W/Z+jets cross section measurements at ATLAS

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On behalf of the ATLAS collaboration

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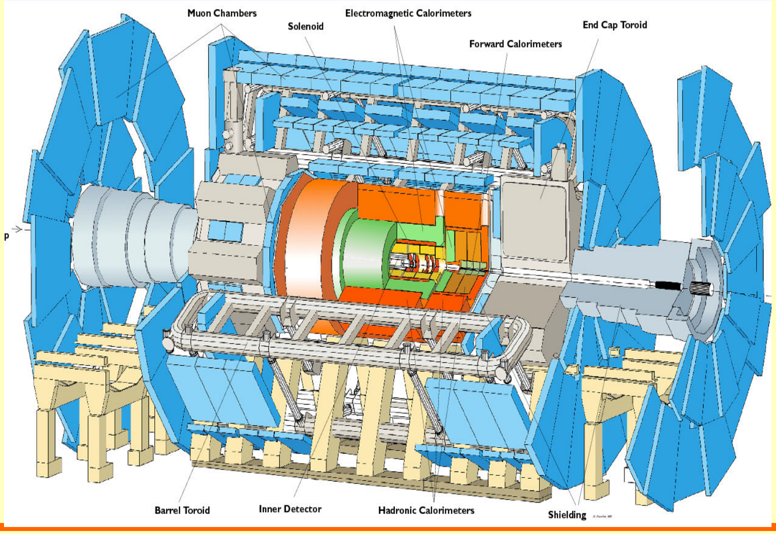
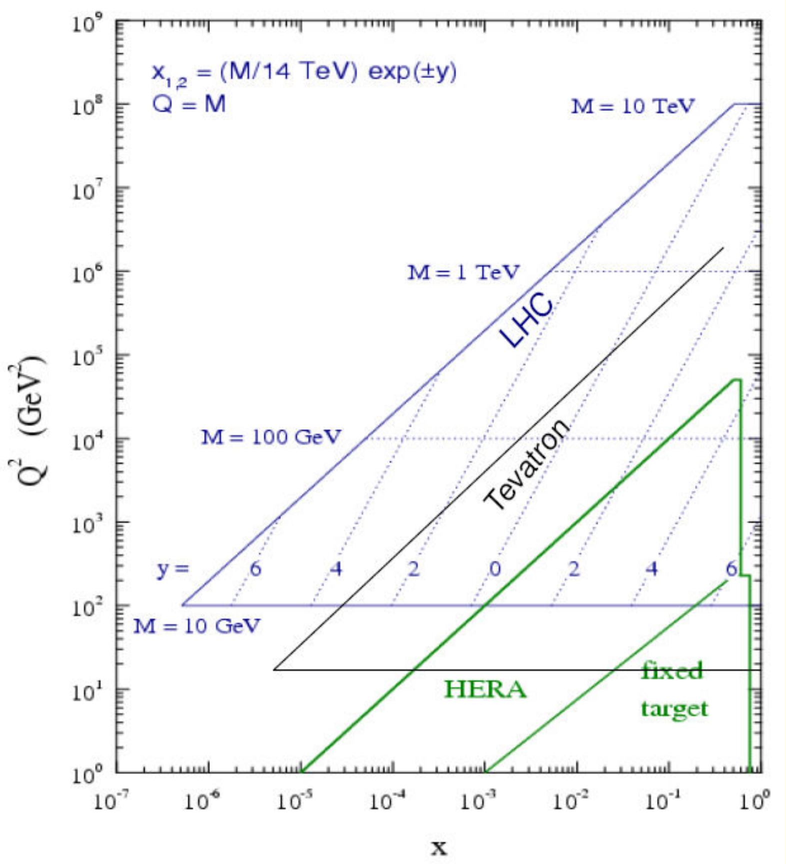


Outline

- Motivation for W/Z+jets studies in ATLAS
- MC data analysis
  - W/Z+jets cross sections as a function of Jet multiplicities, Jet P_T
    - Selected results from the MC analysis at 14 TeV
    - Z+jets (with $Z \rightarrow ee$, $Z \rightarrow \mu\mu$)
    - W+jets (with $W \rightarrow e\nu$, $W \rightarrow \mu\nu$)
    - Discuss some experimental techniques
      - ✓ Efficiencies, unfolding etc
- Predictions of systematic uncertainties
- Theoretical predictions
  - Comparison of LO and NLO QCD calculations
  - Cross section predictions from different generators (matrix element, parton-showers)
- Conclusions

