Decoding beauty

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In the realm of particle physics, there's an ongoing effort to uncover the mysteries of the universe's fundamental particles and forces. At the heart of this endeavor lies the Large Hadron Collider at CERN, the world's largest particle accelerator. The LHCb experiment, located at the LHC, has made significant progress in understanding rare decays in the subatomic world, specifically focusing on the beauty quark. The work presented in this thesis delves into the investigation of rare decays using the LHCb detector, a task demanding precision, innovation, and perseverance.

But why rare decays? These infrequent processes hold the key to uncovering deviations from the Standard Model of particle physics, our current framework for understanding particle physics. Such deviations could point to new, undiscovered physics that might reshape our knowledge of the fundamental processes in the universe. The analyses presented in this thesis focus on decays of the beauty quark baryons, which have been studied less than their meson counterparts. As the branching fraction of the $\Lambda_b^0 \to J/\psi\,\Lambda$ decay is an input for other analyses, the improved measurement in this thesis allows for more precise measurements of other b-baryon decays. The $\Lambda_b^0 \to \Lambda\ell^+\ell^-$ decays are used to test lepton flavour universality, a fundamental property of the Standard Model. The work presented in this thesis provides a path towards the measurement of the lepton flavour universality ratio R_Λ, which will all be the first observation of the $\Lambda_b^0 \to \Lambda e^+e^-$ decay. The LHCb detector has recently been upgraded, including the use of scintillating fibre technology for the new SciFi tracking stations, enhancing its ability to track particles accurately and measure their properties. The upgrade provides an opportunity to study the beauty quark with high precision, and gives an increased sensitivity for measuring rare decays.

From a scientific perspective, the research performed at LHCb is significant. The analyses presented in this thesis contribute to a growing number of tests of the so-called flavour anomalies, potentially hinting at new physics beyond the Standard Model. Beyond CERN, the work has broader implications. Particle physics research often leads to technological innovations with real-world applications. New detector technologies, such as the SciFi detector, for example, have potential uses in medical imaging and material sciences. An example of this is the use of particle detectors in the development of the Positron Emission Tomography (PET) scanner, a medical imaging device used to detect cancer. Additionally, experiments like LHCb promote international cooperation and knowledge sharing, contributing to global scientific progress.

In conclusion, the work presented in this thesis focused on rare decays at the LHCb experiment and discussed the SciFi detector upgrade. The work provides an additional piece in the large puzzle of particle physics, contributing to the ongoing effort to understand the fundamental building blocks of the universe. From uncovering the mysteries of matter to driving practical technological advancements, fundamental particle physics research has far-reaching impacts on both the scientific community and society as a whole.