is large, a second correction using the total cross section for neutron scattering as given by Taylor *et al.*,[3] was used, which represents an upper limit on the correction.[4] In this case, the maximum correction amounted to 28.3 percent. Coulomb scattering and multiple scattering effects were not corrected for, because they were found much smaller than the nuclear scattering effect.

Figure 3 shows graphs of our results. The open and the solid points correspond to the first and second type correction, respectively. The indicated standard deviations are due to the counting statistics only. They are in general consistent with the results of Keck *et al.*,[5] which are also plotted on the graphs. The values are not very consistent in the highest-energy bin. This is not surprising, since the scattering effects are the largest there, and also since the value there is very sensitive to the maximum energy of the bremsstrahlung.

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[3] A. E. Taylor and E. Wood, Phil. Mag. **44**, 95 (1953).
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Neutrons in Coincidence with High-Energy Photoprotons*

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A GREAT deal of effort has been devoted at many laboratories to the study of high-energy protons ejected from various nuclei by approximately 300-Mev bremsstrahlung.[1] It was proposed by Levinger[2] that these photoprotons could be explained on the basis of the disintegration of a quasi-deuteron subunit in the nucleus. The proton energy spectra were in general qualitative agreement with the predictions of this model. However, the possibility existed that the agreement was fortuitous[1]; it was felt that it would be desirable to see if neutrons and protons were emitted simultaneously in high-energy photoproton reactions. The results of a preliminary experiment described below are that neutrons and protons are emitted simultaneously from nuclei and have the proper dynamical relationships. This result removes all doubts concerning the validity of the quasi-deuteron model for the photoproton ejection process.

A proton telescope consisting of three scintillators was employed with an energy spread of about 10 Mev at 135 Mev. In these measurements the proton detector was fixed at 45°. A neutron detector consisting of a cylinder of scintillating liquid 10 cm in diameter and 30 cm long was employed. The efficiency of the neutron detector had been previously determined to be 9 percent with the aid of neutrons from the Harvard cyclotron. Measurements were made of the number of coincidences between these two detectors as a function of the angle of the neutron counter. In these measurements the bremsstrahlung beam from the M.I.T. synchrotron was run at 325 Mev. As a check of the equipment the neutron-proton coincidences from the photodisintegration of deuterium were studied by a $D_2O - H_2O$ subtraction. Measurements were then made of the neutron-proton coincidences from carbon. The results of both of these measurements are shown in Fig. 1.

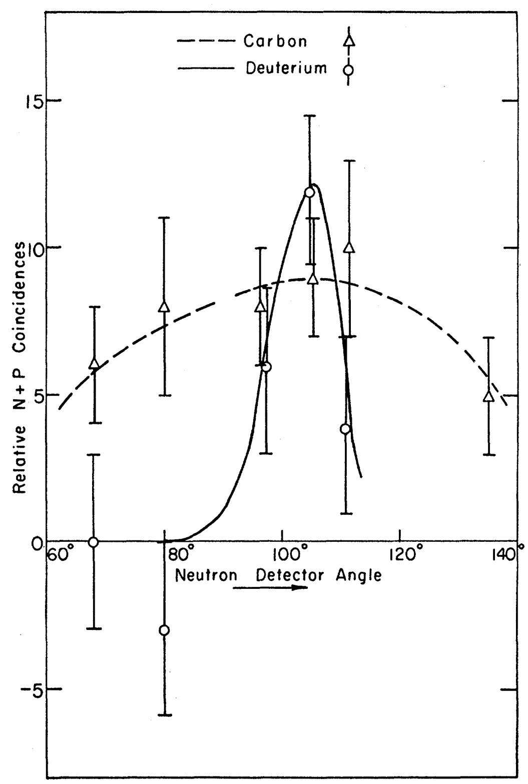

Fig. 1. Neutron-proton coincidences from carbon and deuterium as a function of the angle of the neutron counter. The coincidences are expressed in relative counts per atom per monitor unit.

Unfortunately, the mounting of the equipment did not permit a larger range of angles than that shown in the figure. The oxygen coincidences had the same angular distribution as those from carbon to within the statistics obtained. The accidental coincidence rate was measured and found to be negligible.

If one assumes that the neutrons are emitted in an angular cone around the angle predicted for the neutrons from deuterium and if one assumes that the angular distribution does not extend appreciably beyond the range investigated, one finds that there are about 1.2 neutrons in coincidence with every proton from carbon. The fact that this is greater than unity could be explained by poor statistics, or by the fact that the solid angle subtended by the neutron counter is no doubt due to a lead housing surrounding it. Further investigations are being made of this phenomenon with better geometry; however, the authors feel that most of the time neutrons and protons are emitted simultaneously from carbon and oxygen at these high energies.

