A Streamlined Neural Model for Real-Time Analysis at the First Level of the LHCb Trigger

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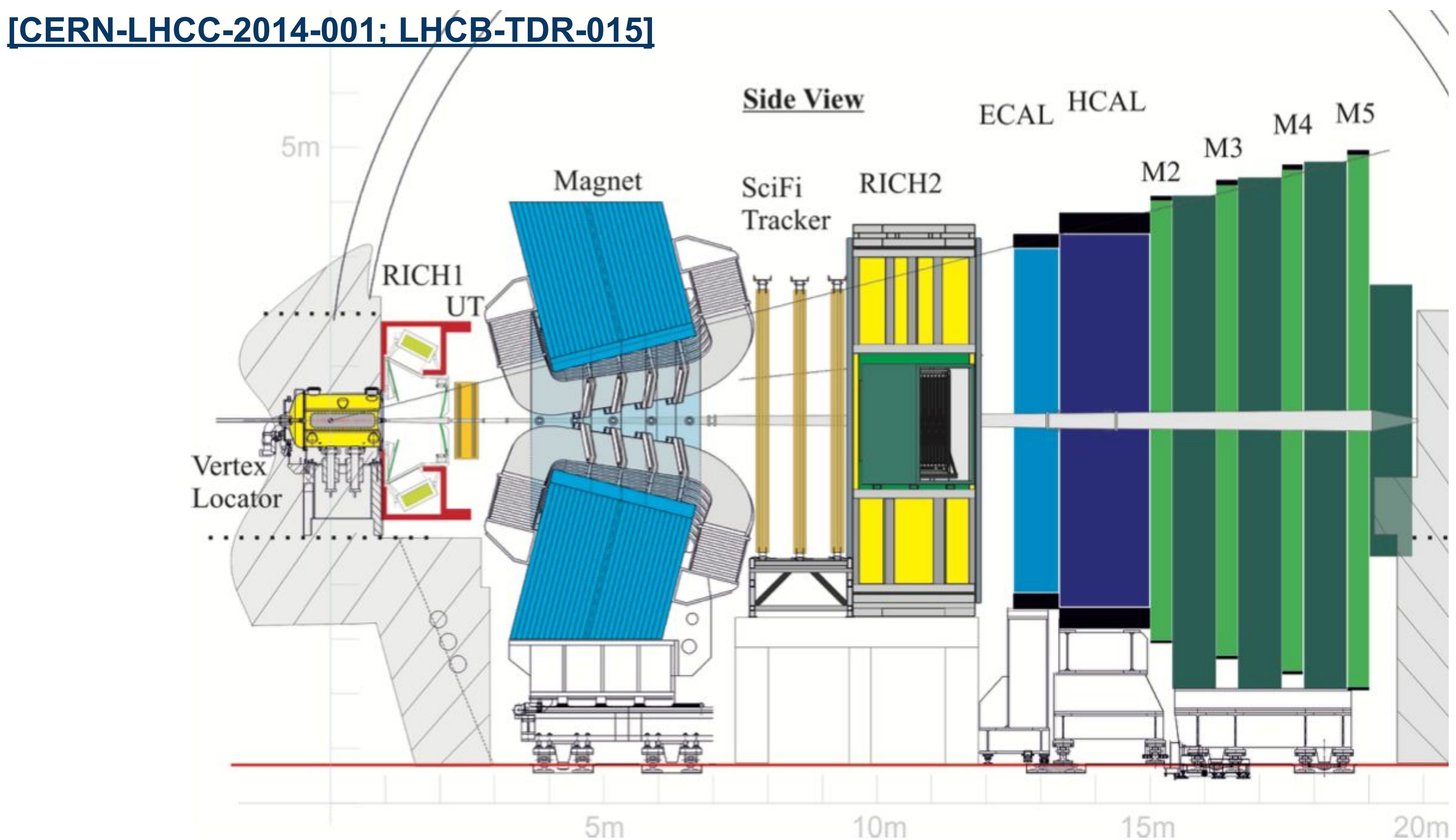
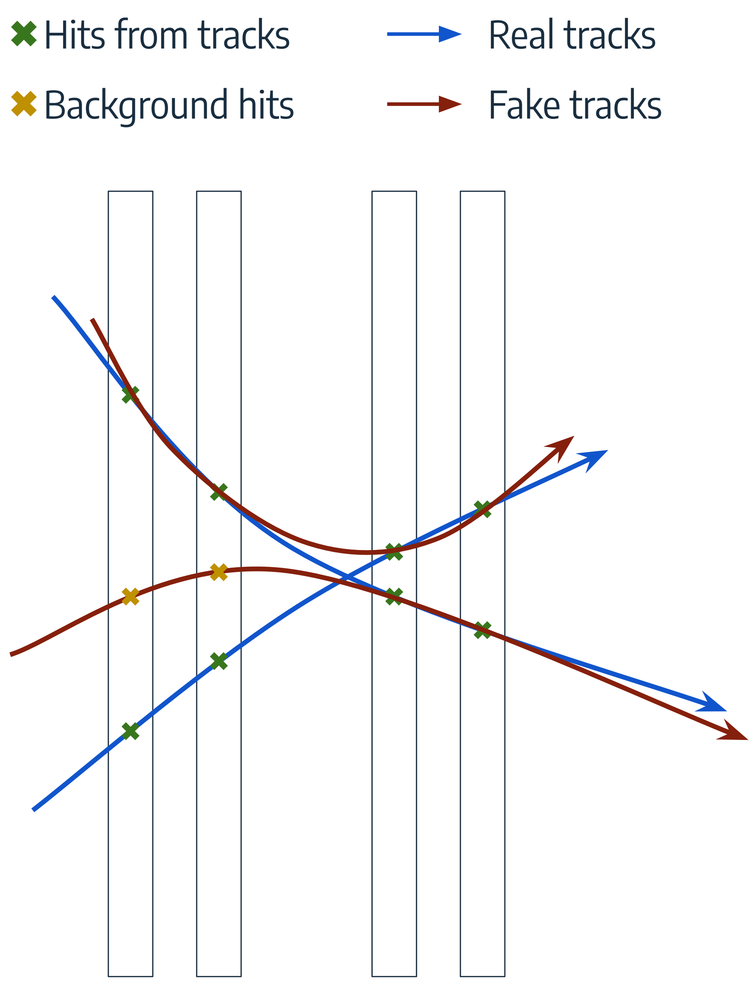
Introduction

