model,

$$f(E)=\sum_k \alpha_k(E/k)^{-s}=E^{-s}\sum\alpha_k k^s.$$

In other words, if the spectrum in case I is well described by a power law, spectrum II will be described by the same power law provided the α_k are constant. This seems to be confirmed by our results (curve II, where the experimental bias is again responsible for the change of slope below $E=120Mc^2$). For $E\geqslant 120Mc^2$ we obtain from 37 cases $s=1.45_{-0.23}{}^{+0.25}$. One should note that Cocconi[6] assumes the k nucleons to be arranged longitudinally in the direction of the primary, whereas we take them to be arranged transversely.[5] At present our results indicate that, assuming a geometrical mean free path in nuclear matter, the experimental values of α_k are very different from what one would expect to find for the Cocconi model applied to the emulsion nuclei. The detailed analysis of our data will be submitted for publication elsewhere.

We wish to express our gratitude to Professor F. G. Houtermans for his interest and encouragement and to Professor Charles Peyrou and Dr. M. Teucher for stimulating discussions. We are also indebted to Dr. Charles Houtermans who was associated with the early stages of this work. Finally we wish to thank Mrs. B. Mesmer, Mrs. R. Müller, and Mrs. G. Riesen for careful scanning of the plates.

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Asymmetry in Neutron Production by Bombarding Targets with 285-Mev Polarized Protons*

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AN asymmetry in neutron production has been observed in the quasi-elastic scattering of polarized protons on the nucleons of carbon, beryllium, and lithium targets.

The polarized proton beam was obtained by scattering the cyclotron beam on an internal beryllium target, using the arrangement of Chamberlain *et al.*[1] This resulting proton beam had a polarization of 65±3 percent, a mean energy of 285 Mev, and a flux of approximately 10^5 protons per second in the "cave" outside the cyclotron shielding.

When targets were bombarded by these polarized protons, neutrons (and protons) were ejected by nucleon-nucleon collisions. The neutrons were counted in 180° center-of-mass coincidence with their recoil protons, and only recoil protons of energy greater than $0.7\,E_0\cos^2\theta$ were accepted. Thus, only quasi-elastic proton-neutron events were recorded. One telescope subtended a solid angle of approximately 1/200 sterad, but the other needed to subtend 1/10 sterad to give good counting rates at large angles.

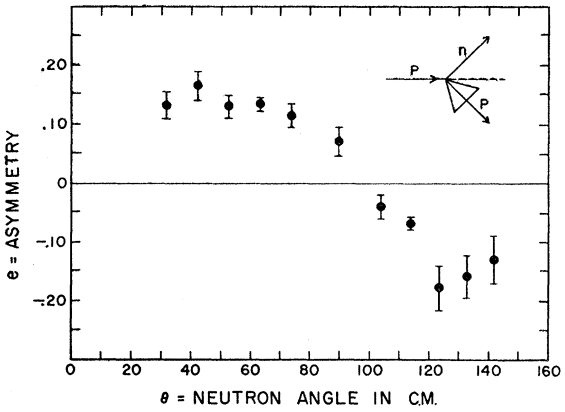

FIG. 1. Asymmetry e plotted as a function of the center-of-mass neutron angle for proton-neutron quasi-elastic scattering from carbon. The errors shown include only counting statistics.

The telescopes used for recording proton-neutron events could also be used for recording proton-proton events.

Alignment of the apparatus was checked by measuring the asymmetry of double scattered protons as in the experiment of Chamberlain *et al.*[1] Our data were found to agree within statistical errors, with their results.

In a p-n collision, it can be shown[2] that each of the scattered nucleons has the same polarization P_{np}, as long as the initial nucleons are unpolarized and nuclear forces are charge-independent. If the incident protons have a polarization P_p, the right-left asymmetry in the counting rate of neutrons is related to the polarization

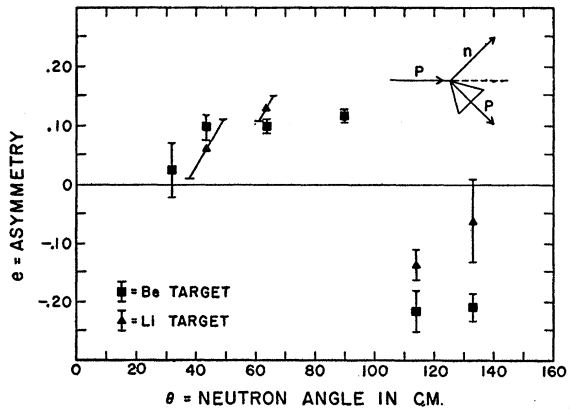

FIG. 2. Asymmetry e plotted as a function of the center-of-mass neutron angle for proton-neutron quasi-elastic scattering from lithium and beryllium. The errors shown include only counting statistics.

