QCD and Top physics results with 2010 ATLAS Data

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**on behalf of the ATLAS Collaboration*

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2nd International Conference on Particle Physics
in Memoriam Engin Arık and Her Colleagues
Doğuş University, İstanbul, Turkey

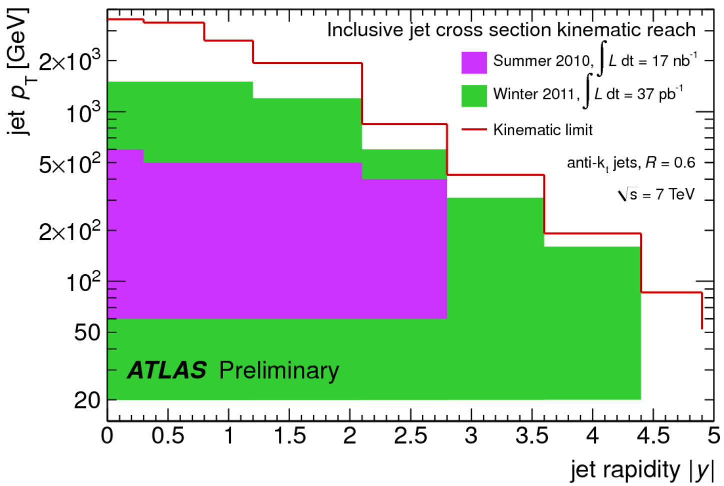
Overview

- Introduction
- Hard QCD:
  - Tests of perturbative QCD at LO and NLO
  - BSM searches in dijet events
- Top Physics:
  - Top cross-section measurement
  - Rediscovery of single top
  - Top pair resonances
- Conclusions

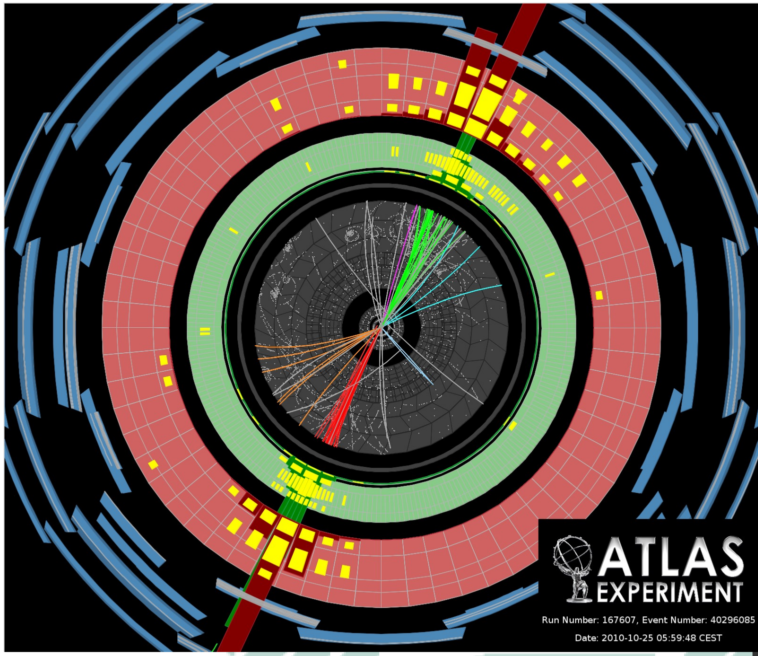
Hard QCD

QCD at LHC

- Energy of LHC unique opportunity to test validity of pQCD predictions at unprecedented energies
- BSM models often produce final states with multijet signatures
- Test of QCD predictions important prerequisite for BSM studies
- Main source of systematics: Jet Energy Scale (JES)

