FCNC t→qH (→bb)

Spanish LHC Network Meeting

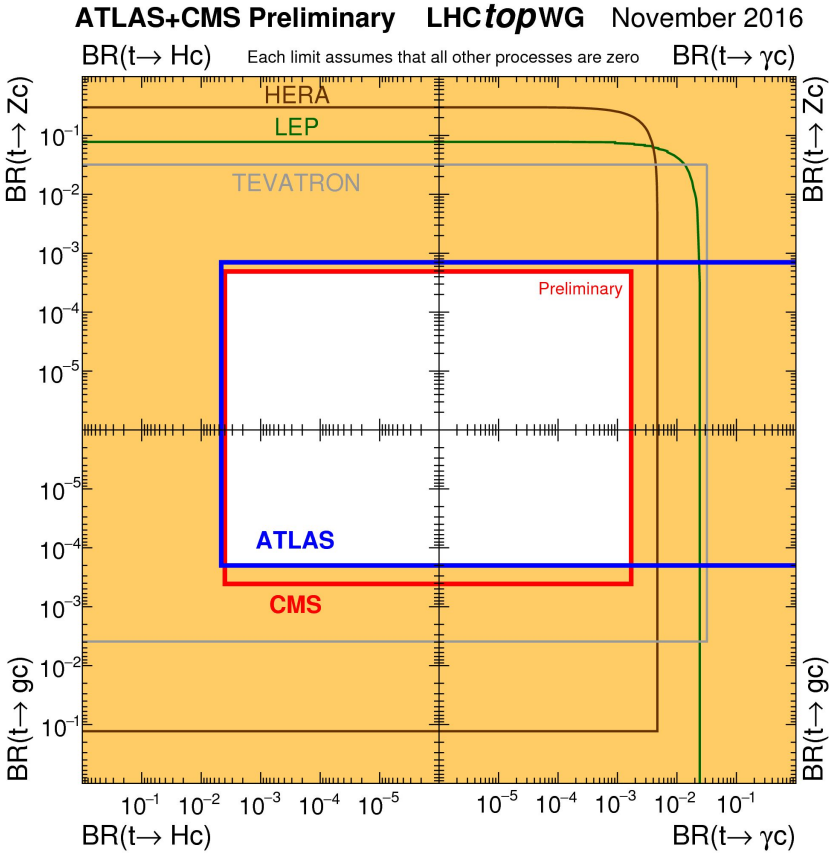
2017-05-09

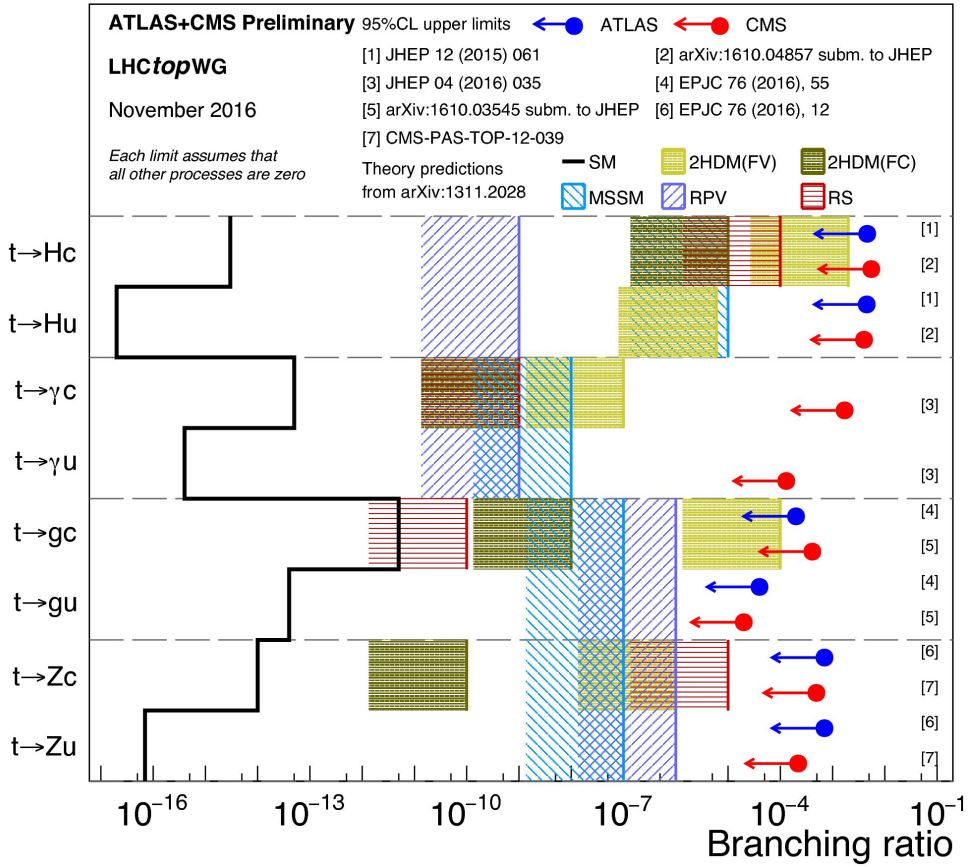
Davide Gerbaudo
on behalf of the IFAE-Top team

