Single Top Production Measurements at ATLAS

Rob Calkins on behalf of the ATLAS collaboration

Northern Illinois University

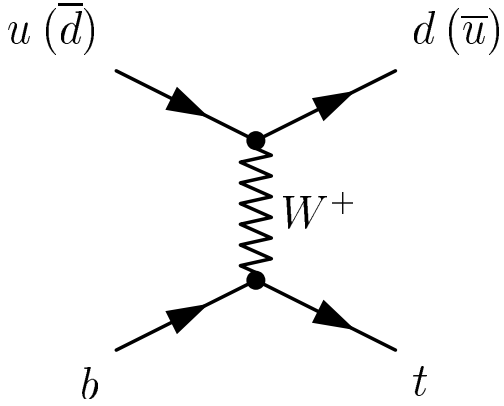
May 8, 2012

Northern Illinois University

Introduction to Single Top

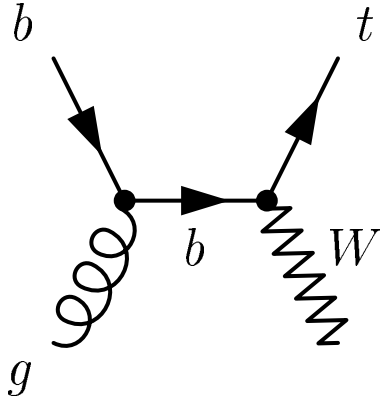
1

t channel



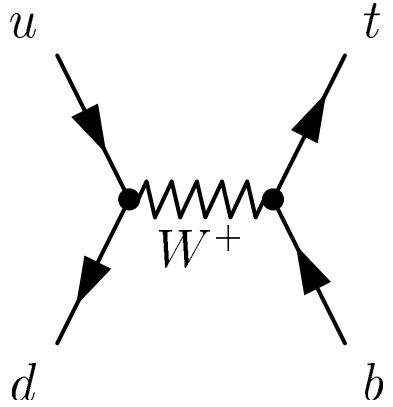
$\sigma_{SM} = 65$pb
(PRD83 091503)

Wt channel



$\sigma_{SM} = 16$pb
(PRD82 054018)

s channel

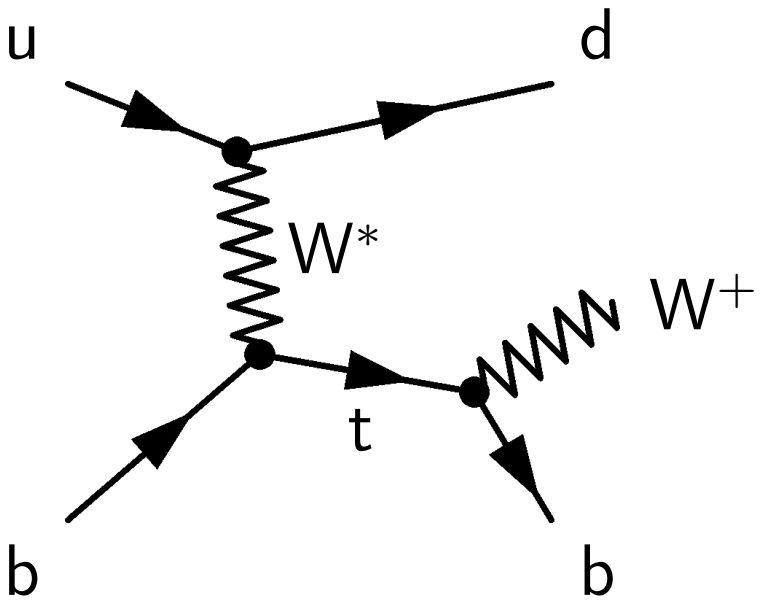


$\sigma_{SM} = 5$pb
(PRD81 054028)

- First observed at Tevatron in 2009 ($\sigma_t \approx 2$ pb , $\sigma_s \approx 1$ pb)
- Single top is an EW process while $t\bar{t}$ is a strong process
- Smaller coupling partially compensated by smaller mass scale $\approx$ comparable production rates to $t\bar{t}$
- Sensitive to many beyond the Standard Model scenarios (FCNC, H^+, wtb couplings,..)

[1] Theory Predictions - Kidonakis NNLO

t-channel: Overview



- Largest cross-section single top production channel
- Lepton (e/μ) + jets final state
- based on 0.70 fb^{-1} of 2011 data

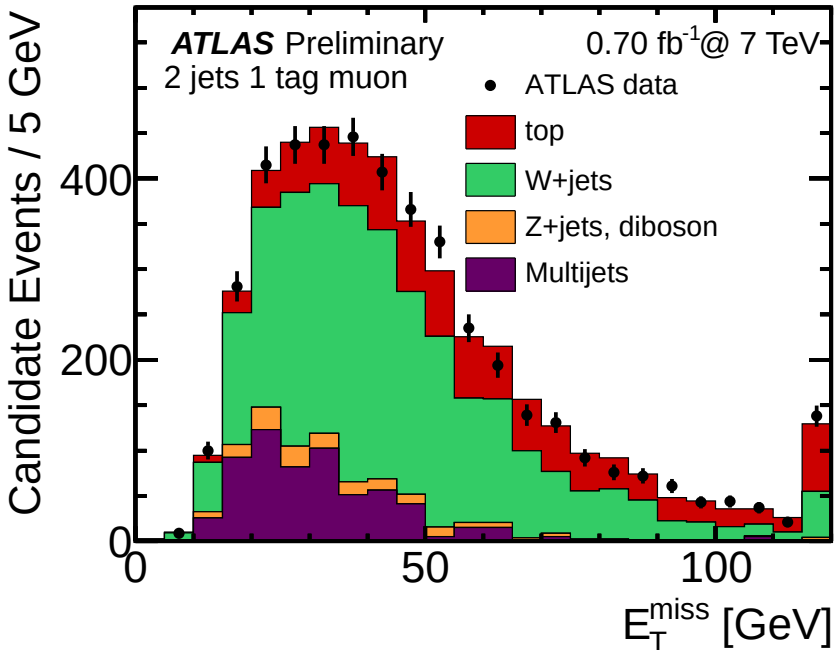
Analysis

- Cut based
- Neural Network based

Pre-Selection

- Single isolated well reconstructed lepton w/ $p_T > 25$ GeV
- 2 or 3 AntiKt(R=0.4) Jets, $p_T > 25$ GeV
- 1 jet b-tagged w/ a secondary vertex tagger, 57% efficiency
- $\not{\mathrm{E}}_{\mathrm{T}} > 25$ GeV
- $\not{\mathrm{E}}_{\mathrm{T}} + M_T(W) > 60$ GeV

t-channel: Backgrounds

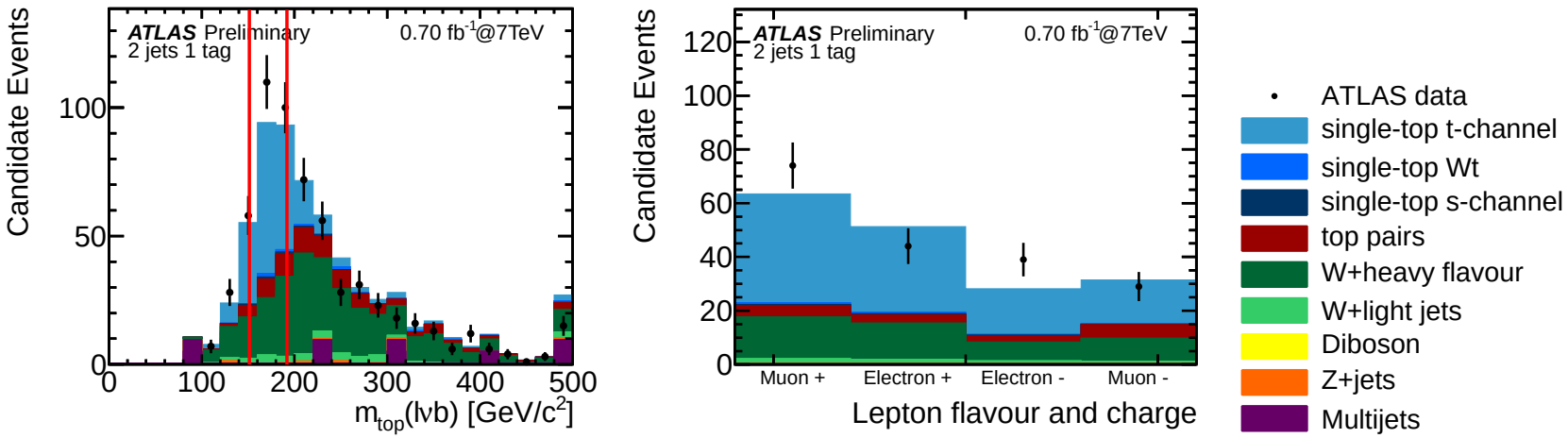


Modeling

- $t\bar{t}$ - MC@NLO
- W/Z+jets - Alpgen + Herwig/Jimmy
- QCD Multijets - Data

- Dominated by W+Jets, top ($t\bar{t}$, Wt and s channels) and QCD multijets
- $t\bar{t}$, Z+jets, dibosons, single top normalized to theory
- W+jets estimated using data-driven method
- QCD multijets modeled using "JetElectrons", normalization taken from fit to $\not{\mathrm{E}}_{\mathrm{T}}$ distribution

