Off-shell and high mass studies at ATLAS and CMS

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for the WG1 Off-shell Subgroup

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Synopsis

→ New publications from CMS and ATLAS on off-shell and high mass Higgs measurements

→ Focus is shifting toward interplay between finding the signal and the role of different BSM couplings

→ Adding different ways of interpreting the observed data from different angles

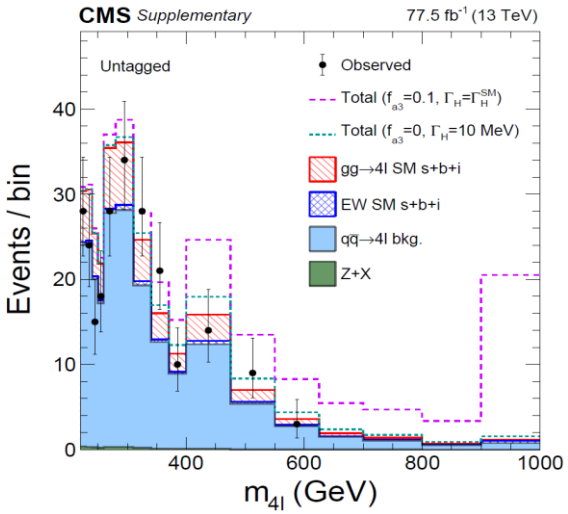
→ New avenues of exploration from other final states / analysis groups

→ Examine 4-top studies as a highlight

Off-shell studies: CMS

4ℓ: PRD 99 (2019) 112003

Measure off-shell - sensitive observables and provide interpretations

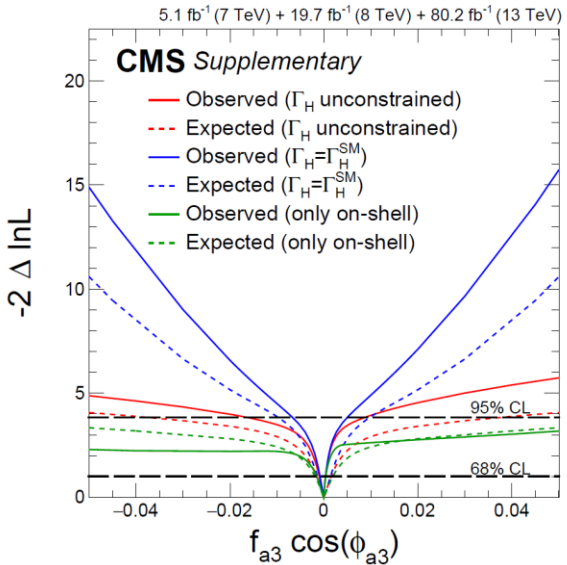


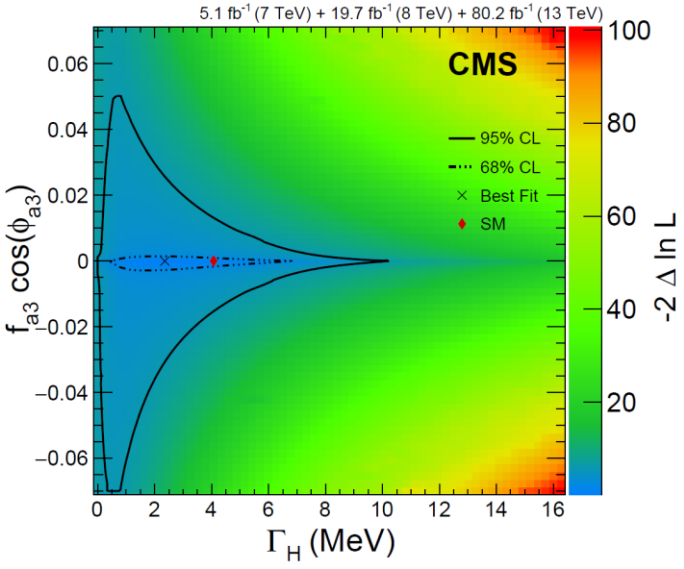
→ Possible BSM couplings, shown as fractional contributions f_{ai}, modify the Higgs contribution and interference with continuum ZZ

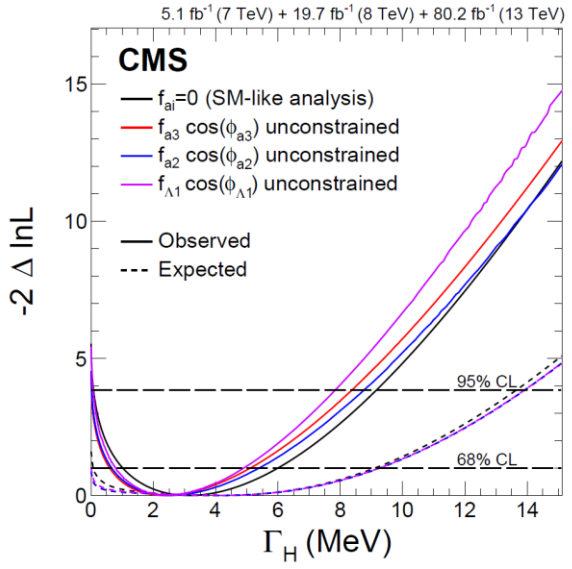
Tighter constraints on BSM couplings after including off-shell

