Measurement of cumulative-neutron and cumulative-proton spectra in 1-GeV proton-nucleus interactions

V. N. Baturin, V. V. Vikhrov, M. M. Makarov, V. V. Nelyubin,
A. A. Naberezhnov, V. V. Sulimov, and L. N. Uvarov
B. P. Constantinov Institute of Nuclear Physics, Academy of Sciences of the USSR

(Submitted 13 August 1982)
Pis'ma Zh. Eksp. Teor. Fiz. **36**, No. 10, 370–372 (20 November 1982)

A comparative study has been made of the spectra of cumulative neutrons and protons produced at an angle of 114° in collisions of 1-GeV protons with ^{9}Be and ^{12}C nuclei. The slope parameters of the inclusive neutron spectra are similar to those of the proton spectra.

PACS numbers: 13.75. – n, 25.40.Rb

Deep-inelastic nuclear reactions which produce particles in a kinematic region not accessible in scattering by a free nucleon have attracted particular interest because the mechanism for the production of the cumulative particles apparently cannot be

 0021-3640/82/220448-04$01.00

explained without introducing some new concepts about the structure of nuclear matter: a high-momentum component of the nuclear wave function, many-nucleon correlations, ultradense configurations, etc.[1] Just how cumulative particles are produced has been the subject of a large number of model-based interpretations, and many experiments have been carried out to study these particles. In most cases the objects of study have been cumulative protons and π mesons; only in Refs. 2 cumulative neutrons have been studied, in pion-nucleus interactions at a momentum of 3 GeV/c. In order to test the existing models, however, it would be extremely interesting to learn about the characteristics of the neutron inclusive spectra and to compare them with proton data. In this letter we report the first measurements of the inclusive spectra of both cumulative neutrons and protons, measured under identical experimental conditions. The cumulative neutrons and protons were produced in the interaction of 1-GeV protons with ^{9}Be and ^{12}Cu nuclei.

Experiments were carried out on the synchrocyclotron of the Leningrad Institute of Nuclear Physics. The protons and neutrons emitted at an angle of 114° from the target were detected by a wide-aperture neutron scintillation spectrometer.[3] The intensity of the incident beam was 2×10^{10} s^{-1}. The energy and species of the detected particles were determined from their time of flight over a 9-m baseline and from the energy evolution in the scintillator of the spectrometer. The time scale was calibrated against the radio frequency of the accelerator. The time resolution was $\pm$ 1.8 ns. The capture angle of the spectrometer was 6.4°. The density of the carbon target was 3.85 g/cm^2, and that of the beryllium target was 2.8 g/cm^2. A high detection threshold, $\sim$60 MeV, was used in order to prevent slow particles from previous microbunches from entering the part of the spectrum under study (the time between microbunches was 75 ns). Lead shielding between the target and the spectrometer was used to measure the background level. This shielding was 110 cm thick and spanned the solid angle of the spectrometer. During the reconstruction of the cross sections, the background was subtracted, the necessary corrections were made for the ionization losses for the protons, and the neutron-detection efficiency was taken into account. This efficiency was calculated by the Stanton program,[4] as modified in Ref. 5. The validity of the efficiency correction was checked by reconstructing the cross sections for three sets of data obtained at various detection thresholds. The resulting cross sections were found to agree with each other within the statistical errors.

Figure 1 shows invariant cross sections for the production of cumulative neutrons and protons for the ^{9}Be and ^{12}C nuclei. The resultant systematic errors are $\pm$ 16% for the neutron cross sections and $\pm$ 9.5% for the proton cross sections. The error in the absolute normalization of the cross-section scale is $\pm$ 20%. We see from this figure that the curve of the invariant cross sections vs the square of the momentum is exponential and can be approximated by the function

$$f(p^2) \equiv \frac{E}{p^2}\frac{d^2\sigma}{dp\,d\Omega} = Ce^{-Bp^2}. \tag{1}$$

The values of the parameters B and C are listed in Table I. The indicated errors include the systematic errors. The basic result of this study is the demonstration that the slopes (the values of the parameter B) of the invariant neutron and proton cross

