Search for Invisibly Decaying Vector Boson Fusion Produced Higgs Bosons with 139/fb of *pp* collisions with the ATLAS Detector

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Abstract - While the Standard Model (SM) predicts a branching ratio of the Higgs boson decaying to invisible particles of O(0.001), the current measurement of the Higgs boson coupling to other SM particles allows for up to 30% of the Higgs boson width to originate from decays beyond the SM (BSM). The small SM-allowed rate of Higgs boson decays to invisible particles can be enhanced if the Higgs boson decays into a pair of weakly interacting massive particles (WIMPs), which may explain the nature of dark matter. The Vector Boson Fusion (VBF) production mechanism of the Higgs boson provides a distinctive signature (with two forward jets that are largely separated in pseudorapidity leading to a large invariant mass) that can be used to target events with invisible Higgs decays, where particles invisible to the detector are a source of missing transverse energy. The most recent ATLAS results of VBF-produced Higgs bosons decaying invisibly are presented, utilizing the full Run-2 dataset of 139/fb of 13 TeV center-of-mass proton–proton collisions. Further interpretations set limits on the VBF production of other heavy scalars, and the WIMP-nucleon elastic scattering cross-section.

MOTIVATION AND SIGNAL

Distinctive topology makes channel most sensitive to $BR_{H\to inv}$

80 fb^{-1} 13 TeV Run 2

Higgs combination of visible channels [3]

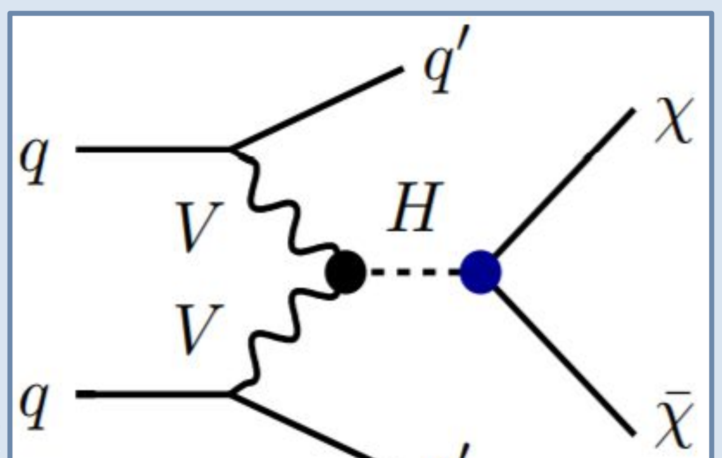
$BR_{H\to undet}$ < *0.12 (0.31)* obs (exp) at 95%CL

SM predicts $BR_{H\to inv}$ ~ 0.0013 - much room remains for BSM

Analysis Improvements

- Improved lepton veto reducing *W*+jets
- Pileup discrimination with vertex tagging, jet timing
- Optimized binning
- Enhanced QCD multijet estimation
- Looser kinematic requirements