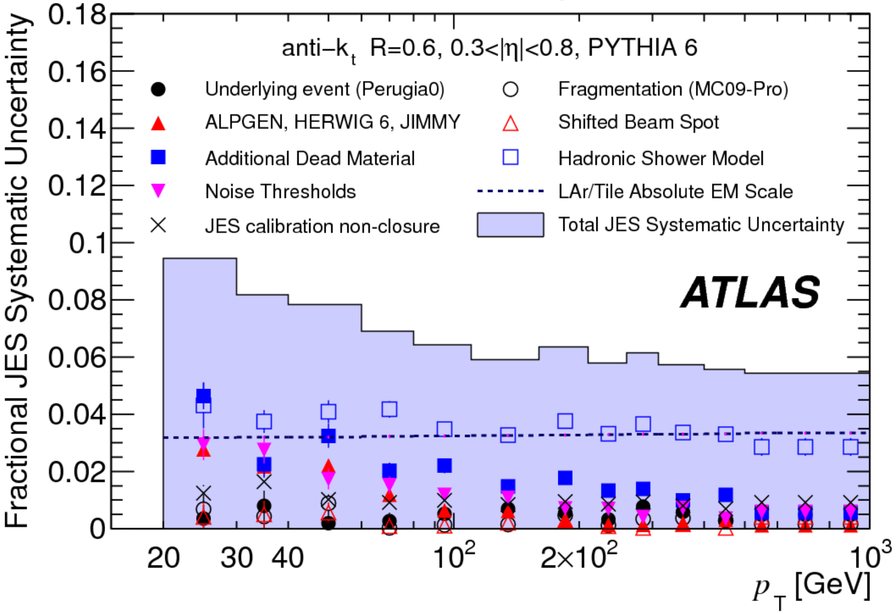


Dijet event, invariant mass = 3.1 TeV →

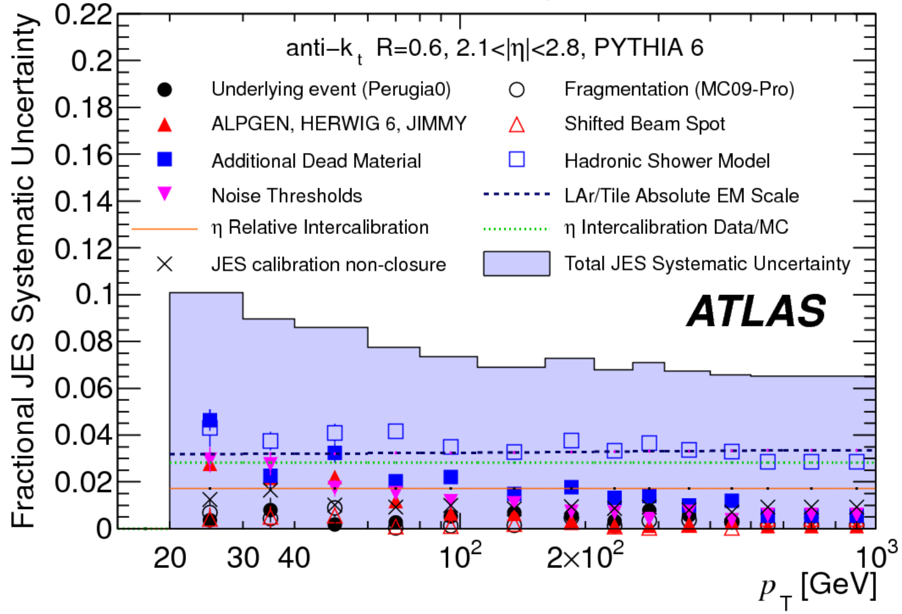


JES uncertainty

Central region

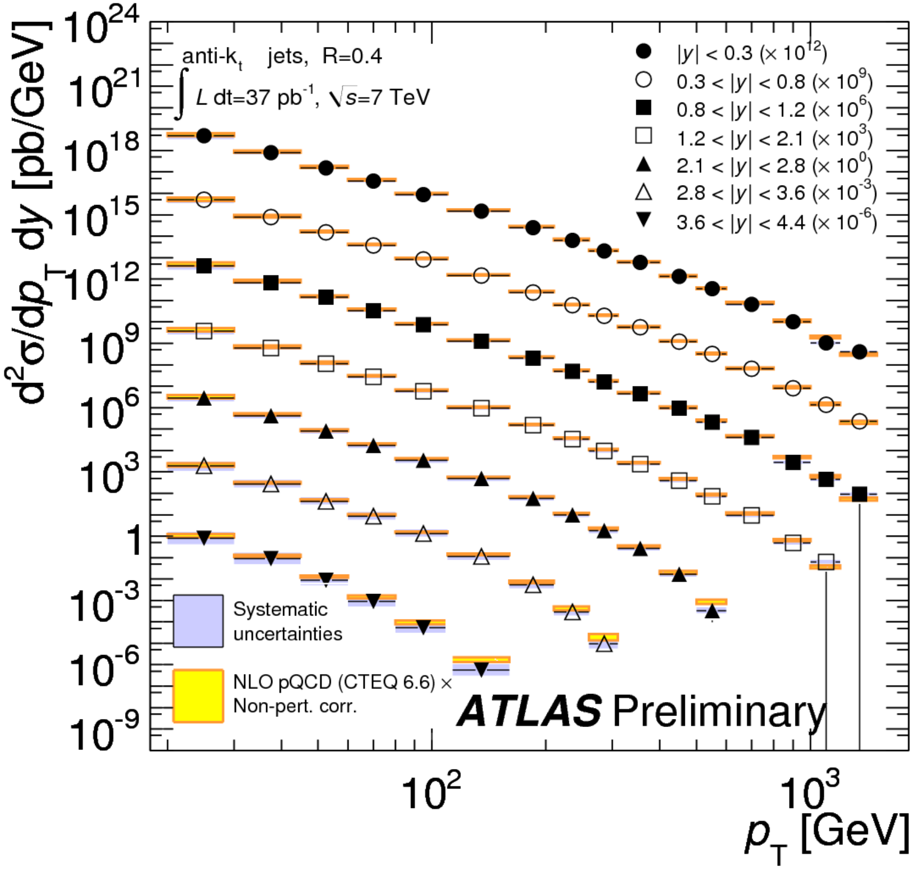


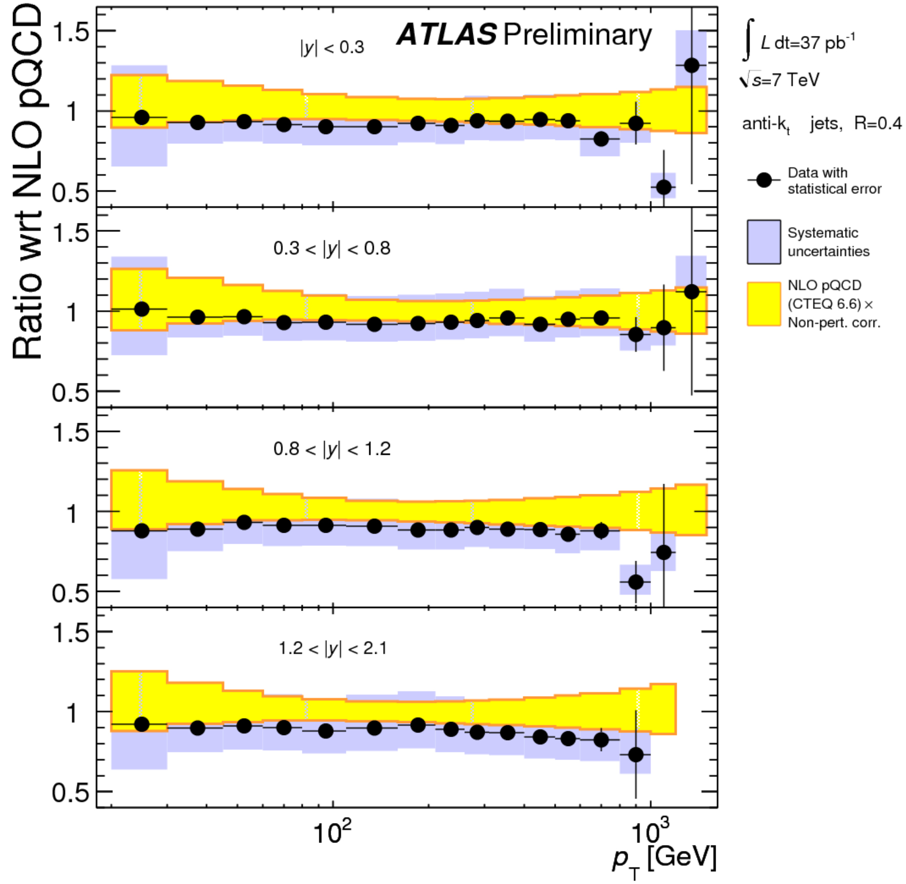
Forward region



Typical uncertainty at ~7% level

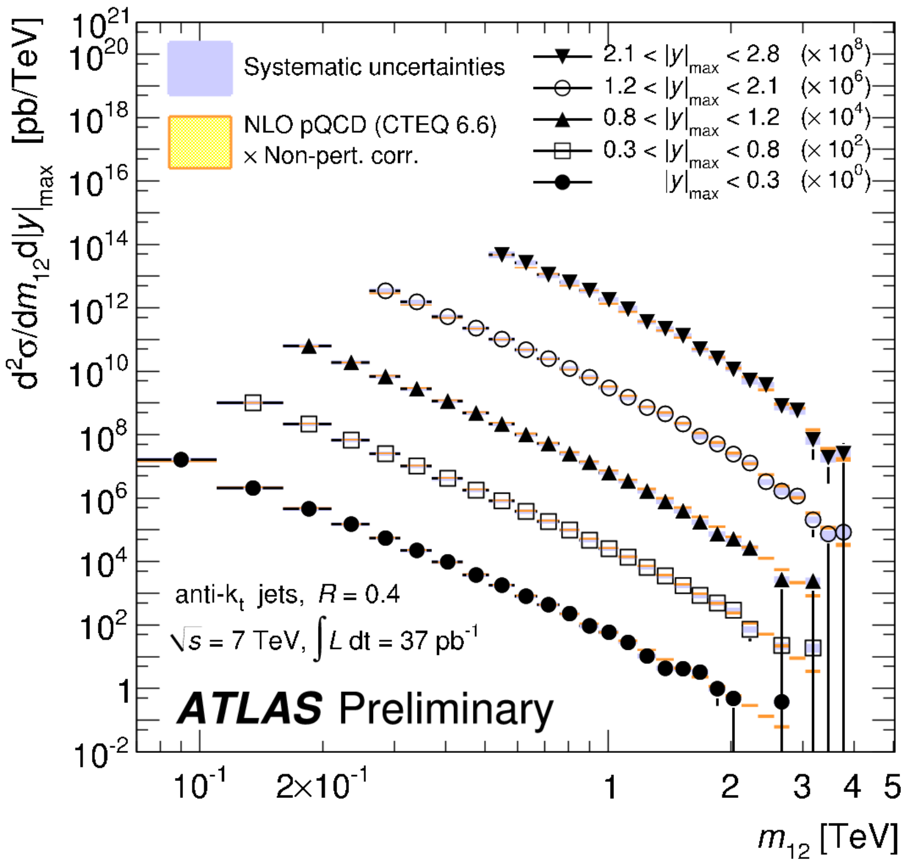
Inclusive jet

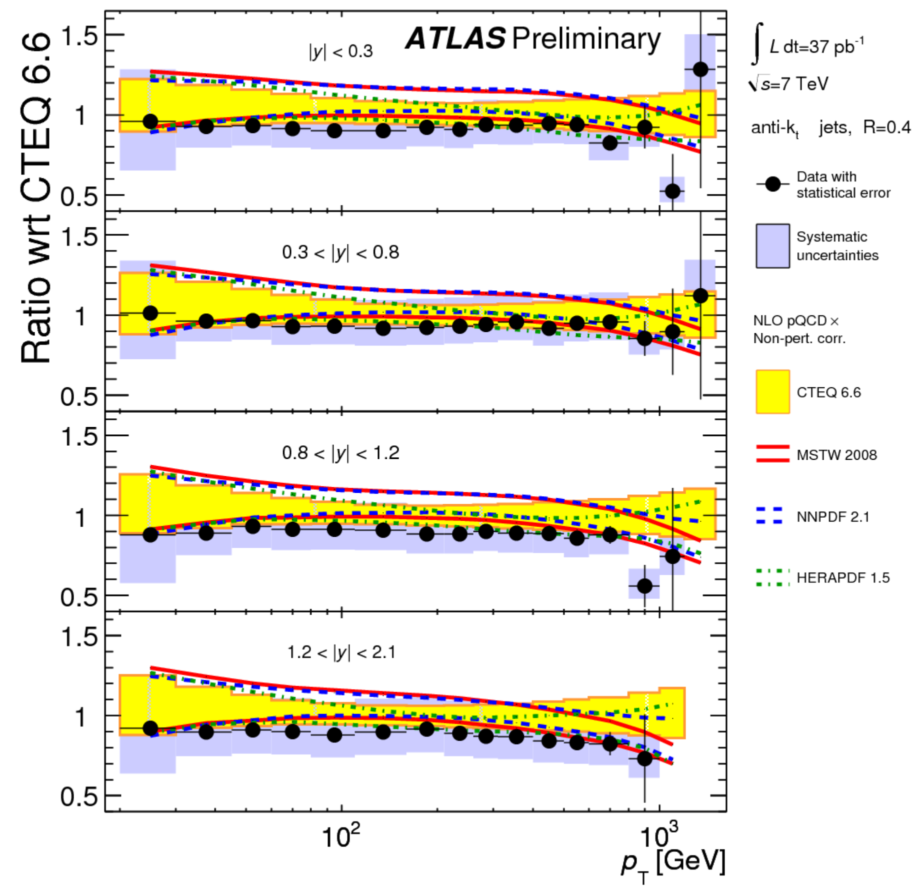




Comparison with NLO with NLOJET++ 4.1.2 and CTEQ 6.6 NLO PDF holds at TeV energy range

