SM H → WW in VBF with ATLAS and CMS

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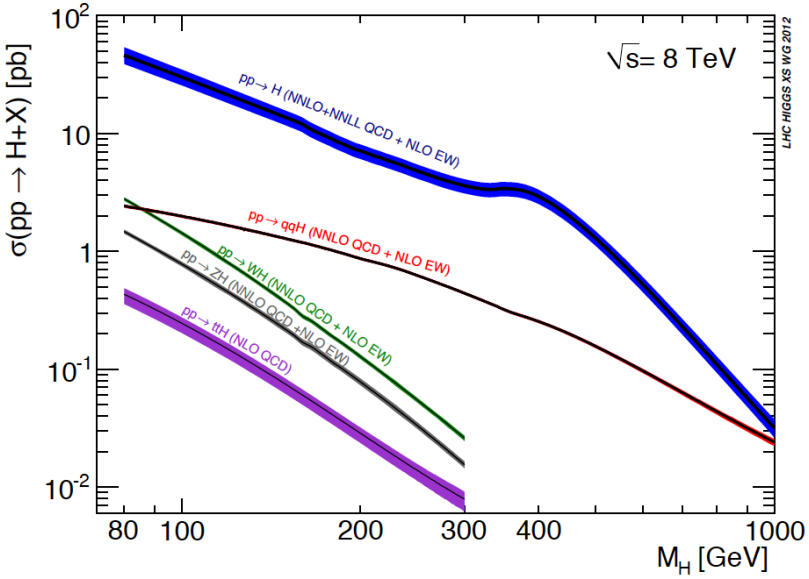
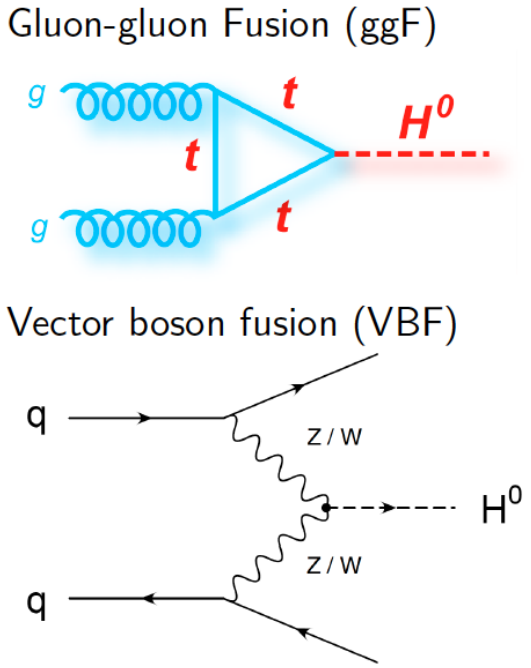
Outline

- Introduction to H → WW in Vector Boson Fusion (VBF)
- ATLAS v.s. CMS: The ICHEP edition.
- Bonus: CMS (ICHEP) v.s. CMS (HCP) – An outsider's view.

Introduction of VBF

- VBF is the second dominant production channel, which is sensitive to direct W/Z couplings. → Important for probing the properties.

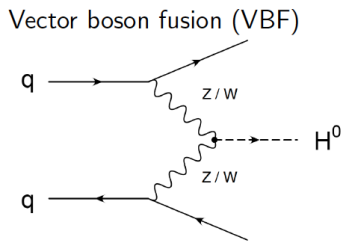




H → WW → *lvlv* in VBF

- Special event topology: Two energetic jets in the forward regions from the incoming/outgoing quarks.

  → Two leading jets well-separated in (pseudo)rapidity.
  → Large di-jet invariant mass



- Suppressed jet activities in the central region:

  → Central jet veto (CJV): No additional jets between the (pseudo)rapidity gap spanned by the two leading jets.

- H → WW → *lvlv* : Two leptons (e or μ) + $E_{\mathrm{T}}^{\mathrm{miss}}$

  → Small $\Delta\phi_{\ell\ell}$ and $m_{\ell\ell}$ if spin-0.