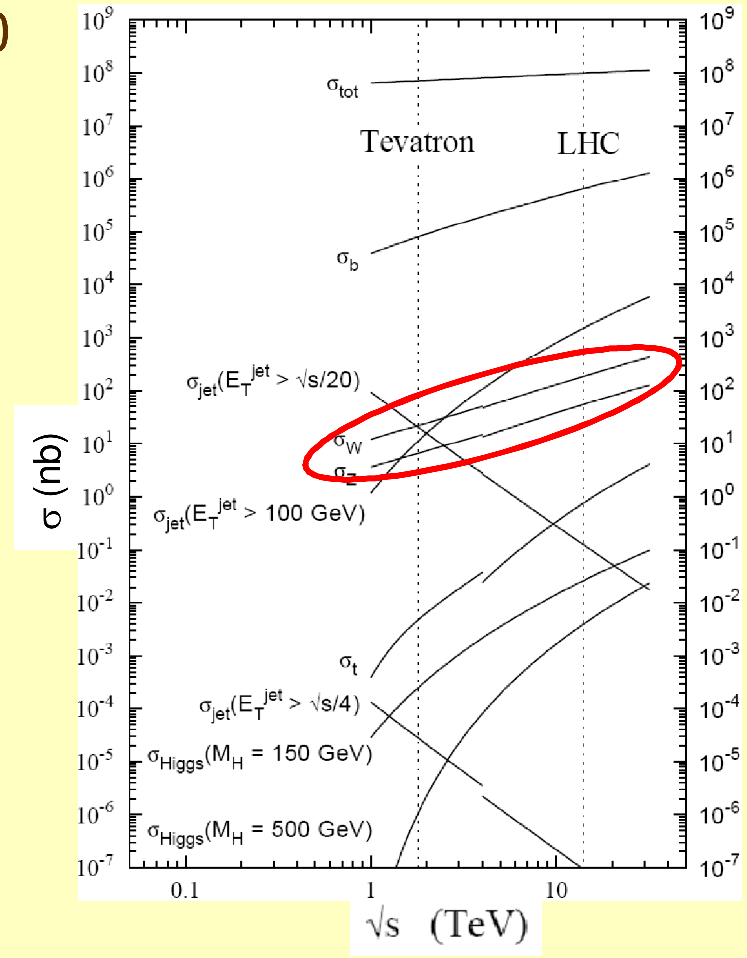
Motivation for W/Z+jets studies

- Probing perturbative QCD
  - Abundance of quark and gluon interaction at LHC to understand QCD
  - Probing PDFs in unexplored region of high Q^2 and low x
    - Inclusive W and Z could be sensitive probe at fairly low Q^2
  - NLO calculations of boosted W/Z bosons
  - Large phase space for additional jets
- Benchmarks analysis
  - Abundant statistics of well understood W/Z along with jets for performance studies
    - Involve all players:
      - ✓ Leptons, jets, missing transverse energy
    - In-situ measurements of leptons efficiency
    - Reconstruction of leptons and missing energy in jetty environment
    - Jet energy balancing
- Background to SM and beyond SM physics
  - Top measurement, SUSY and Higgs searches



W/Z+Jets production at LHC

- W and Z cross section at LHC are ~10 larger than Tevatron
  - Expected statistics at 100 pb^{-1},
    - ~25K Z events in the leptonic channel
    - ~250K W events in the leptonic chanel
    - ~100M triggered jet events
  - Production with multijets enhanced as well
- W/Z+jet production at LHC via qqbar or quark, gluon interactions



MC simulation and event selection

- Analysis done with 1 fb^{-1} pseudo-data at 14 TeV
- Signal event generation with Alpgen (W/Z + Npartons) + Herwig (shower evolution)
  - Using LO PDF set CTEQ6LL and MLM matching scheme
- Background samples generated with Pythia, Alpgen, MC@NLO for dijet, W, Z, top quark samples
- LO and NLO distributions from MCFM(parton level generator)
  - LO calculations for W/Z+ X jets, X=0,1,2,3
  - NLO calculations for W/Z+ X jets, X=0,1,2

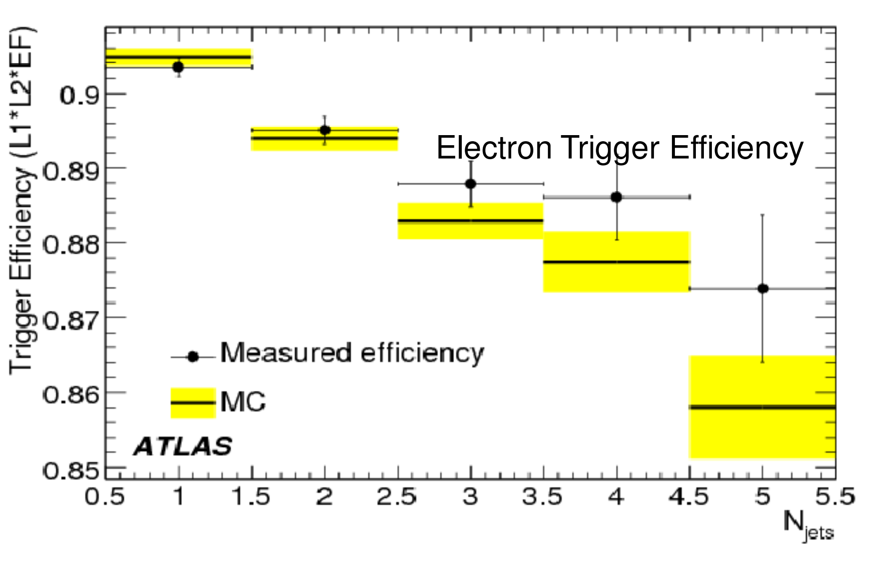
- Z(ee,$\mu\mu$) +Jets selection:
- double isolated lepton trigger
- at least 2 lepton with Pt > 25GeV(e), 15 GeV (μ)
- leptons invariant mass in 10 GeV window
- Jets: Cone 0.4 jets (E_T >40GeV)

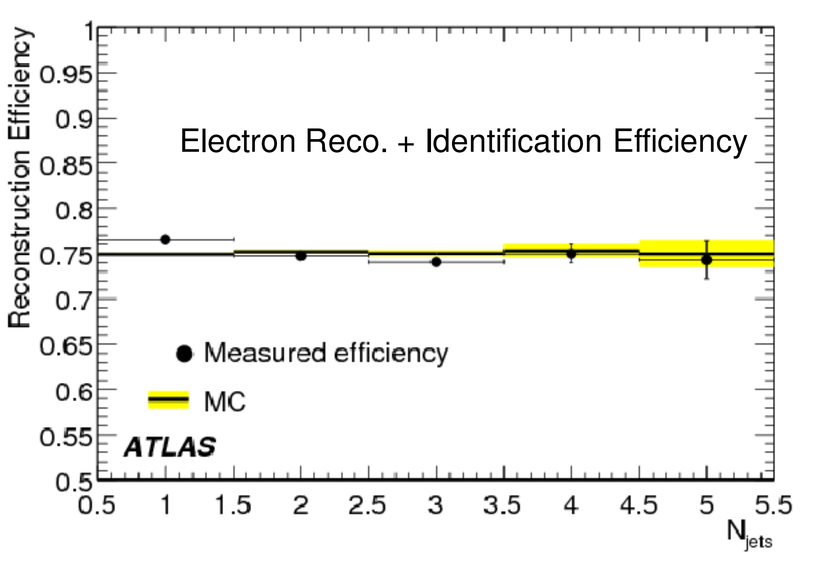
- W(eν,$\mu\nu$) +Jets selection:
- single isolated lepton trigger
- at least 1 lepton with Pt > 25GeV(e), 20 GeV(μ)
- Missing Et > 25 GeV
- Jets: Cone 0.4 jets (ET >40GeV)

