Search for Dark Matter in events with missing transverse momentum and a Higgs boson decaying into b-quarks with the ATLAS detector

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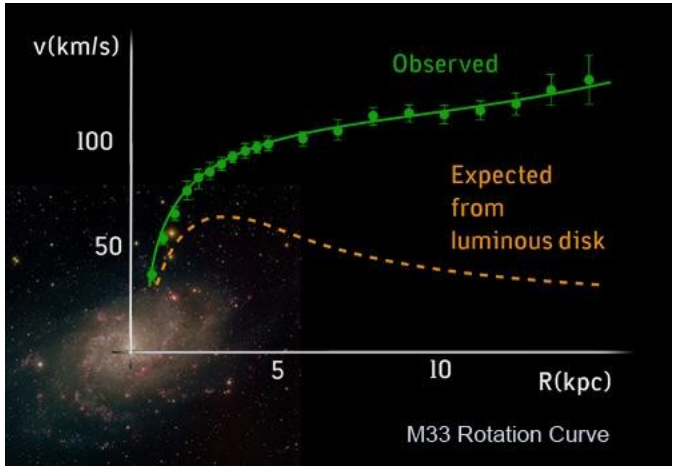
Evidence of Dark Matter



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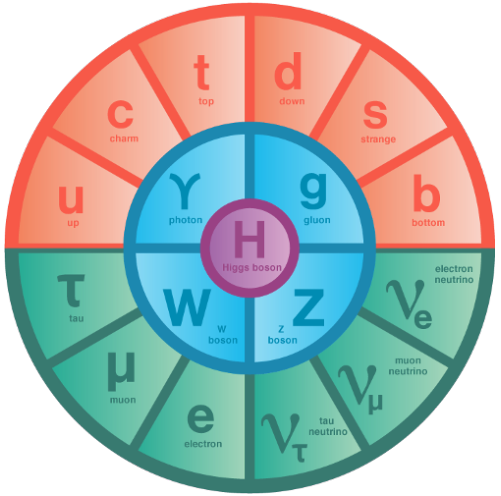
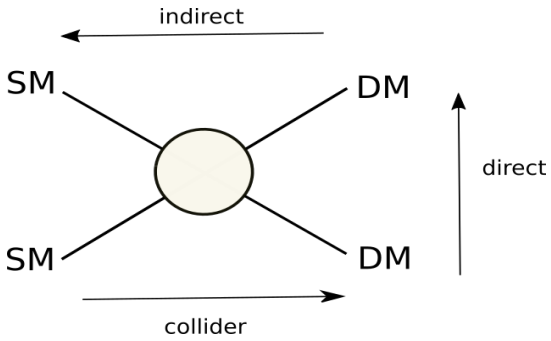


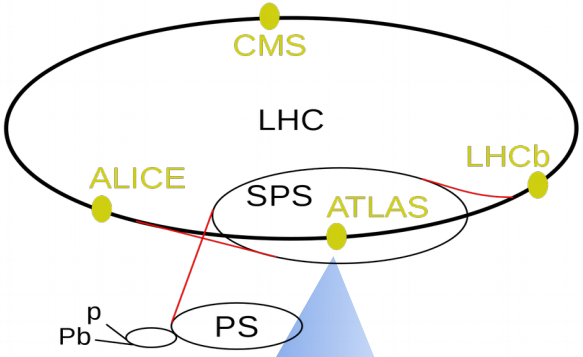
Example of DM evidence:
Rotational curves

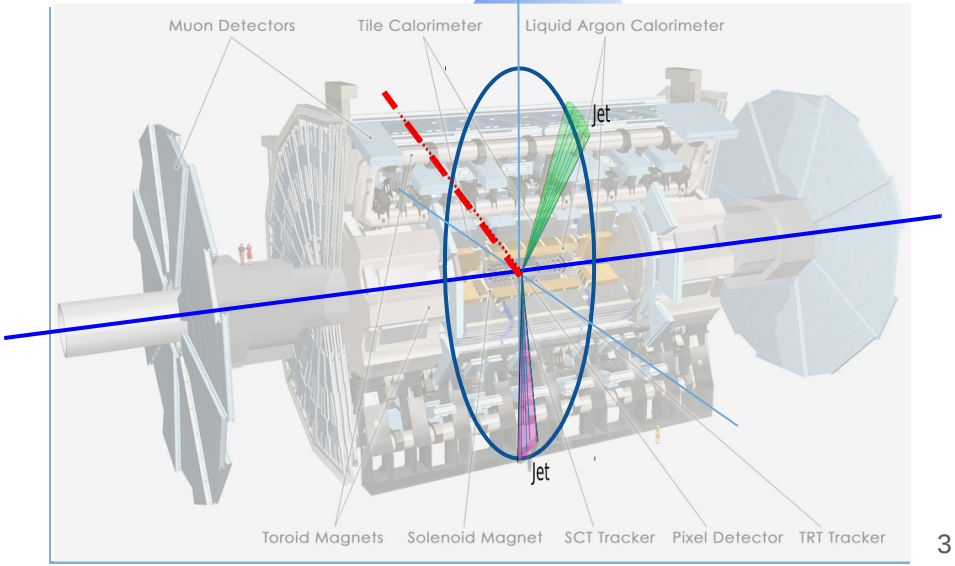
Theories Beyond SM → viable DM candidate
WIMPs (weakly interacting massive particles):

