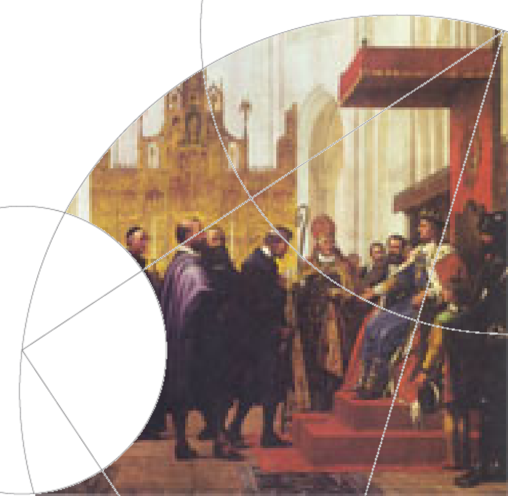
Faculty of Science

ATLAS Standard Model Results

ATLAS EXPERIMENT

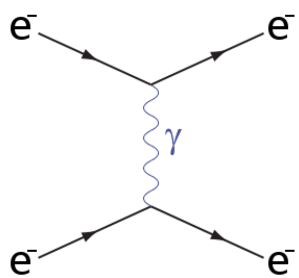
Pavel Jež on behalf of the ATLAS Collaboration
Niels Bohr Institute, University of Copenhagen

QFTHEP '11
September 24 – October 1, 2011
Sochi, Russia

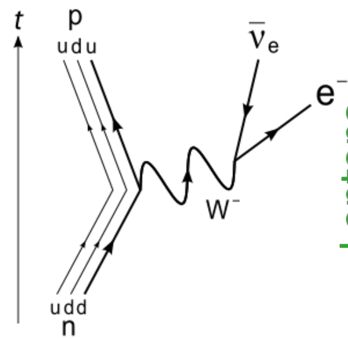


The Standard Model

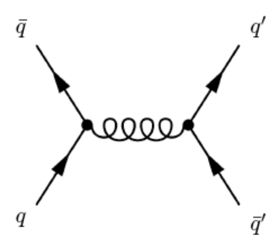
- Quantum Field Theory with local gauge symmetries
  - U(1) (photon exchange, electromagnetic interaction)

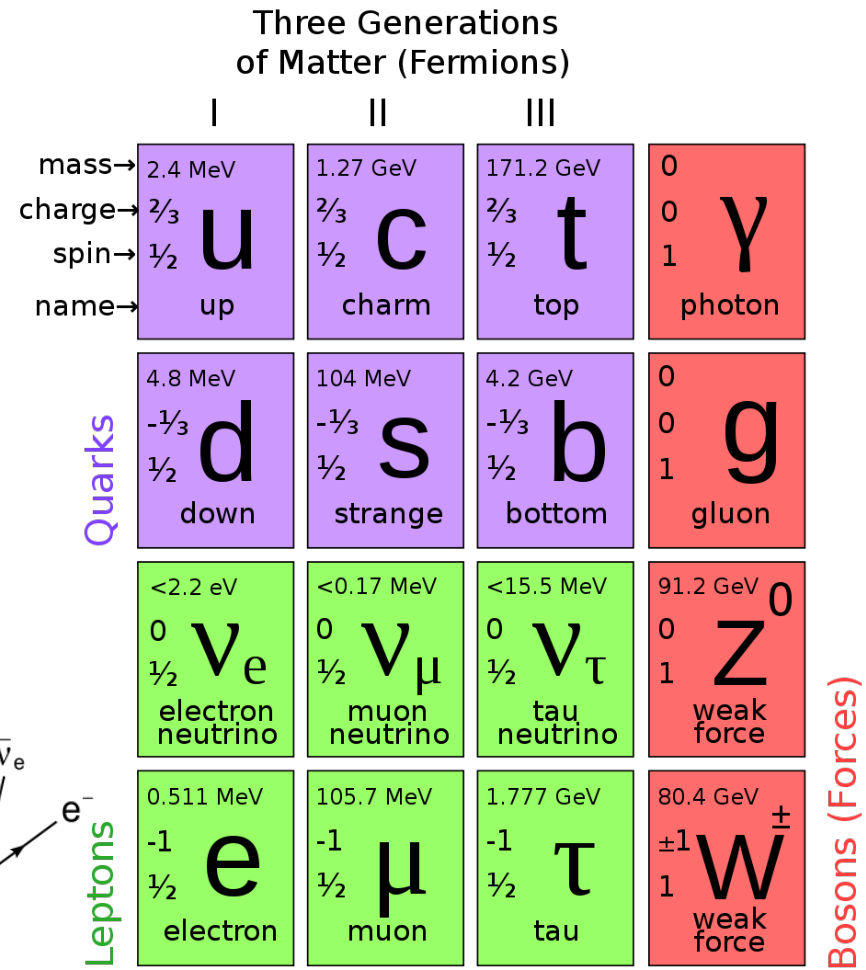


  - SU(2) (W/Z boson exchange, weak interaction)



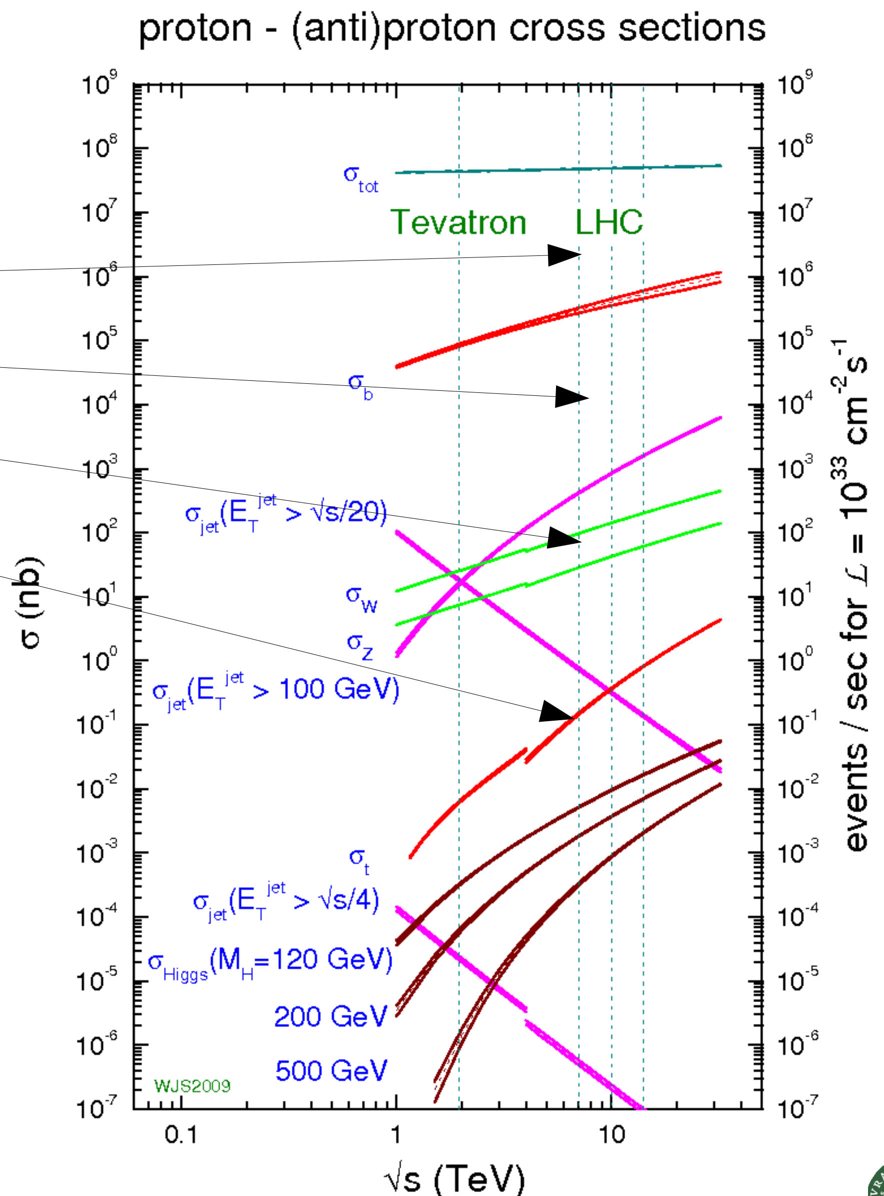
  - SU(3) (gluon exchange, strong interaction)





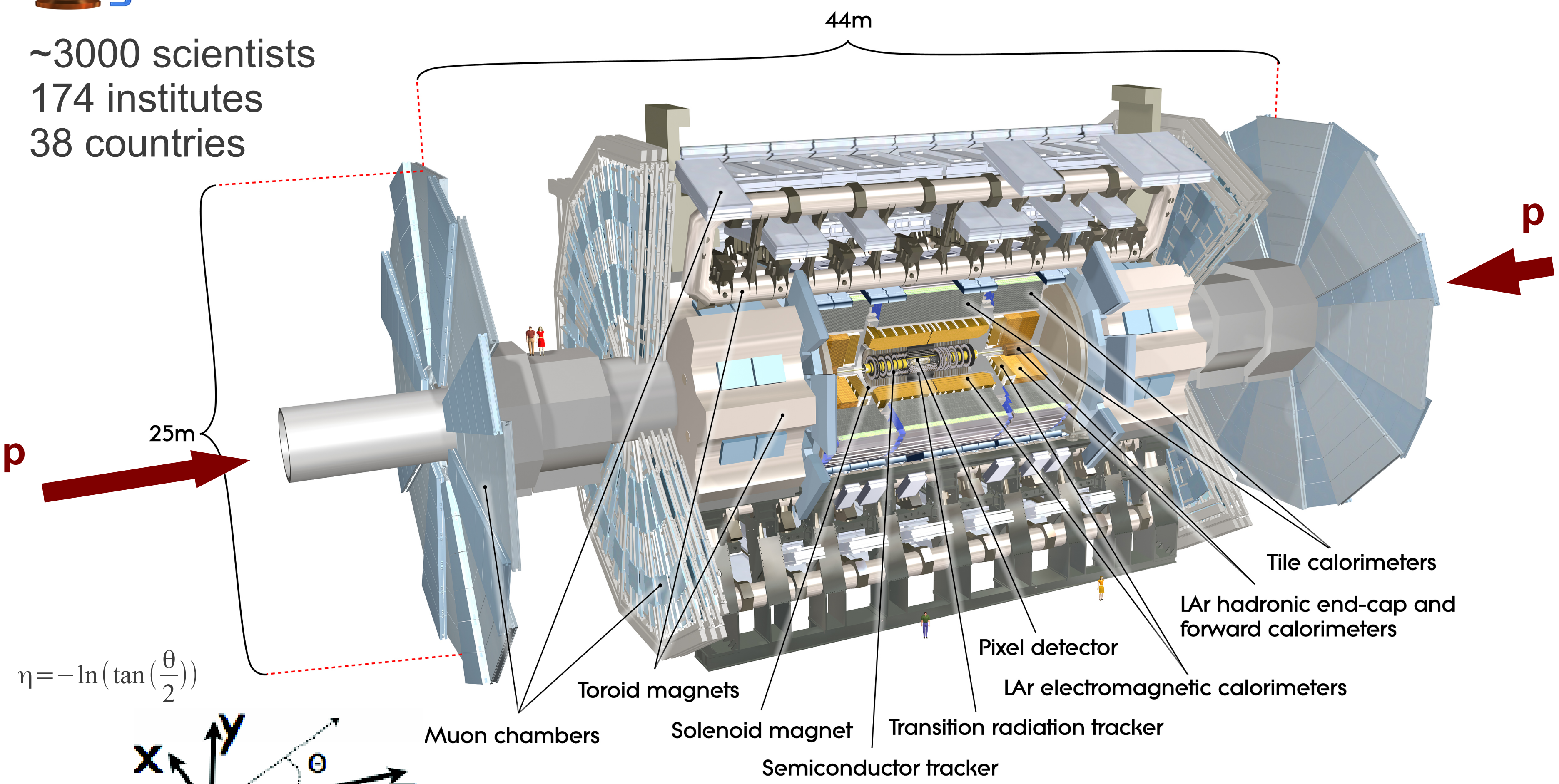
Standard Model at ATLAS

- Re-discovery of the SM
  - Soft QCD
  - Hard QCD
  - W and Z bosons
  - Top quark
- Validating SM predictions at the new energy frontier
- Understanding backgrounds for New Physics searches
- Precise measurement of SM parameters: search for new physics



ATLAS detector

~3000 scientists
174 institutes
38 countries



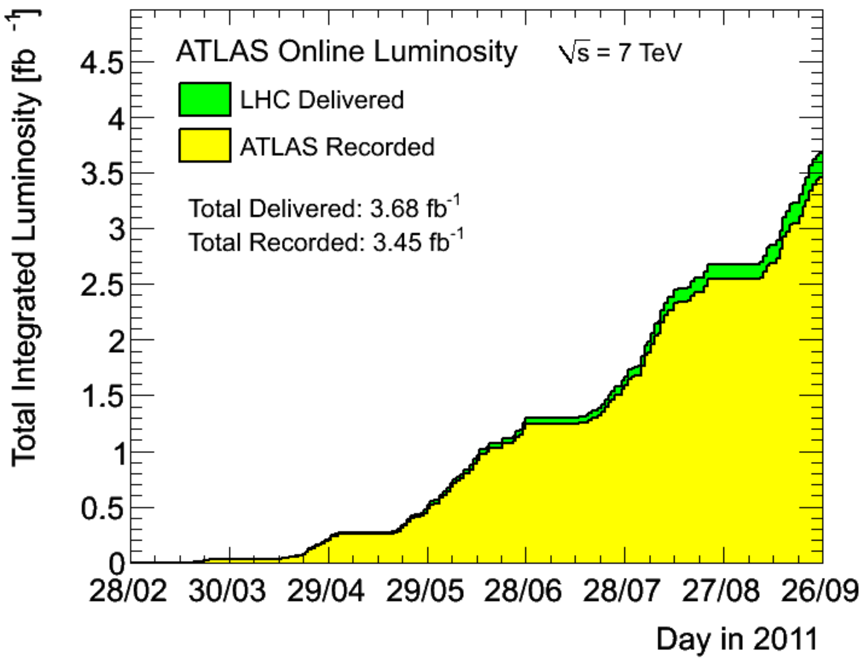
$$\eta = -\ln\left(\tan\left(\frac{\theta}{2}\right)\right)$$

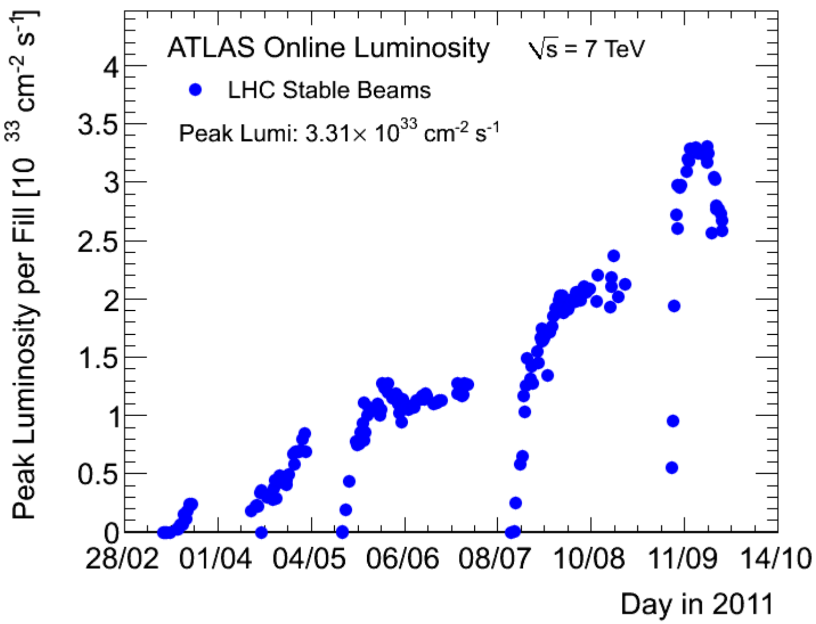
For more details see talk by A. Zaitsev

Data taking summary

Maximum inst. luminosity	3.31 x 10^{33} $cm^{-2}s^{-1}$
Maximum peak events per bunch crossing	21.79
Maximum average events per bunch crossing	15.96
Maximum colliding bunches	1331
Longest time in stable beams for one fill	26.0 h
Fastest turnaround to stable beams	2.11 h

- High data taking efficiency: 95 %
- Fast analysis turnaround
    - Reconstructed events are ready for analysis 3 days after recording



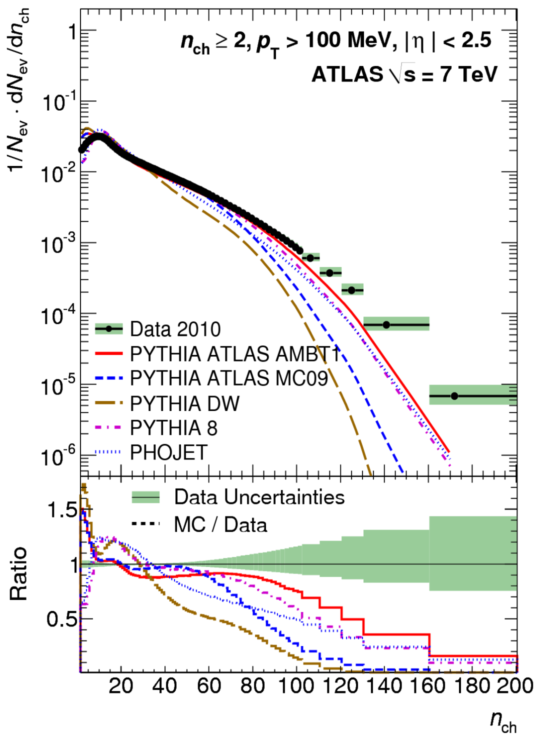


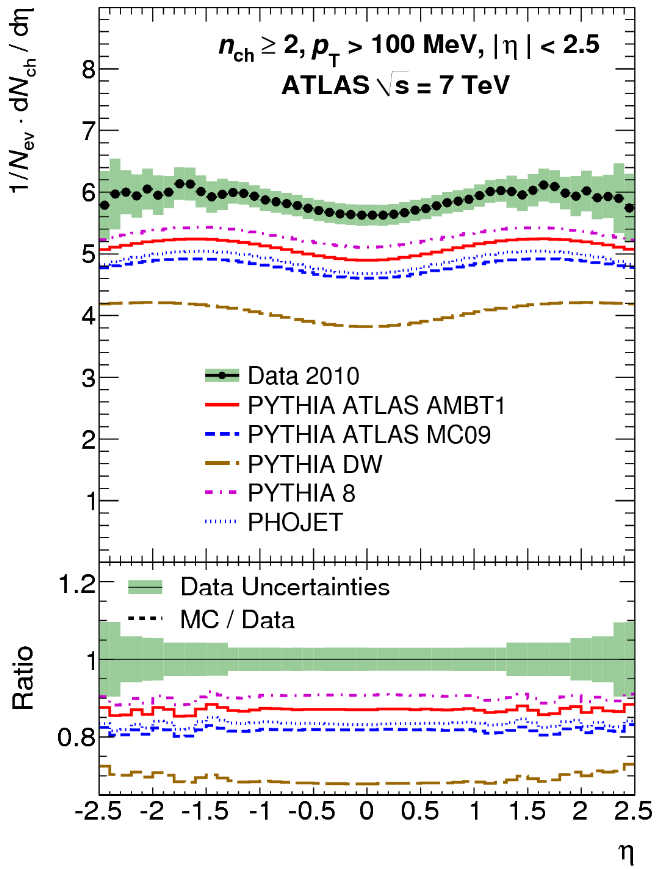
Soft QCD Results

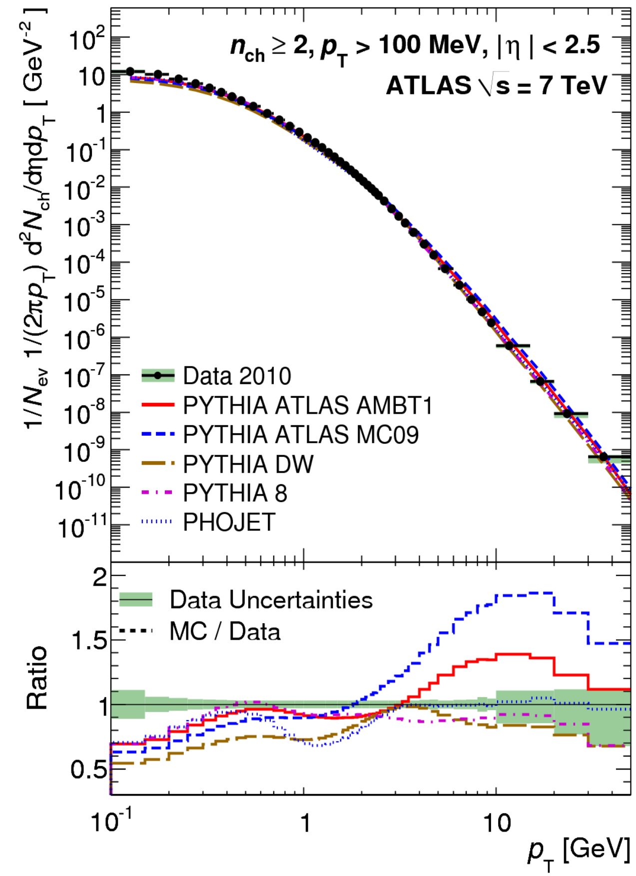
Charge particle kinematics and multiplicities

- Input to the MC generator tunes – current ones in general underestimate the total number of charged particles, although the pseudorapidity distribution shape is correct

New J. Phys. 13 (2011) 053033





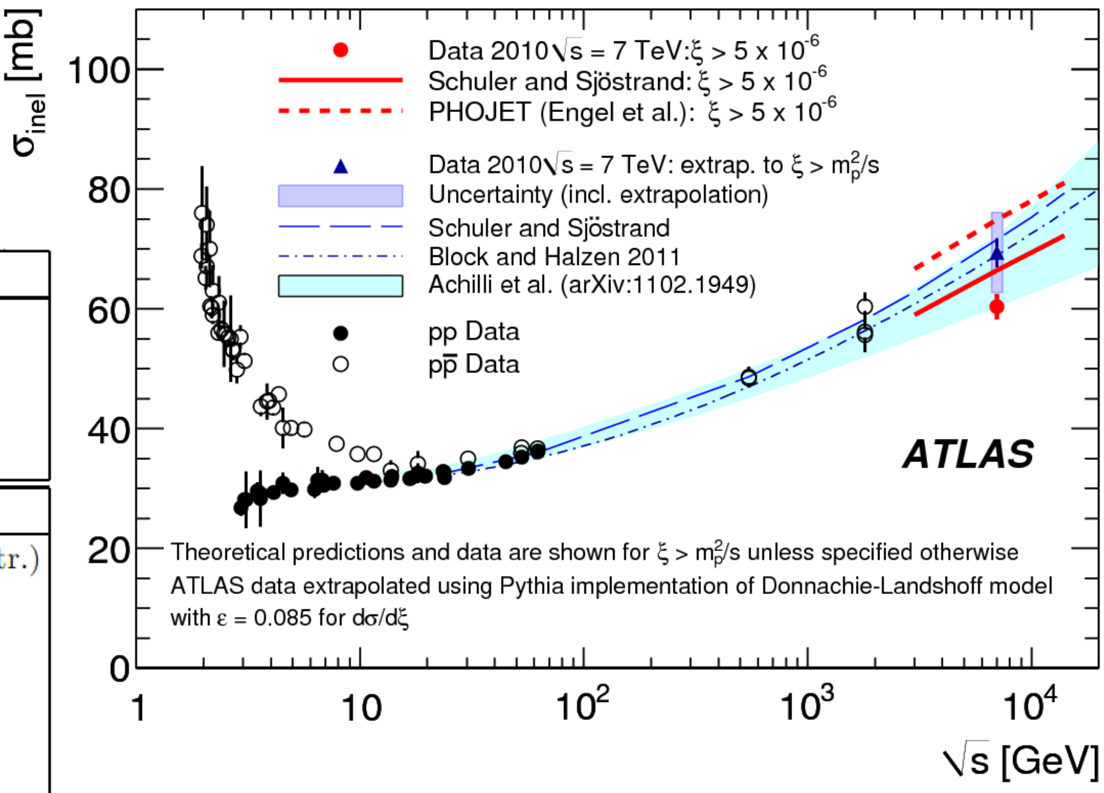


Inelastic pp cross-section at 7 TeV

- First measurement of pp cross-section at 7 TeV
- Consistent with phenomenological predictions

