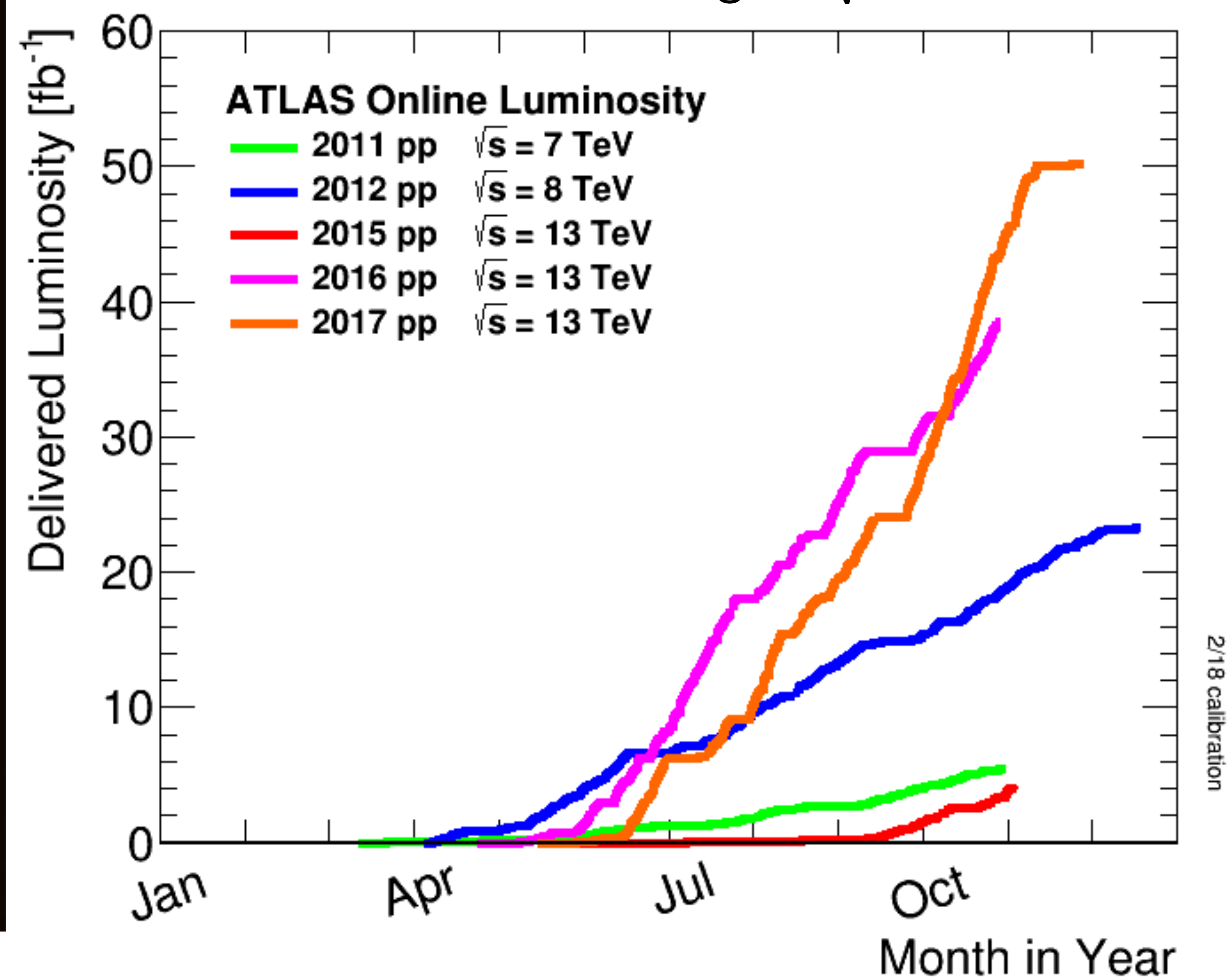
- Search for DM is an highly interdisciplinary challenge, and each field has its own strengths and weaknesses
- Collider searches are particularly powerful at low WIMP masses and can play a relevant role also compared to direct and indirect DM searches
- Mono-X signatures are a powerful tool
  - offer a clear signature to select and identify events
  - depending on the nature of X, allow direct probe of a number of different models

