Data driven methods for a W/Z cross section measurement in ATLAS (electron channel)

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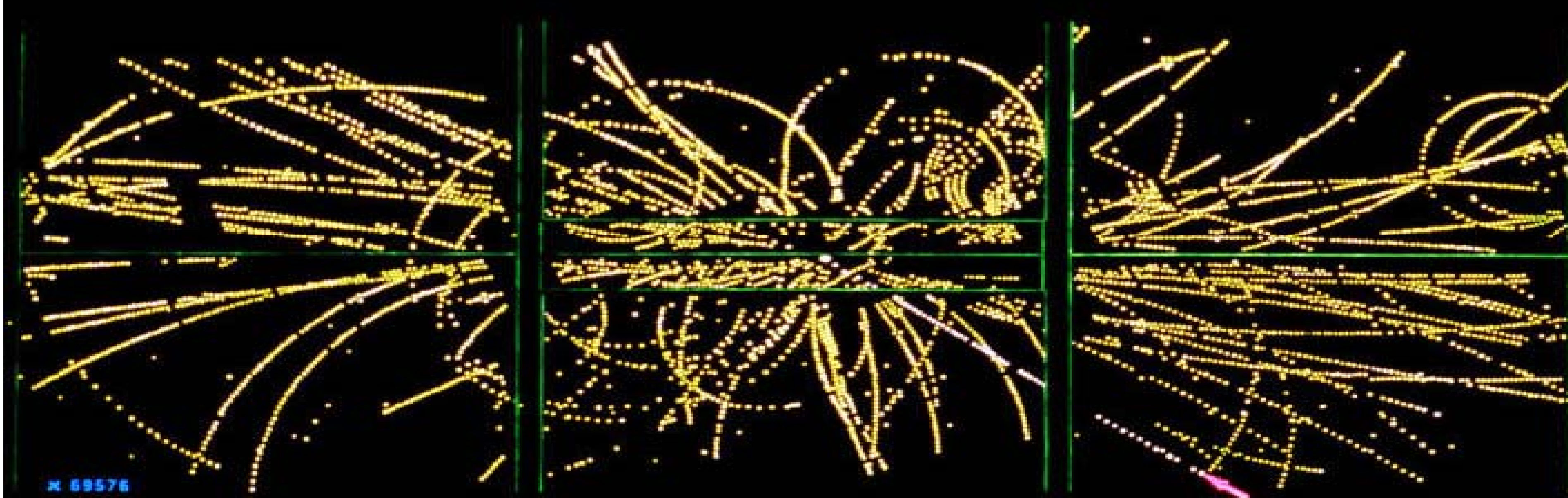


Elements of a W/Z cross section measurement

Number of events (signal-background) counted

Probability that the boson will be reconstructed

Integrated luminosity

$$\sigma = \frac{N_{WZ} - N_B}{A \times \varepsilon_r \times \varepsilon_t \times \int L dt}$$

Probability that the constituents of the event (leptons, MET) will fall within the geometrical acceptance (including smearing corrections)

Probability the event will trigger

Today will talk about smearing corrections to acceptance and the associated impact on calculated cross sections

