Tracking Long-Lived Particles at LHCb with a fully software-based trigger

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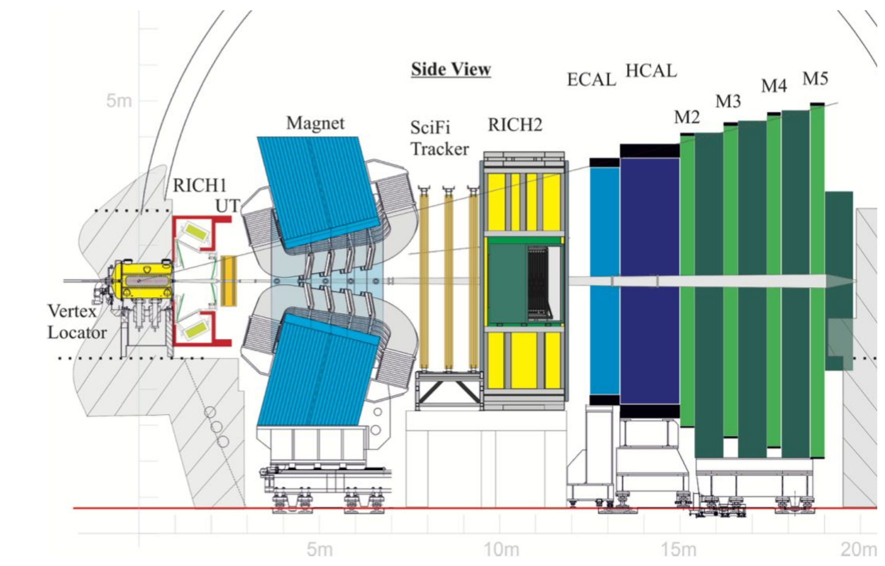
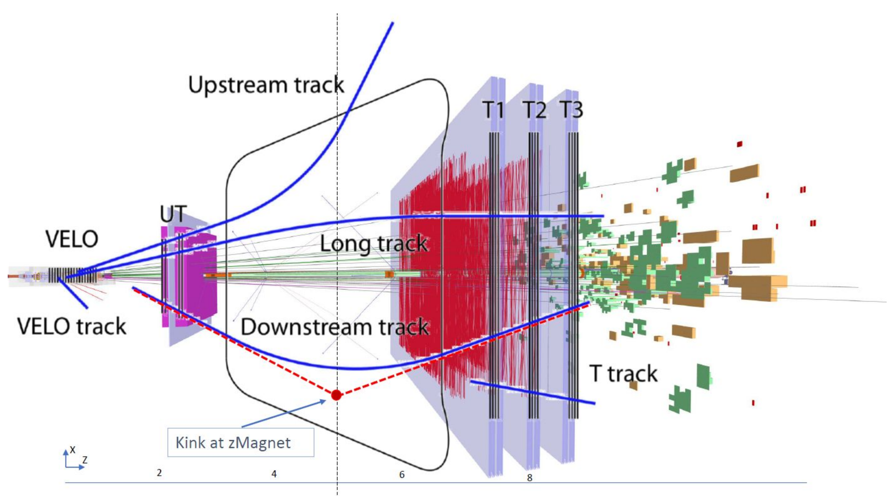
27/11/2023, LHCC poster session, CERN

Introduction



- Run 3 at $\mathcal{L}_{\text{inst.}} = 2 \cdot 10^{33} cm^{-2} s^{-1}$ (**x5 increase** compared to Run2) with $<\mu> = 5.2$.
- A new set of tracking detectors (VELO, UT, SciFi) designed to handle larger track multiplicity and radiation damage.
- All sub-detectors feature triggerless readout electronics operating at **40MHz**.

- **Hardware trigger removal** ➡ Need of software triggers: High Level Trigger 1 (**HLT1**) and High Level Trigger 2 (**HLT2**) to manage a higher throughput of events compared to Run2.
- Different track types depending on the sub-detectors used for their reconstruction:
  - **Long track**: VELO, UT and SciFi;
  - **Downstream track**: UT and SciFi;
  - **T track**: SciFi only.



