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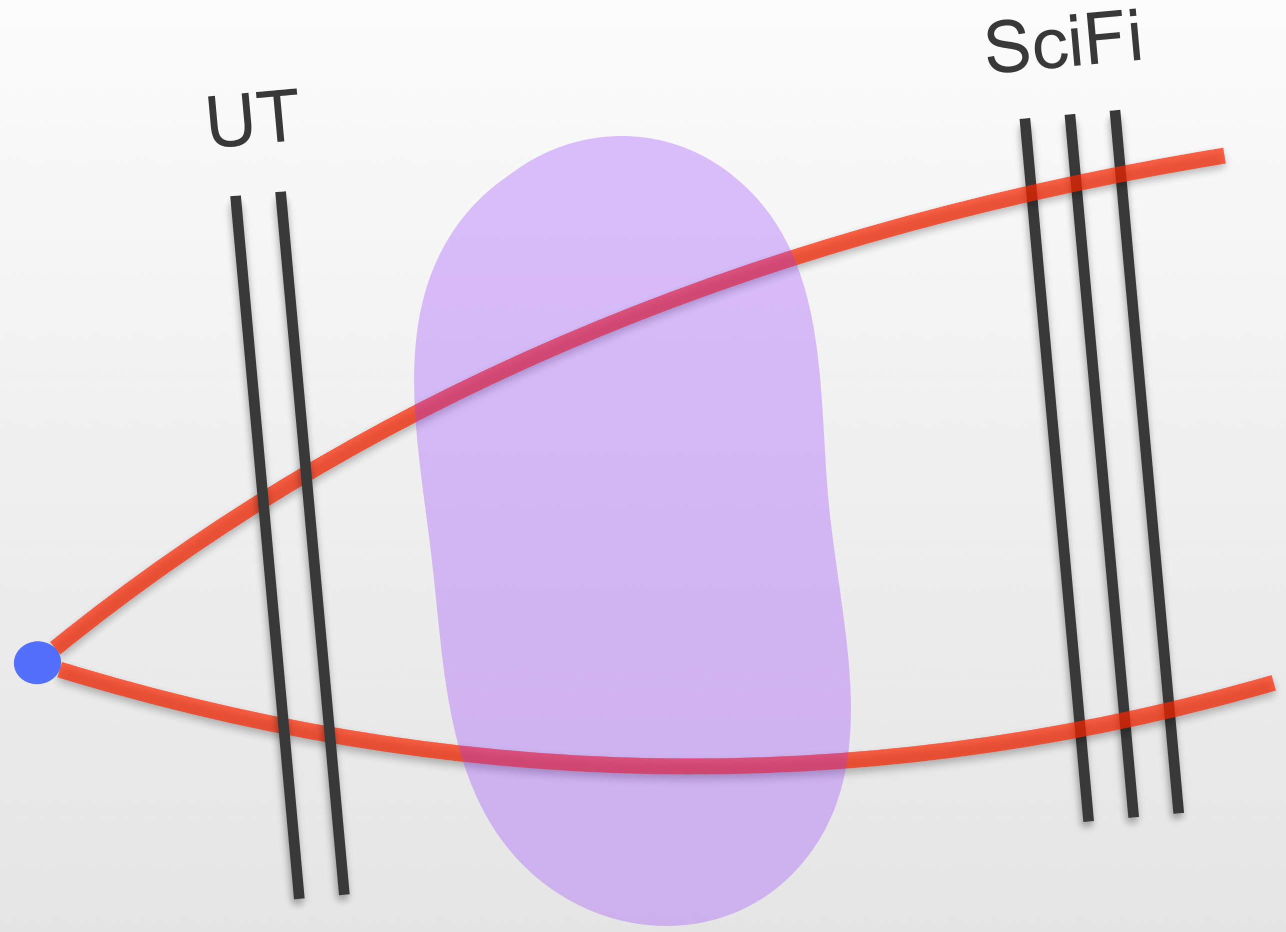

TRACKING AND VERTEXING DOWNSTREAM THE LHCB MAGNET AT THE FIRST STAGE OF THE TRIGGER

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Overview

LHCB OVERVIEW

Dataflow, trigger and tracking systems

WHY DO WE NEED DOWNSTREAM?

Physics motivation from both SM and BSM

DOWNSTREAM TRACKING

Essential steps in track reconstruction and ghost rejection

TRACKING PERFORMANCE

Efficiency, momentum resolution and effect on HLT1

DOWNSTREAM VERTEXING

Vertex reconstruction algorithm and its performance

LHCb overview

01

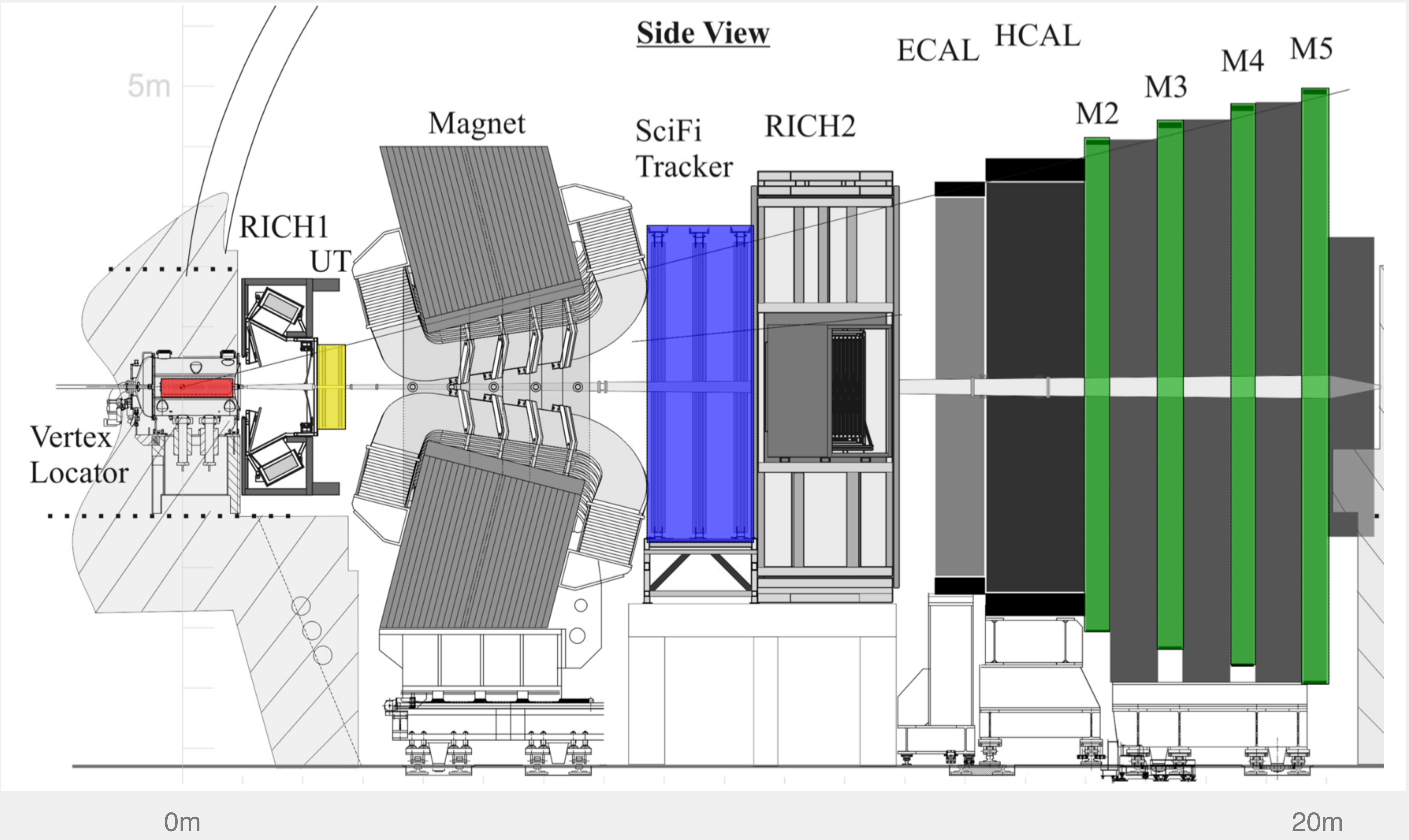
LHCb

LHCb is a specialized b-physics experiment located on LHC (13 TeV, pp collisions)

Forward, single-arm geometry

Strong dipole magnet (4 T)

Just because this is the first talk about LHCb :)