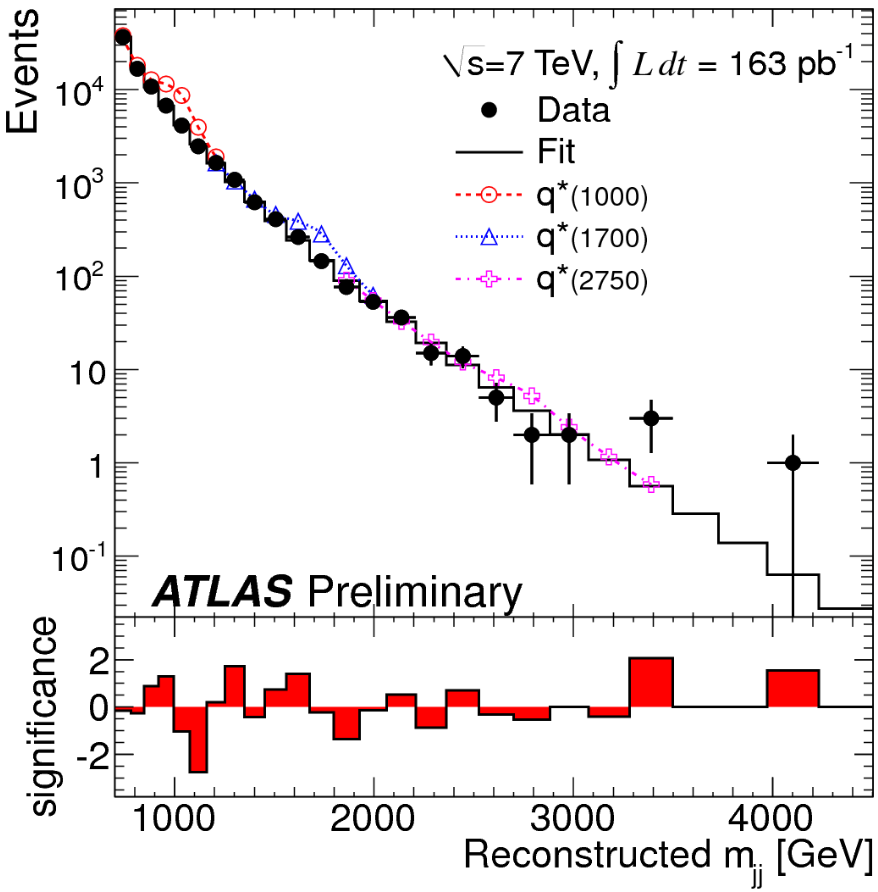
Dijet

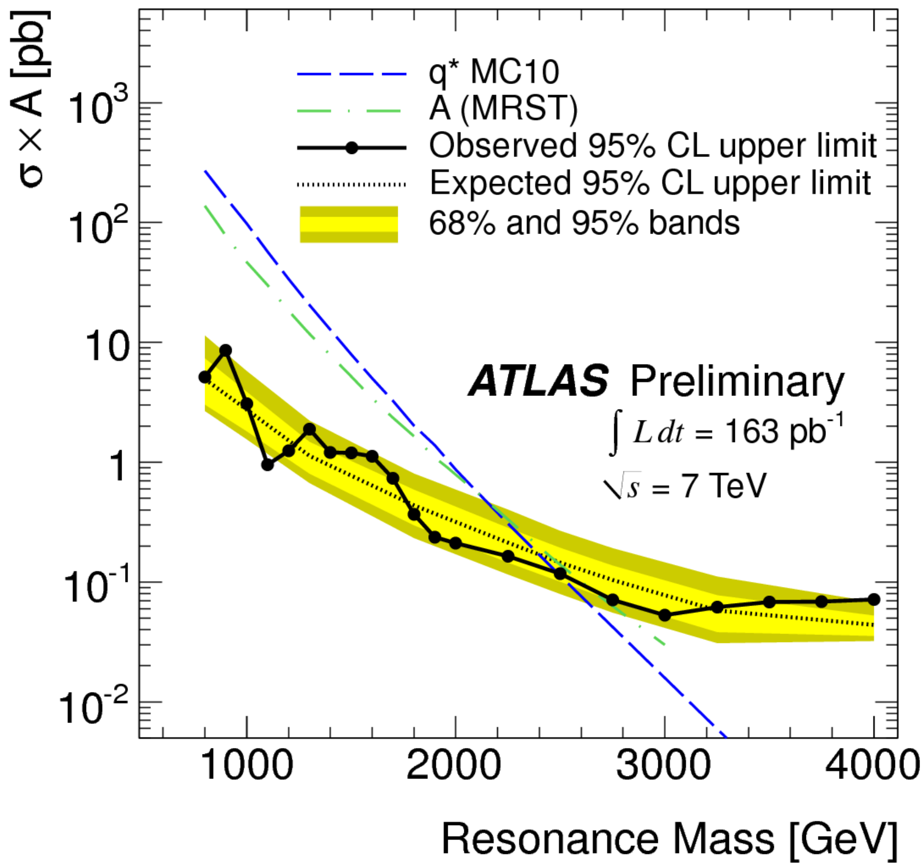




Cross section as a function of dijet mass well described by predictions
PDFs behave well in a range with few available data

Dijet resonance search



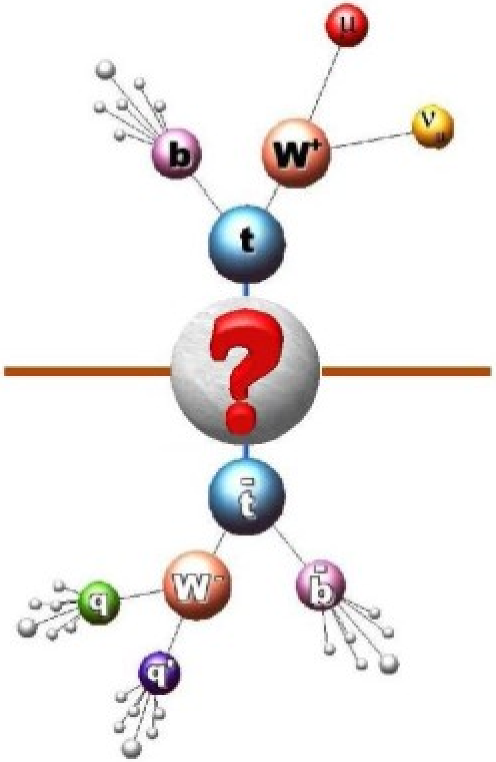


95% CL exclusion limit for excited quark q*: 0.80 < m < 2.49 and axigluon A: 0.80 < m < 2.67 TeV

Top Physics

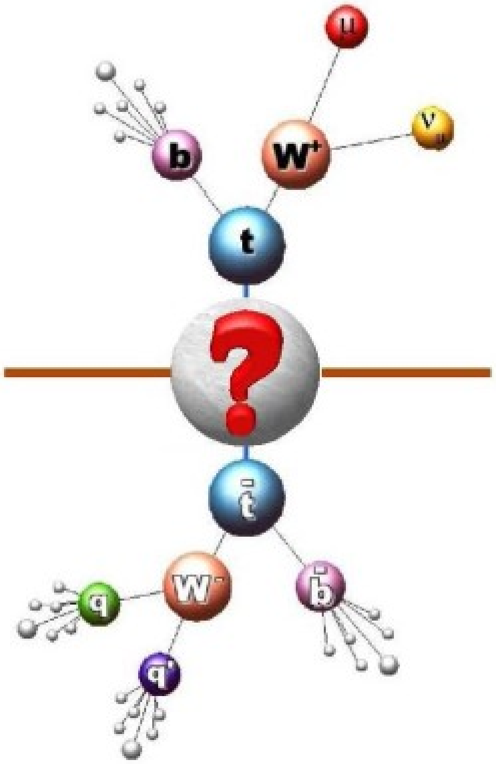
Top Physics at LHC

- LHC is a “top factory” → high volume of data allows to measure top properties with good precision
- σ_{tt} = 165 pb @ 7 TeV → ~9000 top pairs per day at current luminosity
- Heavy quark mass indicates important role in EW symmetry breaking, either via Higgs mechanism or other models
- Pair mode of production via gluon-gluon fusion allows to test pQCD predictions
- BSM physics can manifest itself via resonant pair production
- Electroweak single top mode of production allows to test CKM matrix and chirality of EW coupling
- Background for many other physics processes
- Complex signature benchmark for performance of ATLAS detector



