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RECOIL PROTON POLARIZATION IN ELASTIC $\pi^- - p$ SCATTERING AT 300 MeV AND THE PHASE SHIFT ANALYSIS OF PION-NUCLEON SCATTERING

The theoretical analysis of pion-nucleon scattering in refs.[1,2] has proved the necessity of repeated measurements of recoil proton polarization in $\pi^- - p$ scattering at 300 MeV pion energy.

At the Laboratory of Nuclear Problems of the Joint Institute for Nuclear Research the earlier results[3] on recoil proton polarization have been improved on the basis of richer statistics at the negative pion energy of 300±7 MeV using a Geiger counter hodoscope with controlled pulse supply. The asymmetry of recoil proton scattering by carbon nuclei was measured by means of a spark chamber. The number of events of recoil proton scattering by carbon nuclei, with which the asymmetry has been measured, is increased in this experiment up to 5191 (comparing to 2169 of ref.[3]). In order to obtain better results the analysing power of carbon was measured at 122 MeV and 146 MeV proton energies in addition to previous measurements of carbon analysing power at 136 MeV.

The results of measurements of recoil proton polarization at six values of scattering angles are given in table 1. Table 2 presents polarization values obtained by combining our earlier and new data.

Table 1

θ_π (c.m.s.)	P
146.0°	0.16 ± 0.18
141.0°	0.15 ± 0.12
136.6°	0.28 ± 0.09
131.4°	0.30 ± 0.09
126.4°	0.39 ± 0.11
121.3°	0.29 ± 0.20

Table 2

θ_π (c.m.s.)	P
146.0°	0.06 ± 0.09
141.0°	0.16 ± 0.09
136.6°	0.25 ± 0.06
131.4°	0.33 ± 0.08
126.4°	0.33 ± 0.10
121.3°	0.32 ± 0.18

The phase shift analysis included the above values of recoil proton polarization in elastic $\pi^{-}-p$-scattering at 300 MeV, the data of refs.[4-6] on the angular distributions of both elastic scattering pions of two signs and charge exchange scattering at 317 MeV, the values of total cross sections, positive and negative pion interaction with protons[7], data on proton polarization in $\pi^{+}-p$-scattering[8], and recoil neutron polarization in charge exchange scattering[9]. The programme of the phase shift analysis is described in ref.[10]. Both SPD- and SPDF-analyses were performed. The search for possible phase shift sets was started from random 111 points (the SPDF-analysis). By means of all the above-mentioned experimental material four phase shift sets were found by the SPDF-analysis (see Table 3).

Table 3

	I	II	III	IV
S_{31}	-20.7±0.7	-16.6±1.2	-14.7±1.2	-21.6±0.5
P_{31}	- 8.8±1.5	-1.5 ±1.4	- 0.3±1.5	-10.5±1.2
P_{33}	134.6±0.8	134.4±0.6	134.8±0.6	134.6±0.8
D_{33}	- 0.8±1.1	3.9±0.9	4.8±0.8	- 2.1±0.9
D_{35}	- 1.5±1.1	- 5.8±0.7	- 6.8±0.8	- 0.2±1.0
F_{35}	- 0.5±0.5	0.6±0.3	0.6±0.3	- 1.2±0.5
F_{37}	1.6±0.7	- 1.1±0.5	- 1.7±0.5	2.5±0.6
S_{11}	16.5±1.3	2.1±1.7	24.4±0.9	1.7±0.7
P_{11}	20.7±0.9	29.2±1.0	15.6±0.9	1.2±0.6
P_{13}	- 3.2±0.7	9.0±0.8	0.4±0.8	1.8±0.7
D_{13}	5.6±0.6	2.2±0.7	- 4.0±0.5	- 1.0±0.4
D_{15}	1.6±0.8	- 0.8±0.6	1.6±0.6	13.7±0.6
F_{15}	1.2±0.3	- 3.8±0.5	- 0.8±0.2	- 0.2±0.3
F_{17}	0.0±0.3	- 0.4±0.4	- 3.9±0.3	3.6±0.4
M	58.8	77.7	93.7	98.7

$\bar{M} = 55$

The introduction into the phase shift analysis as free parameters the inelastic coefficients of partial waves $\eta(L_{2T,2J})$, corresponding to the states with the isospin 1/2 gave the values of M 54.0, 81.2, 95.5 and 88.0, respectively, for the first, second, third, and fourth sets. The real parts of phase shifts were but slightly changed in this case within errors in phase shift values. For set I the value $\eta(P_{11})$ is 0.92 with an error of about 1.5%.

