

First look at updated HLT2 forward tracking parameterisations

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Outline

- 1 Introduction
- 2 Overview of forward tracking algorithm
- 3 Current tracking performance
- 4 Tracking performance with new parameterisation
- 5 Conclusion

I've had a look at the HLT2 forward tracking algorithm

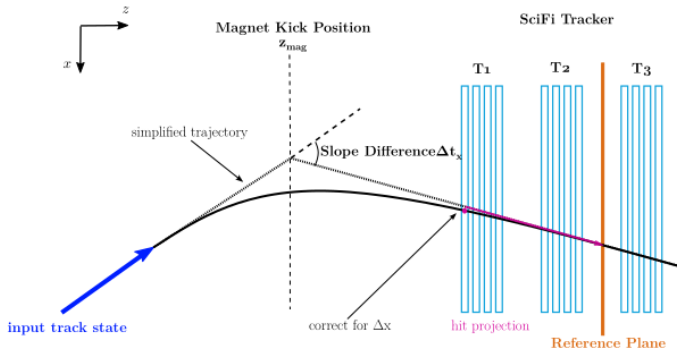
- Relevant code lives in `Rec/Pr/PrAlgorithms/src/`
 - `PrForwardTracking.cpp`
 - `PrTrackModel.cpp`
- Tracking algorithm described in three steps:
 - 1 Trajectories based on equations of motion and detector geometry
 - 2 Parameterise complex calculations using polynomials
 - 3 Determine coefficients by fits to MC
- I plan to update these parameterisations
 - Previous work based on MC from 2019 (DC19)
 - New magnetic field map (presented [here](#))

Based on work by Andre Günther

Many thanks to Andre for the extensive documentation!

- Algorithm described in his thesis: [CERN-THESIS-2023-097](#)
 - All parameterisations are explained thoroughly
 - Numerical results all agree with what is in Rec
- Code available in: [Reco-Parameterisation-Tuner](#)
 - Only minor changes required to get code running with latest environment
 - All parameterisations can be reproduced with files found on Heidelberg computing cluster
 - Moore scripts provided for rerunning with new MC (must be XDIGI)

Overview of forward tracking algorithm

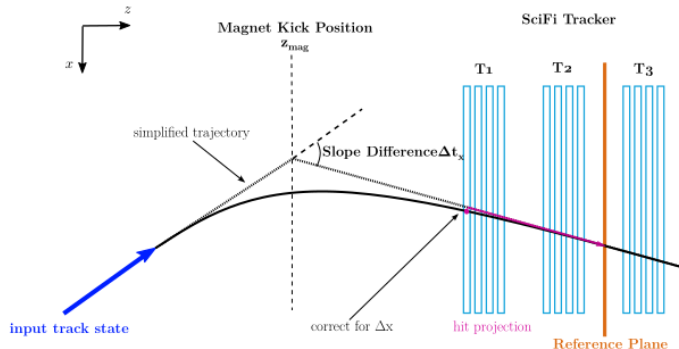


From CERN-THESIS-2023-097

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

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

Overview of forward tracking algorithm

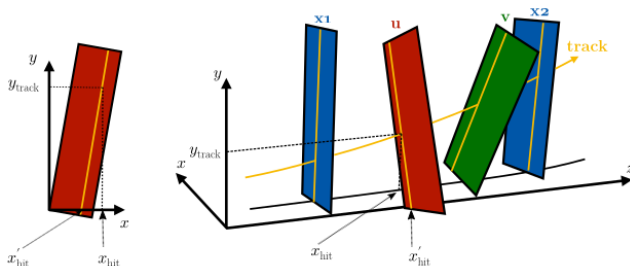


From CERN-THESIS-2023-097

- True path in xz plane deviates due to the SciFi fringe field
- Parameterise trajectory as:

$$x(z) = a_x + b_x(z - z_{\text{ref}}) + c_x(z - z_{\text{ref}})^2 + d_x(z - z_{\text{ref}})^3$$

