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SEMICLASSICAL DESCRIPTION OF HADRON-NUCLEUS COLLISIONS

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1. INTRODUCTION

An incomprehension of the hadron-nucleus collision processes, inherent in physics during tens years, can be measured by the plurality of new existing models which should explain experimental data. The models are often containing many free parameters and, in my opinion, presently there is no model among them which in a convincing manner can account for all hadron-nucleus data in terms of our knowledge of hadron-nucleon interaction.

My belief is that a major difficulties have occured due to incomplete enough picture of the process which should be obtained primarily in experiments.

In fact, what does it mean "To understand and describe the particle-nucleus collision process quantitatively?" A number of examples from the history of classical physics and quantum mechanics teach the general procedure by which we acquire physical understanding, creating finally physical models and theories. There are three elements prerequisite to a qualitative and quantitative understanding of a physical phenomenon: a) Qualitative picture of the phenomenon; b) A precise knowledge of the behaviour of the variables characterizing the phenomenon; c) The boundary conditions.

A qualitative picture is usually based on a few selected experimental results which are first oversimplified and codified for introduction into model or theory that may contain a good deal of additional human invention springing from the physicists imagination, and no from direct experimental facts. On this basis, a theoretical system is built and quantitative predictions are made, which have to be checked by experiments with sufficient accuracy.

A precise knowledge of the behaviour of the variables characterizing the phenomenon should be based on experimental data obtained in many supplementing each other experiments; the experiments form together a complete set of experiments which one might call a "total experiment".

The boundary conditions should be always chosen adequately to the experimental data which have to be used for a testing of the model or theory. It is worth-while to emphasize here that an experimentally obtained characteristic of the process under study may be a result of many effects acting simultaneously and it should be born in mind when this characteristic has to be used for a model testing.

Generalizing from commonly applied procedure for the process discussed here, it can be concluded that this process will be regarded as understood and described quantitatively when characteristics of the outcome observed in the final states of the particle-nucleus collisions will be expressed in terms of corresponding characteristics of the outcomes in the final states of corresponding particle-nucleon collisions and of the data on target nuclei sizes and nucleon density distributions in them.

In my opinion, a major breakthrough has occurred due to complex study of hadron-nucleus collisions in series of our experiments /1-24/; within a relatively short period we are going to achieve a depth of understanding and quantitative description of the particle-nucleus collision, and of the hadron-nucleus collision in particular, that a few years ago I did not expect to see.

The purpose of the present paper is to put on record results of our efforts to understand the hadron-nucleus collision process. We describe here a new picture of the hadron-nucleus collision process obtained experimentally, and we propose adequate free-parameterless model which has to account, in a convincing manner, for all hadron-nucleus collision data in terms of our knowledge of hadron-nucleon collision data.

2. EMPIRICAL BASIS

The empirical basis which is to be described now was obtained in studying experimentally in detail hadron-nucleus collisions at incident hadron energy from about 2 up to about 9 GeV/c momentum /1-24/ and in the analysis of appropriate experimental data available /25-36/ up to about 8000 GeV/c momentum. Let us start with a presentation of experimental data of some crucial value.

2.1. Facts Stated Experimentally

A picture of a physical phenomenon is usually based on a few selected experimental results; we present them here in connection with the problem in question - in order to derive the experimental picture of the hadron-nucleus collision process.

In any collision four general processes may take place: I. The nucleon emission. II. The particle production. III. The fragment evaporation. IV. The fission of the residual target nucleus. Needless to say that it will be conveniently to present the experimental facts separately for the processes I-IV.

We have found experimentally that, as it concerns:

I. The nucleon emission

1. Hadron-nucleus collision events occur in which the projectile with kinetic energy much larger than the pion production threshold is falling on the target nucleus without causing particle production, without causing the pion production in particular; in result of such collision reaction nucleons with kinetic energies from about 20 up to about 400 MeV are intensively emitted from the target nucleus and the incident hadron is deflected through various deflection angles, up to about 180 degrees; when the kinetic energy of the projectile is not higher than a few GeV, and the target nucleus is massive enough, the incident hadron is often absorbed inside the target nucleus /1,10,11,13,16/.

