Measurement of the vector analyzing power in π^+-d elastic scattering at 0.74 GeV/c

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The vector analyzing power has been measured for π^+d elastic scattering at 0.74 GeV/c in the angular range of $\theta_{\mathrm{c.m.}} = 40°–105°$, using a polarized deuteron target in a large aperture spectrometer. A comparison with calculations based on the Glauber model was made.

The pion-deuteron elastic scattering is of importance because it is the simplest example of π-nucleus scattering and it provides a useful testing ground for nuclear phenomena. Several authors have pointed out π-d elastic scattering is of interest in searching for dibaryon resonances.[1–5] Especially, the spin-dependent parameters should be quite sensitive even to the small amplitudes. Recently extensive measurements of the analyzing power in π-d elastic scattering using a polarized deuteron target were made at the SIN facility in the energy range below 325 MeV.[4] The data have been discussed from the viewpoint of the possible existence of dibaryon resonances in the $^3F_3$ and $^1D_2$ waves. The Faddeev approximation for a three-body interaction for one pion and two nucleons was used in this calculation. They concluded that pion absorption may eventually reconcile the existing discrepancies between the experimental data and the calculations. Ungicht *et al.* have also pointed out the possible effects of pion absorption on the polarization observables.[5] The effect might have an important role at higher energies. However, no experimental data on the polarization observables for πd elastic scattering at higher energies have been reported because of the experimental difficulties owing to the very small cross section and large background. Higher energy data are needed to search for high-energy dibaryon resonances in higher partial waves, and can be used to test multiple scattering theories. Recently Akemoto *et al.* measured the backward cross section of πd elastic scattering at 420–1100 GeV/c and found a serious discrepancy between the experimental data and the Glauber calculations.[6]

Here we will show results of the measurement of the vector analyzing power in πd elastic scattering at 0.74 GeV/c. The experiment was performed at the K2 beam line of KEK using the TELAS spectrometer.[7] The TELAS is a large aperture spectrometer in which a spin frozen polarized target was installed near the center of the magnet. The spectrometer has a C-type magnet with a gap of 1 m. In order to obtain a 25 KG field with the homogeneity of 10^{-4}, rectangular pole pieces were attached to the faces of the magnet. This field was necessary to polarize the deuteron dynamically.[8] The magnetic field outside the small pole pieces was about 7 KG. The beam entered the magnet through a hole in the return yoke. This configuration gave a wide angular coverage near the horizontal direction for scattered and recoil particles. The target material of about 11 g of fully deuterated 1,2-propanediol (D-8) was frozen in the form of beads about 1.2 mm in diameter.[9] A horizontal dilution refrigerator was used to cool the target material.[8,10] The polarization of the deuteron was measured by a 16.3 MHz NMR system and was calculated from the shape of the