LHCb Tracking

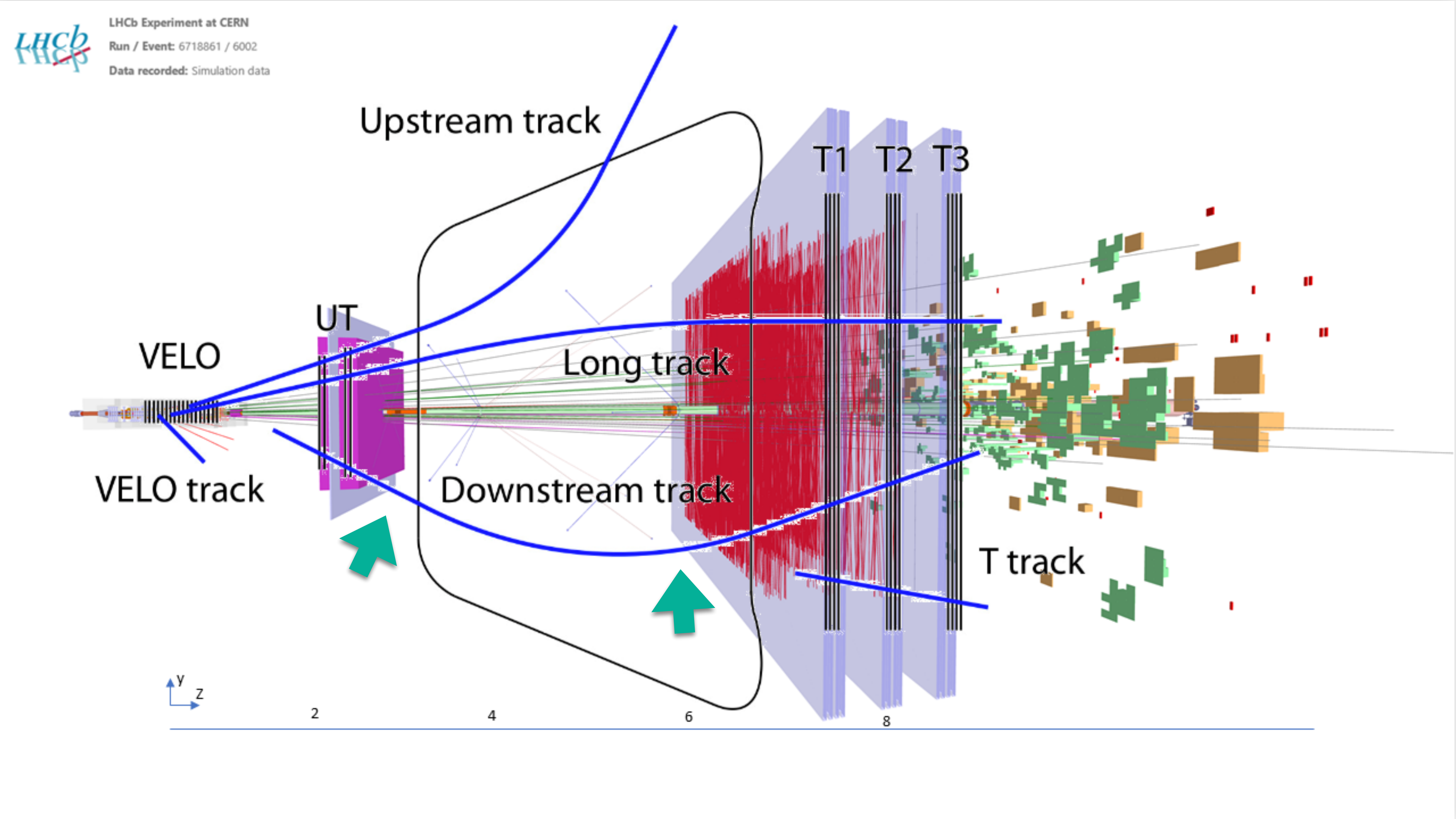
Three tracking detectors:

- VELO *(pixel)*
- UT *(strips)*
- SciFi *(fibers; the only tracker after magnet)*

Two track types are currently used at HLT1:

✓ Long (VELO - SciFi)

✓ Downstream (UT-SciFi; today's topic)



LHCb Dataflow

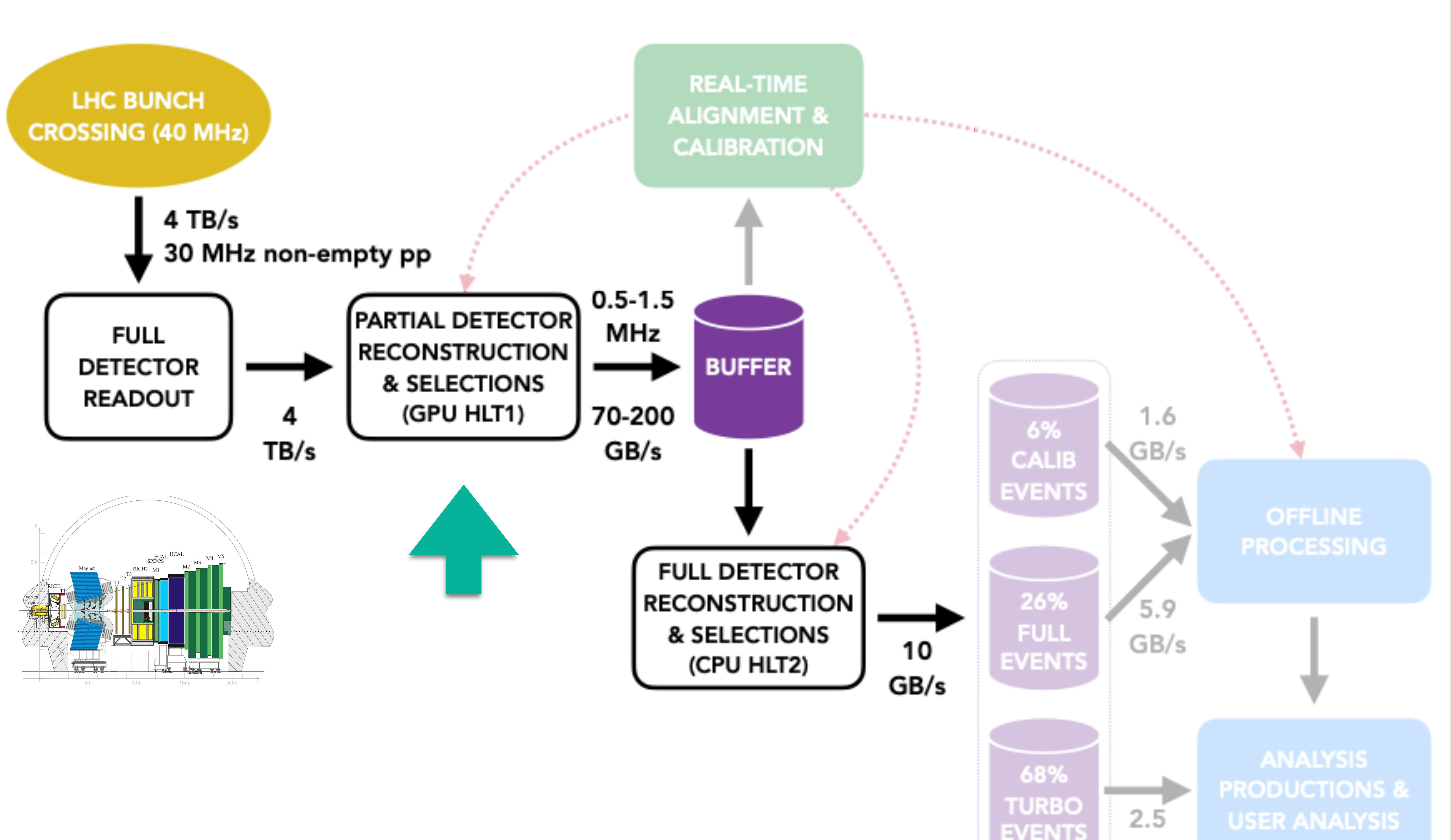
LHCb detector generates 4TB/s of raw data

Effective filtering is crucial, and implemented in:

- High-Level Trigger 1 (HLT1) - GPU-based software trigger (today's topic)
- HLT2 - CPU-based software trigger

No hardware trigger anymore

Together, triggers reduce data flow to 10 GB/s



LHCB-FIGURE-2020-016

Why do we need downstream?

02

Brij Kishor Jashal (2023). Connecting The Dots 2023. Downstream: a new algorithm at LHCb…

Calefice L. et all. Effect of the high-level trigger for detecting long-lived particles at LHCb

Why downstream?

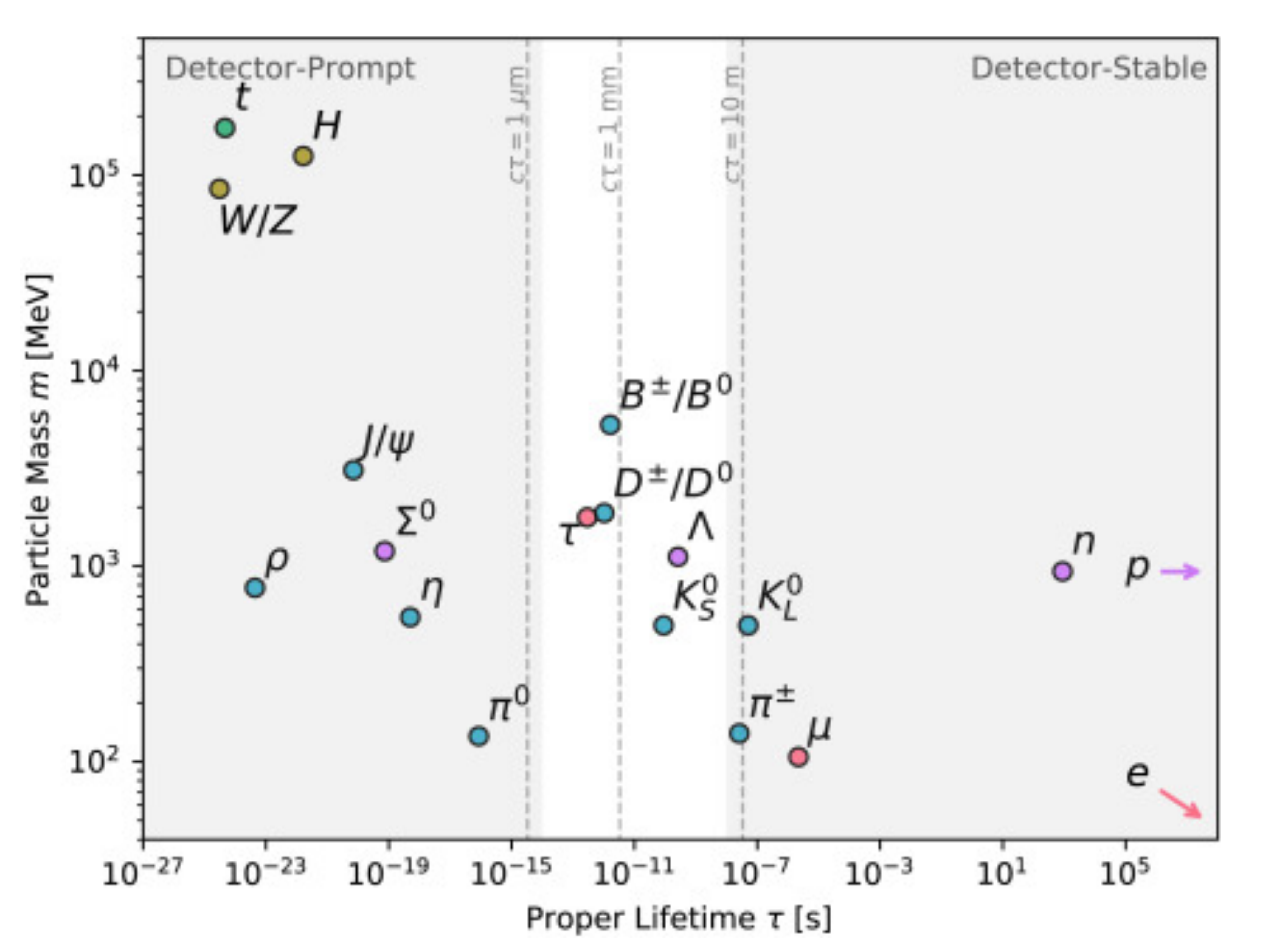
b- and c-meson decays can be reconstructed into long tracks with high efficiency

