

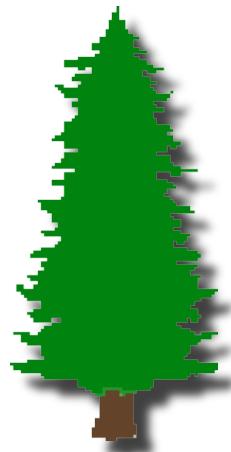


Deep Inelastic Scattering 2009

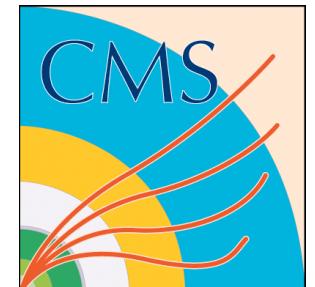
W/Z+jet cross section measurements at the Large Hadron Collider

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for the ATLAS and CMS Collaborations



Outline: W/Z+jets measurements

- Motivation for W/Z+jets studies at LHC
- QCD extrapolations and expectations
- Special calibrations for multi-jet final states
- Selected results from prototype analyses (14 TeV)
 - Z+jets (decays to ee, $\mu\mu$), including Z+b-jets
 - W+jets (decays to e ν , $\mu\nu$)
- Focus on selected experimental techniques
- Predictions of systematic uncertainties
- Conclusions

Motivation for measurements and studies

Probing perturbative QCD

- PDFs in unexplored region of high Q^2 , low x
- NLO calculations of boosted W/Z bosons
- Larger phase space for additional jets

Physics benchmark

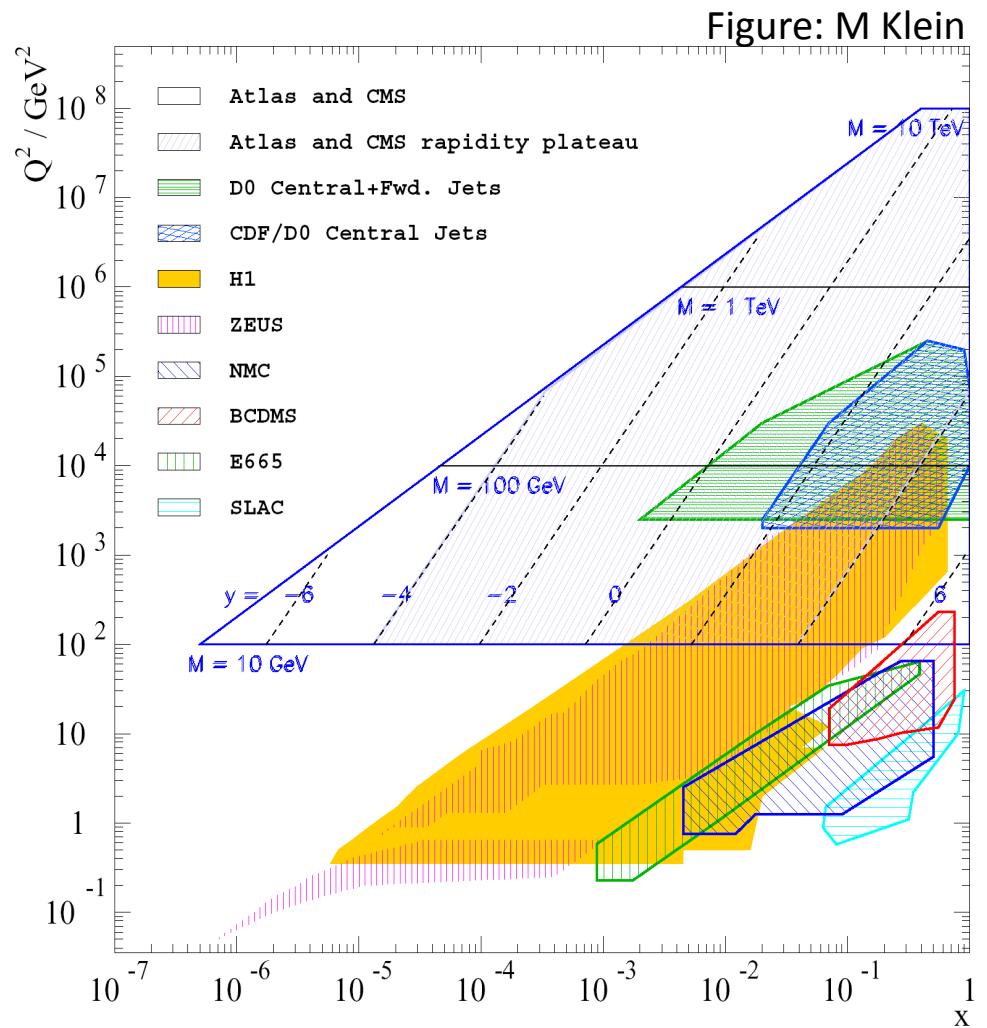
- In-situ calibration of lepton efficiencies
- Jet energy balancing
- Missing transverse energy resolution

New physics

- W+2,4-jet signatures (top quark production)
- Lepton+E_Tmiss+jets (supersymmetry)
- Z+b-jets or W+b-jets (Higgs boson searches)

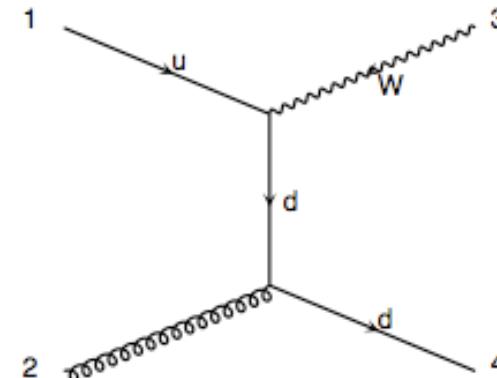
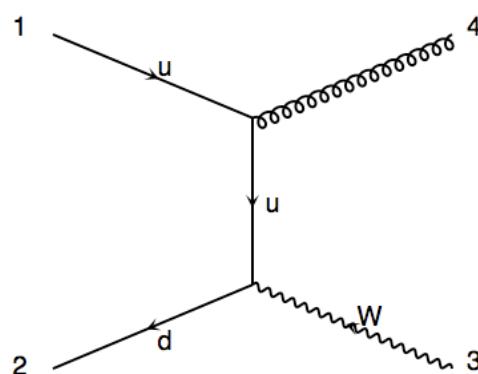
Probes of new PDF regimes

