CREST Research Project 3: Study of hyperon-hyperon, hyperon-nucleon, and high energy nucleon-nucleon interactions (Igor Filikhin - project PI, V. M. Suslov and B. Vlahovic, NCCU, Physics)



Activity:

- Spectroscopy of the 7_{Λ} He hypernucleus
- I. Filikhin, V.M. Suslov and B. Vlahovic Spectroscopy of ⁷_ΛHe hypernucleus within three-cluster model, Physics of Atomic Nuclei, 2009, Vol. 72, No. 4, pp. 580–587.
 - Spectroscopy of the ⁹_ABe and ⁹Be nuclei
- Filikhin, V. M. Suslov and B. Vlahovic, An alpha-cluster model for ⁹ Be spectroscopy, accepted to Phys. Atom. Nucl. (2011).
 B.Vlahovic, I. Filikhin, V.M. Suslov, Low-lying spectra of ⁹ Be and ⁹Be within three-cluster model, 12th International Conference
- on Meson-Nucleon Physics and the Structure of the Nucleon (MENU 2010) AIP Conf. Proc. 1374, 201-204 (2011)
- B.Vlahovic, I. Filikhin, V.M. Suslov, Faddeev calculations for the ⁹ Be, European Physical Journal (EPJ Conferences) 2009.
 - Three body model for ${}^{6}_{\Lambda}$ He and ${}^{12}_{\Lambda}$ Be hypernuclei (in progress)

External Committee Board Meeting November 18, 2011



Faddeev calculation: -6.23 meV



Spectroscopy of the ${\bf 7}_{\Lambda}{\rm He}$ hypernucleus

Our findings are:

• The calculations using OBE simulating potential for NSC97f model of NY-interaction give the 7AHe binding energy (5.35 MeV) which is close to the preliminary experimental value (5.4 MeV or 5.74 MeV ?).

• We discussed the receipt for extracting hyperon binding energy from the three-body calculation. The value obtained in previous calculation by E. Hiyama et al. has to be corrected. The new corrected value agrees with our consideration.

• We predicted new value for He6L ground state energy of 0.25 MeV (compare with the E.Hiyama at al. result of .36 MeV)

• We have found that the ground band of the 7∧He spectrum can be classified as an analog of the 6He ground band



- - - C. Daskaloyannis, M. Grypeos, H. Nassena, Phys. Rev. C 26 (1982) 702.



Numerical results: spectra



O. Hashimoto, H. Tamura / Progress in Particle and Nuclear Physics 2006



Calculated (Cal.) and experimental (Exp.) spectrum of ${}^{9}\text{Be}$ and ${}^{9}_{\Lambda}\text{Be}$. Orbital and total momentum of each levels are shown. Energy is measured from a+ a+L and a+ a+n thresholds, respectively.



Spectroscopy of the ${}^{9}_{\Lambda}$ Be and 9 Be nuclei

Our findings are:

• We found the set of phenomenological potentials to reproduce the ground state $\frac{1}{2}$ + binding energy and excitation energy of the 5/2+ and 3/2+ states, simultaneously.

• Our calculations reproduce well the experimental data for excitation energies

• For ⁹ Be we found the set of local phenomenological potentials that reproduces well the ground state binding energy and reasonable -- the energies of low-lying resonances. Also we give classification of experimental data for low-lying spectrum as a set of spin-flip doublets.

• It is shown that for each energy levels of ⁹_A Be one can establish a correspondence to the ⁹Be spectrum with the exception of several "genuine hypernuclear states", that agrees qualitatively with previous studies.

