Coulomb dissociation of relativistic hadrons on nuclei and giant dipole resonances

M. I. Adamovich, S. P. Kharlamov, V. G. Larionova, and F. R. Yagudina

P. N. Lebedev Physics Institute, USSR Academy of Sciences

(Submitted February 26, 1975)
ZhETF Pis. Red. **21**, No. 7, 458–461 (April 5, 1975)

Dissociation of 9.4-GeV/*c* deuterons and 200-GeV/*c* protons on nuclei, due to the Coulomb momentum of the target nucleus and accompanied by excitation of giant dipole resonance, was observed. The possibilities of using the observed phenomenon to study electromagnetic interactions with mesons and hyperons as targets is discussed.

In[1] we presented the results of an investigation of the dissociation and stripping of 9.4-GeV/*c* deuterons on emulsion nuclei. Continuing these investigations, we have considered cases of proton stripping of deuterons, accompanied by emission of only one slow proton from the target nucleus. In the case of proton stripping of deuterons, the following mechanism of the apperance of slow protons is obvious. A 4.7 GeV/*c* neutron knocks out, after stripping a deuteron, a fast nucleon from the target nucleus and leaves the nucleus in an excited state. As a result, a slow proton is also emitted from the target nucleus. Thus, in proton-stripping events one should expect the number of stripping events with two relativistic charged particles to be comparable with the number of events with one relativistic charged particle. It turns out that the number of events with a slow proton and two relativistic particles is smaller by a factor of five than the number of analogous events with one relativistic particle. It follows therefore that most events with slow protons are not the result of deuteron stripping.

The events in question can be easily interpreted as a result of the dissociation of a deuteron by the Coulomb field of the target nucleus. The dissociation of the deuteron is in this case a process of photodisintegration of the deuteron by a virtual photon, and the appearance of slow protons is the result of the action of this proton on the nucleus as a unit with excitation of giant dipole resonance. A confirmation of this hypothesis is the agreement between the energy spectrum of the protons with the spectrum of the giant dipole resonance. In addition, the ratio of the yield of ordinary dissociation of the deuteron to the dissociation with slow proton agrees with the ratio of the yield of the γn and γp reactions of the giant dipole resonance on silver nuclei. The total cross section of the observed process on Ag or Br is 40 ± 8 mb.

A preliminary analysis shows that similar regularities are observed also in events in which 200-GeV/*c* protons are dissociated on emulsion nuclei (we used part of the experimental material of the ALMT collaboration).[2] The total cross section of the inelastic Coulomb dissociation of the protons with excitation of dipole resonance on Ag and Br nuclei is 3 ± 0.7 mb. A detailed analysis will be presented elsewhere.

The observed phenomenon of Coulomb dissociation of relativistic hadrons with excitation of giant dipole resonance on the target nucleus uncovers new possibilities in elementary-particle physics.

Consider the contribution of the diagram shown in the figure, to the collision of a relativistic hadron of charge e and mass M_1, with a nucleus A of charge Z_e and mass M_A. Here k is the momentum of the virtual photon, p is the momentum of the incident hadron a, and p_2 is the summary momentum of the system $c+d$. At not too high energies, the contribution of this diagram is masked by strong interactions. At large Z_e, however, at relativistic energies ($\gamma \gg 1$, $\gamma = 1/\sqrt{1-\beta^2}$, β is the velocity of the incident hadron), and at small k^2 the contribution of this diagram can be large. In this case the upper vertex of the diagram corresponds to the photoproduction matrix element

$$\gamma + a \to c + d, \tag{1}$$

and the lower vertex corresponds to giant dipole resonance (with emission of a proton or a neutron N). Giant dipole resonance can serve as an indicator of the energy of the equivalent photon in a reaction of the photoproduction type (1). We note that Coulomb dissociation of a 200-GeV/*c* neutron into a proton and a pion was recently investigated in Batavia.[3]

The Coulomb field of the incident hadron can be replaced by a spectrum of equivalent photons[4]

$$n(k)\,dk = \frac{2}{\pi} a Z_e^2 \ln\left(\frac{\eta \gamma M_1}{k}\right) \frac{dk}{k} \tag{2}$$

When the wavelength of the photon exceeds the dimensions of the nucleus

$$k \leqslant \frac{1}{R} \leqslant m_\pi A^{-1/3}, \tag{3}$$

the photon acts coherently on the target nucleus ($k \lesssim 29$ MeV for $A = 109$). Giant dipole resonance has levels in the region 10—30 MeV.

