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Summary of the Research Progress Meeting

Margaret Folden

December 4, 1947

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Summary of the Research Progress Meeting

Margaret Folden

December 4, 1947

Dr. E. Amaldi. Dr. Amaldi of the University of Rome is a visitor at the laboratory and spoke on the scattering cross sections of the proton, deuteron and the carbon nucleus which have been determined for 4.1-, 12.5-, and 13.5-Mev neuterons by detecting the corresponding recoil protons.

His experimental arrangement consisted of a set of three proportional counters as shown in Fig. 1.

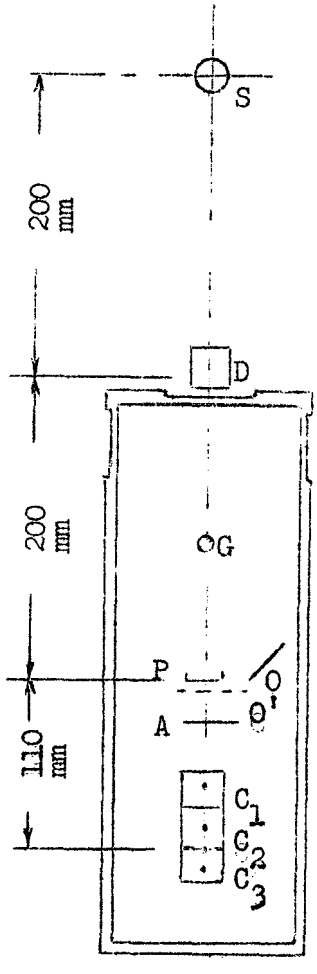

Fig. 1. Arrangement of source and scattering chamber.

Neutrons emitted by the source S impinge on the paraffin layer P whose thickness is negligible with respect to neutron absorption and large with respect to range of recoil protons. Protons projected in the forward direction and fast enough to go through the Al-absorber A, are registered by the coincidence set of three proportional counters, C_1, C_2, C_3. All measurements were performed by counting the triple coincidences with the absorber in position O (obturator opened) and then in position O' (obturator closed) and taking the difference. The absorber A determines minumum energy E_o of the registered recoil protons. Since measurements were taken with protons scattered in the forward direction, the energy of recoil protons is equal to the energy of the impinging neutrons. With E_{max} as the maximum energy of the neutrons emitted by the source S, the difference between the numbers of triple coincidence counted with obturator open and closed is caused only by recoil protons from neutrons with energy lying in the interval $E_o - E_{max}$. The scattering chamber was filled with commercial argon at atmospheric pressure.

Measurements were taken with neutrons from the three reactions Be(D,n), B(D,n), and Li(D,n). The minimum, maximum and average energies are listed in Table I.

Table I.

	E_{max}	E_{min}	E_{av}
D + Be	4.6	3.2	4.1
D + B	13.2	9.4	12.5
D + Li	14.5	11.5	13.5

The scattering cross sections as shown in Table II were calculated from the equation

$$T(z) = e^{-z/\Lambda} + K' + K''$$

where K' and K'' are corrections for "scattering in" and "double scattering"; the percentage of the transmitted neutrons varies according to the law e^{-z} where the thickness of the scatterer is z and where Λ is the mean free path; T is the transmitted fraction of neutrons.

Table II

E_{av}	C	H	D
4.1	$1.99 \pm .004 \times 10^{-24}$	$1.73 \pm 0.06 \times 10^{-24}$	$1.79 \pm 0.08 \times 10^{-24}$
12.5	$1.40 \pm 0.12 \times 10^{-24}$	$0.69 \pm 0.11 \times 10^{-24}$	$0.78 \pm 0.12 \times 10^{-24}$
13.5	*$1.22 \pm 0.037 \times 10^{-24}$	$0.694 \pm 0.019 \times 10^{-24}$	$0.864 \pm 0.028 \times 10^{-24}$

Measurements were then made of the absorption curve of the recoiling particles. When a heavy paraffin layer was placed in the apparatus, curve D of Fig. 2 was plotted as a function of the range in cm of air. From measurements with a light paraffin layer, curve H of Fig. 2 resulted. The count was proportional to

$$\int_0^\infty dx \int_E^\infty f(E)\,d\,E\,\sigma E = \frac{1}{F}\int_E^\infty dE \int f(E)\,\sigma\,E\,d\,E = \frac{1}{F}\,\sigma\,\Phi\,(E)$$

where Φ (E) is the spectrum integrated twice, σ is the cross section, F is the energy loss of recoiling particles.