2. The nucleon emission proceeds monotonically; the number n_N of nucleons emitted in the "projectile-stopped" and "projectile-deflected" events is /37/:

$$n_N = \pi D_0^2 \lambda <\rho> , \qquad (1)$$

where D_0 fm is the nucleon diameter, λ fm is the hadron path in the target nucleus, $<\rho>$ nucleons/fm^3 is the mean nucleon density within the target nucleus along λ. It will be convenient to express the hadron path in units of nucleons per $S = \pi D_0^2 = 10$ fm^2; in this case, formula (1) can be rewritten as:

$$n_N = S\lambda . \qquad (1')$$

3. Any hadron of kinetic energy larger than the pion production threshold causes nucleon emission from the target nucleus in any type collision - when particles are produced or not; the particle production process does not influence the nucleon emission process at any projectile energy; the physical meaning of the quantity λ in formula (1') is: λ nucl/S is the thickness of the nuclear matter layer involved in an any-type collision.

4. Energy and momentum spectra and angular distributions of nucleons appeared in the monotonic nucleon emission process are independent of the projectile energy and identity, and of the number n_N of emitted nucleons, and of the number n_π of produced pions, in the target nucleus system of reference.

5. Any hadron of kinetic energy higher than the pion production threshold loses its kinetic energy in traversing an

atomic nucleus; the energy ΔE_hMeV of the hadron lost on its path λ nucl/S in nuclear matter is /22/:

$$\Delta E_h = \epsilon_h \lambda , \qquad (2)$$

where ϵ_h in MeV/(nucl/S) is the measurable coefficient - for pions $\epsilon_h = \epsilon_\pi \approx 180$ MeV/(nucl/S), for protons $\epsilon_h = \epsilon_p \approx 360$ MeV/(nucl/S).

Formulas (1) and (1´) determine the size and shape of the region in the target nucleus the nucleons are emitted from/41/:

$$G_N = S\lambda \quad \mathrm{fm}^3 \qquad (3)$$

and

$$\langle G_N \rangle = S \langle \lambda \rangle \quad \mathrm{fm}^3 , \qquad (4)$$

where G_N and $\langle G_N \rangle$ are size and the mean size of the region; λ and $\langle \lambda \rangle$ are the thickness and the mean thickness of the nuclear matter layer involved in collisions.

II. The particle production

1. The particle production in hadron-nucleon collisions, in nucleon-nucleon collisions in particular, is mediated by intermediate objects created at first in a 2 → 2 type endoergic reaction at early stage of the collision/38-40/these objects are ejected predominantly along the incident hadron course and behave themselves in passing through nuclear matter as usual hadrons do and decay after the lifetime $\tau \le 10^{-23}$ s; we call these objects "generons".

2. In passing through nuclear matter, generons can produce new intermediate objects, when collide with downstream nucleons; this way a quasilinear cascade of generons develops in nuclear matter along the incident hadron course.

3. The mean number $\langle m \rangle$ of elementary hadron-nucleon and nucleon-nucleon outcomes appearing in a collision, when an incident hadron fell on the nuclear matter layer of the thickness λ nucl/S, is:

$$\langle m \rangle = e^{t} , \qquad (5)$$

where $t = \lambda / \lambda_p$ and λ_p is measurable quantity - the mean free path for the particle producing hadron-nucleon collision in nuclear matter; the distribution of the outcomes $P(m,t)$ is

$$P(m,t) = e^{-t} (1 - e^{-t})^{m-t} . \qquad (6)$$

4. The size G_s of the region in the target nucleus where particle-producing reactions occur is /41/:

$$G_s = \lambda \quad \mathrm{fm} \qquad (7)$$

and the mean value of G_s is

$$\langle G_s \rangle = \langle \lambda \rangle \quad \mathrm{fm} . \qquad (8)$$

III. The nucleon fragment evaporation

1. The relations between the mean multiplicity $\langle n_b \rangle$ of evaporated charged fragments and the multiplicity n_p of emitted protons exist:

$$\langle n_b \rangle = 1.25 \left(n_p + \frac{A - Z}{Z}\right) \qquad (9)$$

and

$$\langle n_b \rangle / (\langle n_b \rangle + \langle n_p \rangle) = \langle n_b \rangle / \langle n_h \rangle = 0.4 , \qquad (10)$$

where A and Z are the mass and charge numbers of the target nucleus; $n_p = 0, 1, 2, \dots DS\frac{Z}{A}$ and D is the diameter of the target nucleus in nucl/S.

