First measurements of the spin rotation parameters R and A in elastic πp scattering near low-lying pion-nucleon resonances

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The rotation parameters R and A have been measured for the first time in elastic πp scattering near the low-lying pion-nucleon resonances. The experiment was carried out at an energy of π^- mesons of 450 MeV with a polarized proton target, a horizontal spin orientation, and a polarimeter consisting of multigap optical spark chambers with television readout.

An experiment to measure the spin rotation parameters R and A is crucial to research on elastic πp scattering, since such measurements are absolutely necessary for an unambiguous reconstruction of the scattering amplitude through an energy-independent phase-shift analysis. The spin rotation parameters have not previously been measured at energies below 6 GeV in πp scattering. In the absence of the corresponding results, the phase-shift analyses have had to make do with the use of criteria for the smoothness of the energy dependence of the phase shifts, of the inelasticity parameters, and of the zeros of the scattering amplitude. It has also been necessary to introduce some additional theoretical limitations, whose validity is not always beyond dispute. Only direct measurements of the parameters R and A can resolve these problems and allow an unambiguous reconstruction of the πp scattering amplitude.

Measurements of the spin rotation parameters R and A require the use of a polarized proton target, with a polarization vector lying in the scattering plane. The experiment is basically one of selecting events of elastic scattering of π mesons by free protons of the target and then determining the polarization P_f of the emitted recoil protons. This determination requires measurement of the angular distribution of the secondary scattering of these protons by nuclei of the analyzer material. The polarization P_f is in general a function of a linear combination of the spin rotation parameters: $R \sin\alpha + A \cos\alpha$, where α is the angle between the momentum of the incident π meson and the polarization vector of the target.

The present experiment was carried out in the π-meson channel of the synchrocyclotron of the Leningrad Institute of Nuclear Physics at a π^- energy $T = 450$ MeV (the corresponding momentum is $p = 573$ MeV/c). The apparatus is placed at the second focus of the π-meson channel. The momentum spread of the particles in the beam is 6%; their angular spreads are $\Delta\theta_x = 1.2°$ in the horizontal direction and $\Delta\theta_y = 1.8°$ in the vertical direction (in all cases we are giving the full width at half-

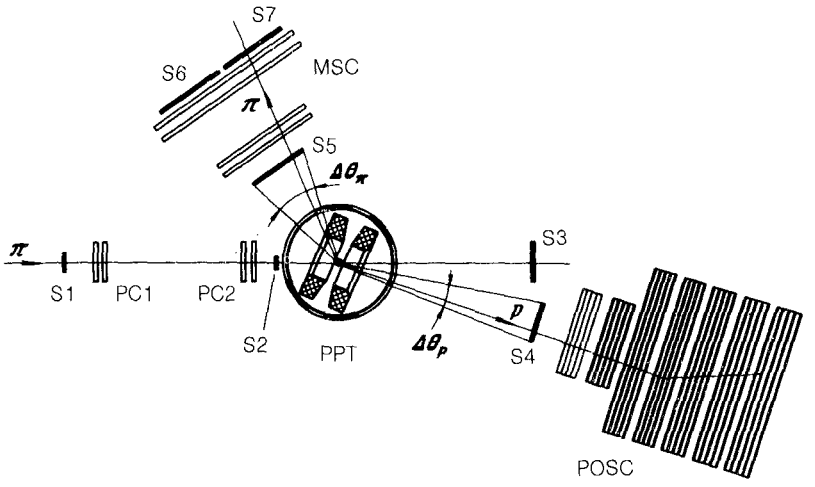

FIG. 1. Schematic diagram of the apparatus. PPT—Polarized proton target; POSC—polarimeter of optical spark chambers; MSC—magnetostrictive spark chambers; PC—proportional chambers; S1–S7—scintillation counters.

maximum of the corresponding distributions). The intensity of π mesons at the target was 2.5×10^4 s^{-1} cm^{-2}.

The experimental apparatus is shown schematically in Fig. 1. The basic units are (1) a polarized proton target (PPT) with a horizontal spin orientation, (2) a polarimeter of optical spark chambers (POSC) with television readout, for determining the polarization of the recoil protons through an analysis of their secondary scattering by the material (graphite) of the analyzer, (3) magnetostrictive spark chambers (MSC), for finding the paths of the scattered π mesons, (4) proportional chambers (PC), for determining the shape of the incident beam and the angular distribution of the particles in it, and (5) a system of scintillation counters, for monitoring the beam and generating a trigger pulse. The angle (α) between the beam direction and the target polarization vector is 35°; this configuration maximizes the solid angles available for the emission of recoil protons and scattered π mesons.

