Charged Higgs & W′ bosons with top physics in ATLAS & CMS

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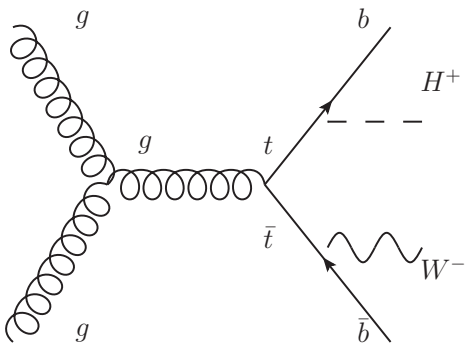
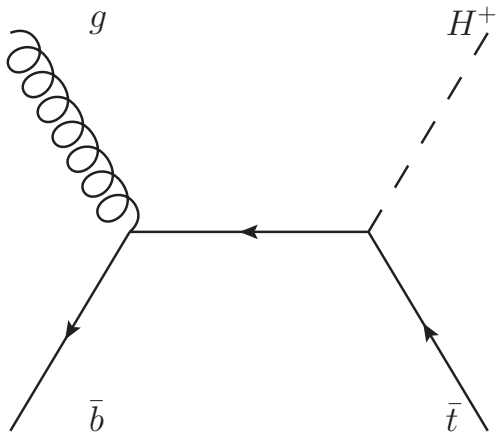
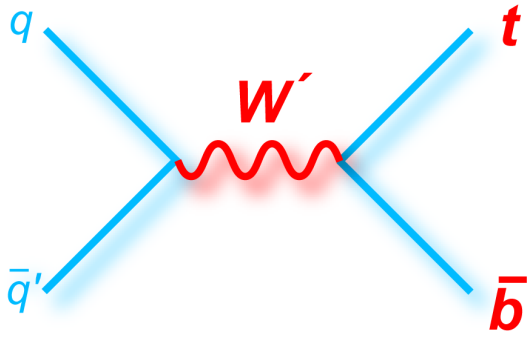
May 18, 2016

Introduction

- Many BSM models predict new heavy bosons.
  - Two Higgs Doublet models (2HDMs)
  - Kaluza-Klein.
  - Little Higgs.
- A charged Higgs boson and a W' can have similar phenomenology.
- Many processes including top quarks.