Probe for Higgs Portal dark matter



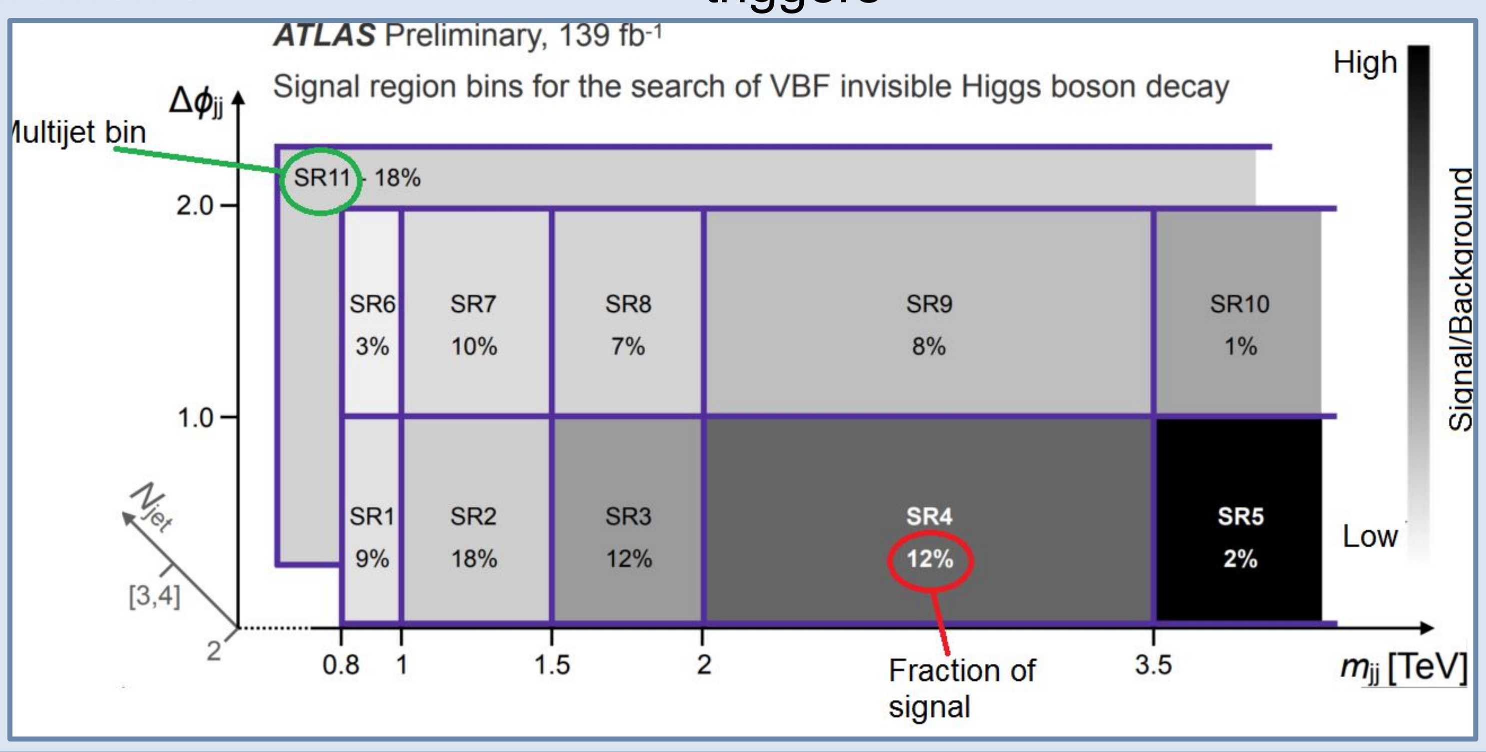
Online event selection via MET triggers

Event

- ℓ,γ veto
- 2-4 jets
- E_T^{miss} > 200 GeV
- H_T^{miss} < 180 GeV

VBF Jets

- $\eta_0 \times \eta_1 < 0$
- $|\Delta\eta_{jj}| > 3.8$
- $|\Delta\phi_{jj}| < 2.0$
- M_{jj} > 0.8 TeV

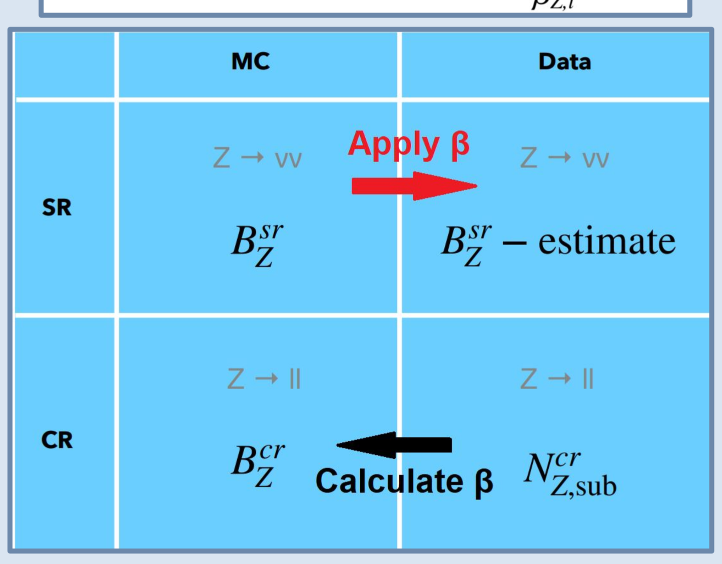


BACKGROUNDS AND FIT

Dominant background = V+jets (95%)

