FSR Mismodelling and In-situ Calibration for W Mass

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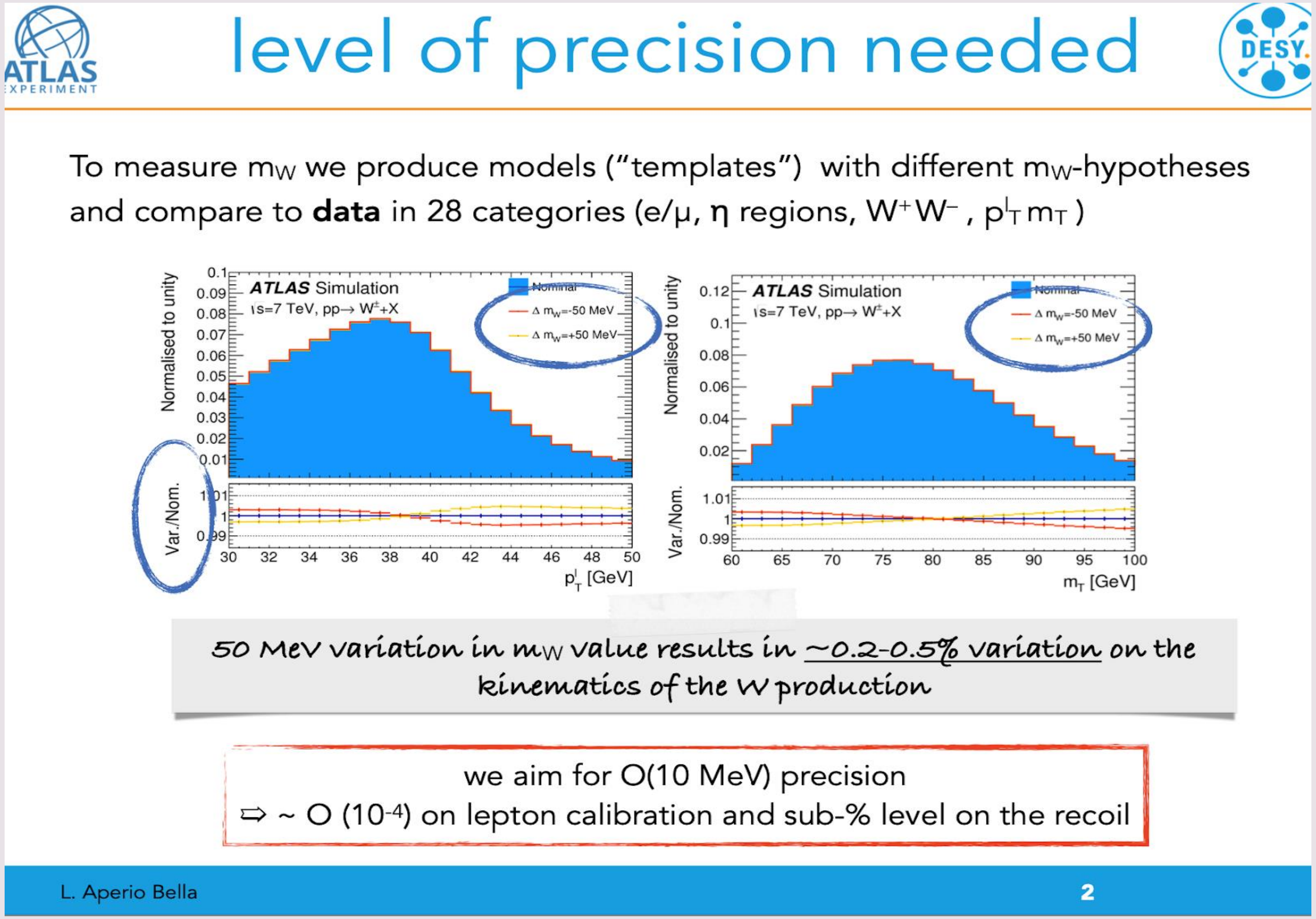
Introduction – Electron Calibration for mW



- Electron energy calibration is one of the dominant sources of uncertainties for mW

	5.02 + 13 TeV			5.02 + 7 + 13 TeV
Unc. [MeV]	m_T	p_T^ℓ	$p_T^\ell + m_T$	$(p_T^\ell + m_T)^{5+13\text{ TeV}} + p_T^{\ell,7\text{ TeV}}$
Electrons	6.9	7.0	5.4	3.6
Muons	3.4	4.2	2.6	2.5
Recoil	2.5	2.4	2.4	1.3
Lumi	0.6	0.7	0.5	0.7
Backg.	2.0	3.1	2.1	1.3
p_T^W	1.5	2.7	1.5	1.2
PDF	4.6	5.1	3.2	2.7
A_i	0.0	0.0	0.0	1.1
EW	0.0	0.0	0.0	3.0
Γ_W	0.0	0.0	0.0	0.0
σ_{syst}	9.6	10.8	7.7	6.5

