tracted from the low-energy amplitudes by means of finite-energy sum rules. This information fixes the relative sign of the ρ and A_2 helicity-flip amplitudes. Corresponding to four sets of assumptions on the behavior of the ω and ω' trajectories four solutions are obtained. Solutions 1-3 give almost identical predictions for the polarization. The predictions of solution 3 are shown as curves III in Fig. 1 and are in reasonable agreement with the data. Solution 4 predicts much smaller polarizations which are inconsistent with the data.

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†Present address: Rutherford High Energy Laboratory, Chilton, Didcot, Berkshire, United Kingdom.

‡Present address: Physics Department, Rutgers, The State University, New Brunswick, N. J.

§Argonne Universities Association Fellow.

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MEASUREMENT OF POLARIZATION IN K^+p ELASTIC SCATTERING AT 1.37, 1.45, 1.71, AND 1.89 GeV/c AND PHASE-SHIFT ANALYSIS*

J. G. Asbury, J. D. Dowell,† S. Kato,‡ D. Lundquist, T. B. Novey, and A. Yokosawa
Argonne National Laboratory, Argonne, Illinois 60439

and

B. Barnett, P. F. M. Koehler, and P. Steinberg
University of Maryland, College Park, Maryland 20742
(Received 16 June 1969)

Measurements are reported of polarization in K^+p elastic scattering at 1.37, 1.45, 1.71, and 1.89 GeV/c. A phase-shift analysis including these new data has been performed. Resonancelike behavior is observed in the $P_{3/2}$ partial-wave amplitude.

We report here measurements of K^+p polarization over a range of c.m.-system angles from 20° to 160° at kaon momenta from 1.37 to 1.89 GeV/c from an experiment still in progress at the Argonne National Laboratory zero-gradient synchrotron (ZGS).

Until recently, our knowledge of the K^+p partial-wave amplitudes above 1 GeV/c came from a phase-shift analysis of total, total inelastic, and differential cross-section data performed by Lea, Martin, and Oades[1] at momenta up to 1.5 GeV/c and later extended to 2.0 GeV/c by Martin.[2] While the bump at 1.25 GeV/c in the K^+p total cross section observed by Cool et al.[3] and

Bugg et al.[4] had been shown from a study of elastic and inelastic processes by Bland et al.[5] to be due to the combined behavior of various partial cross sections, one of the phase-shift solutions found by Lea, Martin, and Oades[1] and Martin[2] showed a resonance (Z_1^*) in the $P_{1/2}$ state at a higher momentum (1.5 GeV/c). The recent polarization measurements of Andersson et al.[6] at 1.22 GeV/c have ruled out this resonant solution and were in good agreement with one of the nonresonant types of solution.

The polarizations reported here are generally large and positive[7] at all momenta and also rule out the resonant solution of Lea, Martin, and Oades[1] which predicts negative polarization at forward angles; however, in contrast to the observations at 1.22 GeV/c, our data at 1.45 GeV/c agree poorly with their nonresonant solution. Similar disagreements are found with the polarization predictions from the phase-shift analysis of Cutkosky and Deo[8] which uses a different approach[9] from that of Lea, Martin, and Oades.[1] We have carried out an energy-independent phase-shift analysis combining our own and other available data, the results of which are discussed below.

The experiment used the newly installed enriched K beam[10] which employs one 15-ft-long electrostatic separator. Final intensities ranged from 1.5×10^4 K^+/pulse ($\pi^+/K^+=6$) at 1.37 GeV/c to 4.0×10^4 K^+/pulse ($\pi^+/K^+=20$) at 1.89 GeV/c under typical operating conditions, with $\Delta p/p = \pm2.5\%$ and 3×10^{11} protons/pulse striking the 3-in.-long Cu production target. A liquid-cell differential Cherenkov detector[11] provided positive kaon identification, while a gas threshold Cherenkov counter gave additional rejection of pions, muons, and electrons. The resulting contamination in the beam signal was less than 1% at all momenta.

The polarized proton target consisted of a lanthanum magnesium nitrate crystal (1.75-in. long $\times$0.75-in. wide $\times$0.75-in. high) inside a continuously filled liquid-He^4 cryostat.[12] The new magnet design allows the scattered particles to be detected in an angular region of $\pm25°$ about the horizontal plane. The target polarization was typically 60%.