Lepton In-situ efficiencies

- Lepton trigger and reconstruction efficiencies measured using data driven method, “tag-and-probe” on Z->ll
  - One lepton passes tight selection (tag)
  - Measure efficiency on 2nd lepton from Z (probe)
- Effect of jetty environment:
  - Trigger efficiency decreases due to isolation requirement at L1
  - Offline reconstruction efficiency not affected

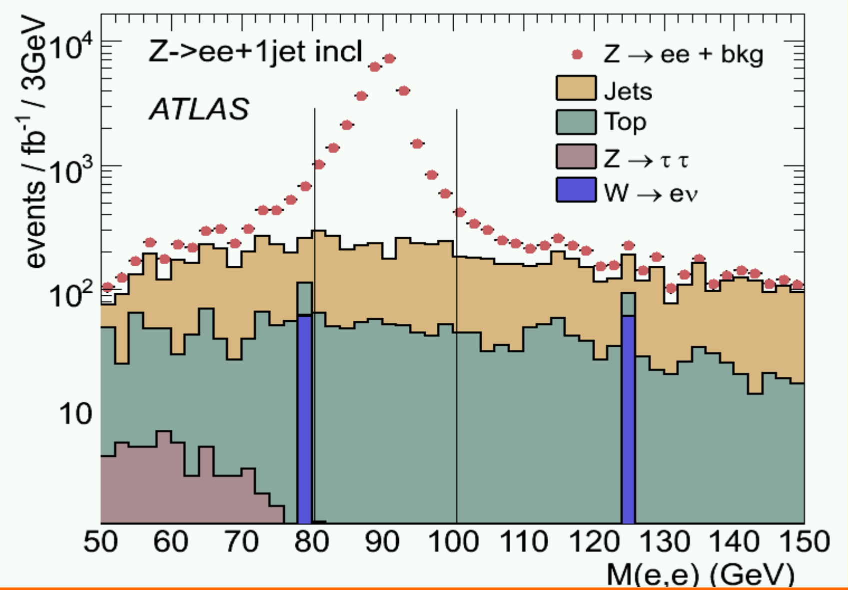
Data here is “pseudo-data”

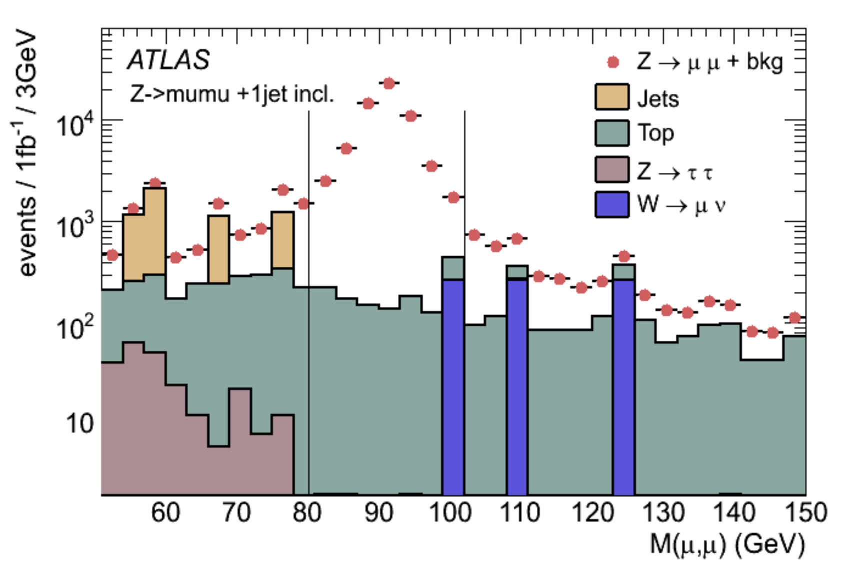




Z+jets analysis (on pseudo data)

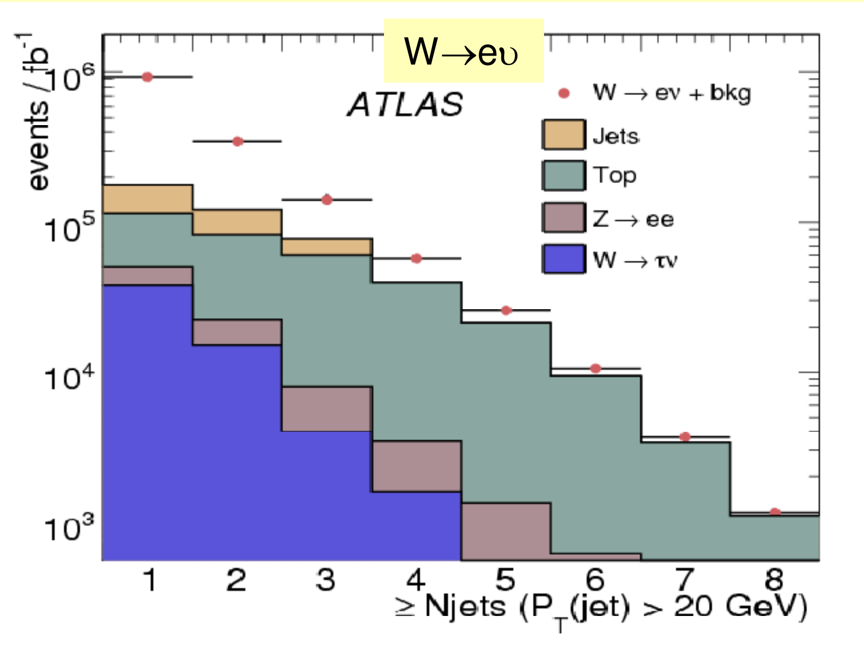
- Signal: Z(ee,μμ) +Jets
- Background:
  - processes with real leptons (ttbar, Z->ττ, W->lυ) estimated and subtracted using MC
  - Weighting factors used for QCD multijets due to the enormous cross section
- Total background~5-15%, with increasing jet multiplicity ttbar dominated QCD background

