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GNN-based algorithm for full-event filtering and interpretation at the LHCb trigger

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The LHCb experiment is currently undergoing its Upgrade I, which will allow it to collect data at a five-times larger instantaneous luminosity. In a decade from now, the Upgrade II of LHCb will prepare the experiment to face another ten-fold increase in instantaneous luminosity. Such an increase in event complexity will pose unprecedented challenges to the online-trigger system, for which a solution needs to be found. On one side, the current algorithms would be too slow to deal with the high level of particle combinatorics. On the other side, the event size will become too large to afford the persistence of all the objects in the event for offline processing. This will oblige to make a very accurate selection of the interesting parts in each event for all the possible channels, which constitutes a gargantuan task. In addition to the challenges for the trigger, the new conditions will also bring a large increase in background levels for many of the offline analyses, due to the enlarged particle combinatorics.

As a combined solution to the previous problems, we propose to evolve from the current signal-based trigger of LHCb towards a Deep-learning based Full Event Interpretation (DFEI) approach, where a new algorithm will process in real time the final-state particles of each event, with two goals: identifying which of them come from the decay of a beauty or charm heavy hadron and reconstructing the hierarchical decay chain through which they were produced. This high-level reconstruction will allow to automatically and accurately identify the part of the event which is interesting for physics analysis, allowing to safely discard the rest of the event. The usage of deep-learning is intended to fight the combinatorics problem, and exploit the complex correlations amongst all the particles in the event.

In this talk, we show the progress in the development of the first DFEI algorithm for LHCb, which is constructed as a sequence of Graph Neural Networks (GNN), where the final-state particles are represented as nodes. The algorithm has evolved from a first version, capable of performing a charged-particle filtering followed by a coarse clustering according to the common beauty-hadron ancestor (https://indico.cern.ch/event/1078058/contributions/453457 to a more complete one. The new developments include the processing of the neutral-particles in the event, on top of the charged ones, and a new reconstruction step in DFEI, whose goal is to infer the hierarchical structure of the decay chains that led to the production of the particles that were pre-selected in the previous steps. This last addition, also based on a GNN, takes inspiration from the reconstruction of the lowest-common-ancestor matrix, a technique recently proposed for the Belle II experiment. We have adapted the method to the LHCb environment, in which the number of possible different beauty- and charm-hadron decay chains to be reconstructed is much higher.

Primary authors: MAURI, Andrea (Nikhef National institute for subatomic physics (NL)); GARCIA PARDINAS, Julian (Universita & INFN, Milano-Bicocca (IT)); ESCHLE, Jonas (University of Zurich (CH)); CALVI, Marta (Univ. degli Studi Milano-Bicocca); SERRA, Nicola (University of Zurich (CH)); MELONI, Simone (Universita & INFN, Milano-Bicocca (IT))

Presenter: GARCIA PARDINAS, Julian (Universita & INFN, Milano-Bicocca (IT))

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