Measurement of the production cross section for W- and Z-bosons in association with jets in ATLAS

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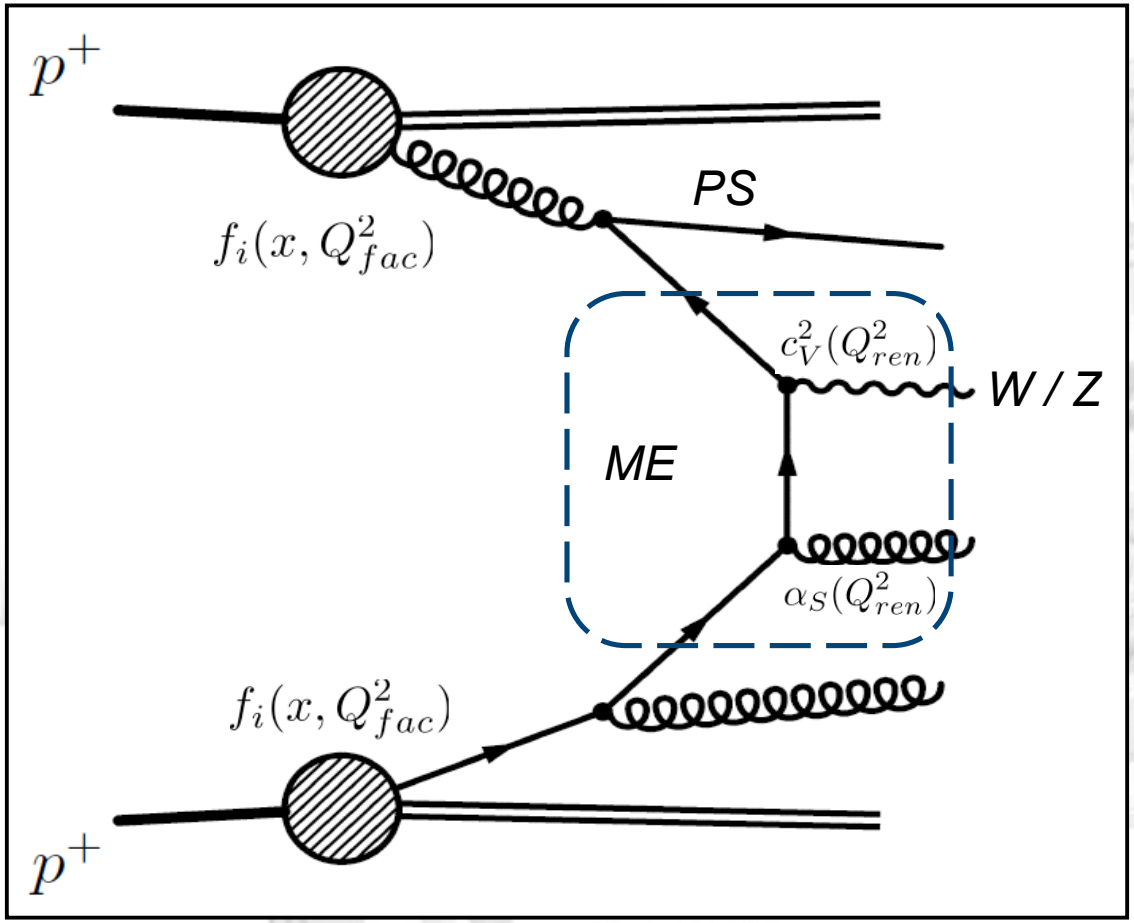
(on behalf of the ATLAS Collaboration)