Acceptance

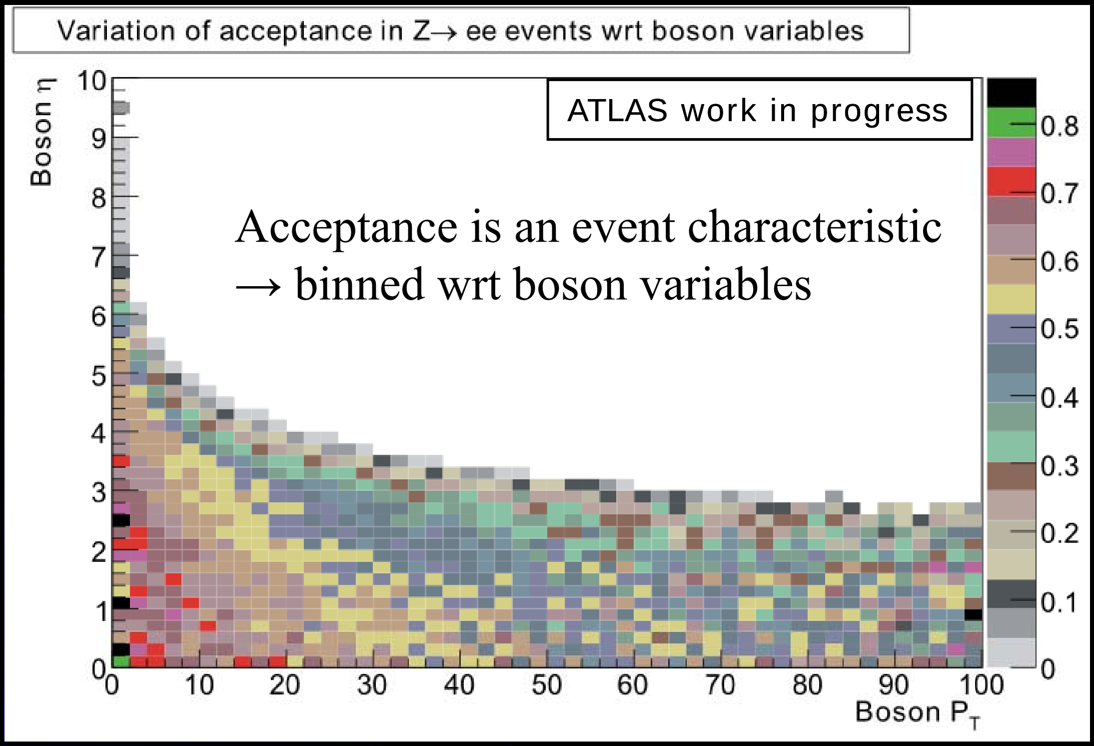
Rel 14

Should really be #events passing cuts at **reconstruction level** (more on this later….)

$$A_{\text{bin i}} = \frac{\#\text{events passing cuts}_i}{\#\text{events in sample}_i} \times \frac{\#\text{events in sample}}{\#\text{events in truth}}$$

Generator information (filter efficiency)

Acceptance lower for forward Z bosons (electrons fail η cuts)



Consider η=0:

→ At P_T=0 electrons are back to back and have the same P_T.

→ As P_T increases electrons become less monoenergetic

→ One electron may be pushed below the Pt threshold

→ As bosonPt increases electrons are more energetic raising acceptance

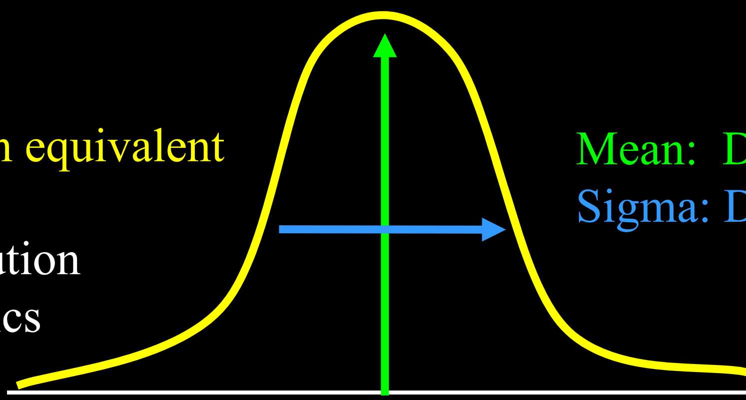
→ Two competing effects cause strange shape of observed distribution

Correcting the acceptance: smearing

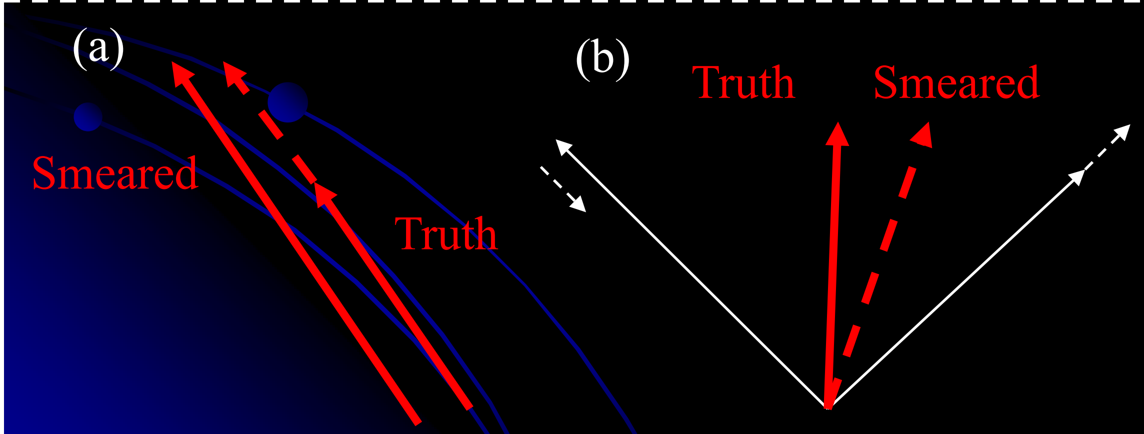
Acceptance calculated at truth level, but in data we cut on the reconstructed quantities
→ May correct for this by smearing truth particles with the resolution/scale to re-obtain the reconstructed distribution, and running through the acceptance cuts

RESOLUTION FUNCTION
Histogram (Reco-Truth), or data driven equivalent

For a given object, have varying resolution functions depending on event kinematics



Mean: Detector **scale**
Sigma: Detector **resolution**



Smear Pt with randomly chosen value from resolution function, either globally (a) or resolved along axes (b)

