SEARCH FOR INVISIBLE DECAY MODES OF THE HIGGS BOSON WITH THE ATLAS DETECTOR

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on behalf of the ATLAS Collaboration



HIGGS INVISIBLE DECAY SEARCHES: WHY? 2

- Standard Model (SM) theory remarkably successful in describing particles and interactions, but:
 - 1. Cannot accomodate general relativity as quantum field theory
 - 2. Hierarchy problem ($m_{H} << M_{Planck}$)
 - 3. Dark Matter
 - 4. ...





• The Higgs boson can play a role in probing BSM physics through searches for invisible decays:

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SM BR(H! invisible) ~ 0.1% (from H! ZZ*! 4!)
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Higgs as a mediator between SM particles and Dark Matter particles (Higgs-portal Dark Matter Model)

MONO-JET SEARCH

Experimental Signature: Energetic jet from ISR + high MET

- High production rate at LHC
- Primarily sensitive to ggF mode 滢 large background

Event Selection

Backgrounds estimation

Results

VBF CHANNEL

Experimental Signature

ZH, Z! CHANNEL

Results

- The limit on the invisible branching ratio extracted with a maximum likelihood fit of the MET distribution
- Data-driven estimates used for the bkgs normalisation (but for ZZ), MET shape taken from MC
- ee and)) results statistically combined



No significant excess observed over SM predictions

95% CL limits results	Run-II result Obs. Exp.	Run-I result Obs. Exp.
Upper limit on BR(H! invisible)	0.98 0.65	0.75 0.62
Upper limit on \$(Z! ##) % BR(H! inv) [fb]	88 58	~300 ~240

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8 TEV COMBINATION OF THE DIRECT SEARCHES ¹⁰

- A statistical combination of the Run-I searches was performed
- VH and VBF searches combined (Mono-jet left outside, since less sensitive to Higgs-mediated interactions), any possible overlap between SRs & CRs removed by jet veto and m_{ii} cuts
- Simultaneous maximum likelihood fit to the event count in SRs & CRs
- Luminosity uncertainty, jet absolute energy scale and resolution uncertainties as well as theory uncertainties treated as fully correlated across the individual searches
- Uncertainty on the soft component of the MET affecting only ZH, Z! ## search

Run-I only Upper limit on BR(H! inv)



Likelihood scan

Sensitivity dominated by VBF search

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INDIRECT CONSTRAINT ON H! INVISIBLE 11

- Use the measured visible rate in a more general couplings fit to constraint the H! invisible
- Visible rates indirectly sensitive to undetectable final states (e.g. BR_{gg}): "_h = BR_{vis} + BR_{inv} + BR_{undetectable}
- Extract a conservative limit on BR_{inv} assuming BR_{undetectable} ~0, as predicted in SM

$$k_h^2 = !_h / !_{h,SM} = \sum_j k_j^2 BR_j / (1 \# BR_{inv})$$

Scale factor for total width



INTERPRETATIONS

SUMMARY OF H! INVISIBLE SEARCHES 13

- "With data collected in the 8 TeV Run ATLAS has carried out a comprehensive programme of searches for the invisible decay of the Higgs boson
- " Great number of analyses involved, different analysis techniques employed
- " No evidence for the Higgs boson invisible decay has been observed
- " Run-I concluded with a statistical combination of the H! invisible direct and indirect search, from the coupling parametrisation:



- " The second run of the LHC offers the possibility to improve Run-I results
- "First result from the ZH, Z! H! invisible channel presented today, many more to come in the next months!

BACKUP

GENERAL METHODOLOGIES FOR BACKGROUNDS 15

Z! & W!

- Z! + jets background constrained using a combination of estimates from W+jets & Z! + jets CRs:
 - # Data control samples with identified e/) & same requirements on jets/MET as in SR
 - # data-driven techniques allow to reduce the theoretical & experimental systematic uncertainties associated with MC predictions

- - with the same trigger as in SR

W!)!&Z!))

Example: Z! !!

Use electrons online trigger

W! e! & Z! ee

MET corrected for removing the contribution of electrons energy cluster in the calorimeter



GENERAL METHODOLOGIES FOR BACKGROUNDS 16

Non-collision background

- Cosmic muons, beam-halo and detector noise give rise to large energy deposits in the calorimeter
- Below the percent level after the mono-jet event selection

HIGGS PORTAL DARK-MATTER MODEL

- Dark matter portal models introduce the existence of a WIMP as dark-matter candidate
- The WIMP is assumed to interact weakly with all the particles but for the Higgs boson
- The combined upper limit from visible & invisible searches is translated into constraint on the coupling of WIMP to the Higgs boson .
- The partial width to the DM particles pairs depends on the spin of the DM particles



Used to deduce the couplings to the WIMP

Couplings re-parametrised in terms of the cross section for scattering between WIMP and nucleon, via the Higgs boson exchange

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