One of the most fascinating challenges in modern physics is to uncover the hidden rules that govern the tiniest building blocks of matter. Among these are baryons – a family of particles that includes protons and neutrons, the familiar components of atomic nuclei, as well as heavier cousins containing strange or charm quarks. Baryons are characterized by their intrinsic spin, a quantum property that acts like a tiny compass needle and plays a central role in how they interact and decay, making them an ideal testing ground for exploring the most fundamental laws of nature.

A particularly interesting class of processes are semi-leptonic decays, in which a baryon transforms into another baryon while emitting lightweight particles such as electrons, muons, and neutrinos. These decays serve as a bridge between quarks and leptons and allow scientists to probe the transitions between different types of quarks, helping to extract values of the so-called Cabibbo-Kobayashi-Maskawa (CKM) matrix elements – fundamental numbers that describe how quarks mix and change identity, forming one of the cornerstones of the Standard Model of particle physics.

To push this research forward, a team of scientists from Poland and Sweden is launching a new study of strange and charmed baryon decays. Their approach takes advantage of the fact that baryons carry spin, which can be "polarized" – aligned in specific directions – to reveal subtle details of their internal structure and decay dynamics.

The work will be carried out at two world-leading facilities. The first is the BEijing Spectrometer III (BESIII) experiment at the Institute of High Energy Physics (IHEP) in Beijing, China, which makes it possible to reconstruct not only how baryons decay but also how they are produced, enabling precise measurements of so-called form factors – mathematical functions that describe the structure of baryons and control their decay patterns. These measurements will help test lepton flavor universality – the principle that electrons, muons, and tau particles should behave in the same way – and refine determinations of CKM matrix elements.

The second is the upcoming Compressed Baryonic Matter (CBM) experiment at the FAIR facility in Germany. Unlike BESIII, which studies baryons produced in electron–positron collisions, CBM will focus on baryons created in high-energy proton–proton and heavy-ion collisions. With its ability to record data at extraordinarily high rates, CBM will be capable of capturing hundreds of thousands of rare baryon decays each day, opening up new possibilities such as studying semi-leptonic decays of hyperons with unprecedented precision.

Together, the results from BESIII and CBM will provide a new window into the behavior of baryons, offering independent checks of the Standard Model's key parameters and potentially revealing hints of new physics. Additionally, the study will explore the roles of the CKM matrix elements, which describe the mixing between different generations of quarks and are integral part for understanding the dynamics of particle interactions.