t-channel: Cut based approach

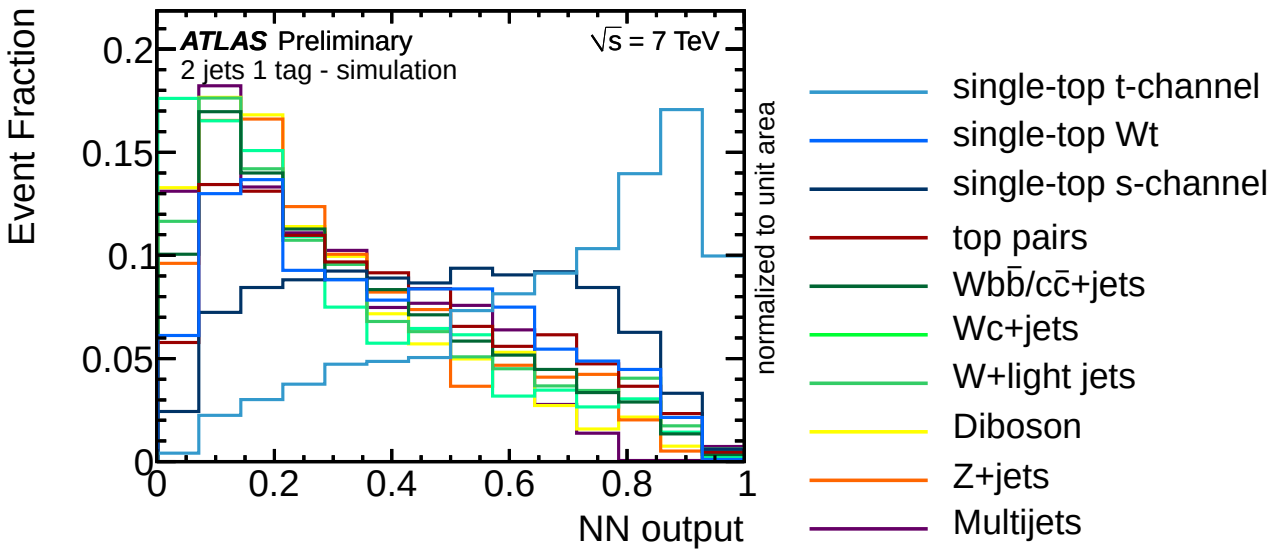


Distributions separated by lepton flavor and charge

Selection Cuts

- $|\eta(\text{light jet})| > 2.0$
- $H_T(\not{E}_T, \text{lepton}, 2 \text{ leading jets}) > 210$ GeV
- 150 GeV $< M_{l\nu b} <$ 190 GeV
- $\Delta\eta(\text{b} - \text{jet}, \text{l} - \text{jet1}) > 1.0$

t-channel: Neural Network based approach

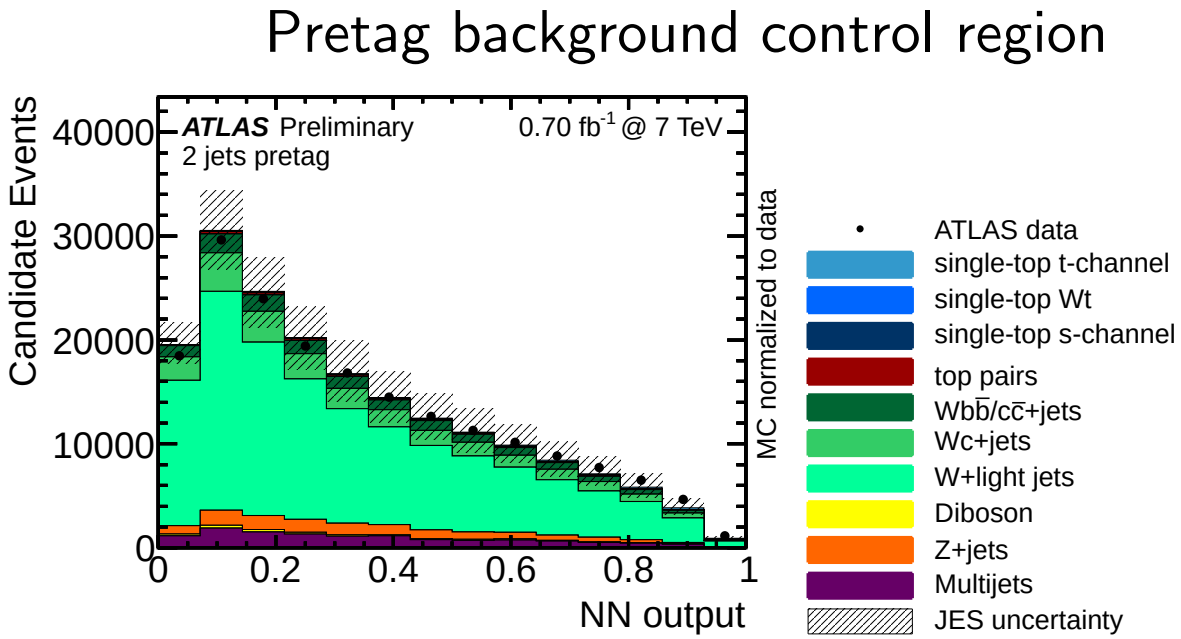


- Four variables from cut based analysis combined with nine additional to produce NN discriminant
- NeuroBayes used with 33 hidden layer nodes
- $M_{l\nu b}$ variable has most discriminating power

Additional variables

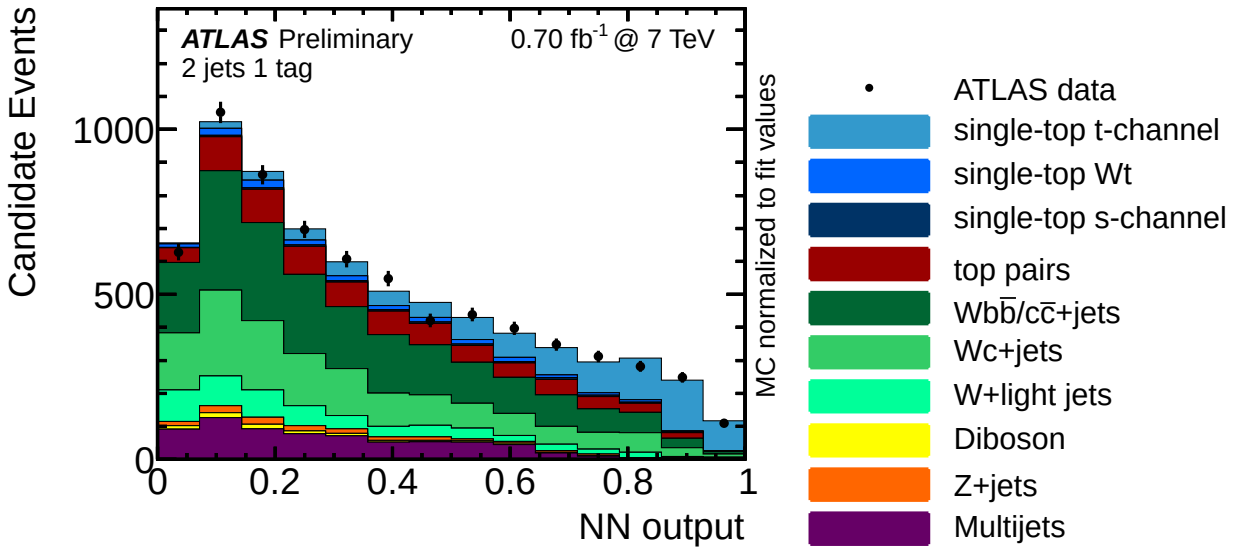
- m(b-jet,light jet)
- $M_T(W)$
- $\eta(l)$
- $p_T(l)$
- Q(l)
- $\not{E}_T$
- $E_T(light-jet)$
- m(b-jet)
- $|\Delta\eta(b,W)|$

