Search For Dark Matter produced in Association with a Standard Model Higgs Boson using the ATLAS Detector

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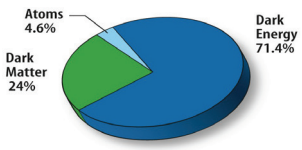
Overview

The Standard Model (SM) of particle physics explains most of the phenomenon observed in high energy physics. However, there are few open questions which SM does not explain, such as ***Dark Matter (DM).***

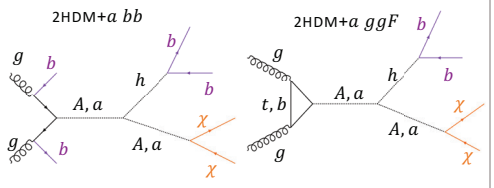
- It has been observed through various experiments that ~24% of the universe consists of DM.
- Although the nature of DM is unknown, it's considered to be stable, and has been seen to interact gravitationally only.
- In addition to Direct and Indirect experiments searching for DM, collider experiments can provide complementarity.



- If DM particles are weakly interacting and are produced at colliders, they will leave E_T^{miss} signature in the detector.
- The model analysed here, predicts DM production in association with a SM Higgs boson (h) and the final state considered is: $\boldsymbol{E_T^{miss}}$ + $\mathbf{h \rightarrow bb}$.

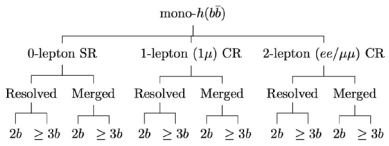
Theoretical Model

- The analysis is based on the Two Higgs Doublet Model (2HDM) containing 2 Higgs doublets and 5 Higgses [1]:
  - Two neutral CP-even H and h
  - One neutral CP-odd A
  - Two charged Higgs bosons $H^{\pm}$
- The model analysed here is an extension of the 2HDM with an additional pseudoscalar a: 2HDM+a.
- The model has two production modes:
  - ggF dominates at $\tan\beta$ = 1 and bb dominates at $\tan\beta$ = 10, where $\tan\beta$ is the ratio of the vacuum expectation values of the two Higgs doublets.
- The DM mass is set at m_χ = 10 GeV and masses of A (m_A) and a (m_a) are varied.



Analysis

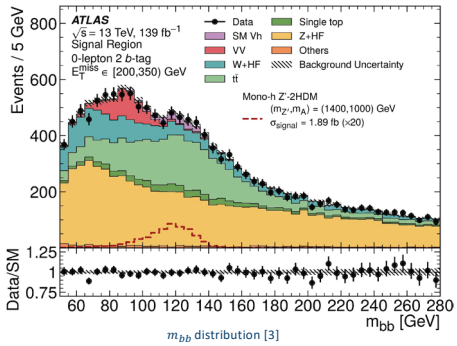
- **Signature:** $\boldsymbol{E_T^{miss}}$ + $\mathbf{h \rightarrow bb}$ reconstructed as:
  - Resolved: 150 < $\boldsymbol{E_T^{miss}}$ < 500 GeV with two distinguishable b-tagged small-R (R=0.4) jets.
  - Merged: $\boldsymbol{E_T^{miss}}$ > 500 GeV with one large-R (R=1.0) jet with two b-tagged variable radius (VR) track jets inside.
- Major SM backgrounds are: W+jets, Z+jets and $t\bar{t}$.
- Analysis regions:



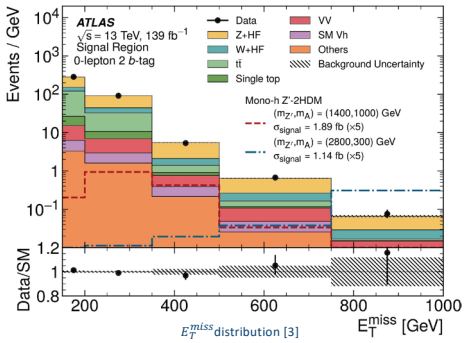
- Each analysis region is binned in $\boldsymbol{E_T^{miss}}$ regions:
  - Resolved: [150, 200], [200, 350], [350, 500] GeV.
  - Merged:
    - 2 b-tagged: [500, 750], > 750 GeV.
    - ≥ 3 b-tagged > 500 GeV.
- A binned profile likelihood fit is performed to check the compatibility of the data with the background-only hypothesis and extract upper limits at 95% CL.