Barcelona Institute of
Science and Technology

FCNC Top Searches

Several searches have been performed over the years.
LHC can improve the sensitivity of several searches by orders of magnitude.

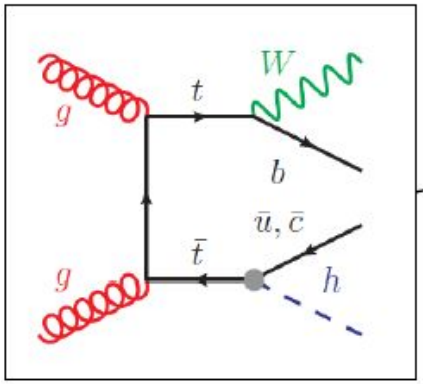




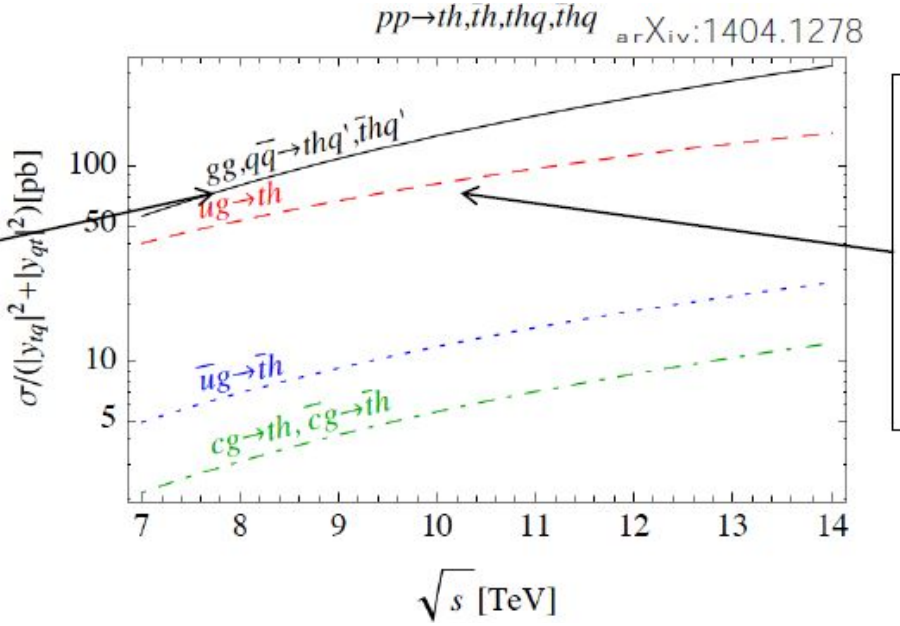
Starting to probe the BR predicted by several BSM models.

