2014 Phenomenology Symposium

Measurement of single top quark production with the ATLAS detector at LHC

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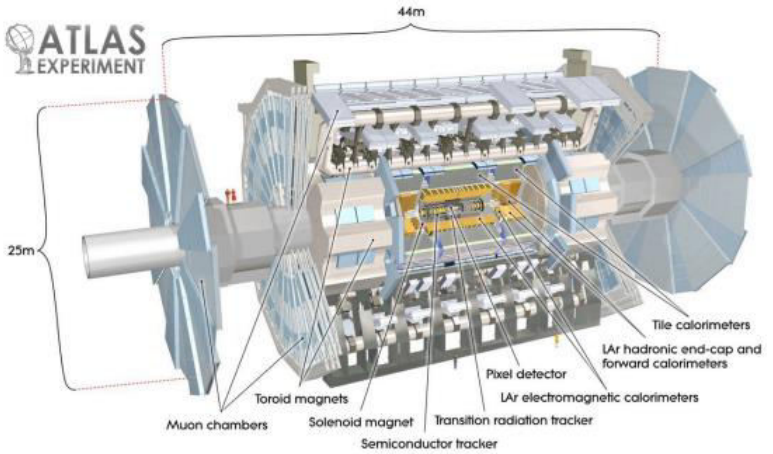
On behalf of the ATLAS collaboration



Single top quark

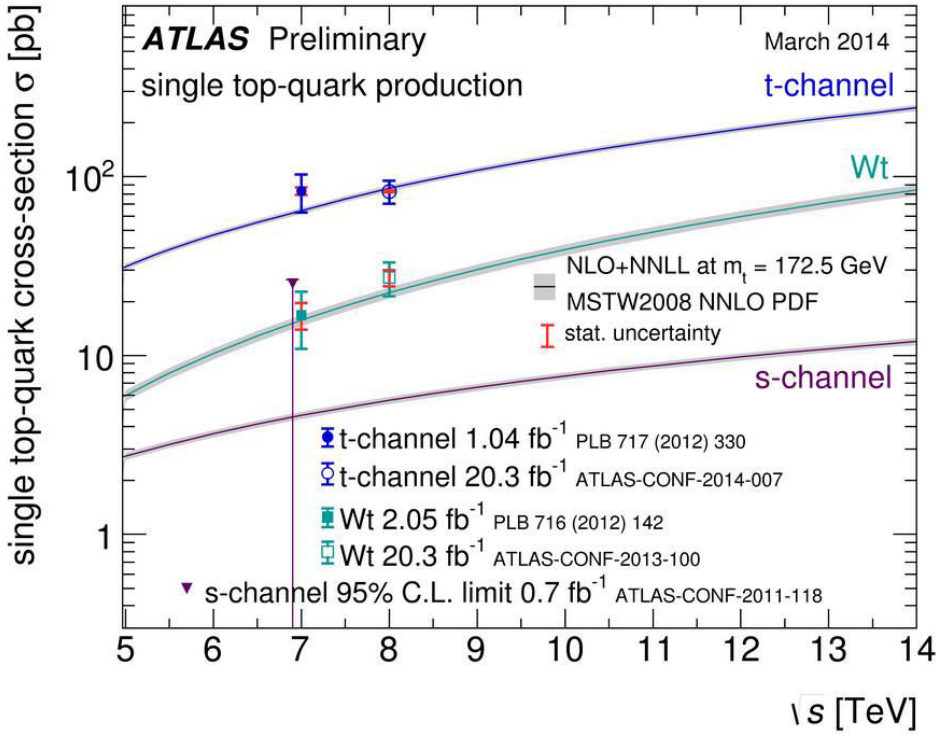
- ATLAS has a very rich top quark and heavy flavour physics program.
- The era of precision measurements of its properties has come.
  - High Production cross section at LHC: top quark factory!
  - Precision measurements to test SM prediction at 7 TeV and 8 TeV

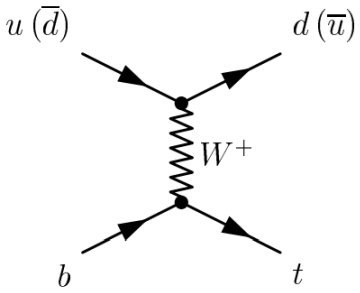
- Measurements in single top events
  - Establish production at LHC, precision test of SM electroweak coupling
  - Measure cross-sections to probe $|V_{tb}|$
  - Top quark polarization/*W* boson helicity
  - Cross-section of *ttbar* vs. single top
  - Search FCNC
  - Anomalous couplings
  - *W'*(*tb* resonance)
  - search for new particles in single top final state, like *b*->Wt, mono top*, etc

Outline

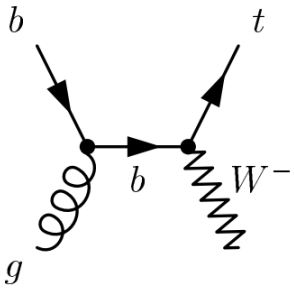
Analyses overview

- *t*-channel fiducial cross section @8TeV
- *Wt* cross section measurement @8TeV
- Top/anti-top quark ratio measurement @7TeV
- FCNC searches @8TeV
- *s*-channel searches @7TeV
- Anomalous coupling analysis @7TeV

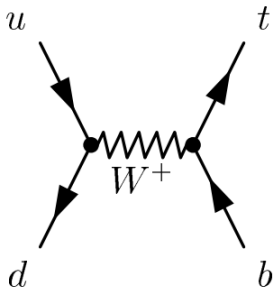




t-channel



Wt-channel



s-channel

Leading order Feynman diagrams for single top quark production in three channel via electroweak interaction.

t-channel fiducial cross-section @ 8 TeV

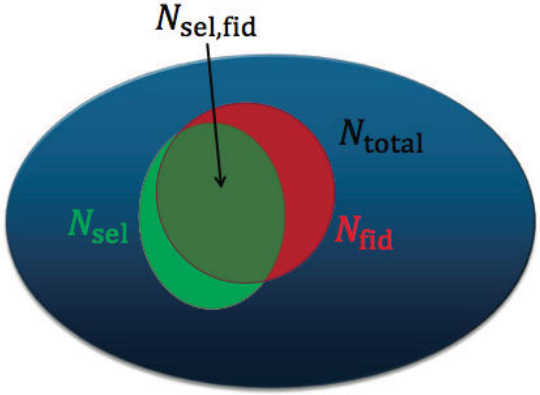
ATLAS-CONF-2014-007

- **Motivation**: To measure where the detector is sensitive, but also to reduce generator uncertainties due to the extrapolation to the full phase space.
- **Selection cuts of the fiducial volume:**

  Lepton P_T >25GeV and $|\eta|$<2.5 , E_T^{miss} > 30 GeV, $\Delta R(l,j) > 0.4$.

  Jet P_T >30GeV and $|\eta|$ <4.5 or >35GeV if 2.75<$|\eta|$<3.5, $m_T(W)$ > 50GeV.

- **Strategy**:
  - Binned likelihood fit to a NN (Neural Network) output to estimate the expected number of single top *t*-channel events.



- **Measurement of the fiducial cross-section**

$$\sigma = \frac{\hat{\nu}}{\epsilon\mathcal{L}} = \frac{1}{\epsilon_{\text{fid}}}\frac{\epsilon_{\text{corr,sel}}}{\epsilon_{\text{corr,fid}}}\frac{\hat{\nu}}{\mathcal{L}} = \frac{1}{\epsilon_{\text{fid}}}\sigma_{\text{fid}}$$

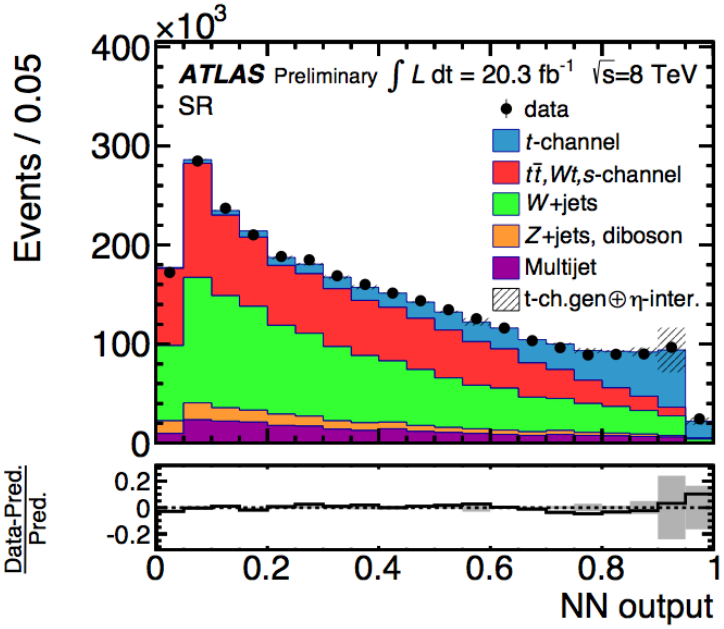
$$\epsilon = \frac{N_{\text{sel}}}{N_{\text{total}}}, \quad \epsilon_{\text{fid}} = \frac{N_{\text{fid}}}{N_{\text{total}}}, \quad \epsilon_{\text{corr,sel}} = \frac{N_{\text{sel,fid}}}{N_{\text{sel}}}, \quad \epsilon_{\text{corr,fid}} = \frac{N_{\text{sel,fid}}}{N_{\text{fid}}}$$

- **Neural Network**
  - NN is trained with 14 variables ($|\eta(j)|$, m(*lvb*), m(*jb*), etc.) to separate the *t*-channel signal from background events considering their correlation.

