Study of Exclusive $B \to \pi \ell \nu$ Decays with Hadronic Full-event-interpretation Tagging in Belle II Data and Extraction of $|V_{ub}|$

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Precision measurements of the magnitudes of the Cabibbo-Kobayashi-Maskawa (CKM)-matrix elements, which characterise the transitions between quarks of different flavours, are essential for testing the unitarity of the Unitarity Triangle (UT) described by the Standard Model of Particle Physics. Of particular interest is the measurement of the magnitude of the matrix element $|V_{ub}|$, which forms the dominant uncertainty in global UT fits. Using an exclusive approach, $|V_{ub}|$ can be measured from the differential decay rate of a decay involving a $b \to u$ quark transition, with the semileptonic B-meson decay $B \to \pi \ell \nu$ (where ℓ is a light lepton, either an electron, e or muon, μ) forming the gold standard for such a measurement.

The Belle II Experiment, located in Tsukuba, Japan, is a second-generation B-meson factory operating at the luminosity frontier, with a total target integrated luminosity of 50 ab^{-1} planned over its full operation, a number equivalent to producing roughly 50 billion B-meson pairs. With this large projected dataset, one aim of Belle II is to significantly improve the precision on the measurements of the CKM-matrix elements, including $|V_{ub}|$.

We present the results of a measurement of $|V_{ub}|$ in an early subset of Belle II data via an exclusive approach of the decays $B^0 \to \pi^- \ell^+ \nu$ and $B^+ \to \pi^0 \ell^+ \nu$. We reconstruct events in which the signal B-meson recoils against the other B-meson in an $\Upsilon(4S) \to B\bar{B}$ decay, which we explicitly reconstruct in a number of hadronic decay channels via a tagging algorithm known as the Full-event-interpretation [1]. We measure the partial branching fractions of these decays as a function of the squared four-momentum transfer to the leptonic system, q^2, and extract a measurement of $|V_{ub}|$ with input from current constraints provided by lattice quantum chromodynamics [2].

[1] T. Keck et al., The Full Event Interpretation – An exclusive tagging algorithm for the Belle II experiment, Comput. Softw. Big Sci. 3 (2019) 6.

[2] J. A. Bailey et al., |Vub| from B → πℓν decays and 2 + 1-flavor lattice QCD, Phys. Rev. D92 (2015) 014024.