Both final-state particles were detected in counter hodoscopes which were placed symmetrically about the direction of the unscattered beam (Fig. 1). On the cryostat side, the interval from 8° to 104° was covered by 24 counters, each subtending 3.8°, and 28 similar counters covered the region from 8° to 120° on the opposite side. The first six θ counters on the cryostat side were subdivided into 1.9° angular bins by three additional counters as shown in Fig. 1. Each bank of θ counters was backed by seven rows of φ counters, each subtending a constant $\Delta\varphi = 3.8°$ at the center of the target.

The regions of kinematic ambiguity, where particle identities could not be established by angular correlations alone, were covered by threshold Cherenkov counters, each subtending $\Delta\theta = 12°$. They were filled with FC75, H_2O, or glycerin, depending on the momentum of the kaons and protons to be separated. Back-up counters behind

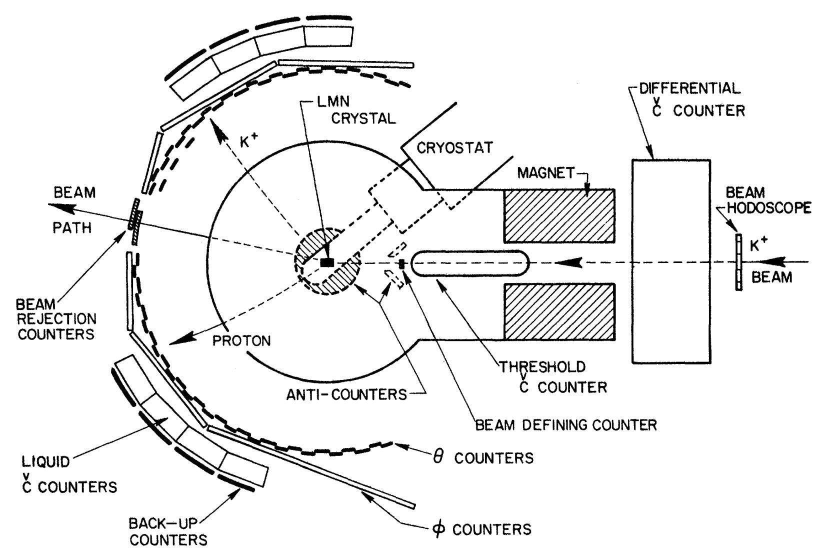

FIG. 1. Plan view of the apparatus.

the threshold detectors ensured that the particles traversed the liquid cells. The admixture of incorrectly identified particles was less than 2%.

Anticounters were used to define the scattering volume, to suppress inelastic background, and to veto unscattered kaons. A fast coincidence between an incident kaon and a particle in the θ, φ hodoscope on the right and left provided the gate for reading the status of every counter into an online ASI-6020 computer. The events were analyzed between beam spills. The resulting conjugate distribution for each counter as well as a variety of beam and counter monitoring tests were displayed on an oscilloscope.

The target polarization was reversed every six hours. At each beam momentum data were taken for a total of about 7×10^8 incident kaons.

The shape of the background produced by quasielastic scattering of kaons from bound protons and by inelastic processes was determined from noncoplanar events ($3 \leq |\Delta\varphi| \leq 5$ bins). After proper normalization, the background was subtracted from the coplanar events ($|\Delta\varphi| \leq 1$ bins) to obtain the number of free K^+p events. The validity of this procedure was established at 1.37 GeV/c with a dummy target containing no hydrogen. The results for the polarization parameter are shown in Fig. 2. The errors shown are statistical only and do not include the uncertainty in the target polarization.

Phase-shift analysis.—An energy-independent phase-shift analysis has been carried out at selected momenta between 0.86 and 1.95 GeV/c using available data on total cross sections,[3,4,13] total inelastic cross sections,[5] differential cross sections,[5,14] and polarizations[6] in addition to our own polarization data. An extensive random search at 1.22, 1.45, and 1.95 GeV/c, including phase shifts up to F wave, yielded two best-fit solutions with comparable χ^2/(number of degrees of freedom) $\cong 2$.[15] Satisfactory fits to the polarization data could not be obtained without the inclusion of F waves which have not been included in previously published analyses. This is a consequence of the rapid rise of polarization at small scattering angles. Smooth curves were drawn through the phase-shift results at these momenta to obtain starting values for searches at the other momenta.

