FSR and line-shape energy tail studies

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Original idea and motivation

See Maarten slides : here

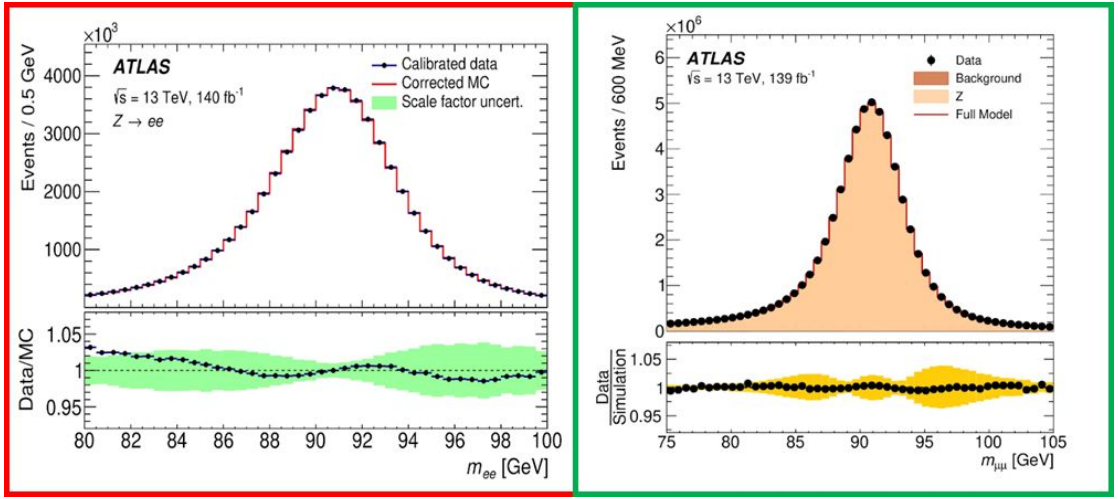
Motivation:

- **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



Egamma 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

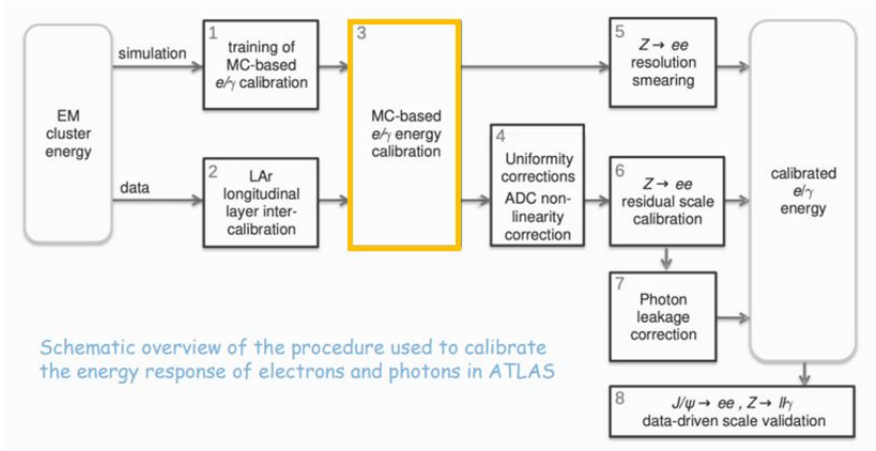
•Situation 2 - FSR is too hard (dR too large) to be within the cluster:

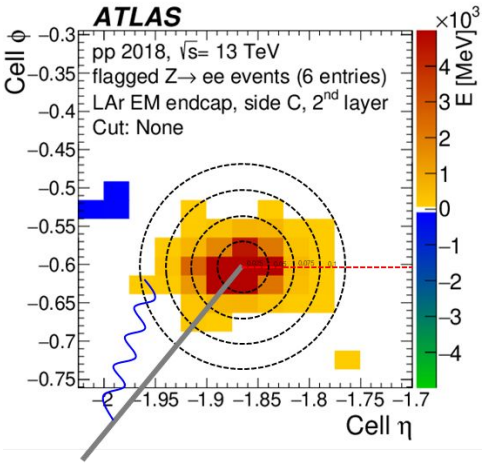
•This is lateral leakage, we completely lose FSR information in this case