Joint constraints on width and BSM couplings

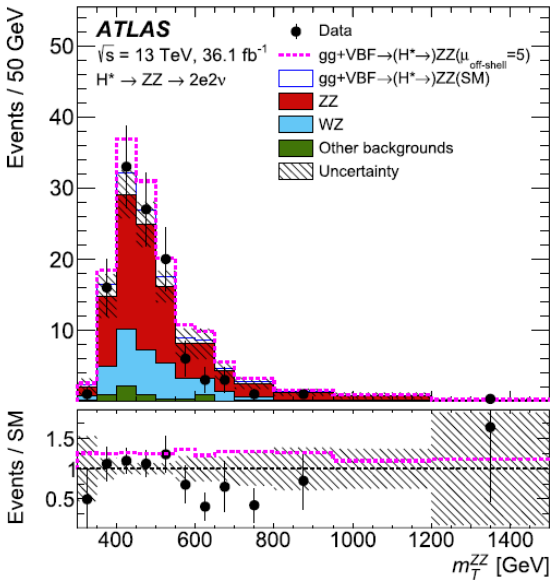
Width constraints with different BSM couplings unconstrained







Off-shell studies: ATLAS



$4\ell + 2\ell 2\nu$: [PLB 786 (2018) 223]

4ℓ: [JHEP 04 (2019) 048]

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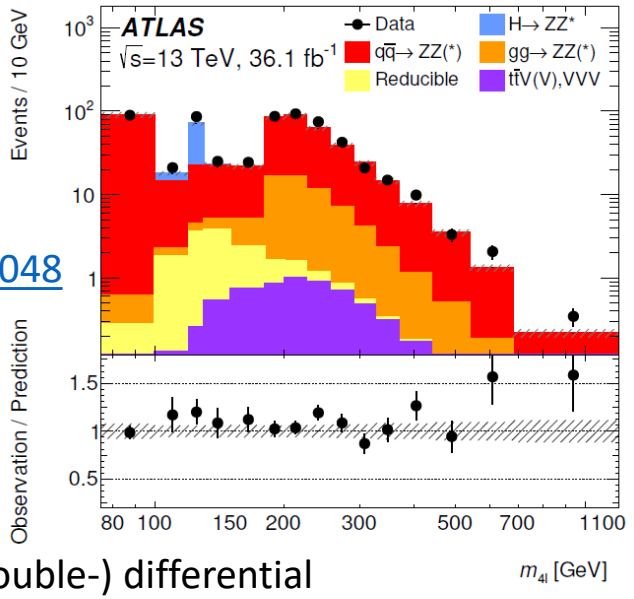
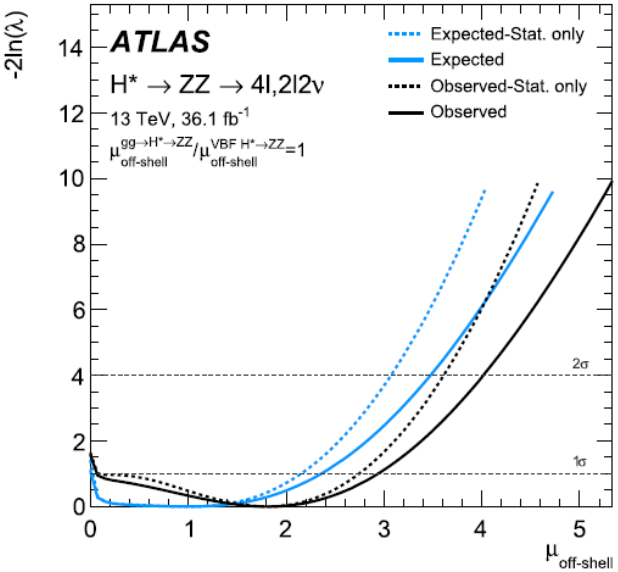
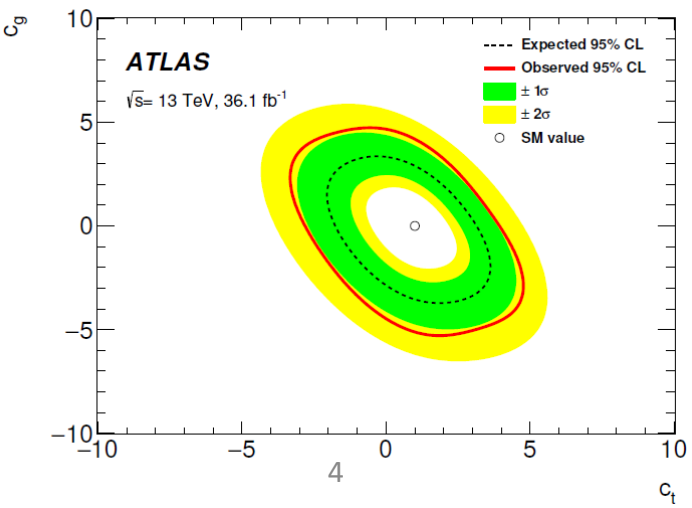


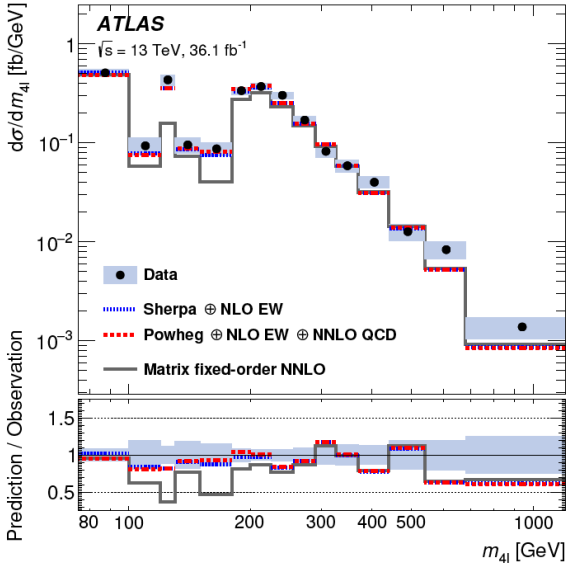
Constrain off-shell signal strength or total Higgs width

