Measurement of the Top Quark Pair Production Cross-Section in the Single Lepton Channel with the ATLAS Experiment.

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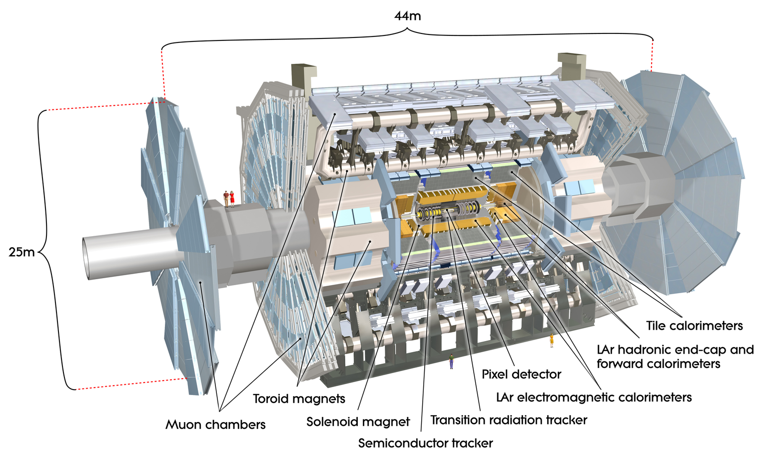
Introduction

Top quark pair production is the new standard candle for high-p_T physics at the LHC. The first basic ingredient is a precise measurement of the production cross-section.
Initial ATLAS and CMS measurements had significant uncertainties, but already with the dataset recorded in 2010 of 35 pb^{-1} at $\sqrt{s}$ = 7 TeV, uncertainties are competitive with Tevatron measurements and theoretical predictions.

ATLAS detector

This measurement is based on the excellent ATLAS capabilities for tracking, tagging and energy deposition measurements. The ATLAS detector was >95% fully functional in 2010.

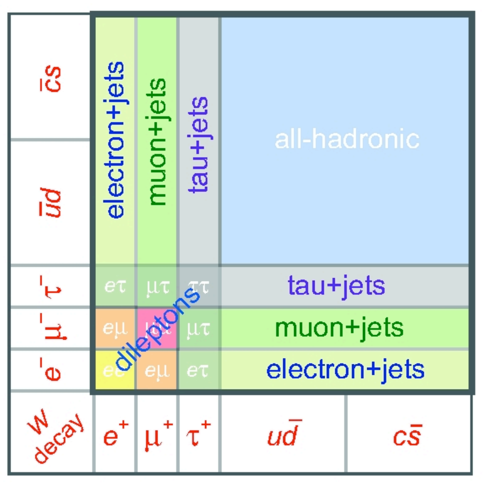


Top quark physics

Measuring the production cross-section is a very good test of perturbative QCD in the Standard Model. Top quark events are the dominant background to some Higgs scenarios and searches for New Physics.

Top pair decay channels

Top quarks do not hadronise but decay almost exclusively via a b-quark and a W-boson. The so-called semi-leptonic channel, in which one W-boson decays hadronically and the other one leptonically, shows best overall performance between statistical and systematic uncertainties. Semi-leptonic decays happen in 45% of all cases. In this analysis only muon and electron final states are considered.