Non-baryonic
Massive
Electrically neutral
Weakly interacting
Stable

Production of Dark Matter in LHC







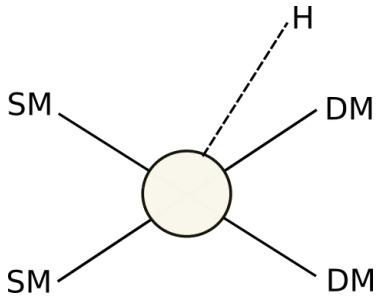
Dark Matter particles escape detection

Proton constituents in the hard scatter have almost no momentum in the transverse plane.

What could create such an imbalance?

Could it be DM particles that recoil against a visible object like a jet, γ, W, Z or a **Higgs boson**?

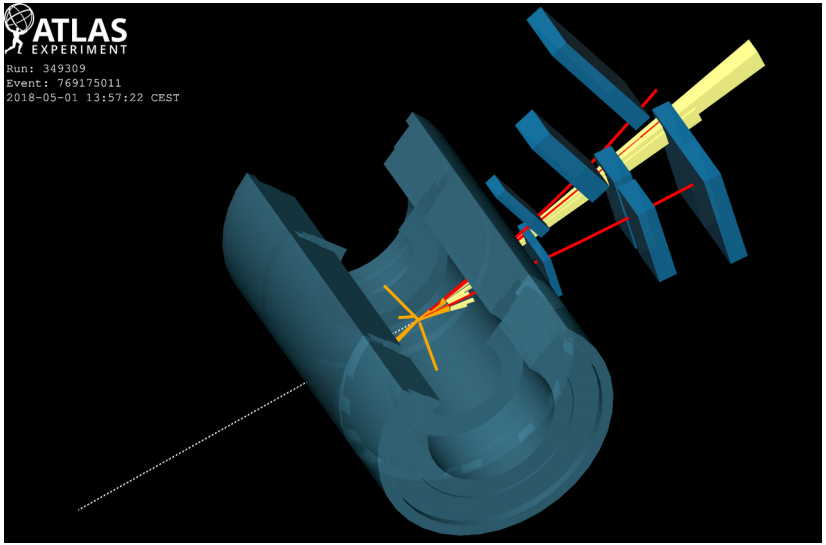
The E_T^{miss} + Higgs(bb) signature



Signal Event Selection

- High missing transverse momentum
- b-jets from the Higgs decay
- No leptons (μ, e, τ)
- Requirements to suppress multijet events

Event display :

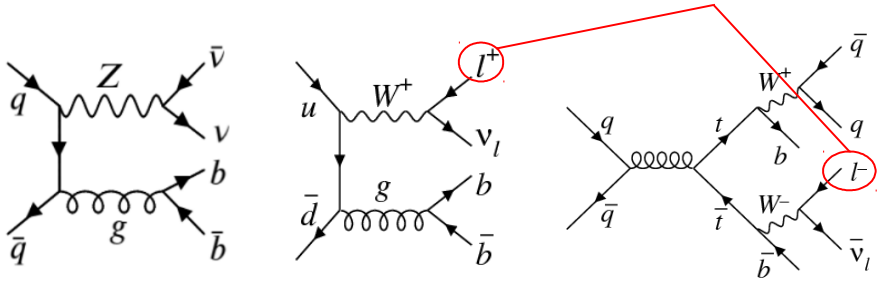


Invariant mass of the jet 121GeV and jet transverse momentum 1.2TeV.
Source: ATLAS Conference Note, ATLAS-CONF-2021-006

Background processes

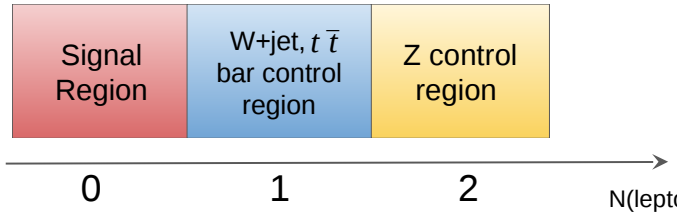
Standard Model process with neutrinos and jets in the final state.

