Single-top quark production cross section using the ATLAS detector

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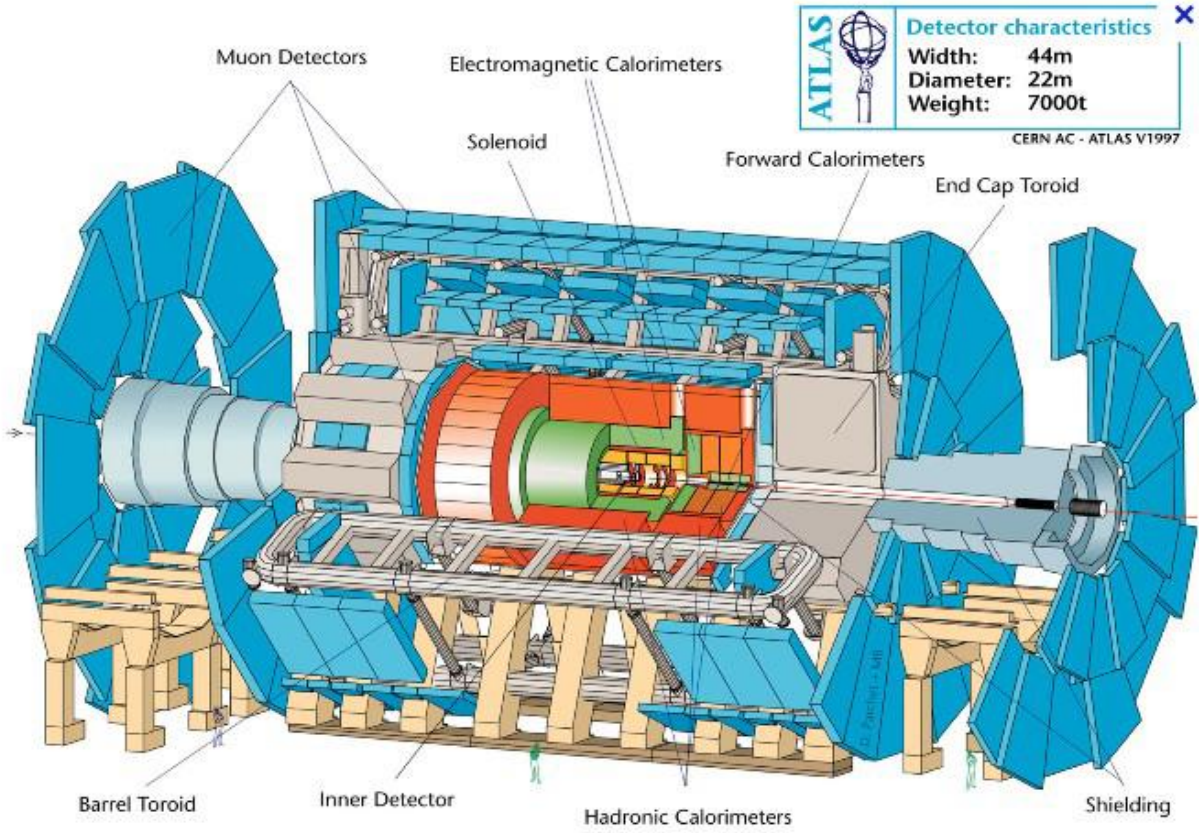
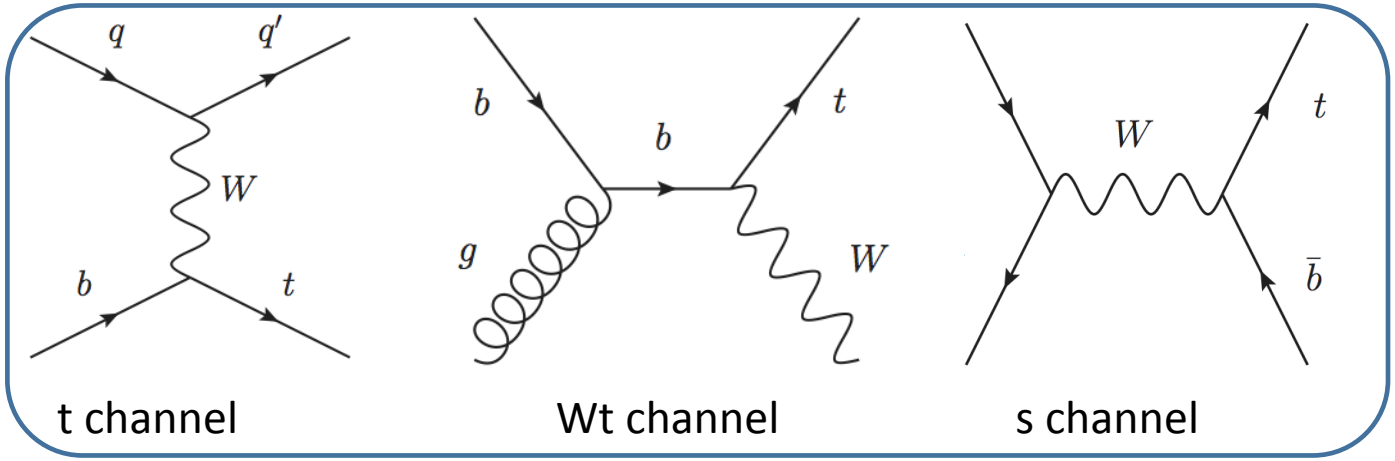
Outline

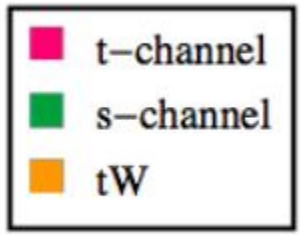
- Introduction
- Precision measurements of t-channel
  - Top-antitop cross section ratio
  - Differential cross section
  - Fiducial cross section
- Wt cross section measurement
- Search for s-channel production
- New physics search
  - FCNC in strong interaction
  - W', b*
- Summary

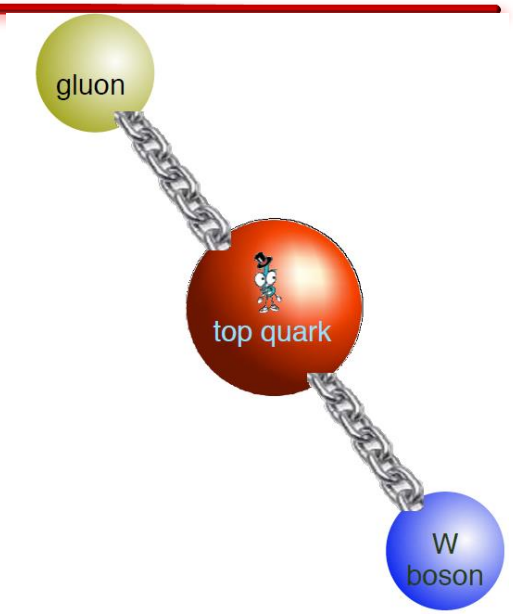


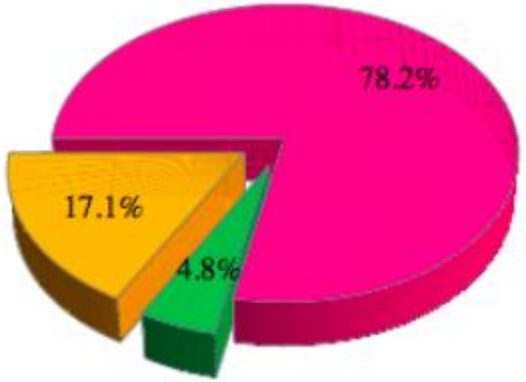
Introduction

- LHC is top quark factory.
  - 15M top quarks produced in 2011 and 2012
  - In pair via strong interaction. σ_{tot}=253pb@8TeV in LHC
  - singly via electroweak interaction. σ_{tot}=114pb@8TeV in LHC
- Single top production in three modes







