MEASUREMENT OF THE SPIN CORRELATION COEFFICIENT FOR pp *SCATTERING AT* 660 MeV

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Submitted to JETP editor December 29, 1961

J. Exptl. Theoret. Phys. (U.S.S.R.) **42**, 1209-1211 (May, 1962)

The spin correlation coefficient C_{kp} for elastic scattering of 660-MeV protons by protons was measured at an angle of 90° in the c.m.s. The result is $C_{kp}(90°) = 0.22 \pm 0.18$.

THE coefficient C_{kp} is defined as the mean value of the operator $(\sigma_1 \cdot \mathbf{K})(\sigma_2 \cdot \mathbf{P})$, where σ_1 and σ_2 are the spin operators of the scattered and of the recoil proton, **K** and **P** are unit vectors directed along $\mathbf{p}' - \mathbf{p}$ and $\mathbf{p}' + \mathbf{p}$; and **p** and **p′** are the initial and final momenta of the scattered proton in the c.m.s. C_{kp} characterizes the correlation between the spin components of the two protons in the plane of scattering. This coefficient was first measured at 380 MeV[1] to select the set of phase shifts at 310 MeV.

The pp scattering amplitude can be written in the form (see [2,3])

$$M = \alpha + \beta(\sigma_1 \mathbf{n})(\sigma_2 \mathbf{n}) + \gamma(\sigma_1 + \sigma_2)\mathbf{n} + \delta(\sigma_1 \mathbf{K})(\sigma_2 \mathbf{K}) + \varepsilon(\sigma_1 \mathbf{P})(\sigma_2 \mathbf{P}). \tag{1}$$

The coefficient C_{kp} is related to the scattering amplitude coefficients by the following equation

$$I_0(\vartheta) C_{kp}(\vartheta) = -\operatorname{Im}(de^*), \qquad d = \delta - \varepsilon, \qquad e = 2\gamma, \tag{2}$$

where $I_0(\vartheta)$ is the differential cross section of elastic pp scattering.

1. EXPERIMENTAL METHOD

A schematic diagram of the experiment is shown in Fig. 1. The 660-MeV proton beam was scattered on a polyethylene target. The scattered and the recoil protons were detected by coincidences between coupled telescopes T_1 and T_2, each of which had a solid angle of 0.7×10^{-3} sr. An analysis of the spin states of the protons after scattering was carried out by means of two indentical graphite targets. The scattering events on the graphite targets were selected by telescopes T_3 and T_4, connected for anticoincidence with T_1 and T_2. Gas discharge chambers were used for finding the direction of motion of the protons before and after scattering on the graphite targets.[4]

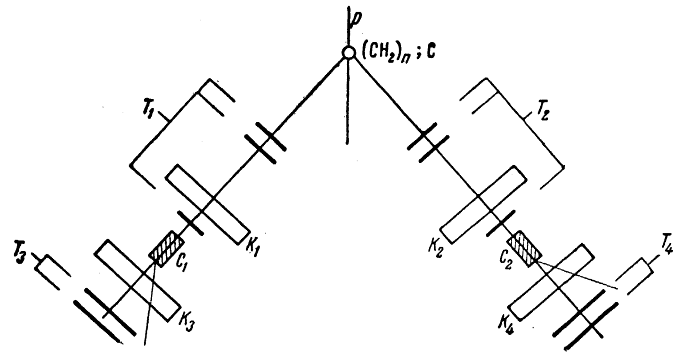

FIG. 1. Schematic diagram of the experiment for measurement of C_{kp}: C_1 and C_2 – analyzing target; K_1, K_2, K_3, K_4 – gas discharge chambers; T_1, T_2, T_3, T_4 – scintillation counter telescopes.

The projections of the tracks on the planes defined by the vectors **K** and **P** were photographed. The scattered protons were analyzed in the first of these planes, and the recoil protons in the second. In reducing the data, we considered protons whose track projection after the second scattering formed an angle between 6.5° and 20° with the direction of motion towards the graphite target. The minimum detectable angle of the second scattering was 4.5°. The choice of a somewhat larger minimum angle enabled us to avoid asymmetry due to a possible inaccuracy in the adjustment of the telescopes T_3 and T_4. The photographs of proton tracks used in the analysis are shown in Fig. 2.

To determine the analyzing power of the graphite target, a method analogous to the one described in [5] was used. By means of a polyethylene absorber, the energy of the proton beam was lowered to 385 MeV. Protons emitted from the first target at an angle of 41° in the c.m.s. and with polarization 0.39 ± 0.03[6] were analyzed by the graphite target used in the correlation measurements. The same interval of the second scattering angles as that used in finding the number of correlated cases