Figures 3(a), (b), (d), and (e) show the phase shifts and inelastic parameters for the two solutions.[16] The curves in Fig. 2 are the calculated polarizations. Solution I shows large absorption in the $P_{3/2}$ state at 1.2 GeV/c which agrees with

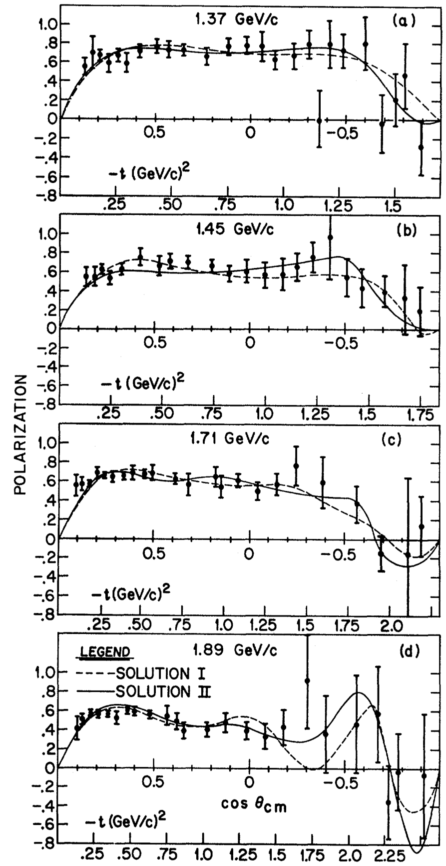

FIG. 2. Polarization parameters at each of the four momenta. The curves represent the two best-fit solutions from our phase-shift analysis.

the conclusion of Bland et al.[5] from a study of the reaction $K^+p \rightarrow KN^*$. The absorptions in the $P_{1/2}$, $D_{3/2}$, and $D_{5/2}$ partial waves are also compatible with values inferred from the work of these authors. The large absorption in the S state is more probably associated with K^*N production and is not inconsistent with the measured cross section for this process. Similar conclusions may be drawn at other momenta studied by Bland et al.[5] The striking feature of Solution I is the resonancelike behavior of the $P_{3/2}$ partial wave at higher momenta. The amplitude

$$A_{l\pm} = [\eta_{l\pm} \exp(2i\delta_{l\pm}) - 1]/2i$$

for this partial wave is plotted in the complex A_l plane in Fig. 3(c).

Solution II, on the other hand, while having reasonable values for $\eta_{l\pm}$, has an energy behavior for the S-wave phase shift which is incompatible with that expected from analyses at low momenta,[1,5] where S waves dominate. Also, the energy dependence of all the phases is less smooth than

