Searches for fourth generation, vector-like quarks and $t\bar{t}$ resonances with the ATLAS detector

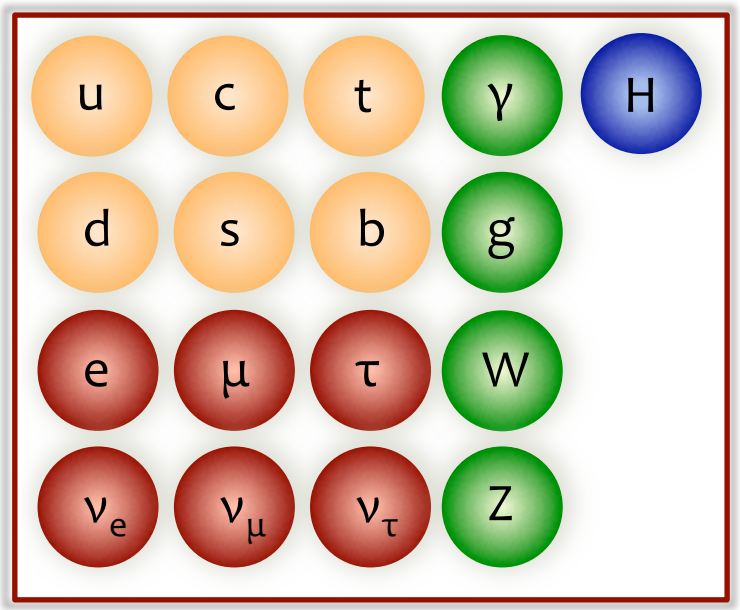
Snežana Nektarijević
Université de Genève, Geneva, Switzerland

On behalf of the ATLAS Collaboration

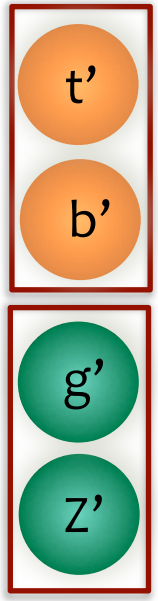
ATLAS

UNIVERSITÉ DE GENÈVE

In this Talk



Standard Model Particles



→ Heavy quarks
- Chiral fourth generation
- Vector-like quarks

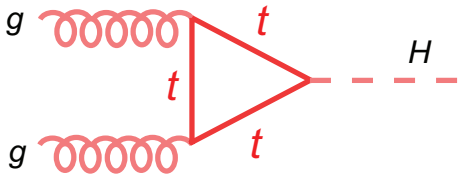
→ Heavy bosons decaying into $t\bar{t}$ pairs
- Topcolor models
- Randall-Sundrum models

… potentially addressing some of the SM open questions

Heavy Quark Searches

Heavy Quarks - *Theory*

J. A. Aguilar-Saavedra, JHEP 0911 (2009) 030
arXiv:0907.3155 [hep-ph]



- Chiral fourth generation quarks
  - additional source of CP violation
    - potentially addressing baryon asymmetry
  - Incompatible with the SM Higgs boson

- Vector-like quarks
  - Postulated by the models addressing the hierarchy problem without SUSY
    - Little Higgs models, extra dimension models etc
  - Left-handed and right-handed components transform the same way under SU(2)xU(1)
  - Cancel quadratic divergences of Higgs mass in the top loop
  - No Yukawa coupling to the Higgs field

VLQ singlet	Decay modes
$T_{+2/3}$	W^+b, Ht, Zt
$B_{-1/3}$	W^-t, Hb, Zb
$T_{+5/3}$	W^+t
$B_{-4/3}$	W^-b

VLQ doublet	Decay modes
$T_{+2/3}$ $B_{-1/3}$	W^+b, Ht, Zt W^-t, Hb, Zb
$T_{+2/3}$ $T_{+5/3}$	Ht, Zt W^+t
$B_{-1/3}$ $B_{-4/3}$	Hb, Zb W^-b

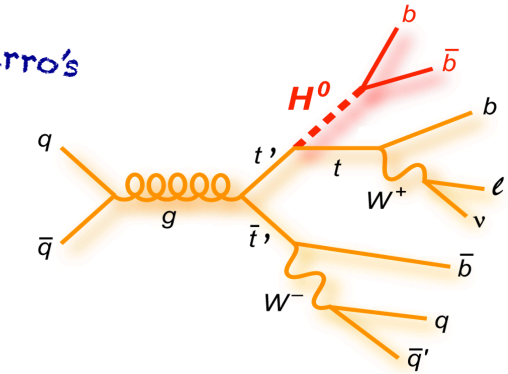
Dominant production mechanism at 7 TeV and 8 TeV: Pair production via strong interaction

$t'\bar{t}' \rightarrow Ht+X \rightarrow l+jets+E_T^{miss}$

ATLAS-CONF-2013-018
14.3 fb^{-1}, 8 TeV

Analysis Strategy

Antonella Succurro's Poster

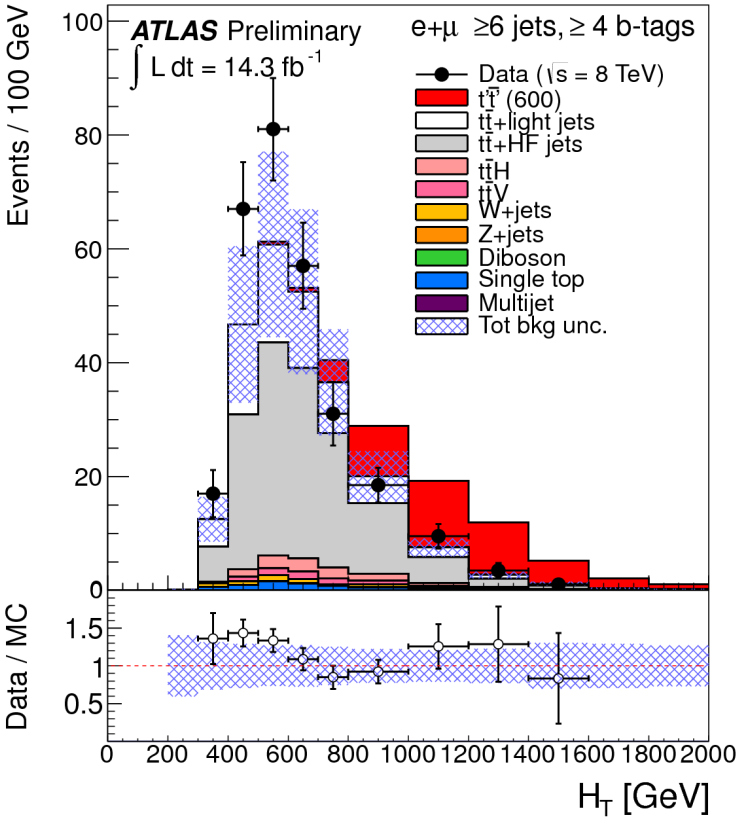


- Search for pair produced vector-like top (t'), in the final state with
  - at least one t'->Ht
  - one W->lν
- Final selection:
  - ≥ 6 jets, ≥ 4 *b* tags
- Discriminant: total transverse momentum H_T:

$$H_T = \sum_j p_T^j + p_T^l + E_T^{miss}$$

- Dominant background:
  - $t\bar{t}$+jets

  $t\bar{t}$+lf and $t\bar{t}$+hf simultaneously fitted to data
- Dominant systematic uncertainties:
  - *b* tagging efficiency, jet energy calibration, modeling (especially $t\bar{t}$+hf)



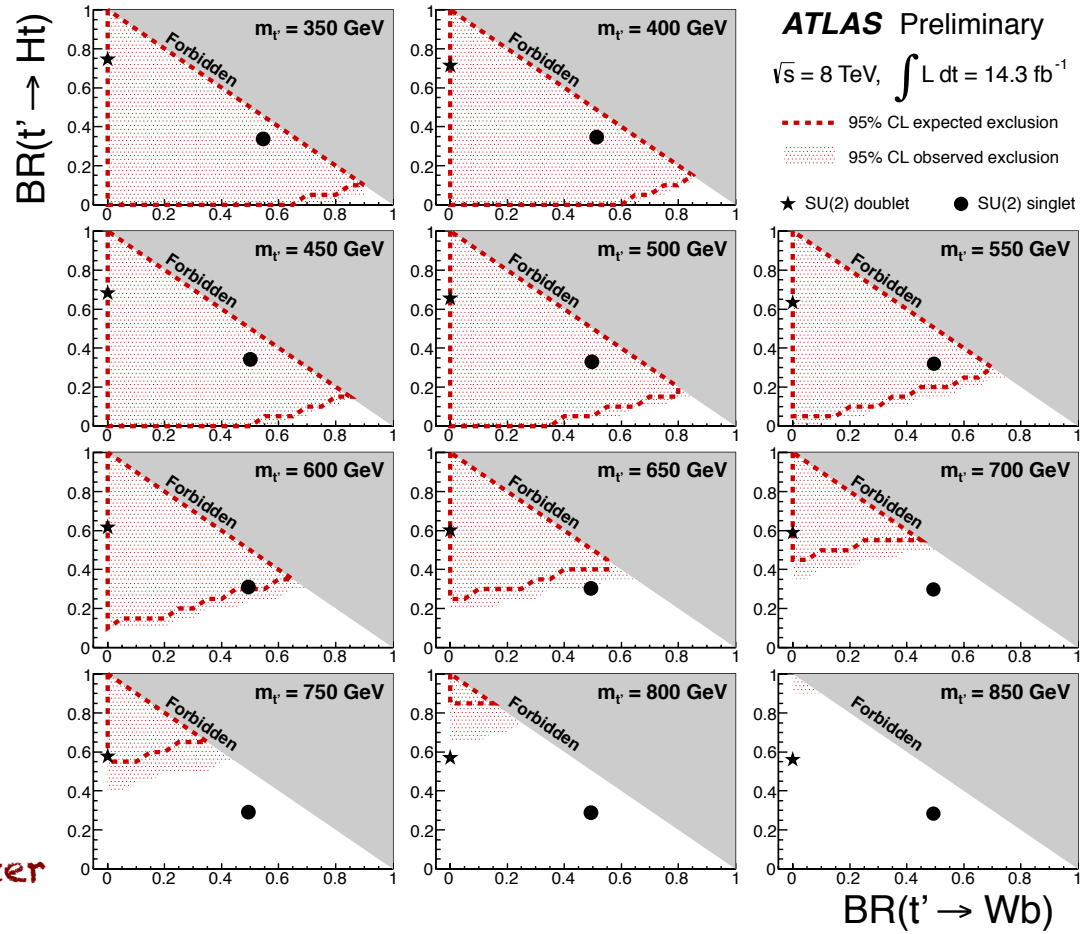
$t'\bar{t}' \rightarrow Ht + X \rightarrow l + jets + E_T^{miss}$