Motivation for W/Z + jets Measurement



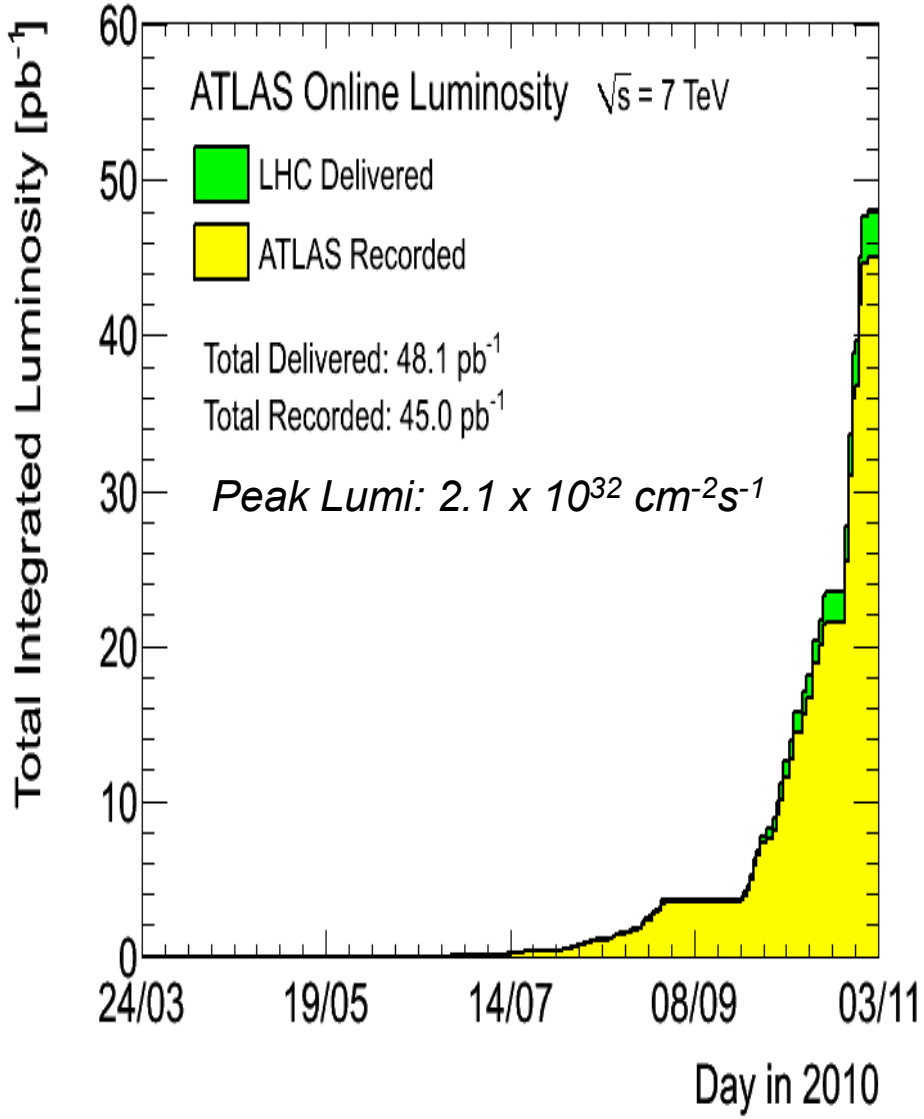
Test of Perturbative QCD

- Parton shower (PS) approach vs matrix elements (ME), and their matching.
- Leading order (LO) vs Next-to-LO (NLO) results.
- Different scales wrt pure QCD events, $Q(m_{W/Z})$.

Control Backgrounds

- SM measurements, e.g. top cross section, W + jets dominating background.
- BSM searches, e.g. zero lepton SUSY search, dominant background from W/Z + jets.

The ATLAS 2010 Data Set



p^+p^+ Collisions at E_{cm} = 7 TeV

All presented results are based on 2010 data.

Integrated Luminosity

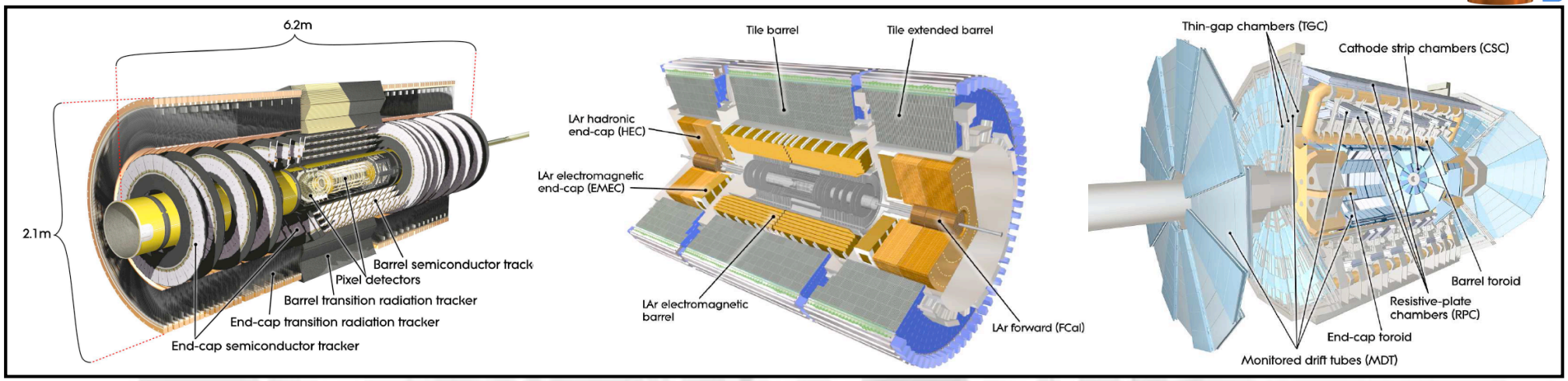
- ATLAS recorded luminosity, 45 pb^{-1}
- Data used in these analysis, 33 pb^{-1}

2010 analysis used electron and muon decay channels.

Events Samples *(l = e or μ)*

- *O(130k)* selected W($l\nu$) candidates per channel.
- *O(10k)* selected Z(ll) candidates per channel.

The ATLAS (W/Z + jets) Acceptance



Inner Detector

- Pixel + SCT, $|\eta| < 2.5$.
- TRT, $|\eta| < 2.0$.

Calorimeter

- LAr + Tile , $|\eta| < 3.2$.
- FCAL, $|\eta| < 4.9$.

Muon Spectrometer

- MDT + CSC, $|\eta| < 2.7$.
- RPC + TGC, $|\eta| < 2.4$. (trigger chambers)

Electrons used within ID acceptance ($|\eta| < 2.5$)

Muons used within trigger acceptance ($|\eta| < 2.4$)

Jets used within main calorimeter acceptance ($|\eta| < 3.2$)

Missing E_T based on full calorimeter acceptance ($|\eta| < 4.5$)

ATLAS W/Z + jets Analysis

Measurements within Kinematic Region well Covered by Detector Acceptance

Electrons
- E_T > 20 GeV
- $|\eta|$ < 2.47
- Excluding, 1.37 < $|\eta|$ < 1.52

Muons
- p_T > 20 GeV
- $|\eta|$ < 2.4

Jets
- Anti-k_T algorithm (R=0.4)
- ***p_T > 20 or 30 GeV (W or Z)***
- $|y$ or $\eta|$ < 2.8
- $\Delta R(l,j)$ > 0.5