But for particles with $\tau > 100ps$ many decays happening out of the VELO detector

- reconstruction with long tracks at HLT1 is impossible

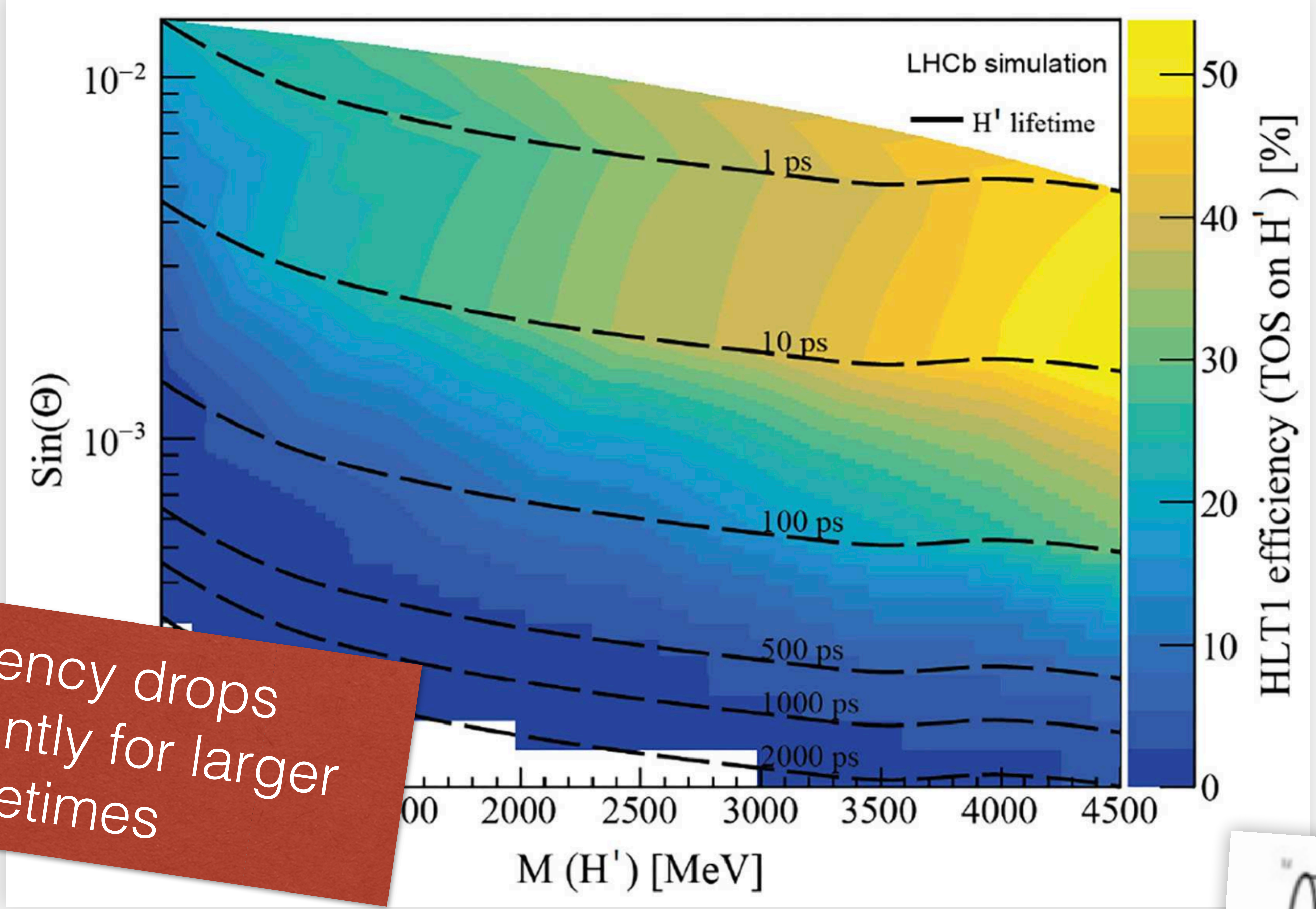
Run 2	LL	DD	TT	HLT1 (eff) TOS
Λ^0	*12%*	*51%*	*37%*	< 10 %
K_s^0	*46%*	*38%*	*16%*	< 25 %

Lawrence Lee et all. Collider searches for long-lived particles beyond the Standard Model



Why downstream? (BSM)

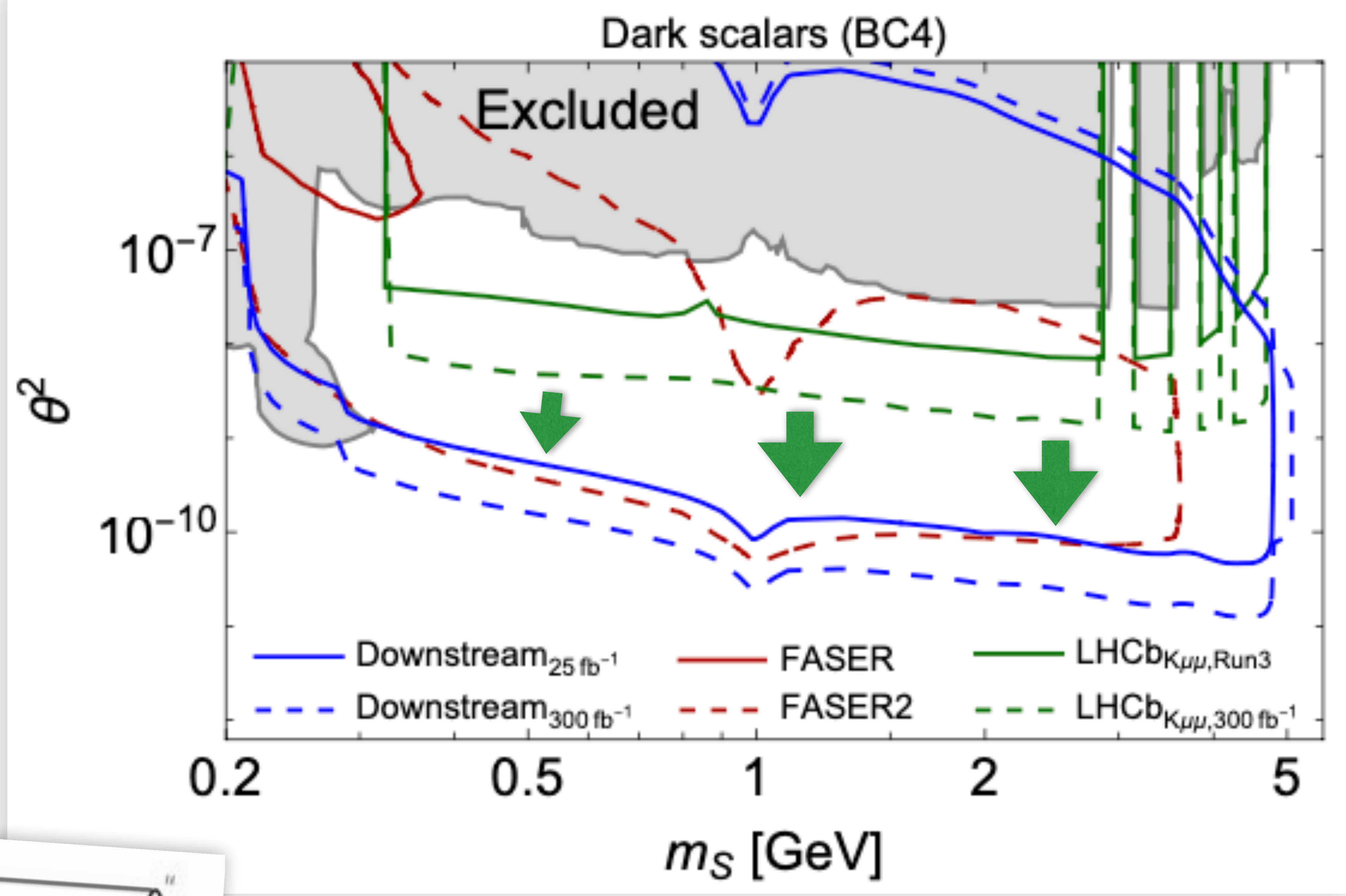
HLT1 TOS efficiency for Run 2 (longs only)



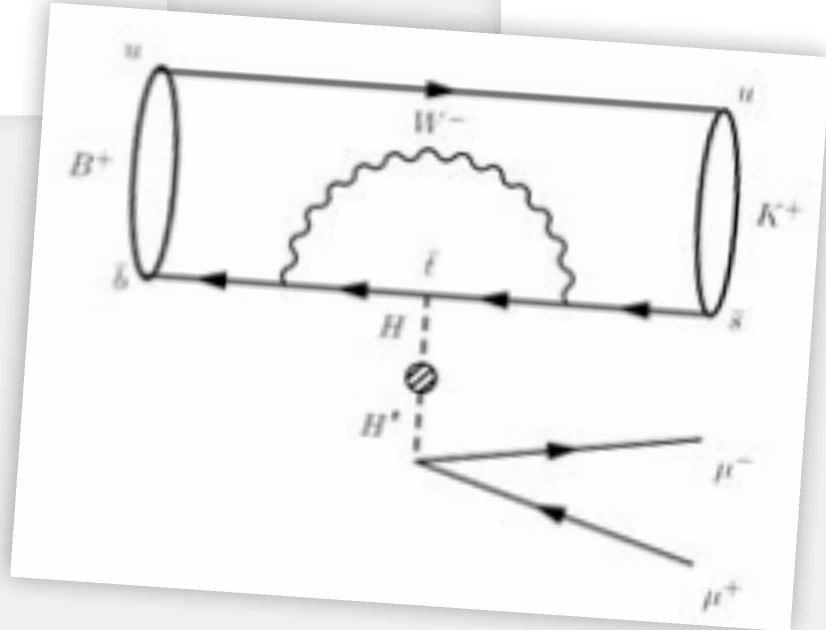
Efficiency drops significantly for larger lifetimes