It was next considered that the particles emitted from heavy paraffin are of three types: recoil deuterons, disintegration protons, and recoil-protons due to light paraffin impurity. The number of these last

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*with copper detector, $1.23 \pm 0.019 \times 10^{-24}$

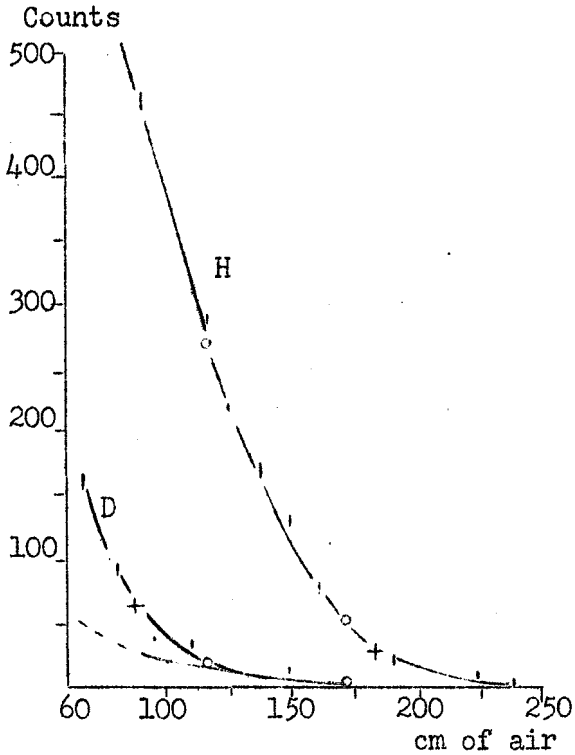

Fig. 2. Absorption curves of recoiling particles.

can be deduced by curve H of Fig. 2 if the percentage impurity (5% and 7%) is known. Thus:

$$N_H = \frac{1}{F_H} \sigma_H \Phi (13)$$

$$N_D = \frac{1}{F} \sigma_e \Phi (13) + \frac{1}{F_H} \sigma_d \Phi (10.9)$$

The energy of the neutrons which gives rise to disintegration protons in the forward direction fast enough to be registered is 10.9 Mev and therefore,

$$\frac{N_D}{N_H} = \frac{F_H}{F_D} \frac{\sigma_e(13)}{\sigma_H(13)} + \frac{\sigma_d (10.9)}{\sigma_H (13)} \frac{\Phi (10.9)}{\Phi (13)}$$

Then together with the total cross section

$$\frac{\sigma_e}{\sigma_e + \sigma_d} = 0.89 \text{ for } 5\% \text{ impurity}$$

$$= 0.93 \text{ for } 7\% \text{ impurity}$$

$$\sigma_d = 9 - 4 \times 10^{-26} \text{ cm}^2$$

where it is assumed that the distribution from both light and heavy paraffin is the same.

In further experiments the elastic scattering of fast neutrons due to the diffraction of the geometrical shadow of the nucleus was investigated and the corresponding cross section σ_s was compared with the cross section of a compound nucleus σ_{nc}.