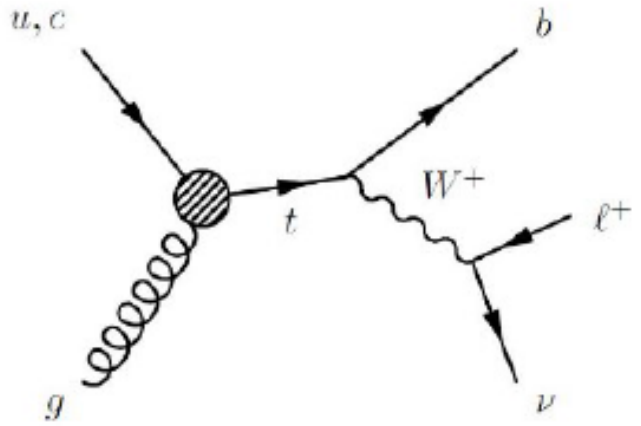


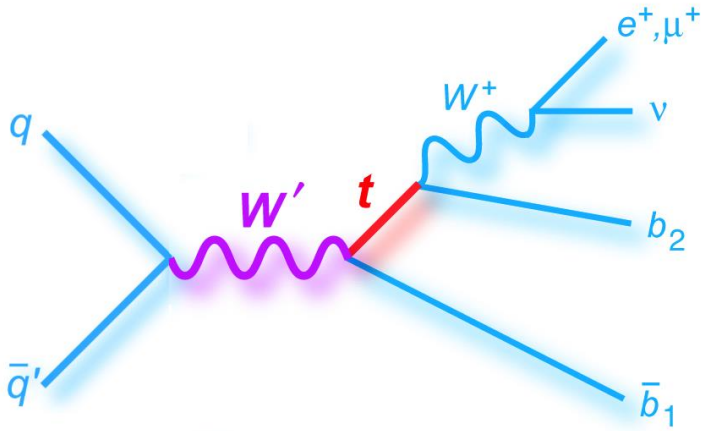
Why looking for single top

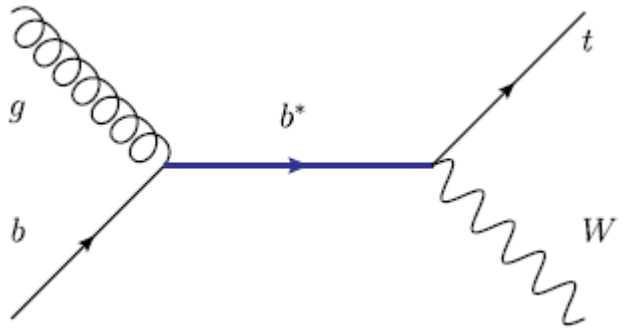
- ✓ Precision test of the standard model
  direct probe of the W-t-b coupling

- ✓ PDF constraints
  top/anti-top cross section ratio

- ✓ Sensitive to new physics
  - Flavor changing Neutral Currents ,
    suppressed by GIM Mechanism
  - new particle: W' boson , b*

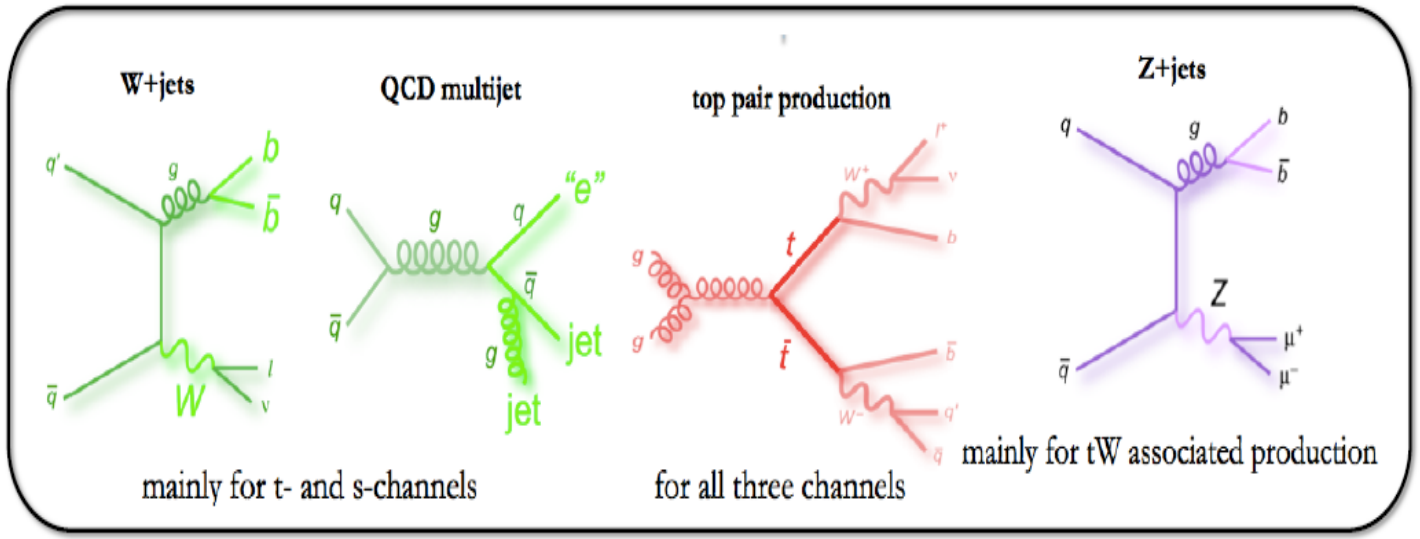






Main Backgrounds

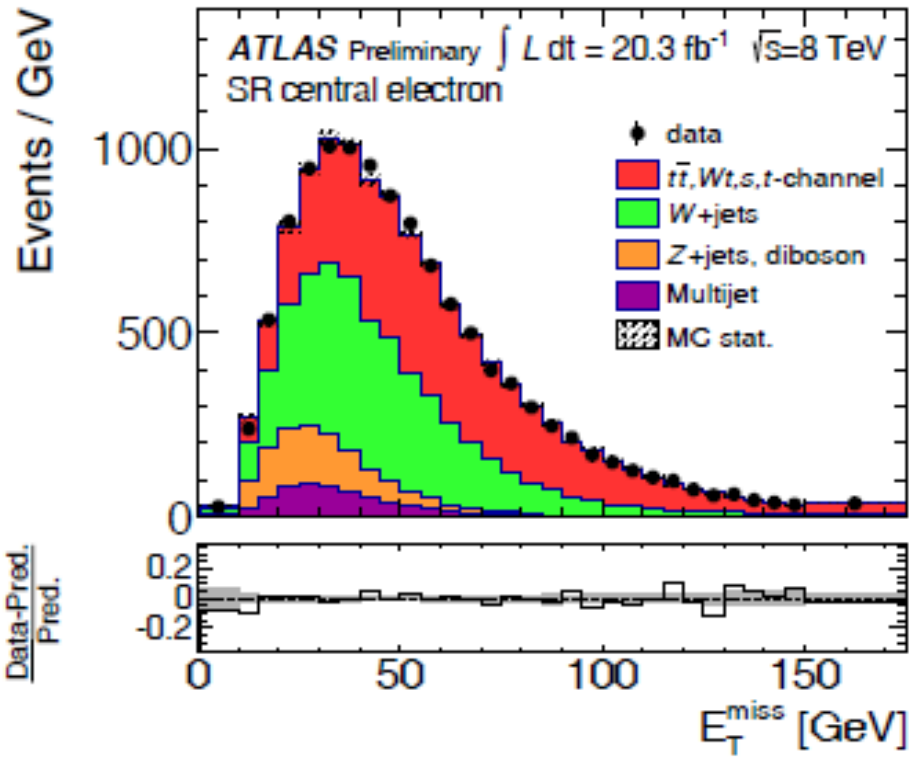
Backgrounds



-top pair, Z+jets: modelled using MC and scale to theory prediction at NNLO

- W+jets: MC modelling and data driven

- Multijet: derived from data with matrix method or maximum-likelihood fit of a multijet model.



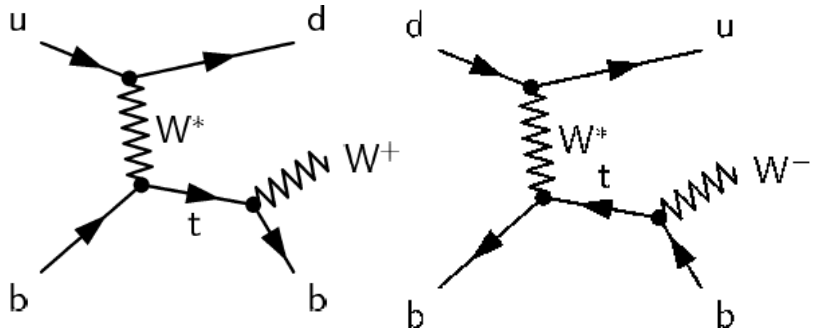
(a) Central electron channel in the signal region