Estimated in each bin with normalization factors from Z and W + jets control regions with detected lepton

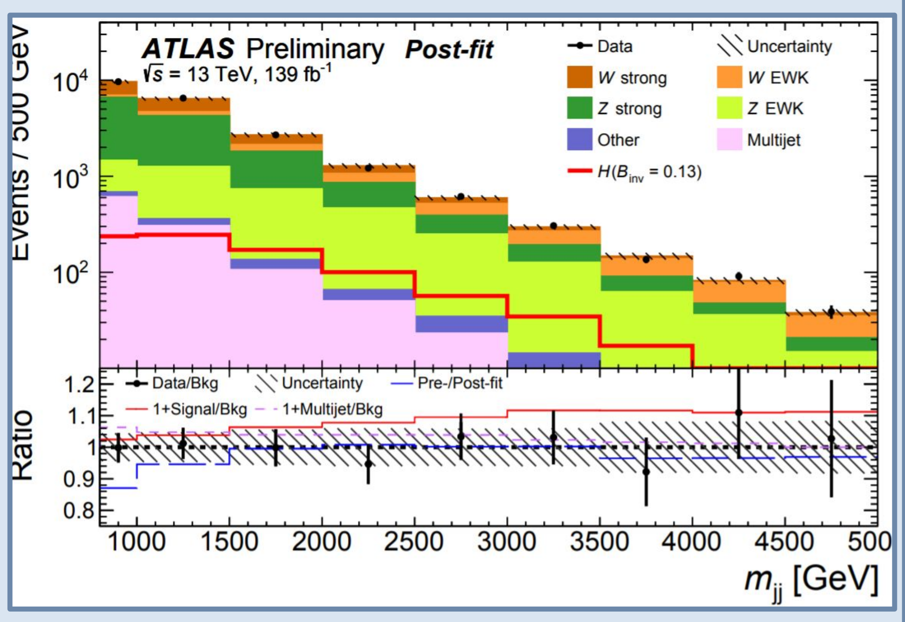
$$B^{SR}_{Z,i} = B^{SR,MC}_{Z,i} \cdot \underbrace{\frac{N^{ZCR}_i - B^{ZCR}_{non\text{-}Z,i}}{B^{ZCR,MC}_{Z,i}}}_{\beta_{Z,i}}$$

