

# Validation of the MadAnalysis 5 implementation of ATLAS-HIGG-2013-03

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This note contains detailed validation material for the MadAnalysis 5 implementation [1] of the ATLAS search [2] for invisible decays of a Higgs boson produced in association with a  $Z$  boson decaying into a pair of leptons at the 8 TeV run of the LHC. Event samples used for the validation were generated with Herwig++ 2.5.2. 100000 events were generated for the benchmark point, defined as  $m_H = 125.5$  GeV and  $\text{BR}(H \rightarrow \text{invisible}) = 100\%$ . Simulation of detector effects was done within `MadAnalysis 1.1.11_patch1b`, using `delphesMA5tune` and the detector card previously used for an ATLAS SUSY analysis [3]. Non-leptonic decays of the intermediate  $Z$  boson were filtered. The cross section for the benchmark point was taken from the paper: 410 fb.

The next pages contain the cut flow, the kinematic distributions used for validation and a validation of limit-setting procedure.

## References

- [1] Analysis code, doi: 10.7484/INSPIREHEP.DATA.RT3V.9PJK
- [2] <https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/HIGG-2013-03/>
- [3] [http://madanalysis.irmp.ucl.ac.be/attachment/wiki/PhysicsAnalysisDatabase/delphesMA5tune\\_card\\_ATLAS\\_dileptonSUSY.tcl](http://madanalysis.irmp.ucl.ac.be/attachment/wiki/PhysicsAnalysisDatabase/delphesMA5tune_card_ATLAS_dileptonSUSY.tcl)

# 1 Cutflows

cut	$ZH \rightarrow \ell\ell + \text{inv. cutflow}$		ATLAS
	# events (scaled to $\sigma$ and $\mathcal{L}$ )	relative change	
Initial number of events	838.9	838.9	
2 OS leptons	256.2	-69.5%	
$Z$ window	244.1	-4.7%	243
MET90GeV	105.1	-56.9%	103
dilepton-MET separation	91.7	-12.7%	
lepton-lepton separation	82.9	-9.6%	
pTmiss-MET separation	76.5	-7.7%	
pTll-MET similarity	63.2	-17.4%	
jet veto	54.8	-13.3%	$44 \pm 1 \pm 3$

Table 1: Cutflow for the benchmark point  $ZH \rightarrow \ell\ell + \text{inv.}$  for  $m_H = 125.5$  GeV. For the lines  $Z$  window and MET90GeV, the ATLAS number has been extracted from Fig. 1 and Figaux. 3a,b,d of [2], respectively.

# 2 Histograms

In the histograms below, the solid lines correspond to the results from the MadAnalysis 5 implementation, while the dashed lines are the official ATLAS results. They correspond to Fig. 1, Fig. 2, Figaux. 3a,b,c,d,e, and Figaux. 5a of [2].

# 3 Limit-setting procedure

Limits are derived using `exclusion_CLs.py`. The 95% CL upper limit on the cross section obtained from the code is compared to the ATLAS value. For  $m_H = 125.5$  GeV, we obtain a limit of  $\text{BR}(H \rightarrow \text{invisible}) < 78\%$  at 95% CL while ATLAS quotes a limit of  $\text{BR}(H \rightarrow \text{invisible}) < 80\%$  at 95% CL (using 8 TeV data only).