Results

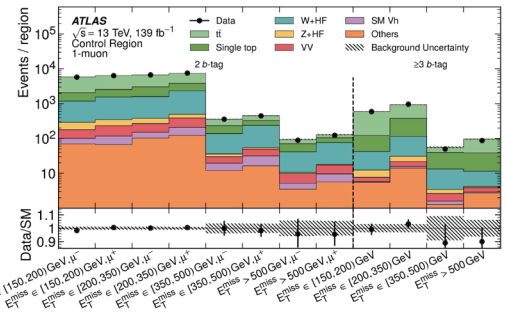
❖ No significant excess in data is observed compared to the predicted SM backgrounds: exclusion limits are obtained on the model parameter space: 2HDM+a: (m_A, m_a)



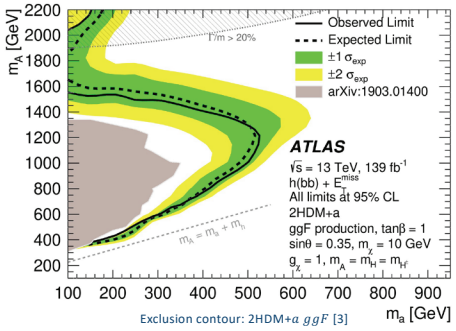
m_{bb} distribution [3]



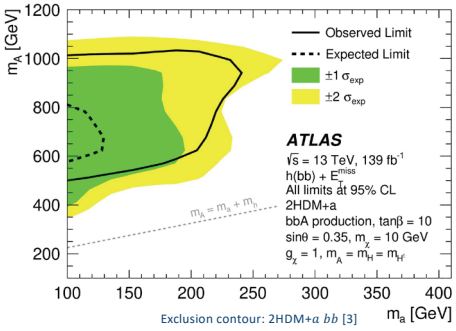
E_T^{miss} distribution [3]



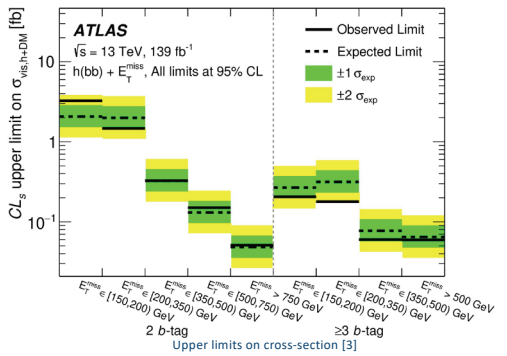
CR modelling [3]



Exclusion contour: 2HDM+a ggF [3]



Exclusion contour: 2HDM+a bb [3]



Upper limits on cross-section [3]

Conclusion

❖ 2HDM+a:
- Significant improvement in ggF exclusion limits compared to 36 fb^{-1} paper [2].
- Increased exclusion for the ggF mode at high m_A and low m_a is due to increased cross-section of $a \rightarrow ah$ process.
- With the inclusion of ≥ 3 b-tagged region, analysis gained sensitivity to the bb production mode.

❖ Model Independent Limits (MIL):
- MIL is obtained by a simultaneous fit of multiple POI (one per region) using one bin that is expected to almost fully contain a Higgs-like resonance.

❖ The analysis is also a part of the 2HDM+a combination work and statistical combination results are available [4].

References

(1) LHC Dark Matter Working Group: Next-generation spin-0 dark Matter models (arxiv:1810.09420).
(2) Constraints on mediator-based dark matter and scalar dark energy models using $\sqrt{S}$ = 13 TeV pp collision data collected by the ATLAS detector (JHEP 1905 (2019) 142).
(3) Search for dark matter in association with a Standard Model Higgs boson decaying into b-quarks using the full Run 2 dataset from the ATLAS detector (JHEP11 (2021) 209).
(4) Combination and summary of ATLAS dark matter searches using 139 fb^{-1} of $\sqrt{S}$ = 13 TeV pp collision data and interpreted in a two-Higgs-doublet model with a pseudoscalar mediator (ATLAS-CONF-2021-036).

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