Measurement of the Inclusive and Fiducial Cross-Section of Single Top-Quark t-Channel Production in pp Collisions at $\sqrt{s} = 8$ TeV

Phillipp Tepel
Supervisor: Dominic Hirschbühl,
Wolfgang Wagner

BERGISCHE
UNIVERSITÄT
WUPPERTAL

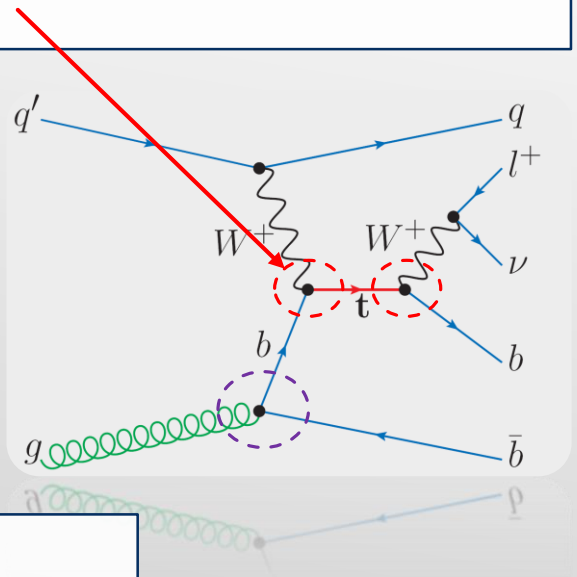
Content

- Event selection
- Background estimation
- Neural Networks
- Measurement

Single Top-Quarks

Dominant production channel: *t*-channel (*tq*)

- $\sigma_t \propto |V_{tb}|^2$
- Test the V-A structure of the W_{tb} vertex: polarisation of top-quarks

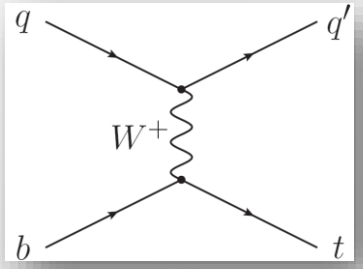


$\sigma^t_{NLO} = 54.9^{+2.3}_{-1.9}$ pb

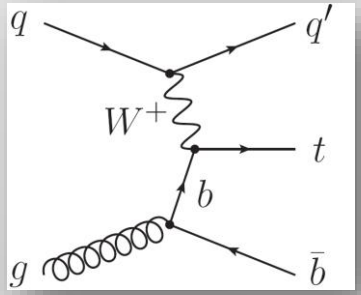
Calulated with HATHOR 2.1
arXiv: 1406.4403

$\sigma^{\bar{t}}_{NLO} = 29.7^{+1.7}_{-1.5}$ pb

5-Flavour-Scheme



4-Flavour-Scheme



b-Quarks in the initial state

- Treatment of *b*-Quarks in the initial state in MC generators / calculations
  - 4-,5-flavour-Schemes
  - e.g. important for $Hb\bar{b}$ production
- σ_t sensitive to PDFs, *b*-Quark PDF, Ratio of *u*/*d*-Quark PDF

Important for new physics

- e.g. FCNC

Next Talk!

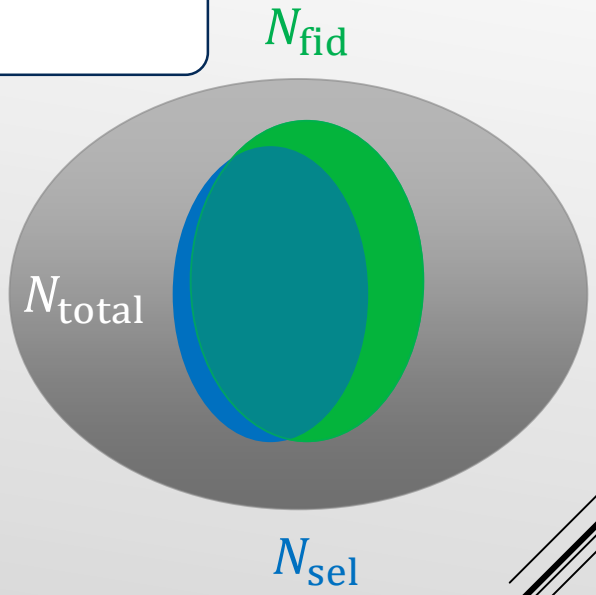
Measurement of Fiducial Cross-Sections

Measure the *tq* cross-section widely independent of the choice of signal MC-generator

Define a fiducial phase-space close to the phase-space of reconstructed and selected data events

