Discussion of high mass Higgs search from CMS

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on behalf of the CMS high mass Higgs combination team

LHCXSWG3
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introduction and outline

Discuss recent CMS result:
http://arxiv.org/pdf/1504.00936v1.pdf

Quickly flash analysis inputs and results

inputs, individual results, systematics and combination

Then go through the discussion questions

Inputs to combination

H decay mode	H production	Exclusive final states	No. of channels	m_H range [GeV]	m_H resolution
$WW \to \ell\nu\ell\nu$	untagged	((ee, $\mu\mu$), eμ) + (0 or 1 jets)	4	145–1000 [ab]	20%
	VBF tag	((ee, $\mu\mu$), eμ) + $(jj)_{VBF}$	2	145–1000 [ab]	20%
$WW \to \ell\nu qq$	untagged	(eν, $\mu\nu$) + $(jj)_W$	2	180–600	5–15%
	untagged	(eν, $\mu\nu$) + $(J)_W$ + (0+1-jets)	2	600–1000 [b]	5–15%
	VBF tag	(eν, $\mu\nu$) + $(J)_W$ + $(jj)_{VBF}$	1	600–1000 [b]	5–15%
$ZZ \to 2\ell 2\ell'$	untagged	4e, 4μ, 2e2μ	3	145–1000	1–2%
	VBF tag	(4e, 4μ, 2e2μ) + $(jj)_{VBF}$	3	145–1000	1–2%
	untagged	(ee, $\mu\mu$) + ($\tau_h\tau_h$, $\tau_e\tau_h$, $\tau_\mu\tau_h$, $\tau_e\tau_\mu$)	8	200–1000	10–15%
$ZZ \to 2\ell 2\nu$	untagged	(ee, $\mu\mu$) + (0 or ≥ 1 jets)	4	200–1000	7%
	VBF tag	(ee, $\mu\mu$) + $(jj)_{VBF}$	2	200–1000	7%
$ZZ \to 2\ell 2q$	untagged	(ee, $\mu\mu$) + $(jj)_Z^{0,1,2\,b\,tags}$	6	230–1000 [c]	3%
	untagged	(ee, $\mu\mu$) + $(J)_Z^{0,1,2\,b\,tags}$	6	230–1000 [c]	3%
	VBF tag	(ee, $\mu\mu$) + $(jj)_Z^{0,1,2\,b\,tags}$ + $(jj)_{VBF}$	6	230–1000 [c]	3%
	VBF tag	(ee, $\mu\mu$) + $(J)_Z^{0,1,2\,b\,tags}$ + $(jj)_{VBF}$	6	230–1000 [c]	3%

[a] EW singlet model interpretation starts at 200 GeV to avoid contamination from h(125).
[b] 600-1000 GeV for $\sqrt{s} = 8$ TeV only.
[c] For $\sqrt{s} = 8$ TeV only.

New results for the paper, supporting documentation

HIG-13-027: update of H→WW→lvjj to full stats
HIG-14-007: update of H→ZZ→2l2q with new categories (merged, VBF)
HIG-14-008: update of H→WW→lvJ (HIG-13-008) to exclusive jet bins

model interpretations

1 SM-like high mass Higgs

Same cross-section, lineshape, interference effects as SM Higgs

Treat the h_{125} as background

2 heavy Higgs partner in generic EWK singlet interpretation

(more on next slide)

Electroweak singlet interpretation

BSM interpretation, generic electroweak scalar mixing with the h_{125} phenomenologically constrained by unitarization:

$$C^2 + C'^2 = 1$$

where C (C') are coupling scale factors related to the SM (heavy Higgs)

The heavy Higgs signal strength and width are given by:

N.B. require $\Gamma' \leq \Gamma_{SM}$

$$\mu' = C'^2 \cdot (1 - \mathcal{B}_{new}) \qquad \Gamma' = \Gamma_{SM} \cdot \frac{C'^2}{1 - \mathcal{B}_{new}}$$

where $\mathcal{B}_{new}$ is branching ratio of heavy Higgs to non-SM decays (e.g. H→hh)

