Search for Dark Matter in the Mono-Higgs ($h \to b\bar{b}$) Channel with the ATLAS Detector at the LHC

Study of Simplified Models

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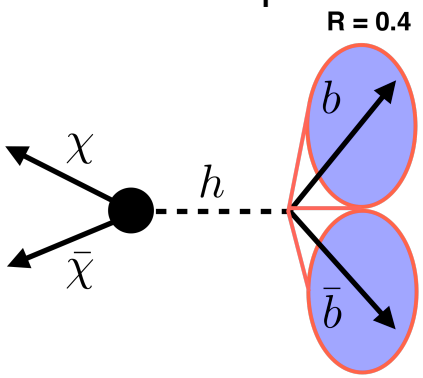
The Mono-Higgs Channel

- Events with large missing transverse momentum ($=E_{\mathrm{T}}^{\mathrm{miss}}$) in association with the SM Higgs boson ($h \to b\bar{b}$) $\Rightarrow \mathcal{B}(h \to b\bar{b}) = 58\%$ for $m_h = 125$ GeV
- Signature: 2 b-jets back-to-back to large $E_{\mathrm{T}}^{\mathrm{miss}}$, and $m_{b\bar{b}} \approx 125$ GeV

Resolved topology

$150\ \mathrm{GeV} < E_{\mathrm{T}}^{\mathrm{miss}} < 500\ \mathrm{GeV}$



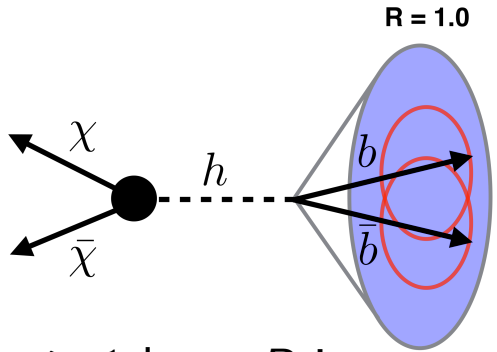
≥ 2 small-R jets (R=0.4)

$\Rightarrow$ b-tagging

$\Rightarrow$ Invariant dijet mass (m_{jj})

Merged topology

$E_{\mathrm{T}}^{\mathrm{miss}} \geq 500\ \mathrm{GeV}$



≥ 1 large-R jet

($R = 1.0$, trimmed, $f_{cut} = 0.05$)

with ≥ 1 track-jets ($R = 0.2$)

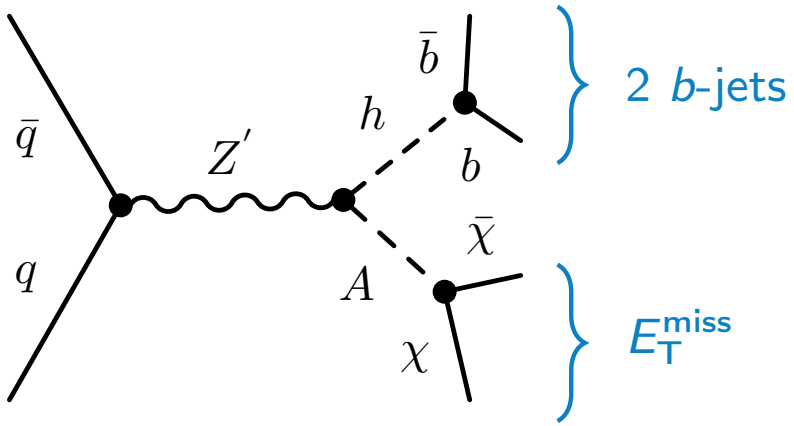
$\Rightarrow$ Leading 2 track-jets for b-tagging

$\Rightarrow$ Mass of leading fatjet (m_J)

- Trigger on $E_{\mathrm{T}}^{\mathrm{miss}}$(threshold 70-110 GeV depending on data period)
- Lepton veto, τ veto, additional b-jet veto
- Additional cuts on jet p_{T}'s and event topology, i.e. $\Delta\phi$, ΔR cuts

Signal and Background Processes

- Benchmark signal model: Z'-2HDM (arXiv:1402.7074) with new massive mediators: Z' und A (pseudoscalar from 2HDM) with $\mathcal{B}(A \to \chi\bar{\chi}) \approx 100$ %



Free model parameters:
$m_A, m_{Z'}, m_\chi, \tan\beta = \frac{v_1}{v_2}, g_{Z'q\bar{q}}$

- $m_\chi = 100$ GeV, $\tan\beta = 1$, $g_{Z'q\bar{q}} = 0.8$
- $m_A, m_{Z'}$ are free ($m_A > 2 \cdot m_\chi$)

