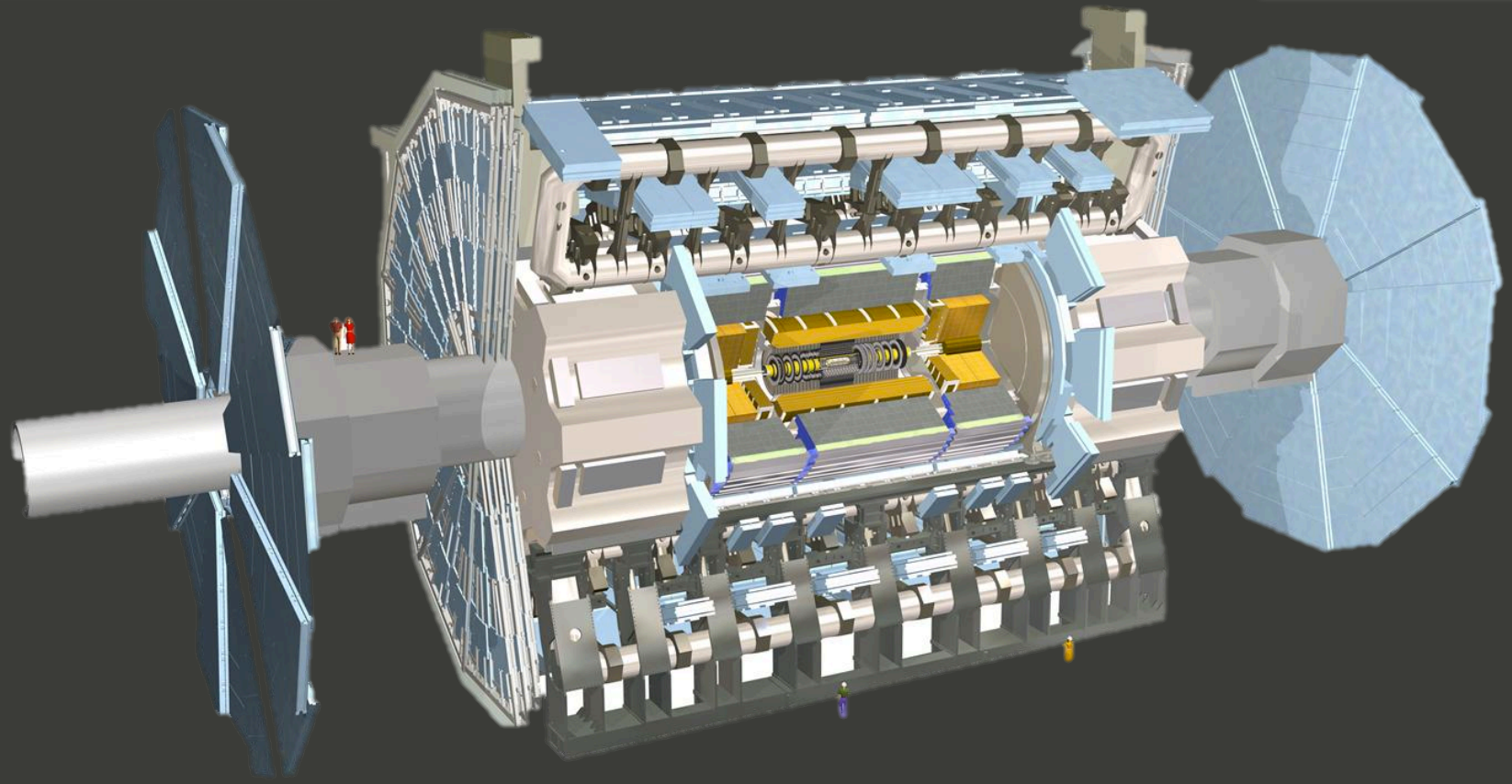
LHCP 2013
Large Hadron Collider Physics Conference
May 13-18, 2013, Barcelona, España

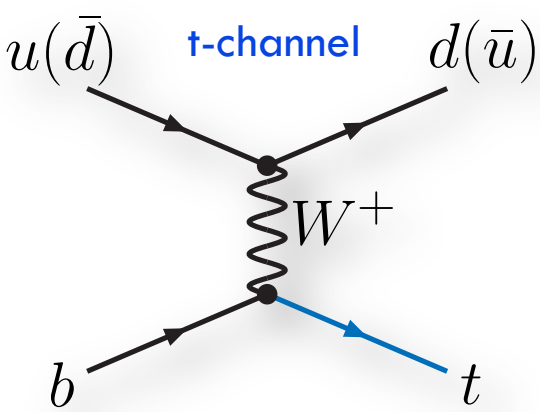


Single top quark production in ATLAS at the LHC

Jan A. Stillings on behalf of the ATLAS collaboration

Single top quark production at the LHC

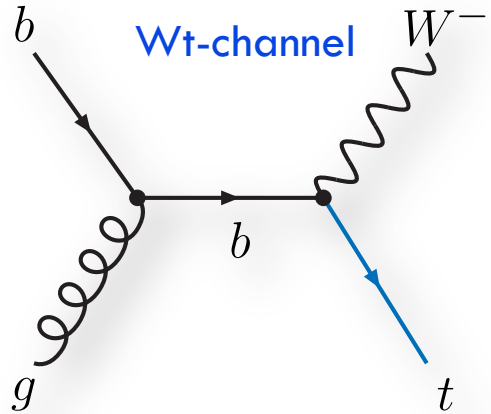
- Production via electroweak interactions, predicted by SM



$\sigma = 64.57^{+2.63}_{-1.74}$ pb @ 7 TeV

$\sigma = 87.76^{+3.44}_{-1.91}$ pb @ 8 TeV

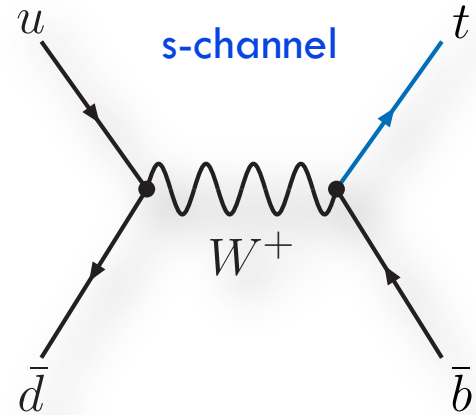
Phys. Rev. D 83, 091503(R) (2011)



$\sigma = 15.74^{+1.17}_{-1.21}$ pb @ 7 TeV

$\sigma = 22.37 \pm 1.52$ pb @ 8 TeV

Phys. Rev. D 82, 054018 (2010)



$\sigma = 4.63^{+0.20}_{-0.18}$ pb @ 7 TeV

$\sigma = 5.61 \pm 0.22$ pb @ 8 TeV

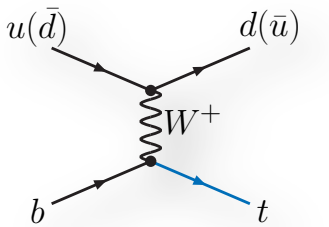
Phys. Rev. D 81, 054028 (2010)

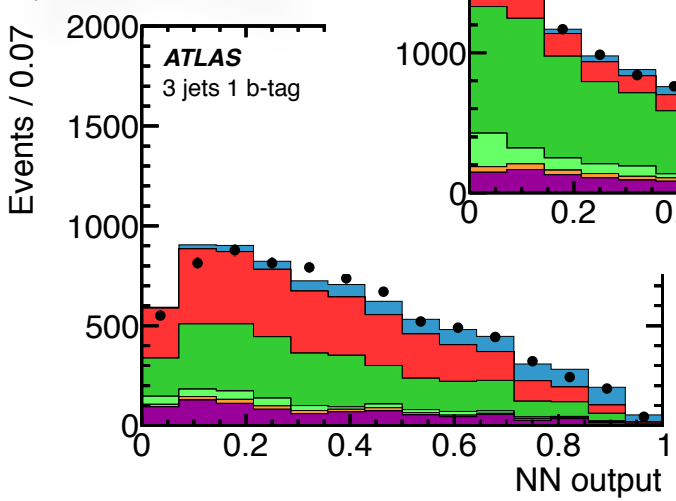
- Cross section measurements to probe Standard Model predictions
- Direct constraint of CKM matrix element $|V_{tb}|$
- Charge asymmetry sensitive to proton PDF (u, d)
- Search for new physics

t-channel

Selection 1.04 fb^{-1} @ 7 TeV

- 1 central lepton, $p_T > 25$ GeV
- 2 or 3 jets, $|\eta| < 4.5$, $p_T > 25$ GeV
- b-tagged central jet
- $E_T^{miss} > 25$ GeV
- $M_T > 60$ GeV – E_T^{miss}





Main uncertainties

- ISR/FSR (14 %)
- b-tagging efficiency (13 %)
- 24 % Total, 5 % stat.

$$\sigma_t = 83 \pm 4(\text{stat.})^{+20}_{-19}(\text{syst.})\ \text{pb}$$

Significance: 6.0 σ exp., 7.2 σ obs.