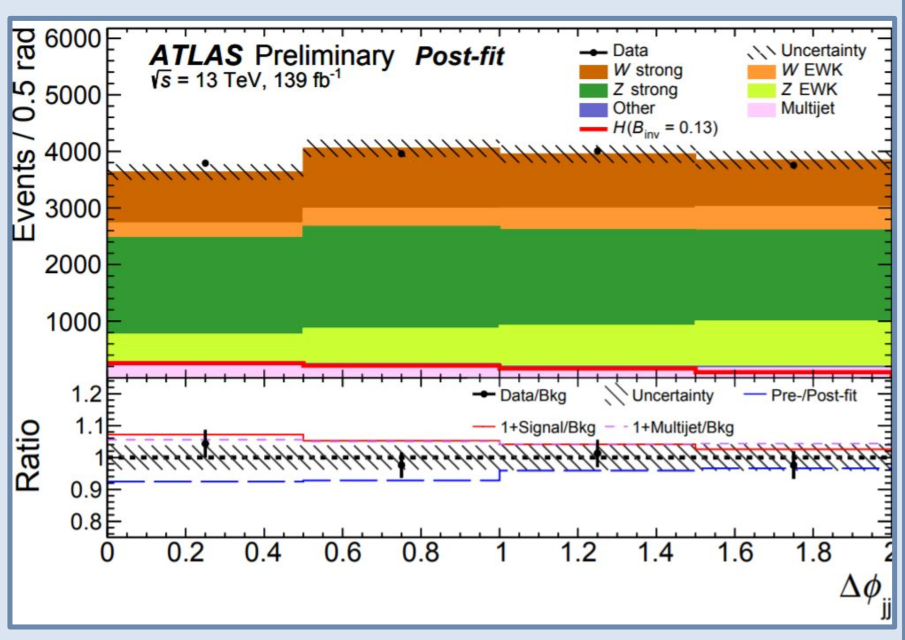


Additional Backgrounds

- Data-driven estimation: QCD Multijet, *W*→ eν (*e* fakes)
- Direct MC estimation: multiboson, *tt*

Post-Fit Spectra





Highest signal sensitivity in high-m_{jj} and low-$\Delta\phi_{jj}$ bins

RESULTS

36 fb^{-1} 13 TeV Run 2 [2]

$BR_{H\to inv}$ < *0.37 (0.28)*$^{+0.11}_{-0.08}$ obs (exp) at 95%CL

139 fb^{-1} 13 TeV Run 2

$\mathcal{B}_{H\to inv.}$ Upper Limit at 95% CL

Observed	Expected	$+1\sigma$	-1σ	$+2\sigma$	-2σ
0.132	0.132	0.183	0.095	0.248	0.071

Impact of Uncertainties on Limit on $BR_{H\to inv}$

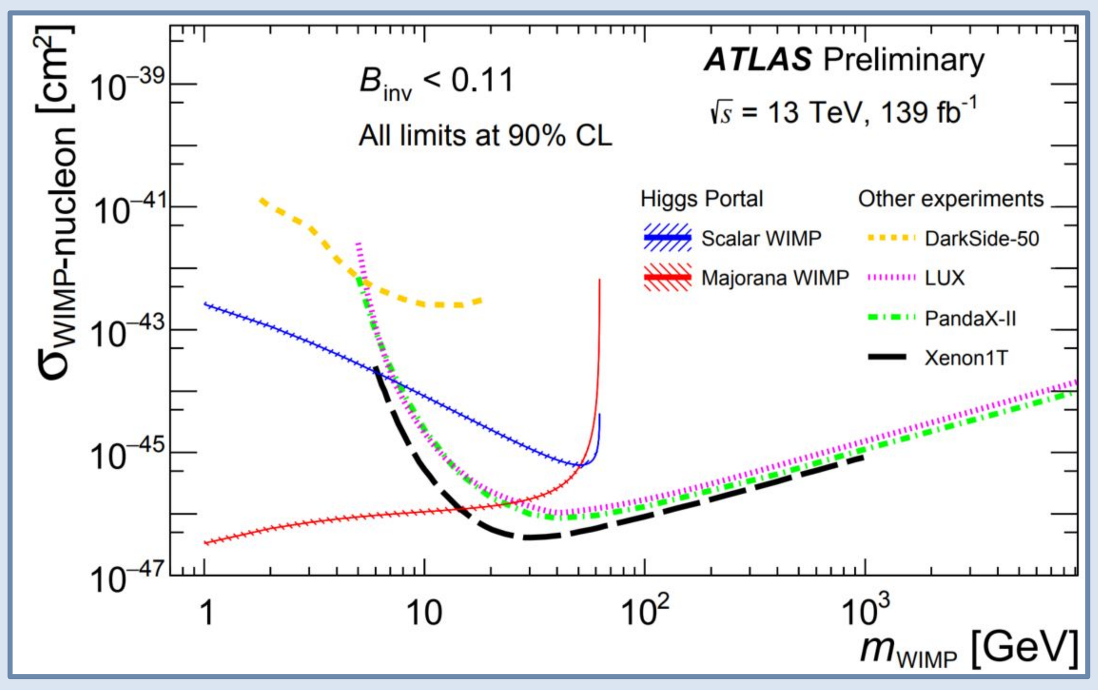
Relative impact Δ on the 95% CL expected upper limit on BR if a group of uncertainties is fixed to best fit values