Overview of forward tracking algorithm

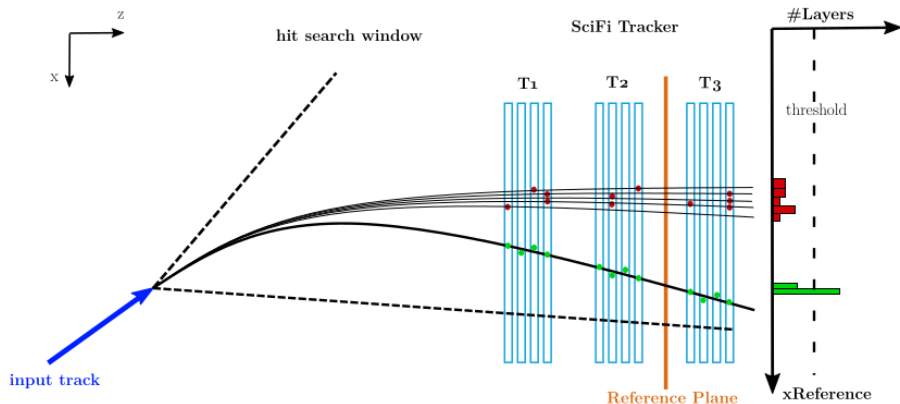


From CERN-THESIS-2023-097

- Hits in stereo layers must be “rotated”, which requires y-position
- Account for small track curvature in yz plane:

$$y_{\text{corr}}^L = \Delta t_x (c_0^L + c_2^L t_x t_y + c_5^L t_x t_y^3 + c_6^L t_x^3 t_y) \\ + t_x (c_1^L + c_3^L t_x t_y + c_4^L t_x t_y^3 + c_7^L t_x^3 t_y)$$

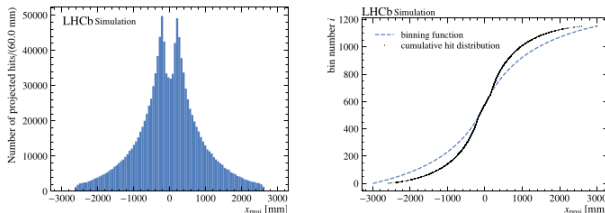
Overview of forward tracking algorithm



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”

Overview of forward tracking algorithm



a: Distribution of projected hits positions from several tracks. **b:** Cumulative distribution of projected hits.

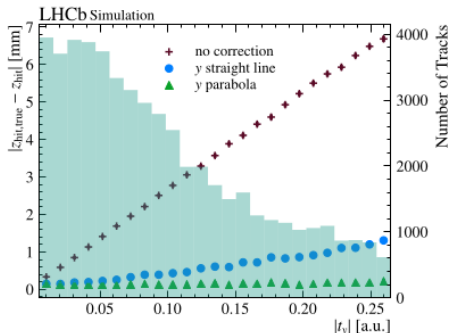
Figure 5.13: Distributions used to determine the binning scheme of the Hough histogram.

From CERN-THESIS-2023-097

- Hits (in reference plane) are not uniform along x-axis
- Transform x by sigmoid function before binning:

$$p_0 + \frac{p_1 x_{\text{proj}}}{1 + p_2 |x_{\text{proj}}|}$$

Overview of forward tracking algorithm



From CERN-THESIS-2023-097

- z-position must then be corrected for small tilt in yz plane
- Assume trajectory in yz plane is a parabola:

$$y(z) = a_y + b_y(z - z_{ref}) + c_y(z - z_{ref})^2$$
$$z'_{hit} = z_{hit} + \tan(0.21^\circ)y(z)$$

Overview of forward tracking algorithm

Finally, obtain momentum from change in track slope Δt_x :

$$\frac{q}{p} = \frac{\Delta t_x}{r_l B_{\text{int}}}$$

The field integral B_{int} is parameterised as:

$$\begin{aligned} B_{\text{int}} = & c_0 + t_y^2(c_1 + c_5 t_y^2 + c_6 t_x^2) + t_x b_x(c_{10} t_x + c_3 + c_7 t_y^2) \\ & + c_{11} b_x^4 + c_2 t_x^2 + b_x^2(c_4 + c_8 t_y^2) + c_9 t_x^4 \end{aligned}$$