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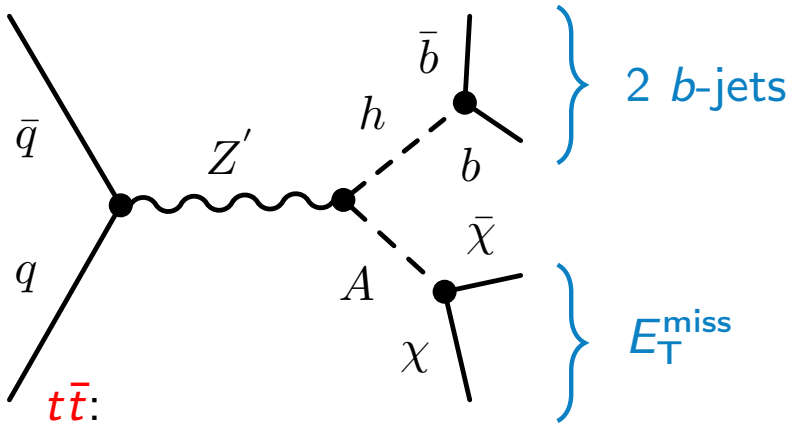

$t\bar{t}$:

- E_T^{miss} from $W \to \ell\nu$ decays, $\geq 2b$-jets

$Z(\to \nu\nu/\tau\tau)$+jets:

- large E_T^{miss} from neutrinos

$W(\to \ell\nu)$+jets:

- E_T^{miss} from $W \to \ell\nu$ decays

$\Rightarrow$ Main backgrounds estimated from combined fit of signal and control regions to data

- Additional backgrounds from MC: SM Vh, diboson, single top quark (and multijet)

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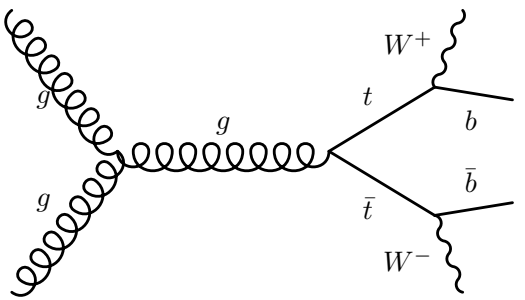
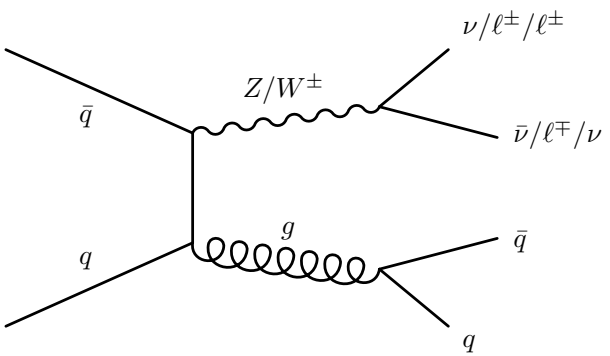
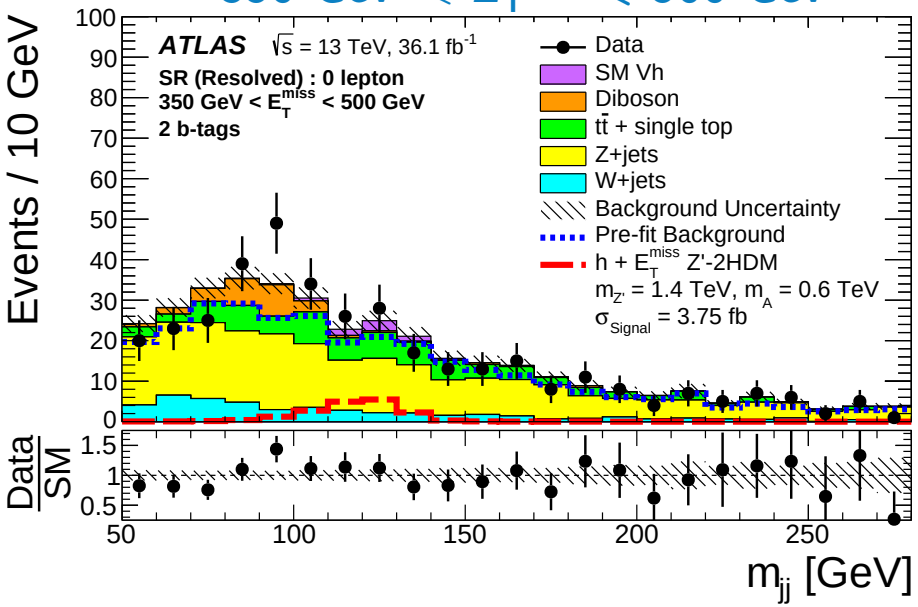