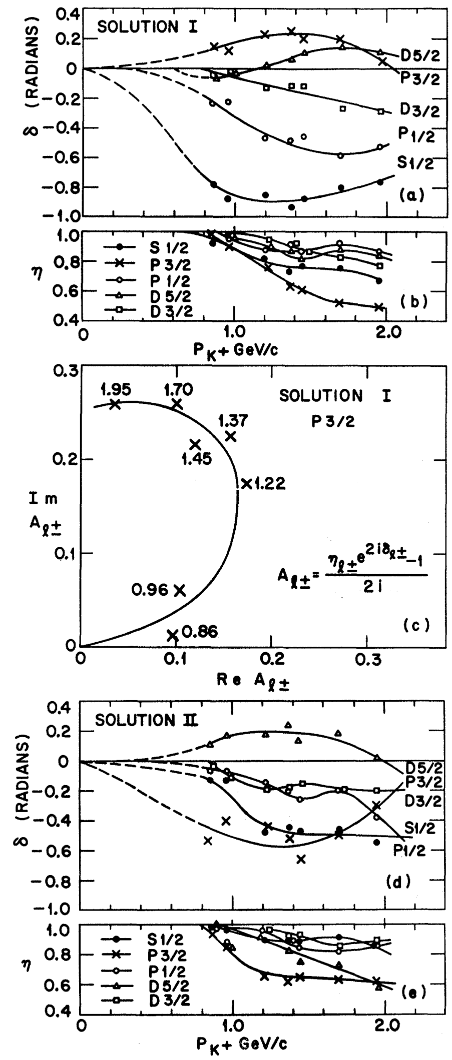

FIG. 3. Phase shifts and inelastic parameters as a function of momentum for S, P, and D waves from the two best-fit solutions, and Argand diagram of the complex scattering amplitude for the $P_{3/2}$ partial wave of solution I.

in solution I.

The energy dependence of the S-wave phase shift alone seems to favor solution I over solution II although on a χ^2 basis they are equivalent in our energy region. They might be distinguished by more precise polarization measurements in the backward hemisphere at the higher momenta. Further measurements are now in progress.

The possible $P_{3/2}$ resonance occurs at a momentum near to where a structure was reported in the K^+p total cross section by Abrams et al.[13] but is not clearly associated with it as this bump is very small (~0.2 mb). There is also a shoulder in the K^+p differential cross-section data of Carroll et al.[14] plotted as a function of s for fixed $u = +0.05\ (\text{GeV}/c)^2$, but this occurs at a somewhat higher momentum (~2.2 GeV/c). Further measurements of differential cross sections and polarizations above 2.0 GeV/c will be required to establish whether the $P_{3/2}$ amplitude is indeed resonant or whether its behavior is merely a consequence of the onset of strong absorption in this partial wave.

The positive polarizations at forward angles are in qualitative agreement with the predictions of simple Regge-pole models[17] and predictions based on finite-energy sum rules.[18]

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[16]The F-wave phase shifts (not shown in Fig. 3) vary monotonically with momentum reaching their largest absolute magnitudes at 1.95 GeV/c, where $\delta_{F7/2}=0.11$, $\eta_{F7/2}=0.88$ and $\delta_{F5/2}=-0.09$, $\eta_{F5/2}=0.83$ for solution I. Corresponding values for solution II are 0.20, 0.91; -0.12, 0.86.

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MEASUREMENT OF THE RATIO OF AXIAL-VECTOR TO VECTOR CURRENT IN THE DECAY $\Sigma^- \to ne^-\bar{\nu}$*

A. P. Colleraine, T. B. Day, R. G. Glasser, R. Knop,† B. Sechi-Zorn, and G. A. Snow
Department of Physics and Astronomy, University of Maryland, College Park, Maryland 20742
(Received 16 June 1969)

From approximately 550 Σ^- electronic decays produced by stopping K^- in liquid hydrogen we have selected a sample of 49 events in which the neutron from the Σ^- leptonic decay is detected by a subsequent n-p scatter. A maximum-likelihood analysis, including the effect of about 20% background, indicates that the magnitude of the ratio of the coupling constants is $|G_a/G_v|=0.23\pm0.16$, in excellent agreement with the prediction of the Cabibbo theory.

In an effort to measure the ratio of the axial-vector to vector current in the weak $\Sigma^-\to n$ transition we have searched for proton recoils associated with scatters of the neutron from $\Sigma^-\to ne^-\bar{\nu}$ decays.[1,2] Approximately 550 such decays have been found in 4×10^5 pictures of stopping K^- in the Brookhaven National Laboratory 30-in. hydrogen bubble chamber.[3] In any doubtful case the Σ^- decay track was gap counted to insure that only electronic decays were included in the sample of events to be examined for recoils.

Each of the $\Sigma^-\to ne^-\bar{\nu}$ events found has been remeasured together with all visible recoil protons within 25 cm of the Σ^- decay vertex; an average of 5 such recoils was associated with each decay. The measurements were processed by the Maryland TVGP-SQUAW fitting program with four constraints overall for the reaction sequence

$$K^-p\to\Sigma^-\pi^+ \ (K^- \text{ at rest}),$$
$$\Sigma^-\to ne^-\bar{\nu},$$
$$np\to np.$$