Z+jets cross section at ATLAS

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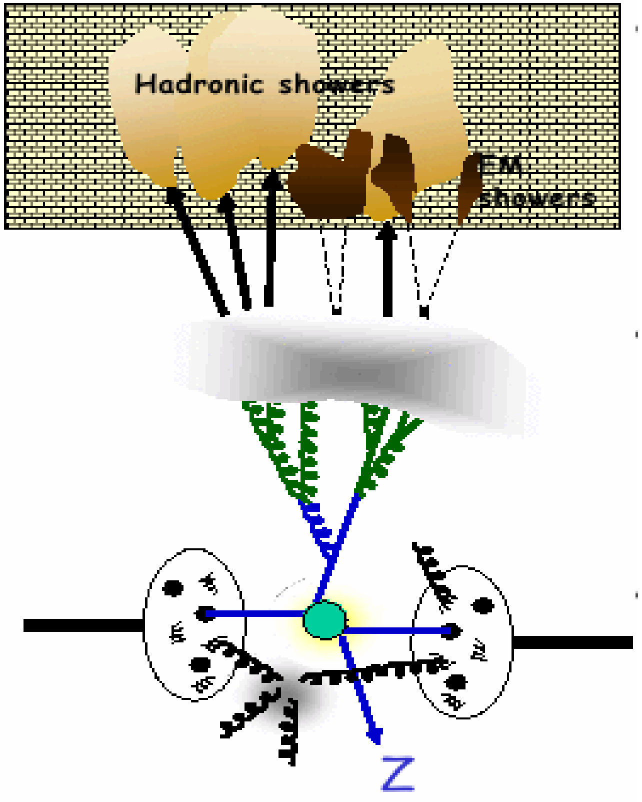
ATLAS collaboration



Intruduction

- **Plan:**

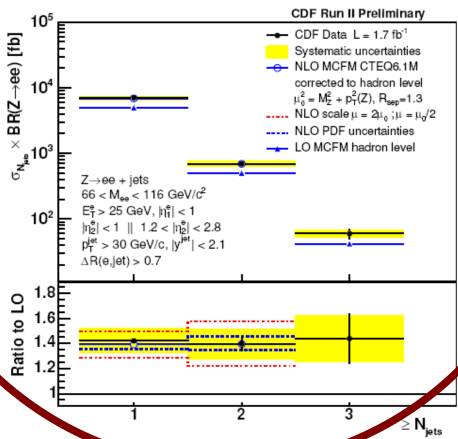
  Measurement of the inclusive Z+jets cross section and comparison with QCD predictions

  -> stringent test of perturbative QCD
  (Z mass delivers a hard scale for pQCD)

  -> derive predictions for backgrounds
  (W/Z +jets) for searches (Higgs, SUSY)

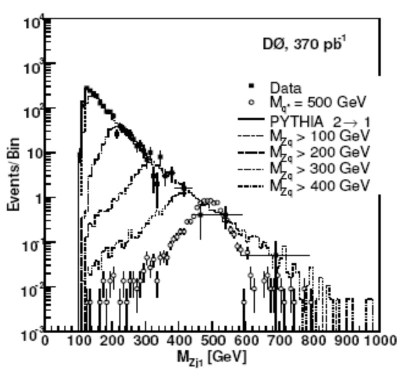
  -> New physics with large jet momenta

Probe standard model predictions

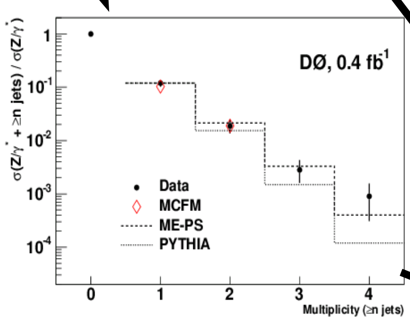


- **Preparation:**
  - Feasibility study with fully-simulated data
    - Trigger and reconsytruction in high-multiplicity environment
    - Analysis techniques
    - statistical and systematic limitations
  - generator validation with theory prediction
    (not the thrust of this study)

Exited quarks, Leptoquarks, ...

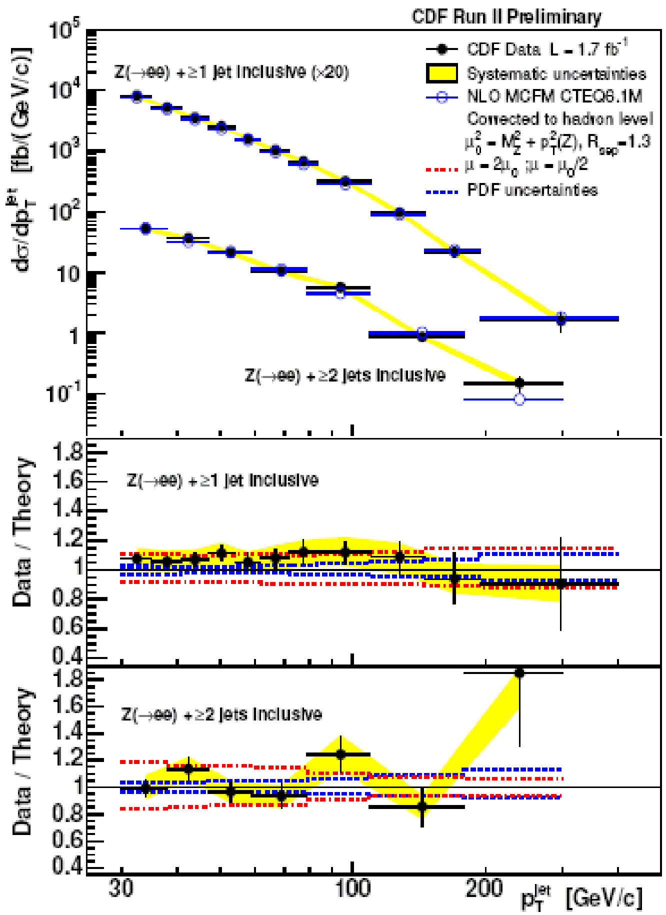


Validation of generators (Pythia, Algpen ..)

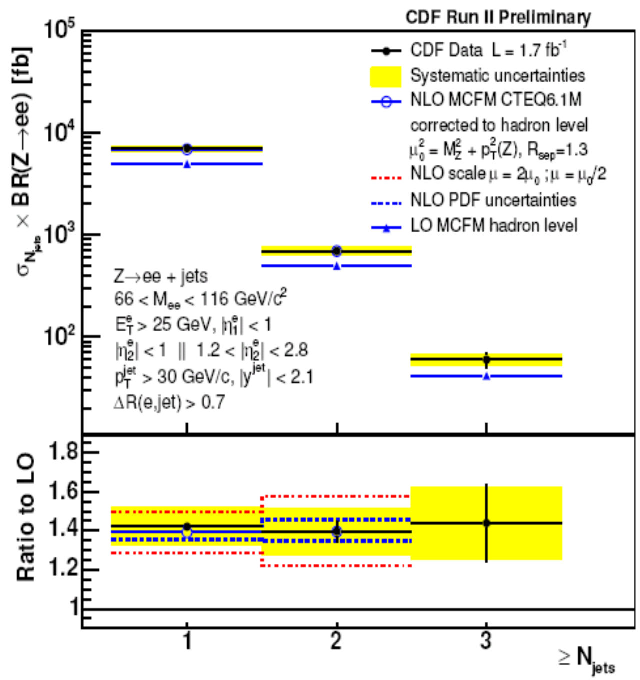


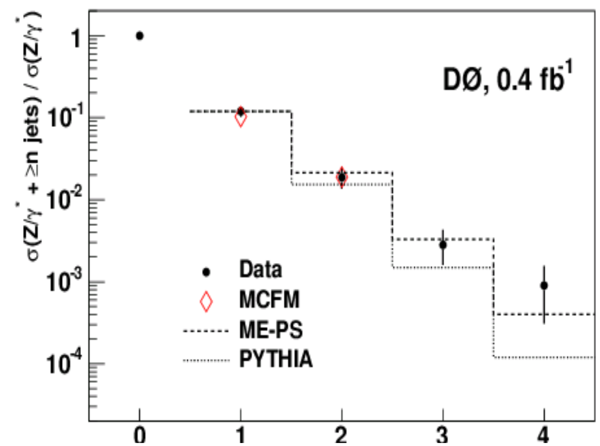
W/Z+jets: Background for Susy and Higgs searches