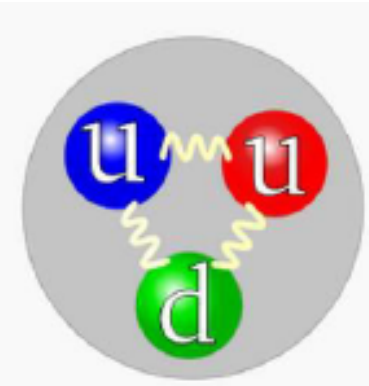
Miss ET distribution after t-channel event selection

t-channel @7TeV: ratio top/anti-top

arXiv:1406.7844, accepted by PRD

$\mathcal{L}$=4.59fb^{-1}



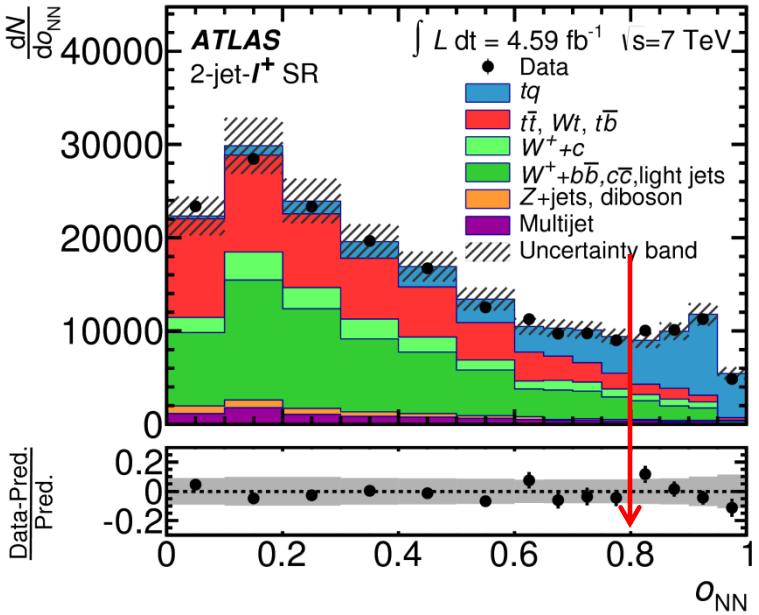


- Top and anti-top quark production asymmetric in t-channel
- Ratio R_t is sensitive to the ratio of u/d quark PDF

$$R_t = \frac{\sigma_t(t)}{\sigma_t(\bar{t})}$$

- Smaller uncertainties due to partial cancelations of common uncertainties

- Signal sample simulated with POWHEG(4F)+Pythia6,CT104f
- Two neural networks training for each 2-jet and 3-jet channel
- Extracted XS by binned maximum-likelihood fit to NN out distribution
- HPR(High purity region): O_{NN}>0.8
  - S/B~1(2) for $l^-(l^+)$



t-channel @7TeV: ratio top/anti-top

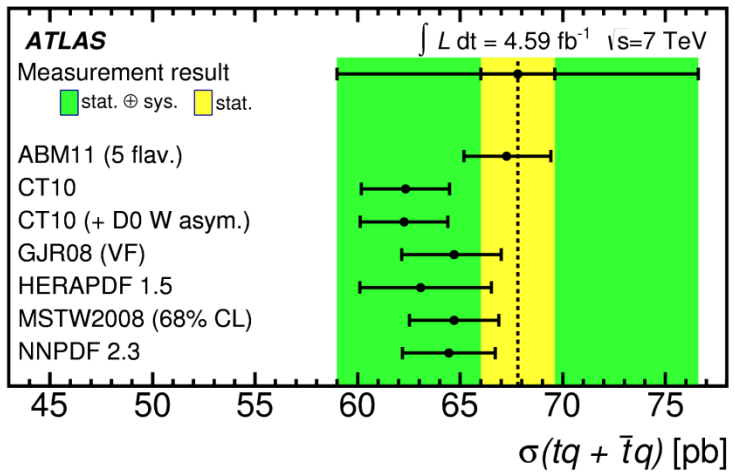
arXiv:1406.7844, accepted by PRD

Top and anti top production cross section and ratio R_t

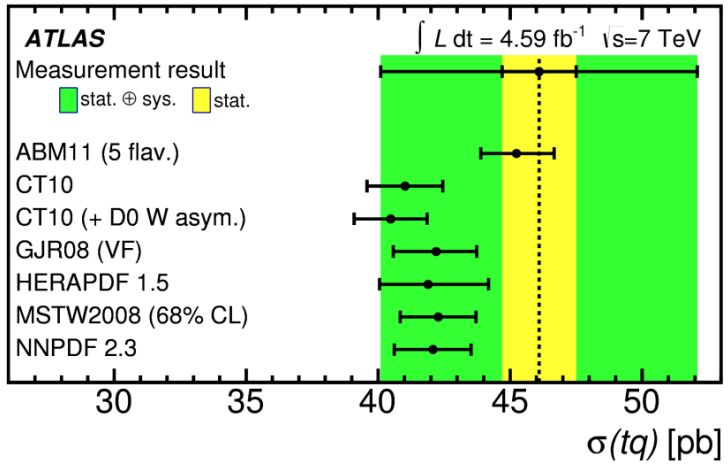
$$\sigma(tq) = 46 \pm 1\,(\text{stat.}) \pm 6\,(\text{syst.})\,\text{pb} = 46 \pm 6\,\text{pb},$$
$$\sigma(\bar{t}q) = 23 \pm 1\,(\text{stat.}) \pm 3\,(\text{syst.})\,\text{pb} = 23 \pm 4\,\text{pb}$$
$$R_t = 2.04 \pm 0.13\,(\text{stat.}) \pm 0.12\,(\text{syst.}) = 2.04 \pm 0.18$$

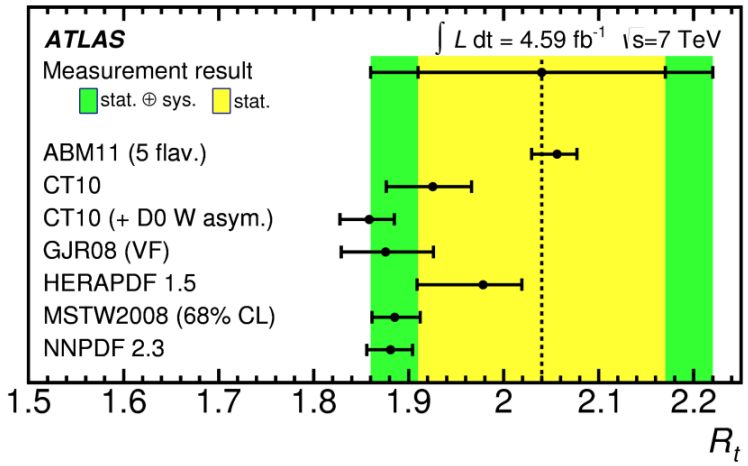
t-channel total cross section at 7TeV

$$\sigma(tq+\bar{t}q) = 68 \pm 2(\text{stat.}) \pm 8(\text{syst.})\text{pb}$$



Prediction from MCFM and Hathor using different PDF sets





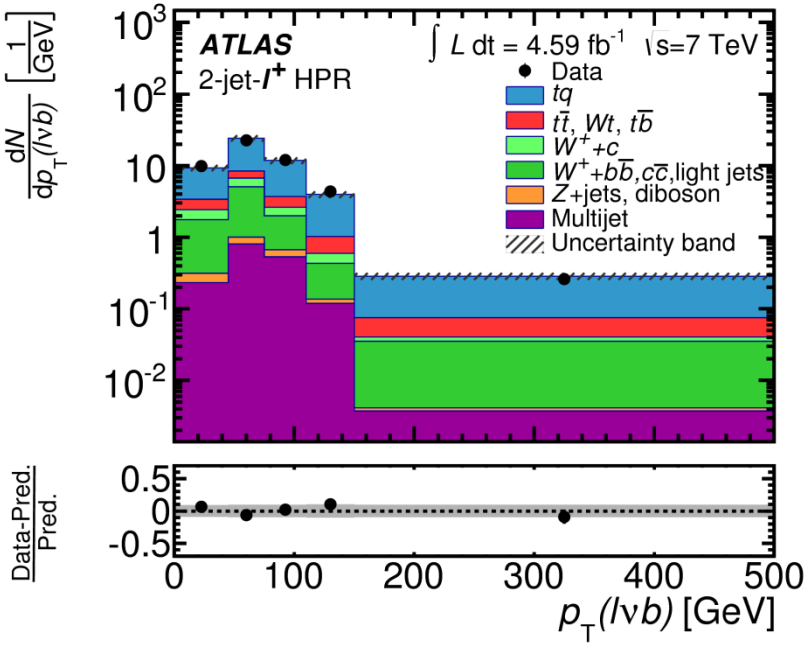
Kruger 2014,

- Improve the precision will constrain the PDF set

t-channel @7TeV: Differential cross section

arXiv:1406.7844, accepted by PRD

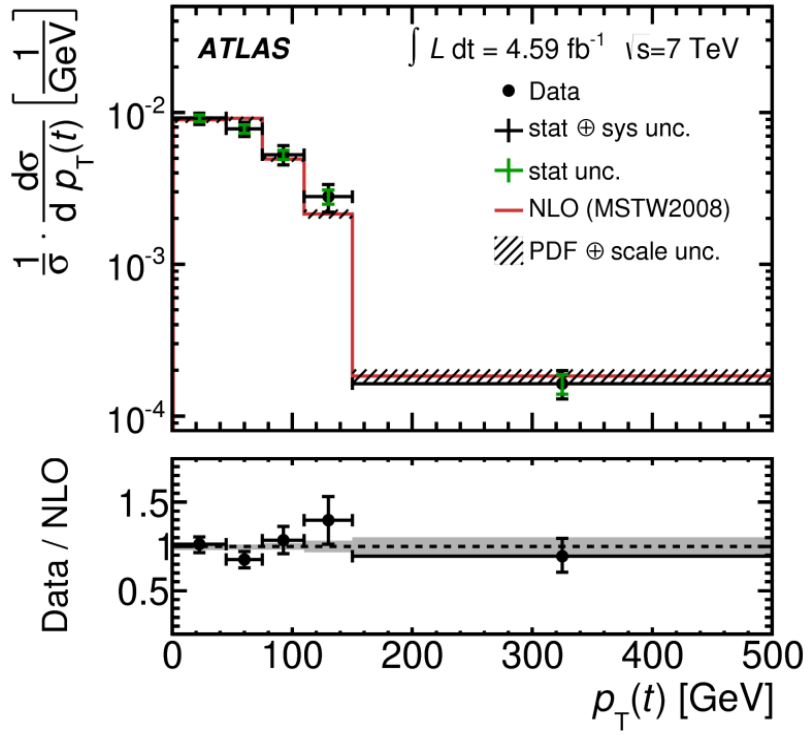
Measured 2-jet channel in high purity region of NN output



Measured distribution of the top-quark pT, distorted by detector effects and acceptance effects.

