Data driven methods for a W/Z cross section measurement in ATLAS

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W/Z reconstruction in ATLAS

Muon trigger used to write Z→μμ and W→μν events to disk

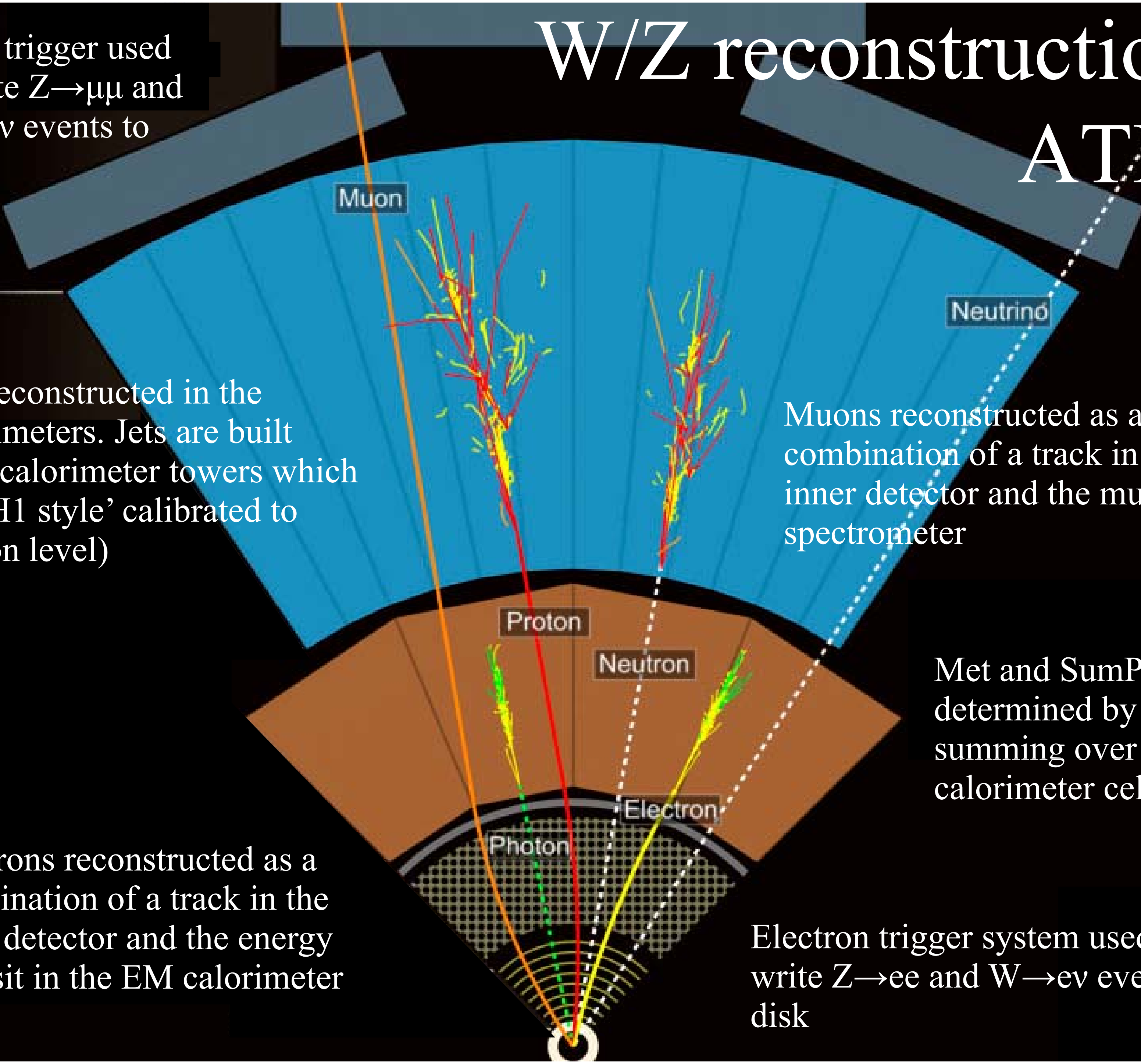
Jets reconstructed in the calorimeters. Jets are built from calorimeter towers which are 'H1 style' calibrated to hadron level)

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.