The construction and working characteristics of the polarized target are described in Ref. 1. The volume of the target is 20 cm^3, and the working medium is propanediol. The target is in a refrigerator with helium-3 pumping, which provides a temperature of 0.6 K. A magnetic field of 2.5 T is produced by a pair of superconducting Helmholtz coils, whose axis lies in the horizontal plane. The magnitude of the polarization is 70%.

The detection part of the apparatus is described in detail in Ref. 2. The total number of spark gaps of the polarimeter is 28; the thickness of the individual graphite electrodes ranges from 0.5 to 2 cm; and the total thickness is sufficient to completely stop the recoil protons. This geometry and also the use of large spark chambers (800×400 mm) provide a high efficiency for the detection of the secondary scattered protons.

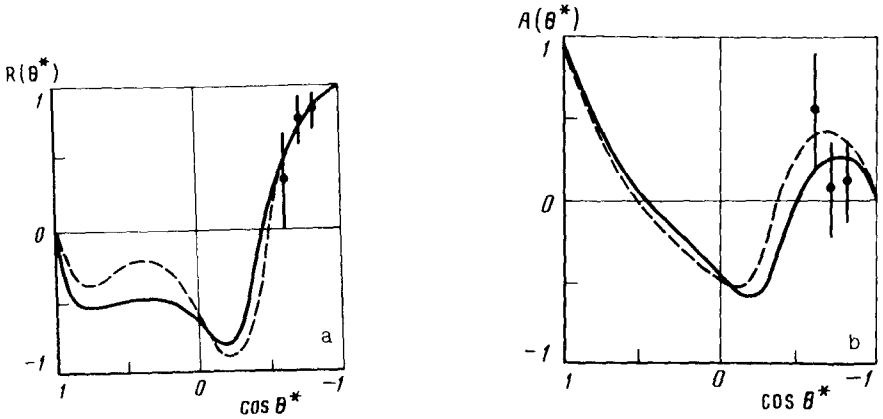

FIG. 2. Results of measurements of the parameters R and A in $\pi^- p$ scattering at the energy of 450 MeV. Solid lines—Predictions of the KH phase-shift analysis[3]; dashed lines—predictions of the CMU-LBL phase-shift analysis.[4]

The apparatus works on line with an ES-1030 computer, which monitors the operation of the apparatus and performs a preliminary data analysis. The complete analysis is carried out on a powerful Cyber 172 computer after the completion of the experiment. The complete data analysis consists of three basic steps: (1) For each event detected in the polarimeter, the point of the secondary (proton-carbon) scattering is found, and the angle of this scattering, θ_2, is determined. "Useful" events, with $20° > \theta_2 > 6°$, are then selected. (2) For the selected events, the angles at which the scattered π meson and the recoil proton are emitted from the target are determined, and cases of elastic πp scattering are selected on the basis of kinematic criteria. (3) The angular distribution of the pC scattering is analyzed for the events selected in the preceding steps. The values of the parameters R and A are determined by the maximum-likelihood method.

Figure 2 shows the experimental results obtained after the analysis of about half of the accumulated data. Only the statistical errors are shown. The curves show the predictions of two phase-shift analyses.[3,4] We see that at the energy of 450 MeV, the phase-shift analyses which have been carried out agree satisfactorily with each other and that these first experimental results on the parameters R and A directly support those analyses. Future experiments will be carried out at energies at which the predictions of different phase-shift analyses are substantially different.

In the course of analyzing the data we found, in addition to the spin-rotation parameters R and A, values of the polarization parameter P. Within the errors, these values agree with the values of P which we measured previously[5] with a polarized target with a vertical direction of the proton spin. This agreement of the results of two independent measurements is evidence that no substantial systematic errors have been overlooked in these experiments.

[1]É. I. Bunyatova *et al.*, Preprint LIYaF-1191, Leningrad Institute of Nuclear Physics, Leningrad, 1986.
[2]A. V. Anufriev *et al.*, Preprint LIYaF-1160, Leningrad Institute of Nuclear Physics, Leningrad, 1986.
[3]G. Höhler, "Pion-Nucleon Scattering," Landolt-Börnstein 1/9b (ed. H. Schopper), Springer-Verlag, 1983.
[4]R. E. Cutkosky *et al.*, Phys. Rev. D **20**, 2804 (1979).
[5]V. S. Bekrenev *et al.*, Nucl. Phys. **A364**, 515 (1981).

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