t-channel: Systematic Uncertainties



- Systematics estimated by generating pseudo-experiments for both normalization and shape
- JES is largest detector modeling uncertainty, incorporates pile-up effects, *b*-tagging data/MC scale factors contribute significantly to systematics
- ISF/FSR also significant physics modeling uncertainties
- Background systematics include normalization and flavor composition

t-channel: Results



[2]

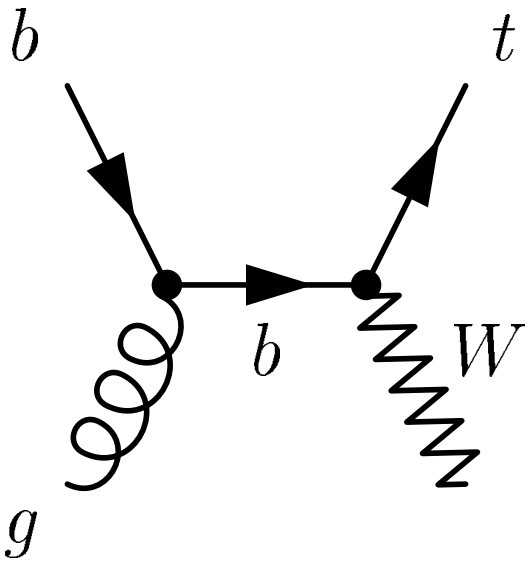
Results

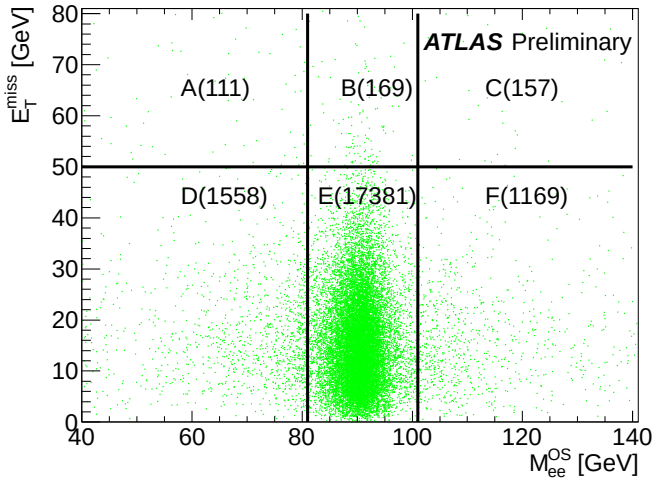
Cut based $\sigma_t = \mathbf{90}^{+32}_{-22}$ pb, NN based $\sigma_t = 105^{+37}_{-31}$ pb, theory $\sigma_t = 65^{+28}_{-19}$pb

- Cut based combines 2 and 3 jet analysis, σ_t extracted using profile likelihood
- NN only uses 2 jet channel, cross-section extract from maximum likelihood fit to NN output

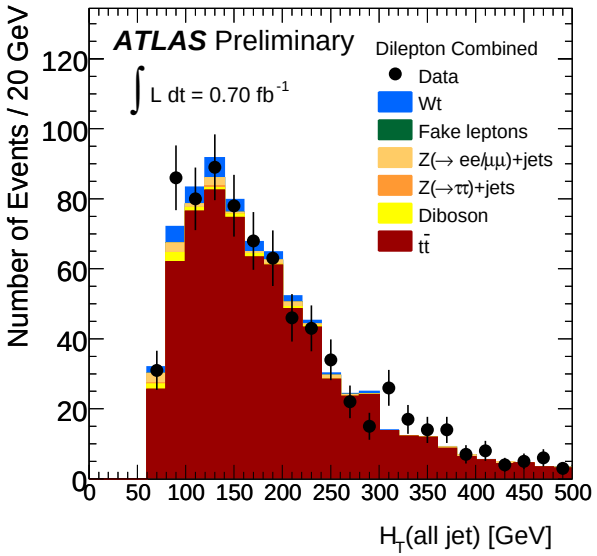
[2] single-top t-channel scaled to measured cross-section

Wt-channel: Overview



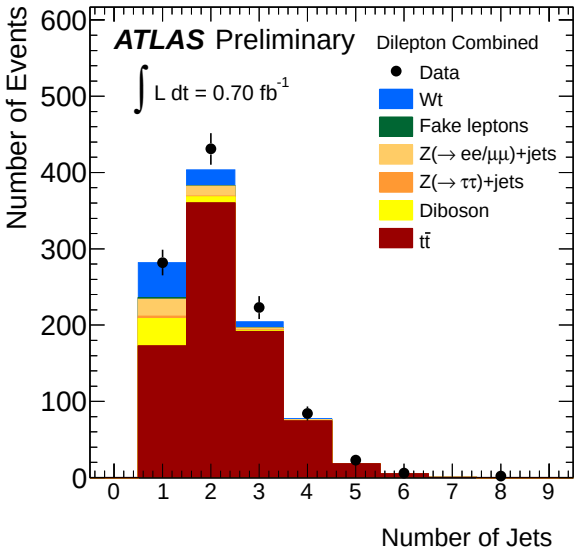


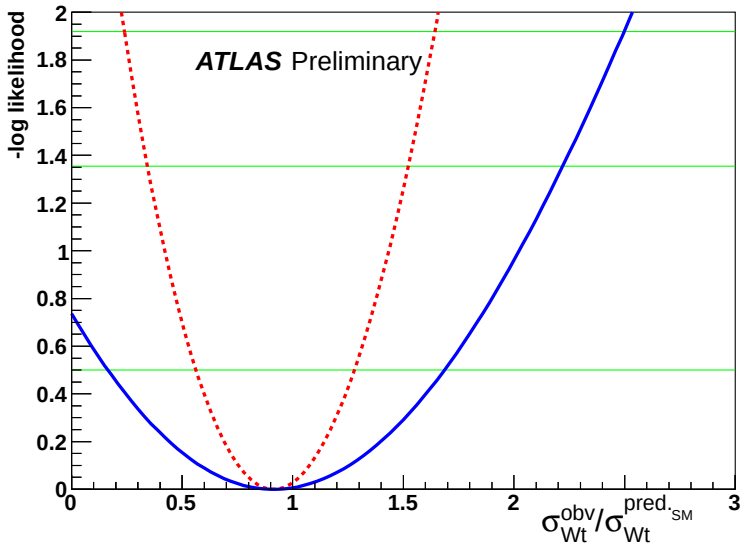
2-Jet $t\bar{t}$ control region



- Dilepton final states +1 jet, large $t\bar{t}$ and Z+jets backgrounds
- Drell-Yan cut out by mass window, N-events in control regions (B,D,E,F) used to fit for background in signal regions (A/C)
- $t\bar{t}$ normalized in 2-jet control region (90% purity) and extrapolated to 1-jet based on MC

