Sensitivity Study of $B \to \pi\nu\bar{\nu}$ with Tagging Methods at Belle II

Boyang Yu
LMU Munich

The flavour-changing neutral-current decays $B \to \pi\nu\bar{\nu}$ are rare processes in the Standard Model, occurring only through penguin or box diagrams at leading order, as illustrated in Figure 1. These decays are highly suppressed and have yet to be observed experimentally. The current upper limits on the branching fractions, set by the Belle experiment, are 1.4×10^{-5} for the charged channel and 9×10^{-6} for the neutral channel[1].

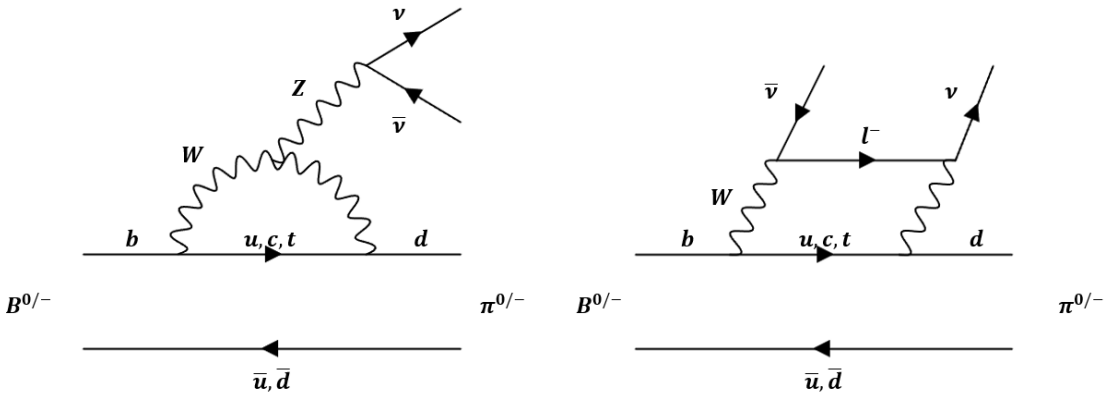

Figure 1: Feynman Diagrams of Penguin (left) and Box (right)

Additionally, the decay $B^- \to \tau^-(\to \pi^-\nu)\bar{\nu}$ (Figure 2) shares the same final states as the charged channel, with a branching fraction on the order of 10^{-5} [1]. As this decay might dominate the charged cases, it is considered as another signal channel in this study.

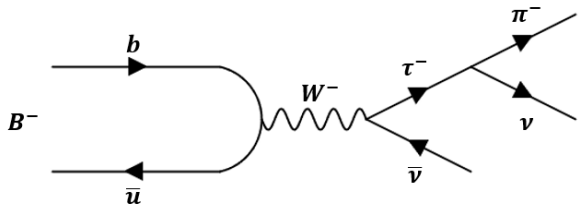

Figure 2: Feynman Diagram of Long-distance Decay

The presence of neutrinos in the final state means that kinematic information is missing, making the analysis challenging. To address this, analysts fully reconstruct one B meson, referred to as the tag-side, either hadronically or semi-leptonically, and identify

a single π meson from the other B as the signal-side. Kinematic and flavour constraints from tag-side are then used to select the appropriate signal candidates - a process known as tagging method.

In previous Belle studies, the NeuroBayes[2] algorithm was employed for hierarchical reconstruction of the tag-side. More recently, the Full Event Interpretation (FEI)[3] has become the state-of-the-art algorithm, offering enhanced hierarchical reconstruction for Belle II analyses. However, the FEI algorithm is limited by its low efficiency, with only about $O(1\%)$ of B decays being successfully reconstructed. To overcome this limitation, we are developing a new algorithm, HyperTagging.

The study is still at an early stage. In this talk, I will present our plan for a sensitivity study of $B \to \pi\nu\bar{\nu}$ using both FEI and HyperTagging as reconstruction algorithms. The goal is to compare their performance and assess the potential of HyperTagging to enhance the detection of rare decays.

References

[1] Navas S *et al.* [Particle Data Group] (2024) "Review of particle physics", Phys. Rev. D **110** (2024) no.3, 030001

[2] Feindt M *et al.* (2011) "A hierarchical NeuroBayes-based algorithm for full reconstruction of B mesons at B factories." Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, Vol. 654 (No. 1). pp. 432-440.

[3] Keck T *et al.* (2019) "The Full Event Interpretation", Comput Softw 3, 6