Advantage:

- Potentially significant reduction of acceptance uncertainties



Write the cross-section

$$\sigma = \frac{N_{\text{total}}}{N_{sel}} \cdot \frac{\hat{\nu}}{\mathcal{L}_{\text{int}}} = \frac{N_{\text{total}}}{N_{\text{fid}}} \cdot \frac{N_{\text{fid}}}{N_{\text{sel}}} \cdot \frac{\hat{\nu}}{\mathcal{L}_{\text{int}}}$$

$$\sigma_{\text{fid}} = \frac{N_{\text{fid}}}{N_{\text{sel}}} \cdot \frac{\hat{\nu}}{\mathcal{L}_{\text{int}}}$$

$\hat{\nu}$ is the fitted expectation value of the number of single top-quark *tq* events

Determined via a Maximum Likelihood (ML) Fit of the NN discriminante

Analysis Strategy

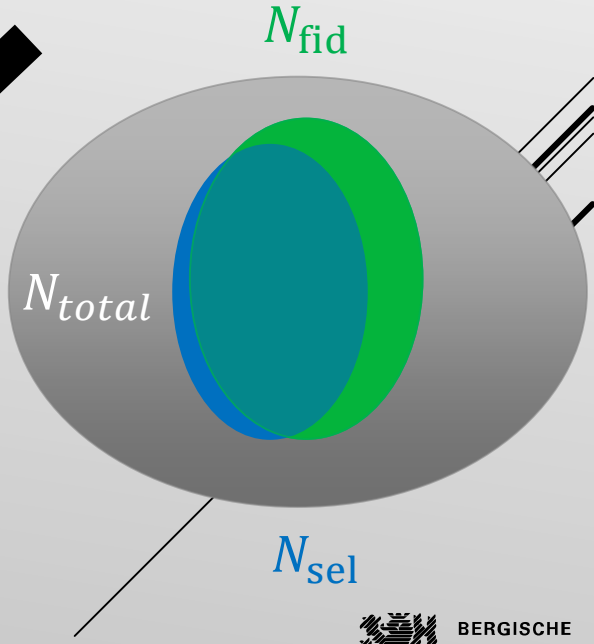
Input Format

Event Selection

Background estimation

Neural Network

MC Truth Event selection



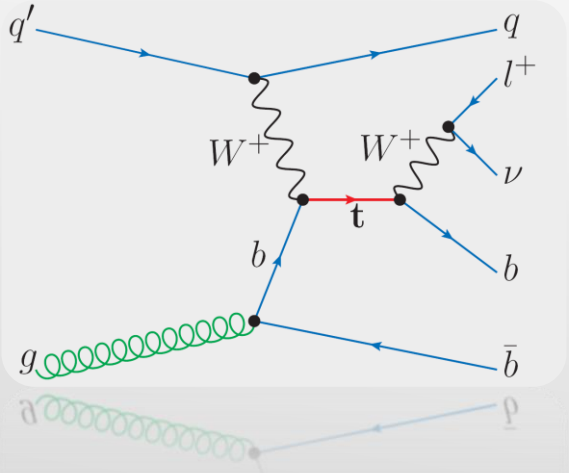
Extract:

$\sigma_{\mathrm{fid}}(t), \sigma_{\mathrm{fid}}(\bar{t})$

Extrapolate:

$\sigma_{\mathrm{total}}(t), \sigma_{\mathrm{total}}(\bar{t}), R_t, V_{tb}$

Single Top-Quark t-channel Selection



Particle level

- 2 Jets
- Jet $|\eta| < 4.5$, $p_{\mathrm{T}} > 30$ GeV
- Lepton $p_{\mathrm{T}} > 25$ GeV
- 1 b-tagged jet (ghost matching)
- $m(\ell, b) < 160$ GeV

Reconstruction level

- 2 Jets + 1 charged lepton
- Jet $|\eta| < 4.5$, $p_{\mathrm{T}} > 30$ GeV
- Lepton $p_{\mathrm{T}} > 25$ GeV
- $m(\ell, b) < 160$ GeV
- 1 b-tagged jet: 50% efficiency

Multijet veto:

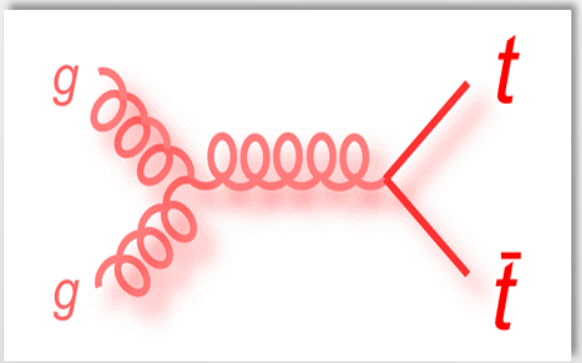
- $E_{\mathrm{T}}^{\mathrm{miss}} > 30$ GeV
- $M_T(W) > 50$ GeV
- $p_{\mathrm{T}}(\ell) > 40\ \mathrm{GeV} \cdot \left(1 - \frac{\pi - |\Delta\phi(j_1, l)|}{\pi - 1}\right)$

Dilepton veto

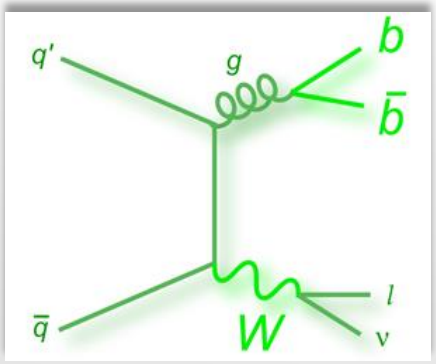
- $p_{\mathrm{T}}(\ell_2) > 10$ GeV

Background Estimation

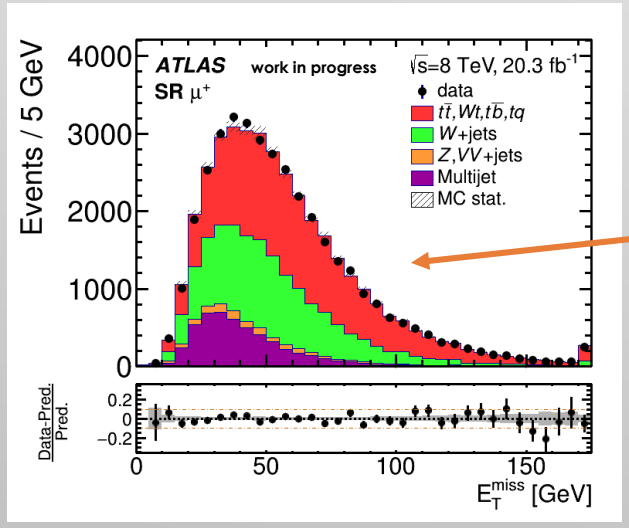
Primary Backgrounds:



$t\bar{t}$



$W + jets$



Other Backgrounds:

- Single top-quark $t\bar{b}$ and Wt production
- $Z + jets$
- Multijets (Normalisation with ML Fit $E_{\mathrm{T}}^{\mathrm{miss}}$-distribution)

W + jets control region

- b-tagged jet@80% Eff. + SR veto

$t\bar{t}$ control region

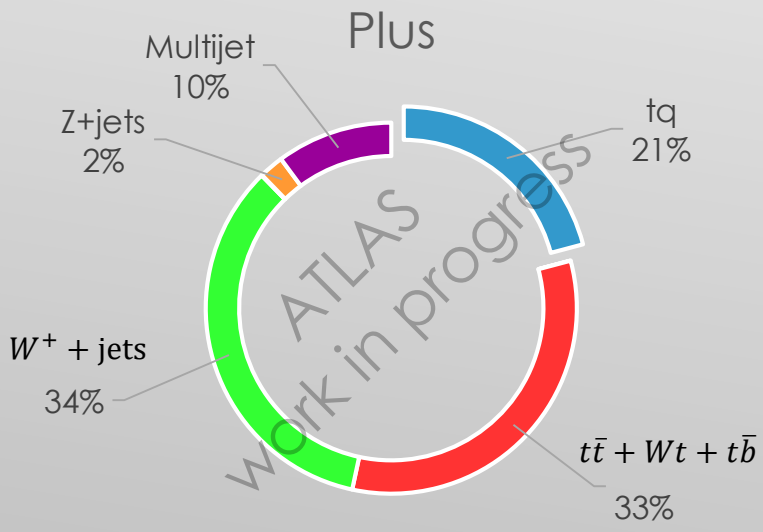
- 2 b-tagged jets @50% Eff.

