

Precision Studies of b -hadron Fragmentation Fractions at LHCb Experiment with 2024 data.

Our universe is made mostly of matter, not antimatter. This imbalance remains one of the biggest open questions in physics. According to current theories, matter and antimatter should have been created in equal amounts during the Big Bang. Yet, for reasons not fully understood, matter won out. One clue may lie in the tiny differences in how particles and their antiparticles behave—a phenomenon known as CP violation.

This project seeks to better understand CP violation by studying how beauty quarks (b -quarks) transform — or "fragment" — into different types of particles, known as b -hadrons, after high-energy collisions. The focus will be on measuring the probabilities that a b -quark turns into specific types of particles, such as B mesons and Λ_b^0 baryons. These probabilities, called fragmentation fractions, are essential inputs for precision tests of the Standard Model of particle physics.

Using new data collected in 2024 from the LHCb experiment at CERN, this research will provide the most accurate measurements to date of how these fragmentation fractions depend on the particle's motion (kinematics), specifically its transverse momentum and pseudorapidity. Previous measurements from earlier data-taking periods were limited in accuracy, but the much larger and higher-quality 2024 dataset offers a unique opportunity for significant improvement. Additionally, higher collision energy in 2024 data will allow for the exploration of the energy dependence of Λ_b^0 production.

The analysis will involve identifying specific decay processes of b -hadrons and comparing their frequencies. Advanced computational methods and statistical models will be used to extract these frequencies from the data. By correcting for detector effects using simulations and data-driven techniques, the team will produce a highly precise map of how fragmentation fractions vary across different conditions.

These results will sharpen our understanding of the fundamental interactions of elementary particles and will improve the accuracy of other measurements testing the validity of the Standard Model in the LHCb experiment, which rely on the knowledge of fragmentation fractions.

The project will be carried out by a team of researchers from IFJ PAN (Kraków) and CERN, using the latest software tools and high-performance computing resources. It builds on the team's expertise and prior contributions to high-energy physics and leverages their active involvement in the LHCb collaboration.

In summary, this project will deliver cutting-edge insights into one of the most fundamental mysteries of the cosmos — why there is more matter than antimatter — by making the most precise measurements yet of how b -quarks become b -hadrons in high-energy collisions at CERN.