2. The mean size G_b of the fragment evaporation region in the target nucleus is as large as the surface layer of the damaged part of the target nucleus with the thickness of about $D_0/2$, formed after the nucleon emission:

$$\langle G_b \rangle = \pi [(1.5 D_0)^2 - D_0^2] \lambda \quad \mathrm{fm}^3 . \qquad (11)$$

IV. Fission of the residual target nucleus

1. In any hadron-nucleus collision, the target nucleus is damaged and relatively large part of it is removed away.

2. The damaged nucleus should be instable and it will decay into smaller nuclei, stable in their final states.

2.2. The Picture of the Hadron-Nucleus Collision Process Obtained Experimentally

If a high energy hadron is incident on an atomic nucleus, it may undergo various processes, when it interacts with nuclear matter. This hadron, as is known from experiments, can traverse the target nucleus without causing particle production [1,3,21,22,42]; in passing through a layer of nuclear matter, it loses monotonically its kinetic energy, by causing emission of nucleons from the target nucleus, according to formula (1), and it is monotonically deflected through small deflection angles, of a few degrees per $\Delta\lambda = 1$ nucl/S; the emitted nucleons are not knocked-out ones, they are rather decay products of some two- or more-nucleon systems emitted when the hadron passed through a layer of nuclear matter. Sometimes, on the background of the "monotonic" passage through nuclear matter, the hadron can come into collision with one of the downstream nucleons leading to a large angle deflection, up to about 180 degrees, or to particle production.

In the larger deflection collisions the recoil nucleons can appear which, if of kinetic energy large enough, may cause monotonic emission of nucleons from the target nucleus as well in their passage through nuclear matter.

The particle-producing collisions are endoergic, or rather quasi-endoergic, reactions of the type $2 \to 2$ leading to appearance of two intermediate objects; the objects are ejected predominantly colinearly with the incident hadron course and behave themselves in nuclear matter as usual hadrons do, and decay after some time $\tau \geq 10^{-23}$ s into commonly observed particles and resonances; if the downstream layer of nuclear matter is thick enough, the quasi-linear cascade of the intermediate objects may develop in it, this way the outcome in a hadron-nucleus collision can be the composition of the outcomes in elementary hadron-nucleon and nucleon-nucleon collisions at correspondingly lower energies.

When the incident hadron and the products of its collision have left the target nucleus, this nucleus is damaged and it is instable. The damage is definitely situated in the nucleus, predominantly at an outer part of it [23]; the damage is of definite shape and the surface of the damaged part of the nucleus is usually large enough. The damaged and instable nucleus strives for a transition into a stable state; it appears as the evaporation of nucleons and nuclear fragments from the damaged surface of the nucleus first of all.

The evaporation leads to some redistribution of nucleons inside the residual nucleus as well and it causes the decay of the residual target into stable nuclei of various A and Z.

The frequency of an appearance of the above described processes in hadron-nucleus collisions depends on the incident hadron energy and on the mass number of the target nucleus. At energies low enough, lower than a few GeV, the events appear in which incident hadron is stopped completely inside the target without causing particle production; in such events the intensive emission of nucleons is observed; the frequency of an appearance of the "stopped" events decreases with the incident hadron energy increase, at energies above a few GeV the events are absent.

Obviously, in many cases the energy loss of the incident hadron, by the nucleon emission, goes in advance of the particle-producing collision of this hadron in nuclear matter.

2.3. The Target Nucleus as a Nuclear Matter Slab

Due to the properties of the nucleon emission process, stated experimentally, one can treat the target nucleus as a lens-shaped slab of nuclear matter of the maximum thickness λ_{max}, mean thickness $\langle\lambda\rangle$, and the thickness $\lambda(b)$ at any distance from its axis, when λ's are expressed in nucleons/S, see for example our former work [44].

Many aspects about the nuclear matter distribution are now so firmly established that it is possible to use them in order to investigate other physical quantities [43]. In particular the quantities λ_{max}, $\langle\lambda\rangle$ and $\lambda(b)$ nucl/S can be obtained without difficulties for any of nuclei [44].

In more than about 90% of hadron-nucleus collisions the emitted nucleon multiplicity n_N is the measure of the thickness $\lambda(b)$ nucl/S of nuclear matter layer involved in the collision, and the mean nucleon multiplicity $\langle n_N\rangle$ nucl/S is the measure of the mean thickness $\langle\lambda\rangle$ nucl/S of the nuclear matter layer involved in corresponding sample of collisions.