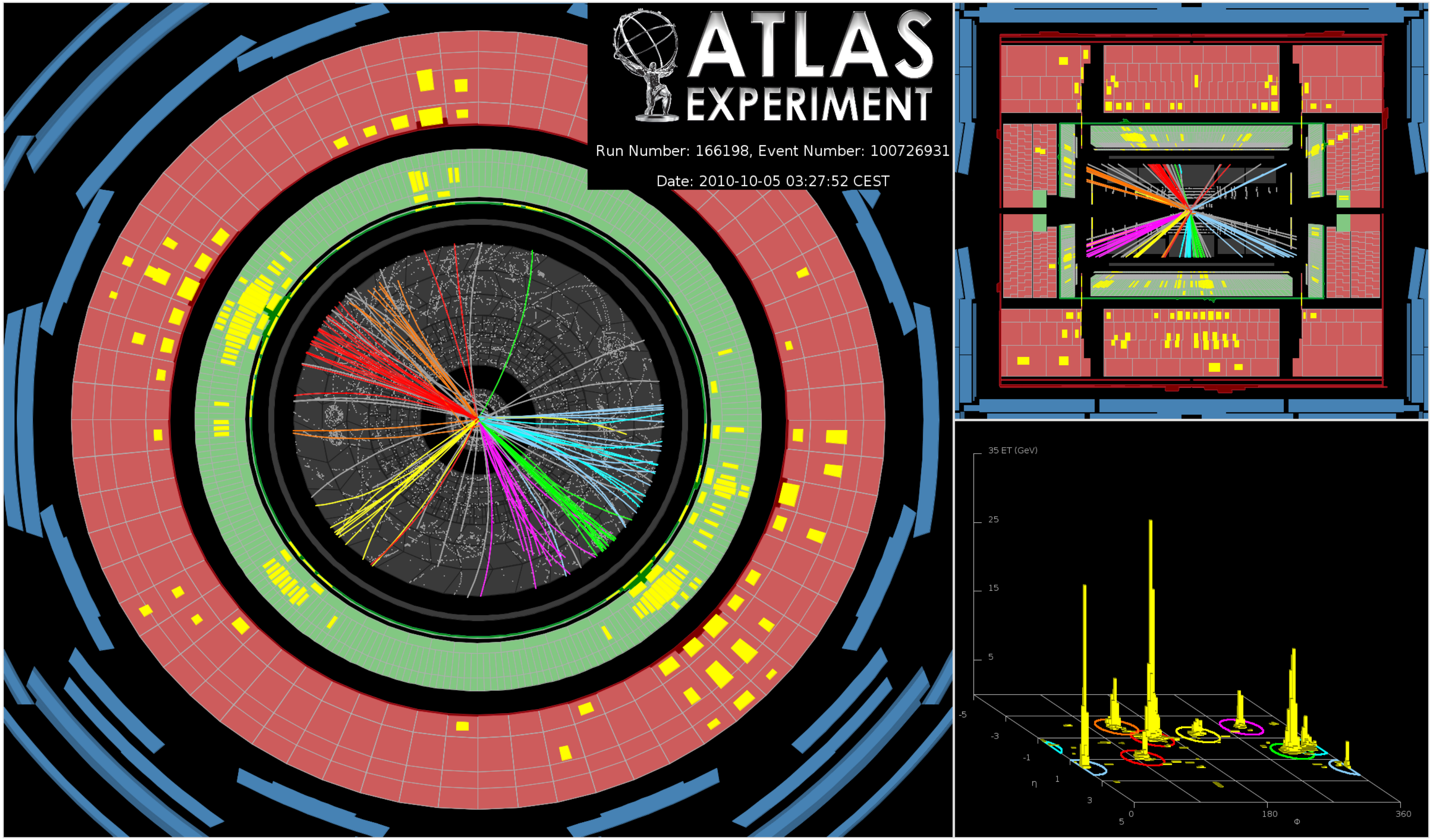
$\sigma(\xi > 5 \times 10^{-6})$ [mb]	
ATLAS Data 2010	60.33 ± 2.10(exp.)
Schuler and Sjöstrand	66.4
PHOJET	74.2
Ryskin *et al.*	51.8 – 56.2

$\sigma(\xi > m_p^2/s)$ [mb]	
ATLAS Data 2010	69.4 ± 2.4(exp.) ± 6.9(extr.)
Schuler and Sjöstrand	71.5
PHOJET	77.3
Block and Halzen	69
Ryskin *et al.*	65.2 – 67.1
Gotsman *et al.*	68
Achilli *et al.*	60 – 75



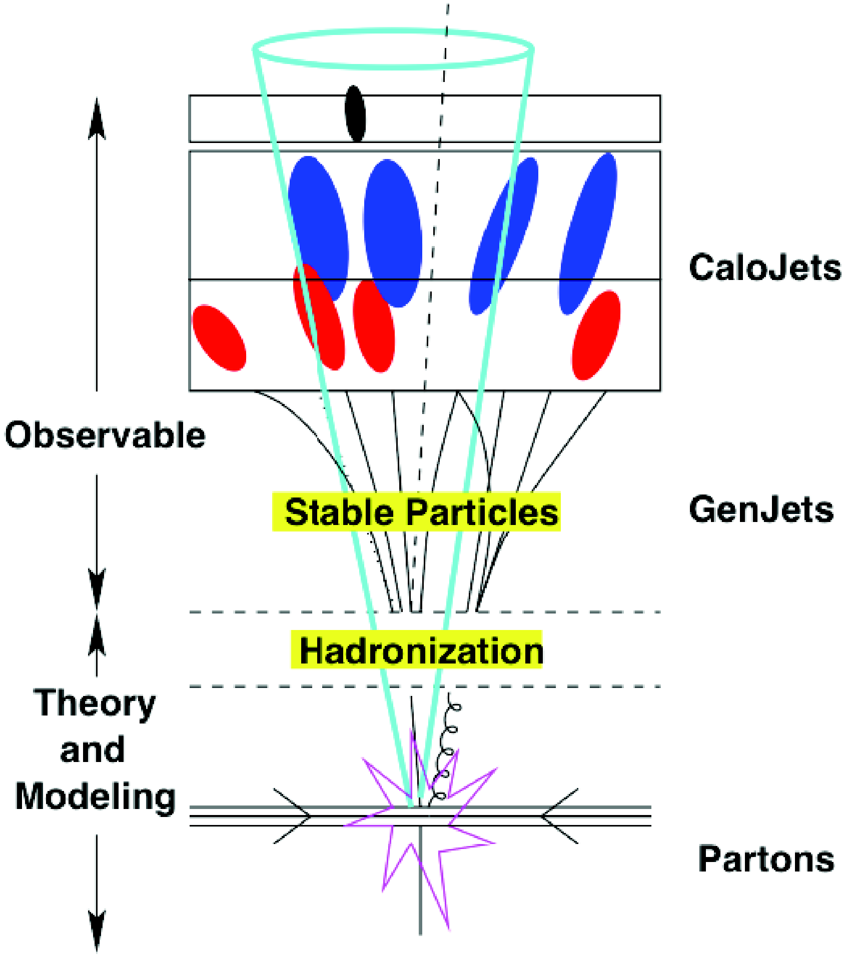
arXiv:1104.0326

Hard QCD Results

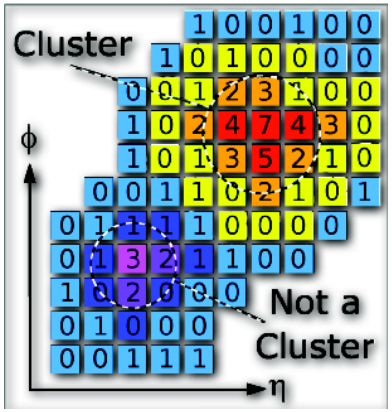


Jets: what they are and where they come from

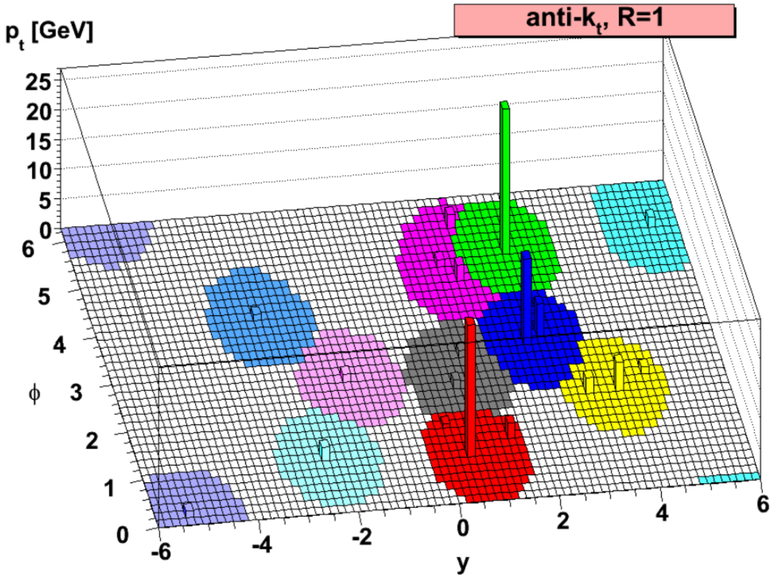
- Jets are showers of highly collimated stable hadrons
  - from partons (quark and gluons) after fragmentation and hadronization
- Predicted by QCD (quark confinement)
  - And experimentally confirmed in 1980's
- Difficult to model and simulate
  - Parton distribution functions
  - Fragmenation and hadronization
  - Calorimeter response
    - In the EM scale
    - To hadrons
- Jet finding and reconstruction
  - Approximate attempts to reverse-engineer the quantum mechanical process of hadronization



Jet reconstruction



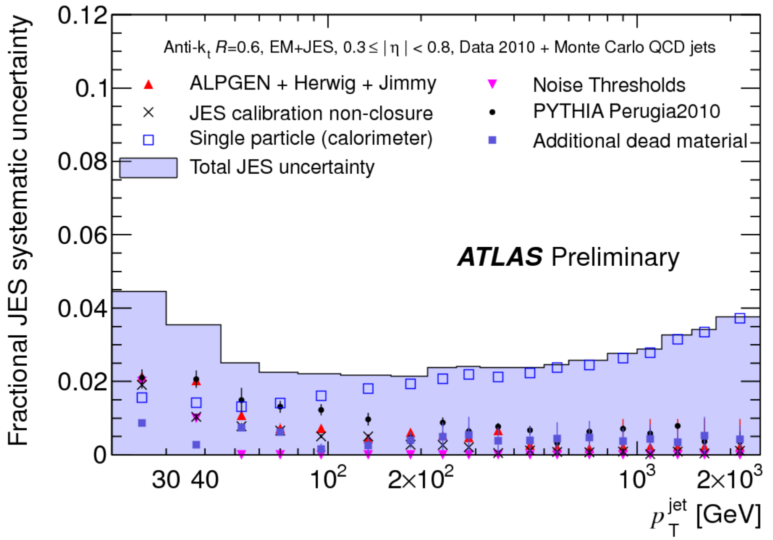
- Energy deposits in calorimeter cells are combined to form 3D clusters
  - Start from cell with E> 4 σ_{noise}
  - Iteratively add all neighbours E> 2 σ_{noise}
  - Include last layer of cells with E> 0 σ_{noise}
- Clusters are combined into a jet with Anti-k_T algorithm
  - Infrared and collinear safe
  - Distance measure $d_{ij} = min\left(\frac{1}{k_{Ti}^2}, \frac{1}{k_{Tj}^2}\right)\frac{\Delta_{ij}^2}{R^2}; \ d_{iB} = \frac{1}{k_{Ti}^2}$
  - If $d_{ij} < d_{iB}$ than combine i and j, otherwise i is a jet
  - Produces regular, cone-like jets
  - At ATLAS, R=0.4 or 0.6

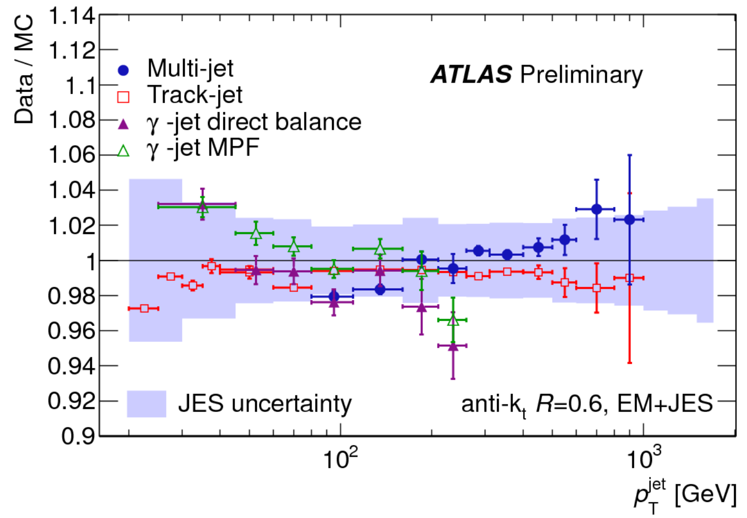


JHEP 0804:063

Jet calibration

- Calorimeter response needs to be corrected for
  - Non-compensating calorimeters
  - Inactive material
  - Out-of-cone effects
- Jet calibration restores the jet energy scale (JES)
- JES uncertainty is the main source of uncertainty for many physics measurements
- Baseline energy scale: EM scale
  - From Z-> ee, test beams, MIP μ
- JES: (η,E)-dependent calibration constants (from MC)
  - Allows direct estimation of JES uncertainty
- EM+JES: ATLAS default calibration



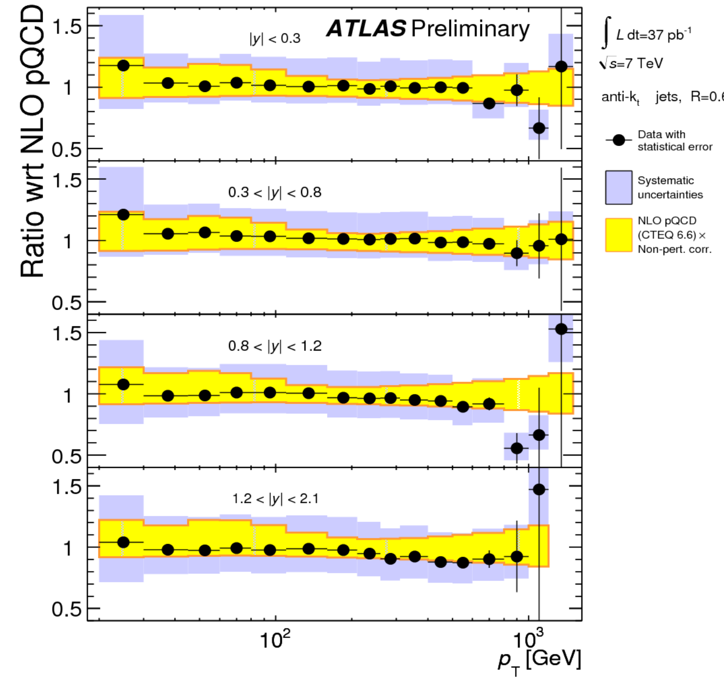


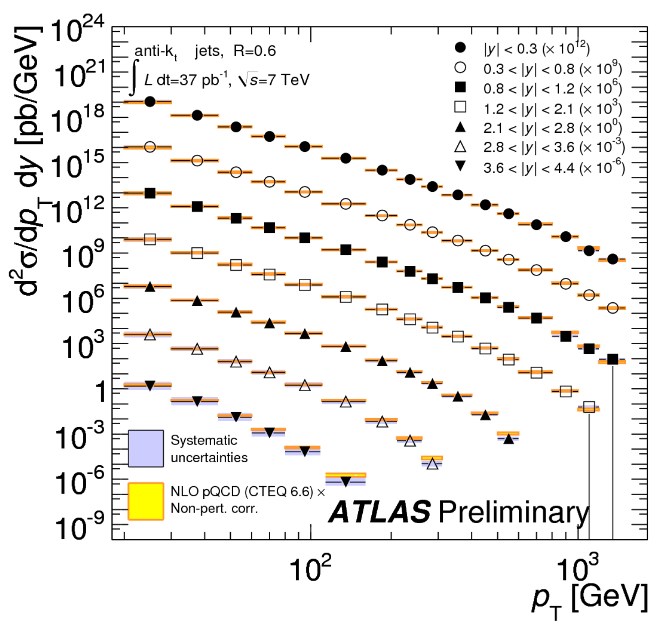
ATLAS-CONF-2011-032

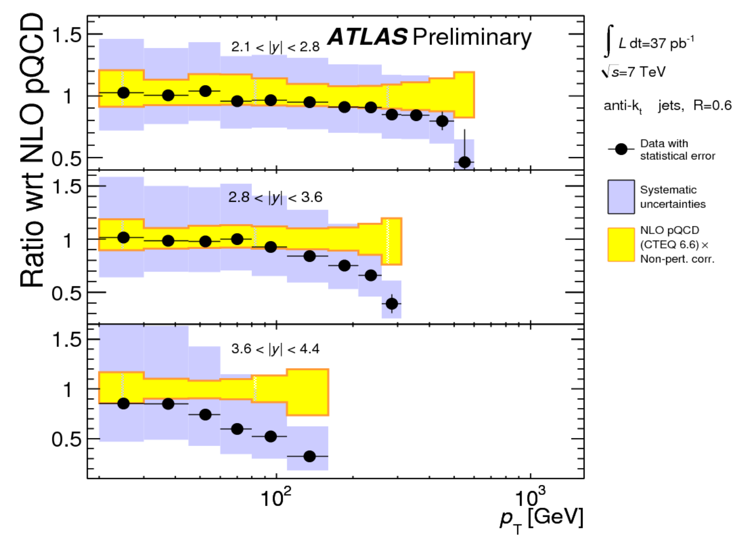
Inclusive jet cross section

- Various rapidity intervals
- Spans over 12 orders of magnitude in x-section
- 20 GeV < p_T < 1.5 TeV
- Systematic uncertainty dominated by JES
- good agreement between data and NLO pQCD
  - Except very forward region: should be able to soon constrain PDFs

ATLAS-CONF-2011-047

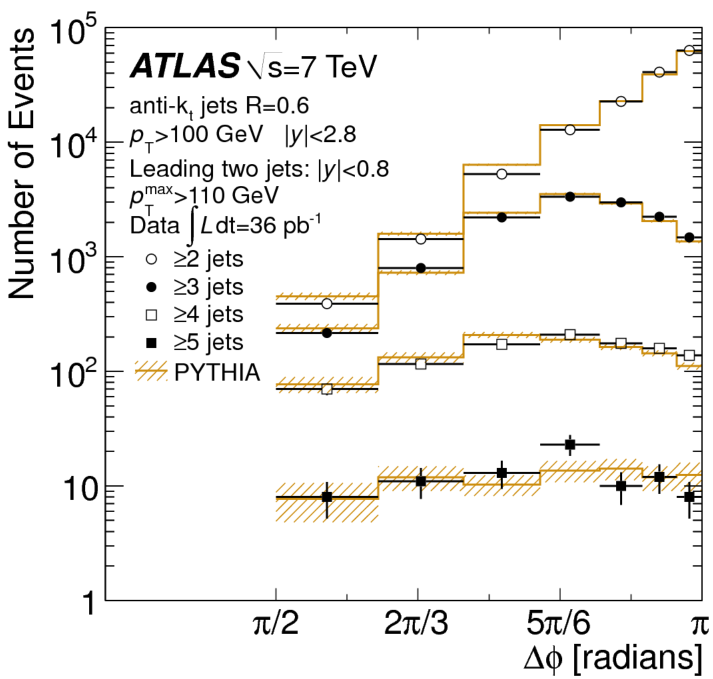


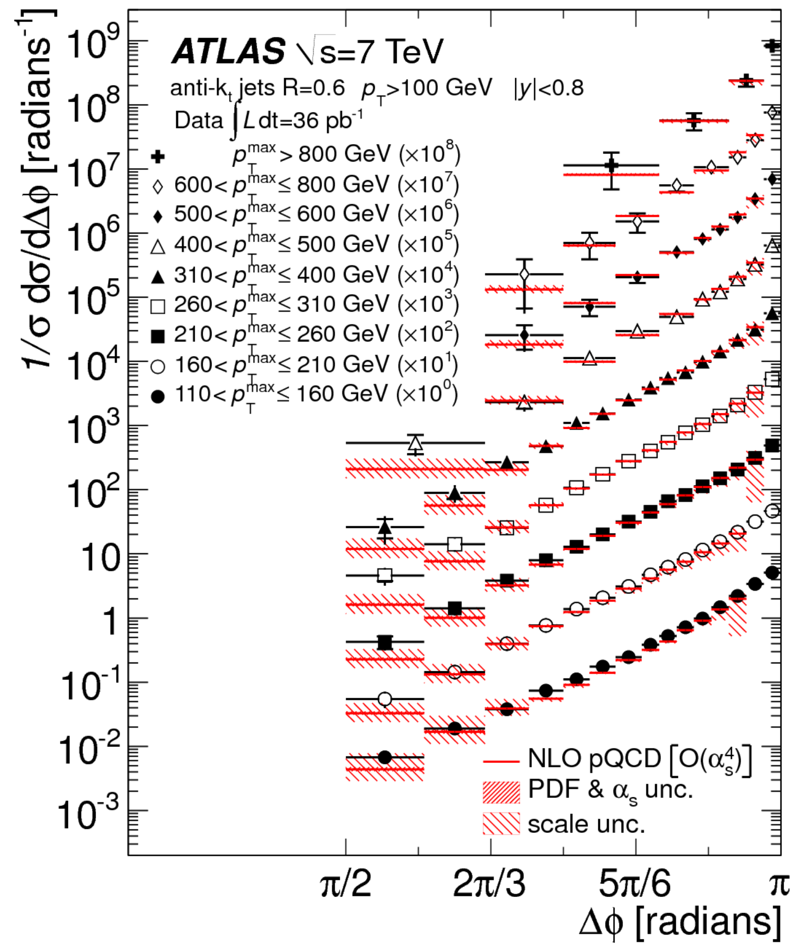




Dijet azimuthal decorrelation

- Indirect way to test extra radiation in the dijet system
- LO and NLO predictions in general describe data well