- Low x & High Q^2 region
- Low- x sea quarks
- Ratio between u & d sea quarks
- Inclusive W and Z results are sensitive probes at slightly lower Q^2
- High statistics at the highest Q^2 values
(in W/Z+4 jets)



QCD expectations for W/Z+jets at LHC

- Assuming 100 pb^{-1} at 10 TeV, we expect
 - 250K W events in the leptonic channels
 - 25K Z events in the leptonic channels
 - 100M triggered jet events
- Production with multiple jets enhanced relative to proton-antiproton collisions
- W/Z + jet production at LHC proceeds via quark-antiquark OR quark-gluon interactions



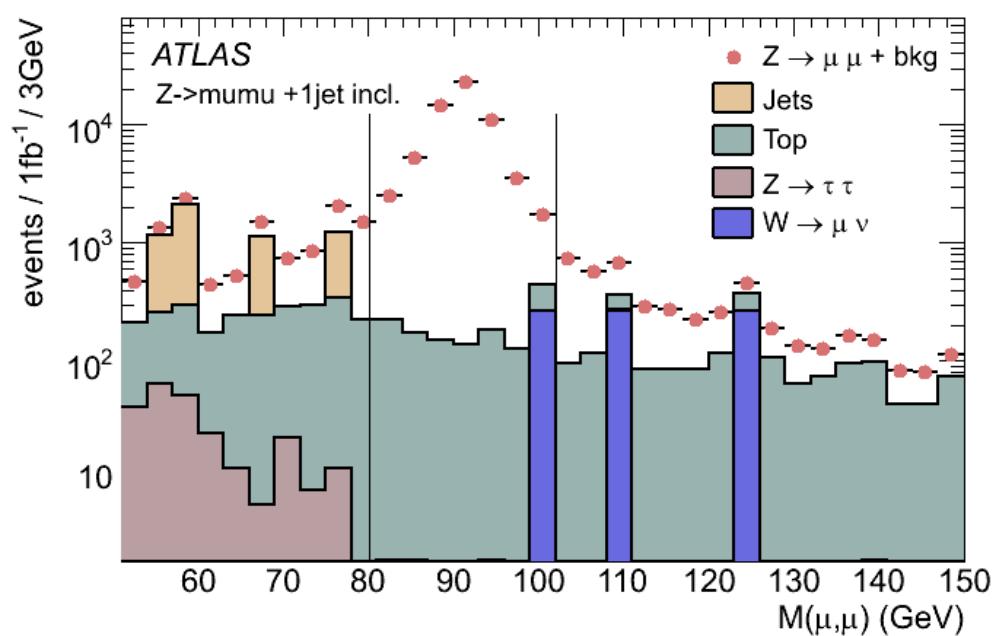
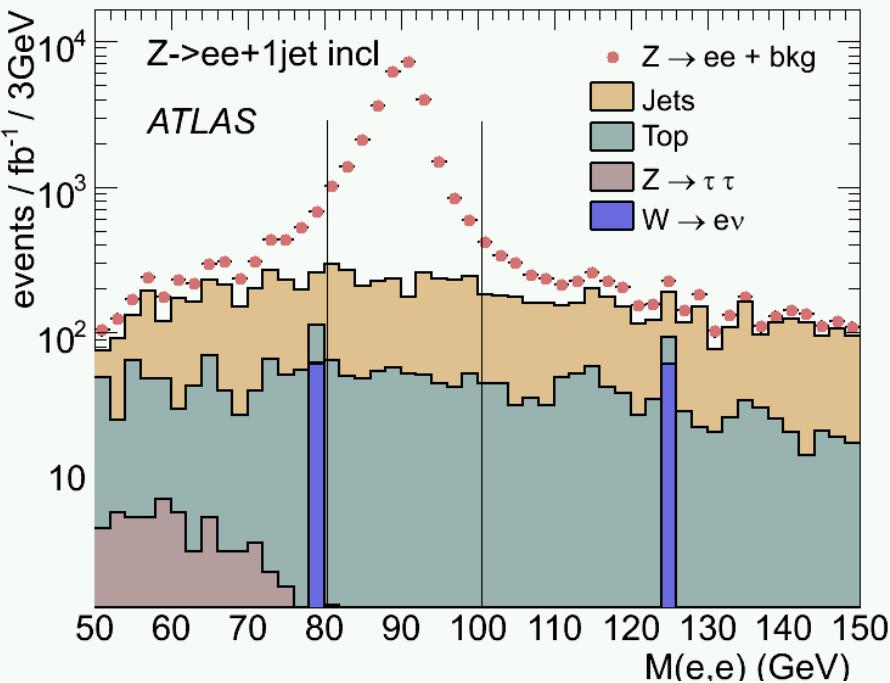
Analysis parameters and input

- Completed studies assume 1 fb^{-1} data at 14 TeV
 - Internal 10 TeV studies are well advanced
- NLO distributions from MCFM with scale $m_z^2 + p_T^2$
- Signal events generation with ALPGEN 2.05 + HERWIG
 - PDF set is CTEQ6LL; matching scheme is MLM (ALPGEN internal)
 - Special jet matching studies for W/Z+heavy flavor generation
- Backgrounds generated with Pythia, Alpgen, MC@NLO for dijets, W, Z, top quark samples
- Active development effort with Sherpa for W/Z+jets