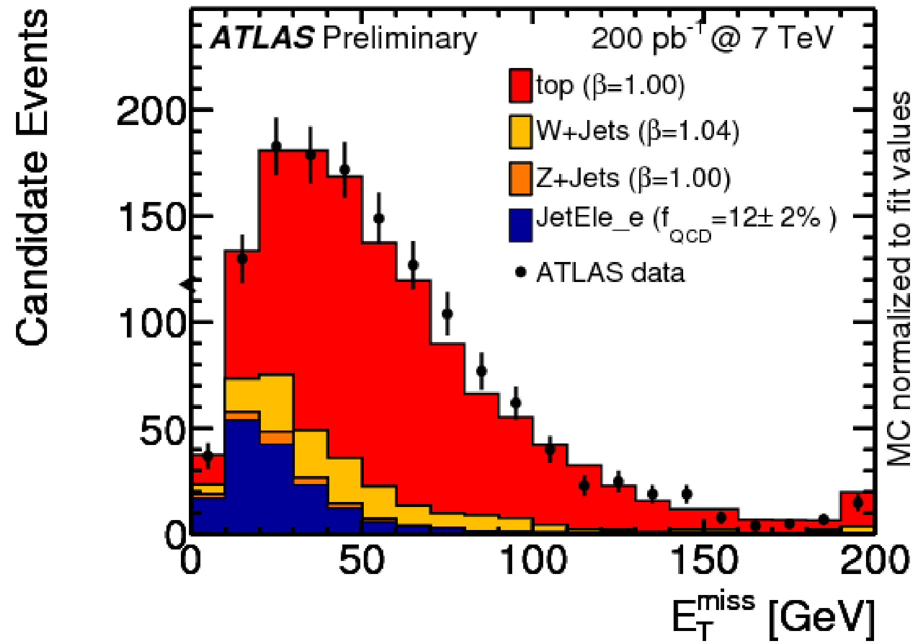
Event Selection

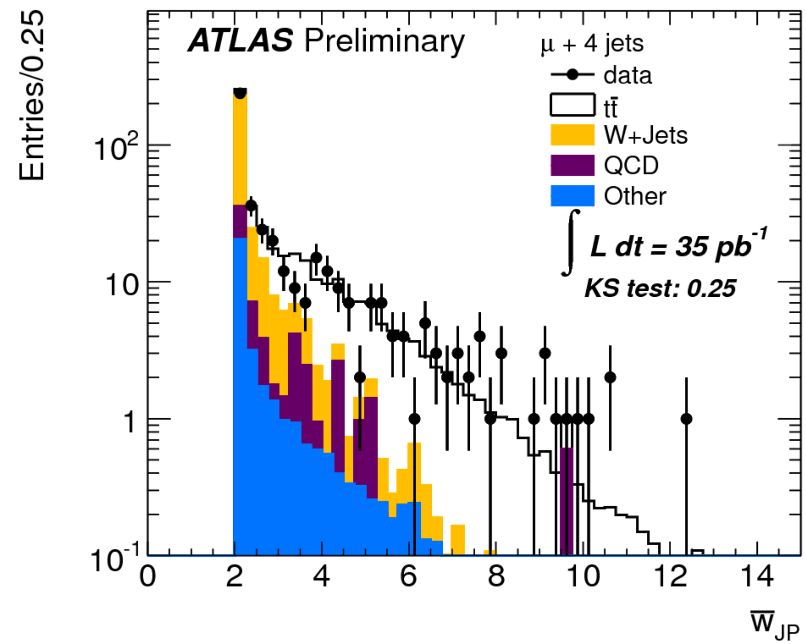
- Object selection common to all top physics analyses, implemented in ATLAS software
- Most studies require at least one top decaying to $Wb \to l\nu b$ to reject QCD background ($l = e, \mu$)
- Trigger selection: single lepton trigger
- Selection cuts:
  - At least one lepton with $p_T > 25$ GeV
  - 4+ jets with $p_T > 25$ GeV (pair production)
    2 jets with $p_T > 25$ GeV (single top)
  - At least one b-tagged jet (50% eff)
  - missing transverse energy > 25 GeV
- To reduce QCD backgrounds further, the reconstruction of a leptonic W candidate can be enforced, with the additional cut:
  - MET + $M_T(W) > 60$ GeV



Background estimation

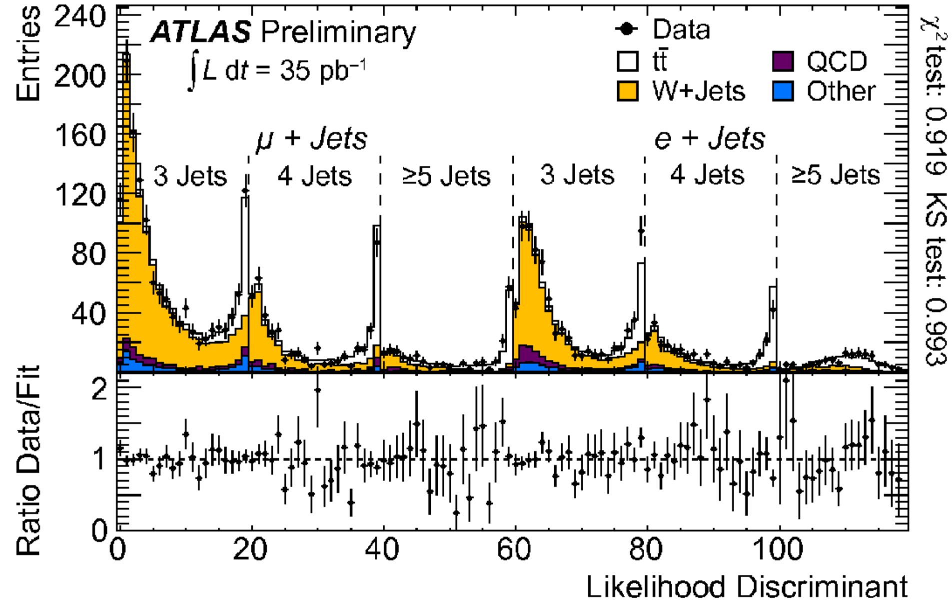
- Main backgrounds from QCD (fake electrons) and W,Z+jets (same signature)
- Estimation either by fitting template shapes to data or using matrix method
- Templates for QCD from data, boson templates from MC
- Fit sensitive to backgrounds in signal-depleted areas:
  - MET for QCD
  - B-tag weight for bosons