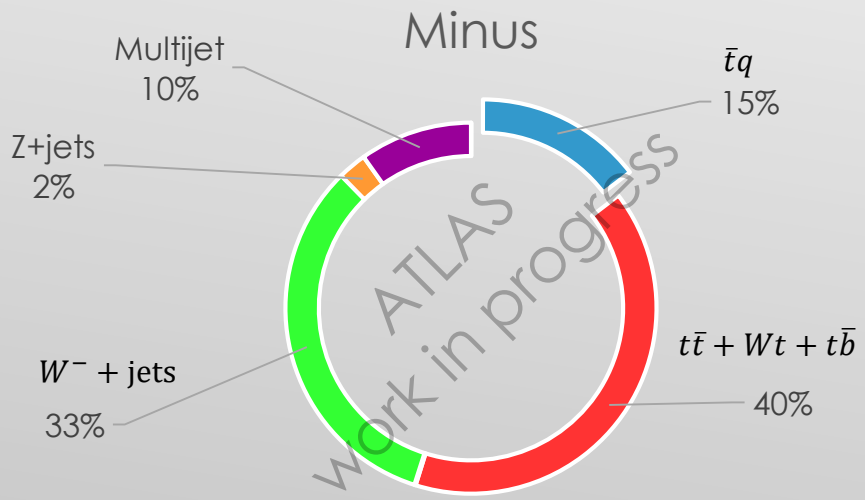
Event yield and signal extraction

Signal extraction

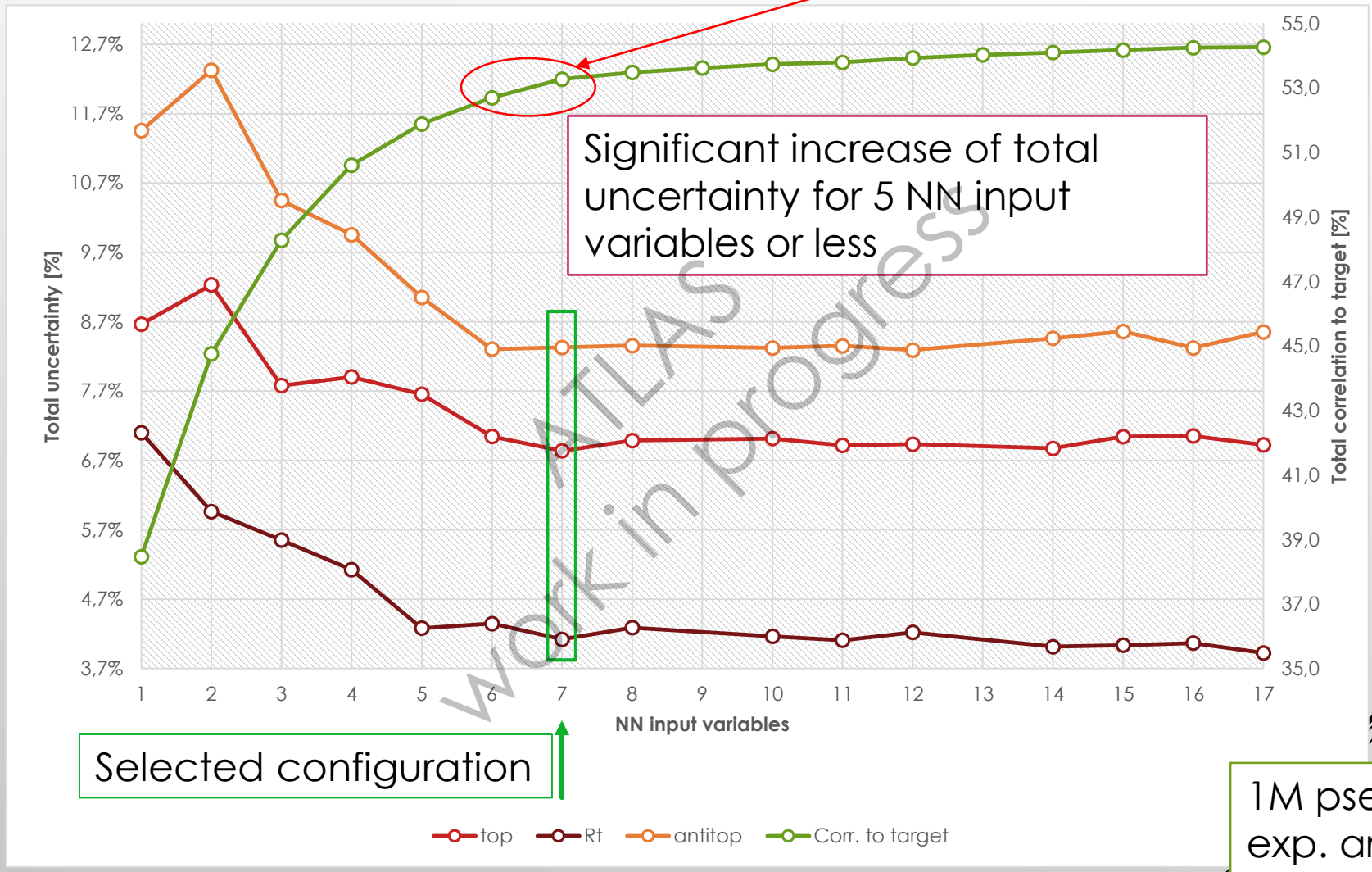
- Only 21 % *tq* events in the signal region
- To improve the sensitivity Neural Networks are employed
- Neural Networks (NN) combine the discriminating power of multiple observables to one discriminant
- Determine which input variables to utilize

