the spectroscopic study which we are now performing are expected to give us more knowledge in the near future.

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Small-Angle *p-p* Cross Sections and Polarization at 300 Mev*

O. CHAMBERLAIN, G. PETTENGILL, E. SEGRÈ, AND C. WIEGAND
Radiation Laboratory, Department of Physics, University of California, Berkeley, California
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RECENT experiments[1] in the energy region 100 to 400 Mev have demonstrated the extreme constancy against energy and angle of the proton-proton differential scattering cross section. Because of the severe experimental difficulties, however, the angles below 20 degrees center of mass, where the nuclear and Coulomb terms in the cross section might reasonably be expected to interfere, have not been thoroughly investigated.

Since the major experimental difficulties in the small-angle region arise mainly from the high background, it is necessary either to take unusual care in the collimation or to define an allowed trajectory for the beam through counters in coincidence. In this experiment we have chosen the latter method. An accompanying paper[2] describes an experiment using the former method.

By using the 312-Mev polarized proton beam[3] from the Berkeley synchrocyclotron, we have been able to measure simultaneously the differential cross section and the asymmetry for polarized protons scattering from a liquid hydrogen target. The experimental arrangement is shown schematically in Fig. 1. Counter No. 3 is a

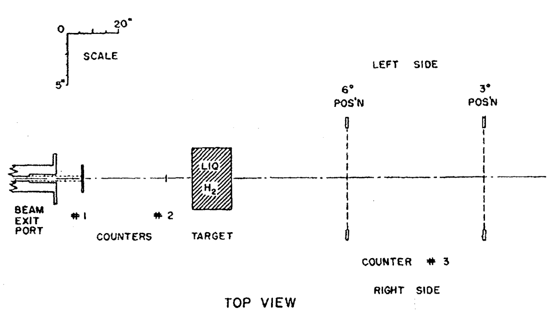

FIG. 1. Schematic representation of scattering arrangement. Note lateral expansion of scale.

symmetrical ring, divided into two parts along a vertical diameter parallel to the polarization of the incident beam. Provision is made for rotating this counter about an axis parallel to the incident beam in order to verify that the response of the two counter halves is equal.

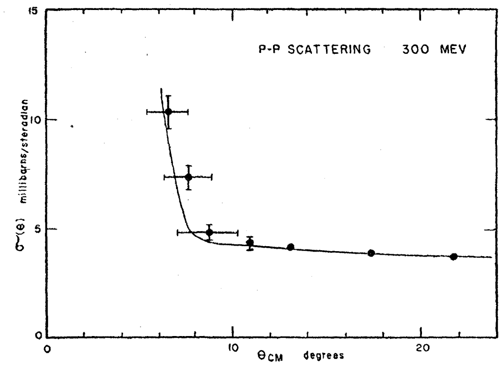

FIG. 2. The differential proton-proton scattering cross section plotted as a function of angle in the center-of-mass system. The solid curve is a visual fit to the data.

The incident beam was monitored by a fast coincidence and scaling system reading the output of the beam defining counters, Nos. 1 and 2. The 1–2 counting rate for all the cross-section data and the bulk of the asymmetry data was held at approximately 800 per second. At this level approximately $3\frac{1}{2}$ percent of the 1–2 counting rate was due to pileup, i.e., two protons passing through the defining system within one resolving time of the counters.

Protons scattered into the left and right halves of counter No. 3 were counted independently, each in coincidence with counters Nos. 1 and 2. A typical value of the fraction of protons scattered into one-half of the counter by the 2.80 grams per square centimeter of hydrogen in the target was 2×10^{-4}. At each angle, data were taken with the target both full and empty. Part of the target empty data was taken with additional absorber inserted in front of counter No. 3 to simulate the stopping power of the hydrogen in the target. The possibility of low-energy contamination of the beam was thus checked. No such contamination was found.

The cross section was obtained by adding the fractions of the beam scattered by hydrogen into the two halves of counter No. 3 and multiplying this by the appropriate geometrical factors for each angle. The results, with statistical errors only, are shown in Fig. 2. Since the relative accuracy is better than the absolute, the values have been adjusted to give 3.7×10^{-27} cm^2 per steradian at 20 degrees (center of mass).[4] The approximate angular resolution is indicated for the smaller angles where it is of interest. The solid curve is a rough fit to the data, taking the angular resolutions into account.

The asymmetry was obtained from the formula, $e=[(f_L-f_R)/(f_L+f_R)](\phi/\sin\phi)$, where f_L, f_R are the fractions of beam protons scattered into the left and right sides of counter No. 3, respectively, and 2ϕ is the azimuthal angle covered by either half of counter No. 3. Since the beam polarization has been previously measured[3] in elastic scattering experiments, we may calculate directly the polarizations arising from the *p-p*

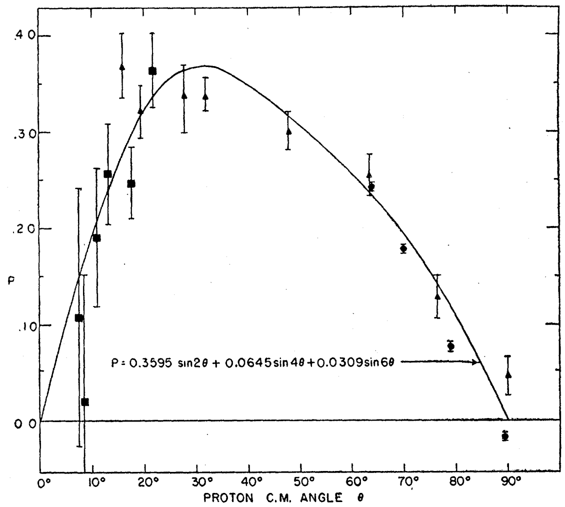

FIG. 3. Polarization produced by proton-proton scattering at 300 Mev, plotted as a function of center-of-mass scattering angle. ● Chamberlain *et al.* (reference 6); ▲ Chamberlain *et al.* (reference 5); ■ Present work.

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).

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Proton-Proton Scattering Experiments at 170 and 260 Mev*

OWEN CHAMBERLAIN AND JOHN D. GARRISON†
Radiation Laboratory, Department of Physics, University of California, Berkeley, California
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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

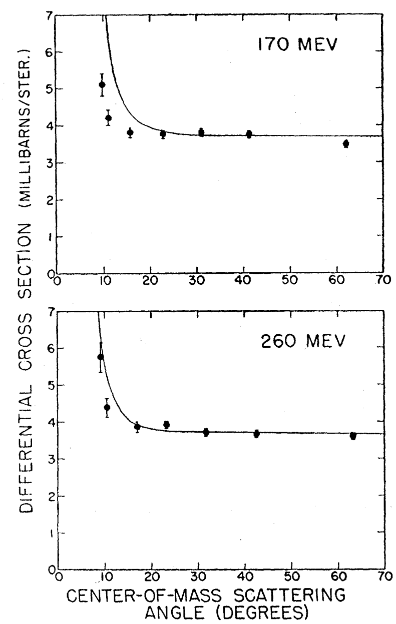

FIG. 1. Center-of-mass differential *p-p* scattering cross sections *versus* center-of-mass scattering angle. The points represent the experimental results, with errors as they apply to the angular distribution. The solid lines show the sum of a constant nuclear cross section and pure Coulomb scattering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