Combination of Higgs to Invisible Direct Measurements

HIG-13-030

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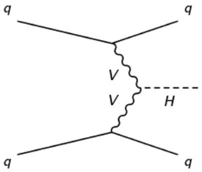
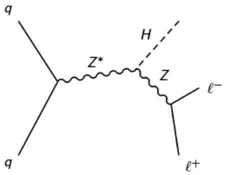
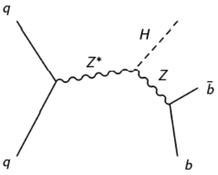
on behalf of the H→invisible analysis groups



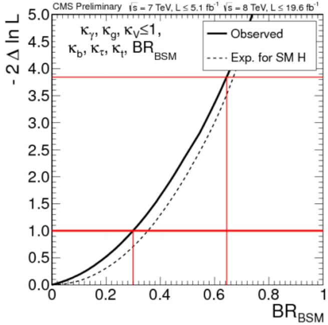




Introduction

- Many BSM theories predict invisible final states of the Higgs:
  - SUSY, Extra Dimensions, etc.
- Direct searches must be performed in the associated production channels
- There are currently three approved CMS Higgs to invisible results in the following channels:
  - VBF (HIG-13-013), Z($\ell\ell$)H(inv) (HIG-13-018), Z($b\bar{b}$)H(inv) (HIG-13-028)
- These results have been combined for a paper (HIG-13-030)

Indirect Result from Visible Decays



- Observed (expected) limit of 64% (67%) at 95% C.L. on BR_{inv} for a 125 GeV Higgs (HIG-13-005)
  - Combination between direct and indirect methods is being investigated e.g. talk by M. Zanetti

Datacards

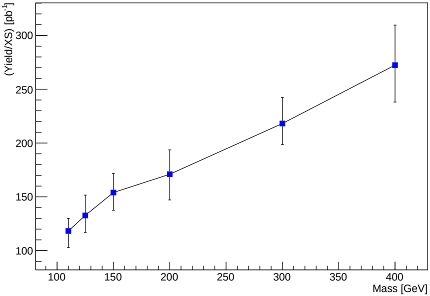
- All three channels have signal MC at different mass points

Channel	Mass Points/GeV
Z($\ell\ell$)H(inv)	105, 115, 125, 135, 145, 175, 200 & 300
Z($b\bar{b}$)H(inv)	105, 115, 125, 135, 145 & 150
VBF	110, 125, 150, 200, 300 & 400

- New VBF datacards were produced for 115,135 and 145 GeV
  - Nuisances are linearly interpolated between mass points.
  - Signal yields are interpolated using the method described below.

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
  - Cross-sections from LHC-HXSWG were used



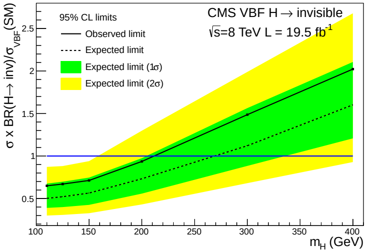
Combination Method

- The cards for the three channels were combined using the standard Higgs combination tool
- The following uncertainties were considered correlated between channels in decreasing order of importance:

Nuisance	Analyses which it affects
Jet energy scale	VBF, Z($\ell\ell$)H(inv)
PDF uncertainties	VBF, Z($b\bar{b}$), Z($\ell\ell$)H(inv)
QCD scale	VBF, Z($b\bar{b}$), Z($\ell\ell$)H(inv)
Luminosity	VBF, Z($b\bar{b}$)H(inv), Z($\ell\ell$)H(inv)
Jet energy resolution	VBF, Z($\ell\ell$)H(inv)
Unclustered energy scale	VBF, Z($b\bar{b}$)H(inv), Z($\ell\ell$)H(inv)
Muon identification efficiency	VBF, Z($\ell\ell$)H(inv)
Electron identification efficiency	VBF, Z($\ell\ell$)H(inv)