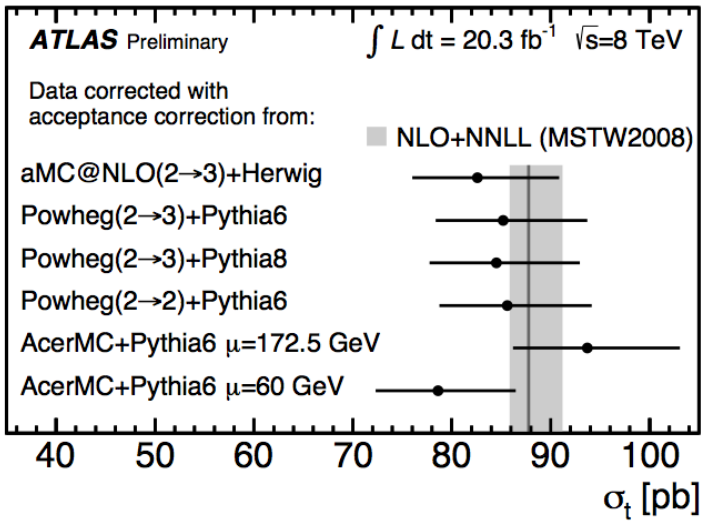
t-channel fiducial cross-section @ 8TeV

ATLAS-CONF-2014-007

- **Results**
  - A binned likelihood fit is performed on the NN output discriminant distribution to ascertain the signal and background fractions.



t-channel=87.76+3.44-1.91pb (Vertical line in this plot)
(Phys.Rev. D 83, 091503(R)(2011)



σ_{fid}= 3.37 ± 0.05(stat.) ± 0.47(syst.) ± 0.09(lumi.) pb

Main uncertainties: JES η-intercalibration(7.9%), *t*-channel generator. (7.9%)

Using various MC generator models, the fiducial cross-section can be extrapolated to the full phase space and can be compared to the NLO+NNLL calculation.

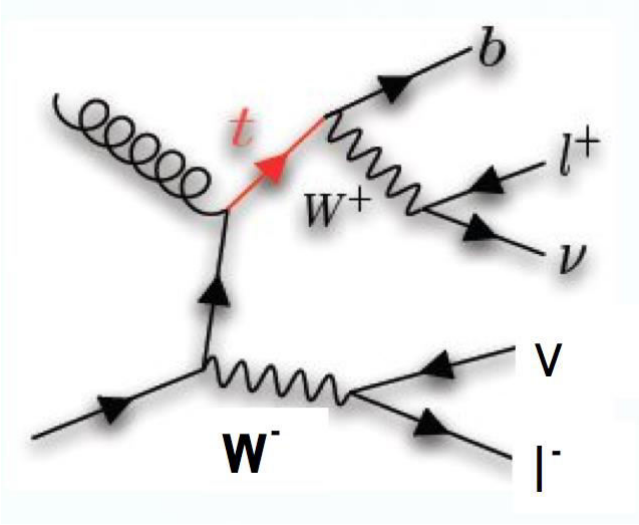
σ_t= 82.6±1.2(stat.)±11.4(syst.)±3.1(PDF)±2.3(lumi.) pb (aMC@NLO)

The value of $|V_{tb}|$ can be extracted using the acceptance of the aMC@NLO +Herwig generators:

$|V_{tb}|$=0.97+0.06-0.07(exp.)±0.06(gen.+PDF+theor.)

Measure *Wt* cross-section in dilepton decay mode @ 8 TeV

ATLAS-CONF-2013-100



Exactly 2 leptons

One e and one μ opposite-sign charge
Electron: P_T > 25 GeV, |η| <2.47
Muon P_T>25 GeV, |η| <2.5

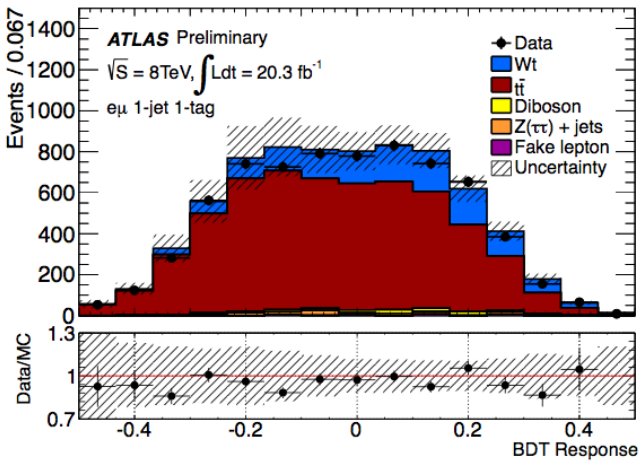
One or two jets, at least one jet is *b*-tagged.

BDT classifier plot for 1-jet events. Good agreement is seen between data and expectation.

- **BDT (Boosted Decision Tree) method**

Separating the *Wt* signal from the large *ttbar* background is challenging.

- ✓ BDT response is derived from 19 input variables (20 for 2 jet bin).
- ✓ The method chooses the most discriminant variables based in their separation power.



Wt channel results

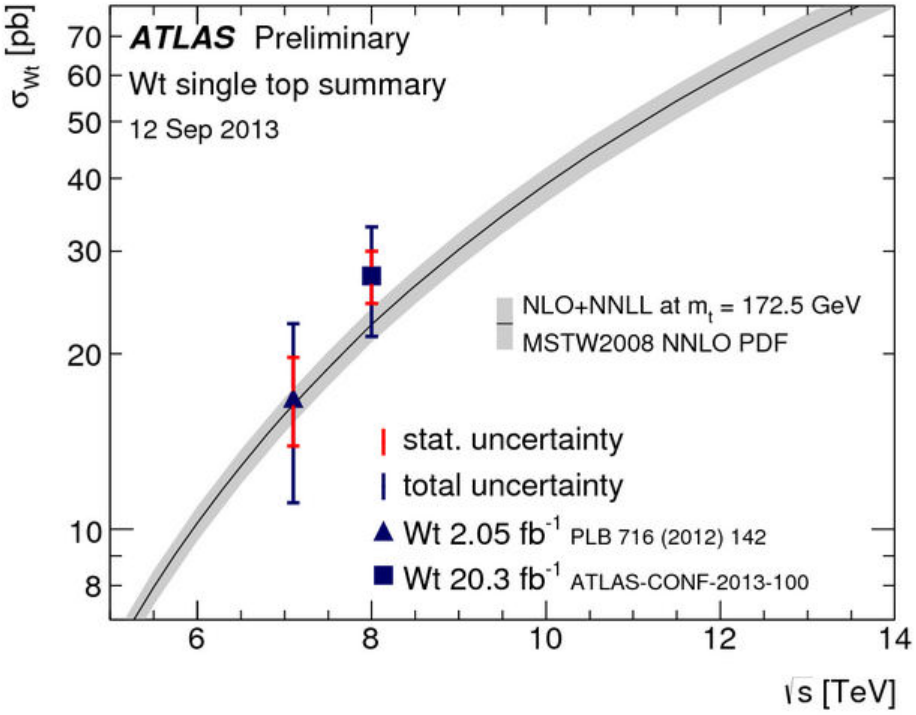
ATLAS-CONF-2013-100

- Cross section extraction:
  - Binned maximum likelihood fit.

- Measured SM *Wt* cross section:

$$\sigma(pp \rightarrow \mathrm{Wt} + \mathrm{X}) = 27.2 \pm 2.8\ (\mathrm{stat}) \pm 5.4\ (\mathrm{syst})\ \mathrm{pb}$$

- Total uncertainty: 21%.
  Main uncertainties: data statistics: 17%,
  flavor tagging 8.4%.