Overview of forward tracking algorithm

In summary, these are the parameterisations used in forward tracking:

- 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

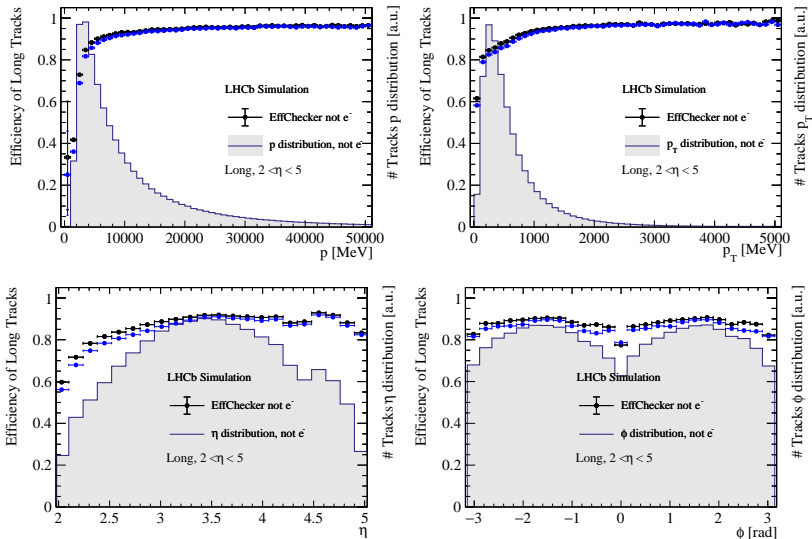
Metrics for tracking performance:

- Tracking efficiency vs p , p_T , η , nPVs, ϕ
 - Reconstructed / Reconstructible
 - Most important metric
- Momentum resolution vs p , η
 - Width of momentum residual distribution
 - Less important since track momentum is determined by Kalman fit

MC samples:

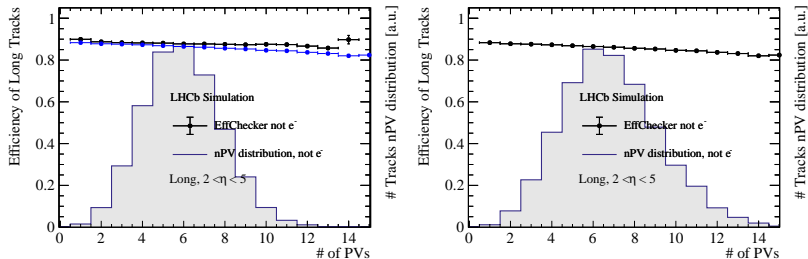
- DC19: Cross check with Andre's work
 - Found on Heidelberg cluster
 - Cocktail of $B_s^0 \rightarrow J/\psi\phi$, $B_s^0 \rightarrow \phi\phi$, $D^+ \rightarrow K_S^0\pi^+$, $Z^0 \rightarrow \mu^+\mu^-$, $D^{*+} \rightarrow [K^-\pi^+]_{D^0}\pi^+$, 50k MagUp/MagDown
- v8.1 field map: Private production
 - Many thanks to Jiahui and Alessandro for your help producing this!
 - Cocktail of $B_s^0 \rightarrow J/\psi\phi$, $B_s^0 \rightarrow \phi\phi$, $D^+ \rightarrow K_S^0\pi^+$, 10k MagDown

Current tracking performance



Black: Results with DC19. Blue: Results with recent MC.

