Update on forward tracking parameterisation update

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Outline

Introduction

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

Reminder: Parameterisations in HLT2 forward tracking

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

Reminder: Parameterisations in HLT2 forward tracking

Last time I presented these parameterisations:

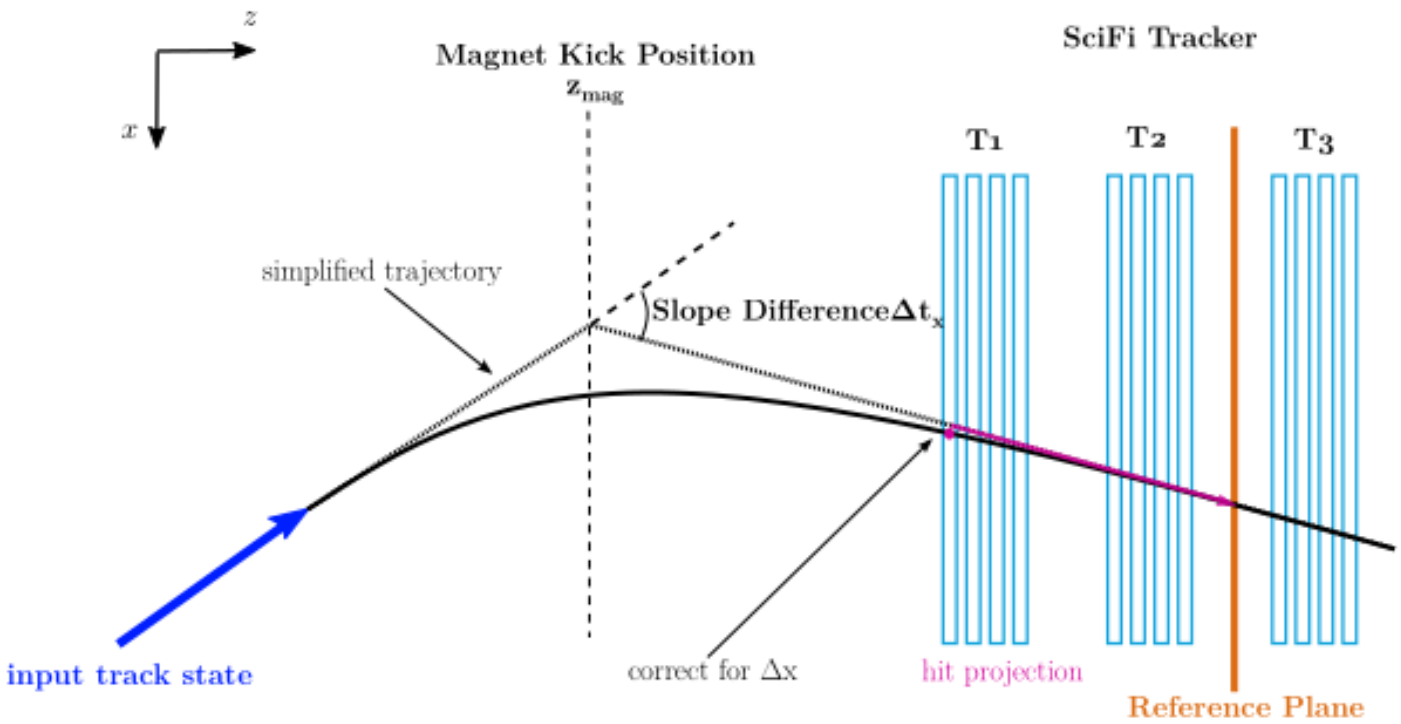
1. z magnet kick position $\leftarrow$ Caused some issues
2. x fringe field correction
3. Stereo angle y correction
4. Hough histogram binning
5. z hit correction with SciFi yz tilt
6. Magnetic field integral

Reminder: Parameterisations in HLT2 forward tracking

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 $\leftarrow$ Improves momentum resolution estimate

Reminder: z_{mag} parameterisation

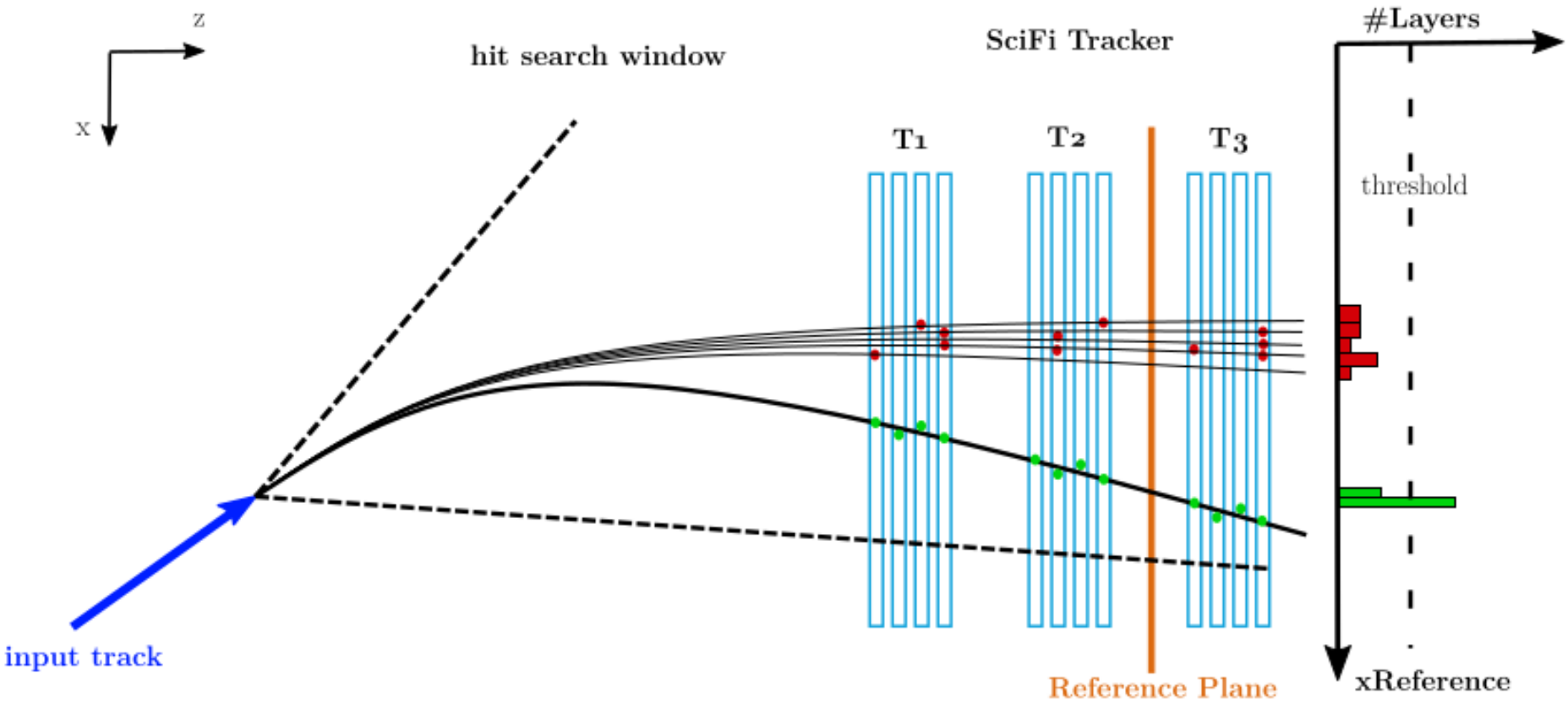


From CERN-THESIS-2023-097

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

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

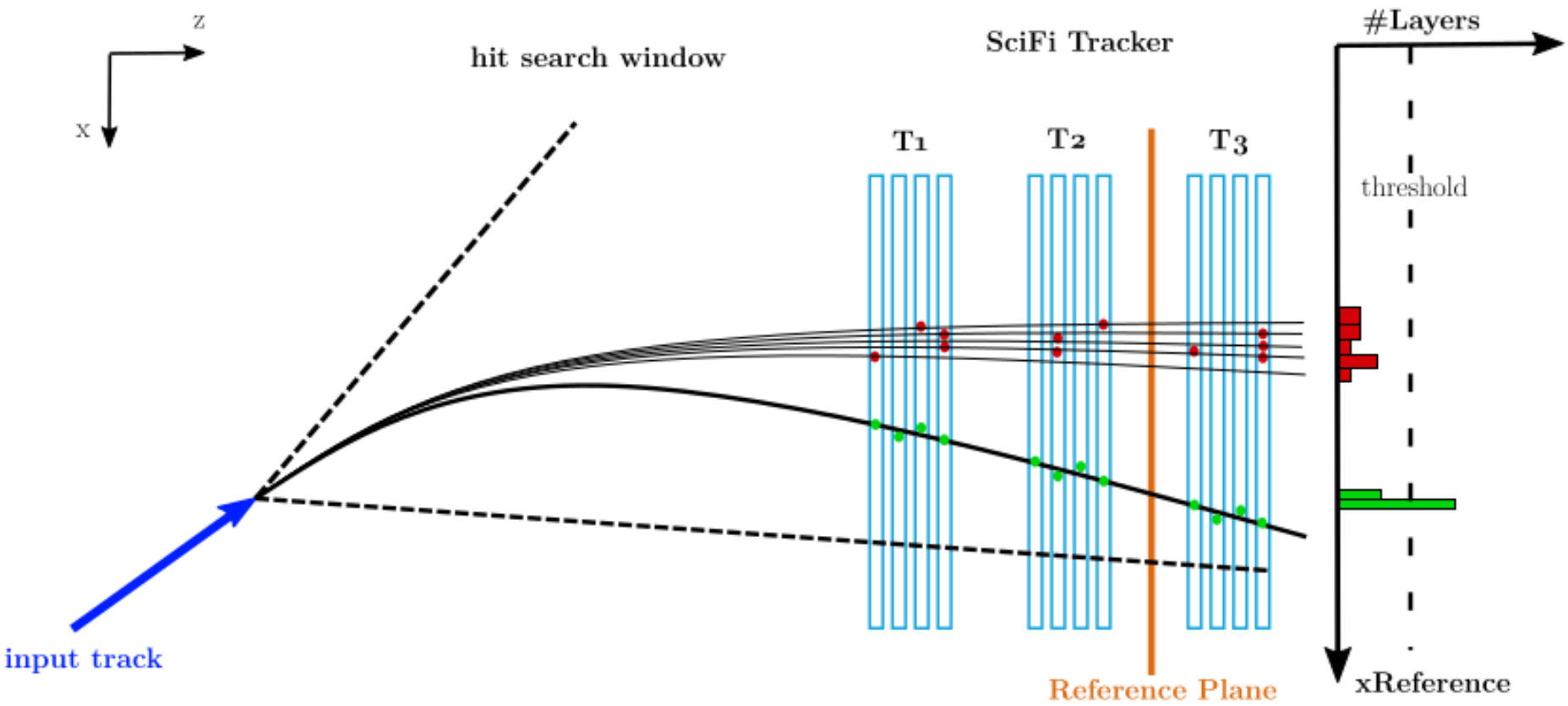
Reminder: Hit mapping to reference plane