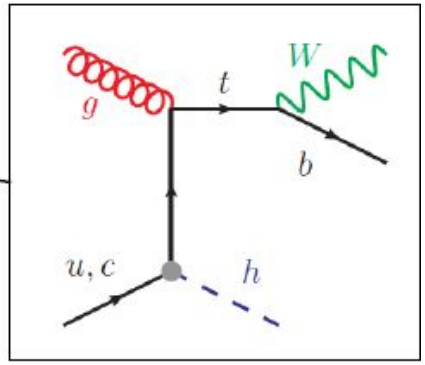
If off-diagonal Yukawa couplings are $\approx\sqrt{m_i m_j}$, then t→Hq is the next interesting spot to investigate.

Phenomenology & Experimental Strategy



$t \rightarrow Hq$ decay



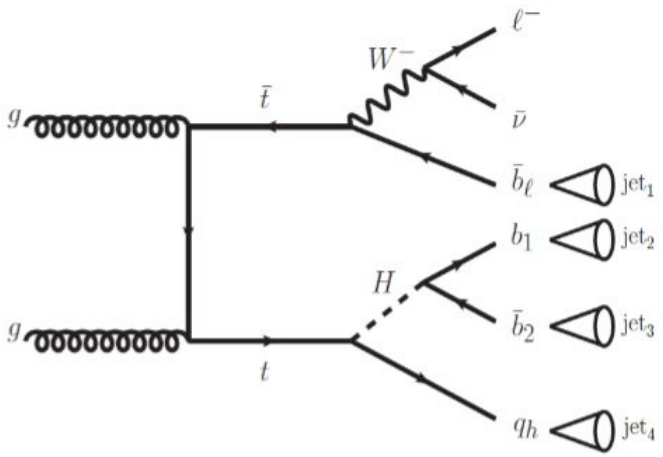


tH production

- Strategies:
  - H→γγ: tiny Br(~0.2%); diphoton+lepton+jets, diphoton+jets final states. Very small background, excellent mass resolution
  - H→WW*, ττ: sizeable Br(WW*: 21.5%, ττ: 6.3%); SS 2ℓ , 3ℓ. Small background, essentially no mass resolution
  - H → bb: largest Br(~58%); lepton+jets. Large background, some mass resolution.
- H→bb **largest Br**, **mass resolution** not as good as γγ, not as bad as WW
- lepton+jets channel: use **single lepton trigger**

Analysis Strategy

- Focus on tt → WbHq → (ℓν)b(bb)q
- lepton+jets final state
- Event pre-selection:
  - Single-lepton trigger
  - e or μ with p_T>25GeV, |η|<2.5
  - ≥4 jets with p_T>25GeV, |η|<2.5
  - ≥2 b-tags (MV1 tagger at 77% eff.)



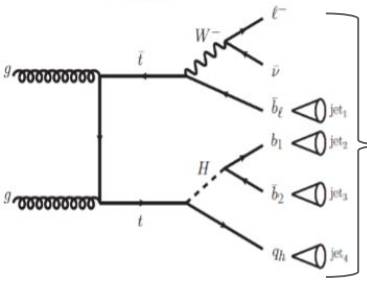
	N_b		
N_{jet}	=2	=3	≥4
=4		Hu,Hc	Hc
=5		Hu,Hc	Hc
≥6			

- Main background: SM tt(→WbWb)+jets
- Same background model and associated systematics as in the ttH(→bb) search
- Categorize events according to the number of jets and of b-tags
  - **Signal-rich channels:** most sensitive to t→Hu, Hc signals
  - **Signal-depleted channels:** primarily used to constrain background systematics via profile likelihood fit
- Re-use and improve Run 1 discriminant

Run1 Discriminant

Combinatorial likelihood discriminant exploiting kinematic and b-tag information:

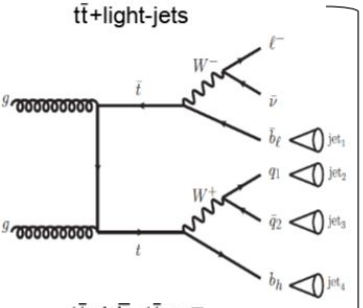
Signal



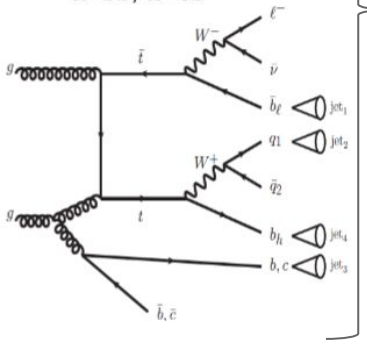
$$P^{\mathrm{sig}}(\mathbf{x}) = \frac{\sum_{k=1}^{N_P} P^{\mathrm{sig}}_{\mathrm{btag}}(\mathbf{x}^k) P^{\mathrm{sig}}_{\mathrm{kin}}(\mathbf{x}^k)}{\sum_{k=1}^{N_P} P^{\mathrm{sig}}_{\mathrm{btag}}(\mathbf{x}^k)}$$

$$\mathcal{D}(\mathbf{x}) = \frac{P^{\mathrm{sig}}(\mathbf{x})}{P^{\mathrm{sig}}(\mathbf{x}) + P^{\mathrm{bkg}}(\mathbf{x})}$$