Prototype Z+jets analyses

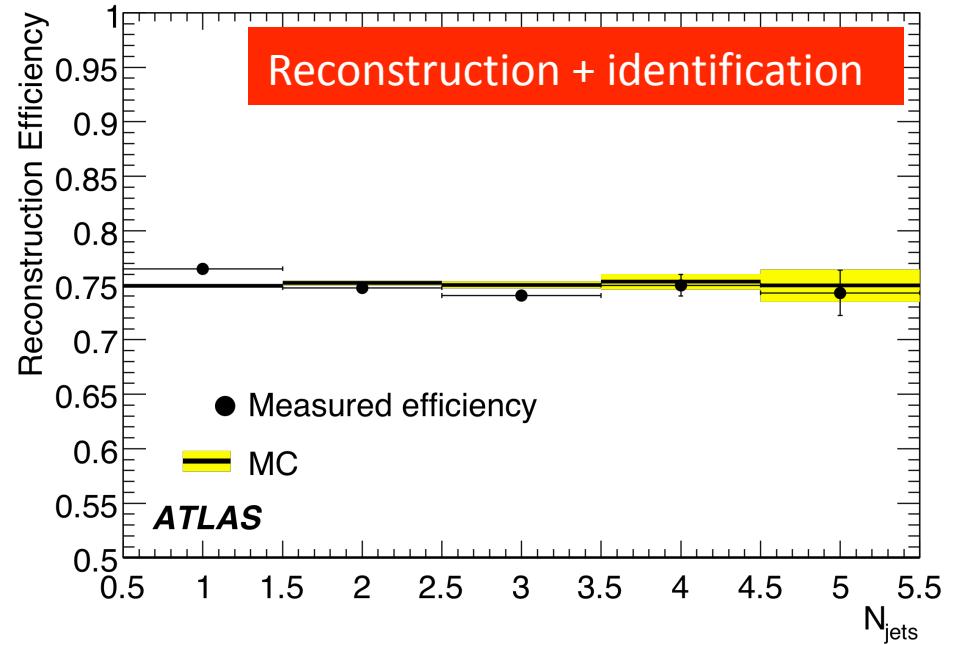
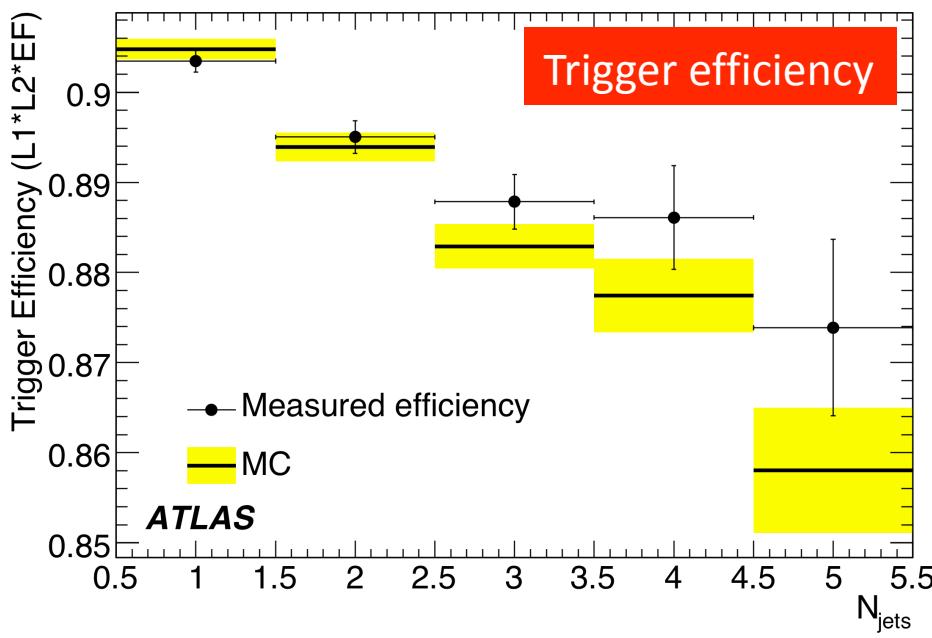
- Isolated di-electron OR single electron trigger
- Electron $E_T > 25$ GeV
- Cone 0.4 jets ($E_T > 40$ GeV)
- Fit Z mass sidebands

- Isolated di-muon trigger
- Offline muon $p_T > 15$ GeV
- High muon acceptance
- Cone 0.4 jets ($E_T > 40$ GeV)



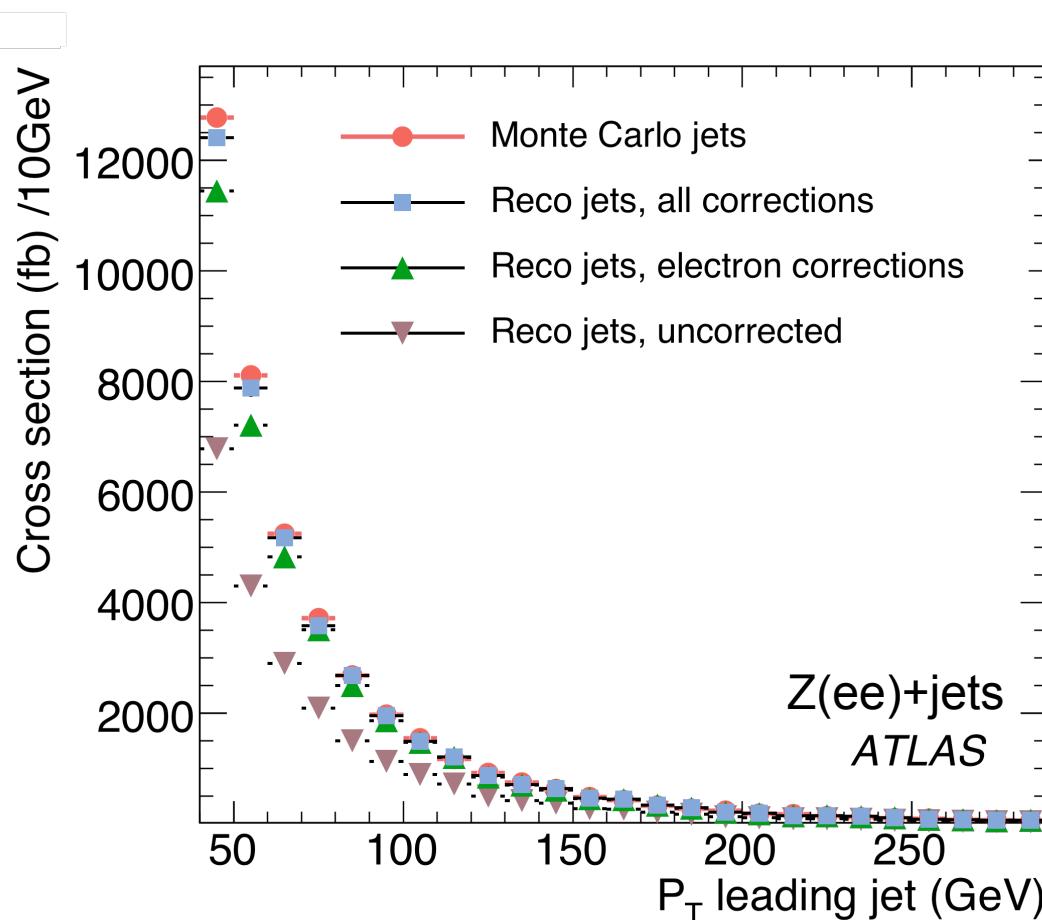
In-situ calibration of electron efficiencies