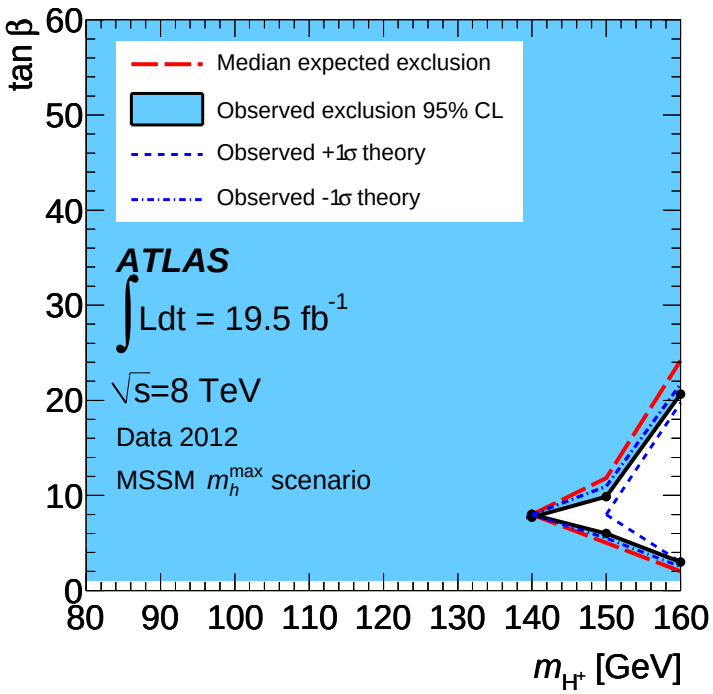


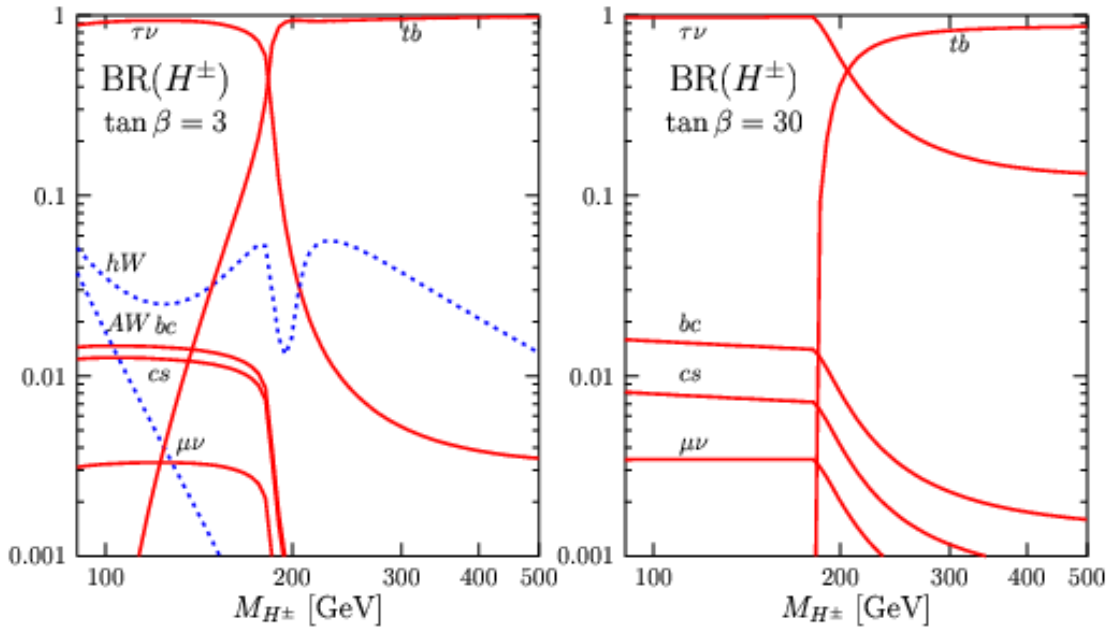




Motivation

- For the H^+ it's natural to look at the heavy decay products due to the mass-dependent coupling.
- With $m_{H^+} < m_{top}$ mostly exluded, the $H^+ \to tb$ channel is the best probe for heavy H^+.





ATLAS collaboration, JHEP03 (2015) 088

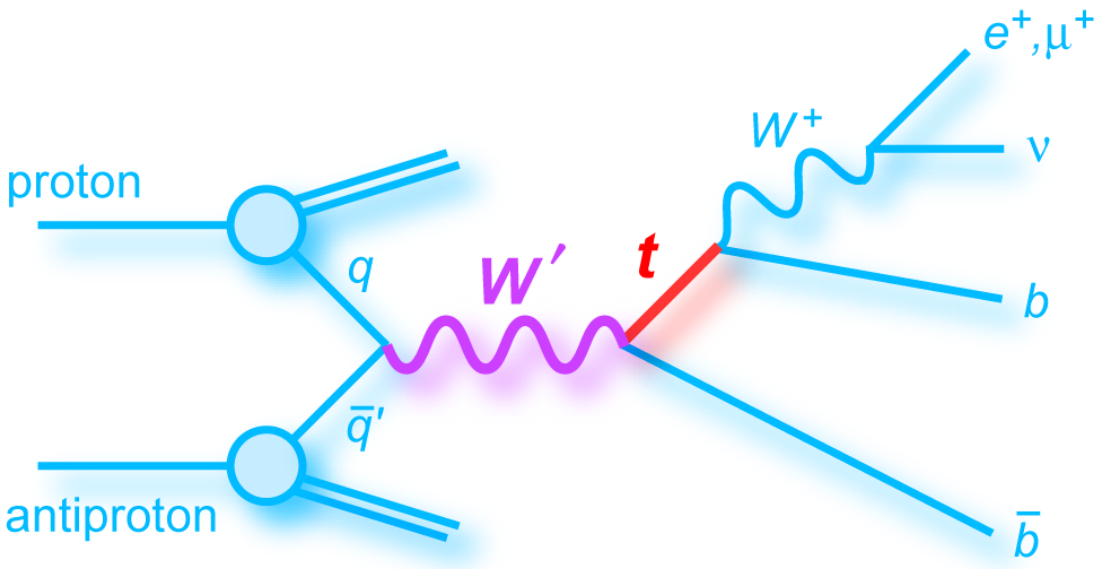
A.Djoadi et.al, arXiv:0901.2030

Motivation

- The W' has in some models an enhanced coupling to the third generation quarks.
- For right-handed W' leptonic decay modes are impossible if the right handed neutrino is heavy.

W' searches with ATLAS and CMS

- Both ATLAS & CMS have published $W' \to t\bar{b} \to l\nu b\bar{b}$ searches for the 8 TeV datasets.
- ATLAS have also published a result for an 8 TeV search in the allhadronic final state.
- The CMS collaboration have a Physics Analysis Summary (PAS) with 13 TeV results with 2015 data.



$W' \to tb$ in the lepton + jets

Signal	ATLAS	CMS
Mass range	0.5-3.0 TeV	0.8-3.0 TeV
Generator	MADGRAPH5+PYTHIA8	SINGLETOP+PYTHIA
PDF	CTEQ6L1	CTEQ6M

