BACKWARD π d SCATTERING BETWEEN 140 AND 260 MeV

(The OMICRON Collaboration)

A. Stanovnik and G. Kernel*)

Josef Stefan Institute, Ljubljana,
and Department of Physics, University of Ljubljana, Yugoslavia.

N.W. Tanner

Department of Nuclear Physics, Oxford University, United Kingdom.

T. Bressani**), E. Chiavassa, S. Costa, G. Dellacasa,

M. Gallio, A. Musso and M. Panighini

Istituto di Fisica Superiore dell'Università di Torino,
Istituto Nazionale di Fisica Nucleare, Sezione di Torino, Italy.

K. Bos***) and E.G. Michaelis

CERN, Geneva, Switzerland.

W. Van Doesburg

Free University, Amsterdam, The Netherlands.

J.D. Davies

Birmingham University, United Kingdom.

ABSTRACT

Differential cross-sections for elastic scattering of pions by deuterons have been measured for centre-of-mass angles between 130° and 175° , and at laboratory energies 141, 177, and 260 MeV for π^+ , and at 151, 185, and 189 MeV for π^- . At 177 MeV and 260 MeV the cross-sections are a factor of 2 lower than the predictions of three-body theories.

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*) Present address: CERN, Geneva, Switzerland.

**) Present address: Istituto di Fisica, Università di Cagliari, Italy.

***) Present address: SIN, Villigen, Switzerland.

1. INTRODUCTION

The interest in pion-deuteron scattering is related to the problem of understanding the extent to which the nuclear interactions in a many-body system can be deduced from known two-body processes. A pion and a deuteron represent one of the simplest of such systems. In recent years, three-body theories have made considerable progress in describing pion-deuteron elastic scattering [1-5]. Such theories exactly sum the multiple scattering series and are thus able to take into account details of the deuteron structure. The energy region where the pion-nucleon interaction is dominated by the $\Delta(1232)$ resonance is of particular interest. The dominance of the Δ -state for the πN interaction and the deuteron bound state for the nucleon-nucleon interaction permits treatment of the two-body interactions in a separable form. Forward πd elastic scattering is largely diffractive and rather insensitive to the details of the πd interaction. Backward scattering, on the other hand, requires large momentum transfer, which increases the importance of higher-order terms in the multiple scattering series, and the differential cross-section is expected to exhibit effects other than diffraction.

Experimental data [6-9] on elastic backward πd scattering are scarce and suffer from poor accuracy as a consequence of the low cross-sections. Nevertheless a discrepancy by a factor of 5 between measurement [8] and a relativistic three-body calculation [5] at 256 MeV backward angles seems larger than the possible experimental error. It was the aim of this experiment to provide more accurate data for the elastic backward πd scattering in the pion energy region between 140 MeV and 260 MeV.

2. EXPERIMENTAL ARRANGEMENT

The experiment was performed at the CERN Synchro-cyclotron, which delivered about 1 μA of 600 MeV protons onto an external pion production target. The momentum resolution of the measurement was determined by the pion transport system and amounted to 3% FWHM. The detection system had a large (~ 1 sr) solid angle for acceptance of πd scattering events covering scattering angles between 130° and 175° .

Multiwire proportional chambers, in front of and behind the target, measured the directions of the incident pion, of the scattered pion, and of the recoiling deuteron. Their angular correlation kinematically determined elastic events without momentum analysis. A system of scintillation and Čerenkov counters provided read-out trigger signals and additional discrimination of the recoiling particles by pulse height and range requirements. The targets were 2-5 mm thick containers filled with D₂O. An extensive description of the apparatus and of the details of analysis can be found elsewhere [10].

3. RESULTS AND DISCUSSION

The values of the measured differential cross-sections for πd backward elastic scattering are shown in table 1 and in fig. 1. As a compromise between the angular resolution and the statistical errors, a bin width of 5° was chosen. The errors quoted in table 1 and fig. 1 are statistical only, and include contributions from background subtraction and from Monte Carlo calculation of the solid angle. Not shown is an additional 10% systematic error arising mostly from inaccuracy in measured chamber positions, target thickness, beam composition, etc. Systematic errors of points at the limits of acceptance (130° - 135° and 170° - 175°) could, however, be as large as 20%. As a test of the apparatus, of the method of analysis, and of the estimated systematic errors, a measurement of 141 MeV $\pi^+ p$ and 185 MeV $\pi^- p$ elastic scattering was performed. The results are consistent with differential cross-sections calculated from known phase shifts [11]. A detailed analysis of experimental errors is presented in ref. 10.