Current tracking performance

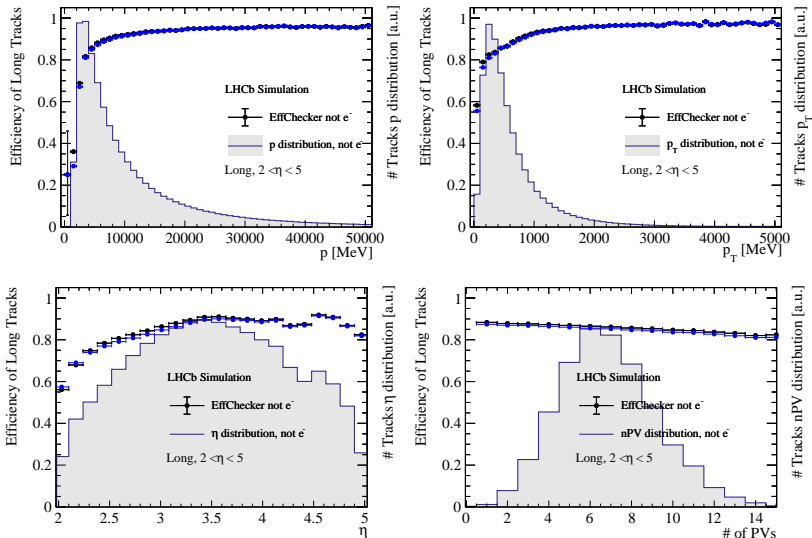


Left: DC19 in black and recent MC in blue. Right: Results with recent MC.

New parameterisation:

- Run Andre's code on recent MC samples
- No change in choice of parameterisation
- Exact numerical changes can be found in this MR: [!4362](#)

Tracking performance with new parameterisation



Black: Old parameterisation. Blue: Updated parameterisation.

Tracking performance with new parameterisation

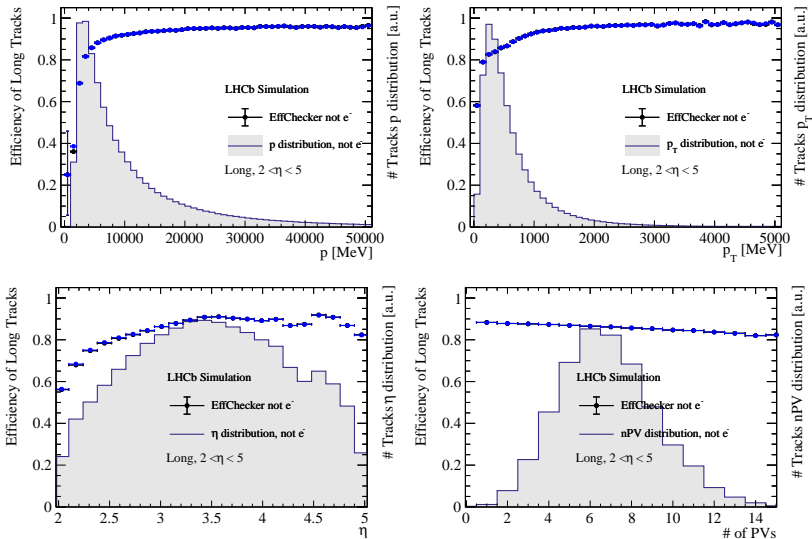
Observations with new parameterisation:

- Changes are generally small
- But it is worrying that performance is strictly worse

What went wrong?

- Not enough time to investigate thoroughly, unfortunately...
- ... so do a simple process of elimination:
 - ① Revert each parameterisation back to the old one
 - ② Rerun reconstruction and check track efficiencies
 - ③ Figure out which parameterisation worsens the performance
- Culprit: z magnet kick position → Use old parameterisation for now!

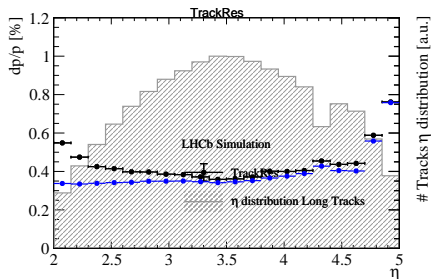
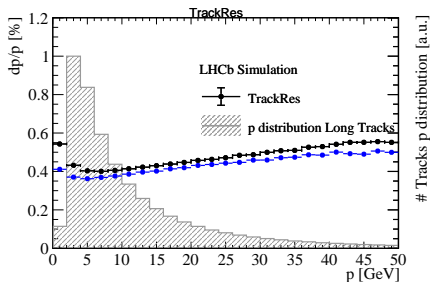
Tracking performance with new parameterisation



