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Combination of Higgs to Invisible Direct Measurements

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on behalf of the H→invisible analysis groups

Introduction

- ▶ Decays of the Higgs boson to invisible final states are a strong indication of BSM physics
- SUSY, graviscalars, etc.
- ▶ Because the final state is invisible the search must be carried out in the associated production channels:
- Search for large missing transverse energy plus associated production

Analyses

- There are two currently approved PASs searching for invisible final states of the Higgs boson.
- VBF (HIG-13-013), ZH→ll+inv (HIG-13-018)
- These two results have been combined and the result is public
- A further analysis, in the ZH→bb+inv channel is in progress (HIG-13-028)
- An indirect limit can also be placed using the signal strength of the visible channels (HIG-13-005)
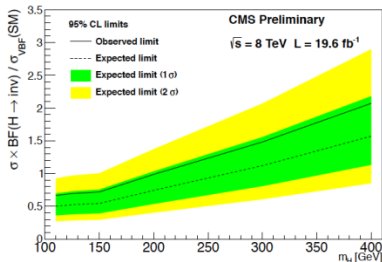- Combination between direct and indirect methods is being investigated e.g. talk by M. Zanetti

Current Indirect Result
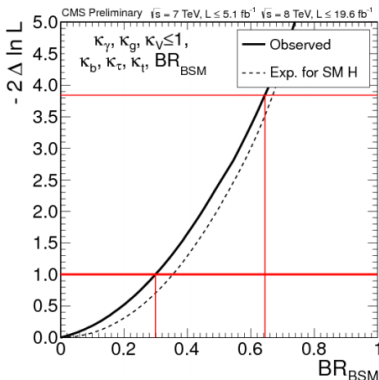
- observed (expected) limit of 64% (67%) at 95% C.L. on BR_{inv} for a 125 GeV Higgs
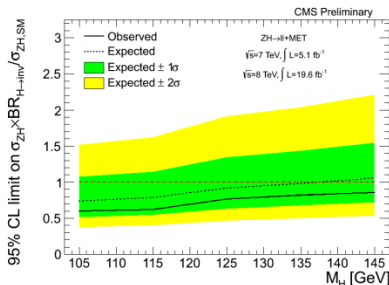
Individual Results: Direct

► VBF

► ZH

► observed (expected) limit of 69% (53%) at 95% C.L. on BR_{inv} for a 125 GeV Higgs

► observed (expected) limit of 75% (91%) at 95% C.L. on BR_{inv} for a 125 GeV Higgs

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Datacards

- ZH analysis (cards from M. Zanetti) has datacards for 105,115,125,135 and 145 GeV
- VBF analysis has datacards for 110,125,150,200,300 and 400 GeV
 - The signal yield is the only Higgs mass dependent part of the datacard
 - New VBF datacards were produced for 115,135 and 145 GeV, with signal yields caluclated using method discussed later
- The VBF cards used for the PAS do not separate out individual sources of error so JES/R correlations are not currently taken into account (see discussion later).

Signal Yield interpolation

- $N_{Signal} = eff. \times acc. \times \mathcal{L}\sigma$
- Luminosity is constant
- Yield over cross-section is thus proportional to efficiency times acceptance
- Signal yields were produced at 115, 125(to cross-check), 135 and 145 GeV for the VBF channel
- Cross-sections from LHC-HXSWG were used
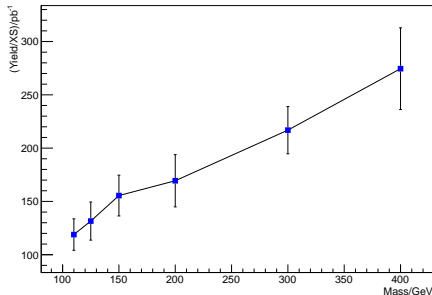
Combination Method

- The cards for the two approved analyses were combined using the standard Higgs combination tool
- The luminosity uncertainties were considered correlated between the analyses
- All other uncertainties were considered not to be correlated between analyses (see discussion later)

