UCRL-17186

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Berkeley, California

Submitted to Physical Review Letters

UCRL-17186
Preprint

UNIVERSITY OF CALIFORNIA

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AEC Contract No. W-7405-eng-48

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October 1966

POLARIZATION IN PION-PROTON SCATTERING FROM 670-3750 MeV/c[*]

Owen Chamberlain, Michel J. Hansroul, Claiborne H. Johnson, Paul D. Grannis[+],
Leland E. Holloway[++], Luc Valentin[**], Peter R. Robrish, and Herbert M. Steiner
Lawrence Radiation Laboratory, University of California, Berkeley, California

Using a polarized proton target, we have measured the polarization parameter $P(\theta)$ in pion-proton scattering for both positive and negative pions. Because there seems to be a great deal of current interest in the analysis of pion-proton scattering we wish to present these experimental results at this time even though we have not yet completed their analysis. The measurement consisted of scattering pions from polarized target protons and observing the asymmetry in scattered intensity, $I(\theta)$, as the target protons' spin directions were reversed. The intensity for scattering from a target of polarization P_T is

$$I(\theta)_{\text{pol.}} = I(\theta)_{\text{unpol.}} \,(1+P(\theta)P_T) ,$$

where the parameter $P(\theta)$ is the same as the recoil proton polarization in scattering pions from unpolarized protons under the assumption that parity is conserved in the process.

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[*] Work done under the auspices of the U.S. Atomic Energy Commission.

[+] Present address: State University of New York, Stony Brook, New York.

[++] Present address: Institut de Physique Nucleaire, Orsay (S. et O.), France.

[**] Present address: Institut de Physique Nucleaire, Orsay (S. et O.), France.

The pion beam was momentum analyzed to within ±1% by a counter hodoscope, and, in the case of π^+, separation of protons was achieved by time-of-flight requirements and a gas Cerenkov threshold counter. The beam was focussed on the one-inch-square target and the entrance angles in both planes were measured by counter hodoscopes in the beam. Detection of final-state particles was made with a pair of crossed-counter hodoscopes--one above and one below the emergent beam. Acceptable events were required to show coincidence among elements of the momentum-, beam-, and final-state hodoscopes, as well as with a small counter just below the polarized target crystals. In the case of kinematical ambiguity between π^+ and p in the final state, distinction was made with a liquid Cerenkov counter beneath the lower hodoscope.

The polarized target[1] consisted of 7 gm/cm^2 of $La_2Mg_3(NO_3)_{12}\cdot 24\ H_2O$ in which the protons of the waters of hydration (3% by weight) could be polarized by dynamic nuclear orientation.[2] The average polarization during the experiment was 50% and was reversed in sign about once every two hours.

Characterization of each accepted event was made by an on-line PDP-5 computer, summaries displayed, and a record written on magnetic tape. In the subsequent analysis, the requirement that the beam and final-state momenta lie in the same plane removed a large fraction of the background from scattering on heavy elements in the target. When attention was restricted to events with a final-state particle hitting a small region of the upper counter array, a plot of numbers of counts *versus* lower-counter-array position showed a clear peak corresponding to elastic scattering from free protons. Once the background had been subtracted, the number of counts in the elastic peak could be used to determine the asymmetry in pion-proton scattering.

The background under the peak was evaluated by using events which failed the coplanarity requirement. For each element of the upper hodoscope a conjugate set of elements in the lower hodoscopes was chosen in a way which was identical to the choice for coplanar elements--except it was displaced perpendicular to the plane of scattering. The set of events selected by these criteria is due to quasi-elastic scattering from bound protons with a transverse component of Fermi momentum and to inelastic scattering. It was verified that the distribution of these events with angle is the same as that for coplanar events outside the elastic-scattering peak regions. In addition, data were taken at some beam momenta with a dummy target which contained elements similar to those of the crystal but no free protons. These dummy data gave results which substantiated those from the non-coplanar events.

In order to verify the validity of our method we measured the polarization parameter in p-p scattering at 1400 MeV/c using essentially the same beam and detection conditions as were used in the $\pi^{\pm}p$ scattering experiment reported here. The results are in good agreement with previous measurements.[3]

The lower limit in momentum-transfer for which measurements could be made was imposed by the requirement that the recoil proton have a momentum of at least 350 MeV/c, so it could easily escape the target and penetrate the detector array. The minimum differential cross section for which polarization measurements were possible was approximately 50 μb/sr (center-of-mass system).