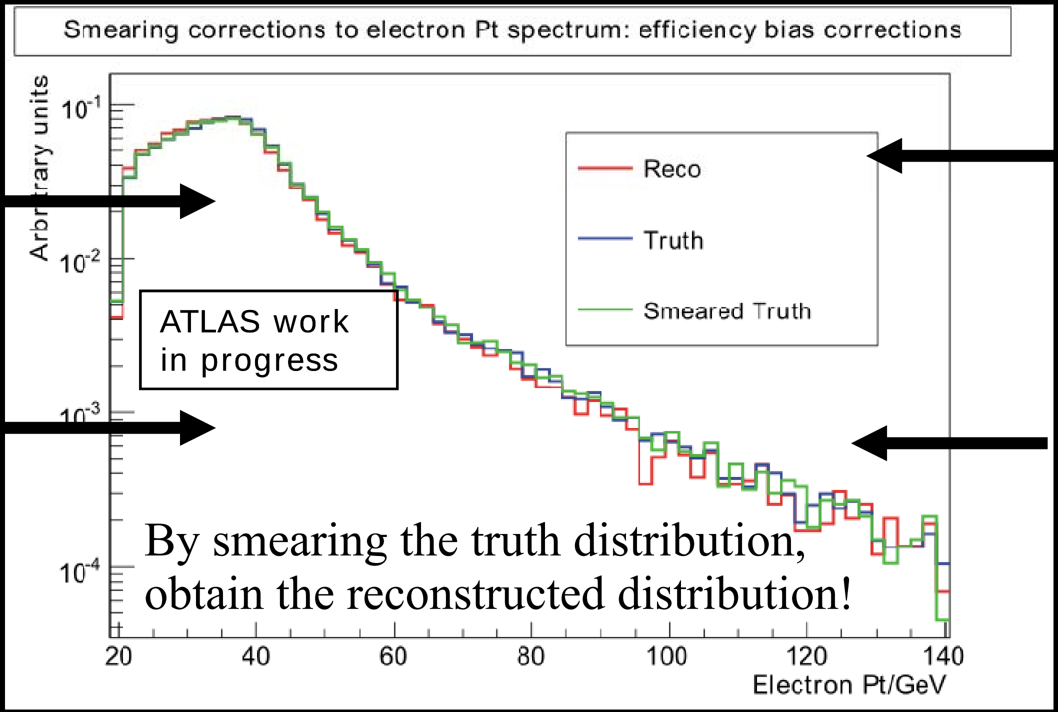
A word on resolution functions…..
Can either:
→ Rely entirely on MC and just use the reconstructed MC distribution (reliance on generator+GEANT)
→ Correct truth distributions using data driven resolution functions (reliance on generator only)

‘Simple’ example: electron smearing

Rel 13

Tweak the binning size to approximately match the resolution

Choose range to avoid bias with events falling just below the selection cut



Use resolution functions dependent on the correct variables

Fold in bias from trigger, reconstruction turn on curves and acceptance variations

Zee and Wenu acceptances (smeared with electron P_T with unsmeared values in parentheses:
28.95 (29.69)%
32.56 (33.04)%

Not surprisingly the effect is larger for Zee than for Wenu

SYSTEMATIC 1: Electron scale and resolution

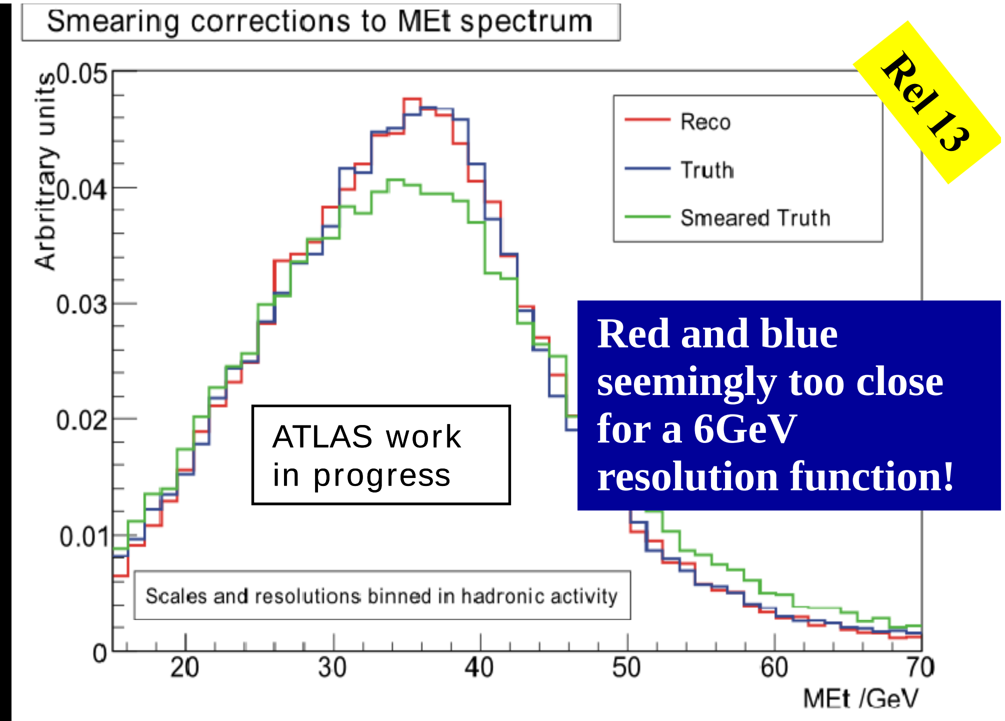
Can surmise electron scale and resolution from Z invariant mass peak and width respectively