Results
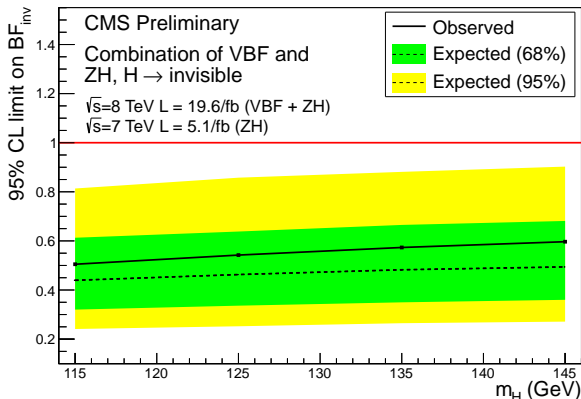
- Observed (expected) limit at 125 GeV is 54(46)%
- Agrees with number produced by M. Zanetti

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Improvements to datacards

- New cards are being produced for the VBF analysis which separate out the uncertainty sources
- CMS standard sources currently being considered:
- lumi_7/8TeV
- CMS_scale_j, CMS_res_j: with their effects propagated through to the met
- CMS_scale_met: Currently this is being treated as being the same as the unclustered energy scale uncertainty
- pdf_qqbar
- These uncertainties are also considered by ZH→ll+inv and will be labelled as such in their datacards

Conclusions

- The results of HIG-13-013 and HIG-13-018 have been combined using the standard Higgs combination tool
- The result is compatible with the SM at the 1σ level
- The combined result gives strongest direct limit on the invisible branching fraction of the SM Higgs
- Work is being done to improve the treatment of systematic errors for paper HIG-13-030 on all of the invisible channels.

Previous Limits

- Current CMS limits on BR_{inv} for a 125 GeV Higgs boson are:
- VBF: observed (expected) limit of 69% (53%) at 95% C.L.
- ZH: observed (expected) limit of 75% (91%) at 95% C.L.
- CMS indirect limit, from visible channels: observed (expected) limit of 64% (67%) at 95% C.L.
- ATLAS also produce an indirect limit and a limit in the ZH channel:
- Indirect limit 60% (no expected limit given)
- ZH: observed (expected) 65% (84%)

VBF Cross-sections

Mass/GeV	σ/pb
110	1.809 ± 0.048
115	1.729 ± 0.046
125	1.578 ± 0.042
135	1.448 ± 0.038
145	1.333 ± 0.035
150	1.280 ± 0.033
200	0.869 ± 0.023
300	0.441 ± 0.011
400	0.254 ± 0.007

Summary of Uncertainties

Background	Source	Uncertainty
$Z \to \nu\nu$		
	Statistics in control region	29%
	MC statistics	14%
	Theory uncertainty	20%
	Jet/MET scale/resolution	5%
$W \to \mu\nu$		
	Statistics in control region	5%
	MC statistics	10%
	Theory uncertainty	20%
	Jet/MET scale/resolution	4%
$W \to e\nu$		
	Statistics in control region	10%
	MC statistics	10%
	Theory uncertainty	20%
	Jet/MET scale/resolution	$^{+5}_{-11}$%
$W \to \tau\nu$		
	Statistics in control region	30%
	MC statistics	20%
	Theory uncertainty	20%
	Jet/MET scale/resolution	$^{+16}_{-2}$%
	Tau ID efficiency	8%
	Electron contamination	5%

QCD	Source	Uncertainty
	Statistics in control region	2%
	MC stats (background)	2%
	Jet/MET scale/resolution	$^{+45}_{-75}$%
	$\not{E}_T$ shape	35%
Other backgrounds		
	Luminosity	4%
	MC statistics	10%
	Jet/MET scale/resolution	28-81%
	Cross-section uncertainty	8-20%
Signal		
	MC statistics	10%
	Jet/MET scale/resolution	11%
	PDF uncertainty	5%
	QCD Scale uncertainty	4%