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Combination of Higgs to Invisible Direct Measurements

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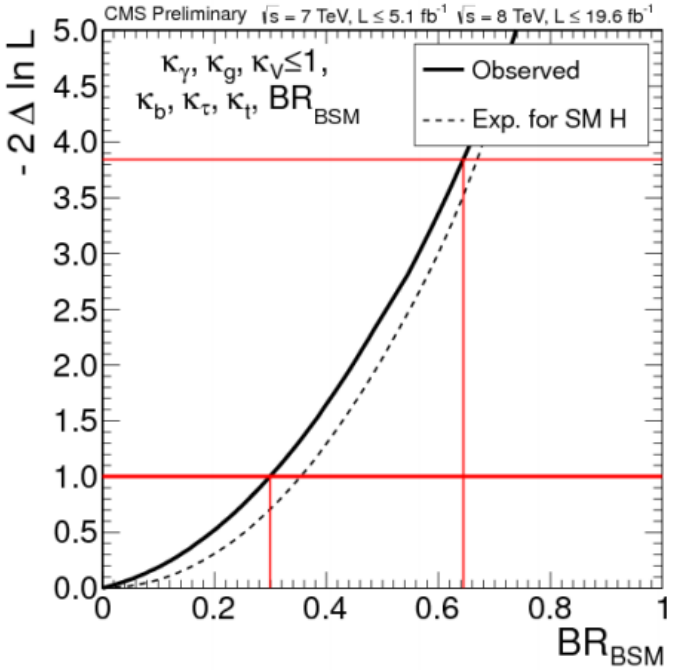
on behalf of the H→invisible analysis groups

Introduction

- All three currently approved Higgs to invisible results have been combined
  - VBF (HIG-13-013), ZH→ll+inv (HIG-13-018), ZH→bb+inv (HIG-13-028)
- Updates to combination since twiki result:
  - ZH→bb+inv has been included
  - Correlations between uncertainties in the three channels are now properly taken into account
  - A combination of the ZH →ll and VBF channels has been performed up to 300 GeV

Current Indirect Result



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

Datacards

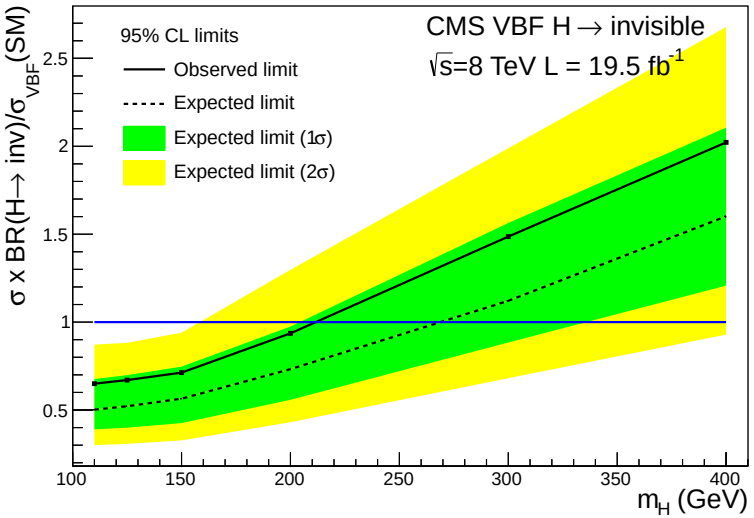
- ZH→ll analysis has datacards for 105, 115, 125, 135, 145, 175, 200 & 300 GeV
- ZH→bb analysis has datacards for 105, 115, 125, 135, 145 & 150 GeV
- VBF analysis has datacards for 110, 125, 150, 200, 300 and 400 GeV
- New VBF datacards were produced for 115,135 and 145 GeV, with the same method as used for the twiki plot

Combination Method

- The cards for the two approved analyses were combined using the standard Higgs combination tool
- A bug was found in the tool that meant that lnN correlated uncertainties were not being properly treated, fixed in latest combine version
- Correlations between analyses were taken into account according to combination group recommendations
- All other uncertainties were considered fully uncorrelated between analyses

