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9.38 GeV/*c* DEUTERON STRIPPING ON PHOTOEMULSION NUCLEI

N. DALKHAZHAV, G. S. SHABRATOVA and K. D. TOLSTOV

Laboratory of High Energies, Joint Institute for Nuclear Research, Dubna, USSR

and

M. I. ADAMOVICH and V. G. LARIONOVA

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

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Abstract: The interaction of relativistic deuterons with photoemulsion nuclei has been investigated. The photoemulsion method makes it possible to precisely measure small angles between relativistic particles in reactions and to select unambiguously the events of inelastic deuteron absorption. Proton stripping in the interaction of 9.38 GeV/*c* deuterons has been investigated.

E | NUCLEAR REACTIONS B, N, O, Ag(d, p), $p = 9.38$ GeV/*c*; measured $\sigma(\theta)$.

1. Experiment

In the experiment BR-2 10×20 cm^2 photoemulsions 400 μm thick were used (the elementary composition† of this emulsion is similar to Ilford G-5). A 100-layer photoemulsion chamber was exposed to an extracted monochromatic deuteron beam from the Dubna synchrophasotron (JINR, Laboratory of High Energies). The density of the deuteron flux in the emulsion was 2.4×10^4 particles/cm^2. The angular spread of the beam did not exceed $\pm 0.12°$, so that we could reliably ignore the tracks of background particles. Besides, the momentum of 158 primary particles measured by the multiple Coulomb scattering method showed that the proton contamination in the deuteron beam was small, and the mean momentum was equal to 9.6 ± 0.8 GeV/*c*. We scanned along the track. Interactions producing stars and one-prong events with angles of 0.1° in the photoemulsion plane were included in the total number of events.

2. Results

2.1. MEAN FREE PATH OF INELASTIC INTERACTIONS

The interactions of deuterons have some peculiarities in comparison with those

† Elementary composition of the BR-2 photoemulsion (number of atoms/cm$^3 \times 10^{22}$):

H	C	N	O	Br	Ag
2.93	1.39	0.37	1.06	1.02	1.02.

of nucleons. In addition to elastic diffractive scattering and absorption, there are proton and neutron stripping and diffractive deuteron dissociation [1]).

Along the 562.2 m deuteron tracks 2430 events were detected, 337 of them with one relativistic track. To determine a mean free path for deuteron absorption and proton and neutron stripping, it is necessary to exclude elastic scattering and diffractive dissociation events. Interactions of this type lead to the production of stars with only one relativistic track emitted at a small angle. These events can easily be omitted in scanning.

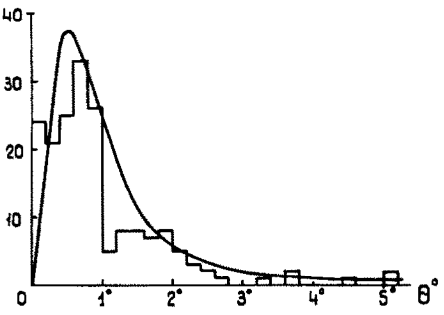

Fig. 1a. Angular distribution of one-prong events. The meaning of the solid line is given in the text.

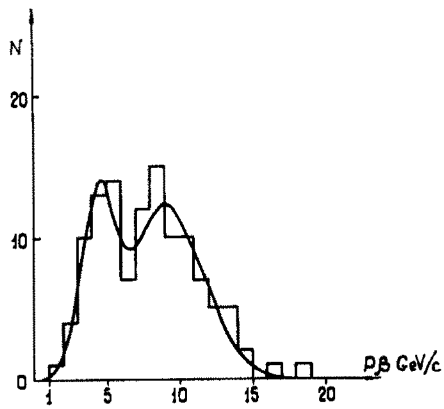

Fig. 1b. Momentum distribution of one-prong events.