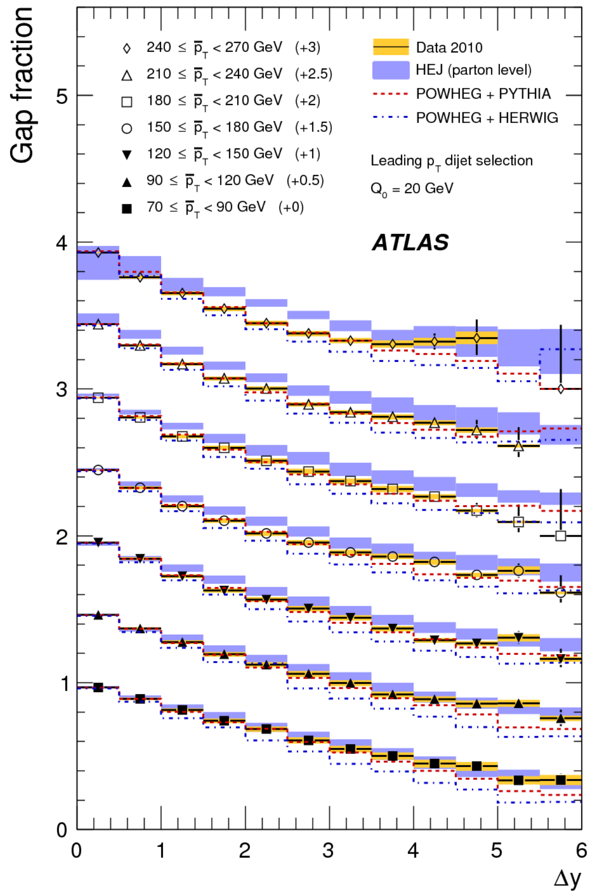
Phys. Rev. Lett. 106 (2011) 172002

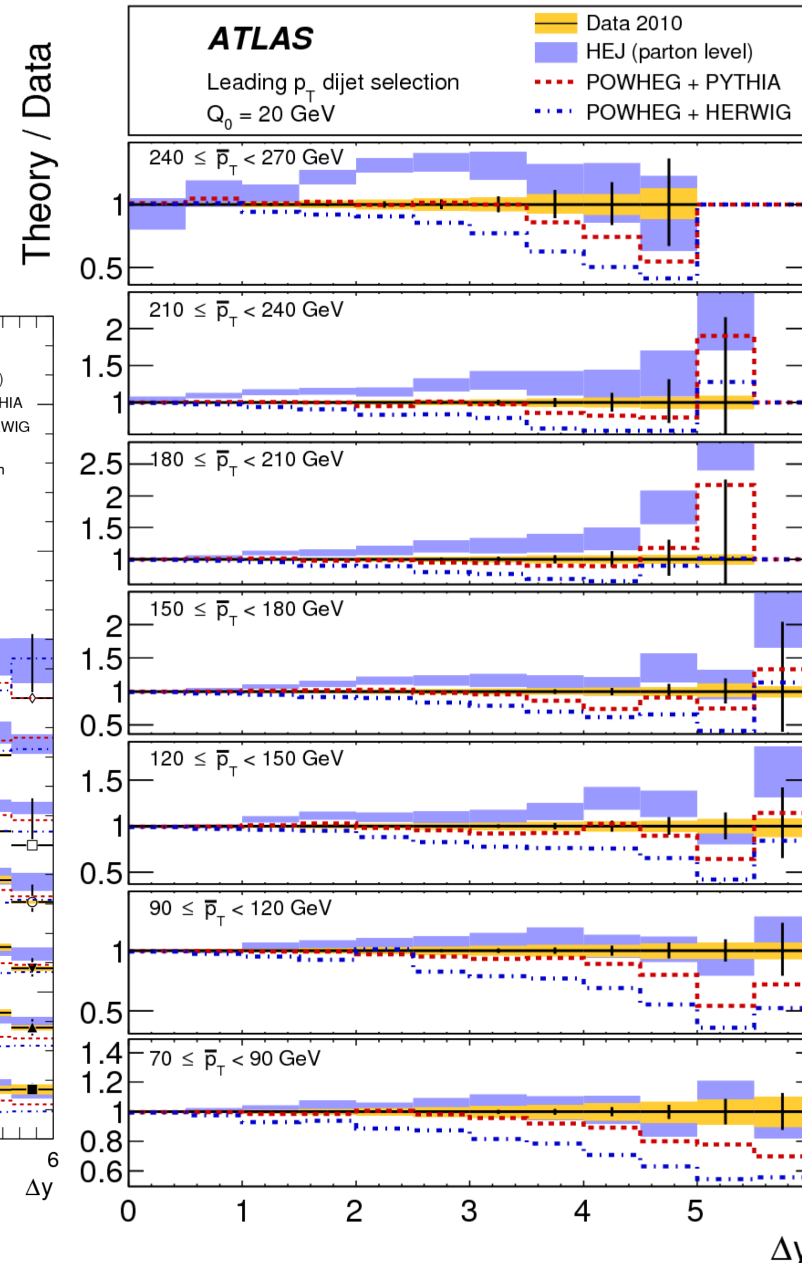
Dijet production with a veto on central jet activity

CERN-PH-EP-2011-100

- Looking for the BKFL-like dynamics, wide-angle soft gluon radiation and color singlet exchange
- Jet Selection:
  - 20 GeV < p_T
  - $|y| < 4.4$
- Di-jet:
  - 2 leading jets

    OR
  - 2 jets with the largest Δy
  - Mean p_T > 50 GeV
- Gap veto: if a jet with p_T is within the rapidity gap
- Better accuracy than theoretical predictions (uncertainty from choice of factorization and renormalization scale)

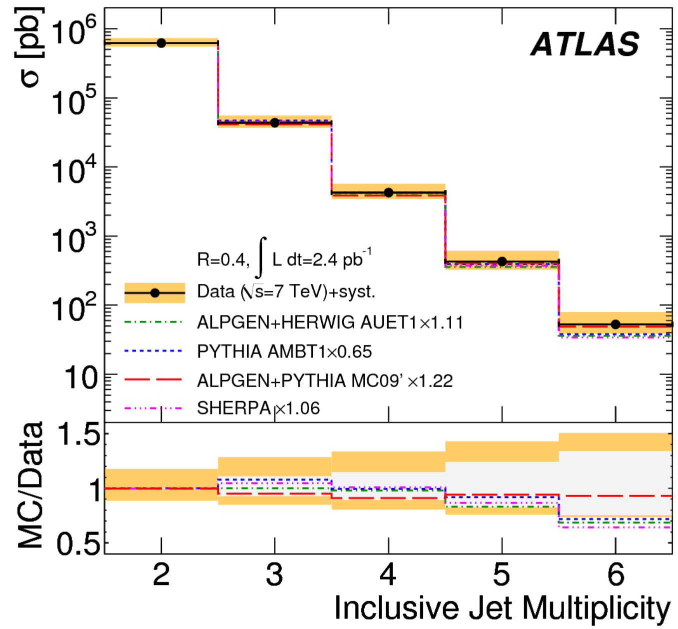


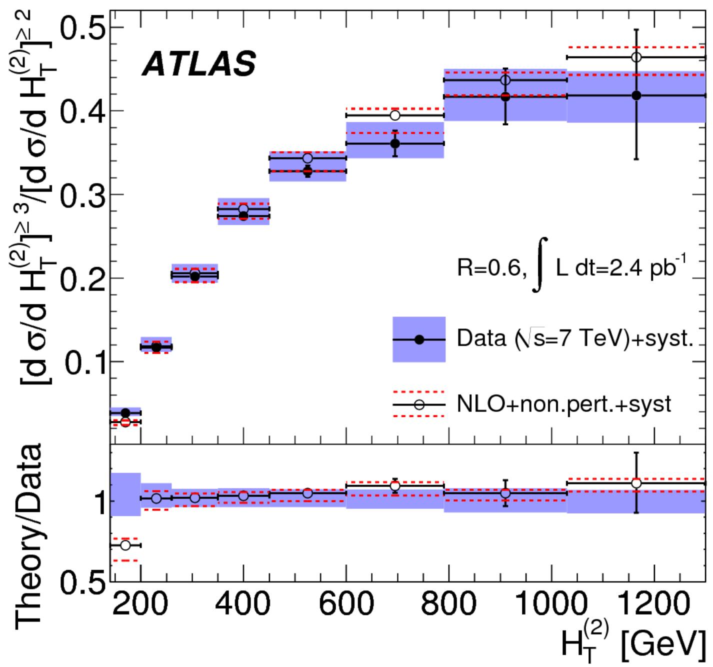


Multi-jet production

CERN-PH-EP-2011-098

- Motivation:
  - Probe of higher-order perturbative QCD
  - Cross-section ratios are calculated at NLO-> possible to extract α_S
  - Background to many new physics searches
- Inclusive jet multiplicity
  - Systematic uncertainty dominated by JES
- Ratio of n-jet cross-section to (n-1) cross section
  - Systematic uncertainty reduced
  - Good agreement with the NLO prediction
- $H_T = \Sigma p_T$ for different multiplicity
  - $H_T^{(2)}$ is scalar p_T sum of the 2 leading jets

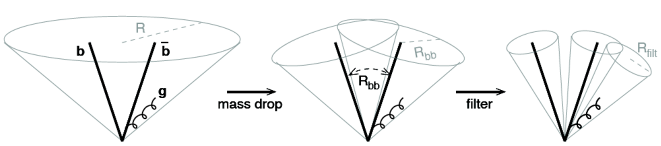


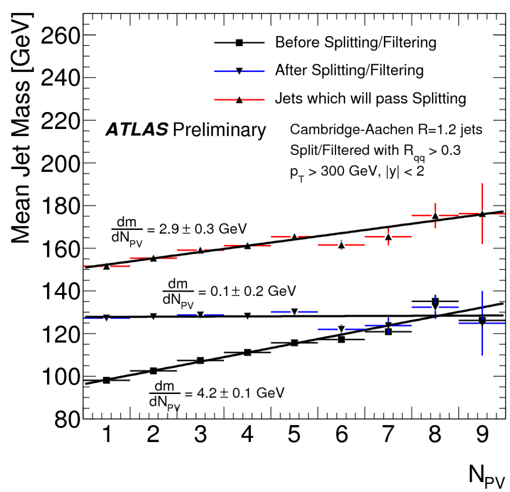


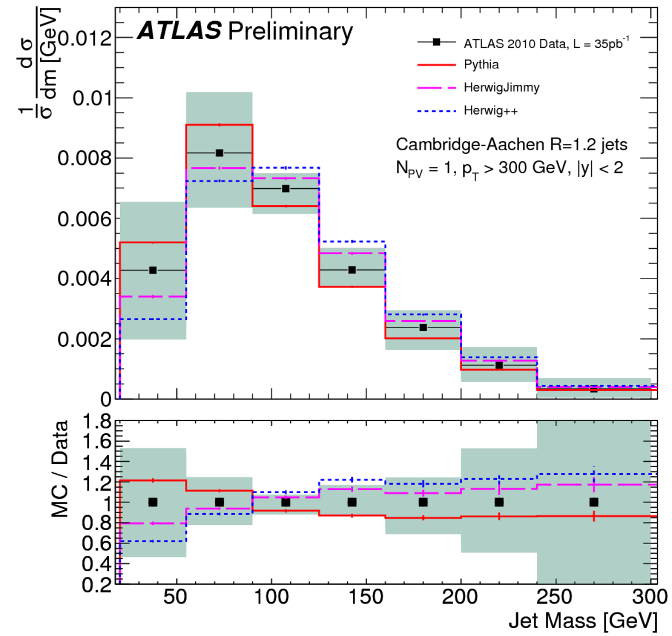
Jet mass and substructure

ATLAS-CONF-2011-073

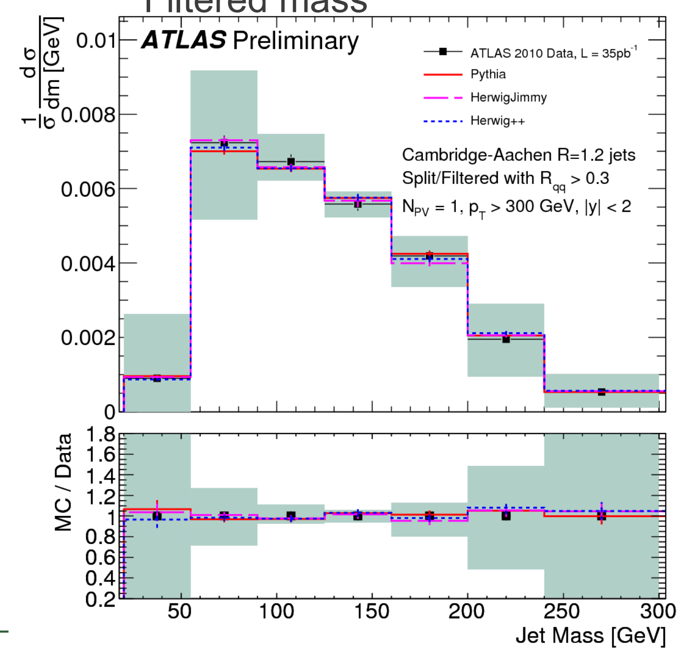
- Motivation:
  - Recovering lost channels in Higgs search (H->bb)
- The fat jets (R=1.0/1.2 for anti-Kt/ and C/A clustering) are split to constituents and soft radiation is filtered out
- Individual jet mass encodes information about both the parton shower and potential presence of heavy particle decays
- Filtering reduce differences between generators and removes impact of pile-up
- World's first measurement of filtered jet mass: extremely good agreement among MC and data after filtering







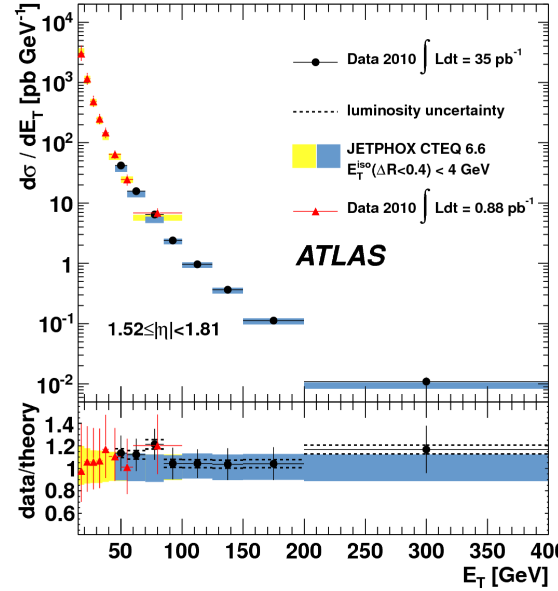
Filtered mass

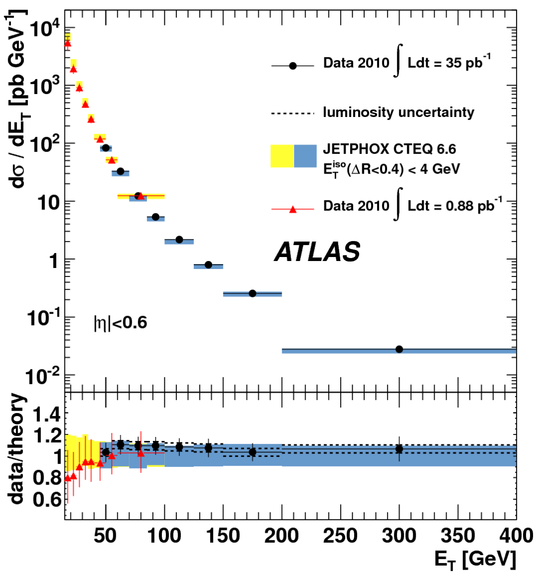


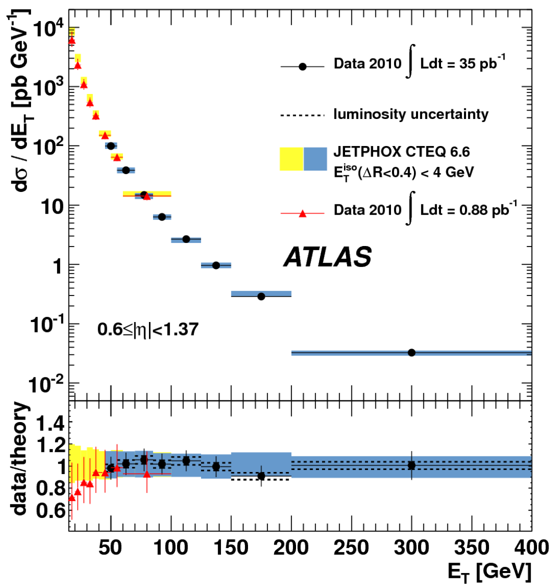
Inclusive isolated prompt photon cross section

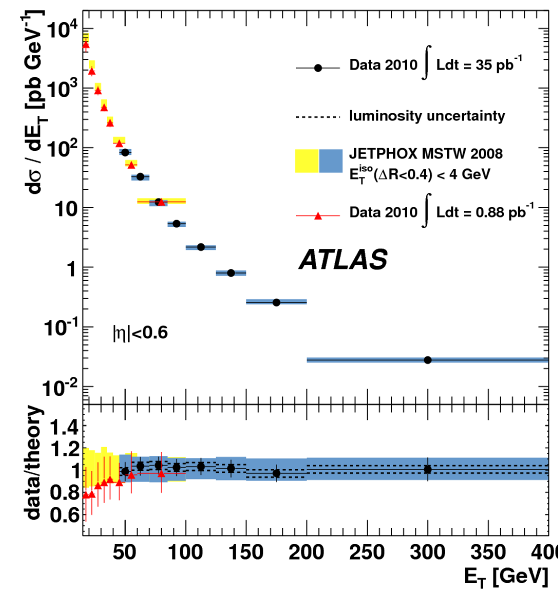
CERN-PH-EP-2011-115

- Motivation:
  - Test of perturbative QCD
  - Sensitive to gluon content of the proton
  - Estimate of QCD background in Higgs and new physics searches
- Good aggreement with NLO prediction, except lower ET (high fragmentation)
- Uncertainty: EM energy scale (5-10 %)

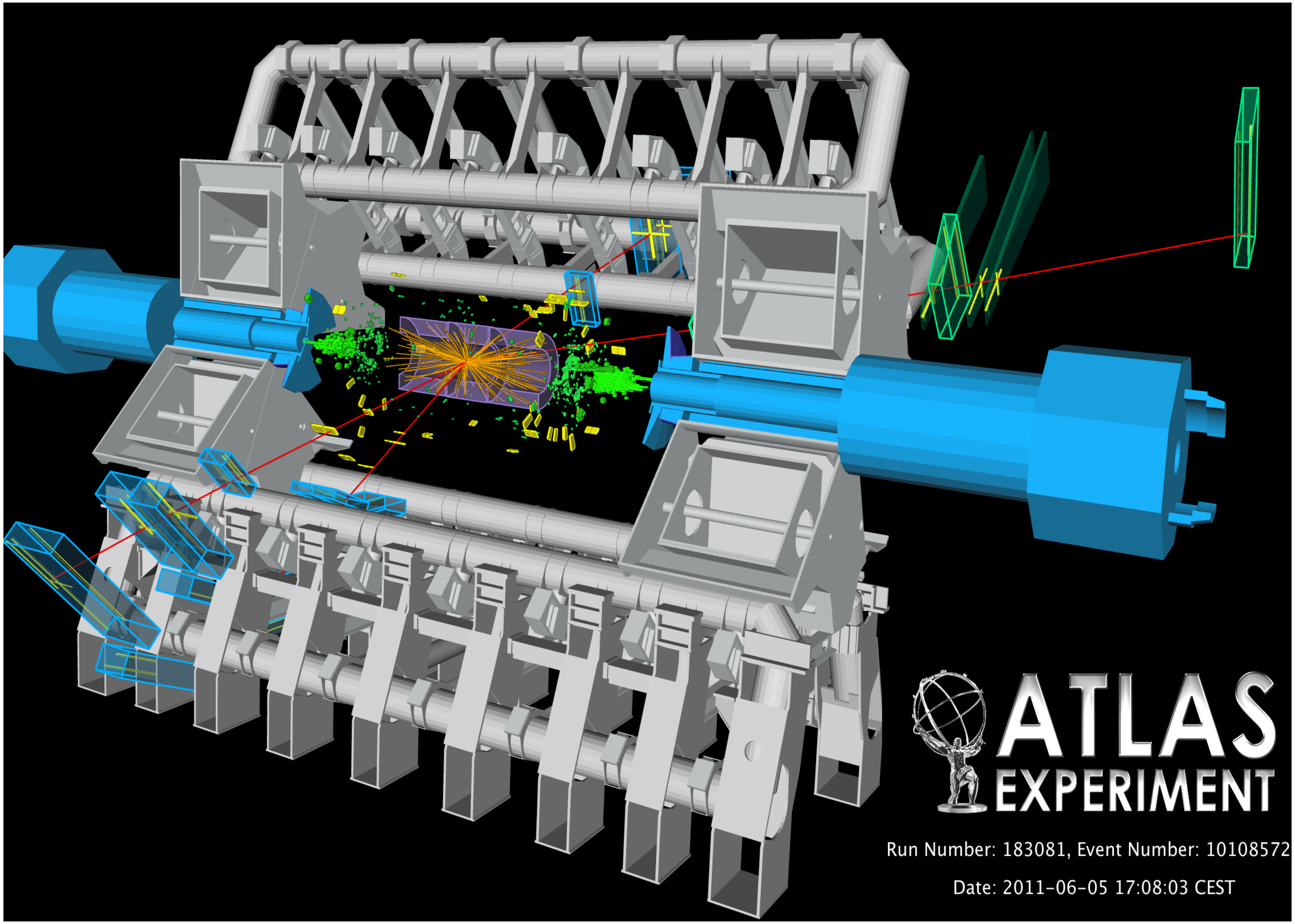








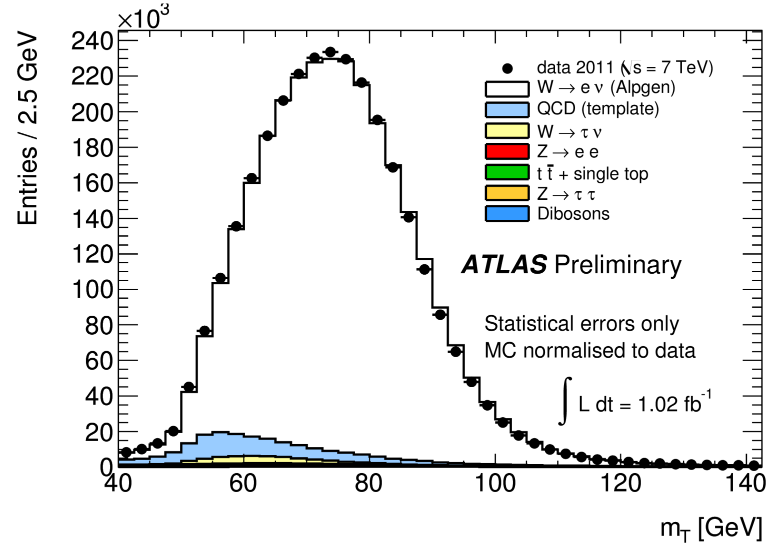
W and Z bosons

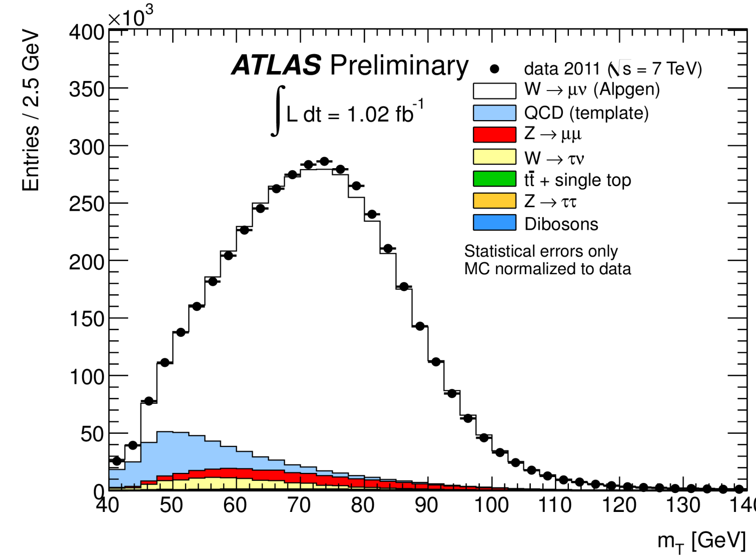


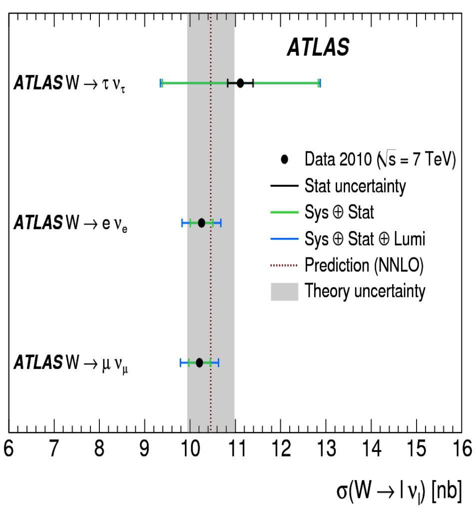
W production cross section

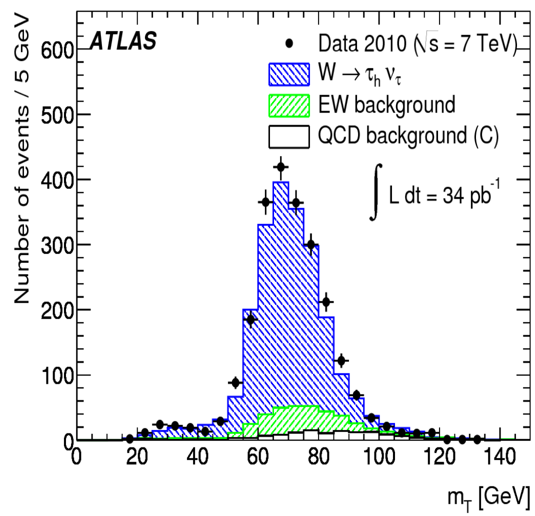
ATLAS-CONF-2011-041
CERN-PH-EP-2011-122

- Inclusive measurement in all three lepton channels
- Event selection
  - Lepton p_T > 20 GeV, tau p_T < 60 GeV
  - Missing E_T > 25 GeV (30 GeV for taus)
- Main uncertainty sources
  - Tau efficiency and energy scale (10%+8%),
  - luminosity (3%)