(Lepton p_T selection based on trigger plateau)

W Selection
- Exactly one *l* (*l* = *e* or μ)
- Missing E_T > 25 GeV
- m_T > 40 GeV

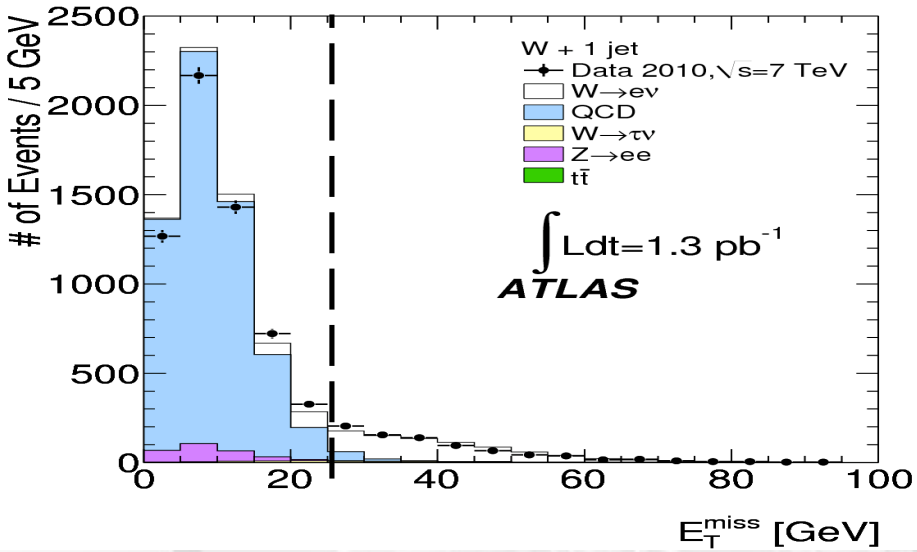
Z Selection
- Exactly two opposite charge *l* (*l* = *e* or μ)
- 66 < m_{ll} < 116 GeV

Results corrected for detector effects, using a bin-by-bin unfolding method.

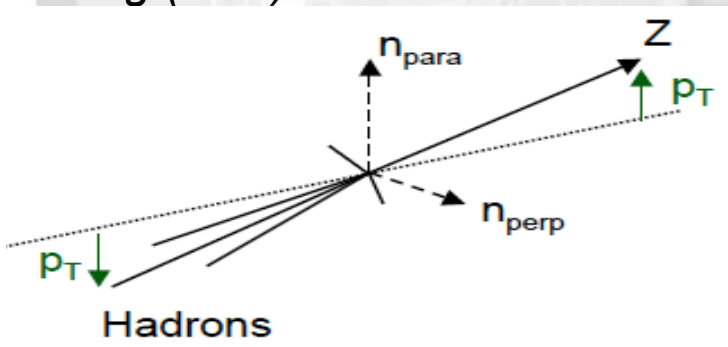
Theory (MC) predictions in same kinematic region
- Jets from all particles with longer lifetime than 10ps, except (W/Z) leptons.
- Lepton momentum include photons radiated within ΔR<0.1.

Backgrounds and Uncertainties

QCD background from Template Fit in Control Region.



Cross check reconstructed MET in W events using (fake) MET in Z events.



Background Estimation

- *QCD background from data.*
- *Electroweak* background from MC.
- *top* background from MC.