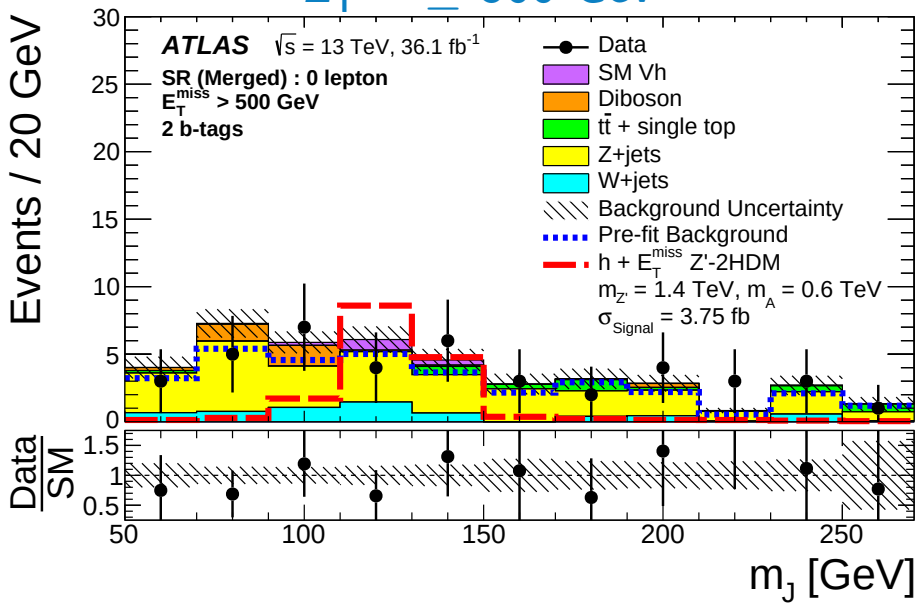
Post-Fit Results of the Signal Regions

PRL 119 (2017) 181804

350 GeV $< E_T^{miss} <$ 500 GeV



$E_T^{miss} \geq$ 500 GeV



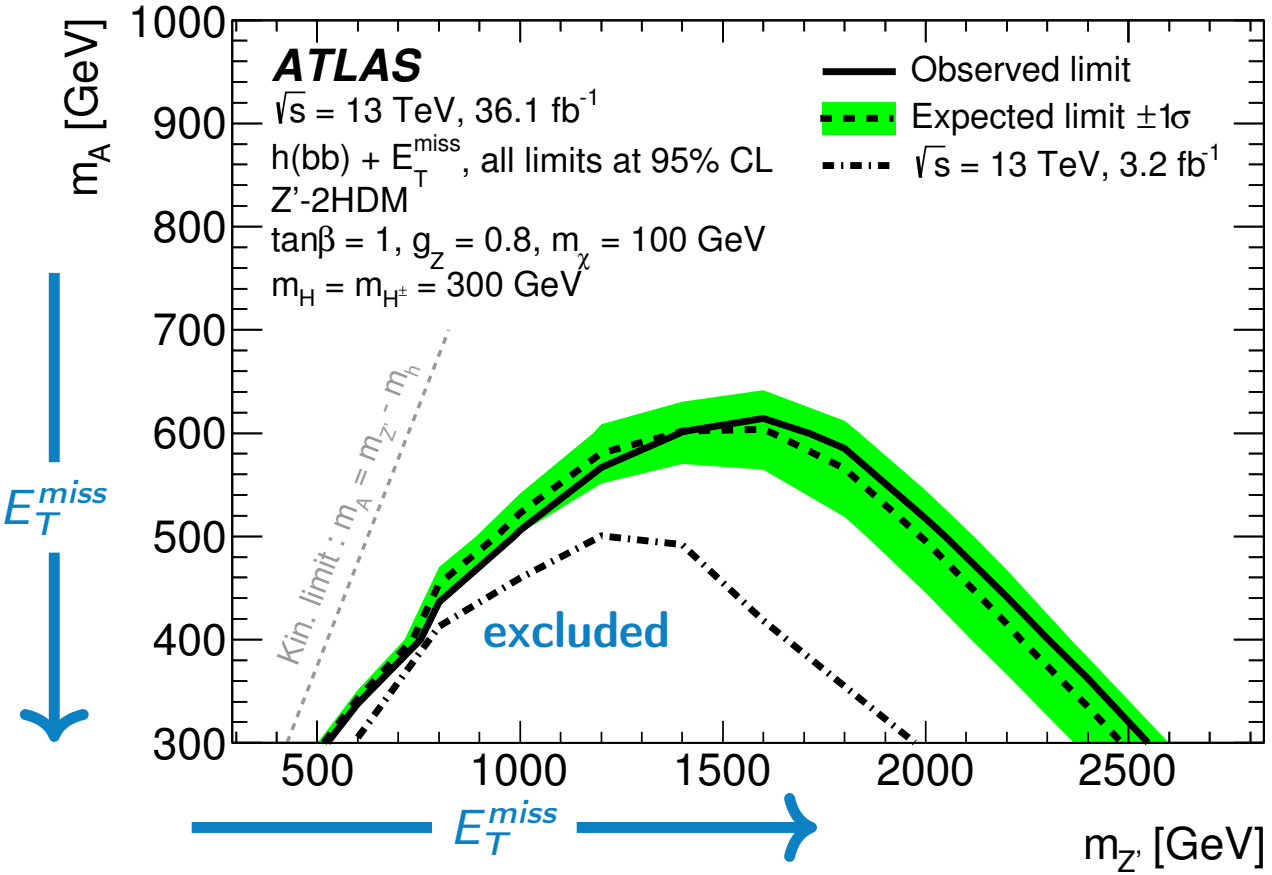
- Event categories: 1 and 2 *b*-jets, and 4 E_T^{miss} bins, i.e. 8 SRs
- 36/fb of data from 2015 and 2016
- Good agreement between data and MC
- No significant deviation from the SM prediction

