Cross Section for Elastic Scattering of Protons by N^{14}†

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The elastic scattering cross section for protons on N^{14} was measured for bombarding energies from 900 kev to 4000 kev and for angles of 90°, 125.3°, 149.4°, and 160.9° in the center-of-mass system. A gas target chamber and a 6-mil thick CsI(Tl) crystal detector were used. The cross section was measured to an absolute accuracy of ±3.5%. An anomaly was observed at 3880±40 kev corresponding to a state in O^{15} at 11.00 Mev previously seen in the yield of gamma rays in the $N^{14}(p,p'\gamma)N^{14}$ reaction.

THE elastic scattering of protons by N^{14} yields information about states in the compound nucleus O^{15}. Since the binding energy of a proton in O^{15} is 7.35 Mev, the information obtained from elastic scattering will concern excited states of excitation generally greater than 7.35 Mev. Hagedorn *et al.*[1] and Ferguson *et al.*[2] have pointed out that the analysis of elastic scattering data from one- to two-Mev bombarding energy is sensitive to the value of the absolute cross section between anomalies. Spin and parity assignments in this range are therefore in doubt because measurements of elastic scattering have differed by as much as 10%.[1–5] For this reason it was felt that publication of our results[6] on the elastic scattering of protons by N^{14} would be useful.

The experimental method was the same as that used in bombardment of N^{15} in the gas target chamber.[7] In the present case tank nitrogen (99.6% N^{14}) was used as the target gas. Figure 1 shows a pulse-height distribution obtained with the CsI(Tl) crystal detector. Most of the data were taken with a discriminator set just below the proton peak in the pulse-height distribution. For bombarding energies greater than 2480-kev inelastic protons are energetically possible. Similarly, above 3120-kev alpha particles from the $N^{14}(p,\alpha)C^{11}$ reaction are possible. Neither group produces pulses which can be confused with those from elastic protons however.

Figure 2 shows the present results. All of the anomalies, except that at the highest bombarding energy, have been observed prior to our initial report[6] by at least one of the laboratories[1–4] which have reported on elastic scattering of protons by N^{14}. The anomaly at 3.88 Mev has been confirmed by Olness *et al.*[5] The large peak in the elastic scattering at 3880±40 kev corresponds to the excited state at 11.00 Mev in O^{15} which was observed in the $N^{14}(p,p'\gamma)N^{14}$ reaction.[8] The energies at which these anomalies were found agree very well with other measurements. The anomaly at 1.74 Mev was found to have an apparent width of 6.5 kev. This was attributed to unevenness in the gas-target-chamber entrance foil since Hagedorn *et al.*[3] have shown this anomaly to have a width of 4 kev. Olness *et al.*[5] found this anomaly to have a width of 6 kev however. The cross sections in Fig. 2, therefore, may not be correct on the narrower anomalies because of this possible energy spread. However, for broad anomalies and the regions between anomalies the cross section is believed correct to ±3.5% since the absolute error in the cross section, exclusive of counting statistics and background subtraction, was ±3% and the error due to both of the latter was always less than 2%.

Table I gives a comparison of cross-section values found at the various laboratories. Comparison energies were chosen at which the energy dependence of the cross section was relatively small. It is interesting that the present results tend to be consistently lower than the Chalk River[2] or Cal. Tech.[1] results and in good agreement with the Minnesota[4] results. According to Ferguson *et al.*[2] this lower value is in the direction to allow pure *s*-wave nonresonant scattering below 2 Mev.

The elastic-scattering curve does not show any effects

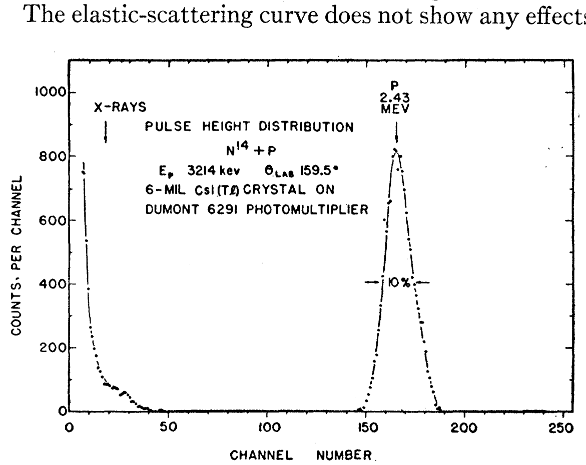

FIG. 1. Pulse-height distribution.

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[1] Hagedorn, Mozer, Webb, Fowler, and Lauritsen, Phys. Rev. **105**, 219 (1957).
[2] Ferguson, Clarke, Gove, and Sample, Chalk River Project Report PD-261, 1956 (unpublished).
[3] G. W. Tautfest and S. Rubin, Phys Rev **103**, 196 (1956).
[4] Bolmgren, Freier, Likely, and Famularo, Phys. Rev. **105**, 210 (1957).
[5] Olness, Vorona, and Lewis, Phys. Rev. **112**, 475 (1958).
[6] Bashkin, Carlson, and Jacobs, Bull. Am. Phys. Soc. **1**, 212 (1956). Douglas, Carlson, Bashkin, and Broude, Bull. Am. Phys. Soc. Ser. II, **3**, 198 (1958).
[7] Bashkin, Carlson, and Douglas, preceding paper [Phys. Rev. **114**, 1543 (1959)].
[8] Bair, Cohn, Kington, and Willard, Phys. Rev. **104**, 1595 (1956).

