PHYSICAL MEANING OF THE MULTIPLICITIES OF EMITTED NUCLEONS IN HADRON-NUCLEUS COLLISIONS

Strugalski Z.

Institute of Physics of the Warsaw Technical University
ul. Koszykowa 75
00-662 Warsaw, Poland

and

Joint Institute for Nuclear Research, High Energy Lab.
Dubna, USSR

ABSTRACT

The analysis of experimental data on hadron-nucleus collisions at energies from about 2 up to about 400 GeV was performed in order to discover a physical meaning of the multiplicity of emitted nucleons. Simple relations between the multiplicities and the thickness of the nuclear matter layer involved in collisions were obtained.

1. Introduction

It is commonly known that when atomic nuclei are bombarded by high energy hadrons, with energies higher than the pion production threshold, the emission of nucleons from the target nucleus, the particle production, and the evaporation of nuclear fragments take place. The presence of events in which intensive emission of nucleons and fragment evaporation appear without particle production leads to the conclusion that the nucleon emission process can proceed independently of the particle production, Strugalski Z., Pluta J. (1974), Strugalski Z., Pawlak T., Pluta J. (1982); the emitted nuclei are with kinetic energies from about 20 up to about 400 MeV, in the emulsion technique the nuclei are known as the so called g-track leaving particles.

In considerations about the nucleon emission, the emission process can be treated separately, because the influence on it by the particle production process is negligible, Strugalski Z.(1984 a,b), and the fragment evaporation is due to the target nucleus destruction in the nucleon emission process, Strugalski Z. (1984 c).

But, the emitted nucleons are constituents of the target nucleus, and it is reasonable to expect that characteristics of these nucleons should be connected with the parameters of the target - with itssize and nucleon density distribution in it. When the connections will be found, simple physical meaning of the multiplicities of the emitted nucleons, of the protons in particular, may be achieved.

The subject matter in this paper is to present results of our investigations in question.

2. Method

The method of experimental investigations is based on two facts: a) It is possible now to realize experiments, using heavy liquid chambers as 4Pi geometry detectors, in which emitted protons and produced pions of any electric charge including zero are registered with the efficiency near to 100 %; additional suplementary information about the target nuclei fragmentation can be obtained from emulsion experiments. Characteristics of the outcomes in hadron-nucleus collisions, such as multiplicities of produced or emitted particles, and momentum and angular spectra can be obtained fully as well. This way, experimental data obtained now are of such a sort as data which one can expect to obtain in a total experiment. b) Now many aspects about the nuclear matter distribution in atomic nuclei are so firmly established that it has been possible to use them in order to investigate other physical quantities, Elton LRB (1961). It is possible, therefore, to estimate the number of nucleons, or protons only, contained within any cylindrical volume centered on the hadron course in an atomic nucleus.

The method of investigation of the physical meaning of the multiplicities of the emitted nucleons, or of the emitted protons in particular, consists in comparison of the data on nucleon multiplicity distribution, obtained in investigations of collisions of definite hadrons with definite target nucleus, with data on distributions of the nucleon numbers contained within some cylindrical volumes centered on various possible hadron courses in the target nucleus; the distributions are determined from the information about the target nucleus size and nucleon density distribution in it.

3. Experiment

In our investigations we have used the 26 and 180 litre xenon bubble chambers, Kanarek T.I. et al. (1959), Kuznetsov E.V. et al. (1970). The first one was exposed to 2.34 GeV/c, 5 GeV/c, 9 GeV/c momentum pions from the synchrophasotron of the Joint Institute for Nuclear Research at Dubna. The second one was exposed to 3.5 GeV/c negatively charged pions from the accelerator of the Institute of Experimental and Theoretical Physics in Moscow. About 20 000 pion-xenon nucleus collision events were analysed, Strugalski Z. et al. (1982, 1983). Additionally, compilations of corresponding data obtained in emulsion experiments were used, Andersson B. et al. (1978), Babecki J. and Nowak G. (1978), Busza W. (1977), Gurtu A. et al. (1974), Otterlund I. et al. (1978), Tsai-Chü et al. (1977).

4. Results

It was found that the thicknesses of nuclear matter layers involved in hadron-nucleus collisions should be naturally and conveniently expressed in number of nucleons per some area $S = \pi D_o^2 \approx 10\ fm^2$, where D_o is the diameter of the nucleon; they can be expressed as well in protons/S, or in neutrons/S. We use these units only later on.

The analysis of the experimental data, in the light of the data on the target nuclei, leads to conclusions that:

1. The number n_p of protons (or of the g-track leaving particles) emitted in a collision is a measure of the thickness λ in protons/S of the nuclear matter layer involved in the collision:

$$n_p \doteq \lambda \cdot S \qquad (1)$$

2. The mean number $\langle n_p \rangle$ of protons emitted in a sample of the hadron-nucleus collisions equals the mean thickness $\langle \lambda \rangle$ in protons/S of the nuclear matter layer involved in the collisions:

$$\langle n_p \rangle \doteq \lambda S \qquad (2)$$

3. At the incident hadron energy larger than a few GeV, the mean number of protons $\langle n_p \rangle$ emitted in hadron-nucleus collisions is:

$$\langle n_p \rangle = \langle \lambda \rangle S \ (1 - \exp(-\langle \lambda \rangle / \langle \lambda_t \rangle)) \qquad (3)$$

where $\langle \lambda_t \rangle$ in protons/S is the mean free path for interaction of the incident hadron with a nucleon in nuclear matter, $\langle \lambda_t \rangle = 1/\sigma_{tot}$, and σ_{tot} is the cross-section for the hadron-nucleus any-type collision.

More information can be found in my previous works, Strugalski Z. (1984 a - c).

5. Remarks

From formula (1) it follows that the nucleon emission proceeds monotonically. But, this formula is accurate when the multiplicity of the emitted protons n_p is not larger than DS, where D is in protons/s the diameter of the target nucleus. In some small number of collision events, in no more than about 10 %, $n_p > DS$. The appearance of such values of $n_p > DS$ is due to the perturbations in nucleon emission process, Strugalski Z. (1984 b).

Formulas (1) - (3) were tested experimentally within the incident hadron energy interval up to about 2000 GeV, where the nucleon emission intensities were under studies. Nevertheless, we hope that the formulas are valid through the total region of the projectile energies above the pion production threshold.

We have investigated mainly the proton emission only, but additional analysis, Strugalski Z. (1984), provided results which incline us to think that formulas (1) - (3) are valid for both the nucleons together, and for the neutrons only, as well.

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