It was discovered during the run that relatively small amounts of electron contamination in the beam could lead to serious background caused by bremsstrahlung and subsequent production of electron-positron pairs in the one-third radiation length of the polarized target crystals. The resulting pairs had momenta which closely paralleled the beam momentum. The polarized target magnet then separated the e^+ and e^- and directed one into each of the final-state hodoscopes. These "events" had good coplanarity and tended to obscure the pion-proton elastic peak. The remedy chosen was to insert approximately one radiation length of Pb at the first focus of our doubly focussed beam.

The results of this experiment are shown in Figs. 1 and 2.[4] The errors shown are statistical only and do not include a ±10% uncertainty in scale due to inaccurate knowledge of target polarization. At those energies where previous measurements have been made, the agreement is good.[5,6,7] It is seen that the polarization is not small even at the highest energies of this experiment and there is considerable structure in angular dependence. In particular the variation in the polarization with energy near the 1924 MeV $I = 3/2$ resonance ($P \simeq 1500$ MeV/c), $T_\pi \simeq 1350$ MeV) is very striking.

Figure 3 is a plot of the momentum-dependence of the coefficients in the Legendre expansion

$$I_0 P = \sum C_i P_i^{\,1}(\cos\theta_{cm})$$

fitted to the π^+ polarization P presented here and the π^+ differential cross section I_0 of Duke et al.[6] Preliminary analysis of these fits indicates that they are consistent with the assignment of $J^P = 7/2^+$ for the 1924 resonance as reported by Duke et al.[6] on the basis of $\pi^{\pm}$-P cross section and π^--P polarization data.

More extensive analysis of these data has been initiated; in the lower energy region a phase shift search is in progress and at higher energies attempts are being made to explain the data in terms of interference of Regge exchange amplitudes with direct channel resonances.

We are indebted to Dr. John Brolley for his help in conducting the experiment. We also wish to thank John Arens, Byron Dieterle, Ray Fuzesy, William Gorn, Charles Morehouse, Michael Paciotti, Stephen Rock, and David Weldon for their contributions throughout the course of this experiment. Finally, we are grateful to the Bevatron operating crew for their constant support.

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FIGURE CAPTIONS

Fig. 1. Plots of the polarization parameter P versus cosine of the pion c.m. scattering angle for π^+p scattering. The errors shown are statistical only and do not include a ±10% uncertainty in scale due to inaccurate knowledge of target polarization.

Fig. 2. Plots of the polarization parameter P versus cosine of the pion c.m. scattering angle for π^-p scattering. The errors shown are statistical only and do not include a ±10% uncertainty in scale due to inaccurate knowledge of target polarization.

Fig. 3. Coefficients in the associated Legendre expansion $I_0P = \sum C_i P_i^1(\cos \theta_{cm})$ versus lab momentum of the pion for π^+p scattering.