(Double-) differential measurements in m_{4l}, p_T^{4l}, $|y_{4l}|$ and D_{ME}

$c_g - c_t$ joint constraints







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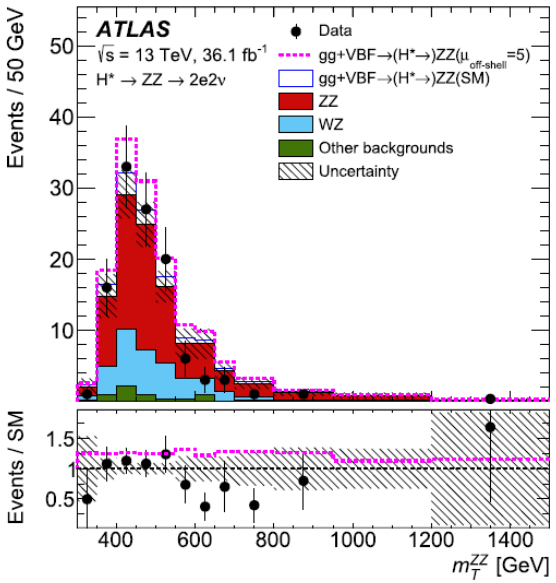

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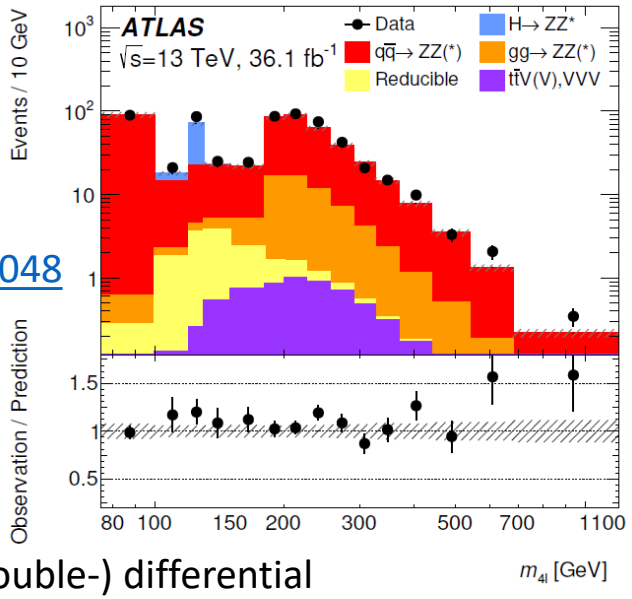

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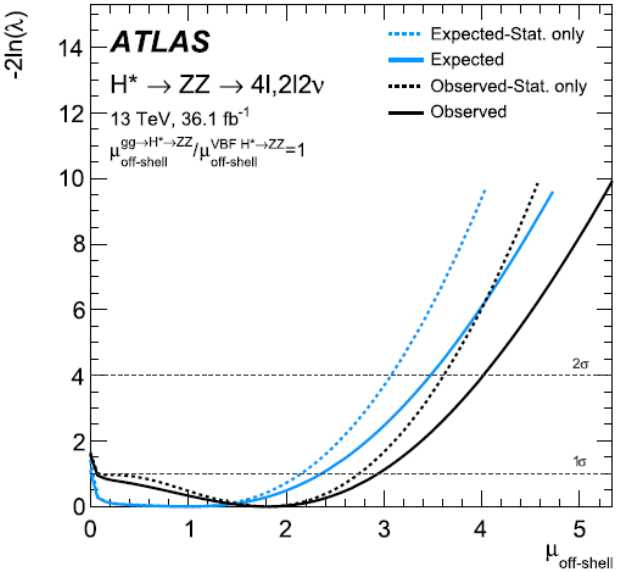