Bayesian unfolding

Good agreement with NLO prediction



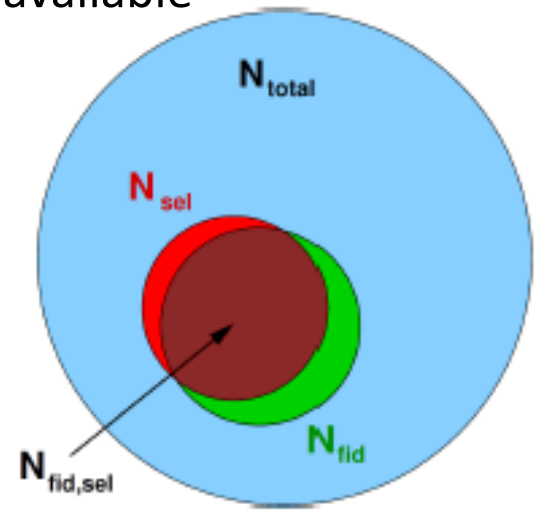
Normalized differential cross section of pT, agreement with the QCD NLO calculation.

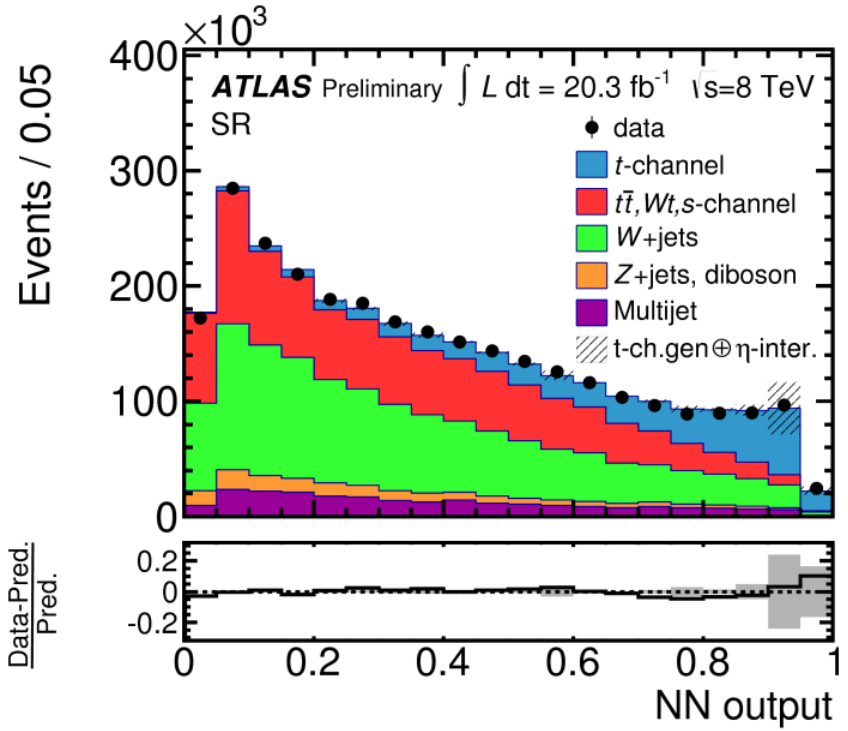
t-channel@8TeV: Fiducial cross-section

-ATLAS-CONF-2014-007

- A fiducial volume within the detector acceptance
  - Definition of fiducial volume using truth particle
  - reduction of modeling uncertainties
  - allows re-interpretation when better MC available

$$\sigma_{\text{fid}} = \frac{\text{P}(\text{fiducial} \mid \text{selected})}{\text{P}(\text{selected} \mid \text{fiducial})} \cdot \frac{\hat{\nu}}{\mathcal{L}}$$





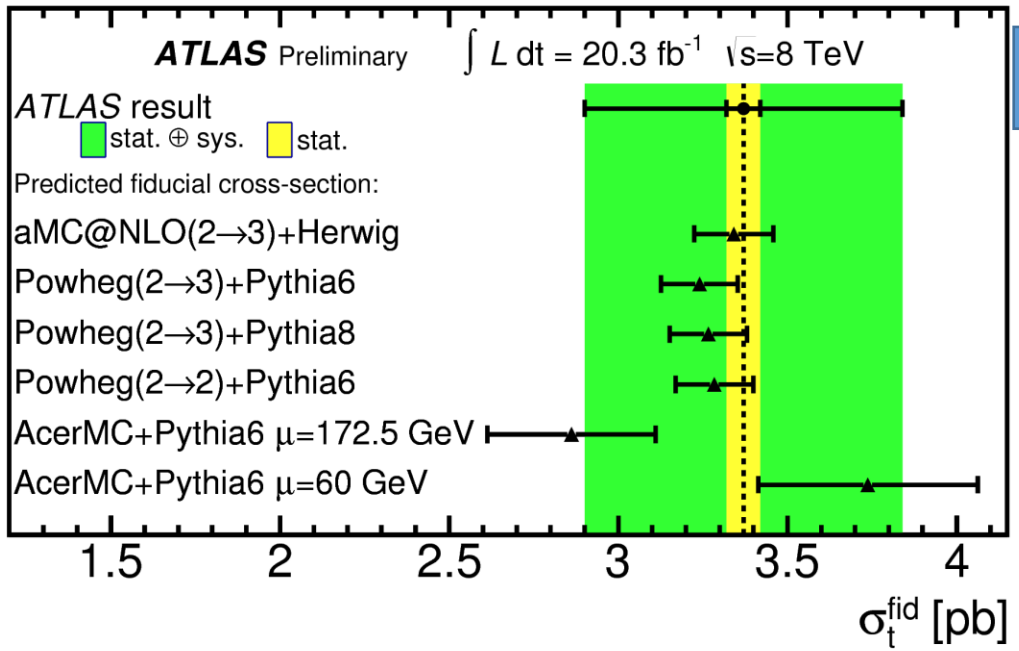
- Generate with AcerMC+Pythia6,CTEQ6L1
  - μ=172.5GeV
  - Combined gq->q'tb and bq->tq' process
- $\mathcal{L}$=20.3fb^{-1}
- A neural network classifier used.
- Binned Max. likelihood fit to NN output to estimate the number **ν** of signal events in fiducial volume.

t-channel@8TeV: Fiducial cross-section

-ATLAS-CONF-2014-007

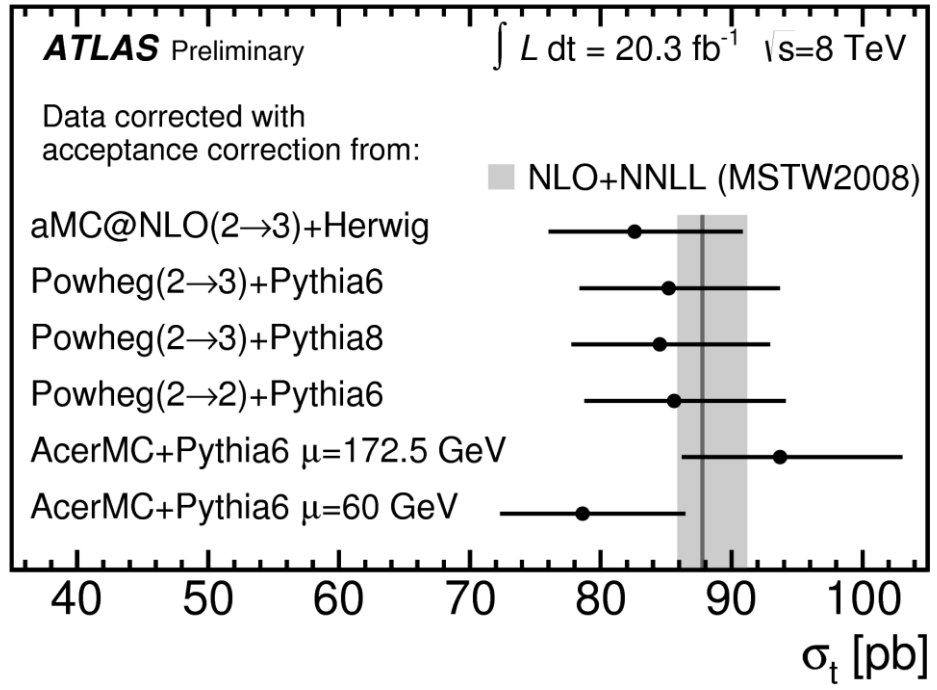
$$\sigma_{\text{fid}} = 3.37 \pm 0.05\,(\text{stat.}) \pm 0.47\,(\text{syst.}) \pm 0.09\,(\text{lumi.})\ \text{pb}.$$

Measured fiducial cross section compared to prediction for different generators .



