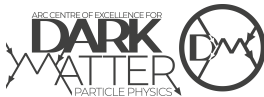


Search for Dark Matter in Invisible Higgs Decays with the ATLAS experiment

Harish Potti

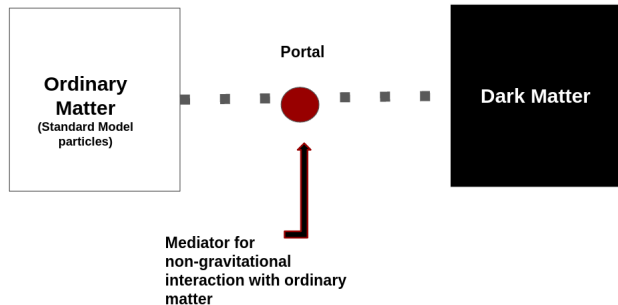
*The ARC Centre of Excellence for Dark Matter Particle Physics &
The University of Adelaide*

24th Australian Institute of Physics Congress - 2022



HIGGS PORTAL TO DARK SECTOR

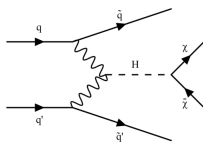
- ▶ The nature of dark matter is still unknown and it is one of the key questions in particle physics



- ▶ Many BSM theories with various mediators
- ▶ Higgs boson could be a mediator between ordinary matter and dark matter
- ▶ Higgs decays into a pair of WIMPs like $\chi\chi$ in these models.

INVISIBLE HIGGS DECAYS

- ▶ In the SM, $B_{inv}(H \rightarrow \text{invisibles}) \sim 0.1\%$ due to $H \rightarrow ZZ^* \rightarrow 4\nu$
- ▶ In many BSM theories, B_{inv} is enhanced due to Higgs decays to stable dark matter particles
- ▶ E.g. SUSY (LSP), large extra dimensions (Graviscalar)
- ▶ Events are tagged using the associated production of W/Z or a recoiling jet

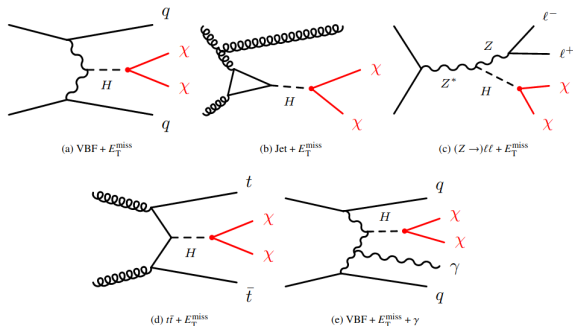


- ▶ Higgs boson will be invisible and will be manifested as the *"imbalance in momentum in transverse direction"* (MET)

ATLAS $H \rightarrow$ INVISIBLES SEARCHES

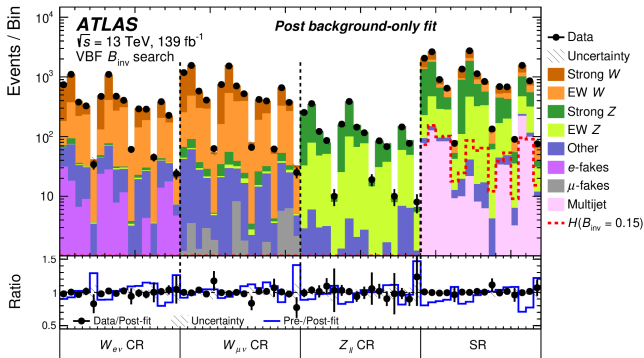
- ▶ ATLAS collaboration has performed five independent searches for invisible Higgs decays with full Run-2 data

Analysis	Results
VBF+MET	JHEP 08 (2022) 104
MET+Z($\ell\ell$)	Phys. Lett. B 829 (2022) 137066
$tt +$ MET	ATLAS-CONF-2022-007
VBF + MET + γ	Eur. Phys. J. C 82, 105 (2022)
Monojet	Phys. Rev. D 103, 112006
Run-1 combination	JHEP11(2015)206
Combination	HIGG-2021-05