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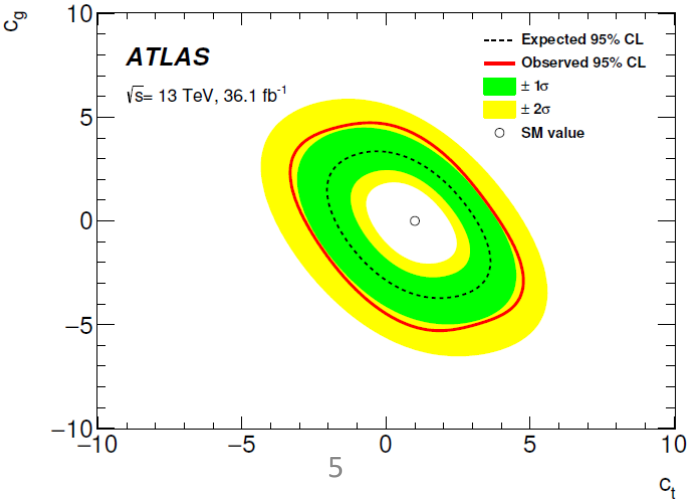
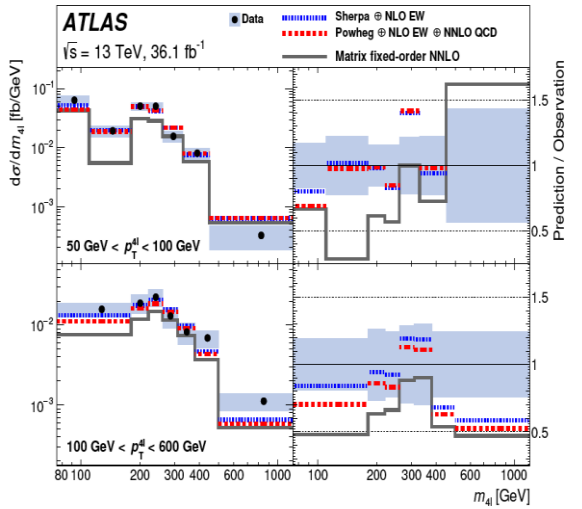
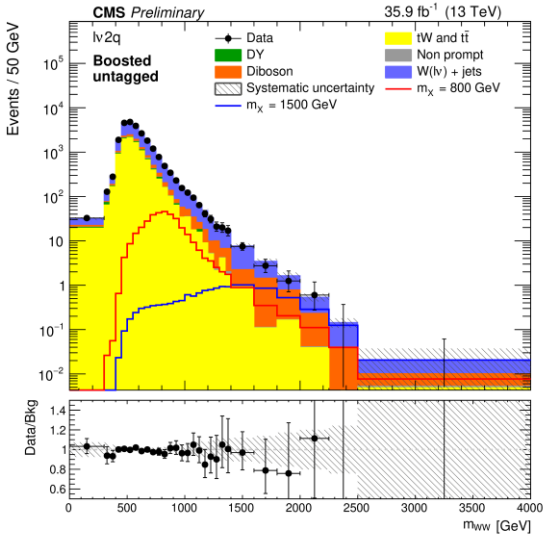




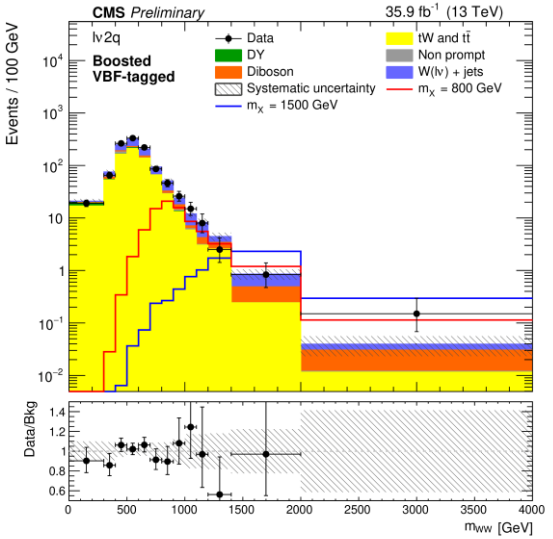
High mass $\mathbf{H \rightarrow WW}$ search (CMS)

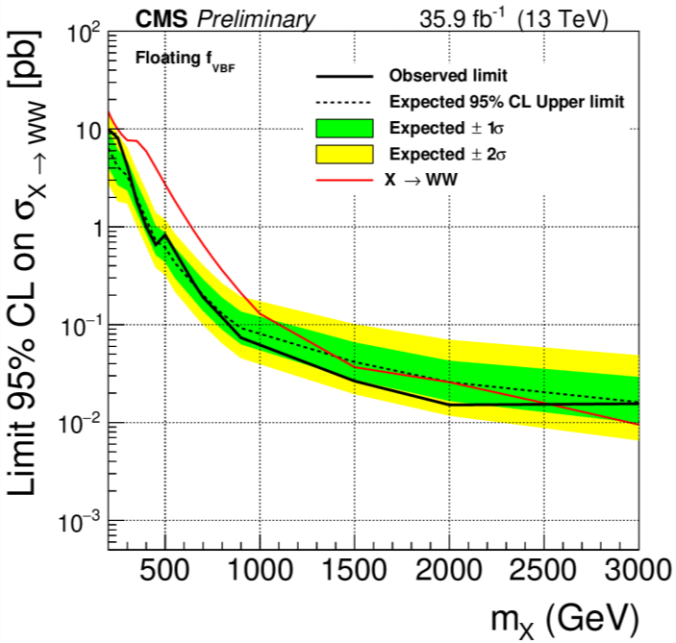


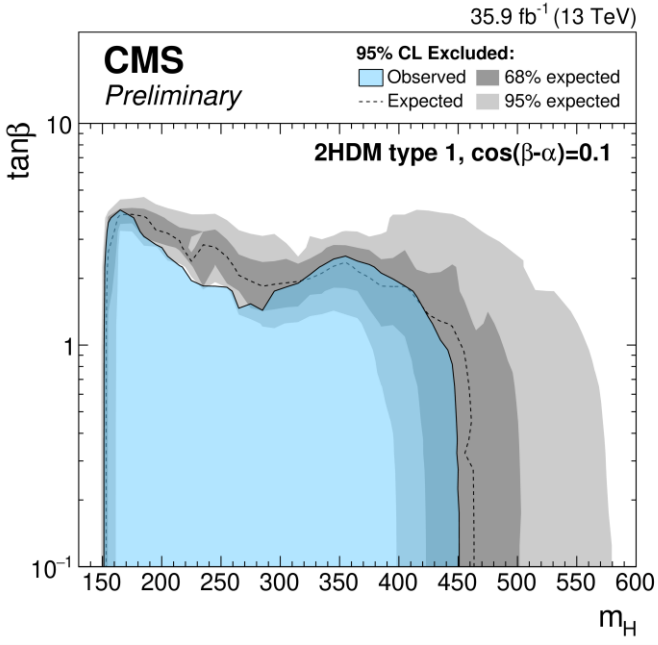
$\ell\nu\ell\nu + \ell\nu q\bar{q}$: CMS-PAS-HIG-17-033 (2019)