Extrapolate inclusive XS

$$\sigma = \frac{1}{\epsilon_{\text{fid}}} \cdot \sigma_{\text{fid}}$$

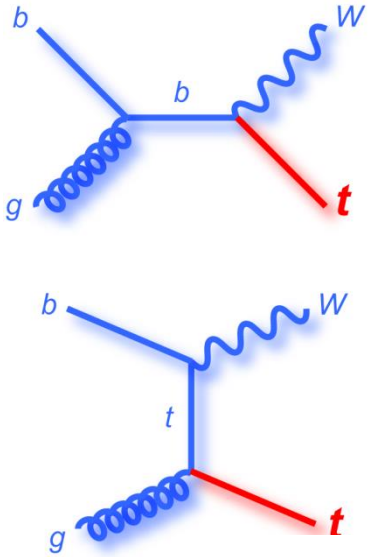


Inclusive t-channel xs using acceptance from aMC@NLO generator

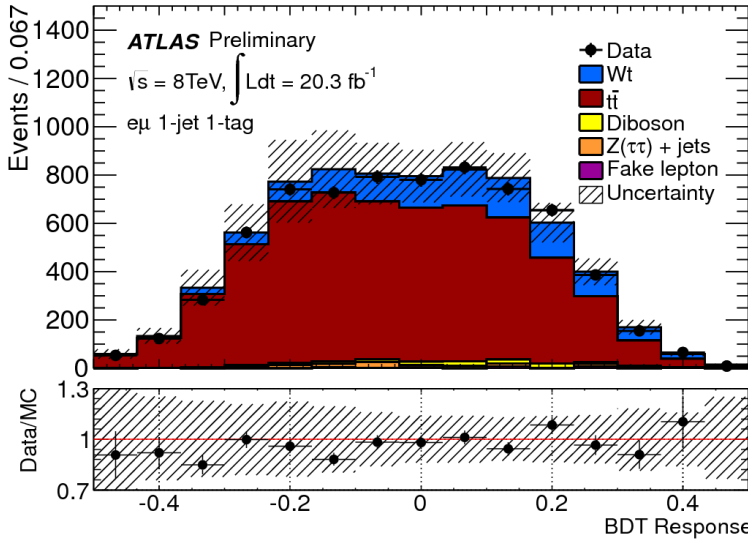
$$\sigma_t = 82.6 \pm 1.2\,(\text{stat.}) \pm 11.4\,(\text{syst.}) \pm 3.1\,(\text{PDF}) \pm 2.3\,(\text{lumi.})\ \text{pb}$$

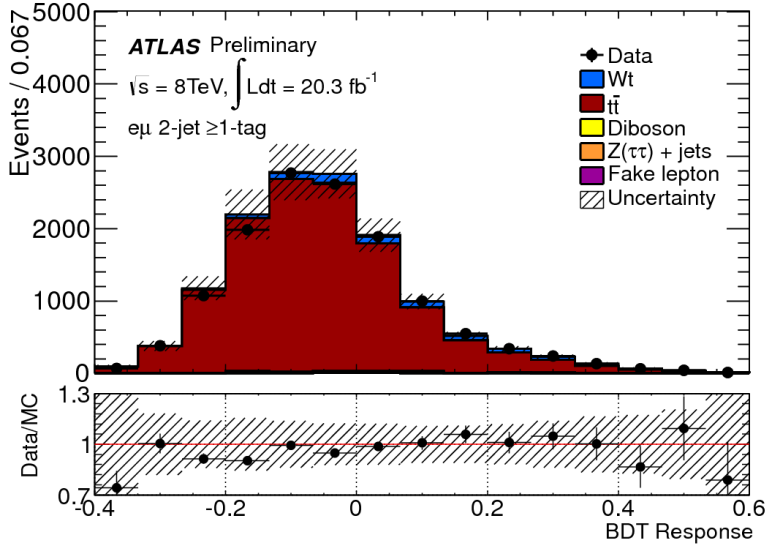
Wt channel@8TeV: cross section

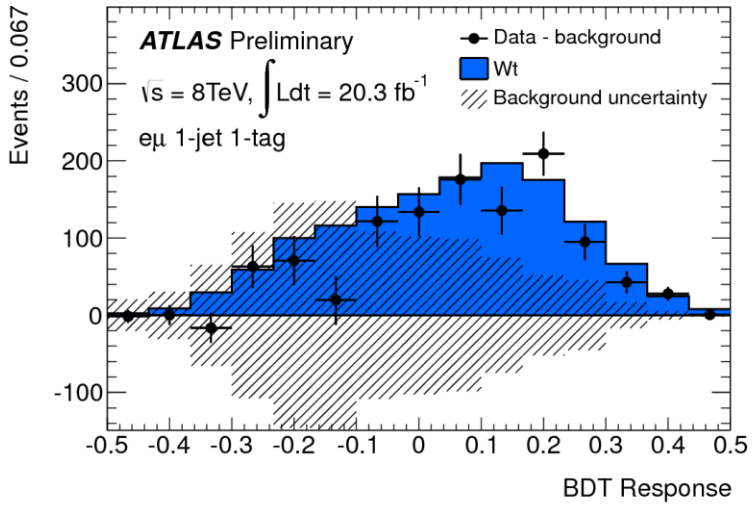
ATLAS-CONF-2013-100



- $\mathcal{L}$=20.3fb^{-1}
- Event selection:
  - 2 leptons(e+μ) channel
  - 1 b-jet
- Generator:
  - POWHEG+CT10







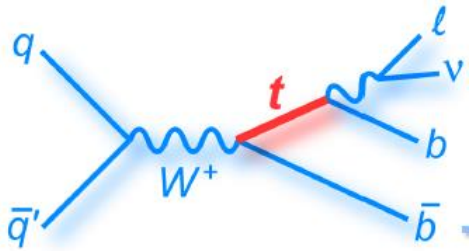
- Boosted Decision Tree classifiers training for 1-jet (SR) and 2-jet (CR) events.
- Maximum likelihood fit to both BDT outputs simultaneously.

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

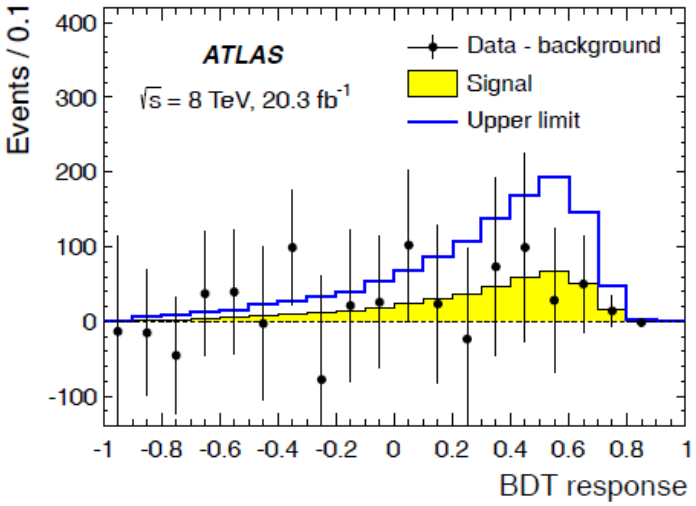
Observed （expected) Significance= 4.2(4.0)σ