2.4. A Hadron as a Projectile

Any hadron, which is to be used as a projectile, should be characterized by its mean free path for any-type collision reaction in nuclear matter:

$$\lambda_{tot} = \frac{1}{\sigma_{tot}}, \tag{12}$$

where σ_{tot} in S/nucleon is the total cross section for elementary hadron-nucleon collision [45], λ_{tot} is in nucl/S. The projectile-hadron should be characterized as well by various mean free paths λ_v nucl/S for various collision reactions; in particular, by the mean free path λ_i for the particle-producing collisions

$$\lambda_i = \frac{k}{\sigma_i}, \tag{13}$$

where σ_i is the inelastic cross section for the elementary hadron-nucleon collision [45] in S/nucl, and k is a measurable coefficient [46], $k = 0.3 \pm 0.3$.

3. DESCRIPTION PROCEDURE

The new way for description of the hadron-nucleus collisions proposed here is based on the experimentally stated facts, presented above. In this section, let us start with a short presentation of the new way for interpretation of the hadron-nucleus collisions /24/.

3.1. New Way for Interpretation of Hadron-Nucleus Collision Data

The clarification of the physical meaning of the observed multiplicity of nucleons emitted in hadron-nucleus collisions provided possibilities for a new interpretation of the data obtained in the collision studies. In particular, the information about the thickness of nuclear matter layer the hadron fell on in a collision gives the possibility of determining the collision impact parameter, which in turn allows one to treat /44/ the target nucleus as a nuclear matter slab. Such a treatment of the target nucleus allows one to consider results of investigations of a sample of hadron-nucleus collisions as results obtained in an absorption experiment in which a beam of incident hadrons fell on the sheets of nuclear matter of definite thicknesses $\lambda = 1, 2, \ldots, n_N(D)$ nucl/S, of definite mean thickness $\langle\lambda\rangle$ nucl/S, and definite maximum thickness λ_{max} nucl/S, where $n_N(D)$ is the mean nucleon multiplicity of emitted nucleons when a hadron traverses the nucleus along its diameter D.

It is obvious, from what has been said above, that we found a new way leading to derivation of relations between the imput and output data in hadron-nucleus collisions in terms of the hadron-nucleon data. There is no any place for any free parameters in these relations.

What is the common feature in the sample of hadron-nucleus collision events collected in experiments performed using any technique - bubble chambers, nuclear photoemulsions, electronic detectors? One common feature can be recognized, and we think it crucial: in games of chance in the collision processes we find events repeating themselves again and again. They are mass phenomena or repeative events; this unlimited repetition, this "mass character" is typically present in the case of all the events under studies.

In fact, as usually is practiced, the observable characteristics correspond to definite reactions: to the sample of collisions of definite identical hadrons with definite target nuclei, at definite energies. We have, therefore, in experiments a practically unlimited sequence of uniform informations. True, in any collision the target nucleus is destroyed, but in any collision identical projectile hadron and identical target nucleus are always involved; it enables us, in attempts to describe the hadron-nucleus collision process quantitatively, to treat the sample of collision events as interaction of a homogeneous monoenergetic beam of parallelly moving hadrons with a "slab" of nuclear matter. This way, this problem is formulated as similar to that in absorption experiments, when the interaction of a particle beam with a slab of a material is studied.

3.2. The Mathematical Formalism

The rational concept of probability applies both to problems in which either the same event repeats itself again and again, or a great number of uniform elements are involved which may be treated as occurring at the same time. We conclude, therefore, that the theory of probability and statistics /47,48/ is the mathematical foundation naturally suitable to provide mathematical formalism for a quantitative description of the hadron-nucleus collision processes, especially of the particle production phenomenon occurring in them.

3.3. Input and Output Data

According to an analogy of the hadron-nucleus collision experiments in which nuclear targets are treated as nuclear matter slabs, to the particle absorption experiments, in which incident particles collide with slab of a material, adequate set of input and output data may be determined without difficulties.

The input data should consist of: a) The identity of the incident hadrons, their momentum and mean free path for various processes which are to be occurring; b) The quantities describing the target nucleus as the nuclear matter slab - λ_{max}, $\langle\lambda\rangle$, λ (b) in nucl/S; c) The set of hadron-nucleon and nucleon-nucleon collision outcomes in dependence on the projectile momentum, this set may vary depending on the set of the hadron-nucleus collision outcome which is to be studied.