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

Electron trigger system used to write Z→ee and W→eν events to disk



W/Z boson studies at the LHC

- W and Z events will be produced in their millions even in early running at the LHC
- Z events in particular will be used initially to calibrate the detector
- Fundamental electroweak parameters may be extracted from precision studies
- These events are an important background for new physics searches

$$\sigma_{WZ}\Gamma_e = \sum_i \frac{N^i_{WZ} - N^i_B}{A^i \times \varepsilon^i_r \times \varepsilon^i_t \times \int L dt}$$

Number of events (signal-background) counted in the detector

Probability that the constituents of the event (electrons, MET) will fall within the acceptance

Probability that the boson will be reconstructed

Probability that the event will trigger (in the electron channel)

We must make corrections to these quantities for resolution **(detector unfolding),** ideally in a **data driven** way → of particular importance in a differential cross section measurement

Trigger analysis performed in collaboration with Mike Flowerdew (Liverpool)

Calculating ε_t

- Single electron trigger (e25i) used to select $Z \rightarrow ee$ and $W \rightarrow e\nu$ events
- e25i efficiency determined using a 'tag and probe' **data driven** method in $Z \rightarrow ee$ events, which also may be applied to calculate $W \rightarrow e\nu$ efficiency
- Measure number of events, N1, where tag electron passes selection and N2, where the probe electron additionally passes selection
- Similar technique used for reconstruction efficiencies, ε_R (Maria Fiascaris and Guillaume Kirsch, Oxford)

Level	Measured single electron efficiency(%)*
Reconstruction	62.26 (0.37)
L1 (wrt OL)	97.94 (0.05)
L2 (wrt L1+OL)	97.02 (0.06)
EF (wrt L2+L1+OL)	97.69 (0.05)

ATLAS three tiered trigger system (L1, L2, EF)

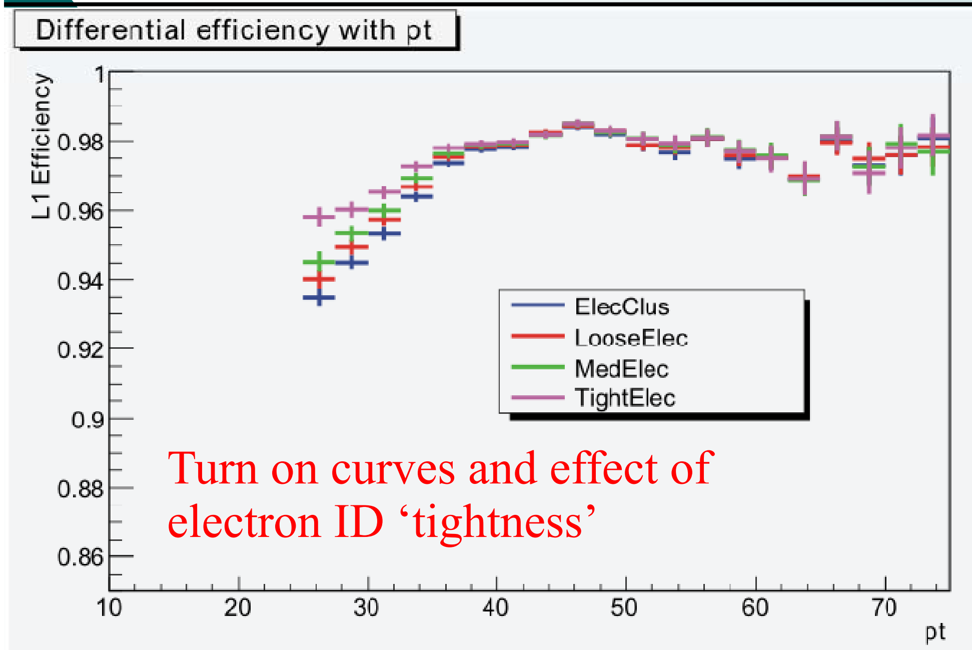
$$\varepsilon_{trig} = \frac{2(N_2 - B_2)}{N_1 + N_2 - B_1 - B_2}$$