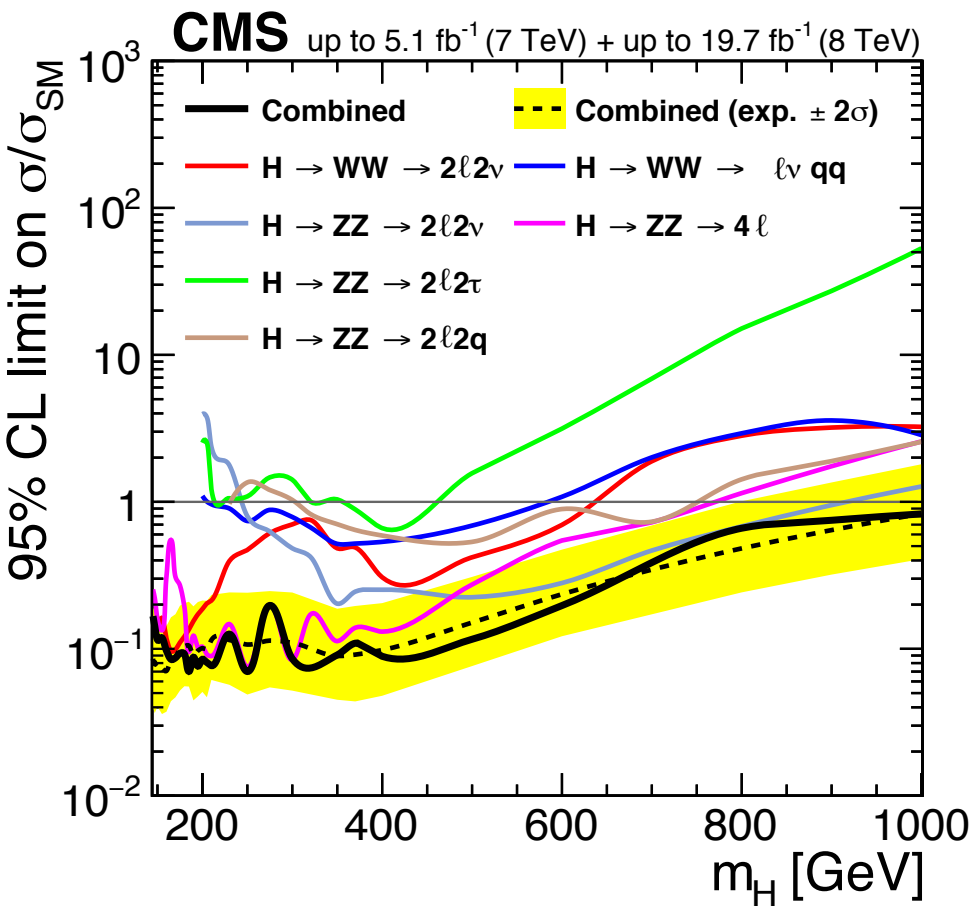
More discussion of signal parameterization in Stefano's slides

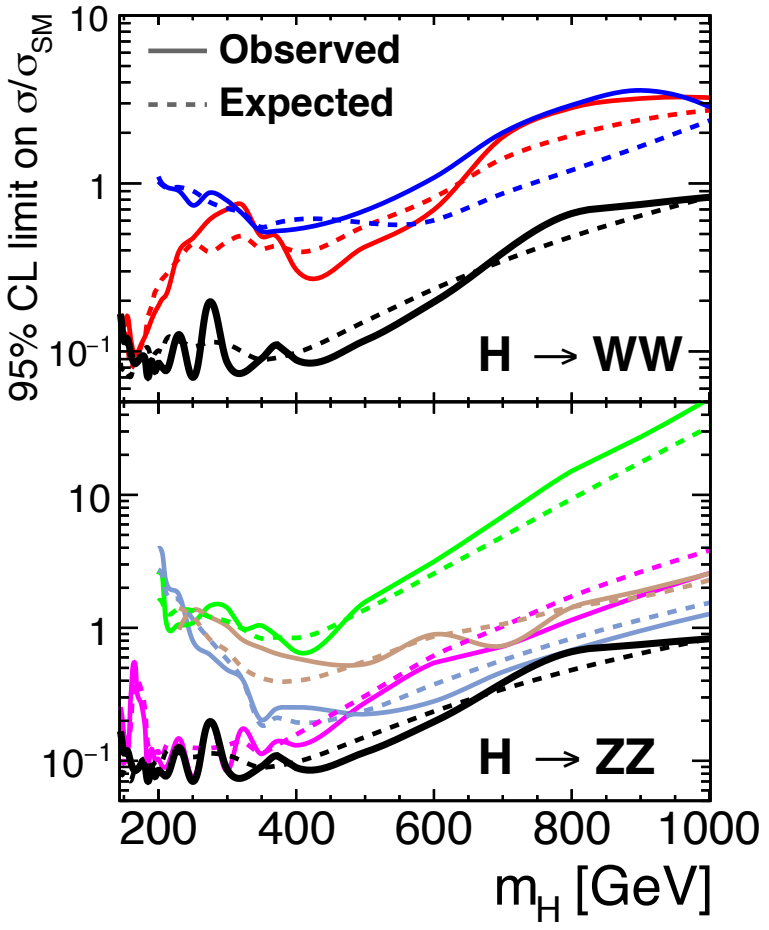
Scanned points:

C'^2 = 0.01, 0.03, 0.05, 0.1, 0.2, 0.3, 0.5, 0.7

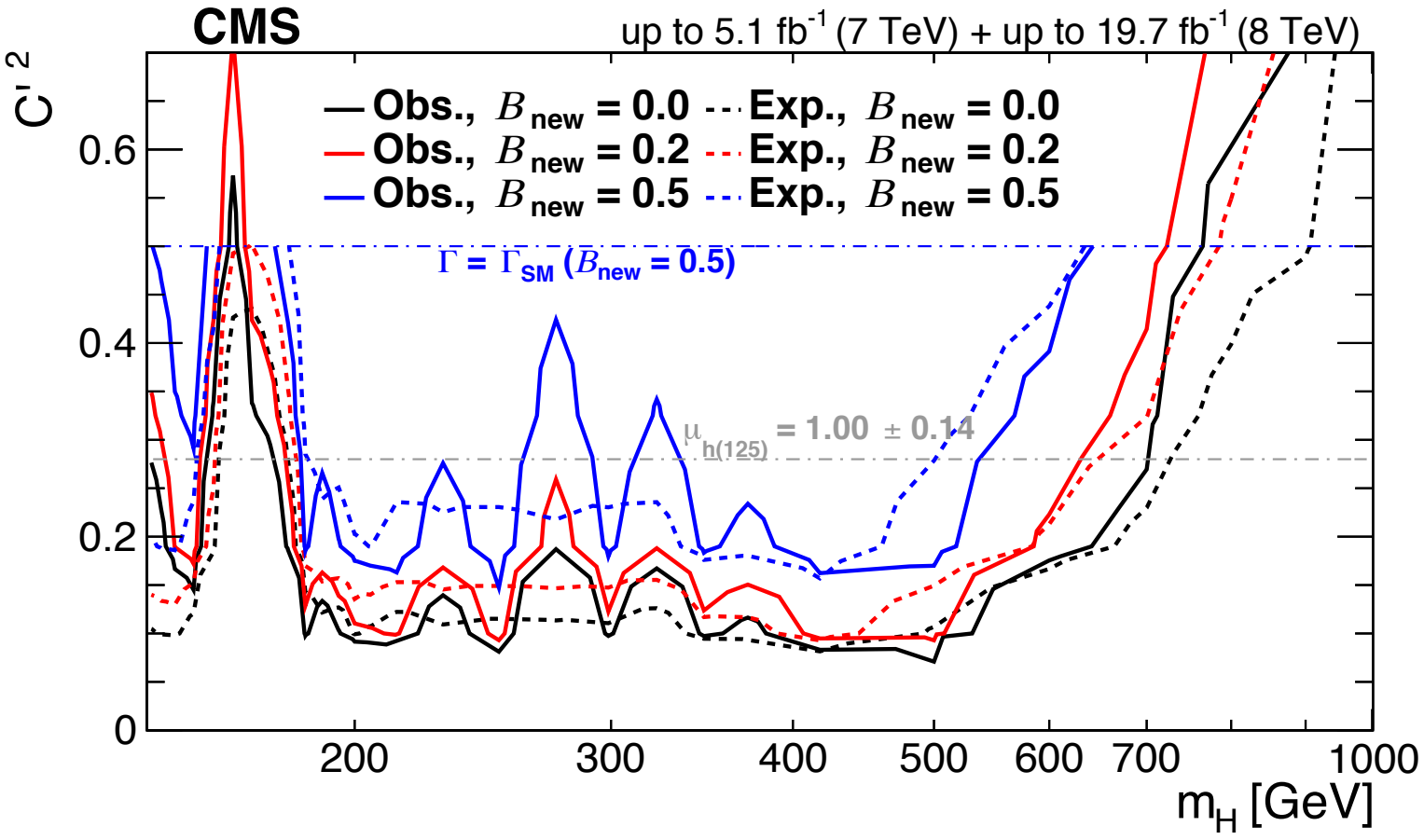
B_{new} = 0.0, 0.1, 0.2, 0.3, 0.4, 0.5

SM Higgs-like results

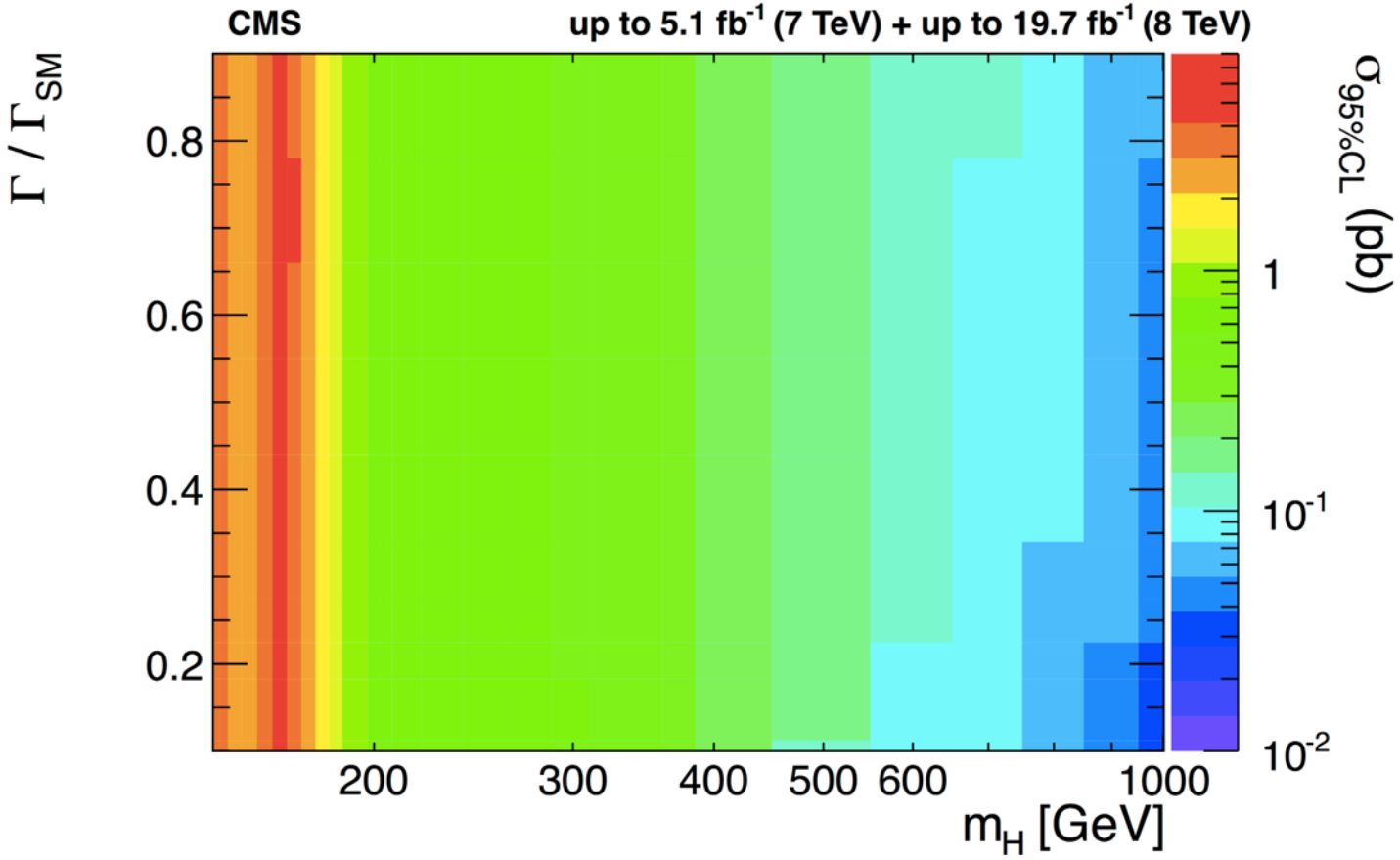




Electroweak singlet interpretation



‘pseudo’ model-independent limits



EWK scalar exclusions (B_{new}=0.0 and 0.1) are mapped to mass/width plane

discussion points

discussion

- How to do the parameterisation vs width and mass.
We should be careful with these results because, as Mario put in his Moriond talk — these scans are “pseudo” model-independent. We take the widths at BRnew = 0.0 and 0.1 and project them onto the width/mass phase space

- How to account for the dependence on the signal cross-section not just the width and mass
This is the case for when the signal cross-section is defined with BRnew = 0. Then we can scan in C’2, for example, to get a scan in mass for a given mass point. For every scanned phase space point, the interference is adjusted with the cross-section.

- Does the parameterisation allow for arbitrary width (and interference) as needed in the 2HDM (or use e.g. 0.1 steps which is OK for EWS)?
It’s just the spacing for the EWS

- Do we go up to the SM width or beyond as well (again needed for 2HDM)?
We make a choice to stop the parameterization when the width becomes larger than the SM case

discussion

- Which generators to use to parameterise the interference? Is this for ggF as well as VBF?
  - Which final states? Only ZZ -> 4l; other ZZ; WW?
  - Which masses, widths, …?

For ggF the interference is considered using either gg2VV (ZZ) or MCFM (WW). Scans are made in width and mass — mass every 100 and width every 0.1xSM width IIRC
For VBF the interference is considered using Phantom for both WW and ZZ and the same procedure is followed.