The output data should consist of: a) Identities of the collision reaction products; b) Distributions of intensities and momentum, and angular spectra of emitted nucleons; c) Distributions of intensities, momentum spectra, and angular distributions of the produced particles in dependence on $n_N(b) = \lambda(b)S$, $\langle n_N\rangle = \langle\lambda\rangle S$; d) Additional various characteristics of the produced particles, if any; e) Distributions of the intensities, momentum spectra, and angular distributions of the nuclear fragments evaporated in dependence on the $n_N = \lambda(b)S$ and $\langle n_N\rangle = \langle\lambda\rangle S$; f) Identities, angular and momentum distributions of the decay products of the residual target nucleus, in dependence on $n_N = \lambda(b)S$ and $\langle n_N\rangle = \langle\lambda\rangle S$.

The input and output data should be in the laboratory system in which the target nucleus is treated as resting.

4. FORMULAS FOR EXPERIMENTAL TESTING

The properties of the hadron-nucleus collision phenomenon, stated experimentally and described in section 2, allow one to treat separately the four main processes: the nucleon emission, the particle production, the target fragment evaporation, and the fission of the residual target nuclei.

4.1. Nucleon Emission Process

Usually, emitted protons are observed only in predominant number of experiments. In order to describe the characteristics of the intensity of the emitted protons the miltiplicity n_N in formula (1) or in formula (1′) should be multiplied by the coefficient [49] Z/A, and the thicknesses $\lambda(b)$, $\langle\lambda\rangle$ and λ_{max} of the target nucleus should be expressed in protons/S correspondingly.

If hadrons pass through nuclear matter without collisions leading to appearance of energetic recoil nucleons, the multiplicity distribution of the emitted nucleons, or the proton multiplicity only, is determined by the distribution $W_0[\lambda(b)S,A] = W_0[n_N,A] = W_0[n_p,A]$ of the $\lambda(b)$ S thicknesses in the target nucleus with a given mass number A. Various processes disturbing the distribution, as the large-angle deflection of the incident hadron, should be taken into account when the distribution $W[\lambda(b)S,A]$ is to be tested by an experiment [49]. Formulas are valid, when $\lambda(b)S \le n_N(D)$.

Energy and angular distributions are the same for all hadron-nucleus collisions, for their description and for an understanding of their physical meaning one needs additional information about the nucleon emission mechanism unknown now [22].

4.2. Particle Production Process

According to the picture of the particle production process obtained experimentally, all what is seen as an outcome in a hadron-nucleus collision at an energy E is a composition of some number m of statistically independent outcomes which could be observed separately in elementary hadron-nucleon and nucleon-nucleon collisions at incident hadron energy values of about E/m. The quantity m is defined by formulas (5) and (6) for a given nuclear matter layer thickness λ nucl/S, if in the formulas λ_i is in units nucl/S, for $t = \lambda/\lambda_i$.

Because the quantity λ_i is measurable one and the thicknesses $\lambda \equiv \lambda(b)$ at any impact parameter b can be estimated for any target nucleus as well, we can treat $P(m,t)$ and $\langle m\rangle$ as known.

In the theory of probability and statistics there are simple relations between a composition of m statistically independent frequency distributions and its moments and the component distributions and their moments. We use these relations and write similar ones for the frequency distributions, average values $\langle v\rangle$ of variables v and for the normalized dispersion $Z = (\langle v^2\rangle - \langle v\rangle^2)^{1/2}/\langle v\rangle$ in the case under consideration.

The relation between the frequency distribution $F_{hA}[v_{hA}(E,h,t)]$ of a variable $v_{hA}(E,h,t)$ characterizing some process in hadron h collision with nuclear matter layer of a thickness $t = \lambda/\lambda_i$ in a target nucleus of the mass number A and the charge number Z, at an energy E, and the frequency distributions $f_{hN}[v_{hN}(E',h,N)]$ of corresponding variable $v_{hN}(E',h,N)$ characterizing corresponding process in collisions of this hadron h with nucleons N, at energies $E' \approx E/m < E$, can be written:

$$F_{hA}[v_{hA}(E,h,t)] = \sum_{m=1}^{m=k} P(m,t)\,\Phi_m\{f_{hN}[v_{hN}(\frac{E}{m},h,N)]\}, \qquad (14)$$

where $k = 1,2,3,\ldots$; Φ_m is the composition of m statistically independent frequency distributions $f_{hN}[v_{hN}(E/m,h,N)]$ including appropriate normalization coefficient. This composition can be obtained simply, if f_{hN} are known [50-52,47,48,53].