Process	Plus	Minus
tq	11244	17
$\bar{t}q$	9	6196
$t\bar{t} + Wt + t\bar{b}$	17518	17101
$W^+ + \text{jets}$	18489	48
$W^- + \text{jets}$	25	13916
$Z + \text{jets}$	1150	1068
Multijet	5461	4177
Total expected	53897	42522
Total Observed	**55695**	**44428**





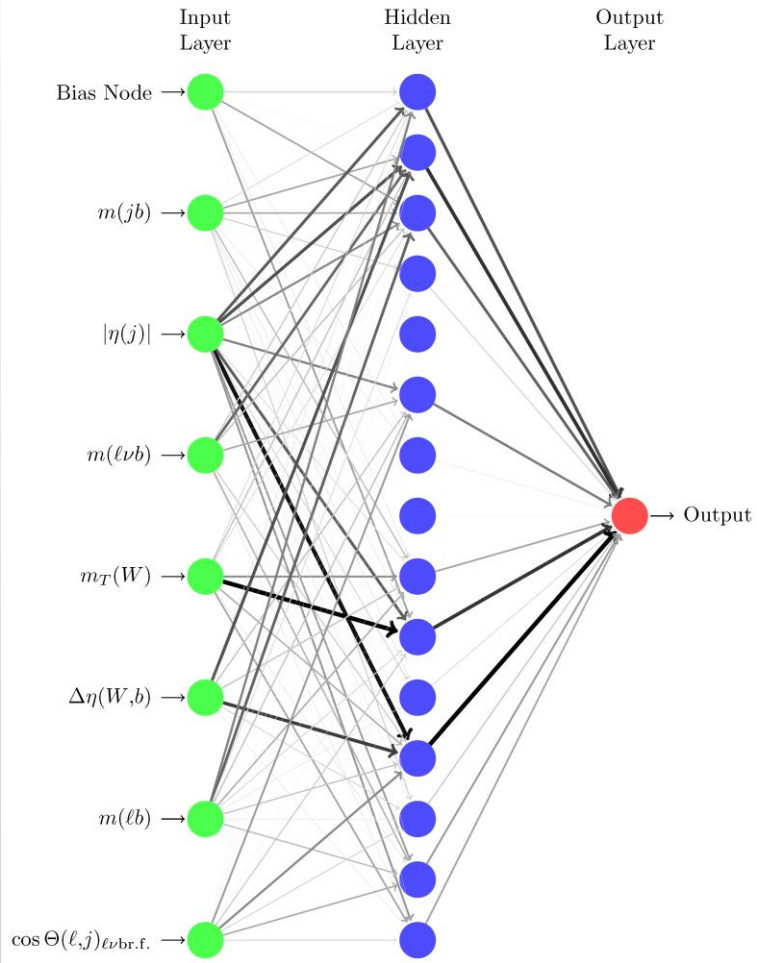
NN input-variable scan

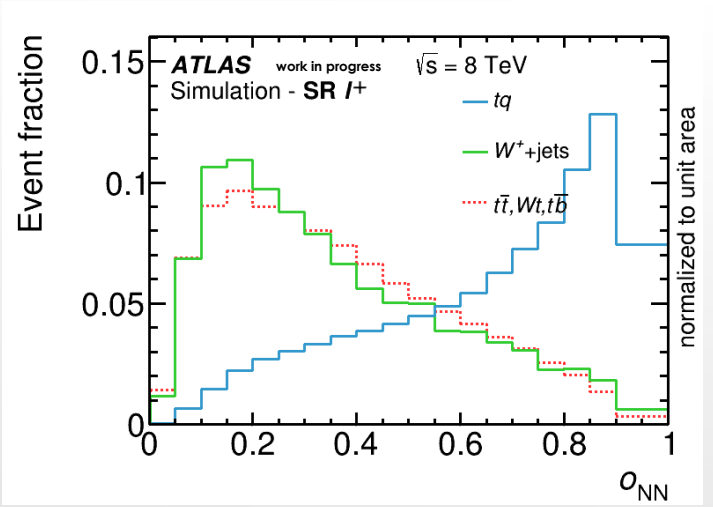


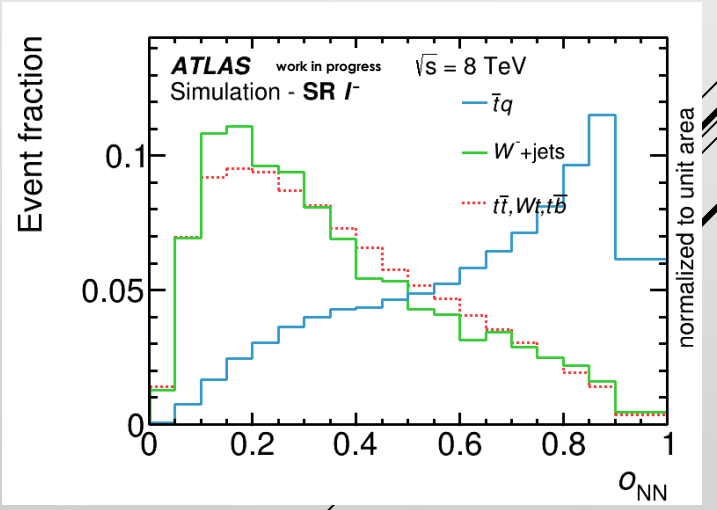
1M pseudo exp. are used

Neural Network

n	Variable	Corr. Loss [%]
1	$m(jb)$	38.5
2	$\|\eta(j)\|$	22.9
3	$m(\ell\nu b)$	18.1
4	$m_T(W)$	15.2
5	$\Delta\eta(\ell\nu, b)$	11.4
6	$m(\ell b)$	9.2
7	$cos\ \Theta(\ell, j)_{\ell\nu b\ r.f.}$	7.8



