

# Update on forward tracking parameterisation update

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I previously presented an update on the HLT2 forward tracking parameterisations

- [Link to Indico here](#)
- Tracking algorithm described in three steps:
  - 1 Trajectories based on equations of motion and detector geometry
  - 2 Parameterise complex calculations using polynomials
  - 3 Determine coefficients by fits to MC
- Parameterisations updated using new MC samples
  - New magnetic field map (presented [here](#))
  - Initially worked with a private MC production
  - Moved to centrally produced samples [here](#)

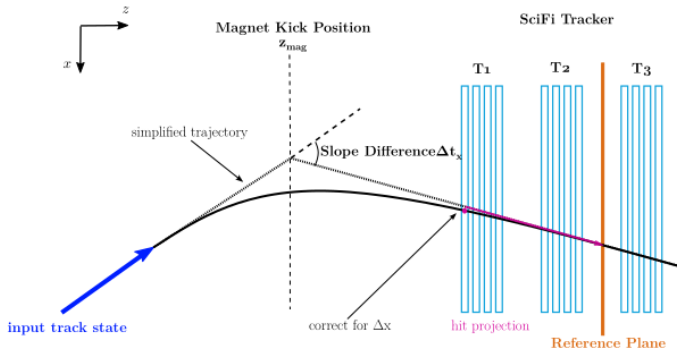
Last time I presented these parameterisations:

- 1 z magnet kick position
- 2 x fringe field correction
- 3 Stereo angle y correction
- 4 Hough histogram binning
- 5 z hit correction with SciFi yz tilt
- 6 Magnetic field integral

Last time I presented these parameterisations:

- ①  $z$  magnet kick position  $\leftarrow$  Caused some issues
- ②  $x$  fringe field correction
- ③ Stereo angle  $y$  correction
- ④ Hough histogram binning
- ⑤  $z$  hit correction with SciFi  $yz$  tilt
- ⑥ Magnetic field integral

# Reminder: $z_{\text{mag}}$ parameterisation

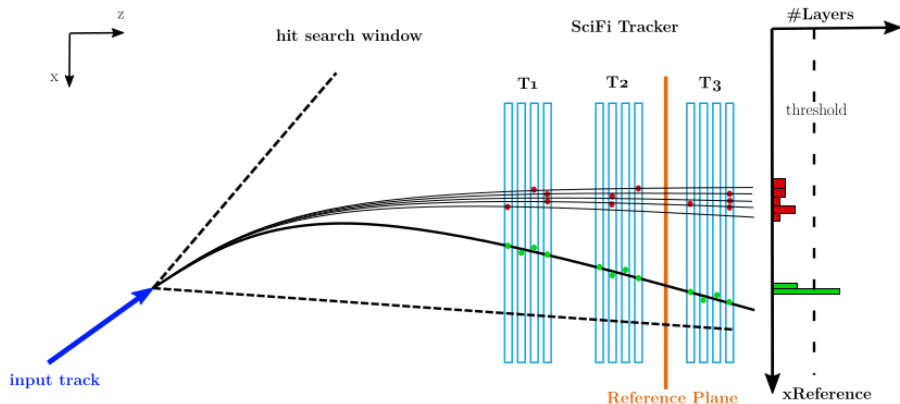


From CERN-THESIS-2023-097

- Simplified track model: Assume magnet “kicks” particle at  $z = z_{\text{mag}}$
- Parameterise  $z_{\text{mag}}$  as:

$$z_{\text{mag}} = c_0 + c_1 t_x^2 + c_3 t_y^2 + \Delta t'_x (c_2 t_x + c_4 \Delta t'_x)$$