Measure m_T^I or m_{WW}, and provide interpretations

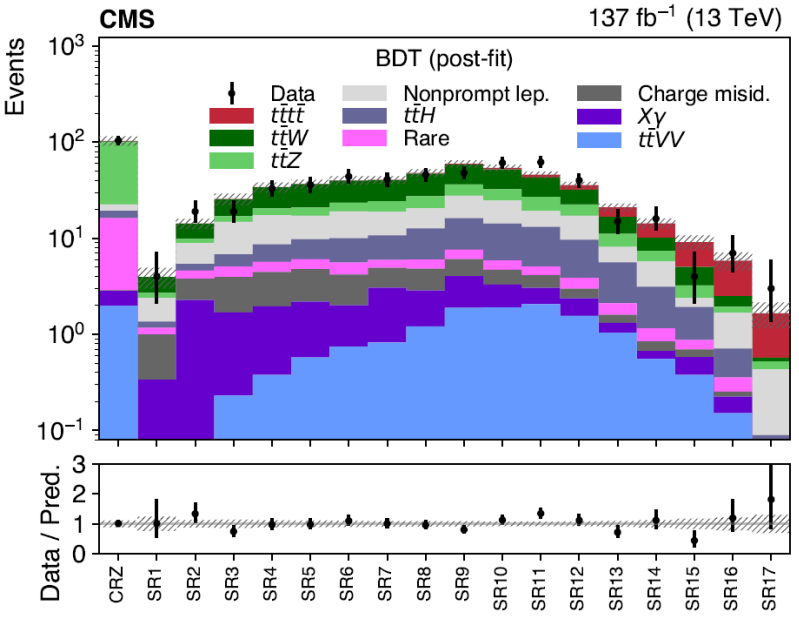
Wide resonance interpretations include the different interference contributions







4-top same-sign final state: CMS



Measure BDT $(N_\ell, N_b, N_{jets}, p_T^{miss}, H_T, \dots)$ shape (or N_ℓ, N_b and N_{jets} bins) and provide interpretations

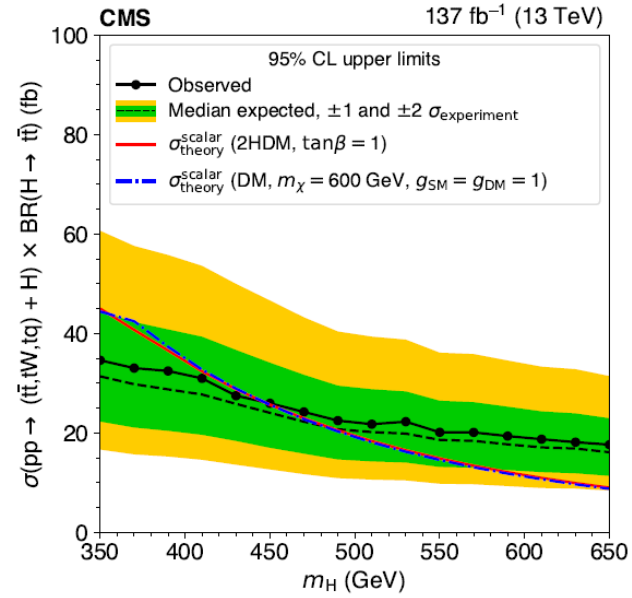
[Submitted to EPJC]

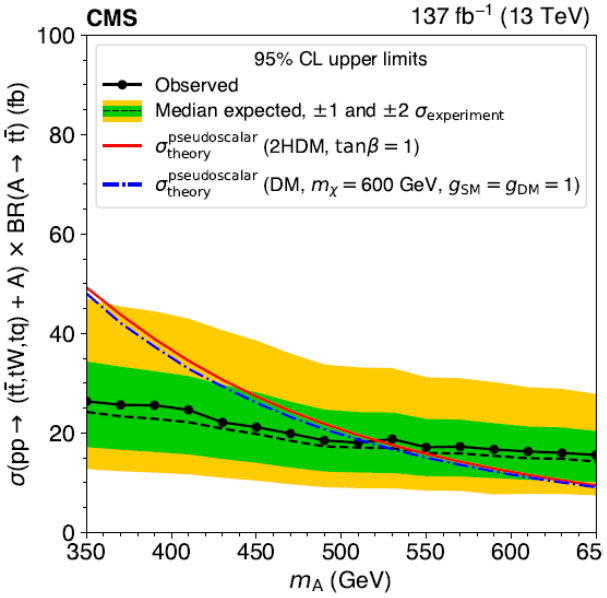
Limits on $\sigma \times BR$ for 2HDM and dark matter particles