  - What about bbH for the future?

There are dedicated analyses for the bbH those we do not consider them here.

- Is this generator-level only and or reco-level checks are needed as well?
- Does width affects the kinematics/acceptance?

Because the kinematics of the process is set by the off-shell mass of the heavy Higgs, we are using only generator-level reweighting. We do of course look at the reconstruction level distributions of the mass distributions and find them to be reasonable.

discussion

- What type of interference is covered?
  - Only heavy H + VV continuum?
  - h+VV continuum (should just be a special case of above I guess)?

We consider H+VV continuum — this is by far the dominant effect. For h+VV is small due to the width of h(125) — we consider for ZZ4L (ggH + ggVV) as a background and it turns out to be a ~few% effect..

- h+ H interference, which becomes important when H is wide

Some references on h+H interference came out as we were finalizing the review so they are not included but we did find some conflicting references on the issue thus it would be nice to come to a commonality on treating this issue for the future within the LHCXSWG.

http://arxiv.org/pdf/1410.5440v1.pdf
http://arxiv.org/pdf/1501.02139v2.pdf

- How do you account for the large contribution of off-shell h->ZZ to the ZZ background spectrum at low tan(B) in 2HDM type 1/2 and high tan(B) in type 2?

We refer to the theorists in this scenario since we did not consider it.

discussion

- How to apply the interference
  - Only to S or S+B?

We apply it to S.

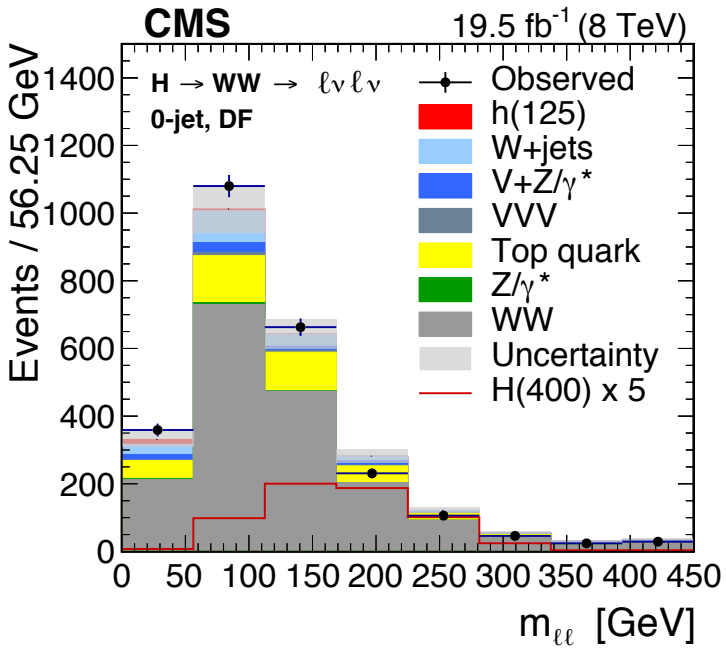
- Does CMS plan to update/change this strategy for 13 TeV
- On what time scale?