Backup

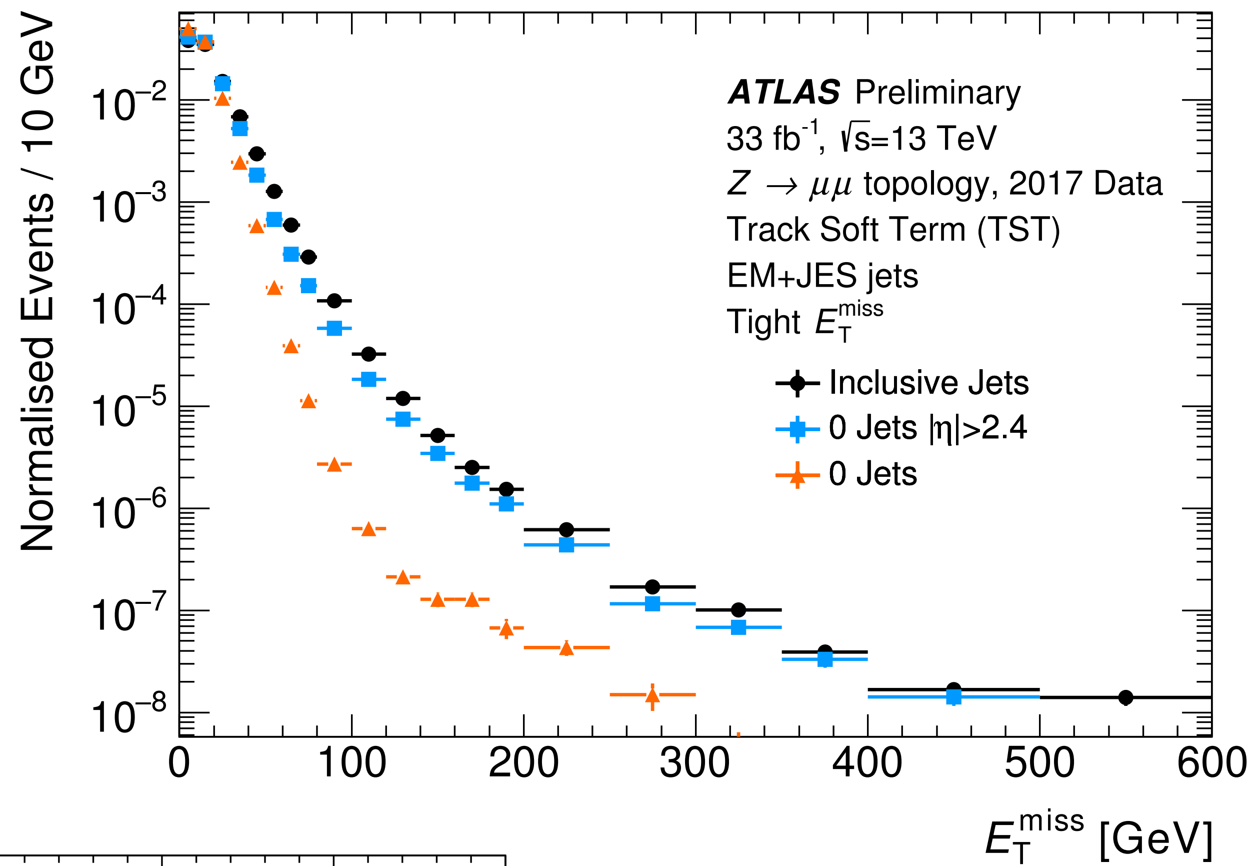
The ATLAS detector