Calefice L. et all. Effect of the high-level trigger for detecting long-lived particles at LHCb

LHCb sensitivity for Run 3



arXiv:2312.14016



Downstream tracking is very important for BSM searches

Downstream tracking

03

Downstream extrapolation

Downstream tracks are reconstructed with following steps:

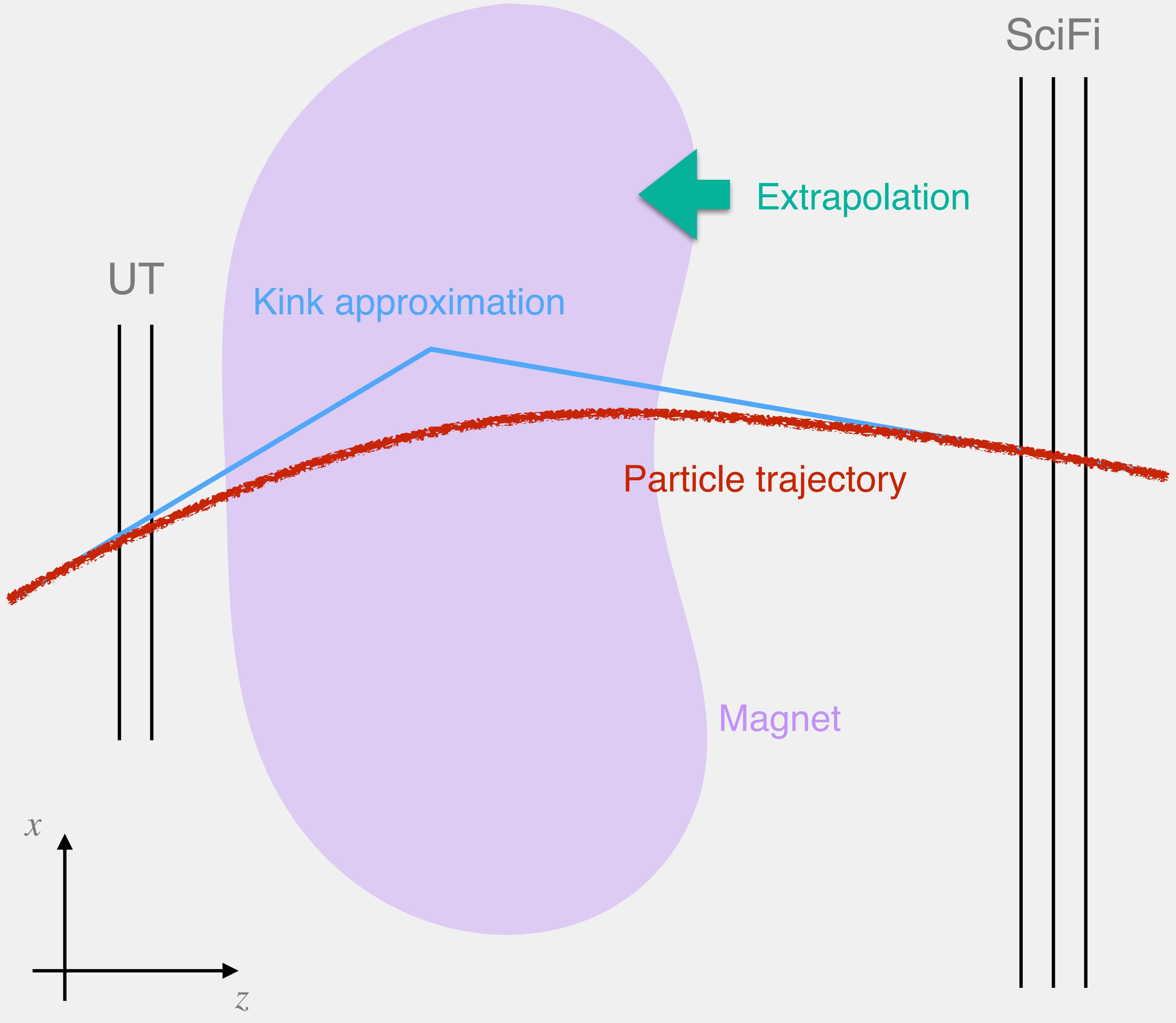
- Reconstruction of SciFi seeds with HybridSeeding
  [Brij Kishor Jashal, Standalone track reconstruction and matching algorithms]
- Extrapolation of SciFi seeds towards UT plane
- Assigning closest UT hits to the extrapolation
- Final track fitting

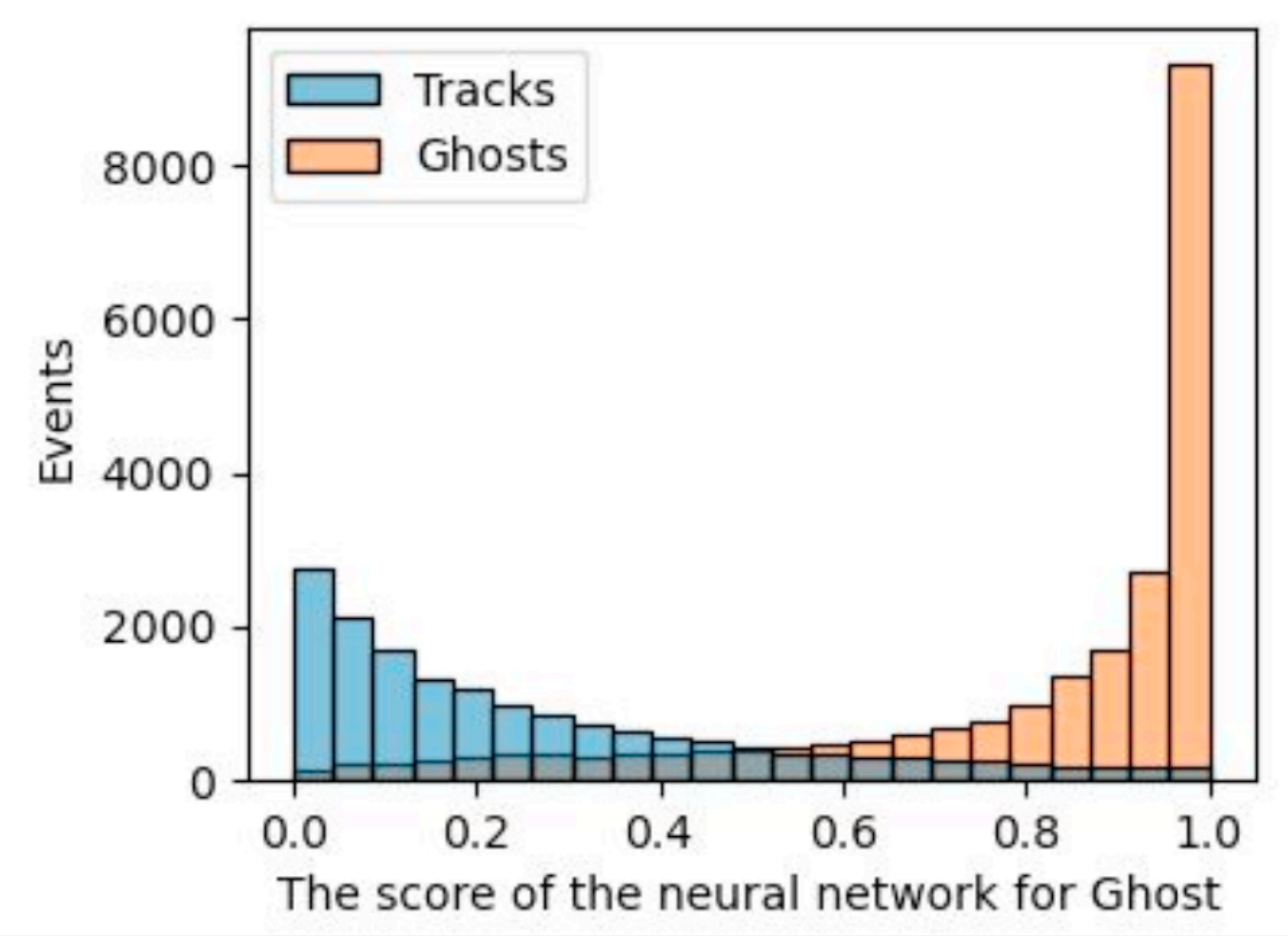
The extrapolation is done using kink approximation (kink position is parametrized):

$$z_{kink} = \alpha_0 + \alpha_1 t_y^2 + \alpha_2 t_x^2 + \alpha_3 \frac{q}{p} + \alpha_4 |x_{SciFi}| + \alpha_5 |y_{SciFi}| + \alpha_6 |t_y| + \alpha_7 |t_x|$$