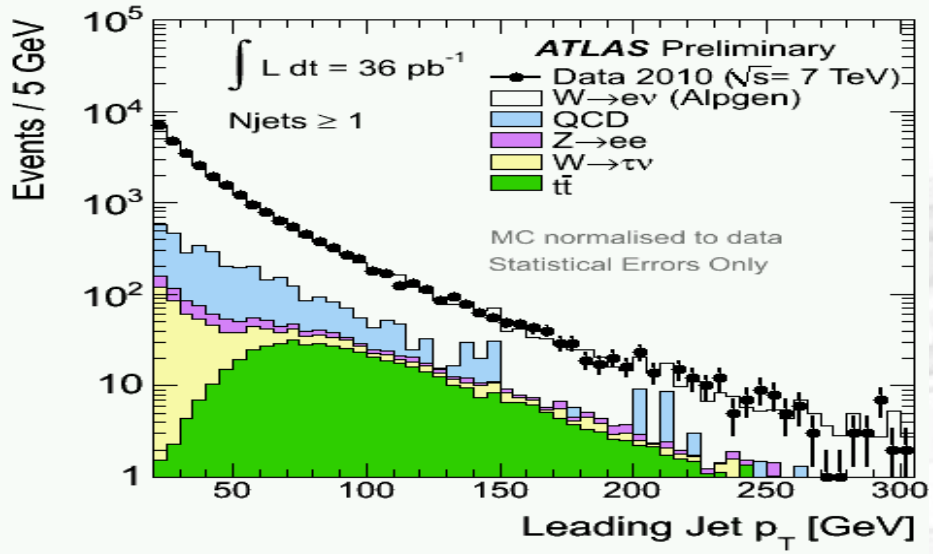
Main Experimental Uncertainties

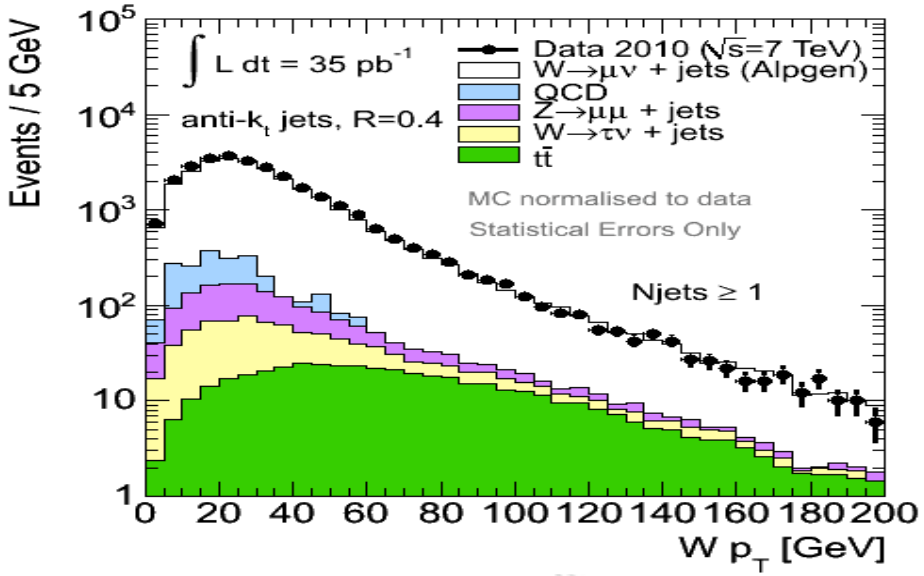
- Jet energy scale (~10%)
- Pile-up removal (~5%)
- Luminosity (~4%)

Estimated from Data

- Lepton reconstruction and efficiencies.
- *Missing E_T (cross checks from data).*

W + jets Results at Detector Level

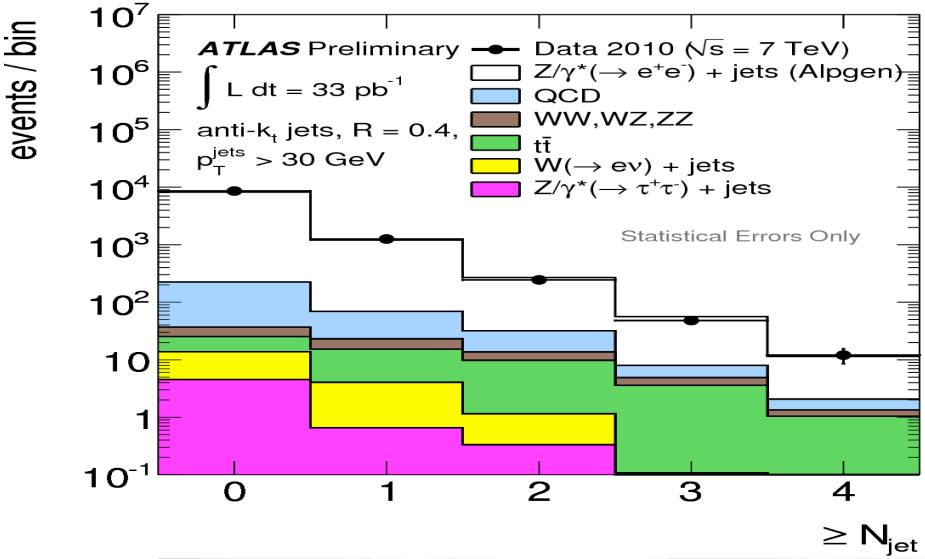


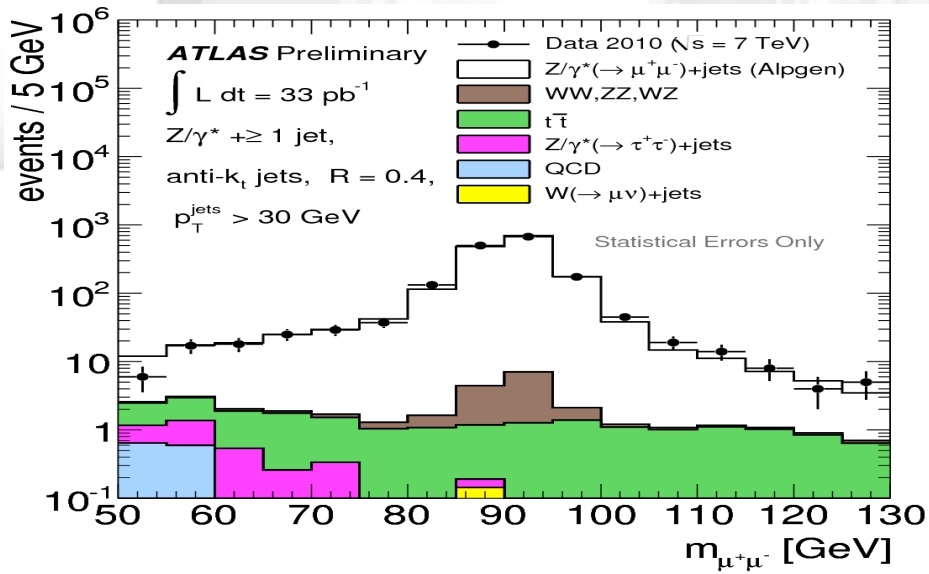


Distributions at Detector Level
(no corrections for detector effects)

- Overall a good agreement with expectation from MC, in both *e* and μ channel.
- Background *O(10%)* in electron and muon channel.
- *QCD* mainly affect electron channel and dominates at low p_T.
- *ttbar* generally becomes more relevant with increasing p_T.
- Cross section measurement based on events with 1 up to 5 (inclusive) jets.