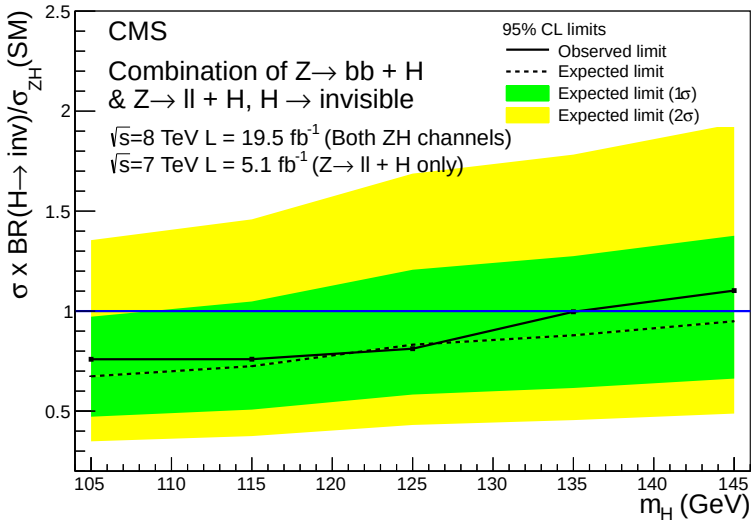
Separate results: Direct

- VBF



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

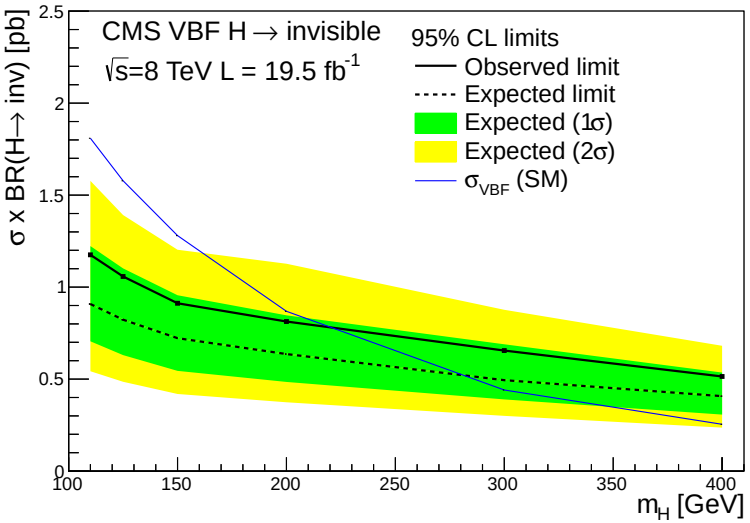
- ZH



- 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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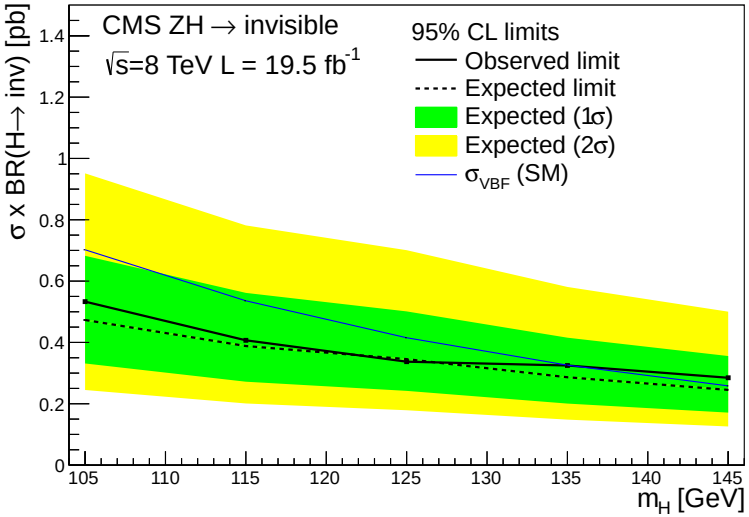

