IRIS-HEP Fellows Program Project Proposal

“Usage of CUDA for improving HLT performance”

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Introduction and Project Description

The primary motivation of our work is to contribute to the expansion of the Standard Model (SM), ensuring its alignment with observable data on cosmological scales - gravitational lensing, rotation of galaxies. Several theoretical frameworks have been proposed to explain those phenomena and one of them is the expansion of SM via the introduction of new particles. These “dark” particles can be long-lived and therefore would leave a clear exotic signature that can be found as an anomaly in low-level data from detectors.

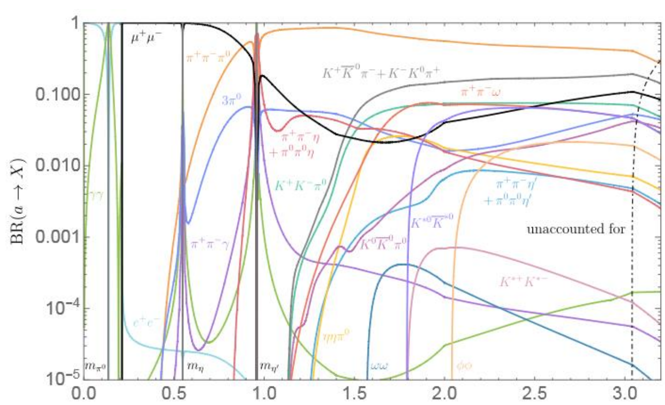
Search endeavors here are complicated by the existence of a massive background, mainly contributed by $b\bar{b}$ and $c\bar{c}$ processes. From there the task of rapid data filtering for anomaly search arises.

At LHCb there are multilevel filtering systems. It uses a fully software trigger with the first stage, HLT1, implemented on GPUs. The second one is implemented on CPUs, HLT2 **[1].**

We will focus our attention on the HLT1. Research in this paper **[2]** proves that it’s possible to process data from HLT1 detector at the rate of 30MHz (real-time) on the currently existing cluster of roughly 500 GPUs running CUDA program. This project is called Allen and serves the main purpose of reducing data rate by looking for primary vertices.

The main goal of the project is to use modernized search for secondary vertices as input for anomaly detection. For the search of anomalies, we will use unsupervised ML techniques such as autoencoder to make it agnostic to the choice of new New Physics models.

One of the possible places for the search of DM particles is Higs boson decay to invisible particles, as the BR of that process is much higher than predicted by SM: <18% vs 0.1%, thus the existence of unknown decay channels is possible. In the targetted theory model, unstable DM particles should decay back to SM particles. Particularly, the so-called "dark shower" **[3]** models assume the existence of a new QCD-like force, which, in turn, results in a large multiplicity of low-mass dark particles decaying hadronically. This process would have a signature of many displaced vertices, often without a dominant exclusive decay mode. **[4]** Such models will be used to study the signal efficiency of anomaly search mentioned above.



branching ratios of a light ALP coupled to SM fermions with $c_f = T^3_{Lf}$.

Technically, this project includes the study of anomaly search settings in the view of possible implementation at HLT1 depending on the required GPU resources for such anomaly search

Preliminary Timeline:

1. Produce simulation samples for dark shower models assuming different values of mass and lifetime of dark hadrons (dark shower particles). The dark pions will be allowed to decay into multiple channels following available theory framework. This part assumes using available MC production pipelines and adjusting them for use in LHCb Run 3. Simulated samples will be produced at Nikhef stoomboot cluster

2. Study number of secondary vertices as a function of displacement with respect to the proton-proton collision point. Study distribution of the number of tracking in secondary vertices

3. Use the background sample for training the unsupervised ML method (first to try: simple autoencoder already used by CMS for SUEPs models)**[5]**. Study the signal efficiency using signal samples, and end up with the ML model for the search.

References:

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[5]
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