- Developments of **new triggers** on **Downstream** (HLT1) and **T tracks** (HLT2)
- Particles reconstructed by **Downstream** and **T tracks** open new opportunities for **physics searches**:
  - **Electric** (**EDM**) and **magnetic** (**MDM**) **dipole moments** are static properties of particles, can be measured exploiting the spin precession in the LHCb magnetic field
    - The EDM violates T and P symmetries ➡ CP violation (via CPT theorem). Sensitive to physics **Beyond** the **Standard Model** (BSM) at the current experimental sensitivity.
    - MDM measurement of particle and antiparticle ➡ **CPT** theorem **test**. Provides experimental test of low-energy QCD models.
  - Search for **BSM** particles to test BSM theories, almost all the models predict **Long Leaving Particles** (**LLP**): sensitivity of the LHCb detector extended to a decay volume up to 7.5 m

HLT2 *Downstream* tracks

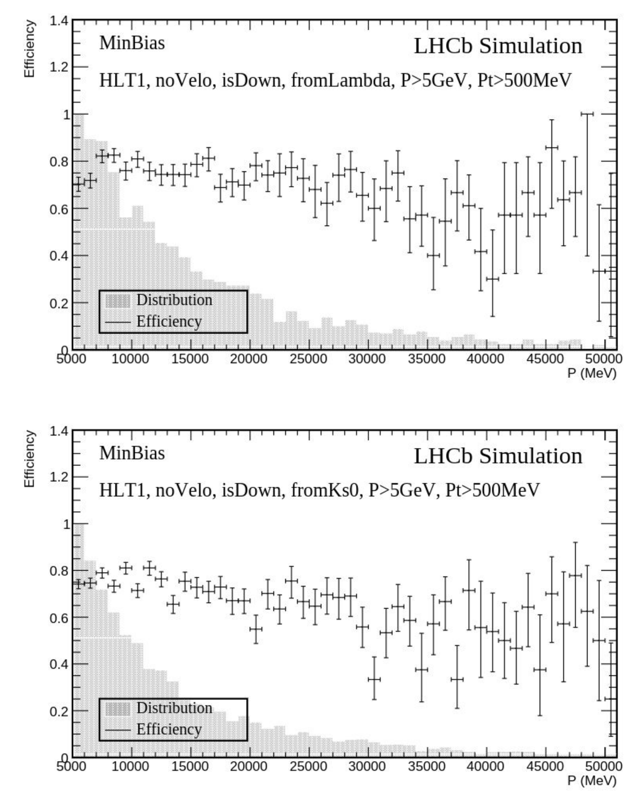
- HLT2 deals with full-reconstruction of Downstream Tracks, work in progress to improve it with Machine Learning algorithms:
- The initial phase helps to identify and tag the real seed tracks from ghost tracks: a machine learning based algorithm has been developed to be integrated with Downstream track reconstruction algorithm, expecting a minimal effect on the efficiency.
- On the second phase, the tracks will be cherry-picked using a **Deep Learning Neural Network** to improve the fake track rejection rate.
- Exploring PyTorch instead of TMVA to improve the performance.