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

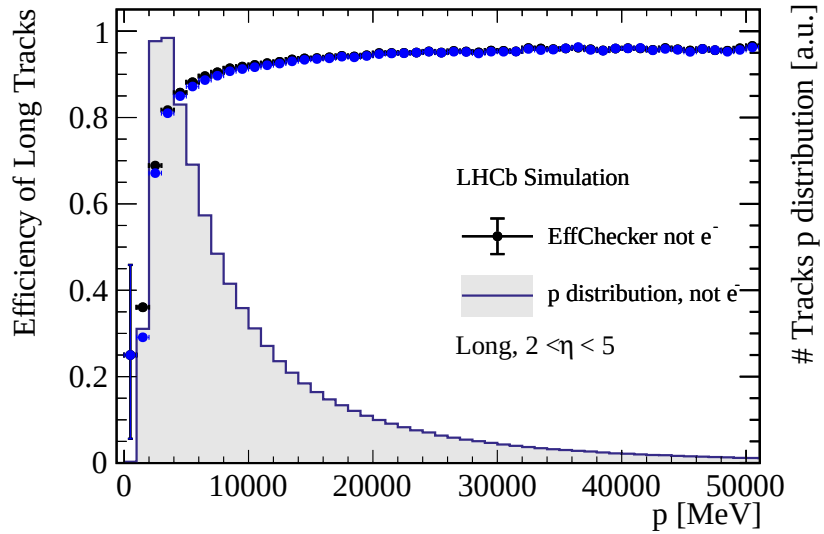
- Mapping depends on momentum, as low momentum tracks bend more
- Define a search window by assuming $p = p_{\mathrm{min}} = 1500$ MeV/c

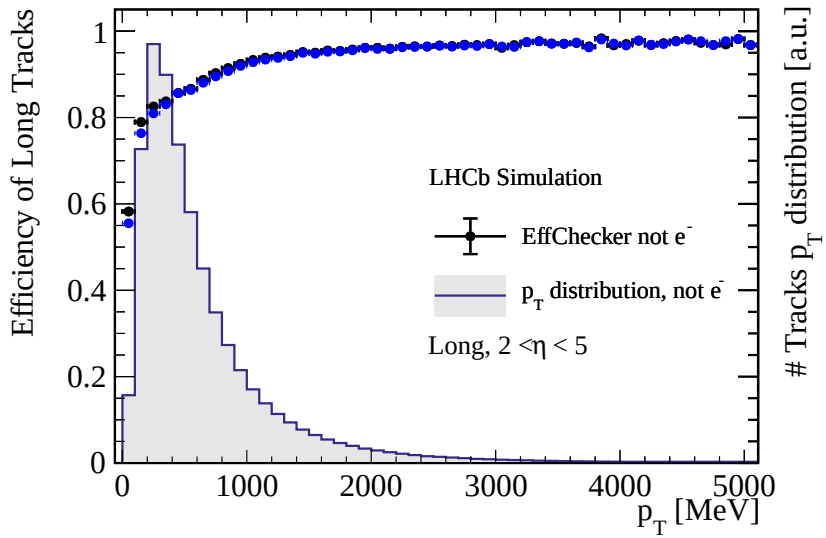
Reminder: Tracking efficiencies with new parameterisation

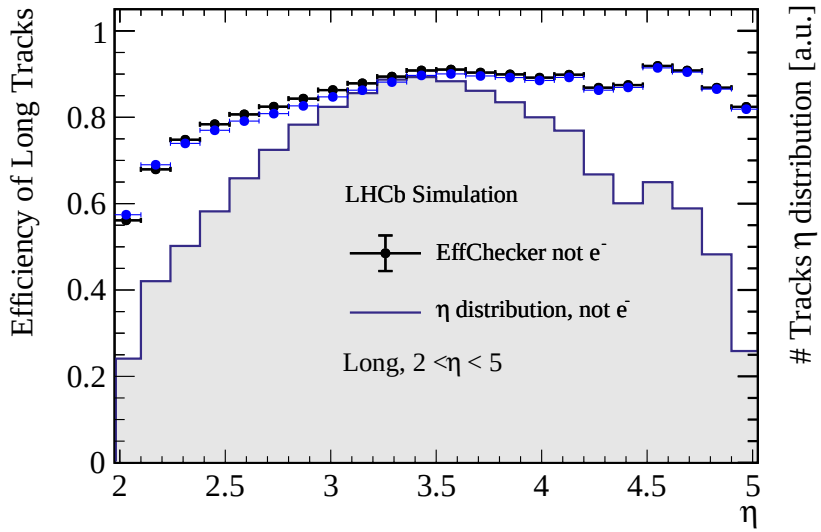
Previously: Performance found to be worse after update

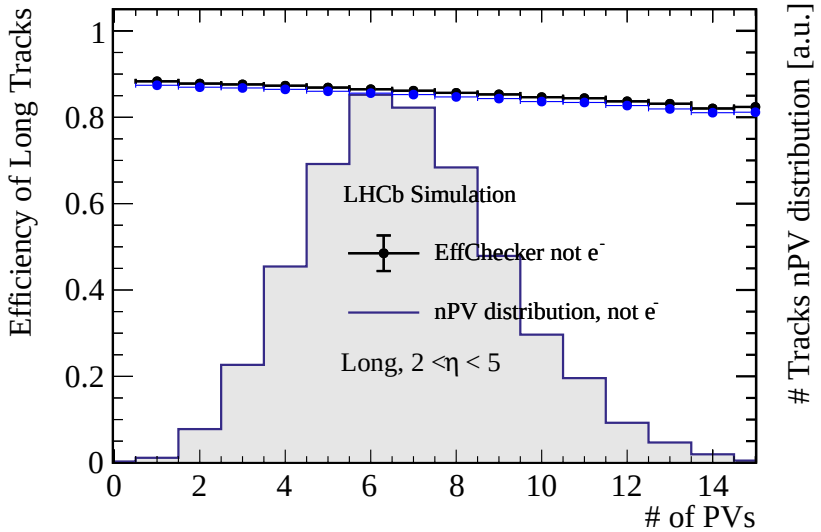
- Traced back to the z_{mag} parameterisation
- Reverting back to old z_{mag} parameterisation
  - Negligible change in performance compared to `2025-patches`
- Possible explanation: Biases in z_{mag} are larger with new MC

