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

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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.

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

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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 ½ in. thick Be target in the 184-in. cyclotron, and collimated into a width of 2½ in. by passing through an aperture in the