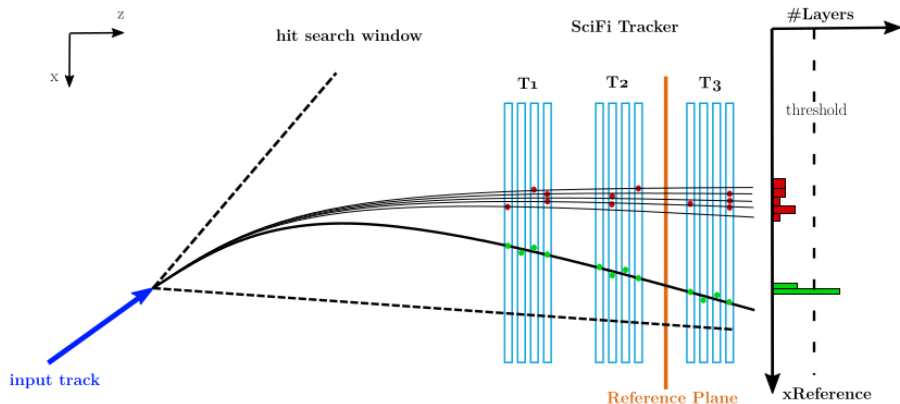
# Reminder: Hit mapping to reference plane



From CERN-THESIS-2023-097

- Once all SciFi hits are parameterised, map hits to reference plane
- Hits from real tracks show peaks in “Hough histogram”

# Reminder: Hit mapping to reference plane



From CERN-THESIS-2023-097

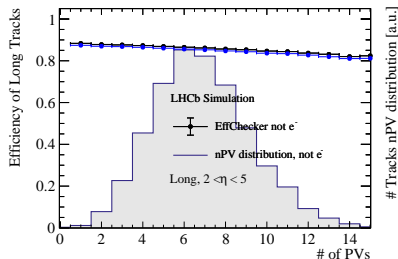
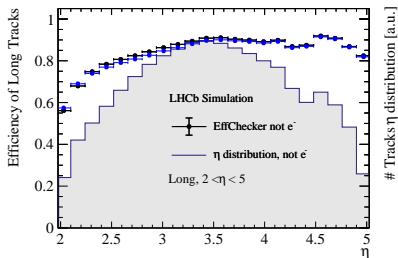
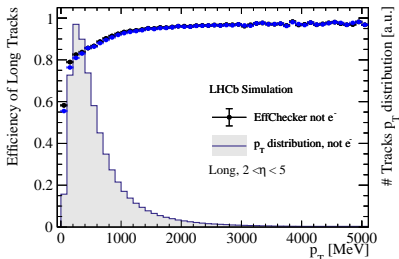
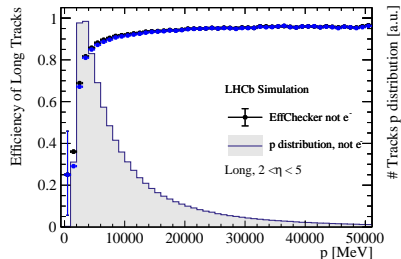
- Mapping depends on momentum, as low momentum tracks bend more
- Define a search window by assuming  $p = p_{\min} = 1500 \text{ MeV}/c$

Previously: Performance found to be worse after update

- Traced back to the  $z_{\text{mag}}$  parameterisation
- Reverting back to old  $z_{\text{mag}}$  parameterisation
  - Negligible change in performance compared to 2025-patches
- Possible explanation: Biases in  $z_{\text{mag}}$  are larger with new MC

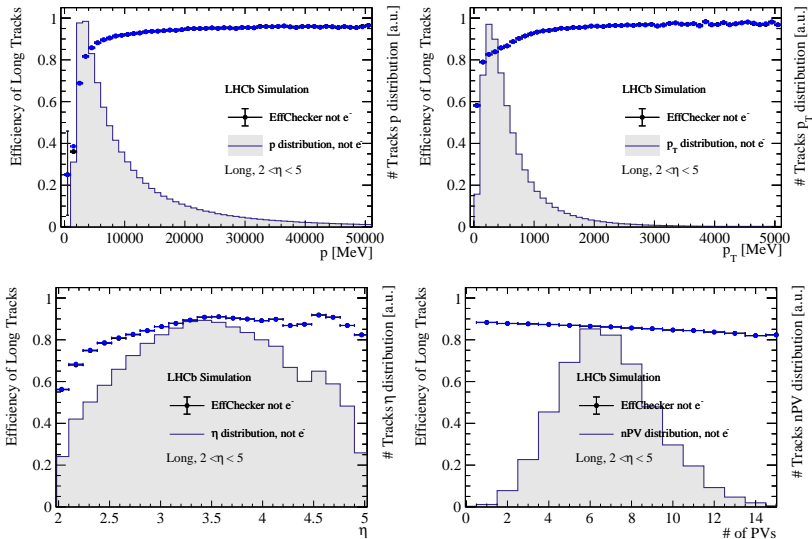


# Reminder: Tracking efficiencies with new parameterisation



Black: Old parameterisation. Blue: Updated parameterisation.