In-situ Electron Calibration Overview

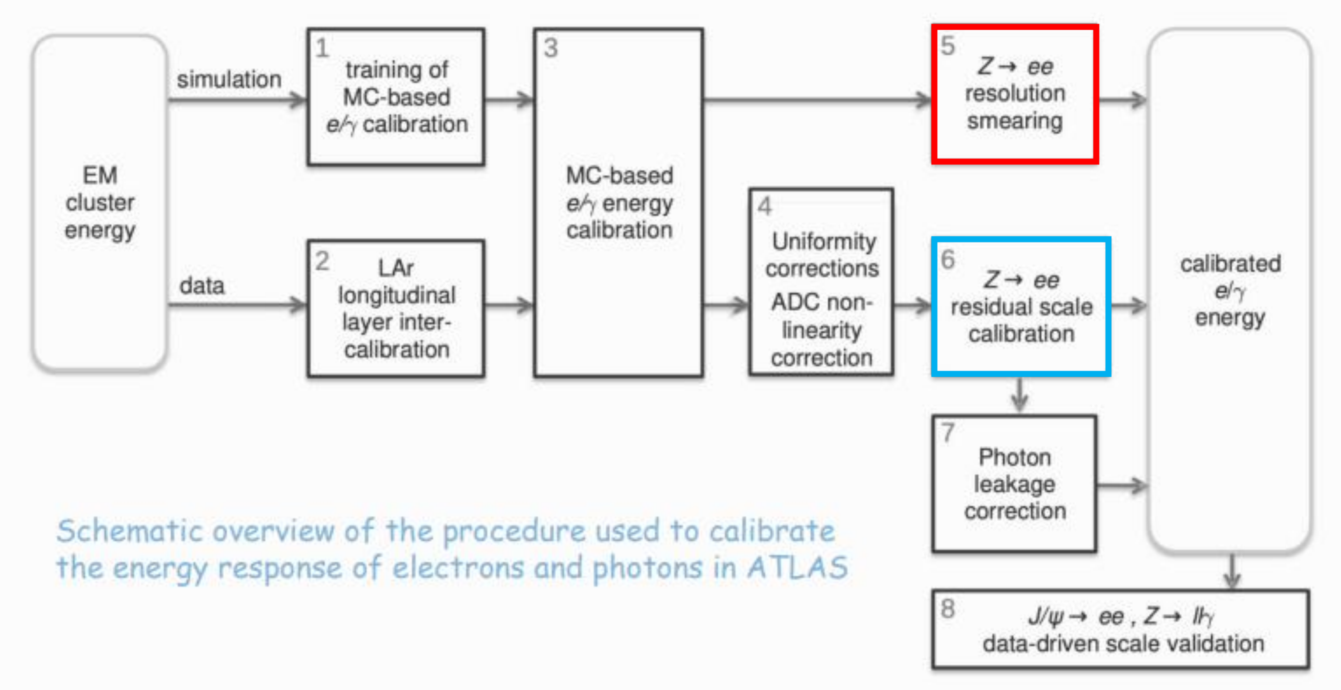
- Electron calibration procedure uses several steps to bring EM calorimeter response inline between data and MC
- In-situ calibration is performed using low pileup Z data at 5 and 13 TeV:
  - Gaussian Smearing, c (constant term):

$$\left(\frac{\sigma(E)}{E}\right)^{data} = \left(\frac{\sigma(E)}{E}\right)^{MC} \oplus C\left(\eta^{calo}\right)$$

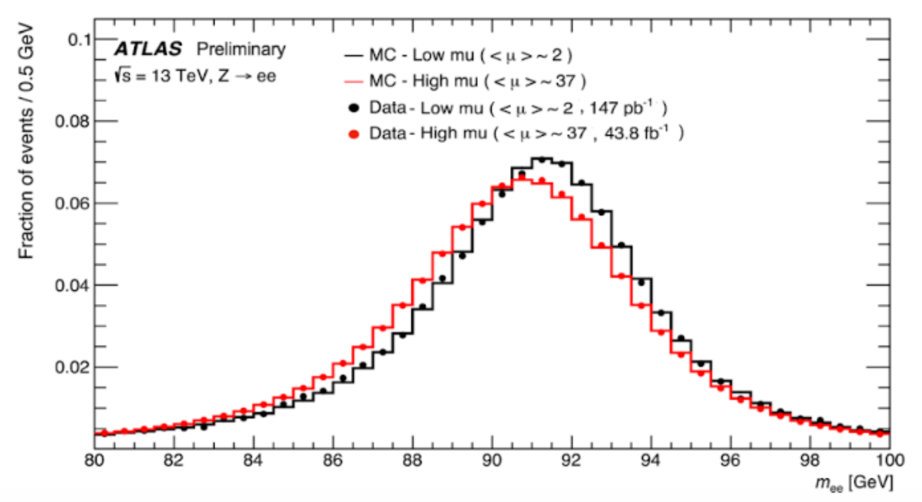
  - Energy Shift, α (scale factor):

