TOP2023

Measurement of the t-channel single top-quark production cross-section in proton-proton collisions at a centre-of-mass energy of 13 TeV with the ATLAS detector

Joshua Reidelstürz
on behalf of the ATLAS Collaboration
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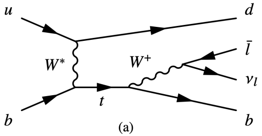
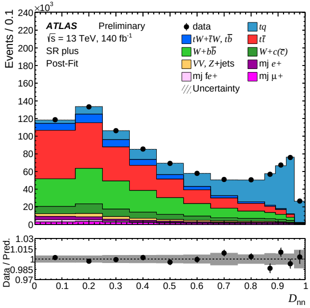
13 TeV t-channel single top quark production

Measurement of the inclusive t-channel top quark and top anti-quark cross section and their ratio $R_t = \sigma_{tq}/\sigma_{\bar{t}q}$

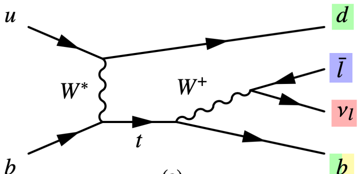
- Precision measurement of the largest single top production channel
- Using the full Run 2 dataset (previous ATLAS result used 3.2 fb^{-1})
- Testing PDFs (particularly using R_t)
- Sensitive to new physics
- Effective field theory interpretation
- Directly constrain $|V_{\mathrm{tx}}|$ CKM matrix elements





Event Selection

- exactly **one charged lepton** ℓ with $p_T > 28$ GeV and $|\eta| < 2.5$
- veto events with additional loose leptons
- exactly **two jets** with $p_T > 30$ GeV and $|\eta| < 4.5$
- exactly one jet with a ***b*-tag**
- $E_T^{miss} > 30$ GeV
- $m_T(\ell E_T^{miss}) > 50$ GeV
- $p_T(\ell) > 40 \cdot |\Delta\Phi(j_1, \ell)/\pi|$
- $m(\ell b) < 160$ GeV

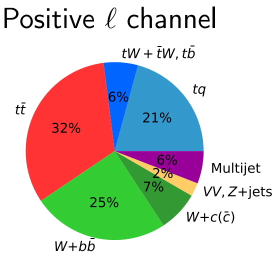


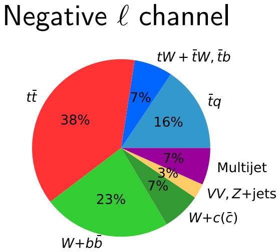
(a)

- Orthogonal regions for multijet normalization:
  - $E_T^{miss} < 30$ GeV for electron multijet
  - $p_T(\ell) > 40 \cdot |\Delta\Phi(j_1, \ell)/\pi|$ for muon multijet

Event yields

Signal separated into 2 signal regions based on charge of lepton



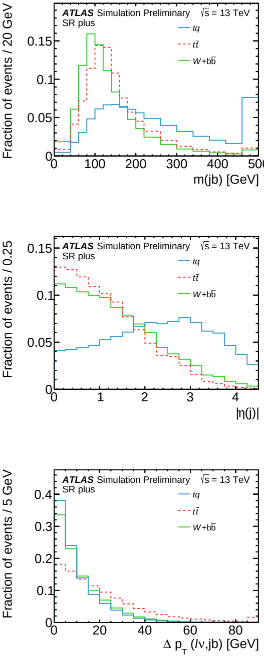


	SR plus	SR minus
tq	169 000 ± 6000	150 ± 150
$\bar{t}q$	90 ± 90	109 000 ± 5000
$tW+\bar{t}W$, $t\bar{b}+\bar{t}b$	50 700 ± 3400	48 800 ± 3400
$t\bar{t}$	264 000 ± 14 000	264 000 ± 13 000
W+$b\bar{b}$, light	202 000 ± 19 000	162 000 ± 16 000
W+$c(\bar{c})$	60 000 ± 13 000	49 000 ± 11 000
Z+jets,diboson	20 000 ± 4000	19 000 ± 4000
Multijet	48 000 ± 10 000	47 000 ± 10 000
Total	814 000 ± 2100	698 800 ± 2000

- Neural network used for signal separation

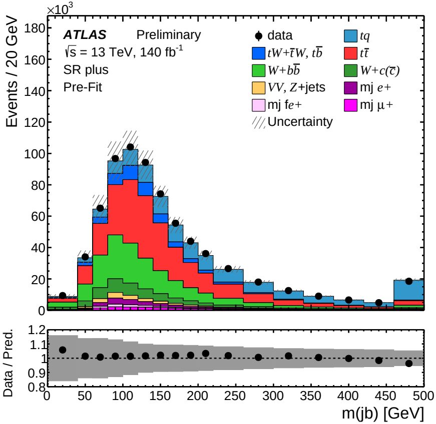
Neural Network Input Variables

No.	Variable
1.	$m(jb)$
2.	$\lvert\eta(j)\rvert$
3.	$\lvert\Delta p_T(W, jb)\rvert$
4.	$\lvert\Delta\phi(W, jb)\rvert$
5.	$m(t)$
6.	$\lvert\Delta\eta(\ell, j)\rvert$
7.	$\Delta R(\ell, j)$
8.	$\lvert\Delta\eta(b, \ell)\rvert$
9.	$m_T(\ell E_T^{miss})$
11.	$H_T(\ell, \text{jets}, E_T^{miss})$
12.	$\lvert\Delta\eta(b, j)\rvert$
13.	$\lvert\Delta\phi(j, t)\rvert$
14.	$\cos\theta^*(\ell, j)$
15.	$\lvert\eta(\ell)\rvert$
16.	S
17.	$\lvert\Delta p_T(\ell, j)\rvert$