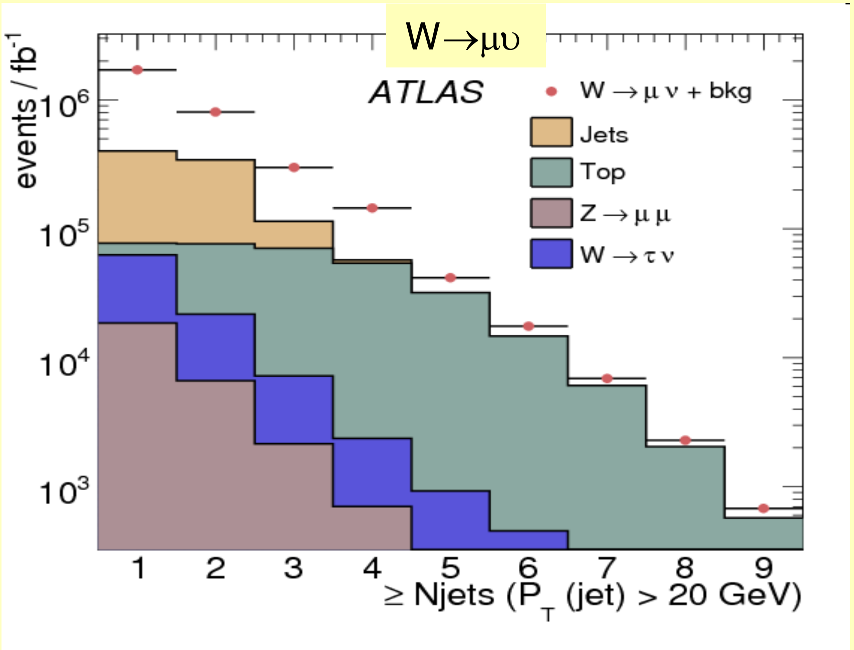




W+jets analysis (on pseudo data)

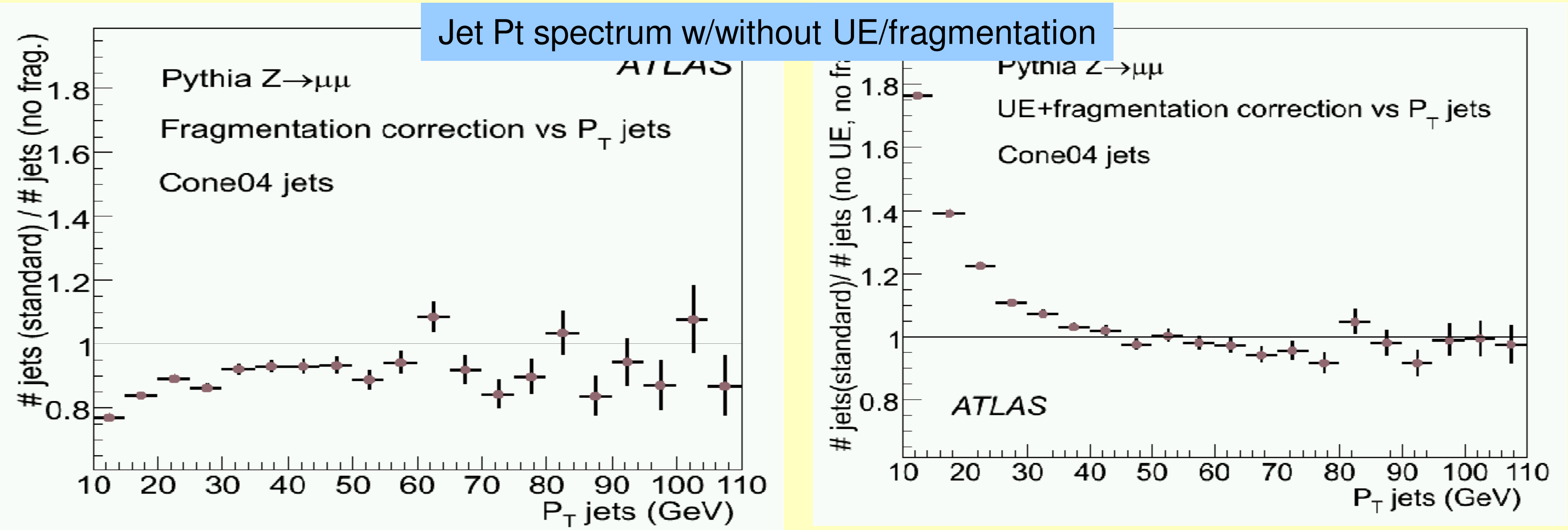
- Isolated electron/muon with pT>20GeV
- Cone 0.4 jets with E_T > 20GeV
- Final result require Etmiss > 25 GeV





