Measuring D and P polarization parameters for p-p scattering at 0.97 GeV

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The results of measurements of the analyzing power of carbon in the energy range 0.65–0.97 GeV and of the polarization parameter P and depolarization parameter D for p-p scattering at 0.97 Gev in the range of angles 30–130° (center-of-mass system) are presented. A phase analysis incorporating new experimental data is carried out.

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Polarization measurements are necessary to determine amplitude and phase in nucleon-nucleon scattering, and are especially important at energies of 0.6–1.2 GeV in connection with the existence of dibaryon resonances.[1]

Polarization and the depolarization parameter D for p-p scattering have been measured for a polarized beam of 970-MeV protons with a polarization $P = 0.306 \pm 0.017$. The polarized proton beam was scattered by a liquid hydrogen target. The variation in the polarization component normal to the scattering plane was analysed by polarimeters consisting of eight wire spark chambers and a hydrogen analyzer for proton polarization. For most of the measurements, the polarization analysis was done both for protons scattered to the right (R-polarimeter) as well as for protons scattered to the left (L-polarimeter). For all the measurements beams were used which were polarized in mutually opposite directions: upward (the L beam); downward, (the R beam), The asymmetries which depend on the P and D parameters, the beam polarization P_1, and the analyzing capability of carbon $P_3(E)$ were measured:

$$\epsilon_3^+ = \epsilon_3^{LL(RR)} = \frac{P + DP_1}{1 + P_1 P} P_3,$$
$$\epsilon_3^- = \epsilon_3^{LR(RL)} = \frac{P - DP_1}{1 - P_1 P} P_3. \tag{1}$$

The measurement technique has been thoroughly discussed, in earlier work[2] and results have been given for measurements of the polarization P and the parameter D primarily for scattering angles $\theta_0 \geqslant 90°$ (center-of-mass system) where the scattered protons have energies for which $P_3(E)$ was known. Further measurements of the D parameters are possible for $\theta_0 < 90°$ if the analyzing power for proton energies in the range 650–970 MeV is known.

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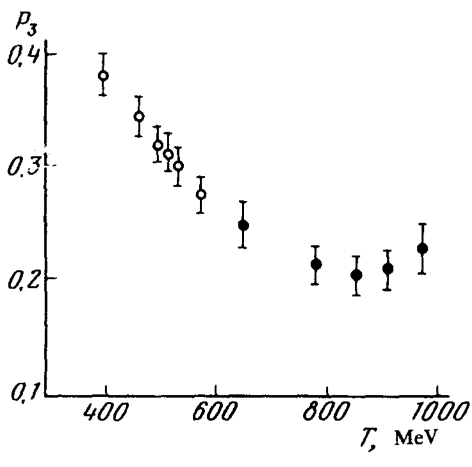

FIG. 1. Function $P_3(E)$: solid circles—results from this work; open circles—data from Ref. 3.

The analyzing power of carbon at energies from 650–970 MeV was determined by the asymmetric scattering of polarized protons by a graphite block 10 cm thick in the 5–15° range. Only single-track events were registered. Polarized 970-MeV protons were decelerated to produce polarized beams at 850, 790, and 640 MeV. Polarized 930-MeV protons were obtained by scattering at an angle of 12.3° by a polarizer target of polyethylene. The kinematic conditions for the particle beam corresponded to *p-p* scattering at an angle of 30° in the center-of-mass system.

Measurements of ϵ_3^+, ϵ_3^-, and the asymmetry P_1P carried out at scattering angles of 30, 40, 50, and 70° in the center-of-mass system lead to a determination of P_3 at the same energies by another technique, since from Eq. (1) it follows that

$$P_3 = \frac{\epsilon_3^+(1 + P_1P) + \epsilon_3^-(1 - P_1P)}{2P}. \quad (2)$$

The values of $P_3(E)$ obtained by both techniques agree with one another within the statistical accuracy of the measurements, indicating the absence of depolarization when the polarized protons are declerated from 970 to 650 MeV. Figure 1 shows $P_3(E)$ averaged over all the measurements. Below 650 MeV the data for the analyzing power of carbon have been taken from Ref. 3.

Polarization for *p-p* scattering was determined by measuring the asymmetry P_1P in the scattering of polarized protons by a liquid hydrogen target using scintillation counters, and is given in Fig. 2.