Wt-channel: Result



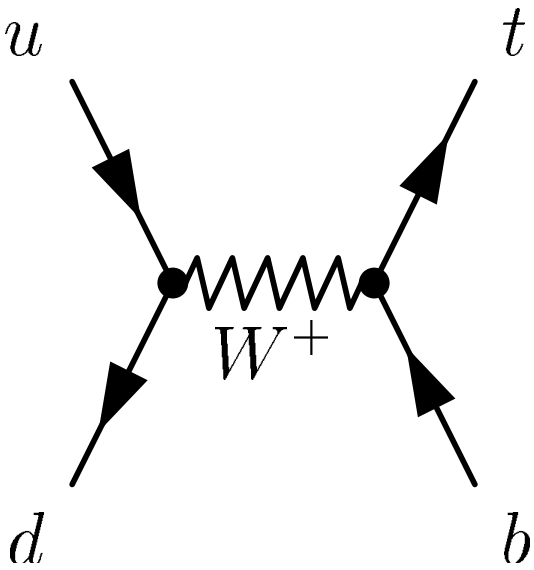


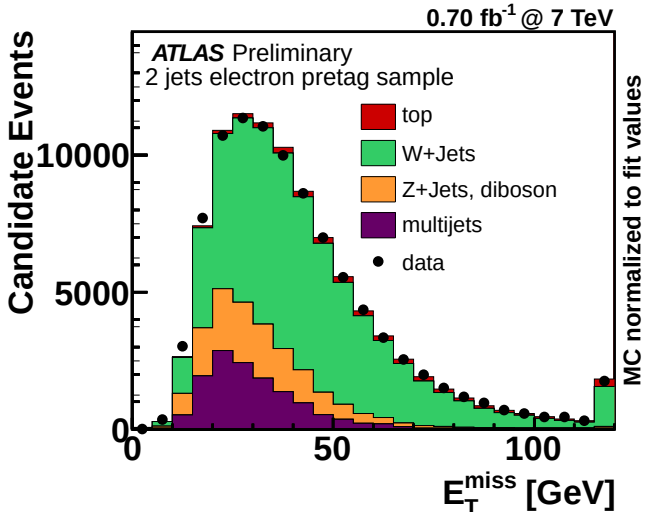
Result

$\sigma_{Wt} < \mathbf{39.1\ pb}$, theory σ_{Wt} =15.7 pb

- Extracted from likelihood with lumi and systematics as Gaussian constrained nuisance parameters
- Measured $\sigma_{Wt} = 14.4^{+11.1}_{-10.7}$ with 1.2σ significance, limit set instead

s-channel: Overview



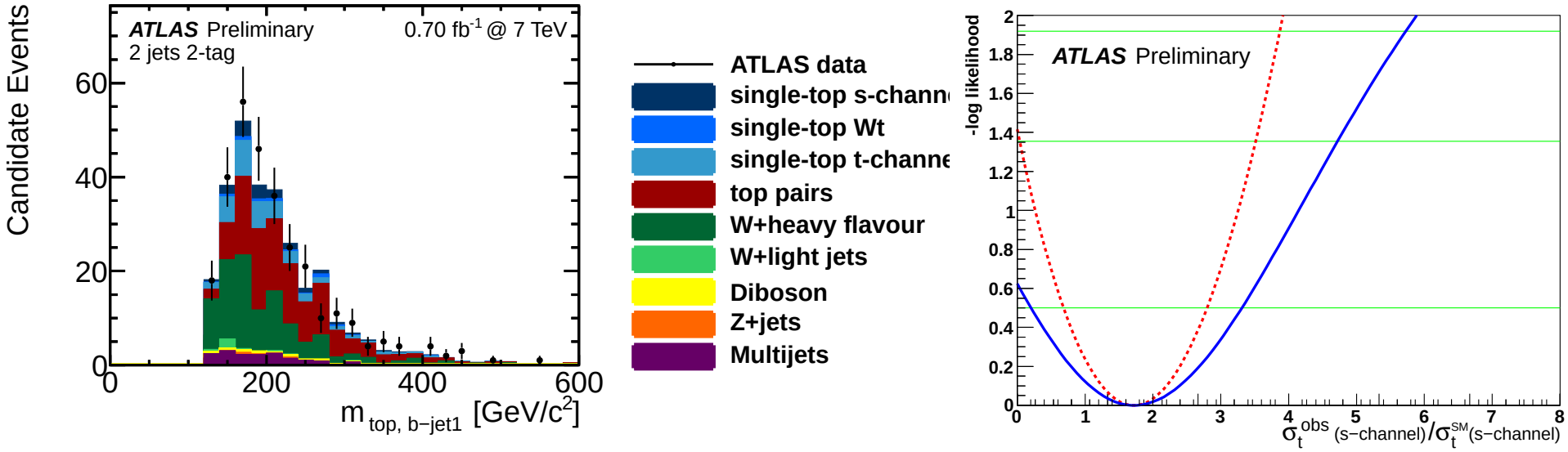


Discriminating Variables

- # of btagged jets
- $M_T(W)$
- $M_{top,b-jet1}$
- $M_{top,b-jet2}$
- $p_T(jet1, jet2)$
- $\Delta R(jet1, jet2)$
- $\Delta R(jet1, l)$

- Lepton, $\not{E}_T$ + 2 b-jet signatures
- Smallest single top production cross-section
- QCD Multijets derived from fit of $\not{\mathrm{E}}_{\mathrm{T}}$
- Cut based analysis, # b-tagged jet most important variable

s-channel: Results

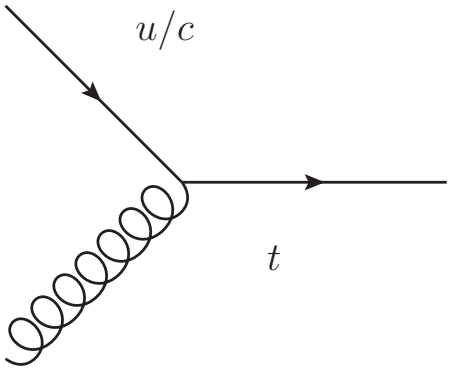


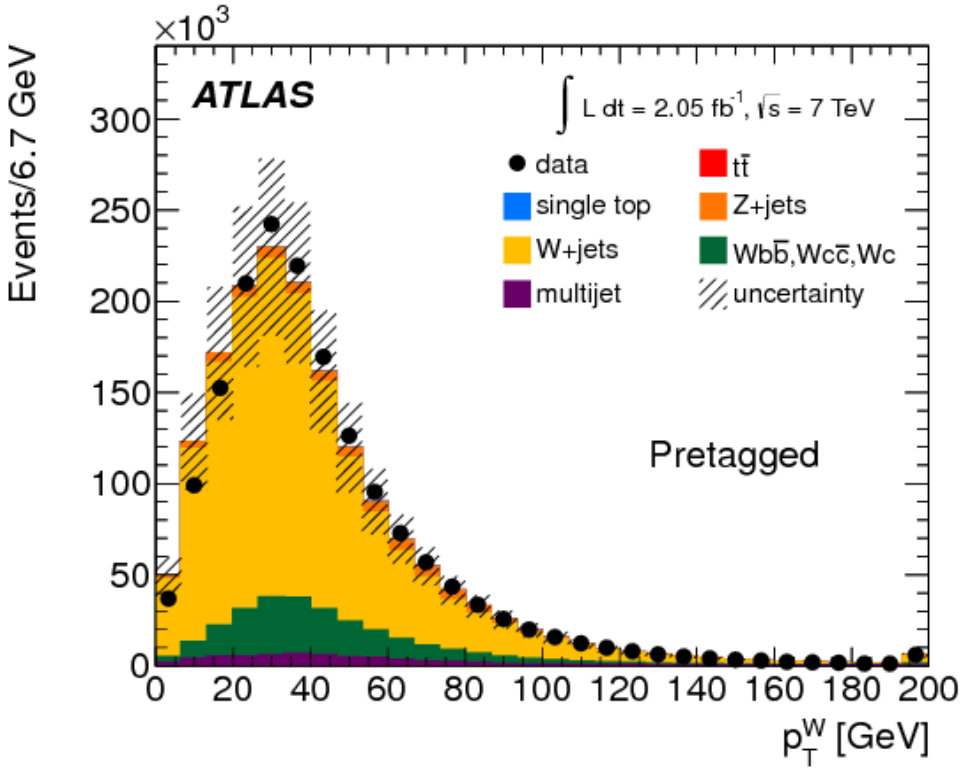
Results

σ_s <**26.5 pb** , theory σ_s =4.6 pb

- $S/\sqrt{B} = 0.98$ in 2-jet, 2-tag event selection
- Statistics limited, MC stats and generator largest systematics
- Limits set using a profile likelihood ratio