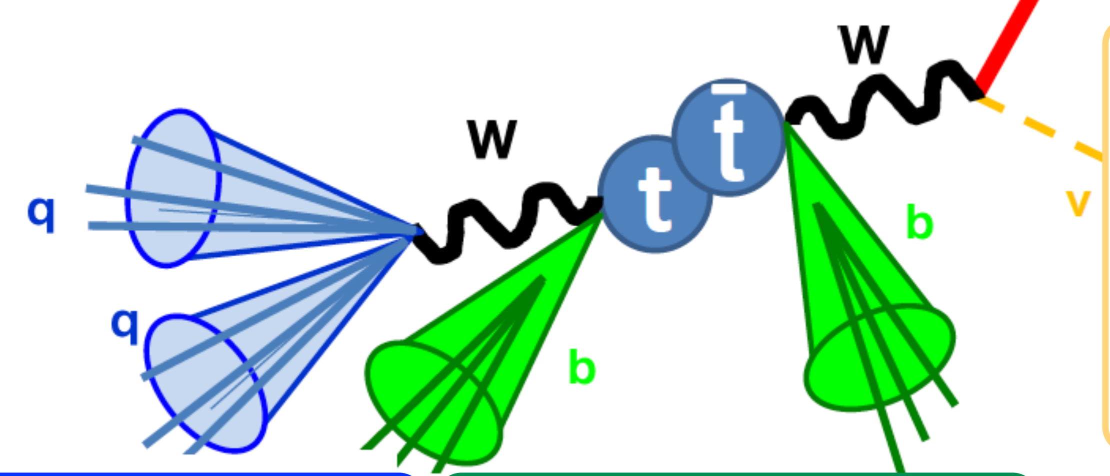


Event selection

The event selection closely follows the event topology. High quality and well isolated leptons are selected to reject most purely hadronic backgrounds.

electrons:
- good isolated calo object
- matched to track
- E_T > 20 GeV
- |η| < 2.47 (excluding transition region barrel-endcap)
- fired the trigger

muons:
- segments in tracker and muon detector
- isolated track
- p_T > 20 GeV
- |η| < 2.5
- fired the trigger



missing transverse E:
- vector sum of calo energy deposits
- corrected for identified objects
- MET > 20 GeV (μ+jets) or > 35 GeV (e+jets)
- m_T(W) > 25 GeV (e+jets) or MET + m_T(W) > 60 GeV (μ+jets)

jets
- topological cluster
- anti-k_T (R=0.4)
- MC-based calibration
- p_T > 25 GeV
- |η| < 2.5

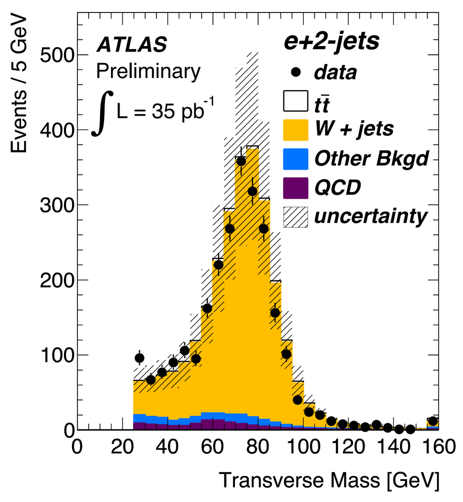
b-jets
- JetProb: use signed impact parameter significance of all tracks to estimate compatibility with primary vertex
- discriminate light flavour jets from heavy flavour jets

event cleaning:
- full detector functionality
- primary vertex with at least 5 tracks
- bad jet veto

Backgrounds

Even though tight selection cuts are applied, not all backgrounds can be rejected. The following backgrounds need to be well understood:
> W+jets production, including heavy flavour jets
> Z/γ+jets production
> diboson production
> single top production
> QCD multi-jet events faking leptons

The first four are estimated using Monte Carlo assisted methods, normalisation is obtained from the fit. Multi-jet background is difficult to model and therefore estimated from data. For the muon +jets channel the matrix method is used whereas for electron+jets a full model is obtained using cut inversion. Below a control plot for the electron +jets channel is shown.