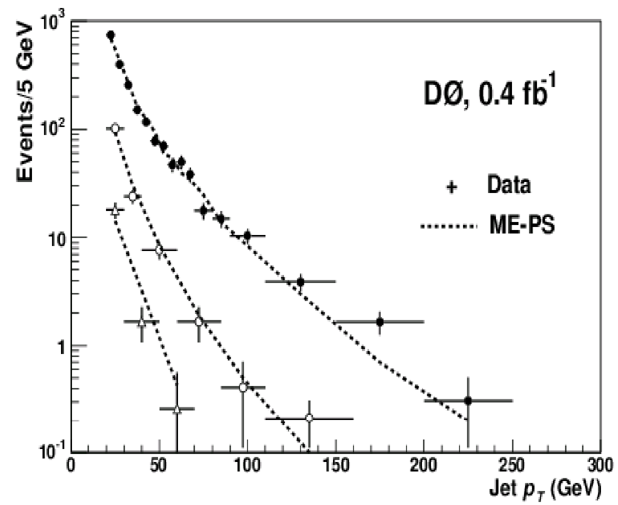
Z+jets cross section at theTevatron



Inclusive and differential cross sections:
- reasonable statistics up to PT(jet)~200GeV
- Data agrees with NLO predictions
- ME+PS yield better description then Pythia



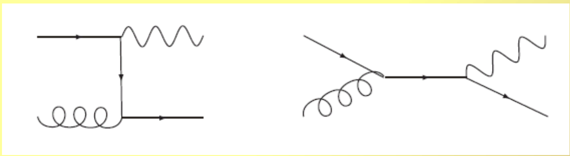




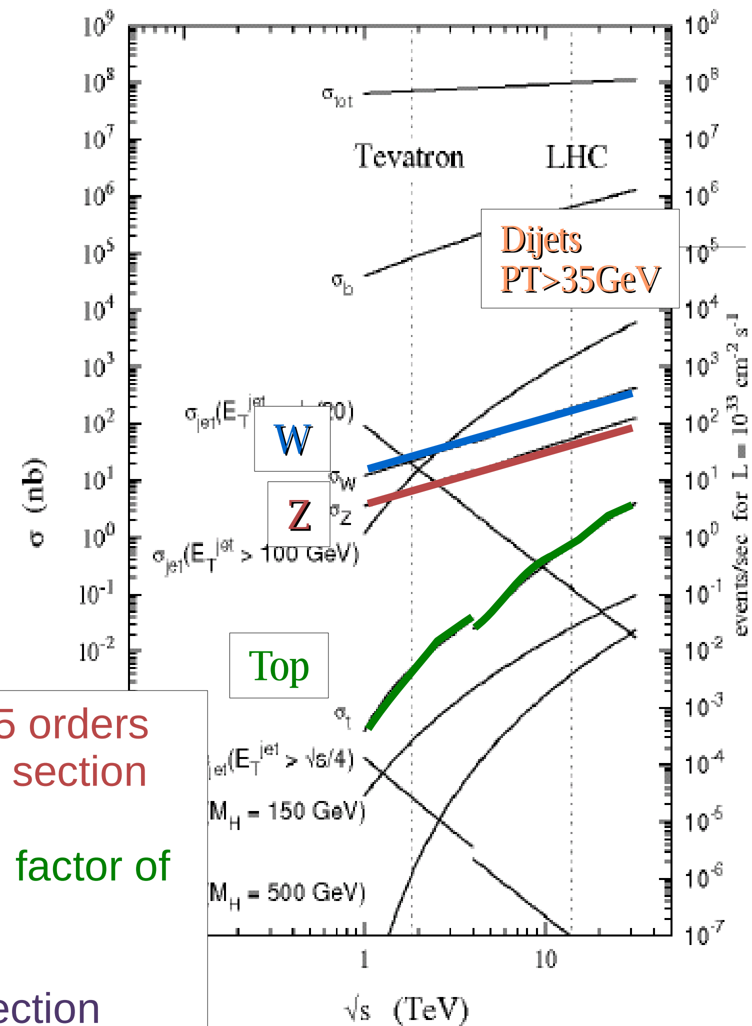
Observables:
- Inclusive jet multiplicity
- PT any jet/leading jet in events with ≥ 1 jet
- PT any jet/next-to-leading jet in events with ≥ 2 jets

Z+jets cross production at LHC

- Compton process: dominating



- Annihilation process



- The Dijet cross section (PT>35GeV) is 5 orders of magnitude larger than the Z->ll cross section
- Top background fraction enhanced by a factor of 10 compared to Tevatron
- W cross factor 10 larger then Z cross section but larger systematics from background

MC samples and Selection

Signal:

- Alpgen+Herwig Z->ee+jets: 400000 evts, >500 pb-1
- Pythia Z->ee (inclusive) : 170000 evts, 120 pb-1

Background:

- Pythia Filtered Dijets: 3012000 evts, 0.015pb-1
  with weighting: ~200 pb-1
- Pythia Ttbar incl: 500000 evts, 625 pb-1
  comparisons with McatNLO, Acer
- Pythia Z->tautau->ll: 170000 evts, 2200 pb-1
- Pythia W->ev: 180000 evts, 17 pb-1

.... Similar for Z-> ▪ μμ,
QCD: Bbbar events with dimuon filter (4+6 GeV)
W background also from Alpgen

QCD background for Z->ee + jets:

- Data:
  - combined Sig+Bkg fit of Z-resonance
  - invert ID cuts
- MC:
  - start with filtered Dijets,
  - discard W,Z,Ttbar
  - apply only very loose electron selection
  - weight with additional rejection from final ID (different for electrons which match or don't to generated electrons)

Electrons:

- Medium electron (shower shape, track match)
- OR of isolated single and DiEM trigger
- PT>25 GeV
- |eta| <2.4, cracks excluded:

Muons:

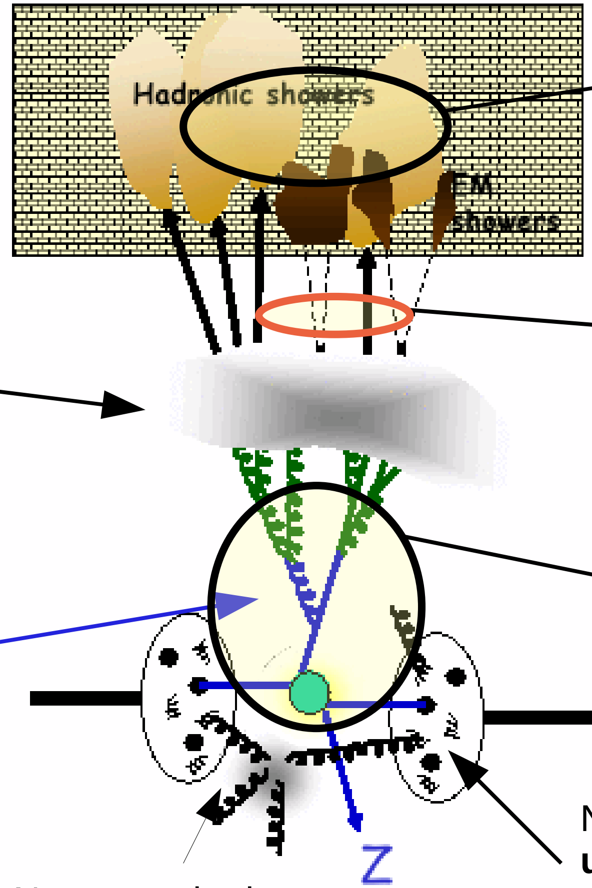
- Inner detector and muon chambers (Staco algorithm)
- ET<15GeV in isolation cone, DR=0.2
- PT>15 GeV
- |eta| <2.4, cracks excluded:

Jets:

- Here: seeded Cone, DR=04
  - Z->ee: cell towers
  - Z->mumu: Topo clusters
- Lepton veto (DR < 0.4)
- ET > 40 GeV
- Eta < 3.0

Z+jets cross section at ATLAS

In order to compare the measured jet cross section with theoretical predictions, both are cor-ected to the hadron level



Reconstructed objects
real data, fullsim MC

Unfold detector effects

hadron(particle)-level)

Correct for non-perturbative effects

Parton Level (~MCFM)
NLO predictions

Non-perturbative:
Fragmentation/ Hadronisation:
phenomenological models
universal, tuned at LEP etc.

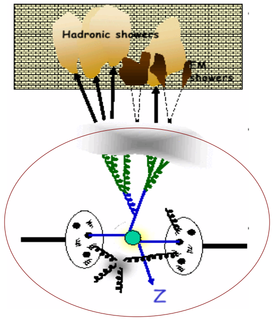
Perturbative QCD:
- Hard interaction: matrix element
- ISR/FSR:
  - MCFM: full NLO correction
  - Event generator: parton shower

Non-perturbative:
Underlying Event:
Collider-specific !
So far extrapolated from Tevatron data
To be extracted with the first data (MinBias etc.)

Non-perturbative but **universal**: PDF measured at HERA etc

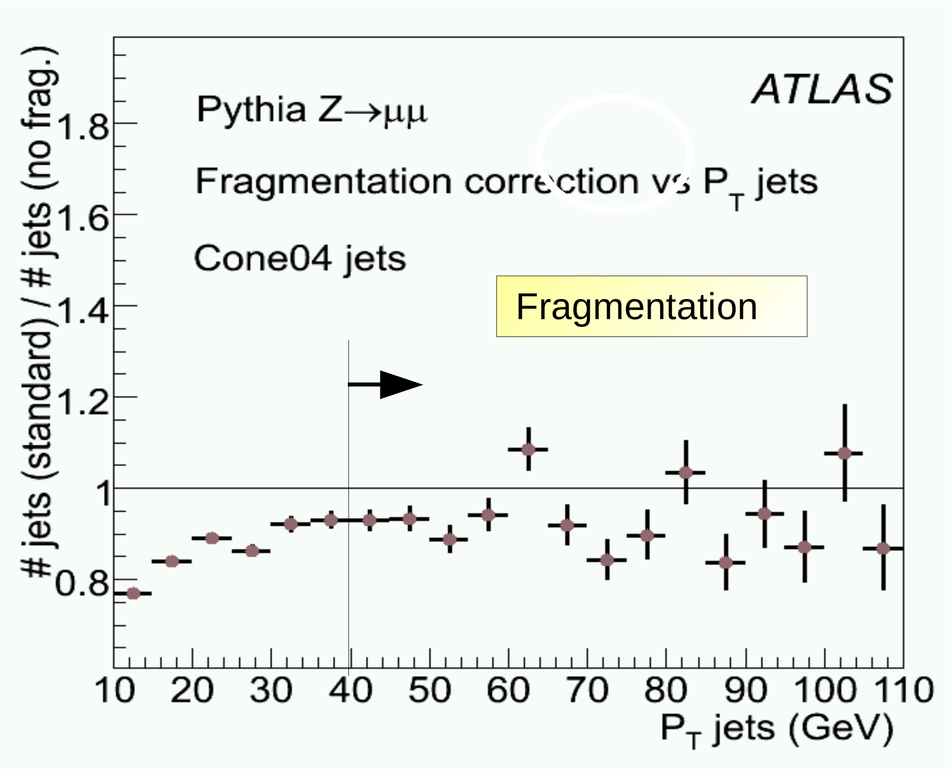
From parton to hadron level

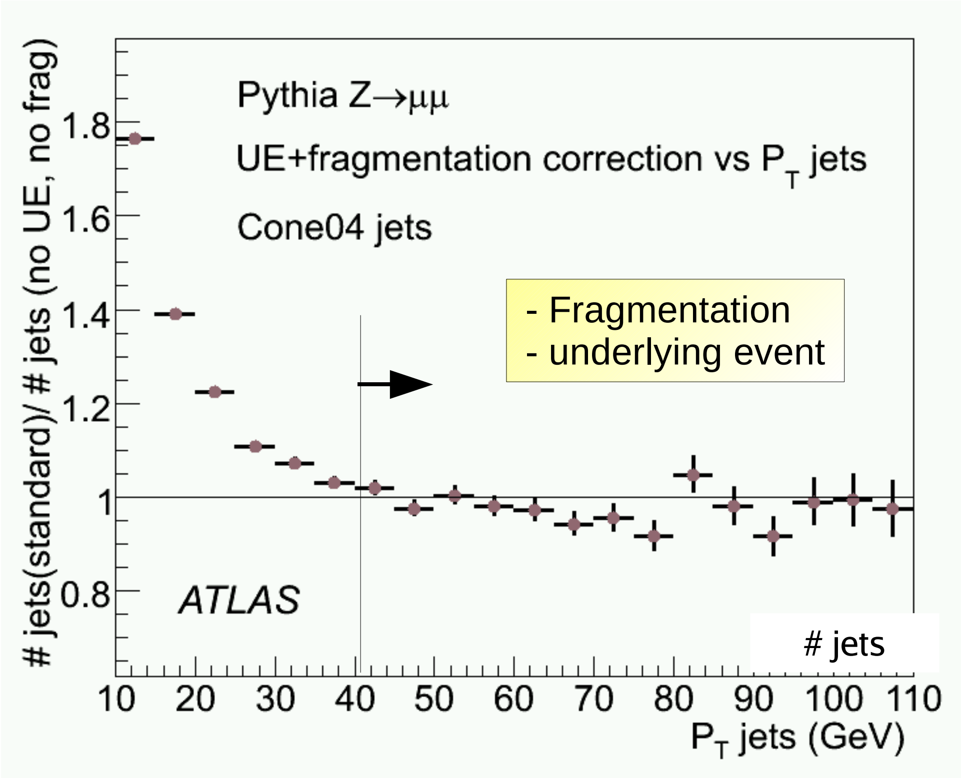
- Generated Pythia Z->mumu
  - standard
  - no underlying event
  - no fragmentation
- Jets clustered with the final state particles
- Compare Jet PT spectrum:
  #evts (standard)/#evts (modified) -> correction for parton-level predictions