- Enough Z+jet events for “tag-and-probe” method
- Hadronic activity affects primary 25 GeV isolated electron trigger as a function of number of jets
- Offline reconstruction efficiency not affected



Unfolding from detector-level to particles

- All results will be compared at hadron (or lepton) level
- Apply UE, jet fragmentation corrections to MCFM results



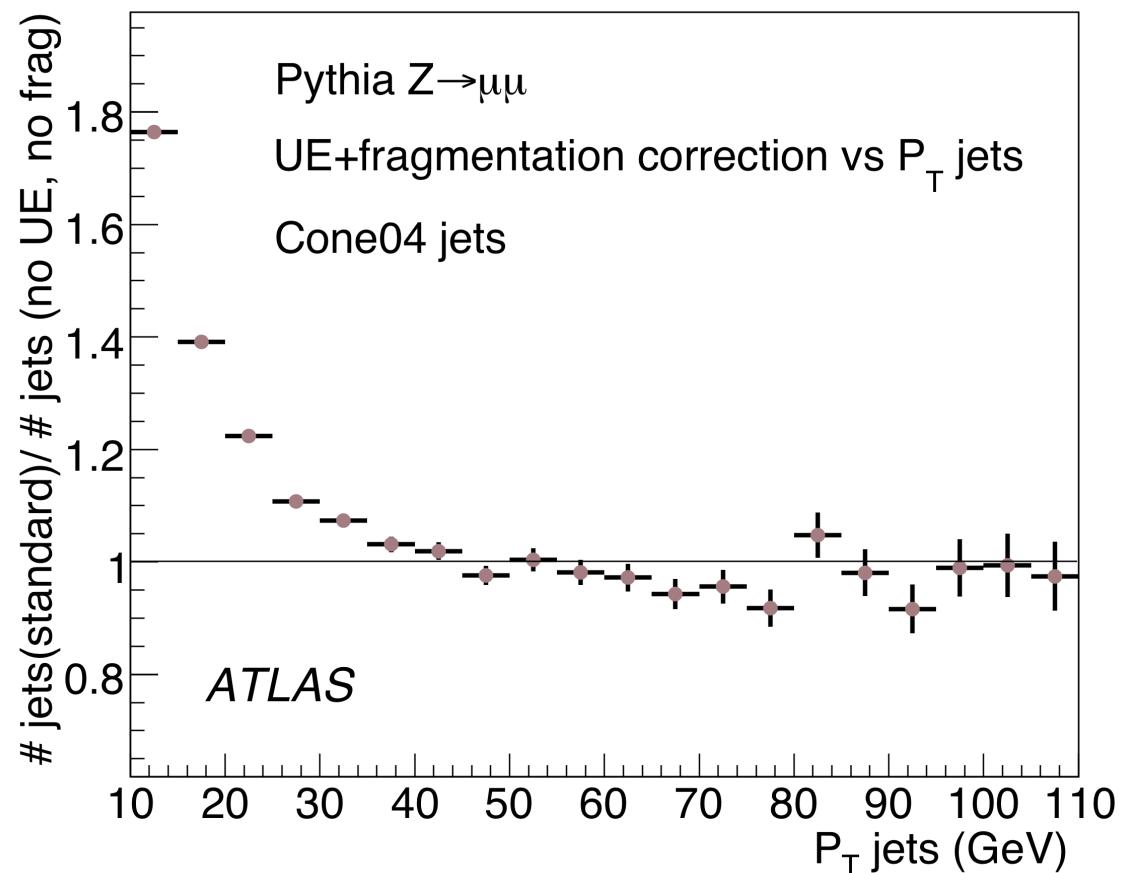
Correct for electron reconstruction and trigger efficiency (largest correction)

Correct for non-linearity of jet energy scale, jet reconstruction efficiency, and jet energy resolutions

Limitations on unfolding to parton level

Derive corrections from hadron to parton level in absence of underlying event and fragmentation

