ON THE ELASTIC BACKWARD SCATTERING OF 660 MEV PROTONS AGAINST CARBON NUCLEI

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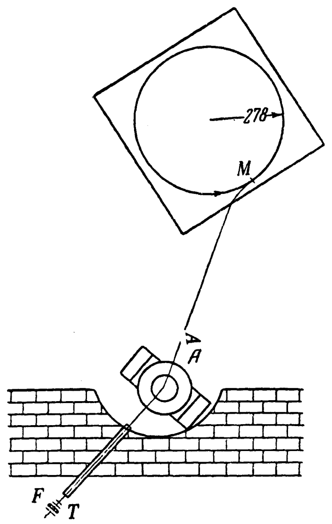
Submitted to JETP editor June 1, 1957

J. Exptl. Theoret. Phys. (U.S.S.R.) **33**, 1147-1149 (November, 1957)

It is shown that the elastic backward scattering of 660-Mev protons by carbon nuclei does not exceed 3×10^{-33} cm^2/sterad. The mechanism for ejection of rapid fragments for nuclei interacting with high-energy nucleons is discussed in connection with this result.

SEVERAL experiments[1-3] on the elastic scattering of protons by deuterons have been recently carried out in the energy range of 340 — 660 Mev; the energy and momentum transfer to the latter particles exceeds in this case by hundreds of times the binding energy of the nucleons in the deuteron. Such elastic scattering is the result of a three-nucleon collision when the two nucleons of the deuteron are tightly bound to each other. On the other hand, it is well known that when nuclei are bombarded with high-energy nucleons, deuterons, and α-particles, nuclei of Li, Be, C, B and other elements are ejected with an energy considerably in excess of the repulsive Coulomb energy between the ejected fragments and the residual nucleus. The characteristic sequence of this process and, above all, the angular and energy distributions of the ejected fragments attest without a doubt to their direct participation in the reaction as distinguished from evaporation from an excited nucleus. It is natural to try to relate these two groups of observations, and assume that the ejection of energetic fragments from nuclei can similarly be explained by a collective interaction of the incident nucleons with the whole nucleus or with a tight aggregate of nucleons within the nucleus. One may further regard such an interaction, by analogy with quasi-elastic nucleon-nucleon scattering, as a quasi-elastic collision of the nucleon with the moving fragments within the nucleus. In that particular case, one must first of all observe a correlation between the direction of emergence of the fragments and the nucleon recoil (specifically, the emergence of the energetic fragments in the forward direction must be accompanied by the emission of an energetic nucleon to the rear); in the second place, the cross section for quasi-elastic scattering by the fragments in the nucleus must be of the same order of magnitude as the cross section for elastic scattering by the corresponding free nuclei. The hypothesis of quasi-elastic scattering of nucleons by fragments inside the nucleus has been discussed in a series of articles,[4-7] together with a more definitive analysis of the available experimental data. It appears that the existing facts can be made to agree qualitatively with this hypothesis if one takes into account the fact that the nucleon, and especially the fragment, undergoes a series of changes in the process of development of an intranuclear cascade. This last circumstance must be underlined as most of the available data was observed from heavy nuclei in photoemulsions.



Experimental arrangement: M — carbon target; A — analyzing magnet; T — telescope; F — filter.

In order to verify the hypothesis of quasi-elastic scattering of incident nucleons by heavy fragments within the nucleus, we have attempted to detect the presence of high-energy protons generated as a result of the backward scattering of 660-Mev protons by carbon nuclei (at angles 180 ± 15°), and to select a group of protons elastically scattered by the carbon nuclei.

Investigations of angular and energetic distributions of high-energy protons scattered into the backward hemisphere present the best experimental possibility for analyzing collisions of high-energy nucleons against nuclei for the purpose of verifying collective interaction. Protons pass more easily through nuclear matter than the heavier fragments, and when the reaction is detected by electronic means, they turn out to be practically the only source of information about an interaction between an incident proton and an aggregate of nucleons.

The experimental arrangement is shown on the figure. The carbon target M is irradiated by the internal proton beam of the synchrocyclotron of the Laboratory for Nuclear Problems, Joint Institute for Nuclear Research. The protons scattering at angle of approximately 180° are deflected by the magnetic field of the accelerator into an analyzing magnet. The particles then travel through a 4 m collimating slit and strike a registering telescope. In order to separate protons from other particles of the same momentum, a filter F is placed between the second and third counter of the telescope. The experimental arrangement permits the use of an intense proton beam while still avoiding excessive noise in the telescope since the main beam from the target goes in the opposite direction to the collimator. At the same time this experimental arrangement does not allow an exact determination of the solid exit angle of the detected protons; it is possible, although this is still not too accurate, to evaluate (as is usually done with internal beams) the intensity of protons incident on the target and the effective number of nuclei which they irradiate.* This experimental arrangement proved very convenient, however, to verify the hypothesis and evaluate cross sections.

The trajectory of the proton beam was traced by means of a thin current-carrying filament.[8] It was shown that particles of comparatively wide momentum range fall in the solid angle subtended by the telescope. The telescope received protons emerging backward with a momentum ranging from its maximum possible value in the indicated angular range for the p–C reaction, to a minimum value corresponding to a proton energy of 350 Mev.

No effect was observed in the experiment. The noise count of the telescope remained unaltered when an absorber was mounted in the path of the proton beam in front of the analyzing magnet, when the target in the synchrocyclotron chamber was rotated by an azimuthal angle of 40°, and again when the carbon target was replaced by a beryllium target. Calculations show the lower limit for elastic backward p–C scattering cross section cannot exceed 3×10^{-33} cm^2/sterad. Such is also the probability of absence of protons ranging in energy from maximum to 350 Mev, corresponding to elastic collisions between protons and aggregates of 8 – 9 nucleons.

These results permit the following conclusions within the indicated degree of accuracy: (a) the mechanism for ejection of fragments consisting of 8 – 12 nucleons differs (at least for most of the fragments) from a quasi-elastic scattering by corresponding fragments inside the nucleus; (b) the interaction between a 660-Mev proton and a carbon nucleus is not accompanied by the backward ejection of a proton of more than 350 Mev.

In view of the obtained results, it is necessary to suggest some other mechanism of collective interaction satisfying particularly the established experimental facts.

The authors wish to thank Professors D. I. Blokhintsev and M. G. Meshcheriakov for discussions of the subjects mentioned, and V. M. Sidorov for a discussion of the experimental arrangement.

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Translated by M. A. Melkanoff
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*This estimate was based on the data of Iu. D. Prokoshkin and A. A. Tiapkin.