$t\bar{t}$+light-jets

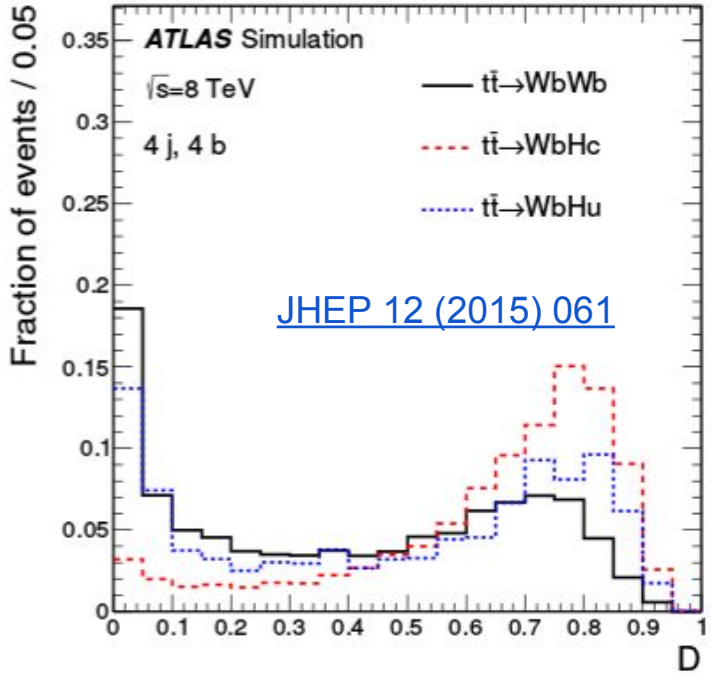


$t\bar{t}+b\bar{b}$, $t\bar{t}+c\bar{c}$

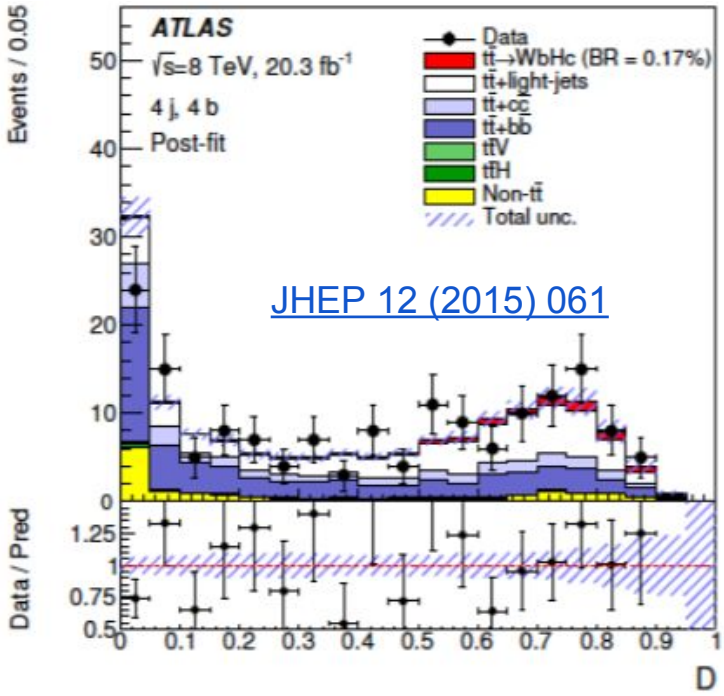


$$P^{\mathrm{bkg}}(\mathbf{x}) = \frac{\sum_{k=1}^{N_P} \sum_{j\in\{b,c,q_2\}} f_j P^{\mathrm{bkg},j}_{\mathrm{btag}}(\mathbf{x}^k) P^{\mathrm{bkg},j}_{\mathrm{kin}}(\mathbf{x}^k)}{\sum_{k=1}^{N_P} \sum_{j\in\{b,c,q_2\}} f_j P^{\mathrm{bkg},j}_{\mathrm{btag}}(\mathbf{x}^k)}$$

Each ***P*** is computed from m(lvb), m(jj), m(jjj) distributions accounting for all valid jet and flavor combinations