Z + jets Results at Detector Level





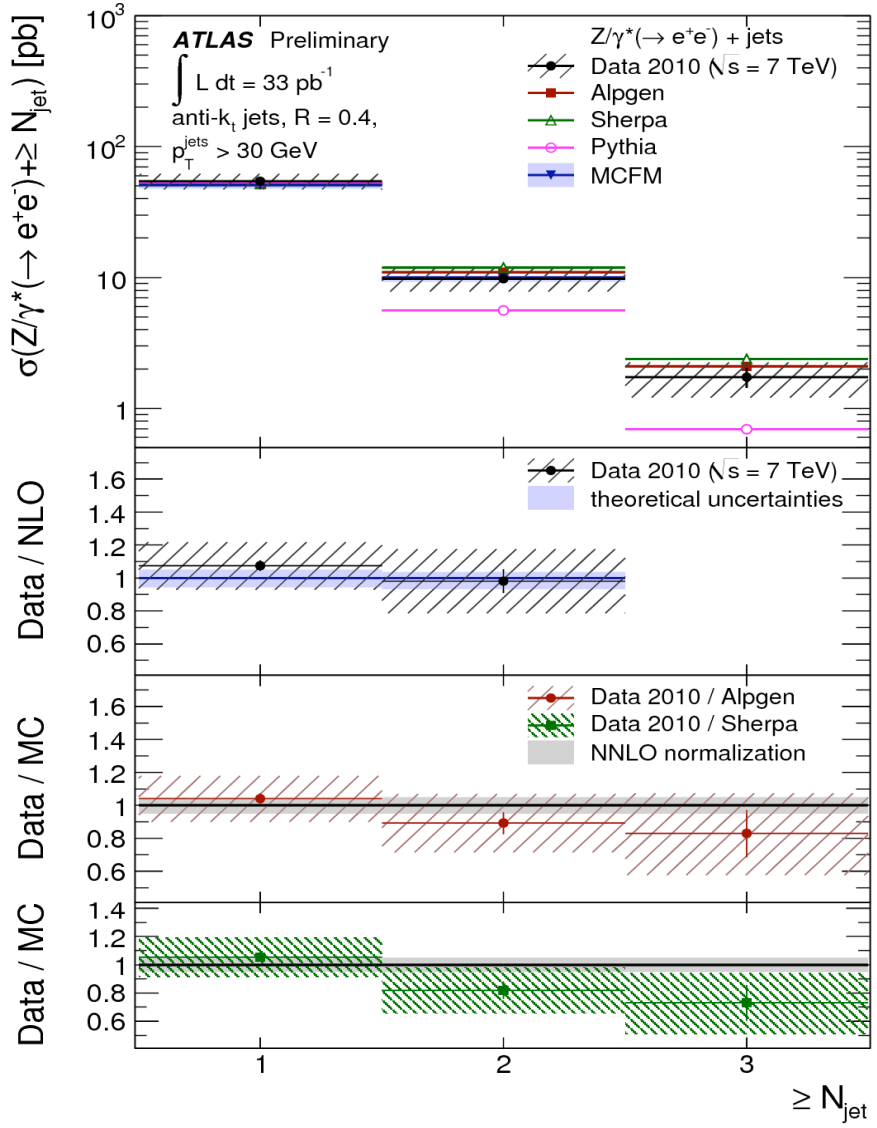
Distributions at Detector Level
(no corrections for detector effects)

- Overall a good agreement with expectation from MC, in both *e* and μ channel.
- Background *O(5%)* in electron and *O(1%)* in muon channel.
- *QCD* mainly affects electron channel and dominates in events with fewer number of jets.
- Main background in muon channel from *ttbar* and *VV* (*V* = *W/Z*).
- Cross section measurement based on events with 1 up to 3 (inclusive) jets.

The Cross Section Results

All results correspond to an Inclusive Measurement of the (unfolded) Differential Cross Sections