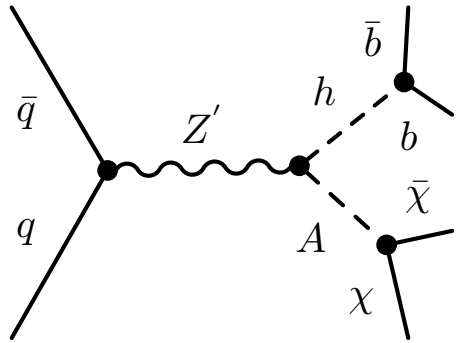
$\Rightarrow$ Exclusion Limits

Exclusion Limits

PRL 119 (2017) 181804

Benchmark signal model: Z'-2HDM



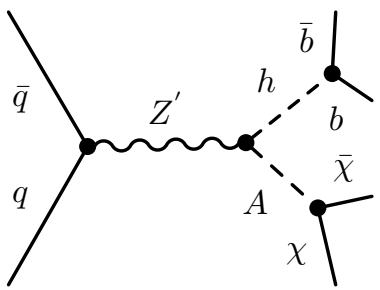


- Exclusion in ($m_{Z'}$, m_A) plane
- $m_{Z'}$ between 500 - 2600 GeV excluded for m_A up to 600 GeV

Simplified Models

Z'-2HDM

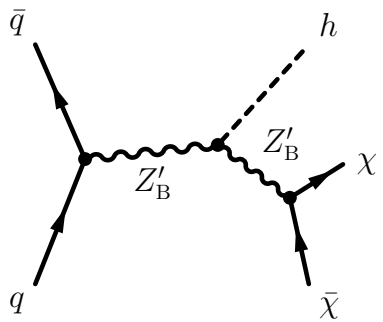
Vector mediator Z' and pseudoscalar A from 2HDM



Used as a benchmark model in
PRL 119 (2017) 181804

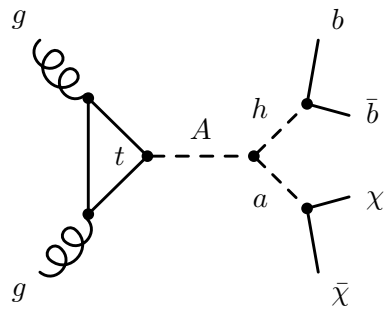
baryonic Z'_B

Only vector mediator Z'_B



a-2HDM

Two pseudoscalar mediators a and A (from 2HDM)