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

Tracking performance with new parameterisation

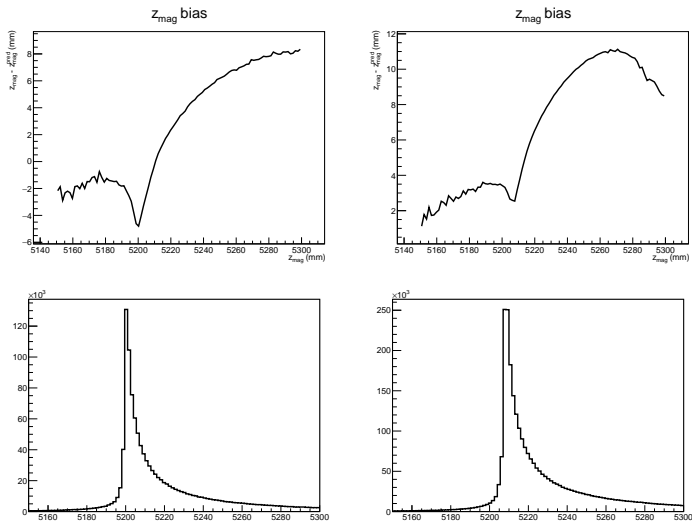
What about momentum resolution?



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

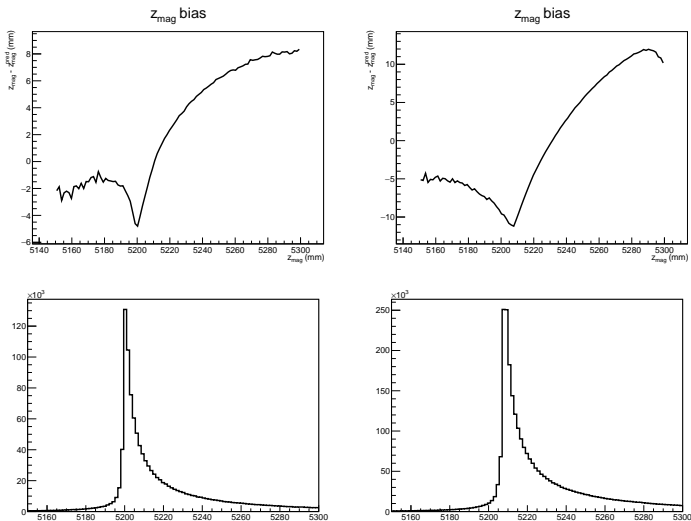
Clear improvement in momentum resolution!

Tracking performance with new parameterisation



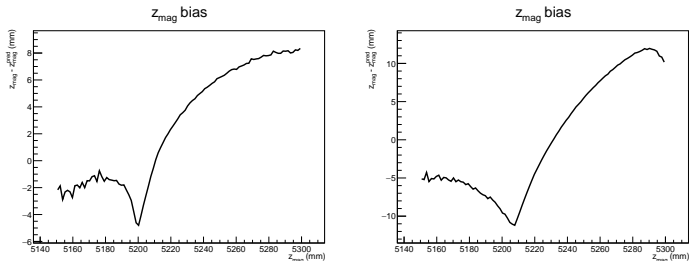
Left: Results with DC19. Right: Results with recent MC (old parameterisation).

Tracking performance with new parameterisation



Left: Results with DC19. Right: Results with recent MC.

Tracking performance with new parameterisation



- In Andre's thesis, the bias in z_{mag} was found to be a few millimetres
 - Sufficient for this simple track model
- However, with the recent MC, this bias seems to be larger...
 - ... probably the choice of parameterisation is not ideal
 - I need to look into different parameterisations

Summary and next steps

- I have attempted to run the forward tracking parameterisations using Andre Günther's code "out of the box"
 - ① Initial results showed a degradation in performance
 - ② Traced the issue to the z_{mag} parameterisation
 - ③ Using the old z_{mag} parameterisation for now:
 - Very small improvement in track efficiencies
 - Noticeable improvement in momentum resolution
- Note: Results are very preliminary! Need to:
 - ① Rerun studies with full set of MC samples
 - ② Look into other parameterisations of z_{mag}

Thanks for listening!