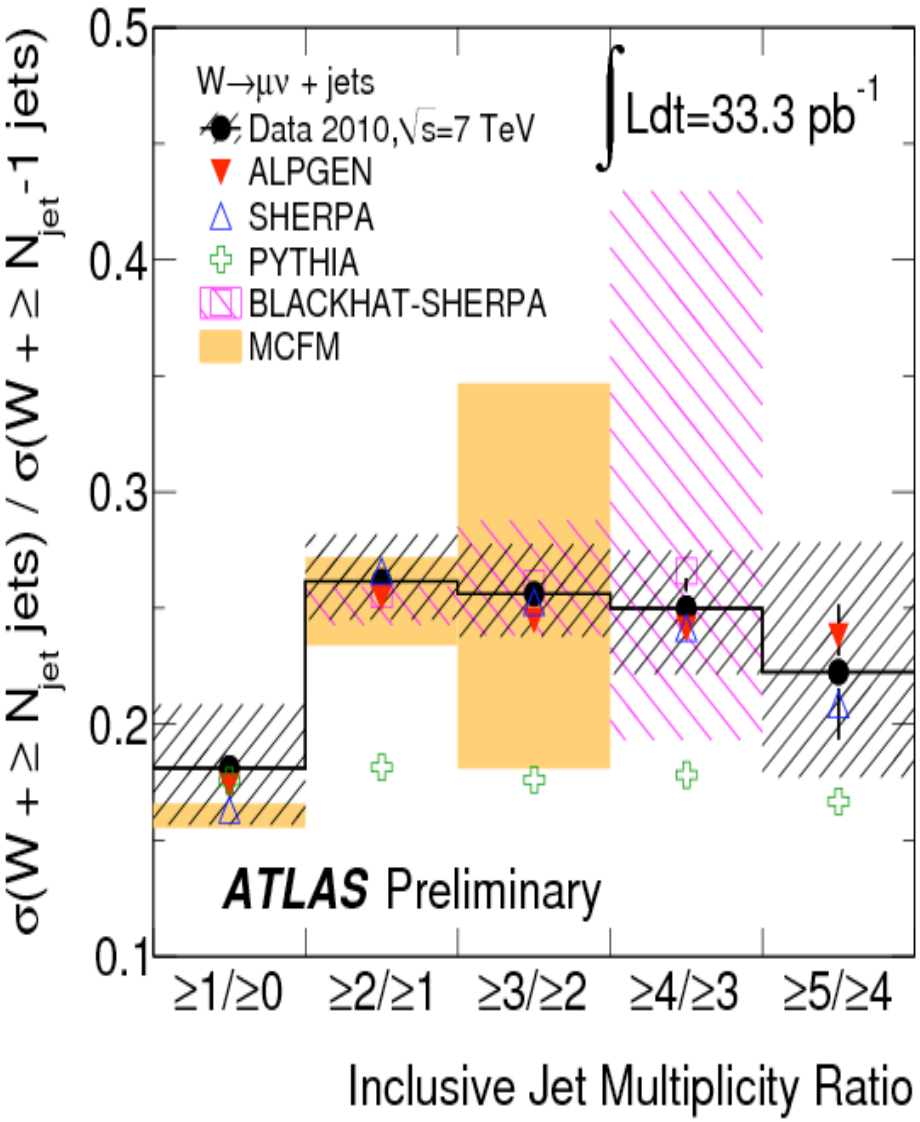
Z + jets Cross Section wrt Jet Multiplicity



Corrected Results in Kinematic Region

- Good agreement with expectation from NLO MC (MCFM).
- Good agreement with cross section predicted by multi-parton ME MC programs (Alpgen and Sherpa).
- Poor agreement with LO plus parton shower MC (Pythia) for events with more than one jet.
- Pythia discrepancy, combination of not properly covered phase space (Z not produced by parton shower) and parton shower approach.

W + jets Cross Section Ratios



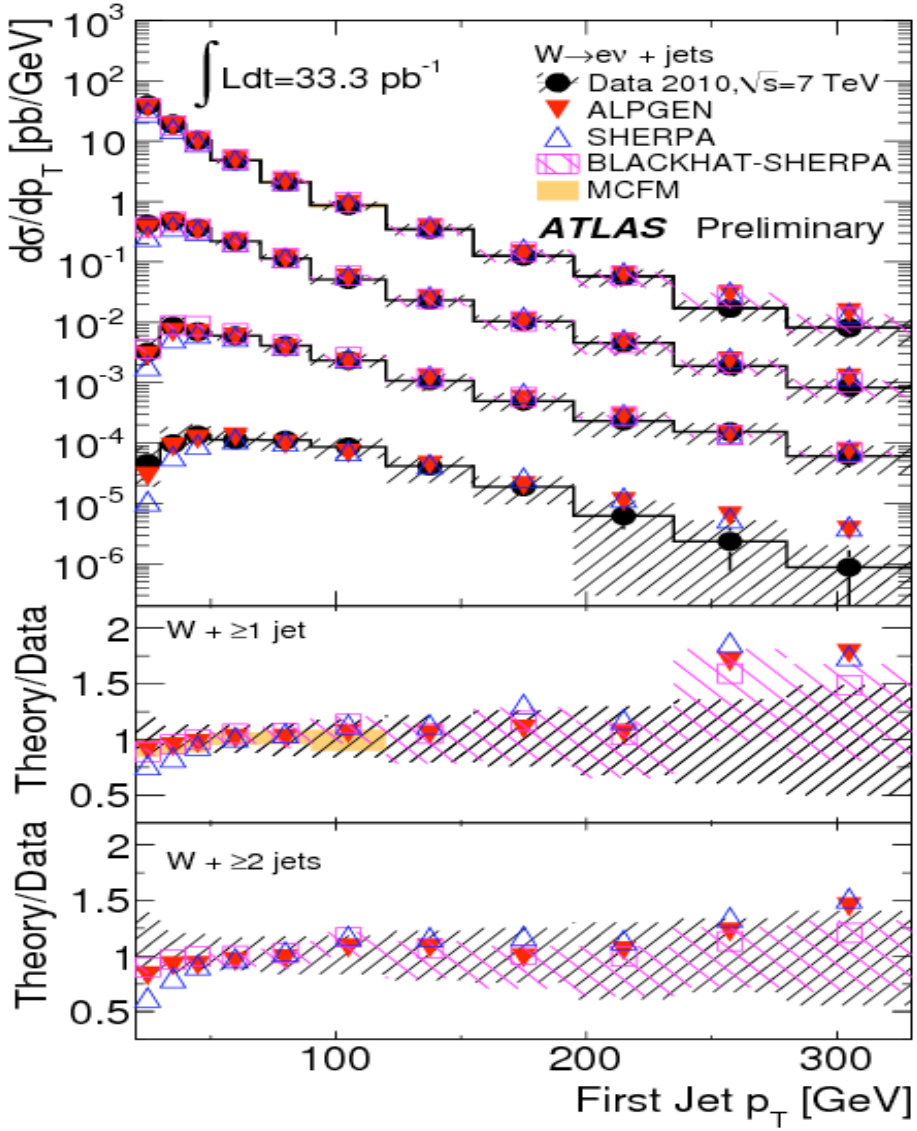
Corrected Results in Kinematic Region

- Ratio reduces some uncertainties, e.g. from luminosity.
- Good agreement with expectation from NLO MC (MCFM and Blackhat-Sherpa).