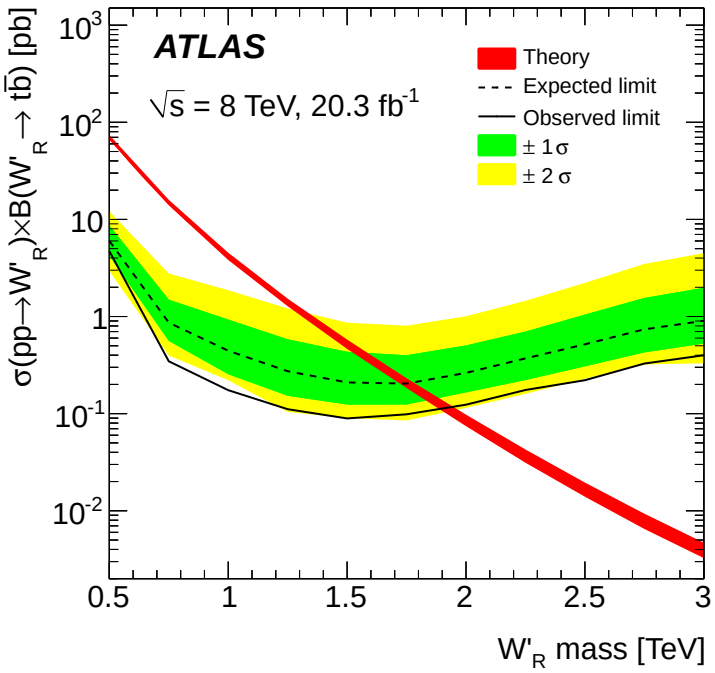
- Normalized to NLO with k-factors.
- Fermionic coupling strength assumed equal to SM W boson.
- W'_L samples include interferenece with SM s-channel tb production.

$W' \to tb$ in the lepton + jets

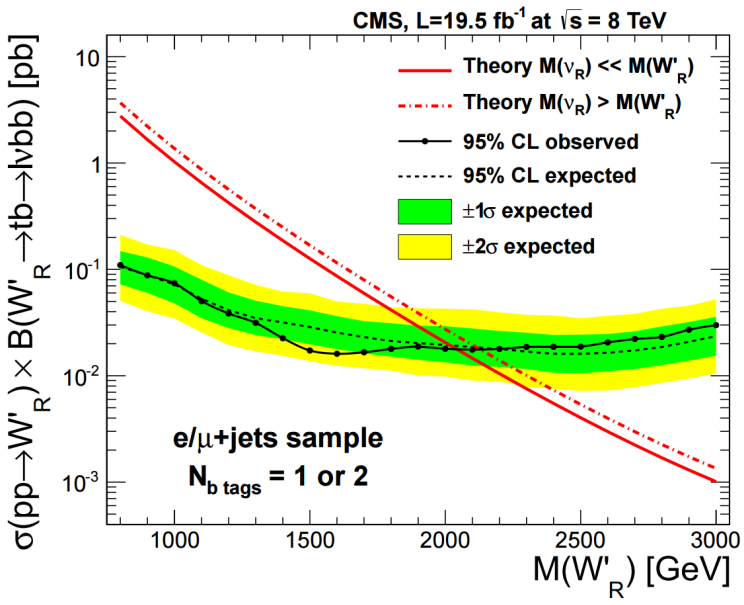
Event selection	ATLAS	CMS
N leptons	== 1	== 1
N jets	2 or 3	≥ 2
N b-tags	== 2	j_1 or j_2
Lepton p_T (GeV)	> 30	> 50
Jet p_T (GeV)	> 25	> 30
		j_1 > 120
		j_2 > 40
E_T^{miss} (GeV)	> 35	20
$m_T(W) + E_T^{miss}$ (GeV)	> 60	-

- CMS produced limits from binned likelihood of the tb invariant mass.
- ATLAS used the CL_S procedure on BDT outputs, with $m_{t\bar{b}}$ as one input.

$W' \to tb$ in the lepton + jets final state



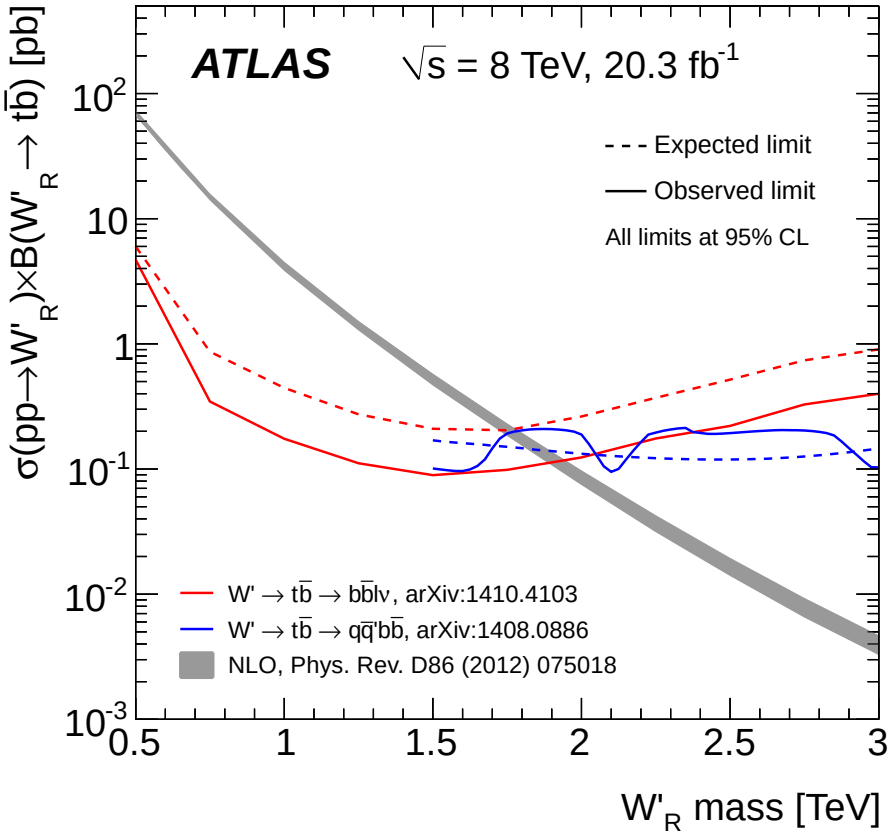
ATLAS collaboration, Physics Letters B 743(2015) 235