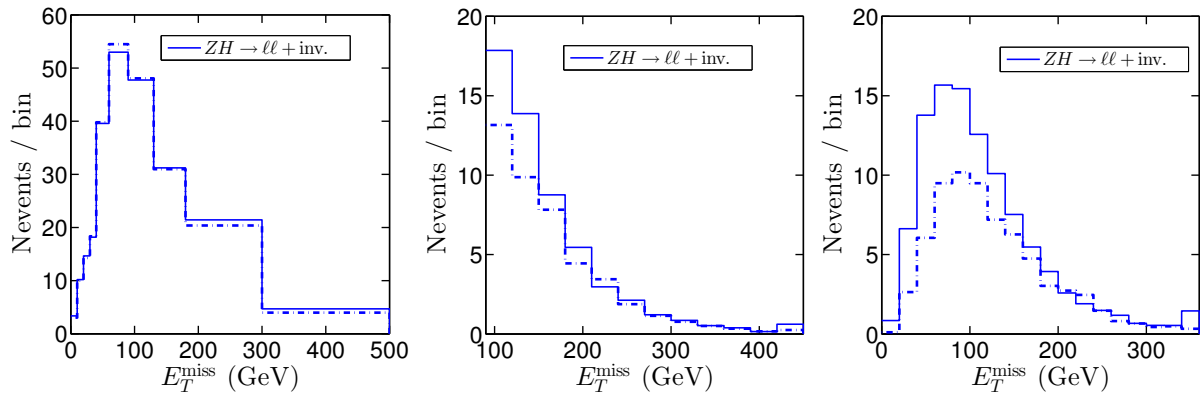


Figure 1: Distribution of the missing transverse energy  $E_T^{\text{miss}}$  after the dilepton mass requirement only (left), after all cuts (middle), and after the dilepton mass requirement, the jet veto, and the cuts on  $\Delta\phi(E_T^{\text{miss}}, p_T^{\text{miss}})$  and  $|E_T^{\text{miss}} - p_T^{\ell\ell}|/p_T^{\ell\ell}$  (right). The left plot corresponds to Fig. 1, the middle one to Fig. 2, the right one to Figaux. 5a of [2]. The middle plot is subject to uncertainties from the extraction of the signal in the histogram provided by ATLAS.

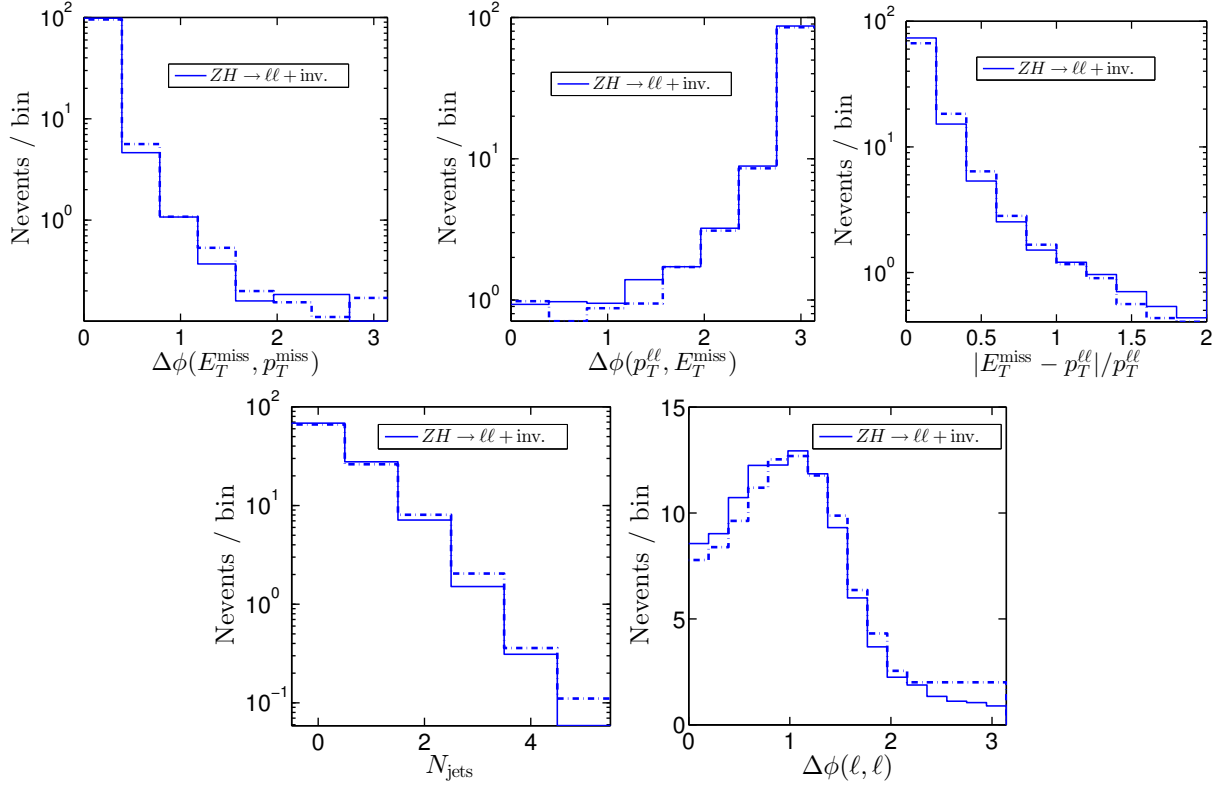


Figure 2: Distribution of various kinematic distributions after the requirements on the dilepton mass and on  $E_T^{\text{miss}}$ . From left to right and top to bottom:  $\Delta\phi(E_T^{\text{miss}}, p_T^{\text{miss}})$ ,  $\Delta\phi(p_T^{\ell\ell}, E_T^{\text{miss}})$ ,  $|E_T^{\text{miss}} - p_T^{\ell\ell}|/p_T^{\ell\ell}$ ,  $N_{\text{jets}}$  and  $\Delta\phi(\ell, \ell)$ . This corresponds to Fiaux. 3a,b,c,d,e of [2]. In the last plot, the dashed line beyond  $\Delta\phi(\ell, \ell) > 2.3$  is only constant because of the plotting range of the histogram provided by ATLAS.