Flavor Changing Neutral Currents (FCNC): Overview

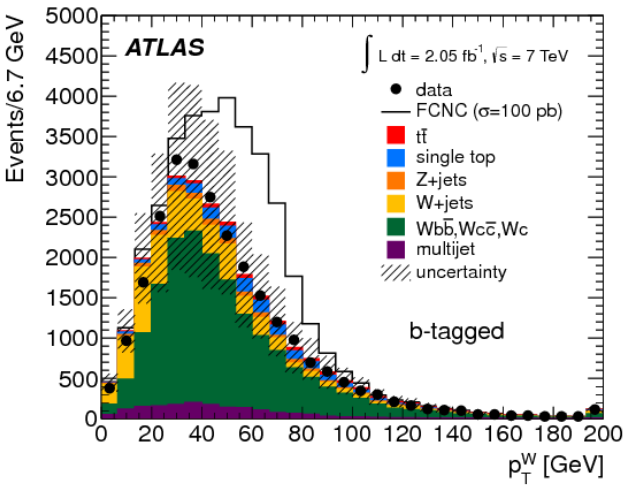


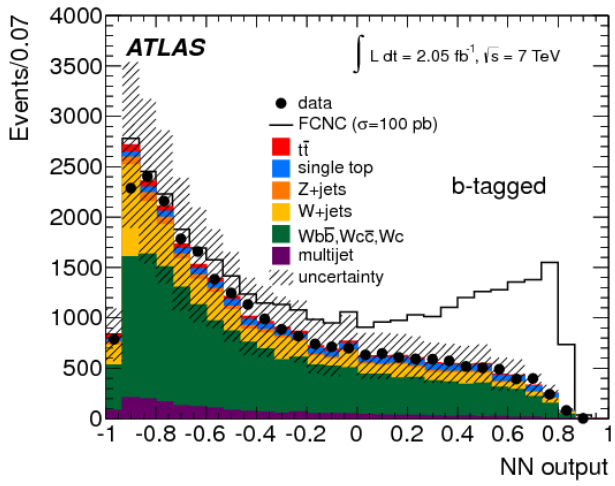


$$\mathcal{L}_{\text{eff}} = g_s \sum_{g=u,c} \frac{\kappa_{qgt}}{\Lambda} \bar{t}\sigma^{\mu\nu} T^a (f_q^R P_R + f_q^L P_L) q G^a_{\mu\nu} + h.c. \quad (1)$$

- $t \to gc$ can be inferred from $gc \to t$, model independent analysis
- FCNC single top samples produced using PROTOS generator
- Lepton + $\not{E}_T$ + Jets final state, large W + jets background

Flavor Changing Neutral Currents (FCNC): Results





- 11 input variables fed into NN
- No excess found, limits set using Bayesian binned likelihood approach

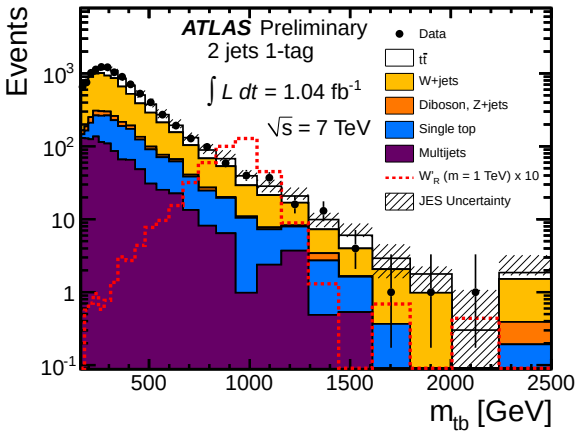
BR $(t \to ug) < 5.7 \times 10^{-5}$,
$BR(t \to cg) < 2.7 \times 10^{-4}$

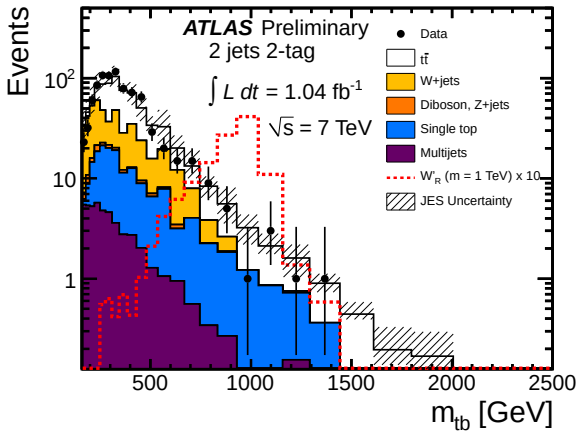
Best limit to date

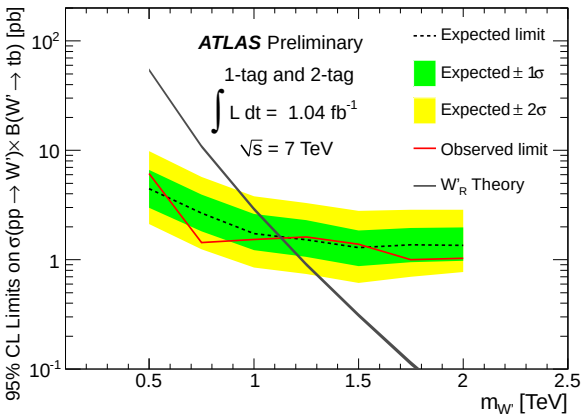
Discriminating Variables

- $p_T(W)$
- $\Delta R(jet, l)$
- lepton charge
- M_{top}
- M_{b-jet}
- η_{b-jet}
- $\Delta\phi(W, b-jet)$
- $p_T(l)$
- $p_T(b-jet)$
- $\cos\theta$ /W-helicity
- $\Delta R(W, b-jet)$

tb Resonances







$$m_{W'_R} < 1.13 \text{ TeV at } 95\ \%\ \text{CL}$$

- Looking for heavy particle decaying into tb final states, lepton, $\not{E}_T$ + 2 b-jet signal
- Apply same selection criteria as s-channel analysis
- BUMPHUNTER tool used to search for excesses, none found
- 95 % CL limits set on right handed W' mass using Bayesian approach, systematics treated as nuisance parameters

Summary

- Cut based $\sigma_t = \mathbf{90}^{+32}_{-22}$ pb, NN based $\sigma_t = 105^{+37}_{-31}$ pb, theory $\sigma_t = 65^{+28}_{-19}$pb
- $\sigma_{Wt} < \mathbf{39.1\ pb}$, theory σ_{Wt} =15.7 pb
- $\sigma_s <$**26.5 pb** , theory σ_s =4.6 pb

- Measured t-channel cross-section at 7 TeV
- Set limits on single top Wt and s channel production
- Looked for single top production through FCNC
- The ATLAS Single top physics program has been highly successful!
- Stay tuned to the ATLAS Top public results page for the latest results!