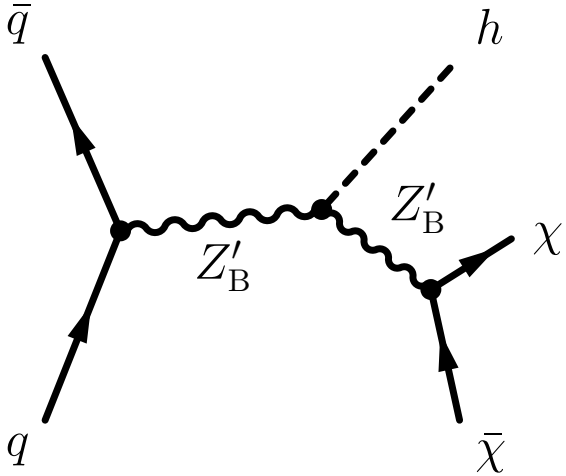


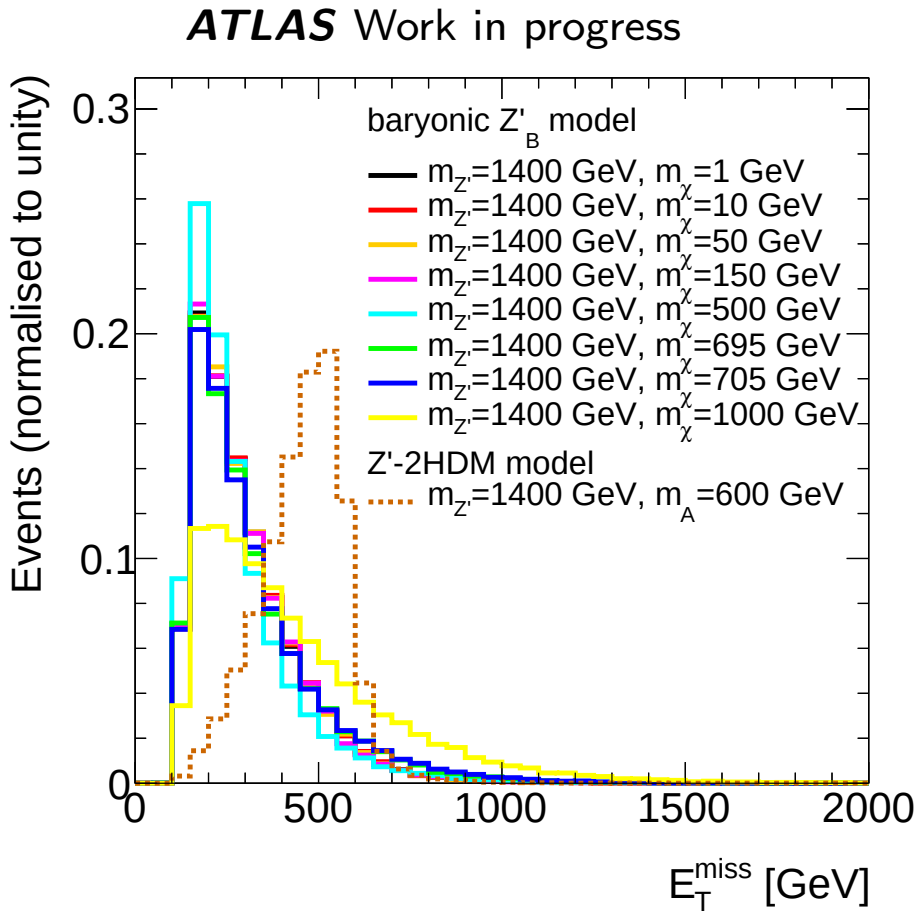
Results of the 2015 + 2016 analysis reinterpreted and published in the
DM summary paper: arXiv:1903.01400 (sub. to JHEP)

Results are used for the interpretation of additional signal models, based on the analysis preservation and reinterpretation within RECAST.

Simplified Model - Vector Mediator

- Baryon charged vector mediator: Z'_B (arXiv:1312.2592)
- $U(1)_B$ symmetry for baryon number is broken by a additional baryonic Higgs scalar h_B with vacuum expectation value v_B





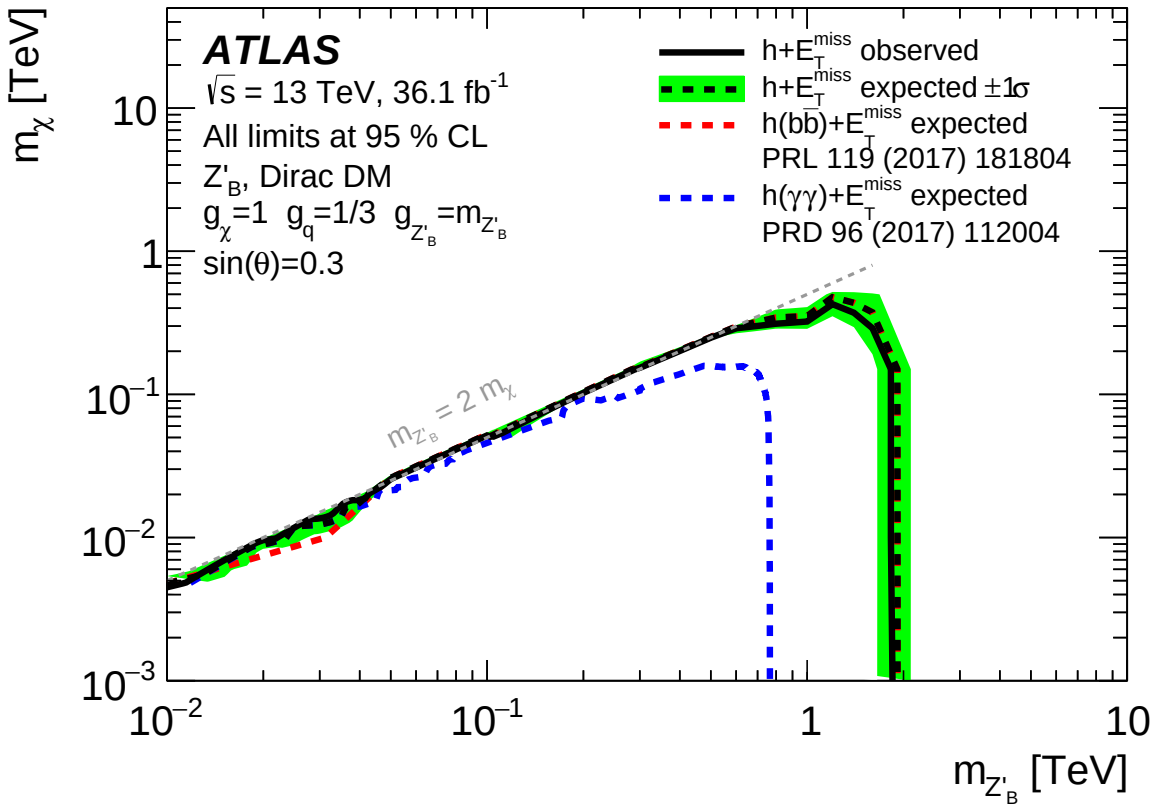
Free model parameters:

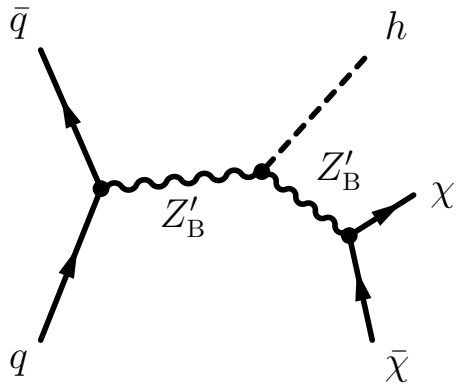
- $\sin\theta = 0.3$: mixing angle between baryonic and SM Higgs
- $g_{Z'_B} = m_{Z'}/v_B$: coupling of mediator to Higgs
- $g_q = 1/3$ and $g_\chi = 1$
- $m_{Z'}$ and m_χ are free

Exclusion Limits - Vector Mediator

arXiv:1903.01400

Signal model: Z'_B



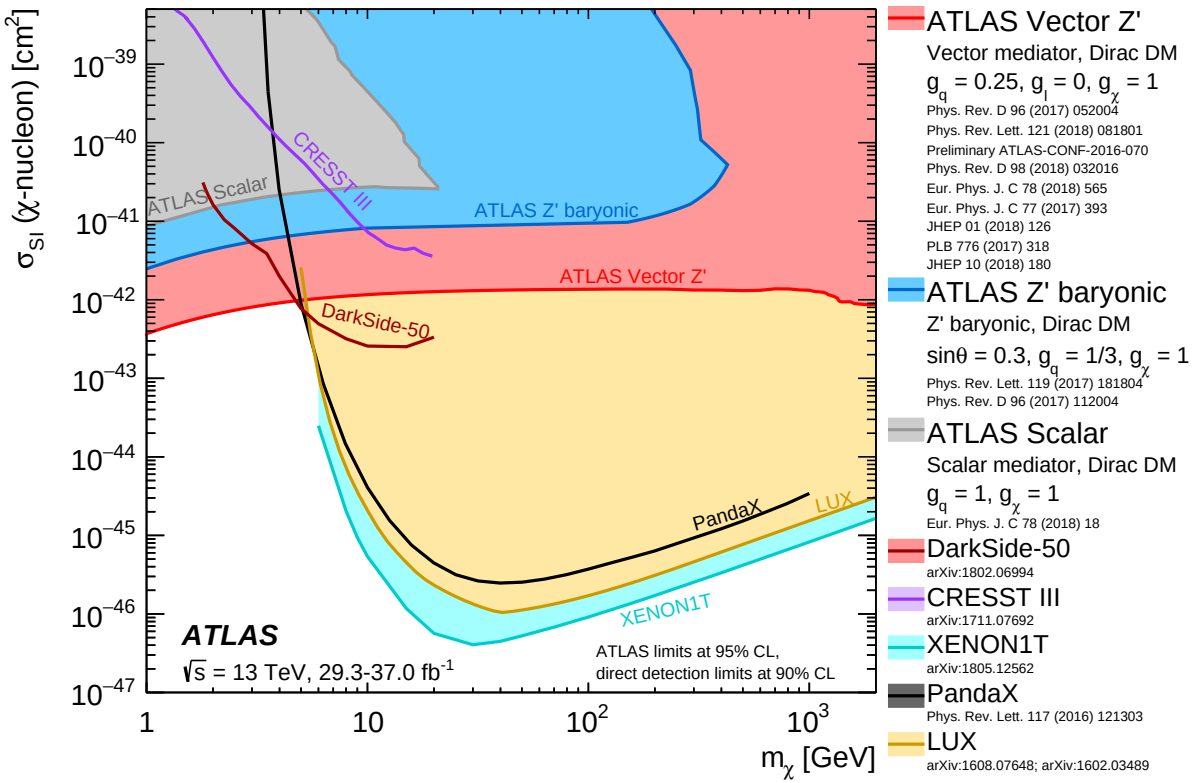


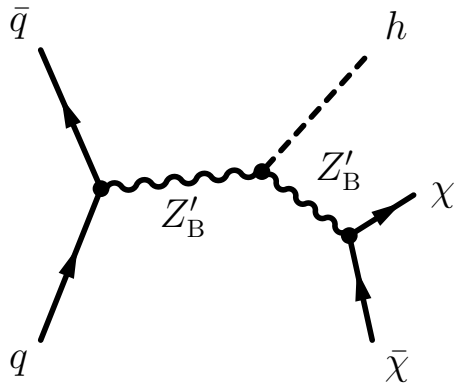
- Exclusion in ($m_{Z'}$, m_χ) plane
- $m_{Z'}$ up to 1.9 TeV excluded