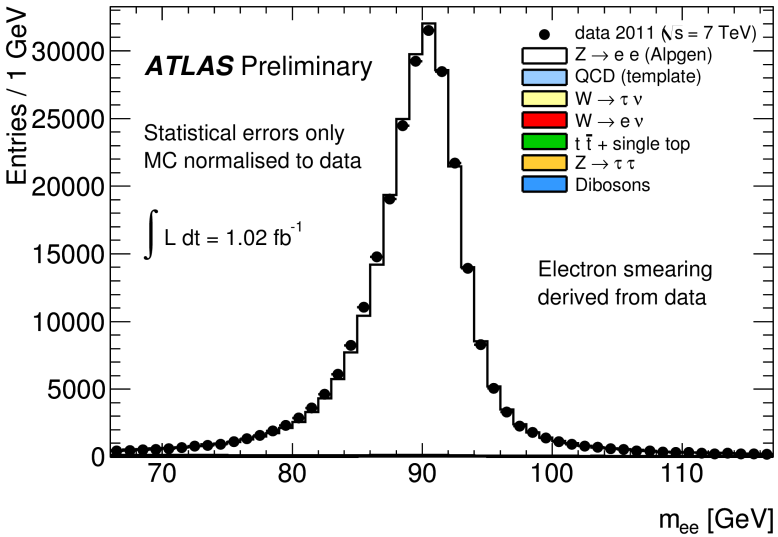


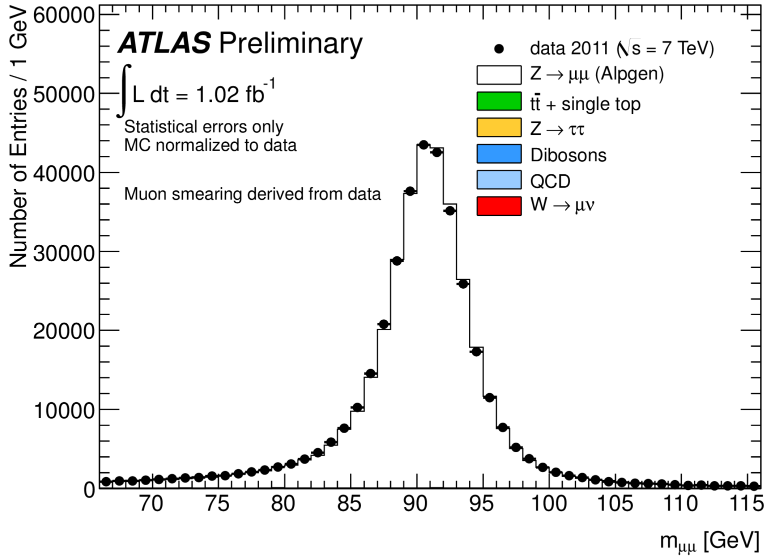


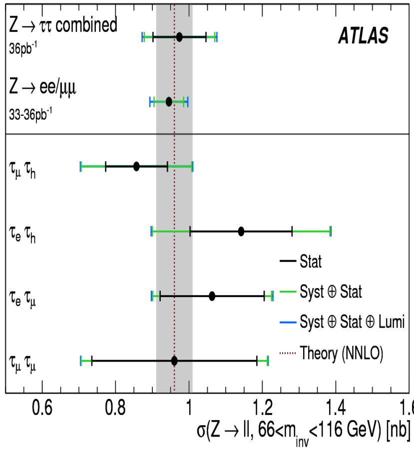
Z production cross section

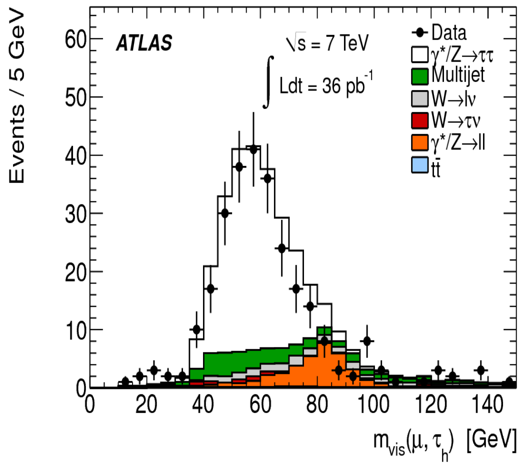
ATLAS-CONF-2011-041
CERN-PH-EP-2011-097

- Inclusive measurement in all three lepton channels
- Event selection
  - e/μ p_T > 20 GeV, 66 GeV< m_{ll} < 116 GeV
  - 4 final states measured for Z->ττ (2 semileptonic+eμ+μμ)
- Main uncertainty sources
  - Tau efficiency and energy scale (8.6%+11%),
  - luminosity (3%)





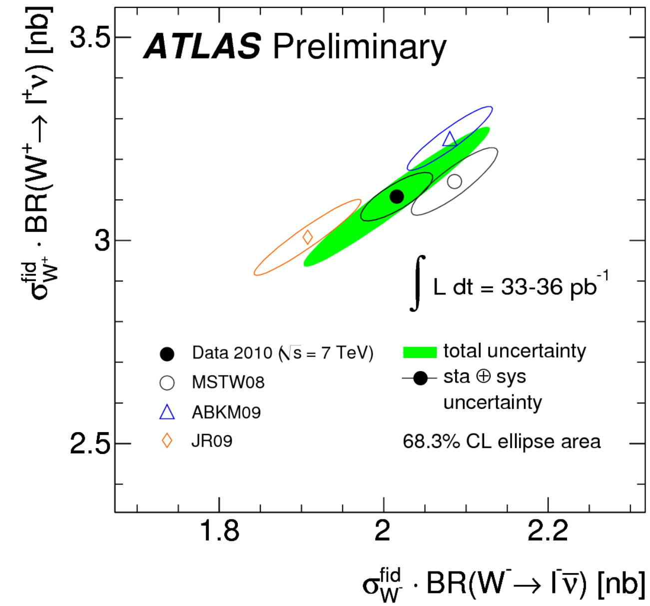


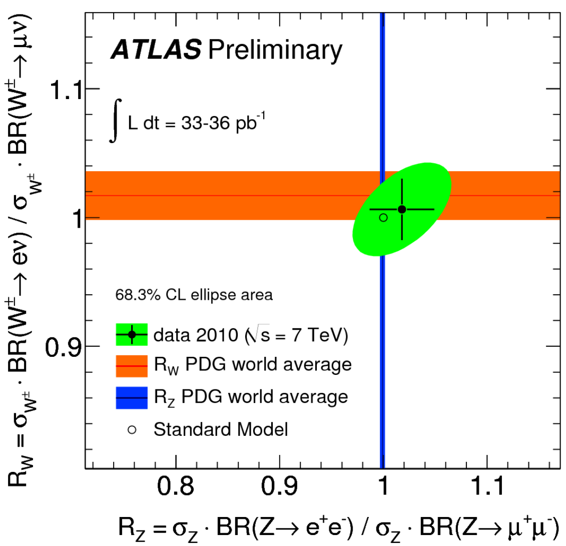


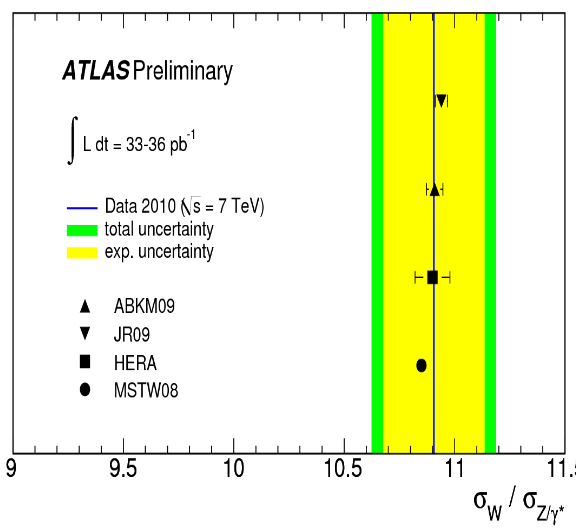
W and Z cross section ratios

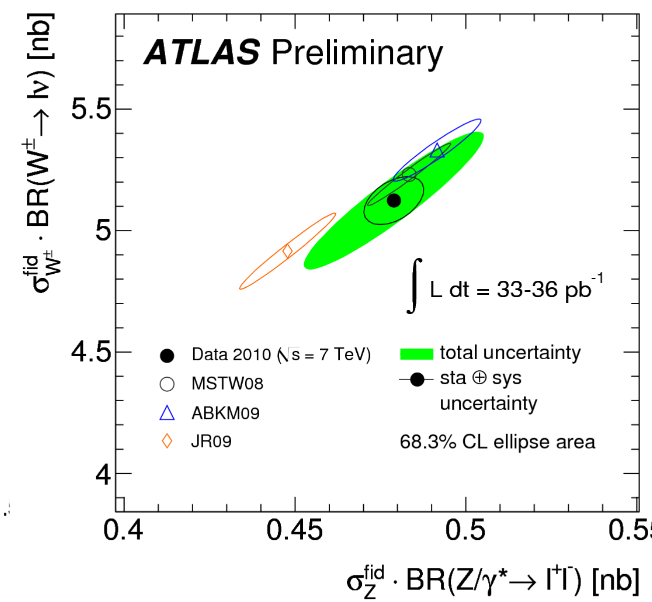
ATLAS-CONF-2011-041

- Systematic uncertainties
  - Luminosity (3.4%)
  - Acceptance corrections (3-4%)
  - Missing E_T requirement (2%)
  - Electron ID (1-2%)
- Good agreement with NNLO QCD
  - Theory evaluated in ATLAS fiducial volume using FEWZ and DYNNLO





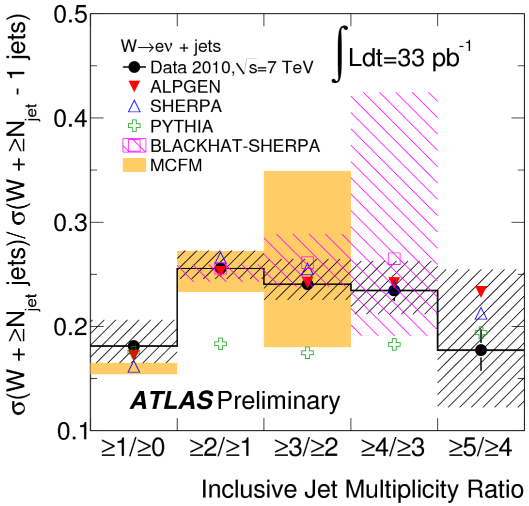


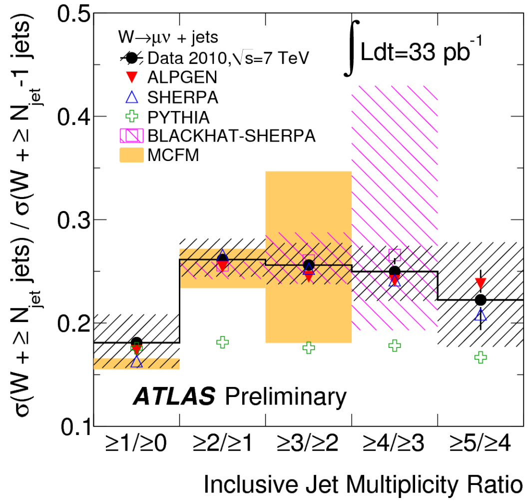


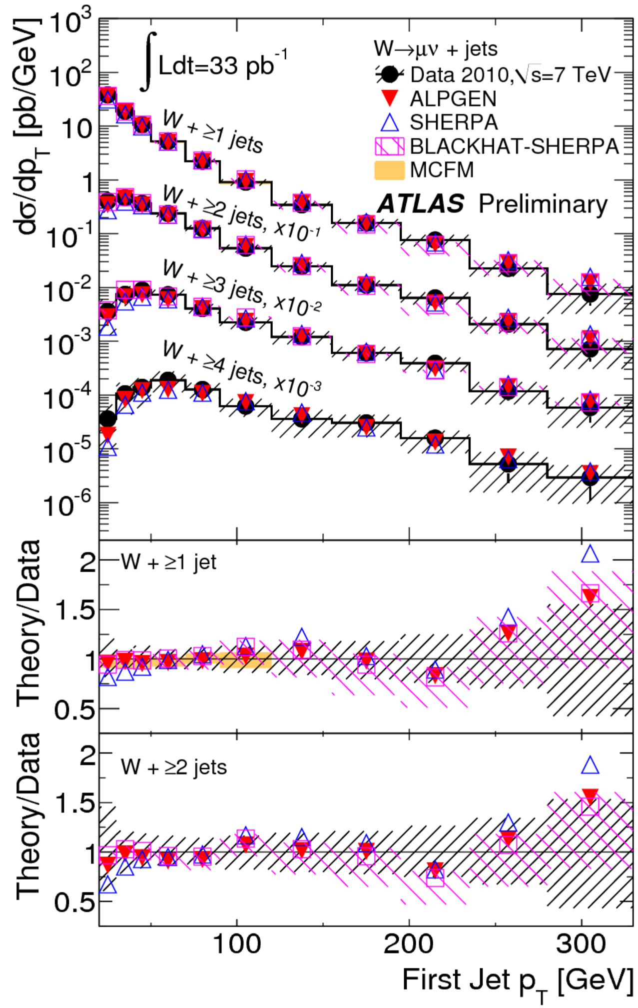
W + jets cross section ratios

ATLAS-CONF-2011-060

- Important test of perturbative QCD
- Background for Higgs/SUSY searches
- Main systematic effects
  - Jet energy scale (10%)
  - Pile-up removal (up to 7% at low p_T)
- Good agreement with theory prediction (except Pythia)







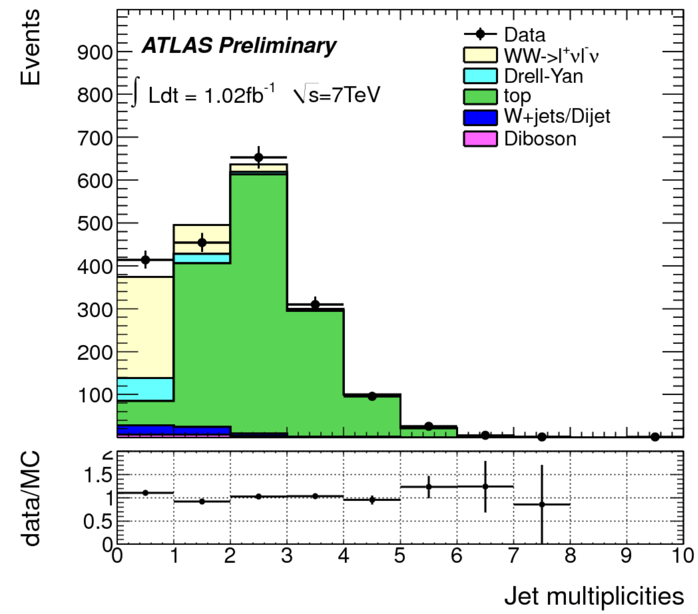
WW production

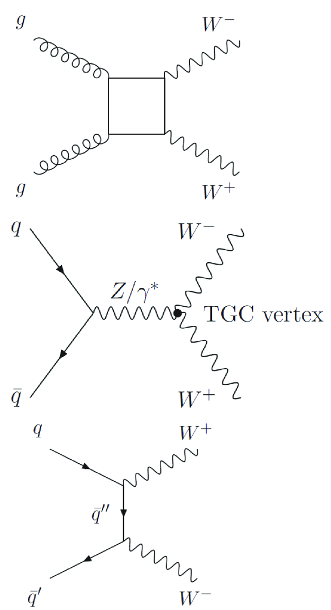
ATLAS-CONF-2011-110

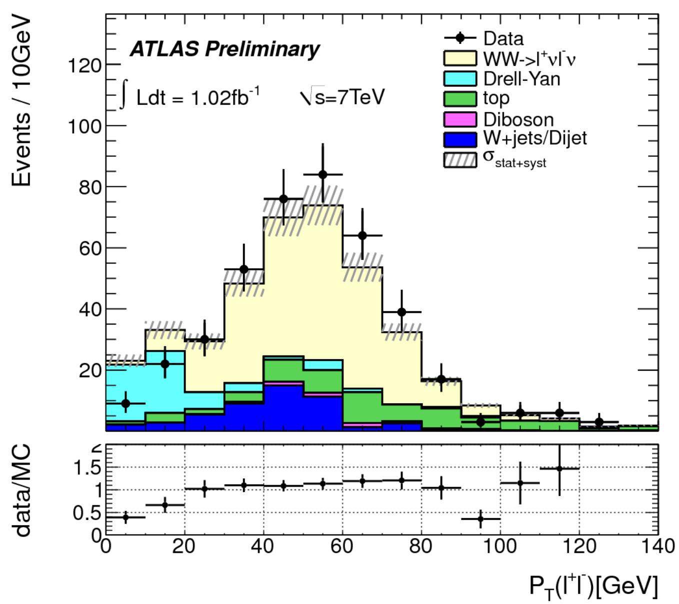
- 3 final states: ee, eμ, μμ
- Overall systematic uncertainty 8.9%(eμ), 9.2% (μμ), 10.3%(ee)

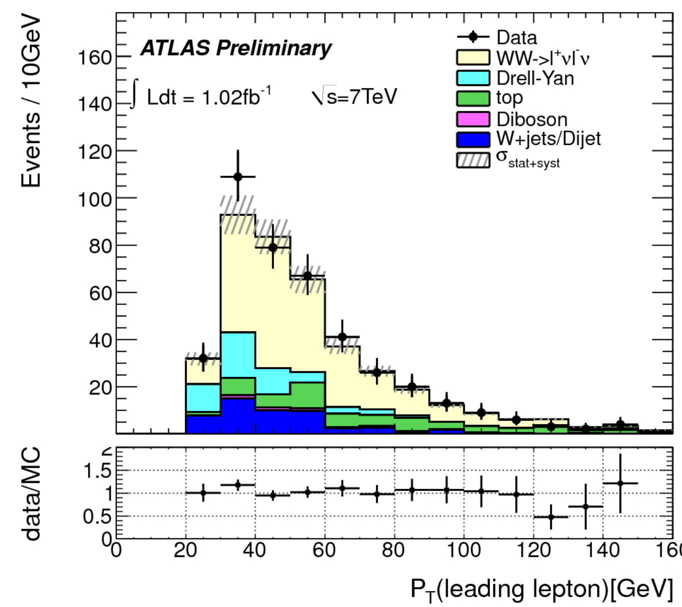
Channels	Total cross-section (pb)	$\Delta\sigma_{stat}$(pb)	$\Delta\sigma_{syst}$(pb)	$\Delta\sigma_{lumi}$(pb)
$e\nu e\nu$	62.1	± 13.5	± 9.1	± 2.3
$\mu\nu\mu\nu$	44.7	± 8.7	± 7.7	± 1.7
$e\nu\mu\nu$	47.3	± 4.8	± 6.2	± 1.8
Combined	48.2	± 4.0	± 6.4	± 1.8

- Good agreement with SM prediction (46 ± 3 pb)









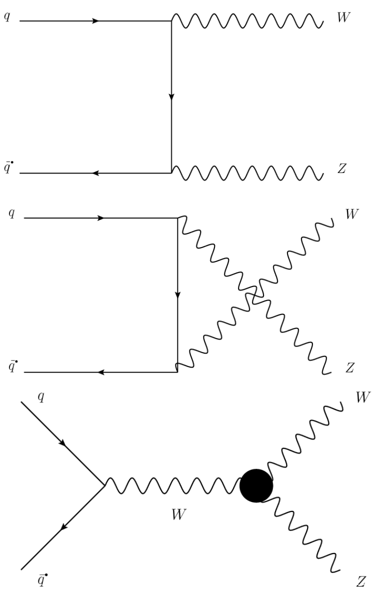
WZ production

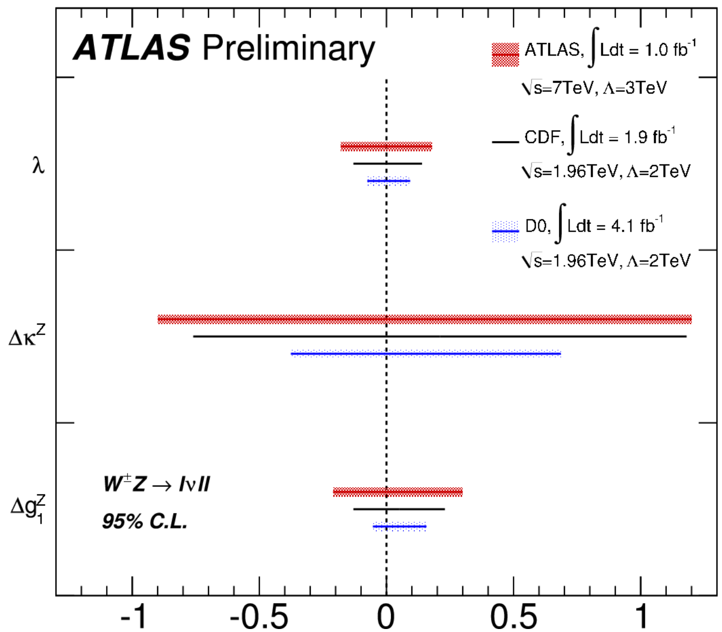
ATLAS-CONF-2011-099

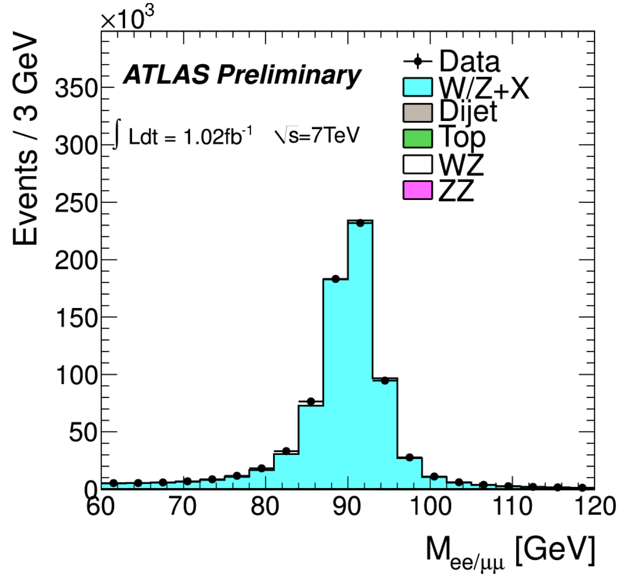
- Important test of the SM: gauge self-interaction
- 4 final states: eee, eeμ, eμμ, μμμ