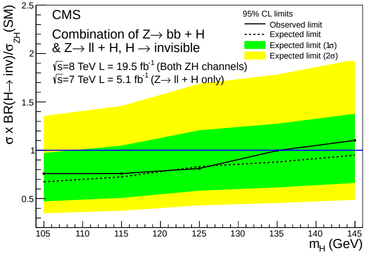
Separate results: Direct

- VBF



- Observed (expected) limit of 67% (52%) at 95% C.L. on BR_{inv} for a 125 GeV Higgs

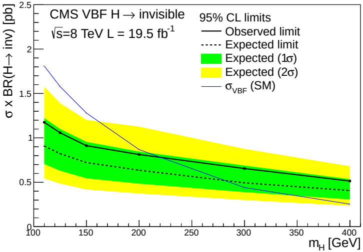
- ZH



- Observed (expected) limit of 81% (83%) at 95% C.L. on BR_{inv} for a 125 GeV Higgs

Separate results: Cross-Section limits

- VBF



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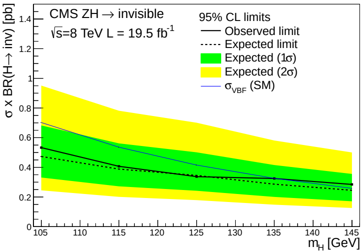

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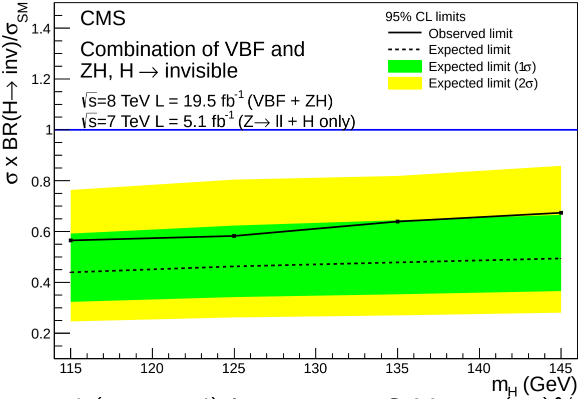
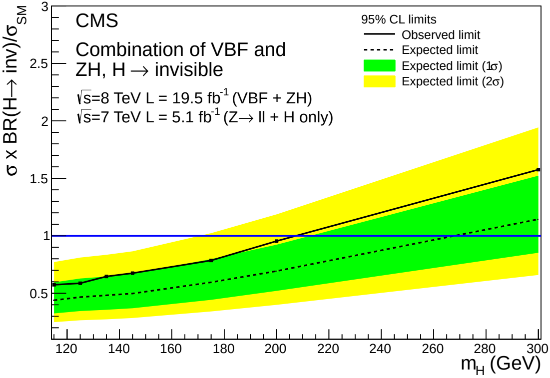
Combined Results



- Observed (expected) limit at 125 GeV is 58(46)%

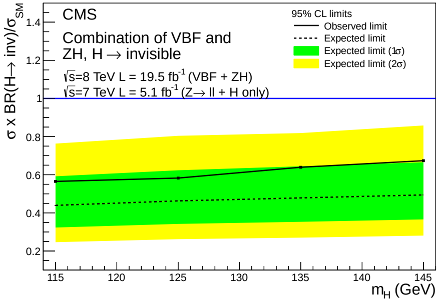
High mass combination

- $Z(\ell\ell)H(inv)$ and VBF both have datacards up to 300 GeV
- The same combination method as used above was used to combine these two channels between 115 and 300 GeV



Conclusions

- All three H→invisible channels have been combined using the standard Higgs combination tool
- The result is compatible with the SM
- The combined result gives the strongest limit on the invisible branching fraction of the 125 GeV Higgs



Backup

Previous Limits

- CMS PAS limits on BR_{inv} for a 125 GeV Higgs boson are:
  - VBF: observed (expected) limit of 69% (53%) at 95% C.L.
  - Z($\ell\ell$)H(inv): observed (expected) limit of 75% (91%) at 95% C.L.
  - Z($b\bar{b}$)H(inv): ovserved (expected) limit of 182% (199%) 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		
	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%