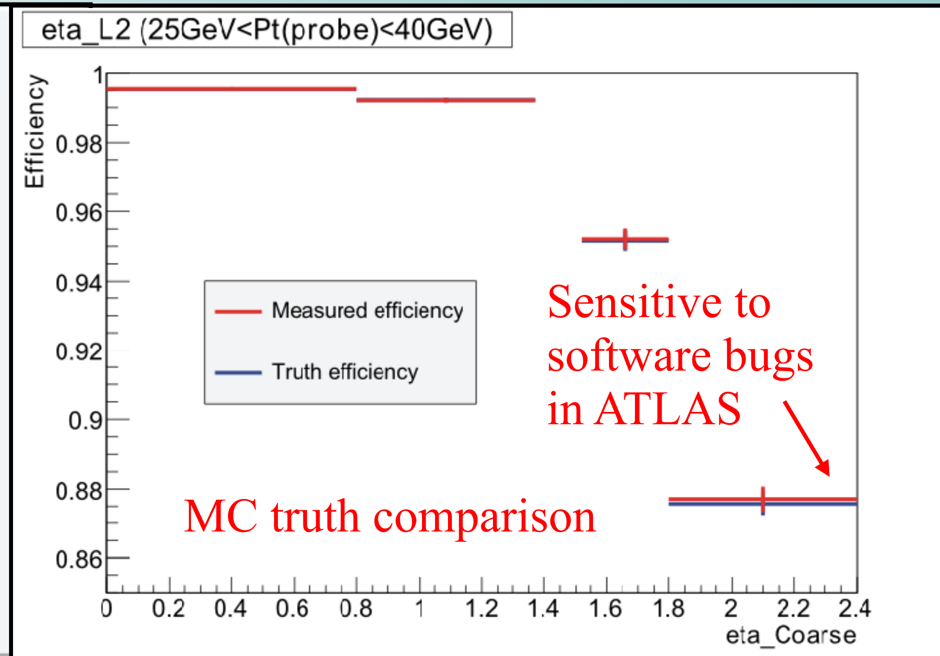
$$Error = \sqrt{\frac{\varepsilon(1-\varepsilon)(2-\varepsilon)}{N_1 + N_2}}$$