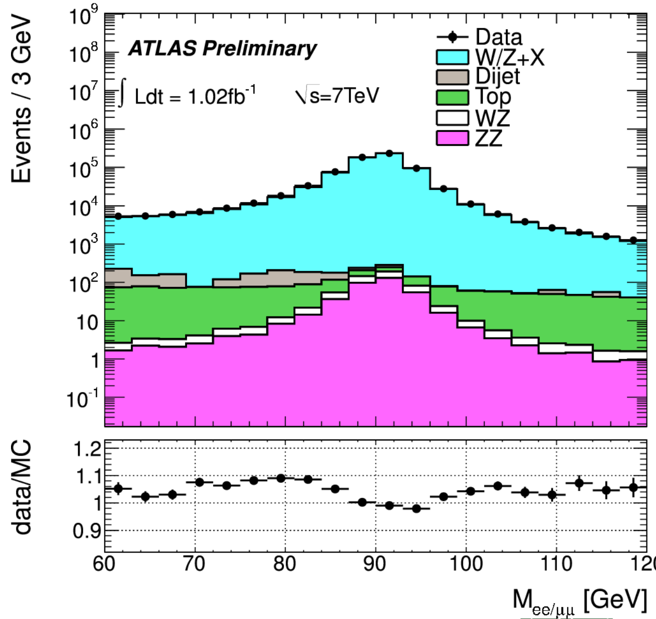
Final State	$eee + E_T^{miss}$	$ee\mu + E_T^{miss}$	$e\mu\mu + E_T^{miss}$	$\mu\mu\mu + E_T^{miss}$	combined
Observed	11	9	22	29	71
Total Background	3.08±0.49	1.98±0.24	3.82±0.56	2.44±0.21	$10.5\pm0.8^{+2.9}_{-2.1}$
Expected Signal	7.55±0.17	11.27±0.20	12.12±0.22	18.16±0.27	49.1±0.4±3.02

- Measured cross section (21 ± 4 pb) in agreement with SM prediction (17 ± 1 pb)



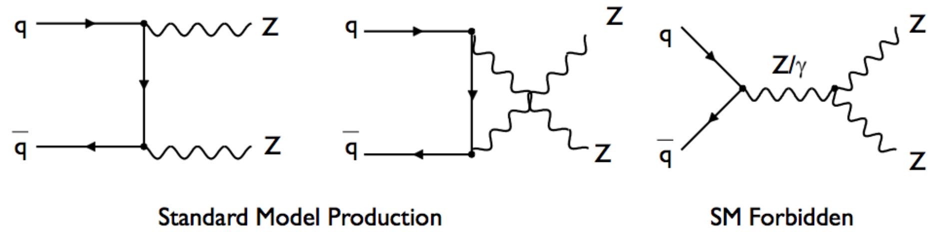






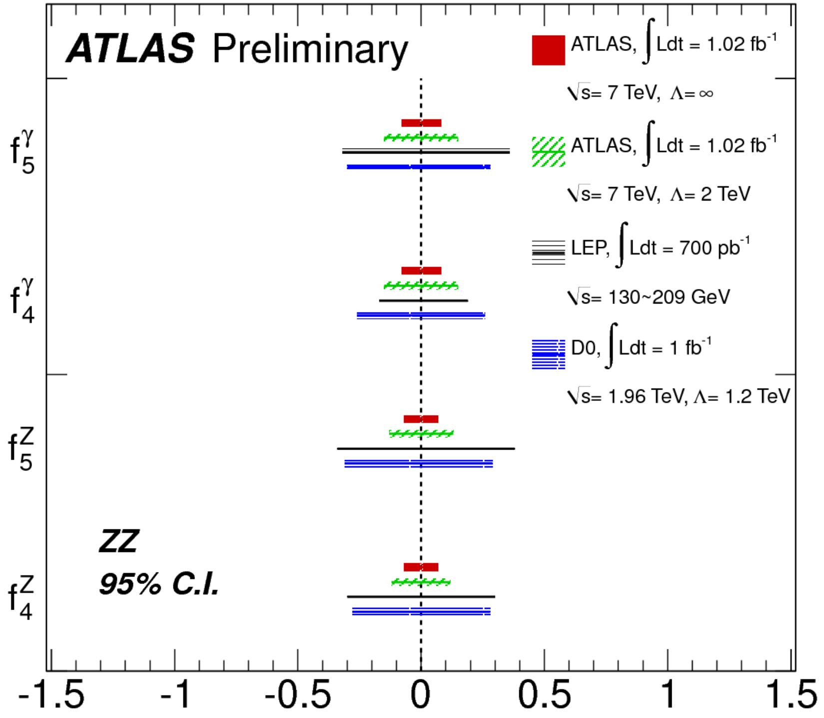
ZZ production

ATLAS-CONF-2011-107

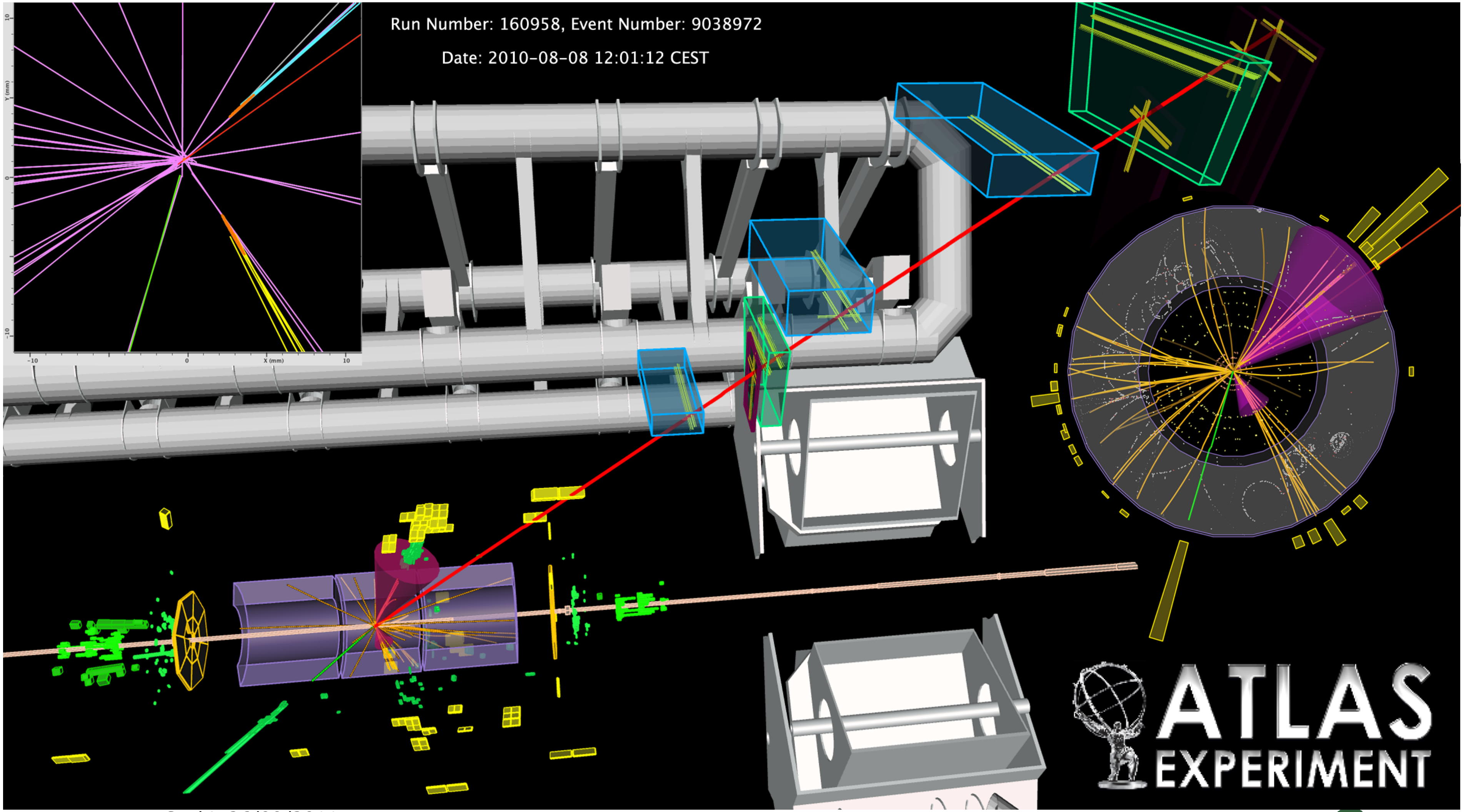


- Search for neutral trilinear gauge couplings (NGC) (forbidden in the SM)
- Background for Higgs search (H->ZZ)
- 3 final states: eeee, eeμμ, μμμμ
- Measured cross section (8.4 ± 3.5 pb) in agreement with SM prediction (6.5 ± 0.3 pb)
- 4 parameters of NGC measured (2 for γ and 2 for Z)
  - Should be 0 if NGC does not exist
  - Better results than LEP and D0

Final State	$e^+e^-e^+e^-$	$\mu^+\mu^-\mu^+\mu^-$	$e^+e^-\mu^+\mu^-$	$\ell^+\ell^-\ell^+\ell^-$
Observed	2	8	2	12
Bkg(data-driven)	$0.01^{+0.03+0.05}_{-0.01-0.01}$	$0.3^{+0.9}_{-0.3} \pm 0.3$	$< 0.01^{+0.03}_{-0.01}$	$0.3^{+0.9+0.4}_{-0.3-0.3}$
Expected ZZ	1.57±0.03±0.11	3.09±0.04±0.06	4.5±0.1±0.2	9.1±0.1±0.3

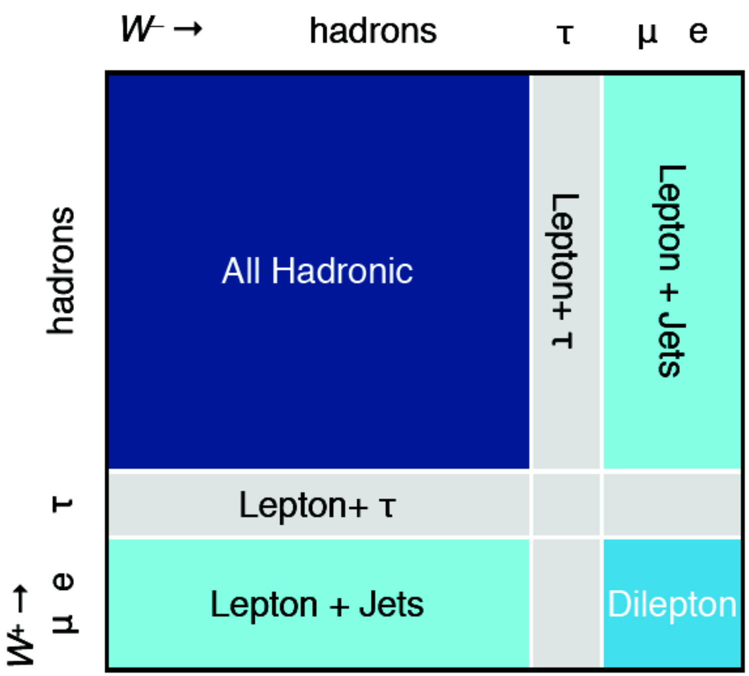


Top quark


Run Number: 160958, Event Number: 9038972
Date: 2010-08-08 12:01:12 CEST
ATLAS
EXPERIMENT

Top quark properties

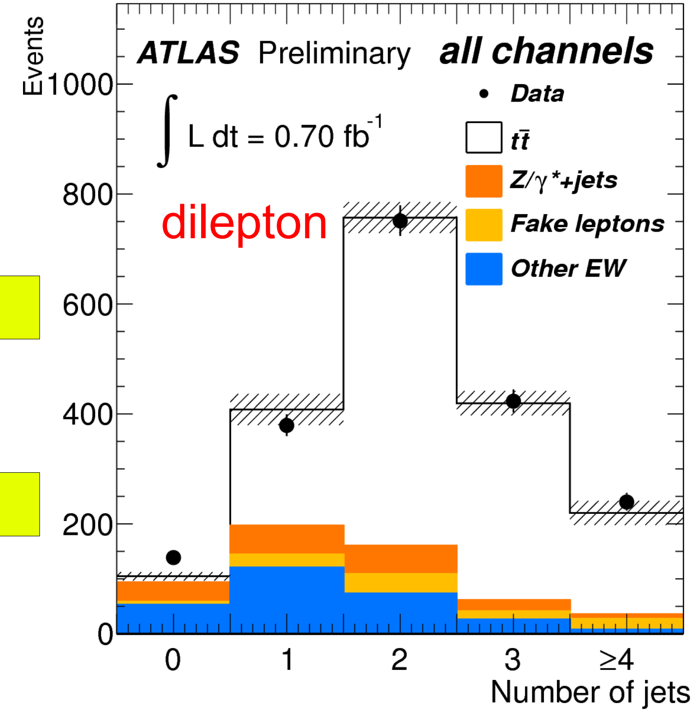
- Top decay in the Standard Model: BR(t->Wb)~1
- Signature: multiple leptons and jets + missing E_T
- Decays of top – antitop pairs characterized by W decay modes
  - All hadronic (45%); large QCD background-> no significance
  - lepton+jets (30 %); moderate backrounds
  - Dilepton (5%); very clean
- Dominant backgrounds for single and dileptonic channels
  - W/Z+ jets
  - QCD jets
- Event selection
  - High p_T leptons, at least 3 jets, cut on missing E_T and transverse mass

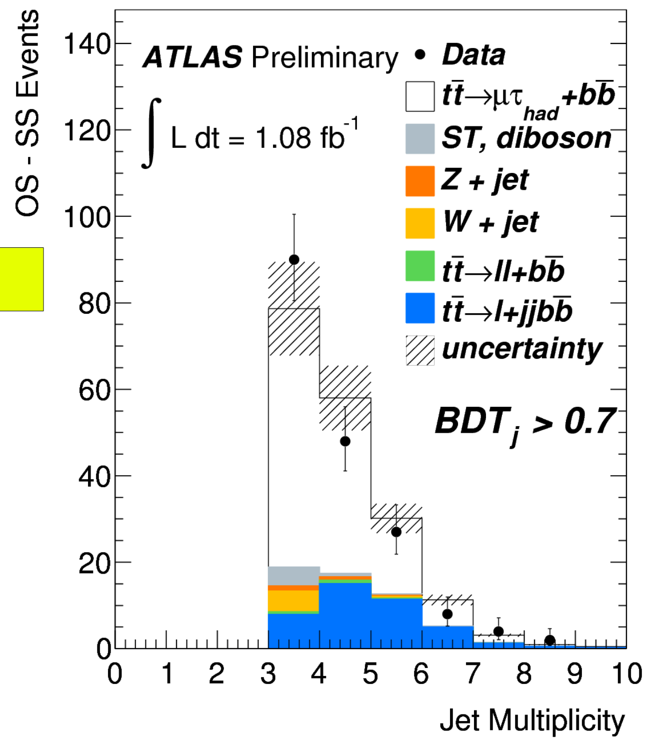


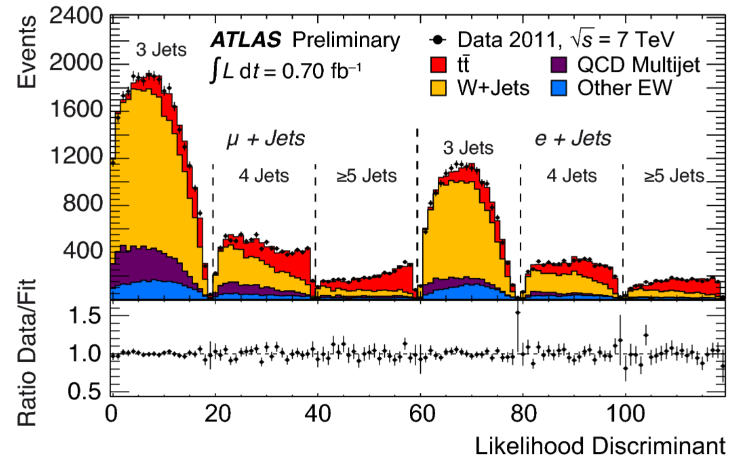
Top quark pair production cross section

- 3 analyses
  - lepton+jets without b-tagging **ATLAS-CONF-2011-121**
    - Simultaneous fit in 6 channels
  - Dilepton w/o b-tagging and with at least 1 b-tagged jet
    - ee, eμ, μμ **ATLAS-CONF-2011-100**
  - $\mu+\tau_h$ + jets
    - Using BDT to identify taus

ATLAS-CONF-2011-119





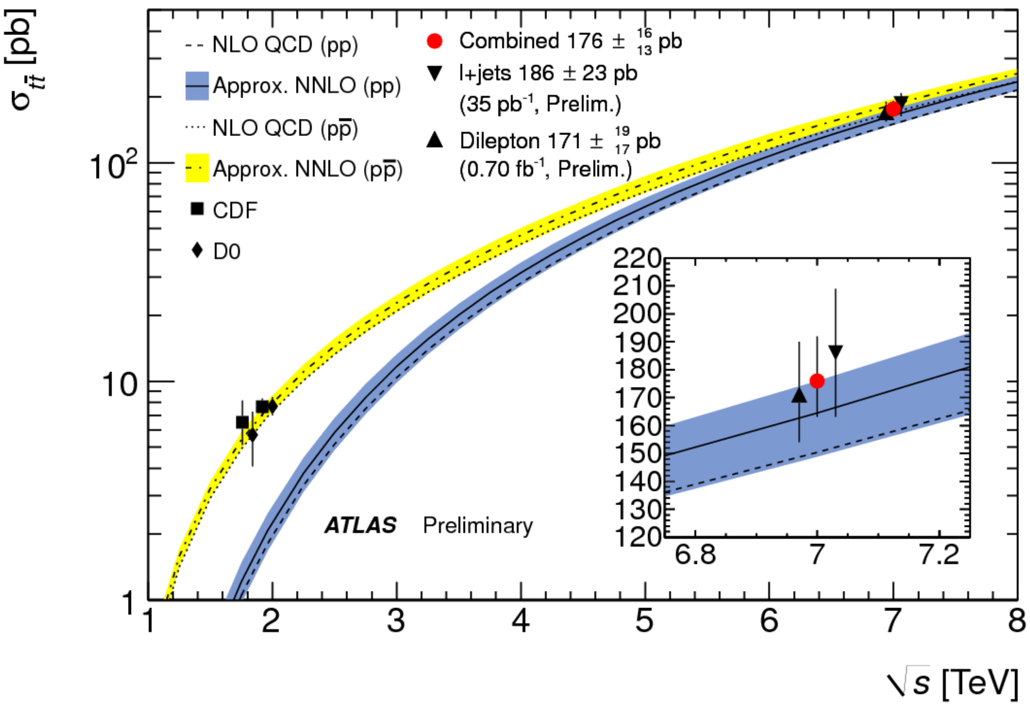


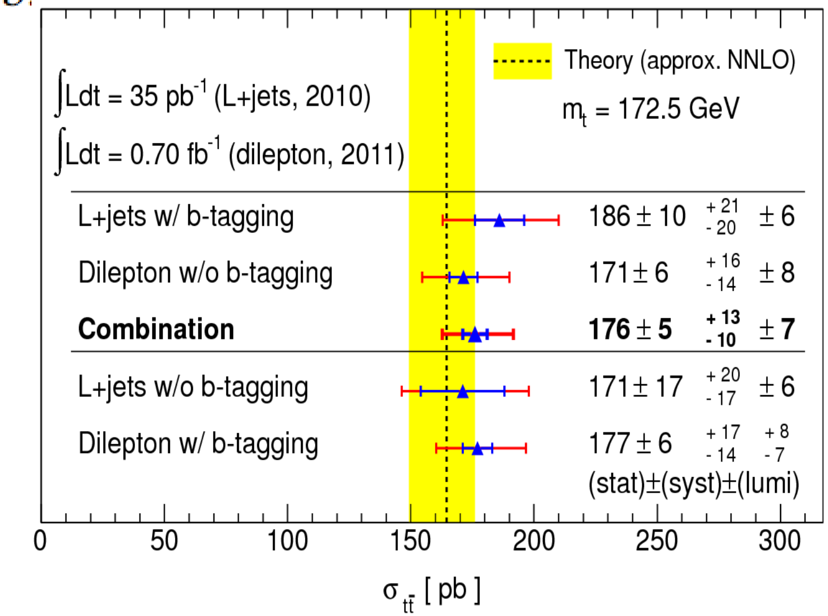
Top quark pair production cross section: combination

ATLAS-CONF-2011-108

- Statistical combination of single lepton and dilepton measurements
- Good agreement with the Standard Model predictions

$$\sigma_{t\bar{t}} = 176 \pm 5\ (\text{stat.}) \pm {}^{13}_{10}\ (\text{syst.}) \pm 7\ (\text{lumi.})\ \text{pb}.$$