CMS collaboration, JHEP05 (2014) 108

Exclusion 95% CL limits	ATLAS	CMS
W'_R	1.92 TeV	2.05 TeV
W'_L	1.80 TeV	2.05 TeV
W'_L with SM interference	1.70 TeV	1.84 TeV

$W' \to tb$ in the allhadronic final state



ATLAS collaboration, Eur. Phys. J.C. (2015) 75

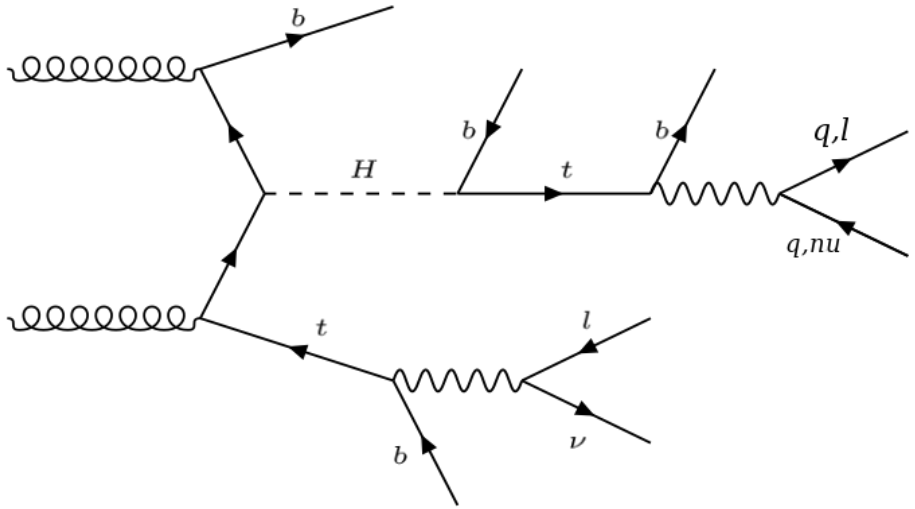
- All-hadronic search is more sensitive in high mass region due to boosted top tagging.

$W' \to tb$ in the lepton + jets final state

- CMS has a PAS out with results from 2015 data (2.2 fb^{-1}).
- Higher p_T thresholds
  - lepton p_T > 180 GeV
  - j_1 p_T > 350 (450) GeV for e+jets (mu+jets).
  - E_T^{miss} > 120 (50) GeV for e+jets (mu+jets).
- No lepton isolation required due to boosted tops.
- XS limits: W'_R excluded below 2.38 (2.17) TeV observed (expected).
- Limits improved with only $1/10$ of the run 1 int. luminosity.

H^+ searches with ATLAS & CMS

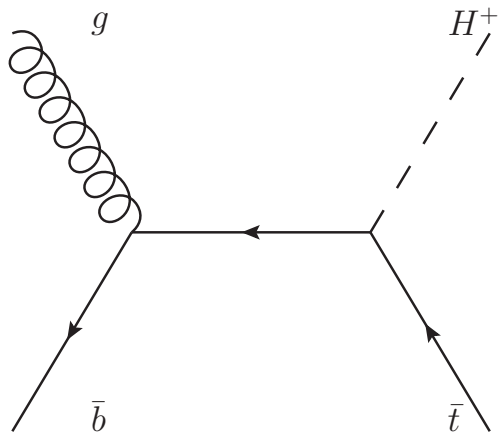
- ATLAS have published 8 TeV results for $H^+ \to tb$
  - Top-associated production: lepton + jets.
  - s-channel production: lepton + jets & all-hadronic.
- CMS has published a search for $H^+ \to tb$ in the lepton + jets, dilepton and $\mu\tau_{had}$ final states and a combination with $\tau\nu$.
- Both experiments have performed searches for light charged Higgs bosons in the $\tau\nu$ and $c\bar{s}$ final states.



Top associated $H^+ \to tb$

Signal	ATLAS	CMS
Mass range	200-600 GeV	180-600 GeV
Generator	POWHEG-BOX+PYTHIA8	PYTHIA6+PYTHIA

- The signal cross section normalization combines four and five flavour production using the Santander matching scheme, while samples are produced with the five flavour scheme.
- The H^+ is simulated with a zero width.