Exclusion Limits - Vector Mediator

arXiv:1903.01400

Signal model: Z'_B



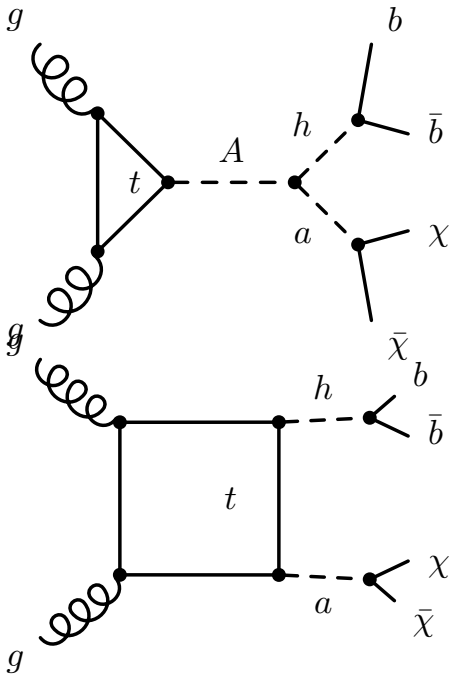


- Exclusion in ($m_{Z'}$, m_χ) plane
- $m_{Z'}$ up to 1.9 TeV excluded
- Model used to set limits on the spin-independent DM-nucleon scattering cross section,

  i.e. for $m_\chi < 3$ GeV

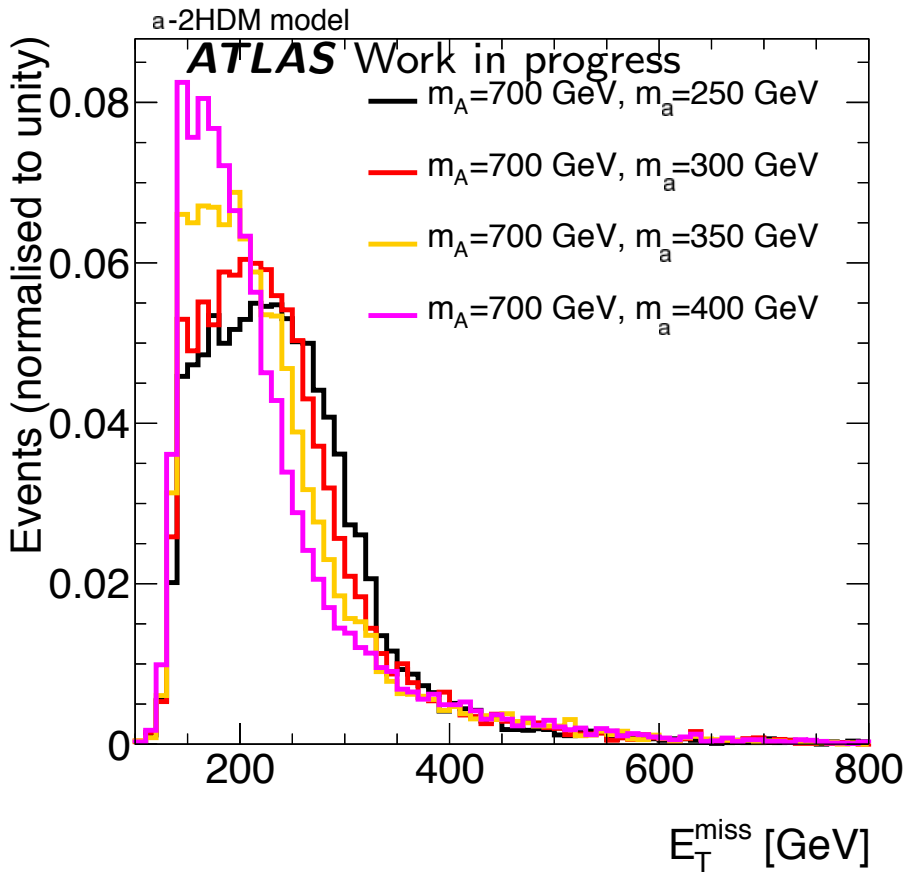
Simplified Model - Scalar Mediator

- *a*-2HDM model with additional pseudoscalar mediator *a* (arXiv:1701.07427)