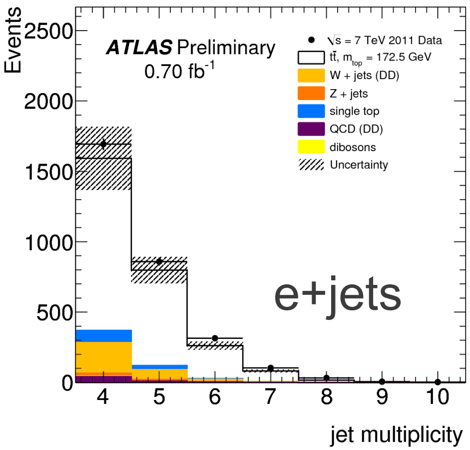


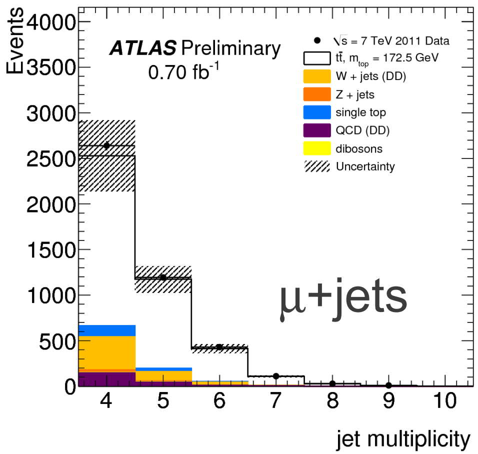


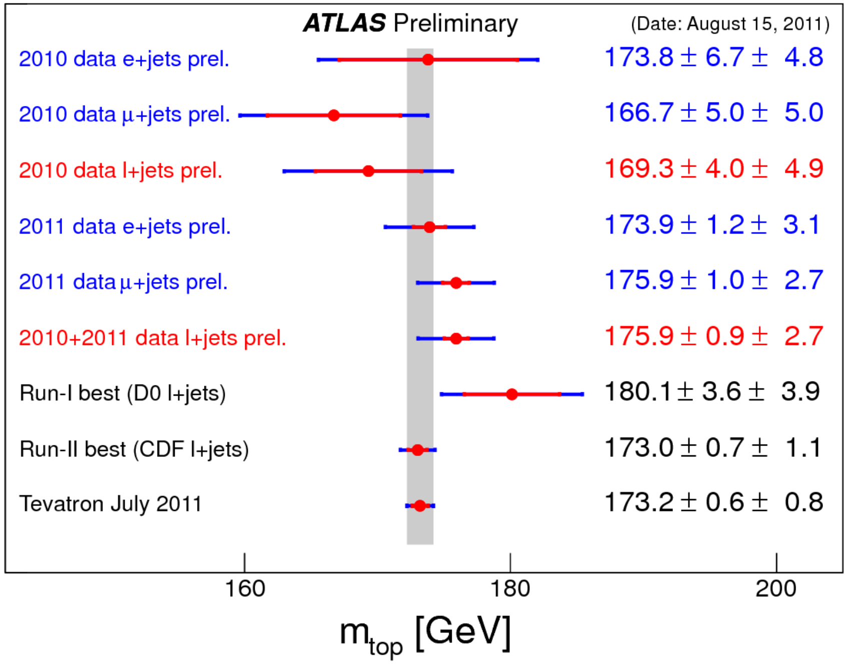
Top quark mass

ATLAS-CONF-2011-120

- Using 2D template fit
  - Templates for reconstructed m_{top} and m_W from MC

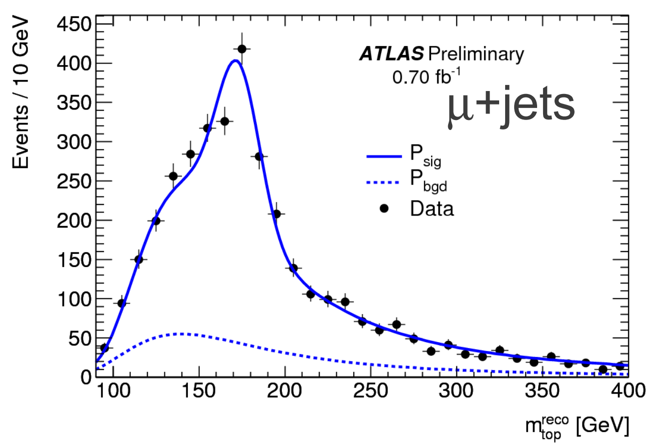


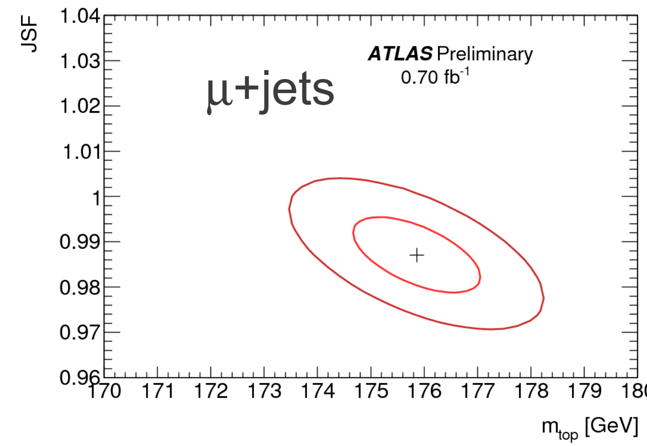




m_{top} = 175.9 ± 0.9 (stat.) ± 2.7 (syst) GeV

- Simultaneously fit distributions of reconstructed m_{top} and m_W to get top mass and global Jet Scale Factor



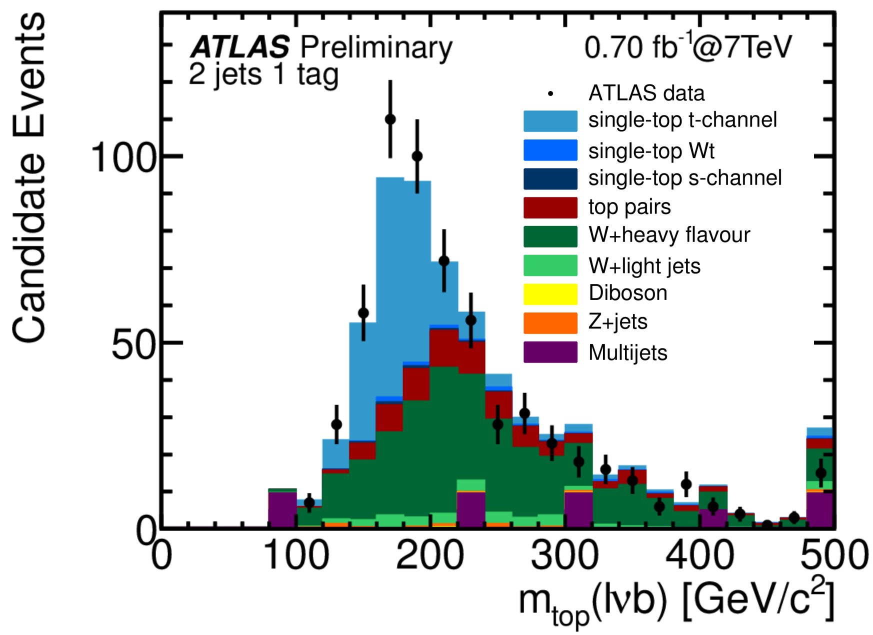


Single top production

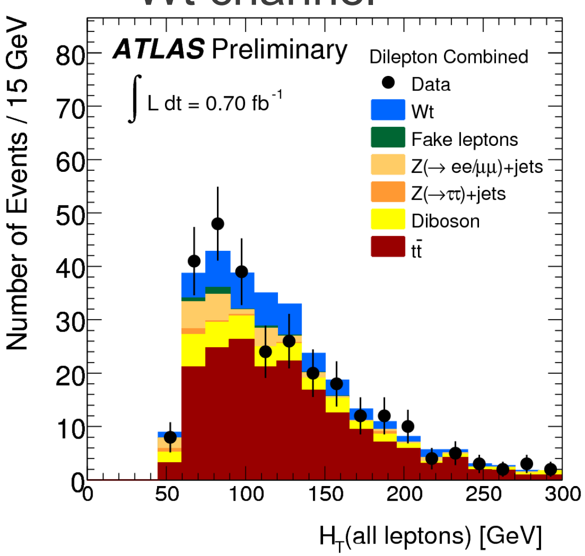
ATLAS-CONF-2011-101
ATLAS-CONF-2011-118

- Analyses in t-channel, s-channel and Wt channel
- Lepton+jets final state
- t-channel:
  - Cut-based and neural network analysis
  - Expected cross section: 64.6 pb
  - $\sigma_t = 90 \pm 5\ (\mathrm{stat})^{+13}_{-10}(\mathrm{syst}) \pm 7\ (\mathrm{lumi})$ pb
    - Consistent with the SM within 1 sigma

t-channel



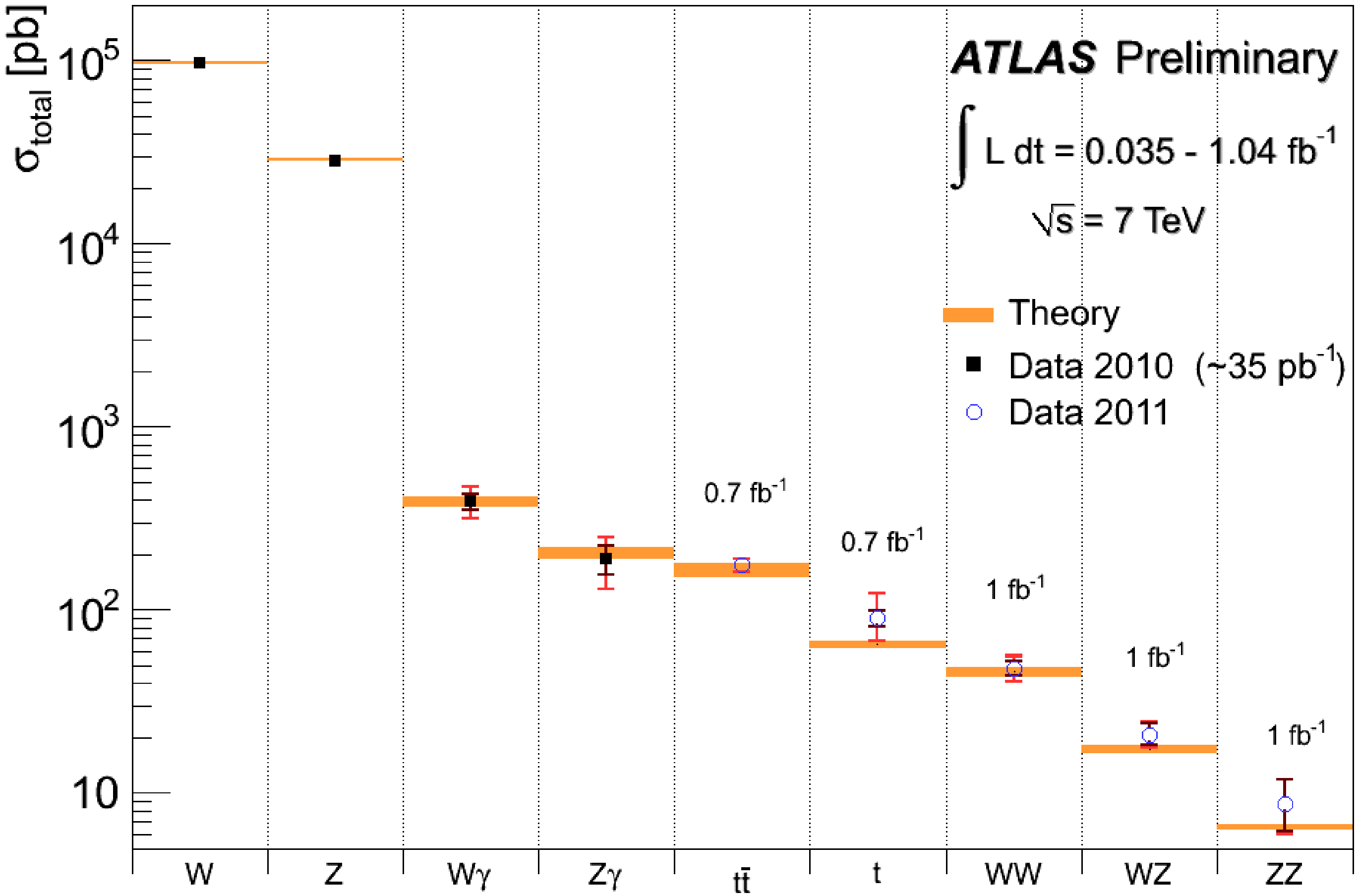
Wt channel



- Wt channel:
  - Cut-based analysis in di-lepton channel
  - Expected cross section: 15.7 pb
  - $\sigma(pp \to Wt + X) < 39.1$ pb (expected limit 40.6 pb)
    - Observed upper limit at around 2.5 times SM cross section
- s-channel:
  - Cut-based analysis
  - Expected cross section: 4.6 pb
  - $\sigma_t < 26.5$ pb
    - Observed upper limit at around 5 times SM cross section

Summary of the Standard Model results

- Only a fraction of the SM results has been reported in this talk



- For the full list of ATLAS SM results go to links:

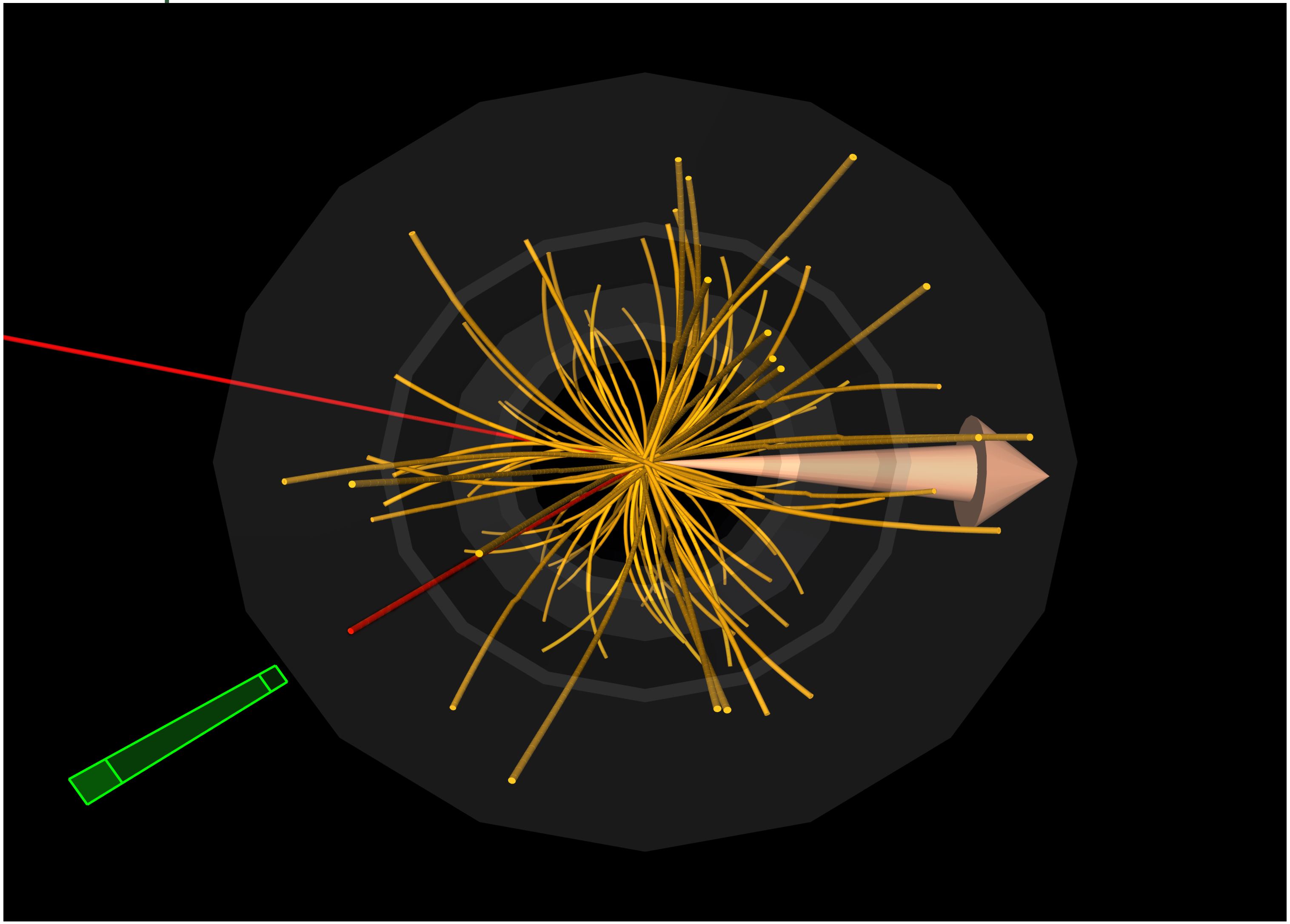
[Standard Model Group results](#)
[Top Group Results](#)

[All ATLAS results](#)

Conclusion

- Large Hadron Collider is performing excellently (at the moment recording at 10.8 pb^{-1}/h)
- ATLAS is recording high quality data and analyzing them with rapid pace
- All parts of the Standard Model have been successfully rediscovered and the amount of data at the moment is large enough to deliver world class measurements with the best sensitivity
- Shown results from 2010 and 2011 data (up to 1 fb^{-1})
- Measured data agree well with (N)NLO predictions
  - Some analysis deliver more precise results than theory predictions
  - Results can be use to constrain MC predictions
- Our current understanding of the SM processes at ATLAS allows us efficient search for the new physics processes

Back Up material

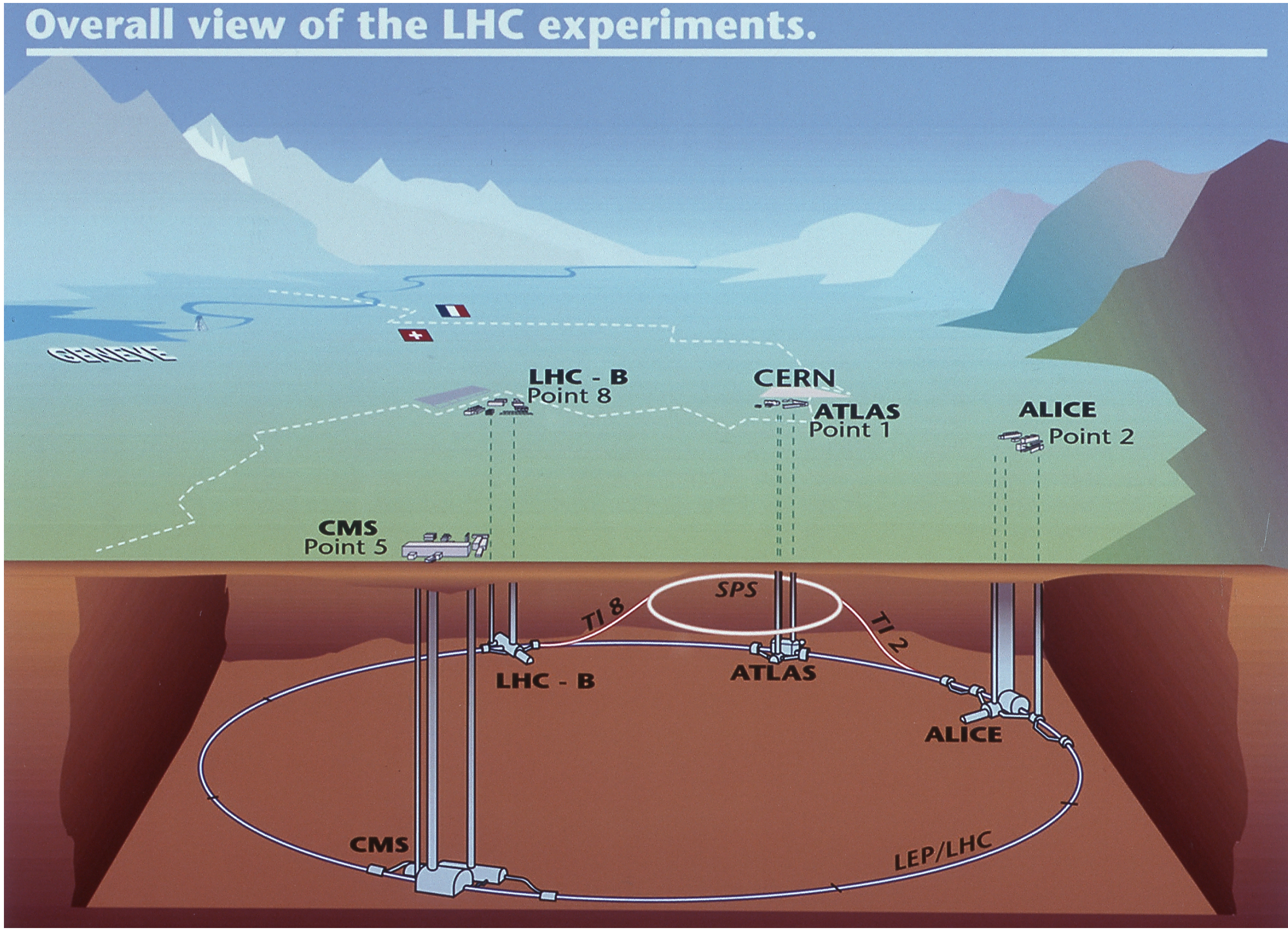


Large Hadron Collider

- 27 km in circumference
- Colliding protons at 3.5+3.5 TeV
- 10^{11} protons per bunch
- 1300 bunches per beam

- Design instantaneous luminosity: 1×10^{34} $cm^{-2}s^{-1}$
- Peak stable luminosity: 2.98×10^{33} $cm^{-2}s^{-1}$

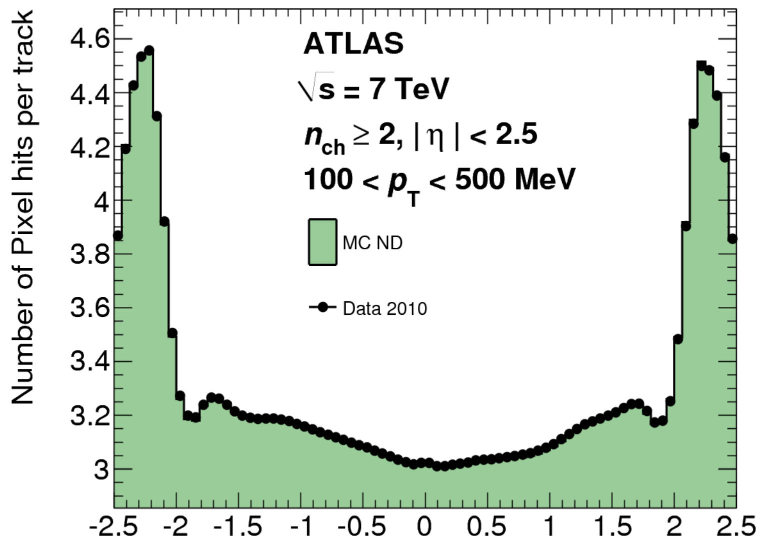
- 4 big experiments
  - 2 general purpose
    - ATLAS, CMS
  - 2 specialized
    - ALICE, LHCb

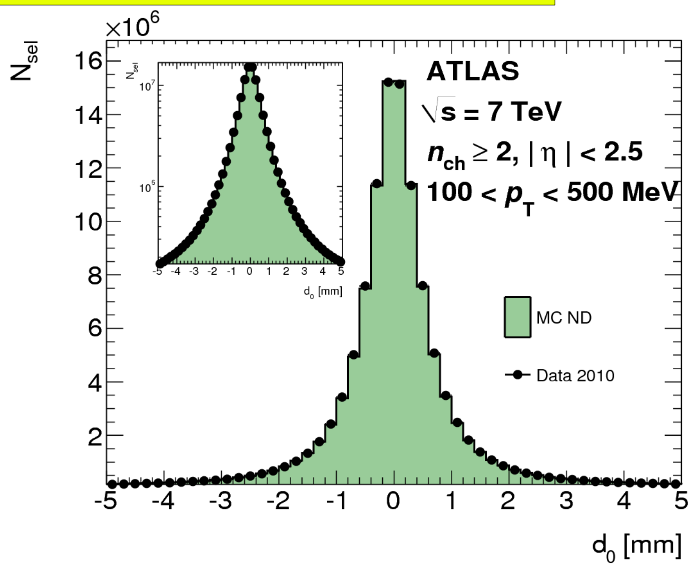


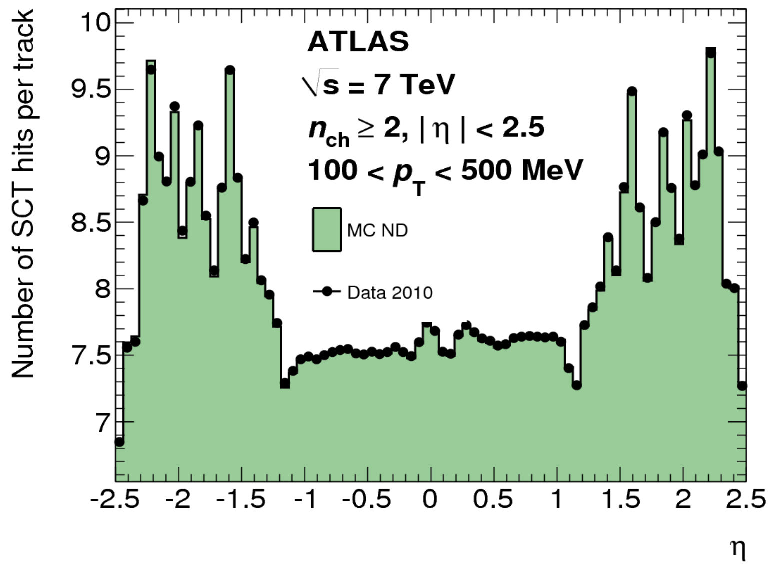
Checking the description of the ATLAS detector