Interpretation

ATLAS-CONF-2013-018
14.3 fb^{-1}, 8 TeV

- Hypothesis testing with CLs method using log-likelihood ratio as test-statistic
  - Scaling factors of $t\bar{t}$+lf and $t\bar{t}$+hf fitted to data
- Limits at 95% CL placed in the BR(t'->Ht) vs BR(t'->Wb) plane

	$\geq$ 6 jets, 2 b-tags	$\geq$ 6 jets, 3 b-tags	$\geq$ 6 jets, 4 b-tags
Prediction	11860 $\pm$ 260	2990 $\pm$ 210	270 $\pm$ 60
Data	11885	2922	318



Bounds at 95% CL:

- Doublet:
  - $m_{t'}$ > 790 GeV
- Singlet:
  - $m_{t'}$ > 640 GeV

The t' search at 7 TeV covers the high BR(t'->Wb) region better (see backup)

X→Same-Sign Dilepton+Jets

Analysis Strategy

ATLAS-CONF-2013-051
14.3 fb^{-1}, 8 TeV

- Very low production rate in the SM
- Relatively model-independent search. Models compatible with this final state:
  - Fourth generation *b'*
  - Vector-like *B* and *T*
  - Positively charged *tt* production
  - $t\bar{t}t\bar{t}$ production
    - In the SM
    - Via contact interaction
- Final states tested include:
  - ≥ 2 same sign leptons ($e^{\pm}e^{\pm}$, $e^{\pm}\mu^{\pm}$, $\mu^{\pm}\mu^{\pm}$)
    - Z veto in $e^{\pm}e^{\pm}$, $\mu^{\pm}\mu^{\pm}$
  - ≥ 2 jets
  - E_T^{miss} >= 40 GeV

Final selection optimized for every signal separately:

Data/Prediction comparison for ≥1 b tag

	ee	$e\mu$	$\mu\mu$
Prediction	2.7 ± 0.6	4.4 ± 1.0	2.3 ± 1.2
Data	3	10	2

- Data driven fake leptons and charge misidentification rate estimation
- Dominant systematic uncertainty:
  - Predicted background cross sections
- Limits extracted by cut and count technique

	b' and VLQ	$t\bar{t}$	$t\bar{t}t\bar{t}$
H_T	$> 650\,\mathrm{GeV}$	$> 550\,\mathrm{GeV}$	$> 650\,\mathrm{GeV}$
$N_{b\text{-jets}}$	≥ 1	≥ 1	≥ 2
Charge	$\pm\pm$	$++$	$\pm\pm$

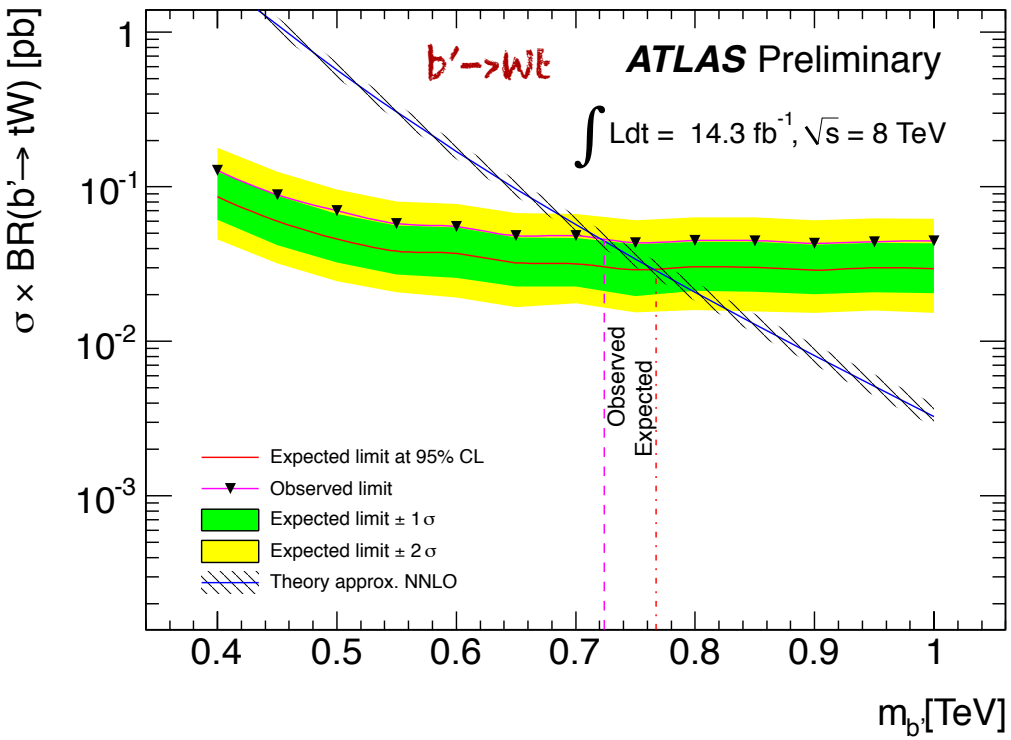
X→Same-Sign Dilepton+Jets

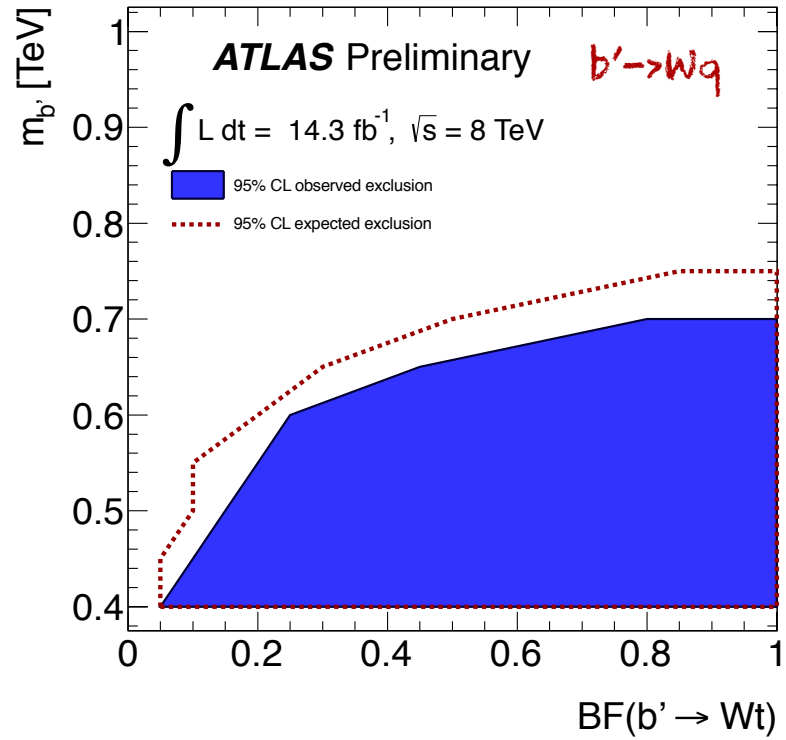
b' Interpretation

ATLAS-CONF-2013-051
14.3 fb^{-1}, 8 TeV

The 95% CL limits found to be:

- $m_{b'} > 0.72$ TeV BR(b'->Wt)=1





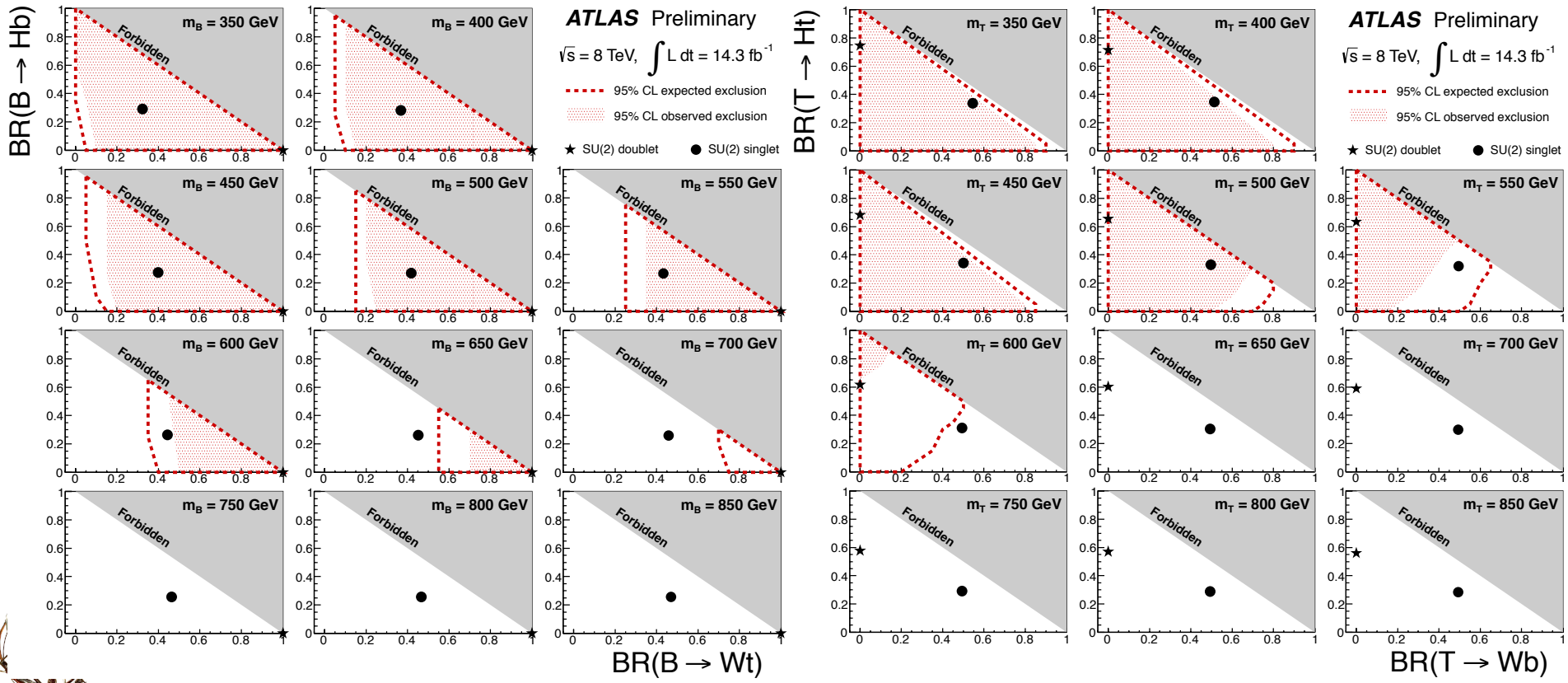
X→Same-Sign Dilepton+Jets

VLQ Interpretation

ATLAS-CONF-2013-051
14.3 fb^{-1}, 8 TeV

The 95% CL limits found to be:

- $m_B > 0.59$ TeV, assuming B ->Wt/Hb/Zb
- $m_T > 0.54$ TeV, assuming T->Wb/Ht/Zt



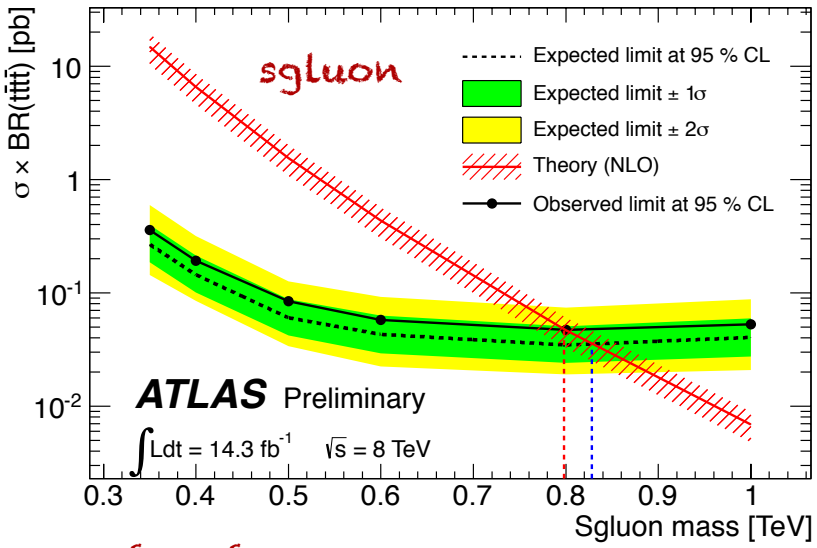
X→Same-Sign Dilepton+Jets

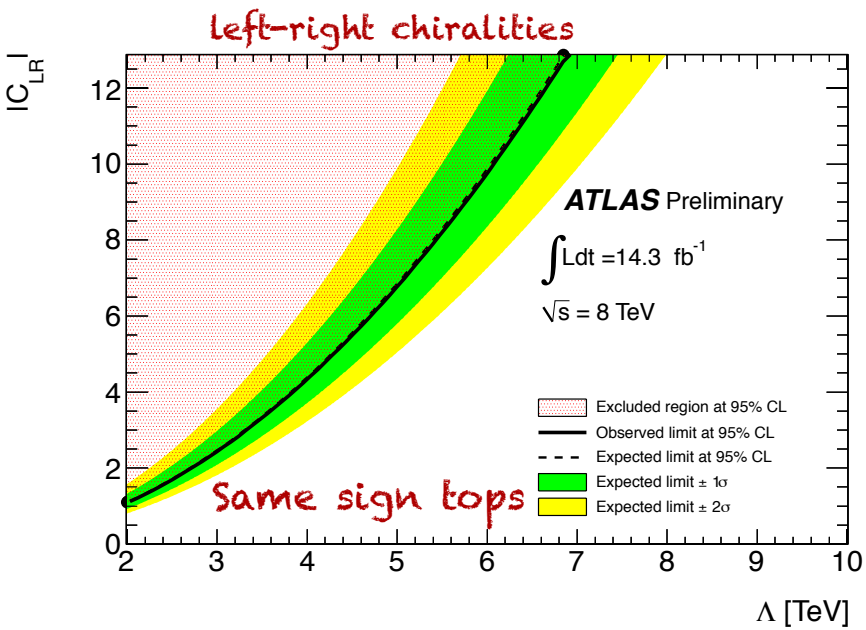
$t\bar{t}$ and $t\bar{t}t\bar{t}$ Interpretation

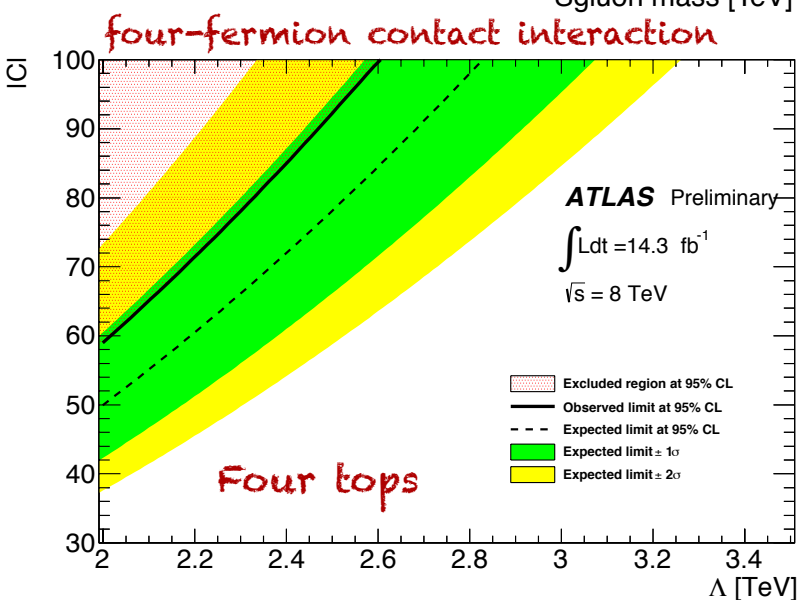
ATLAS-CONF-2013-051
14.3 fb^{-1}, 8 TeV

The 95% CL limits found to be:

- $\sigma(tt) < 0.21$ pb
- $\sigma(t\bar{t}t\bar{t}) < 85\ (59)$ fb in SM (c.i.)
- $m_{sgluon} > 0.80$ TeV
- $m_{KK} > 0.90$ TeV



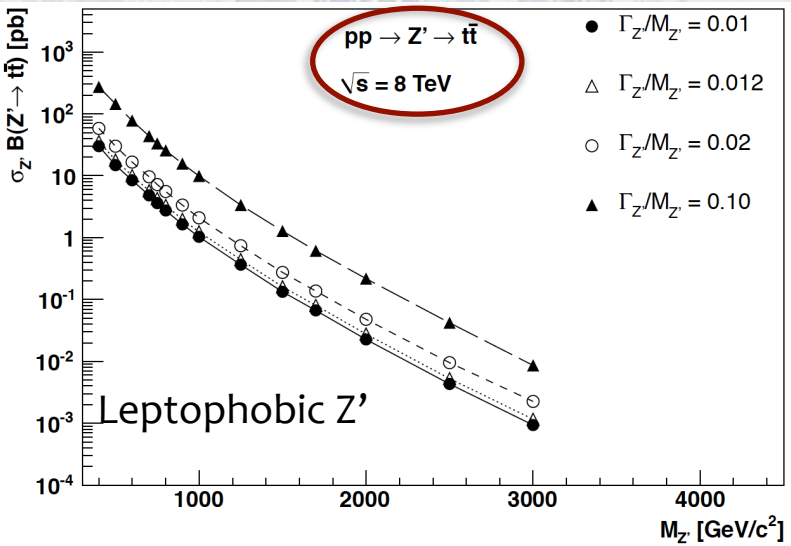


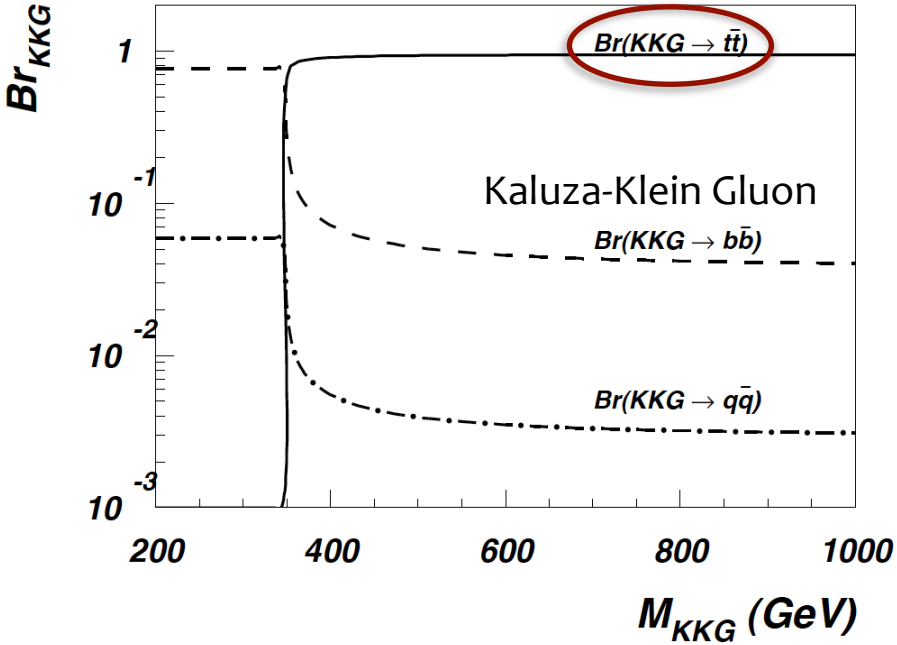


$t\bar{t}$ Resonances Searches

$t\bar{t}$ Resonances
Theory

- Benchmark models used by the LHC experiments:
  - Narrow width leptophobic topcolor Z' boson with Γ/m ~ 1.2%
    - Explains the top quark mass and the EWSB through top quark condensation associated with symmetry breaking of a new strong force
      (Eur.Phys.J. C72 (2012) 2072)
  - Wide width Kaluza-Klein gluon with Γ/m ~ 15%
    - Arises in the bulk Randall-Sundrum model with an extra dimension with warped geometry
      (Phys. Rev. D77 (2008) 015003)