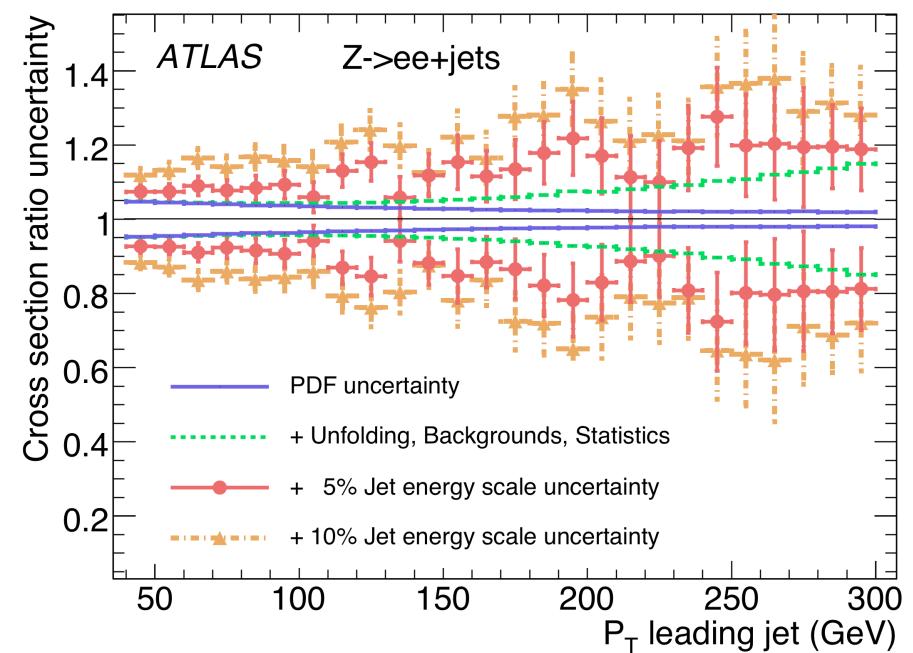
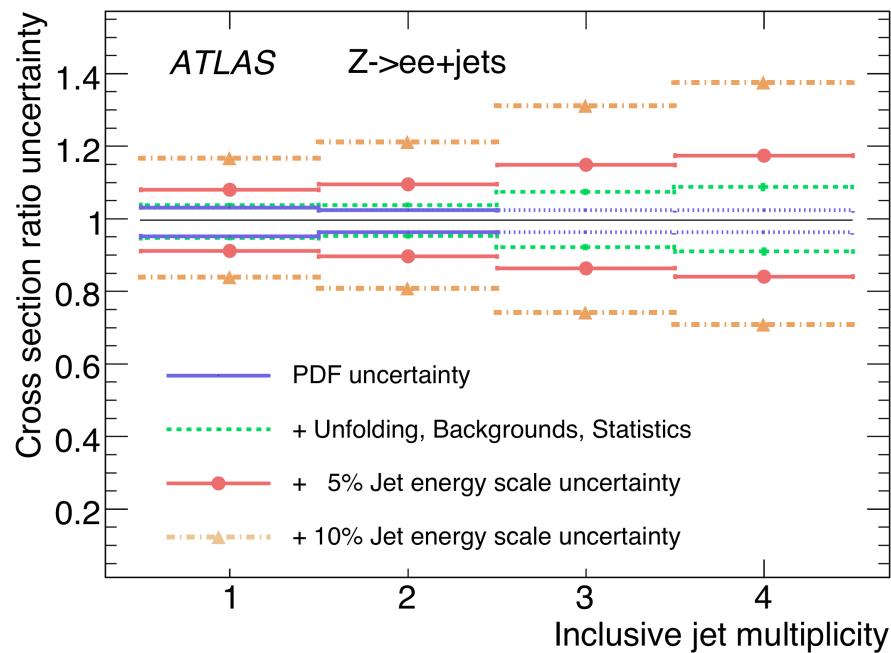
- Underlying event corrections increase jet energies
- Fragmentation reduces jet energies
- Balance achieved above 40 GeV only



Uncertainties on theory comparisons

What can 1 fb^{-1} experiment tell us about cross section?

- Statements limited by expected JES uncertainty
- Larger even than uncertainty from integrated luminosity



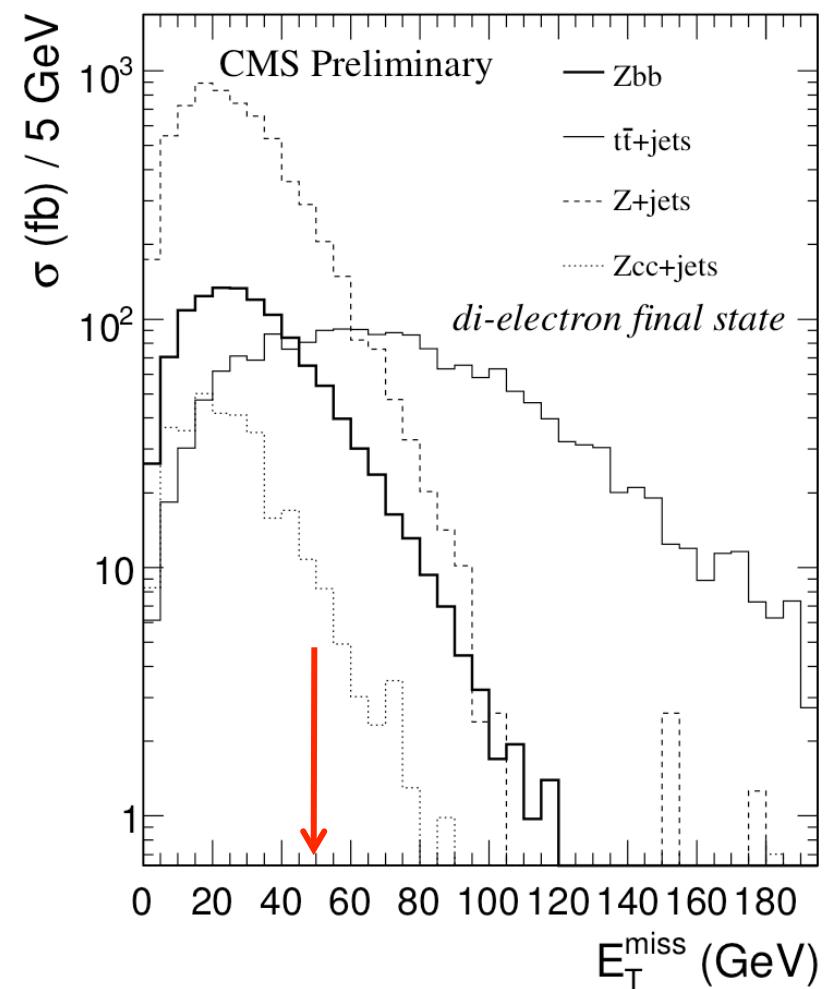
Size of this effect is similar to K-factor for $Z+2$ jets: 20-30%
Also blurs comparison between different event generators

