Nuclear Science Research Division
Three-Body Nuclear Force Laboratory

1. Abstract

Three-body nuclear force (3BNF), the forces where three nucleons (baryons) interact, is a key element in the accurate description of nuclear phenomena. The main topic of this laboratory is the experimental study of the 3BNFs, which includes high-precision experiments on few-nucleon systems, development of nuclear polarization technology, and polarization measurement technology. Our goal is to apply high-precision nuclear forces with the 3BNF to various nuclear phenomena and to accelerate the understanding of nucleosynthesis and neutron star properties, which are of high interest in pure fundamental science, but also to advance the creation of new applied sciences and technologies.

2. Major Research Subjects

(1) Investigtions of few-nucleon systems
(2) Developments of nuclear polarization technology and polarization measurement technology

3. Summary of Research Activity

Few-nucleon scattering offers good opportunities to investigate three-nucleon forces by direct comparison between the rigorous numerical calculations and the high-precision data. In pursuit of establishing the 3*N*F within the framework of the chiral effective field theory (χEFT), we seek to determine the low-energy constants in the 3*N*F sector based on experimental data in few-nucleon scattering systems.

The first planning measurement is the spin correlation coefficient for deuteron-proton (*d*-*p*) elastic scattering at 100 MeV/nucleon. A polarized deuteron beam, a polarized proton solid target, and a measurement system are required to measure the spin correlation coefficient of *d*-*p* elastic scattering. In FY2024, an ion source to provide a polarized deuteron beam was prepared, and beam acceleration tests were carried out at the RIKEN RIBF. As a result, it was confirmed that a beam polarization of 60–80%. In January 2024, a beam irradiation experiment using the whole arrangement of the detector system KuJyaku in conjunction with the polarized proton solid target system was conducted with the unpolarized deuteron beam at 135 MeV/nucleon at the E3A course. As for the polarized proton solid target, it was confirmed that depolarization due to radiation damage of deuteron beams below 10^8 counts/second was negligible. Subsequent analysis showed that the target polarization was as low as 3% and that further development was required. The analysis for the KuJyaku system was performed and found that it is capable of measuring spin observables in *d*-*p* scattering.

Members

Director

Kimiko SEKIGUCHI

Assistant

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List of Publications & Presentations

Publications

[Original Papers]

K. Sekiguchi, "experiments of few-nucleon scattering to explore three-nucleon forces," Few-Body Systems **65**, 45 (2024).

S. Endo, E. Epelbaum, P. Naidon, Y. Nishida, K. Sekiguchi, and Y. Takahashi, "Three-body forces and Efimov physics in nuclei and atoms," Eur. Phys. J. A **61**, 9 (2024).

K. Miki,K. Kameya, D. Sakai, R. Urayama, N. Imai, S. Ishikawa, S. Michimasa, S. Ota, M. Sasano, H. Takeda, T. Uesaka, H. Haba, M. Hara, Y. Hatano, T. Hayamizu, N. Kobayashi, A. Tamii, S. Adachi, T. Chillery, M. Dozono, Y. Fujikawa, H. Fujita, N. Fukuda, T. Furuno, J. Gao, S. Goto, S. Hanai, S. Hayakawa, Y. Hijikata, K. Himi, Y. Hirai, J. W. Hwang, M. Ichimura, D. Inomoto, M. Inoue, H. Kasahara, T. Kawabata, K. Kishimoto, S. Kitayama, K. Kusaka, J. Li, Y. Maeda, Y. Maruta, T. Matsui, T. Matsuzaki, S. Nakai, H. Nishibata, M. Otake, Y. Saito, H. Sakai, A. Sakaue, H. Sato, K. Sekiguchi, Y. Shimizu, S. Shimoura, L. Stuhl, T. Sumikama, H. Suzuki, R. Tsuji, S. Tsuji, H. Umetsu, Y. Utsuki, T. Wakasa, A. Watanabe, K. Yako, Y. Yanagisawa, N. Yokota, C. Yonemura, K. Yoshida, and M. Yoshimoto, "Precise spectroscopy of the $3n$ and $3p$ systems via the ^{3}H$(t, ^3$He$)3n$ and ^{3}He$(^3$He$, t)3p$ Reactions at Intermediate Energie," Phys. Rev. Lett. **133**, 012501 (2024).

