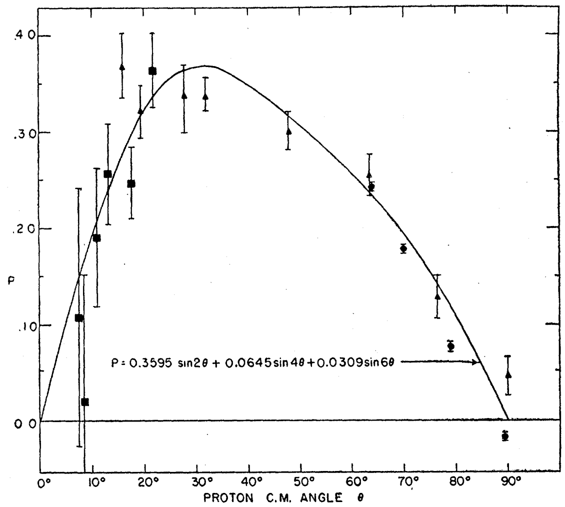

FIG. 3. Polarization produced by proton-proton scattering at 300 Mev, plotted as a function of center-of-mass scattering angle. ● Chamberlain *et al.* (reference 6); ▲ Chamberlain *et al.* (reference 5); ■ Present work.

scattering in this experiment through the relation $P=e/P_B$, where P_B has been taken to be 0.74+0.01. The results are plotted in Fig. 3 in conjunction with previous p-p polarization data[5,6] taken at larger angles. The solid curve, a Fourier analysis of the previous data, seems still in agreement with the new points at smaller angles.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

[1] For a more complete list of references than is possible here, see for example, R. M. Thaler and J. Bengston, Phys. Rev. **94**, 679 (1954).
[2] D. Fischer and G. Goldhaber, following letter [Phys. Rev. **95**, 1350 (1954)].
[3] Chamberlain, Segrè, Tripp, Wiegand, and Ypsilantis, Phys. Rev. **95**, 1348 (1954).
[4] Chamberlain, Pettengill, Segrè, and Wiegand, Phys. Rev. **93**, 1424 (1954).
[5] Chamberlain, Segrè, Tripp, Wiegand, and Ypsilantis, Phys. Rev. **93**, 1430 (1954).
[6] Chamberlain, Donaldson, Segrè, Tripp, Wiegand, and Ypsilantis, Phys. Rev. **95**, 850 (1954).

Proton-Proton Scattering Experiments at 170 and 260 Mev*

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THE differential proton-proton scattering cross section has been measured at 170 and 260 Mev for laboratory scattering angles of 4.4 to 40 degrees with the University of California synchrocyclotron. This experiment is an extension to smaller scattering angles of work completed earlier at this laboratory[1] and is essentially in agreement with this earlier work. The angular region of the differential p-p scattering cross section presented here is of interest because it is in this region that the experimental results are at greatest variance with the theory.[2]

The 340-Mev full-energy proton beam from the cyclotron was reduced in energy by using beryllium absorbers. Following the absorbers the proton beam was collimated and analyzed in a magnet to provide a beam reasonably parallel and homogeneous in energy. A liquid hydrogen target was used.[3] The target presented 5.6 inches of liquid hydrogen to the beam for scattering.

The scattered protons were counted by means of a telescope consisting of two liquid scintillation counters in coincidence. The first counter served to define the solid angle subtended by the telescope at the target. The second counter was placed to the rear of the first and was larger, so that multiple-scattering losses would be small.

The background coincidence counts, consisting primarily of protons scattered from the collimator system and hydrogen target walls, were determined by using a dummy target to simulate the empty hydrogen target. It was found that the dummy target gave a false measure of the true counting background because the stopping power of the full liquid hydrogen exceeded that of the dummy target by the stopping power of the liquid hydrogen. Some of the low-energy protons contributing to the counter background coincidences had insufficient

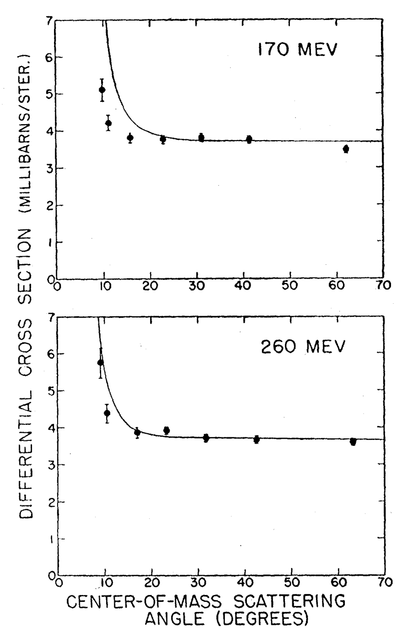

FIG. 1. Center-of-mass differential p-p scattering cross sections *versus* center-of-mass scattering angle. The points represent the experimental results, with errors as they apply to the angular distribution. The solid lines show the sum of a constant nuclear cross section and pure Coulomb scattering cross section. Energies are given for the laboratory system.

range to count when the hydrogen target was in the proton beam, but were able to count when the dummy was in the beam. This effect was appreciable at scattering angles close to the proton beam and was corrected by placing an absorber with just the stopping power of the liquid hydrogen between the two scintillation counters when counts were taken with the dummy target in the proton beam.