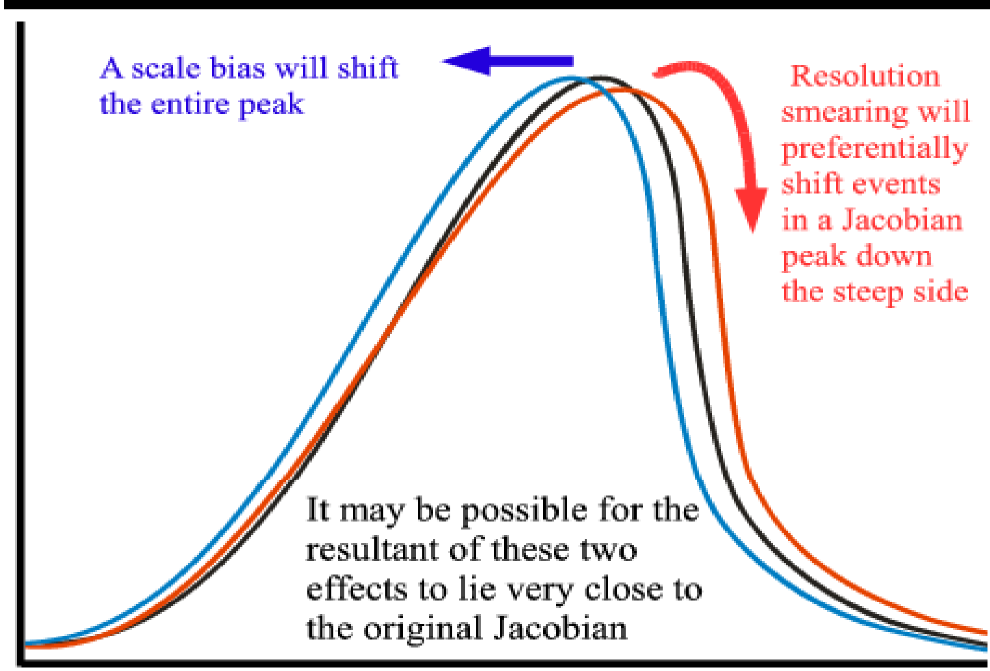
SYSTEMATIC 2: Smearing procedure

Comparison with cutting on reconstructed distribution in MC

Difficult example: MEt smearing

Similar techniques developed on the electrons tried on MEt:
→ a hadronic activity dependent smearing alters distribution much more than resolution/scale naively allows





'out of the box' reco and truth MEt distributions lie almost on top of each other!

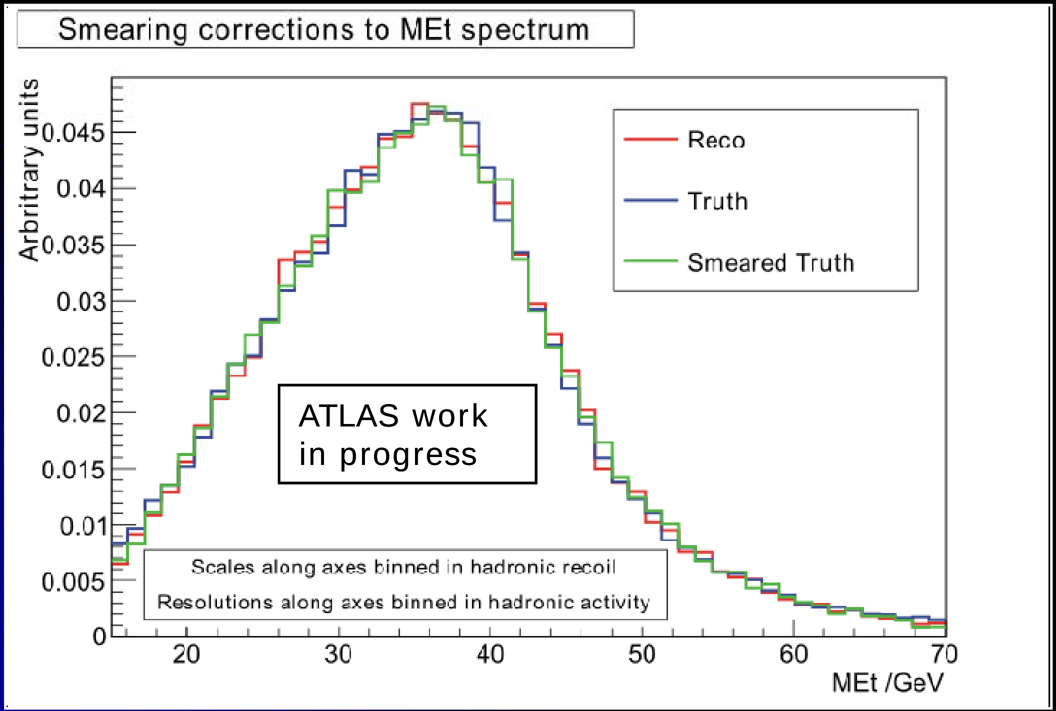
HYPOTHESIS: What if these two separate effects depend on different variables and have the unfortunate effect of cancelling out each other?
→ Need to decouple the effects of MEt resolution and scale!