By Sabin Hashmi Kalavan Kadavath

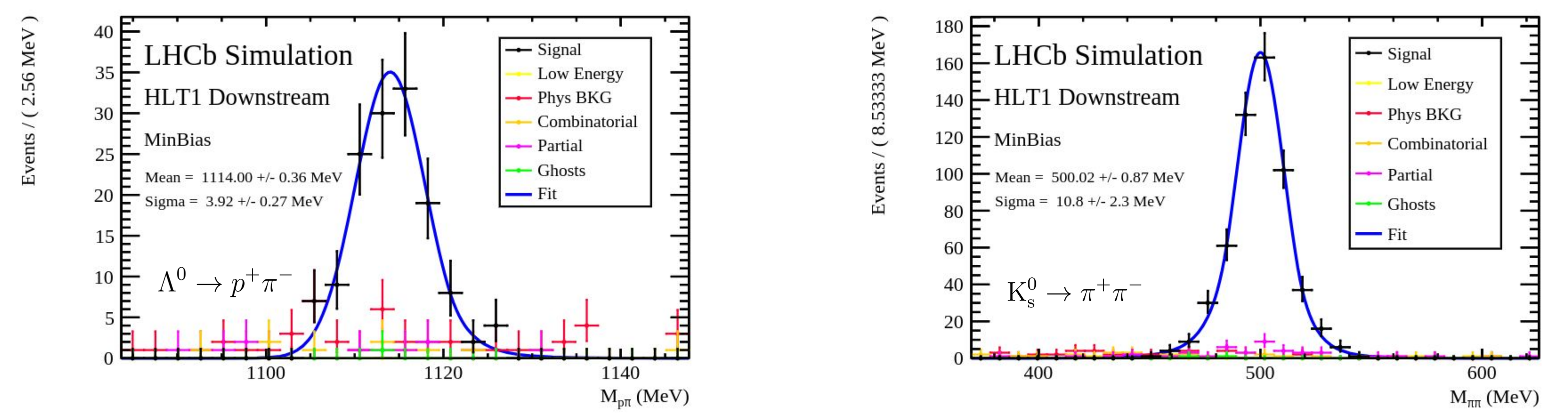
HLT1 *Downstream* tracks

- **HLT1 operates on GPUs** with the Allen project at a input rate of **30MHz**.
- **Downstream tracks** primarily target LLPs that decay after passing the VELO detector.
- New reconstruction algorithms have been developed in **HLT1** for **downstream tracks**.
- The **HLT1 downstream tracking** algorithm maintains consistent tracking efficiency and ghost rate for Λ^0 and K^0_s.
- The **HLT1 downstream vertexing** algorithm successfully reconstructs the mass distribution of Λ^0 and K^0_s utilizing two downstream tracks.

[LHCB-FIGURE-2023-028]



- Integration of new algorithms into the main sequence induces a **minimal effect on throughput**, evidenced by a modest reduction of 5%.



[LHCB-FIGURE-2023-028]

By Brij Kishor Jashal and Jiahui Zhuo

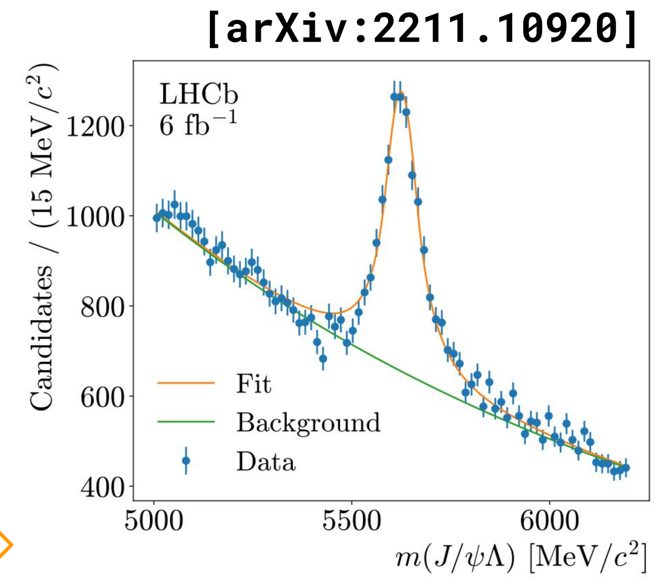
HLT2 *T* tracks

- Physics motivation: search for **EDM** and **MDM** of Λ^0 baryons, expand the search for **BSM LLP** to **$\mathcal{O}$(10 ns)**

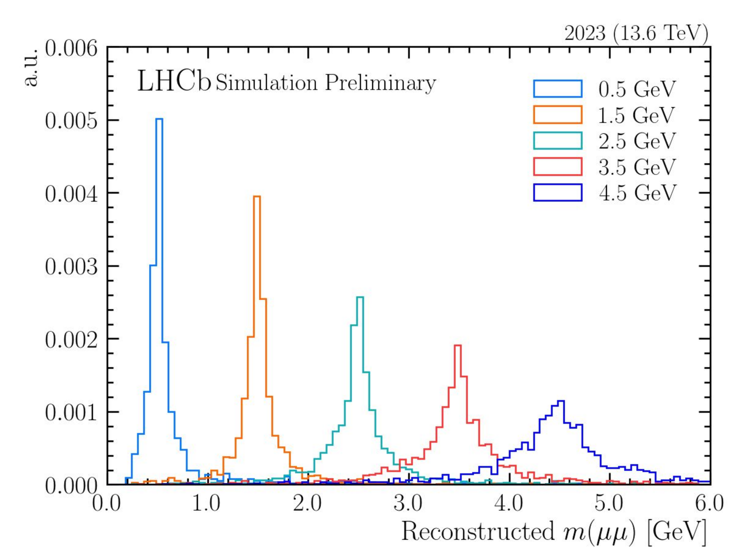
[arXiv:2211.10920]