* This work was supported in part by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.

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Diffuse Surface Optical Model for Nucleon-Nuclei Scattering*

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We report some first results of calculations of the differential cross section for the elastic scattering of 20-Mev protons by medium and heavy nuclei, assuming that the nuclear part of the interaction is described by a spinless, spherically symmetric, complex potential. These calculations, which are accomplished by numerical integration of the partial wave radial equations for values of L up to 13, are performed on SWAC, the National Bureau of Standards Western Automatic Computer. The time required to obtain a complete differential cross section, tabulated at 5° intervals, is 15 to 20 minutes.

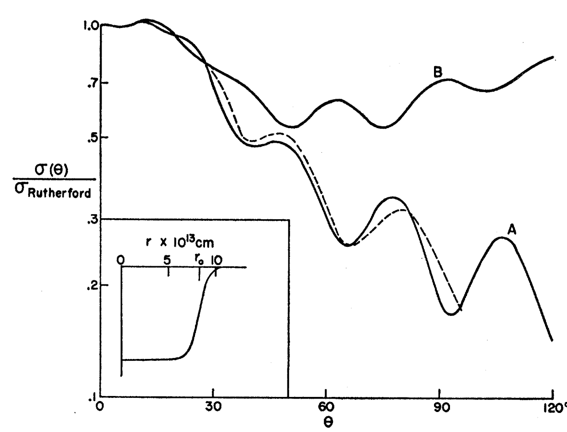

FIG. 1. Elastic scattering of 22-Mev protons by Pt relative to Rutherford scattering. The dashed curve is the experimental result of Cohen and Neidigh (see reference 3), the normalization of which is somewhat uncertain. Curve A is calculated for a diffuse surface model with $V=38$ Mev, $W=9$ Mev, $r_0=8.24\times10^{-13}$ cm, and $a=0.49\times10^{-13}$ cm. The shape of the well is shown in the small drawing at the lower left. Curve B is calculated for a square well of comparable size and depth.

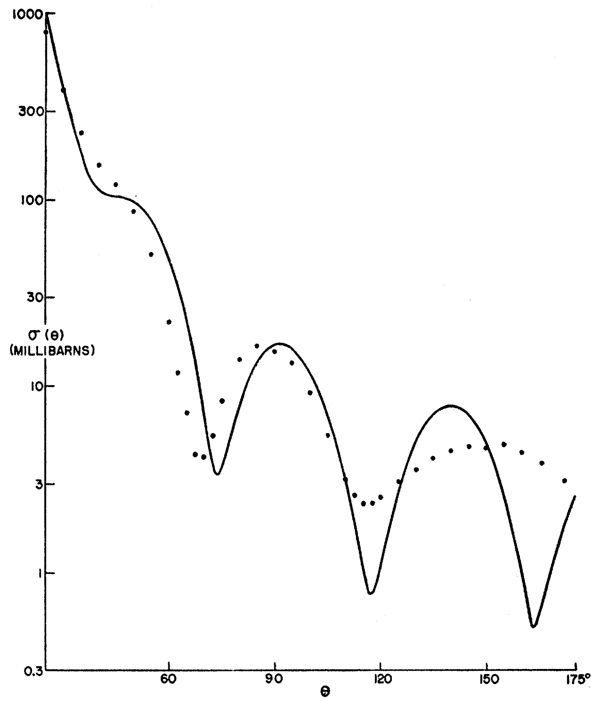

FIG. 2. Elastic scattering of 18-Mev protons by Ni. The experimental points are those of Dayton (see reference 1). The curve was calculated for a diffuse surface model with $V=40$ Mev, $W=10$ Mev, $r_0=5.3\times10^{13}$ cm, and $a=0.35\times10^{-13}$ cm.

Initially, the complex potential was taken to be a square well with all of the nuclear charge essentially on the nuclear surface; this because of the simplicity of the model and because of its apparent success for Al.[1] However, for heavier nuclei, the square well results are in marked disagreement with the experimental cross sections of Gugelot,[1] Burkig and Wright,[2] and Cohen and Neidigh.[3] In particular, the square well predicts scattering at larger angles which is considerably too large as illustrated in Fig. 1 for the case of Pt. This disagreement, which has also been noted by others,[4] persists even if the square well parameters are permitted to vary over an extensive range and if the nuclear charge is assumed to be distributed over the nuclear volume.

Consequently, a nuclear potential which decreases smoothly to zero is now being studied, the assumed form of this potential being

$$V(r)=\frac{V+iW}{1+e^{(r-r_0)/a}},$$

where r_0 is a measure of the nuclear size and a determines the diffuseness of the nuclear surface. The Coulomb part of the interaction is taken to be that arising from a uniform charge distribution over a sphere of radius r_1 (not necessarily equal to r_0).