Top associated $H^+ \to tb$ - ATLAS

- Formed 4 CR and 1 SR from jet categories.
- Simultaneous fit of H_T^{had} in CR and a BDT output in the SR.
- The BDT was trained to separate signal and $tt + bb$ with H_T^{had} being one of the most discriminating input variables.
- The uncertainties with largest impact on the limits come from $tt + bb$ cross section and shape reweighting to NLO.

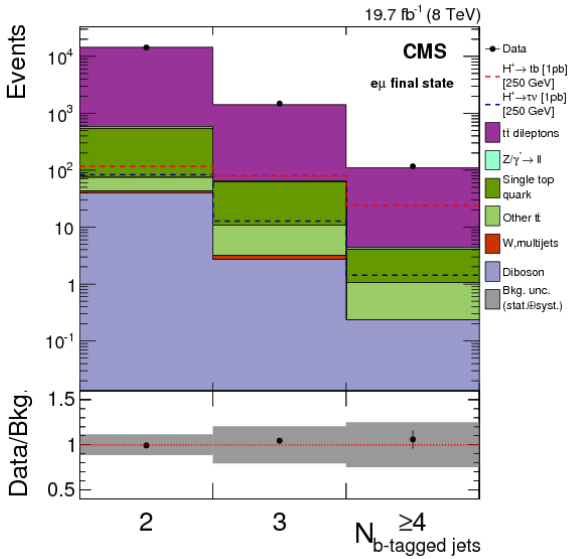
Source of uncertainty	Fractional uncertainty [%]	
	$m_{H^+} = 300$ GeV	$m_{H^+} = 500$ GeV
$t\bar{t}$ modelling	31	33
Jets	21	9.5
Flavour tagging	19	24
Other background modelling	9.6	12
Signal modelling	8.0	3.5
Lepton	1.2	0
Luminosity	1.1	0.4
Statistics	8.9	18

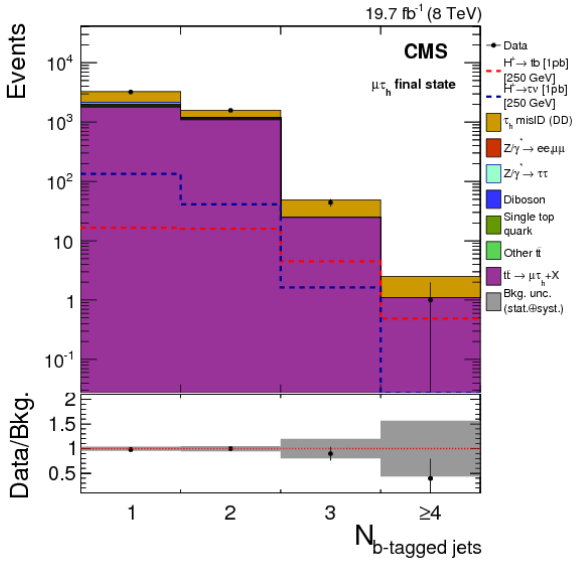
ATLAS collaboration, JHEP03 (2016) 127

Top associated $H^+ \to tb$ - CMS

Dilepton and $\mu\tau_{had}$:

- Limits extracted from event yields binned by the b-tagging multiplicity in dilepton and $\mu\tau_{had}$.
- SM $t\bar{t}$ normalization from simulation except for jets faking τ_{had} which is data driven.
- $tt + bb$ cross section uncorrelated bin-by-bin uncertainty of 44%.