First time W + 3 jets at NLO vs LHC data!

- Good agreement with cross section predicted by multi-parton ME MC programs (Alpgen and Sherpa).
- Poor agreement with LO plus parton shower MC (Pythia) for events with more than one jet *(same reason as on slide 10).*

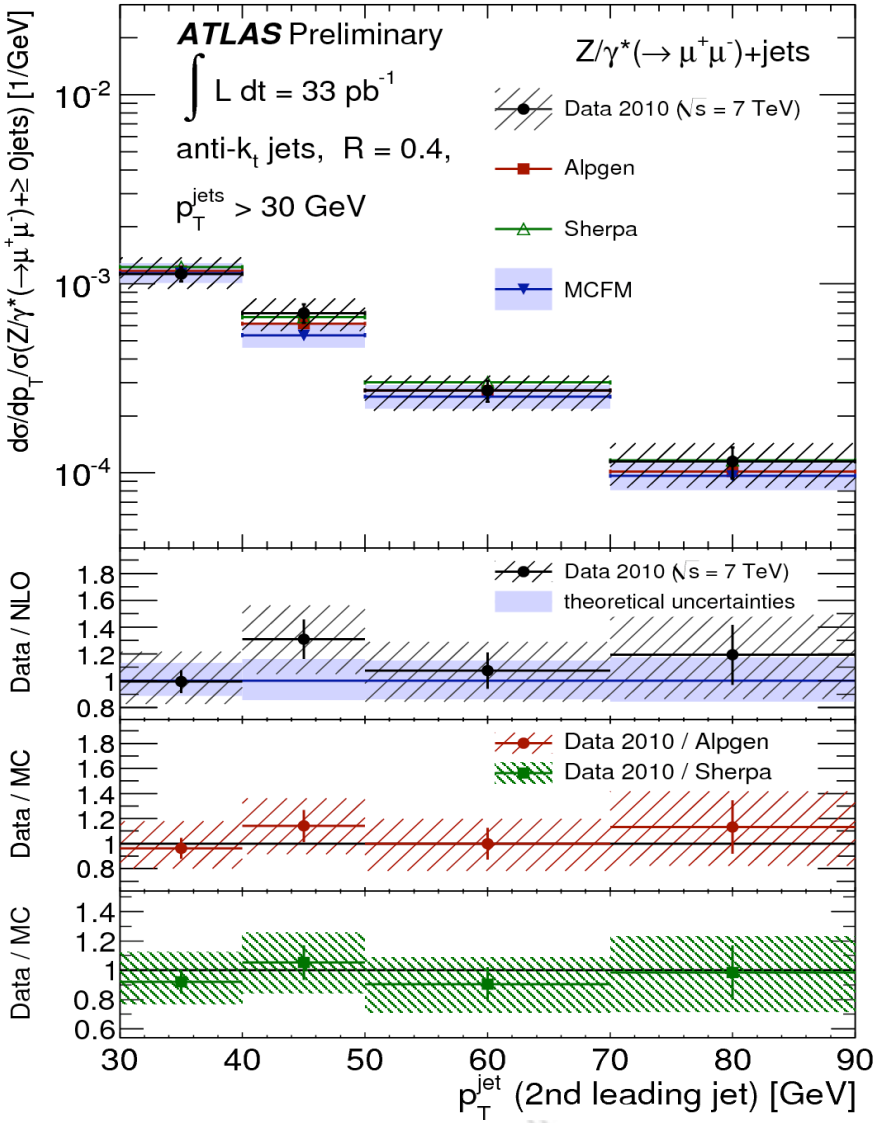
W + jets Cross Section wrt First Jet p_T



Corrected Results in Kinematic Region

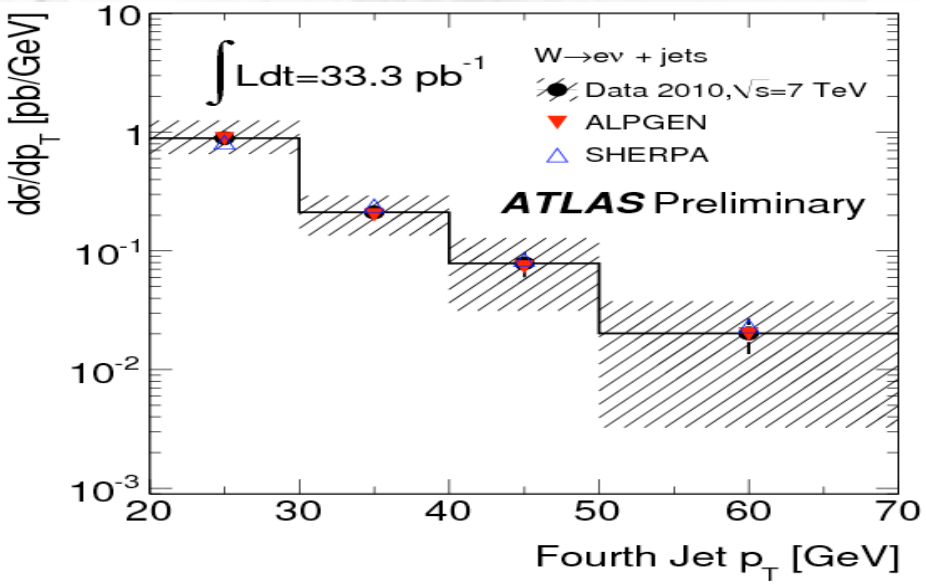
- Measured separately for events with 1 up to 4 jets.
- Good agreement with expectation from NLO MC (MCFM and Blackhat-Sherpa).
- Good agreement with cross section predicted by multi-parton ME MC programs (Alpgen and Sherpa).