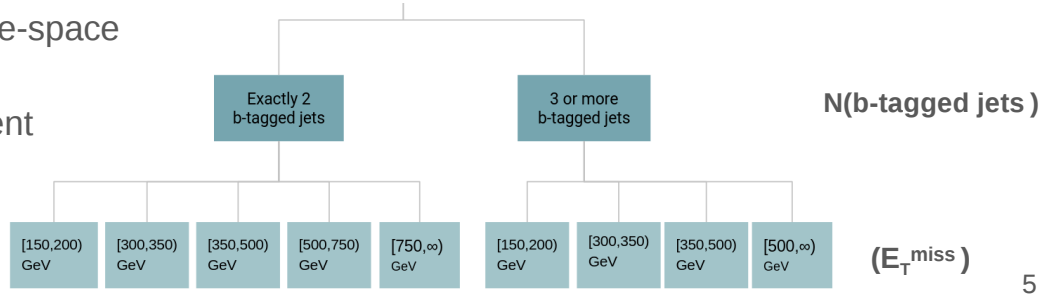
- Largest Contributions:
  - Z(νν)+jets
  - W+jets
  - $t\bar{t}$
- Other : Single top, Diboson, SM VH(bb) $t\bar{t}$ +H, $t\bar{t}$ + V



To estimate the background contributions for V+jets and ttbar:

- Define dedicated data control regions. Phase-space regions with:
  - similar kinematic distributions and event observables
  - populated only by background
- All other : simulation



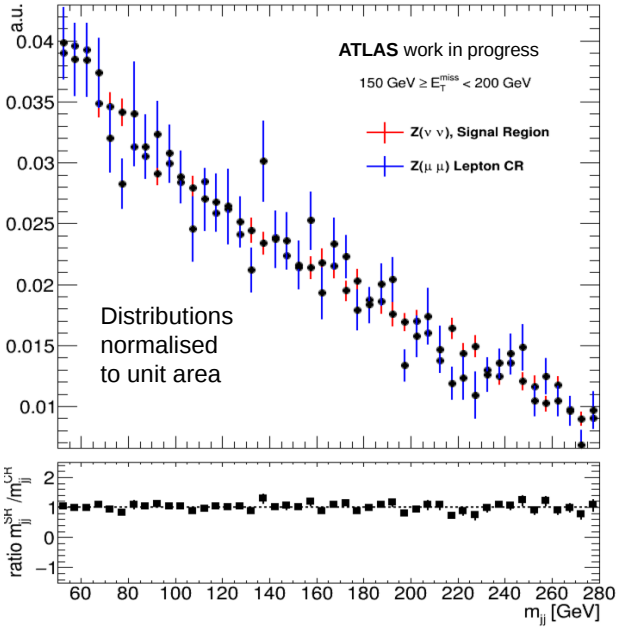


Z control region

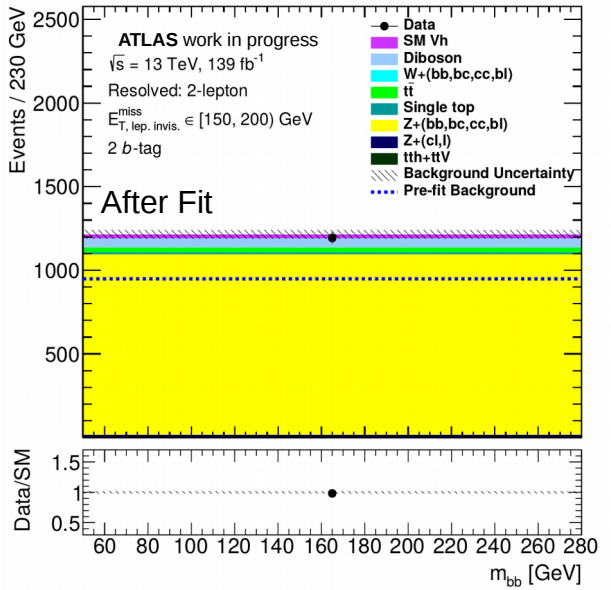
Z(νν)+jets → estimated from Z(ℓℓ) :

- A pair of charged ℓ (μμ **or** ee) in the final state
- | m(ℓℓ) -m(Z) | ≦ 10 GeV

Comparison of Z(νν) simulated events in the signal region and Z(μμ) in the control region:



Selection is applied in **data** and **all bg** simulated events.