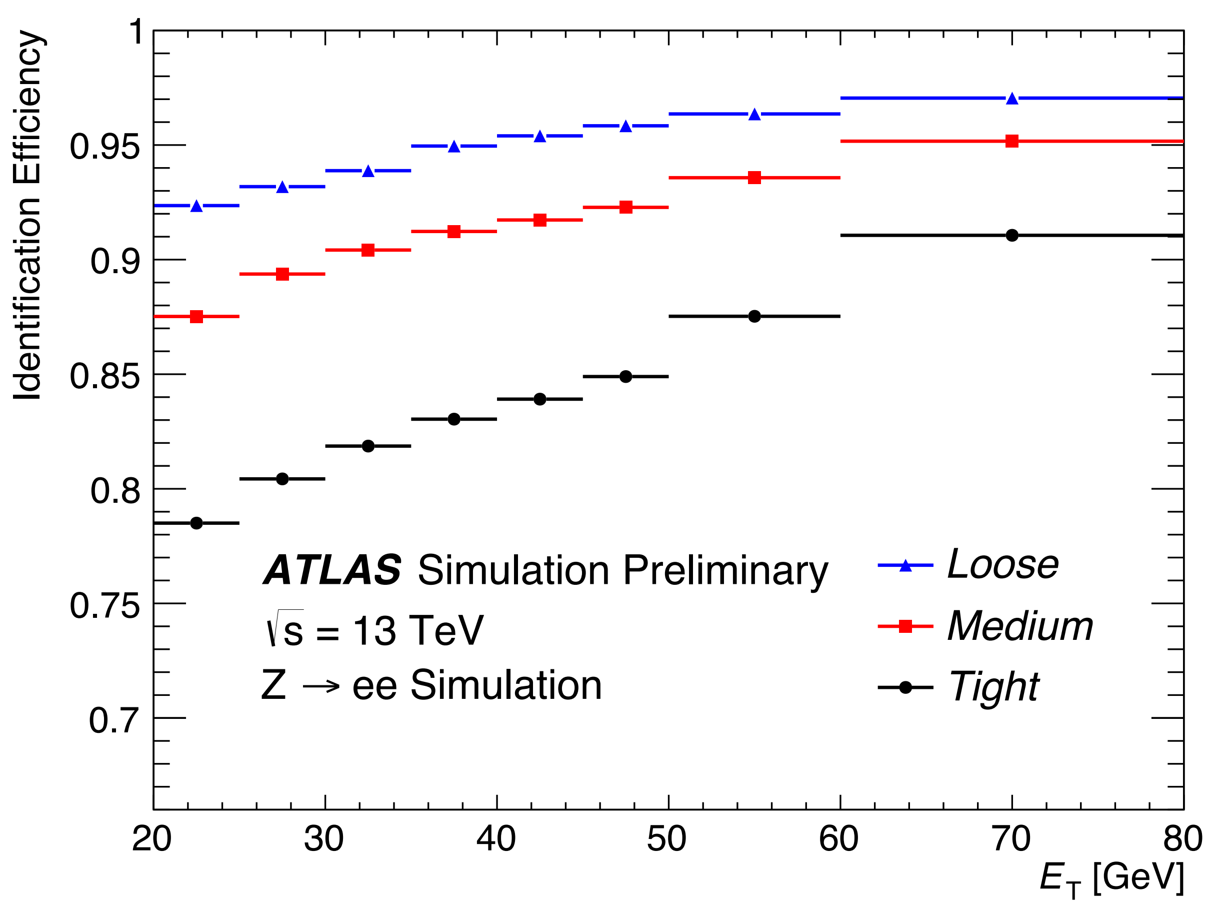


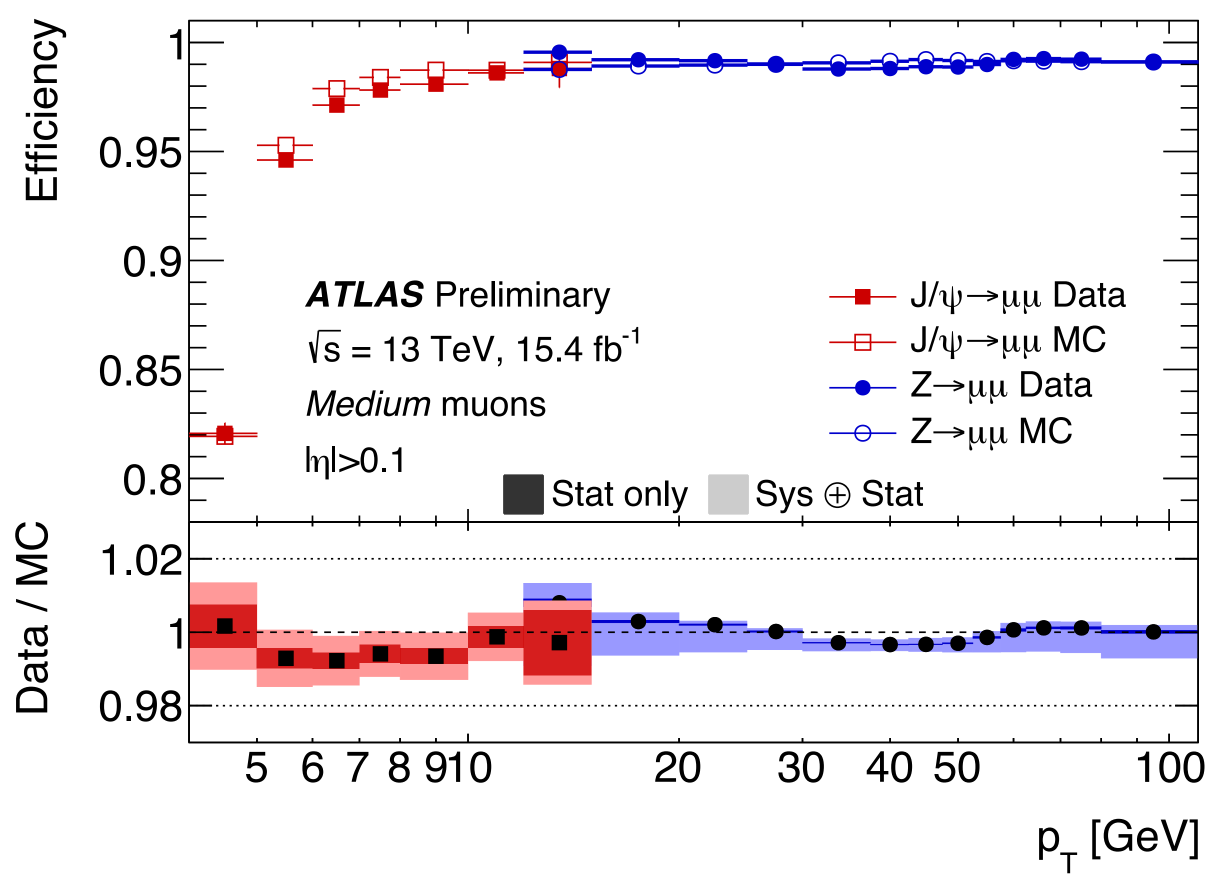
Run 2: collected ~36/fb during 2015 and 2016 data taking at $\sqrt{s}$ = 13 TeV