Unfolding from parton-hadron level

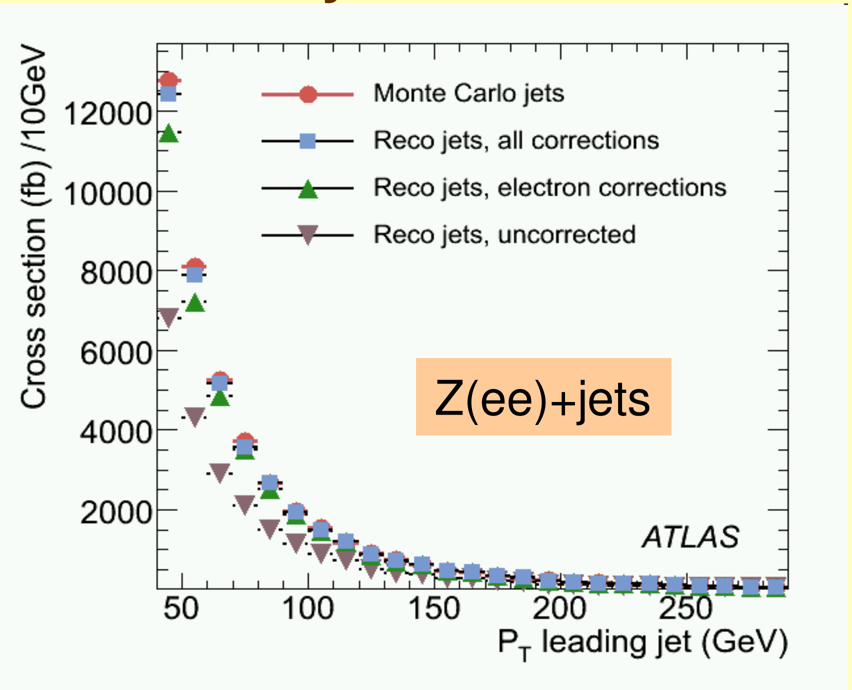
- Measurements compared to theory at hadron(or lepton) level
  - Correct MCFM results for non-perturbative effects
    - Fragmentation
      - ✓ Large out-of-cone energy loss
      - ✓ Reduces jet energies
      - ✓ More low-pt jets
    - Underlying event (UE)
      - ✓ Larger cluster energy deposit
      - ✓ Increases jet energy
  - UE and fragmentation have opposite effects
  - balance achieved above 40 GeV (cut used in cross section measurements)

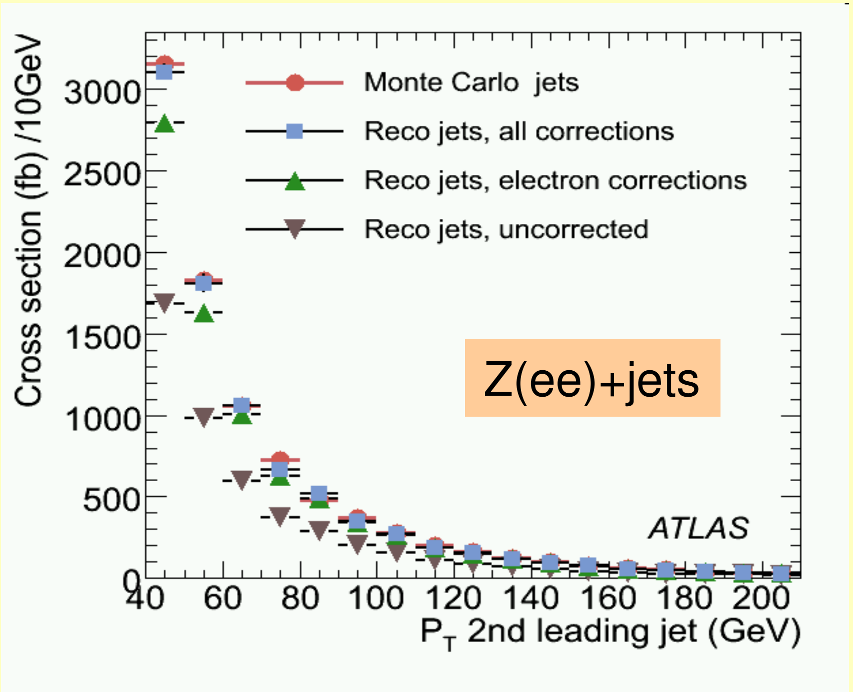


Jet Pt spectrum w/without UE/fragmentation

Unfolding of detector effects

- Need to unfold data from detector level to hadron (lepton) level
  - Correct for electron efficiencies, resolutions
  - Correct for jet reconstruction efficiency, energy resolution
- Reasonable agreement between the pt distribution of truth and corrected jets