-> Fragmentation: energy loss at low-PT
-> Underlying event: additional jets at low-PT increased PT
-> Corrections small for jet PT > 40 GeV
-> from lack of statistics: apply global residual correction for PT > 40 GeV

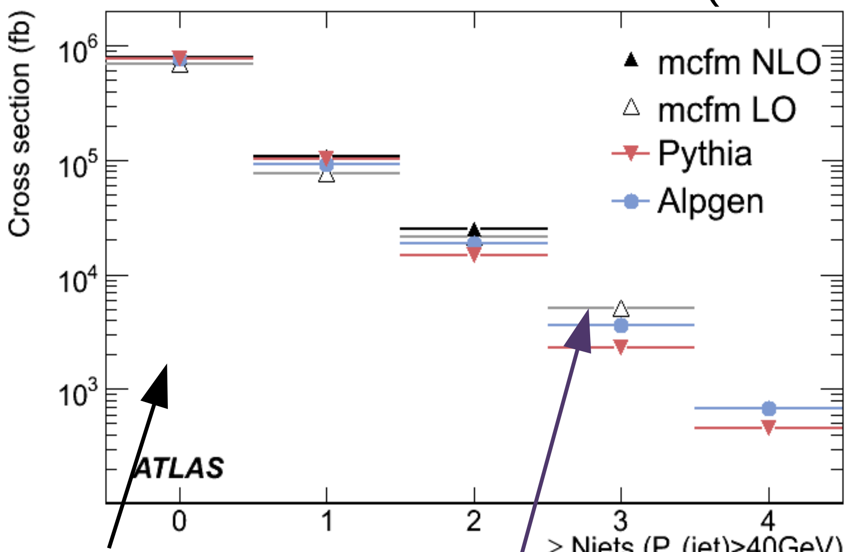
In real ATLAS: tune MC with MinBias data

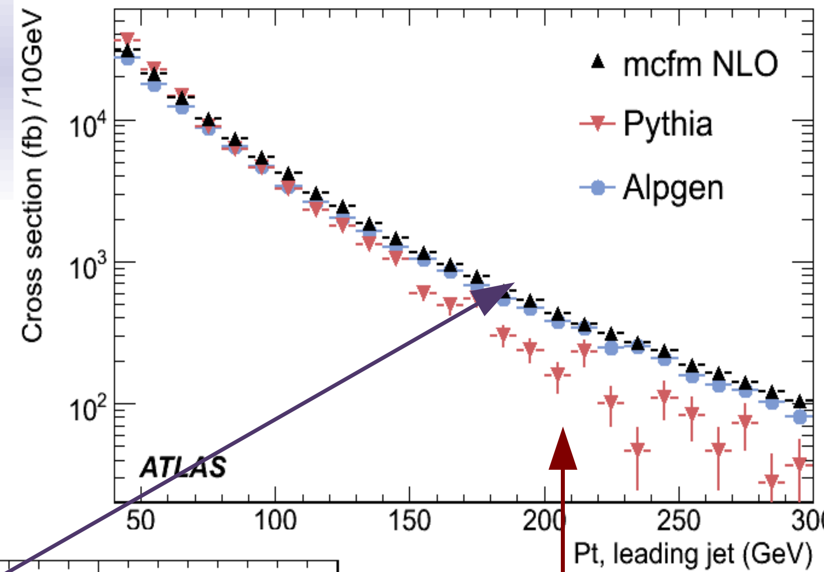




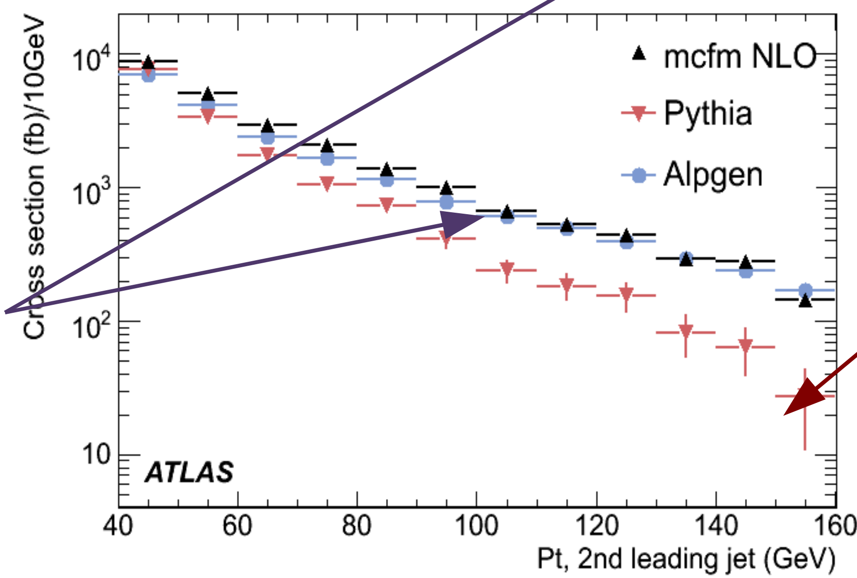
Observables: Generators and MCFM

(Example: Z-> μμ)





Global "k-factor" (1.2-1.3) extracted for our fiducial volume :scaling of the inclusive sample to the MCFM NLO prediction



Alpgen:
- Differential XS agrees with MCFM
- predicts too low jet multiplicities

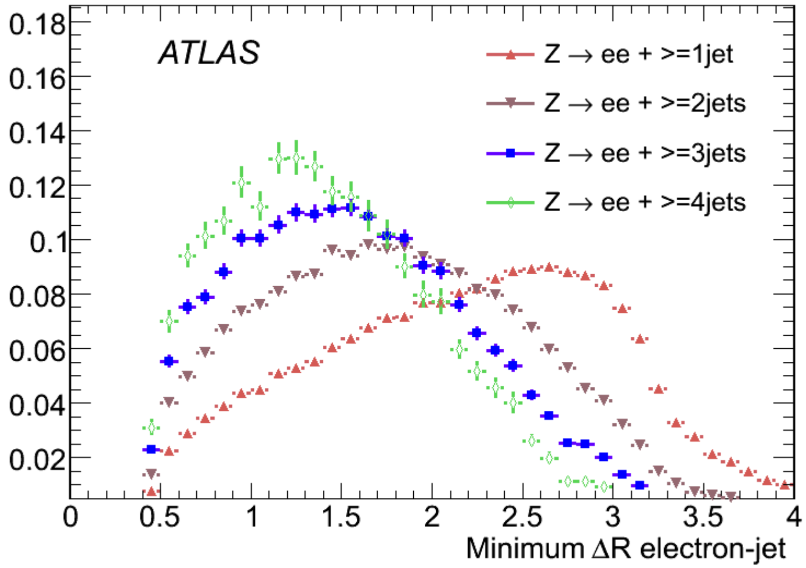
Pythia:
- predicts softer jet spectrum than Alpgen
- too low jet multiplicities