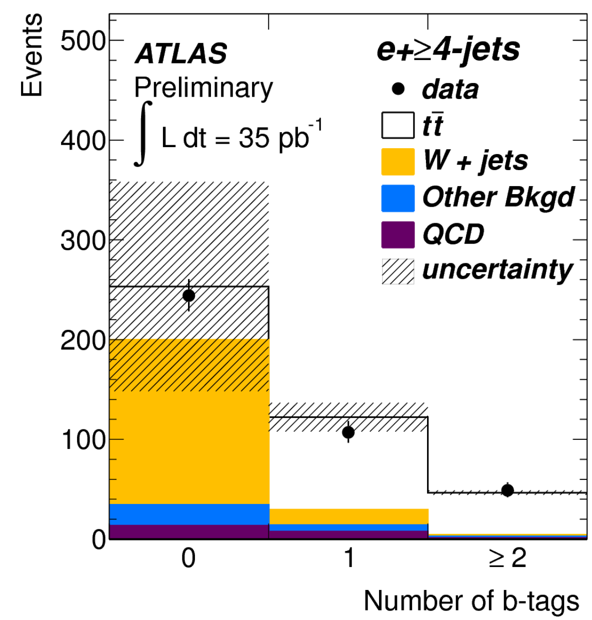




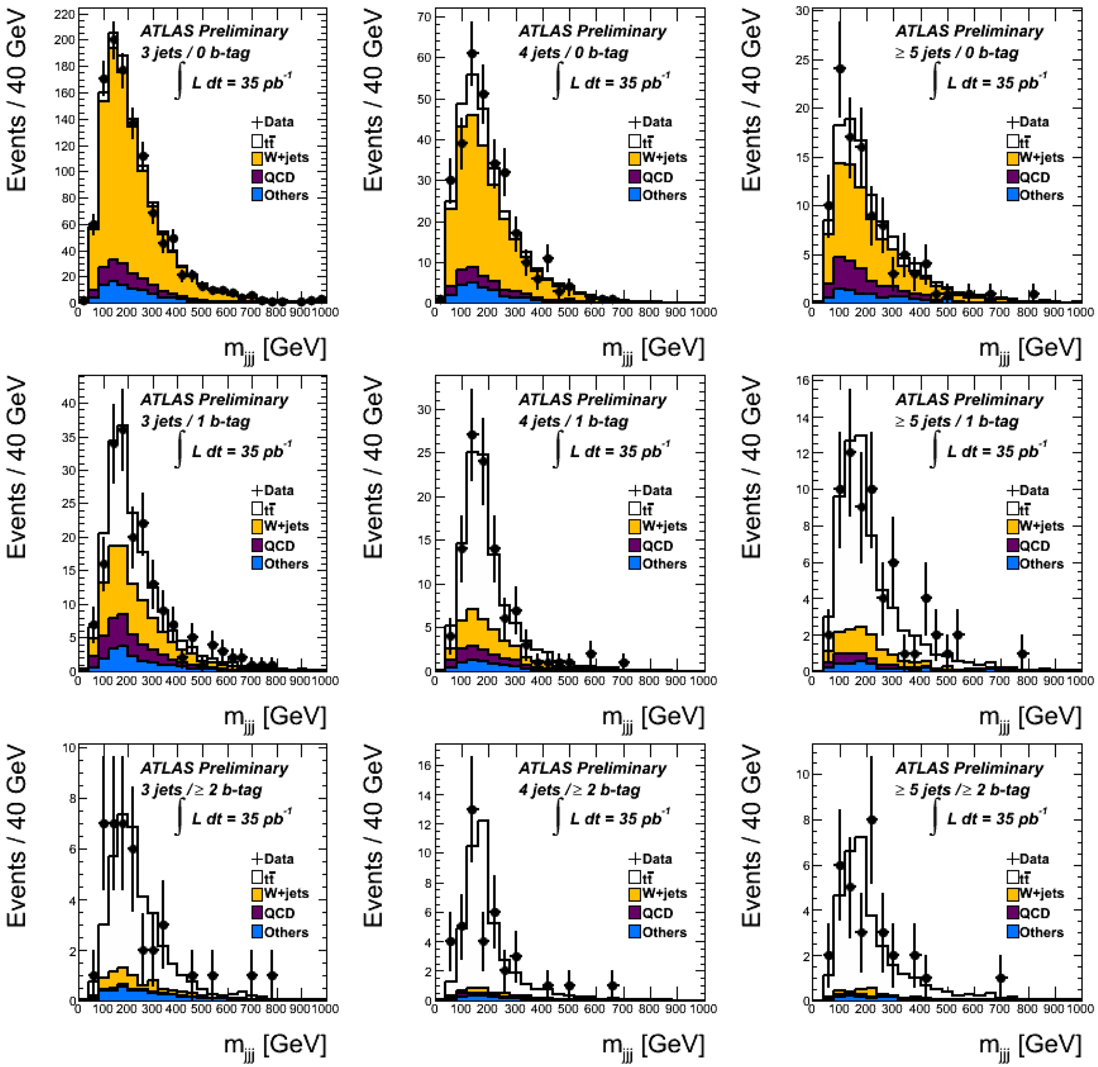
Top pair cross section

- Baseline method in the single-lepton channel, build discriminant *D:*
  - Lepton pseudorapidity
  - Event aplanarity
  - Scalar sum of the transverse energy of all jets except the two leading ones, normalized to the scalar sum of absolute values of all longitudinal momenta in the event
  - The average of the two lowest light-jet probabilities, computed by the b-tagging algorithm
- Discriminant is fitted to data, in jet bins
- Alternative method: fit of the kinematic variables (e.g. invariant mass m_{jjj})



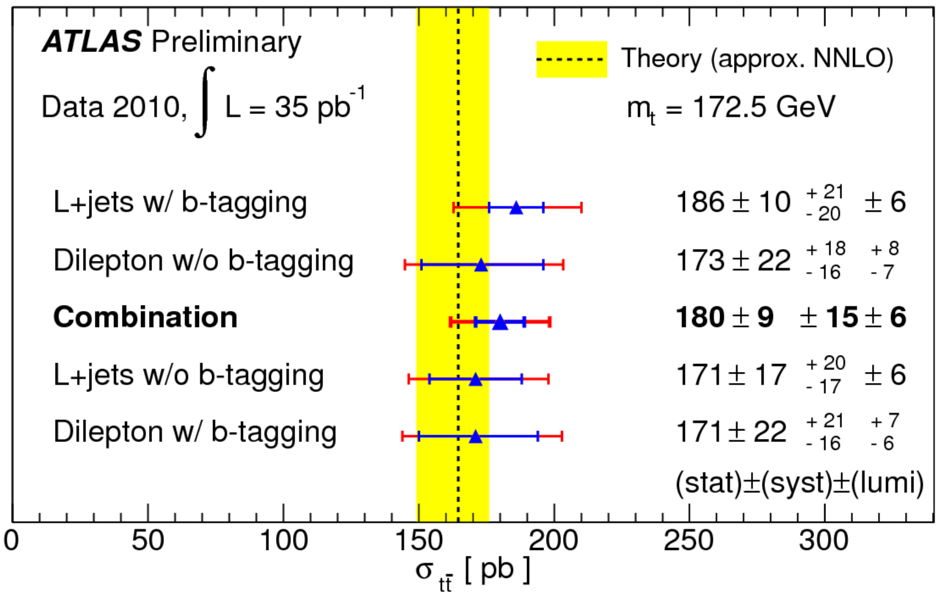


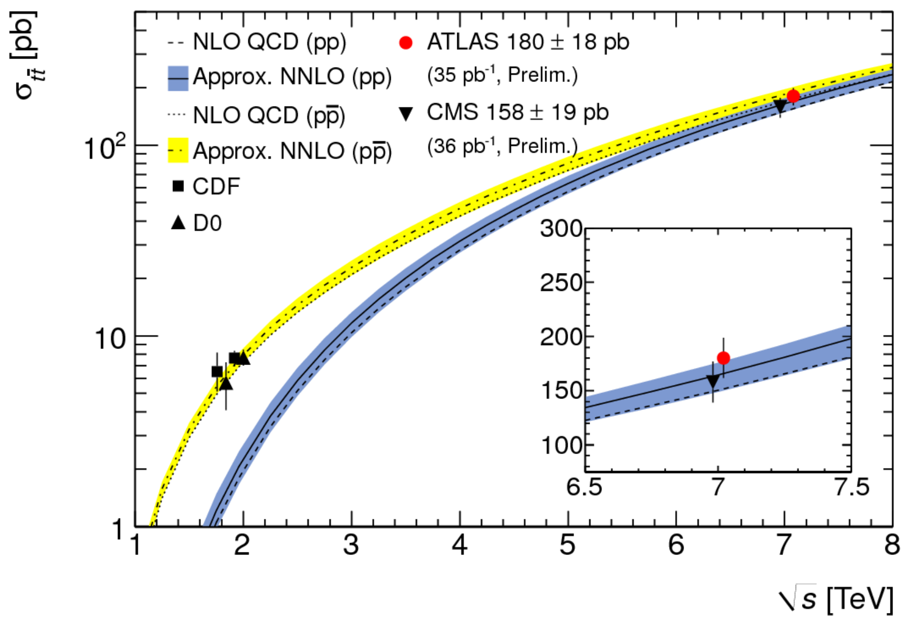
Kinematic fit



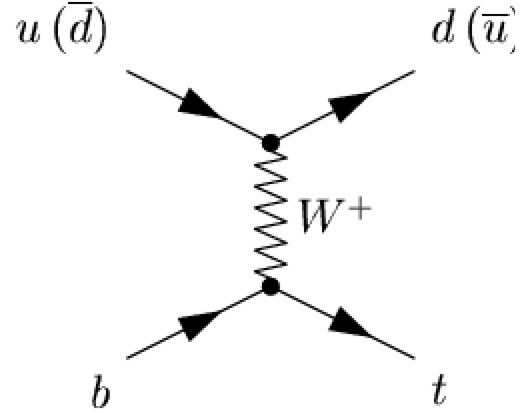
Combined cross section

- Single-lepton and dilepton channels combined to yield top pair production measurement
- Result in good agreement with predictions