The beam was monitored by an ionization chamber, which was calibrated by a Faraday cup.[4] The Faraday cup calibration was done with varying amounts of absorber placed before it, permitting a determination of the energy distribution and mean range of the proton beam. The nuclear loss corrections in the absorber were determined with the use of the absorption cross sections of Kirschbaum.[5]

The measured differential cross sections are shown in Fig. 1. The differential cross section was found to be the same at both energies, within the accuracy of the experiment. The cross sections presented here are much lower than those of some previous workers;[6] however, they are in agreement with more recent work.[7] Figure 1 includes curves drawn for Coulomb scattering plus a constant nuclear cross section. Deviations from the curves should represent interference between Coulomb and nuclear scattering.

The errors indicated in the figure are those determined by combining the known errors affecting the shape of the angular distribution. The errors in the total cross sections are estimated to be about eight percent.

A complete account of the experiment will be published later.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

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1 Chamberlain, Segrè, and Wiegand, Phys. Rev. 83, 923 (1951).

2 Reference 1 contains a number of references on this subject.

3 The target has been described by J. W. Mather and E. A. Martinelli, Phys. Rev. 92, 785 (1953).

4 The ion chamber and Faraday cup are described in reference 1

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6 C. L. Oxley and R. D. Schamberger, Phys. Rev. 85, 416 (1952); O. A. Towler, Phys. Rev. 84, 1262 (1951); Cassels, Pickavance, and Stafford, Proc. Roy. Soc. (London) 214, 262 (1952).

7 Marshall, Marshall, and Nedzel, Phys. Rev. 92, 834 (1953); Chamberlain, Pettengill, Segrè, and Wiegand, Phys. Rev. 93, 1424 (1954); also some unpublished results, Gordon H. Pettengill (private communication).

Small Angle Proton-Proton Scattering at 330 Mev*

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In conjunction with the program on p-p and n-p cross-section measurement, the p-p scattering at 330 Mev has been measured down to small angles (2.2° to 14° lab). In this angular interval the Rutherford scattering and nuclear scattering become of the same order of magnitude and interference phenomena may be expected to occur.

The method used consisted of getting a very highly collimated beam (the electrostatically deflected 340-Mev proton beam of the UCRL 184-inch synchrocyclotron was used) and then detecting with nuclear emulsions the protons scattered from a liquid hydrogen target. A plate camera was constructed holding seven 1 in. by 3 in. 200-micron Ilford G-5 emulsions on the left and right side of the beam. (See Fig. 1.) The emulsions were placed lengthwise in a horizontal row with the emulsion plane inclined at an angle of 43° with the proton beam. Exposures to an integrated flux of 5×10^{10} protons were made with target filled and with target empty. A copper absorber $2\frac{1}{2}$ in. thick was placed in front of the emulsions. During the target-empty exposure additional absorber was added to compensate for the energy loss and attenuation in the liquid hydrogen. One of the plates at 14° (lab) was not covered by absorber so that the attentuation could be determined and the absolute cross section evaluated.

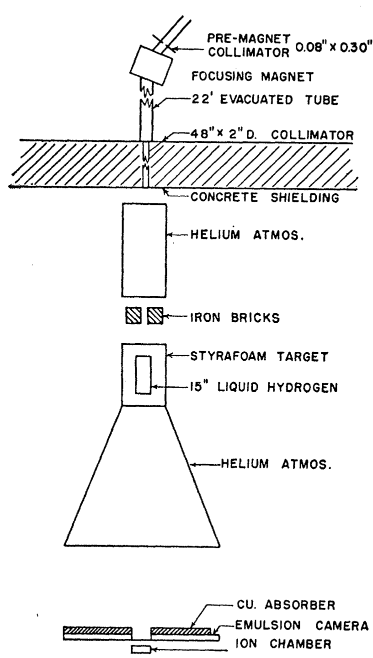

Fig. 1. Plan of the target and camera geometry.

In scanning the plates, the protons were counted as they entered the surface of the emulsion. Since there was a $2\frac{1}{2}$-in. copper absorber in front of the plates, the tracks were more than twice minimum ionizing and quite easily counted. The ratio of "target filled" to "target empty" counts varied from 7.0 to 2.5. The angular resolution at the camera varied from $\pm0.5°$ lab to $\pm0.9°$ lab.