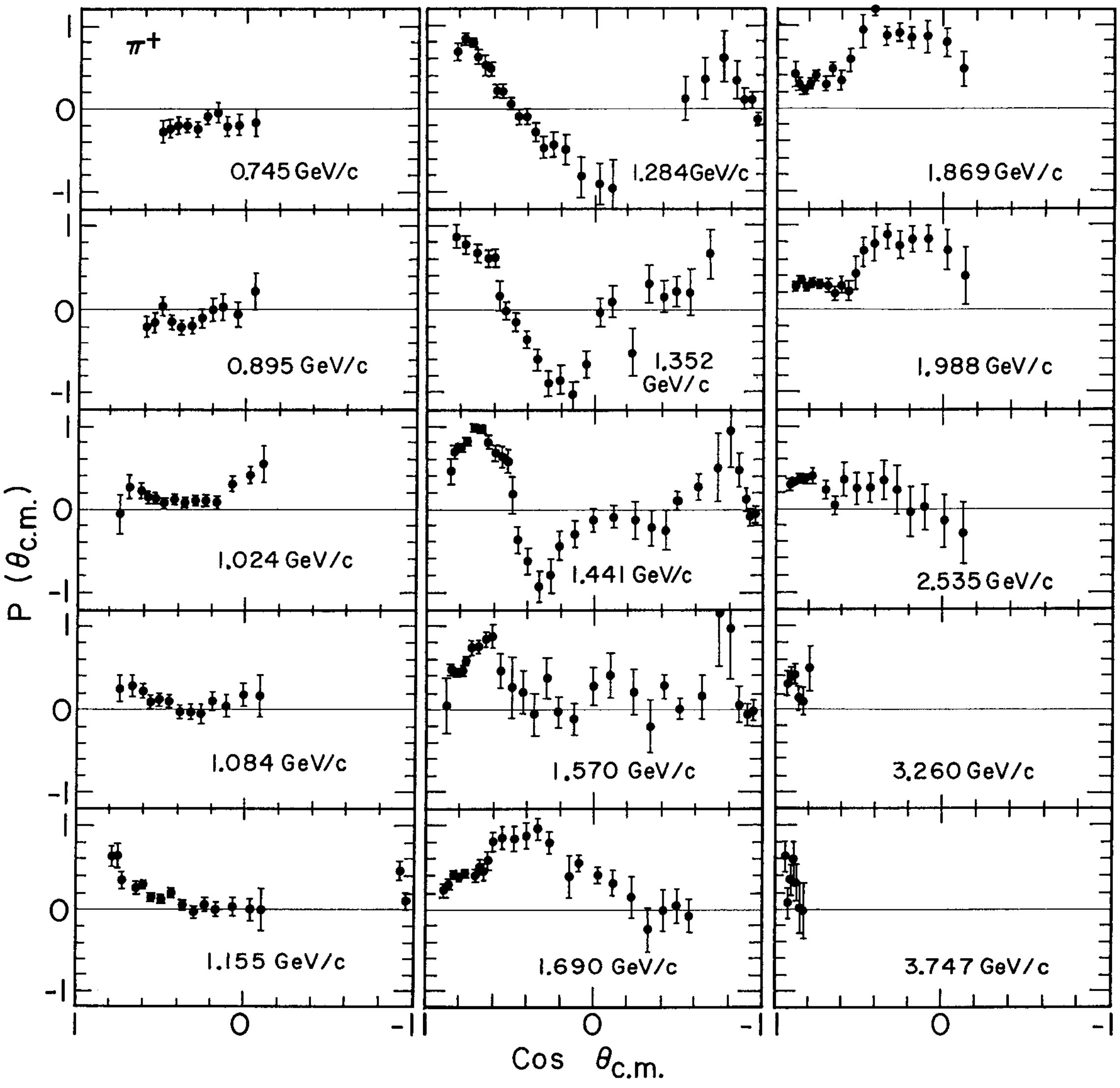

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Fig. 1

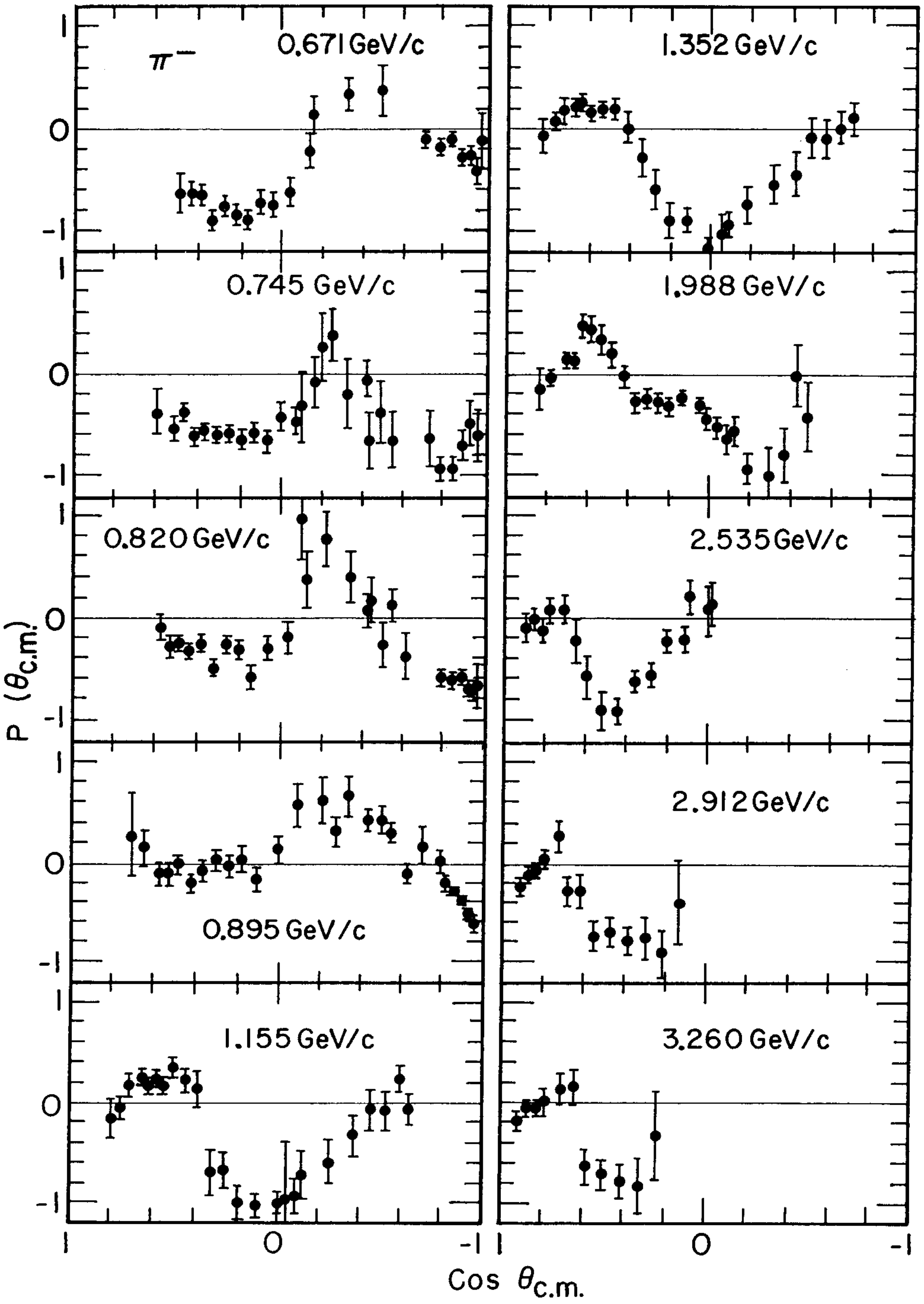