$|V_{tb}| >> |V_{td}|, |V_{ts}|$,
Measured cross-section ~ $|V_{tb}|^2$

$$|V_{tb}| = 1.13^{+0.14}_{-0.13}(\text{exp.}) \pm 0.02(\text{theo.})$$

Phys. Lett. B 717 (2012) 330-350

5.8 fb^{-1} @ 8 TeV

Using refined cuts (jets, E_T^{miss})

$$\sigma_t = 95.1 \pm 2.4\,(\text{stat.}) \pm 18.0\,(\text{syst.})\ \text{pb}$$

$$|V_{tb}| = 1.04^{+0.10}_{-0.11} \quad |V_{tb}| > 0.80\ @\ 95\,\%\ \text{CL}$$

ATLAS-CONF-2012-132

t-channel – top/antitop cross-section

Measurement of separate top quark and antitop quark cross-section

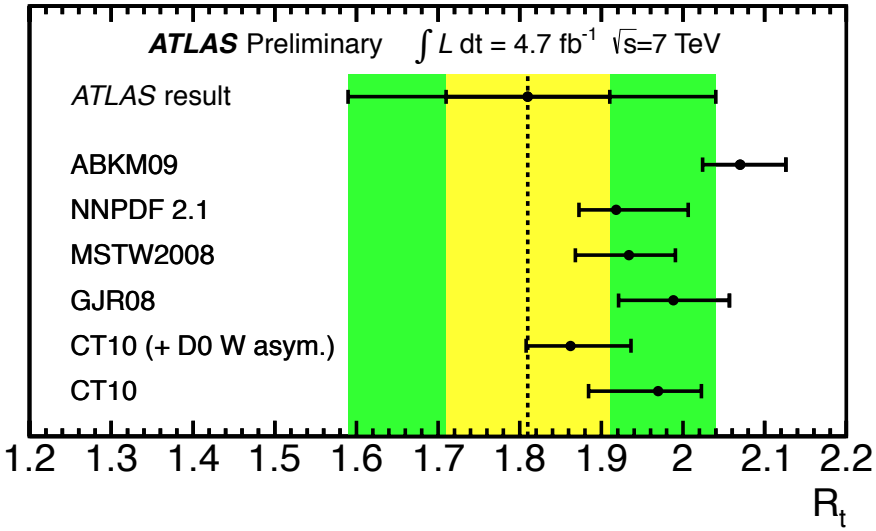
4.7 fb^{-1} @ 7 TeV

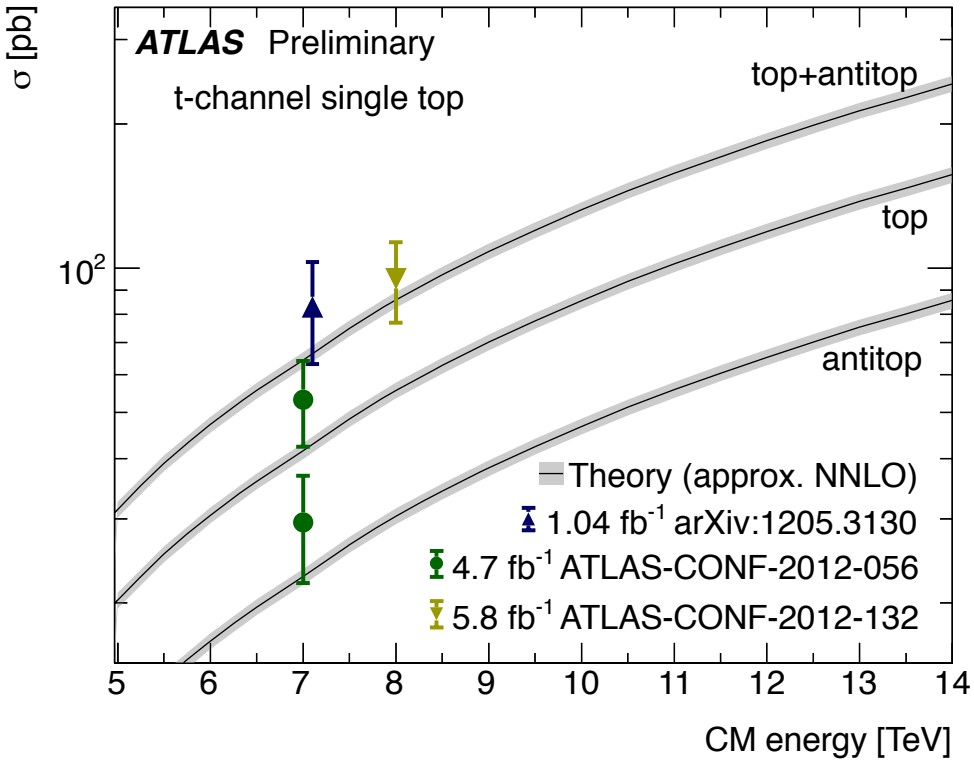
$$\sigma_t(t) = 53.2 \pm 1.7(\text{stat.}) \pm 10.6(\text{syst.})\,\text{pb}$$
$$\sigma_t(\bar{t}) = 29.5 \pm 1.5(\text{stat.}) \pm 7.3(\text{syst.})\,\text{pb}$$

$$R_t = 1.81 \pm 0.10\,(\text{stat.})^{+0.21}_{-0.20}\,(\text{syst.})$$

Main uncertainties

- Cross-section: JES (19.5 %)
- R_t: stat. (5.5 %), bkg. norm. (4.5 %), JES (4 %)



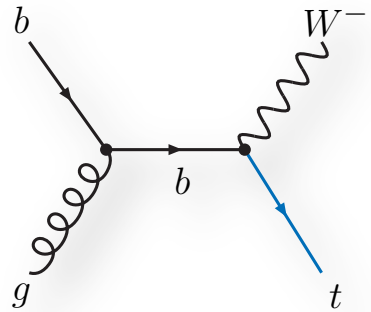


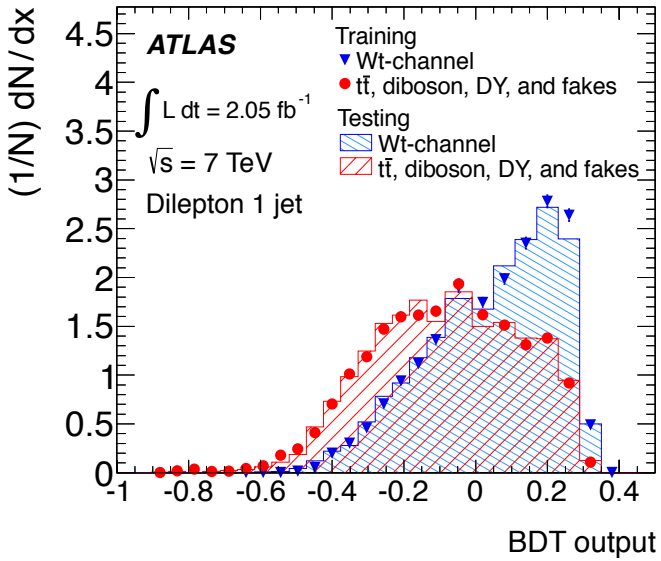
ATLAS-CONF-2012-056

Wt-channel

Phys. Lett. B 716 (2012) 142-159

- Dilepton event selection — 2.05 fb^{-1} @ 7 TeV
  - 2 central leptons, p_T > 25 GeV
  - E_T^{miss} > 50 GeV
  - >1 jet, p_T > 30 GeV
  - Veto cuts against Z decay





- Likelihood fit of BDT output for 1, 2 and 3+ jet bins
- Main uncertainties
  - Statistics (17 %)
  - JES (16 %), Parton shower model (15 %)