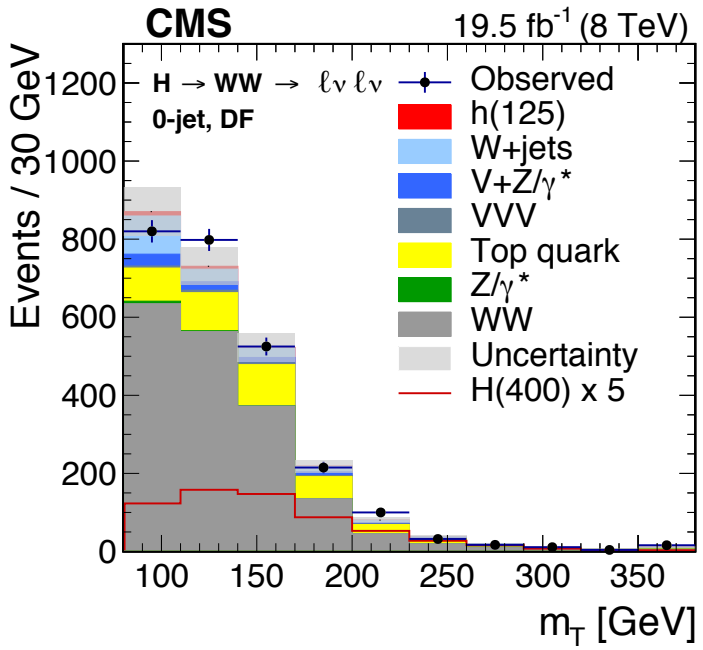
We have not finalized the strategy for 13 TeV but some updates would be nice. 2HDM treatment and a common plan for h+H interference would be a good start. The timescale is also not finalized though individual analysis are likely targeting the 2015 dataset.

backup

Extended in the range from 600-1000 GeV with respect to the individual channel paper

