TABLE I. Comparison of observed and theoretical values of the Ratio R of the scattered intensity to that given by the Rutherford formula.

Angle of scattering (C.M. system)	30°	45°	60°	90°	120°	150°
R observed (interpolated)		5.1	11.8	37	112	310
R calc. (exchange forces)	1.77	4.96	11.5	40.6	119	249
(ordinary forces)		8.10	17.3	43.2	176	503

but not spin coordinates, and H the Heisenberg operator interchanging all coordinates. The constants A and a were taken to be those derived by Present and Rarita[3] from the binding energies of the light nuclei. For ordinary forces $m=h=0$, $\omega=\frac{1}{2}(1+\kappa)$, $b=\frac{1}{2}(1-\kappa)$; and for the exchange forces $m=2b=\frac{1}{3}(1+3\kappa)$, $h=2\omega=\frac{1}{3}(1-3\kappa)$, κ being taken as 0.6 to give the observed energy of the ^1S state of the deuteron. The technique of the calculation was exactly as for the neutron-deuteron investigation.[2]

We are indebted to the Government Grant Committee of the Royal Society for a grant to enable us to employ the Scientific Computing Service to assist in the numerical solution of certain of the integro-differential equations which arose.

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On the Penetrating Component of Air Showers

G. SALVINI AND G. TAGLIAFERRI
Institute of Physics, University of Milan, Milan, Italy
December 10, 1947

THE present note is a preliminary report of some measurements which have been taken at an altitude of 2100 m to gather further information as to (a) accompanying, (b) origin, and (c) frequency of penetrating particles (p.p.) in air showers.[1,2]

One of the arrangements used is represented in Fig. 1. To compare in the same measure the frequency under Fe and Pb, counters P_1, P_2, P_3 and F_1, F_2, F_3 were covered, respectively, with 30 cm of Pb and 10 cm of Pb+30 cm of Fe. The unshielded counters (or trays of counters in parallel) A_1, A_2, B, C, D, L, M, N were situated on the same horizontal level over the shielded counters. Recording took place with neon lamps, thus indicating which of the counters P_1, P_2, P_3, F_1, F_2, F_3, B, C, D, L, M, N were discharged simultaneously with the coincidences of the master counters A_1, A_2.

TABLE I. Experimental results—column 1: order of the coincidences; column 2: frequency (min.$^{-1}$) of the showers that have discharged at least the counters of col. 1; column 3: average density (m^{-2}) of the showers of col. 2; column 4: frequency (min.$^{-1}$) of the coincidences between any one of the shielded counters and the showers of col. 2; column 5: ratio [col. 2×col. 3]/col. 4.

1	2	3	4	5
$A_1+A_2+B+C+D+L+M+N$	$4.9\pm0.3\times10^{-2}$	119 ± 8	$2.2\pm0.11\times10^{-2}$	265 ± 47
$A_1+A_2+B+C+L+M+N$	$6.7\pm0.3\times10^{-2}$	100 ± 7	$2.4\pm0.11\times10^{-2}$	279 ± 45
$A_1+A_2+C+L+M+N$	$9.9\pm0.3\times10^{-2}$	63 ± 4	$2.8\pm0.12\times10^{-2}$	223 ± 31
$A_1+A_2+L+M+N$	$13.1\pm0.4\times10^{-2}$	51 ± 3	$3.0\pm0.13\times10^{-2}$	223 ± 30
$A_1+A_2+C+L+M$	$16.0\pm0.4\times10^{-2}$	48 ± 2	$3.5\pm0.14\times10^{-2}$	219 ± 23
A_1+A_2+L+M	$24.2\pm0.6\times10^{-2}$	41 ± 2	$4.2\pm0.15\times10^{-2}$	230 ± 26