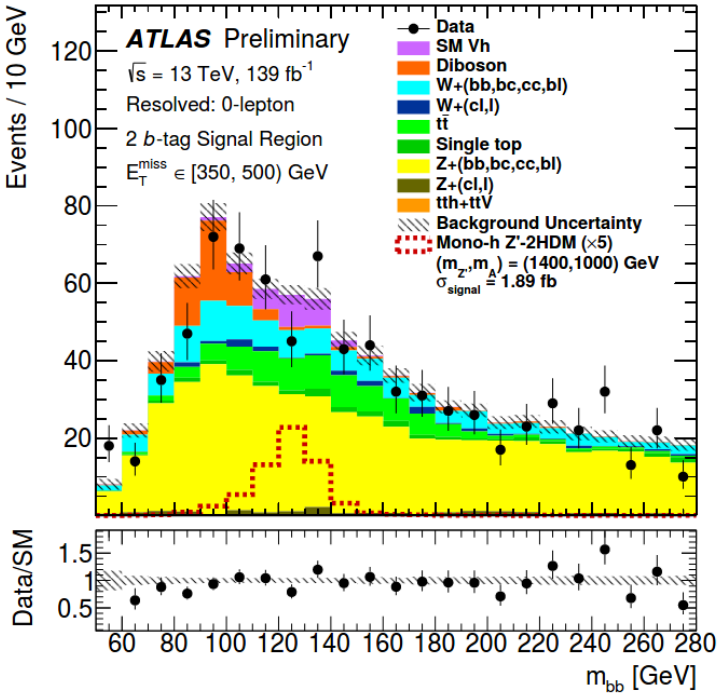
Looking for deviations from Standard Model

Fit the shape of Higgs candidate mass from background (only) simulations to data

Compare data to SM expectation

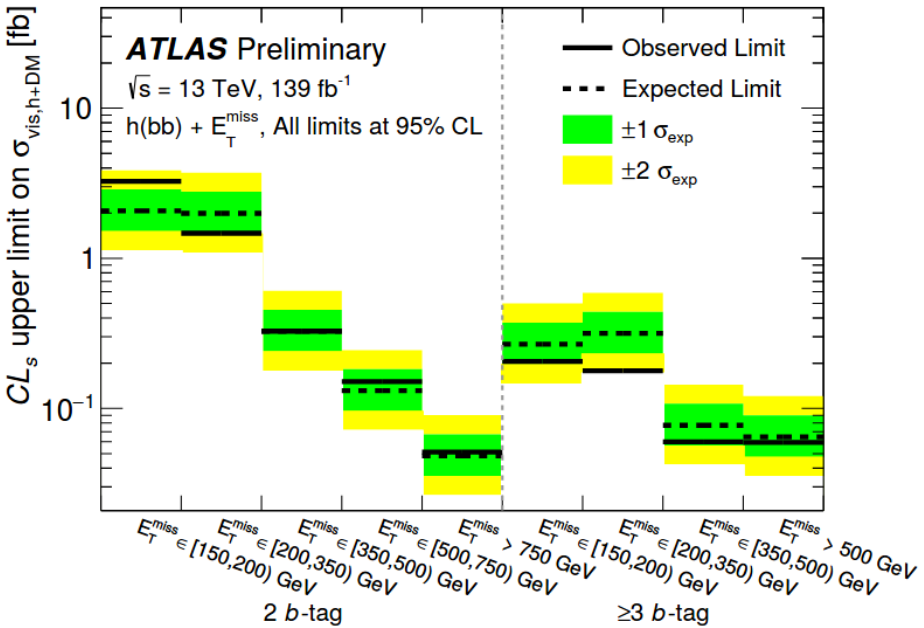
Why the mass:: for signal events we expect a peak ~125 GeV (mass of the Higgs boson)

No significant excess above SM expectations
⇒ Limits on the cross section of new physics



From ATLAS Conference Note, ATLAS-CONF-2021-006

Limits on the cross-section of new physics



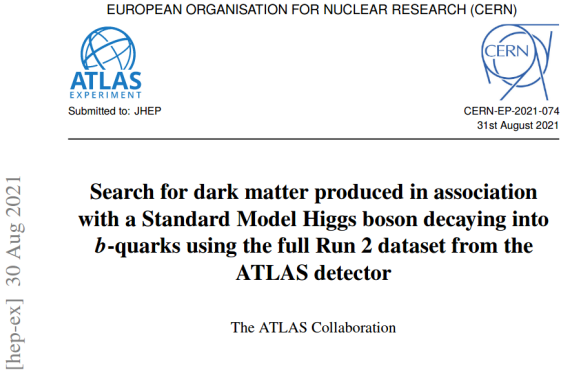
From ATLAS Conference Note, [ATLAS-CONF-2021-006]