•MVA would not correct the energy, and consider this as a lower energy electron

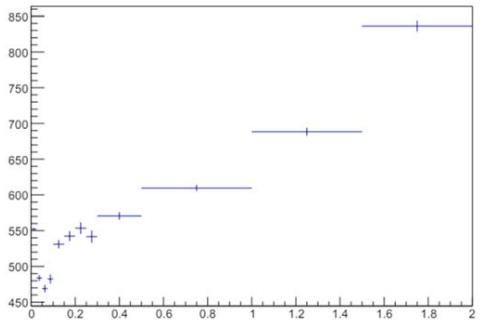
Ideally, the effect of FSR on MVA is the same between data and MC, so cancels. But FSR is not perfectly modelled.

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





Delta R vs Transverse Energy



Effect of close by FRS on MVA ?

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

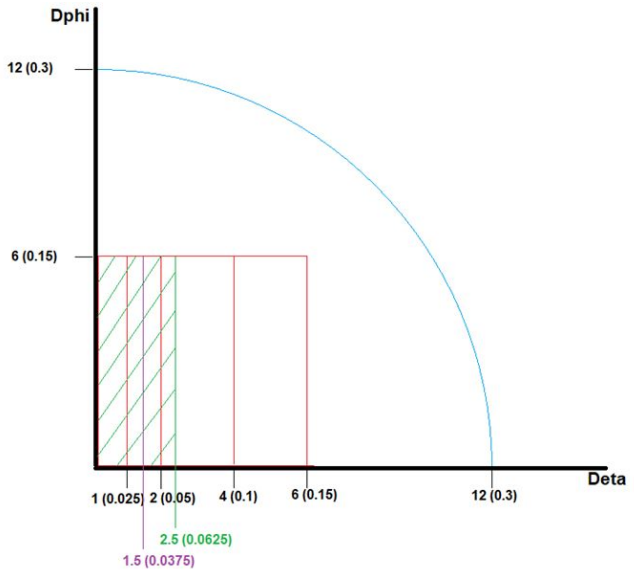
Categories based on dR region containing highest total FSR pT:

- 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)
- Segments chosen since any energy deposit in phi will be absorbed by MVA -> compensates for the energy loss by treating the FSR energy as Brem
- 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

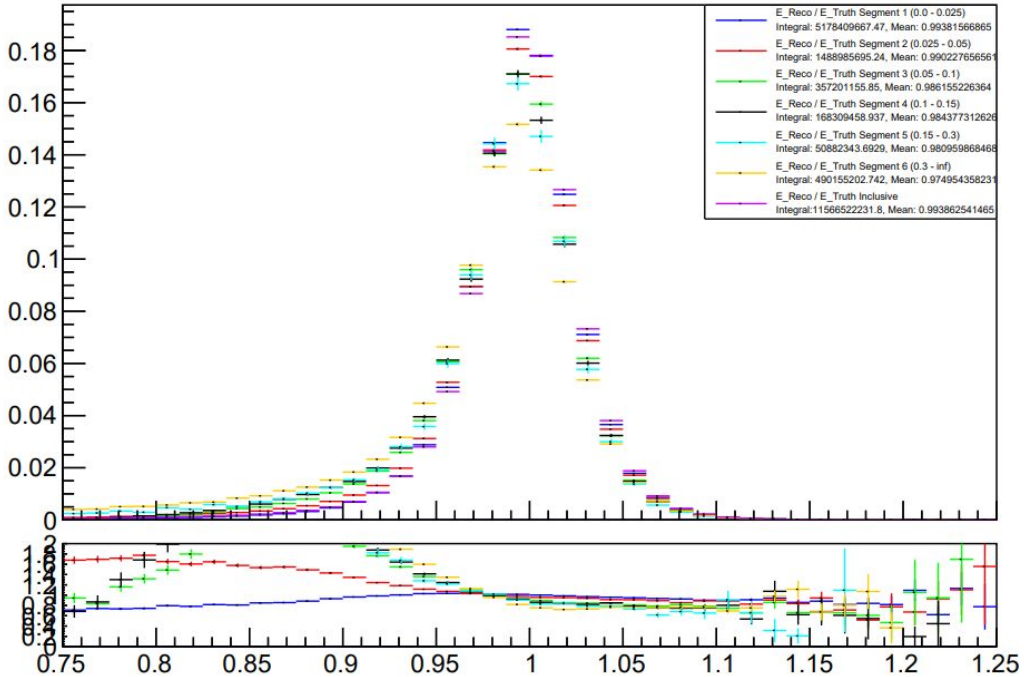
NOTE: Electron trajectory bends in magnetic field (in phi direction only):

