W/Z+Jets production studies in ATLAS

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DIS 2008

EVENT 2958. 1279.

Why study W/Z+jet events?
How do we see such events in ATLAS?
Summary of current MC studies

Why study W/Z+jets?

Detector

- Tests lepton reconstruction & MET in multi jet environment
- Precision tests of jet reconstruction algorithms and techniques

Standard model physics

- Testing ground of pQCD
- Testing LO/NLO predictions
- Tests of BFKL logarithms
- PDF studies

Beyond the standard model physics

- Background to many BSM searches
- Events must be well understood before we start looking for new physics!

W/Z+jets production in ATLAS

- LHC will be a 'W and Z factory'
- Early running will produce $\sim 1\text{fb}^{-1}$ of data:
- ~ 20 million Ws, ~ 2 million Zs that can be seen (electron decay)
- $\sim 1/3$ of these produced in association with jets....

Health warning! Back of the envelope calculation

W/Z+jets reconstruction in ATLAS

Muon trigger used
to write $Z \rightarrow \mu\mu$ and
 $W \rightarrow \mu\nu$ events to
disk

Jets reconstructed in the
calorimeters. Jets are built
from calorimeter towers which
are 'H1 style' calibrated to
hadron level)

Electrons reconstructed as a
combination of a track in the
inner detector and the energy
deposit in the EM calorimeter

Muons reconstructed as a
combination of a track in the
inner detector and the muon
spectrometer

Met and SumPt
determined by
summing over
calorimeter cells.

Electron trigger system used to
write $Z \rightarrow ee$ and $W \rightarrow e\nu$ events to
disk

Current activities

- CSC (Computer Systems Commissioning) activity currently underway in ATLAS to produce public notes on performance and analysis
- This talk summarises the activities of the W/Z+jets CSC note
- The work in the W/Z inclusive CSC note is also relevant
- Electronic and muonic decay channels have been studied
- The focus at the moment is on understanding the detector: current activities include:

- o Leptons (ID, efficiency, background)
- o Methods of background subtraction
- o Jets (reconstruction, algorithms, bjets)
- o Unfolding corrections
- o Evaluating uncertainties

MC simulation and event selection

W/Z+jets sample (used for main analysis)

- Matched Alpgen/Herwig samples (using LO PDF set CTEQ6LL), with generator level filter requiring 1 truth cone04 jet and 1(2) electrons/muons within fiducial requirements

BG and comparison samples

- MC@NLO, Pythia and Alpgen W, Z, dijet and other background samples

Offline procedure (default)

Z EVENTS

- Mass cuts
- 2 leptons

W EVENTS

- 1xMet
- 1 lepton

LEPTON

- $P_t > 25/20/15\text{GeV}$
- Fiducial η cuts
- Track matching
- Inner detector track
- Isolation cut from jets
- Deposit of appropriate shape in calorimeter (electrons)
- Hits in muon spectrometer (muons)

JET

- $P_t > 20$ or 40 GeV
- Fiducial rapidity cuts
- Isolation from leptons
- Seeded cone 04 algorithm used

MET

- $\text{Met} > 25\text{GeV}$ (W events)

Correcting from parton-hadron level

- Data measurements compared to theory predictions at hadron level
→ need to correct theory with respect to fragmentation and underlying event
- Determine corrections by comparing Pythia hadron level results with non perturbative effects switched on/off
- Underlying event and fragmentation have the opposite effect
- Precise behaviour depends on the jet algorithm used

Trigger and reco efficiencies ($Z \rightarrow ee$)

- Single electron trigger (e25i) used to select $Z \rightarrow ee$ and $W \rightarrow ev$ events
- e25i efficiency determined using a ‘tag and probe’ **data driven** method (although results shown are obviously ‘pseudo data’ for the time being....)
- The numbers may be used to determine $Z \rightarrow ee$ or $W \rightarrow ev$ cross section
- Sufficient in inclusive study to consider the efficiency as a function of η and p_t only
- In these more ‘jetty’ events is important to study the efficiency as a function of jet variables (distance to closest jet, hadronic activity, jet multiplicity....)
- Global trigger efficiency $\sim 1.5\%$ lower than in the Pythia inclusive sample