- A direct determination of $|V_{tb}|$ can be extracted from the cross-section:

$$|V_{tb}| = 1.10 \pm 0.12(\mathrm{exp.}) \pm 0.03(\mathrm{theory.})$$

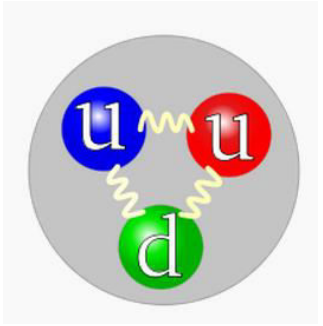
Single top quark: *t*-channel top/anti-top cross-sections and their ratio @7TeV

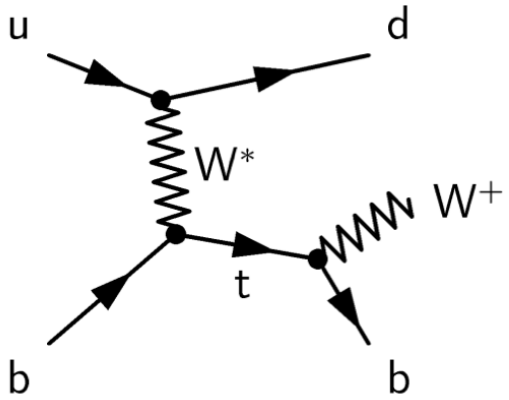
ATLAS-CONF-2012-056

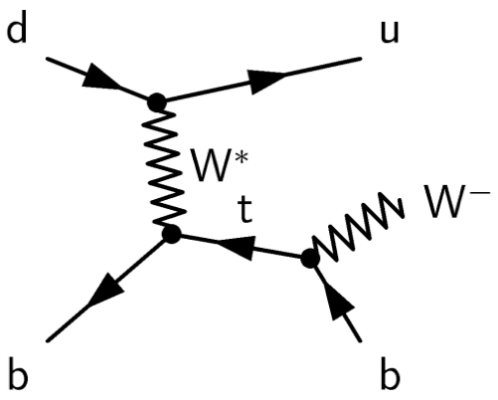
Lepton+jets event selection:

- Select events contain one charged lepton, missing transverse momentum and two or three jets, one of them *b*-tagged.
- Main background: *W*+jets, multijets and top pair, small contributions from *Z*+jets and diboson events.

The ratio $R_t=\sigma_{t\text{-ch}}(t)/\sigma_{t\text{-ch}}(\text{tbar})$ is sensitive to PDFs and new physics.







Predicted cross section:
(7TeV pp collision)

$$\sigma_t(t) = 41.9^{+1.8}_{-0.8}\ \text{pb}$$
$$\sigma_t(\bar{t}) = 22.7^{+0.9}_{-1.0}\ \text{pb}$$

N.Kidonakis, Phys.Rev. D83 (2011) 091503

Single top quark: *t*-channel top/anti-top cross section and ratio @7TeV

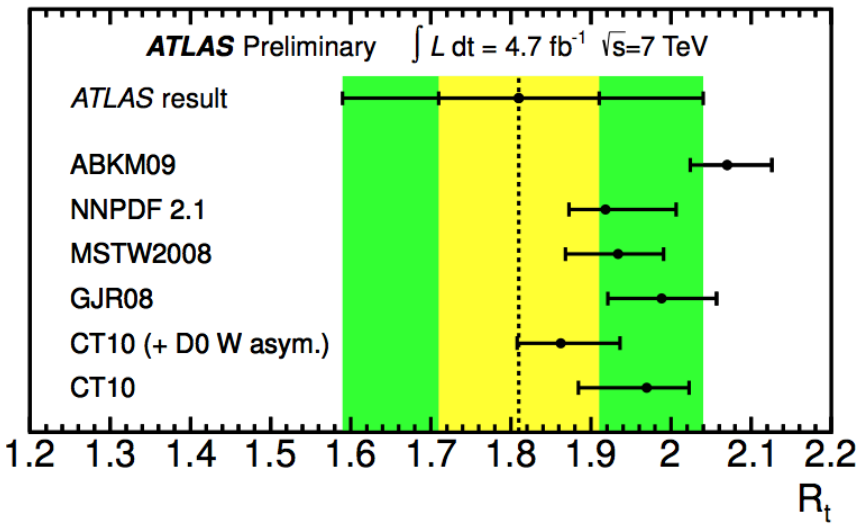
ATLAS-CONF-2012-056

- Binned maximum likelihood fit to all output of Neural Network simultaneously, split according to the charge of the lepton.
- Fit background, *t*-channel top quark and *t*-channel top anti-quark simultaneously to extract their cross-sections and R_t.

$$\sigma_t(t) = 53.2 \pm 1.7\,(\text{stat.}) \pm 10.6\,(\text{syst.})\,\text{pb} = 53.2 \pm 10.8\,\text{pb}$$
$$\sigma_t(\bar{t}) = 29.5 \pm 1.5\,(\text{stat.}) \pm 7.3\,(\text{syst.})\,\text{pb} \quad = 29.5^{+7.4}_{-7.5}\,\text{pb}.$$

$$R_t = 1.81 \pm 0.10\,(\text{stat.})\,^{+0.21}_{-0.20}\,(\text{syst.}) = 1.81^{+0.23}_{-0.22}.$$

(black line in the figure)



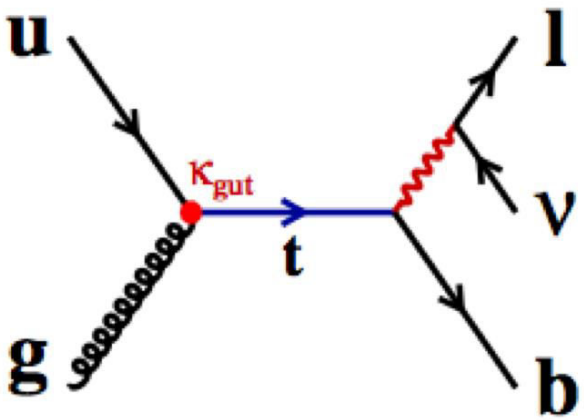
In this figure, predictions of several PDFs (NLO) are shown. The error contain the uncertainty on the renormalisation and factorization scales.

- Main backgrounds: *W*+jets, multijets and top pairs.
- Main systematic: bkg normalization (5%), ISR/FSR(4%) and JES(4%)
- Ratio measurement reduces systematic mainly on lepton eff, JES and top MC gen.

FCNC single top quark search@8TeV

ATLAS-CONF-2013-063

- ✓ **Model independent analysis**
- ✓ **FCNC highly suppressed in SM**
  - ✓ Branch ratio of FCNC top decay *t->qV* no larger than 10^{-12} (*q= u,c; V=Z, γ,g*)
  - ✓ Interesting channel, predicted by many extensions of SM
  - ✓ Observation can provide clear signal of new physics



	SM	2HDM-III	MSSM	R-MSSM	TC2
t → qg	$4{,}6\times10^{-12}$	10^{-4}	10^{-4}	10^{-3}	10^{-5}
t → qγ	$4{,}6\times10^{-14}$	10^{-7}	10^{-6}	10^{-5}	10^{-7}
t → qZ	1×10^{-14}	10^{-6}	10^{-6}	10^{-4}	10^{-5}

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

$$\mathcal{L}_{\text{eff}} = g_s \sum_{q=u,c} \frac{\kappa_{qgt}}{\Lambda} \bar{t}\,\sigma^{\mu\nu} T^a (f_q^L P_L + f_q^R P_R)\, q\, G^a_{\mu\nu} + h.c.$$

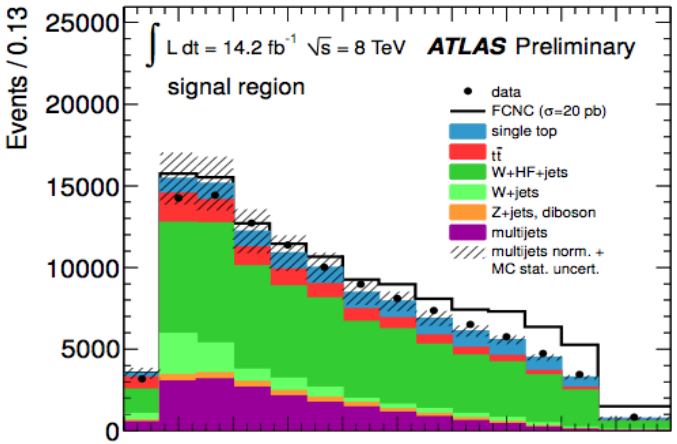
- ✓ ***tqg* coupling best studied in production mode**
  - ✓ Decay *t->qg* overwhelmed by QCD dijets background
  - ✓ Former search in ATLAS @7TeV, with integrated L=2.05fb^{-1}, σ<3.9 pb@95% C.L.