- 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

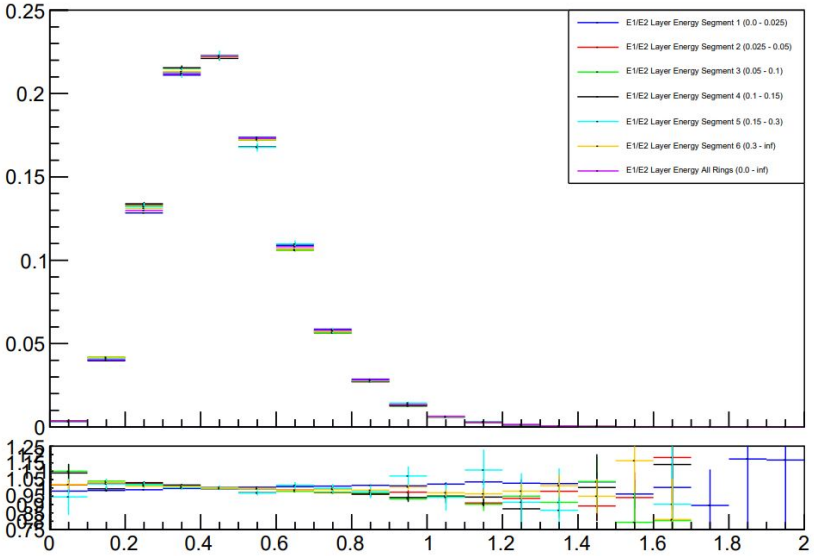
- **Ratio of reconstructed energy to true energy:**
- If electron is reconstructed perfectly, E_reco/E_truth is always 1
- Since energy reconstruction is performed only in a small area around electron (3x5 cells), some energy is lost through hard FSR at higher dR
- By observing the behaviour of the E_reco/E_truth ratio for each dR category, we can find the region(s) which we expect to be affected more.
- Proportion of events with FSR to events without ~ 40%
- FSR produces significantly lower energy tails, which might explain the mass lineshape

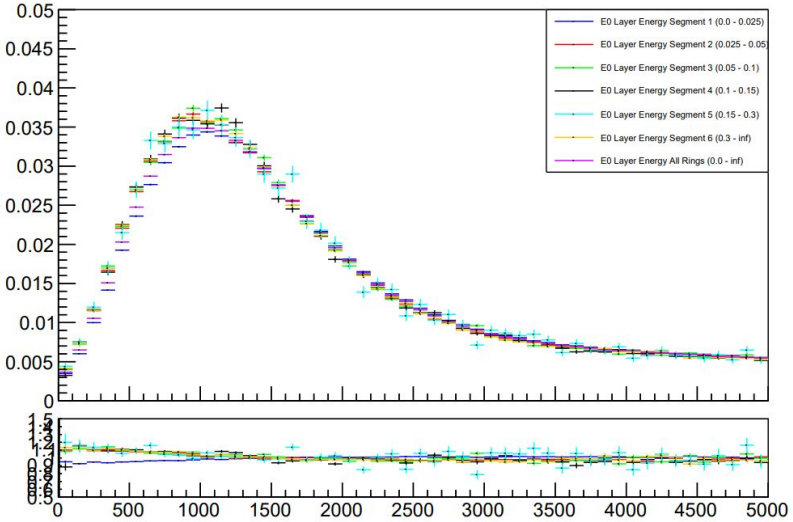


Layer 0 and Layer 1 / Layer 2 Energy

Layer 1 / Layer 2 Energy ratio: ➡

- One of the most important variables for MVA calibration since approx. MVA, E_MVA ≈ 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