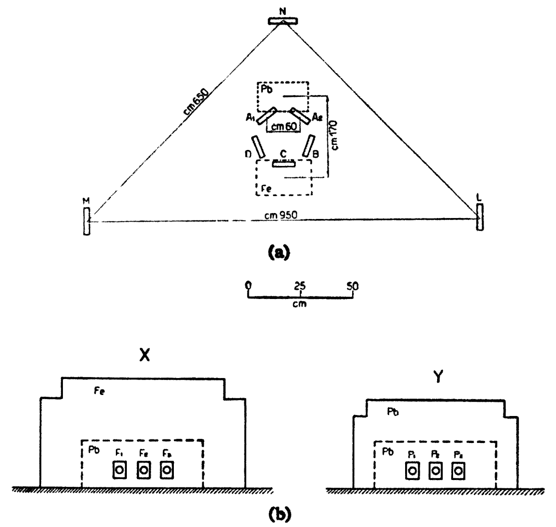

FIG. 1(a) Experimental arrangement. The dotted rectangles indicate the positions of the penetrating particles sets. Surfaces of the counters (or trays of counters in parallel) in cm²: $A_1=A_2=488$; $B=D=112$; $C=224$; $L=456$; $M=N=152$.
(b) Cross sections of the penetrating particles sets X and Y. Surface of each counter: 152 cm².

To clear up point (a) concerning the ratio between the frequency of the soft particles and that of the p.p. associated in showers, we have evaluated the ratio: (frequency of the showers×average density):(frequency of the p.p.) for various average densities Δ of the showers detected by the unshielded counters. As can be seen (Table I, column 5), this ratio is just about constant between $\Delta=119$ m^{-2}, and $\Delta=41$ m^{-2}. This seems to indicate that the p.p. are produced by the soft component, and perhaps not far from the apparatus; if another component generated the p.p., it should be present in the showers with a side distribution like that of the soft component.

(b) Recent works[2,3] suggest that the p.p. are produced in a good percentage in the absorbers. We have seen that the side distribution of the p.p. is not Poissonian, but presents particular associations. In fact, when several shielded counters in the two sets X and Y are discharged at the same time, events are more numerous in which two or three counters are discharged in the same set in comparison to those of two or more counters in different sets. Furthermore, in the same set the coincidences between counters near to each other (1+2, or 2+3) are more frequent than the coincidences 1+3. We think that this result indicates

TABLE II. Coincidences between the shielded counters and the showers having discharged counters A_1+A_2+ at least one of the counters B, C, D, L, M, N. Column 1: number of coincidences with one shielded counter (P_1, or P_2, or P_3; and corresponding F_1, or F_2, or F_3); column 2: the same with two adjacent shielded counters (P_1+P_2, or P_2+P_3; and corresponding); column 3: the same with two non-adjacent shielded counters (P_1+P_3; and corresponding); column 4: the same, with three shielded counters ($P_1+P_2+P_3$; and corresponding); column 5: total number of the events in each penetrating particles set.

	1	2	3	4	5	
Set X	593 ± 25	74 ± 9	15 ± 4	26 ± 6	708 ± 27	Time: minutes
Set Y	554 ± 24	77 ± 9	7 ± 3	33 ± 6	671 ± 26	20,690

that the p.p. are produced, partly at least, in the absorbers and in groups. In the alternative hypothesis that the p.p. are nearly all produced in the air, they should be associated in very narrow showers arising not far from our apparatus. In Table II the association between the events of the same set is given as an example.

(c) Within the limits of statistic fluctuations, we have observed the same frequency and distribution of penetrating events in the two sets X and Y (Table II). In agreement with several authors,[2-4] our measurements indicate that the p.p. are produced with a cross section proportional to Z^2, provided that production takes place in the absorbers by the soft component. It may be noted, however, that in the intermediate hypothesis of a production in the air, as well as in the absorbers, the exponent of Z might be less than two.