A modified scheme…

Rel 13

Hadronic activity is the variable driving the MEt resolution. MEt resolved along certain axes or MEt itself is sensitive to scale (more on this later).

Obtain function, F, of mean of resolution function with respect to MEt or MEt_{perp} → Apply correction from F to measure unbiased behaviour of σ with ΣPt → Calculate smeared value by applying scale from F and smearing from the $\sigma(\Sigma Pt)$

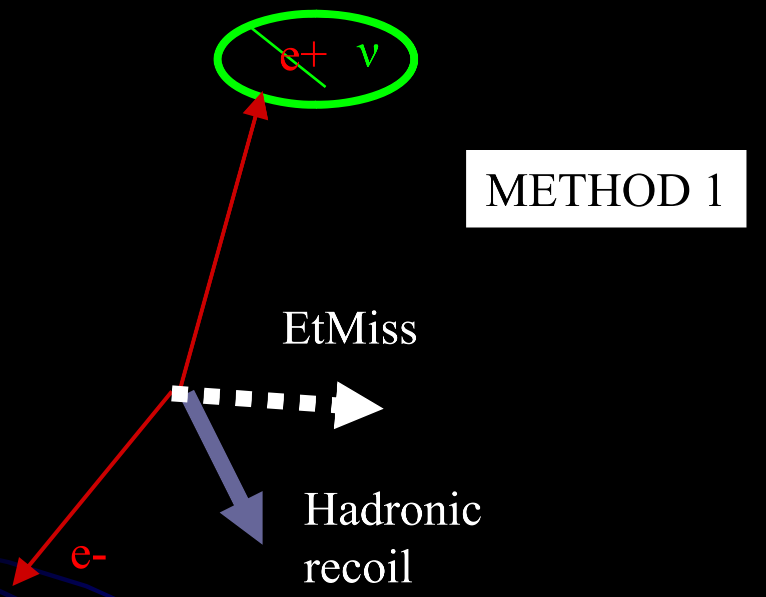


The MEt reco distribution is now obtained succesfully → both (large) scale and resolution corrections have been applied to obtain a distribution lying almost on top of the original one

Correction to the global XS is of the order 1% with a systematic below 0.5%

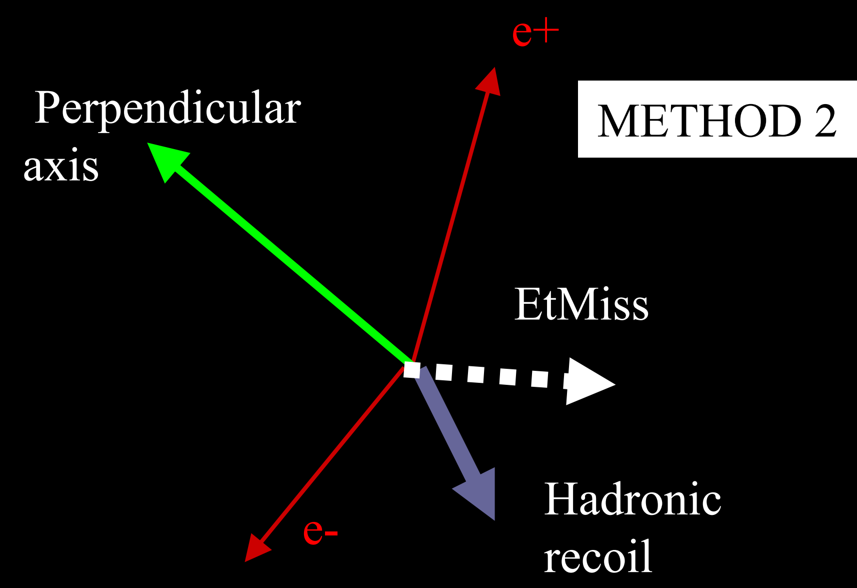
MEt scale and resolution from Zee

Motivation: No real MEt in Zee event → eliminate problem of separating real and fake MEt!



'Neutrinofy' a Z event by pretending one of the electrons is a neutrino and recomputing the MEt in the event

'truth' MEt $=e_1$
'reco' MEt $= -e_2 -$ Hadronic Recoil
where Hadronic Recoil$= -e_1 - e_2 -$ MEt

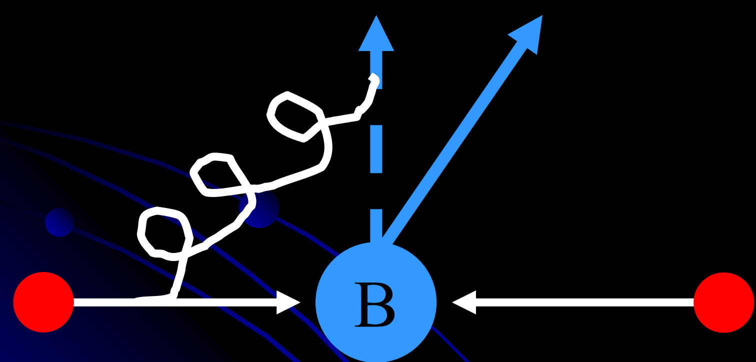


Define an axis ('perpendicular axis') in the transverse plane along which to resolve MEt. Axis at right angles to this ('parallel axis') used for comparison.