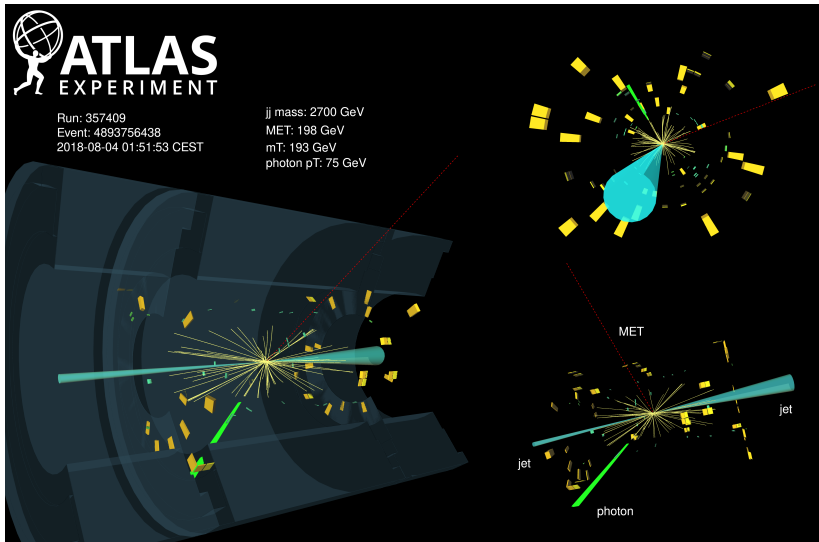


(1) VBF + MET ANALYSIS

- ▶ Most powerful analysis
- ▶ Distinct characteristic is a pair of energetic jets with a wide pseudo-rapidity gap ($|\eta_{jj}|$) and a large invariant mass (m_{jj})
- ▶ Major bkg: V + two jets due to QCD radiation
- ▶ $E_T^{\text{miss}} > 160 \text{ GeV}$, $p_T^{\text{all-jet}} > 140 \text{ GeV}$
- ▶ $B_{inv} < 0.145$ (0.103) at 95% CL

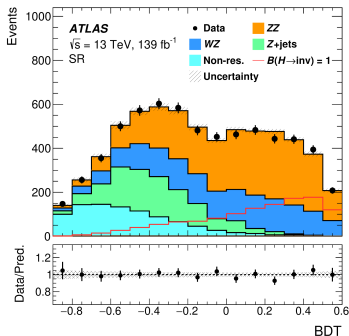


(2) VBF + MET + γ ANALYSIS

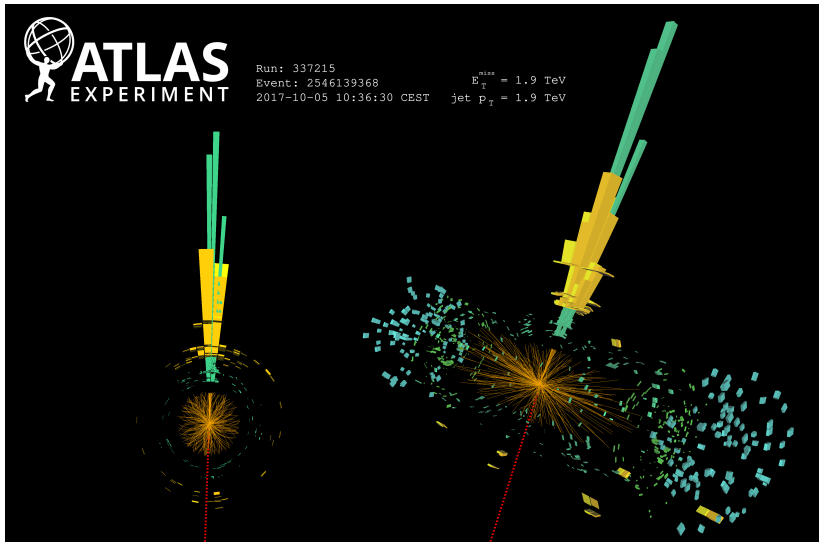


(3) $H \rightarrow$ INVISIBLES: $E_T^{\text{MISS}} + (Z \rightarrow \ell\ell)$

- ▶ Requires $E_T^{\text{miss}} > 90$ GeV and to be back-to-back with $Z \rightarrow \ell\ell$
- ▶ Major backgrounds:
 $(Z \rightarrow \ell\ell)(Z \rightarrow \nu\nu)$,
 $(Z \rightarrow \ell\ell)(W \rightarrow \ell\nu)$, and Z+jets
- ▶ A BDT is trained to separate signal from the backgrounds
- ▶ Eight BDT input variables:
 E_T^{miss}/H_T , $y_{\ell\ell}$, $m_{\ell\ell}$, $\Delta R(\ell, \ell)$,
 $\Delta\phi(\ell\ell, E_T^{\text{miss}})$, etc.
- ▶ Signal region acceptance times efficiency 8%
- ▶ $B_{\text{inv}} < 0.19$ (0.19) at 95% CL (Ref: [2111.08372](#))