- T tracks never used in LHCb for physics analysis due to:
  - poor resolutions,
  - extrapolation through large inhomogeneous magnetic field
  - large combinatorics

Feasibility demonstration of reconstruction with T tracks and performance study addressed in Run 2 data



- Now these challenges must be met within the tight throughput and bandwidth requirements of the Run3 **HLT2 trigger**:



[LHCB-FIGURE-2023-026]

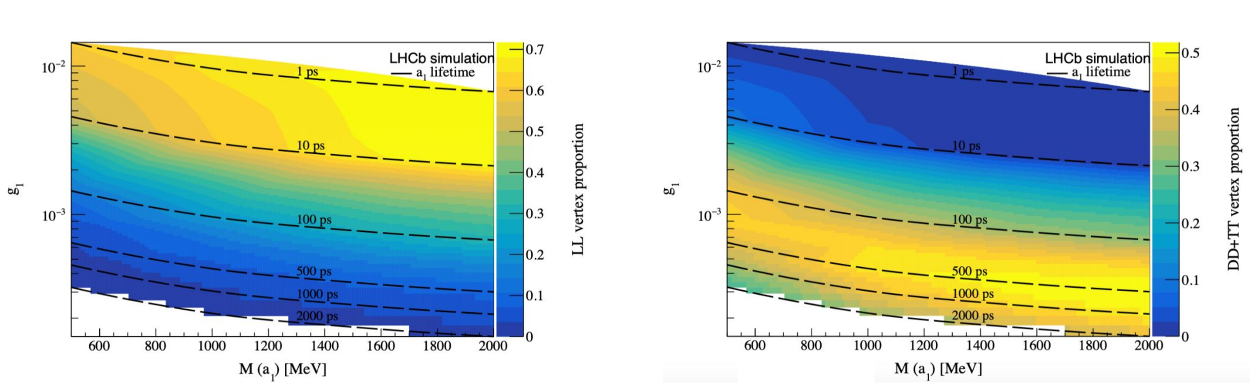
- ❑ Topological **track filtering** with MVAs improve throughput
- ❑ Dedicated vertexing and extrapolation strategies to improve the mass resolution
- ❑ **Output** rates **$\mathcal{O}$(10 Hz)**
- ❑ Lines currently **ready**: $\Xi^0_c \to \Lambda K^- \pi^+$, $J/\psi \to \Lambda\bar{\Lambda}$, $B^0 \to J/\psi K^0_S$, $\Lambda_b \to J/\psi \Lambda$, $\Xi^+_c \to \Xi^- \pi^+ \pi^+$, $\Xi^0_c \to \Xi^- \pi^+$ and more in development
- ❑ Being adapted for BSM searches, e.g. $B \to H'(\to \mu\mu)K$

By Giorgia Tonani

Conclusions

- The introduction of dedicated **HLT1** and **HLT2** lines for **Downstream** and **T tracks** for LHCb Run 3 opens new opportunities for physics research, such as:
  - search for charged final states from **BSM LLP decays**, such as $B \to H'(\to \mu\mu)K$;
  - measurement of electromagnetic dipole moments (**EMDM**) of Λ^0 baryons.
- The improvements in the **HLT1** and **HLT2** reconstruction and selection algorithms for **Downstream** and **T tracks** are now ready for data acquisition during Run 3.

[doi.org/10.3389/fdata.2022.1008737]



Tracking acceptance of $B \to H'(\to \mu\mu)K$ decay