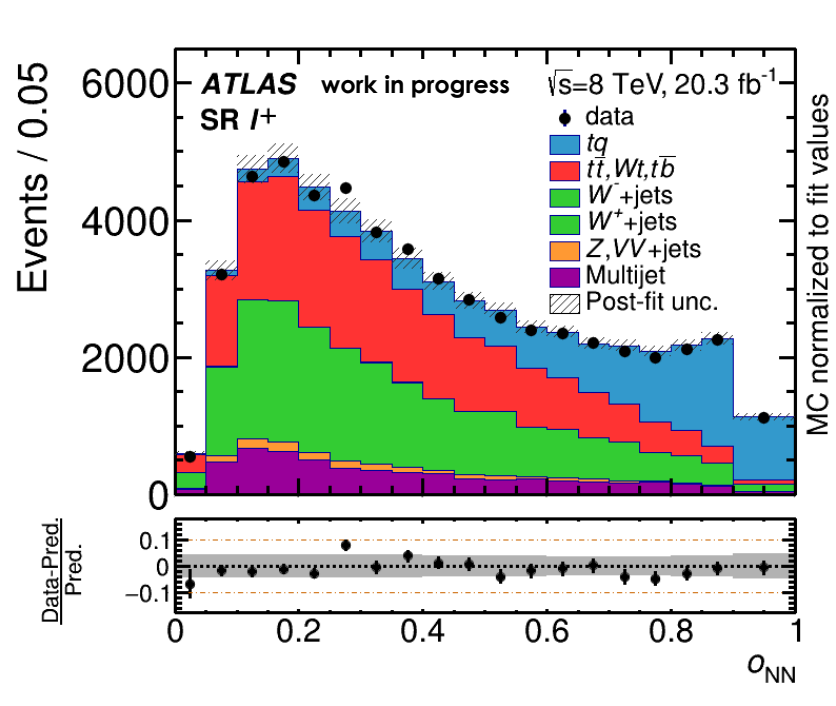


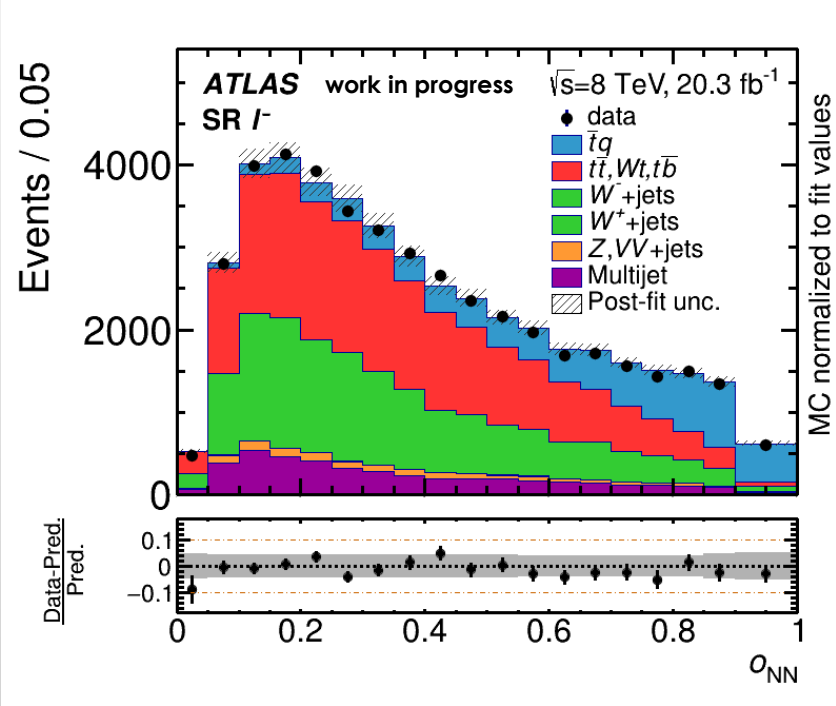


- The correlation of all input variables is used
- Validation of the NN discriminant in both control regions

The Maximum Likelihood Fit

A binned maximum likelihood fit is performed on the NN-output discriminate