$$x_{kink} = x_{SciFi} + t_x (z_{kink} - z_{SciFi})$$

$$y_{kink} = (y_{SciFi} + dy) + t_{y_{mag}} (z_{kink} - z_{SciFi})$$



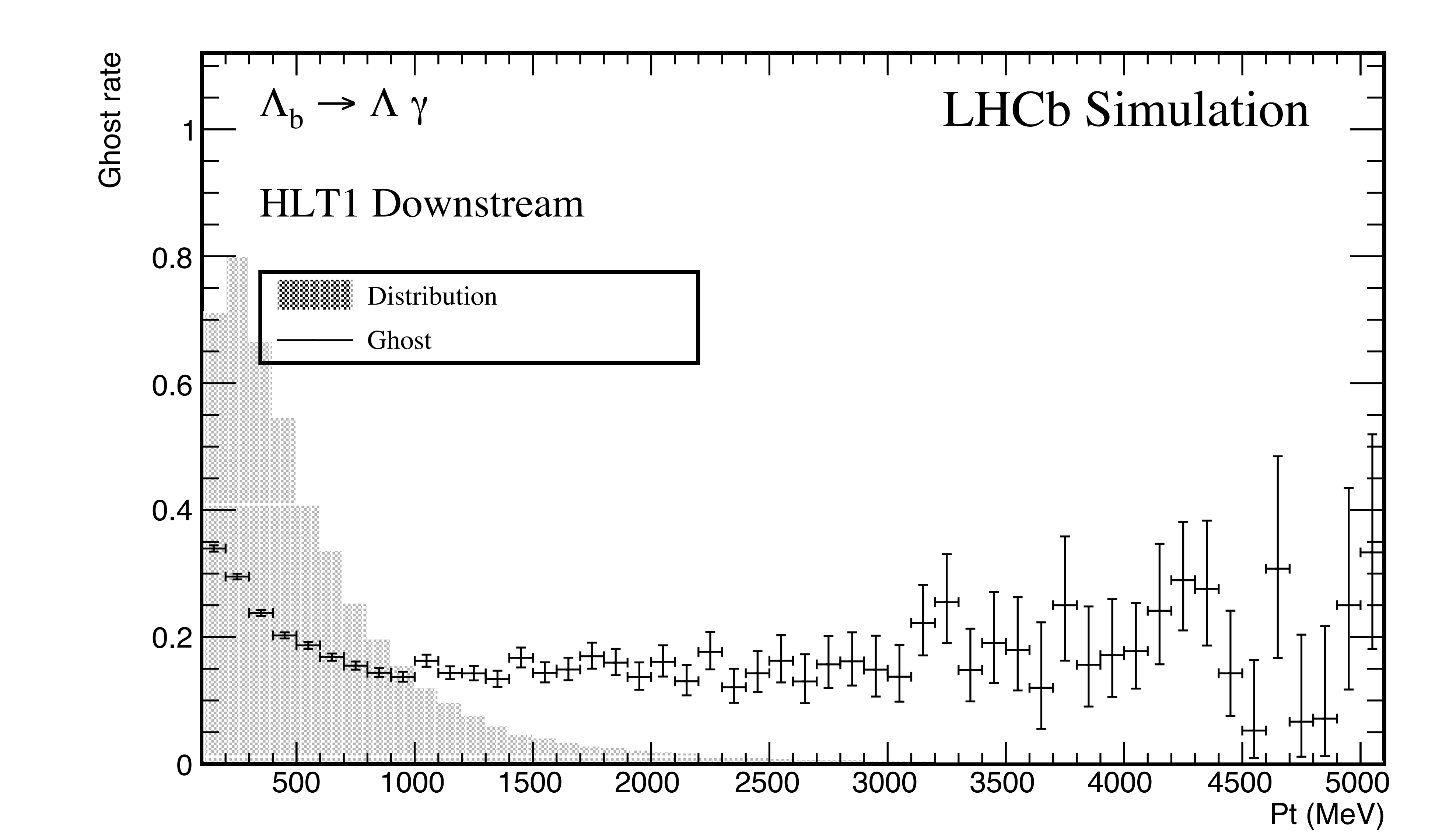


Downstream fake track killer

Fake tracks (≡ ghosts) are filtered out with a single hidden layer fully connected neural network (14 nodes):

- Use reconstructed track states and quality parameters as inputs
- Ghost killer manages to significantly suppress the output ghost rate
- Independent of physics channel

