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Search for an Invisibly Decaying Higgs Boson Produced via Vector Boson Fusion with ATLAS

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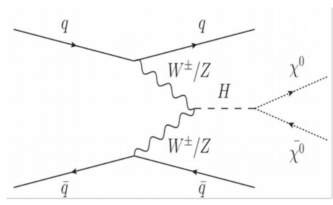
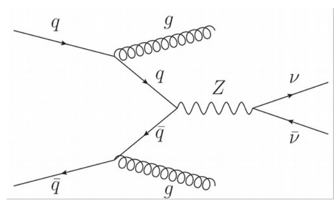
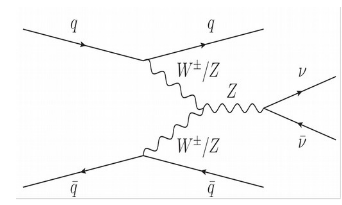


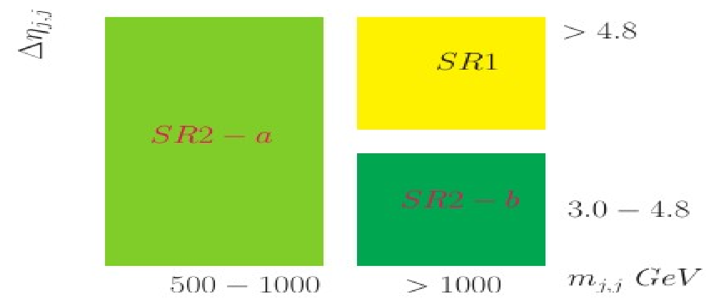
Signal



Strongly produced (QCD) Z+jets



Weakly produced (EW) Z+jets



Abstract

The recently discovered Higgs boson at a mass 125 GeV provides an excellent tool to probe beyond the Standard Model physics. Many extensions of the Standard Model predict the decay of the Higgs boson into weakly interacting neutral particles which do not interact with the detector, that could be candidates for dark matter. Using proton-proton collision data collected by the ATLAS detector during Run 1, searches have been performed for an invisibly decaying Higgs boson that produced via vector boson fusion (VBF). A 95% CL upper bound of 0.28 is set on the branching fraction of H -> invisible, where the expected upper limit is 0.31. The results are interpreted in models of Higgs-portal dark matter as shown in this poster.

Signal Event Selection

Cut	SR1	SR2a	SR2b
p_T^{j1}	>75 GeV	>120 GeV	>120 GeV
Jet 1 Charge Fraction	N/A	>10%	>10%
p_T^{j2}	>50 GeV	>35 GeV	>35 GeV
$\eta_{j1}\eta_{j2}$	<0		
$\Delta\eta_{jj}$	>4.8	$3 < \Delta\eta_{jj} < 4.8$	>4.8
m_{jj}	>1 TeV		$0.5 < m_{jj} < 1$ TeV
$\Delta\phi_{jj}$	<2.5	N/A	
Jet Veto p_T Threshold	30 GeV		
$\Delta\phi_{j,E_T^{miss}}$	>1.6 for j_1, >1 otherwise	>0.5	
E_T^{miss}	>150 GeV	>200 GeV	

Summary of the main kinematic requirements in the three signal regions (SR1, SR2a and SR2b).

Signal Region Process	SR1	SR2a	SR2b
ggF Signal VBF Signal	20 ± 15 286 ± 57	58 ± 22 182 ± 19	19 ± 8 105 ± 15
Z->νν +jets W->lν+jets Multijet Other Backgrounds	339 ± 37 235 ± 42 2 ± 2 1 ± 0.4	1580 ± 90 1010 ± 50 20 ± 20 64 ± 9	335 ± 23 225 ± 16 4 ± 4 19 ± 6
Total Backgrounds	**577 ± 62**	**2680 ± 130**	**583 ± 34**
Data	**539**	**2654**	**636**

Table: The Yield ± the uncertainity in the SRs after all cuts for the different processes.

Motivation

- Various extensions of the Standard Model (SM) allow Higgs boson decays to a pair of stable or long-lived particles.

- Observation of any excess of Higgs decaying into invisible particles can mean evidence of New Physics Beyond the Standard Model (BSM). For example, particles with very low interaction with SM particles, e.g. Dark Matter through the so-called Higgs-portal model [1].

