

Updates on Full Calorimeter Angular Resolution

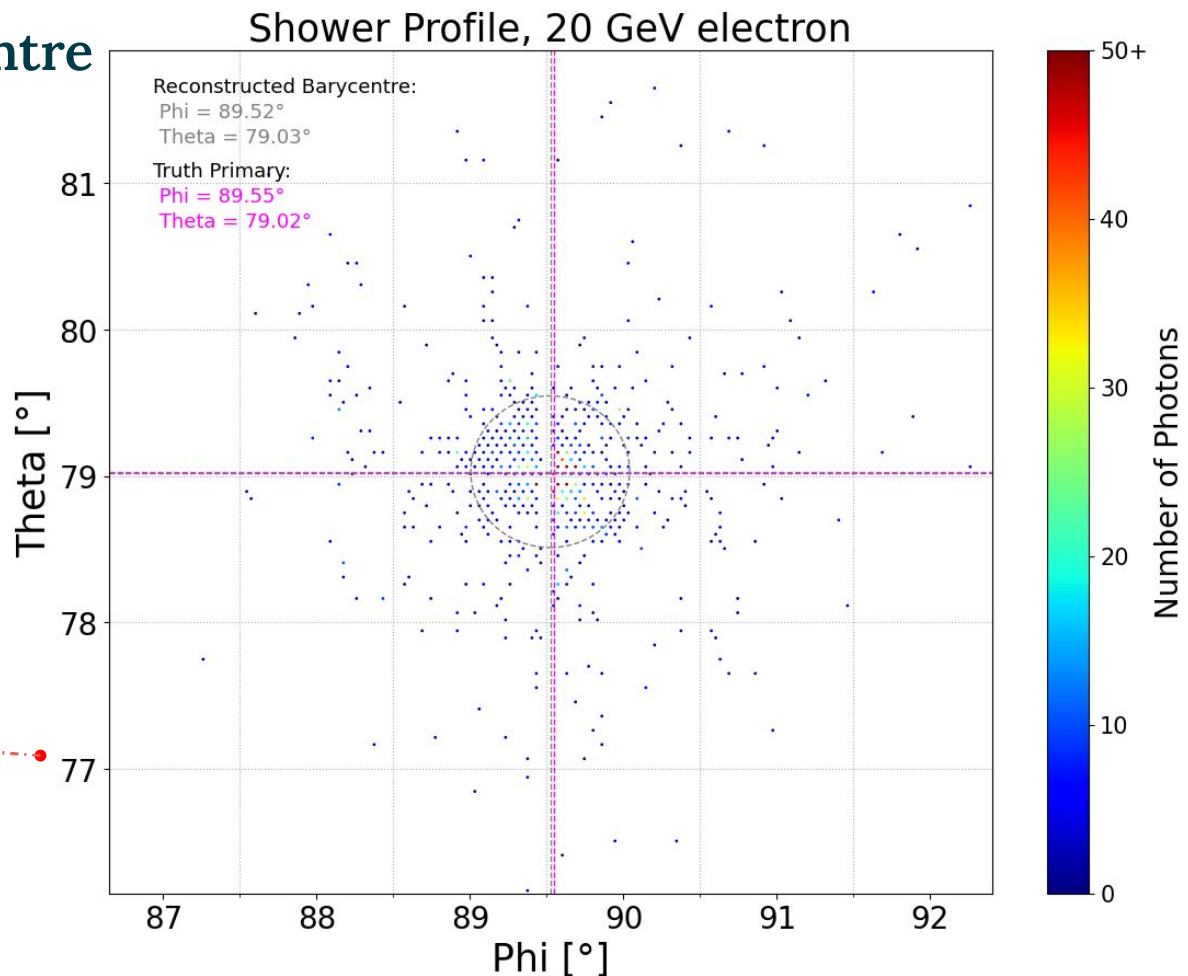
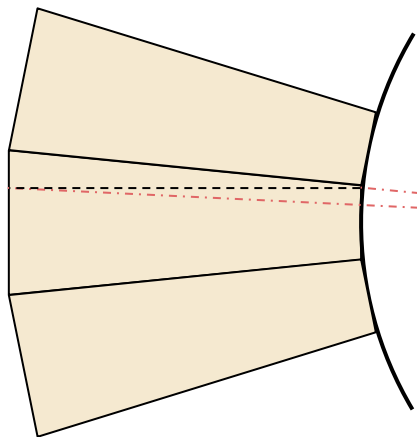
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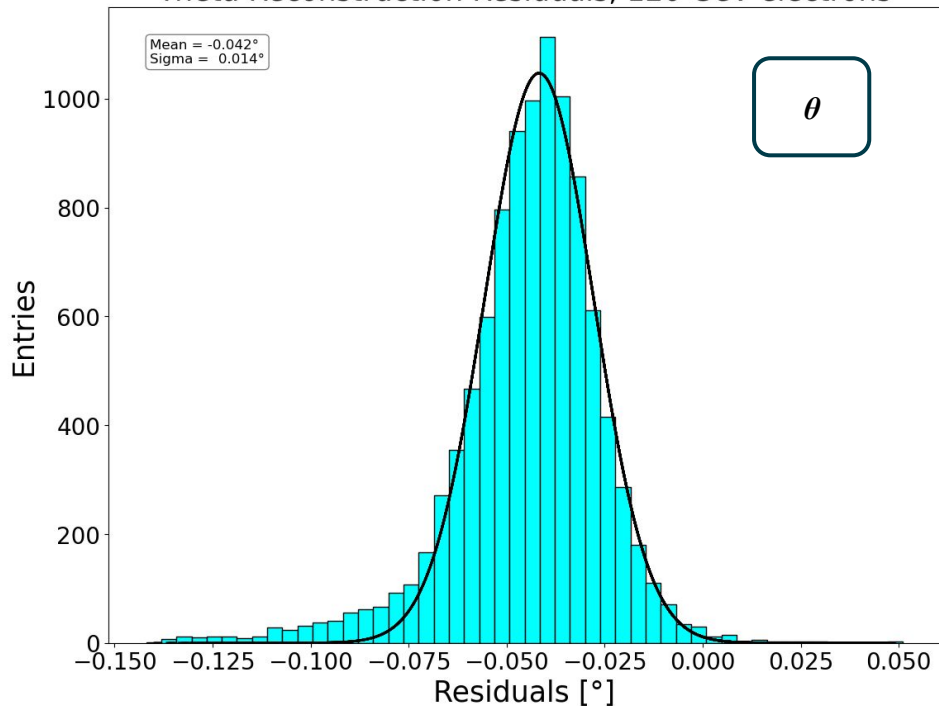
Shower Profile and Barycentre

- *Front-side* reconstruction yields best agreement with truth position for em showers
- Also leads to nice Gaussian shapes in the residuals (Reconstructed Barycentre - Primary Direction)
- However, also observed some tails and biases in the reconstruction