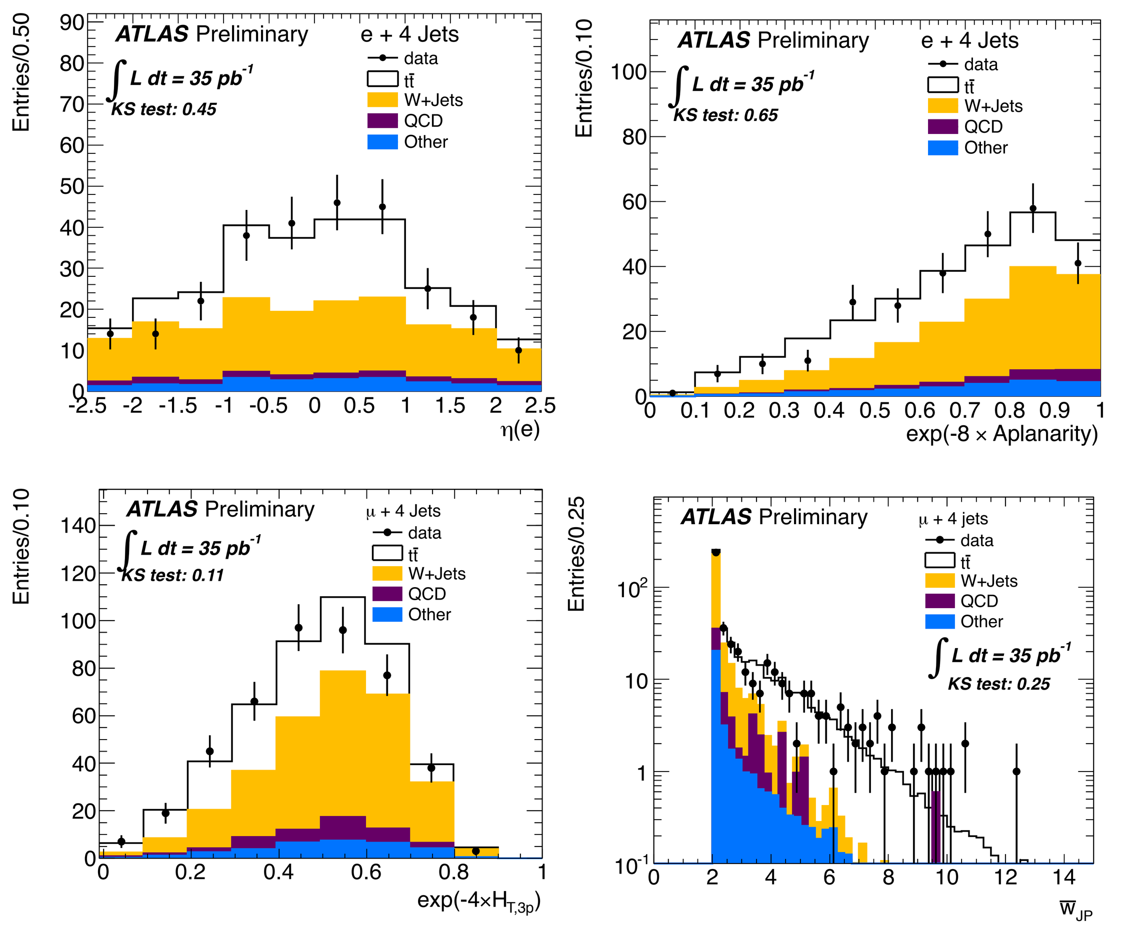
Measurement approach

By using events with 3, 4 and ≥ 5 jets ~80% of all top events after cuts are considered. The major background to top is W+jets production. Therefore, topological differences between top pair and W+jets processes are used to create a projective likelihood discriminant:
> lepton η
> aplanarity
> p_T sum of all but the leading 2 jets divided by p_z sum of all objects
> mean b-tagging weight of the two most b-like jets

The input distributions are shown on the right.

Likelihood discriminant

The likelihood is in the form of D = S / (S + B).
It is constructed for each analysis channel, i.e. for both electron+jets and muon+jets channel in the 3, 4 and ≥ 5 jets bins each.

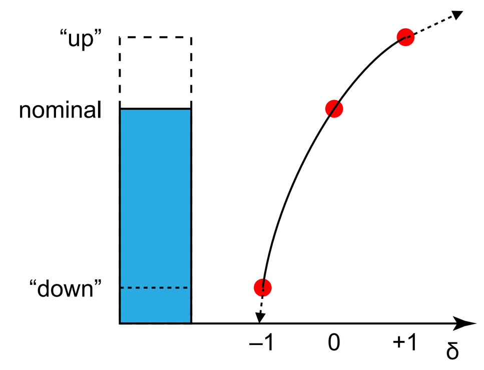


Profile likelihood fit

The fit to data is performed in all analysis channels simultaneously. The systematic uncertainties are considered as additional nuisance parameters δ_i. The parameter of interest, the top pair cross-section is allowed to float freely. All other parameters get Gaussian constraints.