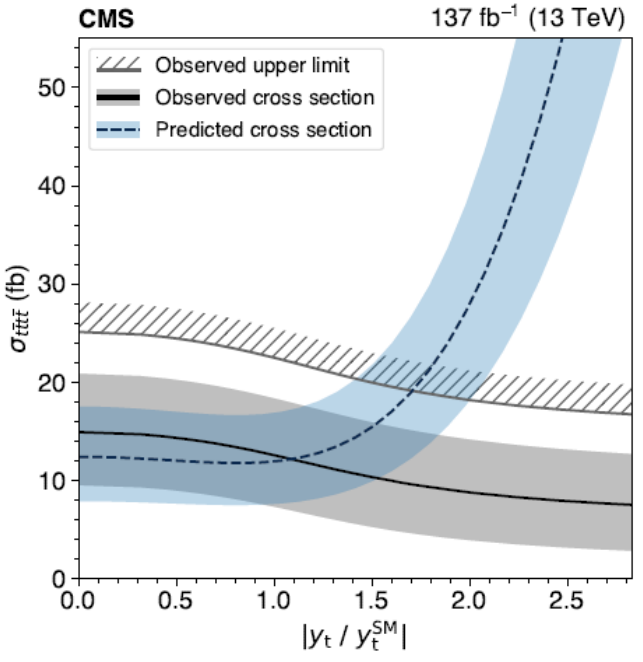
Oblique $\widehat{H} < 0.12$

Constraints on Higgs Yukawa couplings (interference at LO)

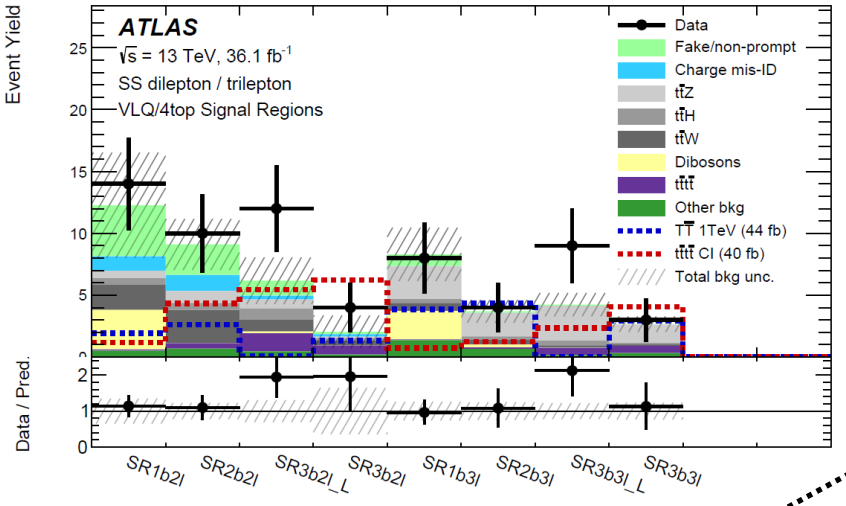
([Modifies] Higgs prop. by $-\widehat{H}/m_H^2$)







4-top same-sign final state: ATLAS



[JHEP 12 (2018) 039](#)

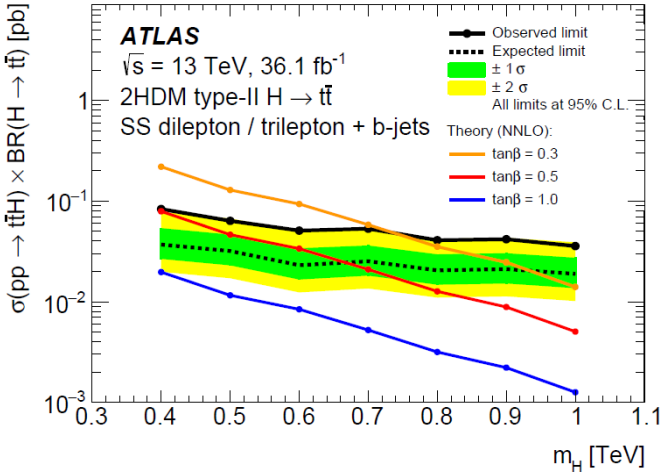
Measure N_ℓ, N_b and N_{jets} bins with H_T and p_T^{miss} requirements, and provide interpretations

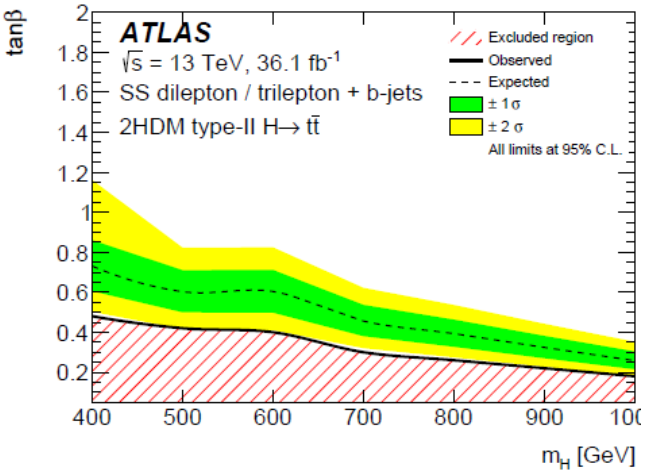
Limits on $\sigma \times BR$ for a 2HDM heavy scalar Higgs