[CERN-LHCC-2014-001; LHCB-TDR-015]

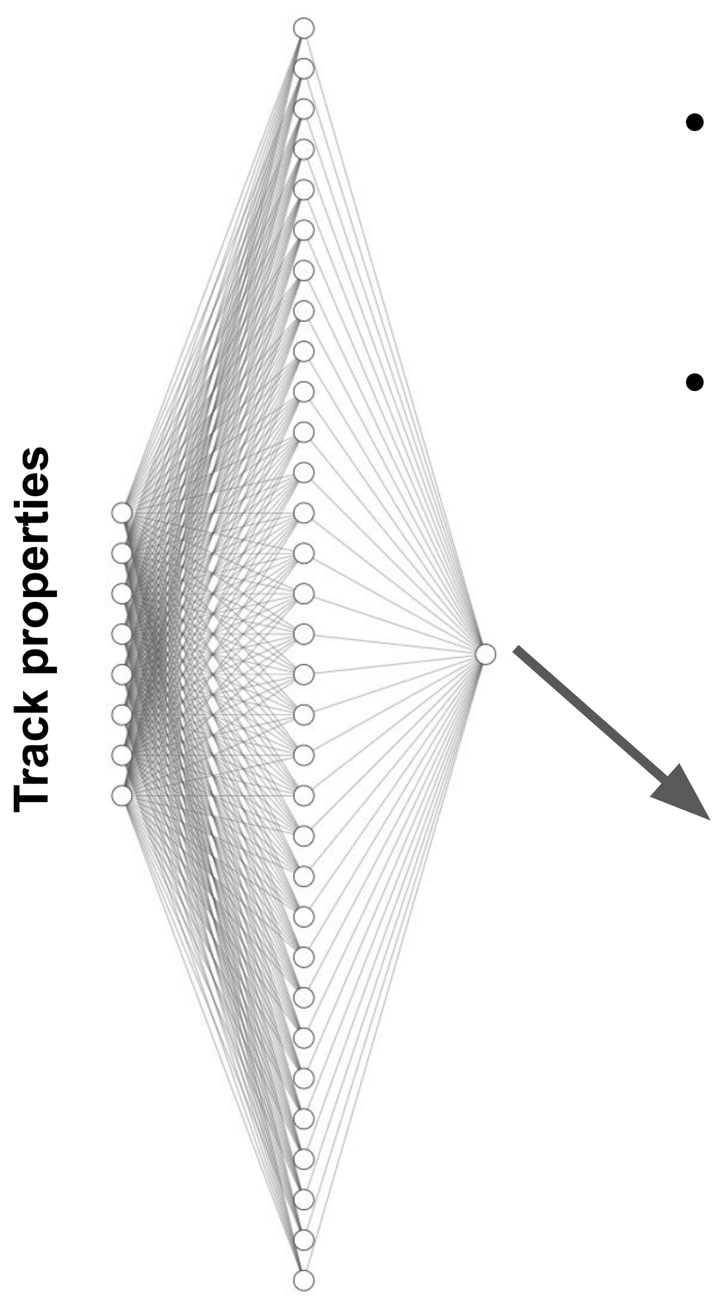


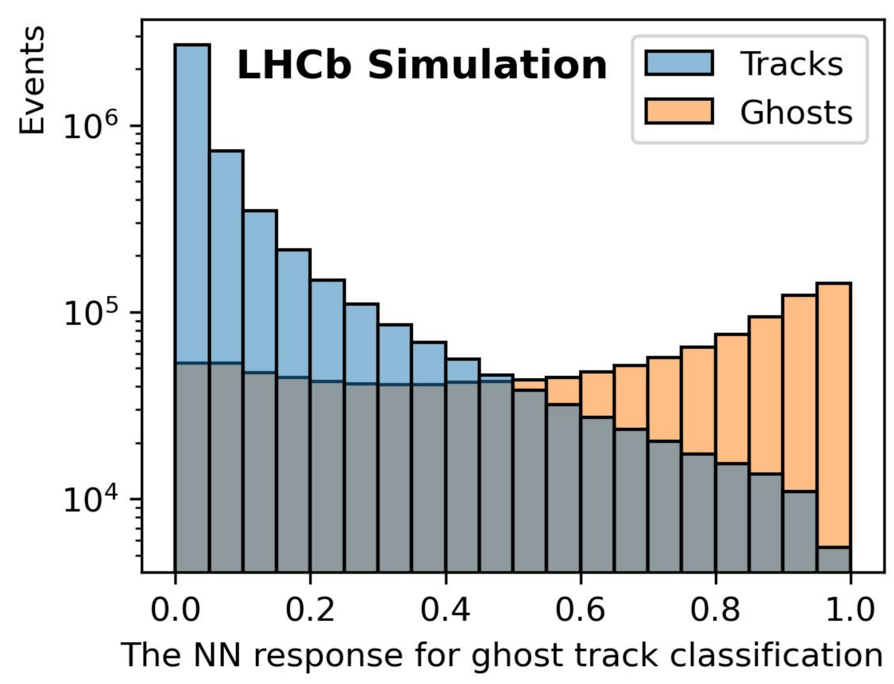
- **LHCb** is one of the four main experiments at the LHC, focused on precise measurements in the **beauty** and **charm sectors**.
- For **Run 3** data-taking, LHCb must handle a $\mathcal{L}_{\text{inst.}} = 2 \cdot 10^{33} cm^{-2} s^{-1}$ (**x5 increase** compared to **Run 2**) with $< \mu >= 5.2$.
- A new set of **tracking detectors** and an upgraded **trigger system** have been designed to handle higher radiation damage and increased **track multiplicity**.