Relevant performances

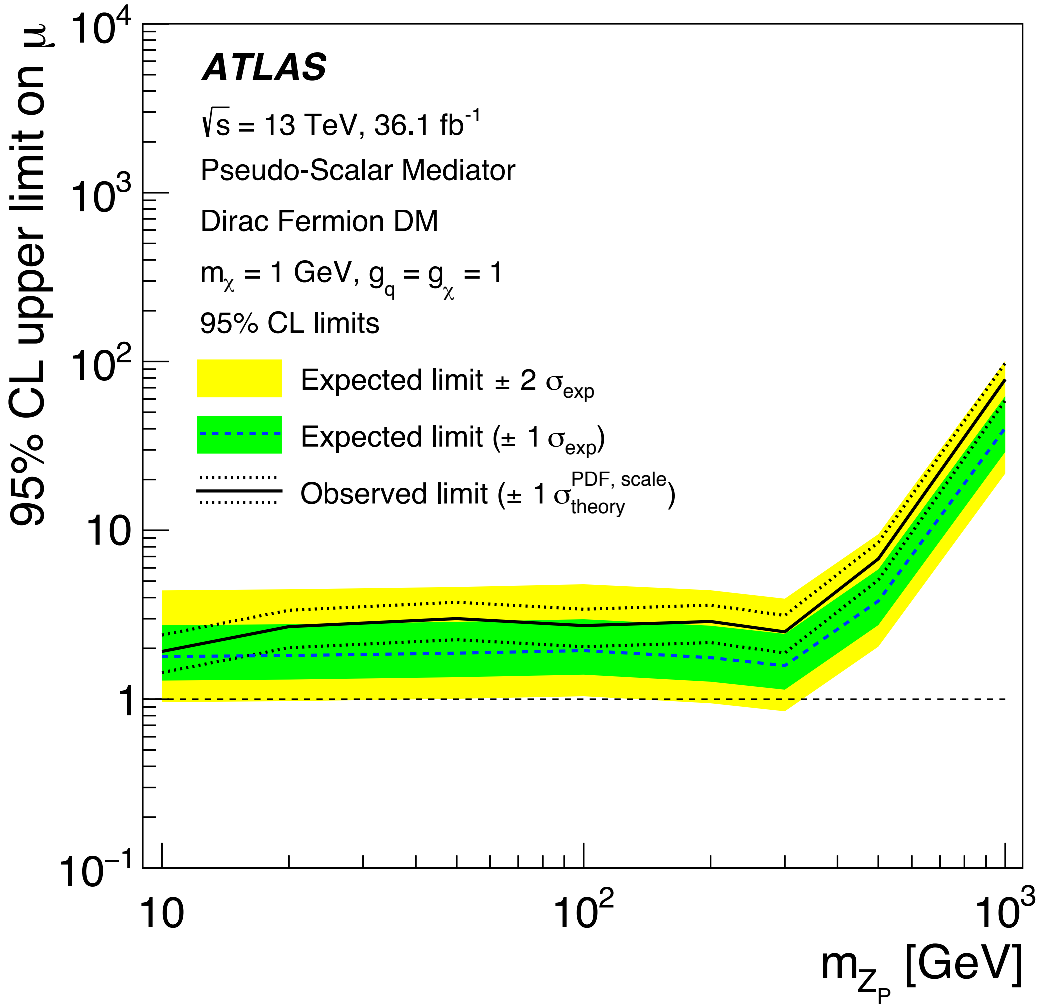




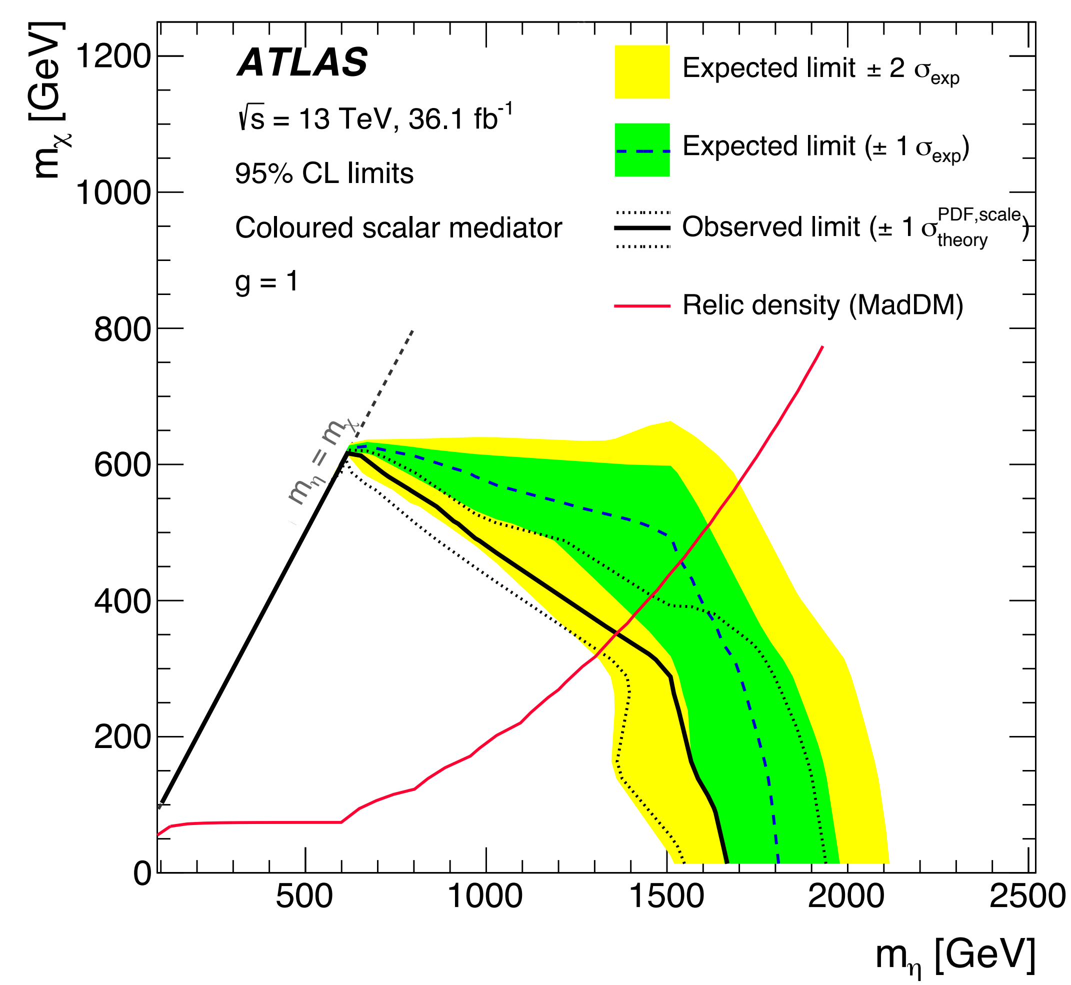