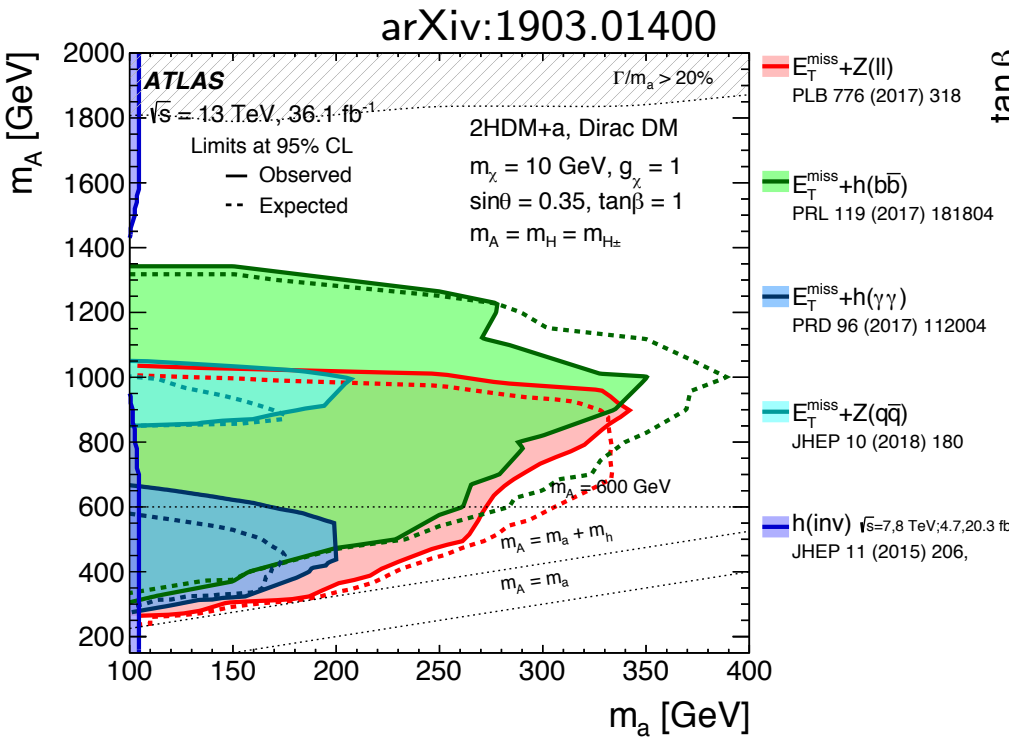
14 Free model parameters, most important ones:

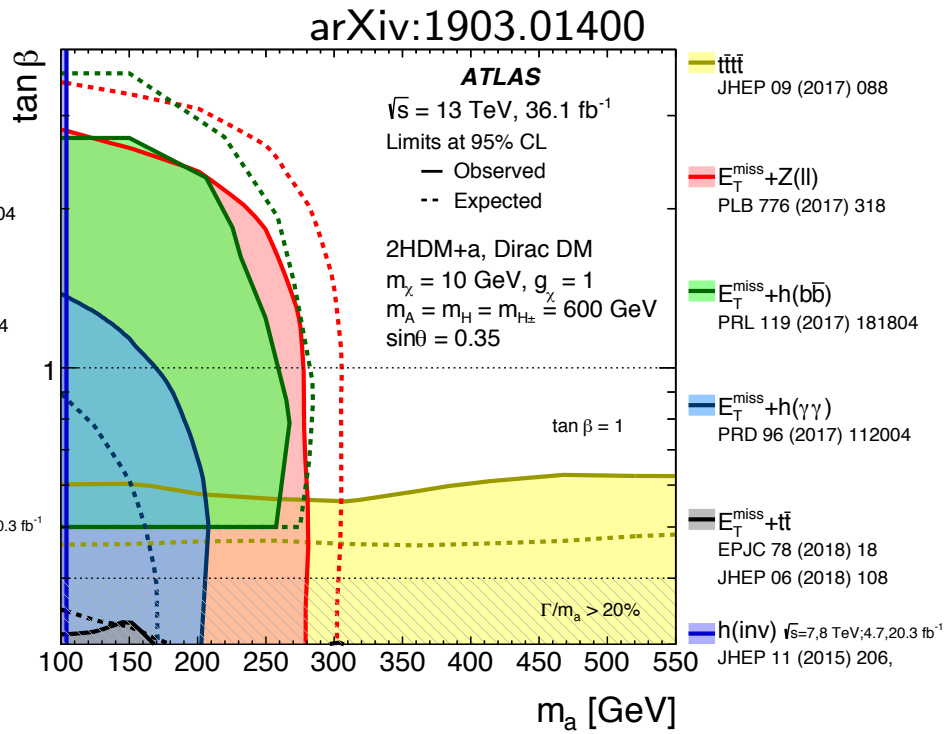
- $\sin\theta = 0.35$: mixing angle of the two CP-odd eigenstates *a* and *A*
- $m_\chi = 10$ GeV
- $\tan\beta$, m_a, m_A are free



E_T^{miss} spectra get harder with increasing m_a

Simplified Model - Scalar Mediator





- Exclusion in (m_a, m_A) plane for $\tan\beta = 1$
- m_A between 280 and 1350 GeV excluded for m_a up to 325 GeV

- Exclusion in (m_a, $\tan\beta$) plane for $m_A = 600$ GeV
- $\tan\beta$ between 0.5 and 2.8 excluded for m_a up to 260 GeV

Summary

- The mono-Higgs channel provides a complementary DM production mechanism compared to other mono-X searches.
- Based on the 36.1/fb dataset, Z' masses up to 2.6 TeV are excluded.
- The results are reinterpreted in terms of additional signal models and published in the DM summary paper:
  - Masses of a baryon number charged vector mediator Z'_B are excluded up to 1.9 TeV. The model provides good sensitivity in the low DM region compared to direct detection experiments.
  - Pseudoscalar mediator masses are excluded between 100 GeV and 350 GeV for $m_A = 1$ TeV and $m_\chi = 10$ GeV.

See for more mono-Higgs ($b\bar{b}$) talks:
T 10.3 - A. Matic
T 79.8 - P. Gadow