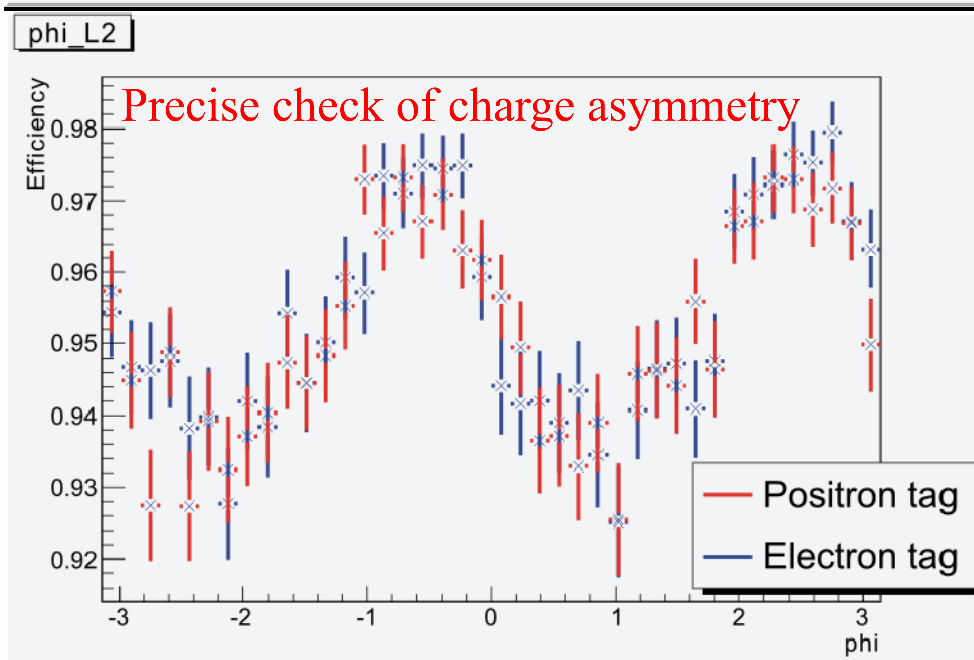
* Tight electron selection

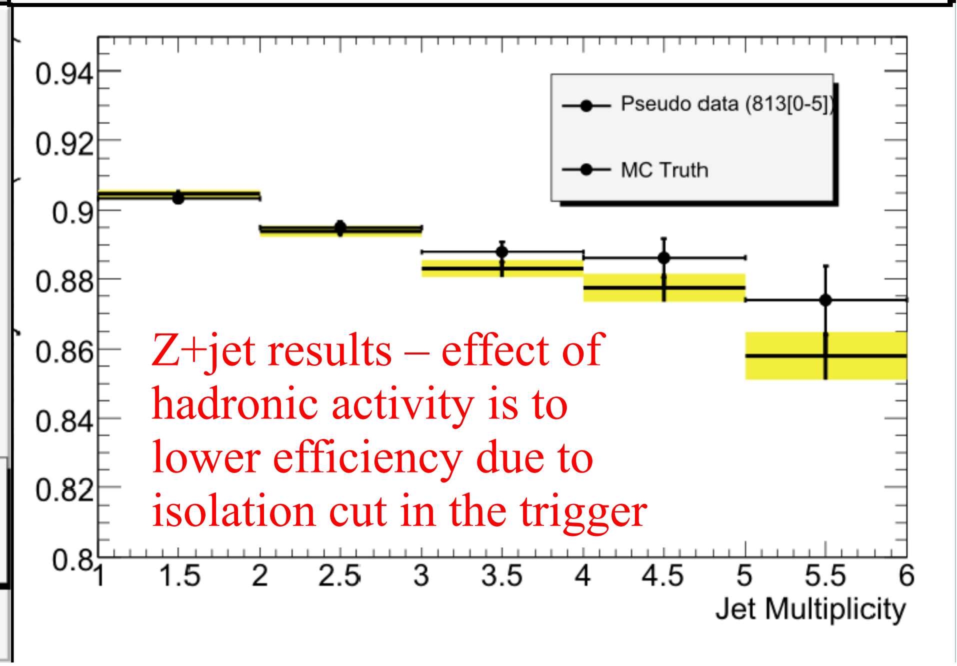
Differential case is computationally harder - must distinguish cases where the two electrons fall in the same bin (case A) and different bins (case B) for statistical treatment…..