Meets HLT1 throughput requirements



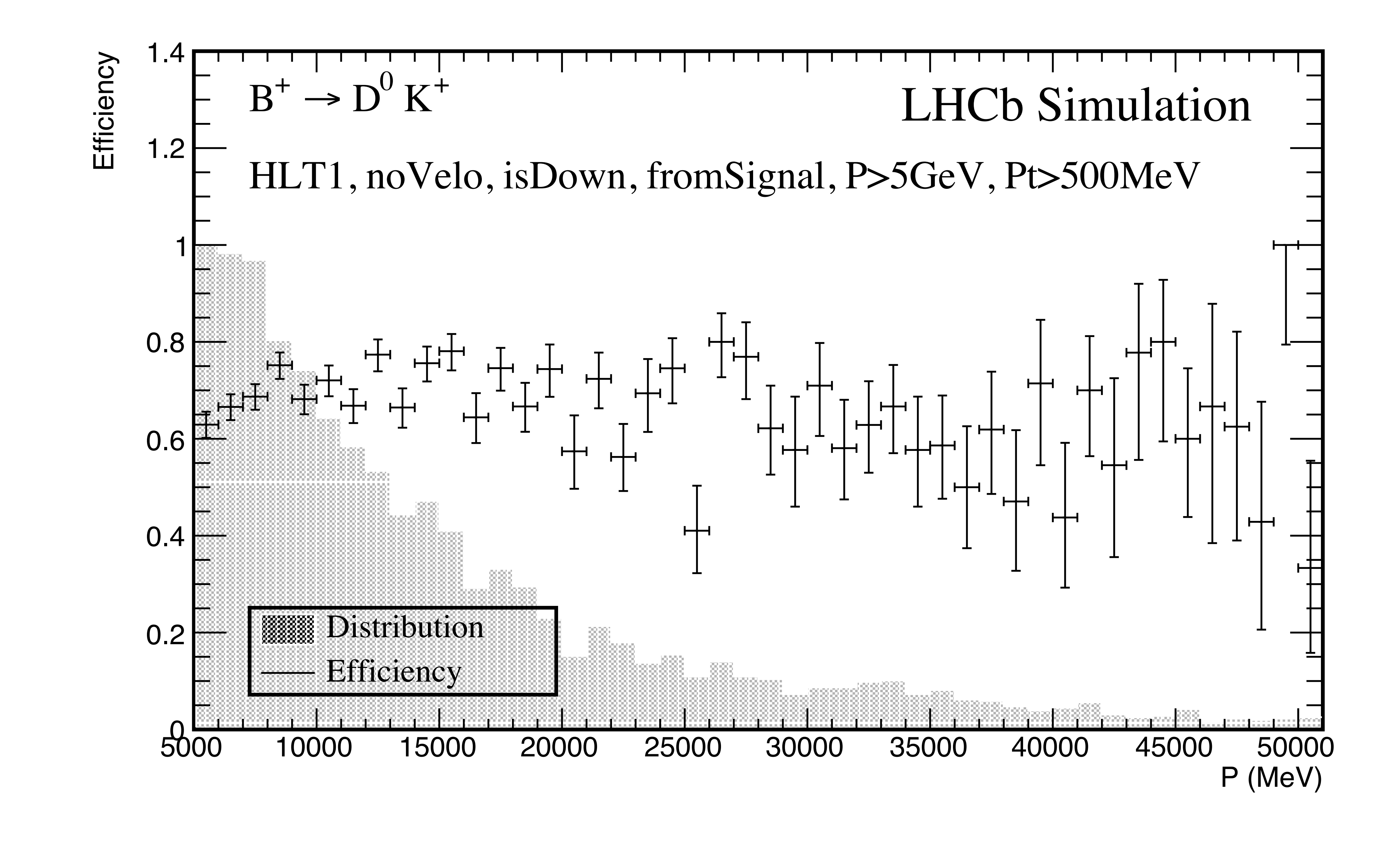
LHCB-FIGURE-2023-028

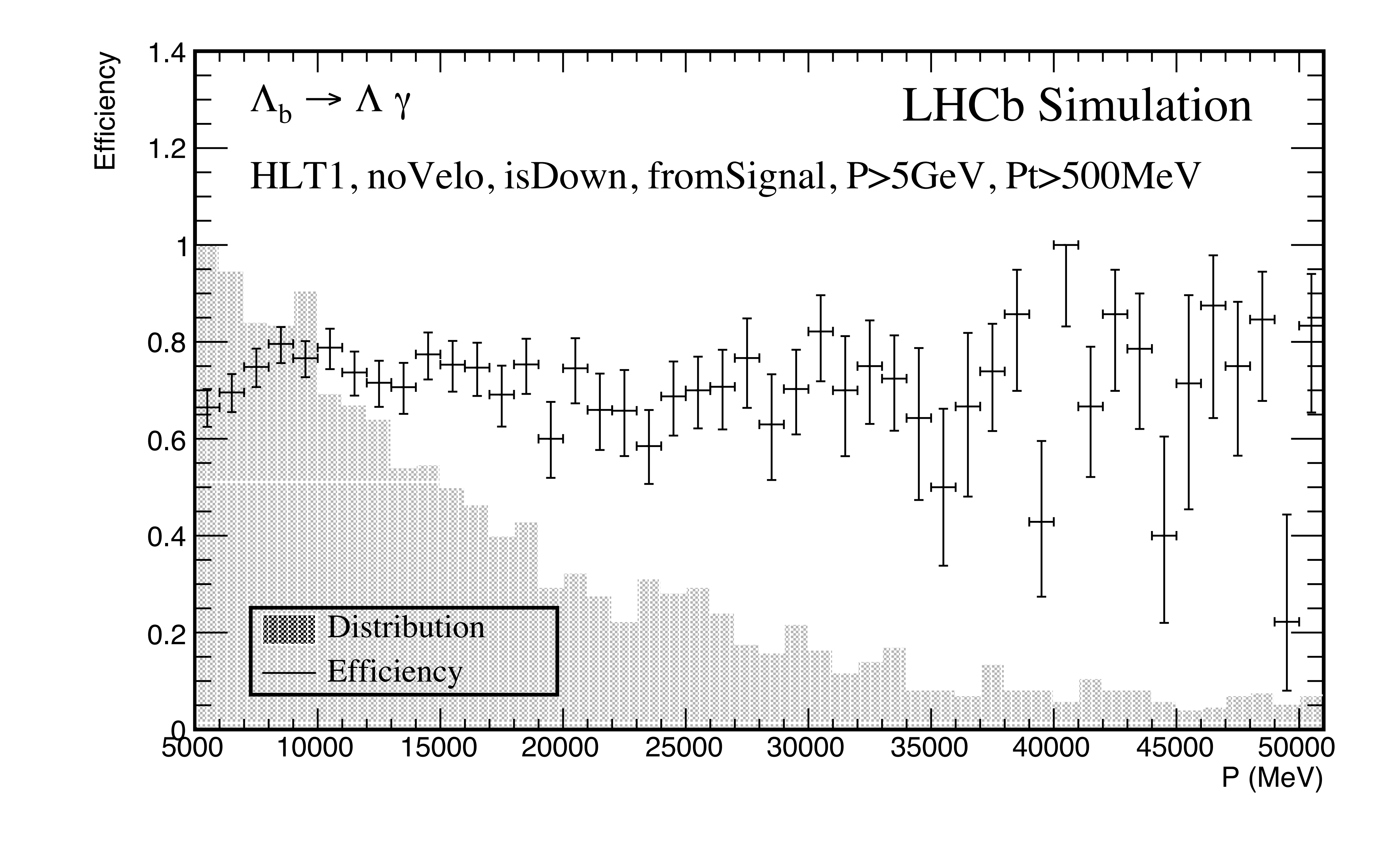
Tracking performance

04

Tracking efficiency

$\approx 75\,\%$



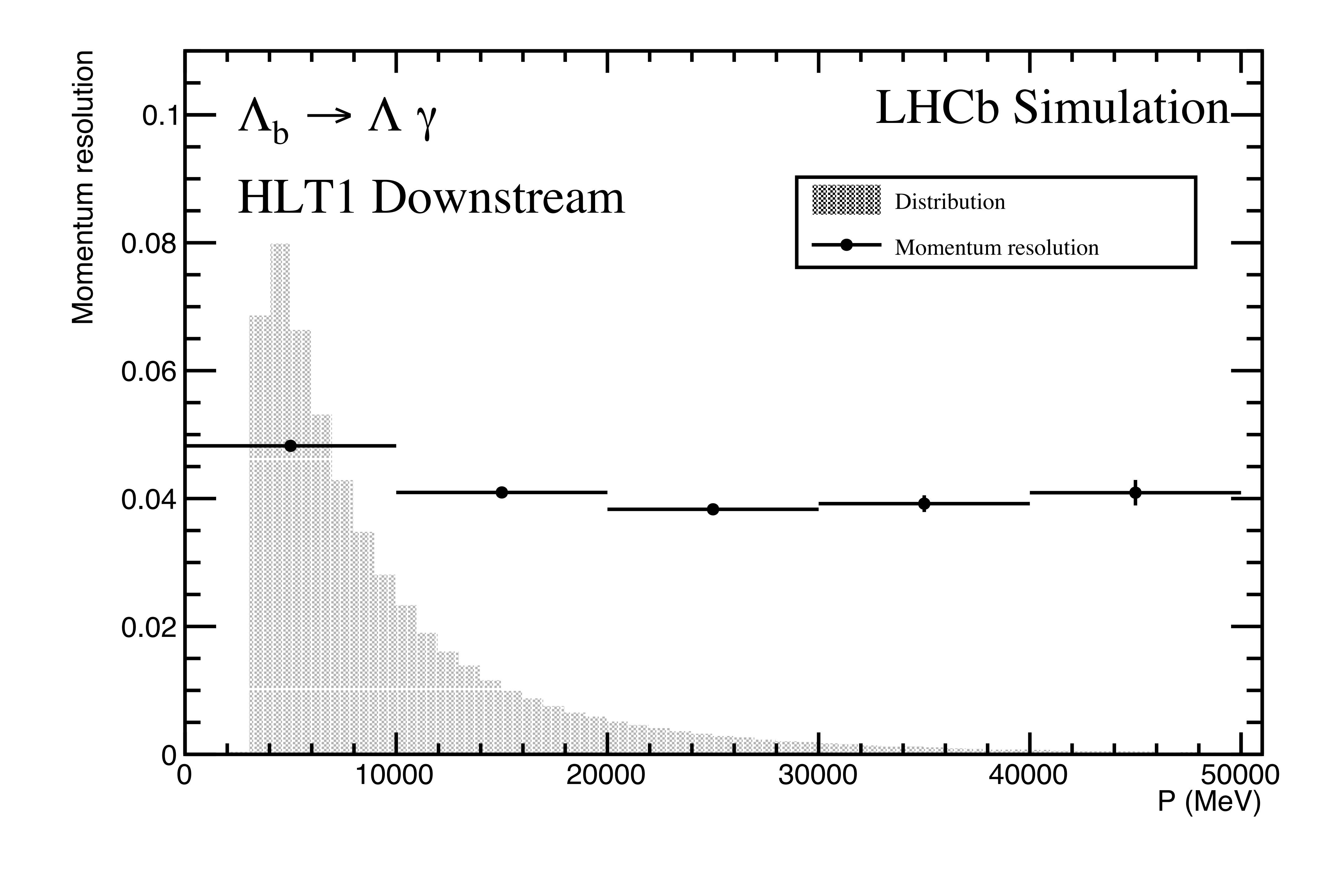


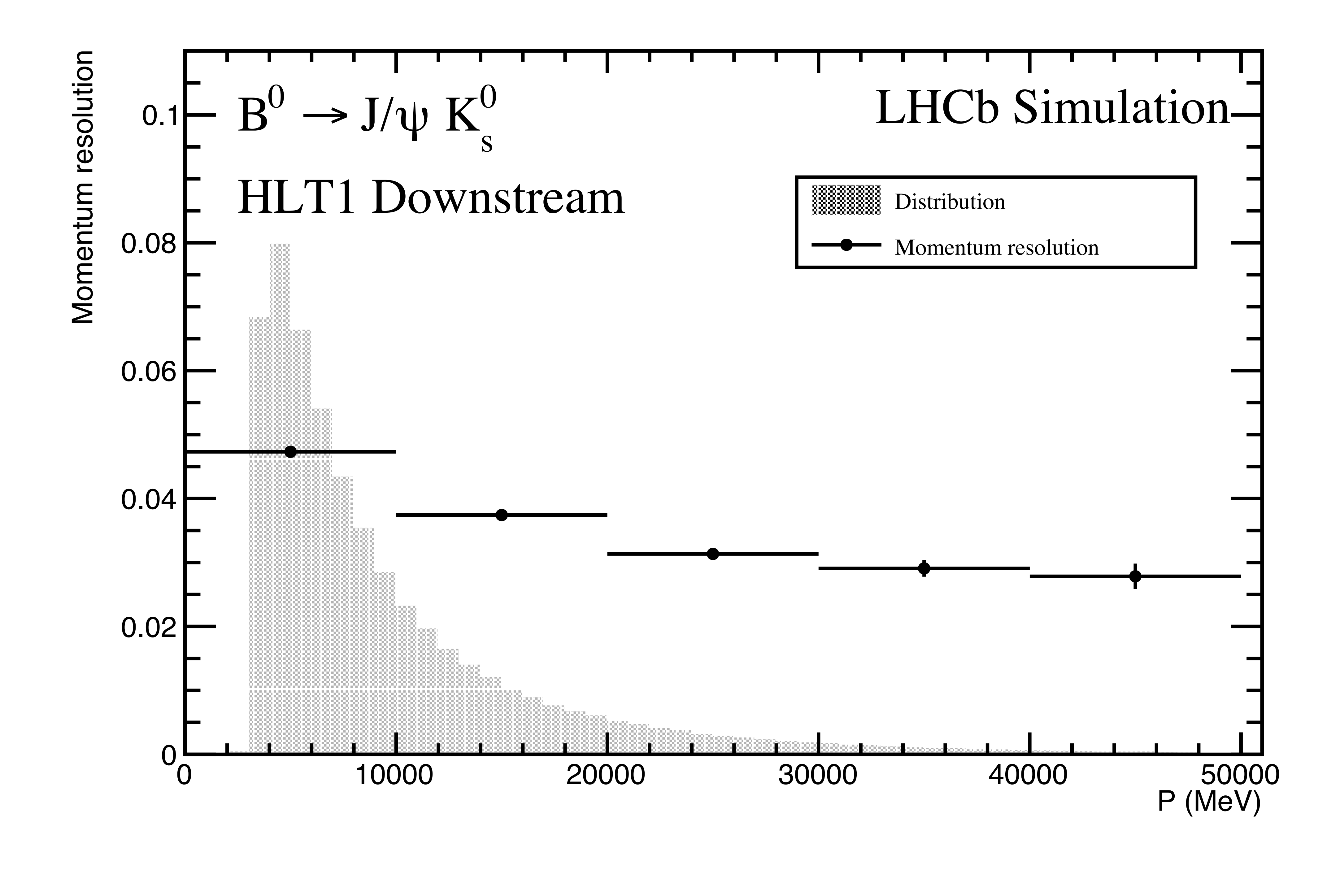
SciFi track reconstruction efficiency

($\approx 90\,\%$) is included!