For the average values of variables, we can write:

$$\langle v_{hA}(E,h,t)\rangle = \langle m\rangle\langle v_{hN}(\frac{E}{\langle m\rangle},h,N)\rangle; \qquad (15)$$

for the normalized dispersions:

$$Z_{hA}[v_{hA}(E,h,t)] = \frac{1}{\sqrt{\langle m\rangle}} Z_{hN}[v_{hN}(\frac{E}{m},h,N)] + 0, \qquad (16)$$

where 0 is for the normalized dispersion of the quantity m.

The quantity $t = \lambda/\lambda_i$ can be related either to any thickness $\lambda = \lambda(b)$ or to the mean thickness $\lambda \equiv \langle\lambda\rangle$ of the target nucleus.

One can find additional information about the problems discussed here in my previous work "Free-Parameterless Model of High Energy Particle Collisions with Atomic Nuclei" [49].

4.3. Nuclear Fragment Evaporation

All what is known now about fragment evaporation process occurring when a hadron collided with a nucleus massive enough may be described by formulas (9), (10), and (11). These formulas, together with the theory of the evaporation process, which should be modified in the light of the picture presented above, will provide a well description of the process in question.

4.4. Fission of the Residual Target Nucleus

The new picture of the hadron-nucleus collision process should help to explain quantitatively experimental results obtained in studies of the fission of residual target nuclei. Maybe, we will be able to predict distributions of probabilities of an appearance of definite final nuclei and their energy and angular spectra.

5. EXPERIMENTAL TESTING

Experimental testing of the presented above picture as a whole has been performed partly - some of observed characteristics of the outcome were tested[38-40,50-52,54,55]. Additionally, special testing of formulas describing the intensities of the nucleon emission and target fragment evaporation has been done[23,24]. Agreement well enough is observed in any case under testing.

More comparisons of formulas proposed should be performed again and again with new more accurate and more complete experimental data later on. Nevertheless, it can be stated by now that our new way for interpretation of the phenomena observed when a hadron collides with a nucleus provides an effective tool for investigations of the hadron-nucleus, nucleus-nucleus, and nucleon-nucleon collisions.

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The Joint Institute for Nuclear Research begins publishing a collection of papers entitled *JINR Rapid Communications* which is a section of the JINR Communications and is intended for the accelerated publication of important results on the following subjects:

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JINR Rapid Communications will be issued regularly.

Стругальский З. E1-85-230
Полуклассическое описание адрон-ядерных столкновений

Выход в адрон-ядерных столкновениях описывается в терминах данных об адрон-нуклонных столкновениях, о размерах ядра мишени и о распределении в нем нуклонов. Набор адрон-ядерных столкновений можно трактовать как взаимодействие пучка адронов с пластиной из ядерной материи. Такая трактовка позволяет анализировать этот набор аналогично тому, как анализируются данные из абсорбционных экспериментов - когда рассматривается взаимодействие пучка частиц с пластиной из какого-то материала. Теория вероятностей и статистика являются естественным математическим аппаратом для анализа такого рода.

Работа выполнена в Лаборатории высоких энергий ОИЯИ.

Сообщение Объединенного института ядерных исследований. Дубна 1985

Strugalski Z. E1-85-230
Semiclassical Description of Hadron-Nucleus Collisions

It is shown how it is possible to describe the outcomes in hadron-nucleus collisions in terms of suitable outcomes in hadron-nucleon collisions and the data on the target nucleus size and nucleon density distribution in it. A sample of hadron-nucleus collision events may be treated as an interaction of a homogeneous monoenergetic beam of hadrons with a slab of nuclear matter. This way, the data on hadron-nucleus collisions are considered similarly as the data obtained in absorption experiments - when the interaction of a particle beam with a slab of a material is studied. The theory of probability and statistics is the mathematical foundation naturally suitable for a quantitative description of the particle-producing hadron-nucleus collisions.

The investigation has been performed at the Laboratory of High Energies, JINR.

Communication of the Joint Institute for Nuclear Research. Dubna 1985