distribution to ascertain the signal- and background fractions





The uncertainty band contains the post-fit uncertainties

Systematic Uncertainties

Types of systematic uncertainties

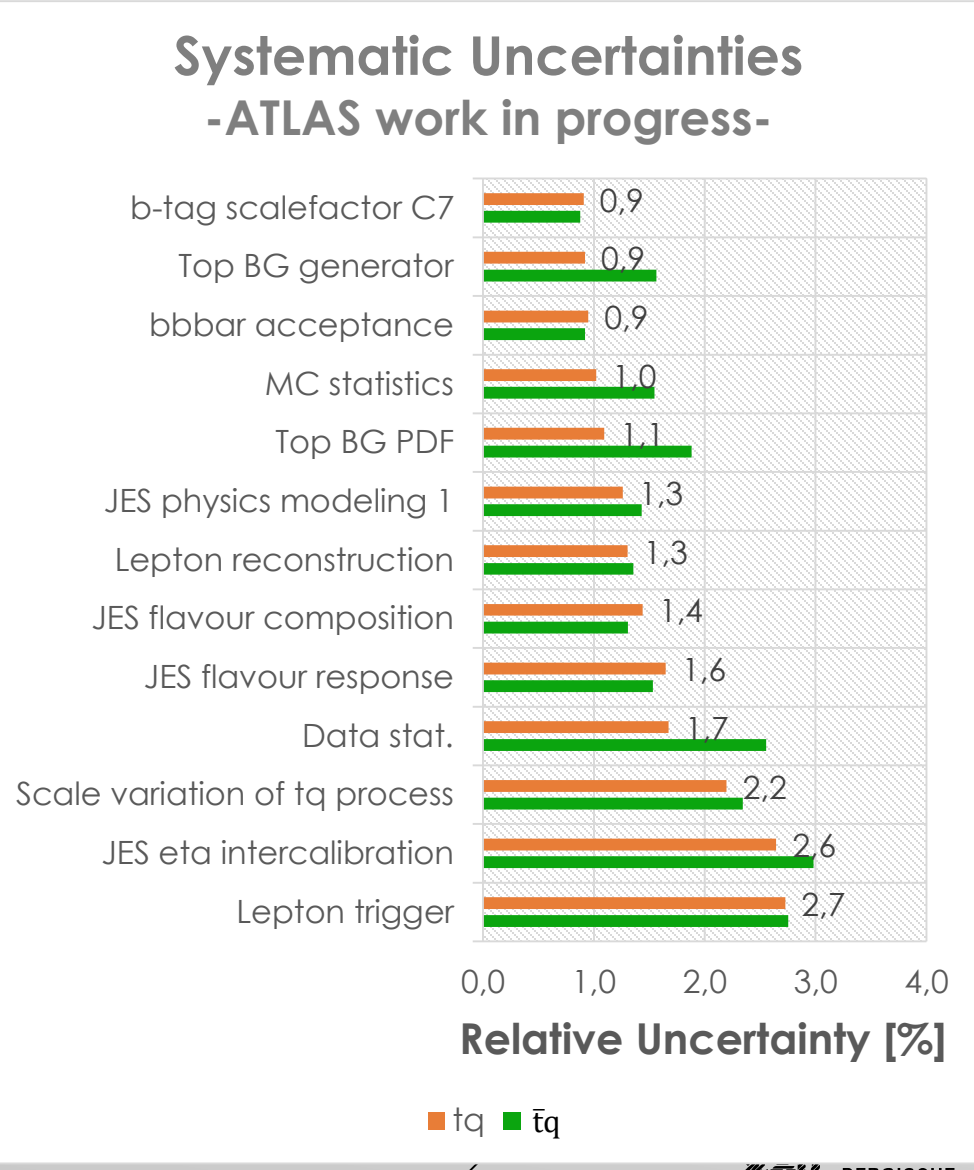
- Object modelling
- Monte Carlo generator
- PDF
- Background normalisation