W/Z + jets Cross Section wrt N^{th} Jet p_T

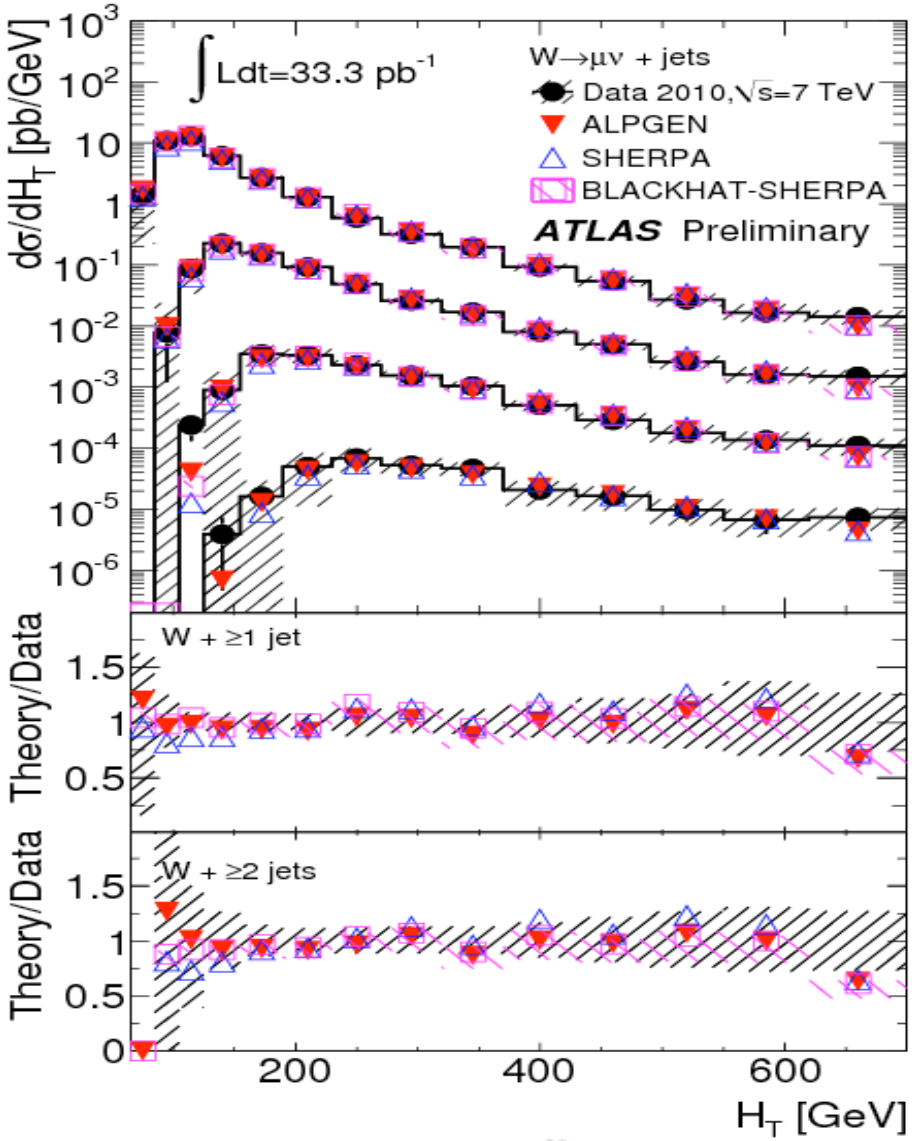


Corrected Results in Kinematic Region

- Good agreement with expectation from multi-parton ME MC, also for the additional jets in the event.



W + jets Cross Section wrt H_T



Corrected Results in Kinematic Region

$$H_T = \sum_i p_T^{jet_i} + p_T^{\ell} + p_T^{\nu}$$

- Quantity used as the characteristic scale of the hard process in multi-parton ME MC.
- Measured separately for events with 1 up to 4 jets.
- Good agreement with prediction from MC.

Conclusions

- Measurements of the W + jets and Z + jets cross sections have been made using the full 2010 data set from the ATLAS experiment.
- The cross section is measured within a kinematic region covered by the detector acceptance, including corrections for detector effects.
- Cross sections have been measured with respect to the number of jets, the p_T of the jets, the H_T as well as the ratio of different jet multiplicities.
- The results show good agreement with NLO predictions, obtained by MCFM and Blackhat-Sherpa.

W + 3-jets at NLO (Blackhat-Sherpa) compared for the first time with LHC data!

- Multi-jet results also show good agreement with predictions from multi-parton matrix element MC programs, obtained by Alpgen and Sherpa.

ATLAS Public Results: https://twiki.cern.ch/twiki/bin/view/AtlasPublic

W + jets: ATLAS-CONF-2011-060 ---- Z + jets: ATLAS-CONF-2011-042