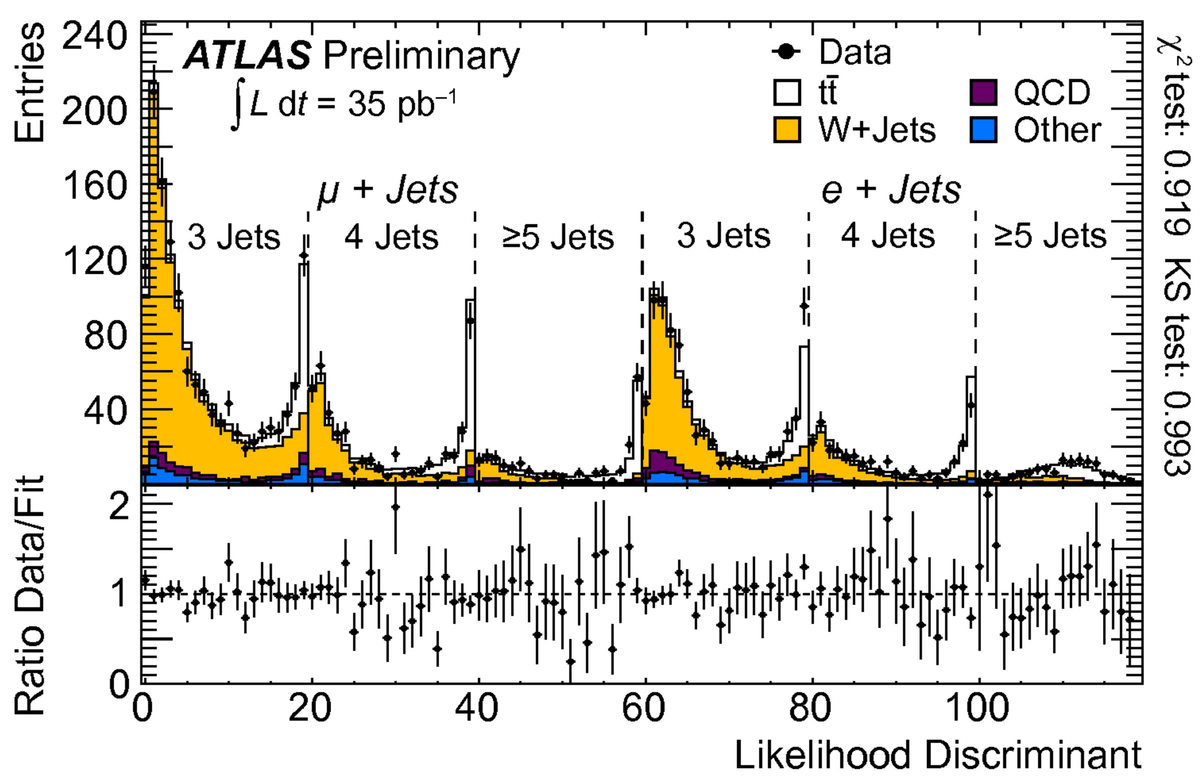
Nuisance parameters

The nuisance parameters are made continuous by using vertical template morphing. Between the nominal and the ±1σ templates quadratic interpolation is used, linear extrapolation beyond.



This approach allows data to constrain the systematic uncertainties. Several tests have been performed to validate this approach. Non-continuous uncertainties such as initial and final state radiation are treated outside the fit.

