# First look at updated HLT2 forward tracking parameterisations

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# Outline

## 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)

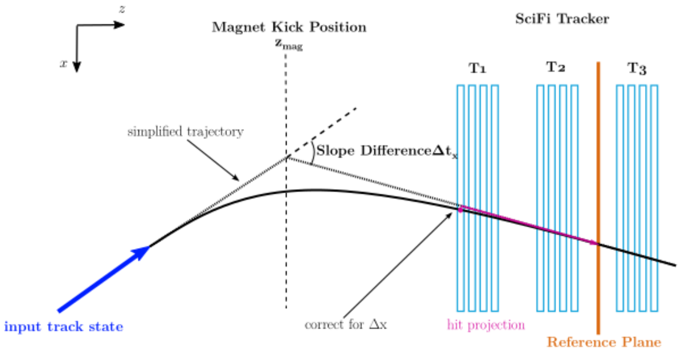
# Introduction

## 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

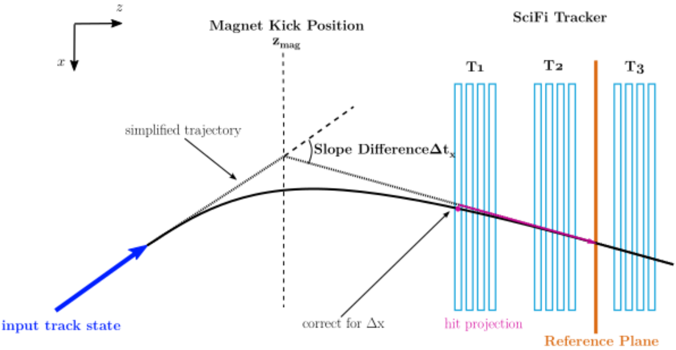



From CERN-THESIS-2023-097

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

$$z_{\mathrm{mag}} = c_0 + c_1 t_x^2 + c_3 t_y^2 + \Delta t_x'(c_2 t_x + c_4 \Delta t_x')$$

# Overview of forward tracking algorithm

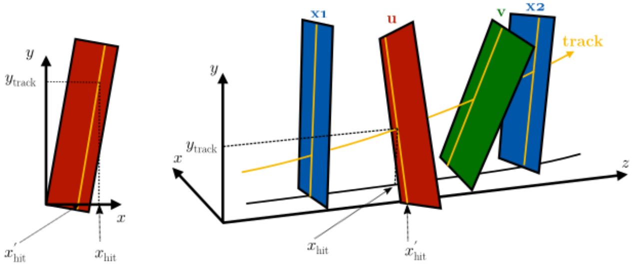



From CERN-THESIS-2023-097

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

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

# Overview of forward tracking algorithm

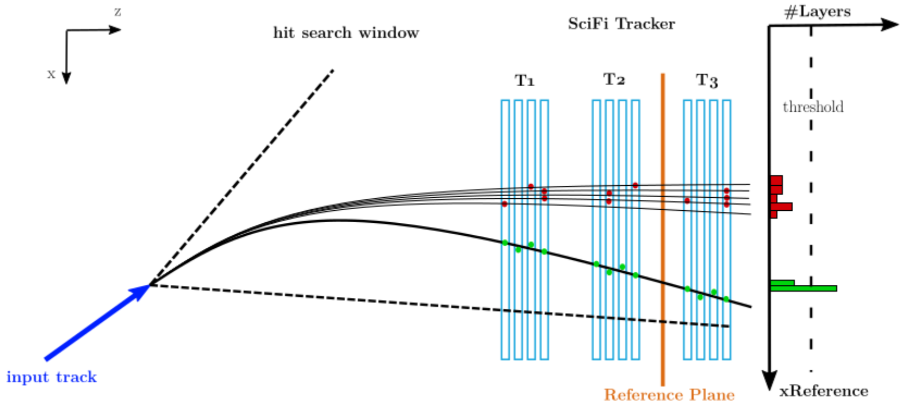



From CERN-THESIS-2023-097

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

$$
\begin{aligned}
y^L_{\mathrm{corr}} =& \Delta t_x(c^L_0 + c^L_2 t_x t_y + c^L_5 t_x t_y^3 + c^L_6 t_x^3 t_y) \\
&+ t_x(c^L_1 + c^L_3 t_x t_y + c^L_4 t_x t_y^3 + c^L_7 t_x^3 t_y)
\end{aligned}
$$

