Search for Dark Matter produced in association with a Standard Model Higgs boson decaying to b-quarks in pp collisions at 13 TeV with the ATLAS detector

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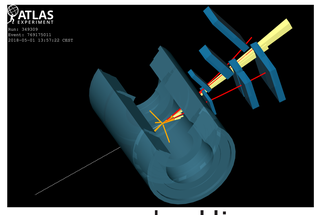
Introduction

- Can Dark Matter (DM) be produced together with a Standard Model (SM) Higgs boson?



- Look for large missing transverse energy and a Higgs boson decaying to two b-quarks ($E_{\mathrm{T}}^{\mathrm{miss}} + h \to b\bar{b}$) from ATLAS pp collision ($\sqrt{s} = 13$ TeV, 139 fb^{-1}).
- Consider two types of DM models for interpretation.
  1. **2HDM+a:** highlighted by LHC DM WG and rich in phenomenology.
  2. **Z'2HDM:** used as a benchmark for high-mass resonances.

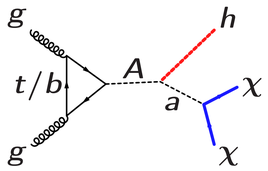
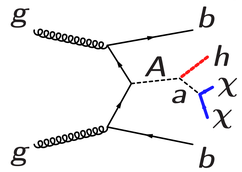


Figure 1: Representative diagrams for 2HDM+a with ggF (left) and bbA (right) production.



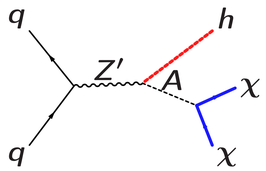


Figure 2: Representative diagram for Z'2HDM.

Event selections and categorization

- Select events with $E_{\mathrm{T}}^{\mathrm{miss}} > 150$ GeV, no lepton, and a $h \to b\bar{b}$ candidate reconstructed with two methods:

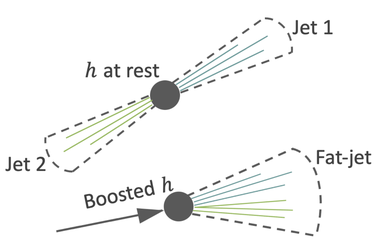


Figure 3: Illustration of resolved and boosted regimes.

  - **Resolved regime** ($E_{\mathrm{T}}^{\mathrm{miss}} < 500$ GeV): 2 b-tagged small-R jets ($R = 0.4$).
  - **Boosted regime** ($E_{\mathrm{T}}^{\mathrm{miss}} > 500$ GeV): 1 single large-R jet ($R = 1$) with 2 associated b-tagged variable-R track-jets.
- Additional kinematic cuts to further suppress background: mainly for multi-jet and $t\bar{t}$.
- Split in $E_{\mathrm{T}}^{\mathrm{miss}}$ to enhance sensitivity to different mediator masses.
- Extra $\geq$3 b-tag bins: target 2HDM+a bbA production.

Background Modeling

- Background modeled with Monte Carlo simulation.
- Main backgrounds: Z, $t\bar{t}$ and W.
- Dedicated control regions (CR) to constrain background normalization:
  - **2-lepton CR** for Z.
    - Require 2 muons or 2 electrons.
  - **1-muon CR** for $t\bar{t}$ and, W.
    - Require 1 muon and no electron.
    - Split in muon charge to disentangle $t\bar{t}$ and, W.
- Leptons treated as invisible particles in $E_{\mathrm{T}}^{\mathrm{miss}}$ calculation to mimic kinematics in signal regions.

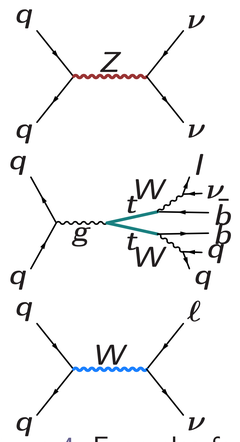
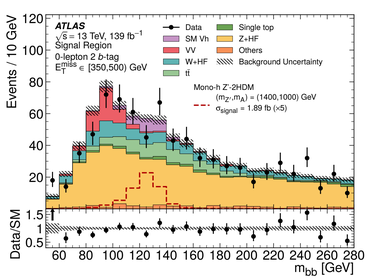


Figure 4: Examples for Z, $t\bar{t}$ and W.