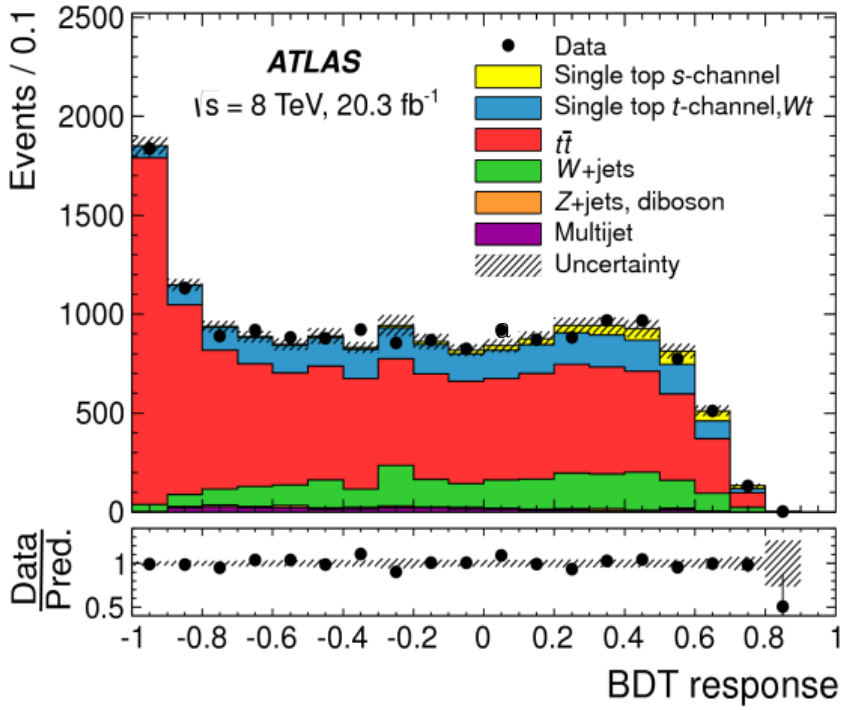
s-channel@8TeV

arxiv:1410.0647 accepted by Phys. Lett. B



- BDT classifier
- Binned max-likelihood fit to BDT response





$\sigma_s = 5.0 \pm 1.7(stat.) \pm 4.0(syst.)pb = 5.0 \pm 4.3pb$

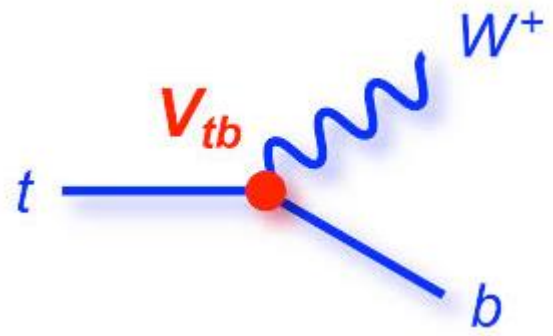
σ<14.6pb @95% CL

Observed(expected) significance=1.3(1.4) σ

Source	$\Delta\sigma/\sigma$ [%]
Data statistics	±35
Simulation statistics	±29
$E_{\mathrm{T}}^{\mathrm{miss}}$ scale	±54
$E_{\mathrm{T}}^{\mathrm{miss}}$ resolution	+0/−3
Jet energy scale	±39
Jet energy resolution	±5
Jet tagging efficiencies	±4
Jet reconstruction efficiency	< 1
Lepton energy scale/resolution	< 1
Lepton efficiencies	+2/−1
Signal modelling & scale	±11
$t\bar{t}$ modelling	±6
$W + jets$ shape modelling	±8
ISR/FSR	±3
PDF	< 1
Background normalization	±7
Multijet normalization	±12
Integrated luminosity	±5
Total systematic	±80
Total	±87

CKM matrix element V_{tb}

- ✓ Single top quark cross section is powerful to probe V_{tb}
- ✓ Allows to test BSM



- ✓ $|V_{tb}|^2$ is extracted from the observed signal top-quark cross section

$$|V_{tb,\,obs}|^2 = \frac{\sigma_{t,\,obs.}}{\sigma_{t.\,SM}} \times |V_{tb,\,SM}|^2$$

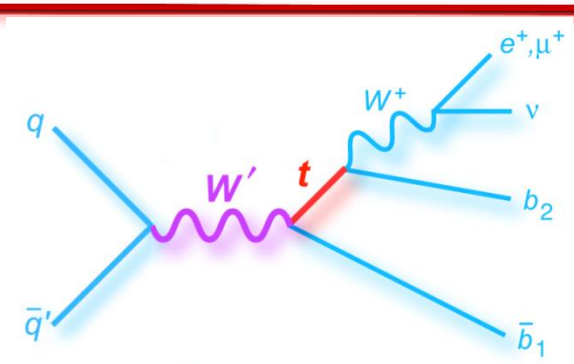
Single-top channel	measurement	Lower limit @95% CL
T-channel@7TeV(4.59fb^{-1}) arXiv 1406.7844	$\|V_{tb}\|=1.02\pm0.07$	0.88
T-channel@8TeV(20.3fb^{-1}) ATLAS-CONF-2014-007	$\|V_{tb}\|=0.97\pm0.10$	0.78
Wt-channel@7TeV (2.05fb^{-1}) PLB716(2012)142-159	$\|V_{tb}\|=1.03\pm0.19$	
Wt-channel@8TeV (20.3fb^{-1}) ATLAS-CONF-2013-100	$\|V_{tb}\|=1.10\pm0.12$	0.72

Search for W' boson @8TeV

arXiv: 1410.4103, submitted to PLB

- Massive gauge boson W' predicted by many BSM theories
- Allowed decay

Decay	hadronic	leptonic
W'_L	✓	✓ + SM interference
W'_R, $m(\nu_R) < m(W')$	✓	✓
W'_R, $m(\nu_R) > m(W')$	✓	–

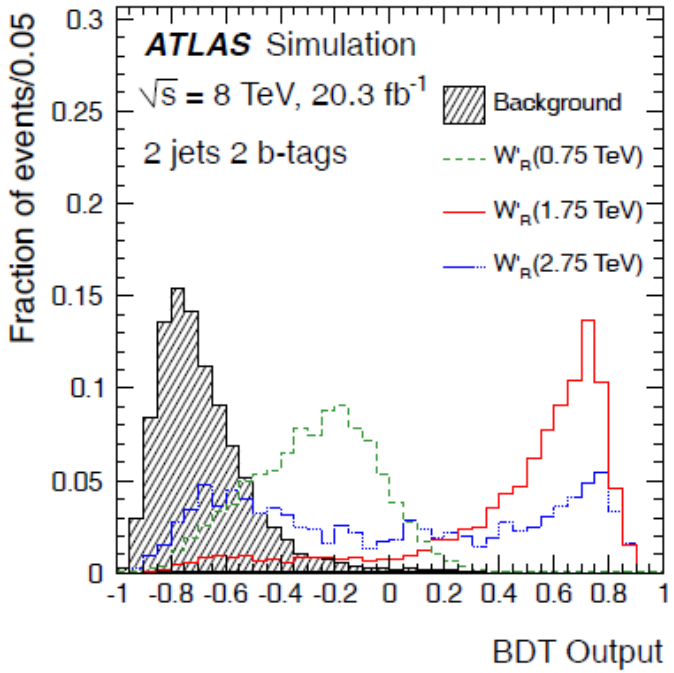


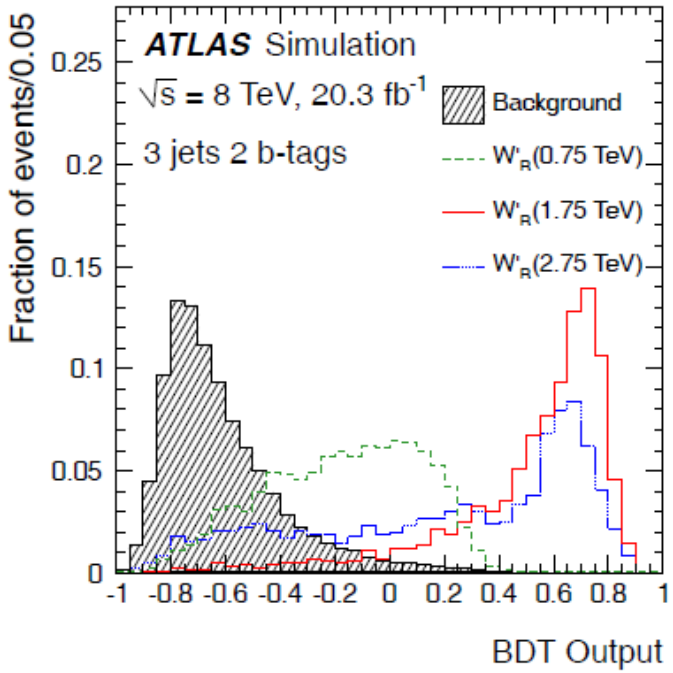
- Signal modelling by MadGraph5+Pythia8+CTEQ6L1
- Cross section scaled to NLO
- Two scenarios W'_L: $g'_L=g_{SM}$, $g'_R=0$
  W'_R: $g'_R=g_{SM}$, $g'_L=0$

$\mathcal{L}$=20.3fb^{-1}

- Single lepton,2-3 jets, exactly 2 b-jets (ε=70%)