$t\bar{t} \rightarrow l+jets+E_T^{miss}$

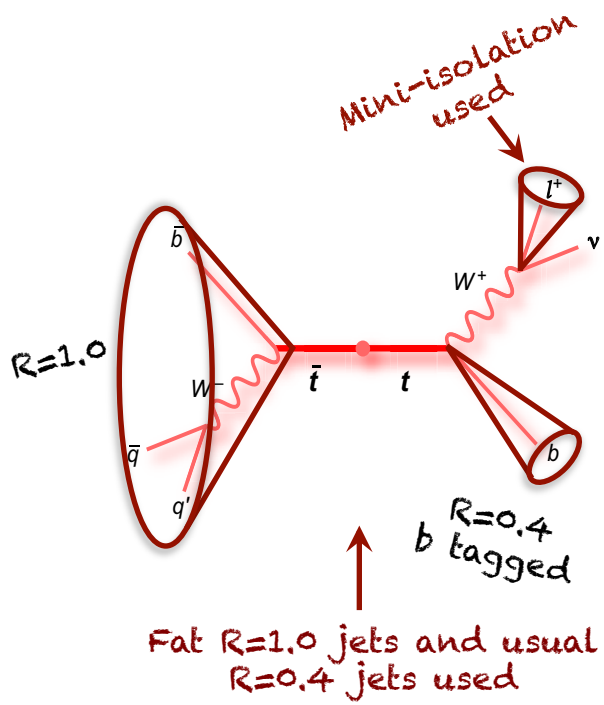
Analysis Strategy

ATLAS-CONF-2013-052
14.3 fb^{-1}, 8 TeV

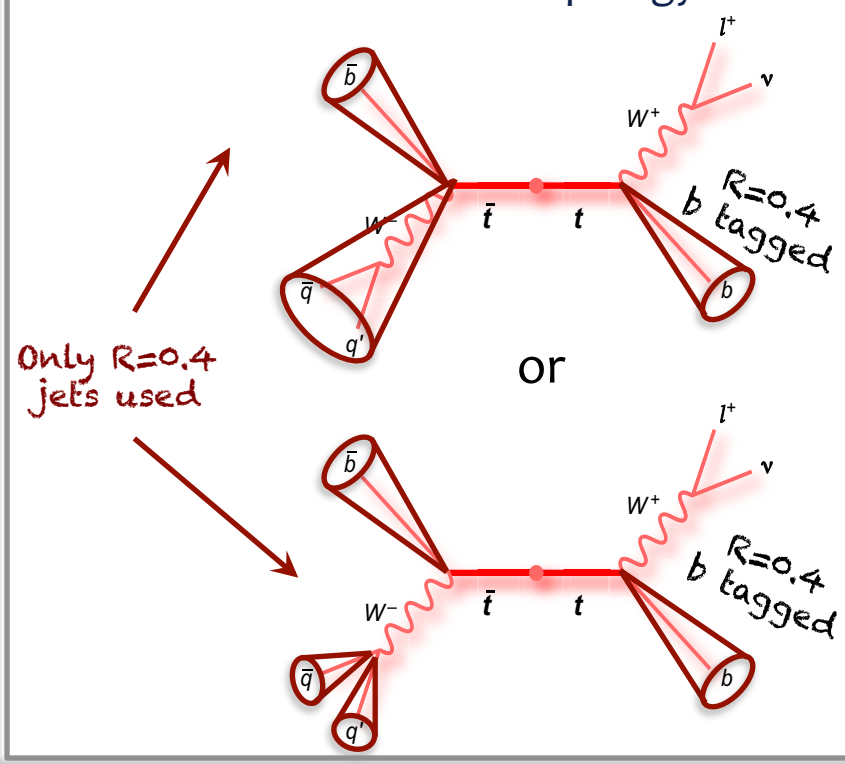
- Search for heavy resonances decaying into $t\bar{t}$ pairs in the $l+jets+E_T^{miss}$ final state

Benjamin Dechenaux's Poster

- Boosted topology:



- Resolved topology:



See backup for the search with fully hadronic final state at 7 TeV

$t\bar{t} \rightarrow l+jets+E_T^{miss}$

Analysis Strategy

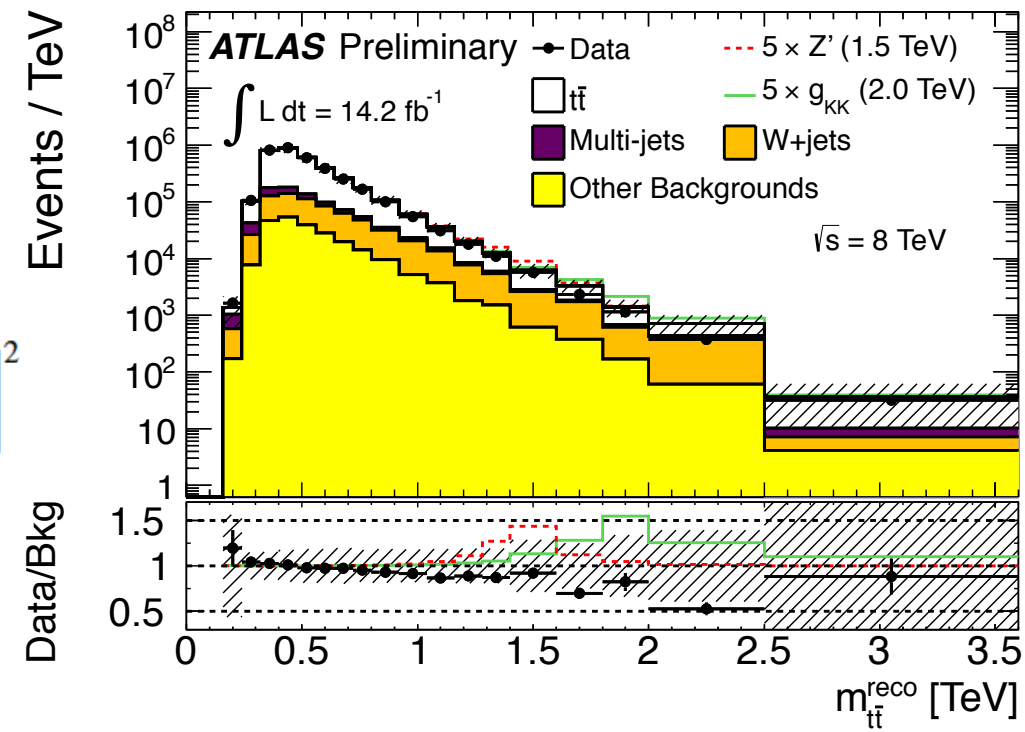
ATLAS-CONF-2013-052
14.3 fb^{-1}, 8 TeV

- Discriminant: reconstructed $t\bar{t}$ mass
- Event reconstruction:
  - Boosted:
    - no ambiguities
  - Resolved:
    - Neutrino p_Z and jet assignment by minimizing the χ^2 function:

$$\chi^2 = \left[\frac{m_{jj} - m_W}{\sigma_W}\right]^2 + \left[\frac{m_{jjb} - m_{jj} - m_{t_h - W}}{\sigma_{t_h - W}}\right]^2 + \left[\frac{m_{j\ell\nu} - m_{t_\ell}}{\sigma_{t_\ell}}\right]^2 + \left[\frac{(p_{T,jjb} - p_{T,j\ell\nu}) - (p_{T,t_h} - p_{T,t_\ell})}{\sigma_{\mathrm{diff}\,p_T}}\right]^2$$

- The dominant systematic uncertainty:
  - $t\bar{t}$ cross section

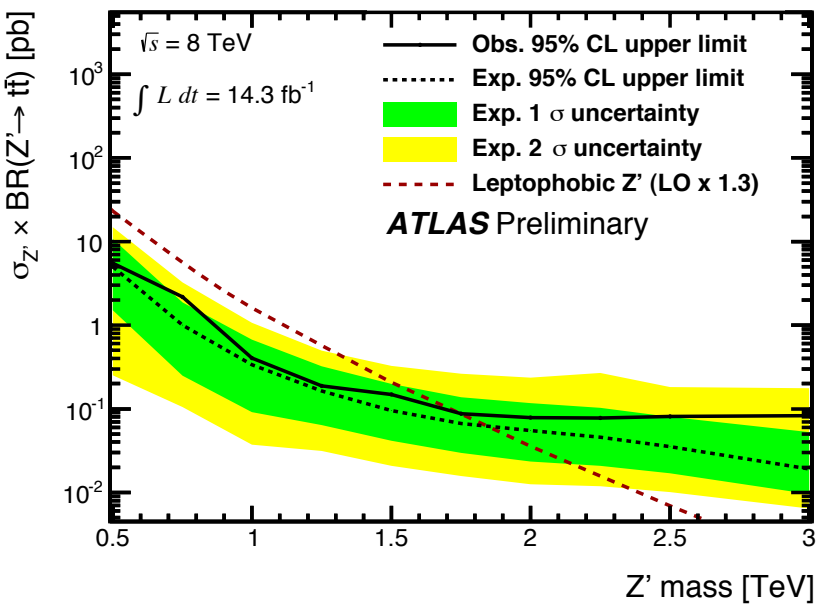
$e+\mu$ Channel	Boosted	Resolved
Prediction	5600 ± 1200	283000 ± 39000
Data	5122	280251

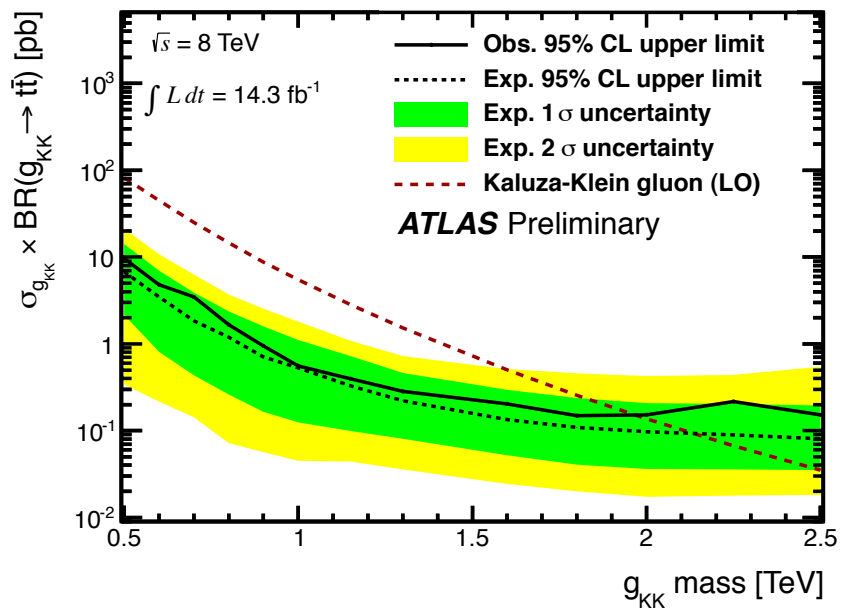


$t\bar{t} \rightarrow l+jets+E_T^{miss}$
Interpretation

ATLAS-CONF-2013-052
14.3 fb^{-1}, 8 TeV

- Data/Prediction agreement scaned over the full $t\bar{t}$ mass range using the BumpHunter, taking the look-elsewhere effect into account
- Bayesian exclusion limits placed





Z' exclusion mass range at 95% CL:
0.5 TeV < $m_{Z'}$ < 1.8 TeV

Kaluza-Klein gluon exclusion mass range at 95% CL:
0.5 TeV < m_{gkk} < 2.0 TeV

Summary

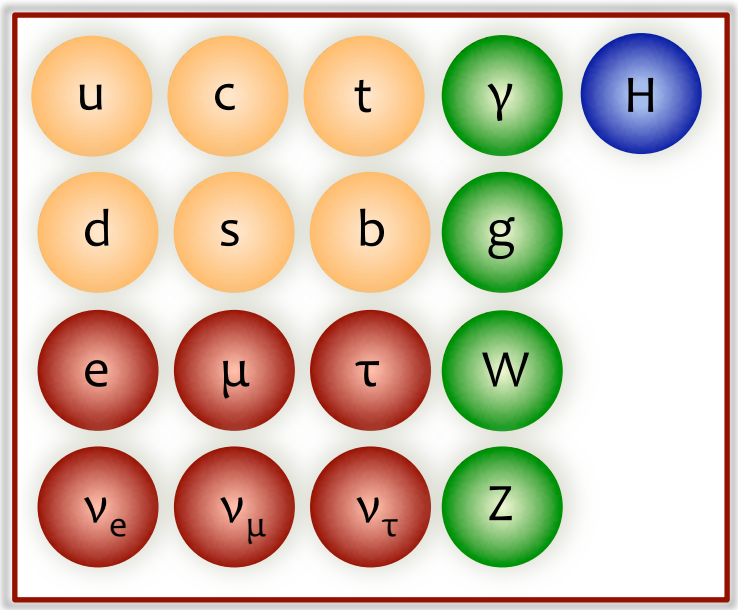
- No evidence of presence of pair-produced fourth generation and vector-like quarks, same-sign top pair production, four top production and heavy bosons decaying into top-antitop pairs has been observed.