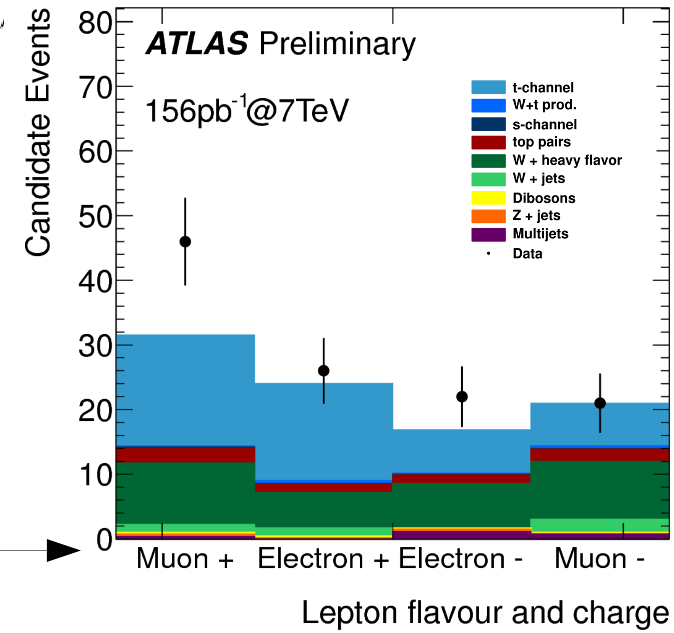


Single top cross section

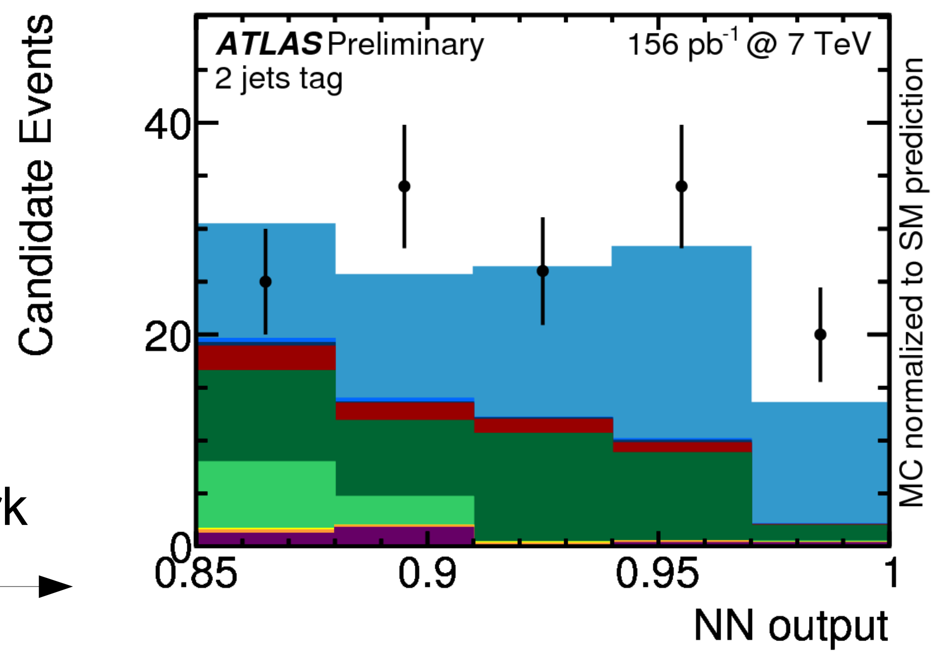


- t-channel single top cross-section estimated with two methods:
  - Cut and count
  - Neural Network discriminant
- Measured cross-section:
  - Cut and count
    $\sigma_t = 97^{+54}_{-30}$ pb → 4.4 σ
  - Neural network
    $\sigma_t = 76^{+41}_{-21}$ pb → 6.2 σ
- Single top rediscovery!