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Fig. 2

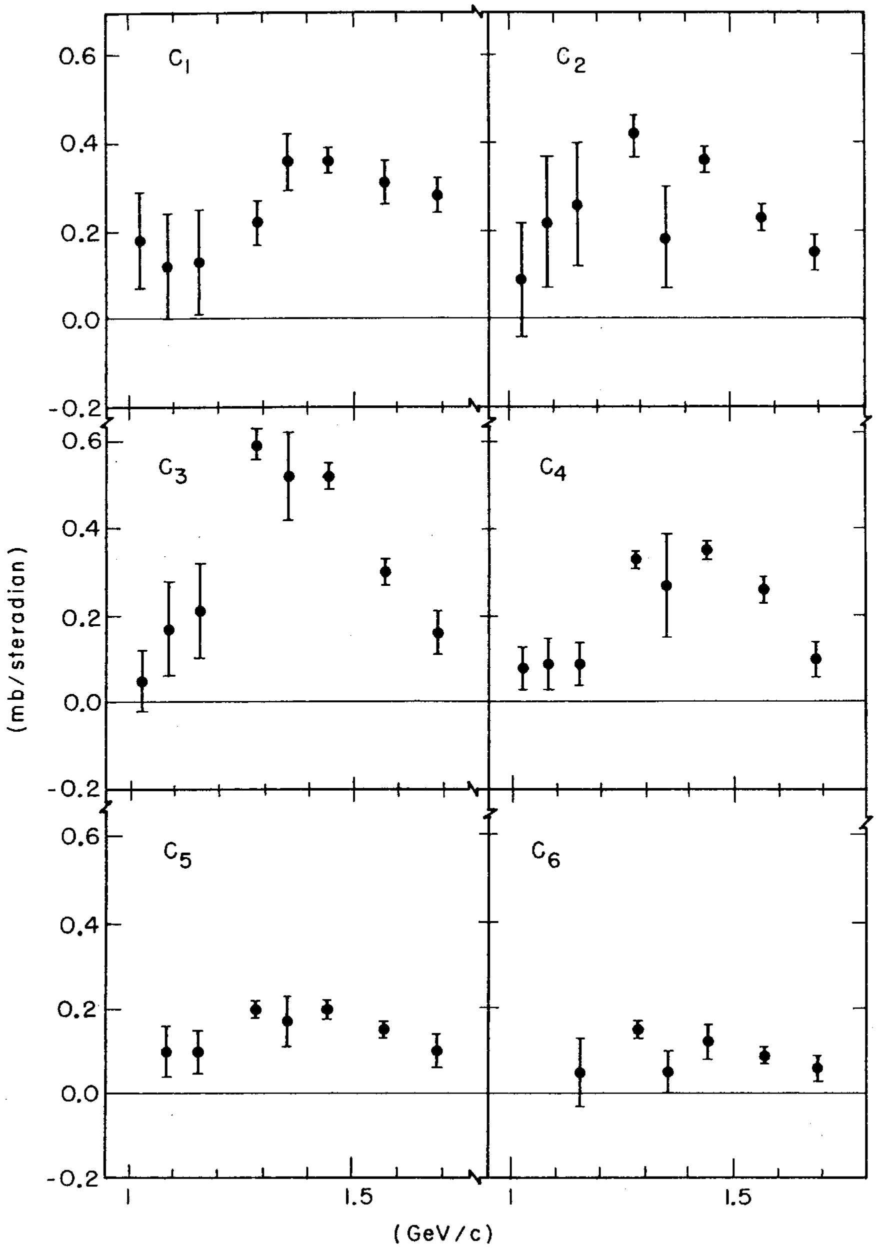

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Fig. 3