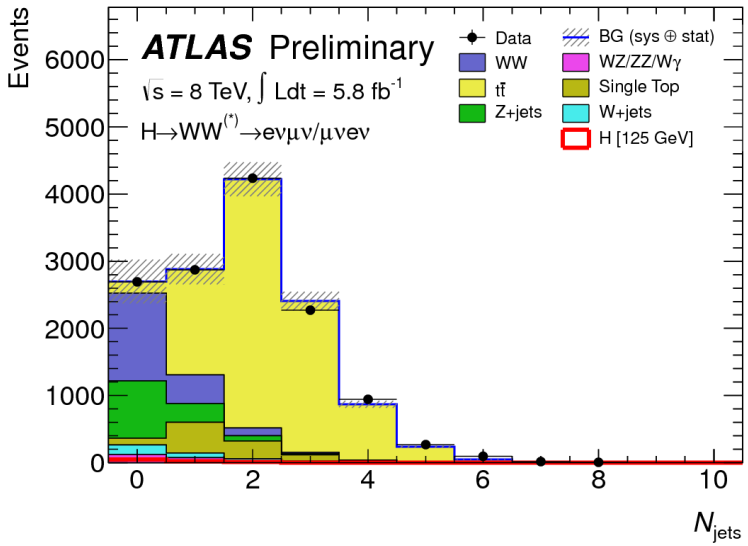
ATLAS v.s. CMS: Pre-selection

- Comparison between ATLAS and CMS ICHEP analyses.
- $H \rightarrow WW \rightarrow e\nu\mu\nu$ + >= 2 jets.

	ATLAS	CMS
Lepton Pt (GeV)	25/15	22.5/10 (for M_H =125)
Jet cone size	0.4	0.5
Jet Pt (GeV)	25/30 (|η|</>2.5)	30
MET definition	$E_{\mathrm{T,rel}}^{\mathrm{miss}} = E_{\mathrm{T}}^{\mathrm{miss}} \sin\Delta\phi_{\mathrm{min}}$ $\Delta\phi_{\mathrm{min}} \equiv \min(\Delta\phi, \frac{\pi}{2})$ $\Delta\phi$ = min. angle btw. MET and leading leptons and jets w/ Pt>25 GeV	*Projected* MET: ~ ATLAS but use only leptons. Take min. btw. all particles and all charged particles from the primary vertex.
MET cut	$E_{\mathrm{T,rel}}^{\mathrm{miss}}$ > 25 GeV	> 20 GeV

After pre-selection

- For >=2 jet, dominant background is Top.



(ATLAS-CONF-2012-098.
no MET cuts applied.)

- Comparing VBF H → WW specific cuts below. CMS uses MH-dependent cuts for di-lepton topology selection. Assume MH = 125 GeV for the following.

ATLAS v.s. CMS: The Cuts

	ATLAS	CMS
Top rejection	b-tagging for jets w/ Pt>25 GeV	b-tagging + soft muons (jet Pt?)
Other bkg.	Vector sum of leading leptons, jets, and MET Pt_tot < 30 GeV	Vector sum of leading leptons' Pt Pt_ll > 45 GeV
	$Z \rightarrow$ veto	No leptons outside $\Delta\eta_{jj}$
VBF Cuts	ΔY_{jj} (Rapidity) > 3.8	$\Delta\eta_{jj}$ > 3.5
	M_{jj} > 500 GeV	M_{jj} > 450 GeV
	CJV: Central jet Pt < 20 GeV	CJV < 30 GeV
	M_{ll} < 80 GeV	M_{ll} < 42.5 GeV
	$\Delta\Phi_{ll}$ < 1.8 radians	$\Delta\Phi_{ll}$ < 100 degrees (~1.75 rad.)
M_T definition	$m_{\mathrm{T}} = \sqrt{(E_{\mathrm{T}}^{\ell\ell} + E_{\mathrm{T}}^{\mathrm{miss}})^2 - \lvert\mathbf{p}_{\mathrm{T}}^{\ell\ell} + \mathbf{E}_{\mathrm{T}}^{\mathrm{miss}}\rvert^2}$	$\sqrt{2 p_{\mathrm{T}}^{\ell\ell} E_{\mathrm{T}}^{\mathrm{miss}} (1 - \cos\Delta\phi_{E_{\mathrm{T}}^{\mathrm{miss}}\ell\ell})}$
M_T cut	No cut. $0.75*M_H<M_T<M_H$ used for plotting.	30 GeV $<M_T<M_H$