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Three-body model for ${}^{6}_{\Lambda}$ He hypernucleus (in progress)



Configuration space Faddeev eqautions:

$$\{H_0 + V_\alpha(u_\alpha) - E\}\Psi_\alpha(\mathbf{u}_\alpha, \mathbf{v}_\alpha) = -V_\alpha(u_\alpha)\sum_{\beta\neq\alpha}\Psi_\beta(\mathbf{u}_\beta, \mathbf{v}_\beta)$$

where V_{α} is a short-range pair interaction in the channel α , $H_0 = -\Delta_{\mathbf{u}_{\alpha}} - \Delta_{\mathbf{v}_{\alpha}}$ is the internal kinetic energy operator, E is the total energy and the wavefunction of the three-body system is given as a sum $\Psi = \sum_{\alpha=1}^{3} \Psi_{\alpha}$ over the three Faddeev components, corresponding to the two-body rearrangement channels.

Three-body models for other hypernucleus (in progress)



Figure 3: Cluster models for light Hypernuclei. The red arrows mean that three-body models are obtained from corresponding two-body models by including one nucleon. a) The ${}_{\Lambda}^{6}$ He and ${}_{\Lambda}^{7}$ Li hypernuclei as two-body and three-body systems. b) Systems ($\Lambda + k * \alpha$)+N and ($\Lambda + k * \alpha$)+N+N, k = 1, 2, 3 (two- and three-body systems). The core nucleus is shown for each k. The nuclei, which will be predicted in proposed work, are also shown. The case shown in Figure (a) is obtained with k = 1.



Figure 4: Hypernuclear chart. The hypernuclei which will be involved in the work on the present project marked by colored backgrounds. The arrows show the nuclei for which the binding energy will be predicted in proposed work. Blue background corresponds to two-body calculations of the type Core+N; the green background corresponds to three-body calculations of the type Corenucleus+N+N; red background corresponds to four-body calculations for the $3\alpha + \Lambda$ system.

Cluster calculations for the ${}^{12}_{\Lambda}$ Be (${}^{12}_{\Xi}$ Be) hypernucleus

In this section we propose to consider hypernuclear systems ${}^{10}\text{Be}+n + \Lambda$ and ${}^{10}\text{Be}+n + \Xi$ as cluster model for the ${}^{12}_{\Lambda}\text{Be}$ and ${}^{12}_{\Xi}\text{Be}$ hypernuclei. The experimental evidence for existence of ${}^{12}_{\Xi}\text{Be}$ was reported in [47] (see also K. Ikeda, et al, Prog. Theor. Phys. 91 (1994) 747; Y. Yamamoto, et al, Prog. Theor. Phys. Suppl. 117 (1994) 281). The phenomenological potential for ${}^{10}\text{Be}+n$ interaction was obtained in [*]. For ${}^{10}\text{Be}+\Xi$ interaction different type of potentials will be proposed (Woods-Saxon and Isle potentials). Note that new experiments for ${}^{12}_{\Xi}\text{Be}$ are planed at the J-PARC 50 GeV Proton Synchrotron (see T. Nagae, *Spectroscopic Study of* Ξ -*Hypernucleus* ${}^{12}_{\Xi}\text{Be}$, *via the* (K-,K+) *Reaction*, HYP06 at Mainz).

JLab Hall A





Experimental data for bound states of ${}^{10}_{\Lambda}$ B given from H. Tamura (γ -Ray Detector Symposium, December 27, 2004)

John Millener: shell-model 5 theory peaks: ${}^{11}B(\frac{3}{2}^-;g.s) \otimes s_{\Lambda}(1^-/2^-), {}^{11}B(\frac{1}{2}^-;2.12) \otimes s_{\Lambda}(1^-),$ ${}^{11}B(\frac{3}{2}^-;5.02) \otimes s_{\Lambda}(1^-/2^-), {}^{11}B(\frac{3}{2}^-;g.s) \otimes p_{\Lambda}(2^+/3^+), {}^{11}B(\frac{1}{2}^-;2.12) \otimes s_{\Lambda}(1^+/2^+)$

[*] C. Romero-Redondo, E. Garrido, D.V. Fedorov, A.S. Jensen, Phys. Lett. B 660 (2008) 32.