- The following 95% CL limits have been placed:

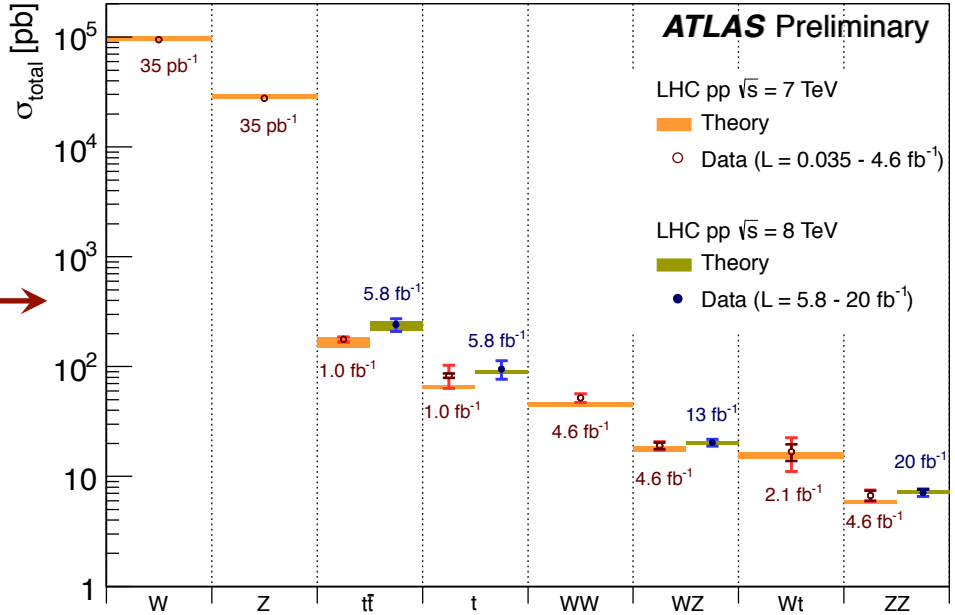
Particle/process	Limit	Decay mode / final state	CME [TeV]
4G t' / $B_{-4/3}$	m > 656 GeV	t'/$T_{+5/3}$->Wb	7
4G b'	m > 720 GeV	b'->Wt	8
$T_{+2/3}$ singlet	m > 640 GeV	t'->Ht	8
$T_{+2/3}$ doublet	m > 790 GeV	t'->Ht	8
$B_{-1/3}$ doublet	m > 590 GeV	Same-sign dilepton	8
leptophobic Z'	$m_{Z'}$ < 0.5 TeV or $m_{Z'}$ > 1.8 TeV	Z'->$t\bar{t}$	8
K-K gluon	m_{gkk} < 0.5 TeV or m_{gkk} > 2.0 TeV	g_{kk}->$t\bar{t}$	8
4-tops production	$\sigma(t\bar{t}t\bar{t})$ < 85 fb in SM $\sigma(t\bar{t}t\bar{t})$ < 59 fb via c.i.	Same-sign dilepton	8
Same-sign top pair production	$\sigma(tt)$ < 21 fb	Same-sign dilepton	8

Backup

Motivation



Standard Model Particles



- The ATLAS detector very well calibrated by the SM precision measurements with 7 TeV and 8 TeV data
- Now we can look for new physics!

Common Object Definitions

- Electrons
  - Isolated EM calorimeter objects matched to inner detector tracks
    - p_T>25 GeV, $|\eta| < 2.47$ excluding $1.37<|\eta|<1.52$
- Muons
  - Track segments from the muon spectrometer matched to inner detector tracks
    - p_T>20GeV, $|\eta| < 2.5$
- Jets
  - Reconstructed from topological clusters with the inclusive AntikT algorithm with R=0.4
    - p_T>20GeV, $|\eta| < 2.5$
- Fat Jets
  - Reconstructed from the locally-calibrated topological clusters using the inclusive AntikT algorithm with R=1

- Common event selection:
  - Single el/mu trigger
  - >=1 primary vertex with >=5 associated tracks

- In lepton + jets searches:
  - Separate el and mu channel

ATLAS Collaboration, ATLAS-CONF-2013-018

14.3 fb^{-1}, 8 TeV

t't'->Ht+X->l+jets+E_T^{miss} – Event Yields

	≥ 6 jets, 2 b-tags	≥ 6 jets, 3 b-tags	≥ 6 jets, ≥ 4 b-tags
$t\bar{t}$+heavy-flavour jets	1500 ± 900	900 ± 400	170 ± 70
$t\bar{t}$+light-flavour jets	9600 ± 1000	1900 ± 350	75 ± 22
W+jets	250 ± 130	50 ± 30	5 ± 3
Z+jets	50 ± 40	9 ± 6	0.5 ± 0.9
Single top	300 ± 70	75 ± 18	7 ± 3
Diboson	1.7 ± 0.6	0.3 ± 0.1	0.03 ± 0.03
$t\bar{t}V$	70 ± 20	36 ± 12	7 ± 3
$t\bar{t}H$	28 ± 4	31 ± 6	12 ± 3
Multijet	49 ± 23	1.7 ± 0.8	0.15 ± 0.06
Total background	11860 ± 260	2990 ± 210	270 ± 60
Data	11885	2922	318
Doublet			
$t'\bar{t}'$(400)	550 ± 70	1100 ± 100	790 ± 160
$t'\bar{t}'$(600)	4.3 ± 1.2	94 ± 7	79 ± 18
$t'\bar{t}'$(800)	0.12 ± 0.05	10.7 ± 0.8	9.1 ± 2.1
Singlet			
$t'\bar{t}'$(400)	290 ± 30	650 ± 80	330 ± 70
$t'\bar{t}'$(600)	2.3 ± 0.4	61 ± 7	36 ± 9
$t'\bar{t}'$(800)	0.06 ± 0.01	6.9 ± 0.7	4.2 ± 1.1

Table 1: Predicted and observed yields in the combined e+jets and μ+jets channels with ≥ 6 jets as a function of b-tag multiplicity. The $t\bar{t}$ background prediction is after fitting to data using the full H_T spectrum (see text for details). Also shown is the expected $t'\bar{t}'$ signal in both the doublet and singlet scenarios for $m_{t'}$ = 400, 600 and 800 GeV. The uncertainties shown are post-fit and include the effect of statistical and systematic uncertainties. The uncertainty on the total background is smaller than the sum in quadrature of the uncertainties on the individual background sources due to the anti-correlation between the $t\bar{t}$+light jets and $t\bar{t}$+heavy-flavour jets components resulting from the fit.

Same-Sign 8 TeV
b'/VLQ Signal Region Event Yields

Table 5: Observed and expected number of events with statistical (first) and systematic (second) uncertainties for the b'/VLQ signal selection.

Backgrounds	Channel		
Samples	ee	$e\mu$	$\mu\mu$
Charge misidentification	$0.6 \pm 0.1 \pm 0.2$	$0.9 \pm 0.1 \pm 0.3$	—
Fakes	$0.8 \pm 0.4 \pm 0.3$	$0.2 \pm 0.4 \pm 0.1$	< 1.1
Diboson			
• WZ/ZZ+jets	$0.3 \pm 0.2 \pm 0.1$	$0.3 \pm 0.1^{+0.4}_{-0.2}$	$0.4 \pm 0.2 \pm 0.1$
• $W^{\pm}W^{\pm}$+2 jets	$0.17 \pm 0.09 \pm 0.05$	$0.3 \pm 0.2 \pm 0.1$	$0.2 \pm 0.1 \pm 0.1$
$t\bar{t} + W/Z$			
• $t\bar{t}W$(+jet(s))	$0.6 \pm 0.2 \pm 0.3$	$1.9 \pm 0.2 \pm 0.6$	$1.3 \pm 0.2 \pm 0.4$
• $t\bar{t}Z$(+jet(s))	$0.18 \pm 0.03 \pm 0.06$	$0.66 \pm 0.05 \pm 0.22$	$0.31 \pm 0.04 \pm 0.10$
• $t\bar{t}W^+W^-$	$0.024 \pm 0.003^{+0.010}_{-0.007}$	$0.072 \pm 0.005^{+0.028}_{-0.020}$	$0.055 \pm 0.004^{+0.022}_{-0.016}$
Total expected background	$2.7 \pm 0.5 \pm 0.4$	$4.4 \pm 0.5^{+0.9}_{-0.7}$	$2.3 \pm 1.2 \pm 0.5$
Observed	3	10	2

Table 8: Event selection efficiencies (in percent), relative to the inclusive cross section for the $b' \to Wt$ and $b' \to Wq$ ($\sim 1/3$ for each $q = u, c, t$) signals, for several generated mass points. They are computed with respect to the generated events passing the lepton filter, and where the W is free to decay hadronically or leptonically.

Process	Channel		
	ee	$e\mu$	$\mu\mu$
b'(400 GeV) $\to Wt$	0.11 ± 0.01	0.39 ± 0.02	0.25 ± 0.02
b'(600 GeV) $\to Wt$	0.30 ± 0.02	0.82 ± 0.03	0.53 ± 0.02
b'(800 GeV) $\to Wt$	0.37 ± 0.02	1.02 ± 0.03	0.64 ± 0.02
b'(1000 GeV) $\to Wt$	0.35 ± 0.02	1.11 ± 0.03	0.63 ± 0.02
b'(400 GeV) $\to Wq$	0.024 ± 0.004	0.082 ± 0.007	0.060 ± 0.006
b'(600 GeV) $\to Wq$	0.09 ± 0.01	0.25 ± 0.01	0.14 ± 0.01
b'(800 GeV) $\to Wq$	0.13 ± 0.01	0.32 ± 0.01	0.19 ± 0.01
b'(1000 GeV) $\to Wq$	0.10 ± 0.01	0.32 ± 0.02	0.20 ± 0.01

Table 9: Event selection efficiencies (in percent), relative to the inclusive cross section for the vector-like T (B) signal for several generated T (B) mass points. Efficiencies are computed assuming the branching ratios from the singlet model.