Statistical analysis

- Pseudo experiments are used to determine impact for each systematic uncertainty

Dominating Uncertainties

- Lepton trigger efficiency
- JES η intercalibration
- Signal modelling



Results

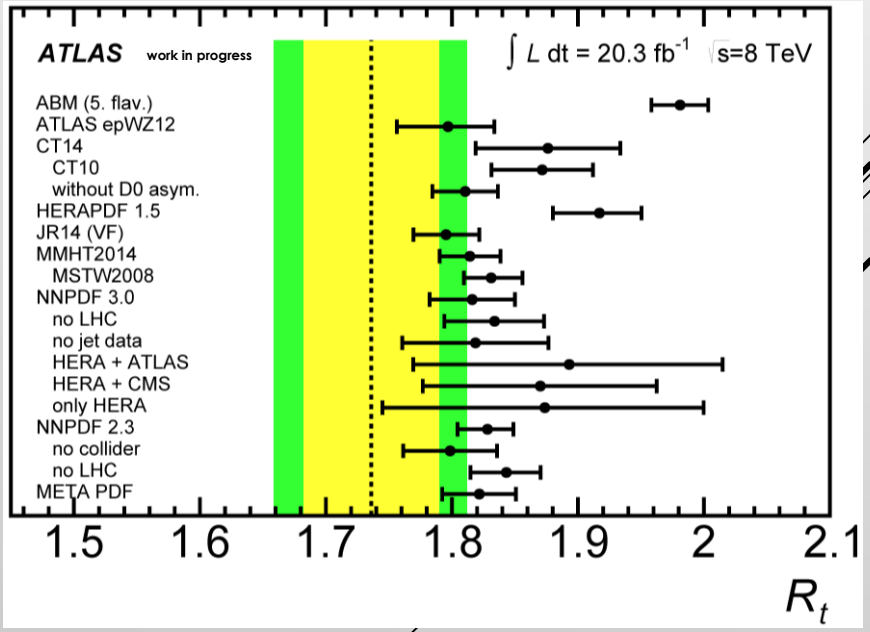
Fiducial Cross-Sections (ATLAS work in progress):

- $\sigma_{\text{fid}}(t) = \frac{N_{\text{fid}}}{N_{\text{sel}}} \cdot \frac{\hat{\nu}(t)}{\int \mathcal{L}\, dt} = 10.02 \pm 0.17(\text{stat.}) \pm 0.68(\text{syst.}) \pm 0.19(\text{lumi})\ \text{pb}$
- $\sigma_{\text{fid}}(\bar{t}) = \frac{N_{\text{fid}}}{N_{\text{sel}}} \cdot \frac{\hat{\nu}(\bar{t})}{\int \mathcal{L}\, dt} = 5.81 \pm 0.15(\text{stat.}) \pm 0.52(\text{syst.}) \pm 0.11(\text{lumi})\ \text{pb}$
- $R_t = \frac{\sigma_{total}(t)}{\sigma_{total}(\bar{t})} = 1.74 \pm 0.05(\text{stat.}) \pm 0.05(\text{syst.})$

Compare $R_t = \frac{\sigma_{total}(t)}{\sigma_{total}(\bar{t})}$, with different PDF set predictions

Uncertainty calculation for R_t is not yet complete

The measured value is compatible with many PDF sets



Conclusions

- The first measurement of the fiducial single-top quark tq and $\bar{t}q$ cross-sections is being finalized.
- The dominant uncertainties are the JES η-intercalibration and the lepton trigger efficiency uncertainty.
- The inclusive production cross-section is in good agreement with NLO fixed order cross-section calculation
- The cross-section ratio R_t is compatible with many PDf-set predictions. The measured uncertainty calculation is not complete yet

Thank you for your attention