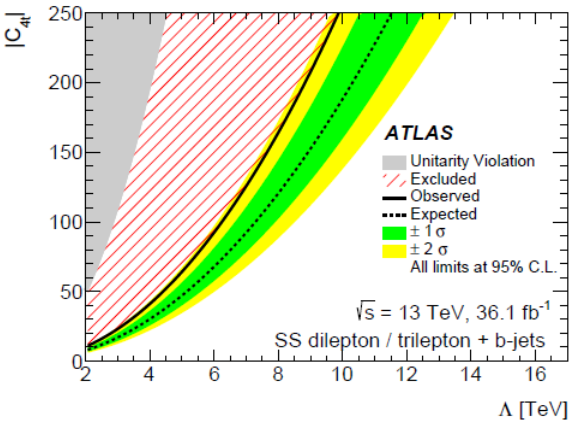
Exclusions of $\tan\beta$ and m_H

Limits on a 4-top contact interaction

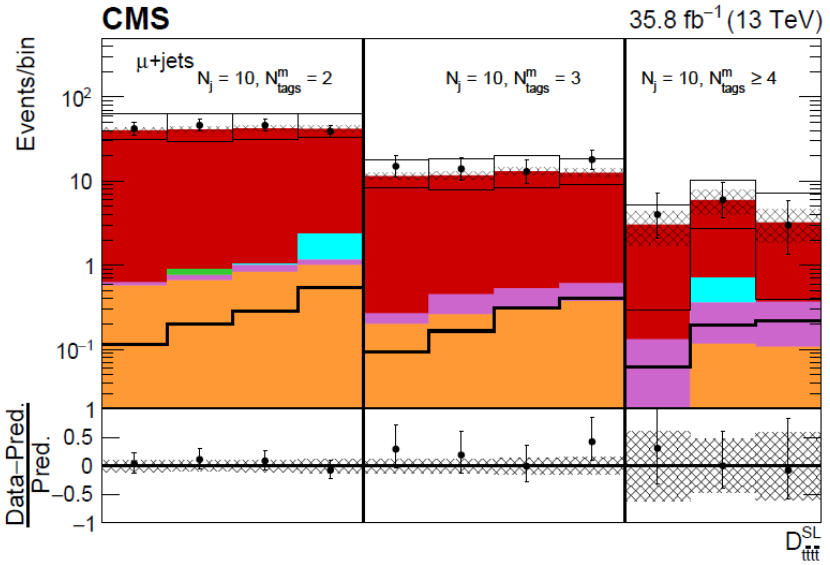
$$\mathcal{L}_{4t} = \frac{C_{4t}}{\Lambda^2}\left(\bar{t}_R\gamma^\mu t_R\right)\left(\bar{t}_R\gamma_\mu t_R\right)$$







4-top single-lepton and opposite-sign final states: CMS



Measure single-lepton and dilepton BDT (function of b tagging and jet variables) shapes, and provide interpretations

Submitted to JHEP

Limits $\sigma_{t\bar{t}t\bar{t}}$ @ 95% CL:
$< 33.1\ fb$
($29.4\ fb$ exp.)

Constraints on EFT couplings

$$\mathcal{O}^1_{tt} = (\bar{t}_R \gamma^\mu t_R)(\bar{t}_R \gamma_\mu t_R),$$
$$\mathcal{O}^1_{QQ} = (\bar{Q}_L \gamma^\mu Q_L)(\bar{Q}_L \gamma_\mu Q_L),$$
$$\mathcal{O}^1_{Qt} = (\bar{Q}_L \gamma^\mu Q_L)(\bar{t}_R \gamma_\mu t_R),$$
$$\mathcal{O}^8_{Qt} = (\bar{Q}_L \gamma^\mu T^A Q_L)(\bar{t}_R \gamma_\mu T^A t_R)$$

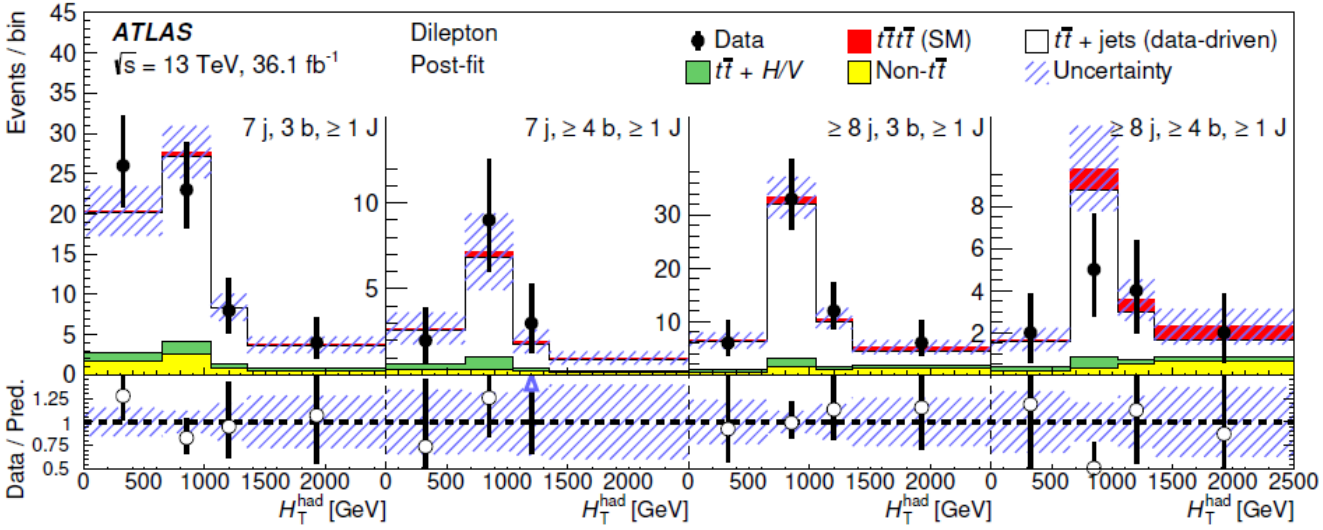
Operator	$\sigma^{(1)}_k$	$\sigma^{(2)}_{j,k}$			
		$\mathcal{O}^1_{tt}$	$\mathcal{O}^1_{QQ}$	$\mathcal{O}^1_{Qt}$	$\mathcal{O}^8_{Qt}$
$\mathcal{O}^1_{tt}$	0.39	5.59	0.36	−0.39	0.3
$\mathcal{O}^1_{QQ}$	0.47		5.49	−0.45	0.13
$\mathcal{O}^1_{Qt}$	0.03			1.9	−0.08
$\mathcal{O}^8_{Qt}$	0.28				0.45