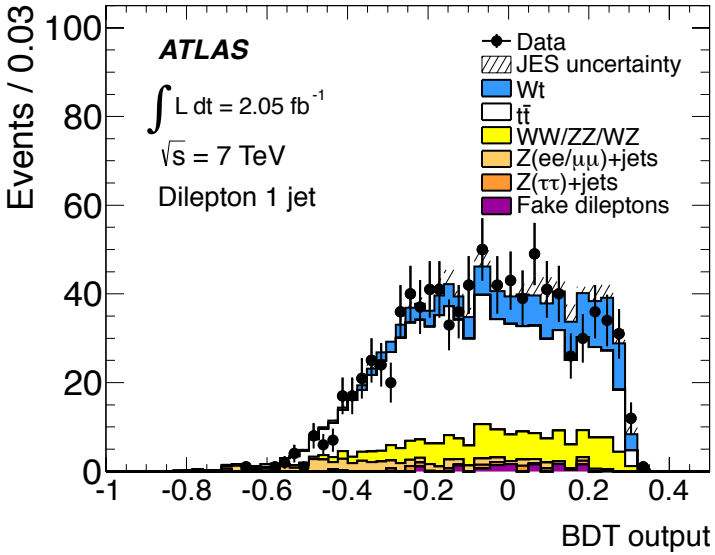
$$\sigma_t = 16.8 \pm 2.9(\text{stat.}) \pm 4.9(\text{syst.})\ \text{pb}$$

Significance: 3.4 σ exp., 3.3 σ obs.

$$\sigma = 15.74^{+1.17}_{-1.21}\ \text{pb}$$

Phys. Rev. D 82, 054018 (2010)

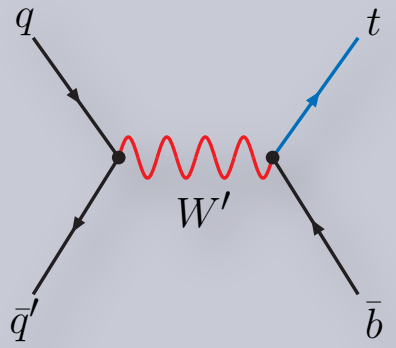
$$|V_{tb}| = 1.03^{+0.16}_{-0.19}$$



New physics searches in single top topologies

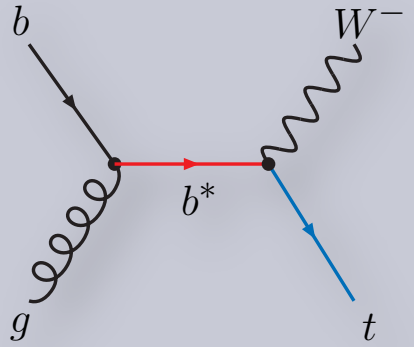
universitätbonn

Search for tb resonances



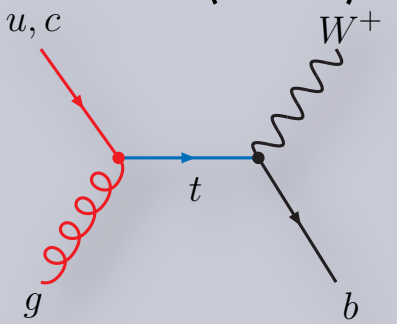
new charged W‘ boson

Search for excited quarks

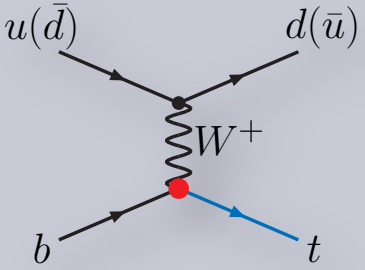


b* quark production

Top quark production via flavour-changing neutral currents (FCNC)



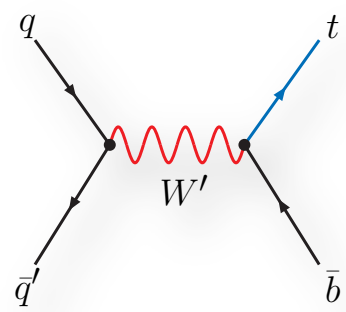
Anomalous couplings



CP violation in top quark decay

Search for W‘ production

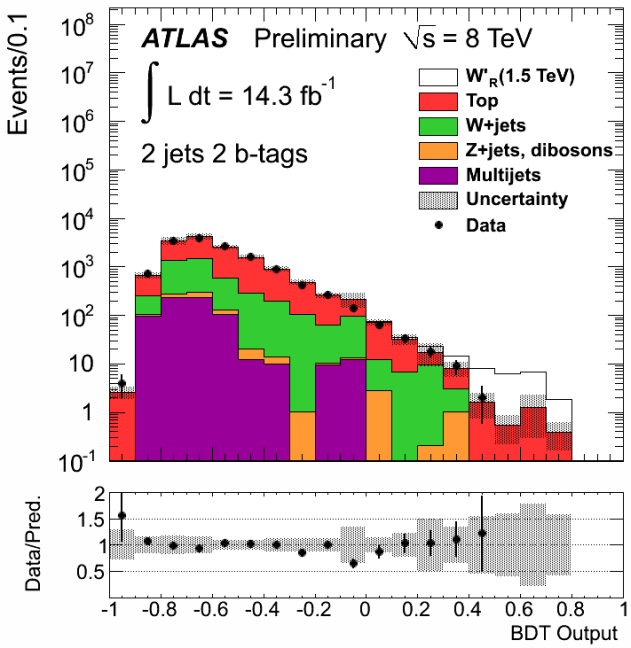
- W‘ model with SM-like couplings
- Sensitivity in lepto-phobic W‘ models complementary to leptonic searches
- Probe right- and left-handed models
- $M_{W'_R}$ = 1.75 TeV to train BDT
- Combination of 2- and 3-jet bins

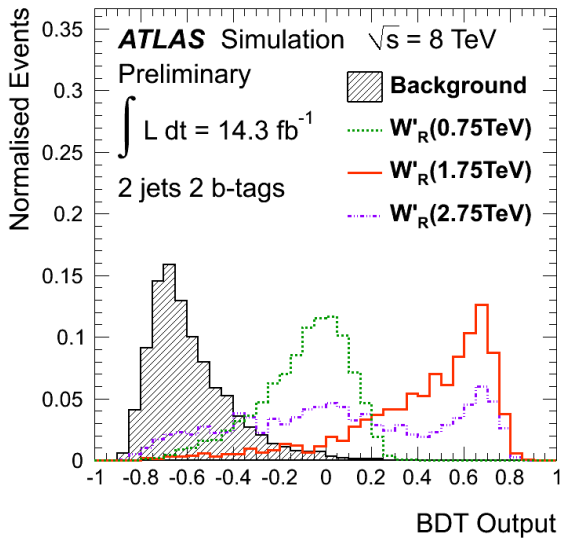


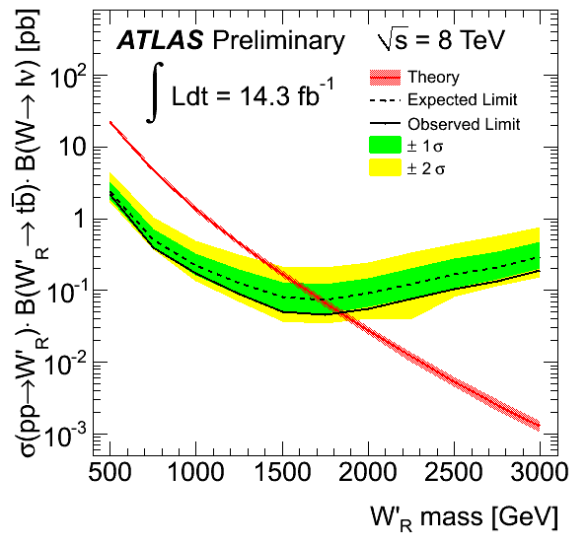
14.3 fb^{-1} @ 8 TeV

New result for LHCP

$$M_{W'_L} > 1.74\,\text{TeV},\ M_{W'_R} > 1.84\,\text{TeV}\ @\ 95\,\%\ \text{CL}$$