Process	Channel		
	ee	$e\mu$	$\mu\mu$
TT (350 GeV)	0.013 ± 0.002	0.038 ± 0.003	0.024 ± 0.003
TT (550 GeV)	0.055 ± 0.004	0.136 ± 0.006	0.082 ± 0.005
TT (750 GeV)	0.065 ± 0.005	0.176 ± 0.008	0.080 ± 0.005
TT (850 GeV)	0.065 ± 0.005	0.171 ± 0.007	0.093 ± 0.005
BB (350 GeV)	0.011 ± 0.002	0.043 ± 0.004	0.024 ± 0.003
BB (550 GeV)	0.068 ± 0.005	0.218 ± 0.008	0.129 ± 0.006
BB (750 GeV)	0.098 ± 0.006	0.269 ± 0.009	0.185 ± 0.008
BB (850 GeV)	0.128 ± 0.006	0.344 ± 0.010	0.191 ± 0.008

ATLAS

Same-Sign 8 TeV
tt Signal Region Event Yields

Table 6: Observed and expected number of events with statistical (first) and systematic (second) uncertainties for the positively-charged top pair signal selection.

Samples	Channel		
	ee	$e\mu$	$\mu\mu$
Charge misidentification	$0.6 \pm 0.1 \pm 0.2$	$0.5 \pm 0.1 \pm 0.2$	—
Fakes	$0.6 \pm 0.4 \pm 0.2$	$1.0 \pm 0.4 \pm 0.3$	$0.7 \pm 0.7 \pm 0.2$
Diboson			
• WZ/ZZ+jets	$0.2 \pm 0.1 \pm 0.1$	$0.5 \pm 0.3 \pm 0.2$	$0.6 \pm 0.3 \pm 0.2$
• $W^{\pm}W^{\pm}$+2 jets	$0.16 \pm 0.08 \pm 0.04$	$0.3 \pm 0.2 \pm 0.1$	$0.2 \pm 0.1 \pm 0.1$
$t\bar{t} + W/Z$			
• $t\bar{t}W$(+jet(s))	$0.7 \pm 0.1 \pm 0.2$	$2.2 \pm 0.1 \pm 0.7$	$1.5 \pm 0.1 \pm 0.5$
• $t\bar{t}Z$(+jet(s))	$0.18 \pm 0.03 \pm 0.06$	$0.59 \pm 0.05 \pm 0.19$	$0.26 \pm 0.03 \pm 0.09$
• $t\bar{t}W^{+}W^{-}$	$0.013 \pm 0.002 \pm 0.005$	$0.053 \pm 0.004 \pm 0.021$	$0.032 \pm 0.003 \pm 0.013$
Total	$2.5 \pm 0.4 \pm 0.4$	$5.1 \pm 0.5 \pm 0.9$	$3.3 \pm 0.8 \pm 0.7$
Observed	3	8	1

Table 10: Event selection efficiencies (in percent), relative to the dileptonic cross section (both W bosons must decay to e, μ or τ), for the positively-charged top pair signal.

Process	Channel		
	ee	$e\mu$	$\mu\mu$
Left-left	0.48 ± 0.02	1.59 ± 0.04	1.27 ± 0.04
Left-right	0.41 ± 0.02	1.46 ± 0.04	1.19 ± 0.03
Right-right	0.40 ± 0.02	1.42 ± 0.04	1.14 ± 0.03

Same-Sign 8 TeV
4-tops Signal Region Event Yields

Table 7: Observed and expected number of events with statistical (first) and systematic (second) uncertainties for the four top quarks signal selection.

Samples	Channel		
	ee	$e\mu$	$\mu\mu$
Charge misidentification	$0.16 \pm 0.04 \pm 0.05$	$0.41 \pm 0.07 \pm 0.12$	—
Fakes	$0.18 \pm 0.17 \pm 0.05$	$0.07 \pm 0.28 \pm 0.02$	< 1.14
Diboson			
• WZ/ZZ+jets	< 0.1	$0.01 \pm 0.09 \pm 0.01$	< 0.11
• $W^{\pm}W^{\pm}$+2 jets	< 0.03	$0.18 \pm 0.16 \pm 0.07$	< 0.03
$t\bar{t} + W/Z$			
• $t\bar{t}W$(+jet(s))	$0.31 \pm 0.04 \pm 0.12$	$0.93 \pm 0.06 \pm 0.35$	$0.65 \pm 0.06 \pm 0.25$
• $t\bar{t}Z$(+jet(s))	$0.09 \pm 0.02 \pm 0.04$	$0.34 \pm 0.04 \pm 0.14$	$0.14 \pm 0.02 \pm 0.06$
• $t\bar{t}W^+W^-$	$0.012 \pm 0.002 \pm 0.005$	$0.039 \pm 0.003 \pm 0.016$	$0.024 \pm 0.003 \pm 0.01$
Total	$0.8 \pm 0.2 \pm 0.1$	$2.0 \pm 0.4 \pm 0.4$	$0.8 \pm 1.2 \pm 0.3$
Observed	1	6	1

Table 11: Event selection efficiencies (in percent), relative to the inclusive cross section, for the four top quarks signals (all decay modes of the W are included).

Process	Channel		
	ee	$e\mu$	$\mu\mu$
Standard Model	0.11 ± 0.01	0.39 ± 0.01	0.28 ± 0.01
Contact interaction	0.15 ± 0.01	0.53 ± 0.02	0.41 ± 0.02
Sgluon (350 GeV)	0.03 ± 0.01	0.09 ± 0.01	0.07 ± 0.01
Sgluon (400 GeV)	0.06 ± 0.01	0.17 ± 0.02	0.13 ± 0.02
Sgluon (500 GeV)	0.13 ± 0.02	0.47 ± 0.03	0.23 ± 0.02
Sgluon (600 GeV)	0.15 ± 0.02	0.61 ± 0.04	0.41 ± 0.03
Sgluon (800 GeV)	0.20 ± 0.02	0.75 ± 0.04	0.48 ± 0.03
Sgluon (1000 GeV)	0.16 ± 0.02	0.57 ± 0.03	0.49 ± 0.03
2UED/RPP (600 GeV)	0.26 ± 0.01	0.93 ± 0.02	0.66 ± 0.02
2UED/RPP (800 GeV)	0.25 ± 0.01	0.88 ± 0.02	0.67 ± 0.02
2UED/RPP (1000 GeV)	0.23 ± 0.01	0.85 ± 0.02	0.67 ± 0.02
2UED/RPP (1200 GeV)	0.22 ± 0.01	0.88 ± 0.02	0.67 ± 0.02

Same-Sign 8 TeV
Table of Systematic Uncertainties

Table 3: Leading sources of systematic uncertainty on the signal and background estimates for the b'/VLQ selection, and their relative impact on the total background estimate. A b' mass of 650 GeV is assumed.

	Uncertainty in %					
	650 GeV b'			Background		
Source	ee	$e\mu$	$\mu\mu$	ee	$e\mu$	$\mu\mu$
Cross section	–	–	–	14.4	25.4	32.9
Fakes	–	–	–	9.7	1.4	10.1
Charge misidentification	–	–	–	7.2	7.1	–
Jet energy scale	4.6	2.5	0.2	3.5	10.2	4.4
ISR/FSR	6.0	6.0	6.0	2.6	4.5	4.0
b-tagging efficiency	4.6	3.1	3.0	2.1	4.4	4.0
Lepton ID efficiency	5.3	4.9	8.2	2.2	3.6	5.4
Jet energy resolution	0.8	0.9	0.3	0.9	2.7	2.0
Luminosity	3.6	3.6	3.6	1.6	2.7	3.6
Lepton energy scale	0.8	0.4	0.0	1.4	0.9	0.1
JVF selection efficiency	2.5	2.9	2.6	1.1	1.5	1.4

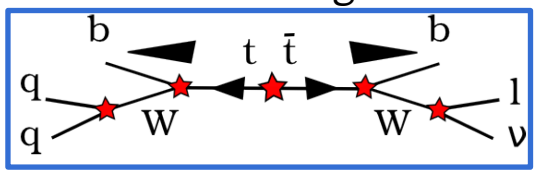
ATLAS Collaboration, PLB 718, 1284 (2013), arXiv:1210.5468

t'$\bar{t}$'->WbWb->l+jets+E_T^{miss}

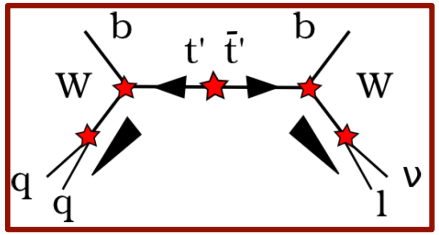
4.7 fb^{-1}, 7 TeV

Benchmark: BR(t'->Wb)=1

dominant bakground



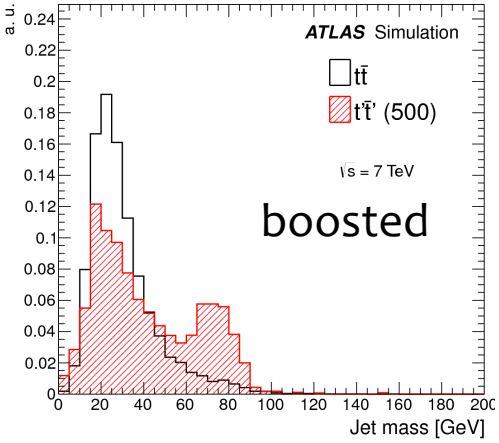
signal

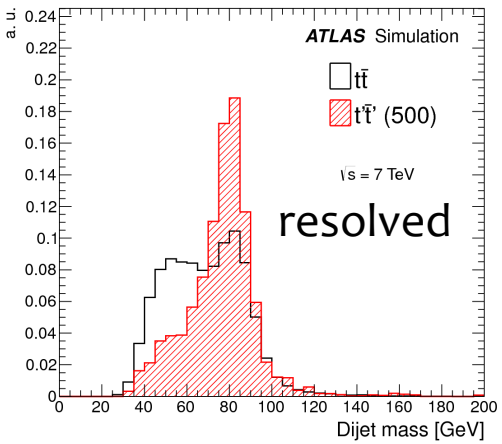


- W_{had} reconstructed in 2 ways:
  - Boosted
    single jet, p_T > 250 GeV, mass in range (60, 110) GeV
  - Resolved
    close-by dijet with ΔR(j,j)<0.8, p_T>150 GeV, mass in range (60, 110) GeV