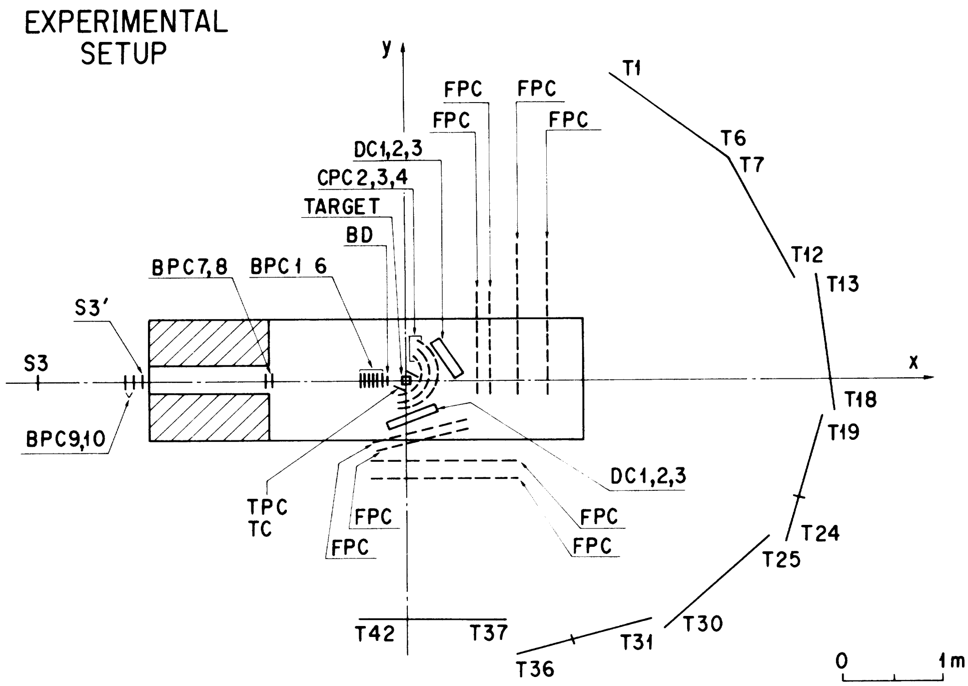

FIG. 1. The layout of counters and chambers inside and outside the spectrometer. (See the text.)

polarized NMR signal.[11] The typical vector polarization of the deuteron was about 40%. As shown in Fig. 1, the target was surrounded by chambers and counters. Proportional chambers (BPC) and scintillation counters (S, BD) in the beam line measured the momenta of the incident particles and the position of the beam incident on the target. Small proportional chambers (TPC) and thin scintillation counters (TC) were put close to the windows of the target cryostat. They were surrounded by half cylindrical proportional chambers (CPC) whose cathodes gave information on vertical coordinates. Outside the CPC particles of interest were incident on a scintillation telescope consisting of three scintillators (DC). These counters were used for identifying recoil deuterons. Eight flat proportional chambers (FPC) were installed in the magnetic field of the spectrometer. A scintillation counter hodoscope (T) surrounded the spectrometer outside the dipole.

The first criterion for a candidate π-d elastic event was that the hit positions in the CPC chambers were consistent. In the analysis the real tracks among many possibilities were selected by applying a spline fit routine. The momenta and angles of the incident, scattered, and recoil particles were calculated by means of this method. The reaction points were determined by means of tracing back of the trajectories toward the target position. The path integration in the magnetic field was made by the Runge-Kutta method. The π-d elastic scattering events were identified by the kinematical constraints on the momenta, angles, velocities, and coplanarity of the scattered pion and the recoil deuteron. A typical example of a time of flight (TOF) distribution of recoil particles triggered by scattered pions is shown in Fig. 2, after the kinematical cut on the pion and the momentum cut on recoil particles are performed. In the case of scattering at angles smaller than 60° c.m., the deuterons stopped in DC and deposited relatively large energies in the scintillator. This information was useful for the identification of π-d events. Most quasielastic π-d events from complex nuclei in the target were rejected by means of a kinematical constraint. Inelastic events were rejected by using measured information on the kinematics of the two charged particles. After all cuts were performed, background events were less than 7% of the true events.

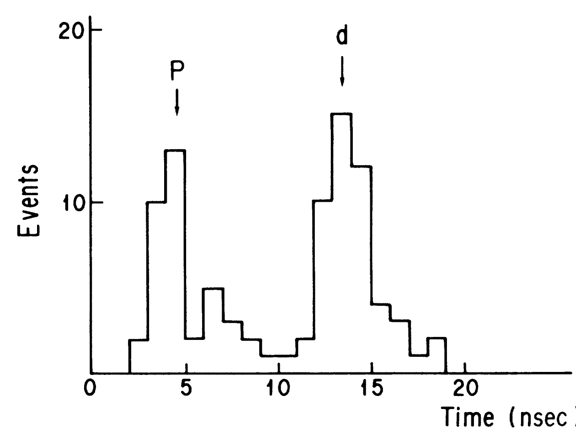

FIG. 2. A typical example of a TOF distribution of recoil particles triggered by scattered π^+, after the kinematical cut on π^+ and the momentum cut on recoil particles are performed.

