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Search for the Lepton Flavor Violating B+ → K+ τ (e, μ) with the Belle and Belle II detectors

Abstract :

For over a decade, many deviations from the Standard Model have been observed in semileptonic B-meson decays, for example, the departure from the lepton flavor universality in b → sll and b → c τ ν transitions. Many New Physics (NP) models trying to explain these results also predict a violation of the leptonic flavor (LFV). In this context, we are searching for the four B± → K± τ± l∓ (l={e,μ}) decay modes with the data sample collected by the Belle experiment. This analysis has never been performed at Belle nor Belle II, while some upper limits on the rates of such modes were previously set by the BaBar and LHCb experiments. For modes with missing energy -- as it is for our channels -- B-tagging is commonly exploited at B-factories to reduce the background. We use the hadronic B-meson reconstruction provided by the FEI algorithm, the official exclusive tagging package at Belle II. The reconstruction of one B-meson allows us to infer the properties of the other one and hence compute the Mrecoil, which is the observable used to extract the signal yield. In the absence of signal, we derive the upper limits on the branching ratios of B± → K± τ l modes, obtained with hadronic FEI and the full Belle dataset. The limits are of the order of a few 10-5 and are the most stringent to date. A key point to improve the experimental sensitivity with the available and future Belle II data is to boost the B-tagging performance and obtain higher efficiency. The first step in this direction consists in improving the description of B+ decays in the Belle Monte Carlo (MC) simulation. In fact, FEI uses machine-learning techniques to efficiently separate the signal from backgrounds. However, such methods are trained on MC, which, if incorrect, can lead to non-optimal FEI performance. One of the consequences is the large discrepancy between data and MC for the FEI tagging efficiency. We revise the MC simulation by focusing on the most relevant modes and significantly reduce the seen discrepancy. Other directions towards a higher efficiency are proposed in this manuscript; they include adding some new decay modes to FEI and recovering only partially reconstructed candidates. This thesis explores the possibility of using a semileptonic tag approach for the B± → K± τ l search. As opposed to the hadronic tag, the momentum of the B-meson cannot be measured; hence, the resolution on the Mrecoil is roughly a factor 5 worse. However, the semileptonic tag approach provides a high reconstruction efficiency because of the large branching ratios of B → D(*) l ν decays; we study how the different conditions in terms of resolution and background composition impact the final sensitivity. Additional constraints can be imposed based on the knowledge of the event kinematics. The usage of this information-only already improves the resolution of Mrecoil, especially for hadronic τ decays. We also try to exploit the vertexing information and study different resolution scenarios with the upgraded detector Belle II and accelerator SuperKEKB. Including those improvements, the semileptonic tag approach is competitive with fully reconstructed hadronic tags. This result is encouraging because it allows to exploit an independent data sample and opens other exciting prospects given the larger Belle II final dataset. The Belle II experiment has already accumulated a sample that is more than half that of Belle. Assuming that the anomalies are not disproved within a few years, the larger dataset combined with an optimized B-tagging strategy might lead to observing the LFV decays or strongly constraining the NP models associated with them.