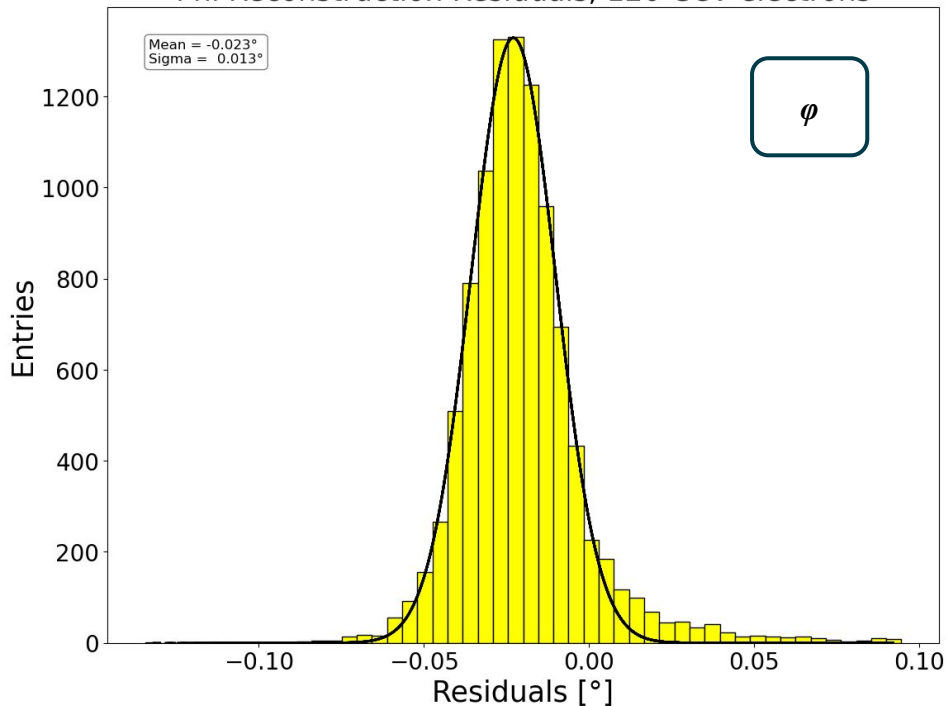
Residuals and Angular Resolution: 120GeV

Theta Reconstruction Residuals, 120 GeV electrons



- Theta bias: Shower maximum develops deep in the calorimeter (but reconstruction based on the front)
- Theta tail: Not sure, but asymmetric tail might be a hint

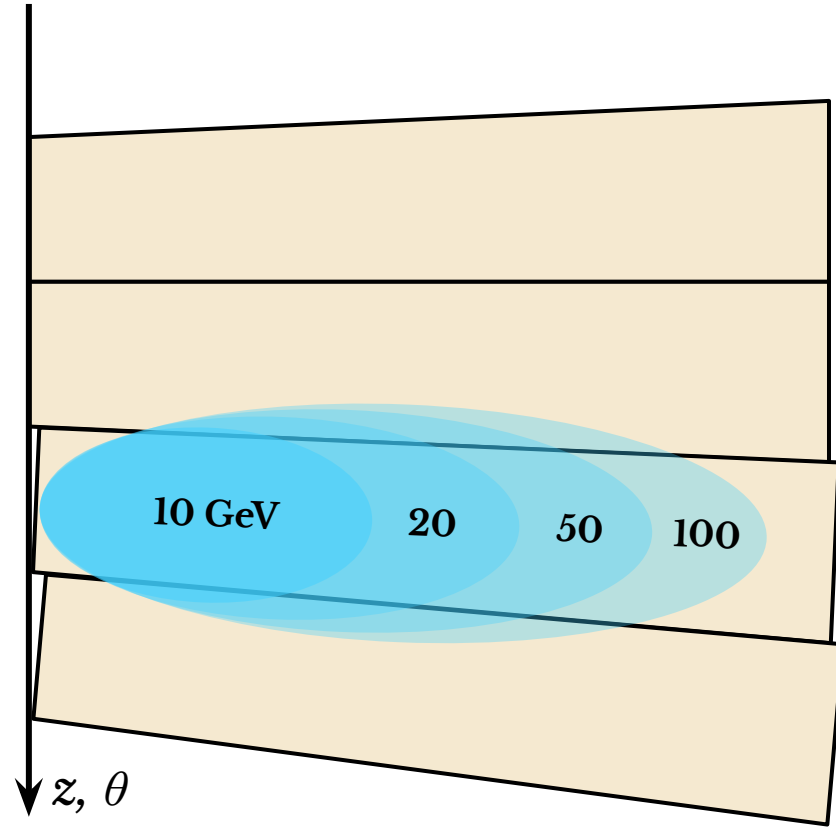
Phi Reconstruction Residuals, 120 GeV electrons



- Phi bias: some uncertainty on the exact fibre phi position
- Phi tail: ??? (towers are **symmetric in phi**, so asymmetric tail is puzzling)