Mono-jet: other interpretations

Pseudo-scalar mediator

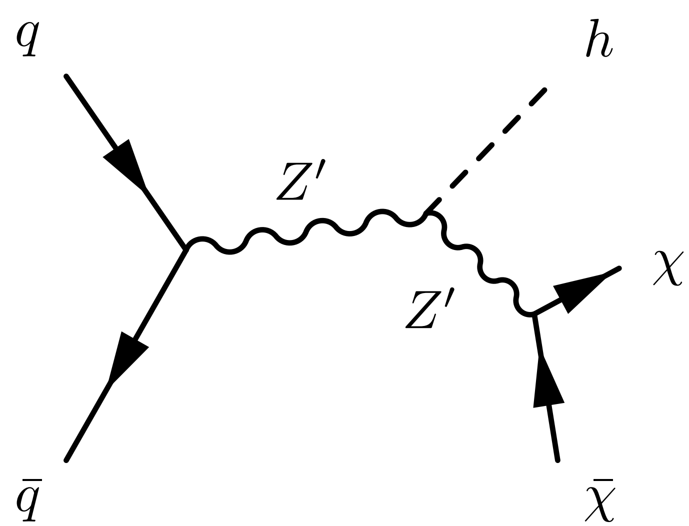


Coloured scalar mediator