Reminder: Tracking efficiencies with new parameterisation



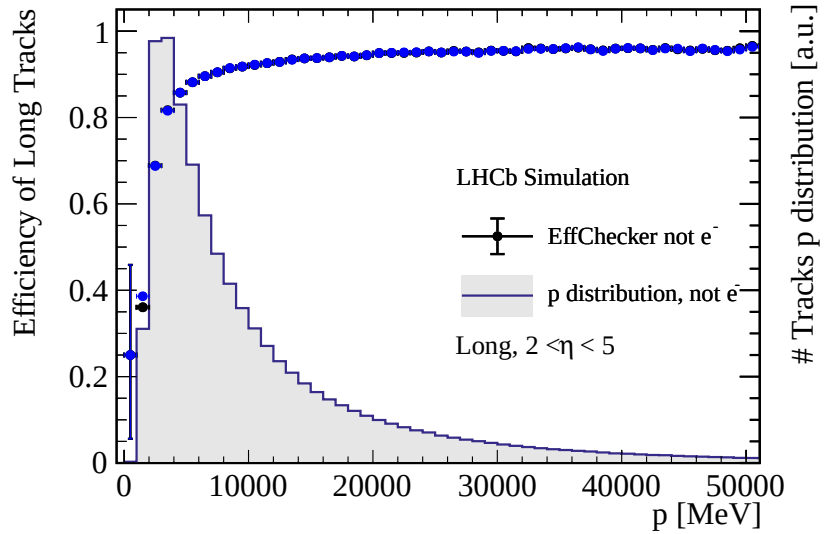


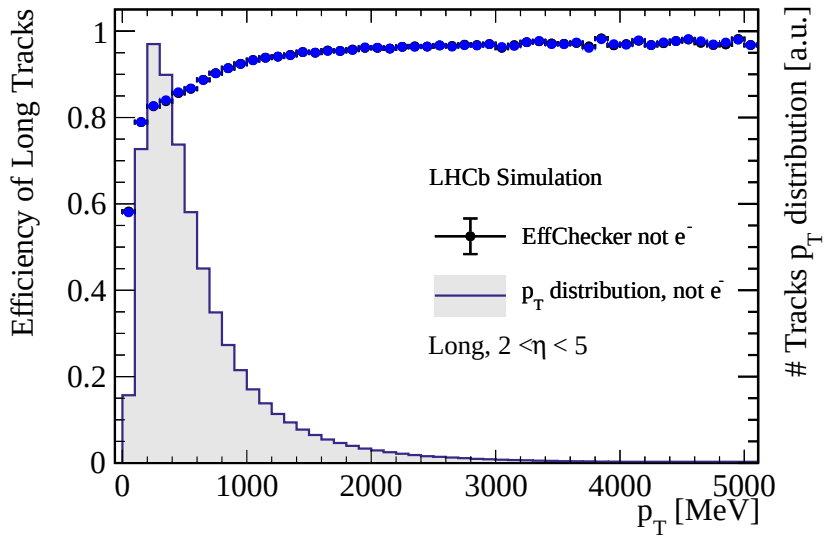


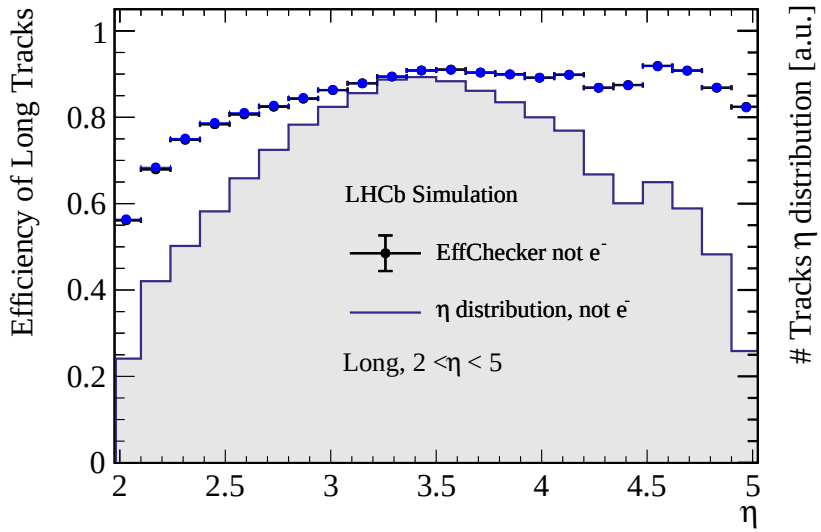


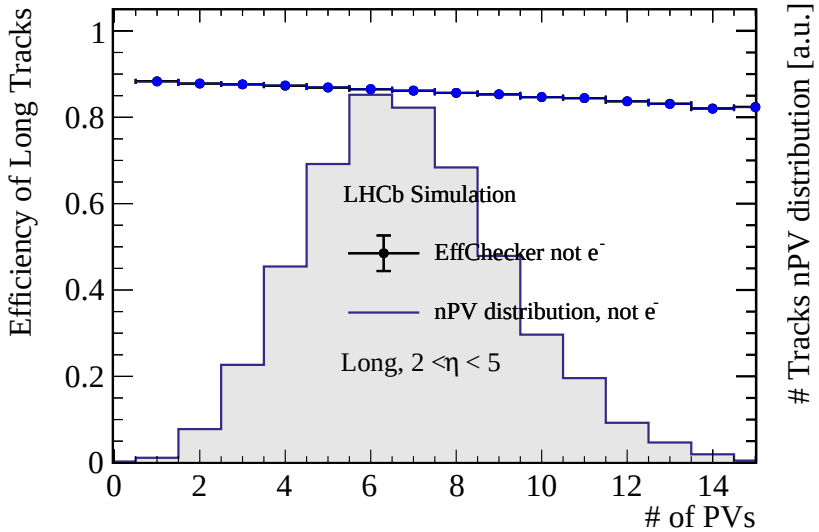
Black: Old parameterisation. Blue: Updated parameterisation.

Reminder: Tracking efficiencies with new parameterisation





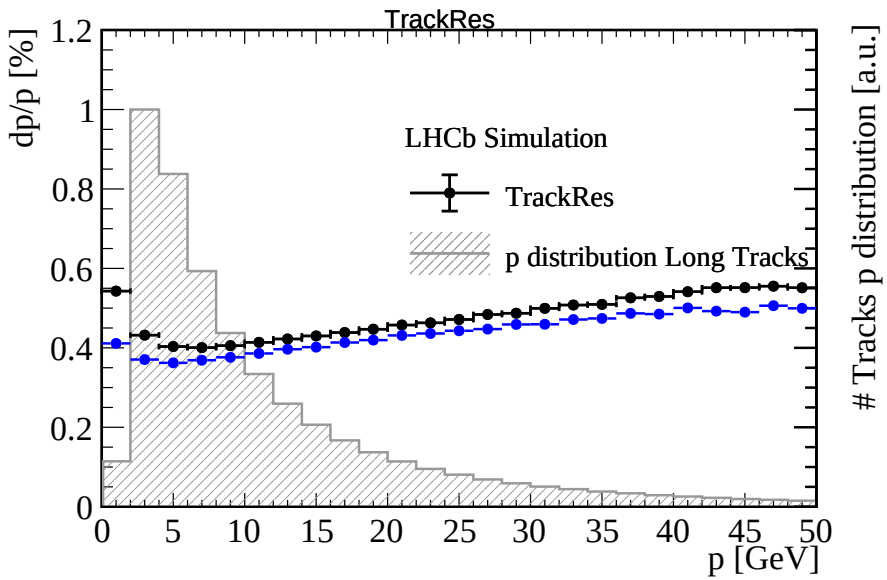


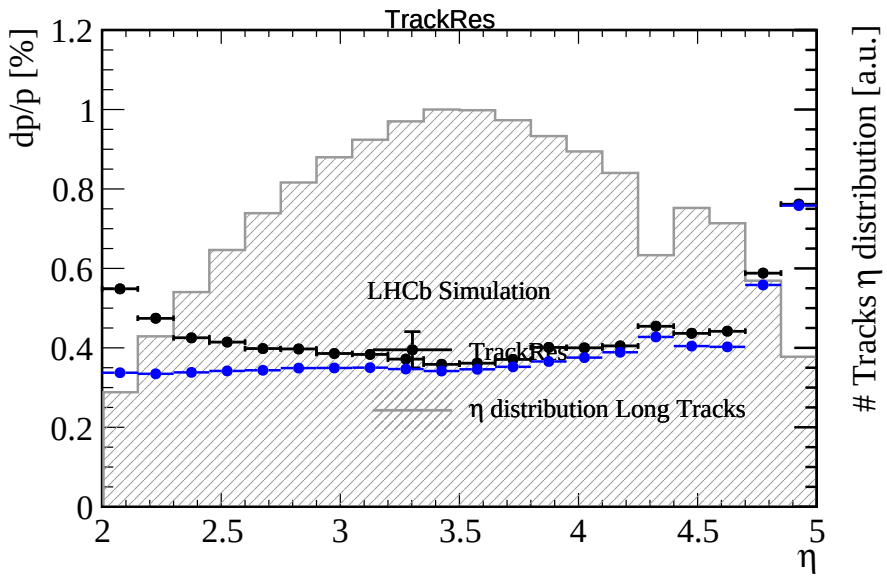


Black: Old parameterisation. Blue: Updated parameterisation with old z_{mag}.

Reminder: Momentum resolution

Despite difficulties with z_{mag}, it would be ideal to update parameterisations using the new field map