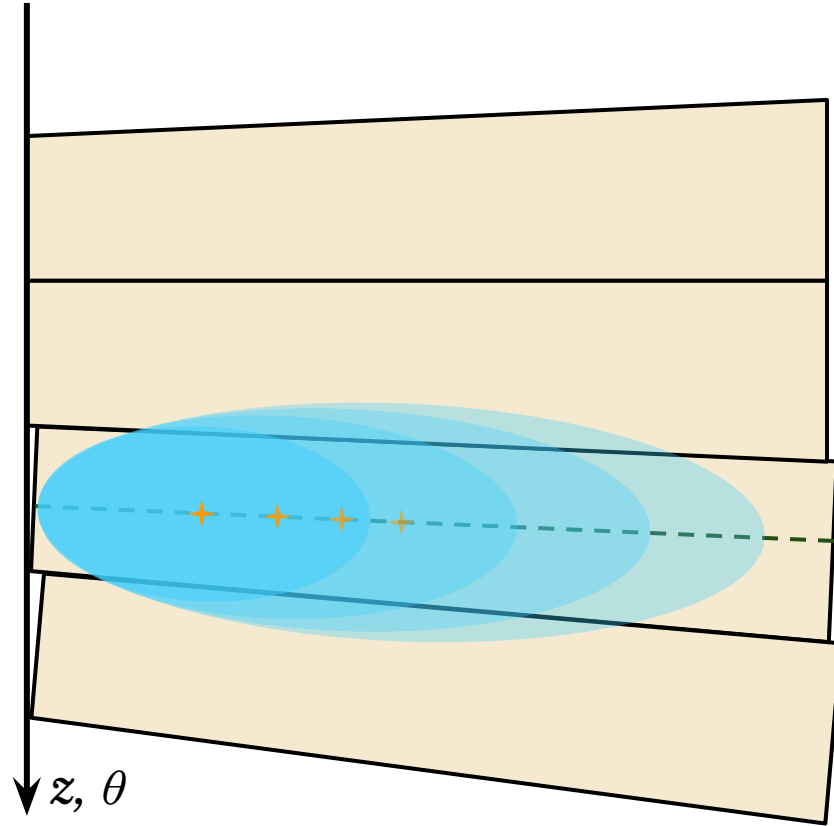
Theta Bias

- Higher energy showers develop deeper in tower



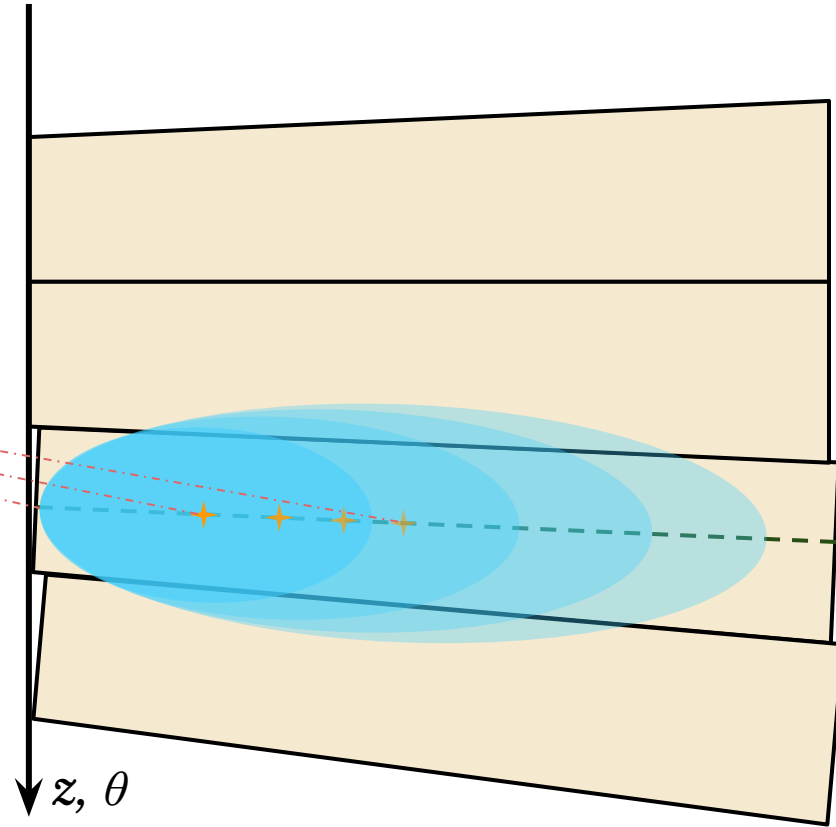
Theta Bias

- Higher energy showers develop deeper in tower
- Shower maximum moving further away from the front face (where reconstruction is based)



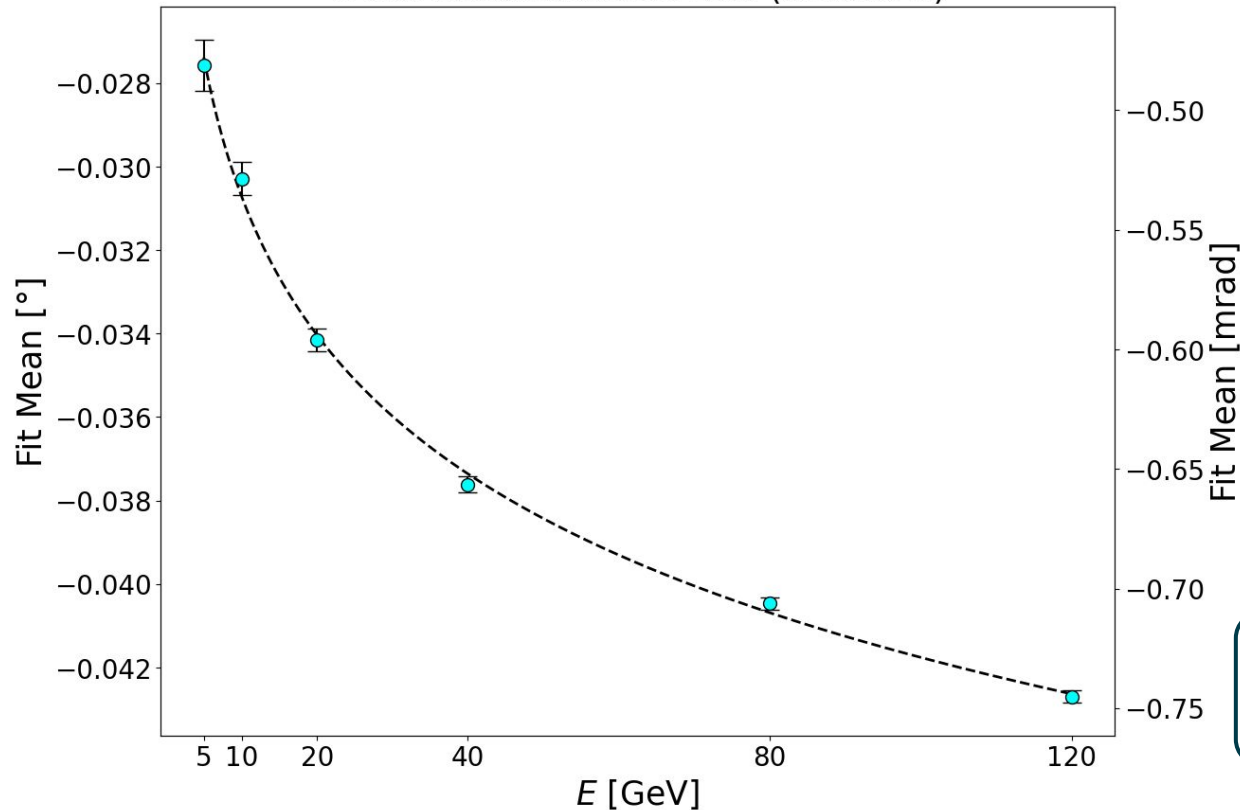
Theta Bias

- Higher energy showers develop deeper in tower
- Shower maximum moving further away from the front face (where reconstruction is based)
- For higher energies the theta of the fibre front tip is misaligned with theta of the shower maximum more and more
- We should see a logarithmic increase in theta bias based on the particle energy



Theta Bias as Function of Energy

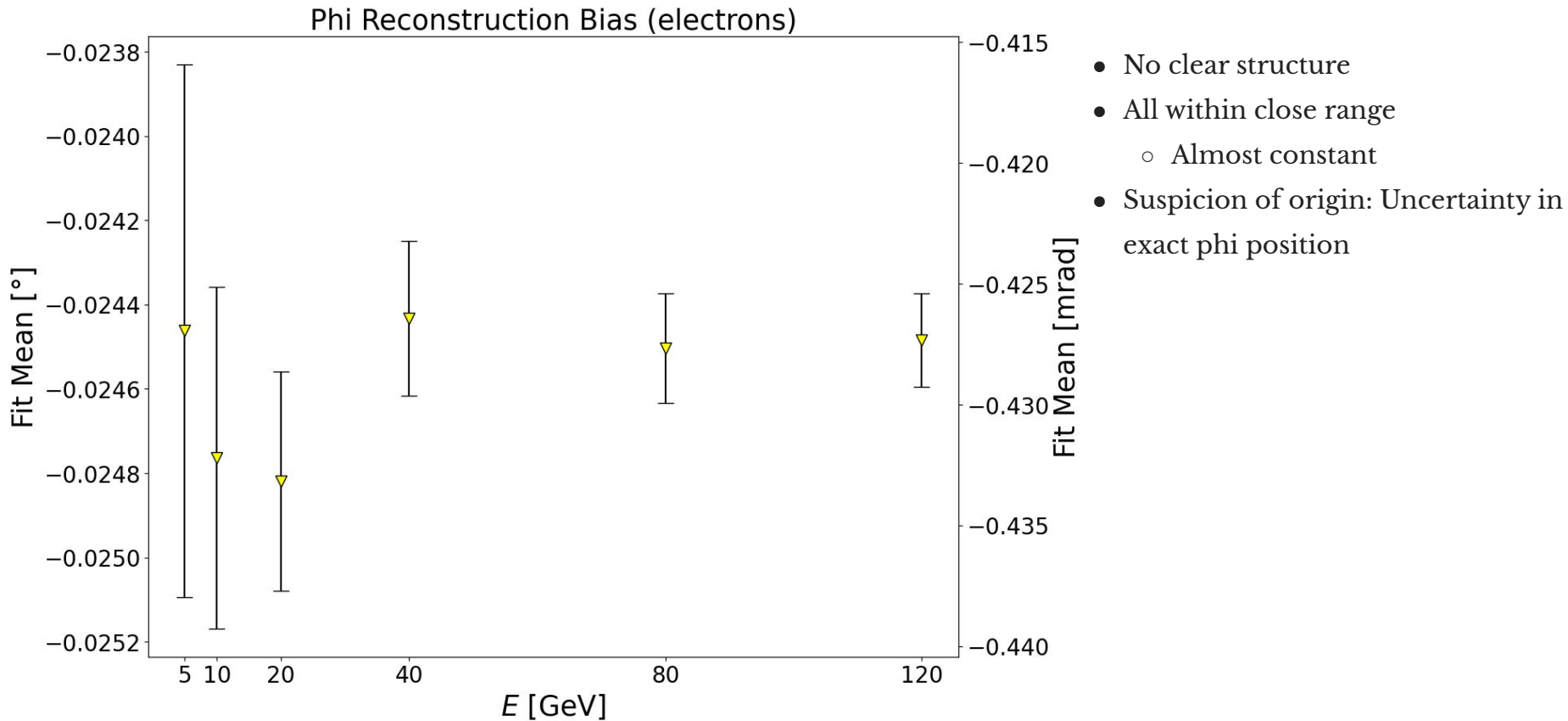
Theta Reconstruction Bias (electrons)