- The tracking detector simulations are in a mature state, charged track measurements are well understood
- Plots show the simulation of the minimum bias tracks in ATLAS (number of hits in Pixel and SCT detectors and transverse impact parameter) and their comparison with data

New J. Phys. 13 (2011) 053033



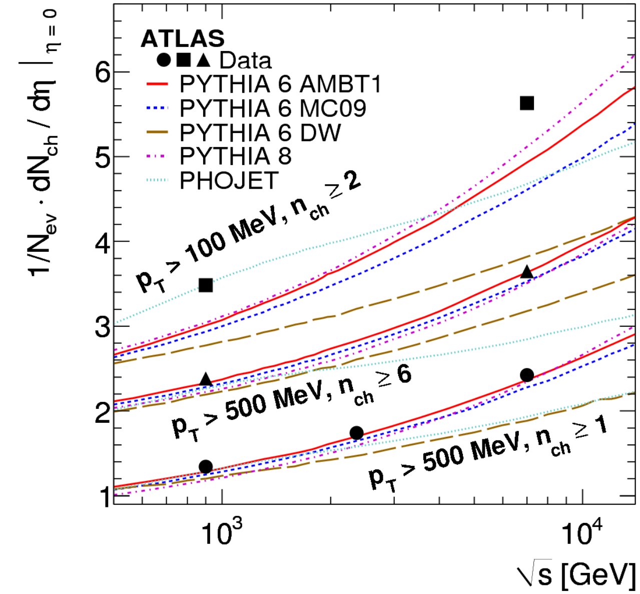


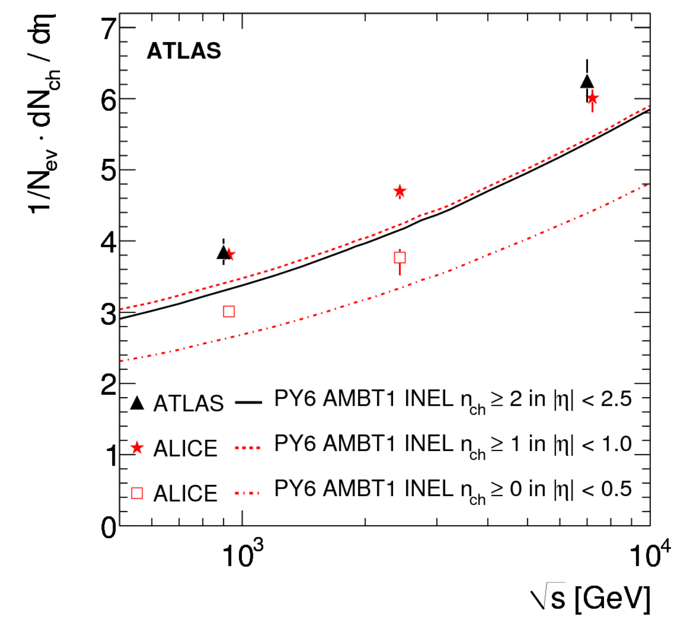


Details of Minimum bias analysis

New J. Phys. 13 (2011) 053033

- Trigger: one or more counters above threshold on either side of MBTS
- Collisons at 0.9 TeV, 2.36 TeV and 7 TeV
- Maximum lumi 1.9 x $10^{27}cm^{-2}s^{-1}$
- Probability of additional vertex: 0.1 %
- Phase space regions:
  - At least one charged particle with $|\eta| < 2.5$ and $p_T > 500$ MeV
    - To study evolution of multiplicity as a function of energy
  - At least two charged particle with $|\eta| < 2.5$ and $p_T > 100$ MeV
    - Most inclusive particle spectra
  - At least six charged particles with $|\eta| < 2.5$ and $p_T > 500$ MeV
    - To reduce contribution from diffractive events
- Event selection
  - Primary vertex (>1 track with $p_T > 100$ MeV and transverse distance to Beam spot < 4 mm)
  - At maximum 1 vertex with 4 or more tracks
  - 10 million events in total @ 7 TeV





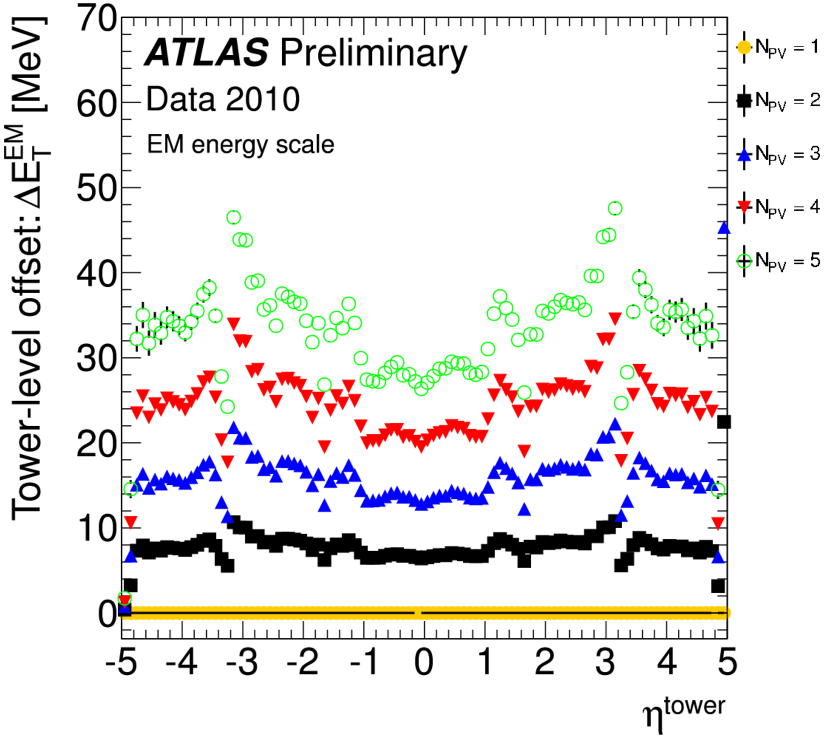
Details of inelastic pp cross-section at 7 TeV measurement

- Variable ξ is defined at particle level by dividing the the final state particles into 2 systems, X and Y
- Mean pseudorapity of the two particles separated by the largest pseudorapidity gap is used to assign all particles with greater pseudorapidity to one system and all the others to the other one
- X is the system with higher mass, $\xi = M_X^2/s$
- Bounded from below by elastic limit ($\xi > m_p^2/s$), experimental limit is $\xi > 5x10^{-6}$ (limited MBTS acceptance)
- Formula: $$\sigma_{inel}(\xi > 5 \times 10^{-6}) = \frac{(N - N_{BG})}{\epsilon_{trig} \times \int L dt} \times \frac{1 - f_{\xi < 5 \times 10^{-6}}}{\epsilon_{sel}}$$

arXiv:1104.0326

Details of jet calibration

- JES uncertainty is estimated using
  - Isolated hadron responce (from testbeam and in-situ)-> for calorimeter JES uncertainty
  - MC samples with systematic variations
  - p_T balance in dijet events
  - In-situ measurement of pileup offset
- JES uncertainty significantly lowered when 2010 data were used



ATLAS-CONF-2011-030

ATLAS-CONF-2011-032

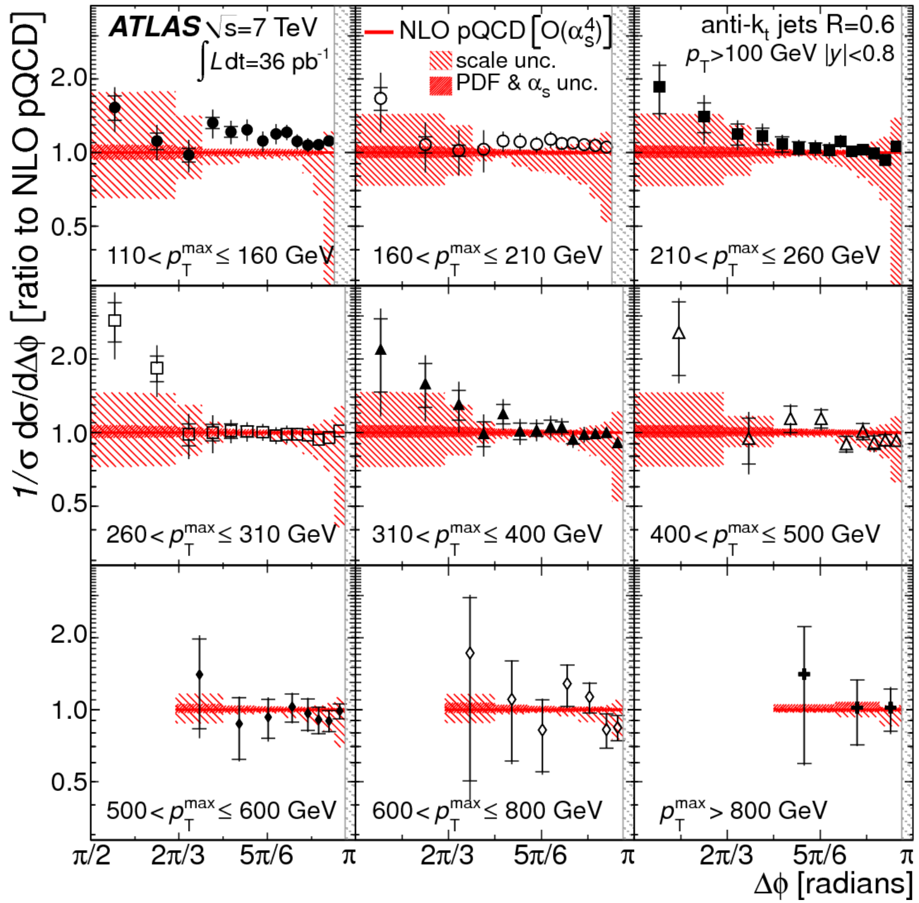
Details of jet cross-section measurement

ATLAS-CONF-2011-047

- Trigger: single jet trigger
- Event selection
  - At least 1 Primary vertex
  - Passing jet quality (to remove non-collision jets)
- Measurements corrected back to particle level by bin-by-bin single corrections using MC
  - True distribution of jet p_T recovered
- Sources of systematic uncertainties
  - Jet energy scale (dominant)
  - Jet energy resolution
  - Jet angular resolution, reconstruction efficiency, modeling of spectral shape in MC
- Theory predictions
  - NLO calculations (NLOJET++,POWHEG) with non-perturbative corrections (Pythia)
  - NLO parton showers and ME matching with POWHEG
  - Uncertainties: PDF, factorisation and hadronization, renormalization scale, α_S

Details of dijet azimuthal decorrelation measurement

- Measure Δφ of leading jets
  - Depends of number of partons: sensitive test of QCD predictions
- Trigger: single jet trigger
- Event selection
  - At least 1 Primary vertex
  - Passing jet quality (to remove non-collision jets)
- Uncertainties
  - JES: 2-17 %
  - Unfolding 1-19 %
  - Jet energy and position resolution 0.5-5 %



Phys. Rev. Lett. 106 (2011) 172002

Details of dijet production with a veto on central jet activity measurement

CERN-PH-EP-2011-100

- Trigger: single jet trigger
- Event selection
  - exactly 1 Primary vertex (to suppress pile-up)
  - Passing jet quality (to remove non-collision jets)
- BKFL-like dynamics: proposes evelution in ln(1/x) (x is Bjorken variable) (cf. DGLAP evolution in ln (Q^2), where $Q^2$is parton virtuality
- Limit of large separation (BKFL-like dynamics) or large momentum wrt veto (soft gluon wide angle radiation) or both at the same time (color singlet exchange)
- BG study for Higgs in VBF
- Theoretical predictions
  - HEJ (parton level)
    - Provides all-order description of wide-angle emissions
    - MSTW 2008 NLO PDF, renormalization scale = p_T of the leading parton
    - Uncertainty dominated by scale choice
  - POWHEG-BOX (full NLO dijet calculation with interface to PYTHIA/HERWIG)
    - Same PDF and renormalization scale as above
    - Most uncertainty from PYTHIA-HERWIG difference

Details of multi-jet production

CERN-PH-EP-2011-098

- Trigger: single and multi (2,3) jet trigger
- Event and object selection
  - All jets must have $p_T > 60$ GeV and $|y| < 2.8$
  - Leading jet must have $p_T > 80$ GeV
  - Passing jet quality (to remove non-collision jets)
  - At least 70 % of charged particle p_T comes from event vertex
  - At least 2 selected jets
- Theoretical predictions
  - ALPGEN +HERWIG/PYTHIA (LO PDF's, factoriazation and renormalization scale= Σp_T)
  - PYTHIA standalone with modified LO PDFs and different tunes
  - SHERPA
  - HERWIG++

Details of jet mass and substructure measurement

ATLAS-CONF-2011-073

- Splitting and filtering procedure:

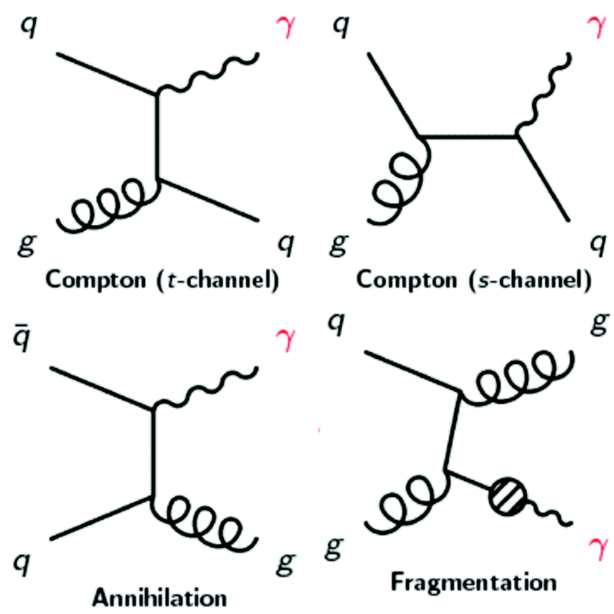
1. Undo the last clustering step of j to get two subjets j_1 and j_2 ordered such that $m_{j1} > m_{j2}$. If j cannot be unclustered (i.e. it is a single particle) or $\delta R_{j1,j2} < 0.3$ then it is not a suitable candidate, so discard j and stop.
2. If the splitting has $m_{j1}/m_j < \mu$ (large drop in mass) and $y_2 > y_{2\mathrm{cut}}$ (fairly symmetric) then go to step 4.
3. Otherwise redefine $j = j_1$ and go back to step 1.
4. Recluster the constituents of j with the Cambridge-Aachen algorithm with an R-parameter of $R_{filt} = \min(0.3, \delta R_{j1,j2}/2)$ finding n new subjets $s_1, s_2 \ldots s_n$ ordered in descending p_T.
5. Redefine $j = \sum_{i=1}^{\min(n,3)} s_i$.

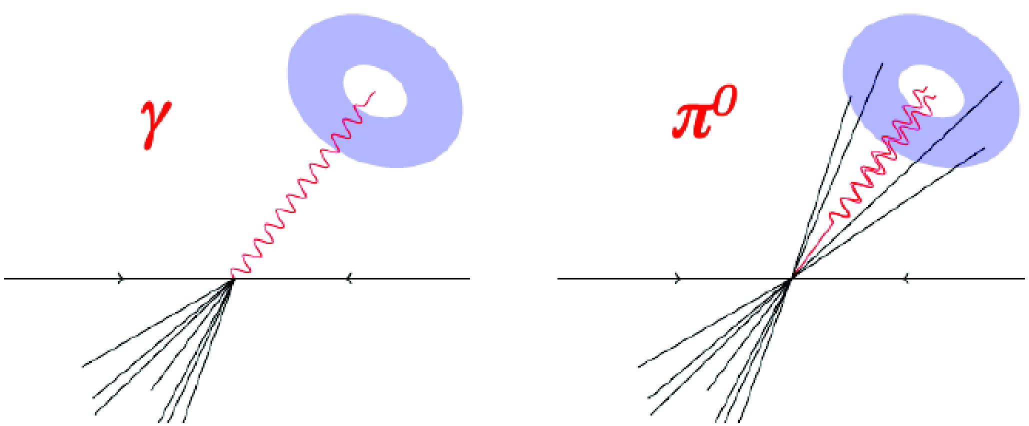
Here $y_2 = \frac{\min(p_{tj1}^2, p_{tj2}^2)}{m_j^2} \delta R_{j1,j2}^2$ and $\delta R_{j1,j2} = \sqrt{\delta y_{j1,j2}^2 + \delta\phi_{j1,j2}^2}$. The algorithm parameters μ and $y_{2\mathrm{cut}}$ are taken here as 0.67 and 0.09 respectively.

Details of inclusive isolated prompt photon cross section measurement

CERN-PH-EP-2011-115

- Photon identification
  - Small energy in the hadronic calorimeter
  - Narrow showers
  - Tracker information to reject photons from conversions
- Isolation energy $E_T^{ISO} = \sum_{cells} E_T$ in $\Delta R = \sqrt{(\Delta\eta)^2 + (\Delta\phi)^2} < 0.4$
  - Subracting energy of the cluster, signal energy leakage out-of-cluster and soft-jet activity from pileup and underlying event (~0.5 GeV)
- Shape of isolation energy determined from data

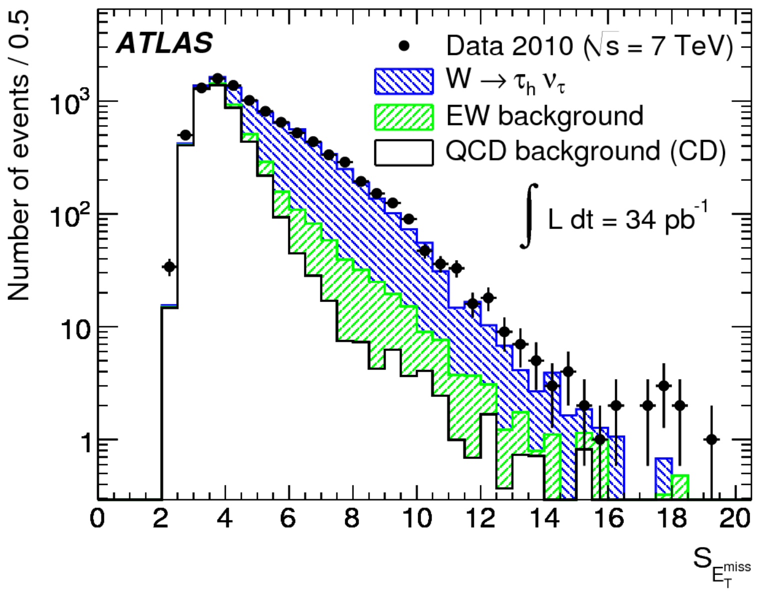




Details of W production cross section measurement

ATLAS-CONF-2011-041
CERN-PH-EP-2011-122

- Inclusive measurement in all three lepton channels
- Event selection
  - Lepton p_T > 20 GeV, tau p_T < 60 GeV
  - Missing E_T > 25 GeV (30 GeV for taus)
  - m_T > 40 GeV (e and μ channel)
  - Missing E_T significance (missing E_T /(0.5* sum E_T))> 6 (tau channel)
  - Veto events with e and μ with p_T > 15 GeV (tau channel)



	$\sigma^{tot}_{W(\pm)} \cdot BR(W \to e\nu)$ [nb]
W^+	$6.333 \pm 0.025(sta) \pm 0.193(sys) \pm 0.215(lum) \pm 0.190(acc)$
W^-	$4.217 \pm 0.021(sta) \pm 0.129(sys) \pm 0.138(lum) \pm 0.127(acc)$
W	$10.551 \pm 0.032(sta) \pm 0.300(sys) \pm 0.359(lum) \pm 0.316(acc)$

	$\sigma^{tot}_{W(\pm)} \cdot BR(W \to \mu\nu)$ [nb]
W^+	$6.215 \pm 0.023(sta) \pm 0.165(sys) \pm 0.225(lum) \pm 0.187(acc)$
W^-	$4.107 \pm 0.020(sta) \pm 0.112(sys) \pm 0.152(lum) \pm 0.123(acc)$
W	$10.322 \pm 0.030(sta) \pm 0.249(sys) \pm 0.377(lum) \pm 0.310(acc)$

$$\sigma(W \to \tau\nu) = 11.1 \pm 0.3(\text{stat.}) \pm 1.7(\text{sys.}) \pm 0.4(\text{lumi.})\ \text{nb}$$

- Triggers
  - Single electron trigger
  - Single muon trigger
  - Tau and missing E_T trigger

Details of Z production cross section measurement

ATLAS-CONF-2011-041
CERN-PH-EP-2011-097

- Inclusive measurement in all three lepton channels
- Event selection
  - e/μ p_T > 20 GeV, opposite charge, 66 GeV< m_{ll} < 116 GeV (e and μ channel)
  - μ p_T > 15 GeV (μτ channel)/ μ p_T > 10 GeV (μμ and eμ channel), e p_T > 16 GeV, hadronic τ p_T > 20 GeV

	$\sigma^{tot}_{Z/\gamma^*} \cdot BR(Z/\gamma^* \to ee)$ [nb], $66 < m_{ee} < 116$ GeV
Z/γ^* Central	$0.972 \pm 0.010(sta) \pm 0.034(sys) \pm 0.033(lum) \pm 0.038(acc)$
Z/γ^* Forward	$0.903 \pm 0.022(sta) \pm 0.087(sys) \pm 0.031(lum) \pm 0.035(acc)$

	$\sigma^{tot}_{Z/\gamma^*} \cdot BR(Z/\gamma^* \to \mu\mu)$ [nb], $66 < m_{\mu\mu} < 116$ GeV
Z/γ^*	$0.941 \pm 0.008(sta) \pm 0.011(sys) \pm 0.032(lum) \pm 0.037(acc)$

Final State	Total cross section ([66, 116] GeV) (nb)
$\tau_\mu \tau_h$	$0.86 \pm 0.08 \pm 0.12 \pm 0.03$
$\tau_e \tau_h$	$1.14 \pm 0.14 \pm 0.20 \pm 0.04$
$\tau_e \tau_\mu$	$1.06 \pm 0.14 \pm 0.08 \pm 0.04$
$\tau_\mu \tau_\mu$	$0.96 \pm 0.22 \pm 0.12 \pm 0.03$
$Z \to \tau\tau$	$0.97 \pm 0.07 \pm 0.06 \pm 0.03$

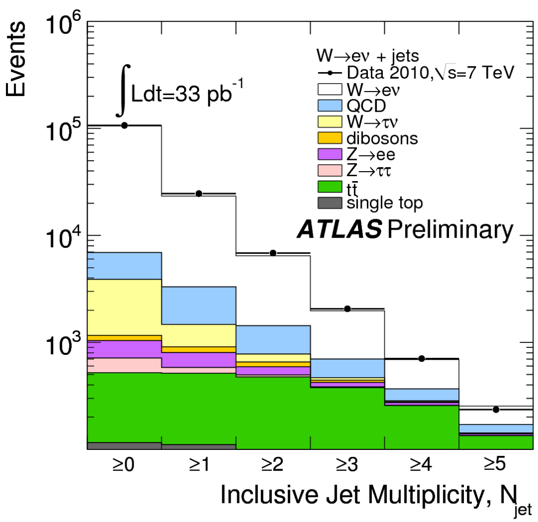
- Triggers (for all channels)
  - Single electron trigger

