Measurement for p–^{3}He elastic scattering with a 65 MeV polarized proton beam

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Abstract

We measured the cross section and the proton analyzing power A_y for p–^{3}He elastic scattering at the angles $\theta = 26.9°$–$170.1°$ in the center of mass system with a 65 MeV polarized proton beam. We compared the data with the rigorous numerical calculations based on the various nucleon–nucleon potentials. For the cross section, clear discrepancy is seen at the angles where the cross section takes minimum. For the proton analyzing power A_y, the calculations have moderate agreements with the data. In this proceedings, we show only the experimental results.

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1 Introduction

One of the most important topics of nuclear physics is to describe the properties of nucleus based on the nucleon–nucleon (NN) interactions combined with the three–nucleon forces (3NFs). 3NFs are key elements to understand various nuclear phenomena, e.g. binding energies of light mass nuclei [1] and equation of state of nuclear matter [2].

To study the dynamical aspects of 3NFs, such as momentum, spin, and iso-spin dependencies, few–nucleon scattering is a good probe. The first indication of the 3NF effects in the few–nucleon scattering was found in the cross section minimum for deuteron–proton (dp) elastic scattering at intermediate energies ($E/A \gtrsim 65$ MeV) [3].

3NF effects could also be seen in four-nucleon scattering. In order to explain 3NF effects in four-nucleon scattering as well as to approach to the 3NFs with the channels of the total isospin $T = 3/2$ we have performed the measurement for the p–^{3}He scattering at intermediate energies. Here we report the cross section and the proton analyzing power A_y for the p–^{3}He elastic scattering at 65 MeV.

2 Experiment

2.1 Experimental setup

The measurement of p–^{3}He elastic scattering was performed in the west experimental hall of the Research Center for Nuclear Physics (RCNP), Osaka University. The atomic beam type High Intensity Polarized Ion Source HIPIS [4] provided polarized protons. The polarized proton beam was accelerated by the AVF cyclotron up to 65 MeV and transported to the experimental hall. The extracted beam was focused onto a carbon foil target at the beam line polarimeter. It was refocused onto the ^{3}He gaseous target in the scattering chamber. After bombarding the ^{3}He gaseous target, the beam was stopped in a Faraday cup. The beam intensity was 20 – 100 nA.

The ^{3}He gaseous target was operated at room temperature under atmospheric pressure. The pressure and temperature of the gaseous target were monitored by using the gas target system [5].

Figure 1 shows the schematic view of the experimental setup. The scattered particles from ^{3}He nuclei were detected by the dE–E detectors which consisted of plastic and NaI(Tl) scintillators. A double-slit collimator system was used to determine the effective target thickness. The measured angles were $\theta = 20°$–$165°$ in the laboratory system ($\theta = 26.9°$–$170.1°$ in the center of mass system).

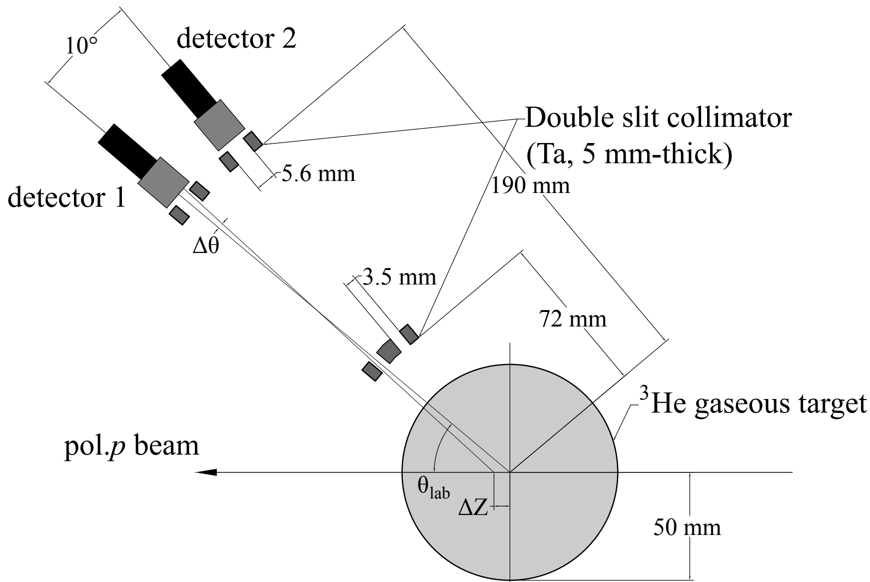

Figure 1: Schematic view of the experimental setup

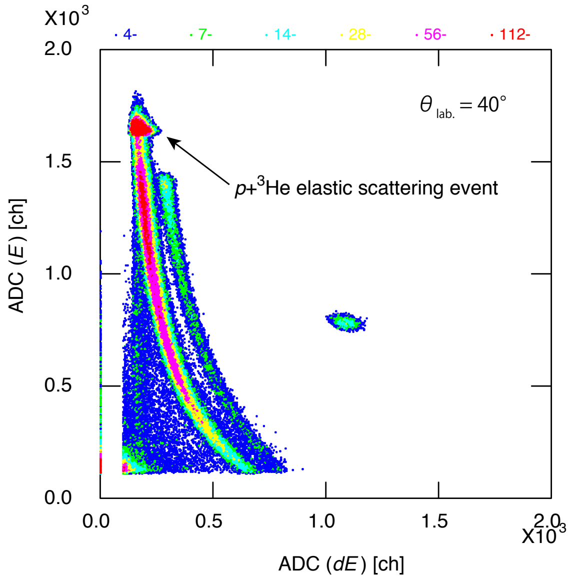

Figure 2: Two-dimensional plot of the light outputs of the dE and E detectors.