- Limits can also be set on σ·BR to invisible particles of any additional Higgs boson over a wide mass range

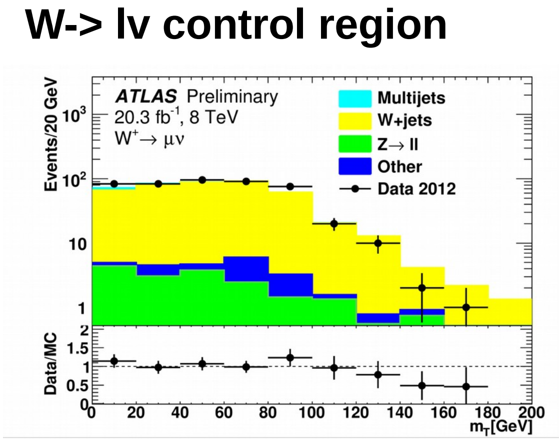
Background Estimation

To reduce the impact of :
theoretical and experimental uncertainties,
statistical uncertainty(limited numbers of MC events)

Both backgrounds, Z → νν and W → lν, are determined from measurements in a set of control samples consisting of Z → ll events, W → lν events (l = e/μ).

W&Z processes are scaled from data using a common factor

W-> lν control region



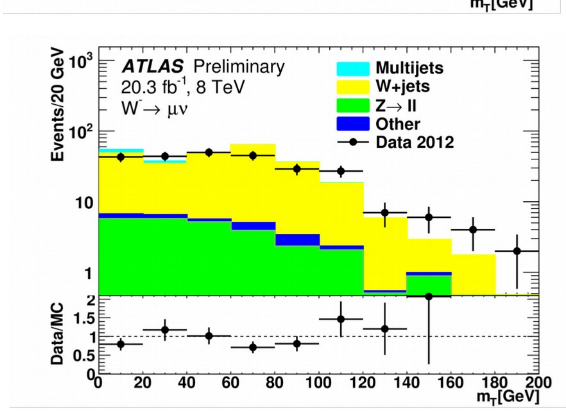


Fig. The transverse mass distributions used in the SR1 W +jets control region after all requirements except for the missing transverse momentum, E_T^{miss} > 150 GeV requirement.

- 1 lepton p_T > 30 GeV (25 GeV in SR2), no additional leptons with p_T > 20 GeV.
- Emulate E_T^{miss} : add the electron and muon momenta vectorially to the E_T^{miss}
- Signal regions selections on jets, and E_T^{miss}

Determine multijet bkg in W CRs

* For SR1, use 4 W CRs for W +/W − → e/μ ν to exploit W+jets charge asymmetry. Use anti-ID/anti-d0 (leptons) control samples for multi-jet. Fit to the transverse mass m_T of the lepton and E_T^{miss} is used to determine the W (→lν)+jets bkg normalization, multijet bkg.

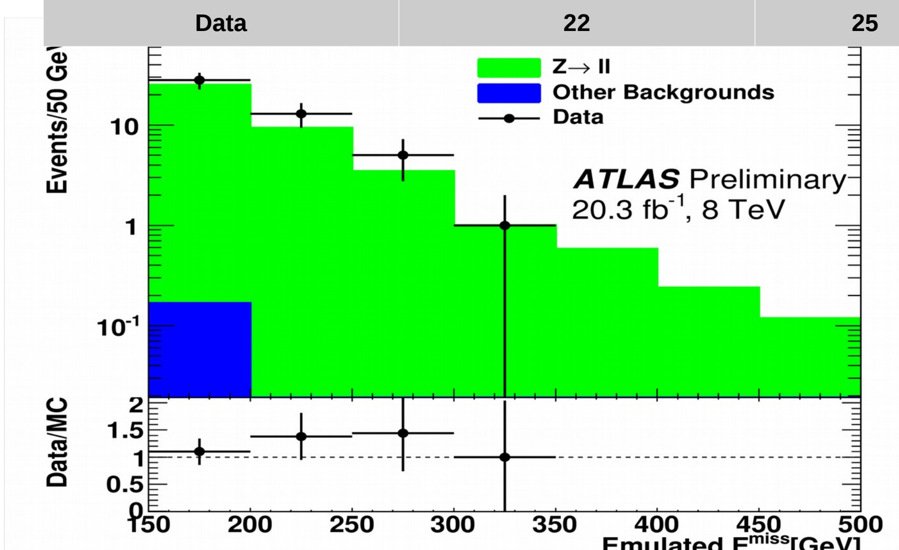
* For SR2, use only 2 CRs W (→ eν/μν)+jets. Reject multijet bkg by cuts E_T^{miss} > 25 GeV, 40 < m_T < 100 GeV. In W (→ eν) CR, use matrix method to reduce multijet bkg to 1% of total bkg in the CR. In W (→ μν) CR use template method =>
the residual of multijet bkg is small