- minimal assumptions on the underlying model
- Produces a limit in the cross-section to observe new physics, instead of only excluding a parameter space for a specific model
- Easier to make comparisons

Summary/Outlook

In this talk:

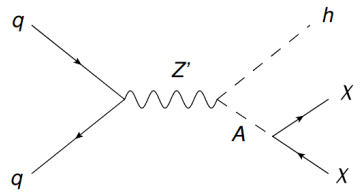
- Pair produced DM particles can be studied when they recoil against a Higgs boson
- Based on signal characteristics→ SR event selection
- Definitions of control regions to estimate the major bg contributions
- No significant deviations from SM expectations → limits on cross-section for new physics

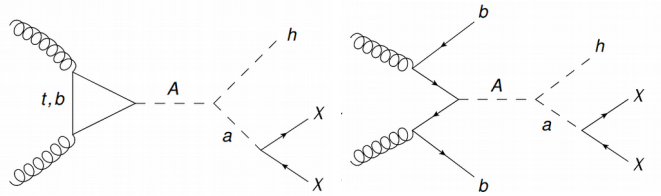


arXiv:2108.13391

What was not included:

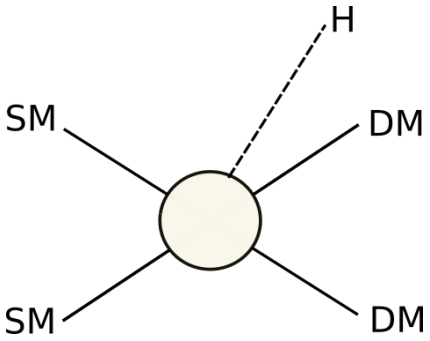
- Interpretation of the analysis results using two Higgs doublet simplified models:
  - Z'2HDM
  - 2HDMa
- Producing limits on the mediator masses

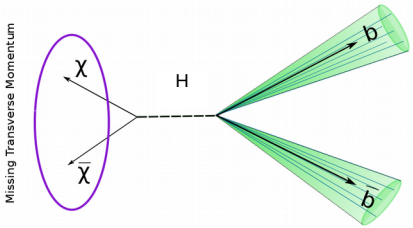


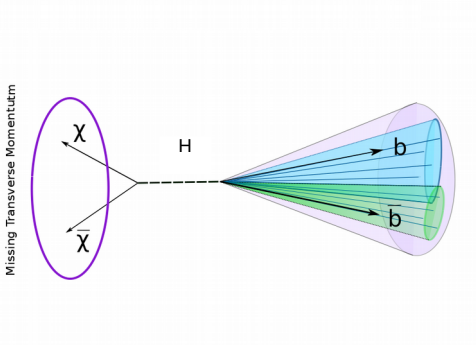


Auxiliary Material

The E_T^{miss} + Higgs(bb) signature







Signal Event Selection

- High missing transverse momentum
- Two small radius jets or one jet with large radius jet
- No leptons (μ, e, τ)
- Quality Requirements to suppress QCD events

Events in the signal region are divided to slices based on the ETmiss:

[150,200) GeV, [200,350) GeV, [350,500) GeV, [500,750) GeV, [750,∞) GeV

And on the number of b-jets : exactly 2, 3 or more

Limits on the cross-section of new physics

Make a hypothesis on the signal strength :