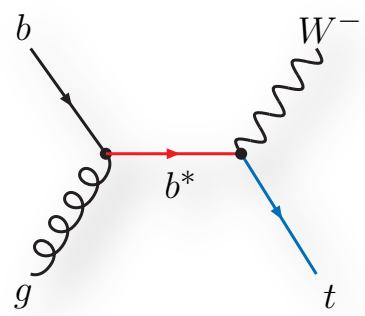


ATLAS-CONF-2013-050

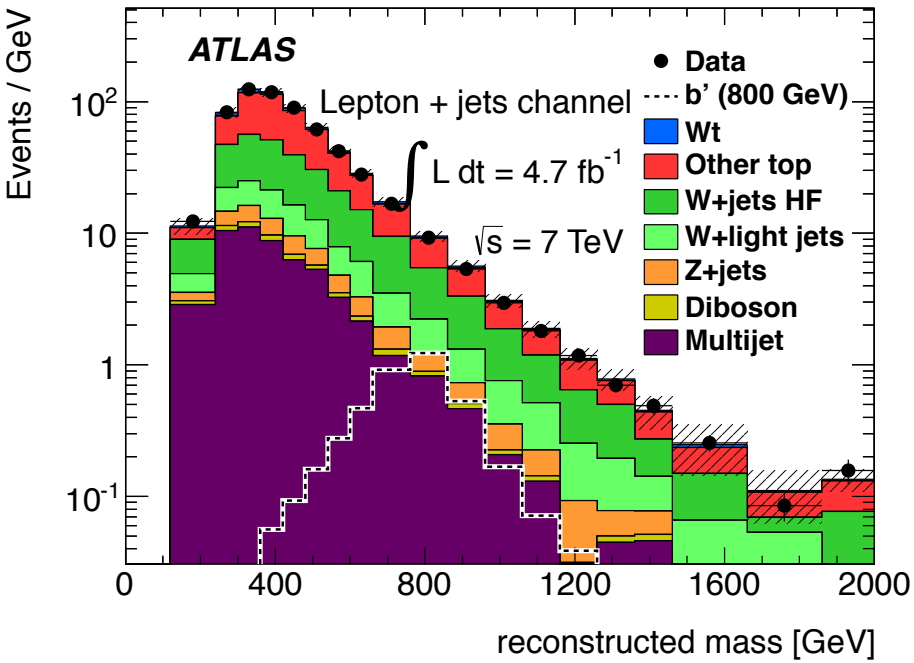
Search for b* production

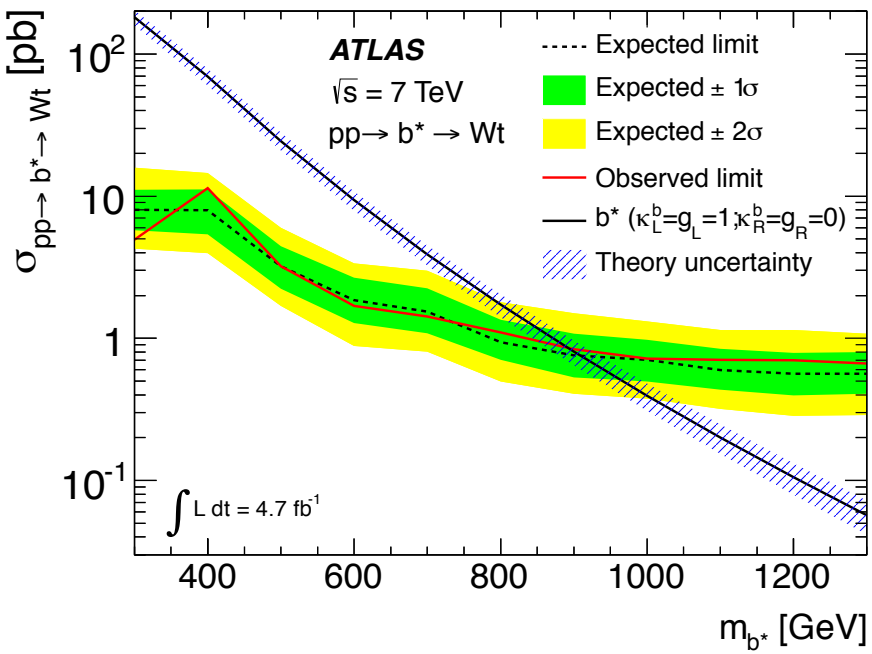
- Consider strongly produced excited quark production decaying electro-weakly to top quark and W boson
- Single and dilepton channels analyzed
- Invariant mass of Wt system and H_T used as sensitive variables

4.7 fb^{-1} @ 7 TeV



$$M_{b^*} > 870\,\text{GeV} \;@\; 95\,\%\ \text{CL}$$

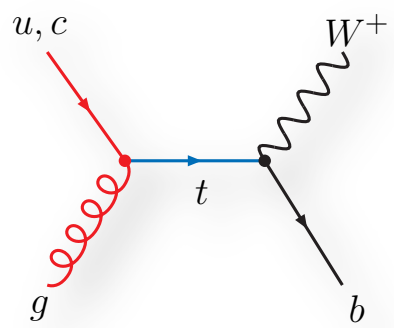




PLB 721 (2013) 171-189

FCNC single top quark production

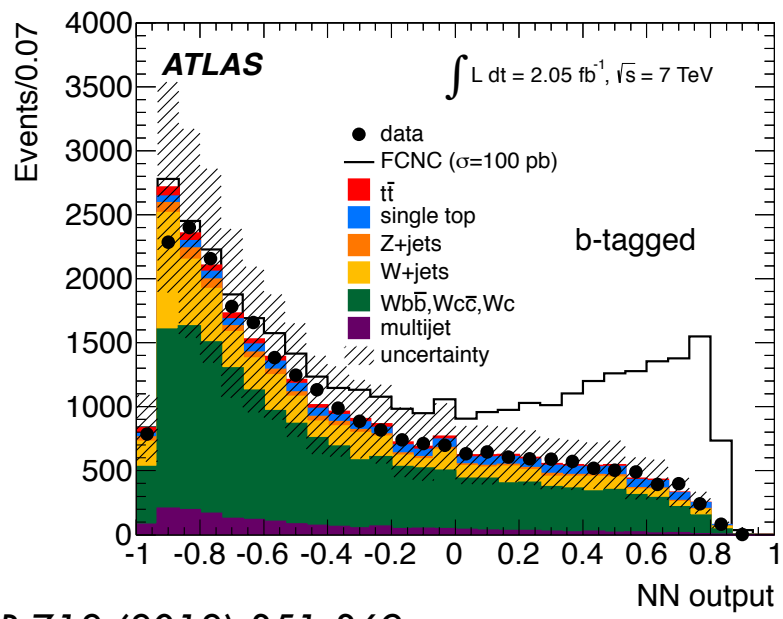
- Same selection as t-channel analysis
  - Require exactly 1 jet
- Measure cross-section of FCNC coupling to u and c quark and interpret in terms of branching ratio
- New physics could enhance FCNC rates involving top quarks

