scintillation counters was used as the meson recording apparatus. In the first and second counters, toluene crystals 30 × 30 × 5 mm in size were used as scintillators; a liquid scintillator (a solution of terphenyl in toluol) 100 mm in diameter was used for the third counter. The first two counters recorded π-mesons incident on the scatterer; the third counter recorded particles which had passed through the scatterer which was in the form of a disc 60 mm in diameter placed in the beam immediately after the second counter. In front of the third counter a lead filter of thickness 5.85 g/cm^2 was placed in order to absorb heavy charged particles formed as a result of the interaction of π-mesons with the nuclei of the scatterer. In order to determine the number of events resulting in the removal of π-mesons from the beam a simultaneous count of double and triple coincidences was made. The efficiency of the last counter was tested in a proton beam of 1 cm^2 cross-section; it turned out to be equal to 96% and practically did not depend on the place at which the particles struck the scintillator.

Element	Cross section in units of 10^{-27} cm^2	
	Measured	geometric*
C	346 ± 21	325
Al	596 ± 30	553
Cu	1058 ± 45	977
Sn	1550 ± 70	1480
Pb	2290 ± 90	2150

The energy of the π-mesons incident on the scatterer, and also the total content of μ-mesons and electrons in the beam were determined separately by measuring the absorption curve for π-mesons in copper using the same geometry as in the experiment being described. These measurements showed that the energy of π-mesons in the beam is equal to 230 ± 6 mev, while the content of μ-mesons and electrons in the beam amounts to 12.5 ± 3%. The scatterer thickness was on the average equal to 5–6 g/cm^2, so that the mean energy of the π-mesons to which the measured cross sections correspond was equal to 225 ± 10 mev.

Corrections were made to the measured cross sections using the data of reference 1 in which the Wilson cloud chamber was used to study the interaction of negative π-mesons with carbon and lead nuclei at an energy of 230–350 mev; these corrections took into account: a) inelastic scattering of π-mesons into the angular interval from 0 to 30°; b) elastic scattering of π-mesons into the angular interval from 30 to 180° and c) fast secondary protons recorded by the third counter. The total cross sections for the inelastic interaction of π-mesons with nuclei obtained by the method described above are given in the Table. It may be easily seen that at an energy of 225 mev these cross sections are equal to the geometric cross sections of the corresponding nuclei. Within the experimental error these results agree with the results of similar measurements carried out in reference 2 at π-meson energies of 216 and 250 mev.

*For the calculation of geometric cross sections the nuclear radius was taken equal to $R = 1.4\ A^{1/3}\ 10^{-13}$ cm.

1 Dzhelepov, Ivanov, Kozodaev, Osipenkov, Petrov and Rusakov, J. Exptl. Theoret. Phys. (U.S.S.R.) 31, 923 (1956).

2 Ignatenko, Mukhin, Ozerov and Pontecorvo, Dokl. Akad. Nauk SSSR 103, 209 (1955).

Translated by G. M. Volkoff
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Nuclear Interactions with 220-mev Deuterons

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(Submitted to JETP editor July 18, 1956)
J. Exptl. Theoret. Phys. (U.S.S.R.) 31, 1086-1088 (December, 1956)

IT is characteristic of the interactions between high-energy deuterons and nuclei that fast protons are emitted. At least three processes exist by which fast protons can be produced in inelastic collisions of high-energy deuterons. As has been shown by Serber[1] and confirmed experimentally by Chupp, Gardner and Taylor[2], when a target is bombarded by fast deuterons there occurs a process wherein a deuteron is split on a nucleus with the neutron being captured by the nucleus and the proton proceeding past with energy which is about half of the deuteron energy. The cross section for this "stripping" process is quite high and is only slightly dependent on the atomic number, varying from 0.1×10^{-24} cm^2 for Be to 0.3×10^{-24} cm for U. Another source of fast protons when various nuclei are bombarded by deuterons is the deuteron disintegration caused by the Coulomb field of the nucleus[3]. This process has a small cross section and is comparable with the cross section for "stripping" only in the case of the heaviest nuclei. Finally, a high-energy proton can be formed by the direct collision of one of the deuteron particles with a nuclear particle. The total number of emitted protons can be approximately equal to the proton yield from "stripping".

