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Abstract

Properties of Hyperon Decays

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Hyperons – bound states made of the three lightest quark flavors – play a significant role in our quest to understand the composition of matter. At low energies, where perturbative Quantum Chromodynamics breaks down, baryon interactions are dominated by forces keeping the quarks confined within the hadronic boundary. Hyperons, owing to their similarities to protons and neutrons, offer complementary information on the structure of matter, which can be probed via electromagnetic interaction. On another note, the observed baryonic asymmetry in the Universe has not been explained by the CP violation mechanism assumed in the Standard Model. Strange baryons offer a unique insight into new CP violation effects investigated in this thesis through weak nonleptonic decays.

At electron–positron colliders, hyperon–antihyperon pairs are copiously produced in vector charmonia decays in an inherently polarized state. We study the case where both baryons transition to fully hadronic final states, where the interference of the parity-conserving and parity-violating amplitudes results in an anisotropic distribution of the daughter particles. The related decay asymmetry parameters and the polarization observables can be extracted from the joint angular distribution of the final decay products. Using the spin-correlation terms within the pair, the baryon and antibaryon asymmetries are simultaneously measured, making these observables excellent candidates for testing CP symmetry.

This work presents a feasibility study of CP-violation tests for hyperon pairs produced in an electron–positron collider with a longitudinally polarized electron beam. The information from the production process with this new assumption is encoded in a “production matrix” and successively modified to account for the nonleptonic decays of the pair. Uncertainties of the CP-violation observables built on the decay asymmetries are parametrized in terms of the spin-polarization observables and extracted using an asymptotic maximum likelihood method. It is shown how the uncertainties are reduced in the presence of the beam polarization, identifying hyperon nonleptonic decays as a CP-violation source complementary to the kaon sector.

The spin-entanglement and polarization properties of the produced hyperons are further studied in the semileptonic decays of the pair. The same modular framework is used to derive the “decay matrix” describing a baryon semileptonic transition in a general way. Parameters related to the semileptonic form factors are defined, and their statistical uncertainties are also extracted using the asymptotic maximum likelihood method. The uncertainties depend on the initial baryon polarization and the spin-correlation properties within the produced pair. This dependence on the spin-polarization observables is shown, and the impact of the variables is compared for different semileptonic decays. In parallel, the modular framework is applied to radiative and Dalitz decays of spin-1/2 baryons to obtain their decay matrices.