Analysis is statistically limited

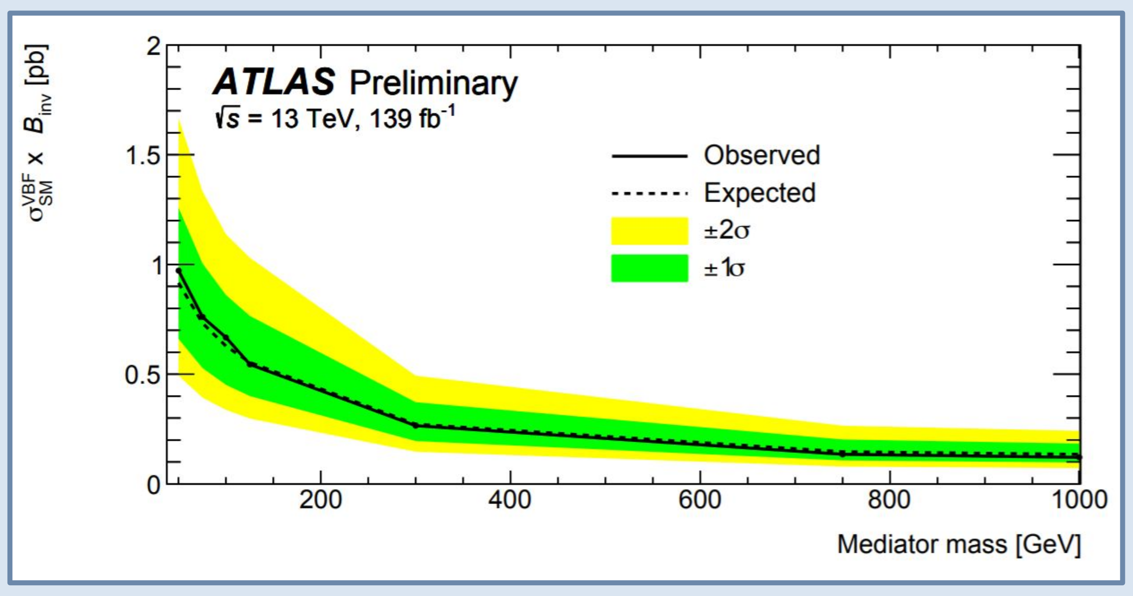
Source	Δ [%]
Jet energy scale	1.8
Jet energy resolution	5.5
Lepton	4.6
Other	1.9
Multijet	7.0
V+jets theory	1.6
Signal theory	1.0
MC stats.	7.9
Data stats.	17.3

[1]

Interpretations



Analysis complementary to direct DM detection experiments



Consider new heavy scalar mediator rather than SM Higgs

HIGGS COMBINATIONS

Run 1 + 36 fb^{-1} Run 2 H→inv Combination

$BR_{H\to inv}$< *0.26 (0.17)*$^{+0.07}_{-0.05}$ obs (exp) at 95%CL

Full Run 2 VBF channel sets stricter limit than past combination [4]

VBF H→inv refines full Run 2 H→undet

$BR_{H\to undet}$< *0.19 (0.25)* obs (exp) at 95%CL

Fit results for Higgs boson coupling modifiers with effective photon and gluon couplings and $\kappa_{W,Z} \leq 1$ [5]

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[1] ATLAS-CONF-2020-008
[2] Phys. Lett. B **793** (2019) 499
[3] Phys. Rev. D 101, 012002
[4] Phys. Rev. Lett. 122 (2019) 231801
[5] ATLAS-CONF-2020-027

ATLAS EXPERIMENT