Binning and selection re-optimized for high mass scenario





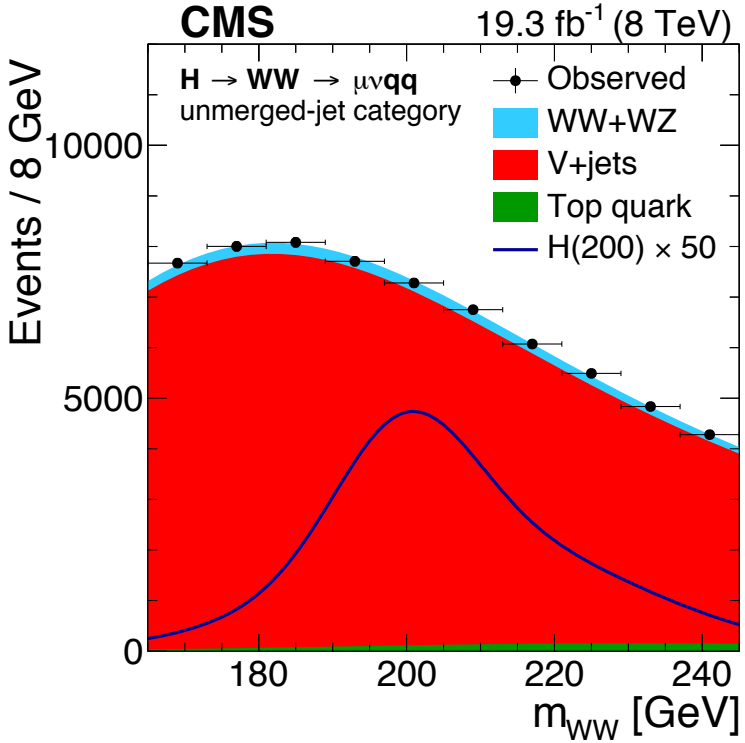
H→WW→lvqq

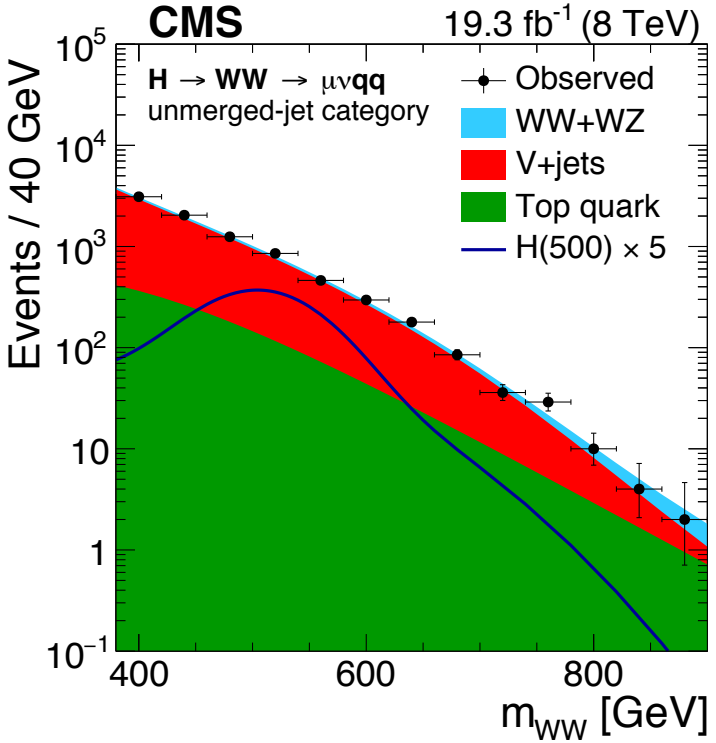
HIG-13-027

resolved jet analysis (lvjj), high stats, large backgrounds, inclusive jet bins

HIG-14-008

merged jet analysis from 600-1000 GeV, exclusive additional jet bins added





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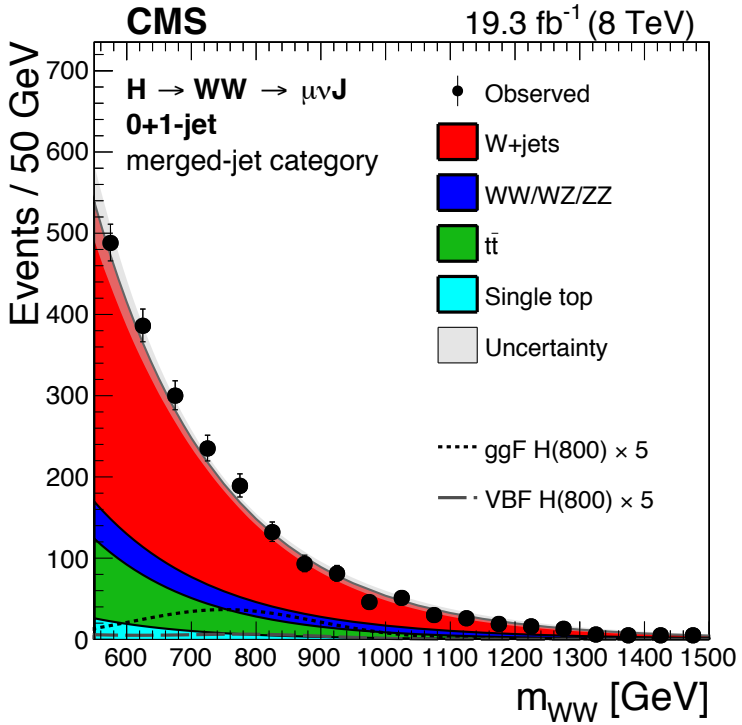
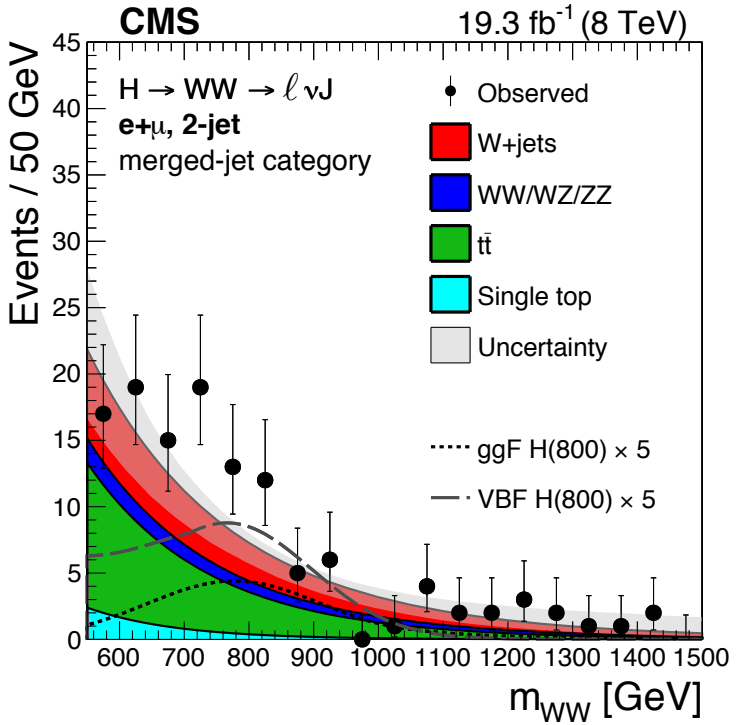
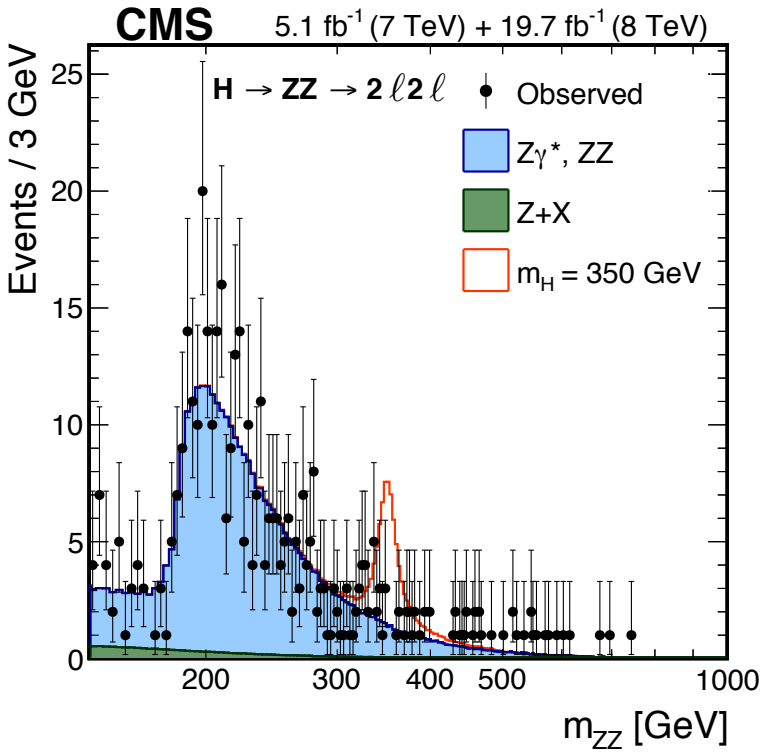
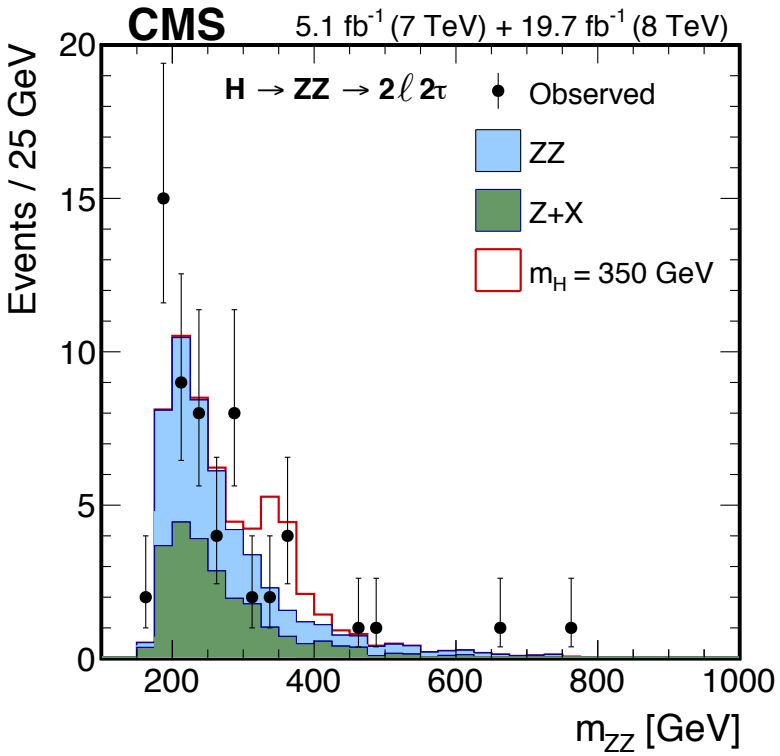