Examples of studies/uses of this method

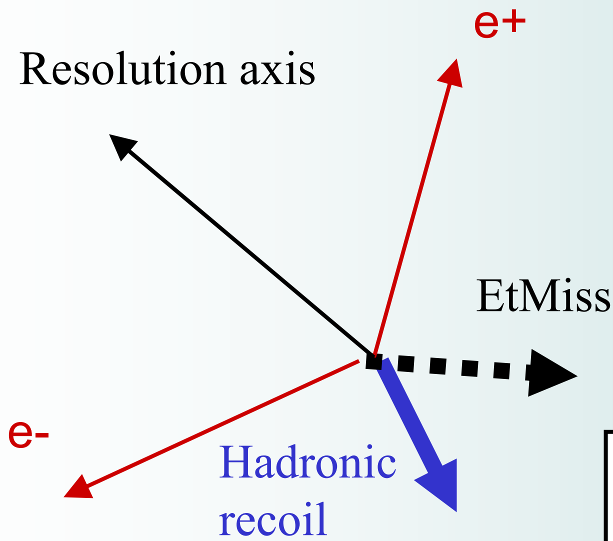








EtMiss scale from Zee events

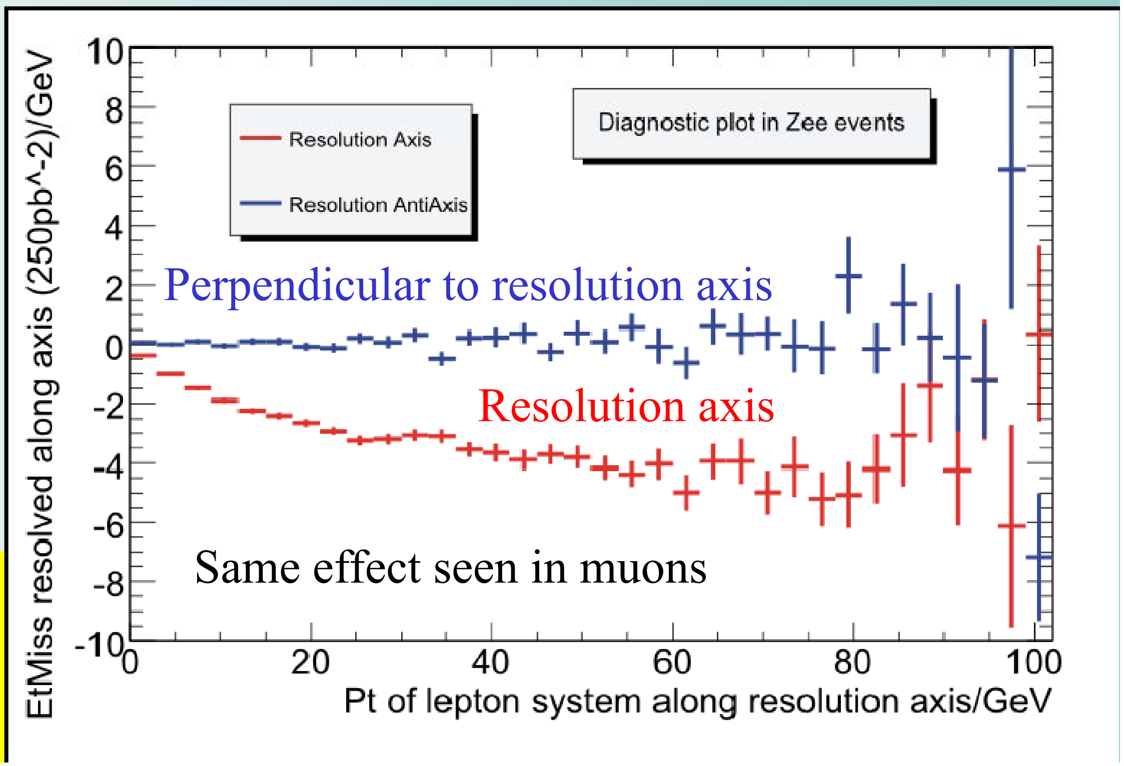


- Define an axis in the transverse plane from the event topology along which to resolve quantities
- Find axis sensitive to lepton-jet balance:

Perpendicular bisector

$$\vec{v}_{\perp} = \frac{\vec{p_t^{e+}}}{|p_t^{e+}|} + \frac{\vec{p_t^{e-}}}{|p_t^{e-}|}$$

