Shell model spectra of light hypernuclei with $\Lambda N$ and $\Lambda NN$ forces: the final results concerned hyperon-nucleon interaction parameters

V.N. Fetisov
Lebedev Physical Institute, Russian Academy of Sciences, Moscow 119991, Russia

Abstract

Low lying spectra of light hypernuclei are analyzed using data on hypernuclear $\gamma$-lines [1] in the framework of the shell model motivated in ref. [2] where in addition to the $\Lambda N$ effective interaction with two-body parameters $\Delta$, $S_\Lambda$, $S_n$ and $T$ [3] the phenomenological zero-range three-body force

$$V = \delta(r_\Lambda - r_1)\delta(r_\Lambda - r_2)(t + t_s\sigma_\Lambda(\sigma_1 + \sigma_2))$$

has been introduced. Matrix elements $(s_\Lambda sp|V|s_\Lambda sp)$, $(s_\Lambda p^2|V|s_\Lambda p^2)$ were calculated with the oscillator wave functions for nucleons and with the Woods-Saxon potential wave functions for a $\Lambda$ particle. The calculations show an extremely weak $t$-dependence of energy splittings and for definiteness sake we take $t=176$ MeVfm$^6$ [2]. Using the $(3/2^+, 5/2^+)$ doublet splitting (DS) in $^9\Lambda$Be and three levels $(1^{-}, 1^{+}, 2^{-})$ in $^{16}\Lambda$O the values of $\Delta$, $S_n$, $T$ and $t_s$ have been found as functions of $S_\Lambda$ in the interval $-0.015 \leq S_\Lambda \leq -0.006$ (MeV). Spectra of $^9\Lambda$Be, $^{10}\Lambda$B, $^{11}\Lambda$B, $^{12}\Lambda$C, $^{13}\Lambda$C, $^{15}\Lambda$N, $^{16}\Lambda$O were calculated with the common values of $S_n$, $T$ and $t_s$ using the total set of the $0\hbar \omega$ nuclear states. Small variations of $\Delta_\Lambda$ were taken into account by the scaling factor $\alpha_\Lambda$ ($\Delta_\Lambda = \alpha_\Lambda \Delta_{16}$) estimated for the Gaussian shape of the $\Lambda N$ potential. The $S_\Lambda$-dependence of the ground state DS in $^{12}\Lambda$C and $^{13}\Lambda$B derived with the NN forces CKB(I,II,III) (the Cohen-Kurath interaction corrected by Barker) [4] excludes the interactions CKB(I,III) whereas the variant CKB(II) reproduces the observed DS (161 keV and 264 keV) in the vicinity of $S_\Lambda \simeq -0.007$. As this takes place, the unobserved DS in $^{10}\Lambda$B does not exceed 70 keV. The acceptable parameters are $\Delta_{16}=0.082$, $S_\Lambda=-0.007$, $S_n=-0.33$, $T=0.023$ (MeV) and $t_s=216.5$ MeVfm$^6$. In this model the calculated values $\Delta$ and $|S_\Lambda|$ are considerable less than ones given in ref. [5]. The description of DS in $^7\Lambda$Li demands the higher value of $\Delta$ that reflects an influence of the cluster structure of $^7\Lambda$Li [6].

References