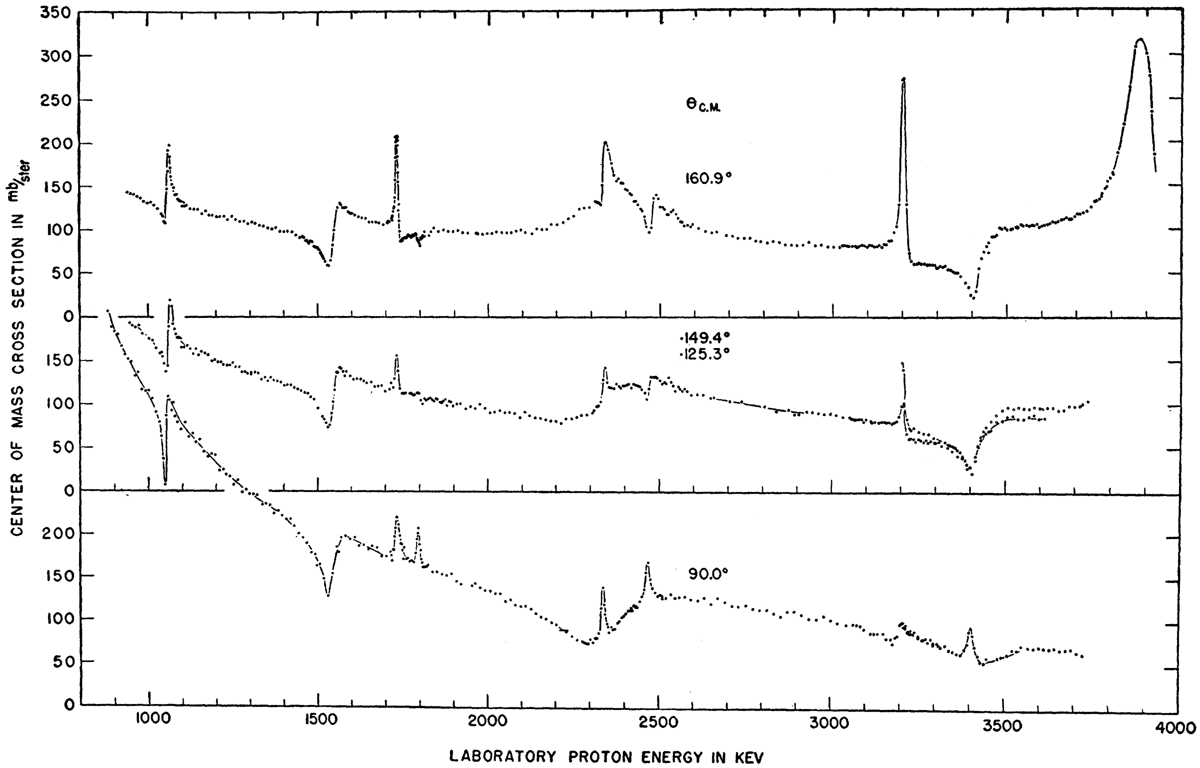

FIG. 2. Cross sections for the elastic scattering of protons by N^{14}.

TABLE I. Absolute center-of-mass cross section in mb/sterad.

E_p \ $\theta_{c.m.}$	90° Chalk River[a]	90° Iowa	90° Minn.[b]	90° Duke[c]	154° Cal. Tech.[d]	153° Chalk River	160.9° Iowa	140.9° Minn.	152° Stanford[e]	168° Duke
950		401±13			150±12		141±5		130±9	135±4
1300	270±12	249±9			114±9	123±6	107±4		101±7	109±3
1650	201±9	187±6	185±8	193±6	111±9	119±5	109±4	114±5	107±8	113±3
2000	140±6	137±5	133±6	146±4		90±4	95±4	88±4		91±3
2800	117±4	115±4	112±5	117±3		90±3	86±3	88±4		83±3
3300		75±3	78±3	83±3			57±2	59±3		57±2

[a] See reference 2.
[b] See reference 4.
[c] See reference 5. The data from Duke (and Stanford) have been taken from the published graphs, making the third digit questionable.
[d] See reference 1.
[e] See reference 3.

which could be attributed to competition[9] from the $N^{14}(p,\alpha)C^{11}$ reaction at its threshold (3.12 Mev).

[9] E. P. Wigner, Phys. Rev. **73**, 1002 (1948); G. Breit Phys. Rev. **107**, 1612 (1957); A. I. Baz, J. Exptl. Theoret. Phys. U.S.S.R. **33**, 923 (1957) [translation: Soviet Phys. JETP **6**, 709 (1958)].

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