Z production with associated b-jets

- W/Z + heavy flavor measurements probe HF PDFs
- Crucial background for low-mass Higgs boson searches

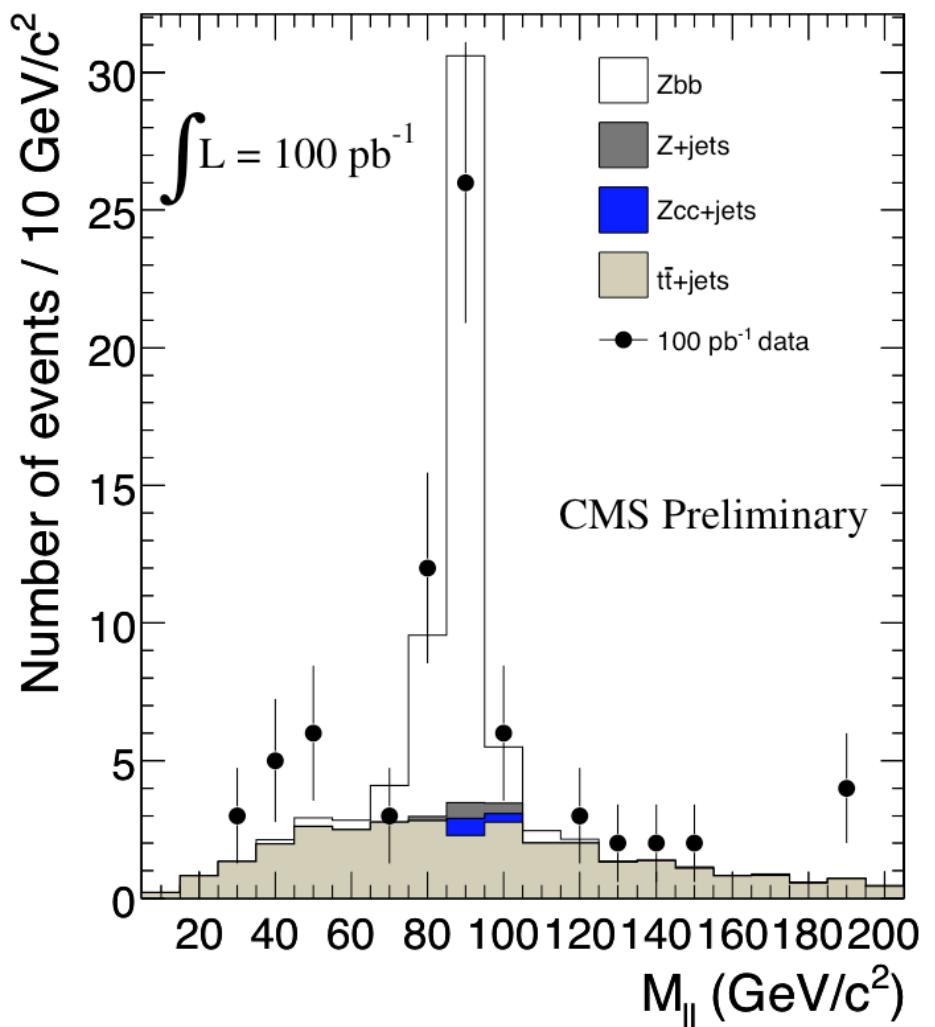
E_Tmiss for all **double b-tagged** events passing lepton selection (“track-counting” b-tagging with 3D IP significance)

- Cone 0.5 jets (30 GeV)
- Check E_Tmiss in top quark background with different-flavor leptons



Z production with associated b-jets

- Dilepton invariant mass peaks only for Z events
- Estimate top quark background from data sample using sidebands
- Zcc HF fraction calculated with Monte Carlo and theory cross sections
- Peak region S/B of 3.6



Z production with associated b-jets

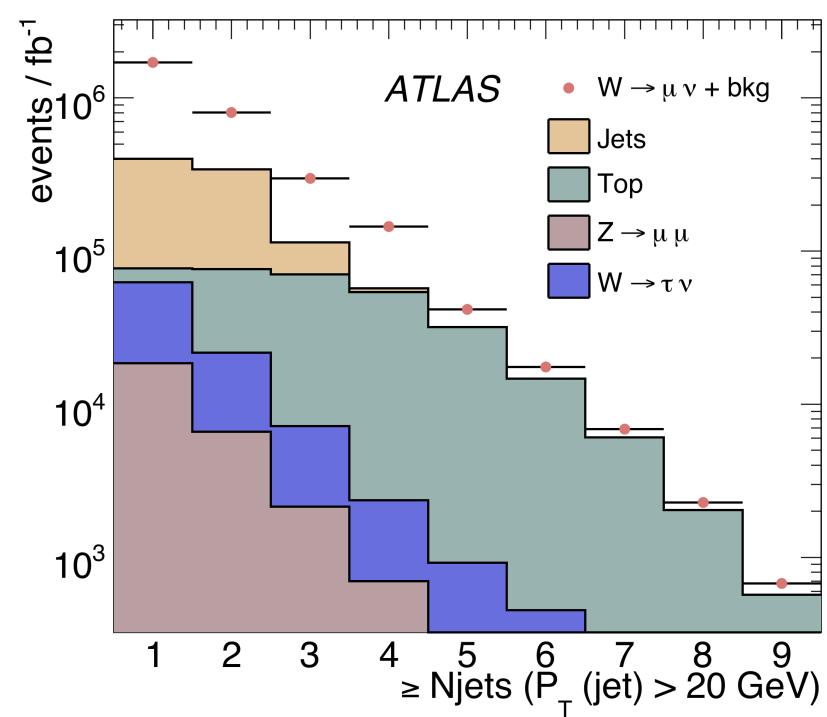
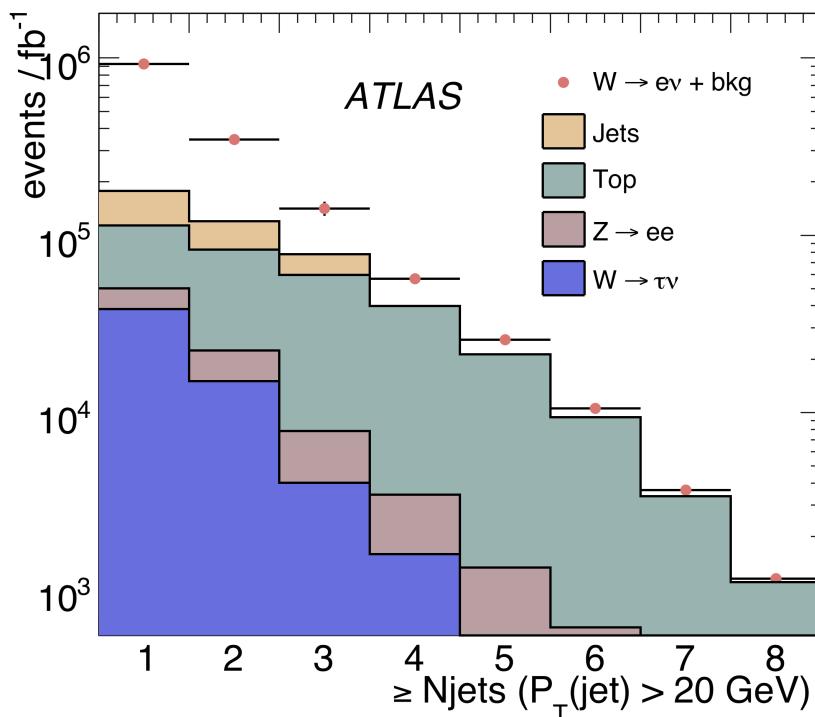
- Experimental uncertainties dominated by b-tagging efficiency in the double-tagged sample
- MC dependence includes NLO/LO kinematic differences
- Total first-year uncertainty estimate: <30% (syst.+stat.)