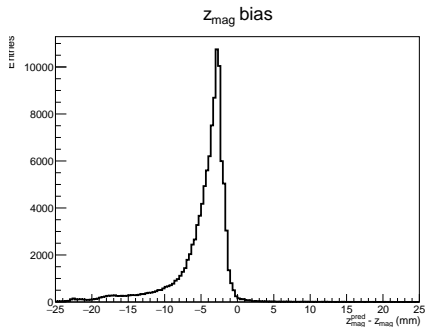
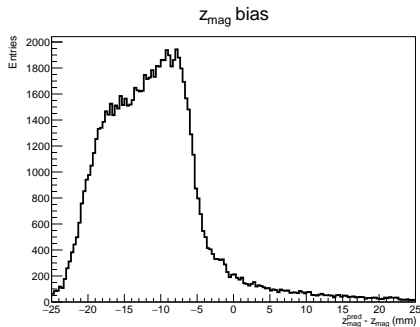
# Reminder: Tracking efficiencies with new parameterisation



Black: Old parameterisation. Blue: Updated parameterisation with old  $z_{\text{mag}}$ .

# Study of $z_{\text{mag}}$ bias

Study bias  $z_{\text{mag}}^{\text{pred}} - z_{\text{mag}}$  of original parameterisation:

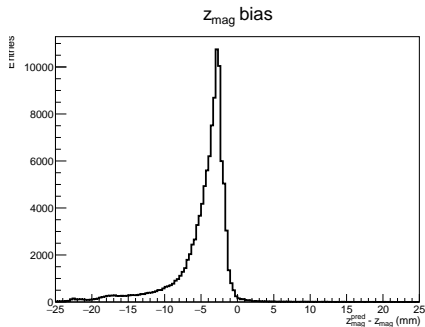
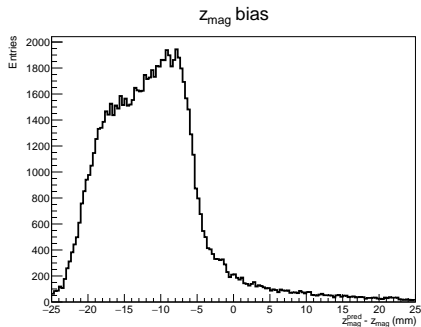


Left:  $p < 7$  GeV. Right:  $p > 7$  GeV.

- Parameterisation struggles a low momentum
  - Large negative bias
  - Very wide distribution

# Study of $z_{\text{mag}}$ bias

Study bias  $z_{\text{mag}}^{\text{pred}} - z_{\text{mag}}$  of original parameterisation:

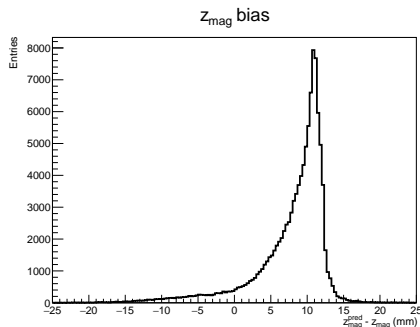
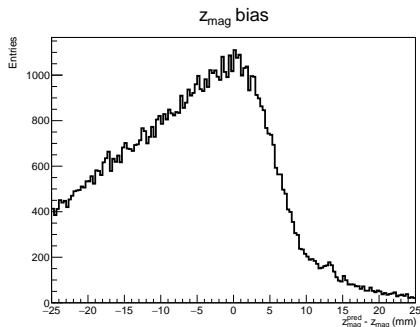


Left:  $p < 7$  GeV. Right:  $p > 7$  GeV.