References

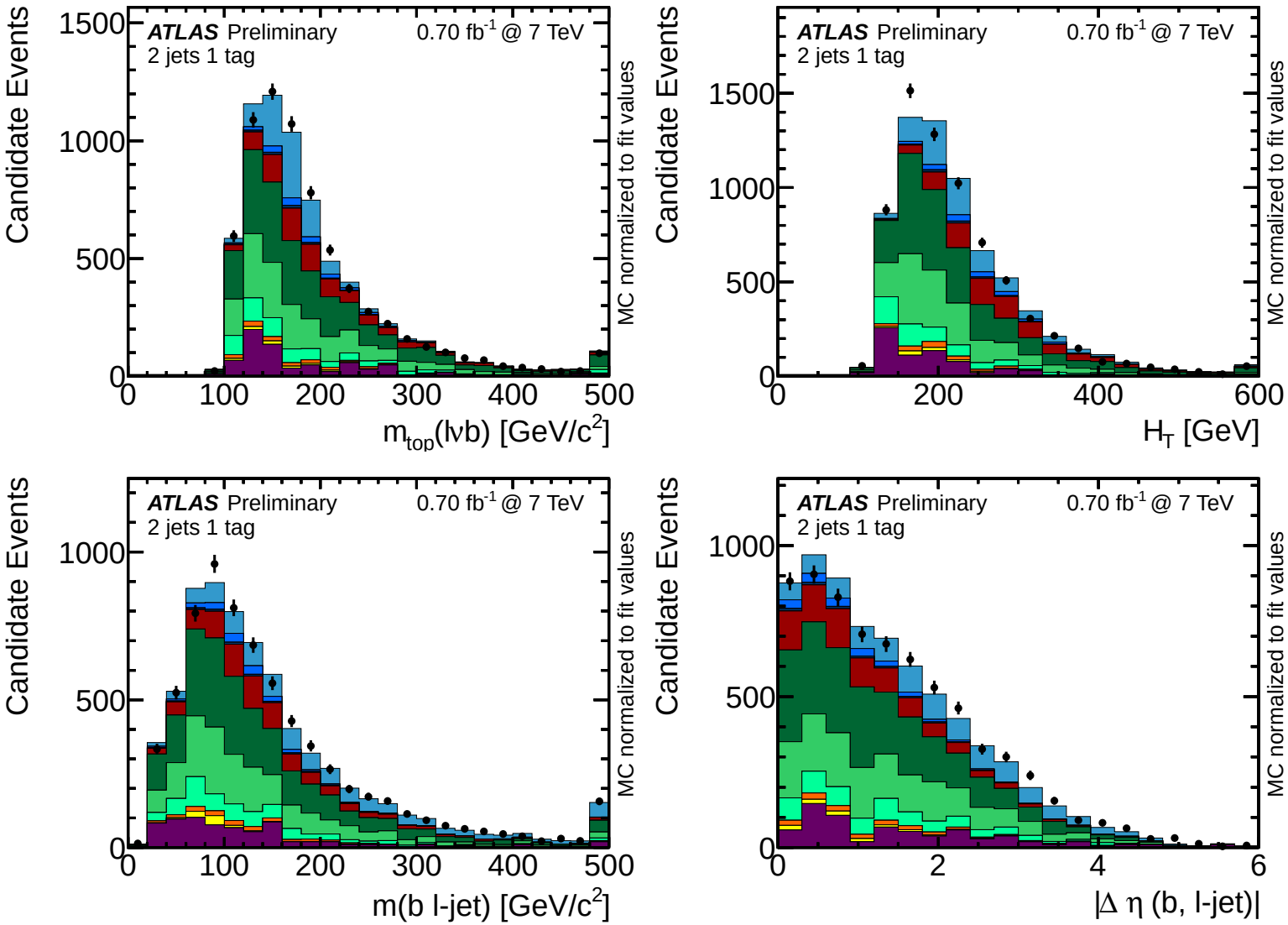
- "Top Public Results"
- "ATLAS-CONF-2011-101: Measurement of the t-channel Single Top-Quark Production Cross Section in 0.70fb^{-1} of pp Collisions at sqrt(s) = 7 TeV with the ATLAS detector"
- "ATLAS-CONF-2011-104: Search for Wt associated production in dilepton final states with 0.70 fb^{-1} of 7 TeV pp collision data in ATLAS"
- "ATLAS-CONF-2011-118: Search for s-channel Single Top-Quark Production in pp Collisions at sqrt(s) = 7 TeV"
- "arXiv:1203.0529v1 [hep-ex]: Search for FCNC single top-quark production at sqrt(s) = 7 TeV with the ATLAS detector"
- "Search for tb resonances in proton-proton collisions at s = 7 TeV with the ATLAS detector"

Backup slides

t-channel Uncertainties

Source	$\Delta\sigma/\sigma$ [%] cut-based 2-jet	cut-based 3-jet	cut-based combined	NN
Data statistics	± 16	± 24	± 13	± 10
MC statistics	± 8	± 11	± 6	± 7
Jet energy scale	+7/-5	+10/-1	+9/-1	+32/-20
Jet energy resolution	+6/-4	+8/-7	+6/-1	± 4
Jet reconstruction	+2/-1	± 1	± 1	+3/-2
b-tagging scale factor	+17/-12	+21/-14	+18/-13	± 13
Mis-tagging scale factor	± 1	± 1	± 1	± 1
Lepton efficiencies	+6/-5	+11/-9	+8/-6	± 5
Lepton energy scale/resolution	± 1	± 1	+2/-1	± 5
Generator	+10/-8	+16/-12	+11/-9	± 7
Parton shower	+9/-7	+14/-12	+10/-9	± 6
ISR/FSR	+19/-16	± 7	± 14	± 13
PDF	+5/-4	+6/-5	± 5	± 4
W+jets shape modeling	± 1	± 1	± 1	± 1
Jet η reweighting	+12/-10	+18/-14	+13/-11	+10/-6
Background normalization				± 3
QCD normalization	± 4	± 8	± 4	
W+heavy flavour normalization	± 2	± 2	± 3	
W+light flavour normalization	± 1	± 1	± 1	
Theory cross sections	± 7	± 13	± 8	
Luminosity	+6/-5	+11/-8	+7/-6	± 5
All systematics	+42/-27	+51/-37	+41/-27	+44/-34
Total	+45/-31	+57/-43	+44/-30	+45/-34