Momentum resolution

$< 5\,\%$

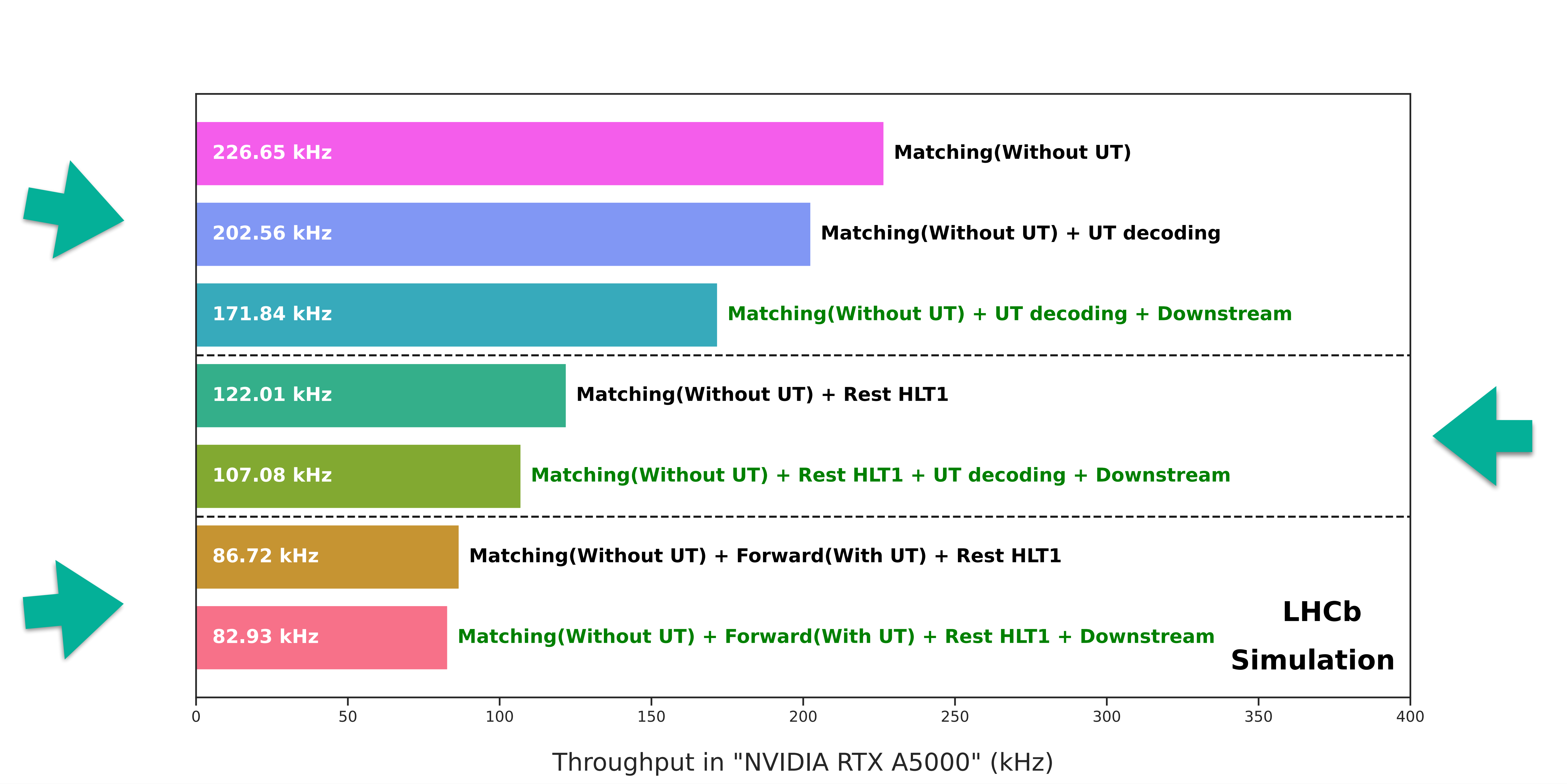




Effect on HLT1 throughput

Only long track reconstruction

2023 condition
4 %



2024 condition (First stage)
12 %

Downstream vertexing

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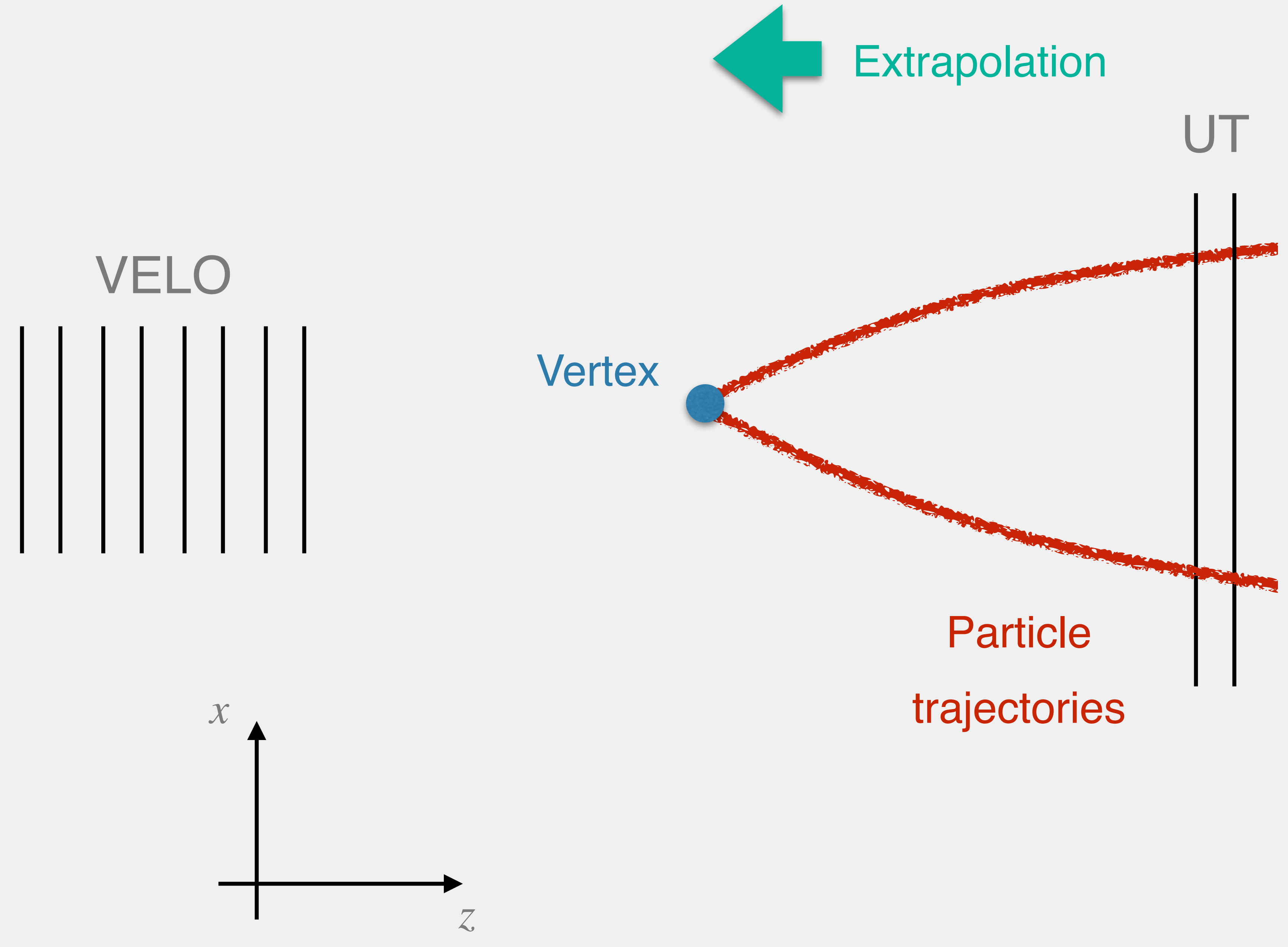
Vertex reconstruction

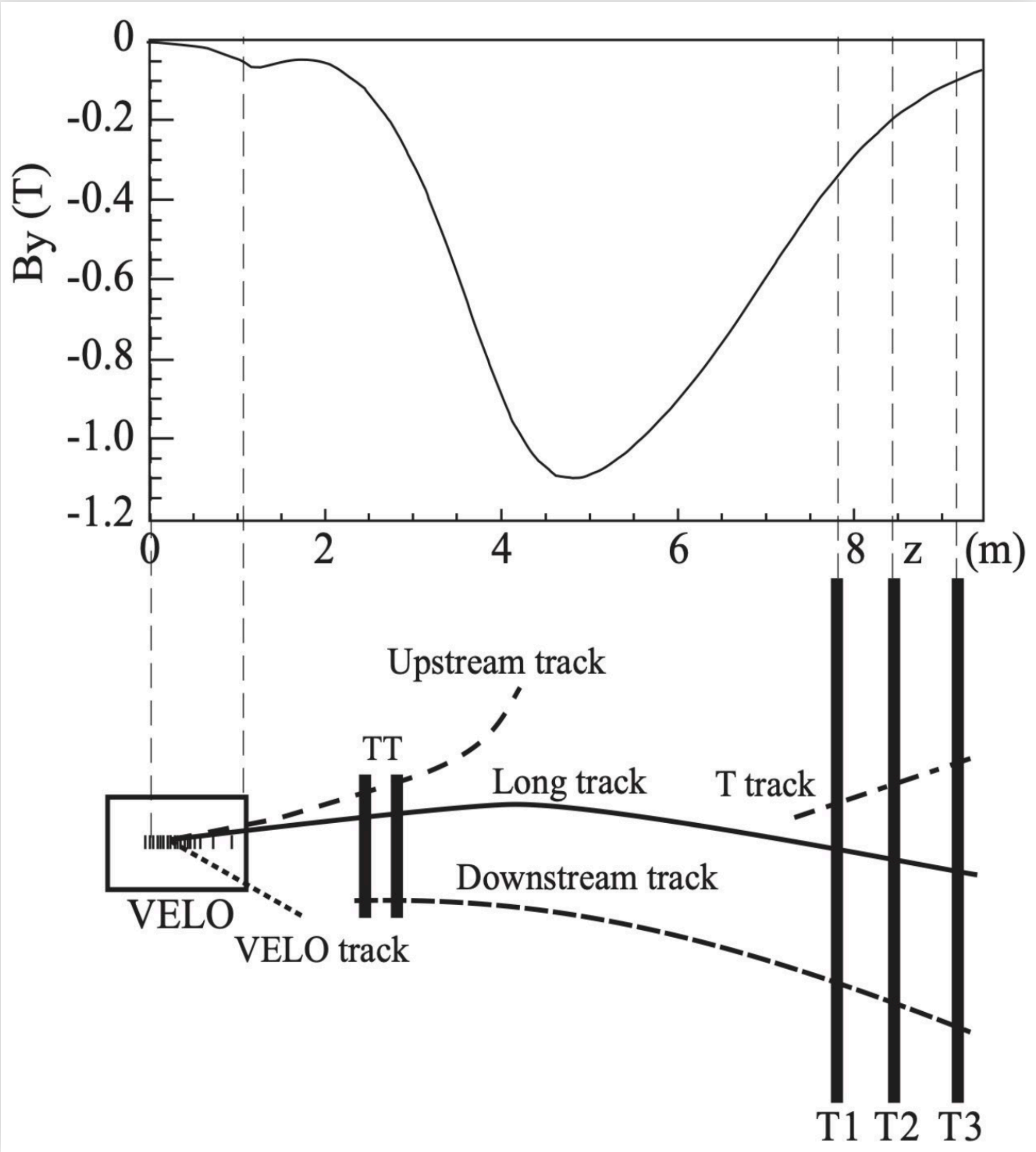


Track extrapolation before UT is also non-linear - due to remaining magnetic field in the region:

$$x(z) = x_0 + t_x(z - z_0) + \gamma(z - z_0)^2$$

where $\gamma = \gamma(\frac{q}{p})$ - coefficient of track non-linearity

Kalman filter-based vertexing algorithm is implemented to reconstruct the vertex of two downstream tracks