Unfolding of detector effects ($Z \rightarrow ee$)

- Need to unfold data (jet and electron resolutions and reconstruction efficiencies) from detector level to hadron level
- Will eventually determine jet resolution and efficiency from real data

BG estimation and subtraction (Z)

- $Z \rightarrow \tau\tau$, $t\bar{t}$ and $W \rightarrow l\nu$ are, for now, estimated and subtracted using MC estimates
- Weighting factors used for QCD due to the enormous cross section of this process
- Fits may be used to estimate QCD backgrounds in real data
- Can also derive this background by inverting selected electron ID cuts

QCD background dominates at a 1 jet signal. At higher jet multiplicity $t\bar{t}$ dominates.

Muons coming from background (particularly $b\bar{b}$) can be rejected using isolation requirements

BG estimation and subtraction (W)

- QCD largest background
- ttbar dominates at high N_{Jets}
- W $\rightarrow\tau\nu$ and Z $\rightarrow ee$ estimated using MC
- Pythia underestimates QCD
- QCD can be estimated from data using photon trigger and normalising to electron spectrum in sideband
- QCD also can be estimated using fake rates

Jet energy scale (JES) uncertainties

- Dominant experimental systematic for W/Z+jets at the LHC
- Miscalibration of $\pm 1, 3, 5\%$ assumed on the jet energy and effect on jet pt calculated
- Main effect on the cross section results from the selection cut on the jet pt
- Within early running (1fb^{-1}) we hope to be within 3% JES uncertainty
→ systematic on the cross section of up to 10%
- JES uncertainty of 1% (ultimate ATLAS goal) yields systematic of 0.5%

PDF uncertainty studies

- Must get these right or SM physics could be misinterpreted as new physics!
- PDF uncertainties often the dominant theoretical uncertainty
- PDF forms determined from combination of theoretical calculations and data
- Free parameters of fit are given in a PDF set with their upper and lower errors
- Overall PDF uncertainties calculated with PDF reweighting on NLO CTEQ6M set
- **PDF uncertainty $\leq$ JES uncertainty**

Cross section results ($Z \rightarrow ee$)

- MCFM predictions corrected (for underlying event and fragmentation) to hadron level
- Data unfolded to hadron level
- PDF and JES uncertainties are included in the error determination
- Cross sections quoted wrt inclusive to factor out luminosity uncertainty in early data

XS ($Z \rightarrow \mu\mu$)

- o Data unfolded to hadron level as before
- o Choice of isolation cone size must be optimised so to balance muon reconstruction efficiency and background rejection
- o Cross sections normalised to NLO
- o MCFM predictions corrected and compared to unfolded reconstructed events

$Z \rightarrow \mu\mu + b\text{jets}$

- A cross section measurement in this channel will provide an important test of pQCD
- Will reduce the current uncertainty on the partonic heavy flavour content
- This channel will be a lot easier at the LHC than at the Tevatron (higher production cross section, smaller background from $Z+c\text{jet}$)

btagging: cutting on the weight parameter (secondary vertex and impact parameter)

Conclusions

- W/Z+jets used as a standard candle to understand the detector
- Understanding necessary in SM and BSM sectors
- Specific findings:
 - Efficiencies $\sim 1\%$ lower than the inclusive due to hadronic isolation
 - Cuts developed so that signals are larger than background sum
 - Tools for estimating the dominant backgrounds from data developed
 - Two main non perturbative effects negligible above a jet Pt of 40GeV
 - Comparisons made between theory (corrected to the hadron level) and data (unfolded from detector level) are in agreement
 - JES dominant systematic. Will be reduced to $\sim 3\%$ after 2 years
 - This is larger than dominant theoretical uncertainty (PDF uncertainties)