Fake track rejection



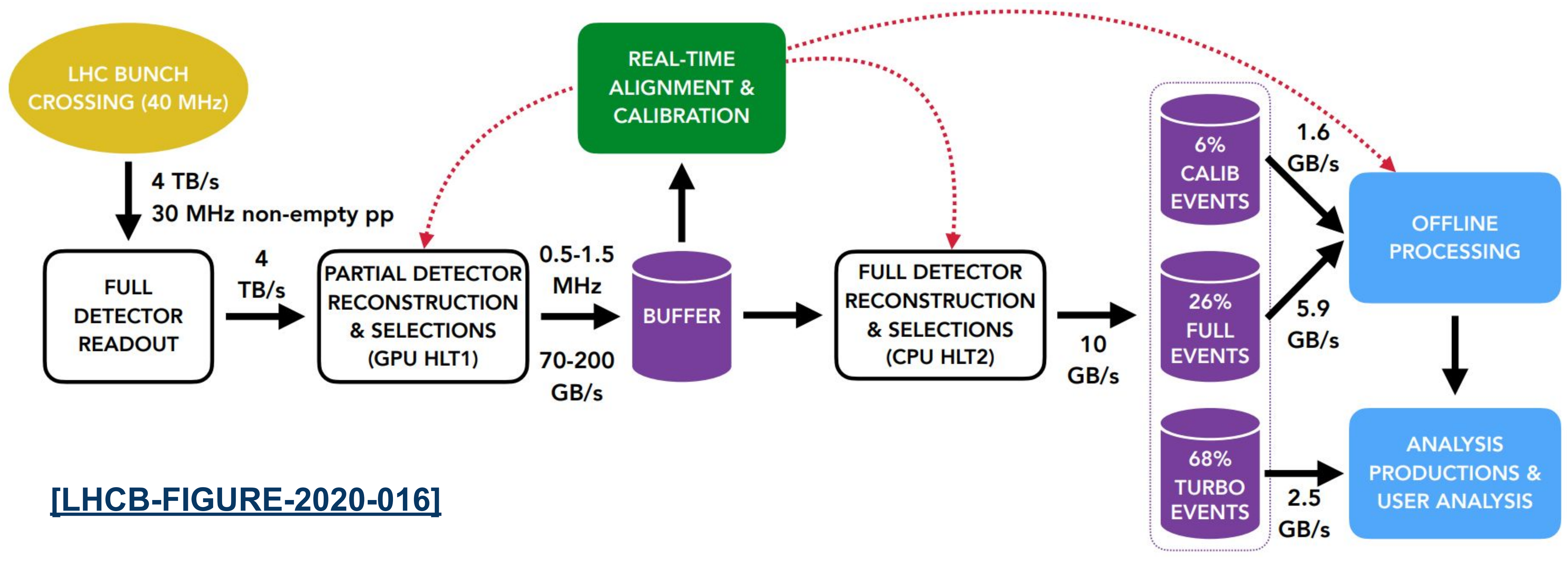
- **Track reconstruction** is the main component of event reconstruction, involving the identification of correct **hit combinations** to trace particle trajectories.
- **LHCb** detectors, like the **UT detector**, can have over **1,000 hits** per layer in each event, leading to a large number of possible hit combinations.
- **Incorrect** hit combinations can lead to **fake tracks**, making their identification and rejection a key challenge in tracking algorithms. The fraction of fake tracks is referred to as the **ghost rate**.
- **Ghost rate suppression** is achieved using a **fully connected neural network (NN)** with a **single** hidden layer of **32** nodes, called **"ghost killer"**, operating at **30 MHz** for real-time analysis.
- The network's **input variables** include **track properties** like slope, position differences before and after the magnet, and the number of hits used in reconstruction.
- The **"ghost killer"** is trained with **minimum bias pp collision simulations**, using a **cross-entropy loss function** to output the **"ghost probability"**, which represents the probability that a track is fake.
- The classifier demonstrates great discriminative power with **negligible impact** on **HLT1 throughput**.



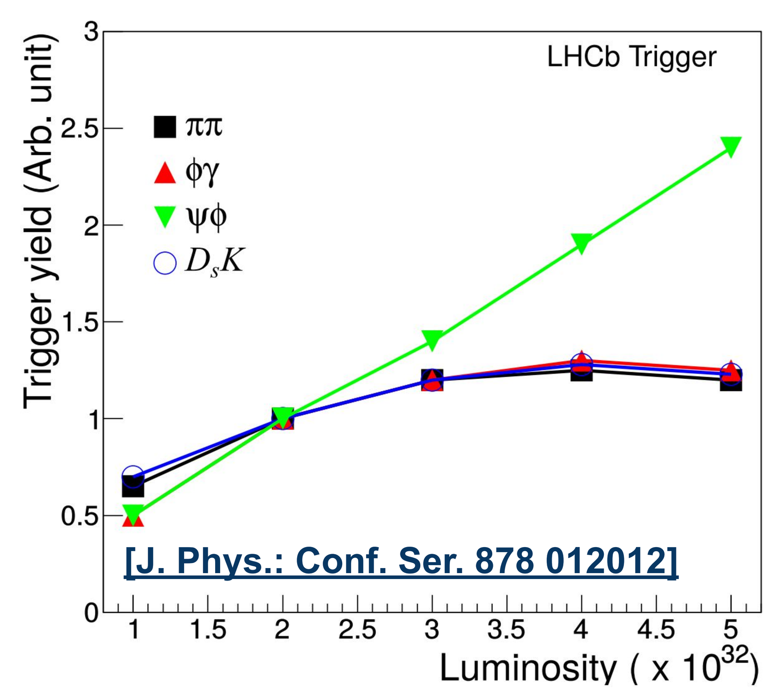


[LHCB-FIGURE-2024-037]