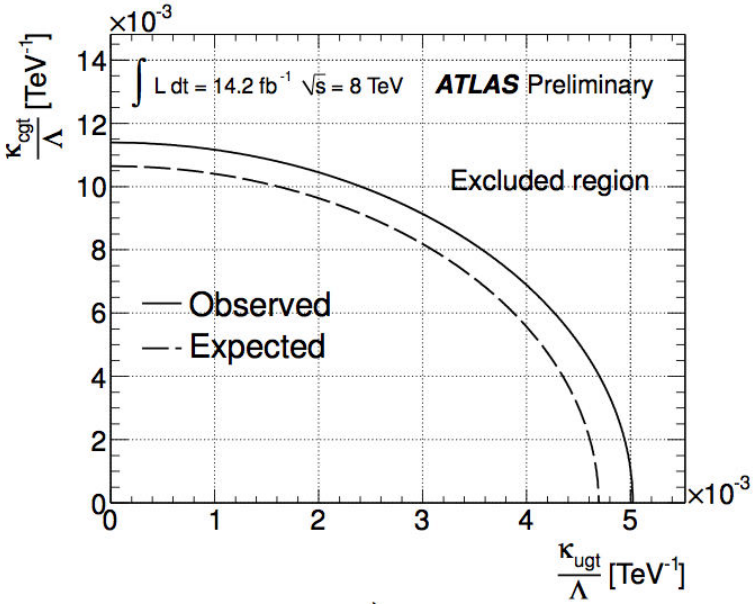
FCNC single top quark search@8TeV

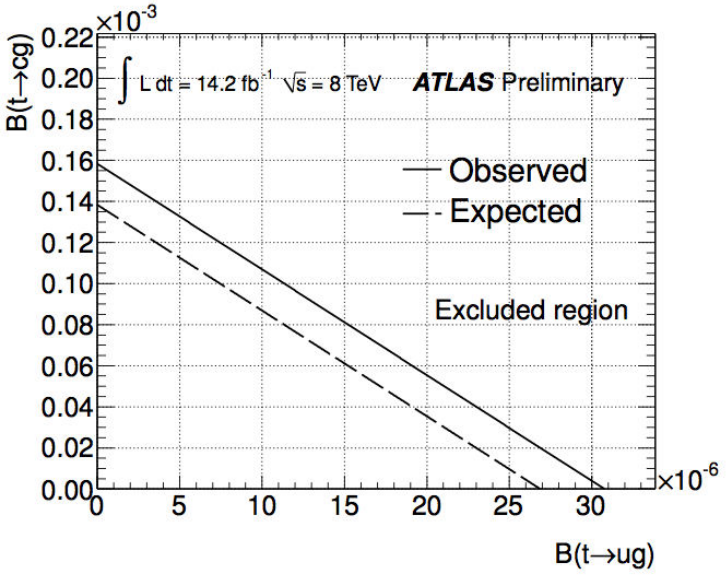
ATLAS-CONF-2013-063

- ✓ Same selection and background modelling strategy at *t*-channel analysis in 1-jet bin.
- ✓ Use Neural Network output as the discriminant.
- ✓ Set limits on cross-section and FCNC coupling to up/charm quark.
- ✓ Translate to top decay branching ratio to *ug* and *cg*

$\sigma < 2.5$pb @95% C.L.







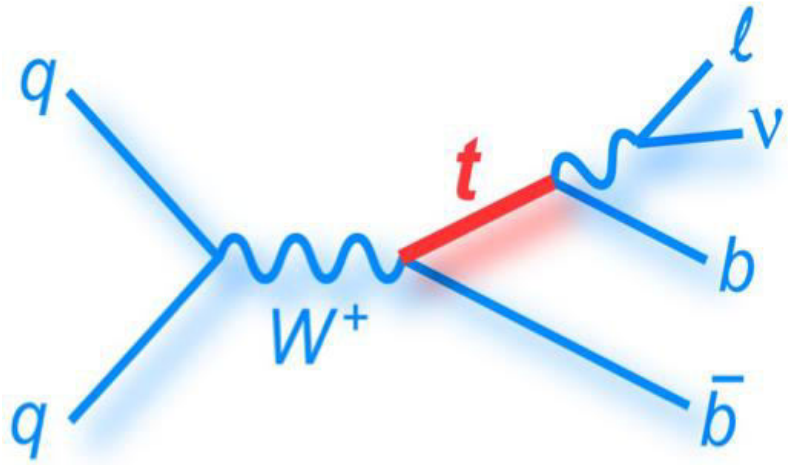
s-channel analysis @7TeV, s-channel limit

ATLAS-CONF-2011-118

- 95% C.L Limits on *s*-channel production
- Integrated luminosity 0.7 fb^{-1}.
- Main uncertainties from:

  Data statistics 100%

  Other from 20-60%
- Dominant bg: *ttbar* (~39%), *W+jets*(~34%)
- MC simulation : *s*-channel, *t*-channel, *Wt, ttbar*, *Z*+jets, Diboson.
- Data Driven: *W*+jets, Multijets



σ_t(s-channel) < 26.5 pb

***Out of ATLAS:**

On 21th, Februray 2014, through a combination of the CDF and Do measurement the first observation of single-top-quark production in the s-channel is claimed.

arXiv:1402.5126 [hep-ex] Tevatron 6.3 s.d observation

Aomalous couplings analysis @7TeV

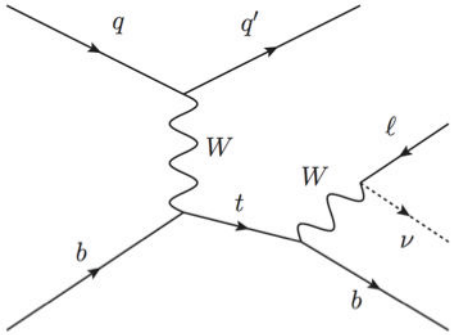
ATLAS-CONF-2013-032

Motivation: Probing the couplings of the *Wtb* vertex offers an interesting window to new physics and single top quark events provide a direct probe of these couplings.

The most general Lagrangian for *Wtb* is :

$$\mathcal{L}_{Wtb} = -\frac{g}{\sqrt{2}}\bar{b}\gamma^{\mu}\left(V_L P_L + V_R P_R\right) t W_{\mu}^{-} - \frac{g}{\sqrt{2}}\bar{b}\frac{i\sigma^{\mu\nu}}{M_W}q_{\nu}\left(g_L P_L + g_R P_R\right) t W_{\mu}^{-} + \text{h.c.}$$

In SM, V_L=V_{tb}=1 and $V_R = g_L = g_R$=0.

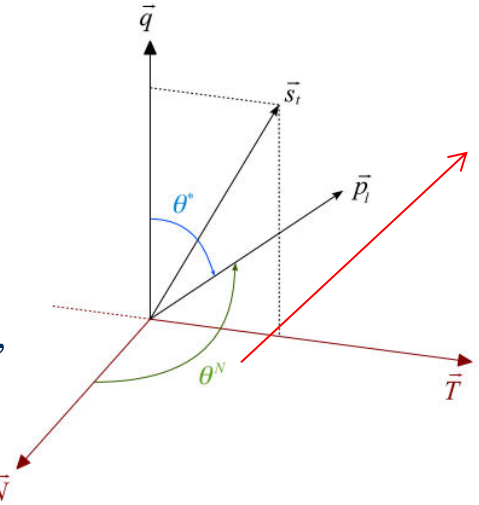


W helicity fraction $F_{+0,1}$ are sensitive to theta which is the angle between the momentum of lepton (p_l) in the *W* boson rest frame and *W* momtum(q) in the top quark rest frame.

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos\theta_{\ell}^{*}} = \frac{3}{8}(1+\cos\theta_{\ell}^{*})^2 F_{+} + \frac{3}{8}(1-\cos\theta_{\ell}^{*})^2 F_{-} + \frac{3}{4}\sin^2\theta_{\ell}^{*} F_0$$

Helicity fractions related with *Wtb* couplings.

In single top *t*-channel events, top quarks are highly polarized (P~0.9), consider the spectator quark in top rest frame, together with the *W* boson momentum.



Used in this analysis.