$$E^{data} = E^{MC}\left(1 + \alpha\left(\eta^{calo}\right)\right)$$

- Electron calibration repeated for low mu analysis due to higher reconstructed Z->ee invariant mass (on average) compared to high mu regime (caused by lower topocluster noise threshold, which results in) higher cluster energy



Schematic overview of the procedure used to calibrate the energy response of electrons and photons in ATLAS

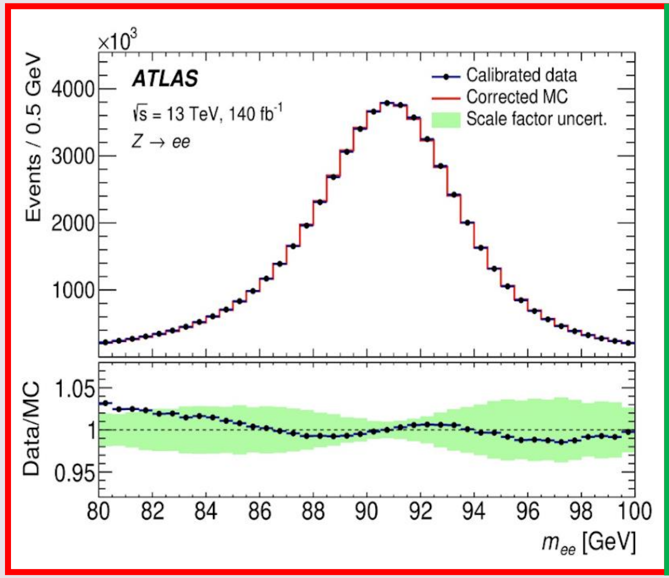


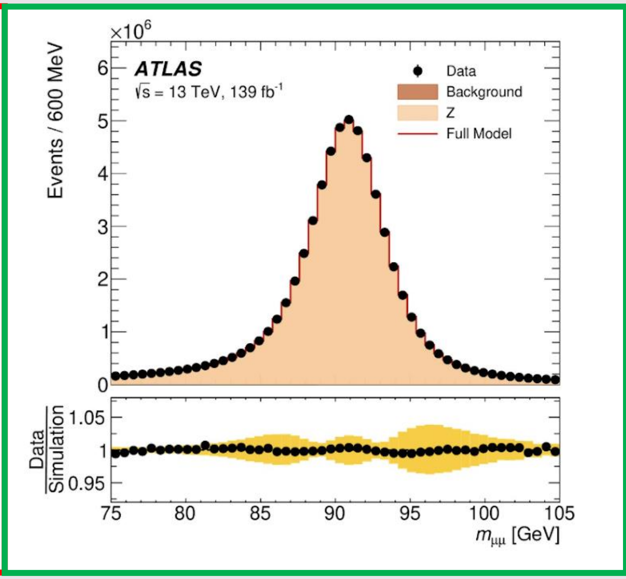
Motivation for FSR Studies

Motivation:

•Z → ee data show an excess of energy tails, since Run1. This generates energy scale systematics that limit the overall calibration precision.
•Muons behave better

Mainly affecting W&Z analyses since mass peaks are very close – other E/gamma calibration systematics become dominant at higher/lower energy scales.





Possible excluded causes studied over the years:

•Calibration per calorimeter layer
•Readout non-linearity
•Lateral shower shapes
•Passive Material variation

Remaining hypothesis motivating the residual lineshape discrepancies:
Effects resulting from imperfect modelling of FSR in MVA calibration stage…

Potential effects of FSR on MVA calibration

•MVA is trained only with single electrons with Bremsstrahlung (other FSR not included)

• If E1/E2 energy distribution is affected by FSR effects, MVA could over/under correct the energy, thus introducing discrepancies in the Z mass lineshape :

