IRIS-HEP Fellows Program Project Proposal

Development of the generic vertex finder in HLT1-level trigger at LHCb

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1. Project Summary

1.1. High-level triggers at LHCb

Currently, the LHCb detector is capable of reading out at a full bunch crossing rate of 30 MHz, or a maximum data rate of 40 Tbit/s. To be able to obtain information about the events of interest for LHCb analysis, it is necessary to significantly reduce the data rate, which is implemented by two software stages. The first stage, called HLT1, performs fast track reconstruction and selection of *pp* collision events at the LHCb based on single- and double-track objects and saves the data to a buffer. In the second step, called HLT2, the detector is aligned and calibrated in near-realtime, and the remaining events are subjected to offline track reconstruction, full particle identification, and track fitting. This approach results in a total output data volume of 80 Gbit/s[1].

In Run 3, HLT1 was improved by implementing it on the GPU, which allowed for parallel event processing. This is the first fully GPU-based trigger used for research at HEP, which offers unique research opportunities. It also became possible to reconstruct the so-called Downstream tracks(Fig1), tracks that left a trace in all tracker systems of the detector except VELO, which expanded the possibilities for studying long-lived particles (LLPs).

The goal of this project is to develop novel HLT1 algorithm to expand LHCb physics reach in QCD as well as searches for New Physics

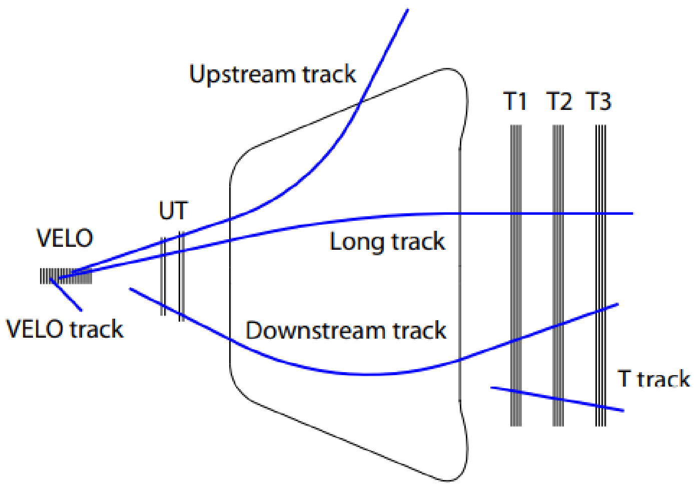

Figure 1: Reconstructed track types for the LHCb upgrade tracking system[2].

1.2. η_c production on LHCb

η_c is ground state charmonium, which is very interesting for QCD research. It can be produced in collisions at the LHC and reconstructed at the LHCb by considering different decay channels.

One of the most interesting channels is the decay into long-lived Lambda baryons $\eta_c \to \Lambda\bar{\Lambda}$. In Runs 1 and 2, the reconstruction of long-lived particles was focused only on Long tracks. In Run 3, it became possible to reconstruct Downstream tracks, and since Lambda baryons are long-lived, there will be more of such tracks. Despite the lower reconstruction precision of the Downstream tracks, they can be used to make brand new measurements of η_c production thanks to very low background rate compared to existing measurements [3].

Therefore, the main task of the project is to write triggers for events with the production of a pair of $\Lambda\bar{\Lambda}$ for GPU-based HLT1 using CUDA and CPU-based HLT2 with adding configurations in Python. These will be selection lines that take into account the formation of Long-Long, Down-Down and Long-Down pairs of baryons. After implementing the algorithms, it is necessary to test them, analyse the background, and determine the effectiveness of such triggers. New trigger lines are aiming at starting taking data already in 2024

1.3. Reconstruction generic displaced vertices in LHCb

Many New Physics scenarios posit the existence of new long-lived particles that could help explain long-standing mysteries in physics, such as Dark Matter. It's possible that such particles are produced in high-energy proton-proton collisions at the Large Hadron Collider. The LHCb detector is a single-arm spectrometer that is very well equipped in the forward part, which allows it to detect LLPs signatures with high accuracy. However, to do this effectively, a specific algorithm is needed that can quickly identify collisions where these long-lived particles appear. This project aims to develop a new algorithm that looks for displaced decay vertices in the LHCb experiment. Once the algorithm is ready, it will need a fast CUDA implementation to run online on the LHCb GPU farm. Additionally, with the help of this algorithm, a trigger selection will be developed. Such a trigger line will dramatically increase the sensitivity for inclusive and many exclusive searches for LLPs at once. This will start with implementing known algorithm as "GenericVertexFinder" and following the speed up of it.

2. Timeline

- **Week 1**: Study the structure of existing selection algorithms at the HLT1 and HLT2 levels. Install and configure all the necessary components and programs for further work.
- **Week 2-4**: Development of selection algorithms for events with the formation of a $\Lambda\bar{\Lambda}$ pair using both Long and Downstream tracks.
- **Week 5-11**: Development of a new algorithms that looks for displaced decay vertices and their implementation on CUDA.
- **Week 12**: Preparation of the final presentation for the project.

References

[1] arXiv:1912.09161, Allen: A high level trigger on GPUs for LHCb

[2] LHCb Collaboration. LHCb Tracker Upgrade Technical Design Report. Technical report, 2014.

[3] R. Aaij *et al.* [LHCb], Eur. Phys. J. C **80** (2020) no.3, 191 doi:10.1140/epjc/s10052-020-7733-0 [arXiv:1911.03326 [hep-ex]].