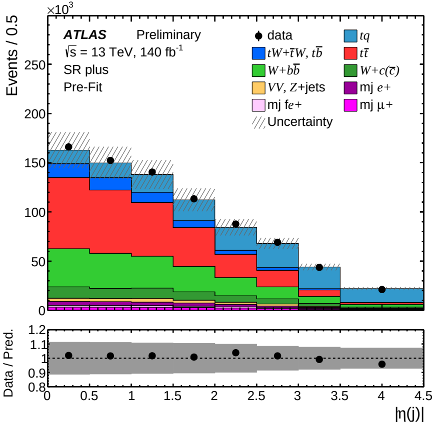


Modeling of Neural Network Input Variables

- Input variables are modeled well in data



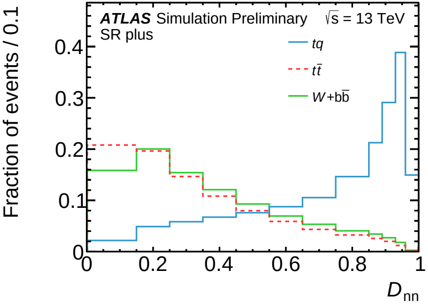
$m(jb)$: invariant mass of jets



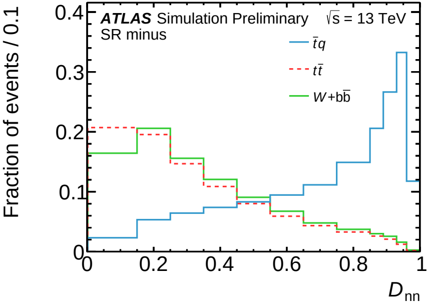
$\eta(j)$: pseudorapidity of light jet

Neural Network discriminant (D_{nn}) shape

- One NN used for both the positive and negative lepton channel
- Good separation of signal and background processes

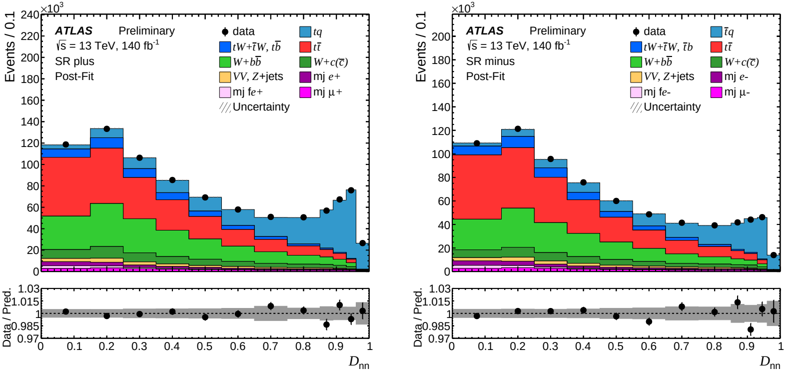


Signal region with ℓ^+



Signal region with ℓ^-

Fit results

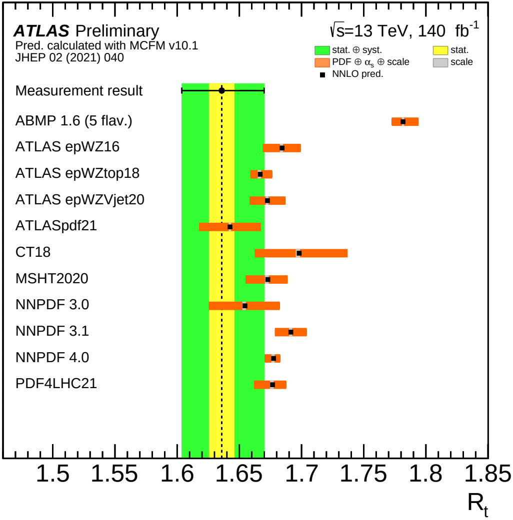


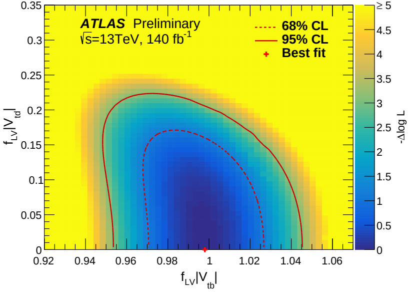
Signal region ℓ^+ Signal region ℓ^-

	σ_t [pb]	$\sigma_{\bar{t}}$ [pb]	σ_{tch} [pb]	R_t
Value	137 ± 8	84^{+6}_{-5}	221 ± 13	$1.636^{+0.036}_{-0.034}$
Relative Uncertainty	$^{+5.9\%}_{-5.5\%}$	$^{+6.6\%}_{-6.2\%}$	$\pm 5.9\%$	$^{+2.2\%}_{-2.1\%}$
Predicted	134.2 ± 2.2	80.0 ± 1.6	214.2 ± 2.7	$1.677^{+0.010}_{-0.014}$

