Subnuclear System Research Division
Strangeness Nuclear Physics Laboratory

1. Abstract

We proposed accurate calculation method called 'Gaussian Expansion Method using infinitesimally shifted Gaussian lobe basis function.' When one proceeds to four-body systems, calculation of the Hamiltonian matrix elements becomes much laborious. In order to make the four-body calculation tractable even for complicated interactions, the infinitesimally-shifted Gaussian lobe basis function has been proposed. The GEM with the technique of infinitesimally-shifted Gaussians has been applied to various three-, four- and five-body calculations in hypernuclei, the four-nucleon systems, and cold-atom systems. As results, we succeeded in extracting new understandings in various fields.

2. Major Research Subjects

(1) Structure of Hypernuclei and neutron-rich nuclei from the view point of few-body problem
(2) Structure of exotic hadron system
(3) quantum atomic system and ultra cold atomic system
(4) Equation of state for neutron star

3. Summary of Research Activity

(1) We study Λ hypernuclei of C and B isotopes. We calculated Λ binding energies of these Λ hypernuclei and found halo structure in the Λ $1p$ state with extended wave functions. In addition, we propose to measure electric-dipole transition between Λ $1p$ and $1s$ states to see evidence for this hyperon halo structure.
(2) Bound states of double-heavy tetraquark systems are studied in a constituent quark model. We have two bound states for $T = 0$, $J^{\pi} = 1^{+}$ in bbu-bar u-bar system. One is deeply bound state and the other is a shallow bound state. The former state is in good agreement with the result by lattice QCD.
(3) We investigate the miscibility of two kinds of bosons with repulsive interactions. In addition to the known miscible and immiscible phases, we predict a partially miscible phase due to quantum fluctuations. It leads to the formation of mixed bubbles that are similar to quantum liquid droplets found in attractive mixtures and could be observed in experiments.

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List of Publications & Presentations

Publications

[Original Papers]

Y. Kim, E. Hiyama, M. Oka, and K. Suzuki, "Spectrum of singly heavy baryons from a chiral effective theory of diquarks," Phys. Rev. D **102**, 014004 (2020).

T. -W. Wu, M. -Z. Liu, L. -S. Geng, E. Hiyama, M. P. Valderrama, and W. -L. Wang, "Quadruply charmed dibaryons as heavy quark symmetry partners of the DDK bound state," Eur. Phys. J. **80**, 901 (2020).

Q. Wu, Y. Funaki, E. Hiyama, and H. Zong, "Resonant states of ${}^{9}_{\Lambda}$Be with $\alpha + \alpha + \Lambda$ three-body cluster model," Phys. Rev. C **102**, 054303 (2020).

A. Nay L. Nyaw, K. Nakazawa, *et al*., "Observation of double-strangeness nuclei using nuclear-emulsion technology," Bull. Soc. Photogr. Imag. Jpn. **30**, 2 22–25 (2020).

T. Yamashita, Y. Kino, E. Hiyama, S. Jonsell, and P. Froelich, "Near-threshold production of antihydrogen positive ion in positronium-antihydrogen collision," New J. Phys. **23**, 012001 (2021).

S. H. Hayakawa, K. Nakazawa, *et al*. (J-PARC E07 Collaboration), "Observation of coulomb-assisted nuclear bound state of Ξ^{-}-^{14}N system," Phys. Rev. Lett. **126**, 062501 (2021).

J. Yoshida, K. Nakazawa, *et al*., "CNN-based event classification of alpha-decay events in nuclear emulsion," Nucl. Instrum. Methods Phys. Res. A **989**, 16430 (2021).

N. Yamanaka and E. Hiyama, "Weinberg operator contribution to the nucleon electric dipole moment in the quark model," Phys. Rev. D **103**, 035023 (2021).

Q. Meng, E. Hiyama, A. Hosaka, M. Oka, P. Gubler, K. U. Can, T. T. Takahashi, and H. S. Zong, "Stable double-heavy tetraquarks: Spectrum and structure," Phys. Lett. B **814**, 136095 (2021).

P. Naidon and D. S. Petrov, "Mixed bubbles in Bose-Bose mixtures," Phys. Rev. Lett. **126**, 115301 (2021).

[Proceedings]

J. Carbonell, E. Hiyama, R. Lazauskas, and F. M. Marques, "^{19}B isotope as a ^{17}B-n-n three-body cluster close to unitary limit," J. Phys. Conf. Ser. **1643**, 012120 (2020).

Presentations

[International Conferences/Workshops]

P. Naidon (invited), "A partial mixing of quantum gases," Yamada Conference LXXII: The 8th Asia-Pacific Conference on Few-Body Problems (APFB2020), Kanazawa, Japan, March 1–5, 2021.

P. Naidon (invited), "Mixed bubbles in repulsive Bose-Bose mixtures," The 5th Symposium on Clustering as a Window on the Hierarchical Structure of Quantum Systems, September 24, 2020.

T. Fukui (oral), "Chiral three-body force and shell evolution," Yamada Conference LXXII: The 8th Asia-Pacific Conference on Few-Body Problems in Physics (APFB2020), Kanazawa, Japan, March 1–5, 2021.

C. Schmickler, "Origin of the three-body parameter of the Kartavtsev-Malykh crossover trimer," Yamada Conference LXXII: The 8th Asia-Pacific Conference on Few-Body Problems in Physics (APFB2020), Kamazawa, Japan, March 1–5, 2021.

[Domestic Conferences/Workshops]

P. Naidon (poster), "A new kind of bubble," The 22nd RIKEN Interdisciplinary Exchange Evening, September 25, 2020.

福井徳朗 (口頭発表), 「カイラル相互作用による軽い核のクラスター構造の理解に向けて」, 日本物理学会第 76 回年次大会, オンライン, 2021 年 3 月 12–15 日.

[Seminars & Lectures]

P. Naidon (invited), "Universal few-body physics," 4-Part Lecture at Hokkaido University Nuclear Theory Group, February 16, 2021.
P. Naidon (invited), "Mixed bubbles in repulsive Bose-Bose mixtures," Kindai University, December 16, 2020.
P. Naidon (invited), "Universal few-body physics," 2-Part Lecture at Strange Nuclear Physics School 2020, December 2–5, 2020.
P. Naidon (invited), "QCD-like phase diagram of resonantly interacting SU(3) Fermi gases," Kyushu University, July 10, 2020.

Press Releases

「極低温での新しい量子相 "混合バブル" を予言—混和性・非混和性の中間に存在する部分混和性の発見—」, 2021 年 3 月 22 日.