- Event reconstruction:
  - b candidates:
    2 jets with the highest *b* tag probability; p_{T1} >160 GeV and p_{T1} > 60 GeV
  - W_{lep} : *l*+ν (neutrino p_z calculated analytically – quadratic equation)
  - Choice of the neutrino p_z solution and *b* jet assignment made by minimizing Δm(t',$\bar{t}$')

- Analysis specific selection:
  - $E_T^{miss}+m_T(W_{lep})$ > 60 GeV
  - H_T > 750 GeV
  - == 1 W_{had}
    - Boosted, if >= 3 jets
    - Resolved, if >=4 jets and no boosted W_{had}
  - >= 1 b tagged jet
  - ΔR(l,ν) < 0.4, min(ΔR(l,$b_{1,2}$)) > 1.4, min(ΔR(W_{had},$b_{1,2}$)) > 1.4



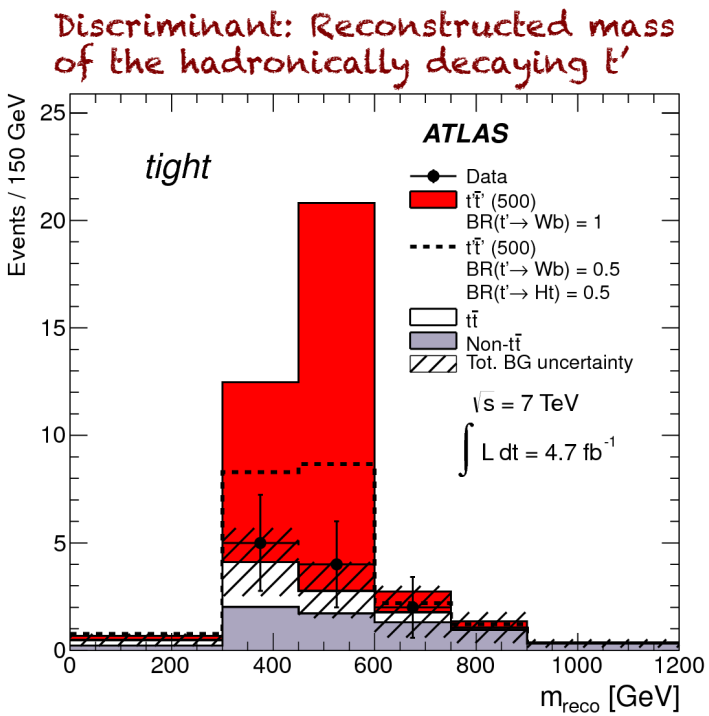


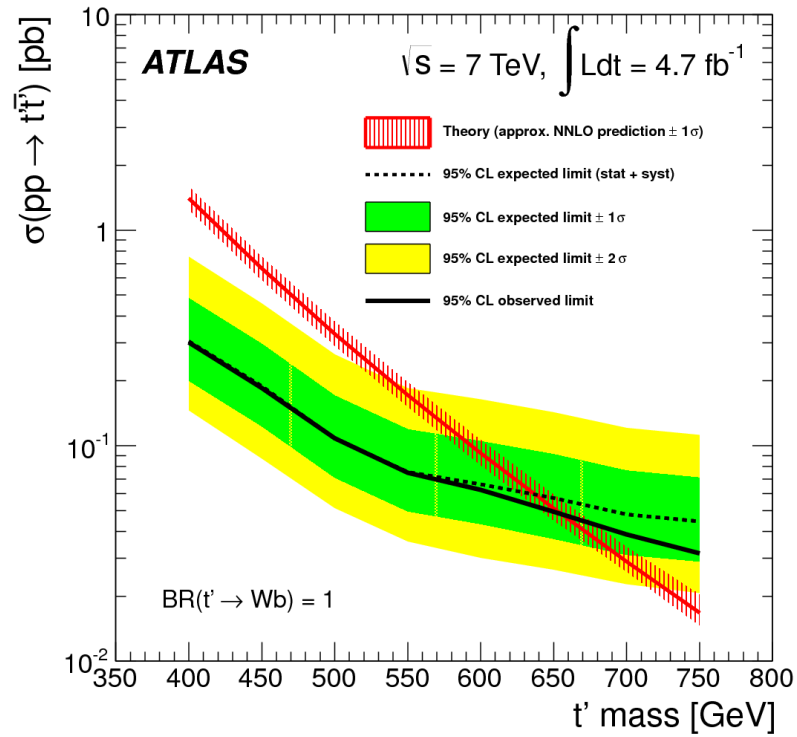
ATLAS Collaboration, PLB 718, 1284 (2013), arXiv:1210.5468

t'$\bar{t}$'->WbWb->l+jets+E_T^{miss}

4.7 fb^{-1}, 7 TeV

Benchmark: BR(t'->Wb)=1





- Dominant systematic uncertainties: tt Modeling
  - choice of the MC generator, ISR/FSR fragmentation models
- Hypothesis testing with the CLs method

- Observed limit 656 GeV at 95% CL for
  - Fourth generation *t'*
  - Vector-like quark $B_{-4/3}$

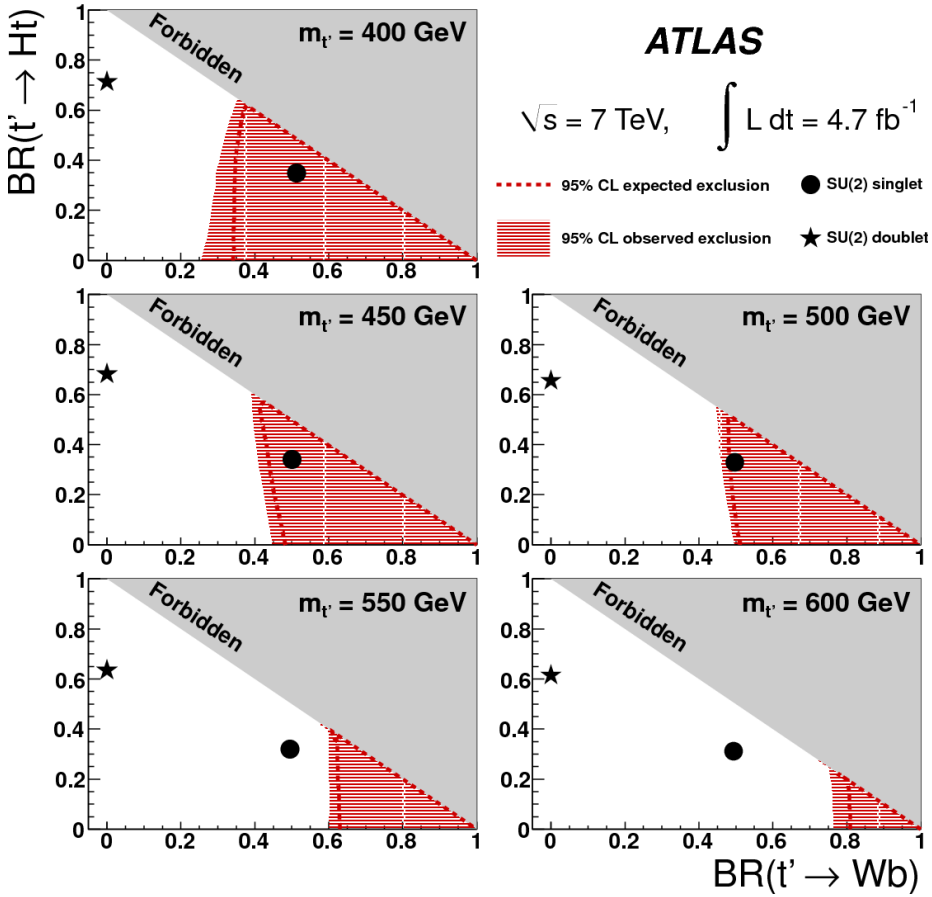
ATLAS Collaboration, PLB 718, 1284 (2013), arXiv:1210.5468

t'$\bar{t}$'->WbWb->l+jets+E_T^{miss}

4.7 fb^{-1}, 7 TeV

- Reinterpretation in terms of VLQ $T_{2/3}$:
  - Three decay modes:
    - *T -> Wb/Ht/Zt*
  - Limits in the mixing plane of B.R (*T->Wb*) and B.R. (*T->Ht*)

- Interpretations:
  - Singlet scenario:
    - m_T > 500 GeV
  - Doublet scenario:
    - not accessible with this analysis



ATLAS Collaboration, PLB 718, 1284 (2013), arXiv:1210.5468

4.7 fb^{-1}, 7 TeV

$t'\bar{t}'$->WbWb->l+jets+E_t^{miss} – Event Yields

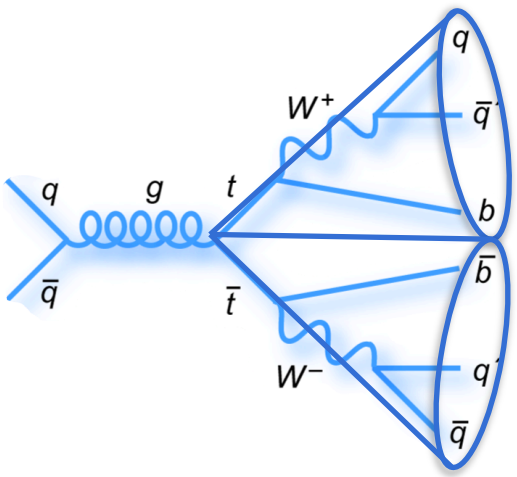
	loose selection	*tight* selection
$t\bar{t}$	94 ± 26	4.2 ± 2.9
W+jets	5.4 ± 4.2	2.0 ± 1.4
Z+jets	0.5 ± 0.4	0.2 ± 0.2
Single top	7.2 ± 1.7	1.1 ± 0.5
Dibosons	0.1 ± 0.1	0.04 ± 0.04
Multi-jet	5.9 ± 8.4	3.8 ± 3.2
Total background	113 ± 30	11.3 ± 4.8
Data	122	11
$t'\bar{t}'$(500 GeV)		
$Wb : Zt : Ht = 1.0 : 0.0 : 0.0$	47.4 ± 6.3	28.2 ± 3.6
$Wb : Zt : Ht = 0.5 : 0.0 : 0.5$	25.4 ± 3.6	11.2 ± 1.5

Table 1: Number of observed events, integrated over the whole mass spectrum, compared to the SM expectation for the combined e+jets and μ+jets channels after the *loose* and *tight* selections. The expected signal yields assuming $m_{t'} = 500$ GeV for different values of $BR(t' \to Wb)$, $BR(t' \to Zt)$ and $BR(t' \to Ht)$ are also shown. The case of $BR(t' \to Wb) = 1$ corresponds to a fourth-generation t' quark. The quoted uncertainties include both statistical and systematic contributions.