Results

- A **simultaneous fit** in m_{bb} spectrum to all $E_{\mathrm{T}}^{\mathrm{miss}}$ and b-tag bins of signal and control regions is performed to test different signal hypotheses.
- Main systematic uncertainties include background modeling (~20%), b-tagging (~4%) and jet energy resolution (~20%).
- **No significance excess** found in all tested signal models.



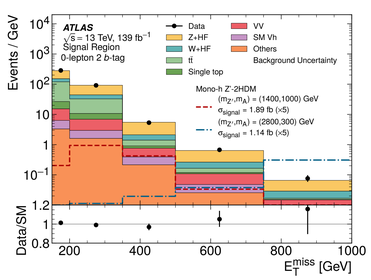


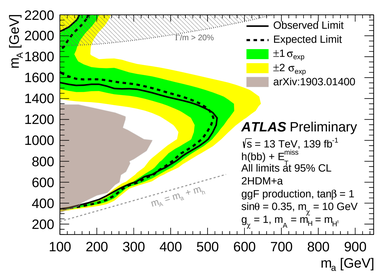
Figure 5: Example fit distributions in m_{bb} (left) and in $E_{\mathrm{T}}^{\mathrm{miss}}$ (right).

Interpretation

- Exclusion limits are set on benchmark models:
  - **2HDM+a** (Fig. 6)
    - Exclusion region set in m_a-m_A plane with tanβ set at 1 (10) for ggF (bbA) production.
    - Large sensitivity improvements with respect to 36 fb^{-1} results.
    - First time reaching sensitivity to bbA production.
  - **Z'2HDM** (Fig. 7)
    - Exclusion region set in $m_{Z'}$-m_A plane.
    - Exclusion of $m_{Z'}$ extends to 3.6 TeV.

See results!

- Finally, upper limits are set on visible cross-sections in a model-independent context for each signal region exclusively (Fig. 8).
  - $\sigma_{\mathrm{vis},h(b\bar{b})+\mathrm{DM}} \equiv \sigma_{h(b\bar{b})+\mathrm{DM}} \times \mathcal{B}\left(h \to b\bar{b}\right) \times (\mathcal{A} \times \epsilon)$
  - m_{bb} bins are merged into a single bin to reduce model-dependency.



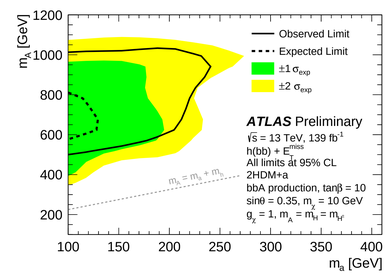


Figure 6: 2HDM+a exclusion with ggF (left) and bbA (right) production.

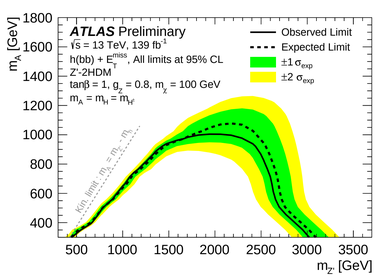


Figure 7: Z'2HDM exclusion.

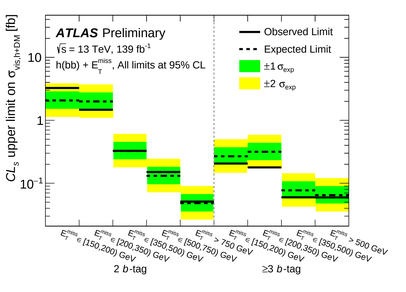


Figure 8: Upper limits on visible cross-sections.