Anomalous coupling @7TeV

ATLAS-CONF-2013-032

The forward-backward asymmetry (AFBN) of the angular distribution between the momentum of lepton(p_l) in the W boson rest frame and the normal direction N is directly related to Im(g_R) at leading order:

$$A_{FB}^{N} \equiv \frac{N_{evt}(\cos\theta_N > 0) - N_{evt}(\cos\theta_N < 0)}{N_{evt}(\cos\theta_N > 0) + N_{evt}(\cos\theta_N < 0)}$$

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

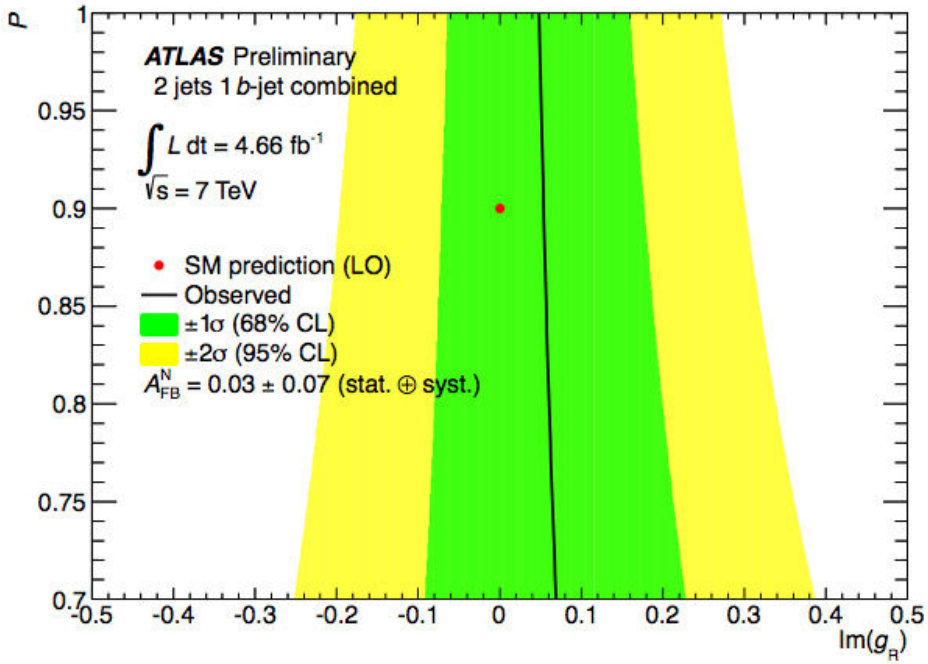
$$A_{\mathrm{FB}}^{\mathrm{N}} = 0.031 \pm 0.065\,(\mathrm{stat.})\ ^{+0.029}_{-0.031}\,(\mathrm{syst.})$$

Main systematic:
t-channel generator (~2.4%),
ttbar generator and parton shower(~1.0%)

This measurement is consistent with SM (zero in SM leading order).

No CP violation found.

Constraints in the top quark polarisation versus I(g_R) plane from the ANFB measurement.



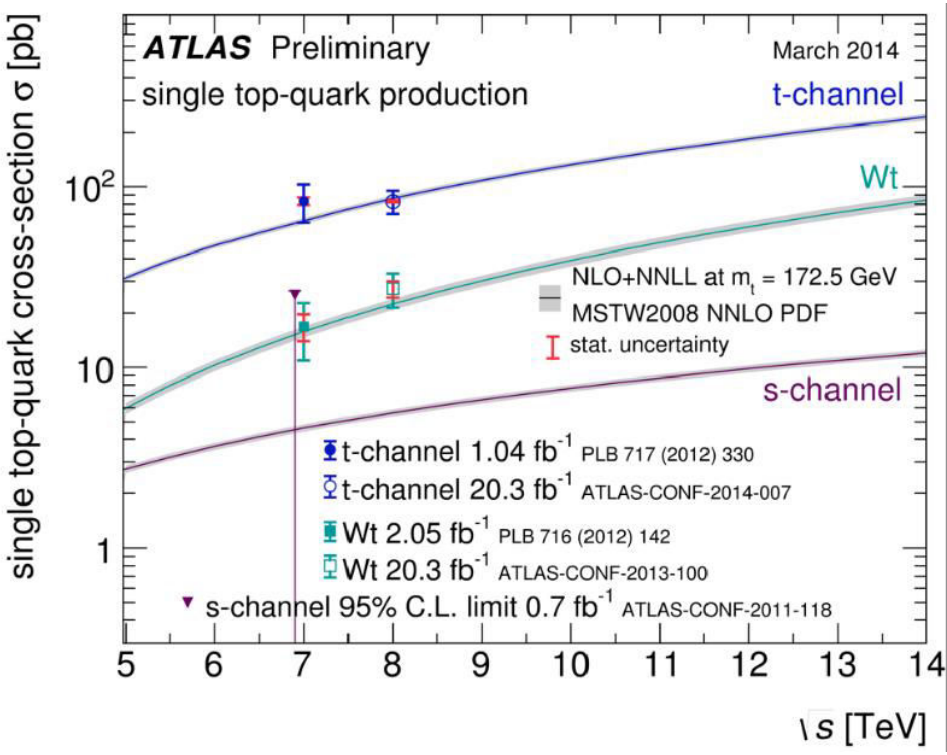
Summary and outlook

Measurement of three SM single top-quark model

✓ A fiducial cross-section has been obtained and the total inclusive *t*-channel cross-section is calculated using various MC generators.

✓ *Wt* 4.2 σ observation (4.0 σ expected).

✓ Top/anti-top quark cross-section ratio is measured and the measurement is in agreement with current SM/PDF.



Search for new physics

✓ The most stringent to date on FCNC single top-quark production processes for *qg->t* .

✓ Measurement of a CP-violating forward-backward asymmetry AFBN is consistent with CP invariance in top quark decays.

Stay tuned for next year!

Backup

s-channel analysis @8TeV

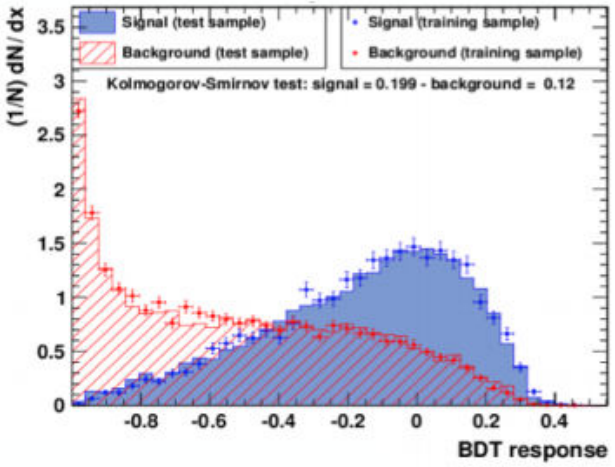
to be updated if approved

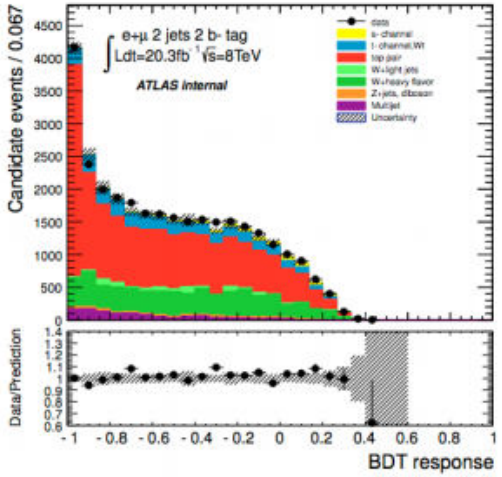
Results	ATLAS
S-channel XS	6.4 +6.6 –6.4 pb
Symmetrized total uncertainty	+/- 107%
Limit	4.4*SM
Significance	1.5 σ

Motivations: Improve results provided at 7 TeV (ATLAS-CONF-2011-102)

Strategy: Multivariate analysis. 1 lepton, 2 *b*-tag jet.

- Train one BDT against the main bkgs (ttbar, W+h.f jets) using as input variables the well modeled distributions with separation power> 5%.
- Application of the BDT algorithm to different samples of selected events.





- A binned log-likelihood fit is performed on the BDT response: $L(\beta^t, \beta^t bar; \beta_j^b) = \prod_{k=1}^{M} \frac{e^{-\mu_k} \cdot \mu_k^{n_k}}{n_k!} \cdot \prod_{j=1}^{B} G(\beta_j^b; 1.0, \Delta_j)$
- Extraction of the observed nominal *s*-channel cross-section.
  - Dominant systematics are MET scale, MC statistics and JES.
- Extracted limit has improved with respect the 7 TeV (~5·SM), expected to be ~4·SM.
- Systematics down to ~100% but still large.