ATLAS v.s. CMS: The Results

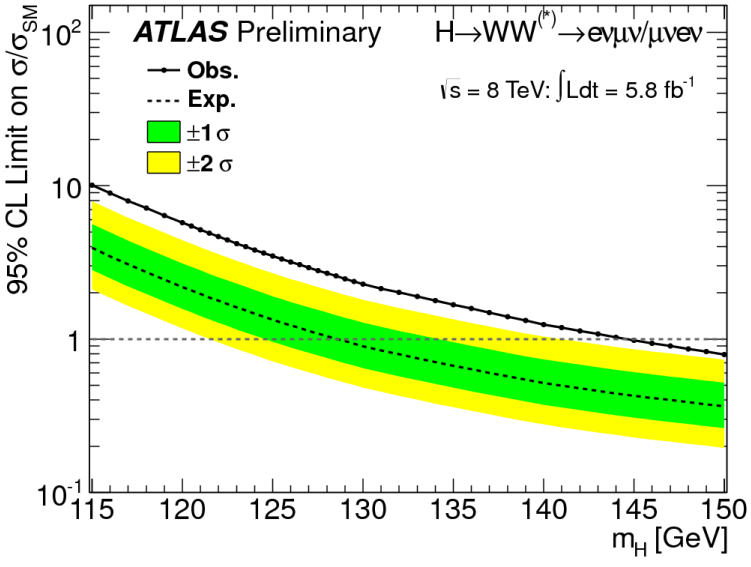
ATLAS: (5.8 fb-1. ATLAS-CONF-2012-098)

H+ 2-jet	Signal	WW	$WZ/ZZ/W\gamma$	$t\bar{t}$	$tW/tb/tqb$	Z/γ^* + jets	W + jets	Total Bkg.	Obs.
$\geq$ 2 jets	14.5 ± 0.2	139 ± 3	30 ± 2	7039 ± 24	376 ± 11	104 ± 12	71 ± 4	7759 ± 29	7845
b-jet veto	9.6 ± 0.2	95 ± 2	19 ± 1	356 ± 6	44 ± 4	62 ± 9	21 ± 2	597 ± 12	667
$\lvert\Delta Y_{jj}\rvert > 3.8$	2.0 ± 0.1	8.3 ± 0.6	2.0 ± 0.4	31 ± 2	5 ± 1	4 ± 2	1.4 ± 0.5	52 ± 3	44
Central jet veto (20 GeV)	1.6 ± 0.1	6.5 ± 0.5	1.3 ± 0.3	16 ± 1	4 ± 1	1 ± 1	0.5 ± 0.3	29 ± 2	22
$m_{jj} > 500$ GeV	1.1 ± 0.0	3.2 ± 0.4	0.7 ± 0.2	6.2 ± 0.7	1.8 ± 0.6	0.0 ± 0.0	0.0 ± 0.2	12 ± 1	13
$\lvert p_T^{tot}\rvert < 30$ GeV	0.8 ± 0.0	1.7 ± 0.3	0.3 ± 0.1	2.5 ± 0.5	0.8 ± 0.4	0.0 ± 0.0	0.0 ± 0.2	5.4 ± 0.7	6
$Z \rightarrow \tau\tau$ veto	0.7 ± 0.0	1.8 ± 0.3	0.3 ± 0.1	2.4 ± 0.4	0.8 ± 0.4	0.0 ± 0.0	0.0 ± 0.2	5.2 ± 0.7	6
$m_{\ell\ell} < 80$ GeV	0.7 ± 0.0	0.6 ± 0.2	0.1 ± 0.1	0.8 ± 0.3	0.3 ± 0.2	0.0 ± 0.0	0.0 ± 0.2	1.9 ± 0.5	3
$\Delta\phi_{\ell\ell} < 1.8$	0.6 ± 0.0	0.5 ± 0.2	0.1 ± 0.1	0.5 ± 0.3	0.3 ± 0.2	0.0 ± 0.0	0.0 ± 0.2	1.4 ± 0.4	2
After M_T cut H+ 2-jet	0.34 ± 0.07	0.10 ± 0.14	0.10 ± 0.10	0.15 ± 0.10	-	-	-	0.35 ± 0.18	0