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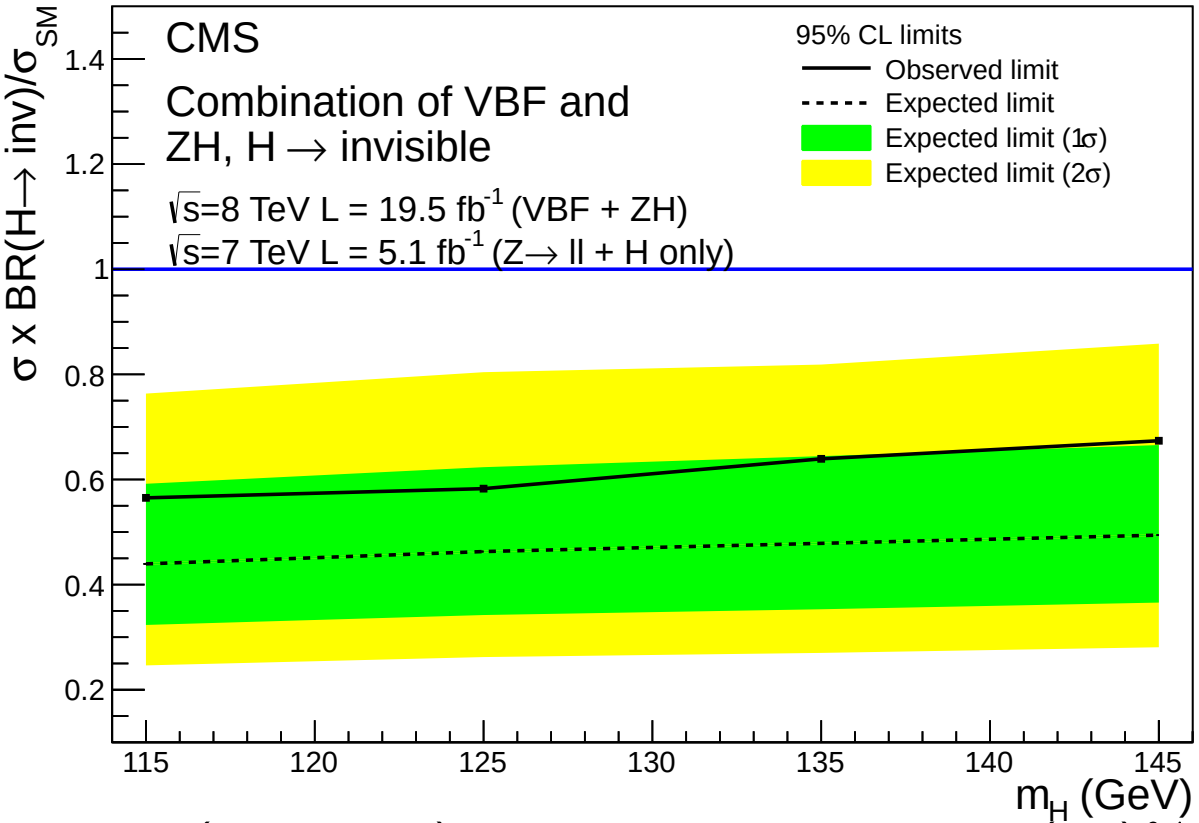
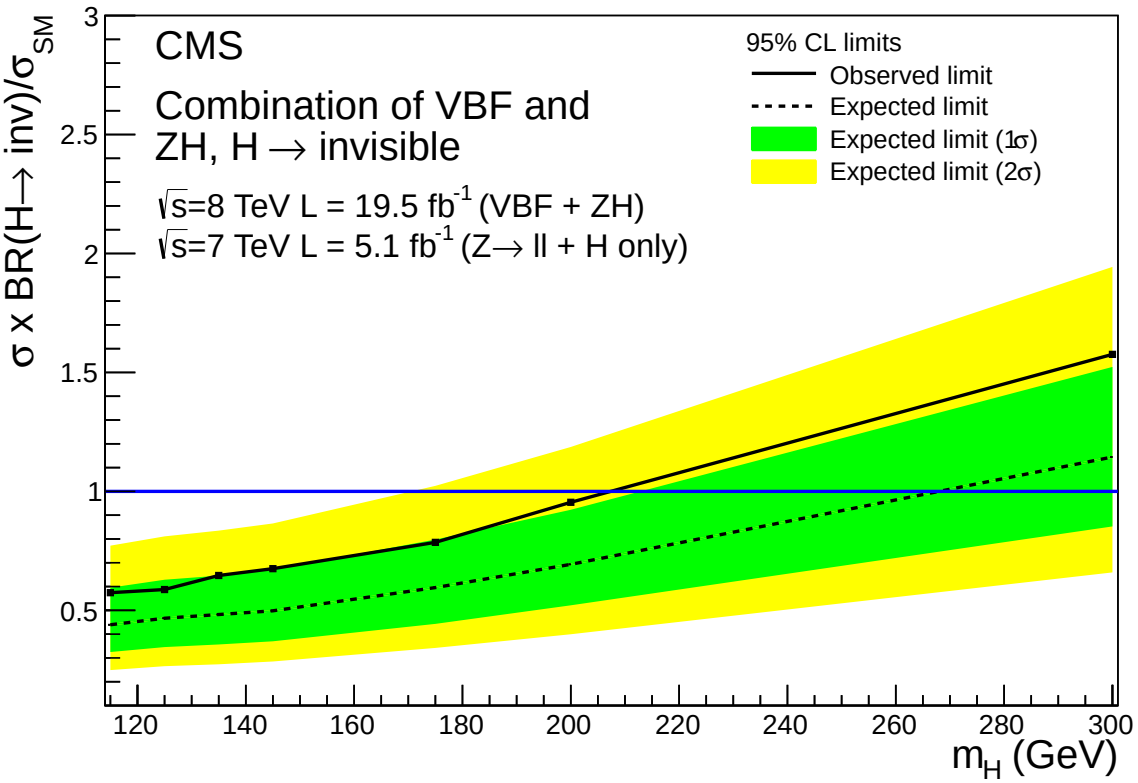
Combined Results