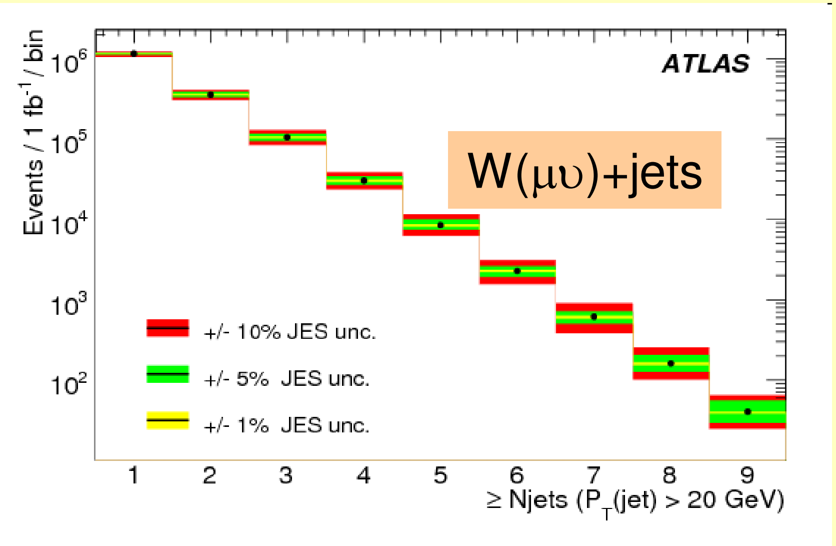


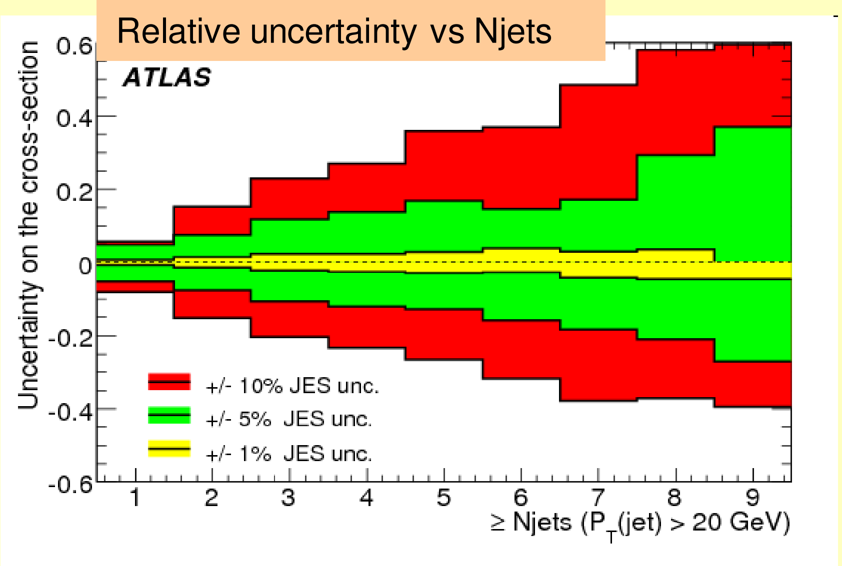


Systematic uncertainties

Jet energy scale (JES) uncertainties

- Dominant experimental systematic for W/Z+jets at the LHC
- ATLAS goal is to have JES uncertainties ~1-2%
  - With early data expect uncertainities~5-10%
- Shift jet energies in W($\mu\nu$)+jet events to estimate effect
  - Shift energies by ±1, ±5, ±10%
- Systematic on cross section~10-20% for JES uncertainty of 5%
- Ultimate goal of 1% yields systematic of within 5%
- Expect to use Z+jets for jet balancing calibration as well

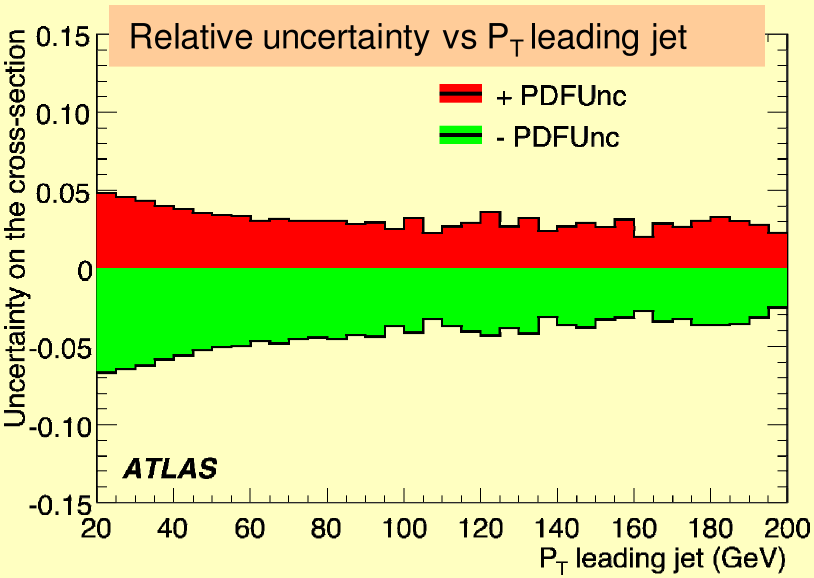


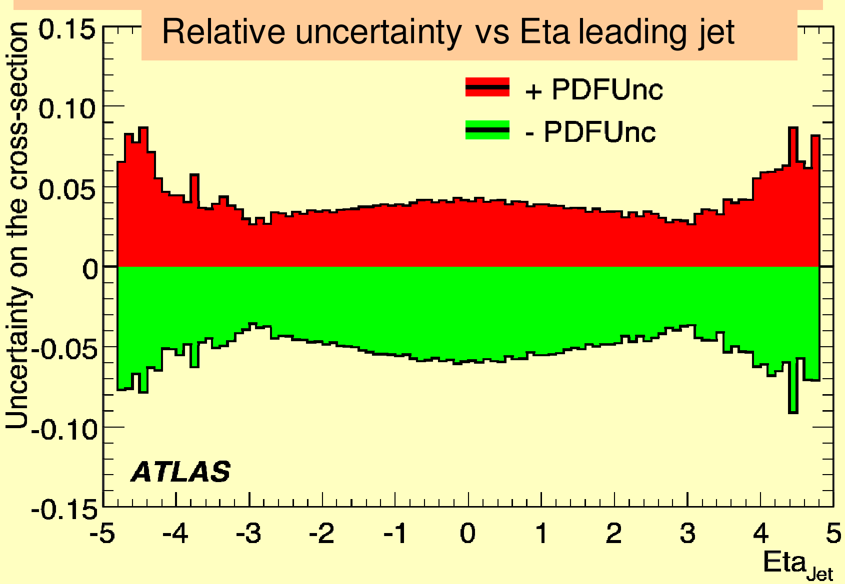


PDF uncertainties

- Dominant source of theoretical uncertainties
  - Effect every cross section calculation at LHC
- PDF uncertainties calculated with reweighting W(eν)+jet events from CTEQLL to CTEQ6M(NLO)
- Investigate effect of CTEQ6M error sets on cross section
  - Affect jet acceptance through η and p_T
  - Effect on cross section < 5%