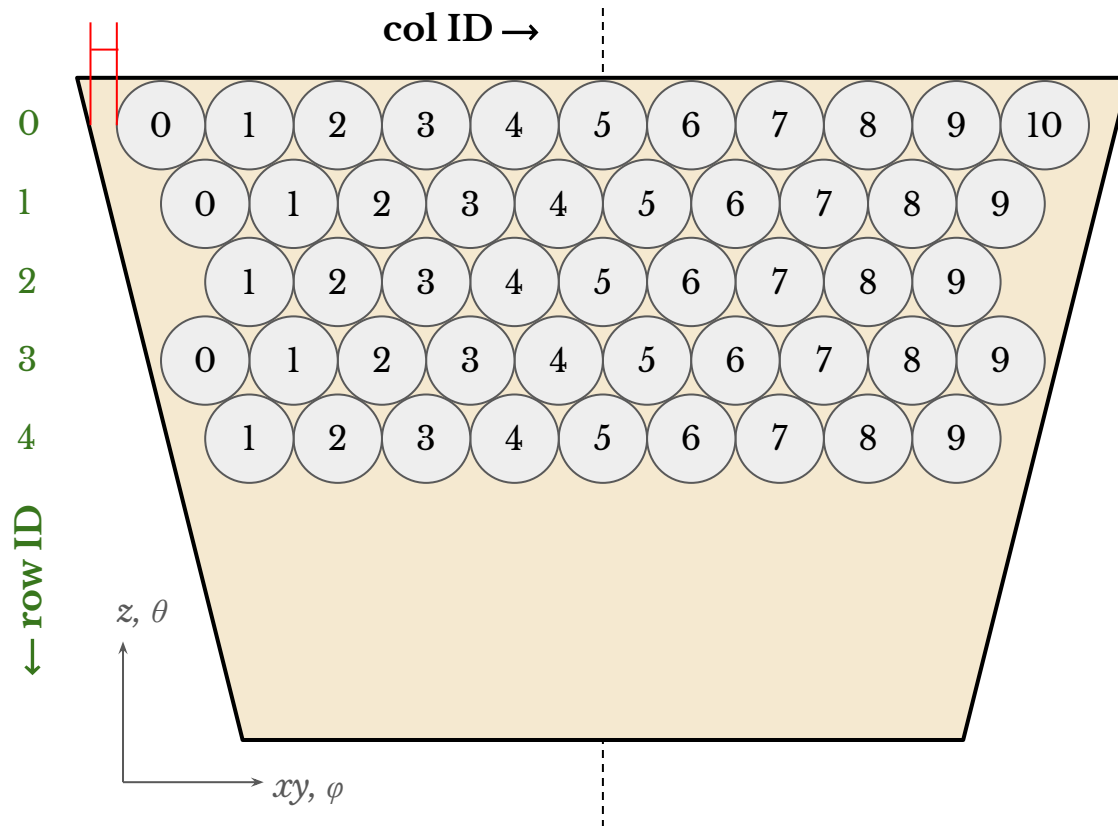
- Indeed, this is the case
- Might need an energy dependent correction to theta barycentre
- Effect on the scale of 1–2 mm

This clears the mystery of Theta bias and can hopefully be corrected for. Let's look at Phi bias next!

Phi Bias as Function of Energy



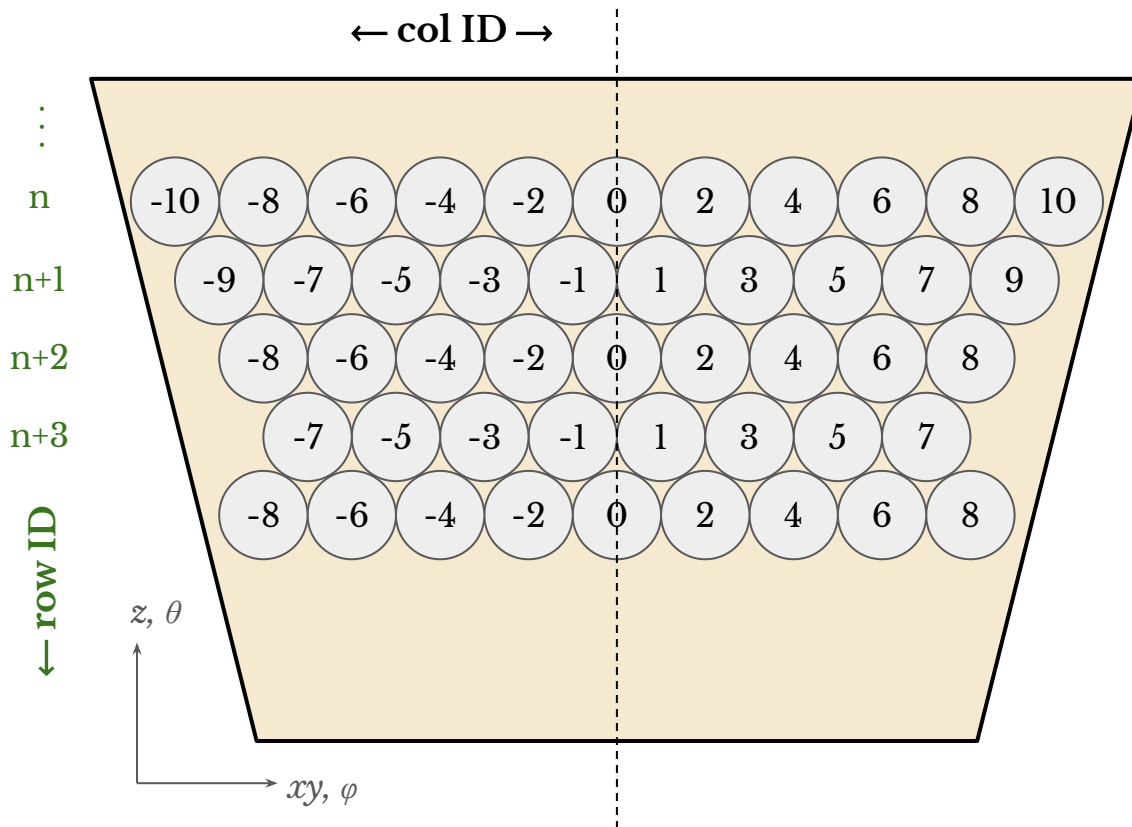
Phi Position Reconstruction



- Phi reconstruction only based on Fibre ID
- Column ID starts on one side with 0 (reference tube)
- Increases for every tube
- Col ID persistent for columns in later rows

- No inherent way of knowing the gap to the tower edge for very first tube
 - Possible to calculate from tower variables, but *cumbersome*
 - First tube position not well defined within the tower
 - Imm ‘uncertainty’ for all tubes

