A Novel Approach to Precision Determination of Vub Using Strange-Quark Fragmentation in Semileptonic Bs Decays

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The precise measurement of the Cabibbo–Kobayashi–Maskawa (CKM) matrix element Vub is an ongoing gap in our understanding of quark flavor physics and provides an important test of the Standard Model. Traditional approaches to measuring Vub are limited by theoretical and experimental uncertainties. The aim of this study is to develop a novel machine-learning approach that exploits strange fragmentation to improve the identification of signal events relevant for Vub? measurements. A gradient-boosted decision trees classifier was developed. The classification was performed in two stages. First, a track-level classifier was trained to identify kaons originating from strange fragmentation and distinguish them from other tracks in the event. In the second stage, an event-level classifier was applied. This classifier combines information from multiple tracks together with global event variables to determine whether the tracks in the event are consistent with a Bs signal decay. At the track level, the model achieved a 25% increase in ROC AUC compared to traditional selection methods. In addition, event level showed improved separation between signal and background, with improvement consistent with the track-level results. This suggests that the fragmentation approach can improve the efficiency of signal selection. This method is designed to be generalizable with analyses performed at CERN in the LHCb experiment and could improve sensitivity in measurements of Vub. More precise measurements of Vub would help test CKM matrix unitarity and resolve discrepancies between inclusive and exclusive determinations. Improving the precision of these measurements strengthens the ability of flavor physics experiments to test the consistency of the Standard Model.

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