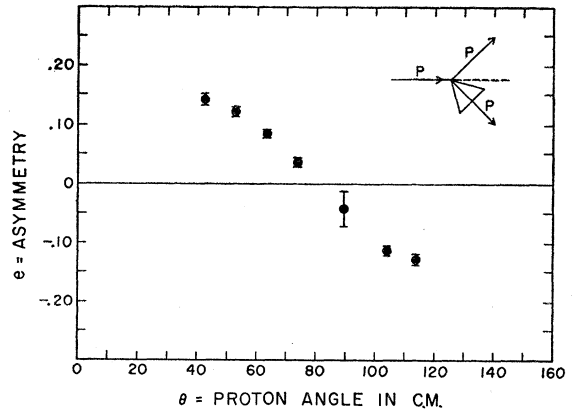

FIG. 3. Asymmetry e plotted as a function of the center-of-mass proton angle for the proton-proton quasi-elastic scattering off carbon. The errors shown include only counting statistics.

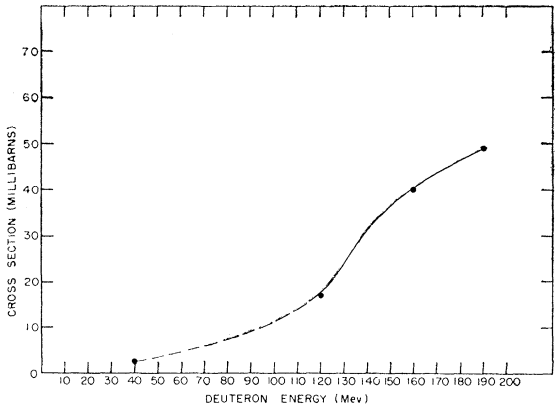

FIG. 1. Cross section for the production of Pa^{237} by deuteron bombardment of U^{238}.

P_{np} by the usual equation, $e=(L-R)/(L+R)=P_pP_{np}$; where e is the asymmetry, and L and R are the neutron counting rates at equal angles to the left and right. In the present experiment, this gives $P_{np}=e/0.65$.

Figures 1 and 2 give the quasi-elastic asymmetry e for neutrons from carbon, beryllium, and lithium targets. For angles greater than 90° center-of-mass the neutrons were defined by the telescope with poor angular resolution.

It should be noted that the nonzero neutron asymmetry at 90 degrees center-of-mass indicates[3] the presence of both odd and even terms in the scattering analysis. A subsequent experiment by Chamberlain *et al.*[4] using a liquid deuterium target gives results in good agreement with our data on carbon.

Figure 3 shows the asymmetry of quasi-elastic proton-proton scatters in carbon, obtained at the same time as the neutron data.

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

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New Isotope Protactinium-237†

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THE bombardment of Th^{232} with energetic deuterons and helium ions has been used to study the isotopes of protactinium.[1] The heaviest isotope previously produced by this method was Pa^{235}, a negative beta particle emitting isotope with a twenty-three-minute half-life.[2] Until recently it has been assumed that reactions of the type $(d,2pxn)$ would have very small cross sections; consequently, little work has been done on the protactinium isotopes produced by high-energy deuteron bombardment of uranium.

In the bombardment of U^{238} with high-energy deuterons, the isotope Pa^{237} is produced by the reaction $(d,2pn)$. A sample of U^{238} was irradiated with 190-Mev deuterons, and a protactinium sample was chemically separated as soon as possible. From the decay of the negative beta particle emitted, one can determine that there is present an isotope with a half-life shorter than twenty-three minutes. However, accurate determination of the half-life of this isotope is difficult since large quantities of Pa^{235} are also produced. By chemically separating uranium from a protactinium fraction at fixed periods, the half-life and the mass assignment of this new short-lived protactinium isotope were determined. The uranium fractions were counted for β^- particles and gamma rays. The ratio β^-/γ in the separated uranium fraction was the same as that for a sample of U^{237} produced by other methods, and the separated uranium fractions decayed with the 6.7-day half-life of U^{237}. From this series of experiments, one obtains a half-life of 10.5 ± 1 min for Pa^{237}.

The cross section for the production of Pa^{237} was determined by bombarding one-mil uranium foils in the internal beam of the 184-inch cyclotron and then isolating the protactinium formed. The energy of the bombardments was determined by the radius of bombardment. The beam current was monitored by using the known cross section for the production of Na^{24} from aluminum.[3] The chemical yield was determined by adding a known amount of Pa^{231} to each sample. The amount of Pa^{231} present after purification was measured by pulse analyses of the alpha particles. The cross section as a function of energy is shown in Fig. 1.

It should be emphasized that these are only approximate cross sections. The largest errors enter in the resolution of the twenty-three minute Pa^{235} from the