$$N^{obs} = \mu N^S + N^B$$

"dummy" signal with cross-section of 1fb

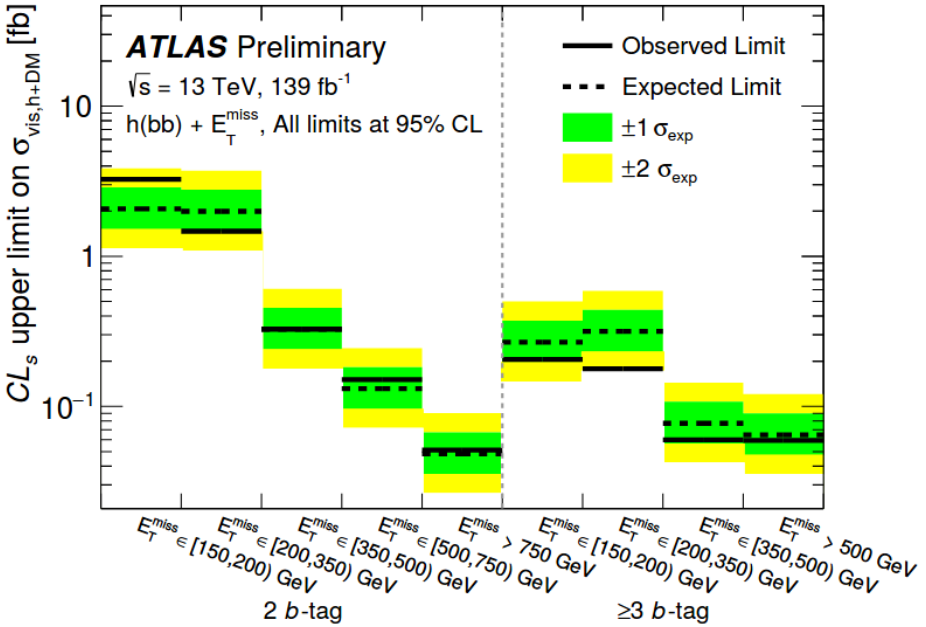
$$CL_s = \frac{p_{s+b}}{1 - p_b}$$

p-value from signal +background hypothesis

p-value from background only

Any hypothesis with CLs > 0.05 is rejected for 95% CL.

- The steps are repeated for several values of μ ⇒ Find μ for CLs = 0.05
- Translate this to visible/observed cross-section



From ATLAS Conference Note, ATLAS-CONF-2021-006

One lepton control region

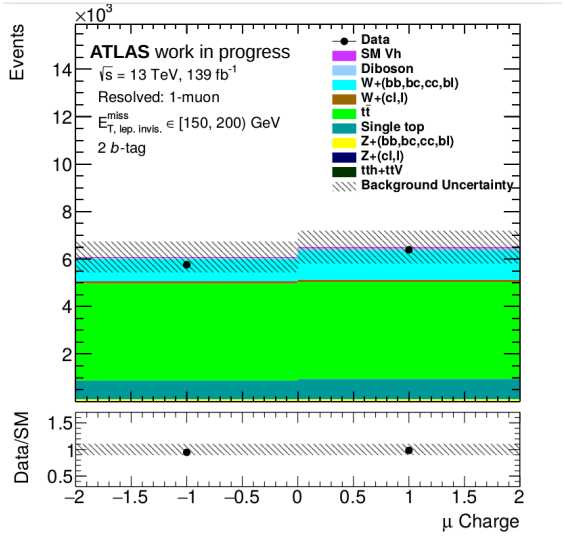
To estimate ttbar and W+jets background

- Select events with **exactly one μ, no other leptons**

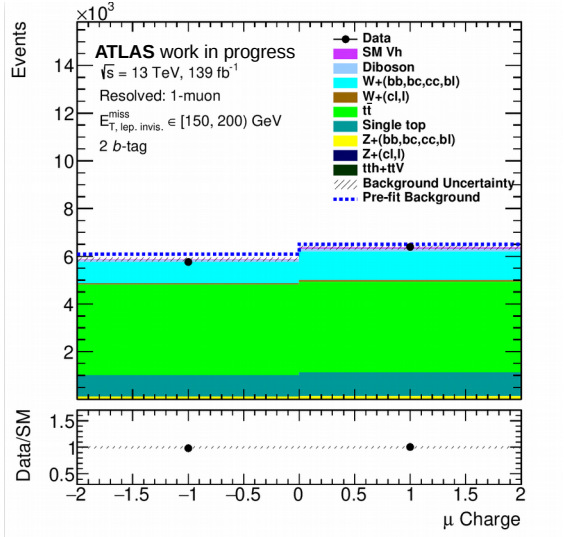
To separate ttbar and W+jets we use the μ charge asymmetry

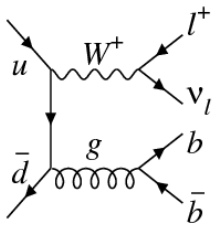
- For one lepton control region→ **fit μ charge**
- The normalization of W+jets, ttbar and Z(νν) will be estimated by the fit