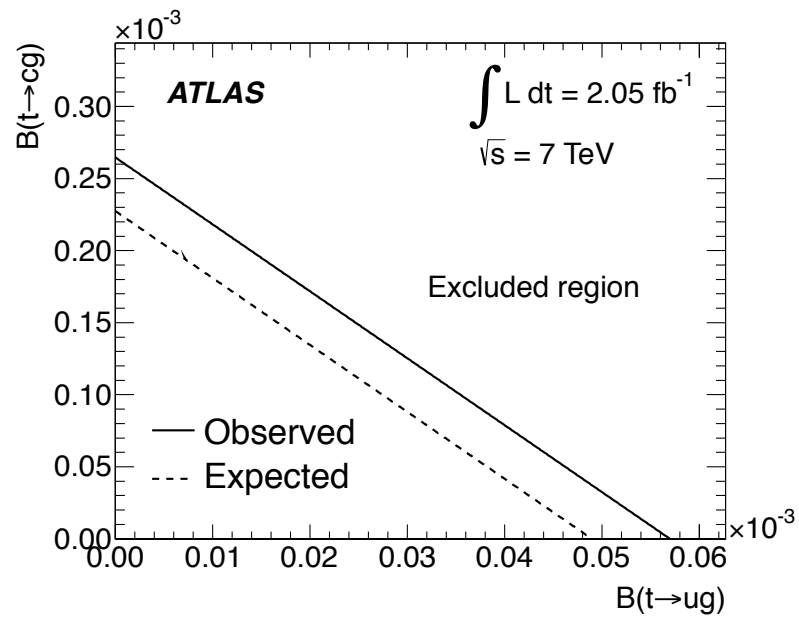


2.05 fb^{-1} @ 7 TeV

$$\sigma < 3.9\,\text{pb} \;@\; 95\,\%\ \text{CL}$$

Best limit on FCNC in ugt and cgt coupling



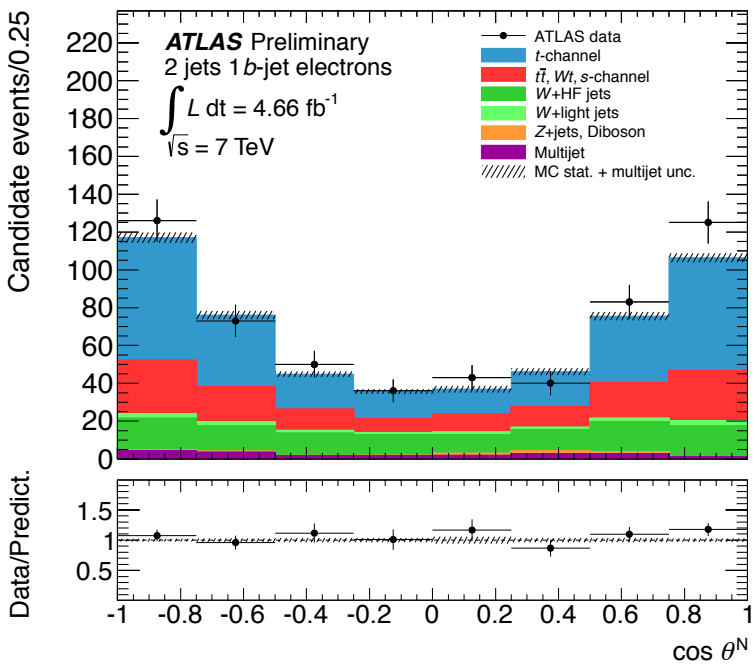


PLB 712 (2012) 351-369

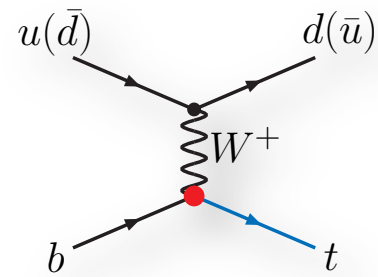
Anomalous couplings

- Normal vector to top quark spin polarisation and spectator quark
- Angle θ^{N} between lepton in W boson rest frame and normal vector
- Standard model:

$$V_L \simeq 1, V_R = g_{R,L} = 0, P = 0.9$$



ATLAS-CONF-2013-032

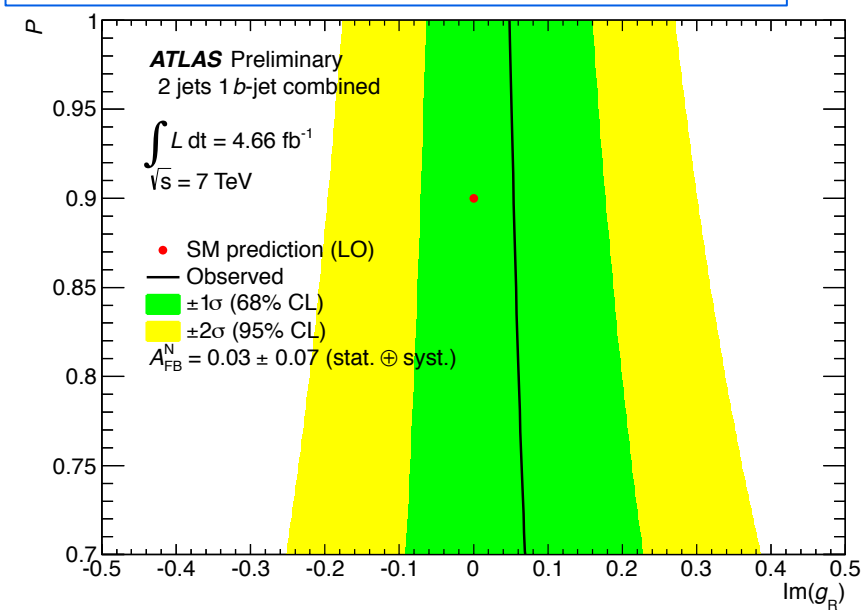


4.7 fb^{-1} @ 7 TeV

$$A_{\mathrm{FB}}^{\mathrm{N}} = 0.031 \pm 0.065\,(\mathrm{stat.})\,^{+0.029}_{-0.031}\,(\mathrm{syst.})$$

$$A_{\mathrm{FB}}^{\mathrm{N}} = 0.64\,P\,\mathbb{I}(g_R)$$

$$\mathbb{I}(g_R) = [-0.20, 0.30]\ @\ 95\,\%\ \mathrm{CL}$$

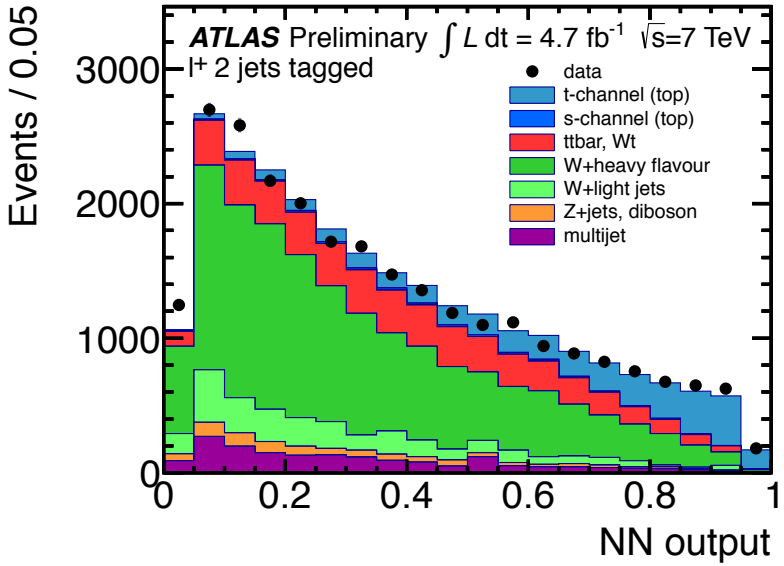


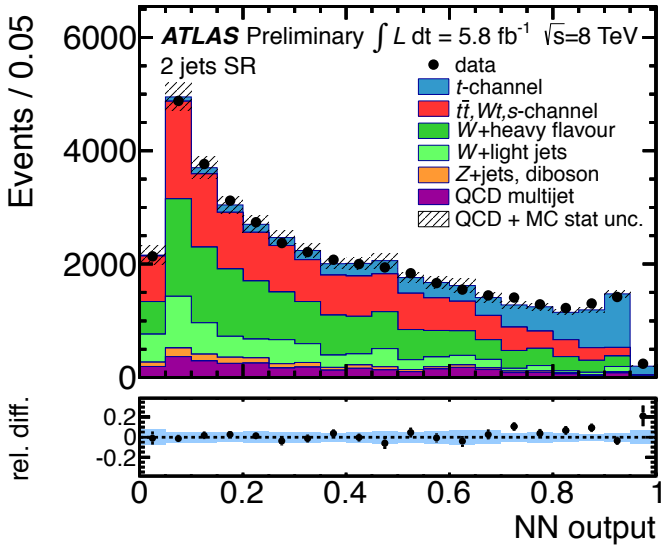
Summary

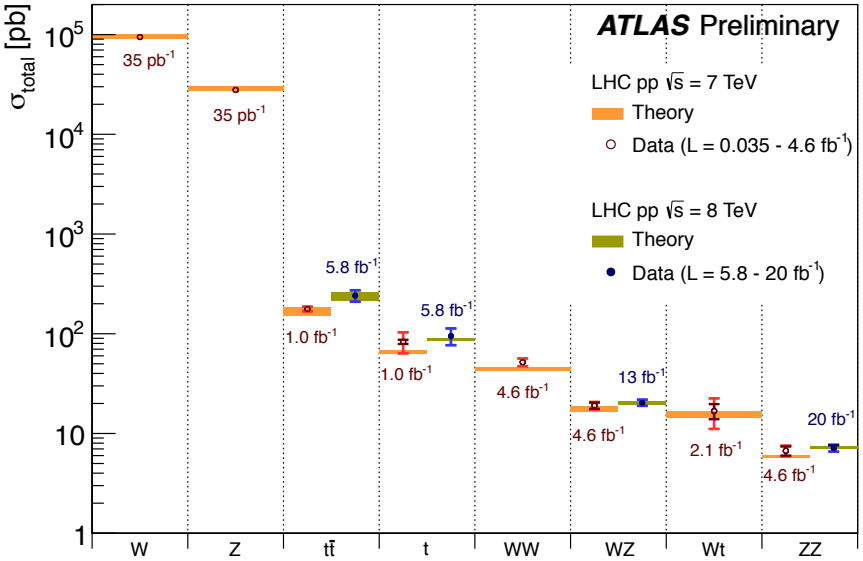
- Standard model verification
  - High significance isolation of t-channel events at 7 and 8 TeV
  - top & antitop quark production cross-sections measured
  - First evidence for *Wt* production (3.3 σ)
  - Limit on s-channel production cross-section
- New physics searches
  - World's best limit on FCNC ugt/cgt coupling
  - First limit on imaginary part of g_R coupling constant
  - Searches for exotic b* quarks and W' bosons extended limits
- Many new analyses at 8 TeV in the ATLAS pipeline
- Systematic limitations pose new challenges

