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

Sabin Hashmi Kalavan Kadavath[1], Brij Kishor Jashal[2,3], Giorgia Tonani[2,4] and Jiahui Zhuo[2] on behalf of the LHCb RTA project


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Introduction

- HLT3 deals with full-reconstruction of Downstream Tracks, work in progress to improve it.
- The initial phase helps to identify and tag the real seed tracks from ghost tracks: a machine
- Exploring PyTorch instead of TMVA to improve the performance.
- On the second phase, the tracks will be cherry-picked using a
- Particles reconstructed by T track
- Different track types depending on the sub-detectors used for their reconstruction:
  - Long track: Velo, UT and SoFi;
  - Downstream track: UT and SoFi;
  - T track: SoFi 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

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 \( \Lambda^0 \) and \( K^0 \) utilizing two downstream tracks.
- Integration of new algorithms into the main sequence induces a minimal effect on throughput, evidenced by a modest reduction of 5%.

HLT2 tracks

- Physics motivation: search for EDM and MDM of \( \Lambda^0 \) baryons, expand the search for BSM LLP to \( \phi \) (10 ns)
- 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:
  - Topological track filtering with MVAs improve throughput
  - Dedicated vertexing and extrapolation strategies to improve the mass resolution
  - Output rates \( \phi \) (10 Hz)
  - Lines currently ready: \( B \rightarrow H'(\rightarrow \phi p)\)
- Being adapted for BSM searches, e.g. \( B \rightarrow H'(\rightarrow \phi p)\)

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 \( \bar{B} \rightarrow H'(\rightarrow \phi p)\)+
  - measurement of electromagnetic dipole moments (EDM) of \( \Lambda^0 \) 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.