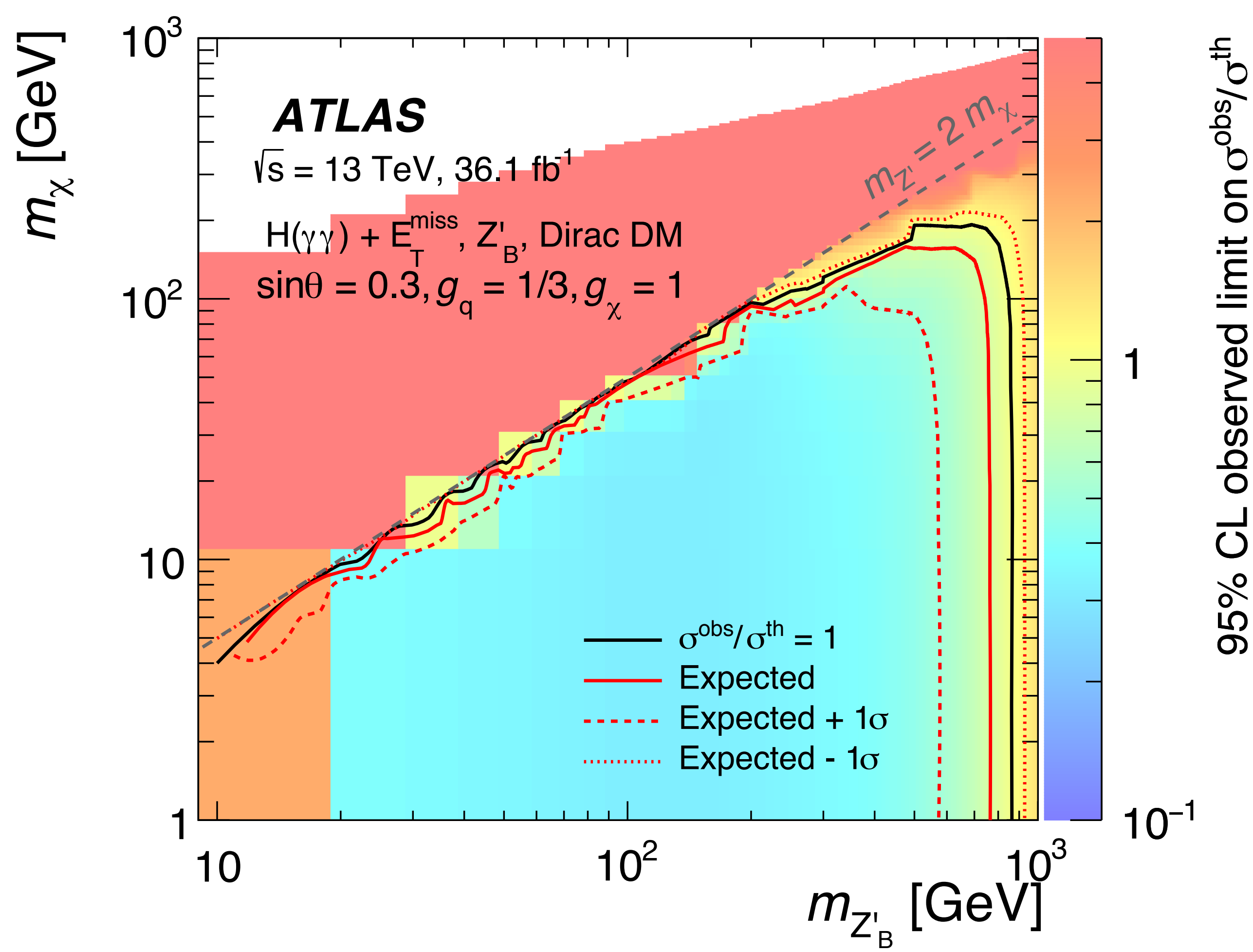


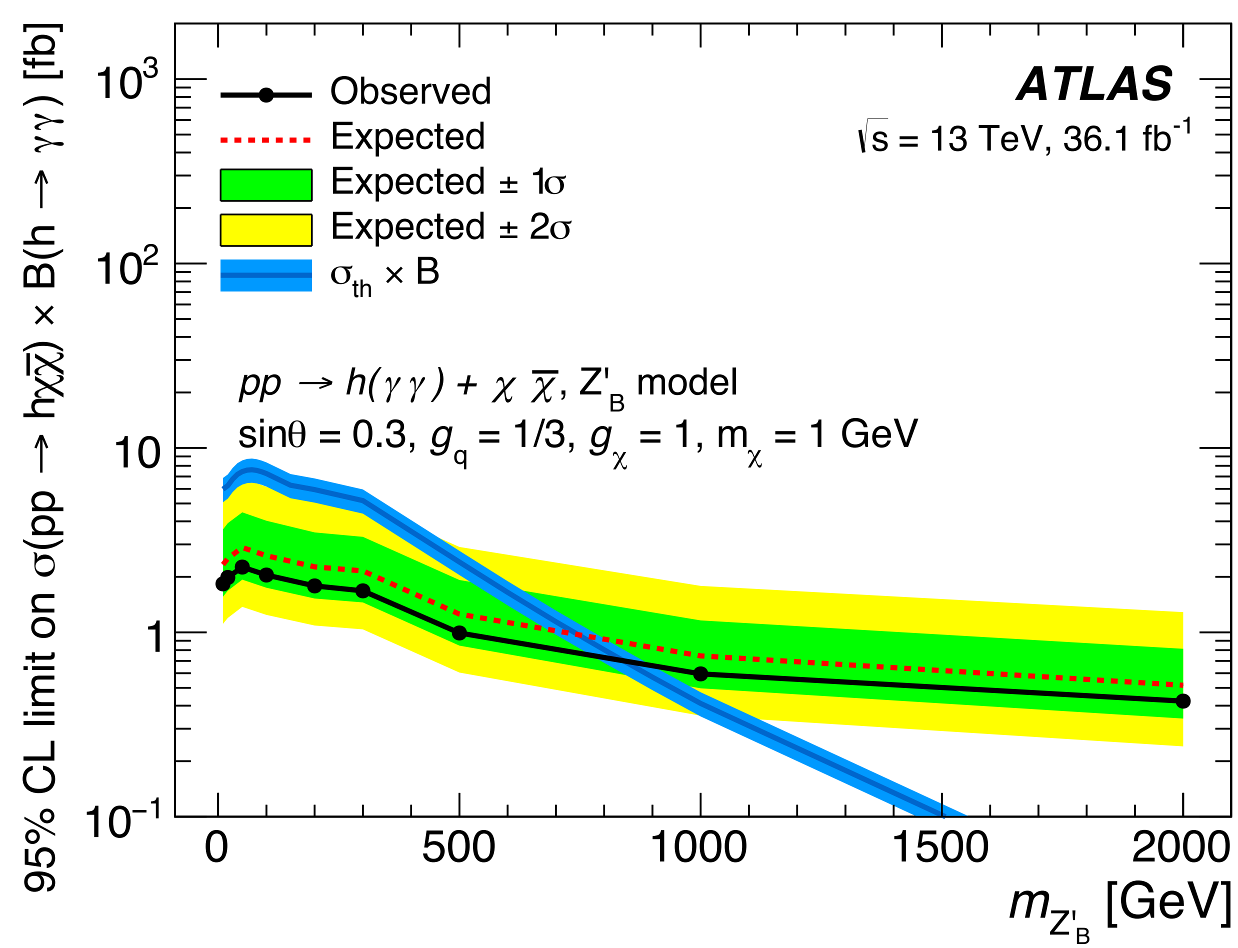
Other models for mono-H search

results from mono-H(γγ)



Pure Z’ model which couples both to Higgs and DM





DM searches

AV mediator with non-zero couplings to leptons