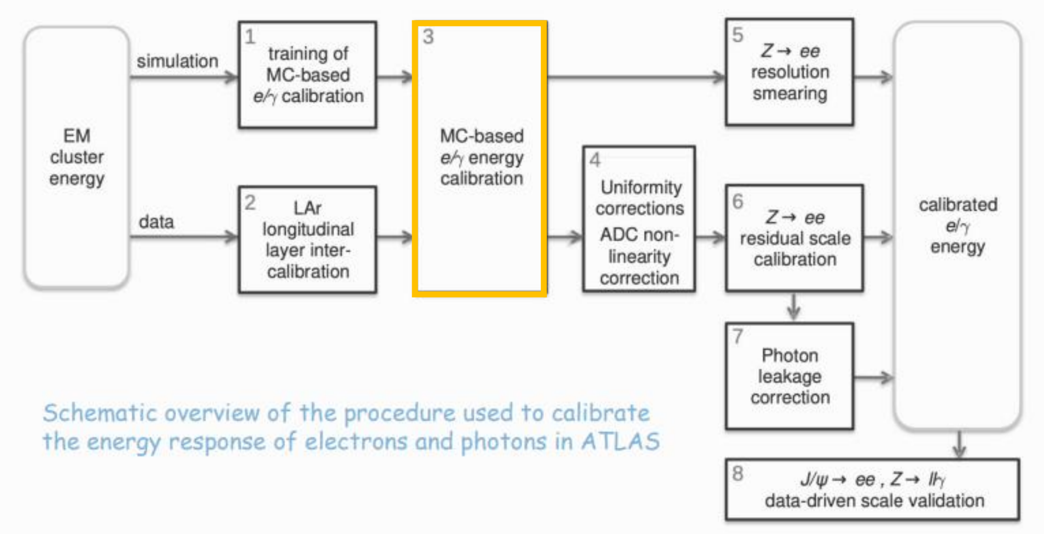
•Situation 1 - A slightly higher pT/harder FSR deposited within the cluster can modify E0,E1,E2, E1/E2

•Situation 2 - FSR is too hard (dR too large) to be within the cluster:

- This is lateral leakage, we completely lose FSR information in this case
- MVA would not correct the energy, and consider this as a lower energy electron

Ideally, the effect of FSR on MVA is the same between data and MC, so cancels. But FSR is not perfectly modelled.

Aim to study Mee w/ different FSR to see if we can reproduce the data/MC lineshape



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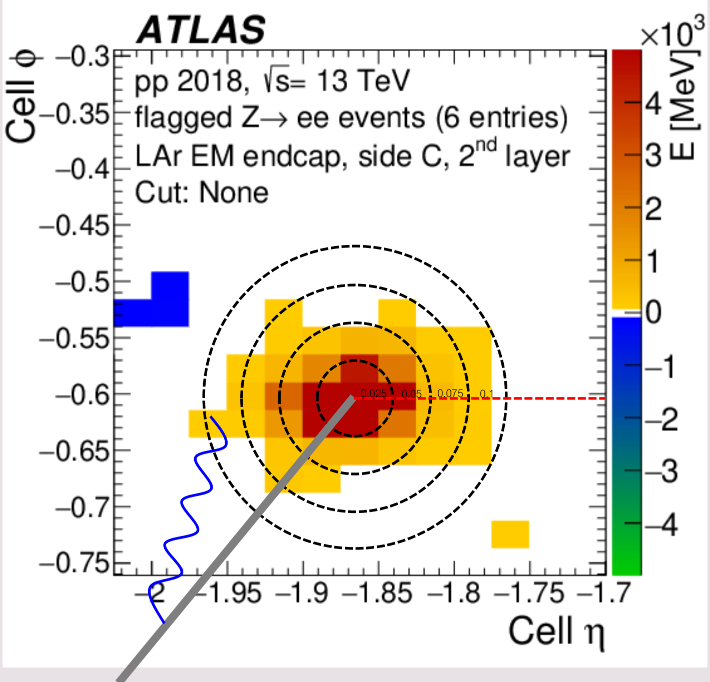
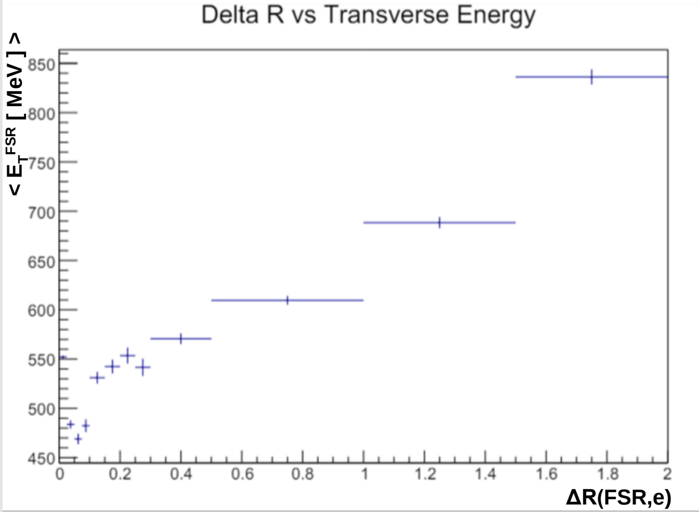