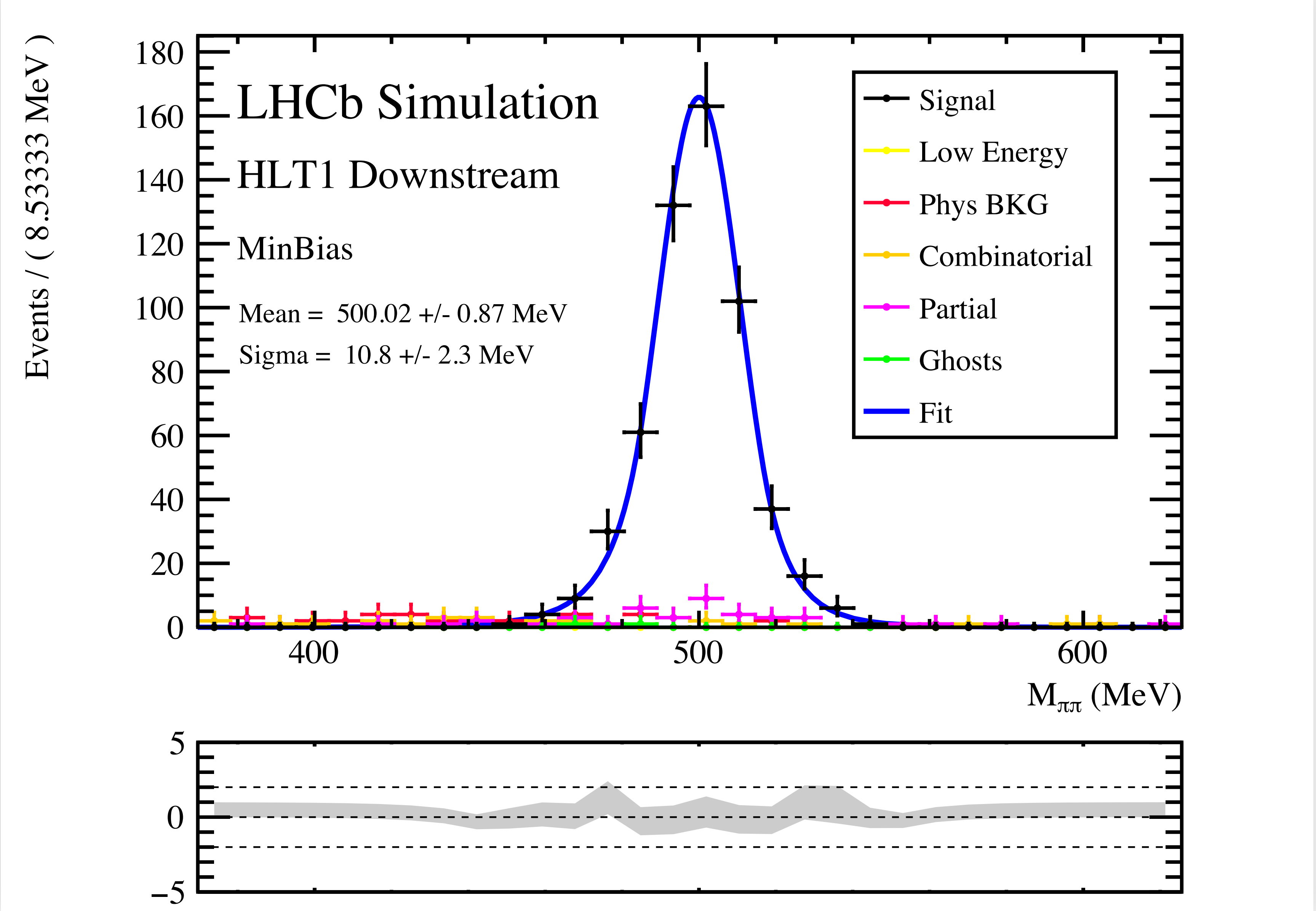
Vertex selection

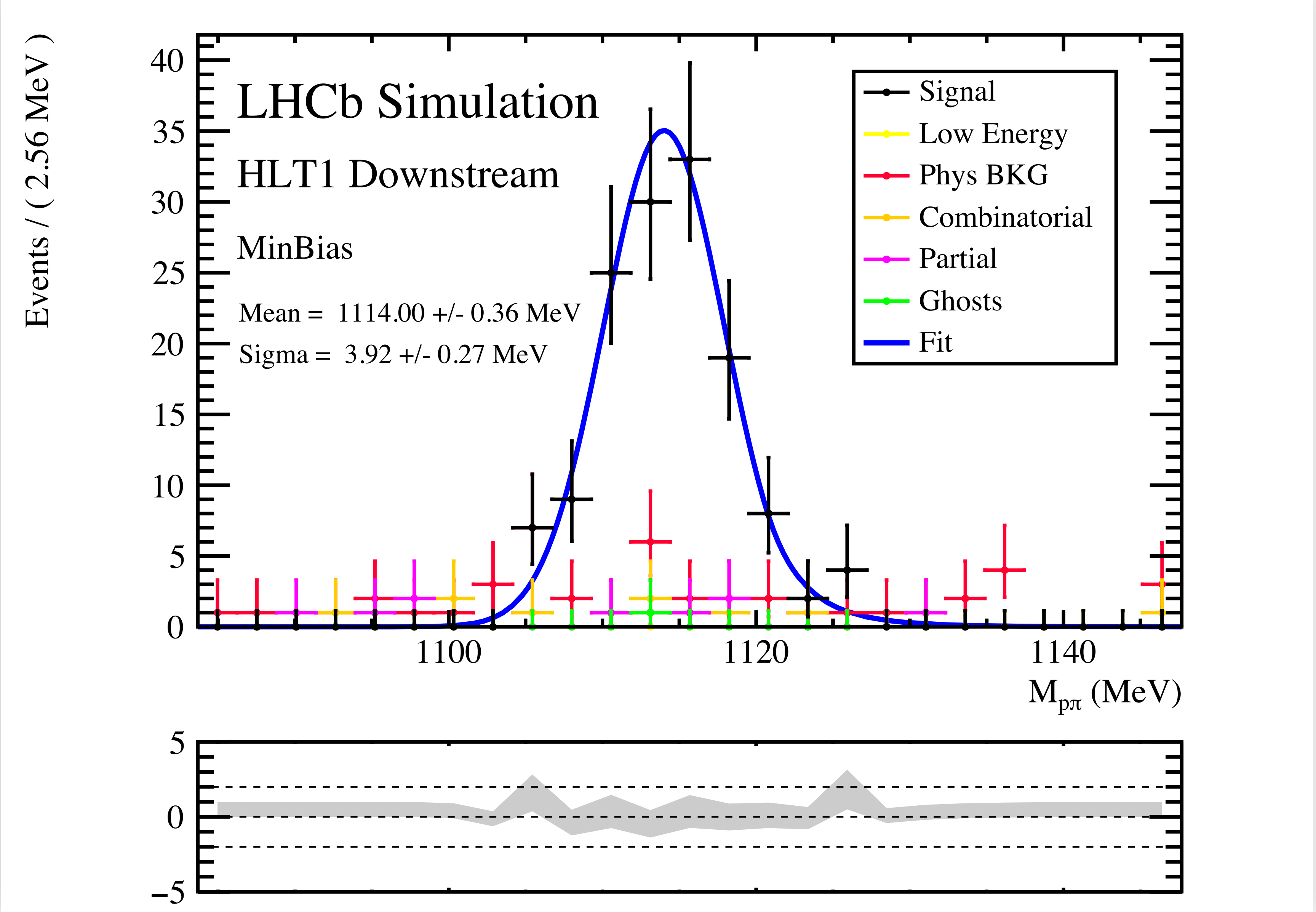
Vertexing algorithm successfully reconstructs the mass distribution of Λ^0 and K_s^0 utilizing two downstream tracks in HLT1

NN-based classifier for monitoring and selection at HLT1

Facilitating UT commissioning and online calibration

Prepared now for Run 3





LHCB-FIGURE-2023-028

Brij Kishor Jashal (2023). Connecting The Dots 2023. Downstream: a new algorithm at LHCb…

Summary

- ✓ First implementation of Downstream track & vertex reconstruction at HLT1!
- ✓ Small effect on throughout: only $4.3\ \%$ drop (2023)
- ✓ Physics efficiency of tracking $\approx 75\ \%$ and independent of the physics channel
- ✓ First implementation of a NN at HLT1 for fake track killing and selection line
- ✓ No bias on Λ^0 and K_s^0 mass reconstruction; $\sigma_M < 4$ MeV for Λ^0 (10 MeV for K_s^0)
- ✓ Expected huge impact on physics

Stay tuned!

Channel	DD/LL proportion	Interest
***b*-hadron decays**		
$\Lambda_b^0 \to \Lambda\gamma$	3.4	γ polarization, BR
$\Xi_b^- \to \Xi^-\gamma$	25	γ polarization, BR
$\Omega_b^- \to \Omega^-\gamma$	13	γ polariation, BR
$B^+ \to K_S^0 K_S^0 \pi^+$	2.8	CPV, BR
$B^+ \to K_S^0 K_S^0 K^+$	2.7	CPV, BR
$B_s^0 \to K_S^0 K_S^0$	3.6	CPV, BR
Charm physics		
$\Lambda c^+ \to \Lambda K^+$	4.4	Polarization studies
$\Xi_c^- \to \Xi^-\pi^-$	8.4	Polarization studies
$D^0 \to K_S^0 K_S^0$	1.8	CPV
$J/\psi \to \Lambda\bar{\Lambda}$	4.8	Polarization studies, BR
Strange physics		
$K_S^0 \to \mu^+\mu^-$	0.6	BR
$K_S^0 \to \mu^+\mu^-\mu^+\mu^-$	0.8	BR
$K_S^0 \to \gamma\mu^+\mu^-$	0.8	BR

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BACKUP

00

SciFi track reconstruction efficiency

LHCB-FIGURE-2022-010