

Non-mesonic weak decay of Λ -hypernuclei: a new determination of the Γ_n/Γ_p ratio[☆]

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Abstract

Theoretical descriptions of the non-mesonic weak decay of Λ -hypernuclei are unable to reproduce the experimental values of the ratio $\Gamma_n/\Gamma_p \equiv \Gamma(\Lambda n \rightarrow nn)/\Gamma(\Lambda p \rightarrow np)$. In this contribution we discuss a new approach to this problem. We have incorporated a one-meson-exchange model for the $\Lambda N \rightarrow nN$ transition in finite nuclei in an intranuclear cascade code for the calculation of double-coincidence nucleon distributions corresponding to the non-mesonic decay of ${}^5_\Lambda\text{He}$ and ${}^{12}_\Lambda\text{C}$. The two-nucleon induced decay mechanism, $\Lambda np \rightarrow nnp$, has been taken into account within a local density approximation scheme using a one-pion-exchange model supplemented by short range correlations. A weak decay model independent analysis of preliminary KEK coincidence data for ${}^5_\Lambda\text{He}$ allows us to extract $\Gamma_n/\Gamma_p = 0.39 \pm 0.11$ when the two-nucleon induced channel is neglected (i.e., $\Gamma_2 = 0$) and $\Gamma_n/\Gamma_p = 0.26 \pm 0.11$ when $\Gamma_2/\Gamma_1 = 0.2$.

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1. Introduction

An old challenge of hypernuclear studies has been to secure the “elusive” theoretical explanation of the large experimental values ($\simeq 1$) of the ratio, Γ_n/Γ_p , between the neutron-

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and proton-induced non-mesonic decay rates, $\Gamma_n \equiv \Gamma(\Lambda n \rightarrow nn)$ and $\Gamma_p \equiv \Gamma(\Lambda p \rightarrow np)$ [1,2].

Because of its strong tensor component, the one-pion-exchange (OPE) model supplies very small Γ_n/Γ_p ratios, typically in the interval 0.05–0.20 for s - and p -shell hypernuclei. On the contrary, the OPE description can reproduce the total non-mesonic decay rates observed for these systems. Other interaction mechanisms are then expected to correct for the overestimation of Γ_p and the underestimation of Γ_n characteristic of the OPE. Those which have been studied extensively in the literature are the following ones: (i) the inclusion in the $\Lambda N \rightarrow nN$ transition potential of mesons heavier than the pion (also including the exchange of correlated or uncorrelated two-pions) [3–6]; (ii) the inclusion of interaction terms that explicitly violate the $\Delta I = 1/2$ rule [1,7,8]; (iii) the inclusion of the two-body induced decay mechanism [9–12] and (iv) the description of the short range $\Lambda N \rightarrow nN$ transition in terms of quark degrees of freedom [13], which automatically introduces $\Delta I = 3/2$ contributions.

Some progress in the theory of non-mesonic decay has been experienced in the last years. A few calculations [4–6,13] with $\Lambda N \rightarrow nN$ transition potentials including heavy-meson-exchange and/or direct quark contributions obtained ratios more in agreement with data, without providing, nevertheless, an explanation of the origin of the puzzle [1]. Very recently, the $\Lambda N \rightarrow nN$ interaction has been studied within an effective field theory framework [14] with a weak decay model consisting of OPE, one-kaon-exchange and $|\Delta S| = 1$ four-fermion contact terms.

In the light of the experiments under way and/or planned at KEK [15], FINUDA [16] and BNL [17], it is important to develop different theoretical approaches and strategies for the determination of Γ_n/Γ_p from data. In this contribution we discuss an evaluation of nucleon–nucleon coincidence distributions in the non-mesonic weak decay of ${}^5_\Lambda\text{He}$ and ${}^{12}_\Lambda\text{C}$ [18]. This work is motivated by the fact that, in principle, correlation observables permit a *cleaner* extraction of Γ_n/Γ_p from data than single-nucleon observables. This is due to the elimination of interference terms between n - and p -induced decays [1], which are unavoidable in experimental data and cannot be taken into account by the Monte Carlo methods usually employed to simulate the nucleon propagation through the residual nucleus. For a detailed discussion of this issue see Ref. [18].

The calculations are performed by combining a one-meson-exchange (OME) model describing one-nucleon induced weak decays in finite nuclei with an intranuclear cascade code taking into account the nucleon final state interactions. The two-nucleon induced channel is also taken into account, treating the nuclear finite size effects by means of a local density approximation scheme.

We also perform a weak interaction model independent analysis to extract an estimate for Γ_n/Γ_p using preliminary results from KEK [15,19] on two-nucleon angular and energy correlations. The resulting Γ_n/Γ_p values for ${}^5_\Lambda\text{He}$ turn out to be substantially smaller than those obtained from single nucleon distributions analyses [20,21] and fall within the predictions of recent theoretical studies [5,6,13].

The work is organized as follows. In Section 2 we give an outline of the models employed to describe the non-mesonic weak decay and we discuss the main features of the intranuclear cascade simulation accounting for the nucleon propagation inside the residual

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