PDF uncertainty <= JES Uncertainty



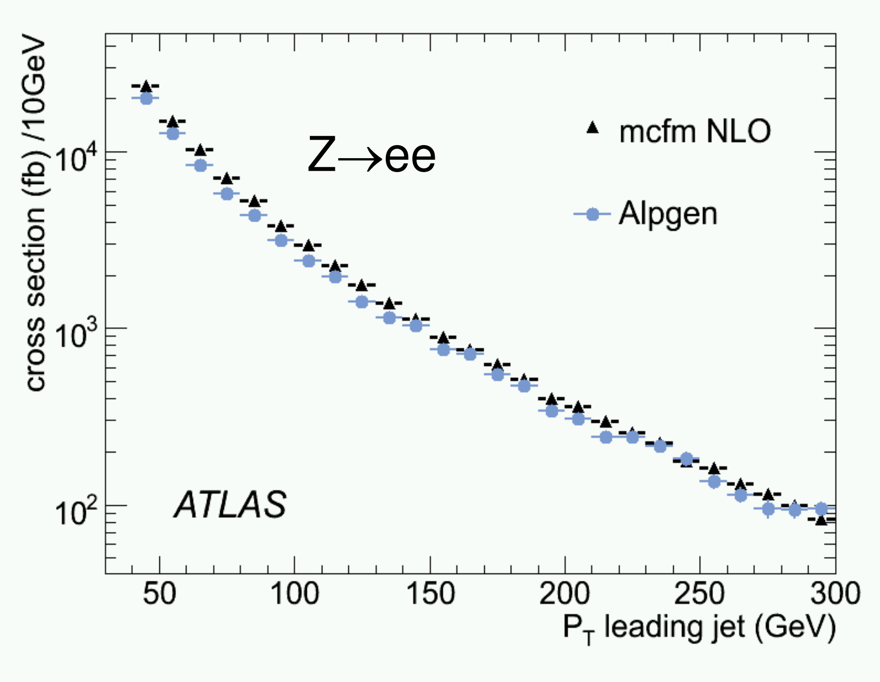


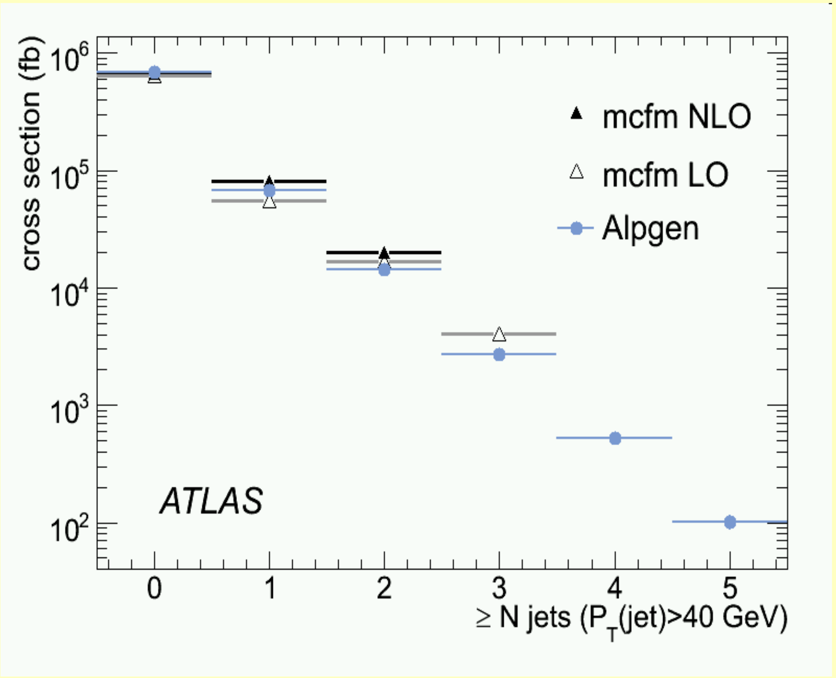
Z+jets cross section

- MCFM results corrected to hadron level
  - Included UE and fragmentation corrections
- Pseudo Alpgen data unfolded to hadron level
  - JES and PDF uncertainties included
- Good agreement between pseudo data and MC

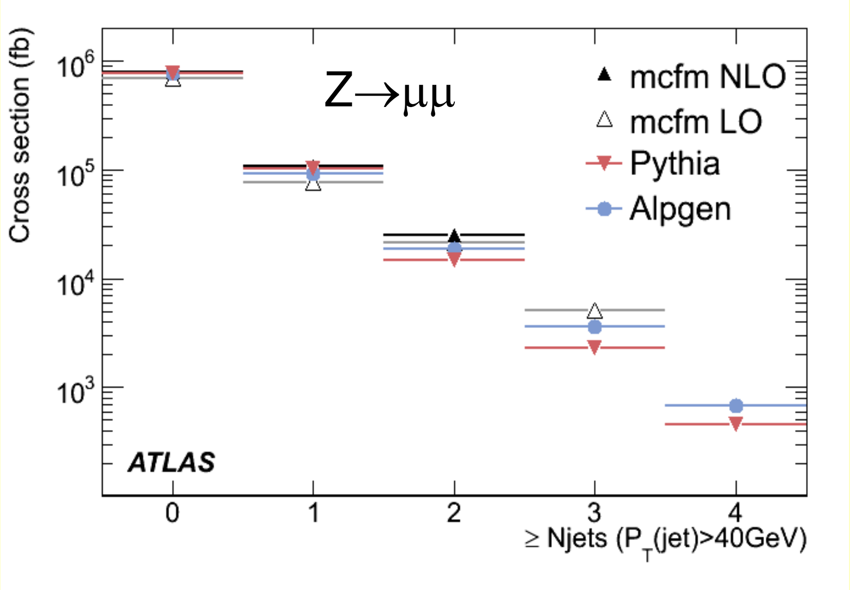
Cross section:

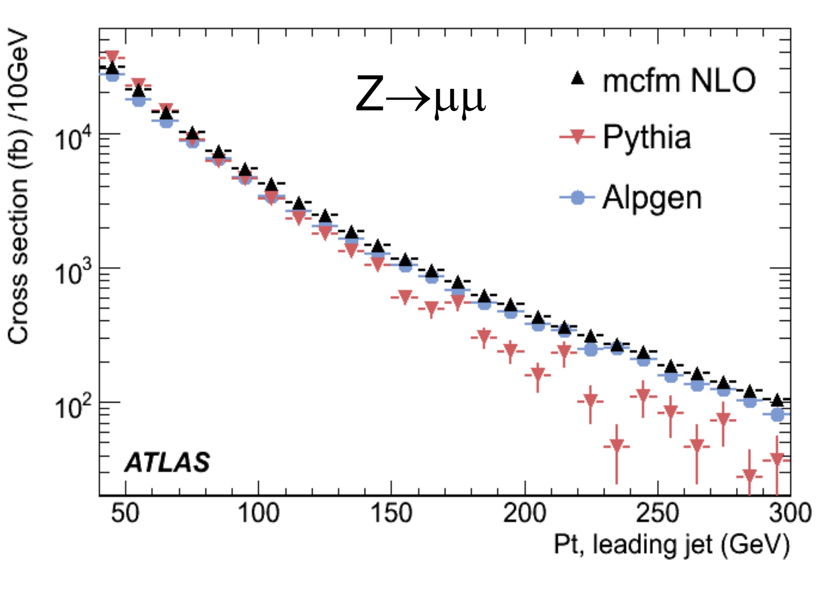
$$\sigma = \frac{N^{sig} - N^{bkg}}{A \bullet \varepsilon \bullet \int L dt}$$





Theoretical Predictions

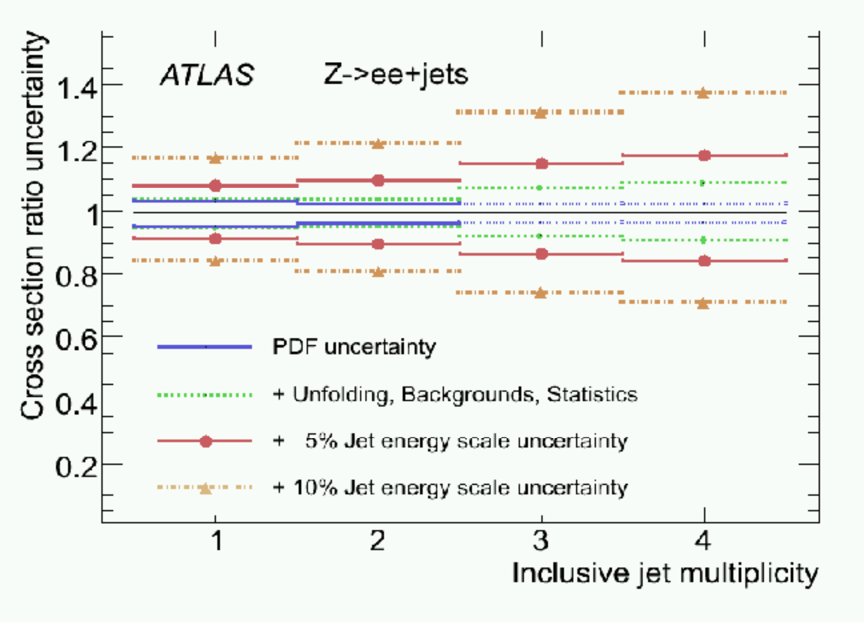


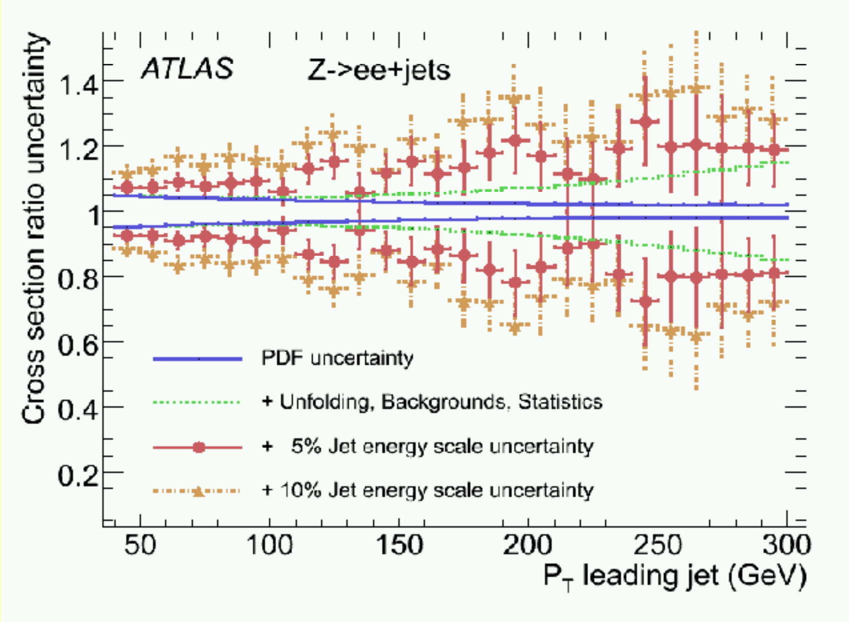


- Comparison of LO and NLO predictions:
  - corrections 20-30% for N_{jets} =1,2
- Generators comparison:
  - Alpgen vs MCFM
    - ✓ lower Alpgen XSection Njets >1
    - ✓ Pt Spectrum agrees
  - Pythia vs Alpgen/MCFM
    - ✓ lower average multiplicity
    - ✓ Softer pt spectrum

Comparison of pseudo-Data and Theory

- Effect of systematic uncertainties on comparison at 1 fb^{-1}
- JES uncertainties is the dominant source of systematic
  - Larger than PDF uncertainties, statistical errors
  - Similar to the effect of K factor for Z+2 jets (NLO/LO)~20-30% for JES uncertainties of 10%





Conclusions

- W/Z+jets measurements test perturbative QCD
  - Improve background estimates to new physics
- Comparison between LO/NLO calculations at hadron level
  - Corrections~20-30%
- Comparison between different MC generators
  - Difference~10-60%
- Effect of unfolding
  - Non-perturbative effects spoil jet unfolding below 40 GeV
- Effect of experimental uncertainties
  - JES is the dominant source of uncertainty in the early data