The equivalent photon energy E_γ in the antilaboratory frame (the hadron a is at rest) is determined by the formula

$$E_\gamma = \kappa \frac{pk}{M_1}, \tag{4}$$

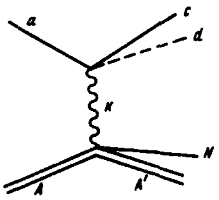

Diagram of Coulomb dissociation of a hadron with excitation of giant dipole resonance on the target nucleus.

where $\kappa = 2$ for k antiparallel to the incident hadron, and $\kappa = 1$ for k perpendicular. It follows therefore that, for example when a 60-GeV/c pion interacts with a heavy nucleus and the giant-resonance nucleons are registered, an electromagnetic interaction of pions takes place in its system, with energy equivalent to $E_\gamma = 12$ GeV (at $k = 0.015$ GeV). At a pion energy 200 GeV we have for the pion target an electromagnetic interaction with energy equivalent to 40 GeV.

We present a list of the possible physical experiments with registration based on giant dipole resonance: 1) Study of the electromagnetic form factors of pions, kaons, and hyperons in Coulomb scattering by nuclei. In these experiments, one can use the beams of the existing accelerators of the Joint Institute for Nuclear Research and Institute of High Energy Physics. 2) Study of the polarizability of pions, kaons, and other elementary particles by means of elastic scattering of Coulomb photons by corresponding hadrons at not too high energies. In this case we can use meson-factory pion beams. At high energies (the accelerators of JINR IHEP), it becomes possible to investigate the elastic scattering of photons, kaons, etc (the Compton effect on mesons and hyperons). 3) Investigation of the photoproduction of pions on pions in kaons in the energy region up to 12 GeV at the existing energies of the IHEP beams of pions, and kaons. 4) Determination of the quantum numbers of mesonic resonances, for example, the X^0 meson (η' meson) in the interaction of relativistic α particles (at the energies of the IHEP accelerator) with the Coulomb field of nuclei (coherent photoproduction of the X^0 meson on helium nuclei). 5) Use of the pion as a target to solve the same problem ($\gamma + \pi \to \pi + X^0$) at the energies of the IHEP accelerator. 6) Use of relativistic nuclei for the investigation of the production of hypernuclei ($\gamma + a \to K + a_\Lambda$).

In conclusion, we note that the use of the procedure to excite giant resonance on the target nucleus is easily realized in the experiment. To this end it suffices to measure the energy of the slow protons or neutrons emitted from the target. In addition, it is possible to use a difference method to determine the cross sections at a definite energy.

---

[1] N. Dalkhazav, G.S. Shabratova, K.D. Tolstov, M.I. Admaovich, and V.G. Larionova, Nucl. Phys. **A222**, 614 (1974).

[2] Alma-Ata—Leningrad—Moscow-Tashkent Collaboration, Yad. Fiz. **20**, 94 (1974) [Sov. J. Nucl. Phys. **20**, 48 (1975)].

[3] T. Ferbel, Proceedings of the Fifth International Symposium on many particle Hadrodynamics, Eisenach and Leipzig, GDR, June 4—10, 1974, p. 868.

[4] A.I. Akhiezer and V.B. Berestetskiĭ, Kvantovaya élektrodinamika (Quantum Electrodynamics), Nauka (1969), p. 462 [Interscience].