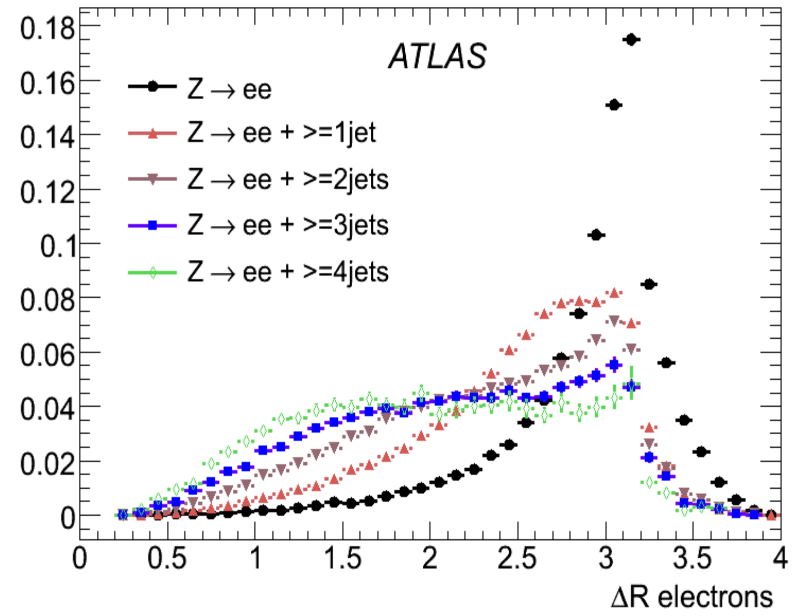
Errors:
- generators: statistics
- MCFM: PDF, residual fragmentation correction

Side remark: replacing CTEQ6m by CTEQ6l PDFs does not account for differences (XS increases by 5%/ 10%/ 15% for Z+1/2/3 jets)

Feasibility study on fully-simulated data

Lepton reconstruction with large jet multiplicity

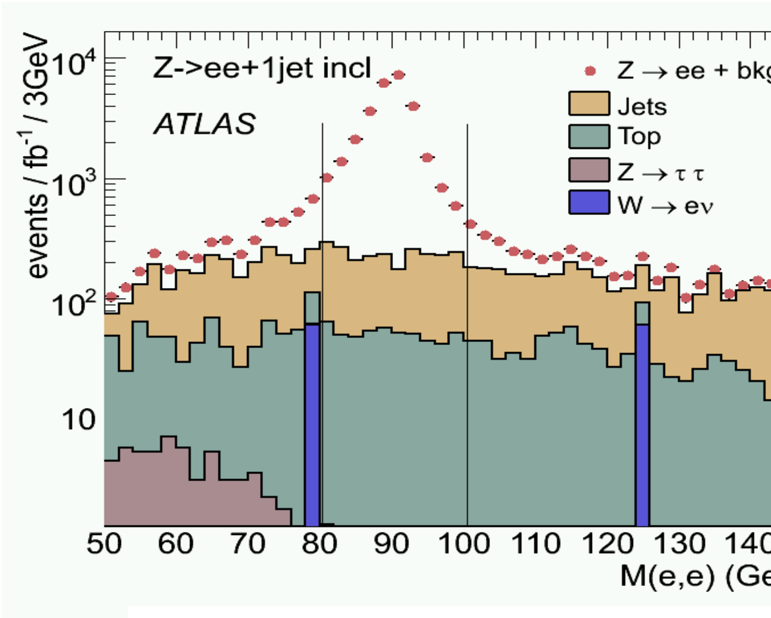


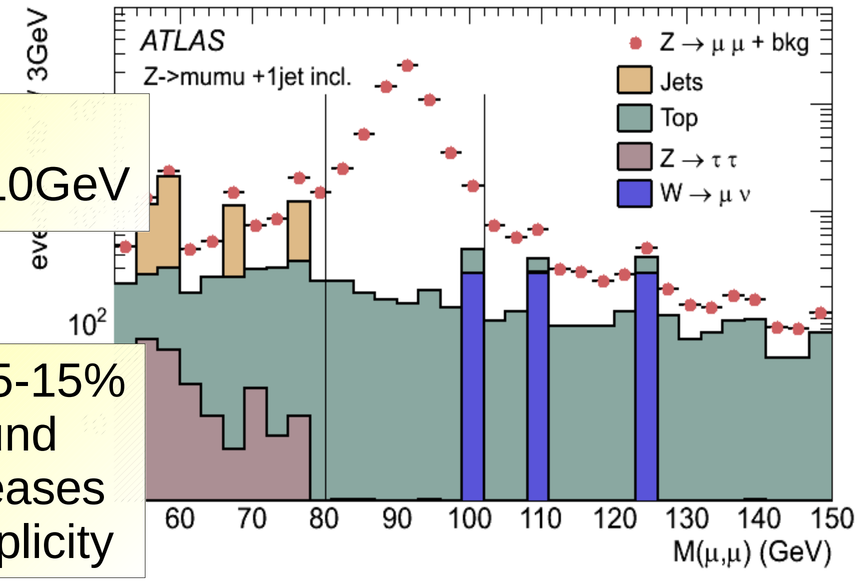


- DR between electrons and between electrons and jets becomes smaller with increasing jet-PT / jet multiplicity
-> check for bias in trigger and reco efficiency

- Electron trigger isolation for large jet multiplicity:
  - efficiency loss of 20% for trigger electron for low DR(el, jet): 0.4-0.6 recovered by OR-ing of single and di-electron trigger ✓
- Electron reconstruction for large jet-PT (high multiplicity):
  - Z reco efficiency stable vs jet PT (minimum DR>0.2 between electrons) ✓
- Muon isolation with large jet multiplicity:
  - Z->mumu: avoid bias by reducing Isolation cone from 0.4-0.5 to 0.2 ✓

Signal and backgrounds





Selection:
M(ll) in $M_Z \pm$ 10GeV

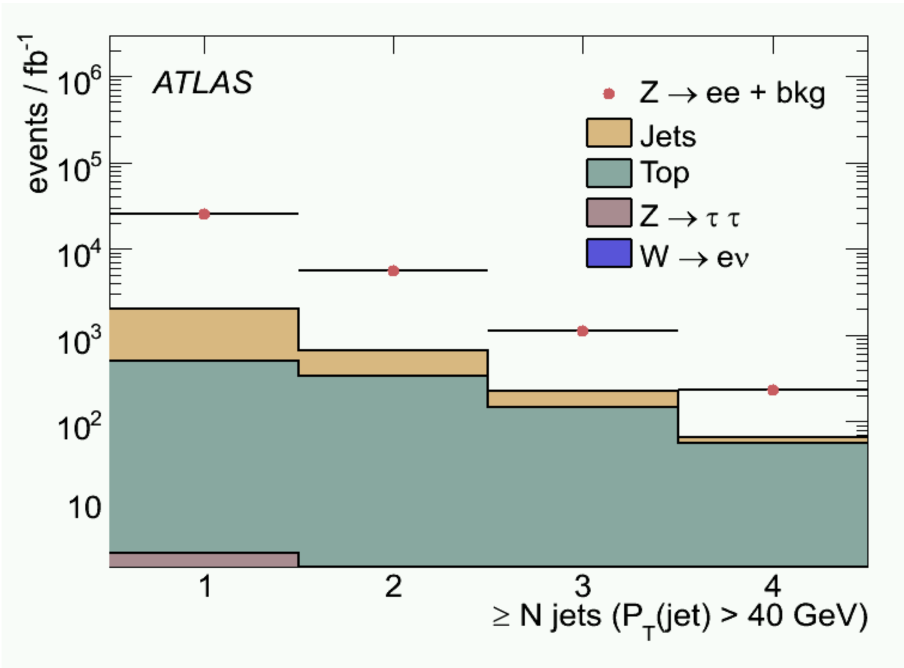
Background 5-15%
Top background
fraction increases
with jet multiplicity