$$\vec{v}_\perp = \frac{\vec{p}_t^{\,e+}}{\left|p_t^{e+}\right|} + \frac{\vec{p}_t^{\,e-}}{\left|p_t^{e-}\right|}$$

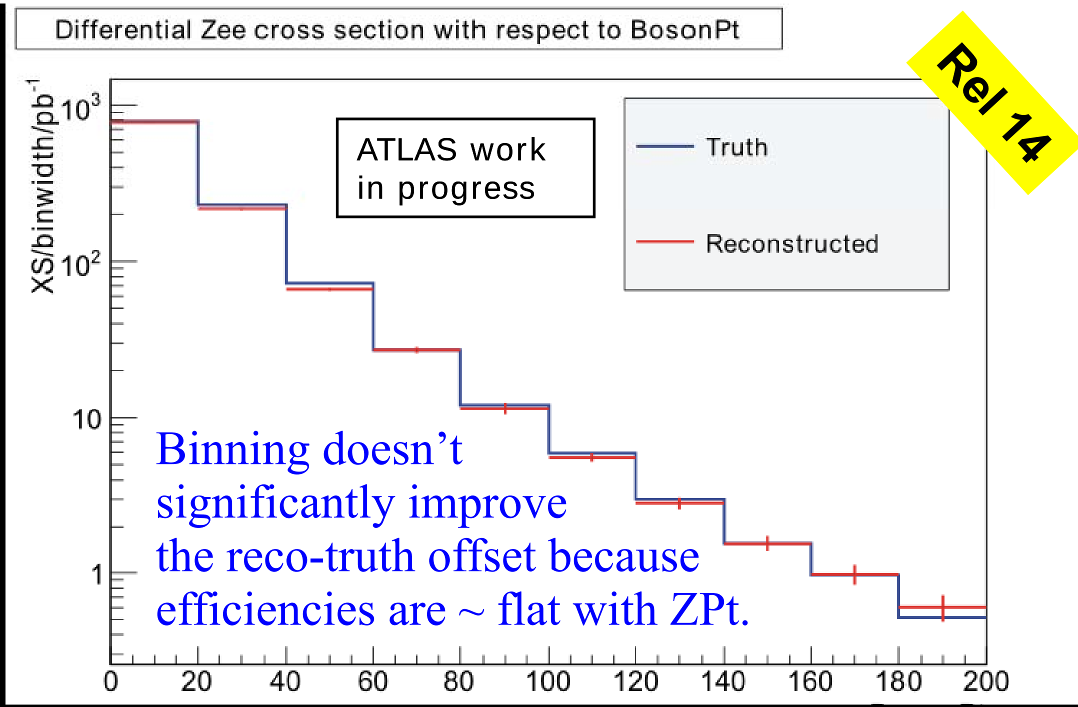
Differential cross sections: P_T

xy component of boson momenta (P_T) depends on off-Z axis radiation of the incoming partons. Predications of the low P_T region require gluon resummation, the parameterisation of which is partially determined from data.