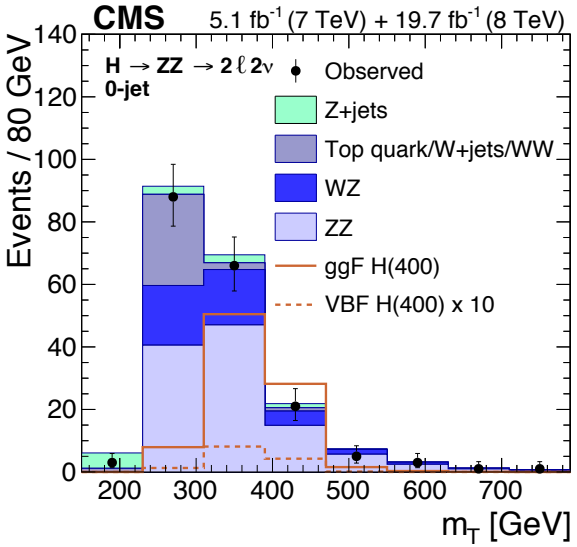


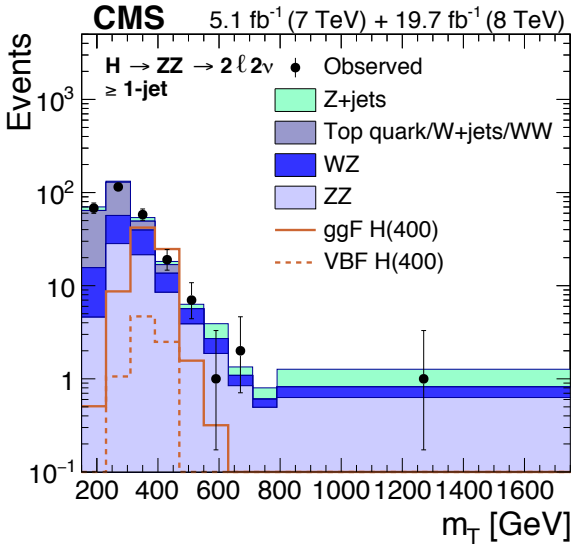
Few changes w.r.t. individual channel paper except for detailed study of the interference effect in ggH and VBF and signal shape parametrization (see talk from Stefano)

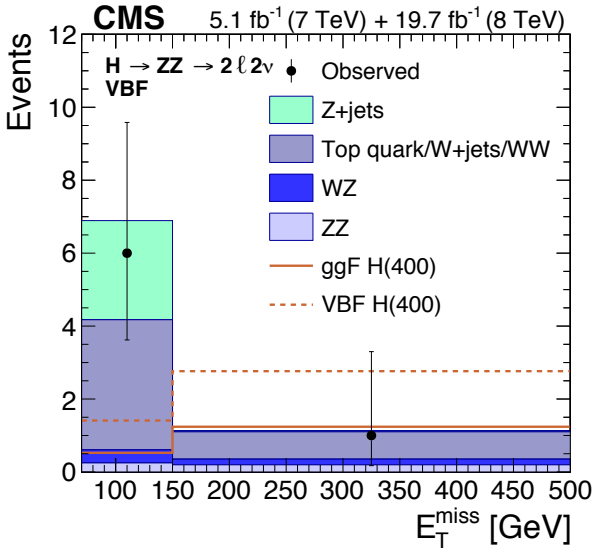




Also, few changes w.r.t. individual channel paper except for updated signal treatment