The results of the SPD-analysis are presented in Table 4. Phase shift set III turned into phase shift set I. Note that the introduction of inelasticity into the SPD-analysis reduced the value of M for the first solution from 107.6 to 79.0.

Table 4

	I	II	IV
S_{31}	-20.7 ± 0.5	-18.3 ± 0.6	-19.4 ± 0.6
P_{31}	-6.5 ± 0.5	-4.4 ± 0.5	-5.5 ± 0.5
P_{33}	131.9 ± 0.5	135.4 ± 0.6	135.5 ± 0.6
D_{33}	1.5 ± 0.4	1.9 ± 0.3	1.4 ± 0.3
D_{35}	-3.5 ± 0.4	-4.0 ± 0.4	-3.1 ± 0.4
S_{11}	13.8 ± 1.6	-6.5 ± 1.3	-7.2 ± 0.7
P_{11}	16.4 ± 0.7	28.9 ± 1.4	-3.5 ± 0.5
P_{13}	-4.5 ± 0.7	8.4 ± 0.4	2.3 ± 1.1
D_{13}	2.9 ± 0.2	5.1 ± 0.4	-5.5 ± 0.3
D_{15}	0.8 ± 0.3	-0.1 ± 0.3	15.4 ± 0.7
M	107.6	151.4	192.8

$\bar{M} = 63$

In one of the variants of the phase shift analysis Lind's /11/ results were used as the data on charge exchange scattering of negative pions. (The angular distributions of neutral pions were obtained from the measurements of the time of flight of recoil neutrons). The following values of M were found: 68.5, 200, 118, and 165, respectively, for the first, second, third, and fourth phase shift sets with $\bar{M} = 61$. However, the value of the normalized parameter ϵ^{π^0} (see ref. /10/) greatly differed from zero and turned out to be (0.24 ± 0.03). The real parts of scattering phases were changed slightly comparing to those in table 3. The inelasticity coefficient η shifted from unity in the state P_{13} /$\eta(P_{13}) = 0.97$/ but not in the state P_{11}. This result disagrees with the conclusions of all other analyses both at 310 MeV and at the neighbouring energy values /12-15/.

A considerable deviation of the normalization parameter ϵ^{π^0} from zero and the suppression of inelasticity in the state P_{11} seem to indicate some incompatibility of Lind's data with the remaining available information on $\pi - p$ scattering.

Dispersion relations for pion-nucleon scattering provided[16] the values of the real parts of forward scattering amplitudes equal to $-(0.66 \pm 0.06)\frac{h}{m_\pi c}$ and $-(0.04 \pm 0.01)\frac{h}{m_\pi c}$ for positive and negative pion scattering by protons, respectively. For D_+ and D_- our phase shift sets give the following values:

Sets	$D_+/\frac{h}{m_\pi c}$	$D_-/\frac{h}{m_\pi c}$
SPD I	−0.72 ± 0.01	−0.09 ± 0.02
SPD II	−0.70 ± 0.01	0.00 ± 0.02
SPD IV	−0.70 ± 0.01	−0.09 ± 0.02
SPDF I	−0.69 ± 0.01	0.02 ± 0.03
SPDF II	−0.69 ± 0.01	−0.05 ± 0.02
SPDF III	−0.69 ± 0.01	−0.15 ± 0.02
SPDF IV	−0.69 ± 0.01	0.08 ± 0.02

For the SPDF I set the obtained value of the real part of the scattering amplitude D_- differs by two standard deviations from the predicted value. Introducing as initial data the values of D_+ and D_- predicted by dispersion relations into the phase shift analysis causes the increase of M in sets I, II, and IV by 4.9, 0.7 and 17.4, respectively. In this case set III turns into set I.

Our set I (table 3) is similar to set II of Vik and Rugge[7]. As is known, the phase shift analyses of pion-nucleon scattering below 1 GeV are based on set II of Vik and Rugge at 310 MeV.

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