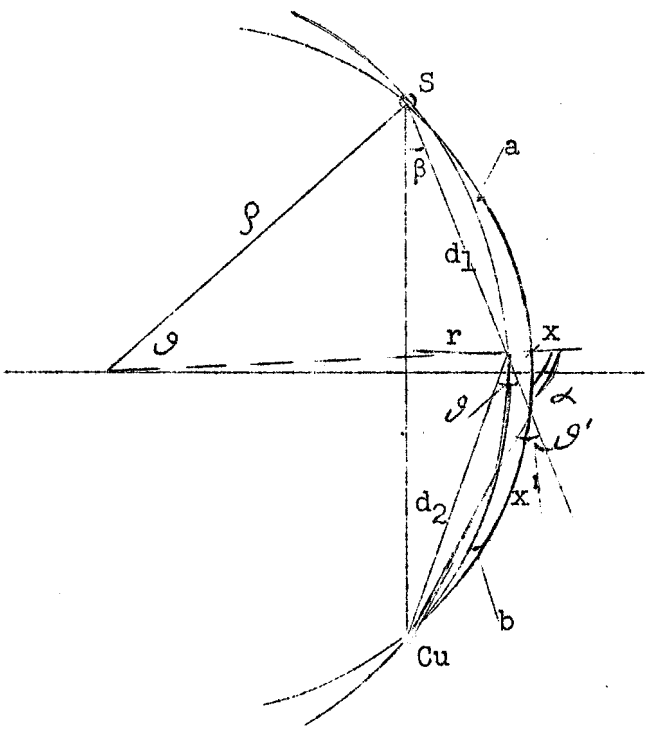

Figure 3.

The principle of the method is shown in Fig. 3 where S is the neutron source, Cu the copper detector, D the distance from S to Cu, and ds is the elementary arc of the circle. The scatterer consisted of a cylinder of rotation with axis S-Cu whose cross section is shown in Fig. 3 as a polygon outlined between designations a and b.

It was deduced that

$$n(\vartheta) = \pi D \sigma_s'(\vartheta) N \cdot \frac{\sin^2 \vartheta}{\sin \vartheta \sin \vartheta'} \cdot \sin(\vartheta' - \vartheta)(\beta_2 - \beta_1) F$$

Finally,

$$F = \frac{\Lambda}{x + x'} \cdot \left(1 - e^{\frac{-x + x'}{\Lambda}}\right)$$

where $n(\vartheta)$ is the number of neutrons received at Cu following single scattering, D is the distance from S to Cu, σ_s' is the differential elastic scattering cross section, N is the number of atoms per cm^3 in the scattering medium, F is the neutrons absorbed in the scatterer and Λ is the mean free path.

Three kinds of measurements were described where neutrons of D + Li reaction were used and were detected by means of the copper activity produced according to the reaction $^{63}Cu(n,2n)\ ^{62}Cu$(9.9 min) which has a threshold at about 11 Mev.

(1) Measurements of the total cross section

$$\sigma = \sigma_s + \sigma_{nc}.$$

(2) Measurements of the cross section for absorption + inelastic scattering σ_a.

(3) Measurement of the angular distribution of the elastically scattered neutrons. Values found are listed in Table III.

Table III

	*f (10)	σ_a	$\frac{2\sigma_a}{\sigma}$
Al	0.96	0.99 ± 0.06	1.03 ± 0.06
Fe	0.93		1.04 ± 0.05
Hg			0.88 ± 0.06
Pb	1.01	2.22 ± 0.05	0.88 ± 0.03

*f is the effect of diffraction

σ_a was about one-half the total cross section σ. The differential cross section for elastic scattering has a minimum at about 25° and a maximum at about 35 - 40°.

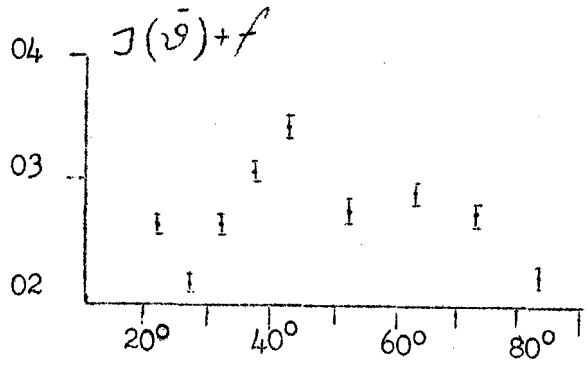

Figure 4.

From the position of the minimum and using a diffraction formula a value of the nuclear radius of about $10 \cdot 10^{-13}$ cm was deduced.

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