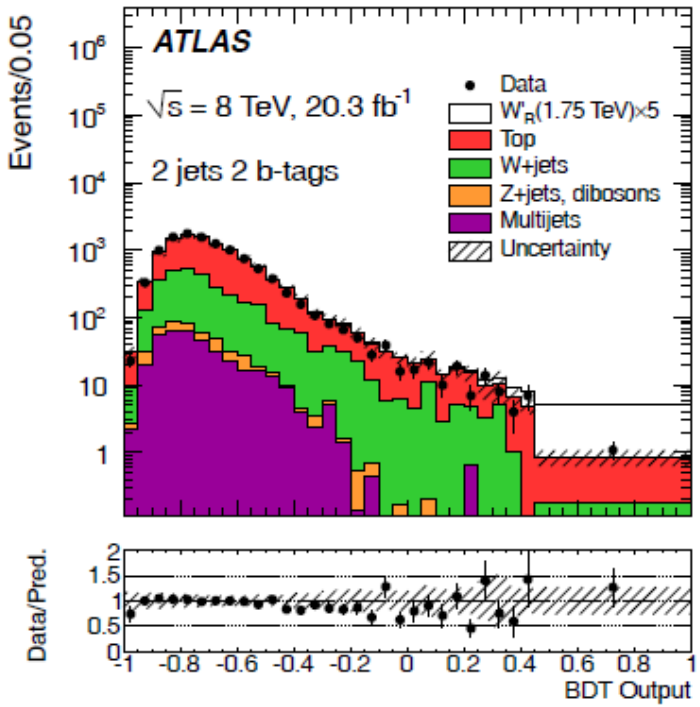
- BDTs trained for each 2-jet and 3-jet event
- Training signal: W'_R at mass=1.75TeV

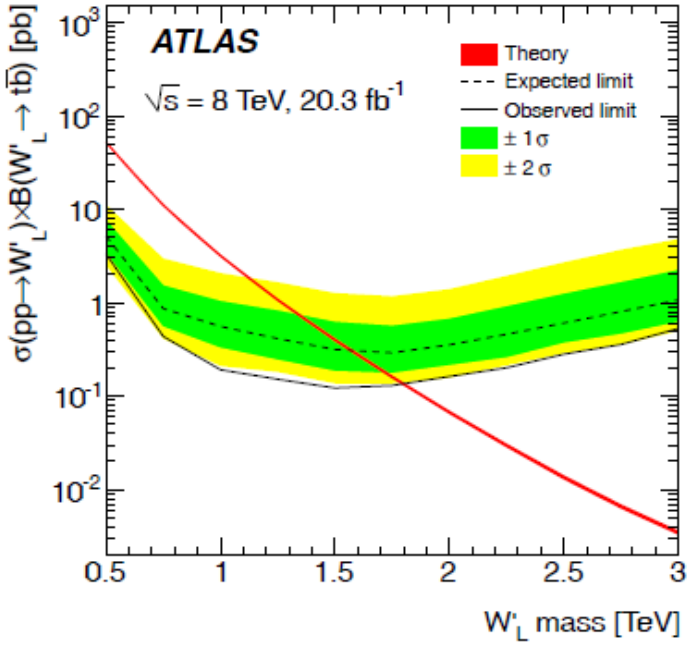


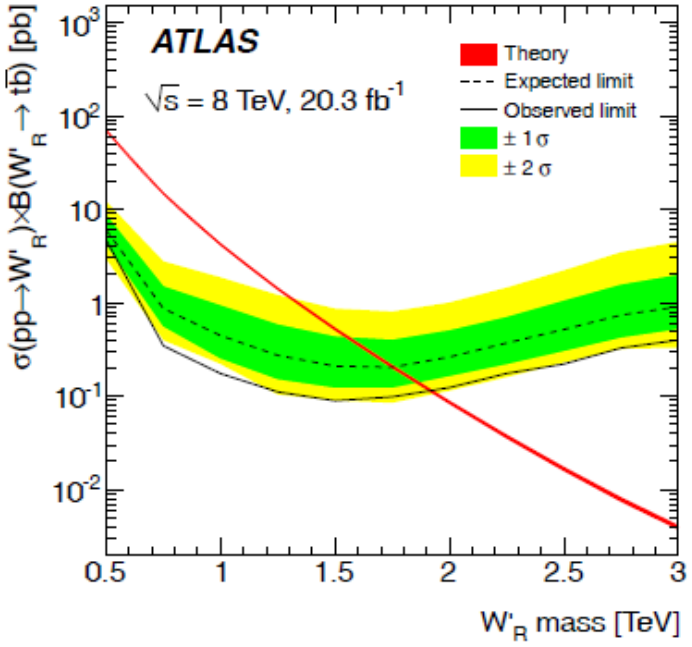


Search for W' boson @8TeV

arXiv: 1410.4103, submitted to PLB







- no excess data over the background in the full BDT output.
- Hypotheses testing use log-likelihood ratio

W' mass limits @95% CL

- $M(W'_L)$>1.80TeV (expected: >1.57TeV), without interference with s-channel,
- $M(W'_L)$>1.70TeV (expected: >1.54TeV), with interference with s-channel
- $M(W'_R)$>1.92TeV, (ecpected: >1.75TeV)

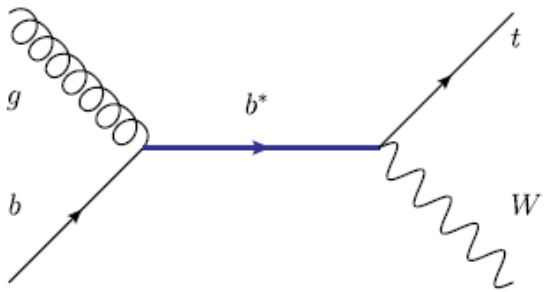
Search for single b* at 7TeV

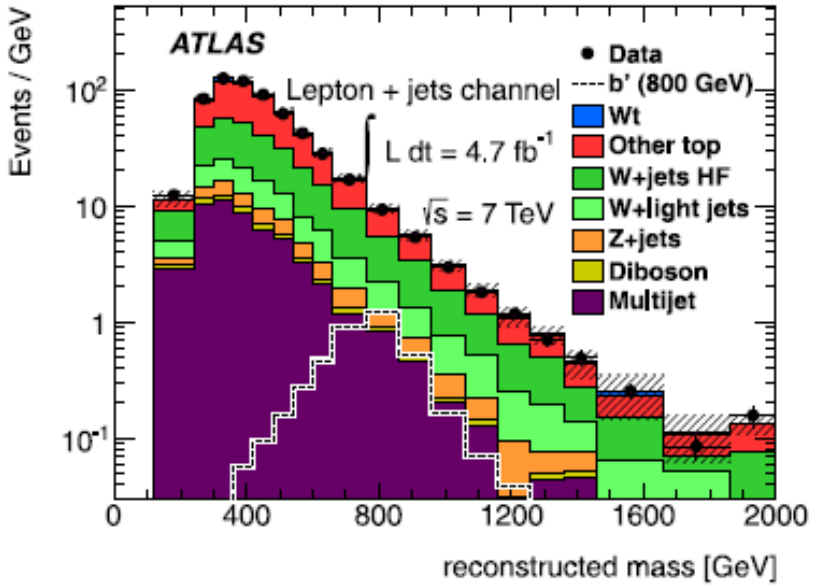
PLB721(2013)171-189

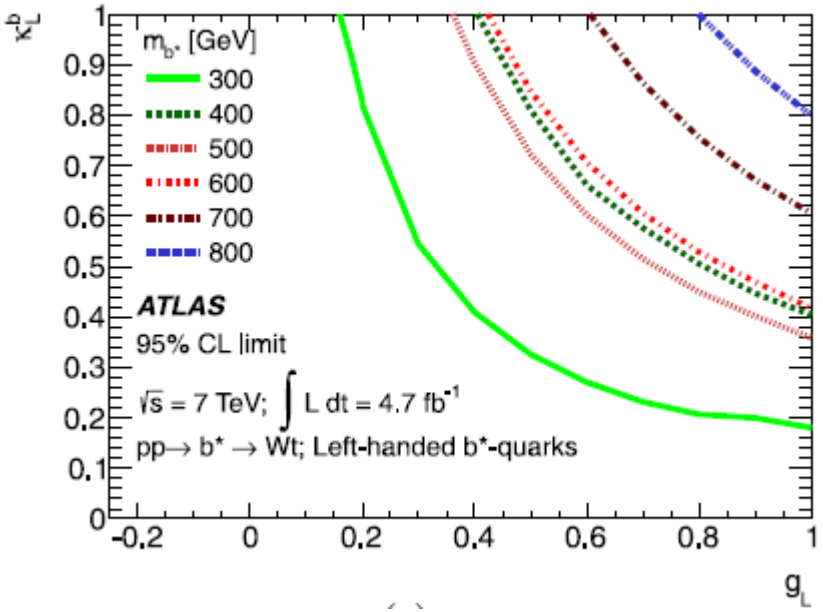
Search the excited b quark coupling to the third generation of fermions
Generate with MADGRAPG+Pythia+CTEQ6L1