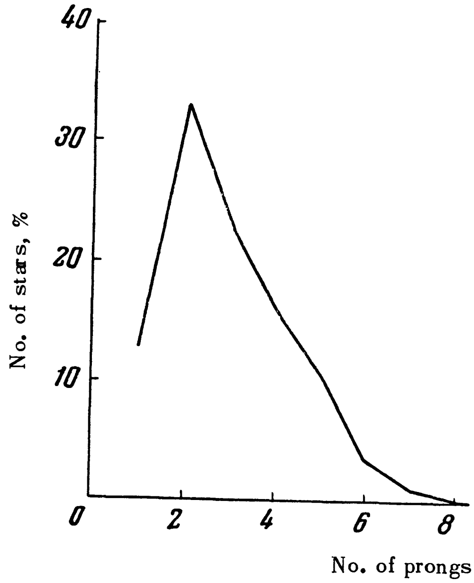

FIG. 1. Star distribution by number of prongs.

The present note presents the results of investigations of an interaction between fast deuterons and the elements contained in nuclear emulsions. We determined the mean free path for star production, the star distribution according to the number of prongs and the angular and energy distributions of the secondary protons.

Electron-sensitive plates covered with a 200μ emulsion were irradiated by a beam of 220-mev deuterons inside a synchrocyclotron. By area scanning, 1570 stars were found, of which number 698 contained one or two gray tracks that were assumed to be proton tracks. The gray tracks were all whose grain density was less than 1350 grains per mm, corresponding to proton energy $\geq$ 50 mev. The star distribution according to the number of prongs for 1570 disintegrations is given in Fig. 1, from which we see that the average number of prongs per star is 3.

The mean free path for nuclear interactions of 220-mev deuterons was determined by on-track scanning. In combined tracks of 994.6 cm we detected 53 inelastic collisions. Hence the mean free path for nuclear interactions of 220-mev deuterons in the emulsion was 18.8 ± 2.6 cm. The mean free path as calculated from the geometric cross sections of the nuclei of the emulsion (excluding hydrogen atoms) was 23.0 cm. Thus the mean free path for 220-mev deuterons in this work was very close to the value which corresponds to the geometric cross section.

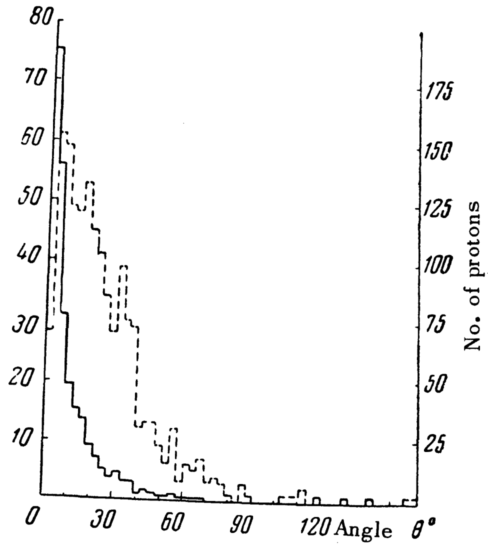

FIG. 2. Angular distribution of fast protons. Per unit solid angle (right-hand scale) - the solid line; per annular zone (left-hand scale) - the dashed line.

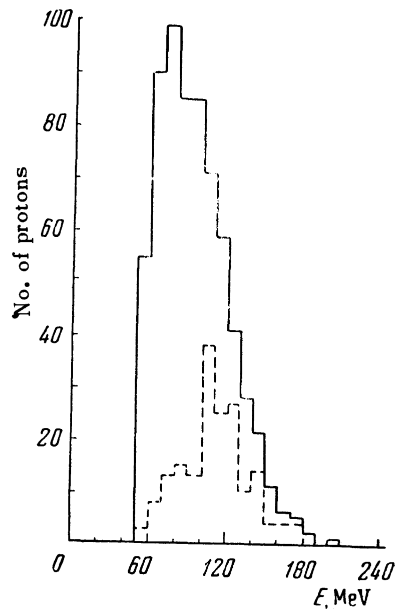

FIG. 3. Energy distribution of fast protons. Solid line - 655 protons; dashed line - 179 protons; $\theta \leq 10°$

