Contribution ID: **83** Type: **poster presentation**

|Delta I| = 1/2 rule of hyperon decays in covariant baryon chiral perturbation theory

The ΔI = 1/2 rule is a universal pattern in weak interactions: decays involving an isospin change are dominated by transitions with ΔI = 1/2, far outweighing those with ΔI = 3/2. This regularity is surprising because weak interactions break many symmetries conserved in strong interactions, such as parity (P) and charge-parity (CP). Amid such extensive symmetry violation, the persistence of this rule is unexpected, making it a key puzzle in particle physics.

The famous example of ΔI = 1/2 rule is kaon decays, where it manifests as the isospin I = 0 final state being about 450 times more likely than the I = 2 state in K⟶ππ decays, reflecting the extreme enhancement of the ΔI = 1/2 transition over the ΔI = 3/2 transition. Specifically, the ratio of the real parts of the decay amplitudes, $Re(A_0)/Re(A_2)$, is measured to be approximately 22.4, a value far larger than naive expectations (Eur. Phys. J. C (2017) 77:10).

Lattice QCD calculations have offered key insights into the ΔI=1/2 rule. They reveal that the two dominant contributions to the ΔI=3/2 K⟶ππ correlation functions have opposite signs, leading to significant cancellation in ReA_2, with this effect present in calculations using physical quark masses and kinematics and for heavier pions at threshold. These contributions, which partially cancel in ReA_2, are the largest in ReA_0 and carry the same sign, thereby enhancing this amplitude (Phys. Rev. Lett. 110, 152001). These calculations, performed with physical quark masses and kinematics, have successfully reproduced the experimental value of A_2 and provided a non-perturbative foundation for understanding the rule's origin, though the precise dynamical mechanisms behind the large enhancement remain an active area of investigation (Phys. Rev. D 102, 054509).

Hyperons, as the hadronic counterparts of kaons, offer a complementary system to study the ΔI = 1/2 rule. Studying the ΔI = 1/2 rule in hyperons can provide supplementary information for understanding kaons and the relevant dynamical mechanisms in weak interactions. Early experimental results had large uncertainties, but theoretical studies, particularly within heavy-baryon chiral perturbation theory (HBChPT), suggested that the ΔI = 1/2 rule might also hold in hyperon decays, such as $\Lambda \longrightarrow p\pi^-$ and $\Lambda \longrightarrow n\pi^0$. These theories expect that observables like the ratio of asymmetry parameters ($\alpha\_\Lambda_0/\alpha\_\Lambda_-$) should approximate 1 if only ΔI = 1/2 transitions dominate. However, recent experiments, such as BESIII, reported deviations of around 10% in such ratios, suggesting at non-negligible ΔI = 3/2 contributions and challenging the strict validity of the rule in hyperon systems (arXiv:2508.03950). These results indicate that some important contributions may have neglected in previous theotical framework, such as some counterterms or parts of loop diagrams, which play a significant role in baryonic weak decays.

To address this discrepancy, we made efforts to re-examining the ΔI = 1/2 rule in hyperon decays using extended frameworks.We applied EOMS chiral perturbation theory to analyze the latest experimental data, with a more complete set of Feynman diagrams calculated.This research contributes to a deeper understanding of the ΔI = 1/2 rule and serves to examine the validity of chiral perturbation theory.

Research field of your presentation

Theoretical high-energy nuclear physics

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Session Classification: Young Scietist Session 5 (Poster)