【Grant-in-Aid for Scientific Research (S)】

Broad Section B

Title of Project：　Determination of Three-Nucleon Forces via Three-Nucleon Scattering

SEKIGUCHI Kimiko
(Tohoku University, School of Science, Associate Professor)

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【Purpose and Background of the Research】

Understanding the strong nuclear force is of fundamental importance to decipher the natural way of building mater in the Universe. In the last two decades, three-nucleon forces (3NFs) that appear when more than two nucleons interact have been shed light. Establishment of high-precision two-nucleon potentials and achievements of the ab-initio calculations with these forces strongly suggest the necessities of 3NFs in describing various nuclear phenomena.

Few-nucleon scattering offers good opportunities to investigate 3NFs by direct comparison between the rigorous numerical calculations and the high-precision data. Our previous study of deuteron-proton (*dp*) elastic scattering at intermediate energies (E/A～100 MeV) draws the following conclusions: i) The 3NF is clearly needed for the cross section minimum region. ii) The spin dependent parts of the current 3NF models are deficient. iii) The short-range components of the 3NFs are required for high momentum region.

Recently, remarkable theoretical work of the nuclear force based on the chiral effective field theory, the theory of low-energy QCD, opens up new possibilities of exploring detailed properties of the 3NFs, including spin, iso-spin, and short-range terms. Meanwhile, high-precision experimental data are needed to determine the low-energy constants of this theoretical framework.

The project's motivation is to establish high-precision three-nucleon forces by the experimental data of *dp* elastic scattering at intermediate energies. We perform the measurement of spin correlation coefficients for *dp* elastic scattering at the energy of interest.

【Research Methods】

Cross section minimum angular region for *dp* elastic scattering is a golden window where we can clearly pin down 3NF effects. In this project we especially focus on the measurement of spin correlation coefficients for which a few sets of data exist only. Together with this the theory group formulates the scheme to perform the rigorous numerical calculations based on the chiral EFT nuclear potentials up to the 5th order (N4LO). The experiment is performed at RIKEN RIBF where high-quality polarized deuteron beam is provided (See Fig.1). We construct the polarized proton solid target for which dynamic nuclear polarization using p-Terphenyle,$C_{18}H_{14}$ is applied. We also construct the large angular acceptance detector system to measure the azimuthal dependent polarized cross section in the wide angular range.

【Expected Research Achievements and Scientific Significance】

3NFs established by the project contain rich information of the properties of these forces, including momentum, spin, and iso-spin dependences. The potential is expected to be applied to the ab-initio calculations of nuclear structures, reactions and nuclear matter properties. The obtained results would provide deep insight for various nuclear phenomena, e.g. neutron-rich nuclei related to nucleosynthesis, and neutron star properties. The low energy constants determined by the *dp* elastic scattering data hold the information which will connect the nuclear interactions to the dynamics of quarks and gluons in the future.

【Publications Relevant to the Project】

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- K. Sekiguchi, H. Witala et al., Phys. Rev. C. **96**, 064001 (2017).
- E. Epelbaum, H.-W.Hammer, and U.-G.Meissner. Rev. Mod. Phys. **81**, 1773 (2009).
- E. Epelbaum et al., Eur. Phys. J. A **56**, 92 (2020).

【Term of Project】 FY2020-2024

【Budget Allocation】 151,600 Thousand Yen

【Homepage Address and Other Contact Information】

http://lambda.phys.tohoku.ac.jp/nuclphys2/
kimiko@lambda.phys.tohoku.jp

Fig.1：Layout of measurement of spin correlation coefficient for *dp* elastic scattering