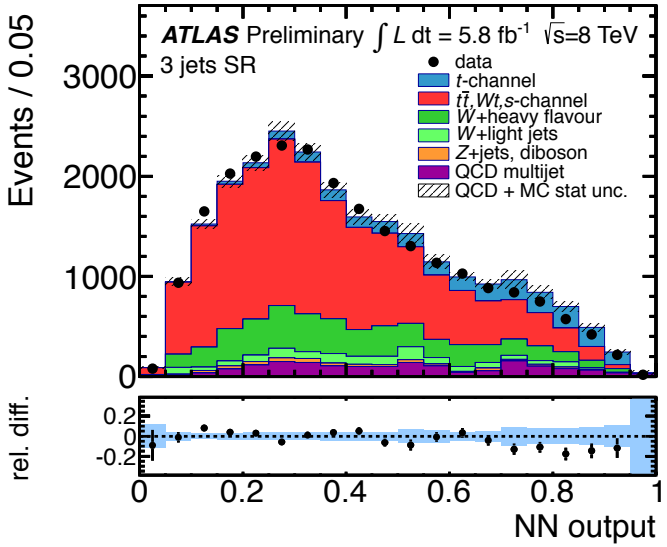
Backup slides

t-channel


ATLAS Preliminary ∫ L dt = 4.7 fb-1 √s=7 TeV
l+ 2 jets tagged
data
t-channel (top)
s-channel (top)
ttbar, Wt
W+heavy flavour
W+light jets
Z+jets, diboson
multijet
Events / 0.05
NN output

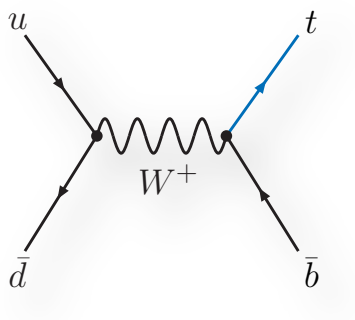

ATLAS Preliminary ∫ L dt = 5.8 fb-1 √s=8 TeV
2 jets SR
data
t-channel
tt̄,Wt,s-channel
W+heavy flavour
W+light jets
Z+jets, diboson
QCD multijet
QCD + MC stat unc.
Events / 0.05
rel. diff.
NN output


ATLAS Preliminary
LHC pp √s = 7 TeV
Theory
Data (L = 0.035 - 4.6 fb-1)
LHC pp √s = 8 TeV
Theory
Data (L = 5.8 - 20 fb-1)
σtotal [pb]
W
Z
tt̄
t
WW
WZ
Wt
ZZ


ATLAS Preliminary ∫ L dt = 5.8 fb-1 √s=8 TeV
3 jets SR
data
t-channel
tt̄,Wt,s-channel
W+heavy flavour
W+light jets
Z+jets, diboson
QCD multijet
QCD + MC stat unc.
Events / 0.05
rel. diff.
NN output

s-channel

- Same selection as t-channel
- 2 b-tagged central jets with $p_T > 25$ GeV
- Optimized additional cuts to enrich signal events

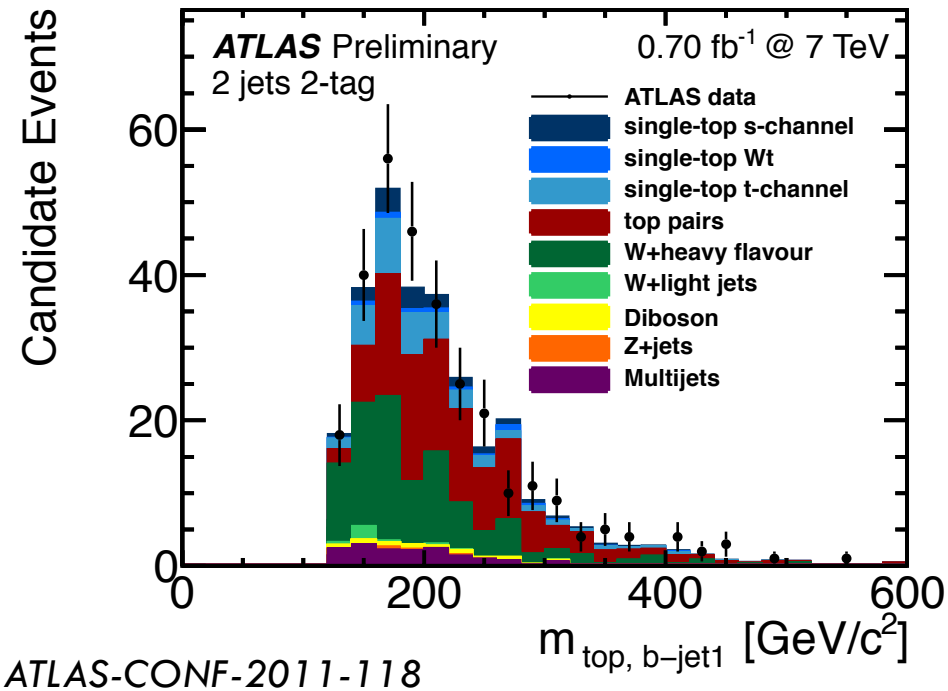


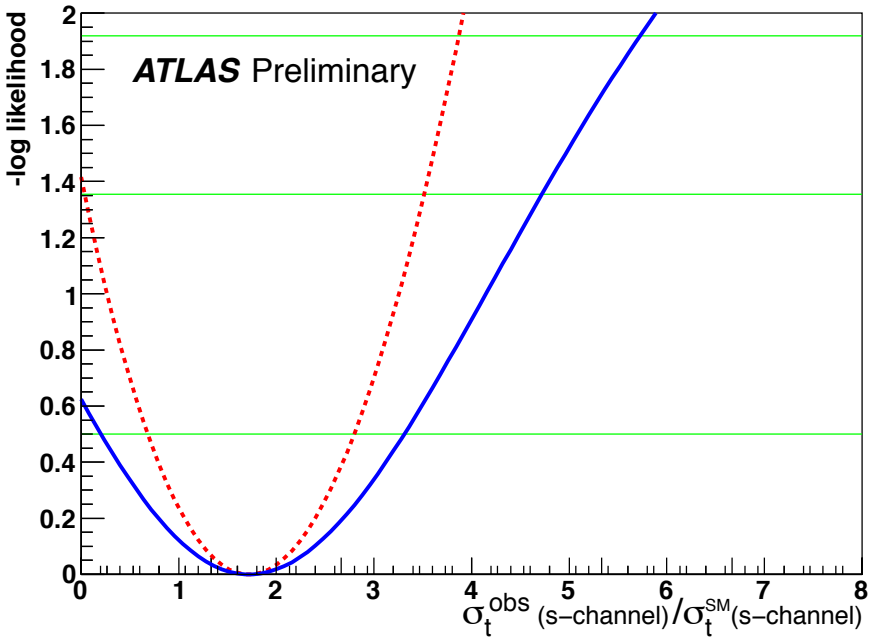
0.7 fb^{-1} @ 7 TeV

Main uncertainties:

- Statistics (100 %)
- Systematics (20-60 %)

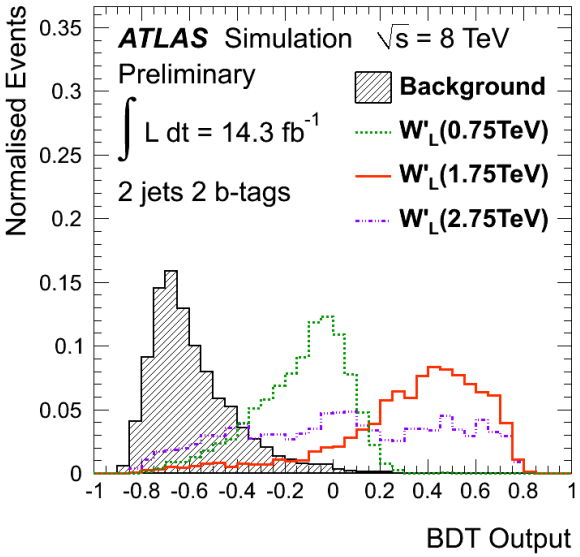
$$\sigma_t < 26.5\,\text{pb} \text{ @ } 95\,\%\ \text{CL}$$