The comparison of our data with those of other existing experiments is shown in fig. 1. Owing to the smooth energy dependence of the backward elastic cross-section, small energy differences between various experiments are not significant.

A recent experiment performed at SIN [12] covers the angular region complementary to that of our data. Our results at pion energies 141, 177, and 260 MeV represent, within experimental errors, a smooth continuation of the SIN angular distributions at 141, 181, and 254 MeV, respectively. Other measurements although

of poorer accuracy, agree [7,9,13] with our data except for some earlier results [6,8] (see fig. 1).

In the vicinity of 180 MeV we have performed three measurements -- 177 MeV π^+d , 185 MeV π^-d , and 189 MeV π^-d -- for which the observed differences in cross-sections are within the estimated errors. Assuming a smooth energy dependence of the backward cross-section, it follows that the difference in backward elastic scattering for positive and negative pions is smaller than the uncertainties of our experiment*).

Compared with earlier data, the present experiment provides a more stringent test of various theoretical approaches. The results of one of the latest relativistic three-body calculations, which takes account of all S and P pion-nucleon partial waves [14], are shown in fig. 1. As may be seen from this figure, the agreement of theory and experiment is quite good at 142 MeV. However, calculations at higher energies (180 MeV and 256 MeV) predict backward cross-sections almost two times higher than the values measured by this experiment.

Possible reasons for the poor agreement could be due to effects such as: the omission of the $^1P_1$ channel of the N-N interaction [15]; P_{11} pion-nucleon inelasticity [14]; dibaryon resonances [16,17]; the $\Delta\Delta$ component in the deuteron ground-state wave function; pion absorption [18]; ρ -meson exchange [18]; or off-energy-shell two-body interactions [15].

4. CONCLUSIONS

Differential cross-sections for πd elastic scattering at backward angles from this experiment show a smooth continuation of data measured recently at SIN [12]. No differences between the π^+d and π^-d results have been observed within the limits of accuracy. A significant disagreement -- by almost a factor of 2 -- between three-body theory and experiment at backward angles and higher

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*) The 185 MeV cross-section was measured with a preliminary apparatus on a different beam line and about half a year before the rest of the data were taken, so its consistency with the other results of our experiment reflects the systematic errors.

energies (180 MeV and 260 MeV) was found, and should probably be attributed to effects not taken into account in theoretical calculations.

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Table 1
Values of differential cross-sections for pion-deuteron elastic scattering
in the centre-of-mass system and in units of microbarns per steradian

θ_{cm} / T_{lab}^{π}	141 MeV π^+d	151 MeV π^-d	177 MeV π^+d	185 MeV π^-d	189 MeV π^-d	260 MeV π^+d
130-135°	1240 ± 160	1050 ± 140	346 ± 85		316 ± 87	
135-140°	1320 ± 100	1230 ± 75	441 ± 40	379 ± 30	447 ± 55	99 ± 12
140-145°	1305 ± 80	1180 ± 100	418 ± 35	425 ± 22	355 ± 22	108 ± 11
145-150°	1510 ± 80	1205 ± 120	491 ± 45	399 ± 34	442 ± 29	117 ± 12
150-155°	1340 ± 70	1210 ± 60	451 ± 35	381 ± 14	442 ± 34	126 ± 11
155-160°	1570 ± 80	1200 ± 60	478 ± 35	387 ± 16	452 ± 59	130 ± 12
160-165°	1560 ± 100	1380 ± 80	418 ± 60	375 ± 19	406 ± 44	137 ± 15
165-170°	1630 ± 180	1280 ± 110	470 ± 60	372 ± 27	359 ± 52	159 ± 24
170-175°	1370 ± 340	1180 ± 300	353 ± 140	324 ± 70	350 ± 175	178 ± 59

Figure caption

Fig. 1 : Differential cross-sections for scattering of pions at backward angles in the centre-of-mass system. Solid points belong to the results of the present experiment with pion laboratory energies as indicated. Data of Pewitt et al. [6] (142 MeV), Norem [7] (182 MeV), Gabathuler et al. [8] (141, 185, and 256 MeV), SIN [12] (142, 181, and 254 MeV), and Los Alamos [13] (140 MeV) are shown for comparison. The curves represent the results of a calculation by Lamot et al. [14] at 142, 180, and 256 MeV.

Fig. 1

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