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A METHOD FOR STUDYING ELASTIC SCATTERING AT HIGH ENERGIES

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A nuclear recoil technique is described in which nuclear photographic plates are employed as a nuclear detector. The scattering of 660-Mev protons on He^4 is used to illustrate the application of the method. The possibilities of the method are discussed.

A basic difficulty in the study of elastic scattering of high-energy nucleons (hundreds of Mev and higher) is the separation of pure elastic scattering from competing inelastic processes. Moreover, unfavorable background effects lead to certain difficulties in the study of small-angle scattering at high energies.

All these difficulties can be removed relatively simply if the recoil-nucleon technique is employed. The method is based on the following. When a particle of mass M_1 is scattered on a nucleus (particle) of mass M_2, the latter, as a result of the collision, acquires an energy E_2. The energy E_2 can be readily calculated from the kinematics of an elastic collision. By recording the recoil nucleus, we can establish the very act of scattering, while the energy distribution of the recoil nuclei can provide a check on the elasticity of the scattering process.

The angle by which the particle of mass M_1 is scattered can be estimated from the approximate formula

$$\operatorname{tg}\vartheta_1 \approx \sqrt{2M_2E_2}/p_0 \ll 1, \qquad (1)^*$$

where p_0 is the momentum of the incident particle.

If we choose a detector which can record low-energy recoil nuclei, then it is possible to study small-angle elastic scattering. The best such detector is nuclear emulsion for the following reasons:

1) If the recoil-nucleus tracks are chosen in a given direction, the background can be readily eliminated.

2) From a study of the recoil-nucleus range distribution the elasticity of the scattering process can be checked.

3) Scattering at different angles can be studied with the aid of nuclear emulsion in a single experiment. In this way, the error in determining the intensity of the bombarding beam is eliminated.

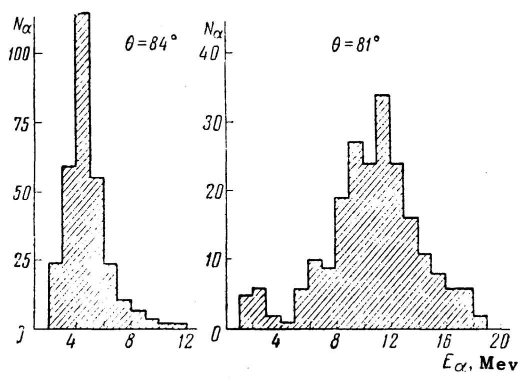
4) In polarization measurements, nuclear emulsion makes possible an estimate of the scattering intensity to the right and to the left of the beam in the same experiment.

We used the recoil-nucleus technique for the study of elastic scattering of 660-Mev protons on He_2^4. After passing through a window covered by a copper foil 70 μ thick, the proton beam entered a volume filled with helium at atmospheric pressure. The recoil nuclei (α particles) emitted at a given angle relative to the direction of the proton beam were recorded with the aid of nuclear emulsion plates.

The α-particle tracks were selected in accordance with the following criteria: 1) a given angle of inclination relative to the plane of the plate; 2) the angle between the track and a given direction in the plate was $\leq \varphi_0$; 3) the track should be located in a given area of the emulsion.

These criteria can be obtained by calculation and also by means of a radioactive source. A radioactive source of α particles also serves to determine the geometrical conditions of the experiment (solid angle of the detector).

The figure shows the energy distribution of the α particles recorded at angles $\theta = 81°$ and $\theta = 84°$. As seen from the figure, the half-width of the peak



*tg = tan.

is 3 — 6 Mev. This corresponds to a resolution of ~ 1% of the energy of the recorded scattered nucleons. The method permits the accumulation of relatively good statistics (statistical error ~ 8%) in 3 — 4 hr of accelerator operation and a small expenditure of time on the measurements.

The position of the peak in the energy distribution of the recoil nuclei uniquely determines the scattering angle, which gives an additional independent check of the angle.

Elastic scattering down to angles θ_{min} can be studied by this method. The lower limit θ_{min} is determined by the minimum range of the recoil nucleons which can be reliably measured in the emulsion. To illustrate the characteristics of these minimum angles we consider energies available in the existing proton accelerators. We give below the values of θ_{min} (in the l.s.):

Proton energy, Mev	660	1000	10000	25000
θ_{min} (pp scattering), deg	2.5	1.5	0.25	0.1
θ_{min} (pHe_2^4 scattering), deg	7.5	4.5	0.8	0.3

For the scattering of protons by deuterons, tritons, and He_2^3, the angles lie between those of pp and pHe_2^4 scattering. The proposed nuclear-recoil technique can be applied to the scattering of elementary particles (nucleons, electrons, photons) by light nuclei ($A \leq 4$) as well as to the scattering of complex nuclei composed of 2 — 4 nucleons by the corresponding light nuclei. Information on polarization can be obtained from the study of the scattering of recoil nuclei with nonzero spin by emulsion nuclei. For this, of course, it is necessary to know the properties of the emulsion as a polarization analyzer.

In conclusion, the author takes this opportunity to express his gratitude to Professor A. P. Zhdanov for his constant interest in this work.

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