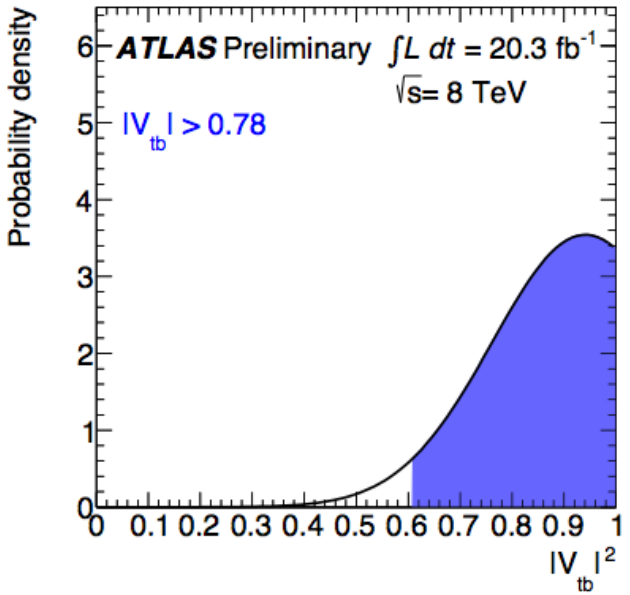
Fiducial Volume cut

Object	Cut
Electrons	$p_T > 25$ GeV and $\|\eta\| < 2.5$
Muons	$p_T > 25$ GeV and $\|\eta\| < 2.5$
Jets	$p_T > 30$ GeV and $\|\eta\| < 4.5$
	$p_T > 35$ GeV, if $2.75 < \|\eta\| < 3.5$
Lepton (ℓ), Jets (j_i)	$\Delta R(\ell, j_i) > 0.4$
E_T^{miss}	$E_T^{miss} > 30$ GeV
Transverse W-boson mass	$m_T(W) > 50$ GeV
Lepton (ℓ), jet with the highest p_T (j_1)	$p_T(\ell) > 40$ GeV $\left(1 - \frac{\pi - \|\Delta\phi(j_1,\ell)\|}{\pi - 1}\right)$

$$
\begin{aligned}
|V_{tb}| &= 0.97 \pm 0.01\,(\text{stat.})^{+0.06}_{-0.07}\,(\text{syst.}) \pm 0.06\,(\text{gen.} + \text{PDF})^{+0.02}_{-0.01}\,(\text{theor.}) \pm 0.01\,(\text{lumi.}) \\
&= 0.97^{+0.06}_{-0.07}\,(\text{exp.}) \pm 0.06\,(\text{gen.} + \text{PDF} + \text{theor.}) \\
&= 0.97^{+0.09}_{-0.10}.
\end{aligned}
$$

14 NN variable ordered by their importance.

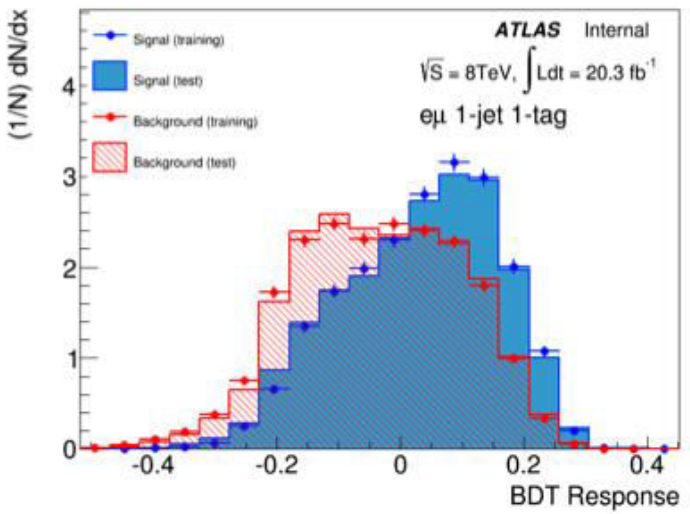
Variable	Definition
$\|\eta(j)\|$	pseudorapidity of the light quark (untagged) jet (j)
$m(\ell\nu b)$	top-quark mass reconstructed from the charged lepton, neutrino and b-quark jet
$m(jb)$	invariant mass of the tagged (b) and light quark jet (j)
$m_T(W)$	transverse mass of the reconstructed W boson
$m(\ell b)$	invariant mass of the lepton (ℓ) and the tagged jet (b)
$\eta(l\nu)$	pseudorapidity of the reconstructed W-boson
$\cos\Theta(\ell, j)_{\ell\nu b\,\text{r.f.}}$	cosine of the angle θ between the charged lepton and the light quark (untagged) jet (j) in the rest frame of the reconstructed top quark
$H_T(l, \text{jets}, E_T^{miss})$	scalar sum of the transverse momenta of the jets, the charged lepton and the missing transverse momentum
E_T^{miss}	transverse missing momentum
$\Delta R(\ell\nu b, \ell)$	ΔR of the reconstructed top quark and the charged lepton
$p_T(\ell\nu)$	transverse momentum of the reconstructed W-boson
$\eta(\ell\nu b)$	pseudorapidity of the reconstructed top quark
$\eta(b)$	pseudorapidity of the b-quark jet (b)
$p_T(\ell\nu b)$	transverse momentum of the reconstructed top quark

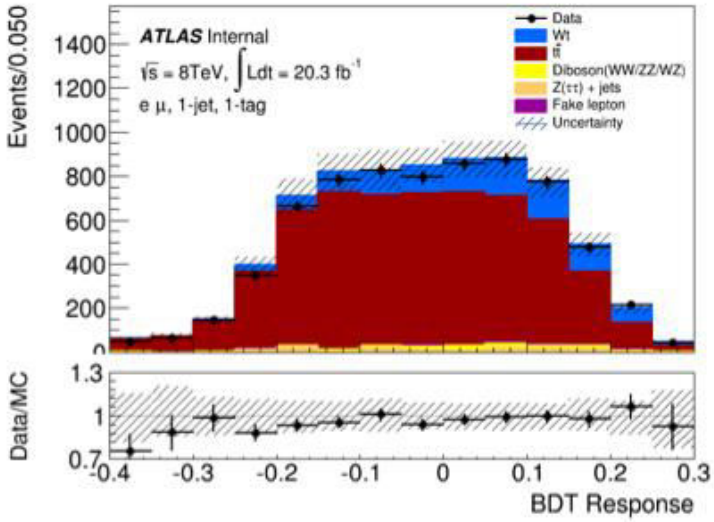


BDT, eu, 1-jet

- Summary table for the BDT input

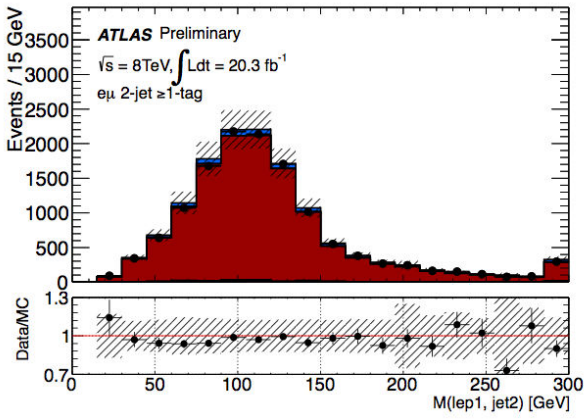
Variable	S($\times 10^3$)
$p_T^{sys}(l_1, l_2, E_T^{miss}, j_1)$	37.6
$\Delta\phi\ ((l_1, l_2),(E_T^{miss}, j_1))$	20.9
$\Delta p_T\ ((l_1, l_2, j_1), E_T^{miss})$	19.5
$\Delta p_T\ ((l_1, l_2),(E_T^{miss}, j_1))$	16.4
$\Delta\phi\ ((l_1, l_2), j_1)$	11.9
$p_T^{sys}\ (l_1, l_2, j_1)$	11.0
$H_T\ (l_2, E_T^{miss})$	9.7
$\Delta R\ (l_1, j_1)$	9.4
$\Delta p_T\ (l_1, E_T^{miss})$	9.1
$p_T^{sys}\ (l_1, j_1)$	9.0
$\Delta\phi\ (l_1, j_1)$	8.8
E_T^{miss}	8.7
$\sum E_T$	8.6
$H_T\ (l_2, E_T^{miss}, j_1)$	8.5
$\Delta R\ ((l_1, l_2), j_1)$	8.4
$p_T^{sys}\ (l_1, E_T^{miss}, j_1)$	8.2
$p_T^{sys}\ (l_2, E_T^{miss})$	8.0
$p_T^{sys}\ (l_1, l_2, E_T^{miss})$	7.8
$H_T\ (E_T^{miss}, j_1)$	7.4
$\Delta\phi\ (MET, j_1)$	7.0