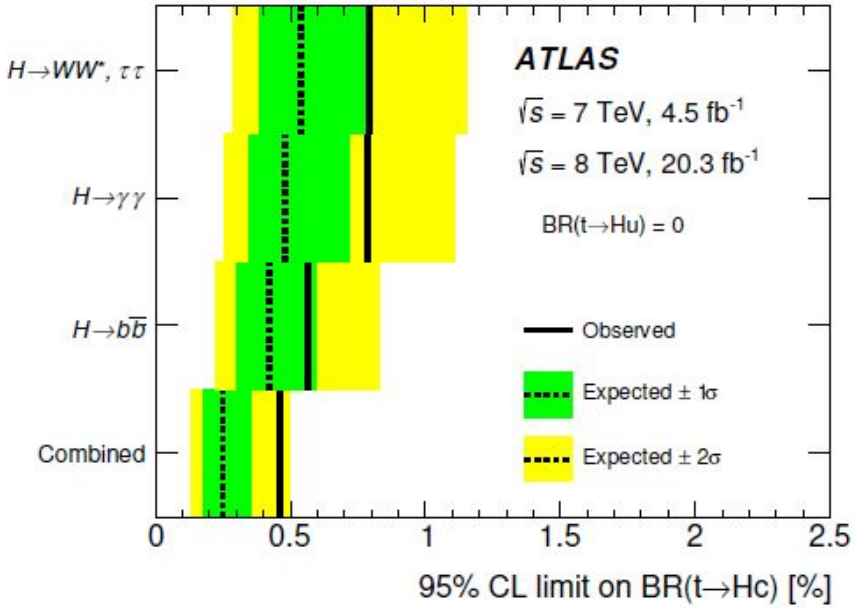
JHEP 12 (2015) 061

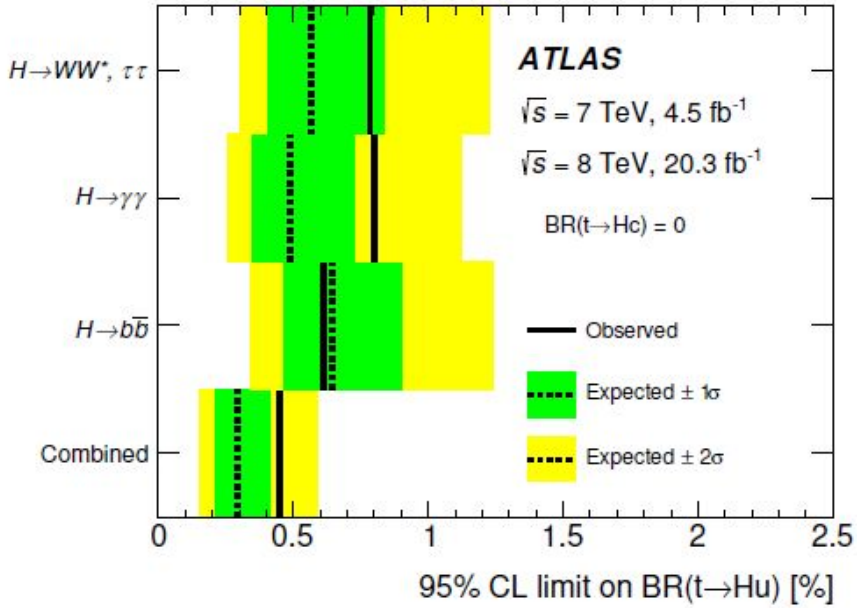


JHEP 12 (2015) 061

Run 1 Result: Upper Limits

JHEP 12 (2015) 061



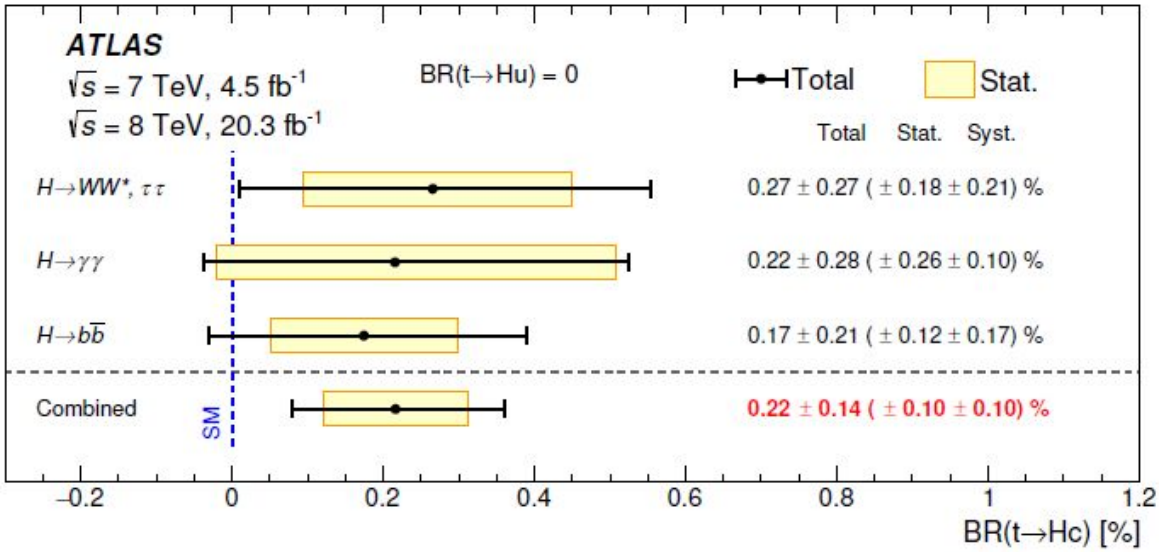


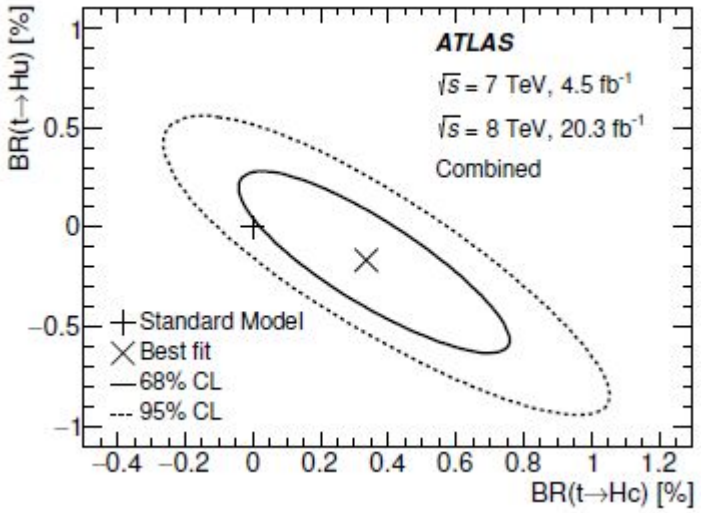
Collab	Decay mode	Limit BR($t \to Hc$) [%] Observed	Expected	Limit BR($t \to Hu$) [%] Observed	Expected
CMS	$H \to \gamma\gamma$	0.47	0.67	0.42	0.60
	$H \to WW, ZZ, \tau\tau$ (SS 2ℓ, 3ℓ, 4ℓ)	0.93	0.89	0.82	0.82