Figure 2 gives the angular distribution of secondary protons. It can be seen that a considerable fraction of the particles are emitted in directions close to the line of motion of the deuteron. About 90% of the fast protons are emitted in the forward hemisphere; 30% of these are in a narrow cone of 30° apex angle. The half width of the angular distribution is 18°, which exceeds the calculated half width (9.5°) for the angular distribution of protons resulting from "stripping". The gray tracks are distributed symmetrically to the right and left of the direction of the incident deuteron.

The energy distribution of the protons (Fig. 3) was obtained by counting the grains in the tracks. The energy spectrum covers the range from 50 to 210 mev and possesses a sharp maximum at 80-90 mev. The half width of the energy distribution of all protons is 70 mev.

The dashed line in Fig. 3 is a histogram which represents the energy distribution of protons whose emission angle was not greater than 10°. The peak of this distribution is at about 110 mev, which is half of the initial deuteron energy. The half width of the distribution is 40-50 mev, which agrees with the calculation of $\Delta E_{1/2} = 2(\epsilon_d/E_d) = 45$ mev for the transparent nucleus model and with $\Delta E_{1/2} = 34$ mev for an opaque nucleus. A comparison of the theoretical and experimental results shows good agreement. Therefore the protons included in the above energy distribution resulted predominantly from the disintegration of deuterons by nuclei.

Our analysis of the angular and energy distributions of the protons enables us to state that two processes are mainly responsible for the emission of fast protons; these are "stripping" and a cascade process.

1 R. Server, Phys. Rev. 72, 1008 (1947).

2 Chupp, Gardner and Taylor, Phys. Rev. 73, 742 (1948).

3 S. M. Dancoff, Phys. Rev. 72, 1016 (1947).

Translated by I. Emin
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A Static Solution of the Nonlinear Meson Equation

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(Submitted to JETP editor Jan. 25, 1956)
J. Exptl. Theoret. Phys. (U.S.S.R.) 31, 1082-1083 (December, 1956)

IN order to explain the phenomenon of saturation of nuclear forces and to provide a basis for a nuclear shell model Schiff proposed the simplest nonlinear generalization of the Klein-Gordon equation for meson theory[1]

$$\Box\varphi - k_0^2 - \lambda\varphi^3 = 0, \qquad (1)$$

where k_0 and λ are constants. The renormalized equation of the pseudoscalar theory with pseudoscalar coupling has the same form in the case of weak interaction.[2]

If we restrict ourselves to the static approximation we shall obtain for the spherically symmetrical case the equation

$$d^2u / dx^2 - (u^3/x^2) - u = 0, \qquad (2)$$

in which the variables $x = k_0 r$, $u = \sqrt{\lambda r}$ have been introduced.

This equation has been discussed by many authors largely in connection with the phenomenon of nuclear saturation, and in such cases the equation was discussed for the case of a certain given nucleon source density.[3-8] In the present note we shall obtain asymptotic solutions of Eq. (2), and shall also integrate the equation numerically.

According to a theorem due to Hardy,[9-10] every rational function $R(x, u, u')$ is necessarily monotonic along the solution $u(x)$ of the differential equation of the form

$$u'' = P(x, u) / Q(x, u),$$

where Q, P are polynomials in u, x. The application of this statement to the ratio of any two arbitrary terms of equations $Qu' - P = 0$ allows one to find asymptotic solutions of the differential equation for $x \to \infty$. The limit of such a ratio may be equal to $\pm\infty$, 0, or to a constant different from zero, and it is guaranteed that there must exist at least one ratio which tends to a constant different from zero. A similar result may be shown to hold for an equation of the type

$$u'' = P(u, x) / Q(u, x).$$

That solution of Eq. (2) is of physical interest