Z-> ll control region

- 2 same-flavor, oppositely charged leptons with p_T > 20 GeV
- $|m_{ll} - m_Z|$ < 25 GeV
- For SR1 control sample, leading lepton p_T > 30 GeV.
- Single electron or muon triggers with p_T > 24 GeV
- Emulate the offline E_T^{miss} : add the electron and muon momenta vectorially to the E_T^{miss}
- Signal region selections on jets and E_T^{miss}

SR1

Background	Z(→ ee)+jets	Z(→ μμ)+jets
QCD Z->ll EW Z->ll Others	10.4 ± 1.5 7.4 ± 0.8 0.3 ± 0.2	14.0 ± 1.5 8.2 ± 0.8 0.2 ± 0.1
Total	**18.1**	**22.4 ± 1.7**
Data	**22**	**25**



Emulated E_T^{miss} distribution in the Z(→ ll)+jets CR in SR1.

SR2a | **SR2b**

Background	Z(→ ee)+jets (SR2a)	Z(→ μμ)+jets (SR2a)	Z(→ ee)+jets (SR2b)	Z(→ μμ)+jets (SR2b)
QCD Z->ll EW Z->ll Others	116 ± 3 17 ± 1 8 ±1	121 ± 4 17 ± 1 10 ± 2	26 ± 2 16 ± 1 2 ± 1	28 ± 2 16 ± 2 3 ±1
Total	141 ± 3	148 ± 5	44 ± 3	47 ± 3
[illegible]	[illegible]	139	33	38

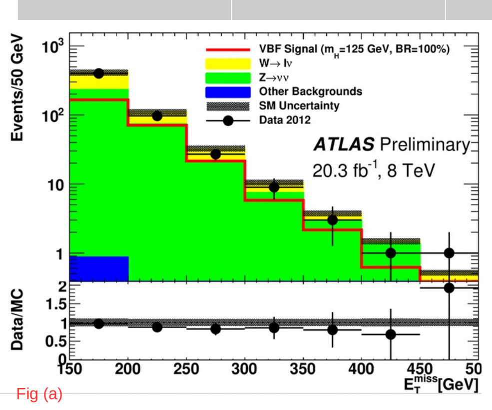


Fig (a)

Data and MC distributions after all the requirements in SR1 for fig (a) E_T^{miss}
The background histograms are normalized and the VBF signal (red histogram) is normalized as well

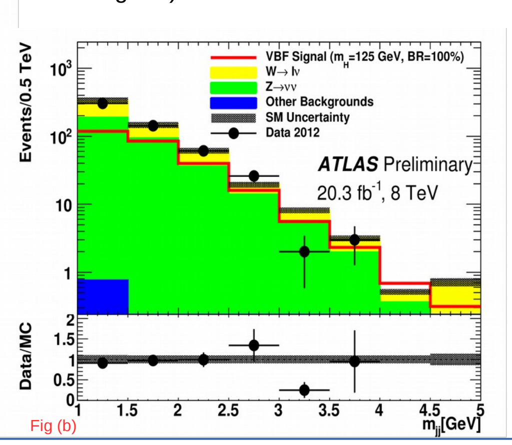
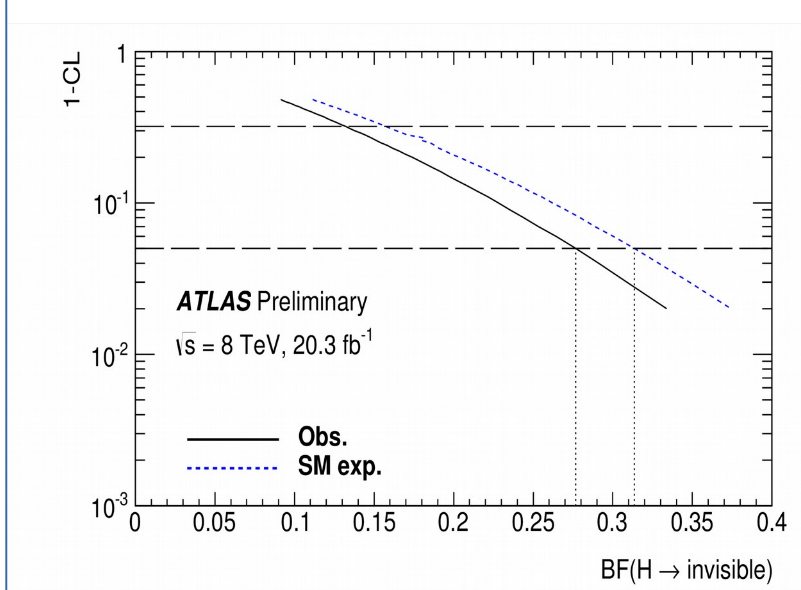