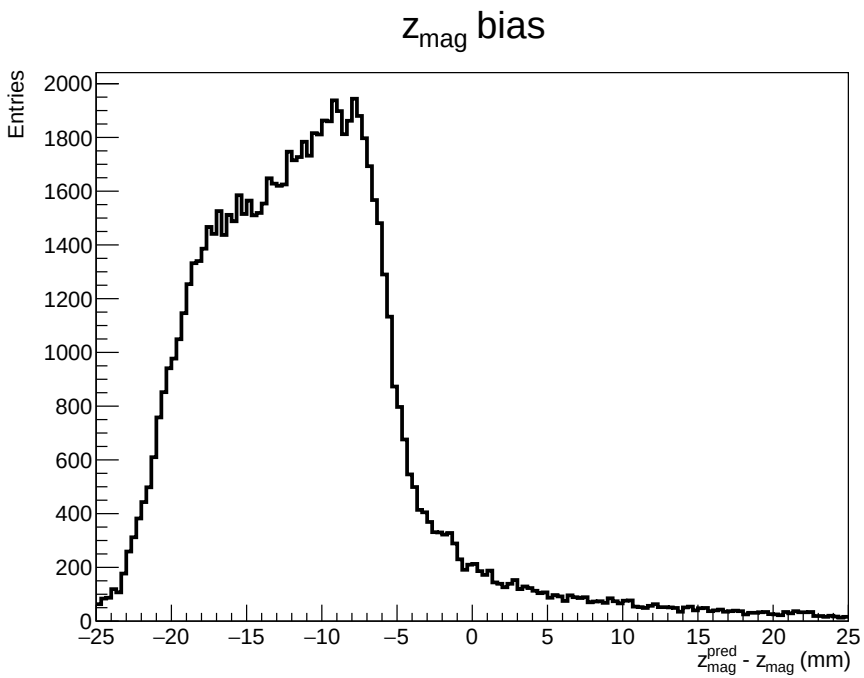


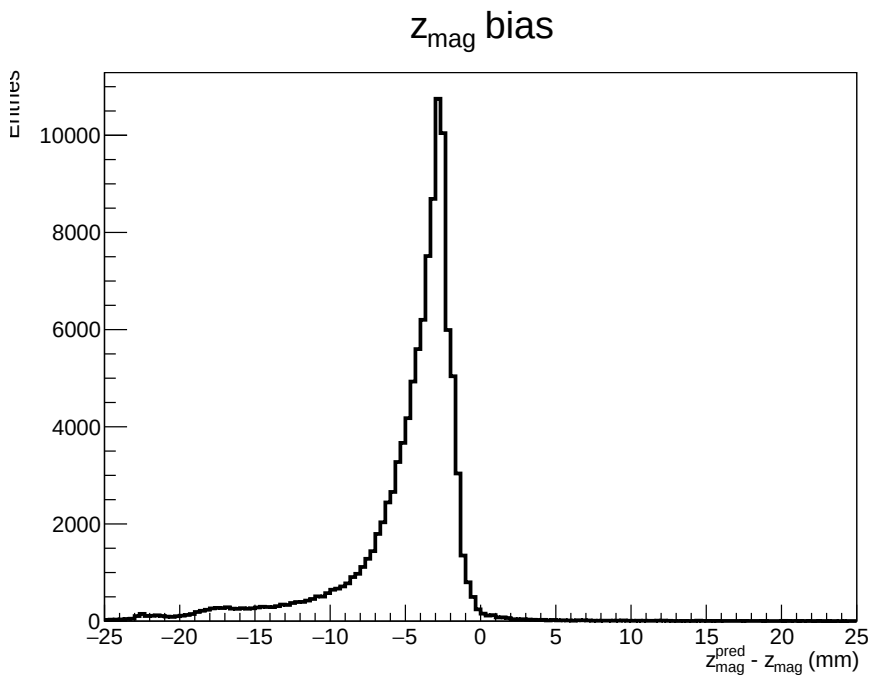
Black: Old parameterisation. Blue: Updated parameterisation with old z_{mag}.

Clear improvement in momentum resolution!

Study of z_{mag} bias

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



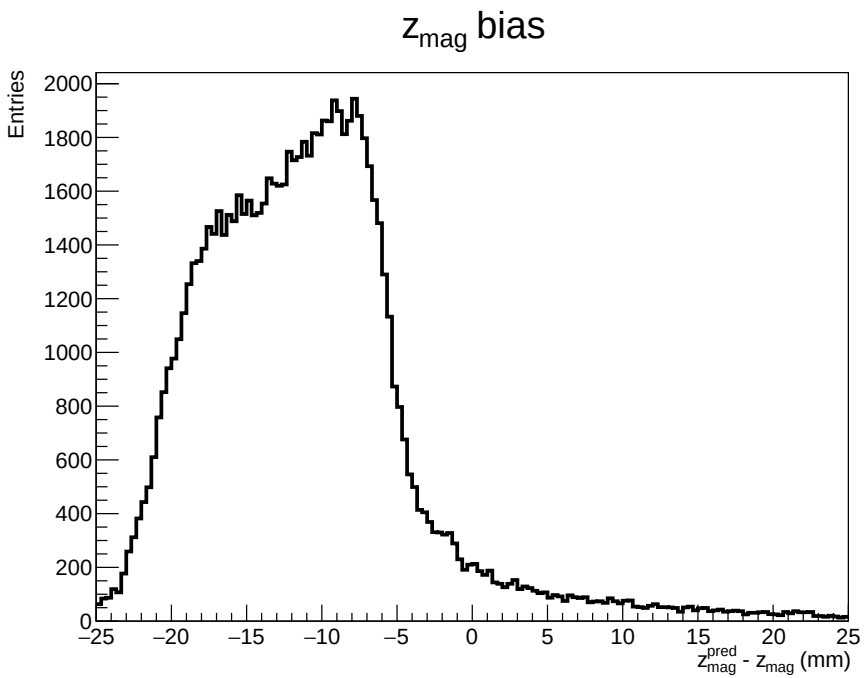


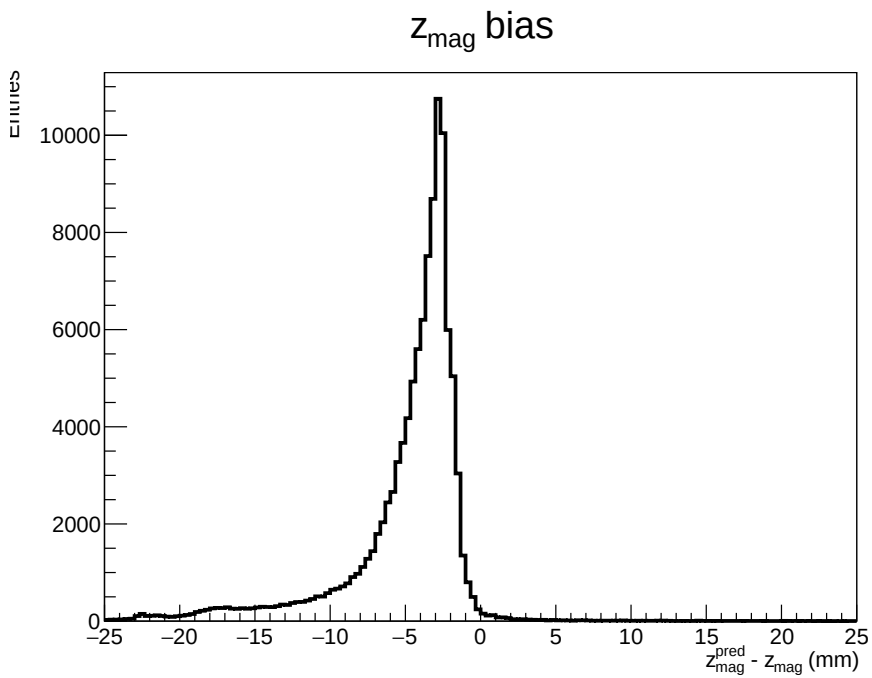
Left: $p < 7$ GeV. Right: $p > 7$ GeV.

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

Study of z_{mag} bias

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



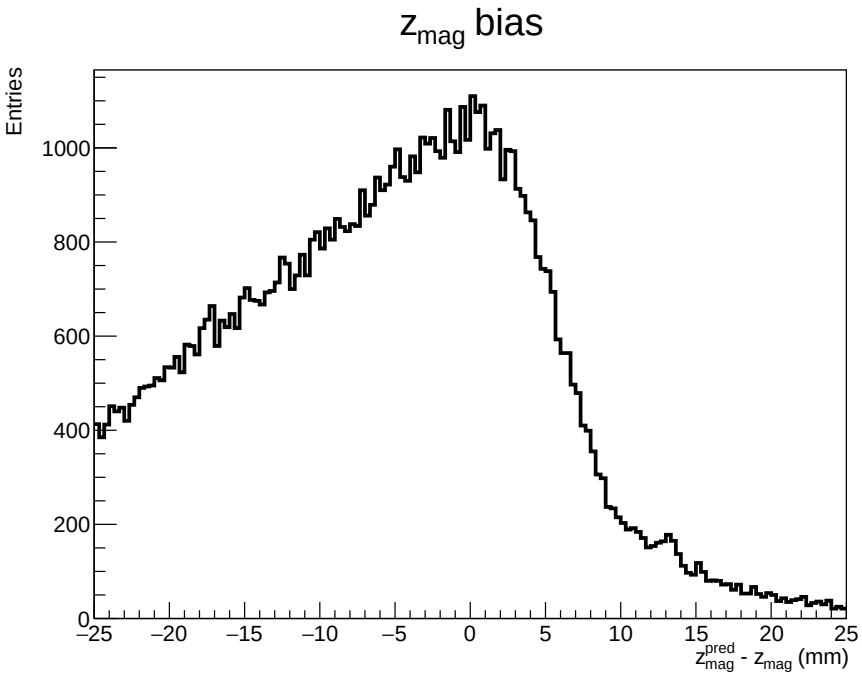


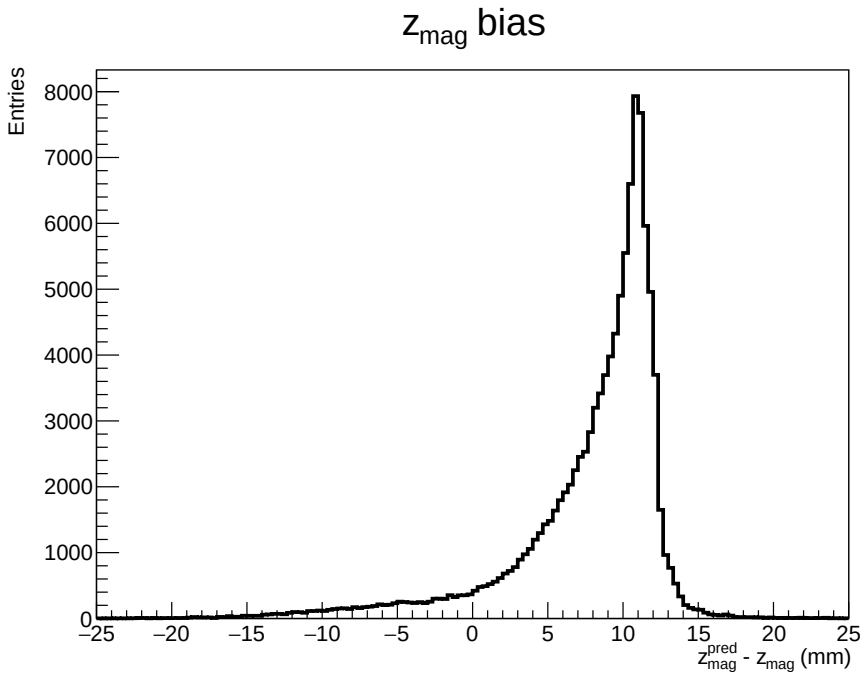
Left: $p < 7$ GeV. Right: $p > 7$ GeV.

