Quark-Pauli effect in the three baryon-octet systems

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We investigate the quark-Pauli effect in the three baryon-octet systems by calculating the eigenvalues of the corresponding normalization kernel. The quark-Pauli blocking effect is weak in the Λnn system, while it is strong in the $\Sigma^- nn$ system. The quark-Pauli repulsion is probably not a candidate for the repulsive three-body hyperon-nucleon interaction conjectured for the neutron star. It prevents the appearance of the Σ^--particle with increasing baryon density.

KEYWORDS: quark-Pauli effect, quark model, hyperon, three-body system

1. Introduction

The Pauli principle, among the quark-constituents of baryons, often brings important repulsive effects in the two-baryon system. For example, the repulsive Σ single-particle potential in nuclei [1] is considered to originate from the strong Pauli repulsion in the $\Sigma N(I = \frac{3}{2})\,{}^3S_1$ state [2]. It is interesting to study the quark-Pauli effect in the three-baryon systems because it is relevant to the neutron-star structure as well as the hypernuclear structure [3].

Earlier studies have been conducted on the quark-Pauli effect in the three-baryon systems. Toki, Suzuki and Hecht investigated the role of quark-Pauli effects on the central density of ^{3}He by the normalization kernel for the 9-quark 3-nucleon system [4, 5]. Takeuchi and Shimizu investigated the effect of quark antisymmetrization on the kinetic energy of n-nucleon $|\mathrm{N}^n\rangle$ and hypernuclear $|\Lambda\mathrm{N}^n\rangle$ systems ($n \leq 4$) by a simplified quark-cluster model [6].

In the present report, we investigate the quark-Pauli effect in the three-baryon systems including Λ, Σ, and Ξ-hyperons as well as the nucleon by investigating the eigenvalue of the corresponding normalization kernel.

2. Nine Quark Three Octet-Baryon States

The octet baryons (B_8) with spin $S = \frac{1}{2}$ contain N,Λ,Σ, and Ξ, all belonging to a member of the flavor $SU(3)$ symmetry $(\lambda\mu) = (11)$ in the Elliott notation [7]. They are classified by the $SU(2) \times U_1$ subgroup label $a = YI$, the hypercharge Y and the isospin I: $N(YI = 1\frac{1}{2})$, $\Lambda(YI = 00)$, $\Sigma(YI = 01)$, $\Xi(YI = -1\frac{1}{2})$. Assuming that B_8 is a three quark cluster, we describe its orbital part $\phi^{(\mathrm{orb})}(123)$ by the $(0s)^3$ harmonic-oscillator wave function with a common size parameter. Since $\phi^{\mathrm{orb}}(123)$ is completely symmetric and the B_8 color wave function $C(123)$ is completely antisymmetric, its spin-flavor part represented by $W^{[3]}(123)$ must be totally symmetric. By specifying the z-components of spin and isospin by S_z and I_z, respectively, a full quark-model description of B_8 reads

$$B_{S_z\alpha}(123) = \phi^{(\mathrm{orb})}(123)W^{[3]}_{S_z\alpha}(123)C(123), \tag{1}$$

where $\alpha = aI_z$.