Application of Correlation Polarization in the Phase Analysis of $p-p$ Scattering

A. G. ZIMIN

(Submitted to JETP editor December 14, 1956)
J. Exptl. Theoret. Phys. (U.S.S.R.) 32, 1239-1240
(May, 1957)

EXPERIMENTS ON THE three-fold scattering of 310 Mev protons by protons have been conducted recently in Berkeley [1]. In these experiments there were measured two quantities which characterize the change of polarization of one of the interacting particles in the ensuing scattering, namely, the depolarization D and the rotation of the polarization R. Together with the scattering cross section and the value of the polarization, this gives the four essential quantities which characterize the scattering matrix. Phase analysis, carried out with the aid of the designated quantities [2], yields five groups of permissible phases with momenta $l \leqslant 4$.

State	Number of group 1	2	2*	3	4
$^1S_0$	−10.9±4.9°	−19.5°	−27±3.9°	−10.1±4.9°	−0.3±4.6°
$^1D_2$	13.3±1.5°	4.3°	4.8±1.2°	12.8±1.4°	12.9±1.2°
$^1G_4$	1.1°	1.3°	1.0°	1.0°	−1.0
$^3P_0$	−4.1±2.7	−36	−25.4±3.8	−14.3±4.3	−64.7±3.8
$^3P_1$	−19.8±1.6	−11.7±2	−7.3±2	−26.7±1.9	8.1±1
$^3P_2$	22.6±1.3	18.8	23.1±1.5	−12.6±1.9	8.1±1
ε_2	−1.8±2	9.3	7.5	−0.8±4	0.2±6.2
$^3F_2$	2.0±1.1	−0.5	−1.4±1.8;	−1.3±2	−2.1±1.3
$^3F_4$	−0.5±0.9	2.5	2.6±1.5;	3.2±1	3.3±0.5
ε_4	−0.9	1.5	0.9	1.1	−1.3
$^3H_4$	−1.1	2.1	−0.7	1.4	2.2
$^3H_5$	0.9	−1.4	0.9	0.1	−2.0
$^3H_6$	−0.6	1.6	−0.8	1.3	0.3
$^3F_3$	−2.6±1.1°	0.2	1.5±0.7	2.1±1.5	3.0±2.2°

Such lack of single-valuedness arises because the four designated quantities do not constitute a complete set of experimental data. For a single-valued phase analysis, it is necessary to carry out supplementary experiments, *viz:* there-fold scattering with the application of a field or else with correlation polarization. As Chamberlain reports [6], the application of magnetic fields in three-fold scattering does not produce complete single-valuedness of the phase analysis. As shown by the calculations which follow, the values of correlation polarization corresponding to different phase groups differ markedly from one another. This fact makes possible the complete separation of the designated groups by measuring only a single correlation polarization.

As is known [3,4], the measurement of the correlation polarization, *i.e.*, $\langle \sigma_i^{(1)} \sigma_k^{(2)} \rangle (i, k = x, y, z)$, can be carried out through two-fold proton-proton scattering. Here two quantities are measured directly:

$$\sigma_{\mathrm{I}} = \sigma_{yy} = \sigma_{y'y'} \text{ and } \sigma_{\mathrm{II}}$$

$$= \sigma_{xz} \cos 2\vartheta + {}^1/_2 (\sigma_{xx} - \sigma_{zz}) \sin 2\vartheta = \sigma_{x'z'}.$$

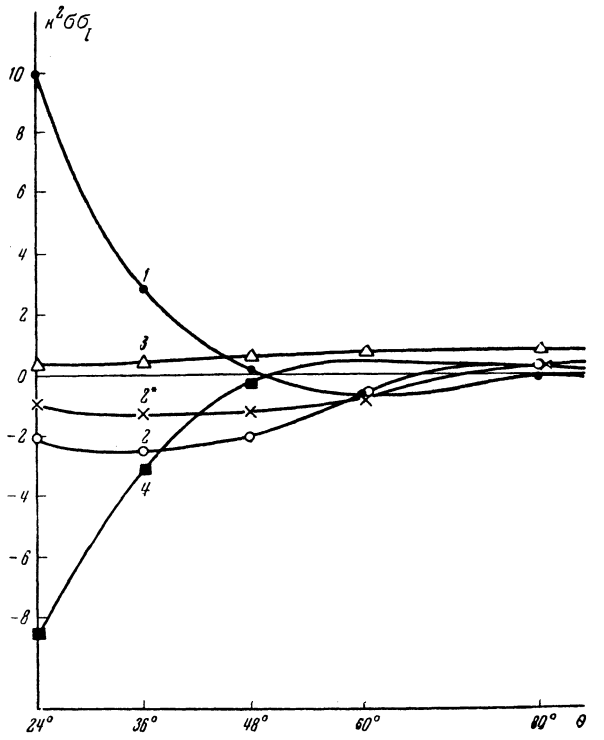
where ϑ is the scattering angle in the laboratory coordinate system, and the primed quantities refer to the coordinate system with axes x' and z' which are oriented in the directions taken by the two scattered particles. Measuring the component combinations of the tensor $\sigma_{ik} = \sigma_i^{(1)} \sigma_k^{(2)}$, the expression for the matrix parameters of the scattering