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

Study of z_{mag} bias

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

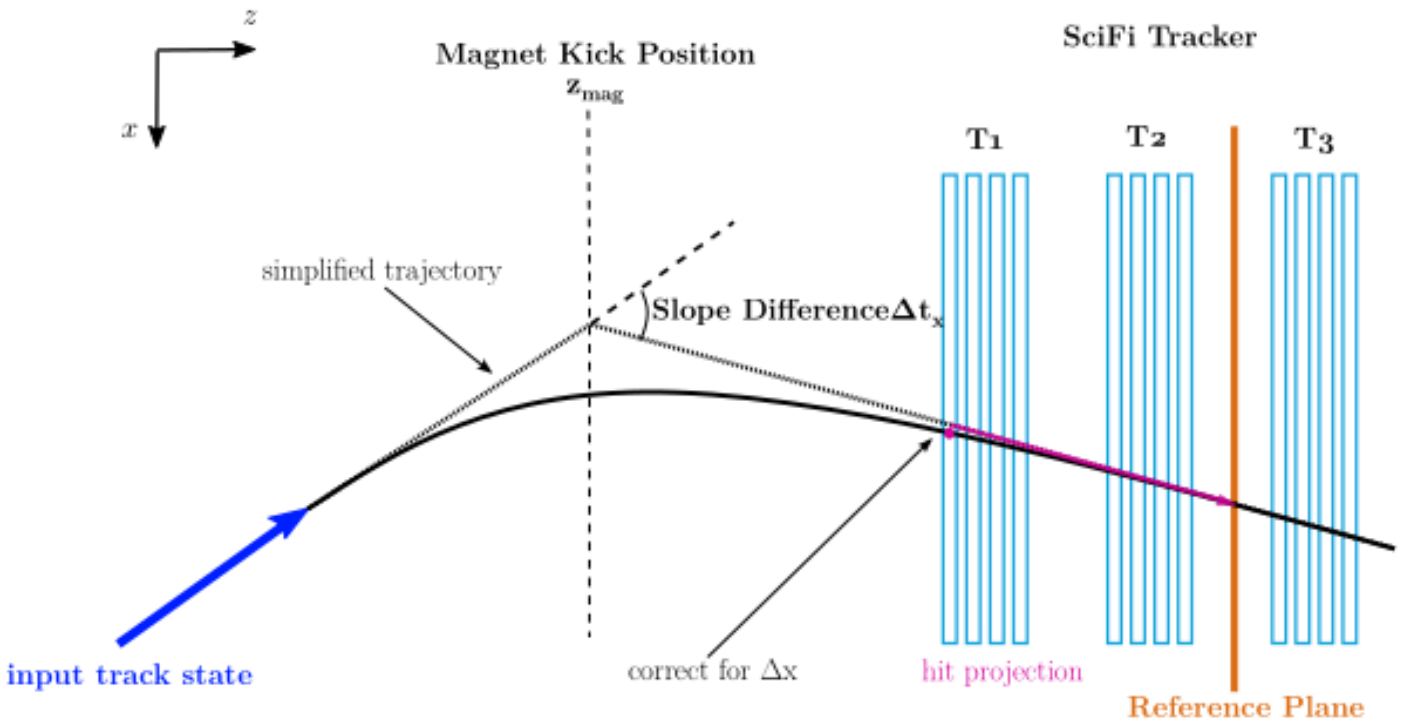




Left: $p < 7$ GeV. Right: $p > 7$ GeV.

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

Reminder: z_{mag} parameterisation

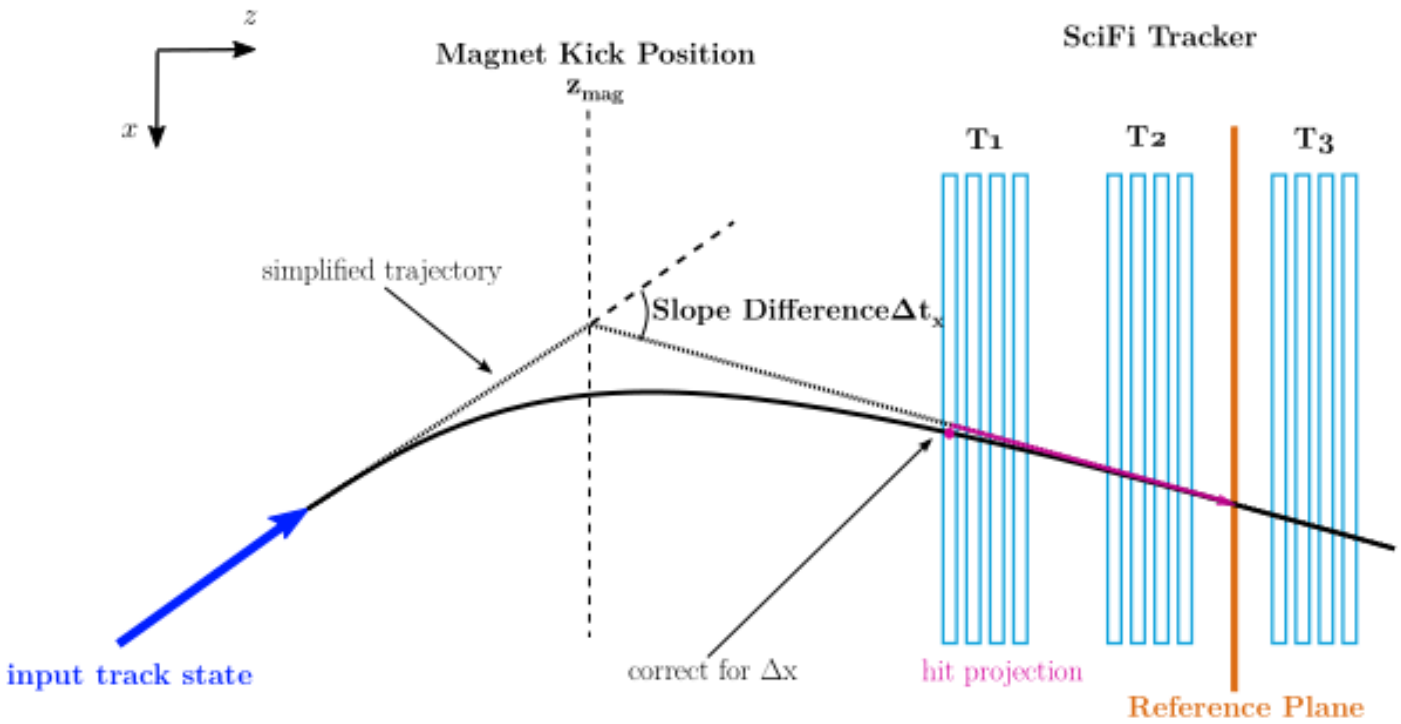


From CERN-THESIS-2023-097

- Original z_{mag} parameterisation:

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

Improved z_{mag} parameterisation



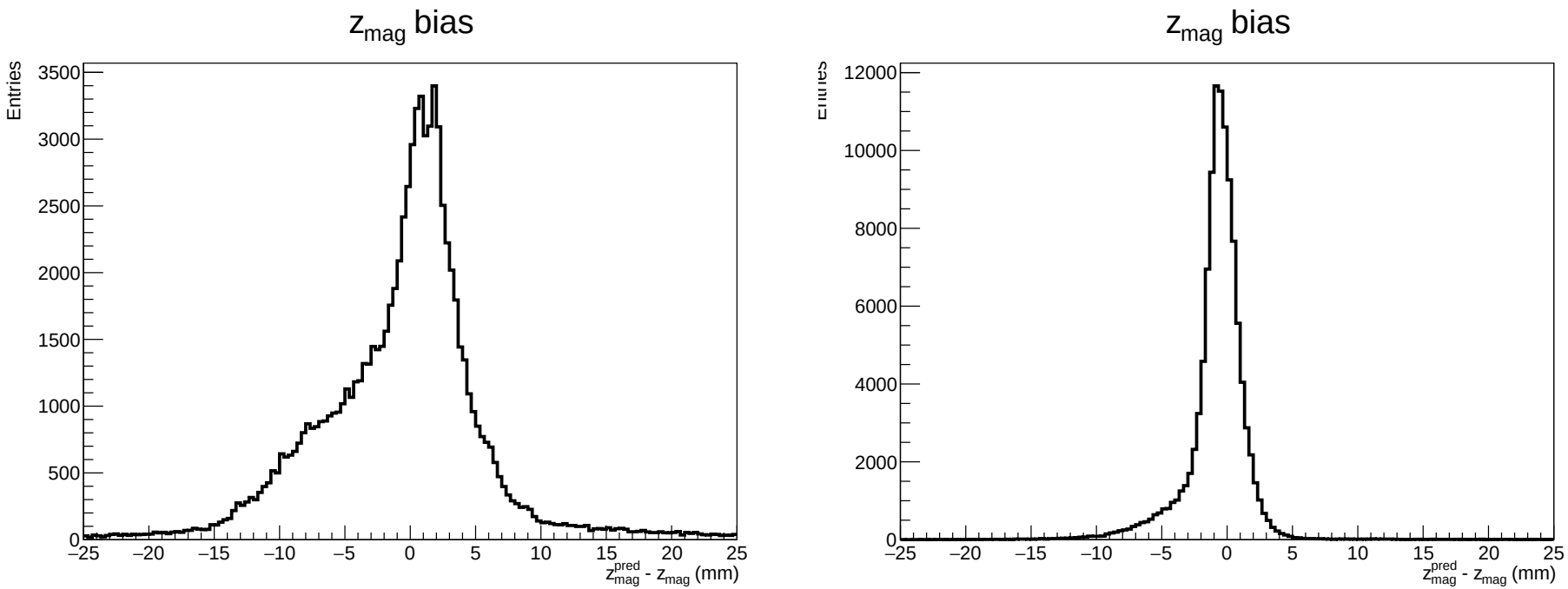
From CERN-THESIS-2023-097

- After trial and error, this parameterisation was obtained:

$$z_{\mathrm{mag}} = c_0 + c_1 t_x^2 + c_3 t_y^2 + \Delta t_x' (c_2 t_x + c_4 \Delta t_x') + (c_5 + tx^2 + ty^2 + |\Delta t_x'|^2)|\Delta t_x'|$$

Study of z_{mag} bias

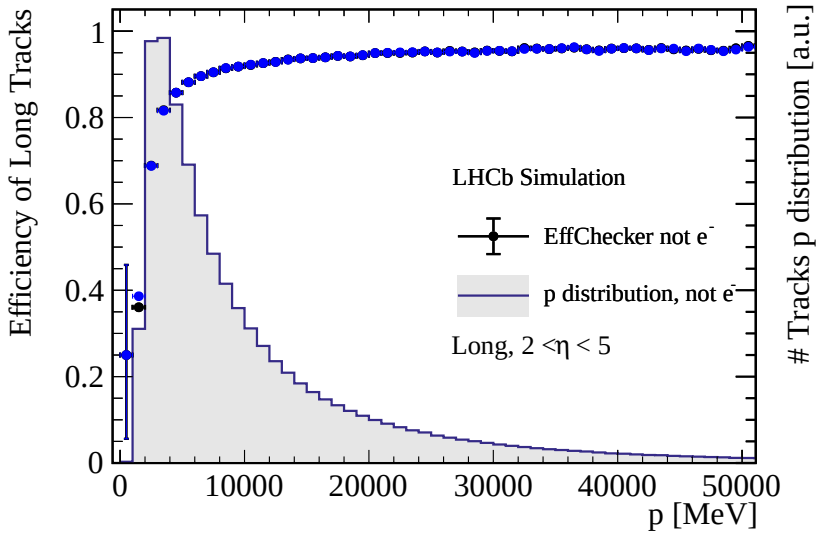
Check biases with new improved parameterisation:

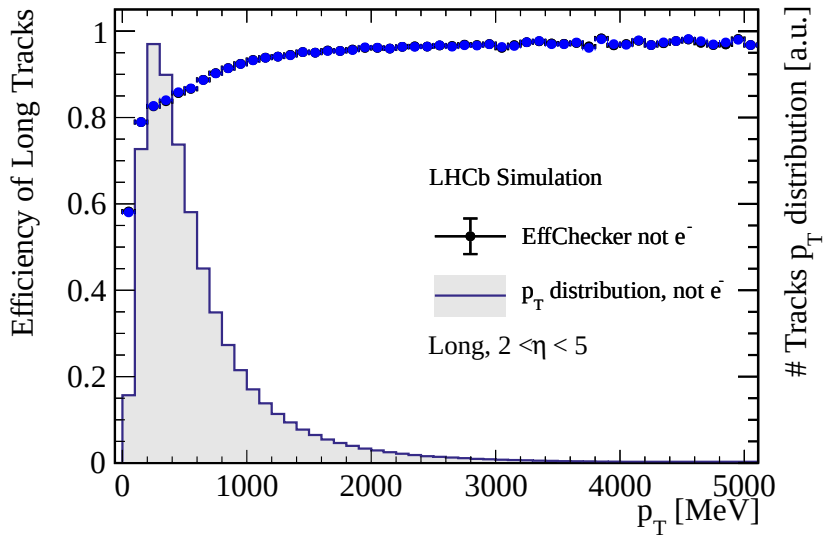


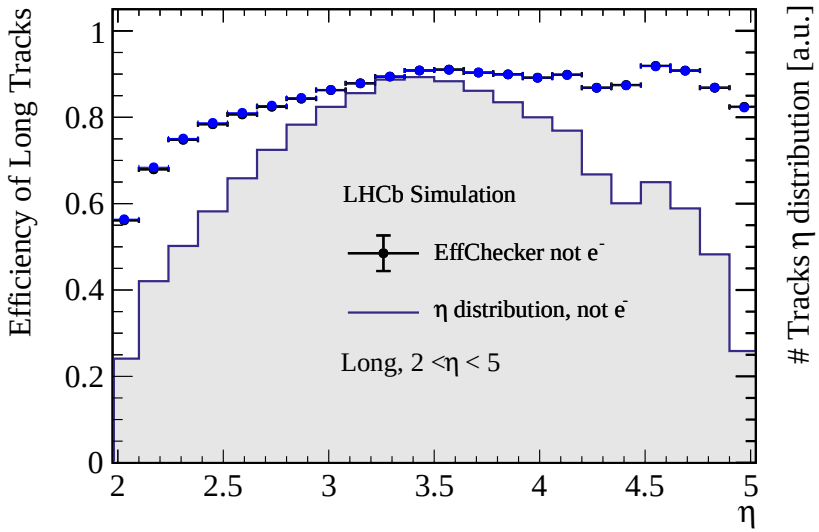
Left: $p < 7$ GeV. Right: $p > 7$ GeV.

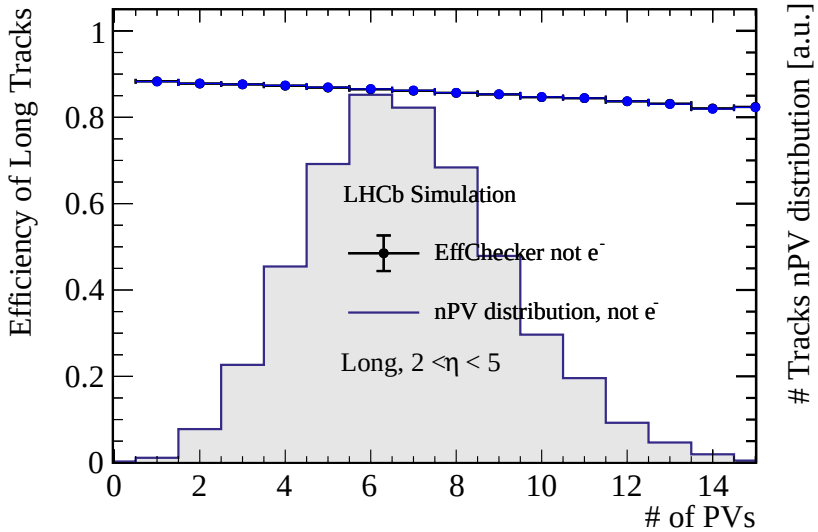
- Huge improvement in biases:
  - Almost symmetric and unbiased distribution at high momentum
  - Mostly unbiased at low momentum, with a left tail