LHCb Trigger system



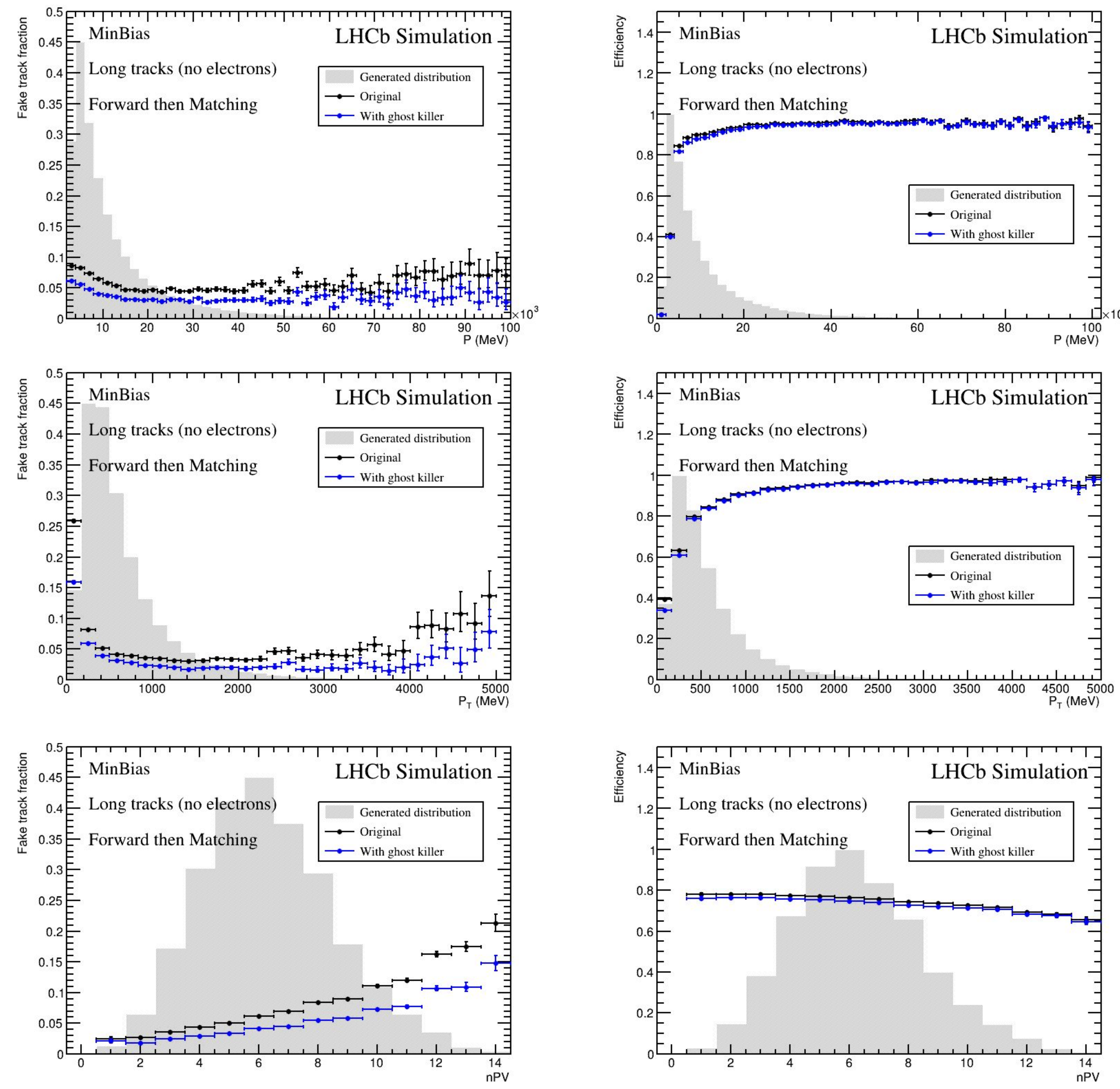
[LHCB-FIGURE-2020-016]



[J. Phys.: Conf. Ser. 878 012012]

- The hardware trigger (**L0**) faced saturation in many hadronic channels under high luminosity, leading to its **removal** in **Run 3**.
- **HLT1** now serves as the **first-level trigger**, directly processing read-out data at **30 MHz** and outputting filtered data to the buffer at **1 MHz**.
- Unlike the **L0** trigger, **HLT1** and **HLT2** perform **Real-Time Analysis (RTA)**, including clustering, tracking, and vertexing, to identify particles and make trigger decisions based on their properties.
- To handle the high **throughput** requirements, **HLT1** now runs as a **GPU-based** application called **Allen** during data-taking, though it also support a CPU mode for offline development.

Performance



[LHCB-FIGURE-2024-037]

Summary

- The **"ghost killer"** reduces the total fake track fraction from **6.7%** to **4.4%**, with about **1%** efficiency loss at the **tracking level**, and **negligible** impact on throughput at **30 MHz**.
- Since the total **HLT1 output rate** is limited, the improved track **purity** actually enhances the **final efficiency** after bandwidth division.

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