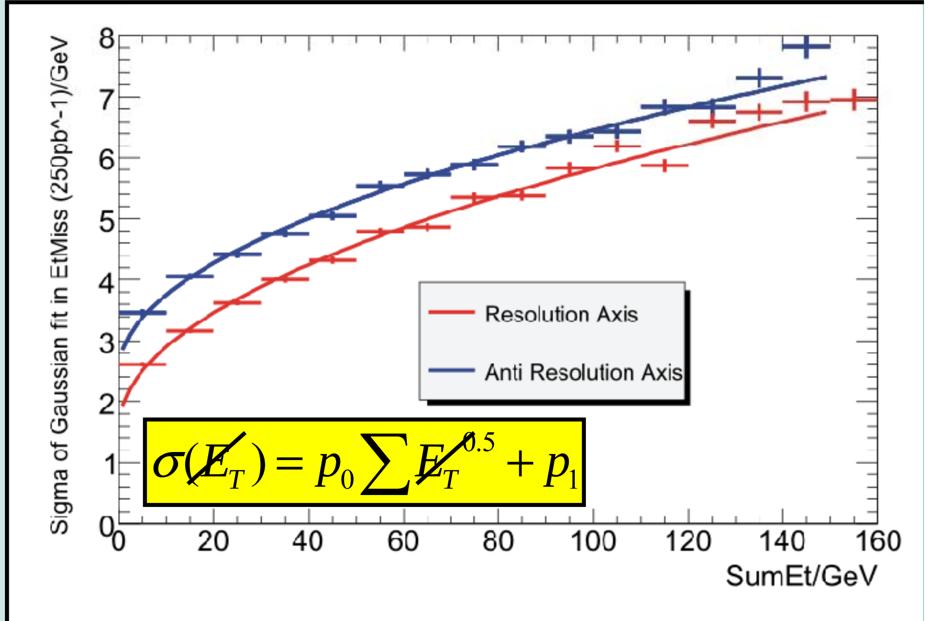
Y axis quantity (red) negative
→ EtMiss anti parallel to axis
→ Magnitude of hadronic activity underestimated
(reason for this as of yet unknown – current ongoing study…..)



This method is very sensitive to biases of this type and will be very important in first data!