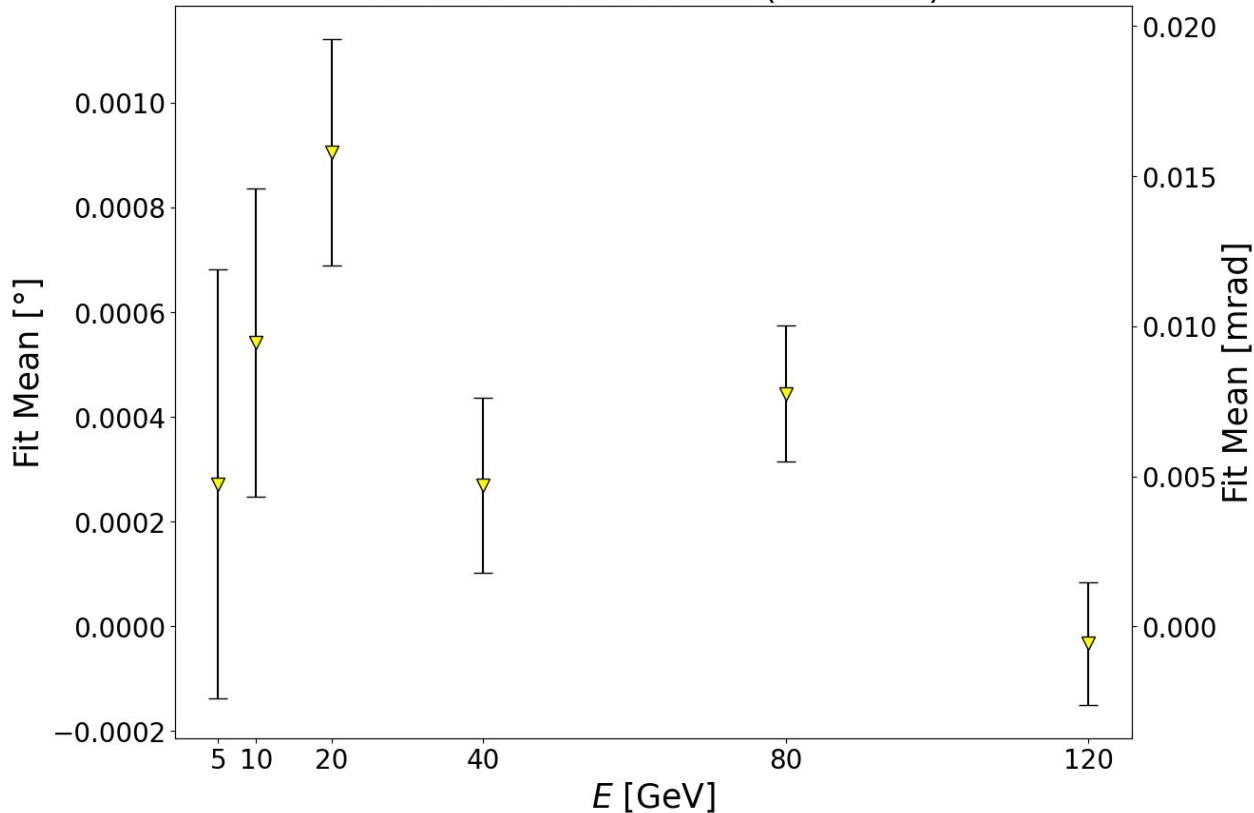
Phi Position Reconstruction Updated



- So I have changed the column IDs:
- Col ID is now 0 for tube in the exact centre of the tower
 - Tower centre acts as reference (position well defined)
 - Position in tube in tower is exactly known
 - Positive ID on one side, negative on other
- ID increases/decreases by two
 - Immediately know if in row with even or odd number of columns
 - Really easy to calculate distance d from centre
$$d = \text{colID} \times r$$
- Now exact fibre phi is easily known

Phi Updated Bias as Function of Energy

Phi Reconstruction Bias (electrons)



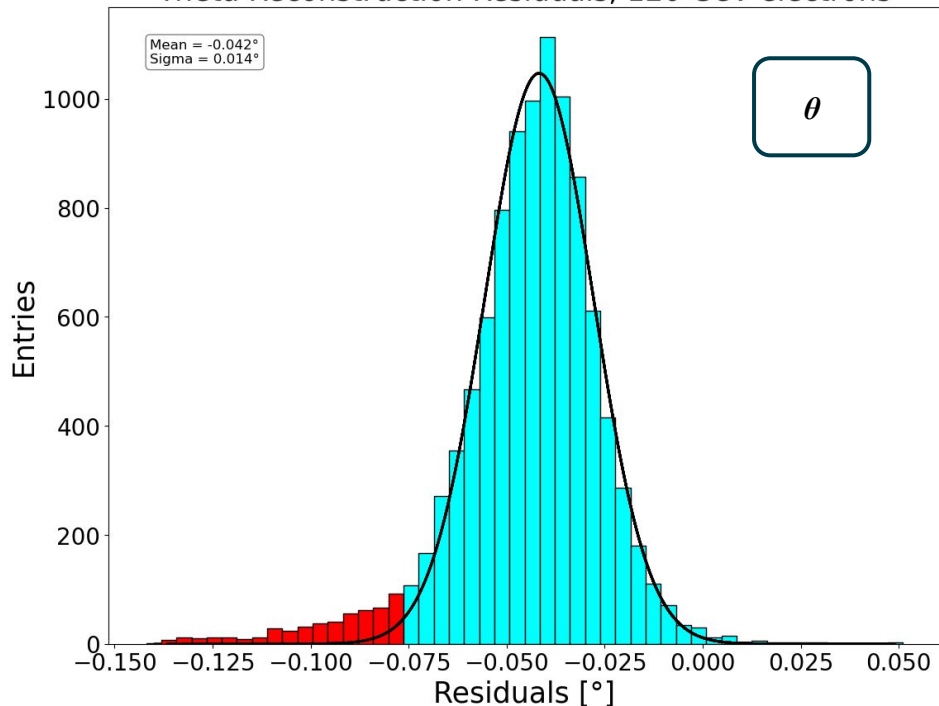
- Still no structure
- Biases shifted much closer to 0
- Most nominal values are positive
 - Likely not significant

Phi bias solved!

Only the tails still remain ...

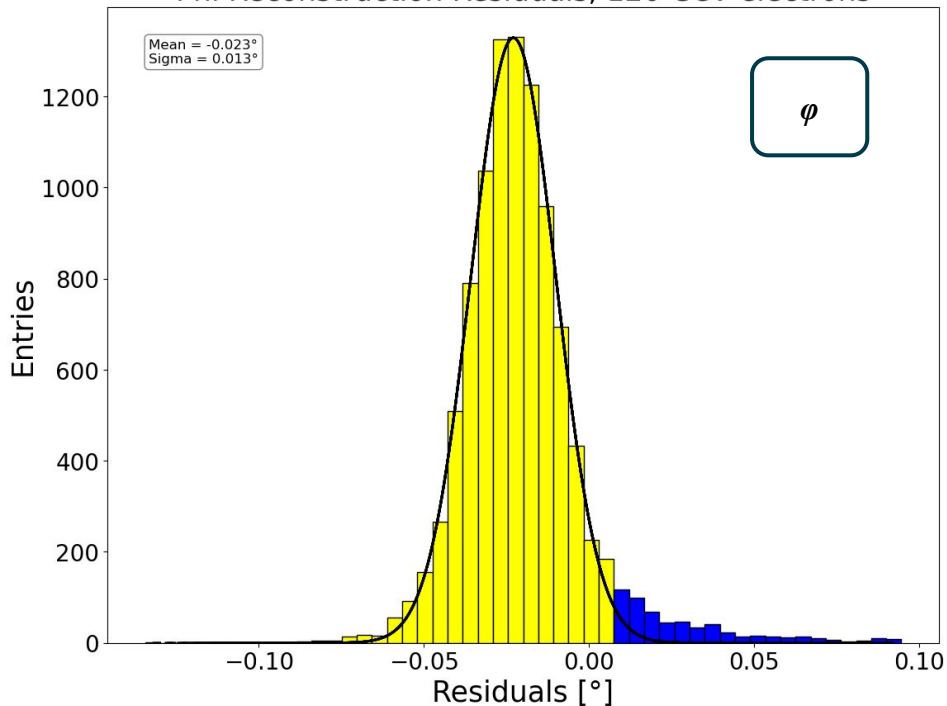
Selecting the Tails

Theta Reconstruction Residuals, 120 GeV electrons



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- Theta tail: Not sure, but asymmetric tail might be a hint