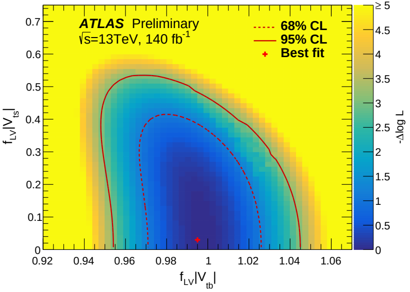
Results

- Agreement with almost all PDF predictions
- EFT interpretation yields 95% confidence interval: -0.29 $< C_{qQ}^{(1,3)} <$ 0.07
- $|f_{\mathrm{LV}} \cdot V_{tb}| = 1.016 \pm 0.031$
- Currently best determination of this quantity
- $|V_{tb}| > 0.95$ at the 95% CL

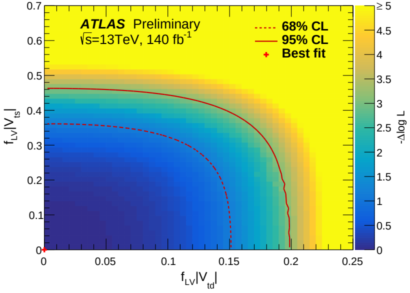




Scan Vtb Vtd



Scan Vtb Vts



Scan Vtd Vts

- 2D scans of CKM matrix elements
- Remaining CKM matrix element assumed to be constant
- Small dependence of $|V_{tb}|$ on $|V_{ts}|$ and $|V_{td}|$

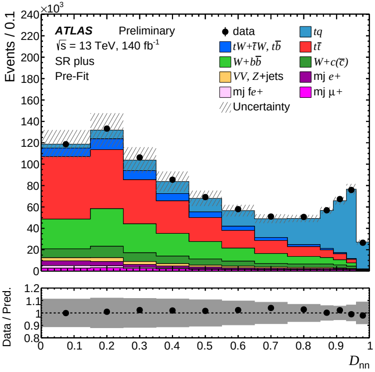
Summary

- First single top t-channel measurement using full run 2 dataset
- Most precise measurement of these cross sections and R_t
- Largest uncertainty sources are signal modeling uncertainties for the cross sections and background modeling for R_t
- EFT interpretation constraining $C_{qQ}^{(1,3)}$
- Setting constraints on CKM matrix elements
- Most precise direct measurement of $|f_{\mathrm{LV}} \cdot V_{tb}|$

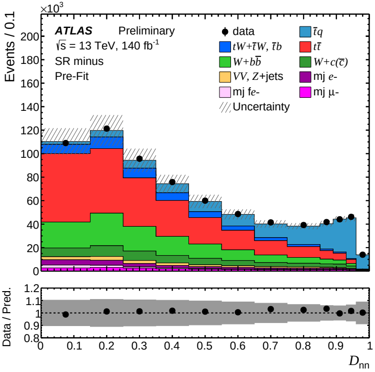
Backup

Prefit Plots

- Neural network used for signal separation
- Maximum LH fit of neural network output distribution is used to measure the cross section



SR plus



SR minus

Impact of uncertainty groups

Impact of different groups of systematic uncertainties on $\sigma(tq)$, $\sigma(\bar{t}q)$, $\sigma(tq+\bar{t}q)$ and R_t given in %

Uncertainty group	$\sigma(tq)$	$\sigma(\bar{t}q)$	$\sigma(tq+\bar{t}q)$	R_t
Data statistical	+0.4 / −0.4	+0.5 / −0.5	+0.3 / −0.3	+0.6 / −0.6
Signal modelling	+4.9 / −4.5	+5.2 / −4.7	+5.0 / −4.6	+0.9 / −0.9
Background modelling	+1.8 / −1.6	+2.1 / −1.9	+1.8 / −1.6	+1.5 / −1.4
MC statistical	+1.1 / −1.0	+1.4 / −1.3	+1.2 / −1.1	+0.8 / −0.8
PDFs	+0.4 / −0.4	+1.2 / −1.0	+0.7 / −0.6	+0.9 / −0.8
Jets	+2.2 / −2.0	+3.0 / −2.7	+2.5 / −2.3	+1.0 / −0.9
b-tagging	+1.6 / −1.5	+1.7 / −1.5	+1.6 / −1.5	+0.2 / −0.1
Leptons	+1.1 / −1.0	+1.1 / −1.0	+1.1 / −1.0	+0.1 / −0.1
Luminosity	+0.9 / −0.8	+0.9 / −0.9	+0.9 / −0.8	< 0.1
Total	+5.9 / −5.5	+6.6 / −6.2	+5.9 / −5.9	+2.2 / −2.1