Fit results



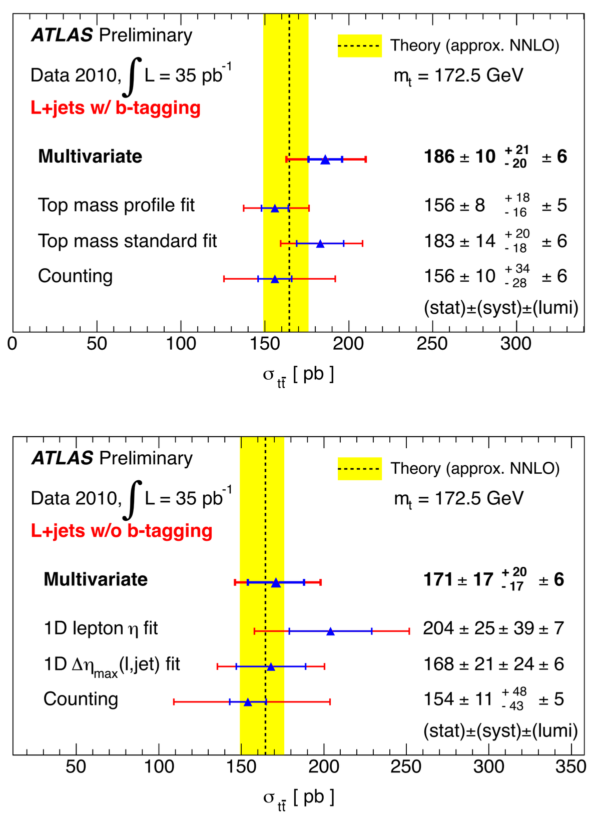
The top pair production cross-section obtained from the fit is:

$$\sigma_{t\bar{t}} = 186 \pm 10(\text{stat.})^{+21}_{-20}(\text{syst.}) \pm 6(\text{lumi.})\ \text{pb}$$

which is in agreement with the Standard Model. The dominant systematic uncertainties are
> b-tagging calibration (7.5%),
> W + heavy flavour contributions (7%),
> initial and final state radiation modelling (4%).

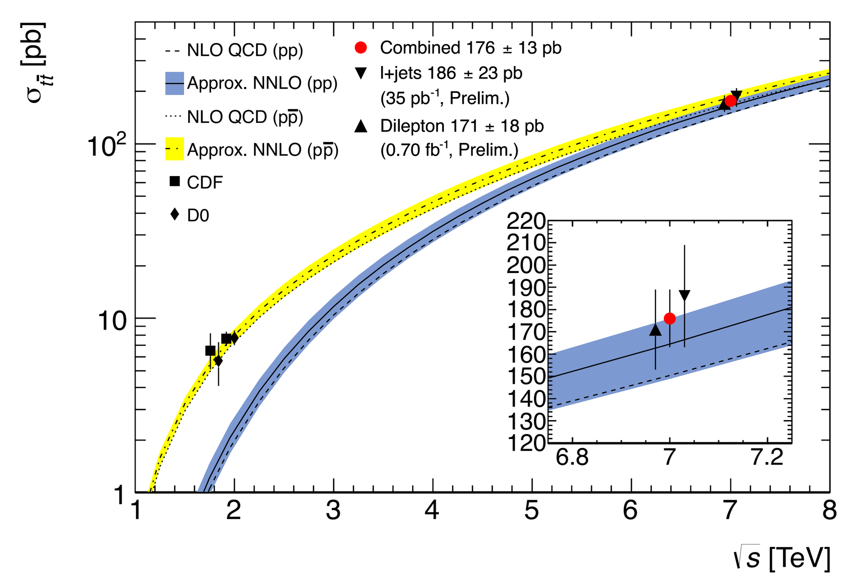
Cross-check results and combination

Several independent measurements with and without b-tagging have been performed by the ATLAS collaboration. They are all in agreement within uncertainties. Shown on the left is a comparison of two other measurements that are also using b-tagging. The measurement presented on this poster yields a relative uncertainty of the top quark pair cross-section measurement of 13% after one year of data-taking.



Combination with dilepton channel measurement

The combination of this measurement with the dilepton analysis without b-tagging using 690 pb^{-1} results in a total uncertainty of 7%. The comparison with theory prediction and Tevatron results is shown below.



References

(1)ATLAS-CONF-2010-099
(2)ATLAS-CONF-2011-035
(3)ATLAS-CONF-2011-040
(4)ATLAS-CONF-2011-

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