Categorising events based on FSR

Events are categorised to probe various kinematic configurations to see how they effect the data/MC discrepancies

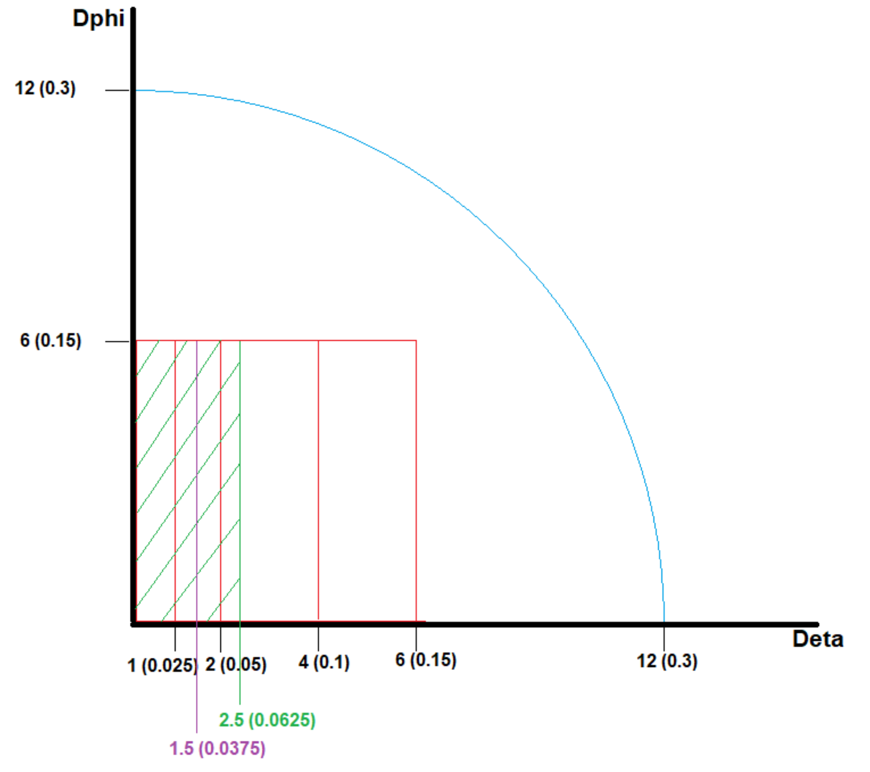
Categories based on dR region containing highest total FSR pT:

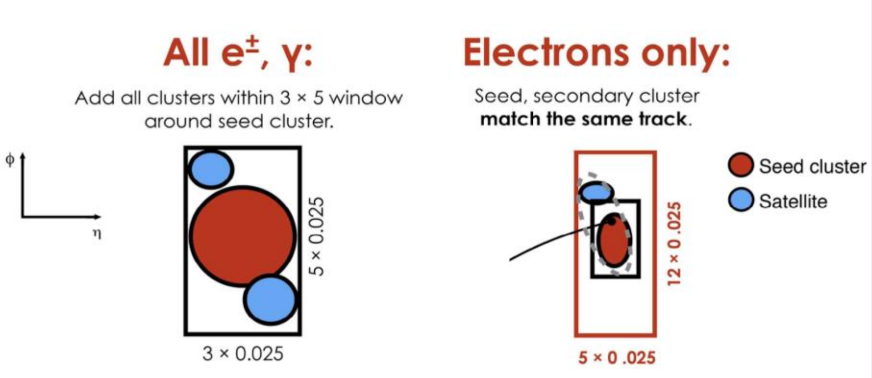
- Match all FSR photons with either leading or subleading electron based on minimum dR – w.r.t. reco electron
- Calculate sum of FSR pT in each region (defined by segments in dEta, dPhi and dR, shown top left)
- Sort electrons accordingly by region with highest total FSR pT

Then investigate differences between various calorimeter and kinematic observables which are relevant to the MVA or in-situ calibration

NOTE: Electron trajectory bends in magnetic field (in phi direction only):