2.2 Experimental procedure

The beam polarizations were measured using the beam line polarimeter. The polarimetry has been performed by p–^{12}C elastic scattering. The analyzing power of p–^{12}C elastic scattering in the region of interest are reported in Ref [6]. The typical beam polarizations during the experiment were around 50 %.

In order to calibrate the absolute value of the cross section for p–^{3}He elastic scattering, we measured p–p elastic scattering using the same experimental setup. The hydrogen gas was used as the target at room temperature under atmospheric pressure. The experimental cross section for p–p elastic scattering were normalized to the cross section calculated by the phase-shift analysis program SAID [7].

3 Results and discussions

Particle identification has been performed using the correlation between the dE and E detectors. Figure 2 shows a two-dimensional plot of the light outputs of the dE and E detectors. The events from the p–^{3}He elastic scattering are clearly seen around the highest ADC channels of the E detector. Time of flight information was also used for the event selection.

The proton analyzing power A_y was extracted by using the yields for the two beam polarization modes ("spin-up" and "spin-down"). It was calculated as,

$$A_y^p = \frac{N^u - N^d}{N^d p_y^u + N^u p_y^d}, \tag{1}$$

where $p_y^{u(d)}$ denotes the beam polarization of the spin-up (spin-down) mode, $N^{u(d)}$ denotes the yields for the p–^{3}He elastic scattering obtained with the spin-up (spin-down) mode.

Figure 3 shows the experimental results of the cross section and the proton analyzing power A_y as a function of the scattering angle in the center of mass system (C.M.). Open circles are the experimental data. Only the statistical errors are shown. The obtained data will be

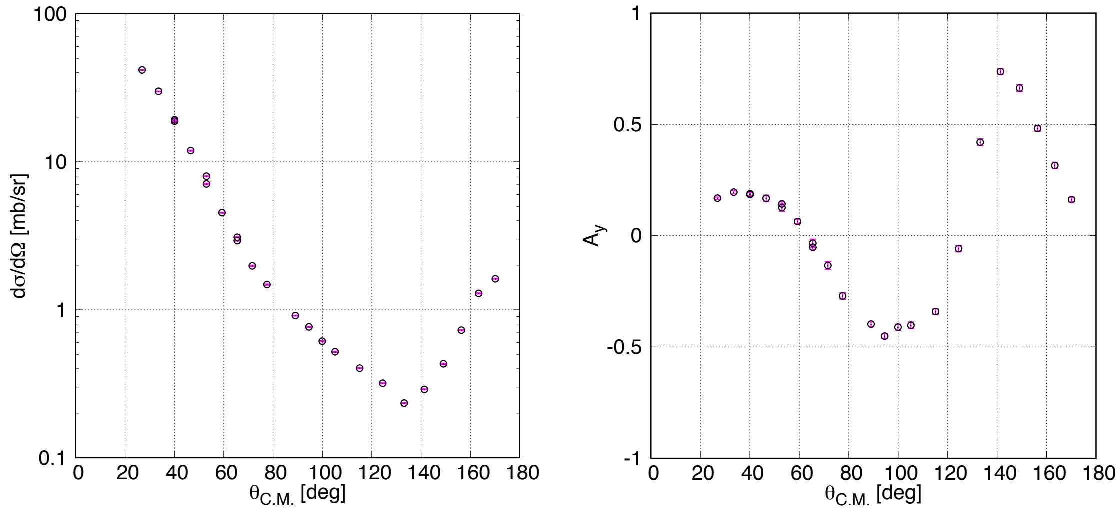

Figure 3: The cross section and the proton analyzing power A_y for the p–^{3}He elastic scattering at 65 MeV with respect to the angles in the center of mass system.

compared with the rigorous numerical four–nucleon calculations based on the several realistic NN potentials, namely AV18 [8], INOY [9], SMS51 [10], SMS53 [10], CD-Bonn [11] and the CD-Bonn potential with the Δ-isober degree of freedom included [12]. In this conference proceedings we present only the experimental results. All the calculations based on the various NN potentials provide similar results. For the cross section, clear discrepancy is found at the angles $\theta_{\mathrm{C.M.}} = 80°$–$140°$. For the proton analyzing power A_y, the angular distribution of the experimental data has a moderate agreement with the theoretical calculations.

4 Summary

We performed the measurement of the cross section and the proton analyzing power A_y for p–^{3}He elastic scattering using the 65 MeV polarized proton beam. Measured angles were $\theta_{\mathrm{C.M.}} = 26.9°$–$170.1°$. The experimental data will be compared with the theoretical calculations based on the various NN potentials. For the cross section, clear discrepancy between the data and the calculations is found at the angles $\theta_{\mathrm{C.M.}} = 80°$–$140°$.

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