K. Sekiguchi, "Review of the experimental activity at RIKEN to explore the three-nucleon interactions," Proceedings of the 10th International Workshop of the Chiral Dynamics, PoS (CD2021) 089 (2024).

Presentations

[International Conferences/Workshops]

K. Sekiguchi (invited), "Deuteron-proton scattering to investigate three-nucleon forces," the 23rd International Few-Body Conference in Physics (FB23) , Beijing, China, September 22– 27, 2024.

Y. Saito, K. Sekiguchi *et al.*, “Plan of spin correlation coefficient measurement of deuteron-proton scattering at intermediate energies,” the 23rd International Few-Body Conference in Physics (FB23), Beijing, China, September 22– 27, 2024.

K. Sekiguchi (invited), “Experiments on three-nucleon forces—recent topics—,” Workshop on Nucleosynthesis and Evolution of Neutron Stars, Yukawa Institute of Theoretical Physics, Kyoto Univertisy, Kyoto, Japan, Janurary 27–30, 2025.

[Domestic Conferences/Workshops]

鈴木小太郎, 関口仁子他, 「偏極陽子固体標的を用いた重陽子-陽子弾性散乱の測定」, 日本物理学会第 79 回年次大会, 北海道大学, 2024 年 9 月 16 日–19 日.

菅原宙希, 関口仁子他, 「重陽子-陽子弾性散乱測定に向けた偏極重陽子ビームの整備」, 日本物理学会第 79 回年次大会, 北海道大学, 2024 年 9 月 16 日–19 日.

髙橋大智, 関口仁子他, 「重陽子-陽子弾性散乱スピン相関係数測定のための室温偏極陽子固体標的の実現に向けた研究」, 日本物理学会第 79 回年次大会, 北海道大学, 2024 年 9 月 16 日–19 日.

関口仁子 (招待講演), 「三体核力～原子核物理の新しい物質観～核データにつなげたいという思い」, 核データ研究会, 熊取交流センター すまいるズ 煉瓦館, 2024 年 11 月 15 日.

関口仁子 (招待講演), 「三体核力研究と核データ応用への期待：三体核力—原子核物理の新しい物質観—」, 日本原子力学会 2025 年春の年会, 核データ部, オンライン, 2025 年 3 月 12 –14 日.

髙橋聖弥, 関口仁子他, 「CW-NMR 法を用いた偏極陽子標的の偏極度測定システムの実装とレーザー光学系の改良」, 日本物理学会 2025 年春の年会オンライン, 2025 年 3 月 18 日–21 日.

丸山凱生, 関口仁子他, 「重陽子-陽子散乱に向けた偏極重陽子ビームの偏極度測定」, 日本物理学会 2025 年春の年会オンライン, 2025 年 3 月 18 日–21 日.

[Seminars]

K. Sekiguchi, “Experiments on Three-Nucleon Forces in Nuclei,” NEWS コロキウム, 大阪大学, 2024 年 5 月 22 日.

関口仁子, 「三体核力～原子核物理の新しい物質観～」, 物理談話会, 大阪公立大学, 2024 年 5 月 23 日.

関口仁子, 「三体核力～原子核物理の新しい物質観～」, ワイン & チーズセミナー, 京都大学, 2024 年 7 月 1 日.

関口仁子, 「三体核力～原子核物理の新しい物質観～」, セミナー, 新潟大学, 2025 年 2 月 18 日.

Award

関口仁子, 令和 6 年度文部科学大臣表彰・科学技術賞 (研究部門), 文部科学省, 2024 年 4 月 17 日.