- Parameterisation works well at high momentum
  - Small and almost negligible bias
  - Very small variance

# Study of $z_{\text{mag}}$ bias

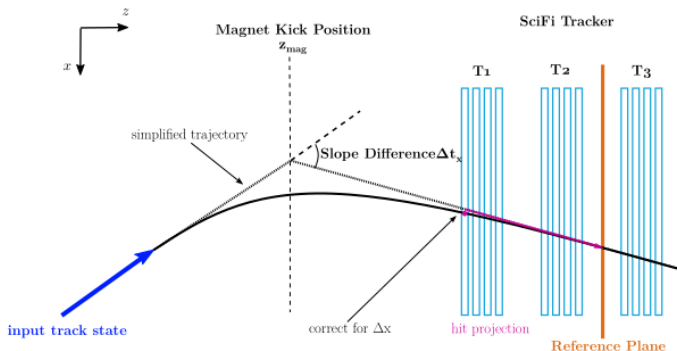
If we only update coefficients of  $z_{\text{mag}}$  parameterisation:



Left:  $p < 7$  GeV. Right:  $p > 7$  GeV.

- Potential explanation of worse performance with new coefficients:
  - Bias is generally worse
  - Parameterisation doesn't describe  $z_{\text{mag}}$  well

# Reminder: $z_{\text{mag}}$ parameterisation

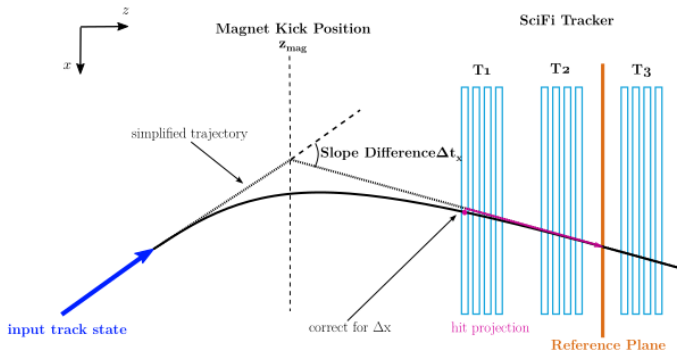


From CERN-THESIS-2023-097

- Original  $z_{\text{mag}}$  parameterisation:

$$z_{\text{mag}} = c_0 + c_1 t_x^2 + c_3 t_y^2 + \Delta t'_x (c_2 t_x + c_4 \Delta t'_x)$$

# Improved $z_{\text{mag}}$ parameterisation



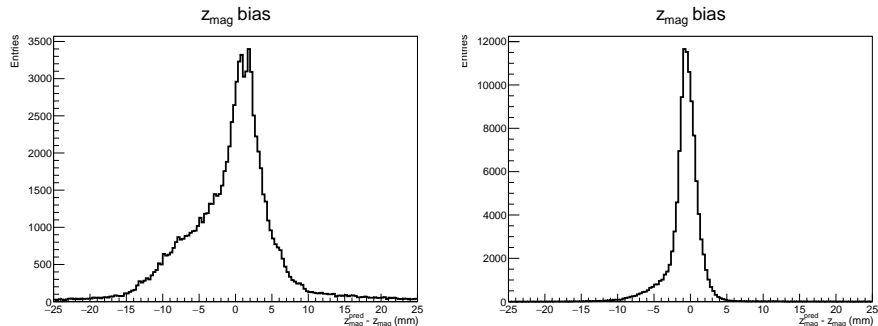
From CERN-THESIS-2023-097

- After trial and error, this parameterisation was obtained:

$$z_{\text{mag}} = c_0 + c_1 t_x^2 + c_3 t_y^2 + \Delta t'_x (c_2 t_x + c_4 \Delta t'_x) + (c_5 + t_x^2 + t_y^2 + |\Delta t'_x|^2) |\Delta t'_x|$$

# Study of $z_{\text{mag}}$ bias

Check biases with new improved parameterisation:

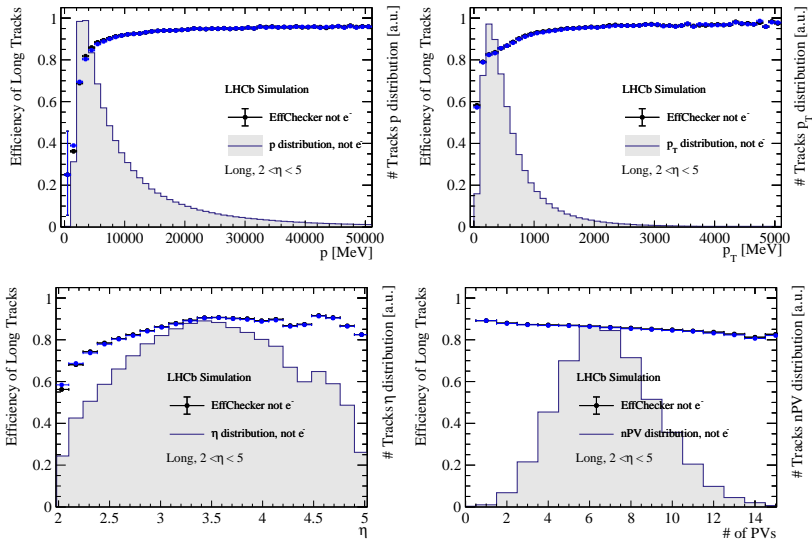


Left:  $p < 7$  GeV. Right:  $p > 7$  GeV.

- Huge improvement in biases:
  - Almost symmetric and unbiased distribution at high momentum
  - Mostly unbiased at low momentum, with a left tail



# Tracking efficiencies with new improved parameterisation

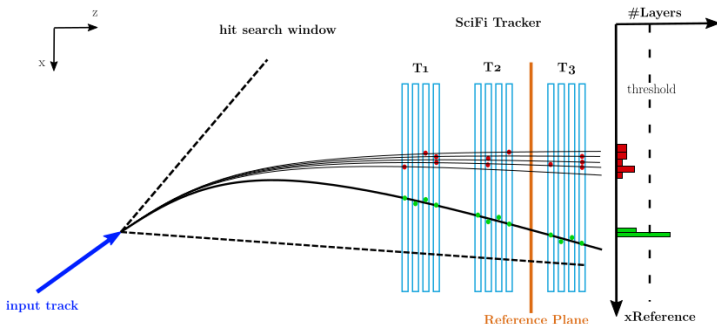


Black: Old parameterisation. Blue: Updated parameterisation of  $z_{\text{mag}}$ .

# Tracking efficiencies with new improved parameterisation

- Perhaps we should keep the original  $z_{\text{mag}}$  parameterisation?
  - Determined by Andre Günther using DC19 MC
- Total tracking efficiency dropped from 86.01% to 85.75% with updated parameterisation
- Efficiencies get worse with more accurate parameterisation...
- ...but perhaps in this case doing the wrong thing is better
- Is there a straightforward explanation for this...?

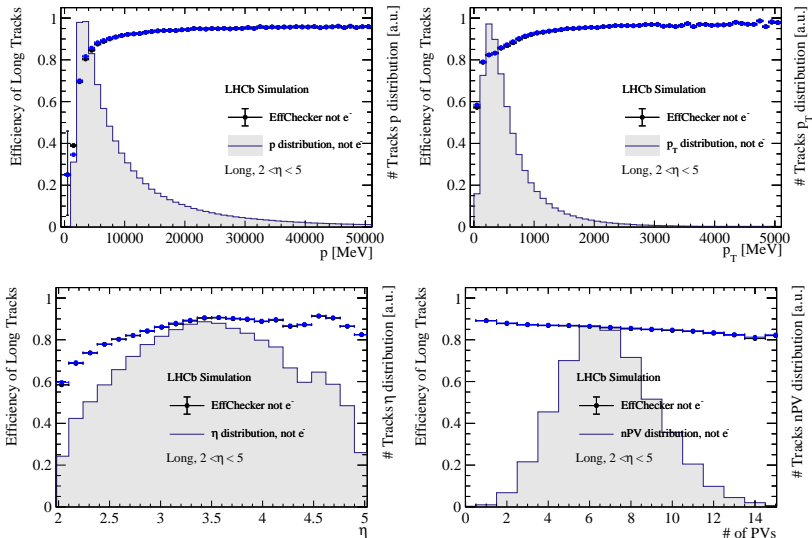
# Reminder: Hit mapping to reference plane



From CERN-THESIS-2023-097

- Define a search window by assuming  $p = p_{\min} = 1500 \text{ MeV}/c$
- My understanding is:
  - $z_{\text{mag}}$  is underestimated  $\rightarrow$  Search window becomes larger!
  - $\rightarrow$  Add  $-9.5 \text{ mm}$  bias at low momentum to improve performance