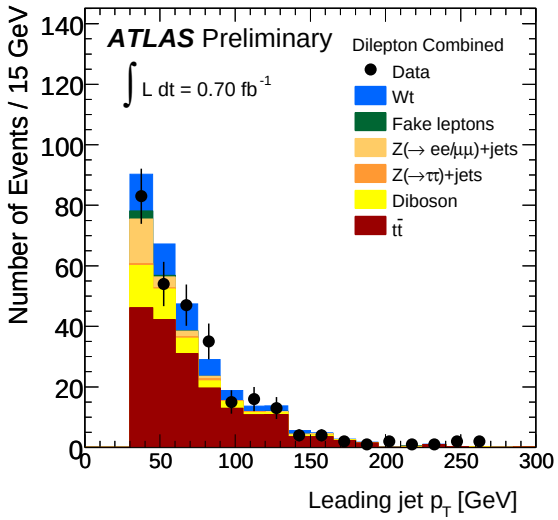
t-channel variables

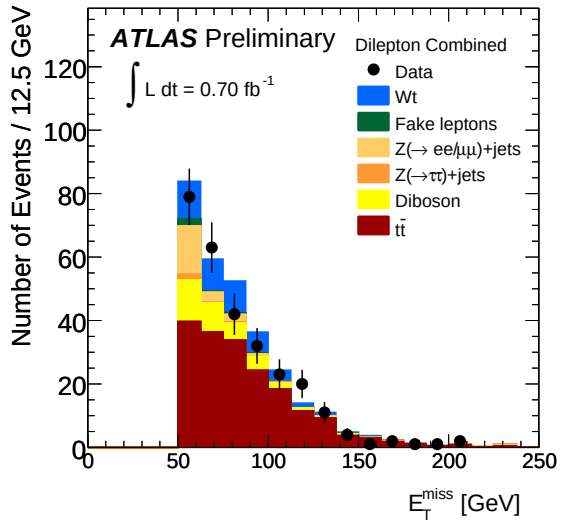


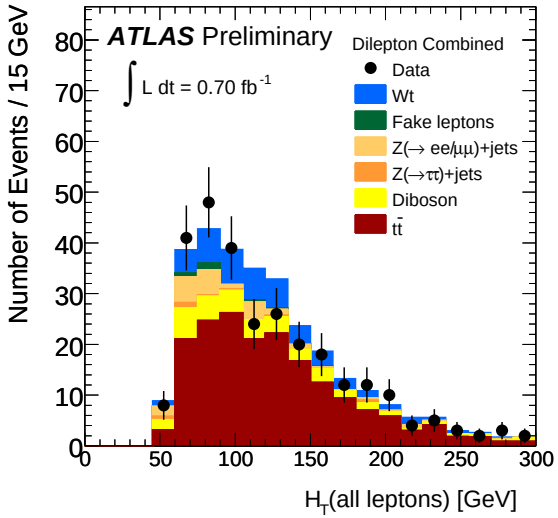
Wt-channel Systematic Uncertainties

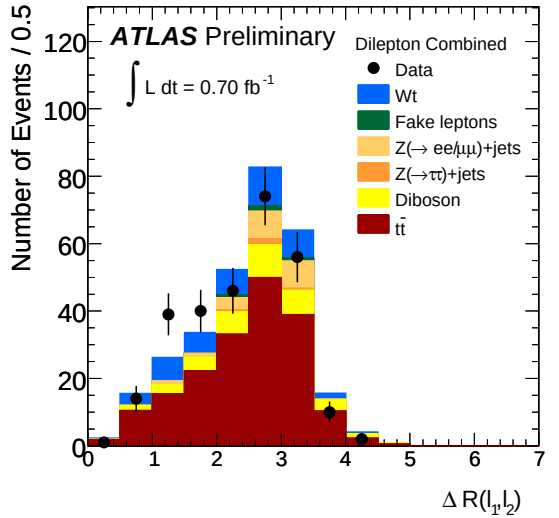
Source	$\Delta\sigma/\sigma$ [%]
Data statistics	+37/-35
MC statistics	+11/-5.4
Lepton energy scale	+7.0/-5.4
Lepton energy resolution	+9.0/-8.9
Lepton efficiencies	+5.3/-2.9
Jet energy scale	+34/-35
Jet energy resolution	+29/-32
Jet reconstruction efficiency	+30/-33
Top pair scaling factor	+23/-24
Drell-Yan background estimation	+2.7/-4.0
Fake lepton background estimation	+4.2/-4.3
Generator	+16/-11
ISR/FSR	+6.0/-1.9
PDF	+5.4/-2.8
Pileup	+10/-6.6
Background cross-sections	+6.9/-6.8
Luminosity	+9.2/-5.9
All systematics	+68/-66
Total	+77/-75

Wt-channel variables





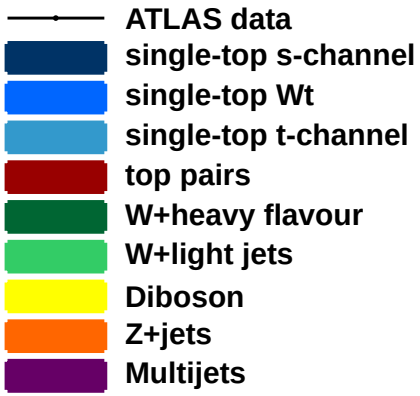


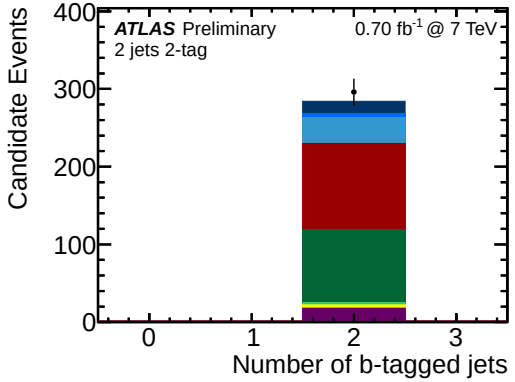


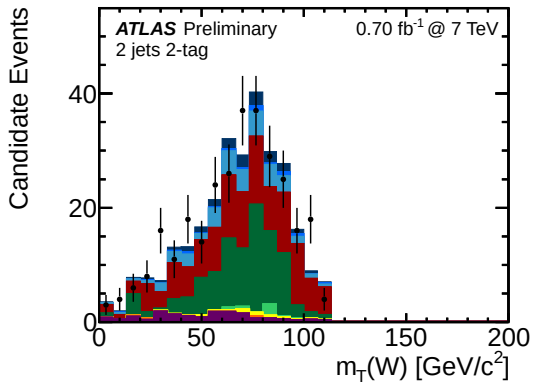
s-channel Uncertainties

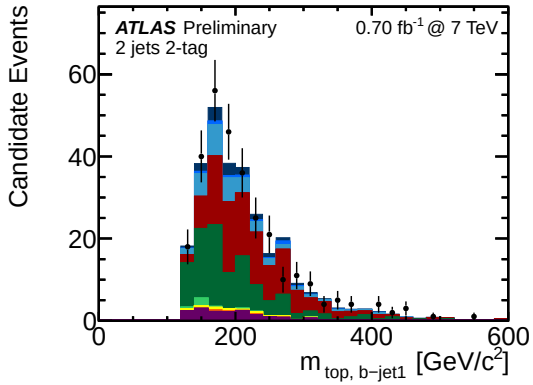
Source	$\Delta\sigma/\sigma$ [%] cut-based
Data statistics	±100
MC statistics	±70
b-tagging	-30/+20
Jet and lepton modeling	-20/+10
MC generator modeling	-60/+20
Multijets normalization	±40
Others	-10/+30
Luminosity	±50
All systematics	-110/+90
Total uncertainty	-160/+150