	$H \to bb$	1.16	0.89	1.92	0.84
	Combination	0.40	0.43	0.55	0.40
ATLAS	$H \to \gamma\gamma$	0.79	0.51	0.79	0.51
	$H \to WW, \tau\tau$ (SS 2ℓ, 3ℓ)	0.79	0.54	0.78	0.57
	$H \to bb$	0.56	0.42	0.61	0.64
	Combination	0.46	0.25	0.45	0.29

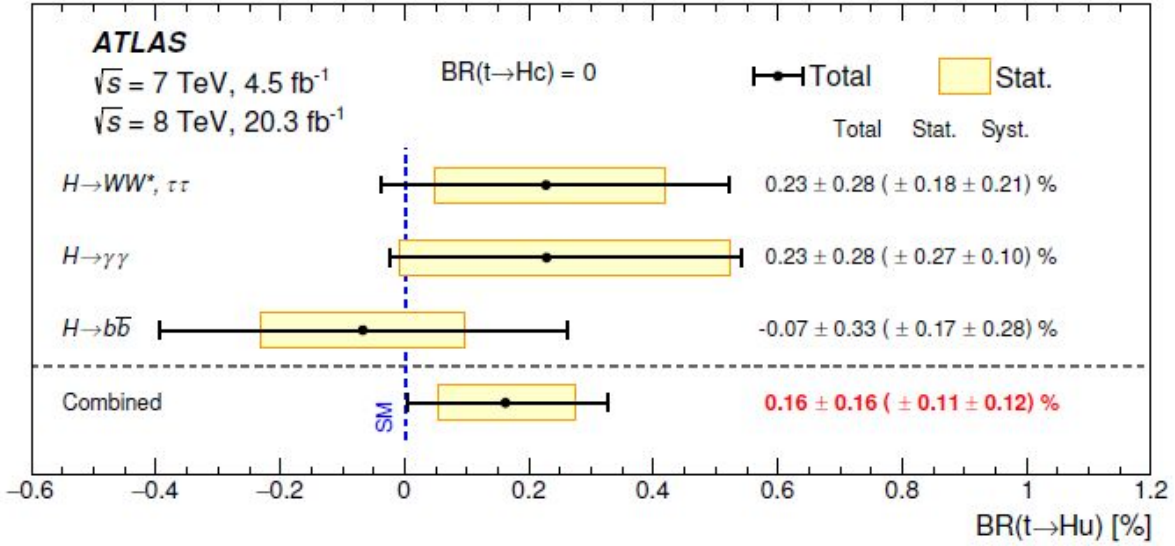
- H→bb: competitive w/ other channels

Run 1 Result: Best Fit Values

JHEP 12 (2015) 061







- Simultaneous measurement of both BRs from H→bb channels
- Perhaps a glimpse of FCNC has already been observed?