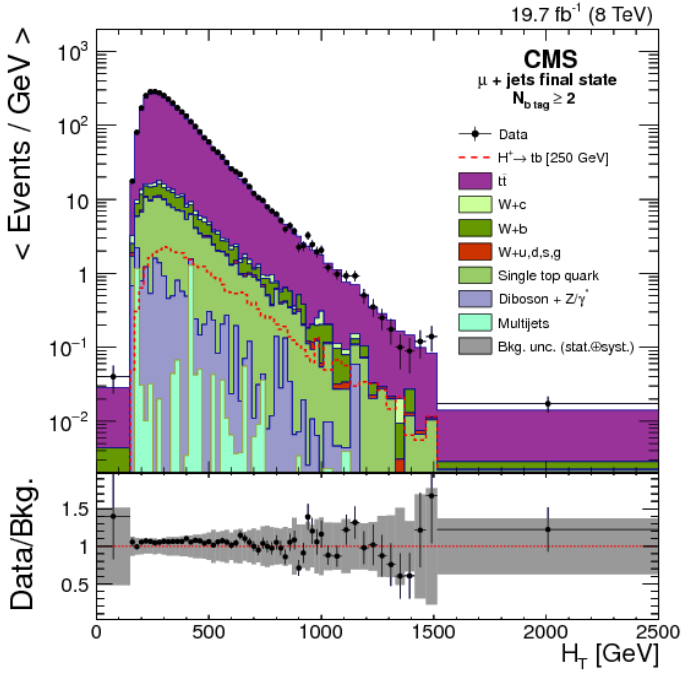


CMS collaboration, JHEP11 (2015) 018

Top associated $H^+ \to tb$ - CMS

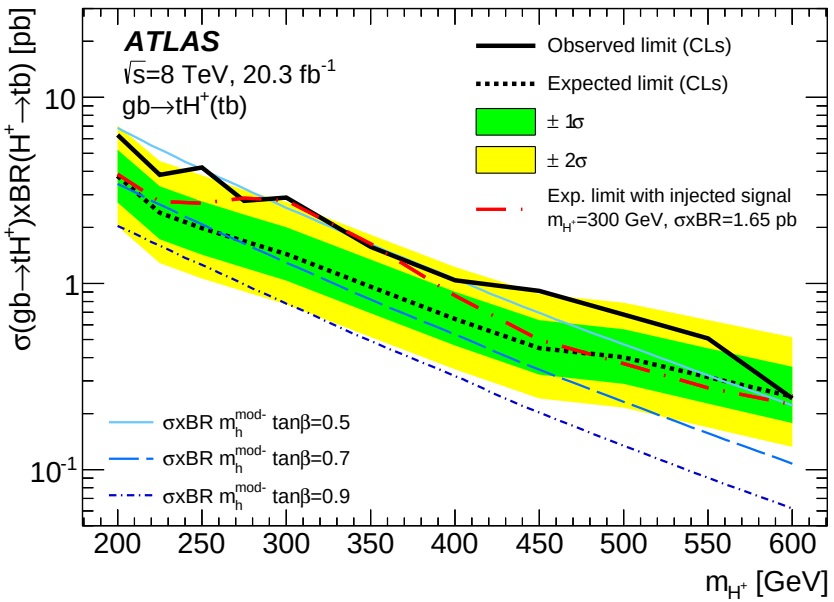
Lepton + jets:

- Limits from simultaneous fit of H_T in CR and SR.
- SM $t\bar{t}$ normalization floating in the fit and limit setting.
- No particlar $tt + bb$ normalization treatment, tt cross section uncertainty of 5% independent of b-tag multiplicity.