Fig. 1a presents the angular distribution of relativistic particles from one-prong stars. The solid line shows the angular distribution of protons from deuteron diffractive dissociation calculated using the Hülten wave function. The cross section for deuteron elastic scattering on nuclei practically vanishes at angles larger than 1°. Therefore one can assume that all events with one relativistic track emitted at angles smaller than 5° are the results of the elastic scattering and diffractive dissociation of deuterons. We have drawn the same conclusion from the analysis of the momentum distribution for the 141 measured one-prong events presented in fig. 1b. The distribution has two maxima: one at 9.0 GeV/c is due to the deuteron elastic scattering, another at 4.3 GeV/c ($p_p = \frac{1}{2}p_d$) is due to the diffractive dissociation of deuterons. The solid line in fig. 1b is the fit of this distribution:

$$\chi(p) = (12.1 \pm 1.8) \exp\left\{\frac{[(9.0\pm 0.7)-p]^2}{13.0\pm 4.8}\right\} + (11.8\pm 3.6)\exp\left\{\frac{[(4.3\pm 0.4)-p]^2}{2.7\pm 1.5}\right\}.$$

The value of χ is equal to 6.7 at 10 degrees of freedom. Thus, one can assume that events with one relativistic track are those of the elastic scattering and diffractive dissociation of deuterons (only 1 % at angles larger than 5°). Then the mean free path for deuteron inelastic interactions (except the process of diffractive dissociation) will be equal to

$$\langle\lambda\rangle_{\rm inel} = 26.9 \pm 0.6 \text{ cm}.$$

2.2. PROTON STRIPPING OF DEUTERONS

The proton stripping of deuterons is known to consist of the collision of the deuteron with the nucleus when only the neutron suffers from inelastic interactions. In this case the angular distribution of protons is mainly due to the Fermi motion of nucleons in the deuteron, and their momentum distribution has a maximum at half the deuteron momentum. The theory of stripping reactions at high energies has been developed by Serber [2]). We want to get some information about the stripping of relativistic deuterons.

To study the stripping effect, the angles between the tracks of secondary relativistic particles and primary deuterons (1675 stars) have been measured. Fig. 2a presents the angular distribution for 590 tracks of relativistic particles at $0° < \theta \leqq 5°$. The distribution falls rapidly, which qualitatively agıees with the calculation of deuteron stripping made on the basis of the Hülten wave function describing the internal motion of nucleons in the deuteron. Besides, we have measured the momenta of relativistic particles from the distribution in fig. 2a. The measurement results are shown in fig. 2b. The momentum distribution has a maximum at half of the deuteron momentum and its shape is similar to the spectrum of particles for one-prong inelastic interactions (fig. 1b) with $p_{\rm max} = 4.3$ GeV/c.

The following processes can be background sources in our case:

(a) small angle production of particles in the interaction of deuteron nucleons with nuclei;

(b) production of particles in the interaction of the deuteron as a whole with nuclei;

(c) $n \rightarrow p$ exchange at the neutron stripping.

Our estimate shows that backgrounds due to the processes (b) and (c) are practically equal to zero. Therefore the estimate of the background contribution to stripping has been made by comparing the observed angular distribution with the distribution of relativistic particles from the 8.7 GeV/c proton interaction according to ref. [3]). The fraction of background particles having the plateau in the angular distribution in the interval 0°–5° is 0.4 ± 0.1. Subtracting this value, we get $W_{\rm st} = 0.18 \pm 0.04$, where $W_{\rm st}$ is the ratio of stripping events to the total number of inelastic interactions.

Let us estimate the cross section $\langle\sigma_{\rm p}\rangle$ for proton stripping on the photoemulsion nucleus. We do not take into account the interaction with hydrogen protons, their fraction being about 4 %. Knowing that the inelastic cross section of the deuteron nucleus is less than the sum of similar cross sections for the proton and neutron, as a consequence of their shielding each other, and assuming that the total cross sections of the proton-neutron interaction are practically equal in any combination,