The parameter D was found using the measured asymmetries:

$$D = \frac{\epsilon_3^+(1 + P_1P) - \epsilon_3^-(1 - P_1P)}{2P_1P_3}. \quad (3)$$

The results of measuring the parameter D are given in Fig. 2 which contains the total

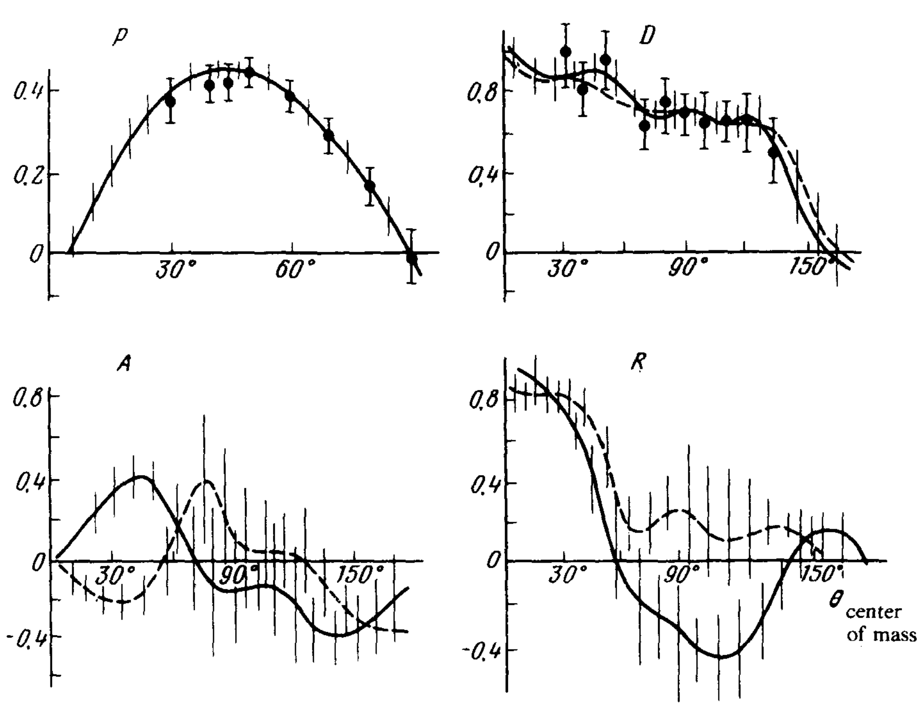

FIG. 2. Polarization parameters for *p-p* scattering: solid circles—results from this work. Solid curves correspond to set 1, dashed lines to set 2. The hatched region indicates the error range.

measurement error, including statistical errors and the error in determining the analyzing capability of carbon.

Our resulting values for the polarization P and the D parameter were used to carry out a phase analysis of *p-p* scattering at 970 ± 30 MeV. In addition, the following data were included in the analysis: σ_t,[4] σ_{in},[5] $d\sigma/d\Omega$,[6] the differential cross-sections in the coulomb interference region,[7] and the difference in the cross-section in the pure spin states $\Delta\sigma_L$,[8] $\Delta\sigma_T$,[1] values for P,[9] and C_{nn}[10] There were 144 experimental points in all. The differential cross-section data were renormalized to the elastic scattering cross-section[5] and the value $d\sigma/d\Omega\,(0) = 17.0 \pm 1.5$.[7] The procedure for finding the phase shifts was carried out by a program for minimizing the χ^2-functional.[11] The actual values for the phase shifts were varied up to values of the orbital momenta $l_{max} \leqslant 6$; the contribution of the higher partial waves was computed by the OPE approximation, and the imaginary part of the phase shifts was computed for the state ${}_3P_{0,1,2}$, ${}^1D_{2,3}$, ${}^3F_{2,3}$, and ${}^1G_4$. A statistically satisfactory description ($\chi^2/\overline{\chi}^2 \sim 1.0$) of the experimental data was also obtained for $l_{max} \leqslant 5$.

A search of the random phase shift values gave more than 40 solutions which require further analysis. As initial values in this work we took the solutions given in Ref. 12, and four solutions with similar values were obtained. From these four solutions only two solutions given in Table I differ significantly outside errors in terms of

TABLE I.

Phase shifts	Set 1 δ	$\pm\Delta\delta$, deg	Set 2 δ	$\pm\Delta\delta$, deg
	Real parts			
^1S_o	−22	14	−35	12
^3P_o	−55	47	−13	14
$^3P_1$	−55	29	−43	9
$^3P_2$	15	13	93	19
$^1D_2$	−17	6	−8	7
ϵ_2	2	9	5	3
$^3F_2$	−13	10	−2.4	2.6
$^3F_3$	8	10	−10.0	5.3
$^3F_4$	5	5	5.1	3.5
$^1G_4$	−1	2	2.3	2.9
ϵ_4	−1	3	−9.8	2.3
$^3H_4$	−0.6	5	1.2	1.0
$^3H_5$	−0.4	5	−1.1	2.4
$^3H_6$	2.4	0.5	5.1	1.4
$^1I_6$	2.5	1.6	−1.7	1.5
	Imaginary parts			
^3P_o	11	31	2	14
$^3P_1$	1	13	14	18
$^3P_2$	11	19	41	5
$^1D_2$	10	8	21	5
$^3F_2$	11	3	0	3
$^3F_3$	22	18	19	5
$^1G_4$	6.7	2.4	3.2	1.8
χ^2	125		123	

phase shift and in terms of the prediction for the observed values. Figure 2 shows the measured parameters corresponding to these solutions. The uncertainty in the behavior of the spin rotation parameters $A(\theta)$ and $R(\theta)$, which is also characteristic of other solutions, indicates the inadequacy of the experimental data even for analyzing *p-p* scattering in the 1-GeV region.

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