Operator	Expected C_k/Λ^2 (TeV^{-2})	Observed (TeV^{-2})
$\mathcal{O}^1_{tt}$	[−2.0, 1.9]	[−2.2, 2.1]
$\mathcal{O}^1_{QQ}$	[−2.0, 1.9]	[−2.2, 2.0]
$\mathcal{O}^1_{Qt}$	[−3.4, 3.3]	[−3.7, 3.5]
$\mathcal{O}^8_{Qt}$	[−7.4, 6.3]	[−8.0, 6.8]

→ Limits with other couplings unconstrained

$$\sigma_{t\bar{t}t\bar{t}} = \sigma^{SM}_{t\bar{t}t\bar{t}} + \frac{1}{\Lambda^2}\sum_k C_k \sigma^{(1)}_k + \frac{1}{\Lambda^4}\sum_{j\le k} C_j C_k \sigma^{(2)}_{j,k}$$

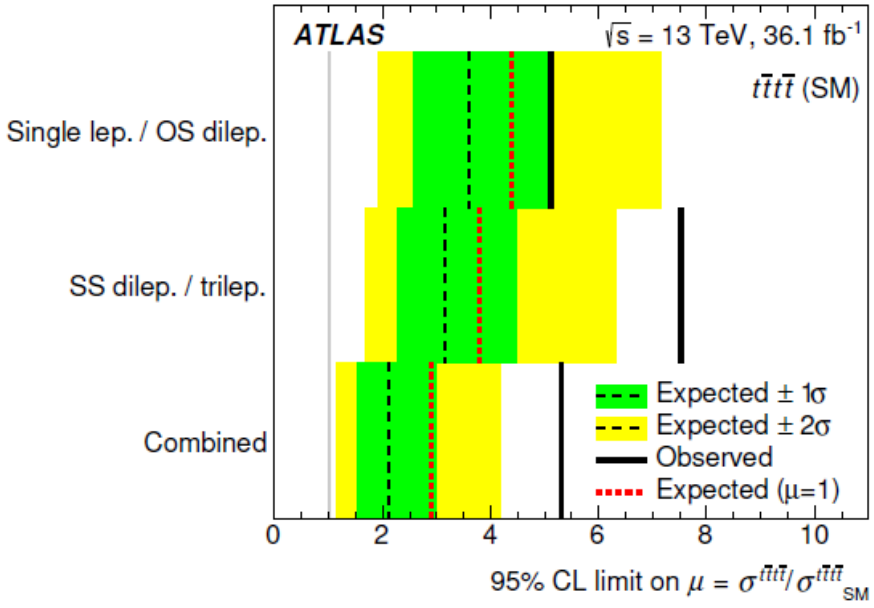
4-top single-lepton and opposite-sign final states: ATLAS

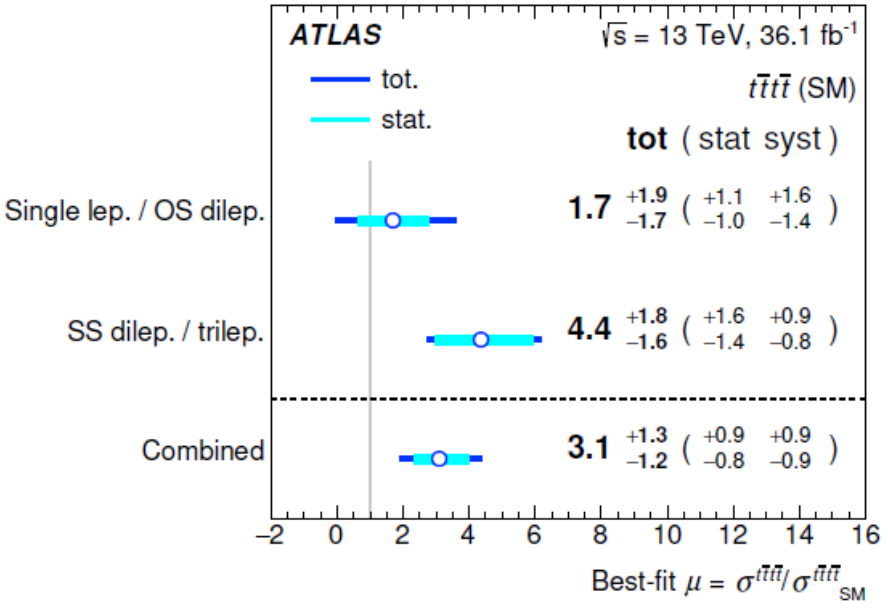


[PRD 99 (2019) 052009]

Measure H_T^{had} shape in signal regions with different jet and b-tagging multiplicities, and provide interpretations

Exclusions of 4-top signal strength





Summary

→ Presented the off-shell Higgs and high mass studies from CMS and ATLAS

→ Interplay of signal detection and potential BSM couplings beginning to attract more attention

→ Important to provide different interpretations to the same observed data

→ Studies from other analysis groups provide valuable interpretations

→ 4-top production from CMS and ATLAS

→ Important to watch analyses groups other than Higgs in the experiments

→ Measurements could also be combined to provide useful and unique constraints for the different interpretations.