# Tracking efficiencies with biased $z_{\text{mag}}$ parameterisation



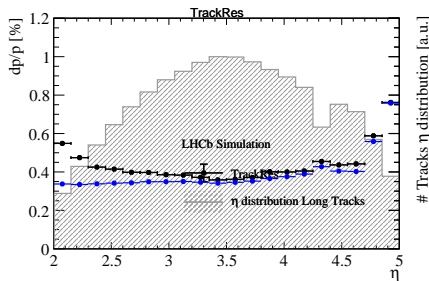
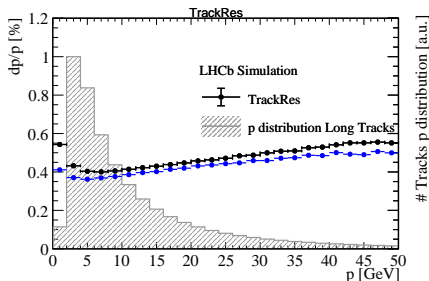
Black: Updated parameterisation. Blue: With bias in  $z_{\text{mag}}$ .

# Conclusion of $z_{\text{mag}}$ studies

- Indeed, the improvement in performance when introducing a bias confirms that it is the search window size that drive the tracking efficiencies at low momentum
- With a bias, efficiency improved from 85.75% to 86.02%
  - Note: With old parameterisation the efficiency was 86.01%
- This motivates us to keep the original  $z_{\text{mag}}$  parameterisation
- In fact, since there is no overall improvement, I propose we do not change the parameterisations for 2025 data taking

# Reminder: Momentum resolution

Previously I showed a momentum resolution improvement:



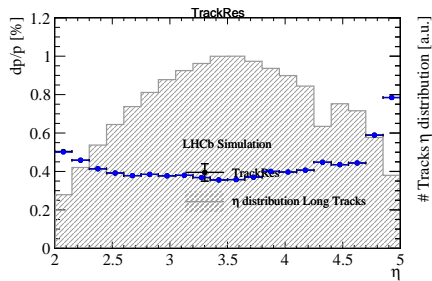
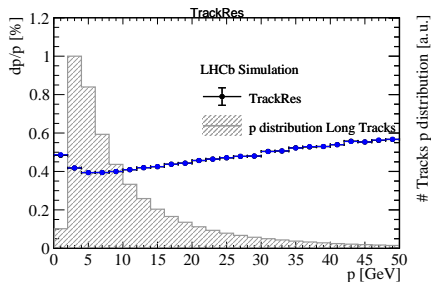
Black: Old parameterisation, old MC. Blue: New parameterisation, new MC.

I must apologise, but this was a mistake on my part

This improvement was not due to the new parameterisation, but due to the different MC used by me and Andre.

# Momentum resolution

Correct comparison, using the same MC sample:



Black: Old parameterisation. Blue: Proposed parameterisation.

No improvement in track resolution, even with new magnetic field parameterisation

- Parameterisations are re-evaluated using centrally produced MC
  - ① Larger MC samples
  - ② Both magnet polarities
  - ③ Larger selection of decay modes
- Possible improvements to  $z_{\text{mag}}$  parameterisation have been explored
  - Biases are reduced, but performance gets slightly worse
  - Reason for this unexpected behaviour:
    - Original parameterisation mostly underestimated  $z_{\text{mag}}$
    - Overestimated search windows in the x-plane
    - More hits included in reconstruction
    - Higher tracking reconstruction
- Once it was understood, tracking efficiencies remain the same
- I propose: Keep current parameterisation



# Next steps

- ① Most urgent: Improve throughput
  - Code was already heavily optimised by Andre...
  - ...but I'll do some quick checks for obvious bottlenecks
  
- ② After June TS: Document work in ParamScriptor
  - Mostly copy Andre's old code, with updated Moore scripts
  - I have already added new samples to TestDB in [this MR](#)
  
- ③ Long term: Make parameterisation code more general
  - In case updates are required in the future
  - A particular parameterisation may work today, but will break with future MC samples

# Thanks for listening!