(4) JET + MET

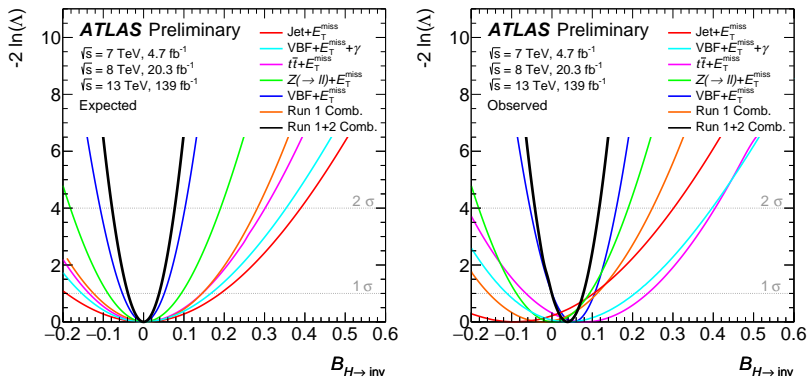


COMBINATION OF THE HINV ANALYSES

- ▶ Overlap removal between the analyses
- ▶ Construction of a simultaneous binned likelihood function by combining the distributions of discriminant from each individual analysis
- ▶ Correlations of systematic uncertainties across individual analyses
- ▶ Likelihood scans and maximum likelihood fit to determine the best-fit branching ratio
- ▶ Setting upper limits on the B_{inv}

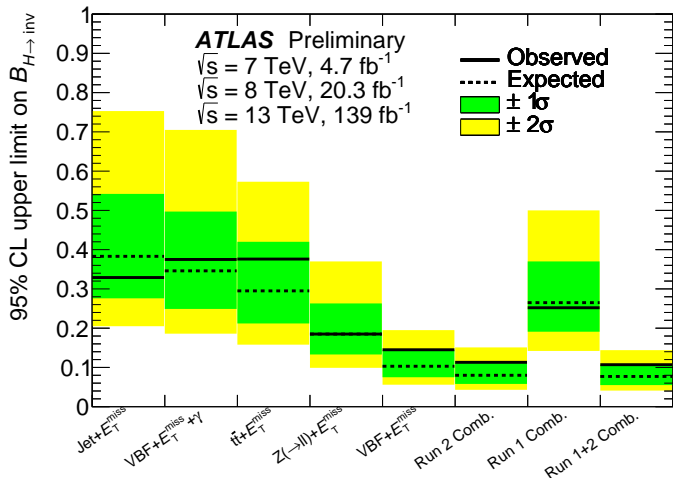
RESULTS FROM THE $H \rightarrow$ INVISIBLES COMBINATION

► Negative Log-likelihood scans for Asimov and Data fits

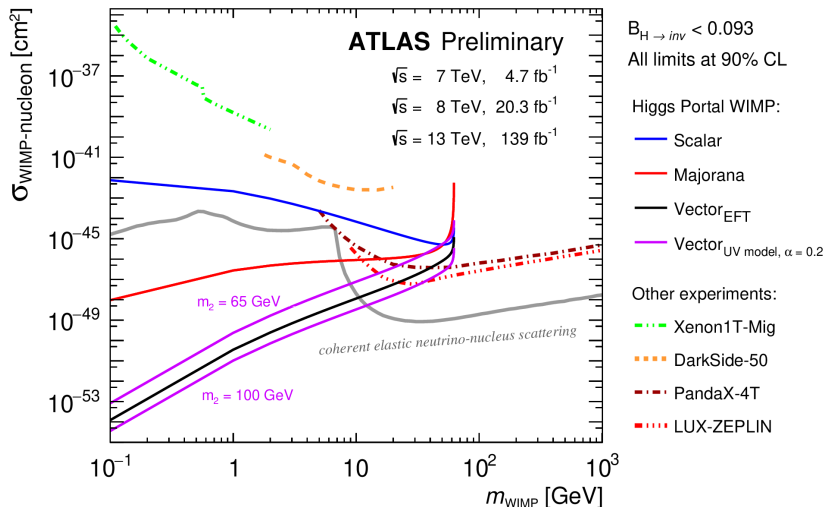


RESULTS FROM THE $H \rightarrow$ INVISIBLES COMBINATION - 2

- Observed (expected) upper limits on the B_{inv}



DARK MATTER INTERPRETATION



SUMMARY

- ▶ MET-based signatures of invisible Higgs boson decays provides a great opportunity to search for DM with the ATLAS experiment.
- ▶ Five independent searches have been performed with the full Run-2 dataset
- ▶ Observed (expected) upper limit from the combination of these searches results in $B_{inv} < 0.107$ (0.077) at 95% CL
- ▶ Many of the searches are statistically limited \implies Large room for improvement with Run-3 data

Thank You!