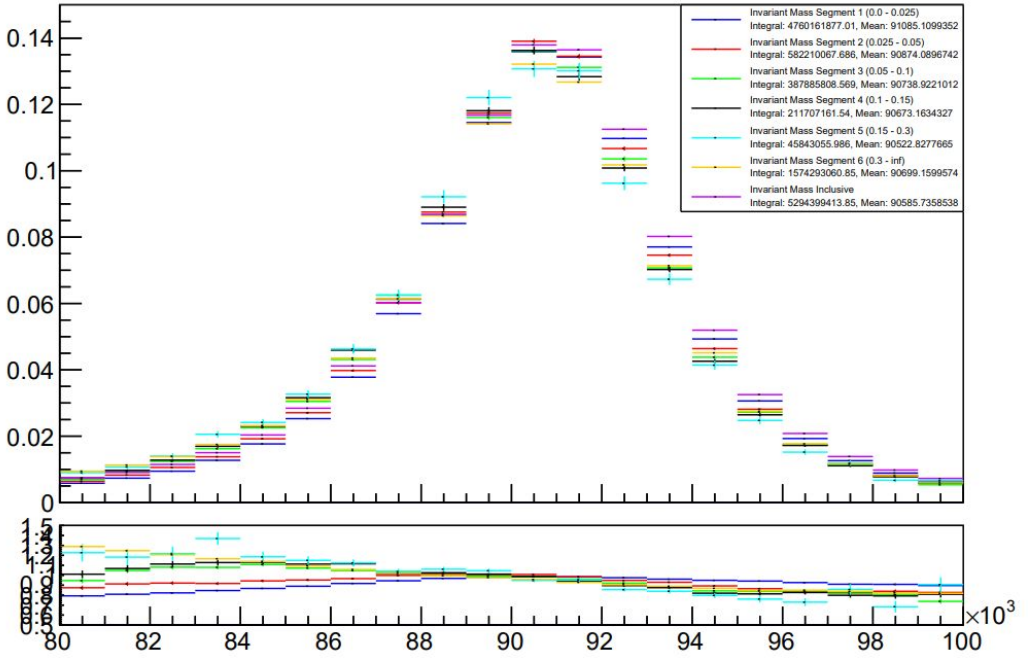
⬅ Layer 0 Energy:

- Another important variable for MVA calibration
- Investigation of this variable is also ongoing, but it is clear the innermost segment shows opposite behaviour to other segments at lower energies

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 leakage from the FSR on the cluster energy→ possible mismodelling by MVA
- At outermost segments, FSR photons do not leak in the electron cluster – causes high tails in low mee spectrum



We are able to select category of events with particular FSR properties that produces significant lower energy tails in mee spectra.

It would be interesting to verify if we could calibrate out

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
- Ideally, we want to also change the mix fraction of different segment to generate "FSR variation samples", and use this as pseudodata to calibrate wrt nominal MC

backup

Idea behind this study

- *A general possibility is that **a fraction of low-energy photons are somehow "lost" from the electron cluster**. This would generate energy tails, without disturbing the muons which are measured "bare" (and look good)*
- *Nearby photons (FSR, Brems)*
  - *Assume mis-modelled ΔR distributions → some energy lost around the cluster. Can the observed disagreement be reproduced with reasonable FSR variations?*
  - *In the case of FSR, the study can be done with existing samples + reweighting **[focus of these studies]***
- *Low-energy response : our main question to this group*
  - *Idea : randomly "kill" FSR or Brem photons entering the calorimeter volume below some threshold, to be varied. Can we reproduce the observed disagreement?*
  - *Idea to modify GEANT shower photons …*