Fig (b)

Data and MC distributions after all the requirements in SR1 for fig (b) m_{jj} .
The background histograms are normalized and the VBF signal (red histogram) is normalized as well.

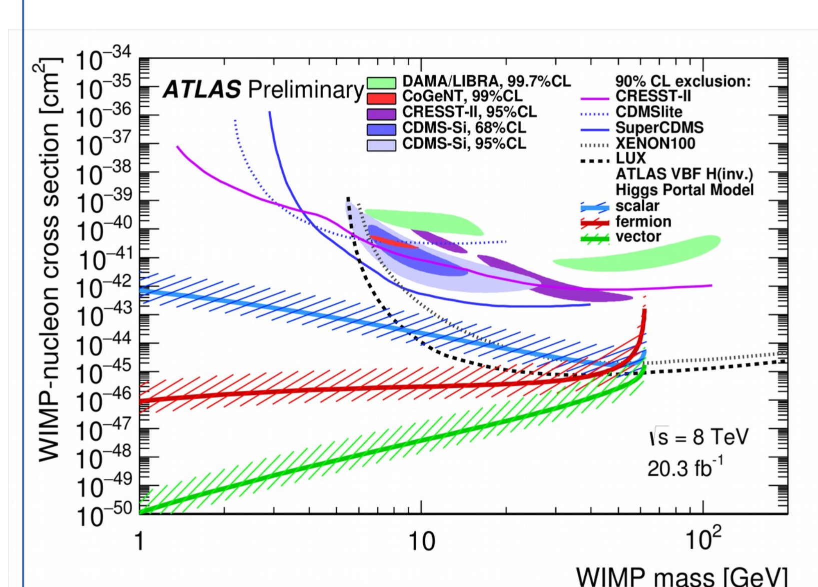
Upper limits

Assuming the SM production cross section, acceptance and efficiency of a 125 GeV Higgs boson, a 95% CL upper bound is set on the BF(H → invisible) at 0.28



Higgs-portal Dark Matter scenario

- In the Higgs-portal Dark Matter (DM) scenario the Higgs boson acts as a mediator between DM and SM particles (with DM mass < m_H /2).
- The 90% CL limit on the BF(H → invisible) is converted into upper bounds on the dark matter-nucleon scattering cross section as function of the dark matter mass



Spin-independent DM–nucleon cross section as a function of the DM mass. The exclusion limits and signals observed by the direct detection experiments are compared to the ATLAS results from the BR(H→ invisible) limit in the Higgs-portal scenario, translated into the spin-independent DM–nucleon cross section using the formulas from Ref. [arXiv:1112.3299 [hep-ph]]. The exclusion limits are shown at 90% CL. The error bands on the ATLAS results indicate the uncertainty coming from the different estimations of the Higgs–nucleon coupling .

References

D. Ghosh, R. Godbole, M. Guchait, K. Mohan and D. Sengupta, Phys. Lett. B 725 (2013) issue, 344 [arXiv:1211.7015 [hep-ph]].
ATL-COM-PHYS-2015-126 and ATLAS-COM-CONF-2013-142
And arXiv:1112.3299 [hep-ph].