Search for $B^+ \to K^+ \nu\bar{\nu}$ at Belle II using a deep graph neural network

The Belle II experiment, located near Tokyo in Japan, is a large international particle physics experiment, aiming at discovering physics processes beyond the Standard Model of particle physics. Belle II has been operating since 2019 at the SuperKEKB asymmetric electron-positron collider facility, which targets the highest ever reached instantaneous luminosity of 6×10^{35} $cm^{-2}.s^{-1}$. Such luminosity will allow Belle II to record during the next decade a unique data set exceeding 50 billion $e^+e^- \to bb$, cc, ττ processes.

Recently the Belle II collaboration announced the first evidence of the $B^+ \to K^+ \nu\bar{\nu}$ decay, measuring a larger branching fraction than the one predicted by the Standard Model resulting in tension of 2.8 standard deviations. Belle II will remain in the foreseeable future the best experiment able to observe decays with neutrinos in the final state which are among the most promising to look for physics beyond the Standard Model.

In Belle II pairs of *B* mesons are produced in electron-positron collisions. As neutrinos from the signal are undetected, the other *B*, referred to as B_{tag}, must be considered to constrain their kinematic and correctly identify the signal decay. There are currently two strategies to reconstruct the B_{tag}: the untagged approach where the signal is reconstructed first and the rest of the event is assumed to be composed of only the other *B;* and the tagged approach, where the B_{tag} is reconstructed generically from one of its thousands of possible decay modes. Currently in the tagged approach the decay modes considered are explicitly defined and the total efficiency of the algorithm is of a few percents. The untagged approach allows a much larger total selection efficiency but at the cost of an increased background so that the physics reach of this method is similar to the one of the tagged approach.

The generic reconstruction of a *B* meson decay is a complex but hierarchical problem, with analogies to machine vision and other fields where deep learning brought tremendous improvements. In the framework of the FIDDLE ANR project we are developing a deep graph neural network to reconstruct a generic *B* decay directly from its final state particles without the need to explicitly define the possible decay modes. Preliminary studies shown that this algorithm can obtain a significantly higher efficiency than the tagged approach at constant background.

During this internship, the student will perform a feasibility study of the search for the $B^+ \to K^+ \nu\bar{\nu}$ decay with the deep graph neural network algorithm and will compare its performances with the tagged and untagged approach.

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