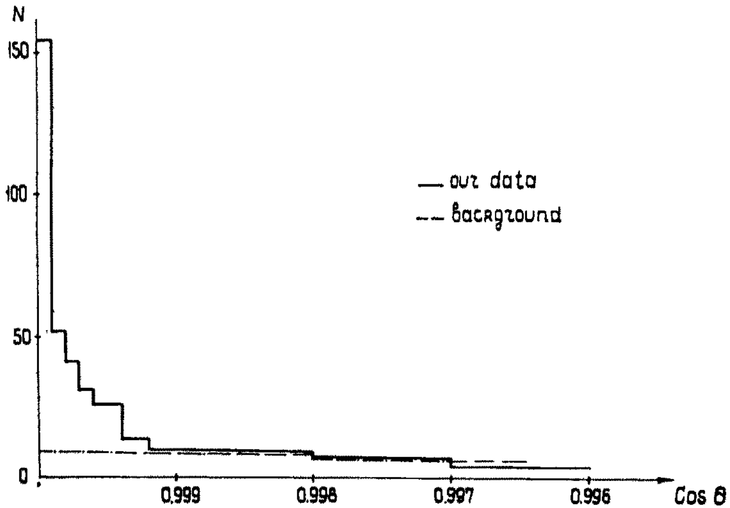

Fig. 2a. Angular distribution of relativistic particles produced by 9.38 GeV/c deuterons. The meaning of the solid line is given in the text.

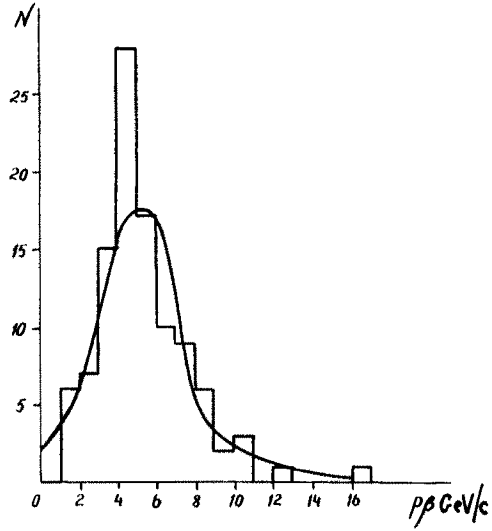

Fig. 2b. Momentum distribution of relativistic particles produced by 9.38 GeV/c deuterons.

we obtain

$$\langle\sigma\rangle_{\rm inel} = 2(1-\delta_{\rm G})\sum\sigma_A N_A/\sum N_A,$$

where σ_A is the total cross section of the proton with the nucleus of atomic weight A, N_A is the number of nuclei of this kind, and δ_G is the so-called Glauber correction. The value of the Glauber correction was taken from refs. [5, 6]). We use the data of ref. [7]) for the cross sections for the interaction of 5 GeV/c protons with C, Cu and Cd nuclei ($\sigma_C = 250$ mb, $\sigma_{Cu} = 800$ mb, $\sigma_{Cd} = 1160$ mb), and the $A^{\frac{2}{3}}$ law in order to calculate the cross section of the interaction with N, O, Ag and B nuclei. Based on these data and using formula (1), we obtain $\langle\sigma\rangle_{\rm inel} = 1150$ mb, the mean photoemulsion nucleus corresponding to $A = 47$. Consequently, $\langle\sigma\rangle_{\rm st} = 1150\ W_{\rm st} = 210 \pm 40$ mb. The same cross sections calculated by the Glauber model according to ref. [8]) for the mean photoemulsion nucleus are correspondingly equal to 950 and 225 mb.

The total cross sections for proton stripping including diffractive dissociation on Al and Cu at the deuteron momentum 3.54 GeV/c, $\sigma_{Al} = (290 \pm 75)$ mb and $\sigma_{Cu} = (550 \pm 137)$ mb, have been determined in ref. [9]). Taking into account the fraction of diffractive dissociation, our value for the stripping cross section is in agreement with the values of ref. [9]) that are about twice as large as the cross sections computed by Serber [2]).

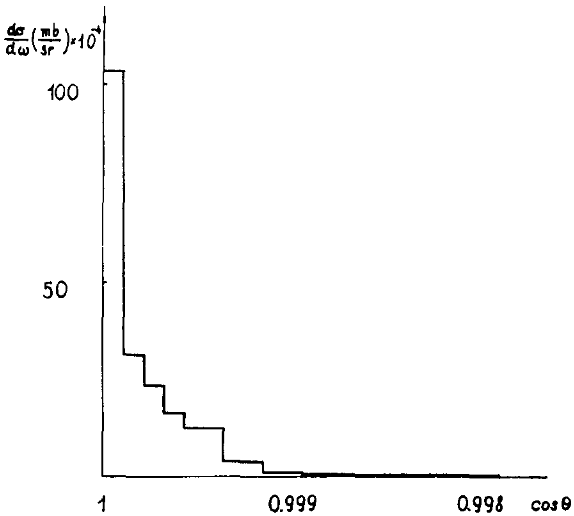

Fig. 3. Differential stripping cross sections on the photoemulsion mean nucleus.