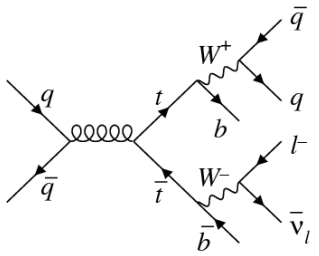
Before Fit



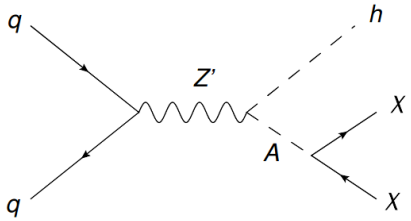
After Fit







Interpretation- part 1 : Z'2HDM model

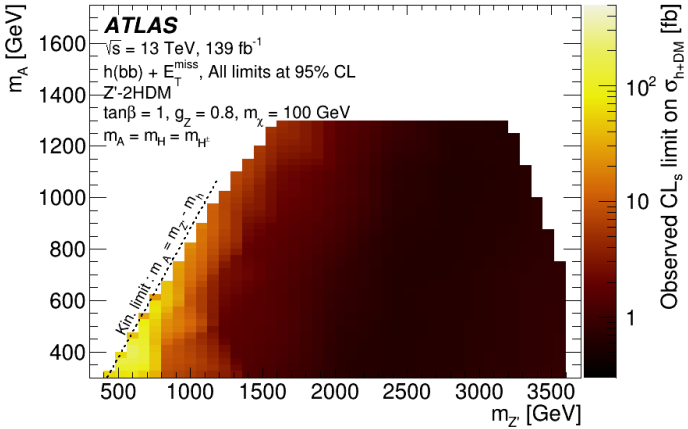


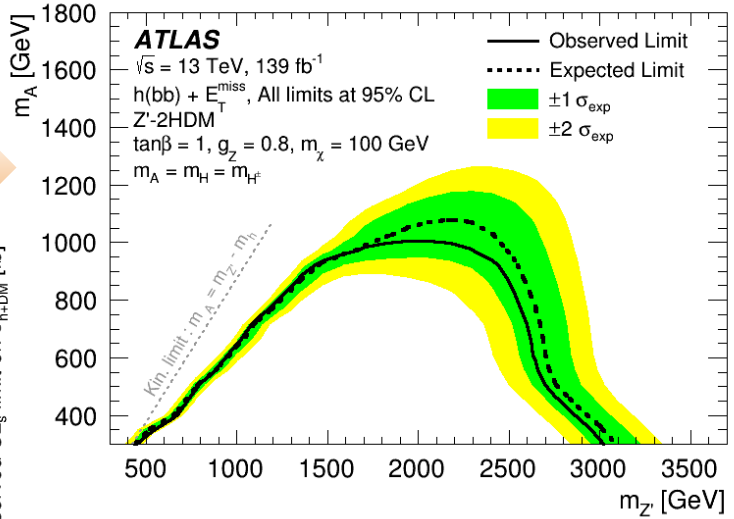
Models that create final state with H(bb) + E_T^{miss} :

Simplified DM mediator model that involve an extended two-Higgs-doublet sector (2HDM)

- **Z'2HDM**:has an additional vector mediator(Z')
- **Scan**: mass of Z' and A
- **Parameter configuration**:

$$m_H = m_{H^\pm} = m_A$$
$$m_\chi = 100\,\text{GeV}$$
$$g_Z = 0.8$$
$$\tan\beta = 1$$