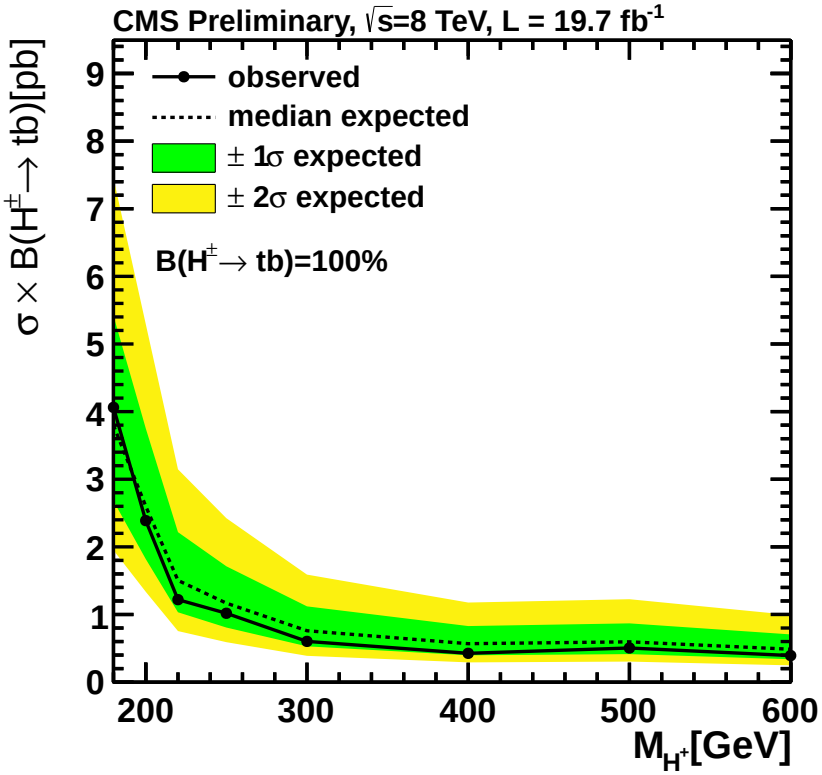


CMS collaboration, JHEP11 (2015) 018

Top associated $H^+ \to tb$ limits



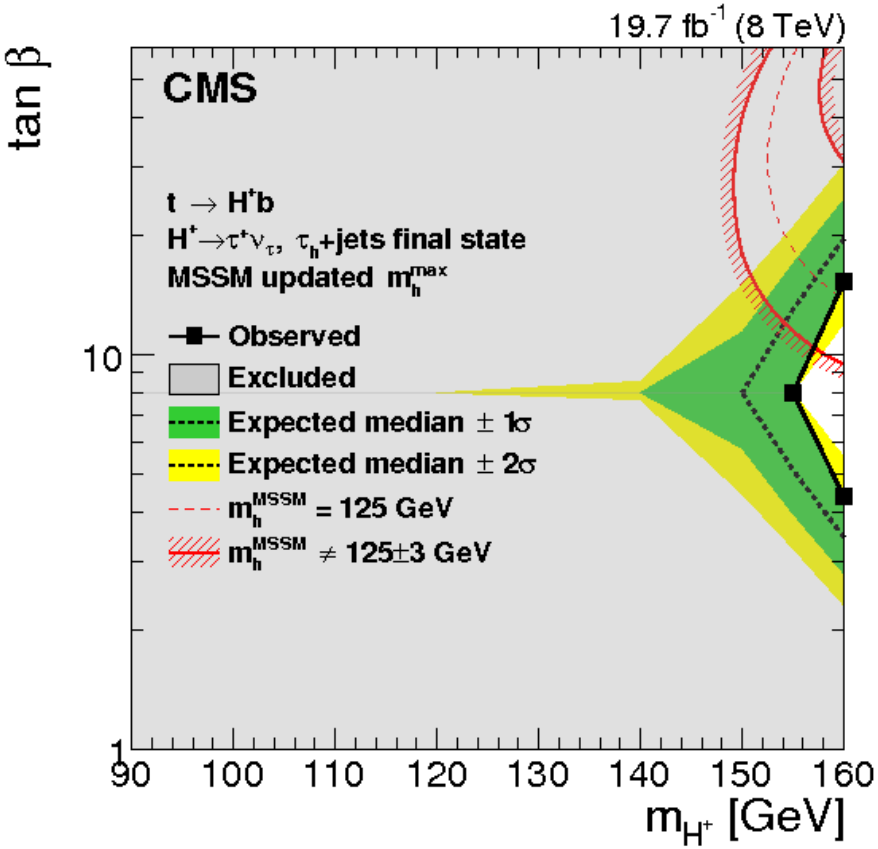
ATLAS collaboration, JHEP03 (2016) 127

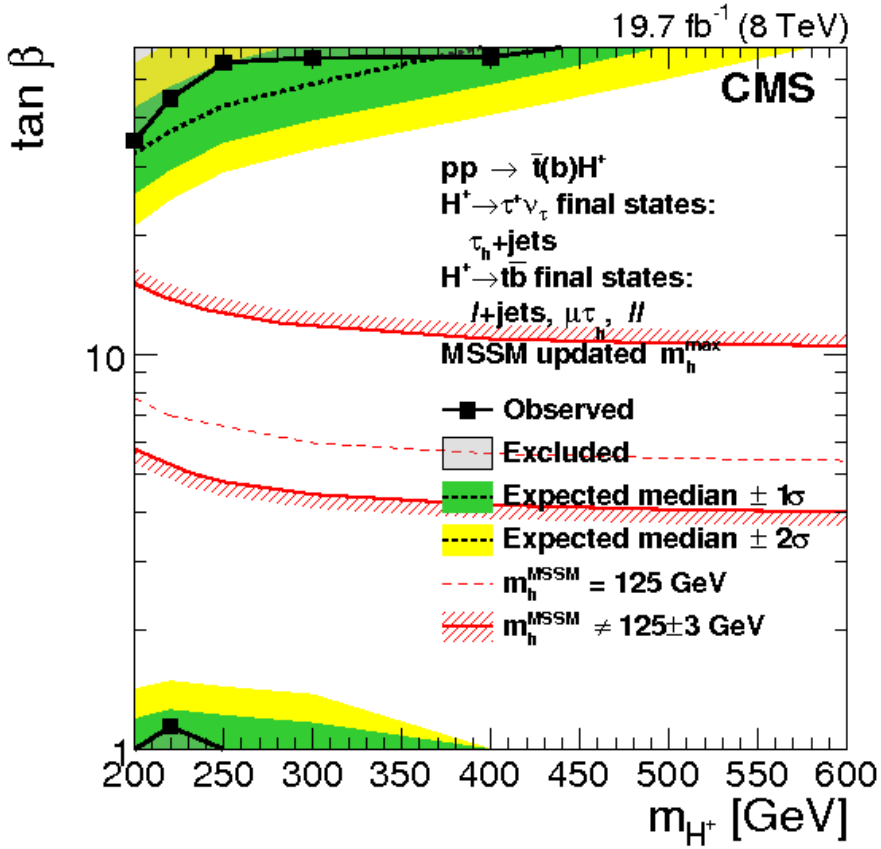


CMS collaboration, JHEP11 (2015) 018

- CMS has published the most stringent limits.
- ATLAS observed limits above the expected for almost the whole mass range, inconsistent with any injected signal.