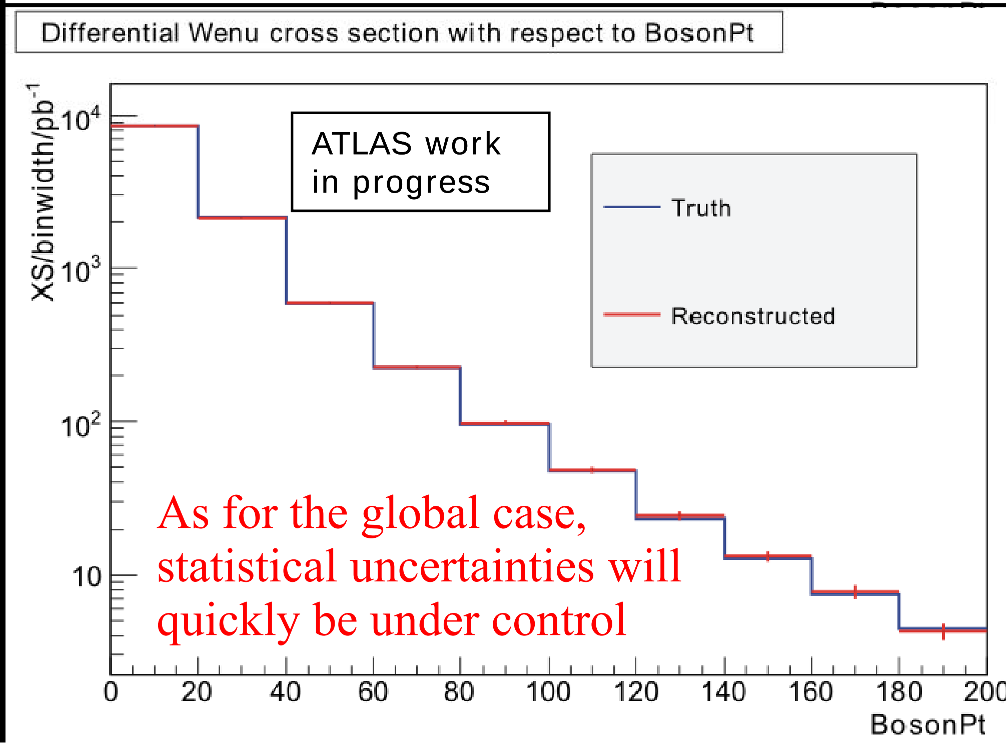


In (eg) D0, uncertainties dominated by:
- → PDF uncertainty
- → Efficiency corrections
- → Resolution corrections

↖ Can we improve this?



Binning doesn't significantly improve the reco-truth offset because efficiencies are ~ flat with ZPt.



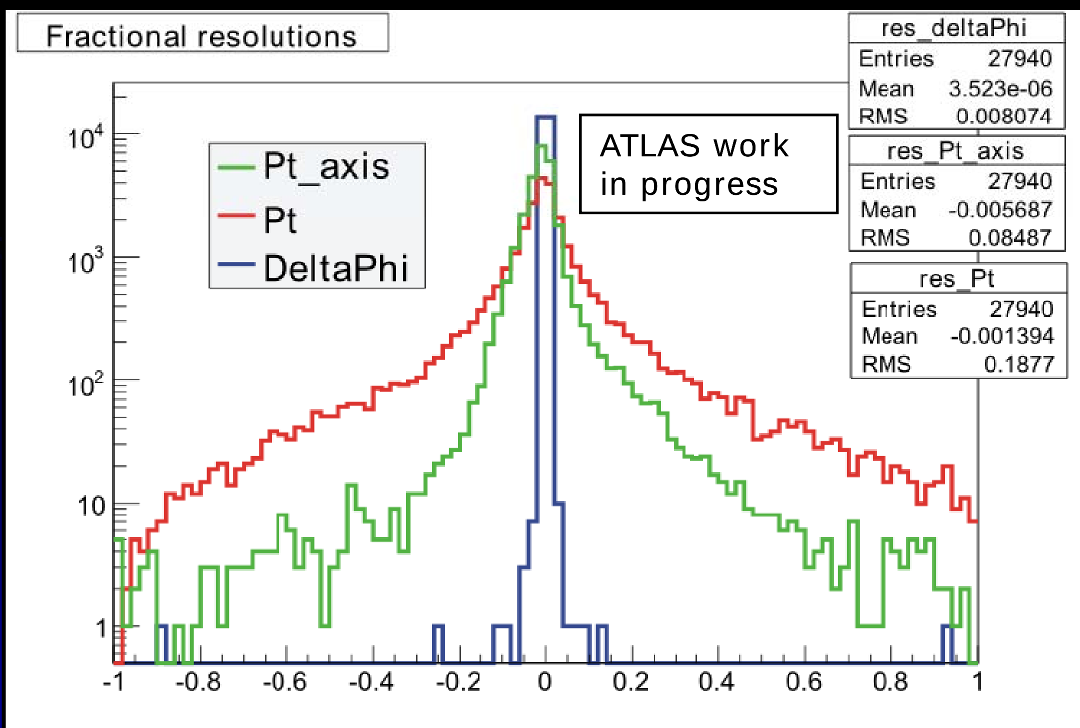
As for the global case, statistical uncertainties will quickly be under control

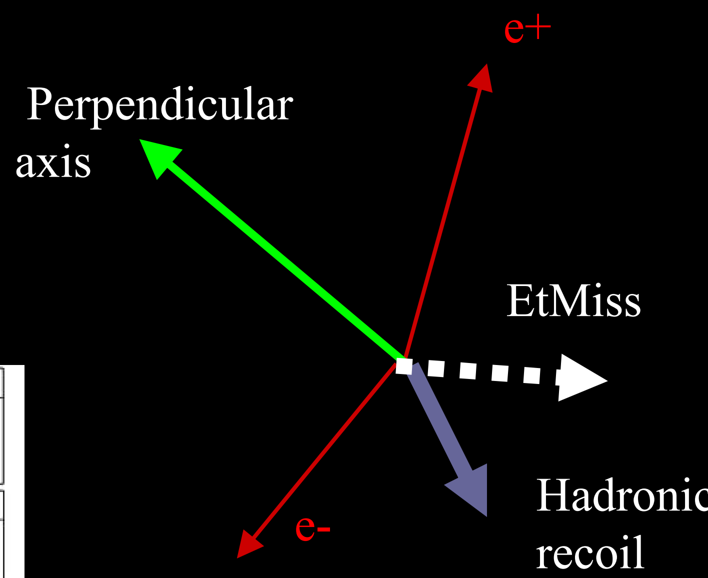
Beating down the systematics→ beyond standard variables

→ Aim is to construct a variable which is sensitive to VP_T but is less sensitive to the lepton resolution

→ Can resolve VP_T along an axis

→ Or to make a measurement using angles alone ($\Delta\theta$ between electrons)?