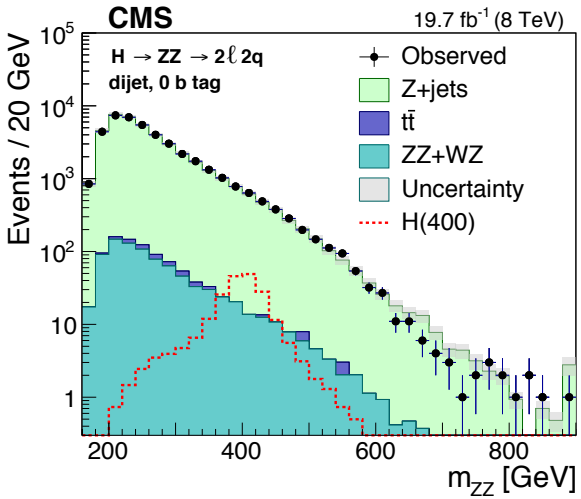


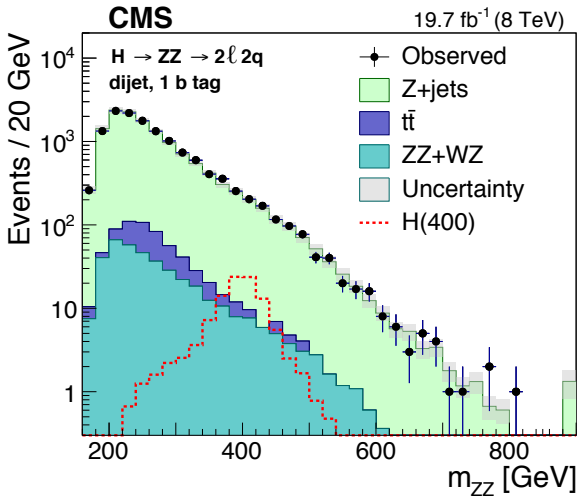


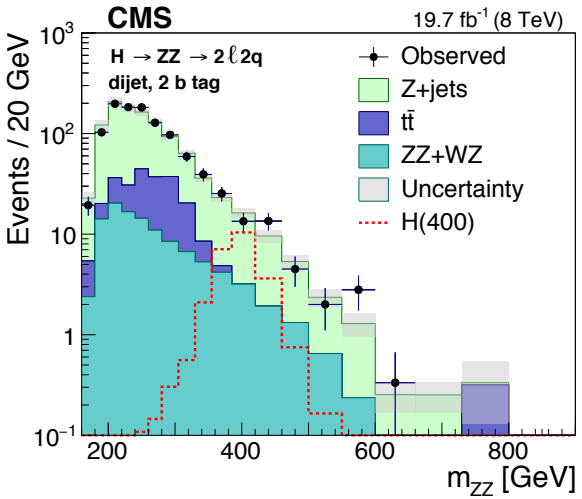


HIG-14-007

Includes new categorizations — untagged and VBF tagged, 0/1/2 b tags, and merged and resolved topologies







systematics overview

Source of uncertainty	$H \to WW \to \ell\nu\ell\nu$	$H \to WW \to \ell\nu jj$	$H \to WW \to \ell\nu J$	$H \to ZZ \to 2\ell 2\ell'$	$H \to ZZ \to 2\ell 2\nu$	$H \to ZZ \to 2\ell 2q$
Experimental sources						
Luminosity, 7 (8) TeV	2.2 (2.6)	2.2 (2.6)	2.2 (2.6)	2.2 (2.6)	2.2 (2.6)	2.2 (2.6)
ℓ trigger, reco, id, iso	1–4	1–2	1–2	0.5–7	2–3	1.8–2
ℓ mom./energy scale	2–4			0.5–30	1–2	0.1–0.4
ℓ misid. rate				30		
JES, JER, E_T^{miss}	2–35	<1	2	5–30	1	1–13
Pileup		<1			1–3	1
b-tag/mistag			2.5		1–3	1–6
W-tag/Z-tag			7.5			0–9.3
Signal selection eff.		10	2			
Monte Carlo statistics	1–20				1–2	0–6
Background estimates						
$t\bar{t}$, tW	20	7	6–30		25	0–15
Z+jets	40–100			20–42	100	16
ZZ	3			13–14	12	
W+jets	40	0.6	8		25	
WW	8–30	10	30		25	
WZ, $W\gamma^*$	3–50		30		5.8–8.5	
Theoretical sources						
$\sigma(gg \to H)$	10–13	10–11	11–13	10–13	10–13	10–13
$\sigma(qq \to H)$	2.6–5.8	2.6–3.6	3.6–5.8	2.6–5.8	2.6–5.8	2.6–5.8
H lineshape				5	2–8	0–7
H–WW (ZZ) interference	1–27		10–50		10–50	
Jet binning	7–35		7–35		30	

N.B. ranges are for m_H or jet bins