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

High mass combination

- Z→ll+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 Higgs to invisible channels have been combined using the standard Higgs combination tool
- The result is compatible with the SM at between the 1 & 2σ level depending on Higgs mass
- The combined result gives strongest direct limit on the invisible branching fraction of the SM Higgs

Backup

Previous Limits

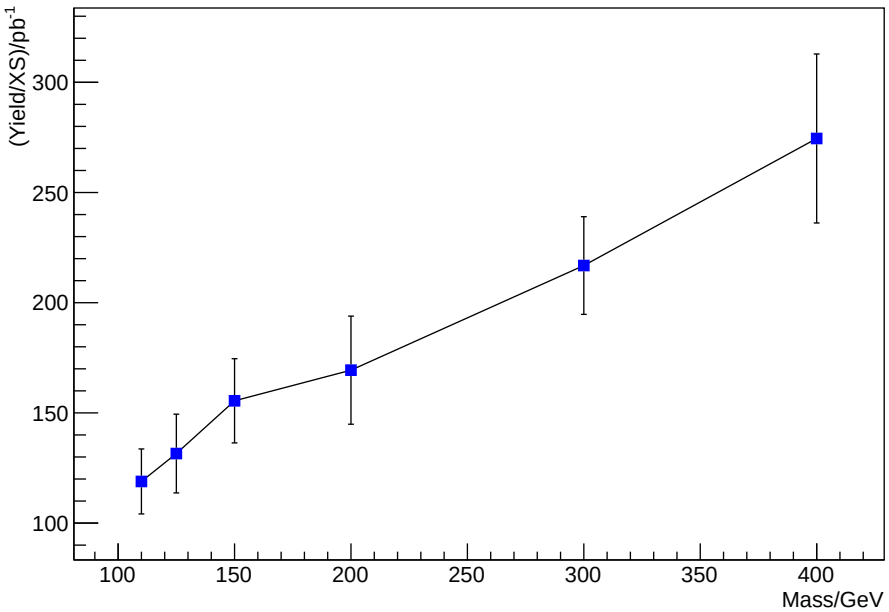
- CMS PAS limits on BR_{inv} for a 125 GeV Higgs boson are:
- VBF: observed (expected) limit of 69% (53%) at 95% C.L.
- ZH→ll+inv: observed (expected) limit of 75% (91%) at 95% C.L.
- ZH→bb+inv: ovserved (expected) limit of 182% (199%) at 95% C.L.
- CMS indirect limit, from visible channels: observed (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

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



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%