Cut and count →

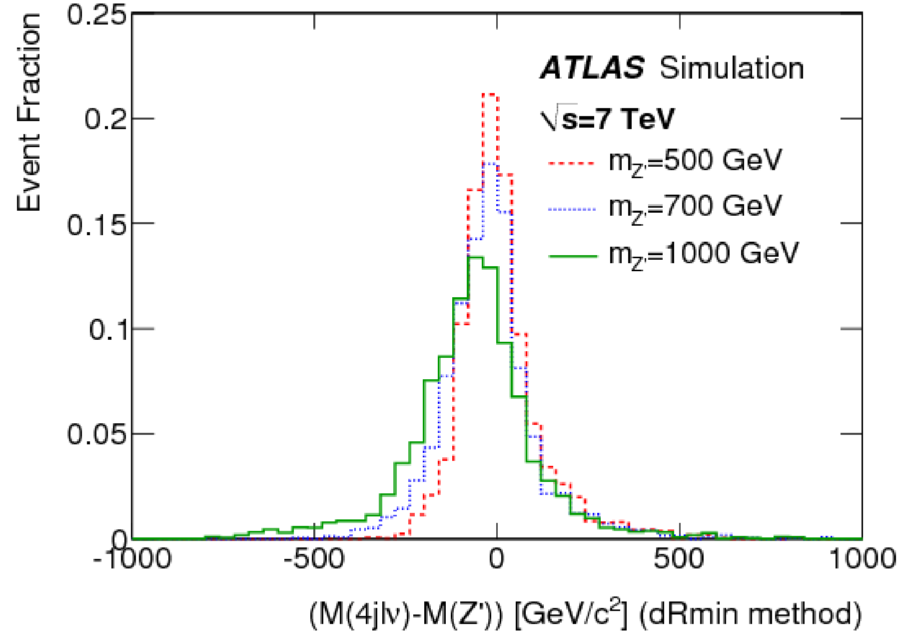


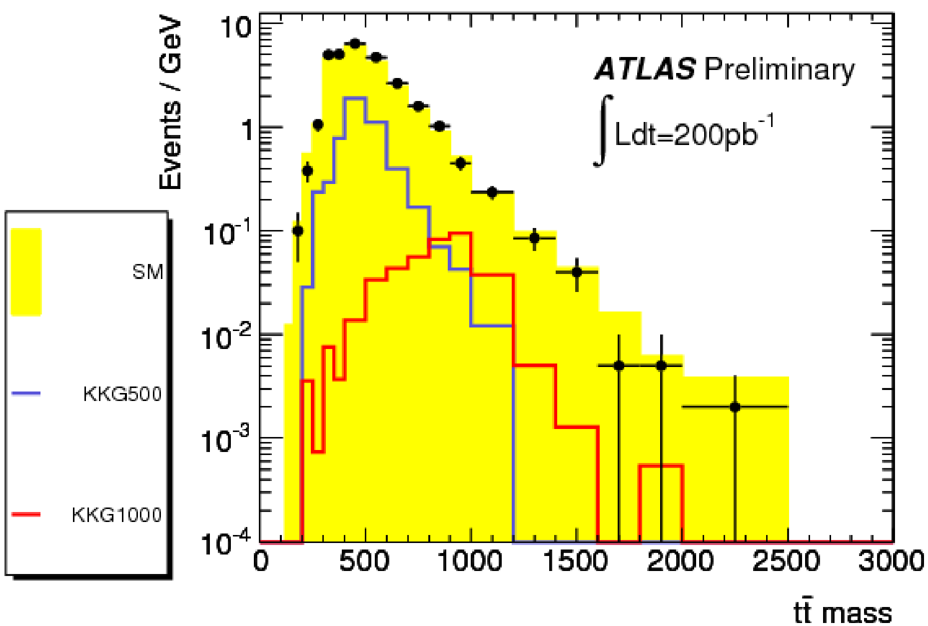
Neural Network →



Top pair resonances

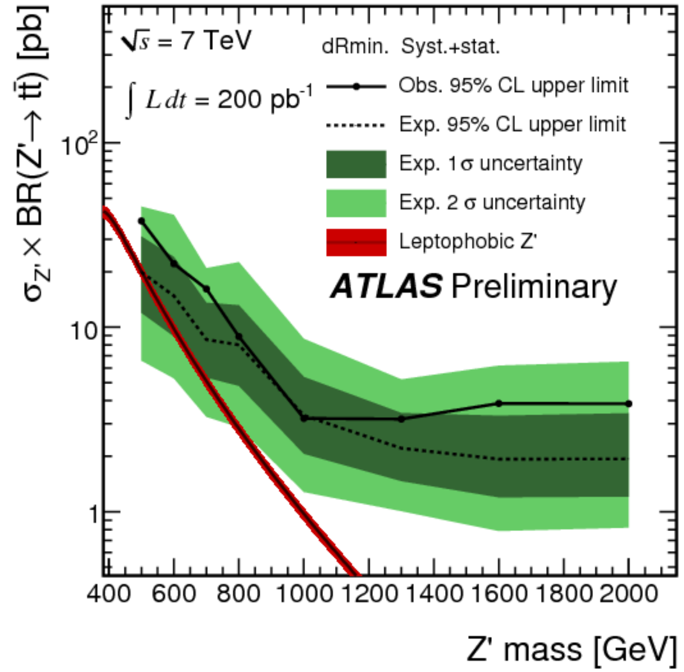
- Search for narrow resonances in the M(4jlν) distribution:
  - Leptophobic topcolor Z'
  - Kaluza-Klein gluons
- Crucial to keep tails in the invariant mass distribution under control
- Influence of ISR and FSR jet reduced by applying *dR* constraint: remove jets if *dR* > 2.5 − 0.015 × m_j
- Method tested on Z` MC with good results

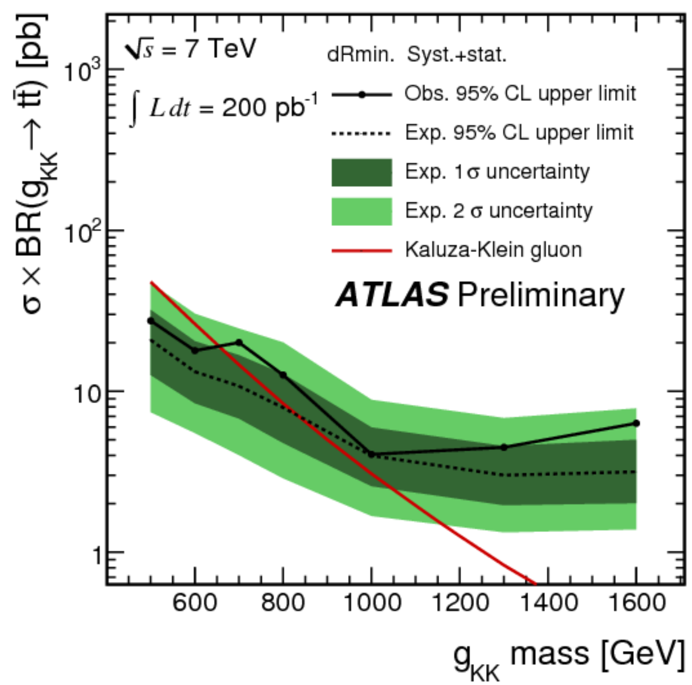




Limit for resonances

- No bump found yet, therefore using Bayesian approach to get exclusion limit
- Multiply for each mass bin the likelihood of data being from SM processes only
- For narrow Z' resonances the observed 95% C.L. limits range from:
  - 38 pb at m = 500 GeV to
  - 3.2 pb at m = 1300 GeV
- Kaluza-Klein gluons with masses below 650 GeV are excluded at 95% C.L.





Conclusions

- Data taken by ATLAS in 2010 allowed to test reliability of detector operation, detector simulation and Monte Carlo models
- First tests of QCD predictions at 1 TeV energy range successful
- PDF on extended energy/momentum range
- Top quark “rediscovered”, precision measurements are underway
- First glance into physics beyond the Standard Model (or lack thereof)
- Starting to exclude some BSM models

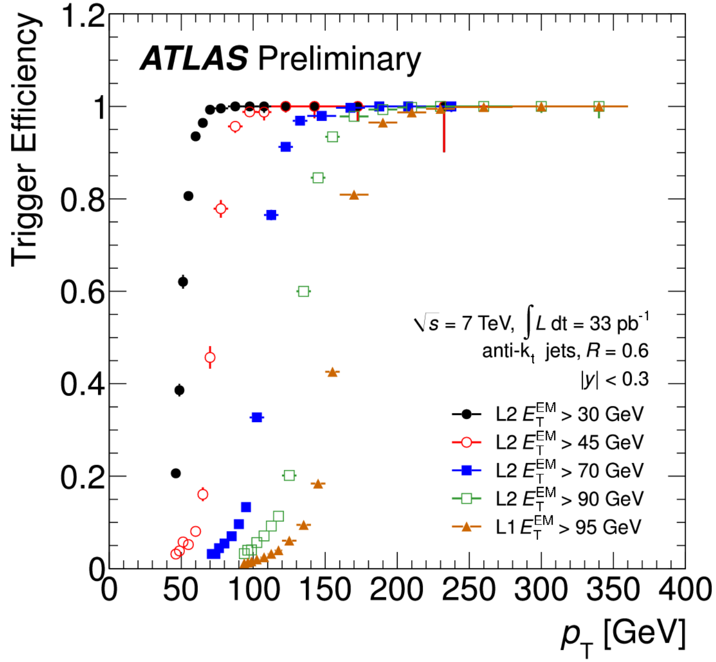
References

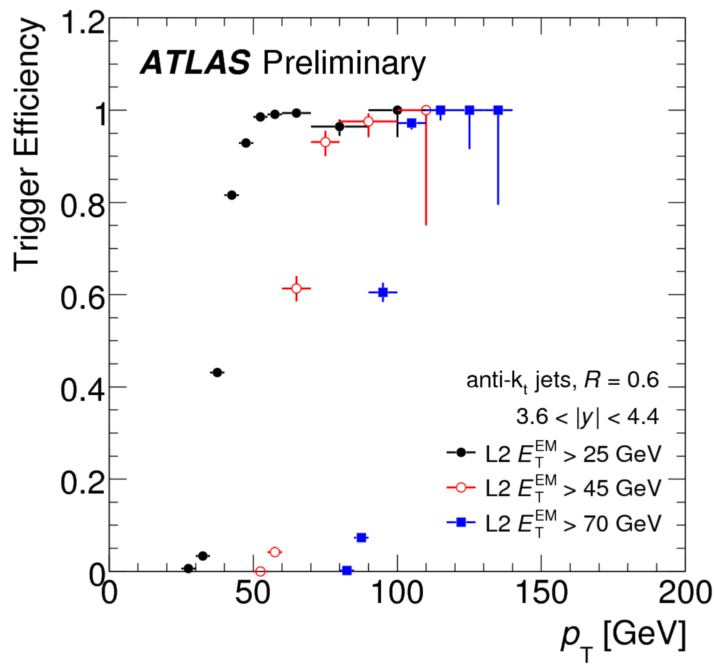
- *Measurement of inclusive jet and dijet cross sections in proton-proton collisions at 7 TeV centre-of-mass energy with the ATLAS detector*, Eur. Phys. J. C71 (2011) 1512
- *Measurement of inclusive jet and dijet cross sections in proton-proton collision data at 7 TeV centre-of-mass energy using the ATLAS detector,* ATLAS-CONF-2011-047
- *Measurement of multi-jet cross-sections in proton-proton collisions at 7 TeV center-of-mass energy,* ATLAS-CONF-2011-043
- *A search for new physics in dijet mass and angular distributions in pp collisions at $\sqrt{s}$ = 7 TeV measured with the ATLAS detector* New J. Phys. 13 (2011) 053044
- *Update of the Search for New Physics in the Dijet Mass Distribution in 163 pb^{-1} of pp Collisions at $\sqrt{s}$=7 TeV Measured with the ATLAS Detector* ATLAS-CONF-2011-081
- *A combined measurement of the top quark pair production cross-section using dilepton and single-lepton final states,* ATLAS-CONF-2011-040
- *Measurement of the top quark pair cross-section with ATLAS in pp collisions at $\sqrt{s}$ = 7TeV in the single-lepton channel using b-tagging,* ATLAS-CONF-2011-035
- *Measurement of the top quark pair production cross section with ATLAS in pp collisions at $\sqrt{s}$ = 7 TeV in dilepton final states,* ATLAS-CONF-2011-034
- *Observation of t-channel Single Top-Quark Production in pp Collisions at $\sqrt{s}$ = 7 TeV with the ATLAS detector* ATLAS-CONF-2011-088
- *A Search for $t\bar{t}$ Resonances in the Lepton Plus Jets Channel using 200 pb^{-1} of pp Collisions at $\sqrt{s}$ = 7 TeV,* ATLAS-CONF-2011-087

