Nonmesonic weak decays of single-Λ and light double-Λ hypernuclei in the meson exchange model

K. Itonaga[a], T. Motoba[b] and T. Ueda[c]

[a] *Laboratory of Physics, Miyazaki Medical College, Kiyotake, Miyazaki 889-1692, Japan*
[b] *Laboratory of Physics, Osaka Electro-Commu. University, Neyagawa, Osaka 572-8530, Japan*
[c] *Chiyoda-cho Arita 1891, Hiroshima 731-1533, Japan*

Hypernuclear weak decay is best suited for studying the hyperon-nucleon and hyperon-hyperon weak interactions because the strange baryons are unstable in free space and are not available for the beam or the target in experiment. Very recently the double-Λ hypernuclei $^{6}_{\Lambda\Lambda}$He is beautifully confirmed by the emulsion experiment and the $\Lambda\Lambda$ binding energy $B_{\Lambda\Lambda}$ is extracted in a good resolution [1]. The present situation urges us to reexamine the strong and weak baryon-baryon interactions with strangeness from the viewpoints of weak decay mechanisms and hypernuclear structures.

We have studied the nonmesonic decays of single-Λ hypernuclei for the light-to-heavy ($A = 4 - 209$) mass systems in the one-π, correlated-2π ($2\pi/\rho$ and $2\pi/\sigma$) and one-ω exchange model and in the framework of the shell model and obtained the following results [2]. Calculated decay rates (Γ_{nm}) are consistent with the experimental data for the s- and p-shell hypernuclei and the decay rates tend to be nearly constant for $A \geq 60$. The ratio of the neutron-stimulated decay rate $\Gamma_n(\Lambda n \rightarrow nn)$ to the proton-stimulated one $\Gamma_p(\Lambda p \rightarrow np)$, Γ_n/Γ_p is very sensitive to the decay interactions. We notice that the correlated-2π and one-ω exchanges are important in explaining the large n/p ratios. Obtained n/p ratios are $0.3 - 0.5$ for the wide mass system which still deviate from the experimental data (≈ 1.0). More ingredients are needed for the decay interactions. The hypernuclear lifetimes are evaluated to be consistent with the general trends of the experimental data which show almost constant over the medium-to-heay mass systems.

The double-Λ hypernuclei are known to have new decay modes, i.e., the hyperon-induced nonmesonic decays $\Lambda\Lambda \rightarrow n\Lambda$, $p\Sigma^-$, $n\Sigma^0$ in addition to the nucleon-induced ones $\Lambda n \rightarrow nn$, $\Lambda p \rightarrow np$. The meson exchange potential models are adopted for the hyperon-induced nonmesonic weak decays [3]. We consider the $2\pi/\sigma$, one-ω and $2\pi/K^0$ exchange for the $\Lambda\Lambda \rightarrow n\Lambda$ process, while the one-π, $2\pi/\rho$ and $2\pi/K^0$ exhange for the $\Lambda\Lambda \rightarrow N\Sigma$ process. The double-Λ hypernuclear wavefunctions of $^{6}_{\Lambda\Lambda}$He and $^{10}_{\Lambda\Lambda}$Be are calculated in the cluster model where the $\Lambda\Lambda$-binding energies are fitted to the experimental data. The short-range correlations are properly treated in the initial and final two baryon systems. We have found that the decay rates of the $\Lambda\Lambda \rightarrow n\Lambda$ process (a few percent of the free Λ decay rate Γ_Λ) are several times larger than those of the $\Lambda\Lambda \rightarrow N\Sigma$ process for both $^{6}_{\Lambda\Lambda}$He and $^{10}_{\Lambda\Lambda}$Be. This is primarily due to the different nature of the decay potentials for those processes. The nucleon-induced nonmesonic decay rates are also evaluated for $^{6}_{\Lambda\Lambda}$He and are compared with the decay rates of $^{5}_{\Lambda}$He.

References

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