$\mathcal{L}$=4.7fb^{-1}

- cut based event discriminate
- Likelihood fit to the cut based distribution of H_T and reconstruction mass







For purely left –handed coupling, M_{b^*} >870 GeV @95% CL

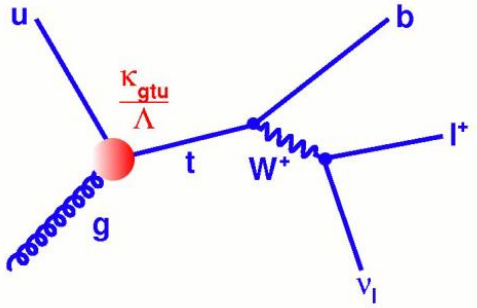
FCNC in single top production @8TeV

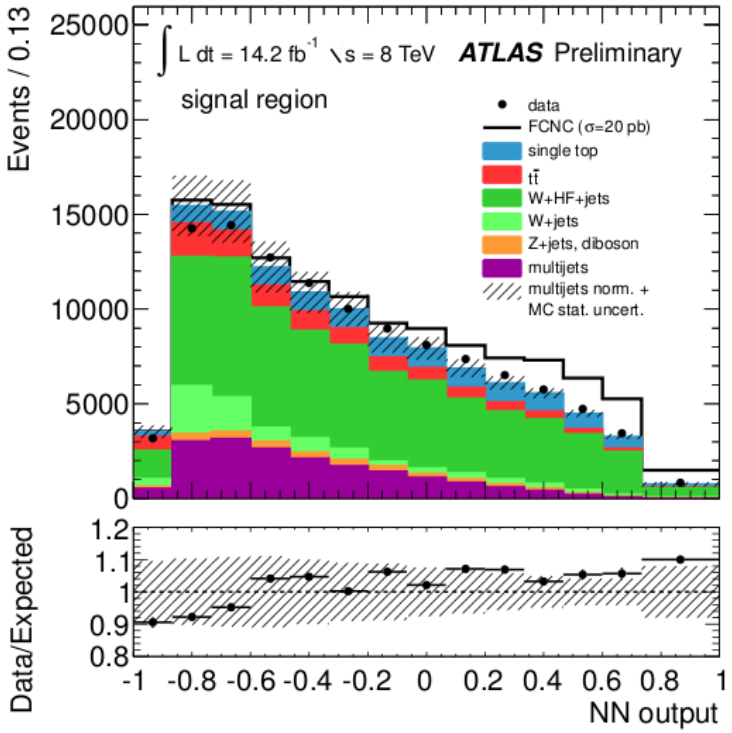
ATLAS-CONF-2013-063

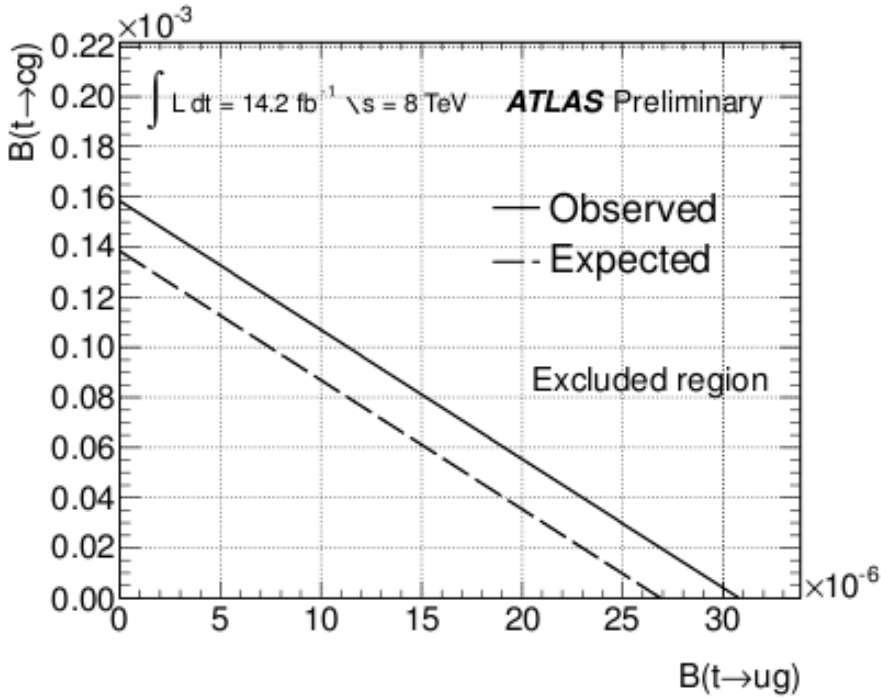
- FCNC highly suppress by SM, but enhanced in many BSM scenarios
- qg-> t-> lvb production has a good sensitivity

- $\mathcal{L}$=14.2fb^{-1}
- Lepton trigger same as W' search
- Simulation with NLO generator MEtop
- Event selection: 1 lepton, 1 b-jet

- Neural network classifier
- Good agreement between data and predicted background
- Binned likelihood fit to the NN output to extract FCNC contribution







- Observed @ 95% CL: $\sigma_{gg\to t} \times B(t \to Wb) < 2.5$ pb

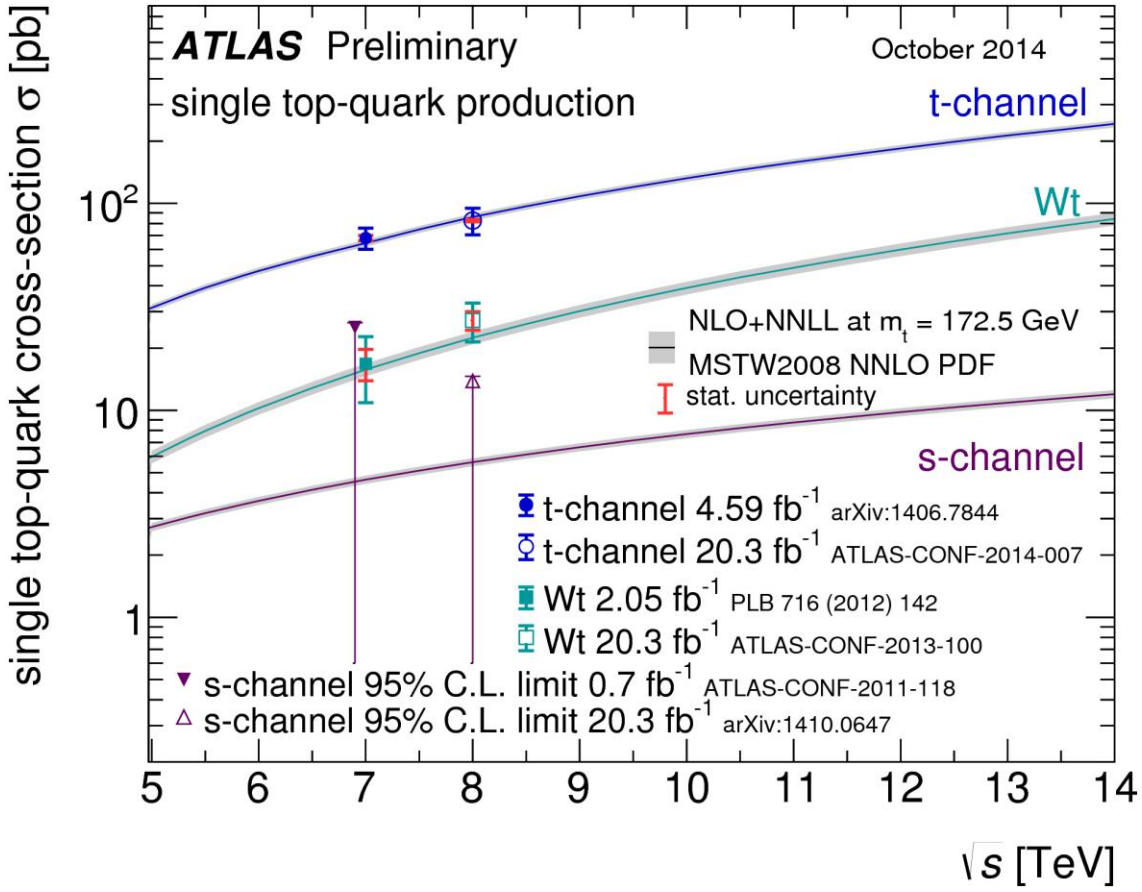
- Upper Limits:

$B(t \to cg) < 1.6 \cdot 10^{-4}$

$B(t \to ug) < 3.1 \cdot 10^{-5}$

summary

- Open the era for precision measurement in single top quark production
  - High precision measurement in the t-channel
- All the measurement are in agreement with SM predictions.
- Show no new physics so far.
- LHC Run-II will push the energy frontier upward and provide higher statistics
- Top physics maybe the first place to find new physics



Thanks !