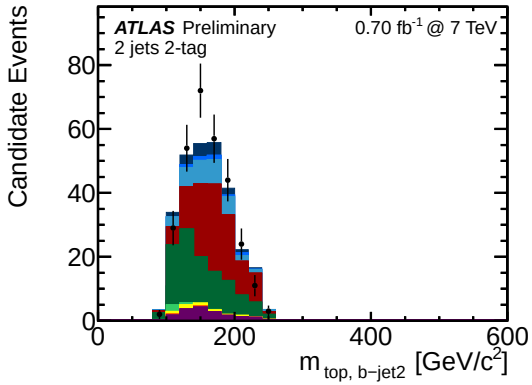
s-channel variables

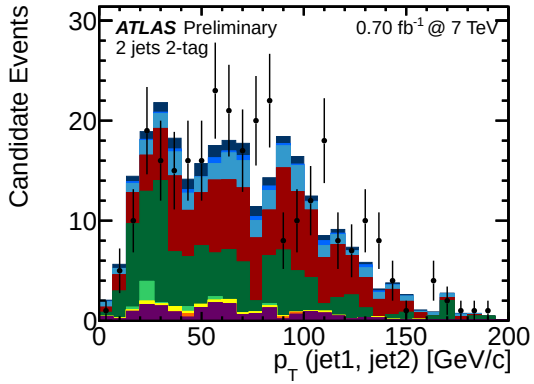


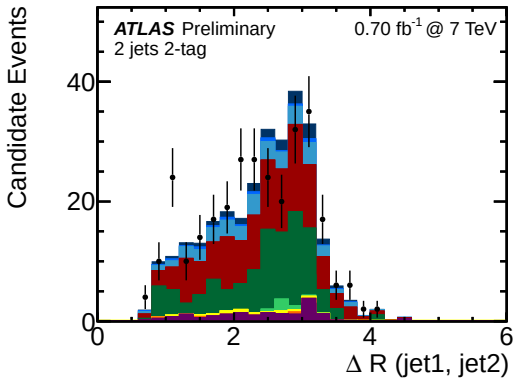


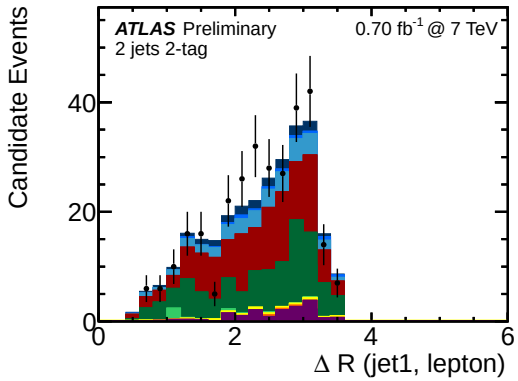




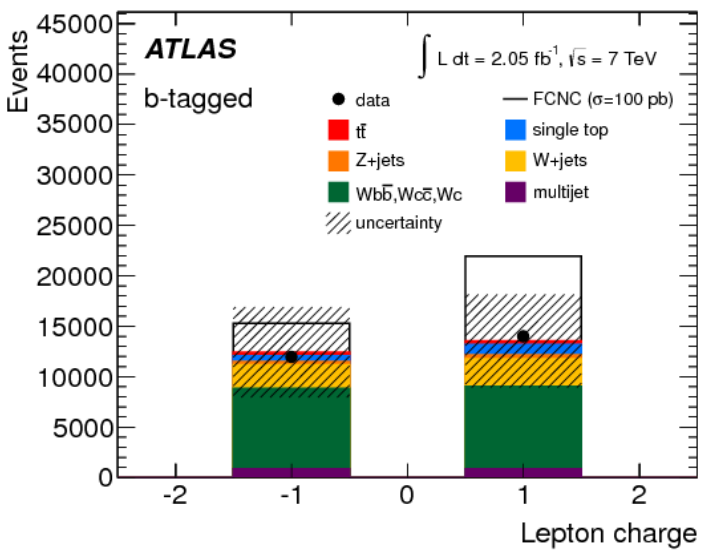


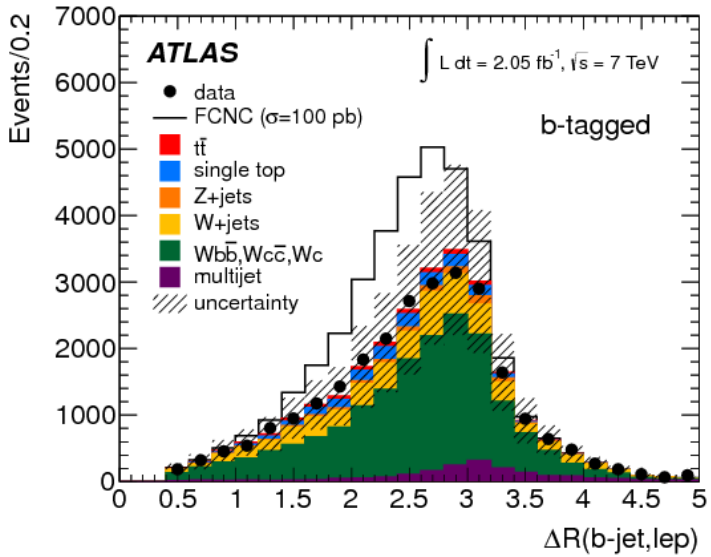


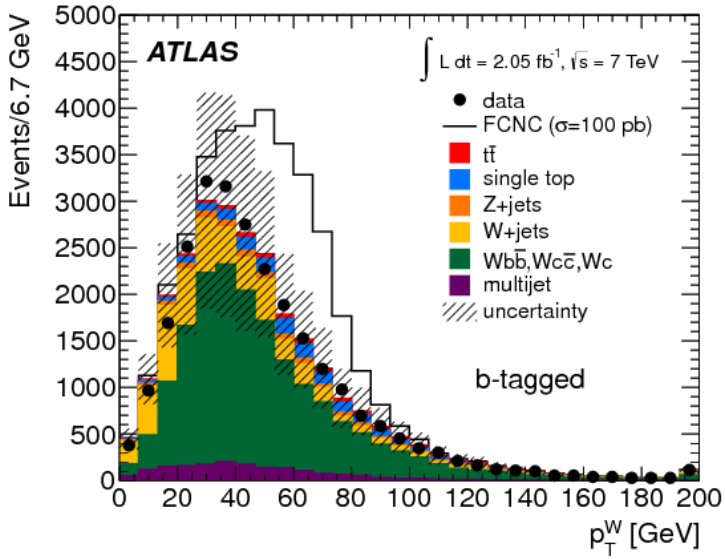




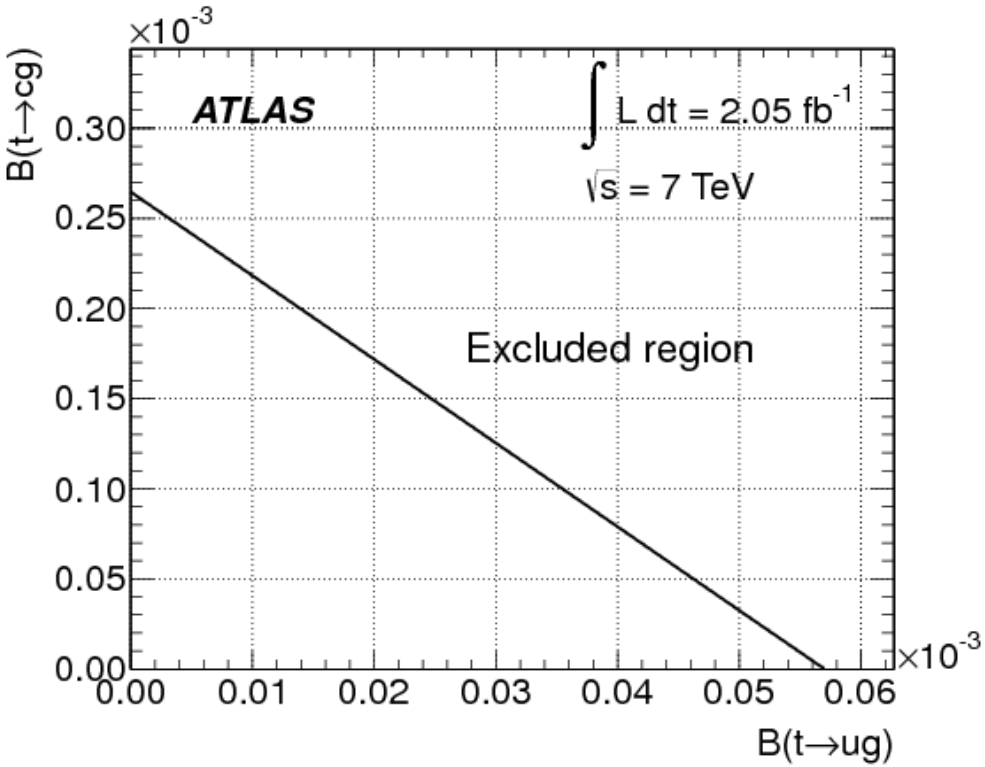
FCNC analysis variables

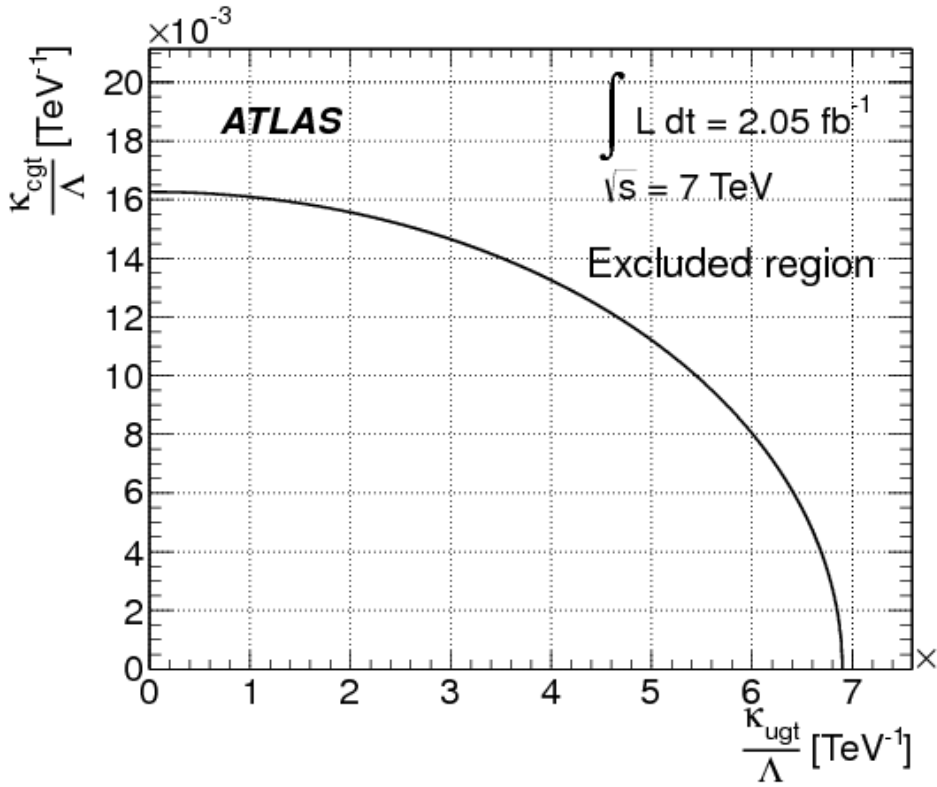






FCNC Limits


ATLAS
∫ L dt = 2.05 fb-1
√s = 7 TeV
Excluded region
B(t→cg)
B(t→ug)
×10-3


ATLAS
∫ L dt = 2.05 fb-1
√s = 7 TeV
Excluded region
κcgt/Λ [TeV-1]
κugt/Λ [TeV-1]
×10-3