CMS preliminary

Source of uncertainty	value used (%)	$\delta(\sigma(Zbb))$ (%)
jet energy scale (JES)	7	7.6
Type 1 missing E_T scale	10 (unclustered E_T^{miss}) + 7 (JES)	7.4
MC p_T^{jet} , η^{jet} dependence	-10,+0	-10,+0
b-tagging of b-jets ($\delta\varepsilon_b$)	8	16
mistagging of c-jets ($\delta\varepsilon_c$)	8	0.5
mistagging of light jets ($\delta\varepsilon_\ell$)	7.6	0.5
$N_Z^{after\ b-tag}$ due to $t\bar{t}$ background subtraction	4	4.6
R	5	0.4
lepton selections	0.5	0.5
luminosity	10	10

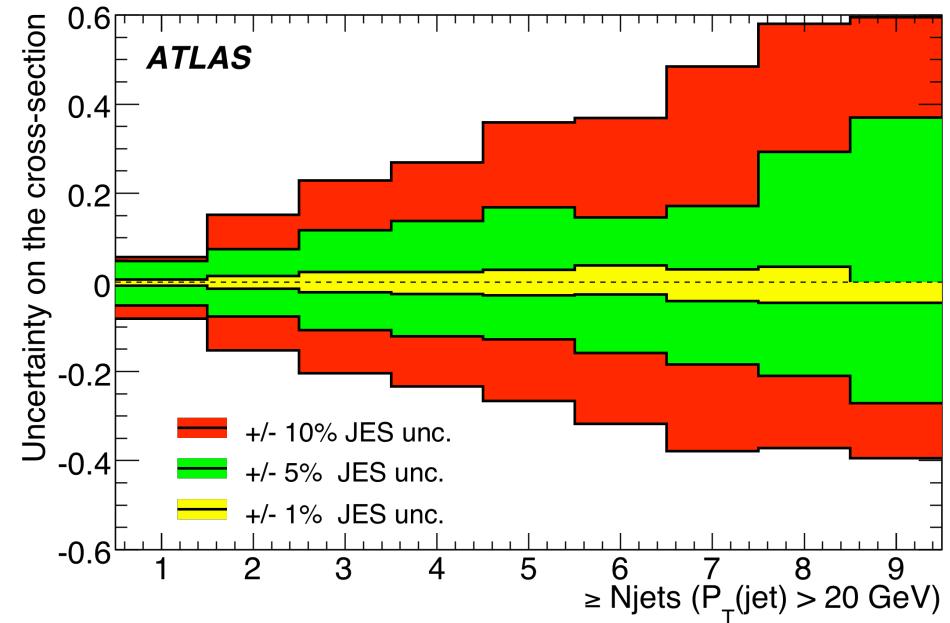
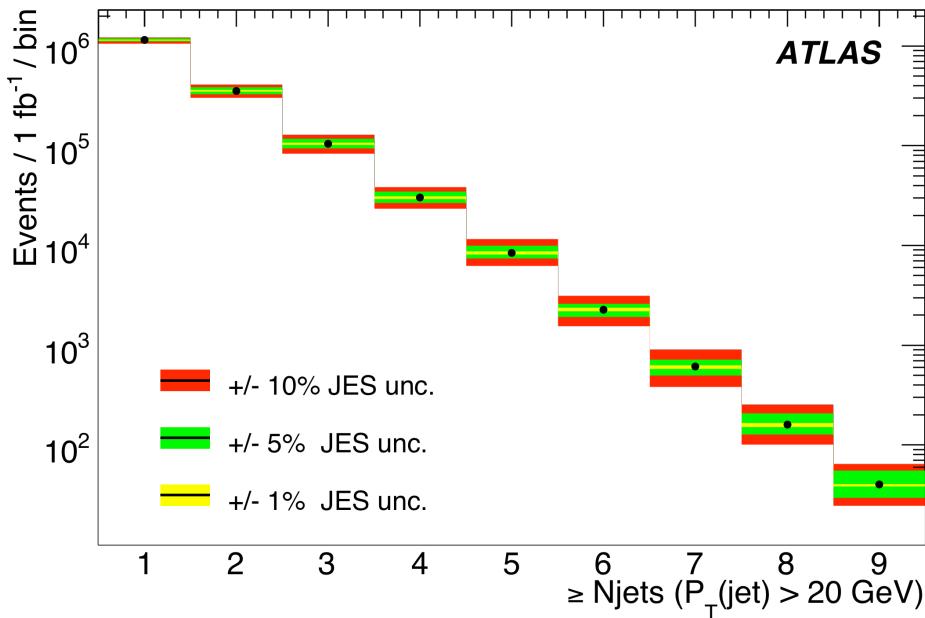
Prototype W+jets analyses