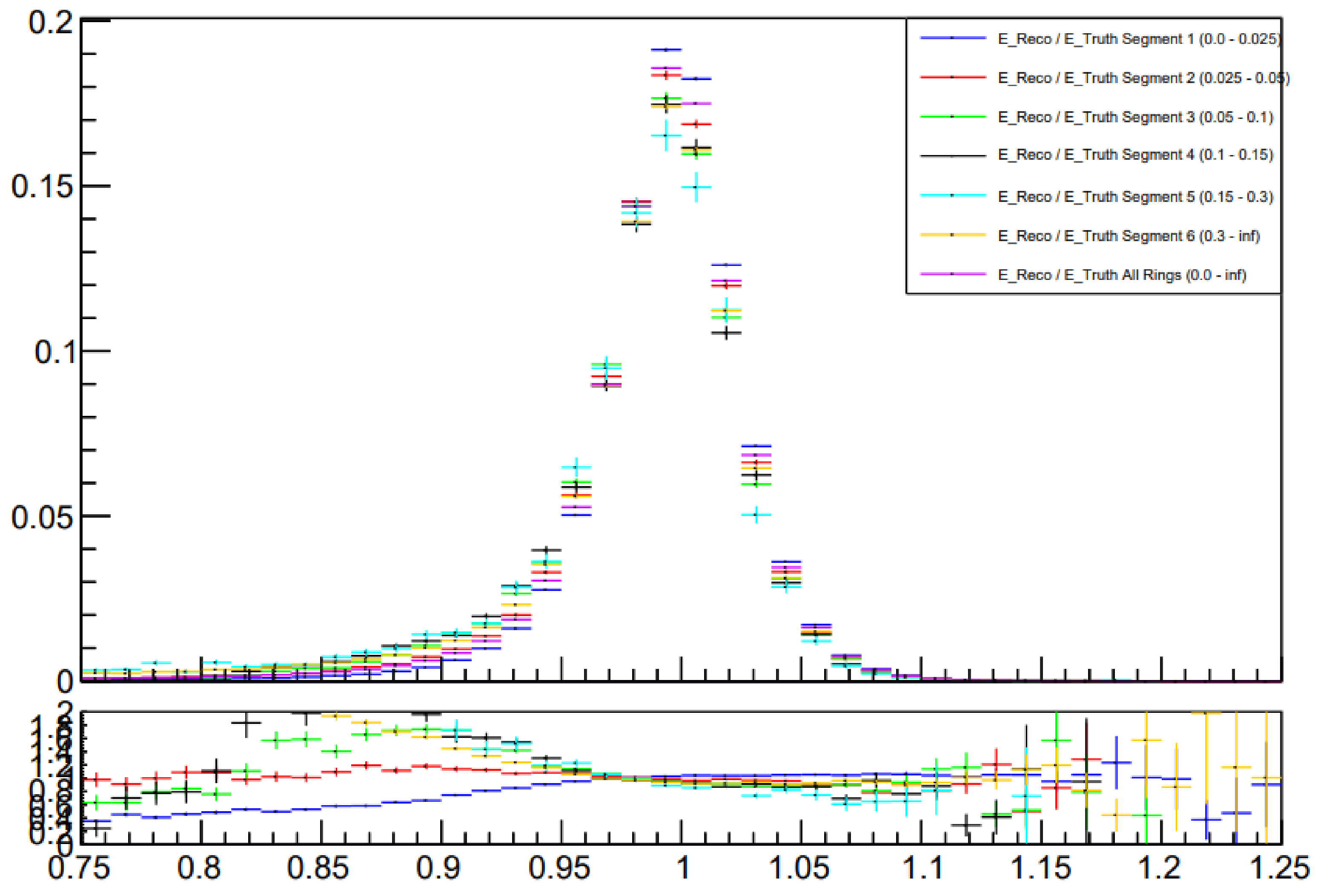
- dR chosen with respect to reco electron instead of truth
- FSR categories are more granular in dEta than dPhi – FSR emitted in phi direction ~ Bremsstrahlung