Fig. 3 presents the differential stripping cross sections on the photoemulsion mean nucleus. According to these values, rather intensive monochromatic neutron beams may be created at existing accelerators for investigations in the field of high energy physics.

The integral angular distribution for the stripping of 13.3 GeV/c antideuterons on carbon has been obtained in ref. [10]). A similar distribution can be plotted based on our data. Both distributions are presented in fig. 4, normalized at an angle of 10.5 mrad. As seen from the figure, the curves correspond up to 10 mrad and then diverge. The difference of our experimental curve at large angles can be connected with proton rescattering in Ag and Br.

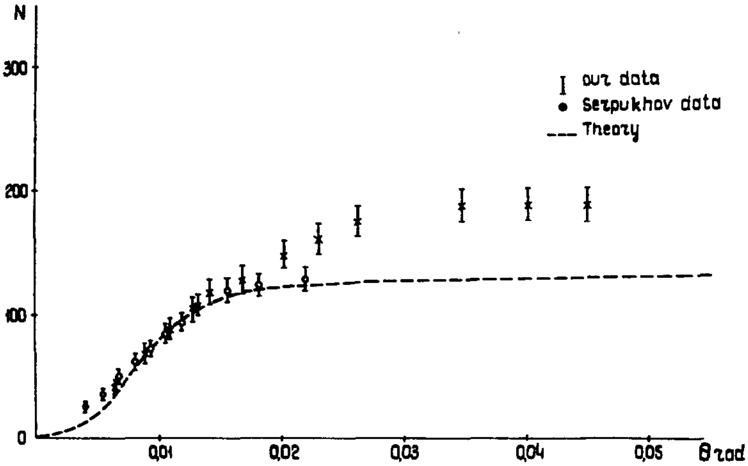

Fig. 4. Integral angular distributions for the stripping of 9.38 GeV/c deuterons on photoemulsion mean nuclei and for 13.3 GeV/c antideuterons on carbon nuclei.

TABLE 1

	Deuteron interactions in which stripping takes place		8.7 GeV proton interaction events
	yes	no	
$\langle n_s \rangle$	2.6±0.1	3.4±0.1	3.2±0.2
$\langle n_h \rangle$	5.1±0.2	8.5±0.4	7.7±0.7

It is interesting to compare the characteristics of events with and without proton stripping of deuterons. Table 1 presents the mean multiplicities of relativistic tracks (n_s) and tracks of dissociation nuclei (n_h). Table 1 also shows similar data on the interaction of protons with photoemulsion nuclei at 8.7 GeV/c. The table points out an essential feature of stripping events. It is easy to understand, since the emission of protons from the nucleus without interaction evidently results in a lower energy release in the nucleus and, consequently, in a smaller number of generated particles and weaker development of the intranuclear cascade.

In conclusion the authors express their gratitude to the engineering-technical staff of the Dubna synchrophasotron, especially to Drs. I. B. Issinsky and V. I. Moroz, and also to the scanners who searched for events and made measurements.

References

1) E. L. Feinberg, JETP (Sov. Phys.) **29** (1955) 115;
A. I. Akhieser and A. G. Sitenko, Proc. Kharkov University **64** (1955) 9;
R. Glauber, Phys. Rev. **99** (1955) 1515
2) R. Serber, Phys. Rev. **72** (1947) 1008
3) V. S. Barashenkov *et al.*, JINR, P-331, Dubna (1959)
4) R. Glauber, Phys. Rev. **100** (1955) 242
5) Y. P. Gorin *et al.*, Yad. Fiz. **14** (1971) 134
6) J. V. Allaby *et al.*, Phys. Lett. **30B** (1969) 500
7) V. S. Barashenkov and V. D. Toneev, Interactions of high energy particles and nuclei with nuclei (Moscow, Atomizdat, 1972)
8) G. Faldt and H. Pilkuhn, preprint CERN TH 1064 (1969)
9) R. L. Lander *et al.*, Phys. Rev. **137** (1965) B1228
10) Y. P. Gorin *et al.*, Yad. Fiz. **13** (1971) 344