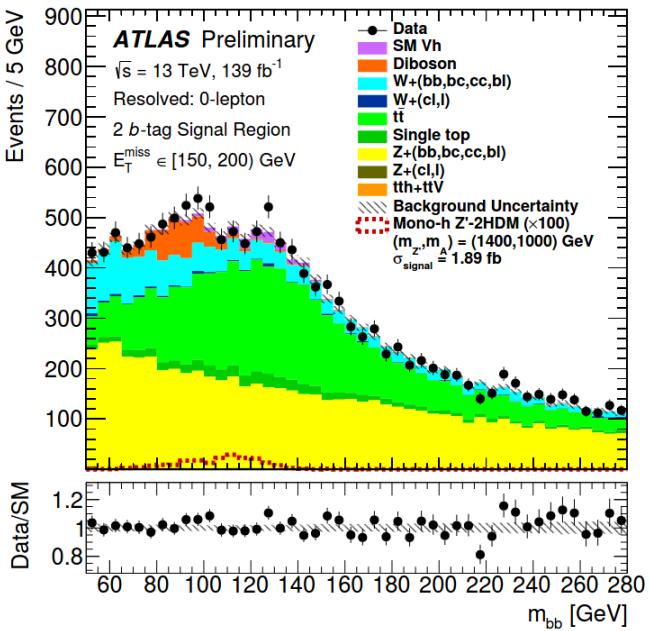


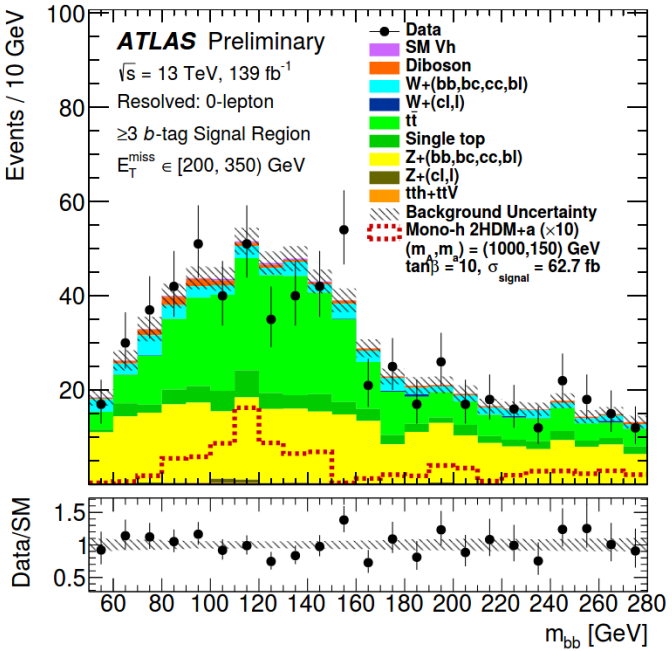


From ATLAS Conference Note, [ATLAS-CONF-2021-006]

From ATLAS Conference Note, [ATLAS-CONF-2021-006]

Distributions of the Higgs candidate mass (Other E_T^{miss} slices)





From ATLAS Conference Note, [ATLAS-CONF-2021-006]

Interpretation- part 2 : 2HDMa model

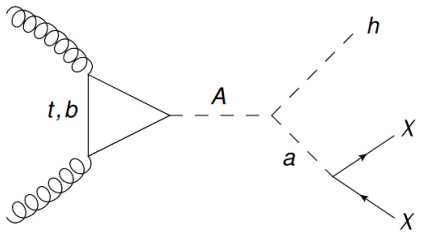
Models that create final state with H(bb) + E_T^{miss} :

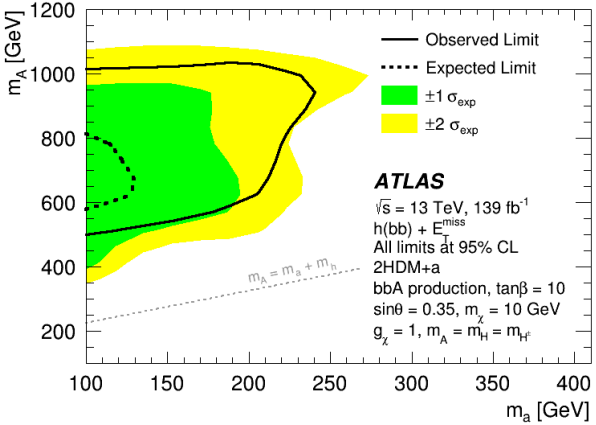
Simplified DM mediator model that involve an extended two-Higgs-doublet sector (2HDM)

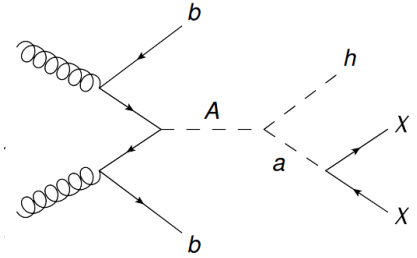
- Includes an additional pseudo-scalar mediator a
- Two production modes : gluon (ggF) and bb induced
- **Scan:** mass of a and A
- **Parameter**

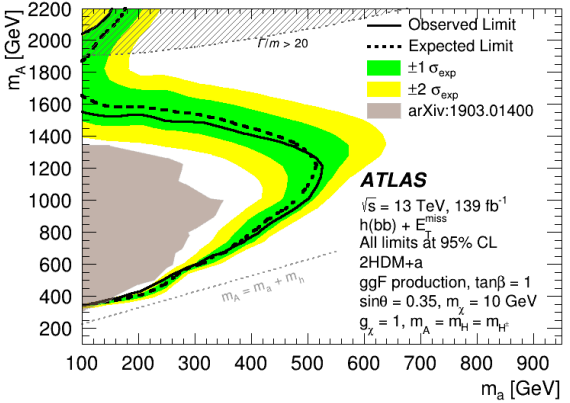
$$m_A = m_H = m_{H^\pm}$$
$$\lambda_{P1} = \lambda_{P2} = \lambda_3 = 3$$
$$m_\chi = 10\,\text{GeV}$$
$$g_\chi = 1$$
$$\sin(\beta - \alpha) = 1$$
$$\sin\theta = 0.35$$

$\tan\beta = 1$ | $\tan\beta = 10$









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