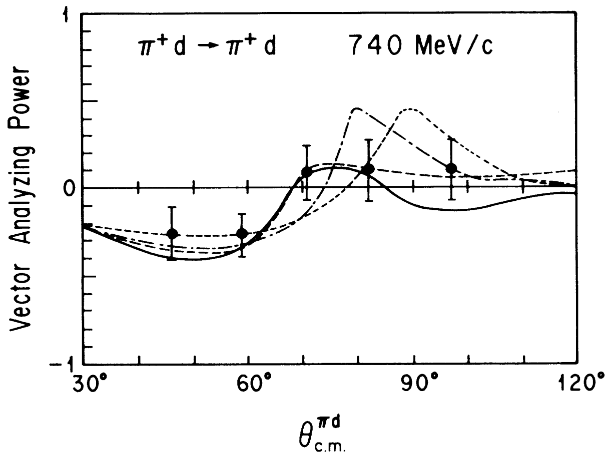

FIG. 3. Vector asymmetry of the π^+-d elastic scattering at 740 MeV/c. (See the text.)

The measurement was made over an angular range of $40° \leq \theta_{c.m.} \leq 105°$ at a pion beam momentum of 740 MeV/c. The experimental results are shown in Fig. 3. Error bars are statistical only. The numerical data are shown in Table I. The data were compared with calculations based on the Glauber model. The dotted and dashed lines in Fig. 3 show the calculations by Kanai *et al.*[1] including only single scattering and single-and-double scatterings, respectively, while the dotted-dashed line and the solid line by Hashimoto[12] include single scattering and single-and-double scatterings, respectively. In the analysis of Kanai *et al.*, the wave function of Reid and the solutions of the Saclay phase shift analysis were used. In the analysis of Hashimoto, the Hamada-Johnston wave function and the phase shifts of the Karlsruhe-Helsinki group were adopted. As reasonably expected, both calculations show that the single pion-nucleon scattering contribution is not sufficient to reproduce the data, especially in the angular range of $\theta^{\pi d}_{c.m.} > 60°$. We find the data agree fairly well with calculations which include single and double scatterings but without including contributions from possible dibaryon resonances. The data are reproduced slightly better by the dashed line estimated using the Reid wave function by Kanai *et al.* It seems that the higher momentum phenomena could be described better by the Reid wave function than by the Hamada-Johnston wave function; the former has endured much testing in intermediate energy nuclear physics.

TABLE I. The results of vector analyzing power.

Scattering angle (c.m.) $\theta_{c.m.}$	Scattering angle (lab) θ_{lab}	Analyzing power and statistical error
40–53	30–40	-0.26 ± 0.15
53–65	40–50	-0.28 ± 0.12
65–77	50–59	0.076 ± 0.15
77–87	59–70	0.094 ± 0.17
87–105	70–90	0.096 ± 0.17

The differential cross sections for π^--d backward elastic scattering at 720 MeV/c are much larger than predictions of Kanai *et al.* and Hashimoto.[6] If the effects of the $^1D_2$, $^3F_3$, and $^1G_4$ dibaryons are included in this analysis, parameters can be found which reproduce $d\sigma/d\Omega$. However, our data of vector analyzing powers are poorly reproduced by these parameters. There are several possibilities which might explain both sets of data. Two of these are as follows:

(i) The effect of other dibaryon resonances not included in the calculation may be important for π-d elastic scattering at 0.74 GeV/c.

(ii) In the calculation of the double scattering term, only the pion propagator is included. Other mesonic contributions and the pion absorption effect need to be considered.

Further experimental study of the spin parameters in π-d elastic scattering is of great importance for understanding the π-d scattering mechanism.

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