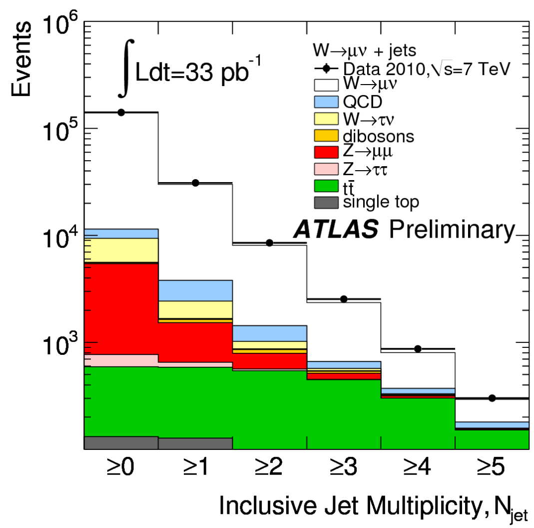
    OR
  - Single muon trigger

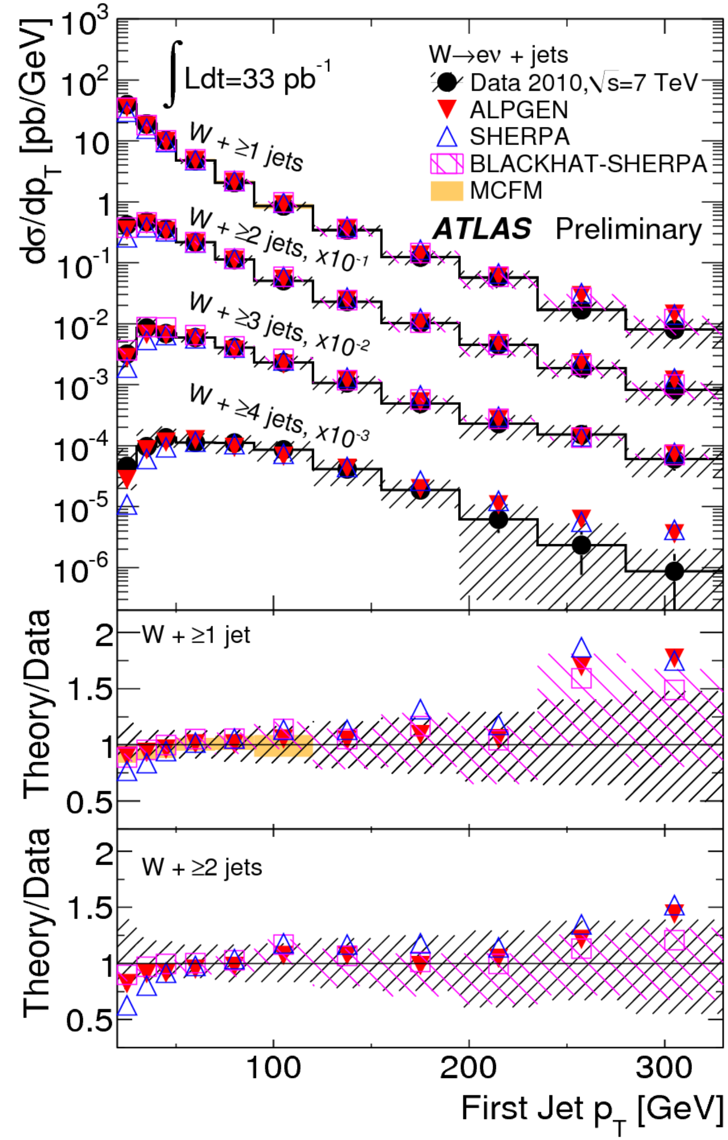
Details of W + jets production measurement

ATLAS-CONF-2011-060

- Event selection similar to the inclusive analysis
- Jet definition
  - E_T > 20 GeV, |y| < 2.8, ΔR(lj) > 0.5, anti-Kt with R=0.4
- Pileup jets rejected using jet-vertex-fraction (sum of momentum from other primary vertices)





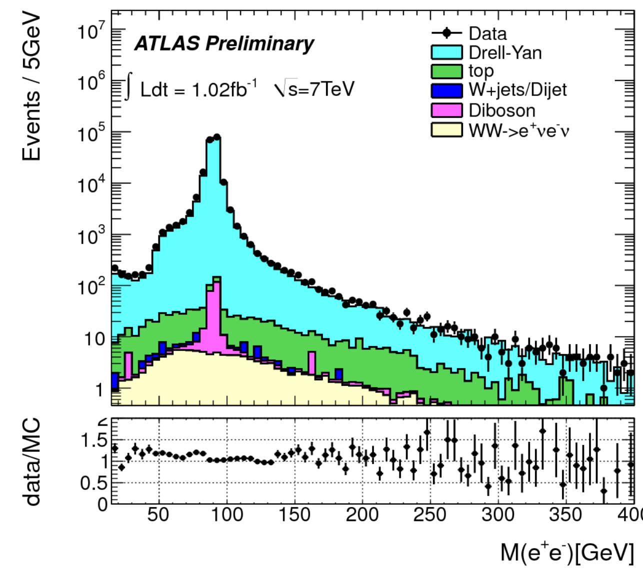


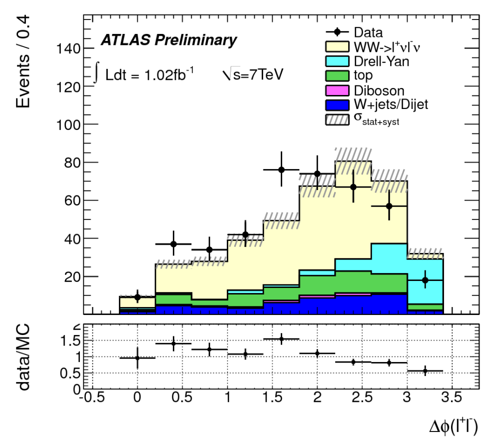
Detail of WW production measurement

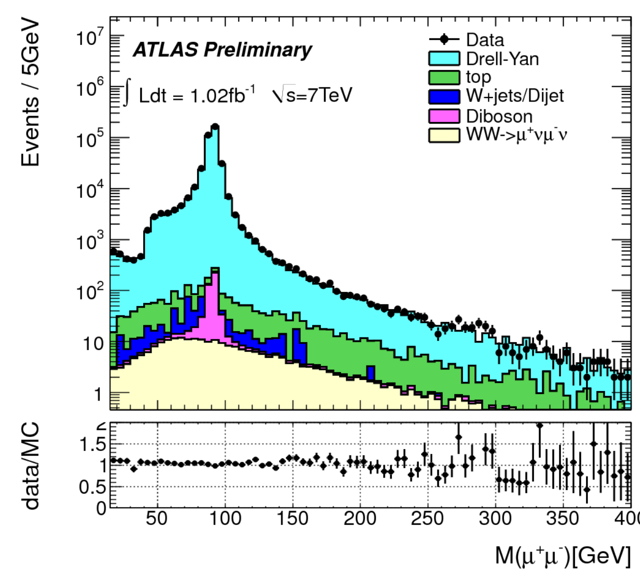
ATLAS-CONF-2011-110

- Event selection
  - 2 good leptons with opposite charge (1 firing the trigger) matched to primary vertex
  - Jet veto
  - M_{ll} > 15 GeV and $|M_{ll} - M_{Z}|$ > 15 GeV
  - For eμ channel M_{ll} > 10 GeV
  - Relative missing E_T > 40 GeV (ee)
  - Relative missing E_T > 45 GeV (μμ)
  - Relative missing E_T > 25 GeV (eμ)

$$E_{\mathrm{T,\,Rel}}^{\mathrm{miss}} = \begin{cases} E_{\mathrm{T}}^{\mathrm{miss}} \times \sin\left(\Delta\phi_{\ell,j}\right) & \text{if } \Delta\phi < \pi/2 \\ E_{\mathrm{T}}^{\mathrm{miss}} & \text{if } \Delta\phi \geq \pi/2 \end{cases}$$

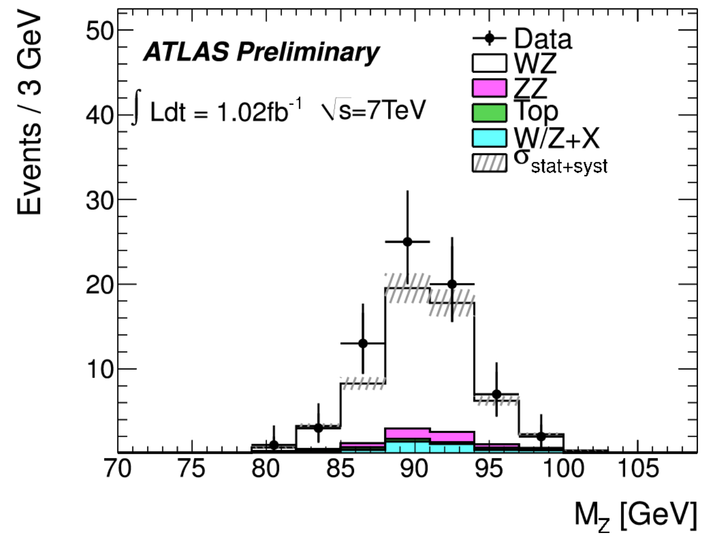






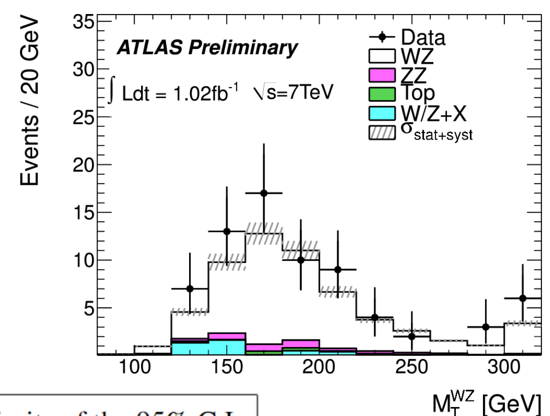
Details of WZ production measurement

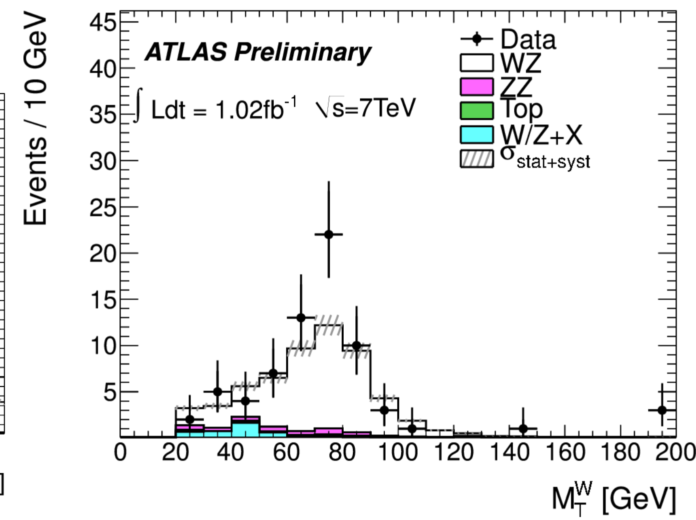
ATLAS-CONF-2011-099



- Event selection
  - 3 good leptons (1 firing the trigger) matched to primary vertex
    - Lepton firing trigger p_T > 20 (25) GeV for μ (e)
  - 2 same flavour leptons have opposite charge and $|M_{ll} - M_Z| < 10$ GeV
  - Third lepton p_T > 20 GeV
  - W transverse mass > 20 GeV $M_T^2 = 2E_{T\ell}E_{T\nu} - 2\mathbf{p}_{T\ell}\mathbf{p}_{T\nu}$

$$\sigma_{WZ}^{tot} = 21.1^{+3.1}_{-2.8}(\text{stat})\ ^{+1.2}_{-1.2}(\text{syst})\ ^{+0.9}_{-0.8}(\text{lumi})\ \text{pb}.$$





Expected limit

Anomalous Coupling	Limits of the 95% C.I.
Δg_1^Z	$[-0.16^{+0.05}_{-0.05}, 0.24^{-0.05}_{+0.05}]$
$\Delta\kappa^Z$	$[-0.7^{+0.2}_{-0.2}, 0.9^{-0.2}_{+0.2}]$
λ	$[-0.14^{+0.04}_{-0.03}, 0.14^{-0.04}_{+0.03}]$

Observed limit

Anomalous Coupling	Limits of the 68% C.I.	Limits of the 95% C.I.
Δg_1^Z	$[-0.17, -0.05], [0.13, 0.26]$	$[-0.21, 0.30]$
$\Delta\kappa^Z$	$[-0.8, -0.2], [0.5, 1.0]$	$[-0.9, 1.2]$
λ	$[-0.15, -0.06], [0.06, 0.15]$	$[-0.18, 0.18]$

$$\frac{\mathcal{L}_{WWZ}}{g_{WWZ}} = i\left[g_1^Z(W^\dagger_{\mu\nu}W^\mu Z^\nu - W_{\mu\nu}W^{\dagger\mu}Z^\nu) + \kappa^Z W^\dagger_\mu W_\nu Z^{\mu\nu} + \frac{\lambda}{m_W^2}W^\dagger_{\rho\mu}W^\mu_\nu Z^{\nu\rho}\right]$$

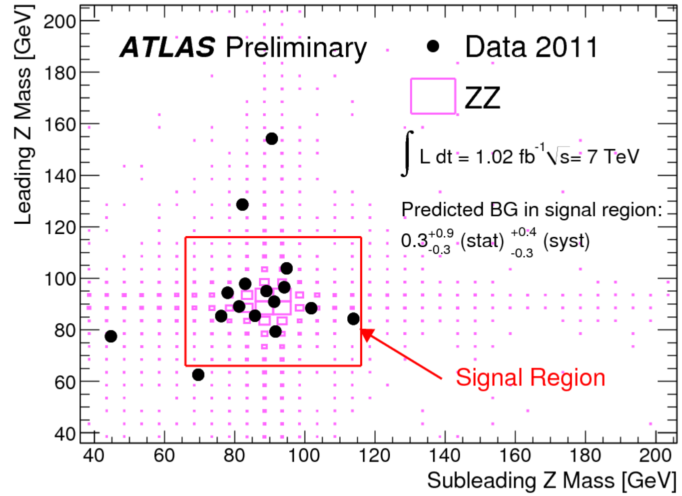
Details of ZZ production measurement

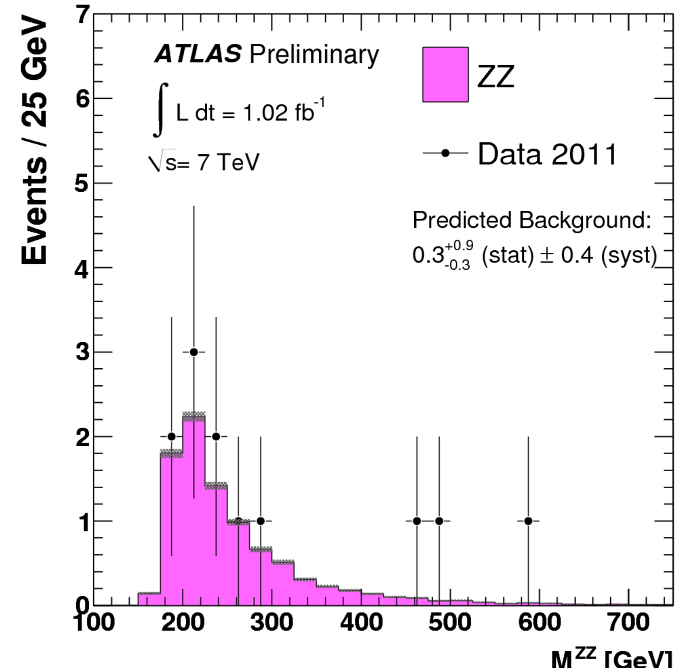
ATLAS-CONF-2011-107

- Event selection
  - 4 good leptons (1 firing the trigger) matched to primary vertex
    - Lepton firing trigger p_T > 20 (25) GeV for μ (e)
  - 2 pairs of same flavour leptons with opposite charge and 66 GeV < M_{ll} < 116 GeV with minimal $|M_{ll} - M_Z|$
  - all lepton p_T > 15 GeV

$$\sigma_{ZZ}^{tot} = 8.4^{+2.7}_{-2.3}\ \text{(stat)}\ ^{+0.4}_{-0.7}\ \text{(syst)}\ \pm 0.3\ \text{(lumi) pb.}$$

- 12 observed events with 0.3 expectation for background
  - Significance of 4.5 σ
- 8 events observed in 4-muon channel, while only 3.3 were expected
  - Probabibility of such fluctuation is 6.4 %





Limit on neutral TGCs (dominated by stat. uncertainty)

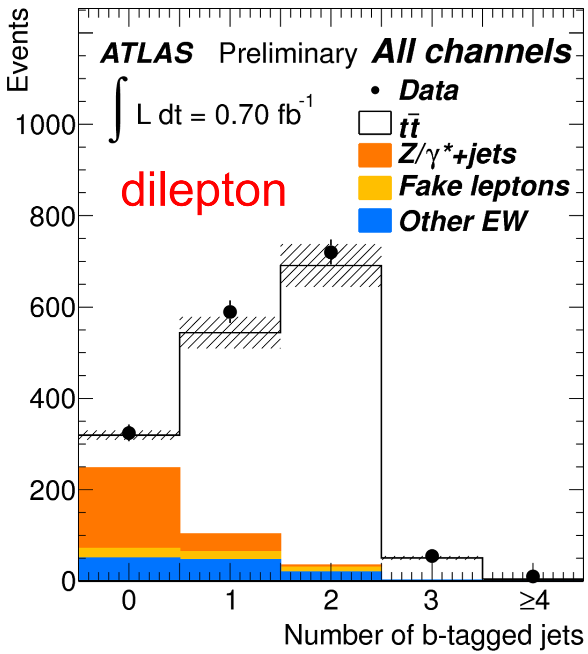
Coupling 95% CI	f_4^γ	f_4^Z	f_5^γ	f_5^Z
Λ = 2 TeV	[−0.15, 0.15]	[−0.12, 0.12]	[−0.15, 0.15]	[−0.13, 0.13]
$\Lambda = \infty$	[−0.08, 0.08]	[−0.07, 0.07]	[−0.08, 0.08]	[−0.07, 0.07]

$$g_{ZZV}\Gamma_{ZZV}^{\alpha\beta\mu} = e\frac{P^2 - M_V^2}{M_Z^2}\left[if_4^V\left(P^\alpha g^{\mu\beta} + P^\beta g^{\mu\alpha}\right) + if_5^V\epsilon^{\mu\alpha\beta\rho}\left(q_1 - q_2\right)_\rho\right]$$

Details of top quark pair production cross section

ATLAS-CONF-2011-100 | ATLAS-CONF-2011-119 | ATLAS-CONF-2011-121

- lepton+jets without b-tagging
  - No b-tagging: smaller systematic error, worse S/B
  - Fit in lepton η, leading jet p_T, aplanarity, $H_{T,3p}$
  - Floating W+jets background
  - Main systematics: JES, ISR/FSR, QCD normalization and shape
  - $\sigma_{tt} = 179.0 \pm 9.8$ (stat.+syst.) ± 6.6 (lumi) pb
- dileptons
  - No b-tagging: missing $E_T > 60$ GeV, Z mass window (ee/$\mu\mu$);$H_T > 130$ GeV (eμ)
  - with b-tagging: missing $E_T > 40$ GeV, Z mass window (ee/$\mu\mu$);$H_T > 140$ GeV (eμ)
  - Z+jets background estimated from data control region
  - Main systematics: JES, b-tagger calibration
  - $\sigma_{tt} = 171 \pm 6$ (stat)$^{+16}_{-14}$(syst)$\pm$ 8 (lumi) pb (no b-tag)
  - $\sigma_{tt} = 177 \pm 6$ (stat)$^{+17}_{-14}$(syst)$^{+8}_{-7}$ (lumi) pb (with b-tag)
- $\mu+\tau_h$+jets
  - missing $E_T > 30$ GeV, μ $p_T > 20$ GeV, $H_T > 200$ GeV, 2 jets ($p_T > 20$ GeV), at least 1 b-tagged jet
  - $\sigma_{tt} = 142 \pm 21$ (stat)$^{+20}_{-16}$(syst)$\pm$ 5 (lumi) pb



SM prediction: σ_{tt} = 164.6 pb

Details of top quark mass measurement

ATLAS-CONF-2011-120

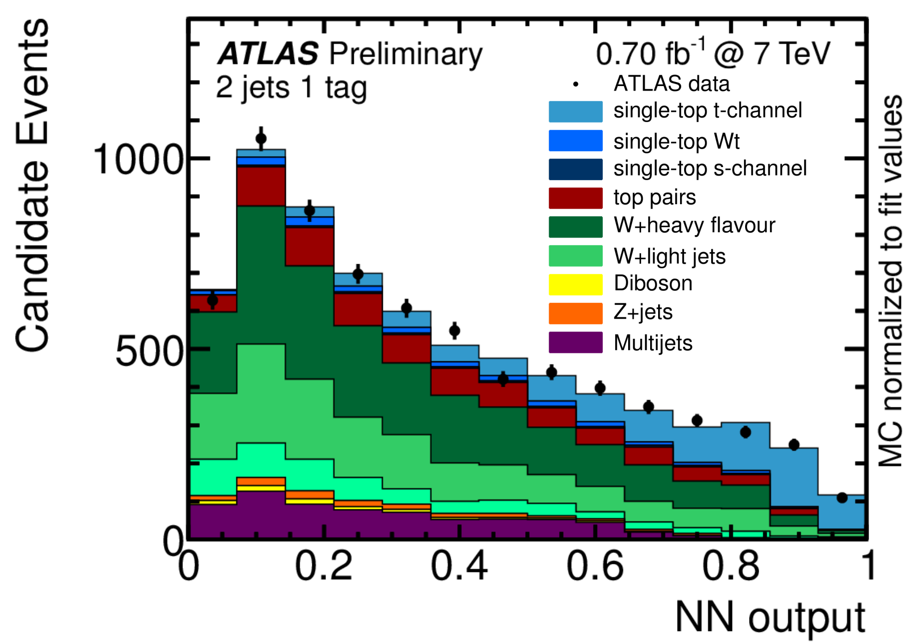
- 2 channels: e+ jets and μ+jets
- Event selection
  - Single lepton trigger fired by exactly one reconstructed lepton with p_T> 25 (20) GeV for e (μ)
  - missing E_T > 35 GeV and $m_T(W)$ > 25 GeV (electron channel)
  - missing E_T > 20 GeV and $m_T(W)+E_T^{miss}$ > 60 GeV (electron channel)
  - At least 4 jets with p_T> 25 GeV, at least one of them b-tagged
- Mass reconstruction
  - Pairs of Light (non-b) jets with reconstructed 50 < m_W < 100 GeV are combined with b-tagged jet => triplet with the maximum p_T is the top candicate
  - Using W mass constraint, correction factor is derived for light jets => applied in top mass reconstruction
  - Using MC, templates for reconstructed top and W mass are made as a function of true top mass and jet scale factor
  - Using maximum likelihood, top mass and jet scale factor are optained for observed distributions of reconstructed top and W mass

Single top production details

ATLAS-CONF-2011-101
ATLAS-CONF-2011-118

- t-channel selection:
  - e/μ (p_T > 25 GeV), 2 or 3 jets (E_T > 25 GeV), E_T^{miss} > 25 GeV, exactly 1 b-tag
  - Descriminating variables: m_{top}, H_T (p_T(lepton) + $p_T(\nu)$ + $p_T(jet_1)+p_T(jet_1)$), |η| of untagged jet (l-jet) and Δη(b-jet,l-jet)
  - NN uses 9 additional variables: m(b-jet,l-jet), H_T, $m_T(W)$, η(lepton), p_T(lepton), lep. charge, E_T^{miss}, E_T (l-jet), m(b-jet), Δη(b-jet,W)

t-channel



- s-channel:
  - Same selection as t-channel, but requiring exactly 2 jets and 1 or 2 b-tag's
  - Cut-based analysis – 7 variables
  - Expecting 285 ± 17 (including 16 ± 6 signal events)
  - Observed 296
  - Profile likelihood ratio used to estimate upper bound on the limit