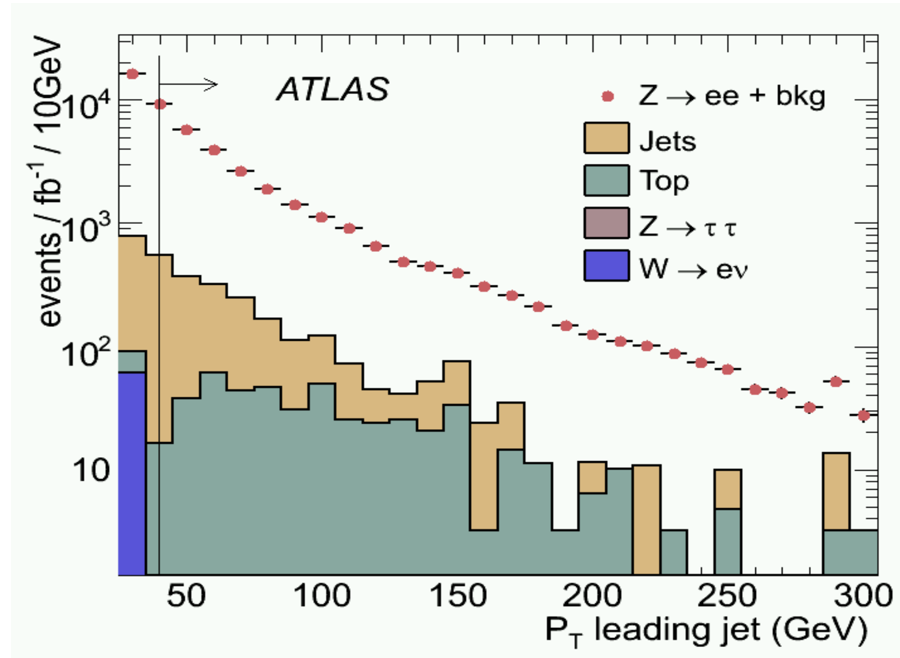
Process	$Z \to \ell\ell + \geq$ 1jet σ (fb)	fraction (%)	$Z \to \ell\ell + \geq$ 2jets σ (fb)	fraction (%)	$Z \to \ell\ell + \geq$ 3jets σ (fb)	fraction (%)
$Z \to e^+e^-$ + jets analysis						
$Z \to e^+e^-$	23520±145	91.9±0.8	4894±45	87.9±1.3	900±15	80.0±2.4
QCD jets	1545±89	6.0±0.4	336±42	6.0±0.8	78±20	6.9±1.8
$t\bar{t}$	496±28	1.9±0.1	333±23	6.0±0.4	146±15	13.0±1.4
$W \to e\nu$	(28±13)	(0.1±0.05)	(5.9±2.6)	(0.1±0.05)	(1.1±0.5)	(0.1±0.05)
$Z \to \tau^+\tau^-$	3.2±1.2	0.01±0.01	(0.67±0.25)	(0.01±0.01)	(0.1±0.05)	(0.01±0.01)
$Z \to \mu^+\mu^-$ + jets analysis						
$Z \to \mu^+\mu^-$	59400±650	96.2±1.0	12600±300	90.1±1.9	2450±100	89.7±3.7
QCD($b\bar{b}$)	1230±550	2.0±0.9	600±300	4.3±2.2	0±110	0.0±4.0
$t\bar{t}$	1140±110	1.8±1.8	790±90	5.7±0.2	275±50	10.2±1.9
$W \to \mu\nu$	0±180	0.0±0.3	0±30	0.0±0.2	0±5	0.0±0.2

Uncertainties: statistical

Z->ee reco Efficiency: ~50% for all jet multiplicities

Observables: Signal and background

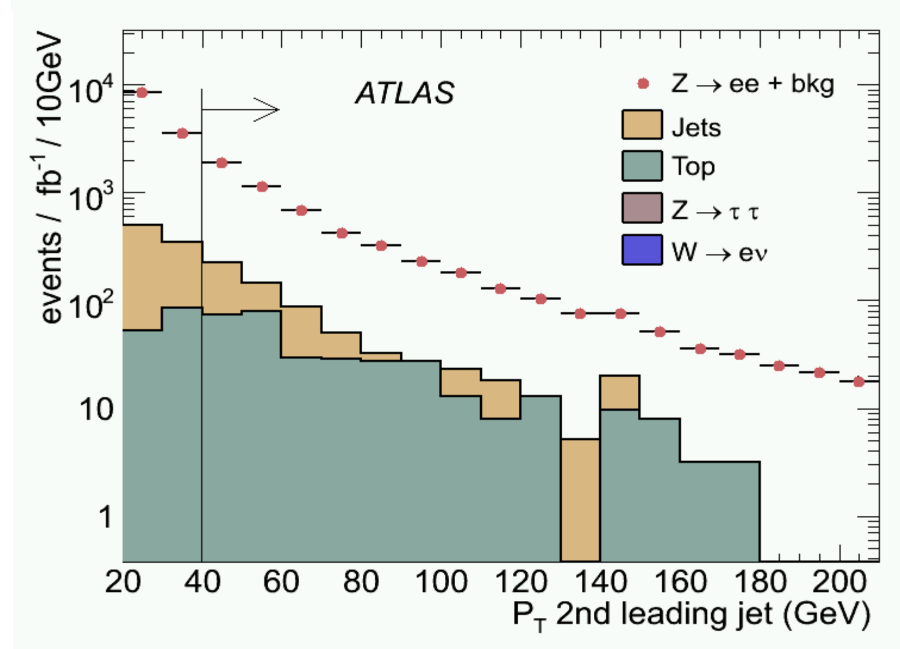




ttbar jets (2 jets from hard interaction) harder then jets from Z+jets and QCD (radiation)

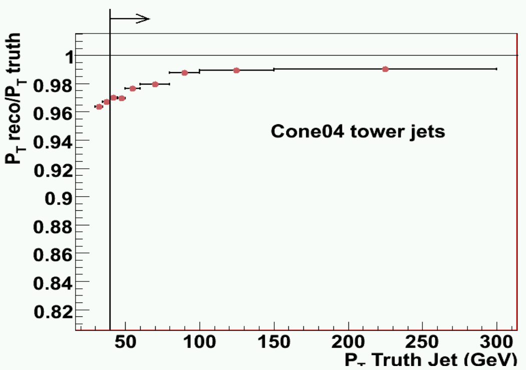
-> need to validate differential ttbar cross section against data in topologies without Z+jets/QCD.:

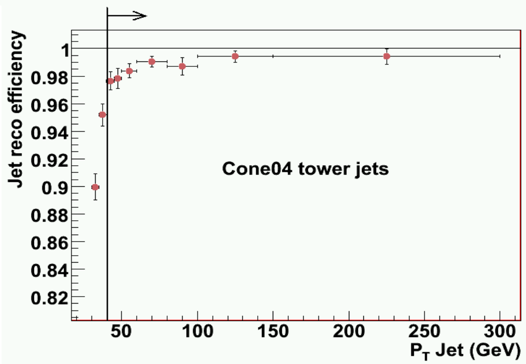
- e+mu+jets
- ll+jets + large ETmiss

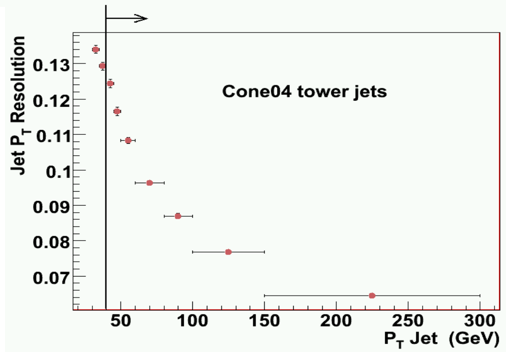


Unfolding of detector effects

Jet distributions which enter the corrections:





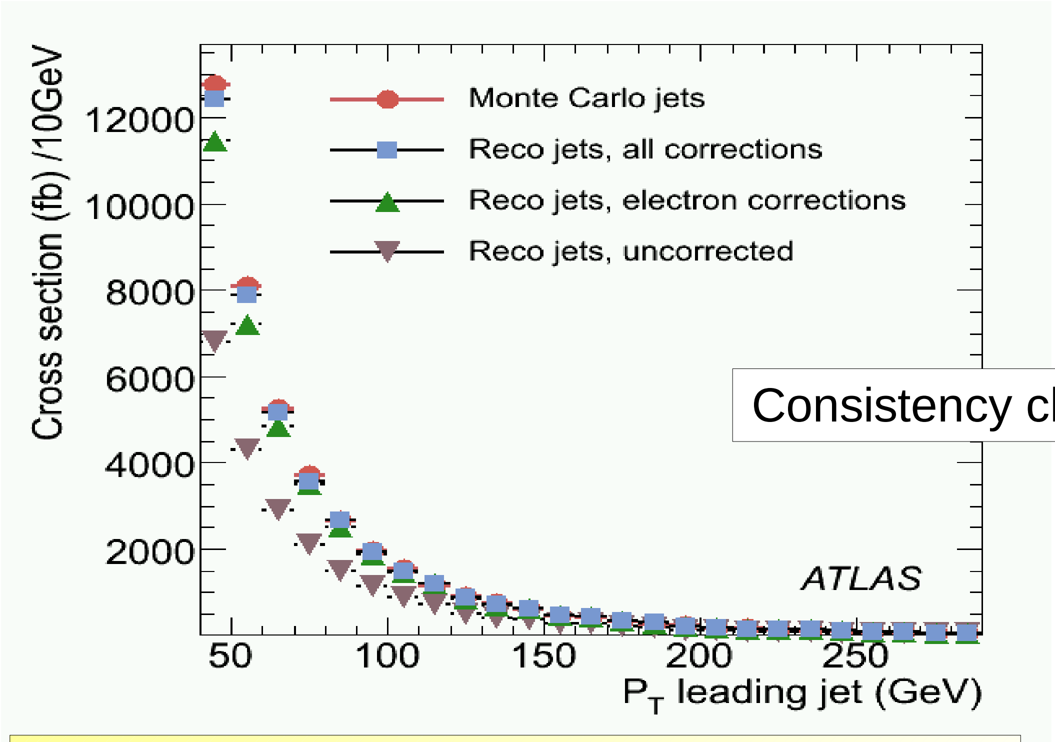


Unfolding corrections:

- Electron (muon) trigger and reco efficiency
- Electron (muon) resolution (small)
- Additional fiducial cuts

- Jet reco efficiency:
- Jet energy scale: non-linearity at low-PT
- Jet resolution -> distorsion of PT shape

Here: Assumed to factorize



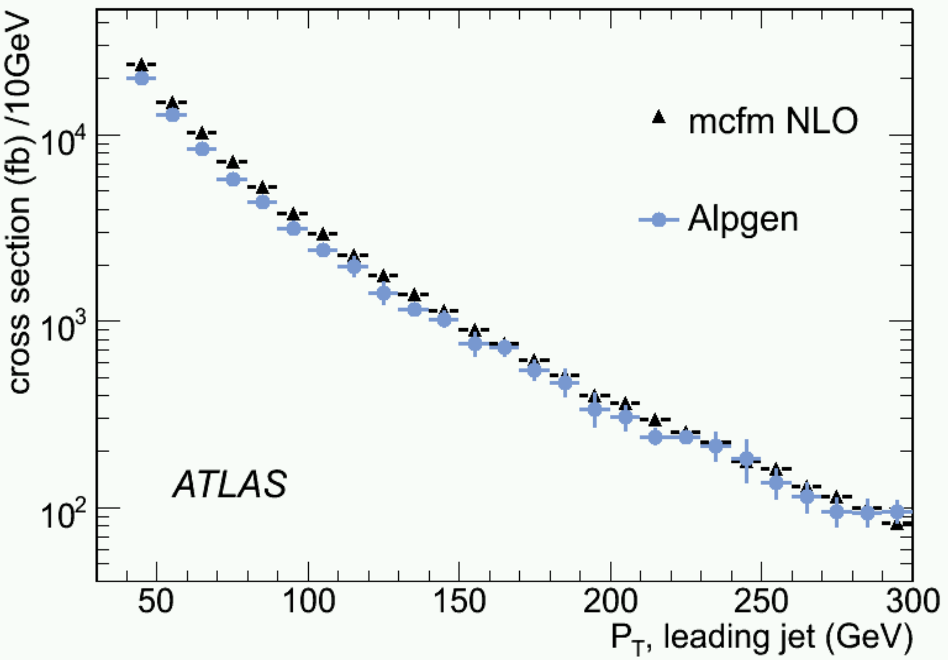
Consistency check

Uncertainties:
- true PT distribution -> < 1.5% error on cross section
- true resolution: < 2-4 % error on the cross section

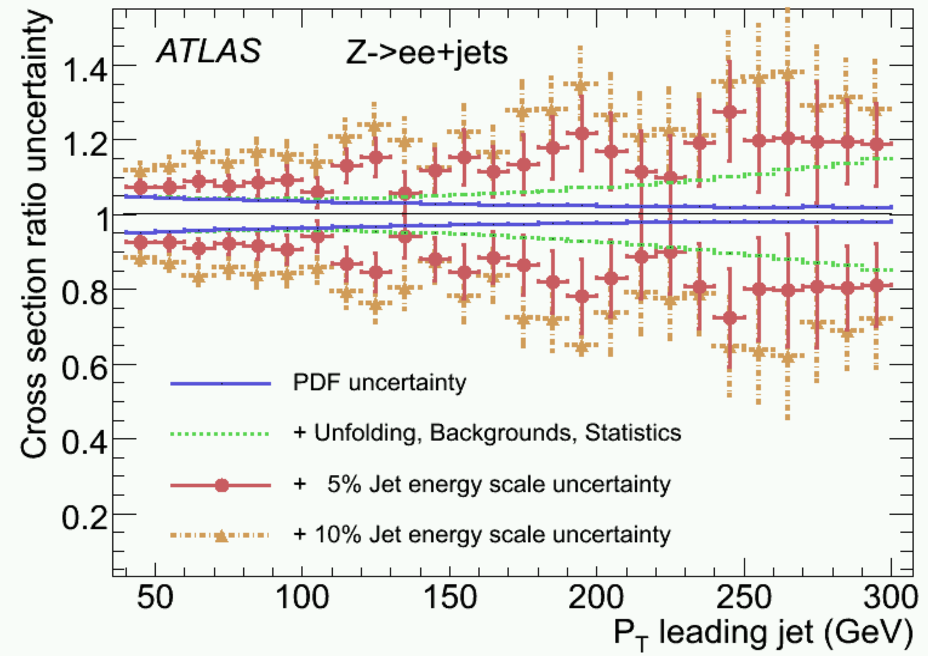
Simulation of the measurement

Differential cross section

Simulation of the measurement:



Uncertainty on the ration data/theory



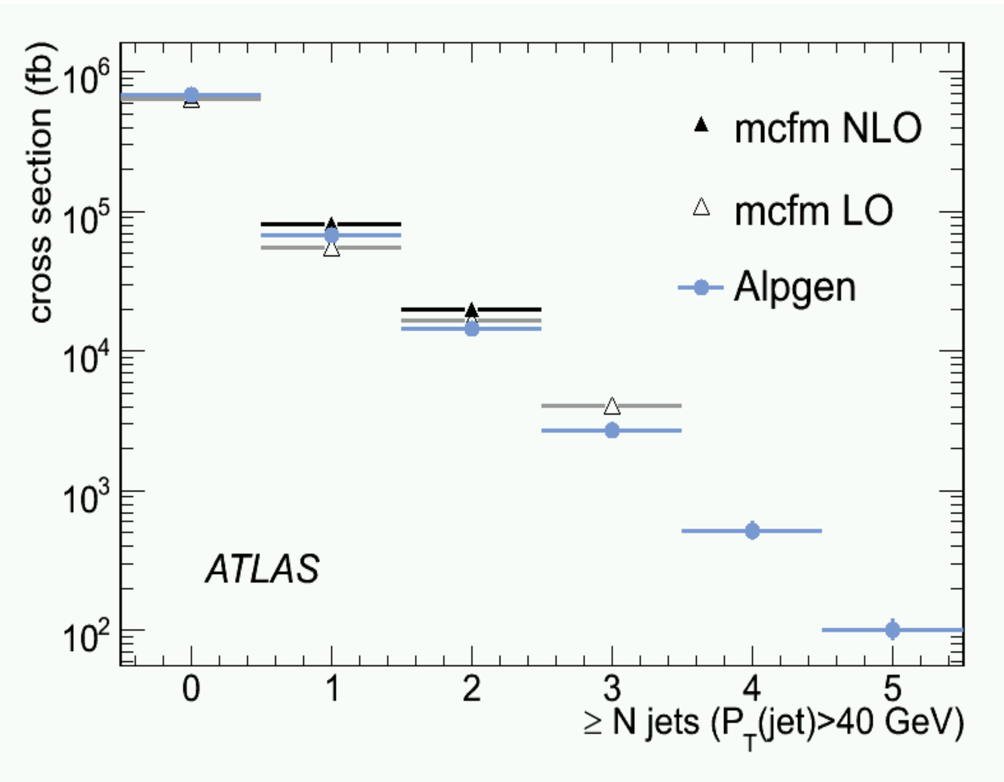
- MCFM:
  - PDF uncertainties from full set of CTEQ6m error functions within MCFM <5%
  - uncertainties from residual correction to the hadron level: %-level
- Reconstructed data:

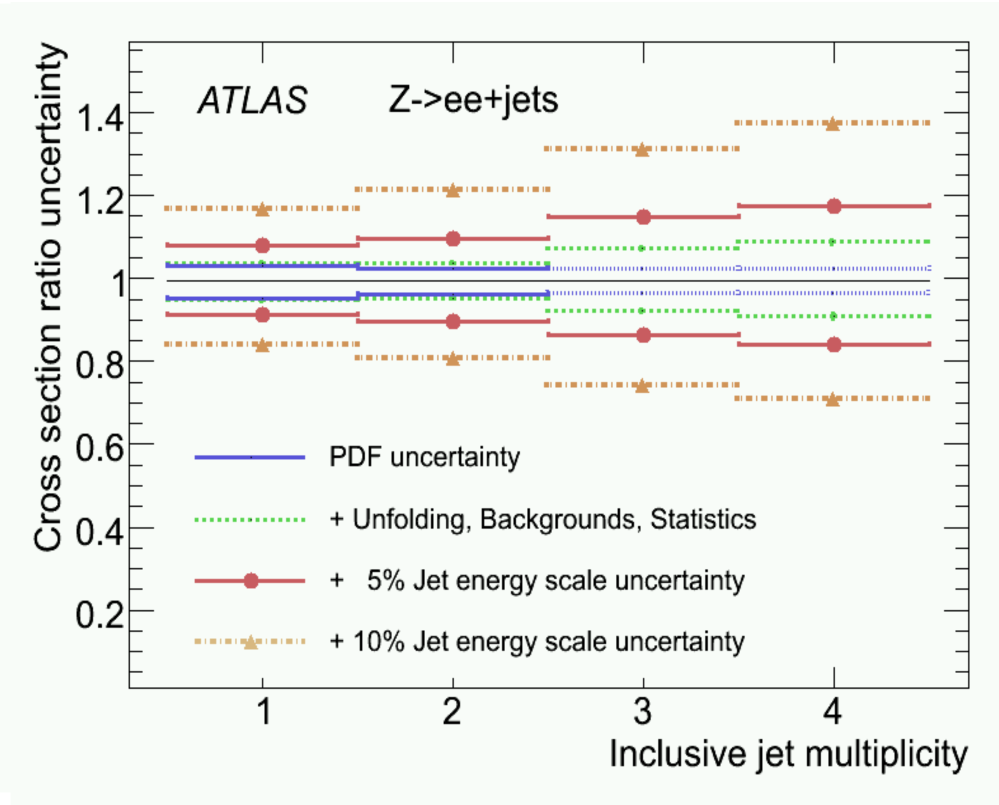
  Statistic and systematic errors scaled to uncertainty expected from data (1fb-1):
  - Statistics: dominant for hard jets (PT >300GeV) and large multiplicities
  - Background subtraction, QCD: assume 20% uncertainty-> %-level uncertainty
  - JES uncertainty -> unfolding: dominant for low/medium PT
  - unknown jet-PT, resolution: %-level uncertainty

  Electron reco efficiency (1%) and luminosity measurement: normalizing to inclusive XS

Simulation of the measurement

Inclusive jet multiplicity





An error of 5% (10%) on the JES scale uncertainty propagates into uncertainty of 8-15%(15-30%) on the cross section ratio measurement

Compare: Difference LO-NLO: 20-30%, Alpgen-Pythia: 10-60% !

Conclusion

- Using fully-simulated MC for signal and background we have performed a feasibility-study for the measurement of the Z+jets inclusive and differential cross section at ATLAS with data corresponding to 1fb-1 and the comparison with NLO fixed-order calculations.

- Lepton triggering and reconstruction in a high-multiplicity environment tested and optimized

- Unfolding techniques from parton- to hadron level and from reco to hadron level have been developed and validated.

- Dominating background source are QCD for low-PT jets / low jet multiplicity and Ttbar for high jet-PT / large jet multiplicity.

- Systematic and statistic uncertainties have been extracted.
  Dominating systematic uncertainty arises from the JES uncertainty
  The expected total uncertainty is at the level of 8-15%(15-30%) for jet energy scale uncertainties of 5% (10%)

- Differences in the predictions from Pythia, Alpgen and theory (fixed-order prediction) are specified: Generators have to be validated and to be retuned with data