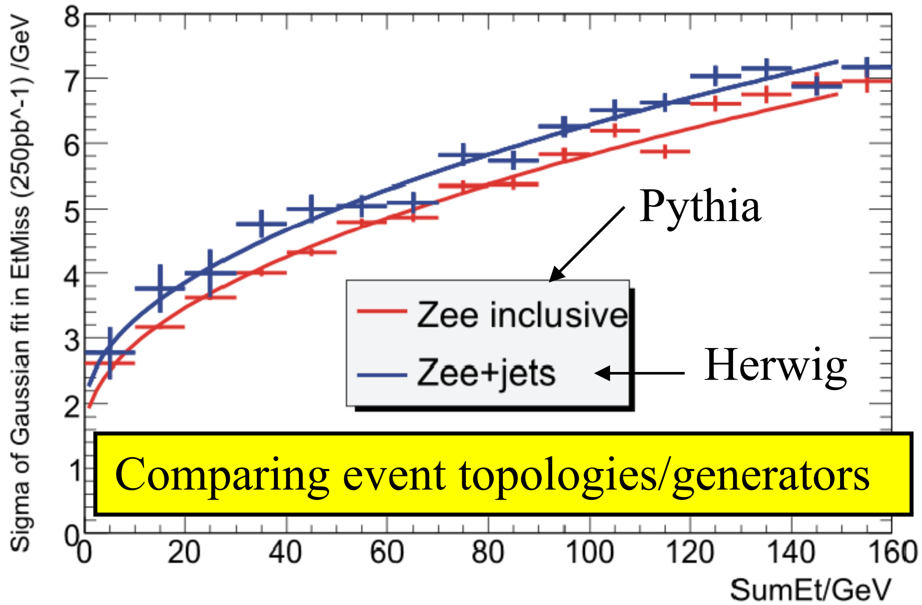
EtMiss resolution from Zee events

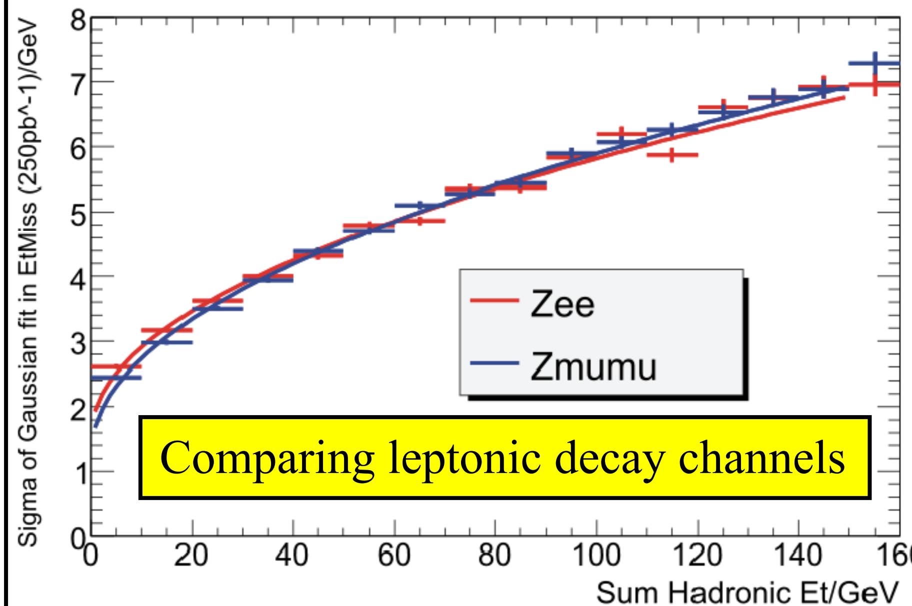
- Axis from previous slide constructed from lepton angles alone
- Will thus yield an optimal measurement of the resolution



Sigma of Gaussian fit of EtMiss projected along resolution axis

Sum of hadronic activity in calorimeter





QCD Background Estimation

- QCD is by far the dominant background in an inclusive analysis
- Logistical problems due to the enormous cross section of the process
- Brute force will not give a QCD spectrum in MC- need to be more clever…..

Control sample
(1 offline electron+jets)