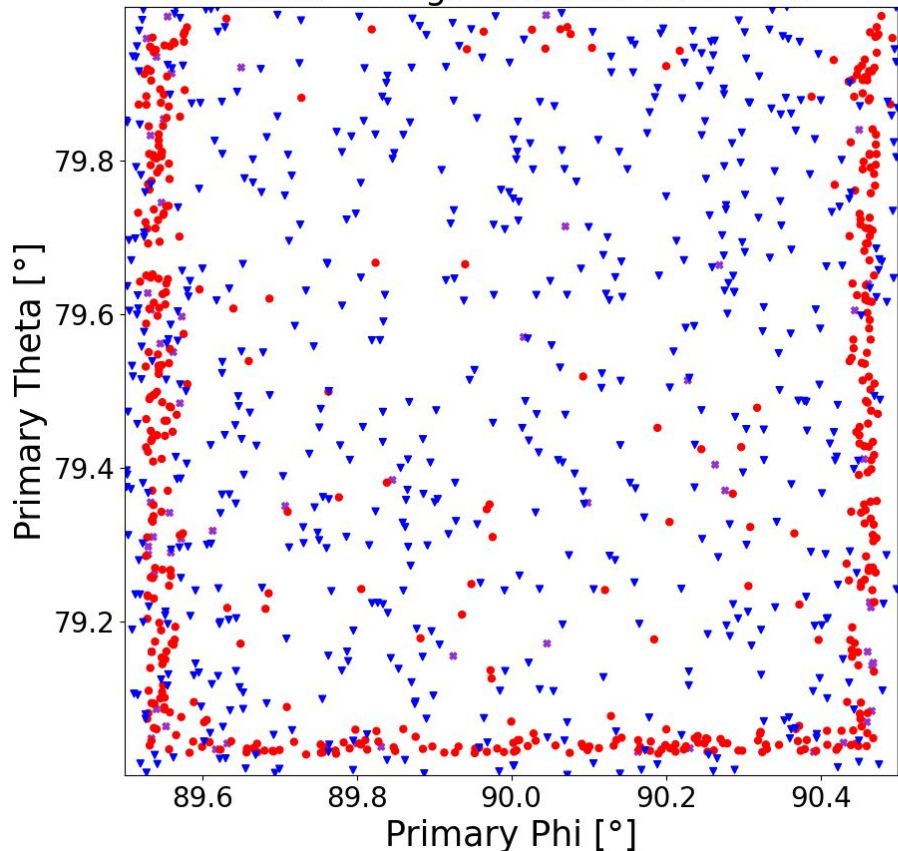
Phi Reconstruction Residuals, 120 GeV electrons



- Phi bias: some uncertainty on the exact fibre phi position
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Primary Positions of 'Tail Events'

Events in Angle Reconstruction Tail



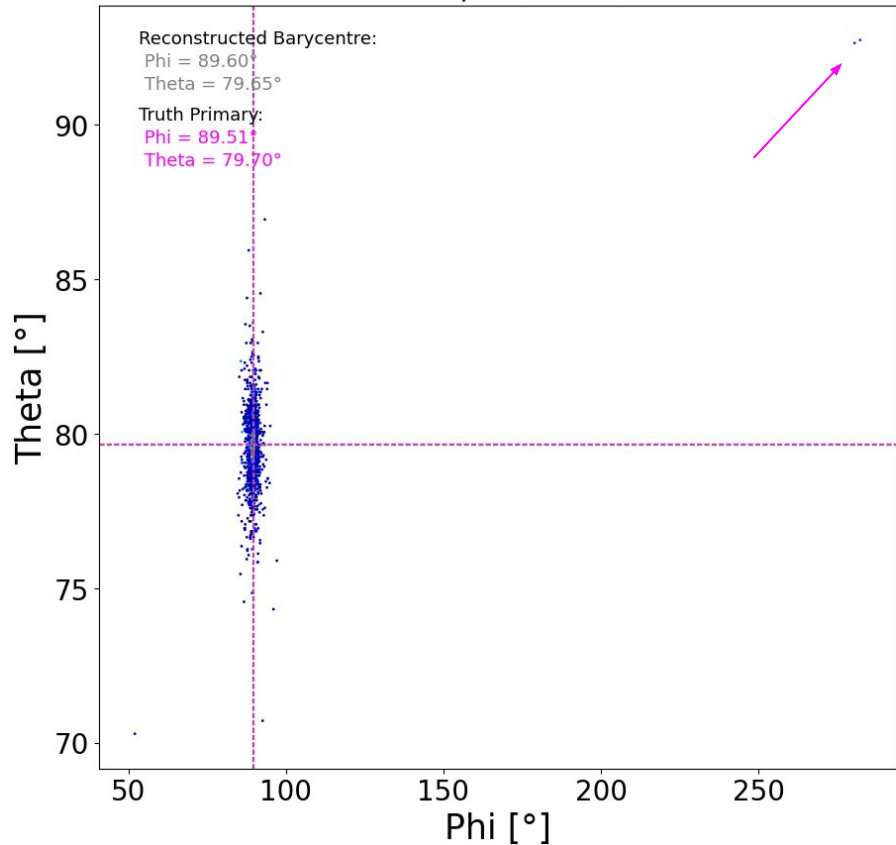
- Theta tail only
- ▼ Phi tail only
- × Both tails

- Clear structure in *theta* tail events:
 - Mostly events hitting the edges of the tower, where gaps can occur (top row directly touches the tower wall, so no gap there)
 - Presumably shower develops much deeper in the tower
 - Events not at the edges presumably hitting a gap between the tubes
- No clear structure for *phi* tail events
 - Still no hint for origin of tail
- A few events in *both* tails, but likely no significant meaning