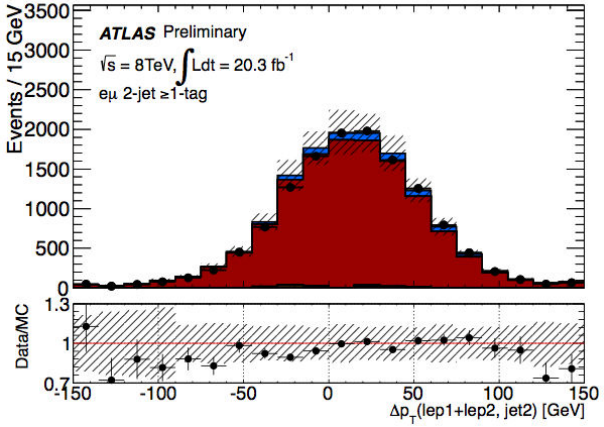




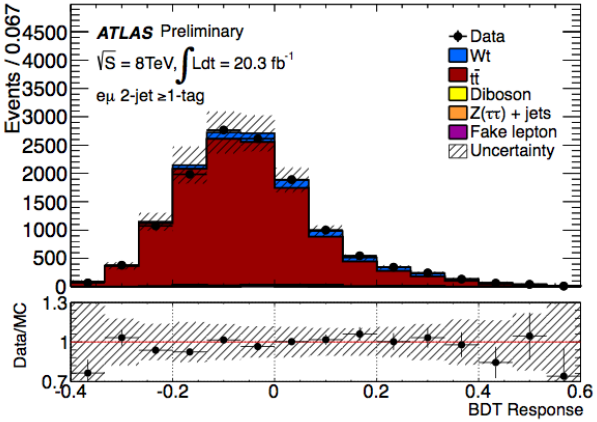
Wt channel: BDT

- Separating the Wt signal from the large ttbar background is chanllenging.
  - BDT response is derived from 19 input variables(20 for 2 jet). These 19 well modeled variables are combined into a powerful one.
  - The method chooses the most discriminant variables based in their separation power:





Two most discriminating variable 2jet events.



BDT classifier plot for 2-jet events.

Wt channel results

- Signal extraction:
  - Maximum likelihood fit.
  - Including 2-jet and >=3 jet

  bin in the likelihood function to

  control top pair.
- Measured SM Wt cross section.

$$\sigma(pp \to \mathrm{Wt} + \mathrm{X}) = 27.2 \pm 2.8\ (\mathrm{stat}) \pm 5.4\ (\mathrm{syst})$$

- Interpreted to |Vtb| by assuming Wt mainly produced from |Vtb|, without any assumption on top decay

$$|V_{tb} \cdot f| = 1.10 \pm 0.12\ (\mathrm{exp}) \pm 0.03\ (\mathrm{theory})\,.$$

where f is a coupling which is allowed to be greater than 1 (f=1 in SM).

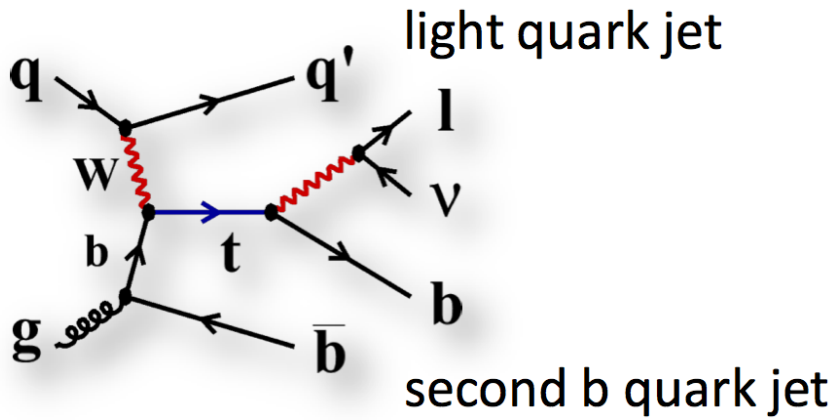
Source	$\Delta\sigma/\sigma$ [%] observed	expected
Data statistics	7.1	8.6
MC statistics	2.8	3.5
Experimental uncertainties		
Lepton modeling	2.4	2.4
Jet identification	0.2	0.6
Jet energy scale	10	12
b-jet energy scale	5.0	6.3
Jet energy resolution	0.7	0.2
$E_{\mathrm{T}}^{\mathrm{miss}}$ scale	4.1	5.0
$E_{\mathrm{T}}^{\mathrm{miss}}$ resolution	4.5	5.3
Flavor tagging	8.4	9.4
Theory uncertainties		
$Wt/t\bar{t}$ overlap modeling	1.4	1.6
PDF	2.5	3.2
Background normalization	3.6	4.4
ISR/FSR	5.9	6.0
Wt generator and PS	11	11
$t\bar{t}$ generator and PS	7.5	9.2
Luminosity	3.7	3.9
Total (syst)	20	23
Total (syst+stat)	21	24

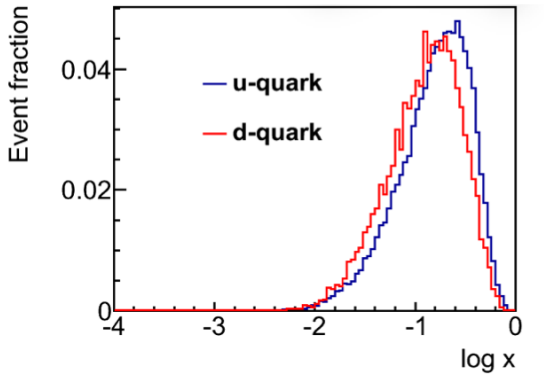
Single top quark: t-channel top/anti-top cross section and ratio @7TeV

ATLAS-CONF-2012-056

Motivation to measure the cross-section ratio R_t in the t-channel:

- ✓ The charge of the top quark is connected to the type of the incoming light-flavour quakr.
- ✓ Momentum fractions for incoming u- and d-quark in t-channel single events: $0.02 < x < 0.5$.
- ✓ PDF prediction for R_t quite different, R_t can provide additional information to further constrain PDFs.
- ✓ Investigating R_t also provides an interesting handle on searching for new physics.





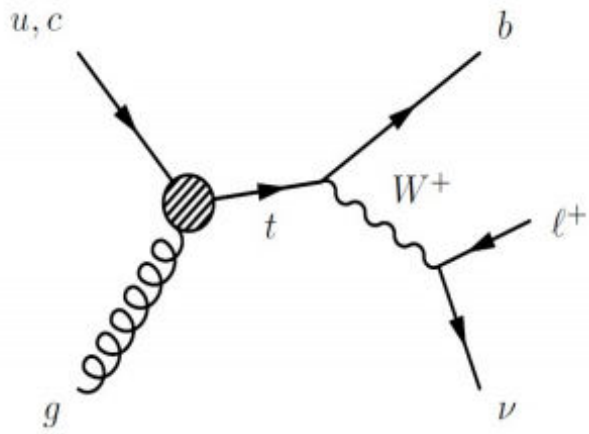
LHC energy at 7TeV

FCNC highly suppressed in SM

- branching ratio of FCNC top decay t → qV no larger than 10^{-12} (q = u, c V = Z, γ, g)
- new physics models allow e.g. top FCNC interactions at much larger rates
- observation would provide clear signal of new physics

	SM	2HDM-III	MSSM	R-MSSM	TC2
t → qg	$4{,}6\times10^{-12}$	10^{-4}	10^{-4}	10^{-3}	10^{-5}
t → qγ	$4{,}6\times10^{-14}$	10^{-7}	10^{-6}	10^{-5}	10^{-7}
t → qZ	1×10^{-14}	10^{-6}	10^{-6}	10^{-4}	10^{-5}

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



tqg coupling best studied in production mode:

- decay t → qg overwhelmed by QCD dijets background
- former search in ATLAS using parts of 2011 data: limit σ(qg→t) ×BR(t → Wb) **< 3.9 pb**
- current limits on branching fractions: BR(t→ug) **< 5.7 · 10^{-5}** BR(t→cg) **< 2.7 · 10^{-4}**

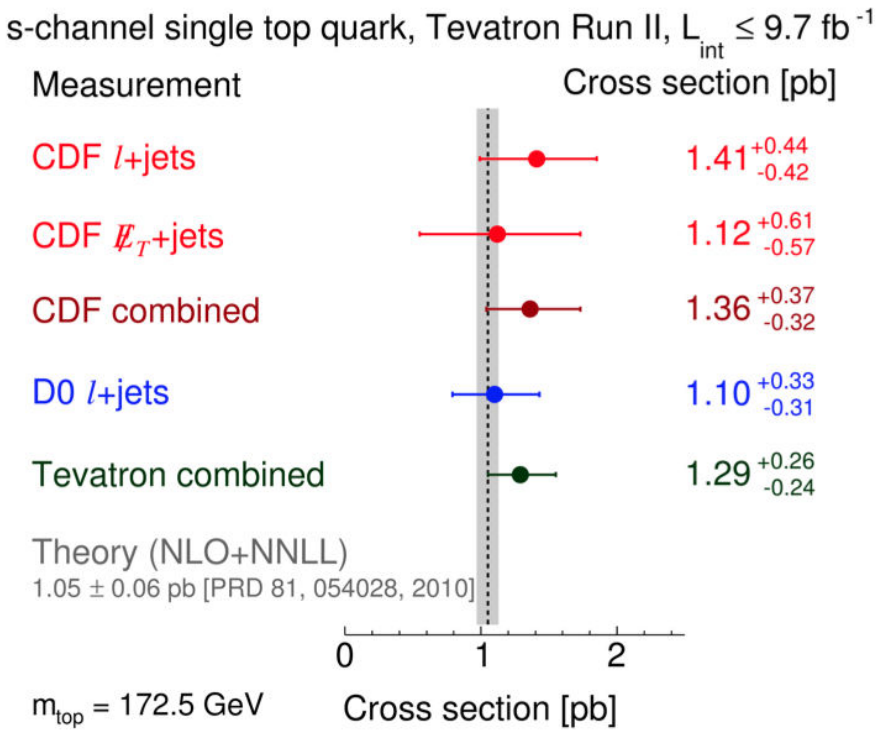
2012 analysis:

- switched to (14.2 fb^{-1}) 8TeV 2012 dataset & NLO signal generator (incl. 2 → 2 processes)

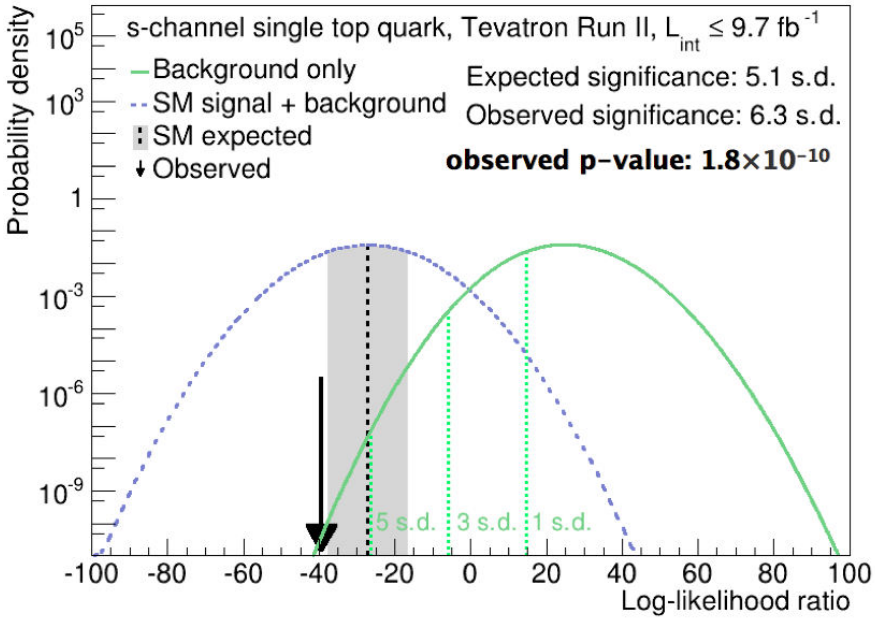
s-channel observation at Tevatron

arXiv:1402.5126 [hep-ex]
Tevatron observation

- On 21th, Februray 2014, through a combination of the CDF and D0 measurement the first observation of single-top-quark production in the *s*-channel is claimed.



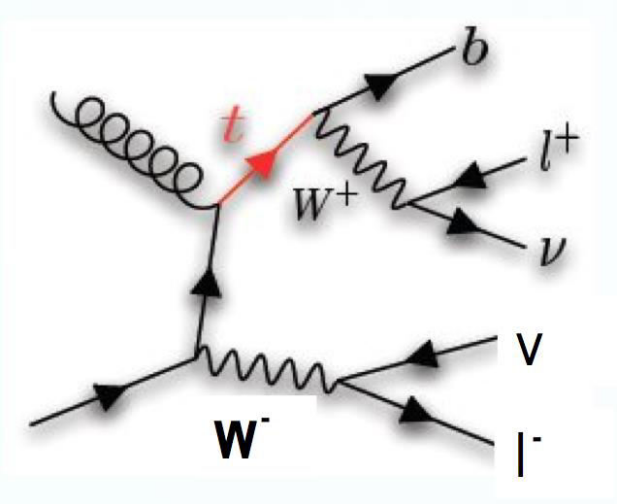
observation of s-channel production: 6.3 s.d.



Measure *Wt* cross-section in dilepton decay mode @ 8 TeV

- Very hard to separate from top quark pair production

ATLAS-CONF-2013-100



Exactly 2 leptons

One e and one μ opposite-sign charge
Electron: P_T > 25 GeV, |η| <2.47
Muon P_T>25 GeV, |η| <2.5

One or two jets, at least one jet is *b*-tagged.

Process	1-jet	2-jet
Wt	1140 ± 190	710 ± 100
$t\bar{t}$	5700 ± 800	12700 ± 1400
Diboson	120 ± 30	79 ± 28
$Z(\tau\tau)$ + jets	110 ± 40	90 ± 40
Fake lepton	27 ± 14	22 ± 11
Total Expected	7100 ± 1100	13600 ± 1600
Data Observed	6906	13159

Simulation

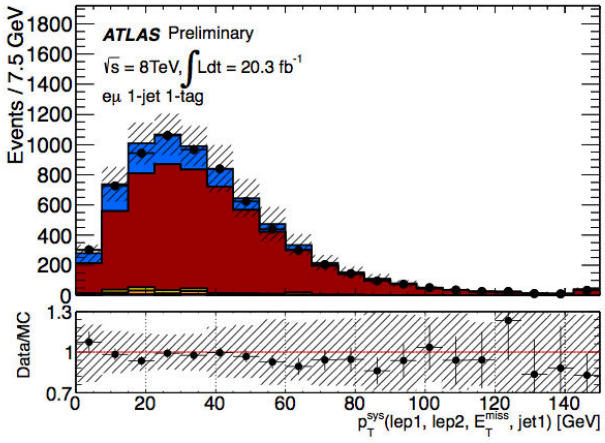
Data, using a matrix method

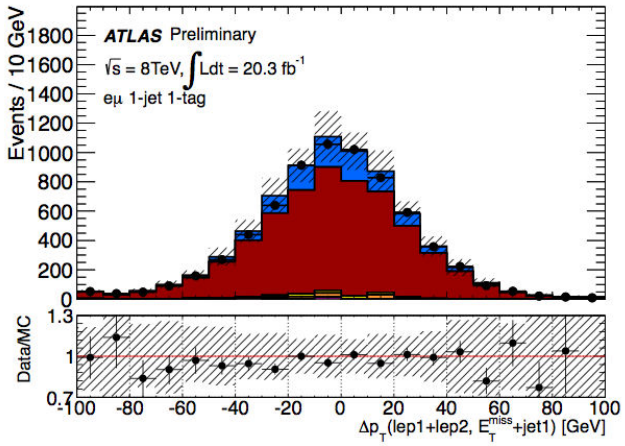
Wt channel: BDT (Boosted Decision Tree)

- Separating the *Wt* signal from the large *ttbar* background is challenging.

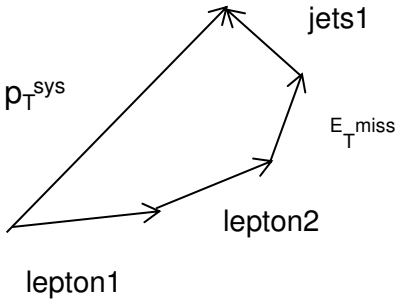
ATLAS-CONF-2013-100

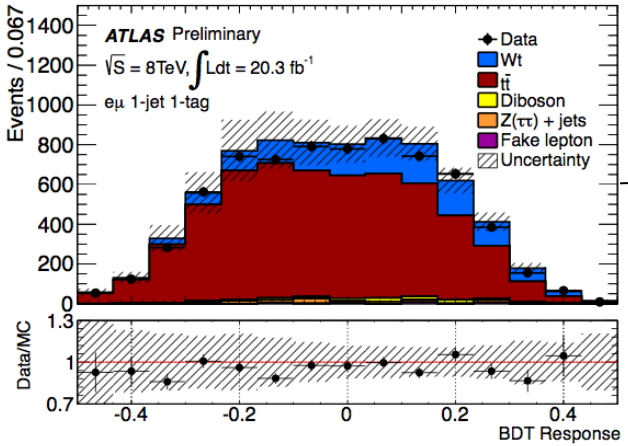
  - BDT response is derived from 19 input variables (20 for 2 jet bin).
  - The method chooses the most discriminant variables based in their separation power:





Two most discriminating variables in 1 jet BDT.





BDT classifier plot for 1-jet events.
Good agreement is seen between data and expectation in 2-jet as well.