E_Reco / E_Truth

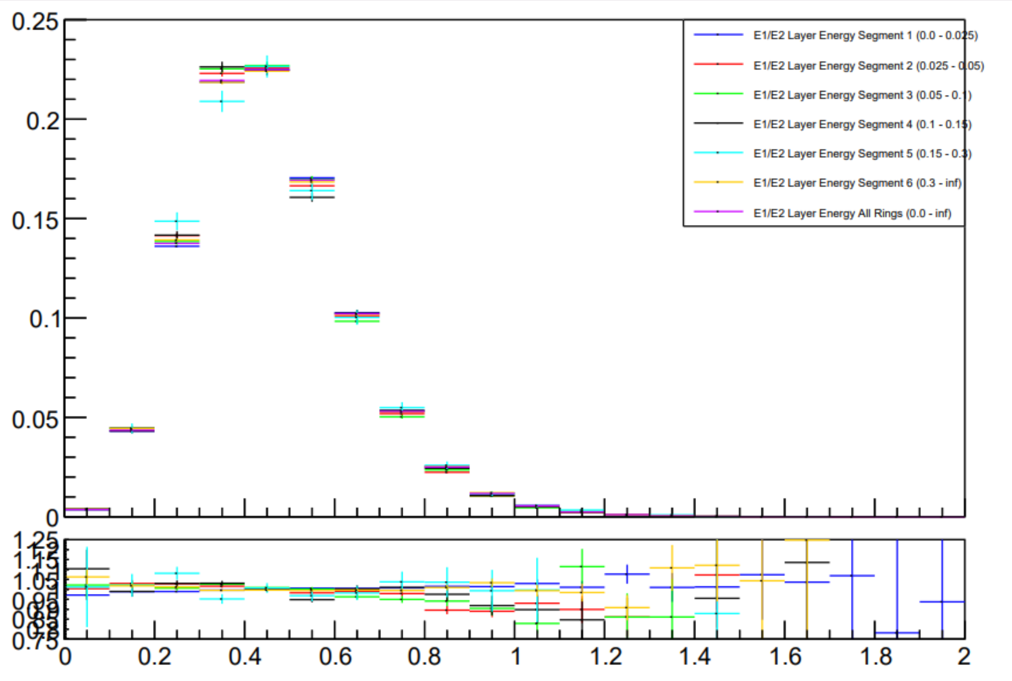
- Ratio of reconstructed energy to true energy:
- If electron is reconstructed perfectly, E_reco/E_truth is always 1
- Since energy reconstruction is performed only in a small area around electron (3x5 cells), some energy is lost through hard FSR at higher dR
- By observing the behaviour of the E_reco/E_truth ratio for each dR category, we can find the region(s) which we expect to be affected most by the MVA mismodelling

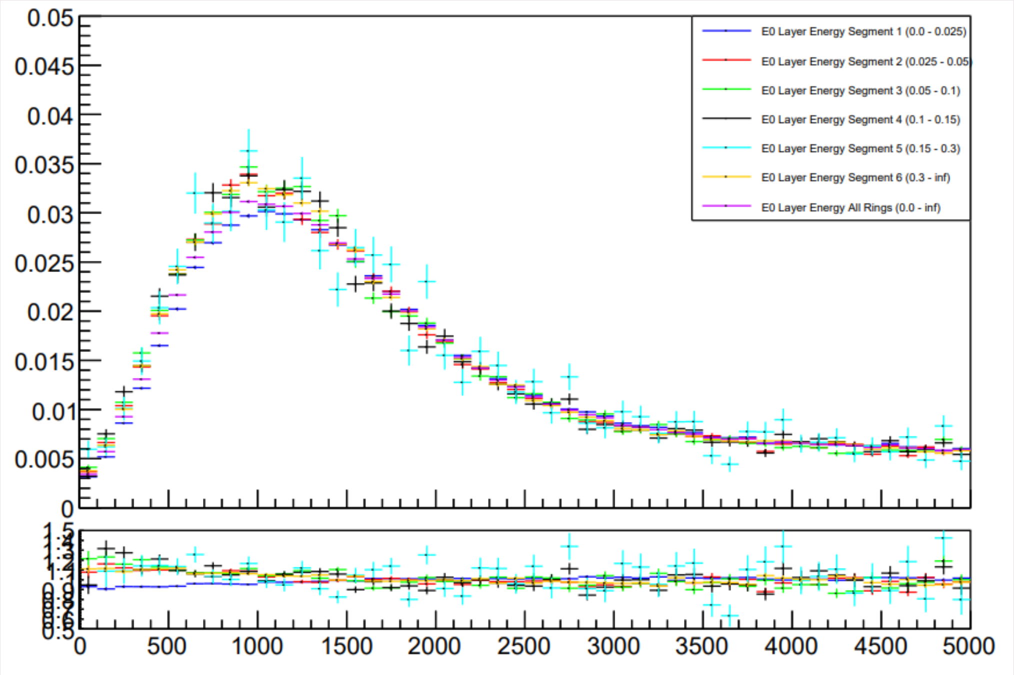


Layer 0 and Layer 1 / Layer 2 Energy

Layer 1 / Layer 2 Energy ratio: →

- One of the most important variables for MVA calibration since approx. MVA, $E_{MVA} \approx E_0 + E_1 + E_2 + E_3$
- Depends both on electron and FSR photon energy and whether FSR is within the cluster
- Investigation of this variable is still in progress and can be followed up in further studies