→ May compare with generator predictions wrt the chosen variable

→ Could transform back to VP_T distribution using unfolding techniques

Similar idea to T.Wyatt, M.Vesterinen (arXiv:0807.4956) although different choice of axis

Unfolding

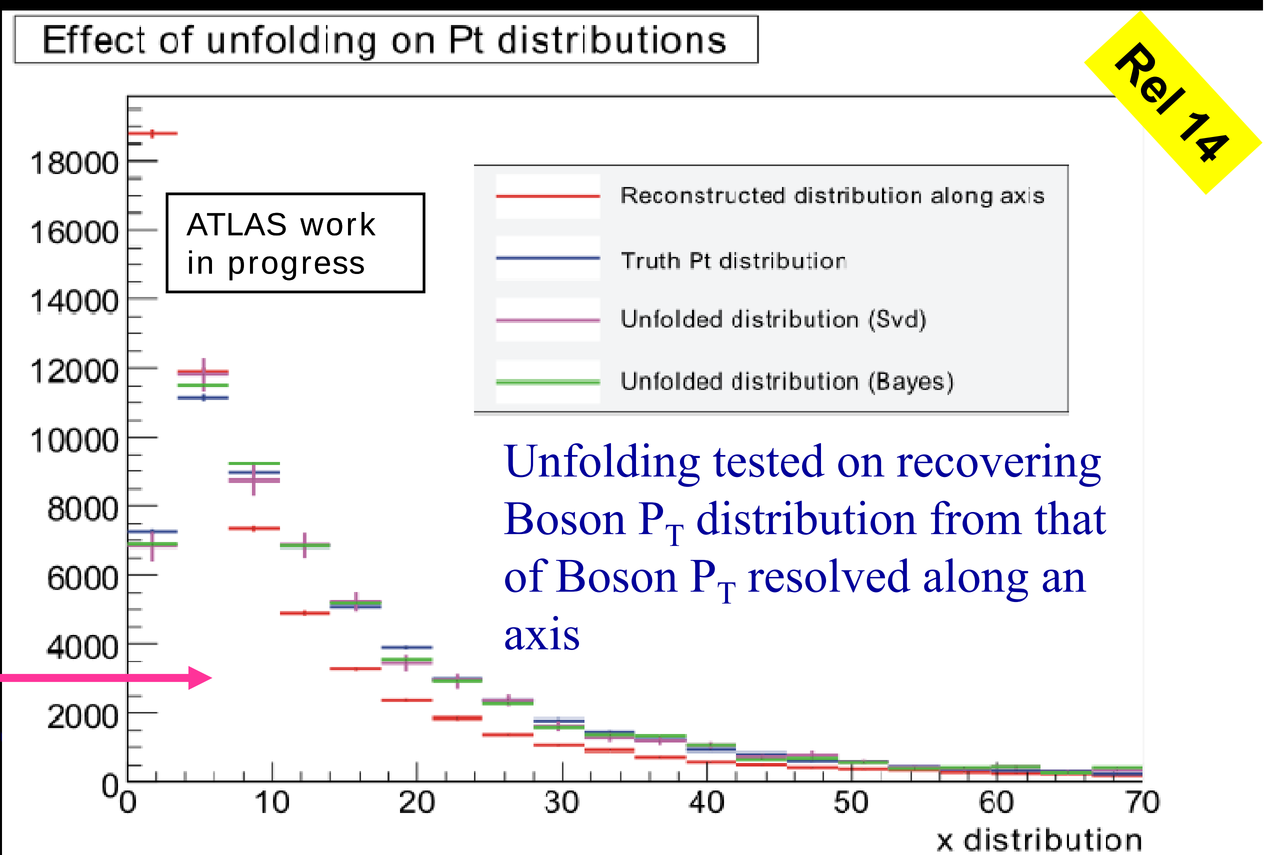
measured dist ↓ Response matrix ↙

$$\nu_i = \sum_{j=1}^{M} R_{ij}\mu_j$$

↑ true dist

→ Unfolding calculates distribution μ given ν
→ Uses a response matrix mapping the true distribution with the measured one
→ Implemented package **(RooUnfold)** to solve for μ by inverting the matrix
→ Weights used to avoid fluctuating solutions (from statistical fluctuations)
→ Unfolding designed to have response matrix trained with event by event (Truth, Reco)

Possible uses for unfolding in W/Z analyses:
→ Using data driven resolution functions to estimate truth distributions from reconstructed ones ('backwards' detector smearing)
→ Transforming from one XS dependence to another



Unfolding tested on recovering Boson P_T distribution from that of Boson P_T resolved along an axis

Conclusions

- 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 MEt)
- Within early running (1fb-1) we should have ~10 million Ws and 1 million Zs to play with!
- In later data differential cross sections and unfolding techniques from data are promising….
- Possibility to exploit angular resolutions in ATLAS to beat down the systematics in a differential XS measurement