$$M = aS + c(\sigma_n^1 + \sigma_n^2) + {}^1/_2 g(\sigma_k^1 \sigma_k^2 + \sigma_p^1 \sigma_p^2) T + {}^1/_2 h(\sigma_k^1 \sigma_k^2 - \sigma_p^1 \sigma_p^2) T + m\sigma_n^1 \sigma_n^2 T,$$

takes the following form:

$$\sigma\sigma_{y'y'} = 2\mathrm{Re}(am^*) + 2(cc^* + hh^* - gg^*),$$
$$\sigma\sigma_{x'z'} = 4\mathrm{Re}(ich^*).$$

The results of the calculation of σ_{I} upon adduction of the phase grouping are shown graphically. The value of σ_{I} proves to be quite dependent upon the group number, especially for angles less than 50 degrees. Therefore measurement of σ_{I} for angles less than 50° permits isolation of the correct phase grouping. σ_{II} is less dependent on the group number, so that calculation of σ_{II} is not of interest (taking



into account the large deviations from the phase values in a given group).

As is shown by phase analysis which takes into account only phases of isotropic states[5] (first approximation), the S-phase, for the energy under consideration should have a large negative value. Groups 2 and 2* show agreement with this statement, besides yielding only minor mean square deviations. Groups 1 and 4, whose phases differ greatly from those of 2 and 2*, show a sharply different behavior of σ_I for small angles. This circumstance permits sorting them out by measuring σ_I.

This work has been carried out on the suggestion of Professor Ia. A. Smorodinskii, to whom I wish to express my appreciation. I also wish to thank Professor O. Chamberlain (USA) for furnishing data on phase analysis.

[1] T. J. Ypsilantis, Experiments on Polarization in Nucleon-Nucleon Scattering at 310 Mev, University of California Rad. Lab., Berkeley (1956).

[2] H. P. Stapp, On the Analysis of $p-p$ Polarization Experiments, University of California Rad. Lab., Berkeley (1956).

[3] Ia. A. Smorodinskii and V. V. Vladimirskii, Dokl. Akad. Nauk SSSR **103**, No 6 (1955).

[4] A. G. Zimin, J. Exptl. Theoret. Phys. (U.S.S.R.) **32**, 1226 (1957), Soviet Phys. JETP, **5**, 996 (1957).

[5] A. G. Zimin, Dokl. Akad. Nauk SSSR **105**, 73 (1955).

[6] O. Chamberlain, *Transactions of Conference on High Energies*, M. (1956).

Translated by D. A. Kellog
248

Polarization of Deuterons in Elastic Scattering

O. D. CHEISHVILI
Tbilisi State University

(Submitted to JETP editor December 25, 1956; resubmitted after revision February 28, 1957)
J. Exptl. Theoret. Phys. (U.S.S.R.) **32**, 1240-1242 (May, 1957)

WE CONSIDER IN THIS WORK several questions concerning the polarization of deuterons during their elastic scattering by nuclei. Lakin[1] and the author[2] made calculations on the polarization of deuterons, but these were based only on general considerations of invariance and did not yield concrete results with regard to polarization. For the interaction potential of the deuteron and the nucleus we shall take (in analogy to the interaction potential of a nucleon with a nucleus[3])

$$V_{dA}(\mathbf{r}) = \int \psi_d^*(|\mathbf{r}_n - \mathbf{r}_p|)\,[V_{nA}(\mathbf{r}_n) + V_{pA}(\mathbf{r}_p)]\,\psi_d(|\mathbf{r}_n - \mathbf{r}_p|)\,d(\mathbf{r}_n - \mathbf{r}_p). \quad (1)$$

The interaction potentials for neutrons and protons with nuclei are taken as

$$V_{nA}(\mathbf{r}) = V_0\rho(r) + V_1\frac{1}{r}\frac{\partial\rho(r)}{\partial r}(\boldsymbol{\sigma}_n\mathbf{L}), \quad (2)$$

$$V_{pA}(\mathbf{r}) = V_0\rho(r) + V_1\frac{1}{r}\frac{\partial\rho(r)}{\partial r}(\boldsymbol{\sigma}_p\mathbf{L}) + V_c(r). \quad (3)$$

The Coulomb interaction potential of the proton with a nucleus is taken as

$$V_c(r) = \begin{cases} (3R^2 - r^2)\,Ze^2/2R^3, & \text{for } r < R \\ Ze^2/r, & \text{for } r > R \end{cases} \quad (4)$$

where R is the nuclear radius and Z is the nuclear charge. The spin-orbital Coulomb interaction is not taken into consideration, since it is small compared with the spin-orbital nuclear interaction.

The calculation is carried out by the Born approximation; it is assumed that the deuteron is in the