ΛΛ Hypernuclei and H dibaryon: A Theoretical Search

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Introduction

The data on strangeness S = -2 hypernuclear system is very less, and no data exist for systems with higher strangeness content. The study of double -Λ hypernuclei could provide valuable information on ΛΛ interaction. Experimentally, double hypernuclei can be produced by separated K^- meson beam accelerator at Brookhaven National Laboratory (BNL), Japanese high energy accelerator research organization (KEK) and European Center for High Energy Physics (CERN). A high statistics measurement of double hypernuclear production has been made using high intensity AGS D6 K^- beam line [1]. The double hypernuclei can be produced via the double strangeness exchange reaction (K^-, K^+) by both direct production or by Ξ^- capture at rest by an emulsion atom. In later reaction meson beam is used to tag the production of Ξ^- hyperon, which is then slowed down in emulsion and captured at rest by an emulsion atom. In the following sections we discuss the theoretical frontiers of double-Λ hypernuclei.

The s-shell ${}_{\Lambda\Lambda}{}^{4}$H, ${}_{\Lambda\Lambda}{}^{5}$H, ${}_{\Lambda\Lambda}{}^{5}$He and ${}_{\Lambda\Lambda}{}^{6}$He Hypernuclei

The theoretical study of double-Λ hypernuclei started soon after the discovery. Among the well established double-Λ hypernuclei, the ${}_{\Lambda\Lambda}{}^{6}$He hypernucleus is best studied [2]. The knowledge of ΛΛ interaction was too poor, the earliest theoretical efforts on ${}_{\Lambda\Lambda}{}^{6}$He are based on a Hartee-Fock mean field calculations, which dates back to 1969. With the advent of Quantum Monte Carlo techniques, the many-body approach aiming to perform microscopic calculations of nuclei and hypernuclei had taken a new turn. The realistic NN and NNN potentials in the non-strange sector to describe nuclear spectra have been evolving for quite a long time. Now, we have well established Argonne v18 N N potential and Urbana type NNN potential. The information on non-strange sector potentials is inevitably required for hypernuclei made up of nucleons and hyperons. Thus, for such systems, these potentials have to be used in conjunction with NN and ΛNN , ΛΛ and ΛΛN potentials.

The earlier calculations however were quite simple based upon central potentials and a wave function involving central correlations. In the simplest approach all the four nucleons of ${}_{\Lambda\Lambda}{}^{6}$He are treated as an alpha cluster and calculations have been performed using αΛ nuclear potentials. On the other hand, central ΛN potentials have been used at a microscopic level. However, as a marked difference this was performed using Nijmegen simulated ΛΛ potentials. Undoubtedly, this study is for from being realistic as it involves only central potentials and correlations. An improved VMC study involving a realistic Hamiltonian and operatorial correlations has also appeared but it ignores space-exchange correlation (SEC) in the wave function [3]. It is evident from a recent work that a study ignoring SEC would be deficient and misleading as it significantly affects every physical observable [4]. The SEC effects are expected to be more evident in ${}_{\Lambda\Lambda}{}^{6}$He hypernucleus because of the presence of a pair of hyperons. The Faddeev-Yakubovsky calculations have been extended to all the s-shell single- and double-Λ hypernuclei. In this approach, several ΛΛ potential models have been used to calculate $\Delta B_{\Lambda\Lambda}({}_{\Lambda\Lambda}{}^{6}\mathrm{He})$, $\Delta B_{\Lambda\Lambda}$ $({}_{\Lambda\Lambda}{}^{5}\mathrm{He})$ and $\Delta B_{\Lambda\Lambda}({}_{\Lambda\Lambda}{}^{5}\mathrm{H})$. The I=1/2 (${}_{\Lambda\Lambda}{}^{6}$H - ${}_{\Lambda\Lambda}{}^{6}$He) hypernuclei are found to be particle stable for all the potential strenghts. Calculations have also been performed on ${}_{\Lambda\Lambda}{}^{4}$H in order to explore bound state for it. However, calculations yield a negative result even for the strong ΛΛ strenghts. In contradiction to it, Nemura found a bound state for ${}_{\Lambda\Lambda}{}^{4}$H in their variational research using 4×4 Hamiltonian. However, various strenghts of this Hamiltonian are uncertain specially those falling in the strangeness S = -2 sector. This subject is open for debate.

The p-shell $_{\Lambda\Lambda}{}^{10}$Be and $_{\Lambda\Lambda}{}^{13}$B hypernuclei

Theoretical complexities increase with increasing baryon number. As a consequence, microscopic calculations based on BB and BBB interactions have yet not performed on these two systems. However, some cluster model calculations on $_{\Lambda\Lambda}{}^{10}$Be are available in the literature. The most recent among them is FaddeevYakubovsky calculations. Some old VMC calculations also exist, where in this hypernucleus is treated as a system of ααΛΛ (two αs+two Λs). There are other p-shell hypernuclear calculations on A = 7 - 10 ΛΛ hypernuclei. Similar calculations are not available on the other event, $_{\Lambda\Lambda}{}^{13}$B.

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H DIBARYON

The H dibaryon is a six quark state (uuddss) in a single QCD bag and not a deutron like baryon molecule. It has strangeness -2, spin and isospin singlet, and positive parity. H dibaryons may exist separate entity inside double hypernucleus, or they can exist inside the core of neutron star. The H dibaryon are directly related to the double-Λ hypernuclei, because the binding energy of two Λs is directly related to the lower limit of H dibaryon mass. The first H dibaryon was predicted by Jaffe [5] using MIT bag model bound by attractive color magnetic interaction between the quarks. Using this model Jaffe calculated its mass about 2150 MeV, which is less than the ΛΛ threshold (2231 MeV) by 81 MeV. Experimentally, the H dibaryon may be produced via (K^-, K^+) reaction, heavy ion collision, p- nucleus annihilation reaction etc. However, no clear experimental evidence has been found for existence of H dibaryon till now. Some theoretical models such as nonrelativistic quark cluster model, Skyrme model, QCD sum rule and lattice QCD which are applied to calculate the mass of H dibaryon. Some of them predict the bound states. The fully Variational Monte Carlo study with space-exchange correlations could provide valuable information about H dibaryon. We are proceeding in this direction.

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References

[1] H. Akikawa *et. al.*, Phys. Rev. Lett. **88**, (2002) 082501.

[2] H. Takahashi *et. al.*, Phys. Rev. Lett. **87** (2001) 121502.

[3] Q. N. Usmani, A. R. Bodmer and B. Sharma, Phys. Rev. C **70** (2004) 061001(R).

[4] A. A. Usmani, Phys. Rev. C 74, (2006) 011302(R).

[5] R. L. Jaffe, Phys. Rev. Lett. **38**, (1977) 195.