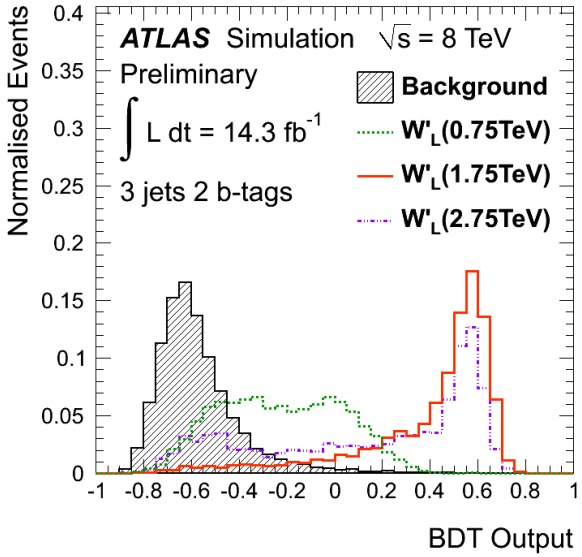


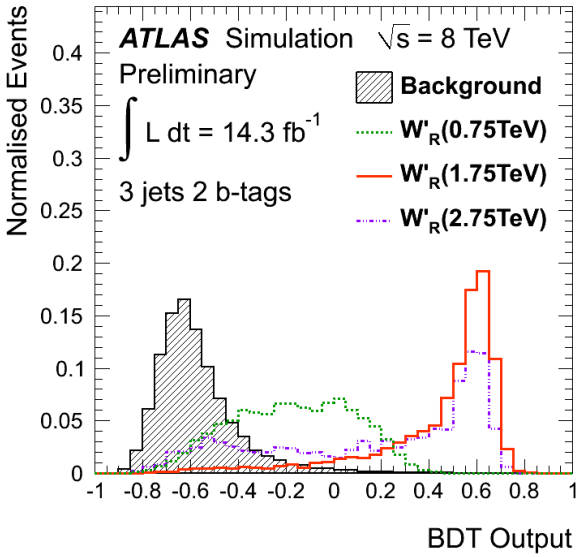


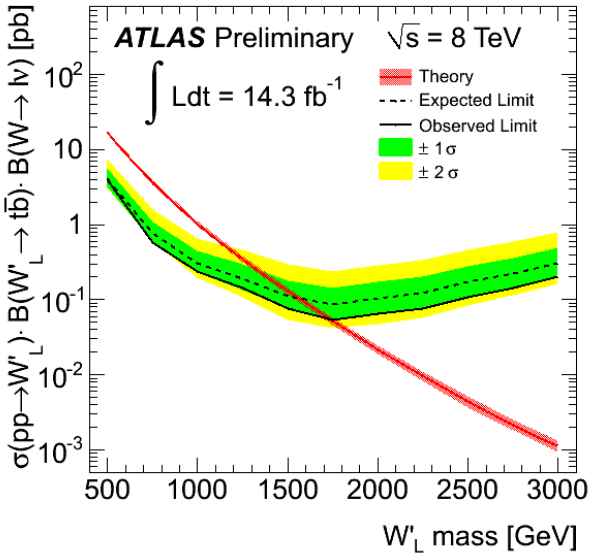
ATLAS-CONF-2011-118

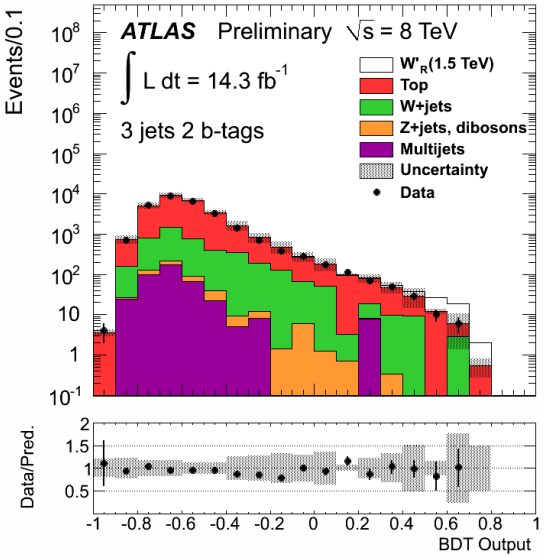
W‘ search


ATLAS Simulation √s = 8 TeV
Preliminary
∫ L dt = 14.3 fb-1
2 jets 2 b-tags
Background
W'L(0.75TeV)
W'L(1.75TeV)
W'L(2.75TeV)
Normalised Events
BDT Output

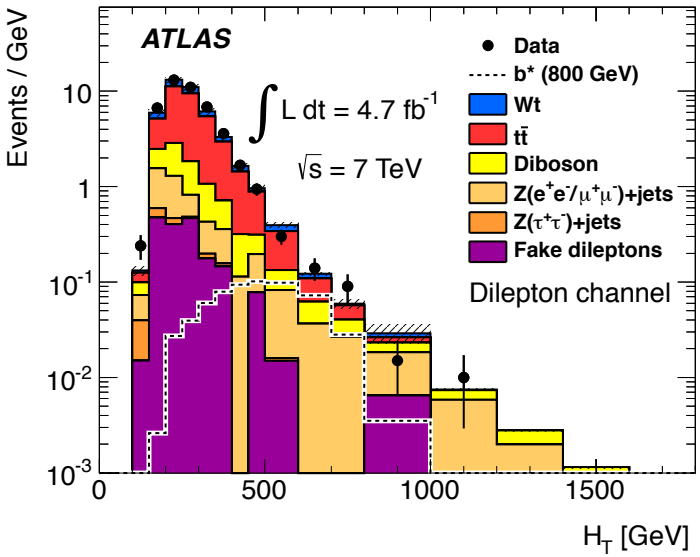

ATLAS Simulation √s = 8 TeV
Preliminary
∫ L dt = 14.3 fb-1
3 jets 2 b-tags
Background
W'L(0.75TeV)
W'L(1.75TeV)
W'L(2.75TeV)
Normalised Events
BDT Output

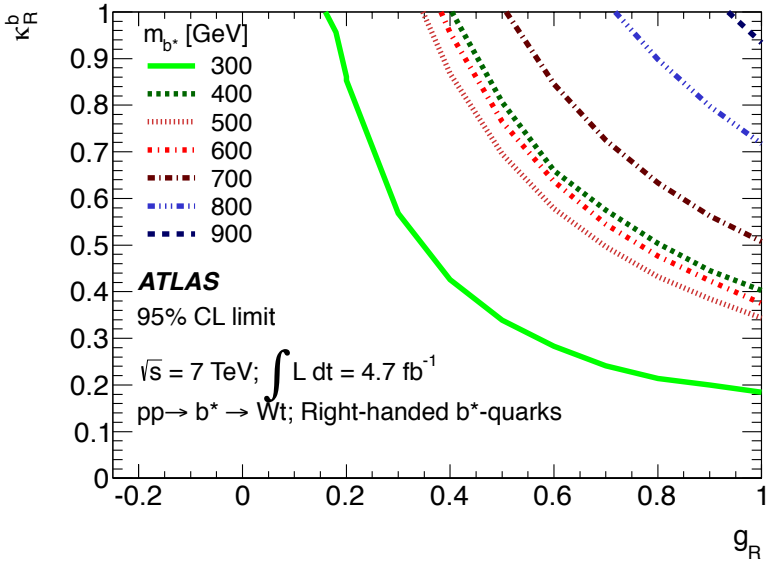

ATLAS Simulation √s = 8 TeV
Preliminary
∫ L dt = 14.3 fb-1
3 jets 2 b-tags
Background
W'R(0.75TeV)
W'R(1.75TeV)
W'R(2.75TeV)
Normalised Events
BDT Output