Neutral Higgs FCNC: Prospects

What are the prospects and what can be improved wrt. Run 1:

- Increase in the cross section and datasets:
  - $\sigma(tt \rightarrow WbHq)$: $\sigma_{13} / \sigma_{8} \sim 3.3$
  - $L_{13} / L_{8} \sim 1.5$ (2015+2016; will be ~5 with full Run2, ~100 fb^{-1})
- Further optimize the object selection
  - Optimized event reconstructions
  - Jets down to p_T>20GeV
- Further optimize the comb. likelihood discriminant
  - Finer b-tagging categorization (tight, loose op. points), e.g. 4T, 3T +1L, etc.
  - → requires pseudo-continuous b-tagging
  - Use b-tagging info to discriminate sig. vs. bkg. (now only used to weight the kin. prob.)
- Reduce systematics on tt+jets/HF modeling ("one-missing-parton" case)

Conclusion and Outlook

- Well defined analysis strategy for FCNC t→Hq (H→bb)
  - leverage Run 1 experience
  - ideas and room for improvement
- Work on full 2015+2016 data analysis and discriminant calculation ongoing
  - from the application of the discriminant to ttH(→bb) learnt useful lessons
- Main limiting factors
  - ttbar modeling

Extra slides

Systematic uncertainties

From [JHEP 12 (2015) 061]

	Pre-fit				Post-fit			
	$WbHc$	$t\bar{t}$+LJ	$t\bar{t}+c\bar{c}$	$t\bar{t}+b\bar{b}$	$WbHc$	$t\bar{t}$+LJ	$t\bar{t}+c\bar{c}$	$t\bar{t}+b\bar{b}$
Luminosity	±2.8	±2.8	±2.8	±2.8	±2.6	±2.6	±2.6	±2.6
Lepton efficiencies	±1.5	±1.5	±1.5	±1.5	±1.5	±1.5	±1.5	±1.5
Jet energy scale	±3.3	±2.9	±2.3	±5.8	±1.4	±1.2	±1.8	±4.1
Jet efficiencies	±1.2	–	±1.9	±1.7	±0.9	–	±1.4	±1.2
Jet energy resolution	–	±1.2	±2.8	±2.9	–	–	±1.0	±1.1
b-tagging eff.	±7.9	±5.5	±5.2	±10	±5.7	±3.9	±3.7	±6.6
c-tagging eff.	±7.0	±6.6	±13	±3.5	±6.3	±6.0	±11	±3.2
Light-jet tagging eff.	±0.8	±18	±3.2	±1.5	±0.6	±13	±2.3	±1.1
$t\bar{t}$: reweighting	±5.9	±2.7	±4.2	–	±3.8	±1.9	±2.3	–
$t\bar{t}$: parton shower	±5.4	±4.8	±10	±4.9	±1.7	±1.5	±6.5	±3.1
$t\bar{t}$+HF: normalisation	–	–	±50	±50	–	–	±32	±16
$t\bar{t}$+HF: modelling	–	–	–	±7.7	–	–	–	±7.4
Signal modelling	±6.9	–	–	–	±6.9	–	–	–
Theor. cross sections	±6.2	±6.2	±6.2	±6.2	±3.9	±3.9	±3.9	±3.9
Total	±17	±22	±54	±53	±7.8	±14	±28	±15

ttbar:
Powheg-Box
+ Pythia6
+ CT10
+ rew. ttbb
(NLO,
massive b,
Sherpa+OL)

Table 2: $t\bar{t} \to WbHc, H \to b\bar{b}$ search: summary of the systematic uncertainties considered in the (4 j, 4 b) channel and their impact (in %) on the normalisation of the signal and the main backgrounds, before and after the fit to data. The $t\bar{t} \to WbHc$ signal and the $t\bar{t}$+light-jets background are denoted by "$WbHc$" and "$t\bar{t}$+LJ" respectively. Only sources of systematic uncertainty resulting in a normalisation change of at least 0.5% are displayed. The total post-fit uncertainty can differ from the sum in quadrature of individual sources due to the anti-correlations between them resulting from the fit to the data.