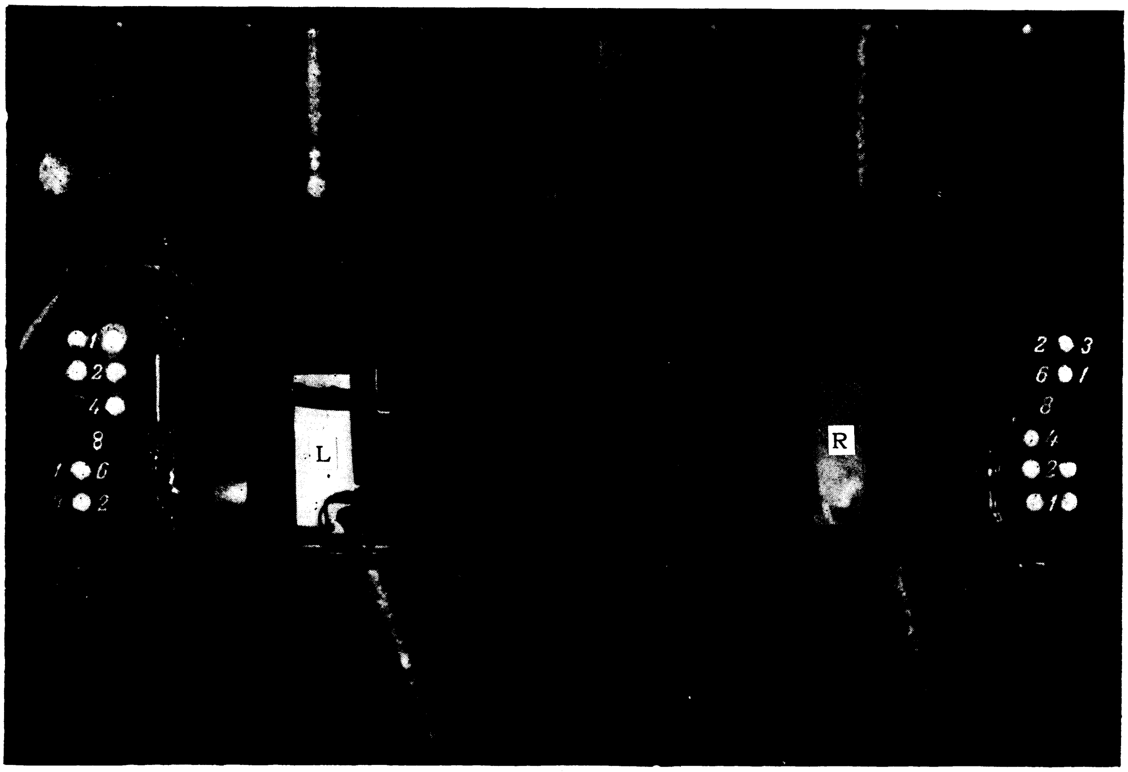

FIG. 2. Photograph of proton tracks corresponding to a correlation event.

was used to find the analyzing power. If $C_{kp}(90°)$ is measured using identical analyzing targets, we can assume that the analyzing powers P_1 and P_2 are identical. As a result of the measurements, it was found that $P_1 = P_2 = 0.5 \pm 0.1$.

2. THE COEFFICIENT C_{kp}

The correlation asymmetry is defined by the relation

$$a = (N_{uu} + N_{dd} - N_{ud} - N_{du})/(N_{uu} + N_{dd} + N_{ud} + N_{du}), \tag{3}$$

where N_{uu} denotes the number of coincidences in which the scattered proton and the recoil proton are deflected upwards after scattering on analyzers. N_{dd} corresponds to the case of deflection of both protons downwards, and N_{ud} and N_{du} correspond to the two possible combinations for the cases of deflection of the protons in opposite directions. The coefficient C_{kp} can be expressed in terms of the asymmetry:

$$C_{kp} = a/P_1P_2. \tag{4}$$

As a result of the measurements, 630 correlated cases were found, distributed in the following way:

$$N_{uu} = 165 \pm 14, \quad N_{dd} = 167 \pm 14, \quad N_{ud} = 146 \pm 13, \quad N_{du} = 152 \pm 13.$$

The numbers of events given here are obtained after subtracting the background from the graphite target placed in the position of the first scatterer.

From Eqs. (3) and (4), we obtain

$$a = 0.054 \pm 0.041, \qquad C_{kp} = 0.22 \pm 0.18.$$

3. DISCUSSION

The present experiment is part of the program necessary to establish the scattering amplitude and to carry out the phase shift analysis. In the energy range smaller than the meson production threshold, five independent experiments are sufficient to establish the scattering amplitude. In view of the important role of inelastic processes at 660 MeV proton energy, it is necessary to carry out at least nine independent experiments. However, as mentioned in [7], in the case of scattering of protons at an angle of 90° in the c.m.s., it is also possible to determine the scattering amplitude for that angle in the inelastic region from five experiments.

The absolute values of the scattering amplitude coefficient have been obtained in [5]. Using these results and the value of C_{kp} obtained in our experiment, we can, using Eq. (2), find the sign of the phase shift $\delta_e - \delta_d$ of the complex coefficients e and d; taking into account that $|e| > 0$ and $|d|$

> 0, we find that $\sin(\delta_e - \delta_d) > 0$ with a probability of ≈ 0.9.

Equation (2) is nonrelativistic. Taking the relativistic correction into account does not influence the result, since it is negligible compared with the error in the determination of C_{kp}.

In order to obtain a more definite result for the phase shift $\delta_e - \delta_d$, it is necessary not only to obtain a more exact experimental value of C_{kp} but also a more exact measurement (compared with presently available data), of the coefficients $C_{nn}(90°)$ and $D_{nn}(90°)$ from which the absolute values of $|e|$ and $|d|$ are determined.

The authors thank L. I. Lapidus, Yu. P. Kumekin, S. B. Nuruchev, and G. D. Stoletov for helpful discussion.

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Translated by H. Kasha
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