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Range of Nuclear Forces in the Neutron-Proton Triplet Interaction

C. G. SHULL, E. O. WOLLAN, G. A. MORTON,* AND W. L. DAVIDSON**
Clinton National Laboratory, Oak Ridge, Tennessee
December 12, 1947

MEASUREMENTS of the coherent scattering of neutrons by hydrogen[1] permit the evaluation of the scattering amplitudes characteristic of the two spin states of scattering, *viz.*, when the neutron and proton spins are parallel or antiparallel. Such evaluation also permits a determination of the range of nuclear forces present in the triplet interaction.

It can be shown that the coherent scattering amplitude for hydrogen in a crystal is given by

$$f_H = 2[\tfrac{3}{4}a_1 + \tfrac{1}{4}a_0], \quad (1)$$

where a_1 and a_0 are the triplet and singlet scattering amplitudes of a free proton when the spins of the proton and the incident neutron are, respectively, parallel and antiparallel. Also, the total scattering cross section of a free proton can be expressed as

$$\sigma_f = 4\pi[\tfrac{3}{4}a_1^2 + \tfrac{1}{4}a_0^2]. \quad (2)$$

Equations (1) and (2) permit evaluation of a_1 and a_0. From neutron diffraction experiments on hydrogen containing crystals, the coherent scattering amplitude has been determined to be

$$f_H = +0.472 \pm 0.040 \times 10^{-12} \text{ cm}.$$

Using this value of the coherent scattering amplitude and Hanstein's[2] value of 21×10^{-24} cm^2 for the total scattering cross section for a free proton, one obtains for the triplet scattering amplitude

$$a_1 = -0.498 \pm 0.025 \times 10^{-12} \text{ cm}.$$

The singlet scattering amplitude determined by this procedure is dependent almost completely upon the value of the free proton cross section and turns out to be $+2.44 \times 10^{-12}$ cm.

Hamermesh and Schwinger[3] have discussed the relationship between the scattering amplitudes and the range of nuclear forces, and when the above values are inserted into their calculations, the range of the neutron-proton triplet interaction becomes

$$r_0 = 1.2 \pm 0.4 \times 10^{-13} \text{ cm}.$$

This value is definitely smaller than the value 2.8×10^{-13} cm ascribed to the singlet proton-proton interaction and is slightly smaller than that found by Sutton, Hall, and others[4] from the scattering of neutrons by *ortho-* and *para-hydrogen*, namely 1.5×10^{-13} cm. This latter difference is, however, within the suggested error of the diffraction result.

Further details on the neutron diffraction experiments will be published in the near future.

* On leave (July 1946 to August 1947) from R.C.A. Laboratories, Princeton, New Jersey.
** On leave (July 1946 to August 1947) from B. F. Goodrich Company, Akron, Ohio.

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Cross Section for the Reaction $C^{12}(n, 2n)C^{11}$ at 90 Mev

EDWIN M. MCMILLAN AND HERBERT F. YORK
Radiation Laboratory, Department of Physics, University of California, Berkeley, California
December 18, 1947

THE formation of C^{11} by high energy particle impact on C^{12} has been studied extensively in this laboratory;[1-3] it has been found that the cross sections for its formation by deuterons, helium ions, and protons become constant above a certain bombarding energy, and this constant absolute cross section in the latter case has been found to be 0.073×10^{-24} cm^2. We have no information on the excitation curve in the case of neutron activation, but an extension of the theory would indicate that it should be flat above about 60 Mev as it is for protons. Whether or not there may be a peak between 20 and 60 Mev depends on the relative importance of "intermediate nucleus" processes compared to non-capture processes. However, such a peak of moderate size would not seriously affect the measurements reported here because of the small number of neutrons in this energy range. Theoretically, the yield on the flat part of the excitation curve should be less for neutrons than for protons if exchange collisions occur, because a (p, n) exchange can lead to C^{11} by evaporation of a proton, while an (n, p) exchange cannot lead to C^{11}.

The measurements reported here were made in a neutron beam produced by stripping deuterons[4,5] in a $\frac{1}{2}$ in. thick Be target in the 184-in. cyclotron, and collimated into a width of $2\frac{1}{2}$ in. by passing through an aperture in the