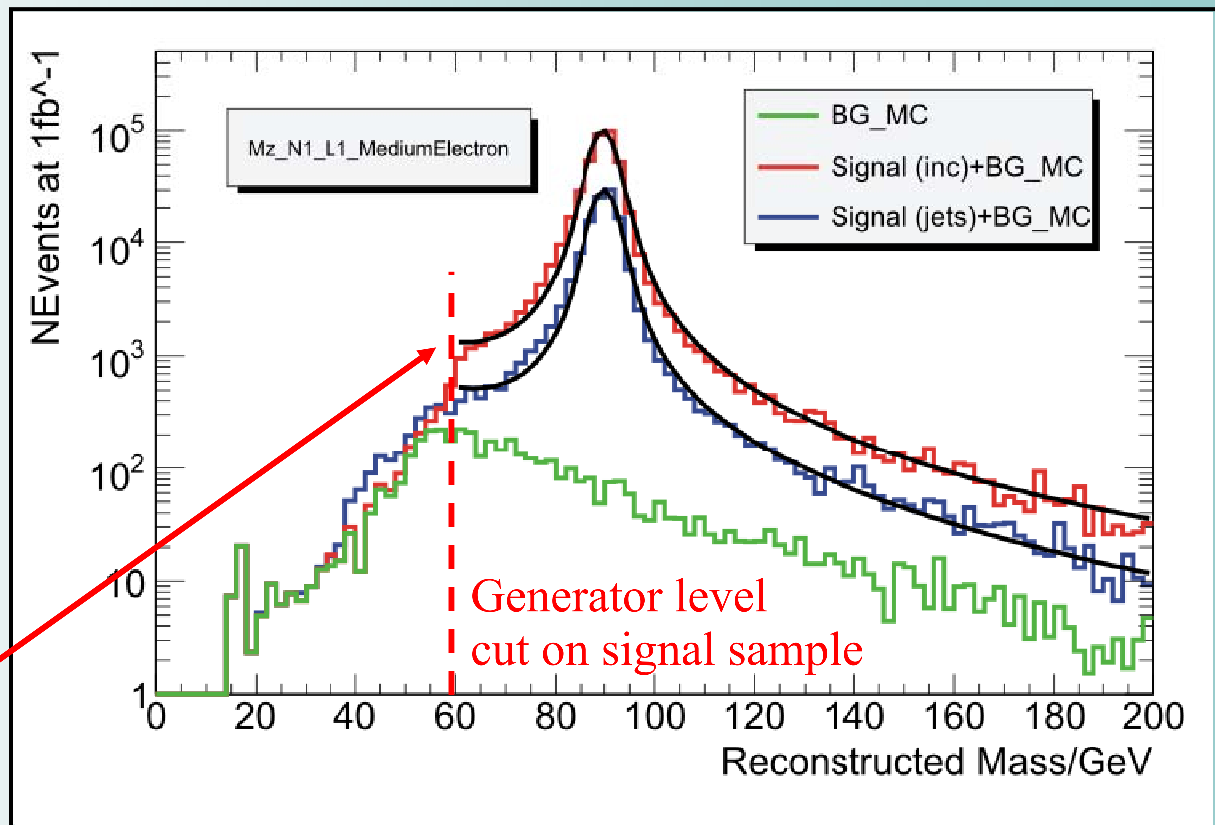
Fake rates (Mike Flowerdew)
P(jet will fake electron)

Energy correction
(what jet energy is at EM level)

Background mass spectrum

Fit and subtract from signal

'Worst case' background in trigger analysis



Cross section results (preliminary!)

- Acceptances calculated from MC (only possible way!)
  - global event acceptance of 0.3256 (W) and 0.3130 (Z)
  - note photon merging not included yet (~3% effect)

- Current global cross section measurement (decaying into electrons):
  17.6nb ± 1.8 (luminosity) ± 0.14 (stat) at ~30 pb (W)
  1.7nb ± 0.17 (luminosity) ± 0.028 (stat) at ~300 pb (Z)

(Without k factor correction)

Assuming 10% error on the luminosity

The main LHC systematic at startup will be the luminosity (to be improved….)

Systematic effects

- Using binned efficiencies in η, P_T: 1%
- Jet veto in W event selection : 3%
- QCD background subtraction : ~1% (trigger and reconstruction studies only)
- Smearing effect (on acceptance) : 0.5% (Z events), 3% (W events)
- Effect of binning acceptances in Pt(W) : 0.5%
- Varying IsEM level : 3% (unexpected!)
- PDF uncertainty : ~5% (for differential cross section measurements)

Unfolding corrections for MEt a high priority!

the ATLAS Experiment

Conclusions

Some ideas for further work…..

- Work on unfolding – not a trivial problem (but necessary for the EtMiss!)
- Differential cross section measurement
- Data driven estimation of electron resolution and scale using the Z peak
- # electrons hidden in jets- can do this from data using muons?

- Z events are immensely important for very early data (calibration)
- The analysis tools for making a cross section measurement for W and Z events in ATLAS are largely in place
- It is of importance that corrections are made by unfolding the data from detector-hadron level and not relying on MC (especially in EtMiss)
- Within early running ($1fb^{-1}$) we should have ~11 million Ws and 1.5 million Zs to play with!