- Isolated electron or muon with $p_T > 20 \text{ GeV}$
- Exclusive counting with Cone 0.4 jets with $E_T > 20 \text{ GeV}$
- Final results require $E_{\text{miss}} > 25 \text{ GeV}$
- Current work on data-driven background estimates



Effect of jet energy scale uncertainties

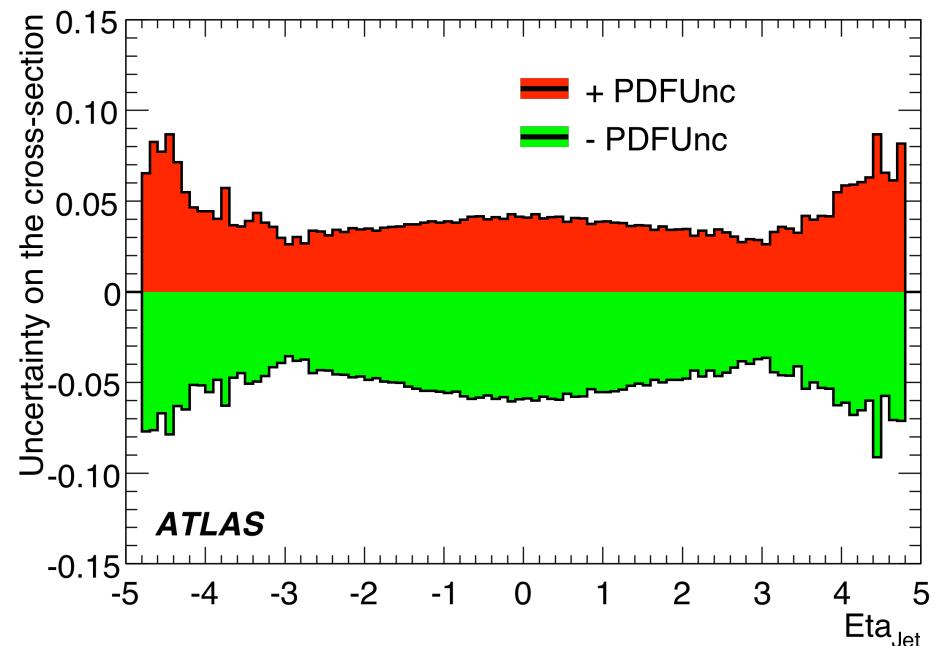
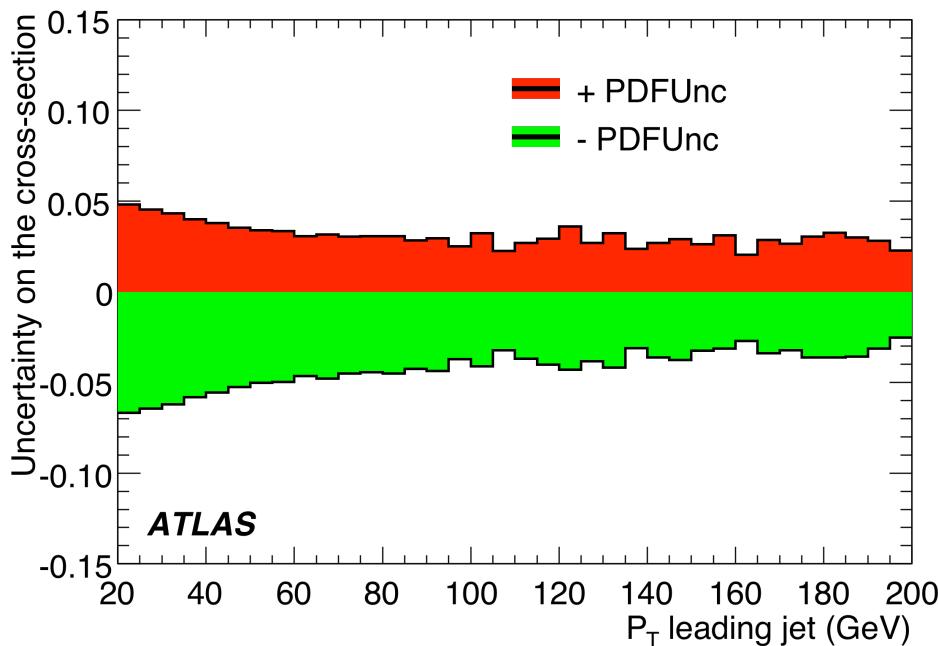
- Uncertainty in energy scale calibration affects multiplicity
- Shift jet energies in $W(\mu\nu) + \text{jet}$ events to estimate effect
- Expect to use $Z + \text{jets}$ for jet balancing calibration, too



Major uncertainty on cross sections, even for JES uncertainty of 5%

Effect of PDF uncertainties

- Reweight $W(e\nu)$ +jet events from CTEQLL to CTEQ6M
- Investigate effect of CTEQ6M error sets on cross section
 - Affects jet acceptance through η and p_T requirements



This 5% uncertainty may be reduced by concurrent gluon PDF measurements with inclusive W events.

Conclusions and outlook

- W/Z+jets measurements test perturbative QCD, improve estimate of background to new physics searches
- Compare to NLO theory calculations at hadron level
- Estimates of experimental systematic uncertainties
 - Jet energy scale uncertainty dominant for cross section
 - Integrated luminosity uncertainty
 - Non-perturbative effects spoil jet unfolding below 40 GeV
- Also pursue early ratios where uncertainties cancel
 - Ratios of W/Z production in inclusive jet multiplicity bins
 - Ratios of Z+1 jet / Z inclusive production