# Spin Correlation Coefficients measurement in *d-p* elastic scattering for determination of the three-nucleon force

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Necessity of the three-nucleon forces (3*N*Fs) have come to light in various nuclear phenomena, for example, discrete states of nuclei, and equation of state in nuclear matters. As numerically exact solutions of the Faddeev equations using 2*N*- and 3*N*-forces are now attainable for observables in nucleon-deuteron (*Nd*) scattering, intricate information on the 3*N*Fs can be extracted by directly comparing high precision data obtained in *Nd* experiments and theoretical calculations.

Different performances of deuteron-proton (*d*-*p*) elastic scattering at 70–300 MeV/nucleon[1–3] have confirmed clear signatures of 3*N*F effects in results of the cross sections below 135 MeV/nucleon, whereas data of spin observables and cross sections at 250 MeV/nucleon or above have suggested deficiencies in the spin dependent parts and high momentum transfer regions of current 3*N*F models.[4,5] It would be interesting to see how these observables are described by potentials based on the chiral effective field theory ($\chi$EFT). Generally, high precision data-sets of *Nd* scattering at 100 MeV/nucleon or below are required[6] in order to determine the low energy constants in the $\chi$EFT 3*N*F sector, including information on short-range nuclear interactions. Regarding this situation, we will commence the measurement of spin correlation coefficients in *d*-*p* elastic scattering at 100 MeV/nucleon. The experiment will be performed at RIKEN RIBF, employing the polarized deuteron beam provided via the polarized ion source,[7] in combination with the polarized proton solid-state target and the detector system, both of which have been newly developed for this experiment.

We conducted our beam experiment at RIKEN in January 2024, aiming to confirm target polarization and proton analyzing powers in *d*-*p* scattering with the new detector system. Unpolarized deuteron beams accelerated by the injector cyclotrons AVF and RRC up to 135 MeV/nucleon bombarded the polarized proton target installed in the E3 room. The target was based on the triplet dynamic nuclear polarization method[8] designed to operate under a low magnetic field of few hundred mT, allowing detections of deuterons and protons with relatively low kinetic energies (∼60 MeV) over a wide angular range. Scattered deuterons and recoiled protons were detected in coincidence measurements by the KuJyaku detector system. The KuJyaku comprises of four multi-wire drift chambers (MWDCs) and 40 plastic scintillators: 36 scintillators (70 $mm^L$ × 70 $mm^H$ × 25 $mm^t$) for protons (Pl-*p*) and 4 scintillators (250 $mm^L$ × 70 $mm^H$ × 10 $mm^t$) for deuterons (Pl-*d*). Nine Pl-*p* detectors were placed every five degrees on left, right, up, and down wings with the Pl-*d* detectors placed as to cover the corresponding angles. This set up enables yield asymmetry measurements with an angular acceptance of 70°–150° in the center-of-mass (CM) frame. MWDCs were set on each wings to track trajectories of deuterons and protons bent due to the static field of ∼0.1 T·m applied to the target. For example, trajectories of deuterons scattered at 150° in CM frame ($E_d$ = 44 MeV) were deflected by 3°. Further analysis using the MWDC data are currently in progress. As shown in Fig. 1, a clear locus of *d*-*p* elastic scattering events obtained by the scintillators were clearly observed.

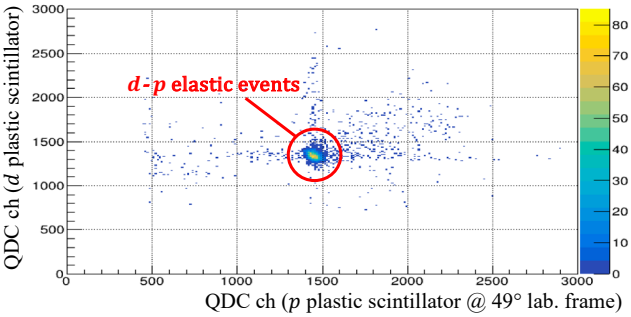


Fig. 1. Locus of the *d*-*p* elastic scattering events obtained with the plastic scintillators for protons and deuterons (two-dimensional light output spectrum after event selection through timing information)

The spin correlation coefficient measurement employing polarized deuteron beam is expected to start next year.

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