Backup slides

Trigger selection

- Combination of three trigger systems to achieve best coverage in η:
  - Central jet trigger, covering |η| < 3.2
  - Minimum Bias Trigger (MBTS) 2.09 < |η| < 3.84
  - Forward jet trigger spanning 3.1 < |η| < 4.9
- Trigger thresholds chosen to achieve >99% efficiency at plateau for each jet pt bin
- Trigger behaviour matches MC expectations
- Prescale factors corrected for a posteriori

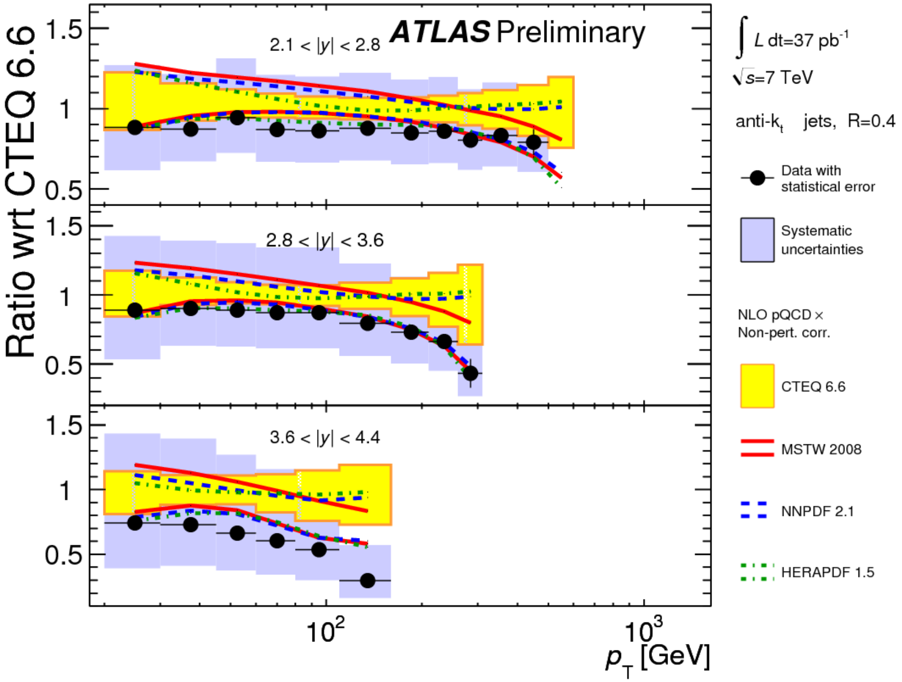


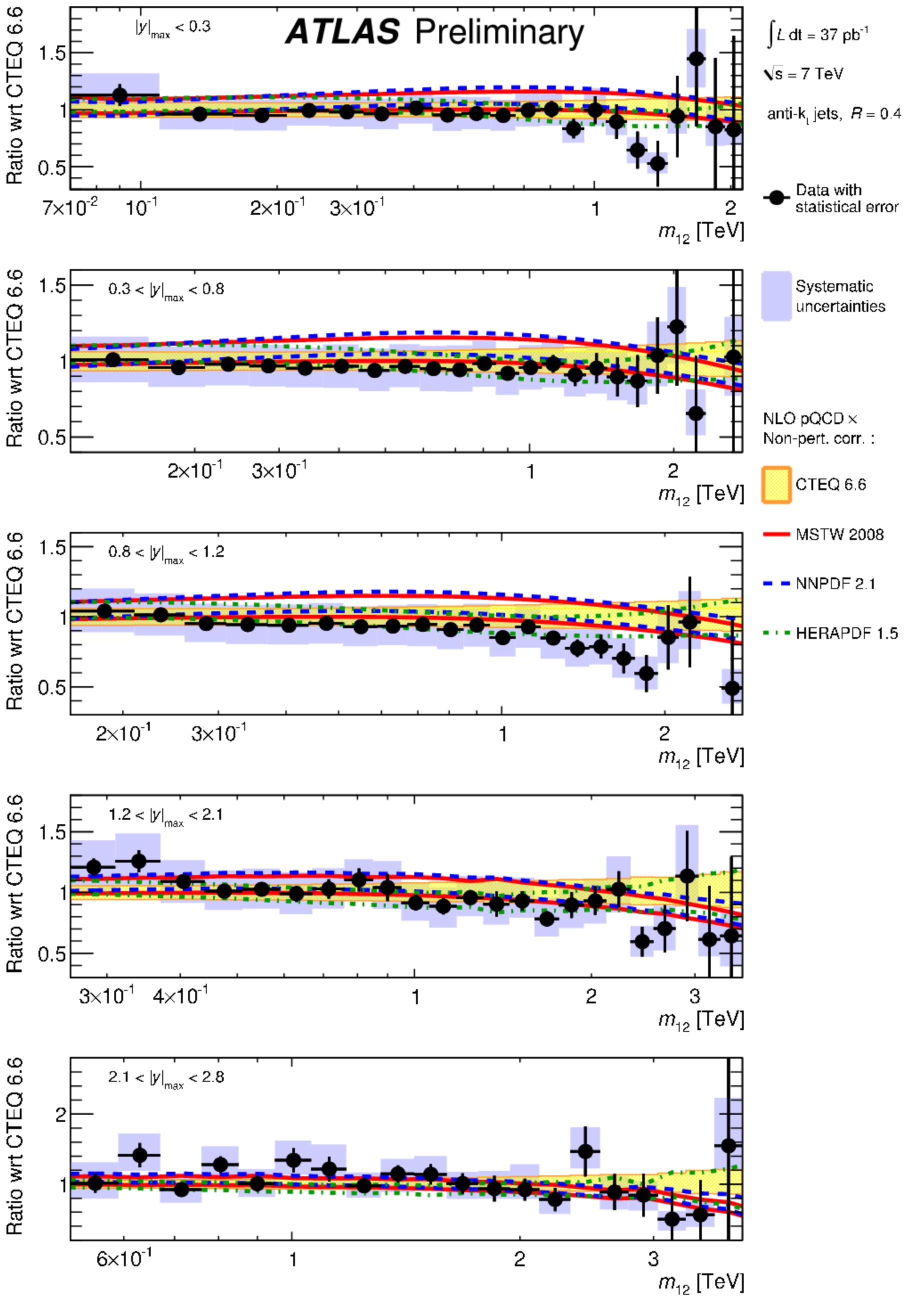


JES uncertainty

- Largest contribution to systematics due to Jet Energy Scale, which is affected by the following uncertainties:
  - Material and Geometry
  - Noise Thresholds
  - EM scale
  - Closure test of the JES calibration
  - JES uncertainty from dijet balance studies
  - Hadronic shower model
  - Event generator models
  - Pile-up
  - Effect of decorrelated JES uncertainty on dijet observables
- All uncertainties are added in quadrature except that from the closure test, which is treated as fully correlated and added linearly
- Maximum uncertainty 10% for the endcap region

PDF


ATLAS Preliminary
Ratio wrt CTEQ 6.6
2.1 < |y| < 2.8
2.8 < |y| < 3.6
3.6 < |y| < 4.4
p_T [GeV]
∫ L dt=37 pb⁻¹
√s=7 TeV
anti-k_t jets, R=0.4
Data with statistical error
Systematic uncertainties
NLO pQCD × Non-pert. corr.
CTEQ 6.6
MSTW 2008
NNPDF 2.1
HERAPDF 1.5


ATLAS Preliminary
Ratio wrt CTEQ 6.6
|y|max < 0.3
0.3 < |y|max < 0.8
0.8 < |y|max < 1.2
1.2 < |y|max < 2.1
2.1 < |y|max < 2.8
m_{12} [TeV]
∫ L dt = 37 pb⁻¹
√s = 7 TeV
anti-k_t jets, R = 0.4
Data with statistical error
Systematic uncertainties
NLO pQCD × Non-pert. corr. :
CTEQ 6.6
MSTW 2008
NNPDF 2.1
HERAPDF 1.5

Multijet cross section