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

[5] A. J. Kirschbaum, University of California Radiation Laboratory Report No. UCRL-1967, October, 1952 (unpublished).

[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 **93**, 1424 (1954); also some unpublished results, Gordon H. Pettengill (private communication).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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(Received July 12, 1954)

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.

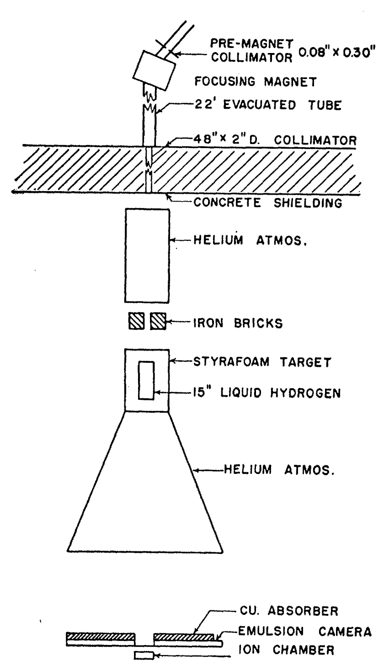

Fig. 1. Plan of the target and camera geometry.

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 ±0.5° lab to ±0.9° lab.

The absolute cross-section determination gives 3.8±0.25 mb/sterad for angles above 20° (c.m.). The principal uncertainty in this value is because of the calibration of the attenuation ($I/I_0=0.79\pm0.04$) in the $2\frac{1}{2}$-in. copper absorber ahead of the emulsions and the scanning efficiency ($\epsilon=0.95\pm0.05$). This value is in good agreement with the recent Berkeley value[1] of 3.72±0.15 mb/sterad. Our angular distribution is shown in Fig. 2, normalized to the 3.7 mb/sterad value. In Fig. 2 is also shown the sum of the Rutherford scattering (calculated) and the nuclear scattering (considered constant at 3.7 mb/sterad). If one considers the differential cross section separated into three terms,[2] $P_{\mathrm{nuc.}}+P_{\mathrm{Ruth.}}+P_{\mathrm{int.}}$, i.e., the nuclear scattering, the Rutherford scattering, and the interference between them, then the difference between the solid curve and the experimental points should represent $P_{\mathrm{int.}}$. There appears to be a net effect of destructive interference in the region of 6° to 14° (c.m.).

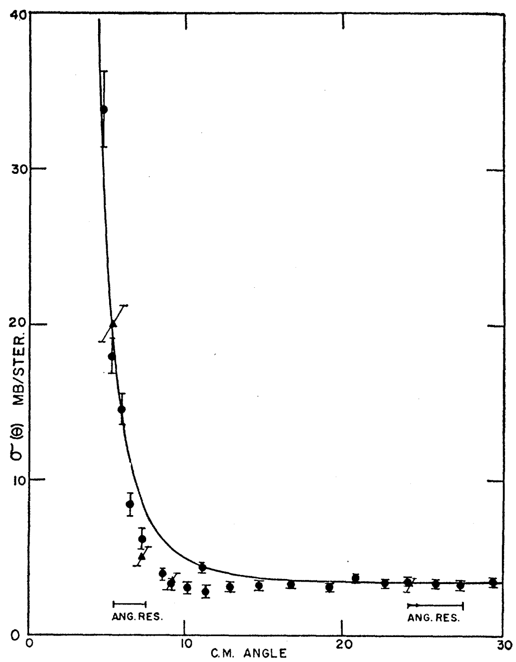

FIG. 2. Differential cross section for 330-Mev *p-p* scattering normalized to 3.7 mb/sterad in the region of pure nuclear scattering. The circles and triangles represent measurements on plates placed on the right and left side of the beam, respectively. The errors indicated are the statistical standard deviations. The solid curve represents the sum of Rutherford scattering and a constant nuclear scattering of 3.7 mb/sterad.

It is interesting to note that the interference term $P_{\mathrm{int.}}$ is extremely sensitive to the relativistic corrections used for Rutherford scattering. The curve in Fig. 2 was drawn according to Møller's[3] formula. In the small-angle approximation this is identical with a modified form of Mott's formula.[4] The latter is obtained when the wavelength of relative motion $\hbar$ is factored out and replaced by its relativistic value,[2] leaving the remaining velocity dependence unchanged. If Mott's formula is evaluated without any relativistic corrections, the resulting scattering is larger by a factor $2\gamma^2/(\gamma+1)=1.55$, and the interference term then appears increased correspondingly. The relativistic approximation used by Van Hove[5] gives a value larger than that given by Møller's formula by a factor $(\gamma+1)/2=1.18$.

We were able to fit the experimental points fairly well by a selection of one *s* and three *p* wave phase shifts. In the symbols of Thaler and Bengston[2] for instance ${}^1K_0=31°$, $\alpha=1.2$, $\beta=0.28$ can give possible sets of phase shifts, where ${}^1K_0$ is the *s* wave phase shift[6] and α and β are functions of the *p* wave phase shifts. However, as was pointed out by Fried,[7] without the use of additional phase shifts this type of analysis is not able to account for the recent[8] polarization data, and a more detailed analysis will be required.

We wish to thank Professors Segrè and Chamberlain for their help and cooperation in this work, and Miss Sheila Livingston for her contribution to the scanning of the plates.

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

[1] Chamberlain, Pettengill, Segrè, and Wiegand, Phys. Rev. **93**, 1424 (1954).
[2] R. M. Thaler and J. Bengston, Phys. Rev. **94**, 679 (1954).
[3] C. Møller, Ann. Physik **14**, 531 (1932).
[4] At small angles Mott's formula (nonrelativistic) for *p-p* scattering, c.m. system, can be expressed as

$$P_{\mathrm{Mott}}=(e^4/M_p{}^2v^4)\sin^{-4}(\theta/2)\ \mathrm{cm^2/sterad},$$

and Møller's formula can be reduced to

$$P_{\mathrm{Mott}}(\gamma+1)/2\gamma^2,$$

where e is the electron charge, M_p the proton mass, v the relative velocity, θ the c.m. angle and $\gamma=(1-v^2/c^2)^{-\frac{1}{2}}$.
[5] L. Van Hove, Phys. Rev. **88**, 1359 (1952).
[6] The estimate of the singlet *s* phase shift was made by Dr. H. P. Noyes using the low-energy meson well parameters of Hall and Powell [Phys. Rev. **90**, 912 (1953)].
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Recoil Spectrum in the Beta Decay of Ne^{19}†

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(Received July 15, 1954)

MEASUREMENTS of the electron-recoil angular correlation in beta decay of He^6 have shown[1,2] that the Gamow-Teller part of the beta interaction is tensor. In the Ne^{19} decay both Fermi and Gamow-Teller components should be present; to identify the Fermi part as scalar or vector we have measured the spectrum of Ne^{19} recoils emitted at nearly 180° from (and in time coincidence with) the positrons.

Figure 1 shows the apparatus used. Recoils, accelerated to 2-kev energy, are detected by a silver