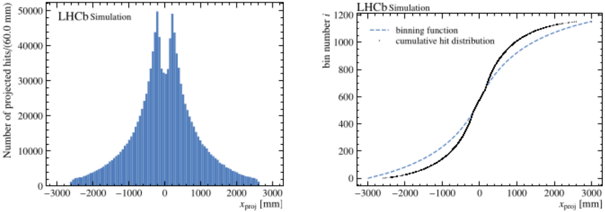
# Overview of forward tracking algorithm




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.

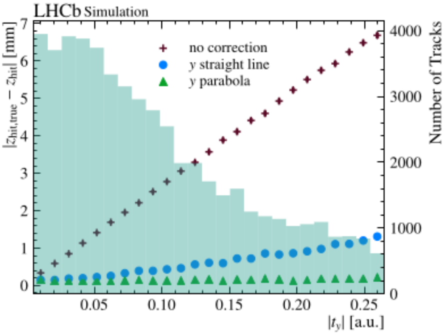
**Figure 5.13:** Distributions used to determine the binning scheme of the Hough histogram.

From CERN-THESIS-2023-097

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

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

# 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:

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

# Overview of forward tracking algorithm

Finally, obtain momentum from change in track slope $\Delta t_x$:

$$\frac{q}{p} = \frac{\Delta t_x}{r_I B_{\mathrm{int}}}$$

The field integral $B_{\mathrm{int}}$ is parameterised as:

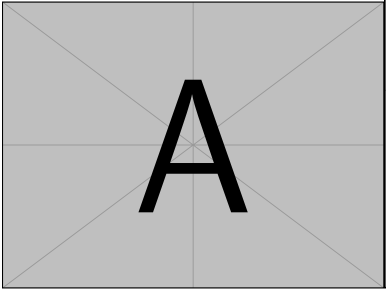
$$\begin{aligned} B_{\mathrm{int}} = & c_0 + t_y^2(c_1 + c_5 t_y^2 + c_6 t_x^2) + t_x b_x(c_{10} t_x + c_3 + c_7 t_y^2) \\ & + c_{11} b_x^4 + c_2 t_x^2 + b_x^2(c_4 + c_8 t_y^2) + c_9 t_x^4 \end{aligned}$$

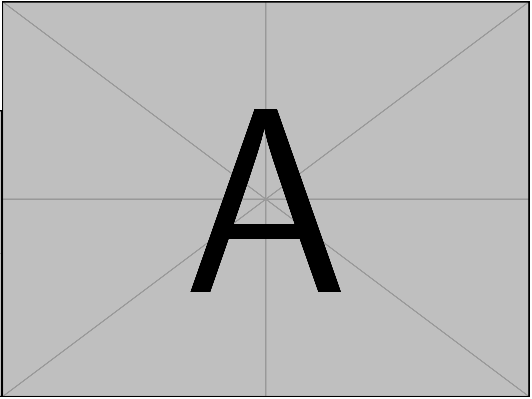
# Overview of forward tracking algorithm

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

# Overview of forward tracking algorithm



# Conclusion

## Summary:

- Reran 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 $z_{\mathrm{mag}}$ parameterisation
    3. Reverting this parameterisation shows very small improvement

## Next steps:

- Rerun studies with full set of MC samples
- Look into other parameterisations of $z_{\mathrm{mag}}$

# Thank you!