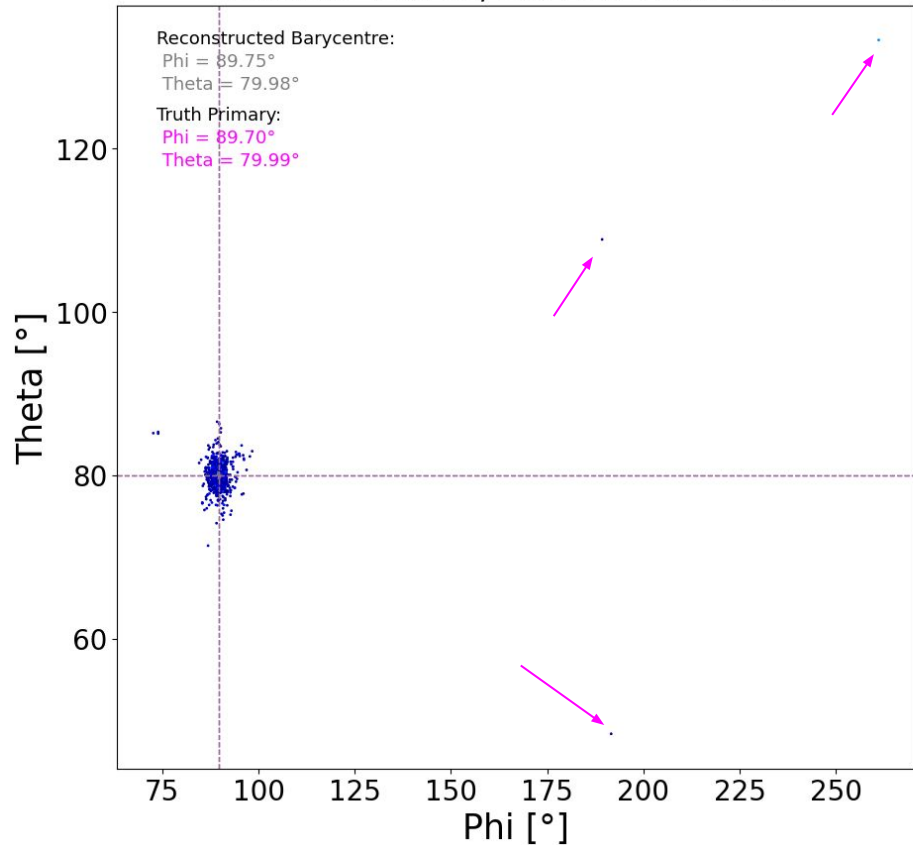
This clears the mystery of Theta tail.
Only mystery of phi tail still remains!

Event Displays for a few Phi Tail Events

Shower Profile, 120 GeV electron

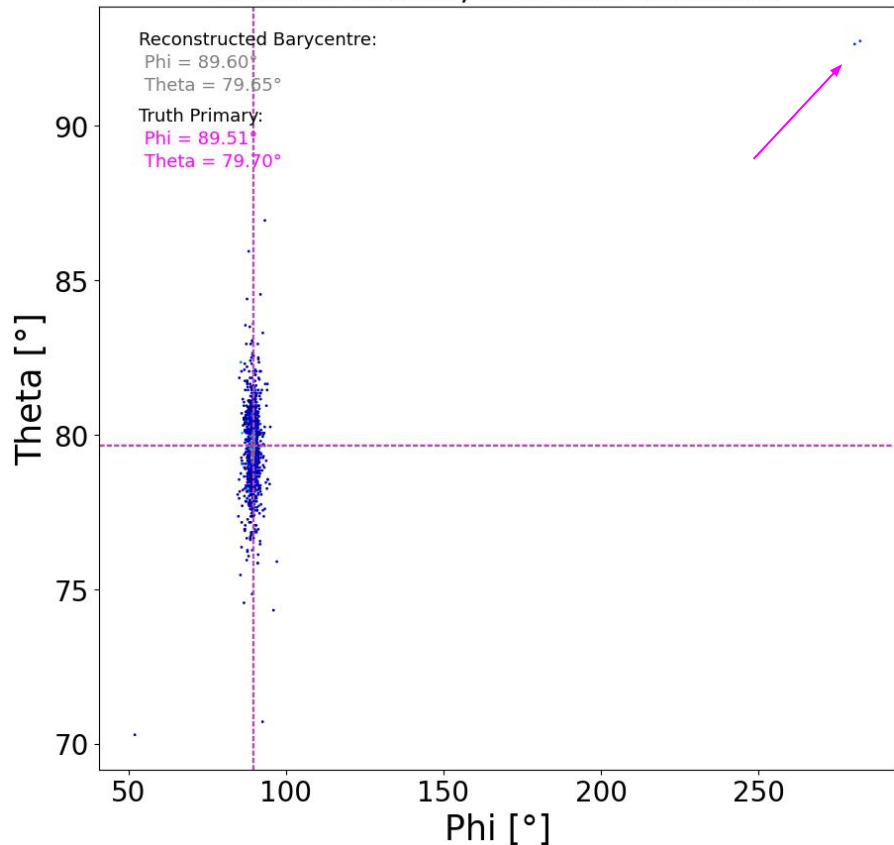


Shower Profile, 120 GeV electron



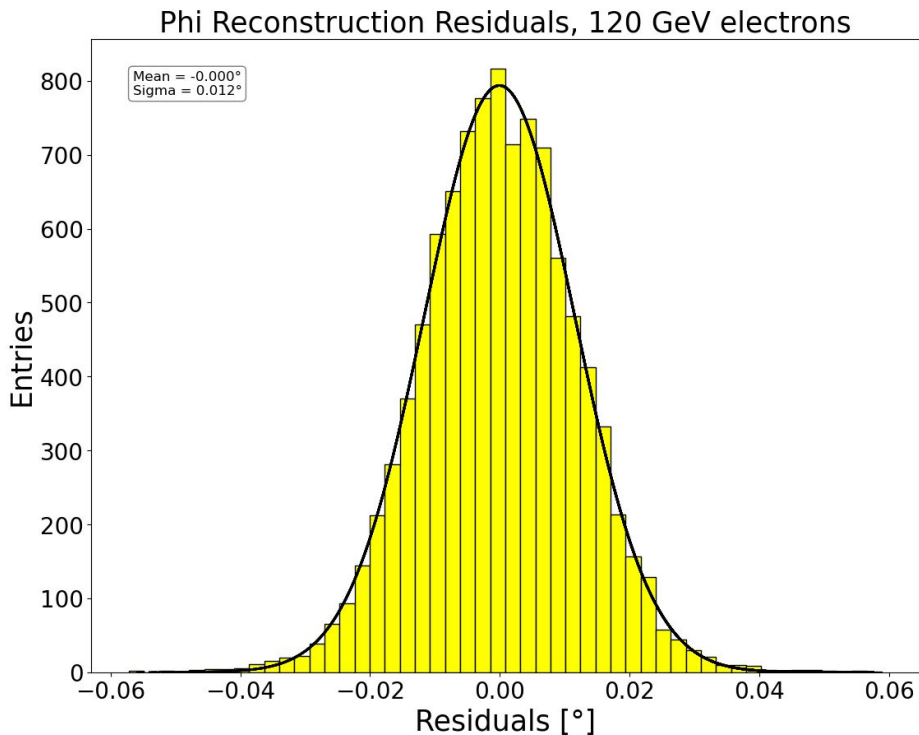
Event Displays for a few Phi Tail Events

Shower Profile, 120 GeV electron



- Events with very far away hits (compatible with back-scattering), pulling the barycentre
- Systematic error: shooting in one specific tower
- Since Phi range is $0-360^\circ$, the 'pull' mostly occurs in positive direction (where we observe the tail)
- Removing these hits could get rid of the tail