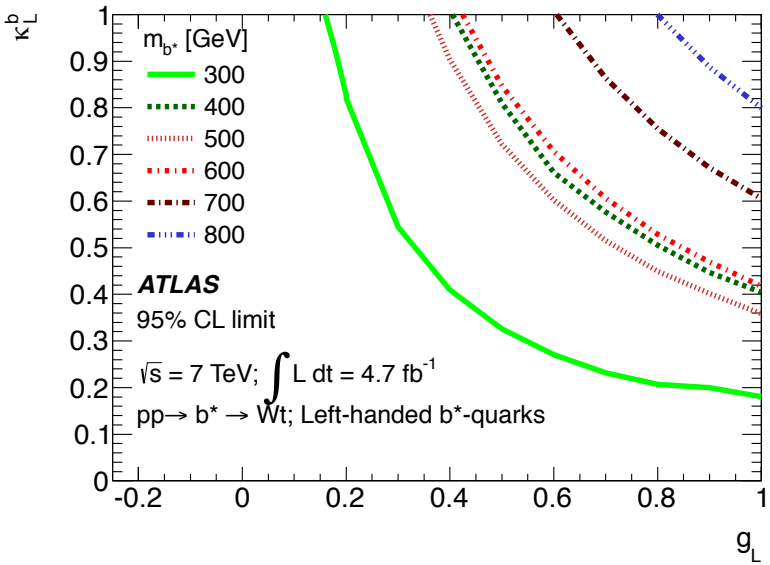

ATLAS Preliminary √s = 8 TeV
∫ Ldt = 14.3 fb-1
Theory
Expected Limit
Observed Limit
± 1σ
± 2σ
σ(pp→W'L)· B(W'L→ tb̄)· B(W→ lν) [pb]
W'L mass [GeV]

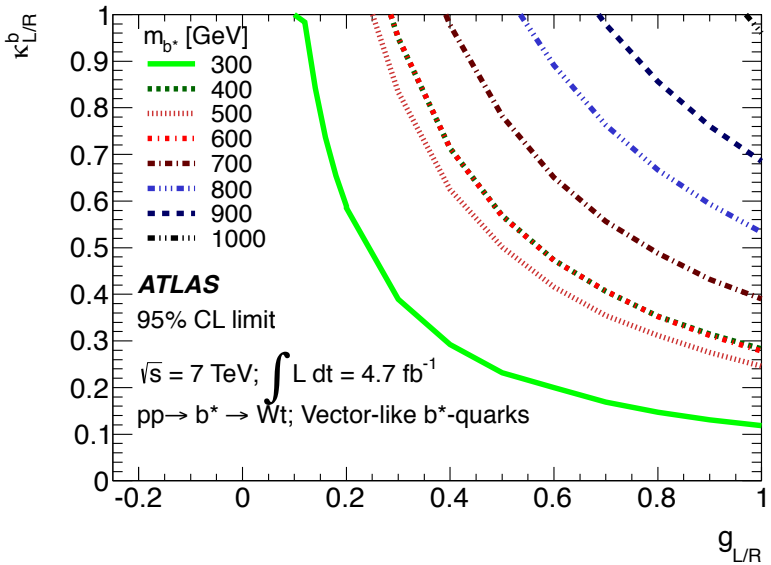

ATLAS Preliminary √s = 8 TeV
∫ L dt = 14.3 fb-1
3 jets 2 b-tags
W'R(1.5 TeV)
Top
W+jets
Z+jets, dibosons
Multijets
Uncertainty
Data
Events/0.1
Data/Pred.
BDT Output

B* search

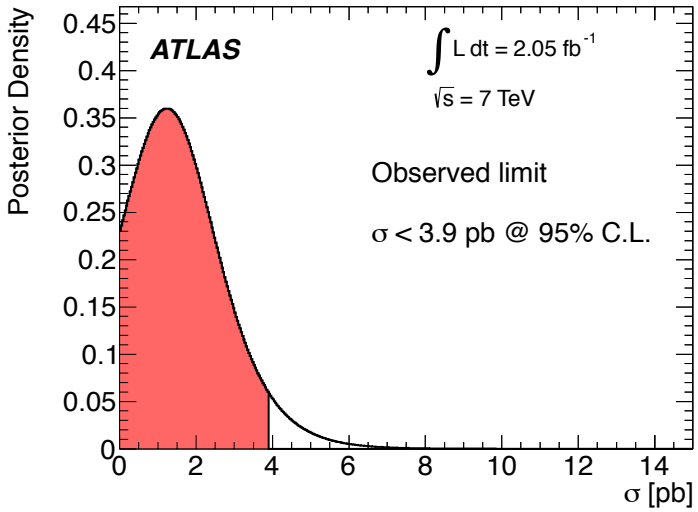

ATLAS
Data
b* (800 GeV)
Wt
tt̄
Diboson
Z(e+e-/μ+μ-)+jets
Z(τ+τ-)+jets
Fake dileptons
∫L dt = 4.7 fb-1
√s = 7 TeV
Dilepton channel
Events / GeV
HT [GeV]

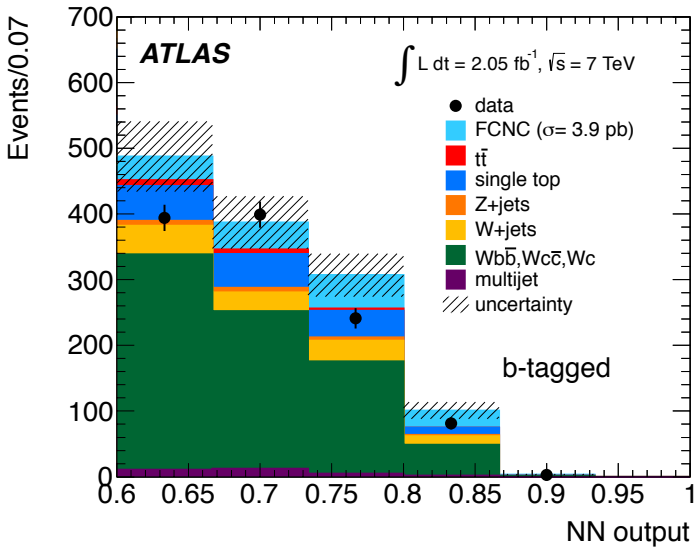

mb* [GeV]
300
400
500
600
700
800
900
ATLAS
95% CL limit
√s = 7 TeV; ∫L dt = 4.7 fb-1
pp→ b* → Wt; Right-handed b*-quarks
κbR
gR


mb* [GeV]
300
400
500
600
700
800
ATLAS
95% CL limit
√s = 7 TeV; ∫L dt = 4.7 fb-1
pp→ b* → Wt; Left-handed b*-quarks
κbL
gL


mb* [GeV]
300
400
500
600
700
800
900
1000
ATLAS
95% CL limit
√s = 7 TeV; ∫L dt = 4.7 fb-1
pp→ b* → Wt; Vector-like b*-quarks
κbL/R
gL/R

FCNC single top quark production

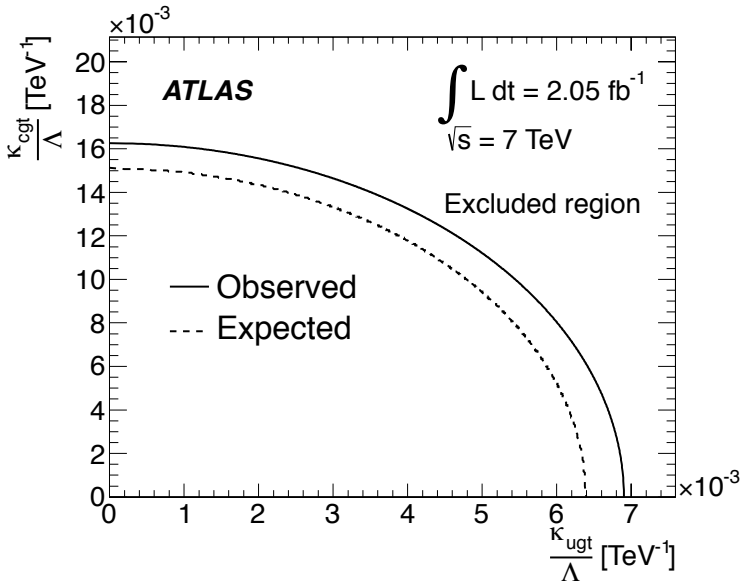




BR	SM	2HDM	MSSM	~~R~~ SUSY	TC2
t → ug	3.7×10^{-12}	–	8×10^{-5}	2×10^{-4}	–
t → cg	4.6×10^{-14}	10^{-4}	8×10^{-5}	2×10^{-4}	10^{-4}

J. A. Aguilar-Saavedra arXiv:hep-ph/0409342v4

(SM) Standard model; (2HDM) two-Higgs doublet model;
(MSSM) Minimal supersymmetric model
(R SUSY) SUSY with R-parity violating
(TC2) topcolor-assisted technicolor model



Anomalous couplings