Tracking efficiencies with new improved parameterisation







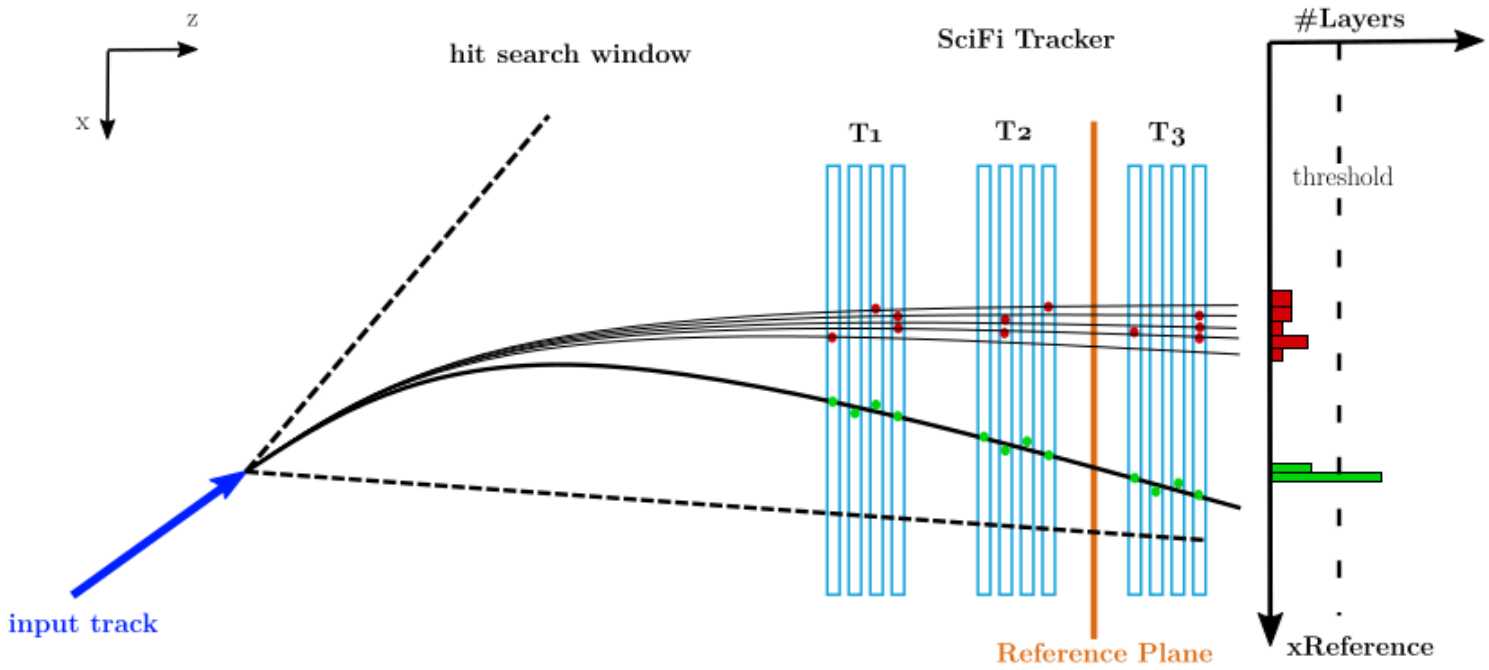


Black: Old parameterisation. Blue: Improved parameterisation of z_{mag} need to update these plots

Tracking efficiencies with new improved parameterisation

- I propose that we keep the original z_{mag} parameterisation
  - Determined by Andre Günther using DC19 MC
- Somehow, tracking efficiencies get worse when using a more accurate parameterisation...
- ...but perhaps in this case doing the wrong thing is better
- Is there a straightforward explanation for this...?

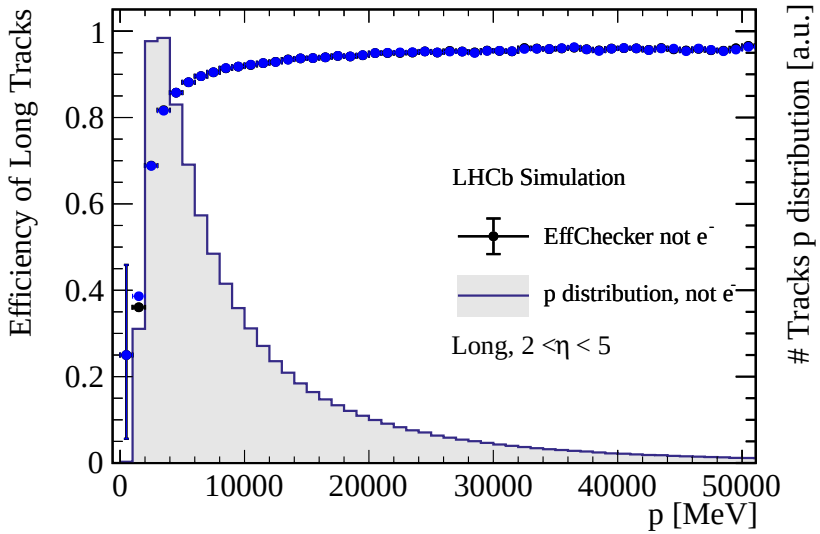
Reminder: Hit mapping to reference plane

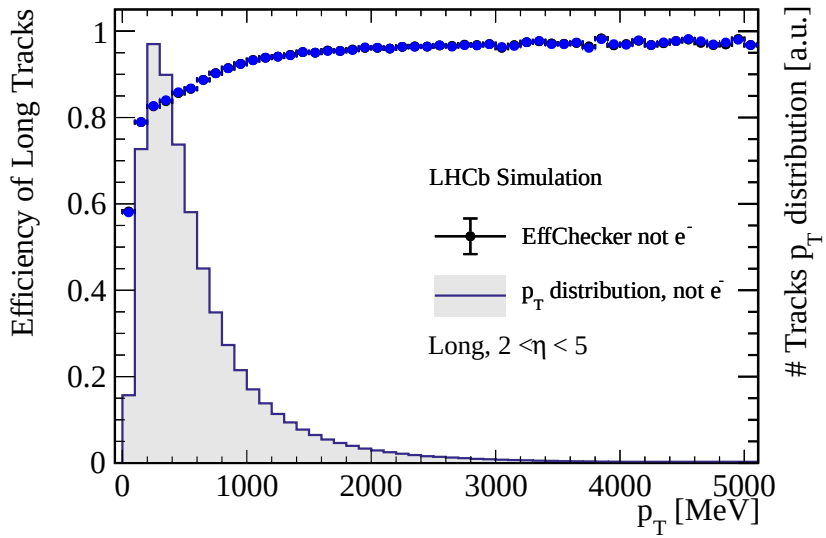


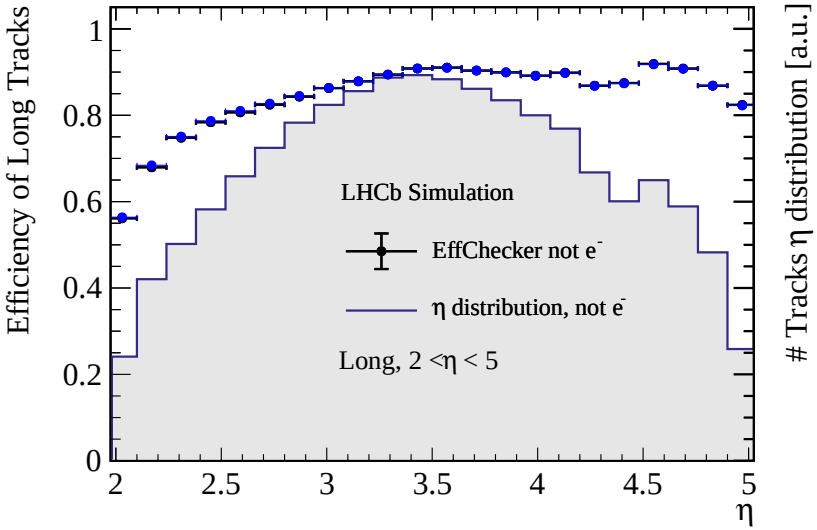
From CERN-THESIS-2023-097

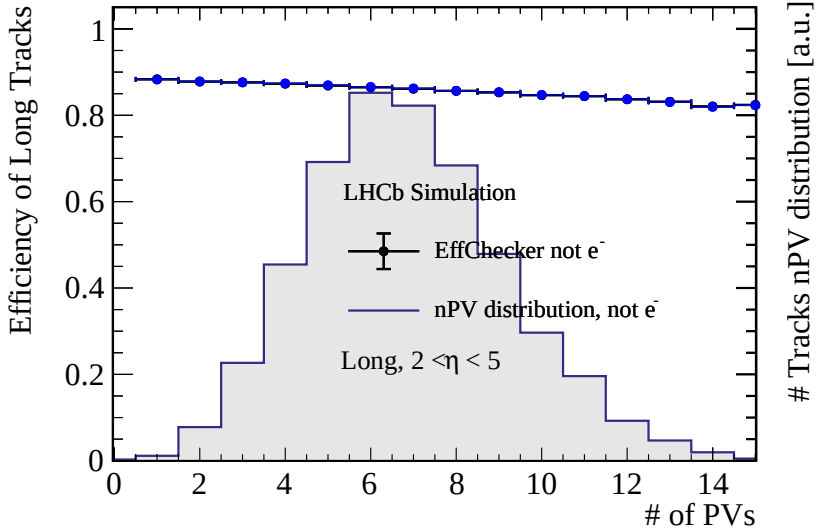
- Define a search window by assuming $p = p_{\text{min}} = 1500$ MeV/c
- My understanding is:
  - z_{mag} is underestimated $\rightarrow$ Search window becomes larger!
  - $\rightarrow$ Add negative bias at low momentum to improve performance