Event Displays for a few Phi Tail Events

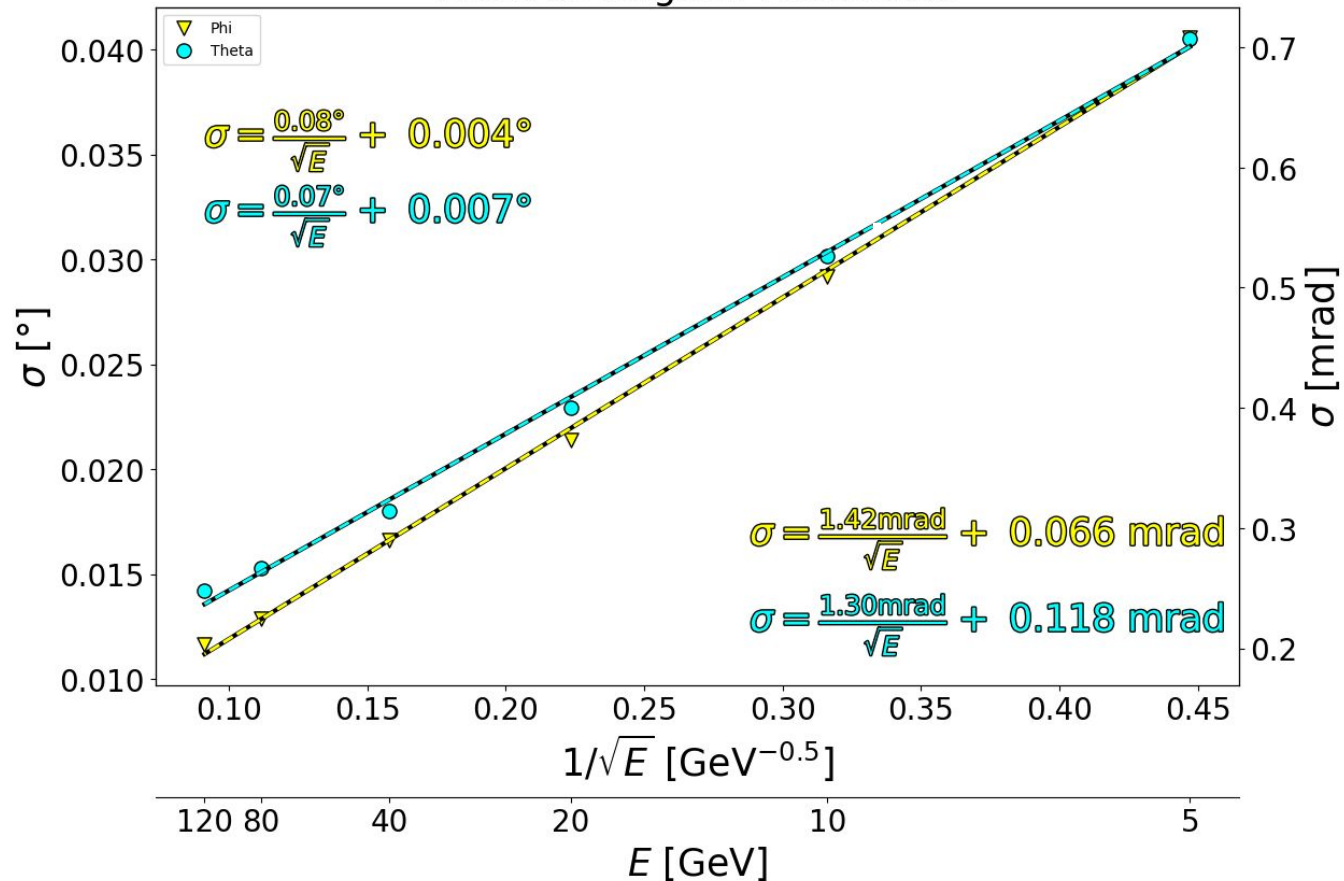


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Indeed, it does.
All mysteries solved!

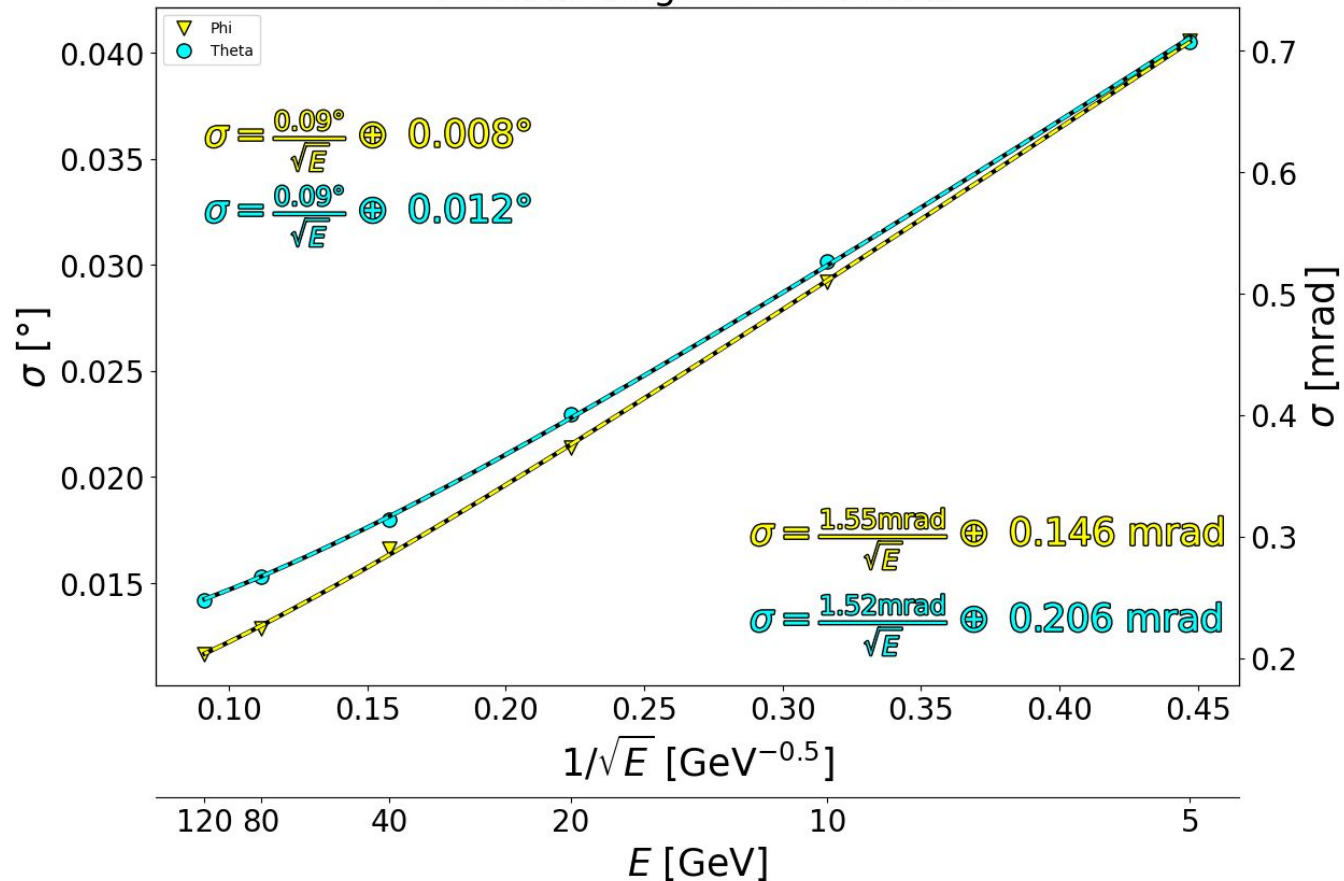
Angular Resolution

Electron Angular Resolution



Angular Resolution

Electron Angular Resolution



Summary

- All previously unknown effects corrected or understood
- Simulation updated for easier reconstruction
- New nominal values for the angular resolution:

$$\varphi : \sigma = \frac{1.42 \text{ mrad}}{\sqrt{E}} + 0.066 \text{ mrad} \quad \text{or} \quad \sigma = \frac{1.55 \text{ mrad}}{\sqrt{E}} \oplus 0.146 \text{ mrad}$$

$$\theta : \sigma = \frac{1.30 \text{ mrad}}{\sqrt{E}} + 0.118 \text{ mrad} \quad \text{or} \quad \sigma = \frac{1.52 \text{ mrad}}{\sqrt{E}} \oplus 0.206 \text{ mrad}$$

linear

quadratic