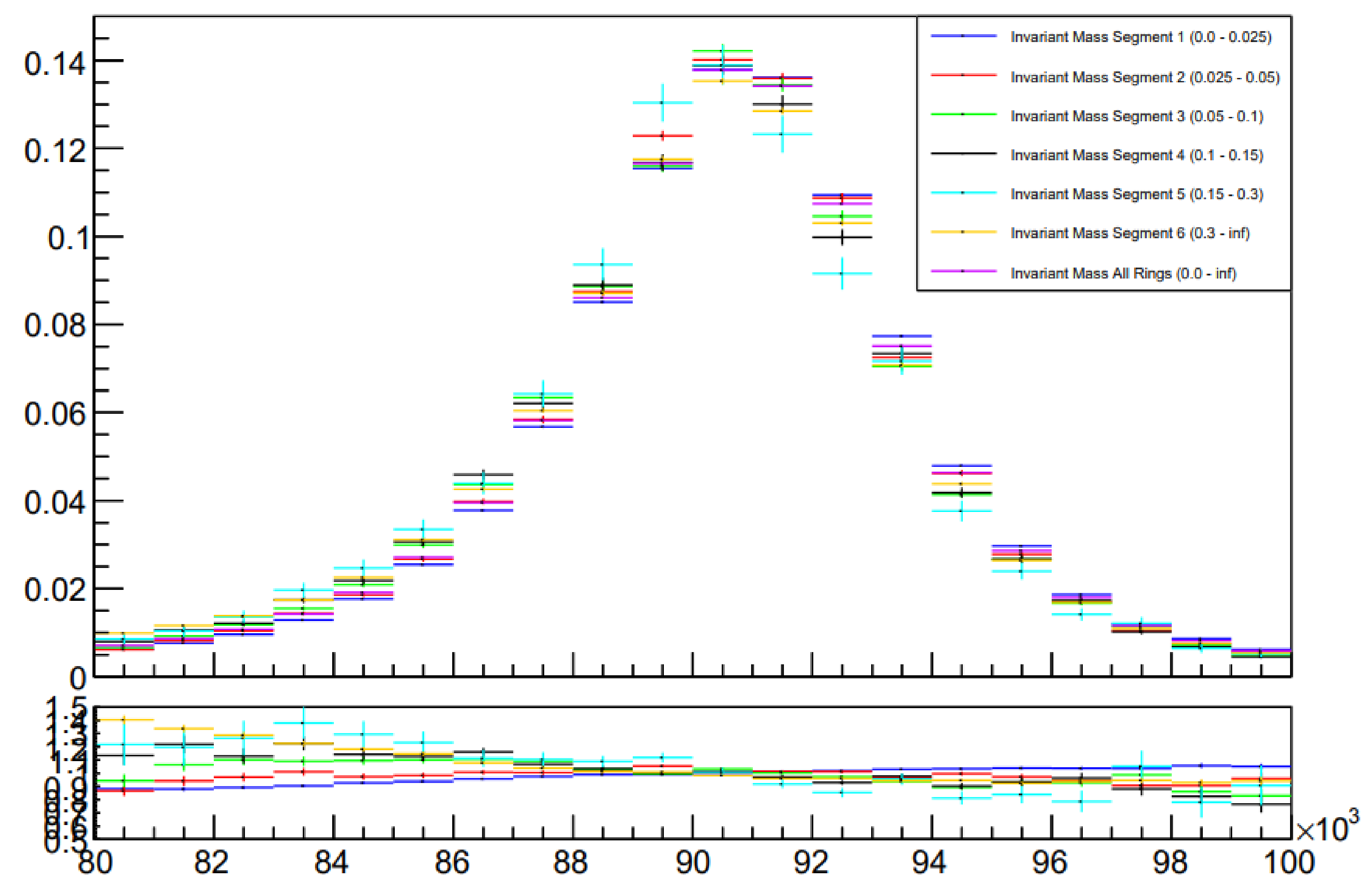
← Layer 0 Energy:

- Another important variable for MVA calibration
- Investigation of this variable is also ongoing, but it is clear the innermost segment remains flat relative to all other segments (as expected)

Invariant Mass

Studying invariant mass for each category shows the effects of mismodelling on the distributions

- Innermost segment (blue) behaves as expected since all energy is within the cluster
- Next segments (red and green) cover the edges of the cluster and satellite regions – potential for lateral leakage and for mismodelling by MVA
- At outermost segments, MVA loses all info about FSR photons – causes similar tails to what we see in Data/MC



Conclusion and Outlook

- Zee data, used in in-situ calibration, shows excess of energy tails which has an impact on overall electron calibration systematics
- After several potential causes have been excluded – we now study effects resulting from imperfect modelling of FSR in MVA calibration stage
- Categorise Zee events based on regions around reco electron with highest total FSR pT
- Study various kinematic and calorimeter observables in each region and compare to full MC sample to see if tails are reproduced
- Using these subsets as “pseudodata”, rerun in-situ calibration to see if FSR impact is absorbed