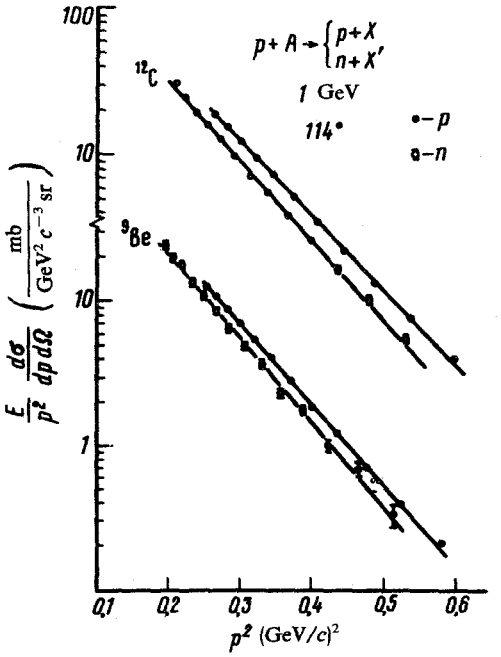

FIG. 1. Invariant cross sections for the production of cumulative neutrons and protons. The lines are drawn by the method of least squares.

sections are approximately equal. This approximate equality seems to suggest that we are not dealing with the scattered incident particle. The approximate equality of the slopes corresponds to the spectator mechanism adopted in the few-nucleon correlation model.[6] The ratio of the neutron yield to the proton yield over the interval $p^2 = 0.25$–0.50 $(\text{GeV}/c)^2$ is 0.71 ± 0.18 for ^{12}C and 0.77 ± 0.20 for ^{9}Be.

These are the first results of a comparative study of cumulative neutrons and protons. In a continuation of this program of study we intend to measure the angular and A dependences of the production of cumulative nucleons.

We wish to thank E. N. Vol'nin, M. I. Strikman, and L. L. Frankfurt for interest in this study and for some stimulating discussions. We are also indebted to A. A. Aleksandrov, V. S. Gusel'nikov, and A. G. Atamanchuk for assistance in the measurements.

TABLE I.

	$p+A \to p+X$		$p+A \to n+X$	
	C	B	C	B
^{9}Be	327 ± 30	12, 9 ± 0, 3	300 ± 45	13, 46 ± 0, 33
^{12}C	440 ± 35	11, 9 ± 0, 3	396 ± 60	12, 65 ± 0, 30

[1]A. M. Baldin, Fiz. Elem. Chastits At. Yadra. **8**, 429 (1977) [Sov. J. Part. Nucl. **8**, 207 (1977)]; G. A. Leksin, Proceedings of the Eighteenth International Conference on High-Energy Physics, Vol. 1, A6-3, Dubna, 1977; V. S. Stavinskiĭ, Fiz. Elem. Chastits At. Yadra. **10**, 949 (1979) [Sov. J. Part. Nucl. **10**, 373 (1979)]; M. I. Strikman and L. L. Frankfurt, Fiz. Elem. Chastits At. Yadra. **11**, 571 (1980) [Sov. J. Part. Nucl. **11**, 221 (1980)].
[2]Yu. D. Bayukov *et al.*, Preprint ITÉF-19, Institute of Theoretical and Experimental Physics, Moscow, 1979; Yu. D. Bayukov *et al.*, Yad. Fiz. **35**, 960 (1982) [Sov. J. Nucl. Phys. **35**, 558 (1982)].
[3]V. N. Baturin *et al.*, Preprint LIYa-594, Leningrad Institute of Nuclear Physics, 1980.
[4]N. A. Stanton, Preprint COO-1545-94, Ohio St. Univ.
[5]R. A. Cecil, B. D. Anderson, and R. Madey, Nucl. Instrum. Meth. **161**, 439 (1979).
[6]M. I. Strikman and L. L. Frankfurt, Yad. Fiz. **29**, 490 (1979) [Sov. J. Nucl. Phys. **29**, 246 (1979)].

Translated by Dave Parsons
Edited by S. J. Amoretty