Top associated $H^+ \to tb$ - CMS



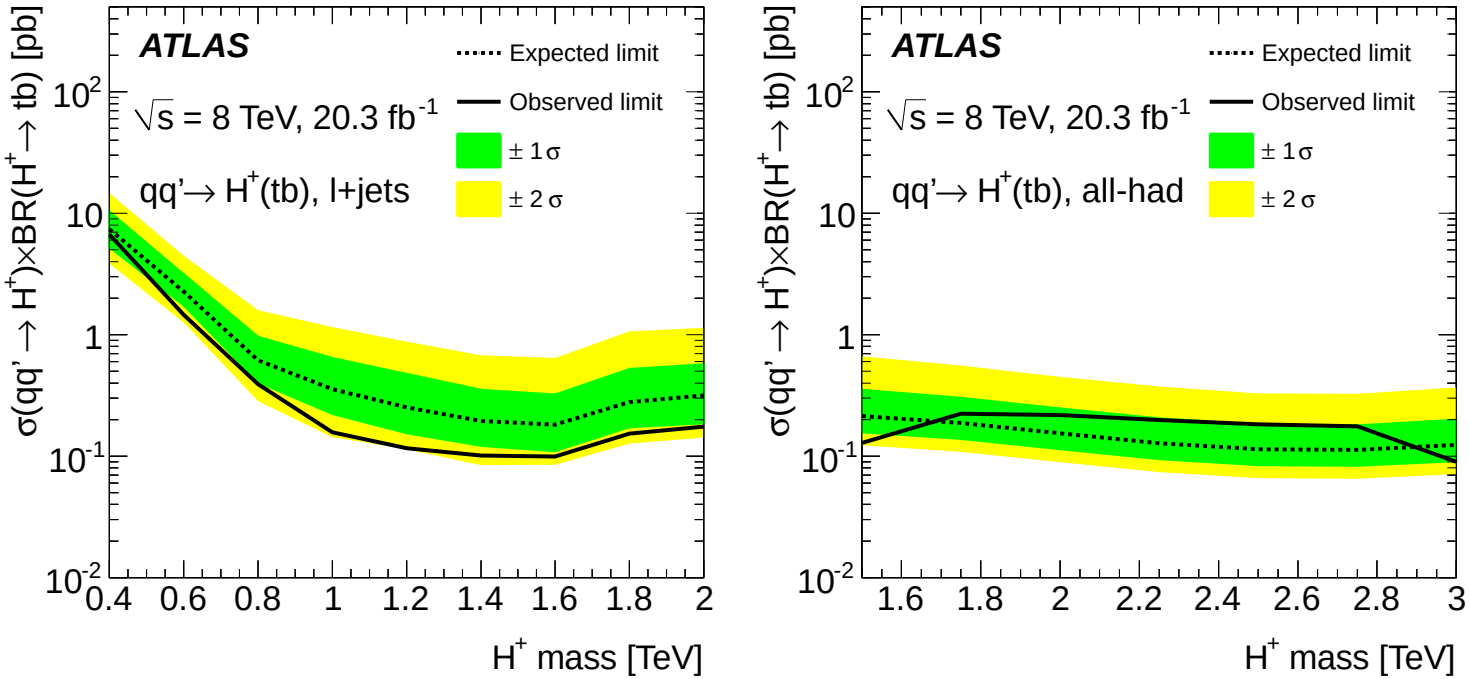


CMS collaboration, JHEP11 (2015) 018

- CMS combination exlusion in the MSSM m_h^{max} scenario.

s-channel $H^+ \to tb$ limits

- ATLAS published a reinterpretation of the W' search as s-channel H^+.
- No exclusion of any type-II 2HDM but first ATLAS probe of H^+ light quark coupling.



ATLAS collaboration, JHEP03 (2016) 127

Conclusion

- Both ATLAS and CMS have published many searches for H^+ and W' in association with tops.
- As evident by the CMS collaborations newest W' result we can expect improved results rather early in run-II, in part due to signal XS scaling faster with CM energy than e.g tt.
- No signs for a W' yet exlusion limits around 2 TeV.
- Large parts of the available parameter space for a H^+ are being excluded, higher mass regions, i.e m_{H^+} > 600 GeV, to be probed in run-II.

Backup

References

- *Search for $W' \to t\bar{b}$ in the lepton plus jets final state in proton-proton collisions at a centre-of-mass energy of $\sqrt{s}$ = 8 TeV with the ATLAS detector*, ATLAS collaboration, Physics Letters B 743(2015) 235-255.
- *Search for $W' \to t\bar{b}$ decays in the lepton + jets final state in pp collisions at $\sqrt{s}$ = 8 TeV*, CMS collaboration, JHEP05 (2014) 108.
- *Search for $W' \to qqbb$ decays in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector*, Eur. Phys. J.C (2015) 75.
- *Search for W' boson resonances decaying into a top quark and a bottom quark in the leptonic final state at $\sqrt{s}$ = 13 TeV*, CMS collaboration, CMS PAS B2G-15-004.
- *Search for charged Higgs bosons decaying via $H^{\pm} \to \tau^{\pm}\nu$ in fully hadronic final states using pp collision data at $\sqrt{s}$ = 8 TeV with the ATLAS detector*, JHEP03 (2015) 088.
- *Search for a charged Higgs boson in pp collisions at $\sqrt{s}$=8 TeV*, CMS collaboration, JHEP11 (2015) 018.
- *Search for charged Higgs bosons in the $H^{\pm} \to tb$ decay channel in pp collisions at $\sqrt{s} = 8$ TeV using the ATLAS detector*, ATLAS collaboration, JHEP03 (2016) 127.