CMS:(5.1 fb-1. CMS PAS HIG-12-017)

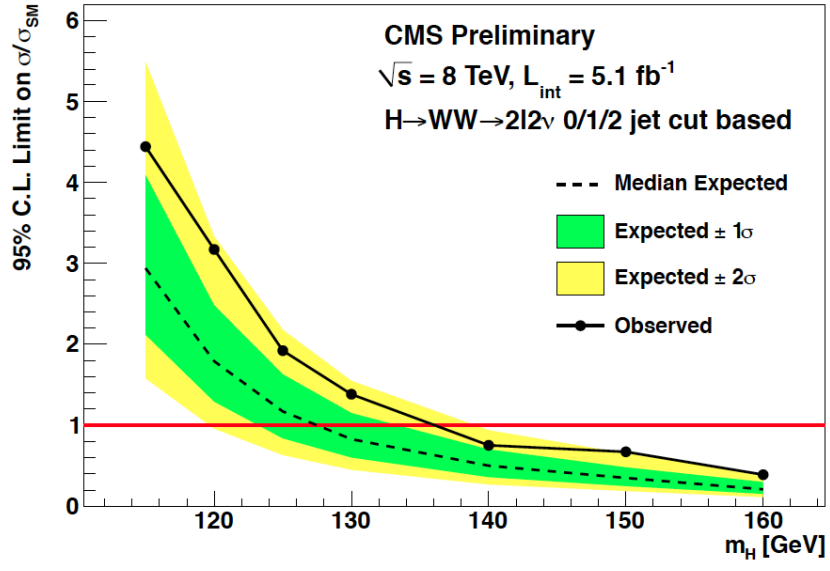
m_H	H $\rightarrow W^+W^-$	pp $\rightarrow W^+W^-$	$WZ + ZZ$ $+Z/\gamma^* \rightarrow \ell^+\ell^-$	Top	W + jets	$W\gamma^{(*)}$	all bkg.	data
2-jet category $e\mu$ final state								
125	1.5 ± 0.2	0.4 ± 0.1	0.1 ± 0.0	3.4 ± 1.9	0.3 ± 0.3	0.0 ± 0.0	4.1 ± 1.9	6

ATLAS v.s. CMS: The Results



Obs./Exp. @ 125 GeV:
3.1/1.6 σ_{SM}

ATLAS-CONF-2012-098



Obs./Exp. @ 125 GeV:
1.2/1.9 σ_{SM}

CMS PAS HIG-12-017

CMS v.s. CMS: ICHEP v.s. HCP

	CMS (HCP)	CMS (ICHEP)
Top rejection	(jets w/ Et>15 GeV used)	b-tagging + soft muons (jet Pt?)
VBF cuts	M_{jj} > 500 GeV	M_{jj} > 450 GeV

CMS: 5.1 fb-1 (CMS PAS HIG-12-017)

m_H	H $\to W^+W^-$	pp $\to W^+W^-$	$WZ + ZZ$ $+Z/\gamma^* \to \ell^+\ell^-$	Top	W + jets	$W\gamma^{(*)}$	all bkg.	data
2-jet category $e\mu$ final state								
125	1.5 ± 0.2	0.4 ± 0.1	0.1 ± 0.0	3.4 ± 1.9	0.3 ± 0.3	0.0 ± 0.0	4.1 ± 1.9	6

CMS:12.1 fb-1 (CMS PAS HIG-12-042)

125	2.8 ± 0.4	0.9 ± 0.5	0.1 ± 0.0	1.5 ± 0.5	0.3 ± 0.2	0.1 ± 0.1	2.9 ± 0.8	2

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Outlook

- ATLAS v.s. CMS for ICHEP: Similar expected significance. CMS has ~2x larger acceptance.
- CMS (ICHEP) v.s. CMS (HCP): Significant improvement (but lack of explanations) in Top background rejection.
- ATLAS has (re-)optimized the H → WW VBF analysis: Public results "coming soon".

Backup