Tracking efficiencies with biased z_{mag} parameterisation







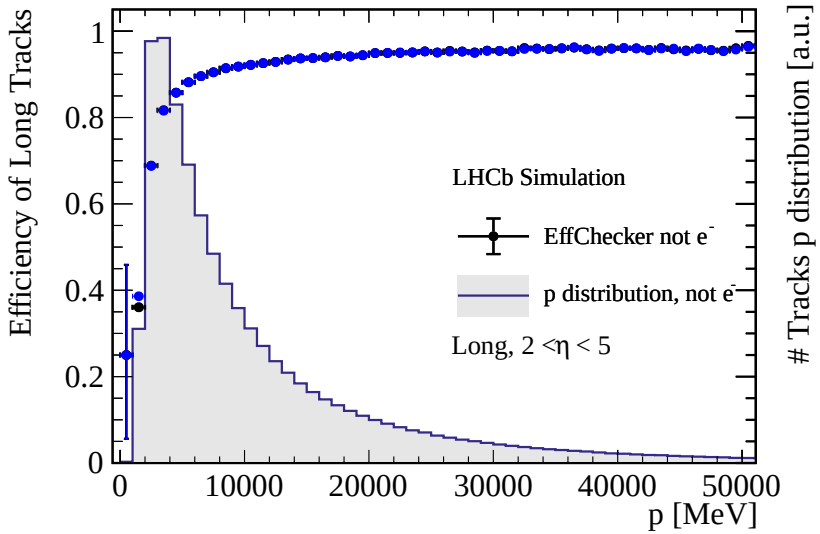


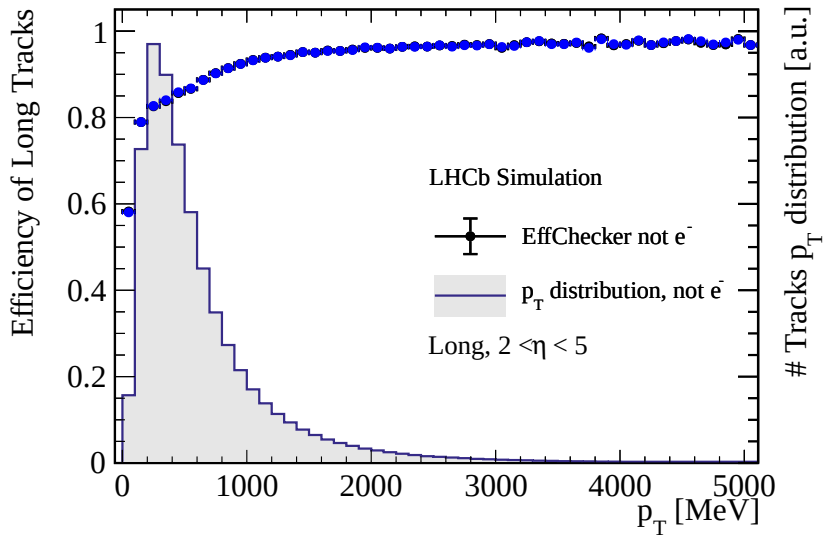
Black: Old parameterisation. Blue: Biased parameterisation of z_{mag} need to update these plots

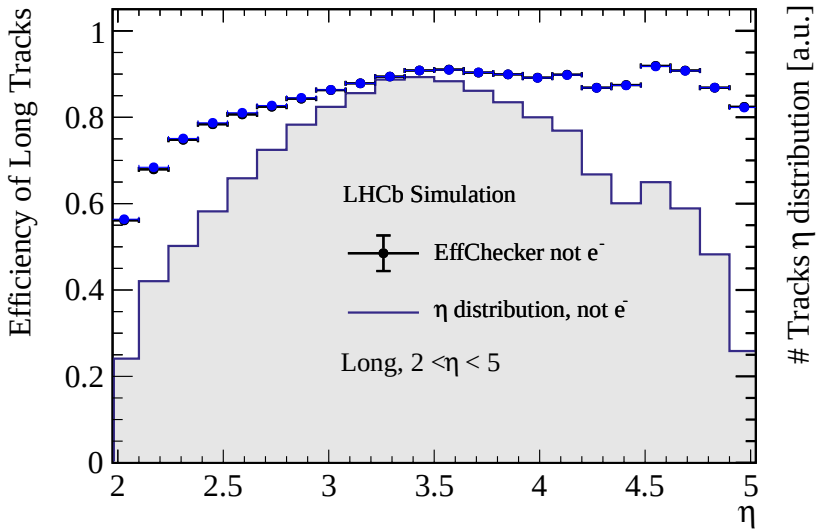
Conclusion of z_{mag} studies

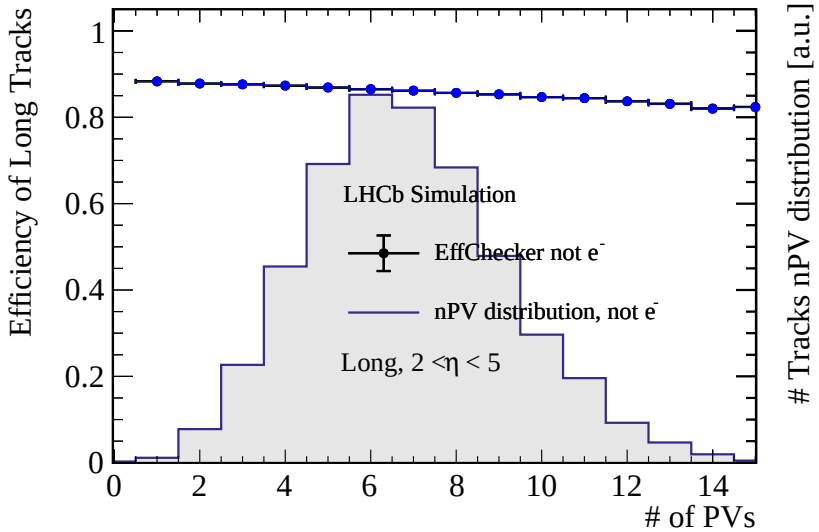
- Indeed, the improvement in performance when introducing a bias confirms that it is the search window size that drive the tracking efficiencies at low momentum
- Motivates us to keep the original z_{mag} parameterisation
- All other parameterisations will be updated using new MC samples
- I have already added these samples to TestDB in this MR
- I will also add documentation to the ParamScriptor repository

Tracking efficiencies with final parameterisation



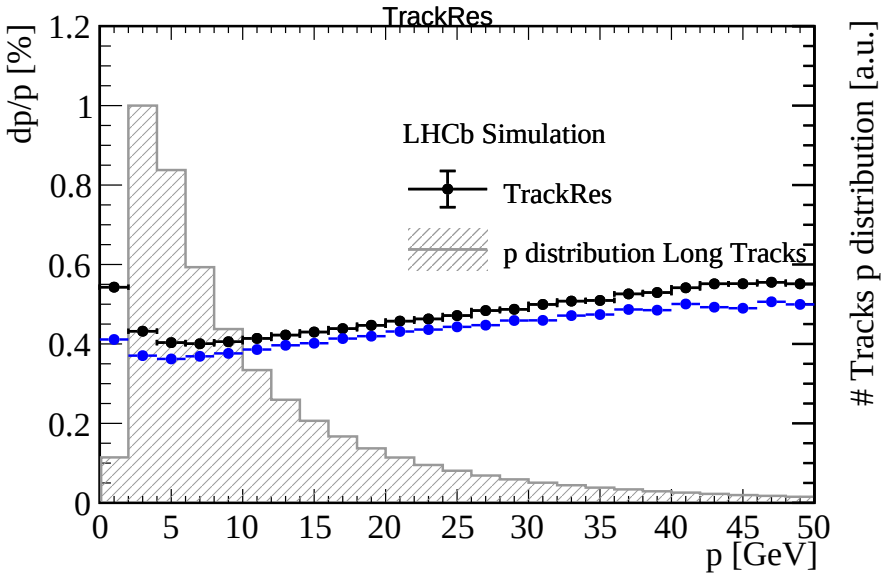


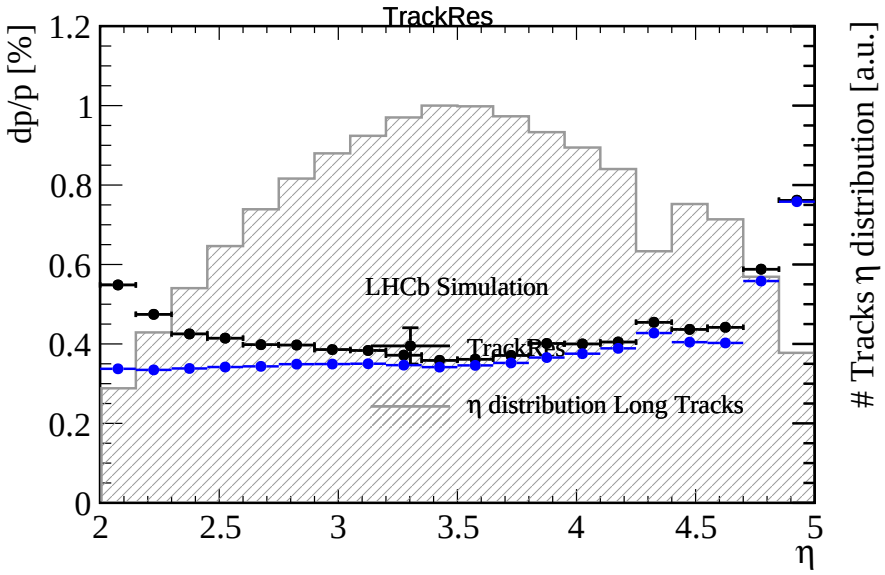




Black: Old parameterisation. Blue: Proposed parameterisation need to update these plots

Momentum resolution with final parameterisation





Black: Old parameterisation. Blue: Proposed parameterisation. need to update these plots

Summary

- All parameterisations have been updated using centrally produced MC
  1. Larger MC samples
  2. Both magnet polarities
  3. Larger selection of decay modes
- Possible improvements to z_{mag} parameterisation have been explored
  - Biases are reduced, but performance gets worse
  - Reason for this unexpected behaviour:
    - Original parameterisation mostly underestimated z_{mag}

    $\rightarrow$ Overestimated search windows in the x-plane

    $\rightarrow$ More hits included in reconstruction

    $\rightarrow$ Higher tracking reconstruction
- I propose: Update all parameterisations except for that of z_{mag}
  - Negligible change in tracking efficiencies
  - Small improvement in momentum resolution

Next steps

1. Get !4362 and !567 merged
2. Document work in ParamScriptor
3. Final step: Improve throughput
   - Code was already heavily optimised by Andre Günther...
   - ...but I'll do some quick checks for obvious bottleknecks

Thanks for listening!