ATLAS Collaboration, JHEP 01 (2013), arXiv:1211.2202

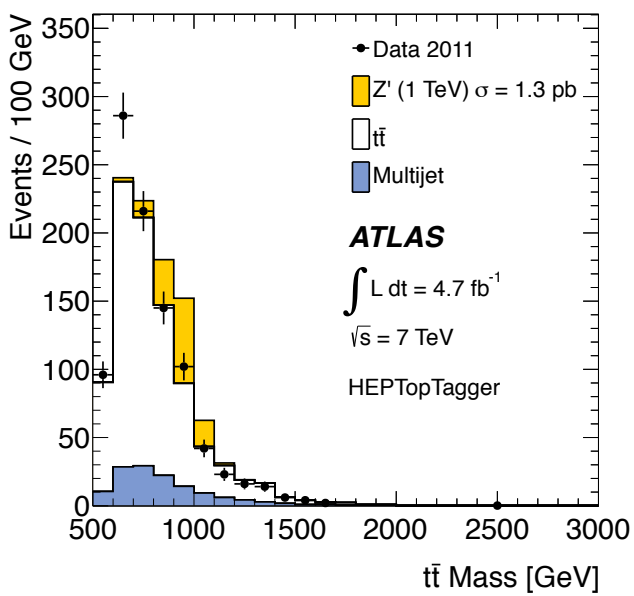
4.7 fb^{-1}, 7 TeV

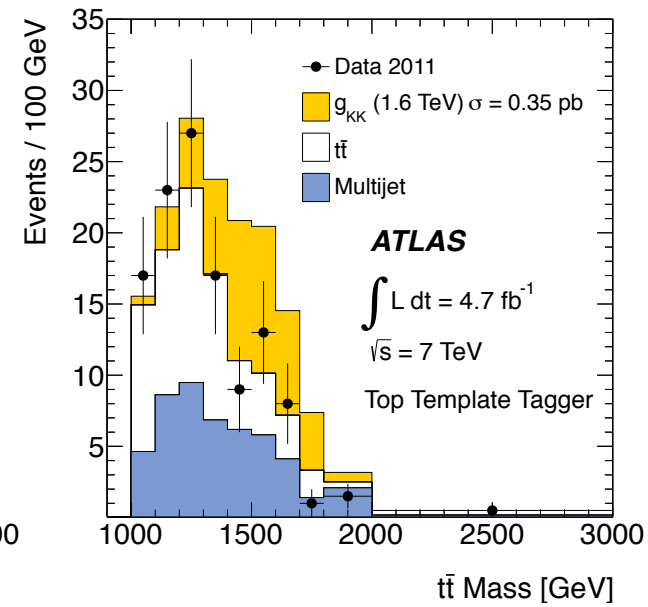
$t\bar{t}$ -> Jets



- Selection
  - High E_T jets or large jet multiplicity trigger
  - >= 2 top tagged fat jets associated with nearby b tagged jets
  - Top taggers:
    - HEPTopTagger, jet p_T > 200 GeV
    - Top Template Tagger, jet p_T > 450 GeV
- Dominant systematic uncertainty:
  - *b* tagging efficiency, jet energy scale, SM $t\bar{t}$ normalization
- Tested resonance models:
  - Narrow width lepto-phobic topcolour Z' boson
  - Kaluza-Klein gluon from the bulk Randall-Sundrum model

Discriminating variable: reconstructed tt mass



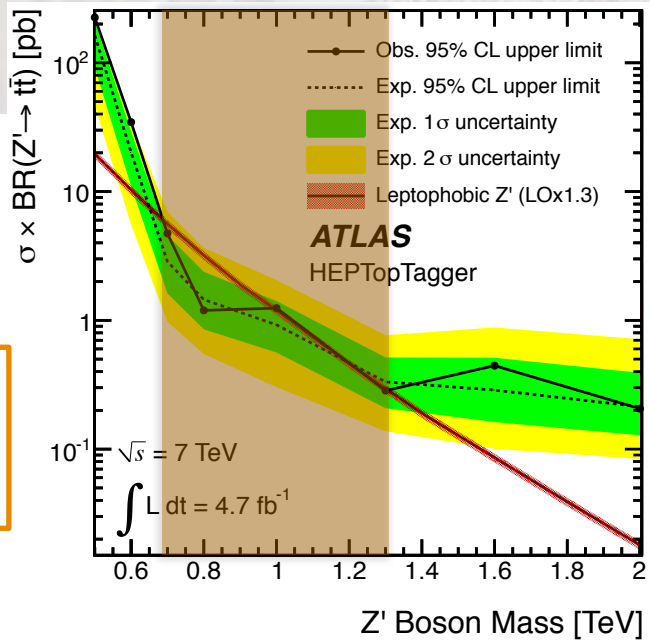


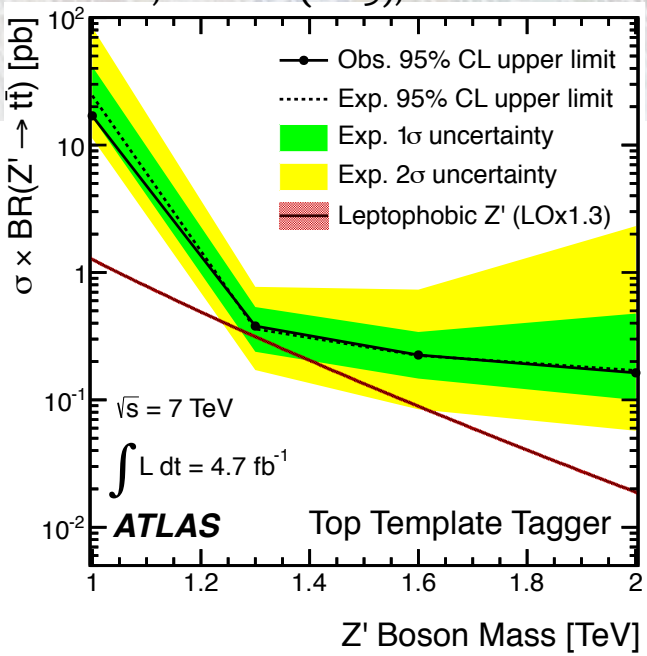
4.7 fb^{-1}, 7 TeV

ATLS Collaboration, JHEP 01 (2013), arXiv:1211.2202

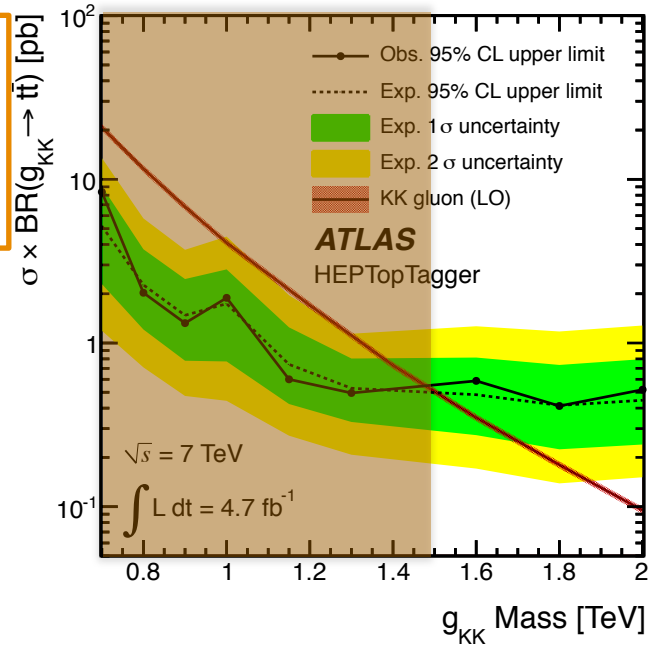
$t\bar{t}$ -> Jets

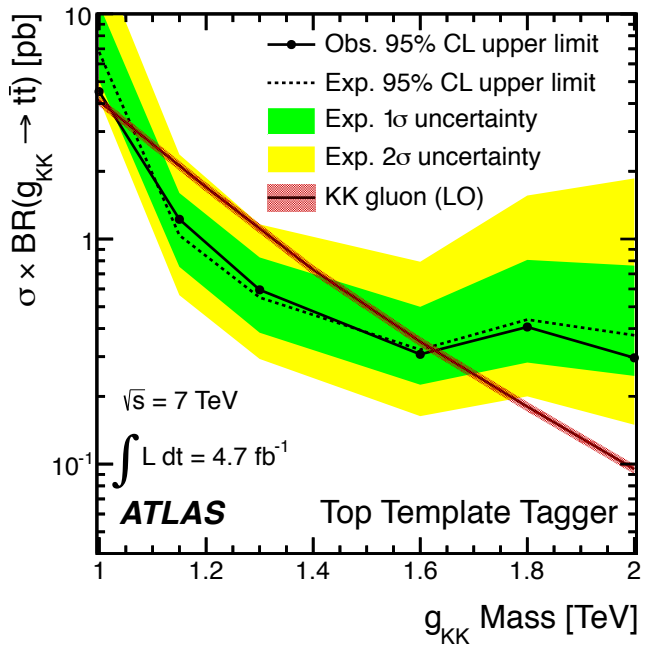
Z' exclusion mass range at 95% CL:
0.7 TeV < $m_{Z'}$ < 1.3 TeV





Kaluza-Klein gluon exclusion mass range at 95% CL:
0.7 TeV < m_{gkk} < 1.5 TeV





$t\bar{t}$->l+ν+jets->l+jets+E_t^{miss} - Event Yields

Table 3: Data and expected background event yields after the resolved and boosted selections. The uncertainty on the normalization of the expected backgrounds yield is listed.

Resolved selection			
Type	e+jets	μ+jets	Sum
$t\bar{t}$	94000 ± 15000	118000 ± 19000	211000 ± 33000
Single top	6800 ± 800	8400 ± 1100	15200 ± 1900
QCD e	3700 ± 1800	0 ± 0	3700 ± 1800
QCD mu	0 ± 0	10000 ± 5000	10000 ± 5000
W+jets	16000 ± 4000	23000 ± 6000	39000 ± 10000
Z+jets	1800 ± 400	1800 ± 400	3600 ± 800
Di-bosons	230 ± 50	320 ± 60	550 ± 100
Total	121000 ± 17000	162000 ± 23000	283000 ± 39000
Data	119490	160878	280251
Boosted selection			
Type	e+jets	μ+jets	Sum
$t\bar{t}$	2100 ± 500	2800 ± 600	4900 ± 1100
Single top	71 ± 15	105 ± 22	176 ± 34
QCD e	39 ± 19	0 ± 0	39 ± 19
QCD mu	0 ± 0	32 ± 16	32 ± 16
W+jets	170 ± 60	310 ± 90	480 ± 140
Z+jets	18 ± 11	33 ± 8	52 ± 15
Di-bosons	2.0 ± 0.8	1.5 ± 1.4	3.5 ± 1.8
Total	2400 ± 500	3300 ± 700	5600 ± 1200
Data	2177	2945	5122