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RELATIVISTIC NUCLEAR PHYSICS: SYMMETRY AND THE CORRELATION DEPLETION PRINCIPLE

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1 Symmetry in modern physics

The understanding of the goal of fundamental investigations consisting in the discovery of universal elementary laws, from which it is possible to obtain deductively the picture of the world, has played the role of a methodological principle. A fabulous success of the gauge symmetry defining the interaction Lagrangians has resulted in an impression that the Standard Model may pretend to the role of such "universal elementary laws". All the "bricks of the universe" (quarks, leptons and gauge fields) and their interactions are known, and physics is becoming like chemistry. Euphoria provoked by the success of the Standard Model has definitely resulted in a reduction of research programs in the field of high energy physics, and in particular in stopping work on the project of the American supercollider (SSC). In any way, this event was the first hard blow that had affected the investigations of fundamental structure of matter. It was just at that time, that in all countries government support of the whole of fundamental science, and especially high energy physics, was essentially slackening.

Fortunately, this dangerous tendency has affected not so strongly relativistic nuclear physics. In 1992, a superconducting accelerator of relativistic nuclei, named the Nuclotron, was built in Dubna [1]. In the USA, the construction of CEBAF is being finished that is designed to study nuclear structure at small distances, and a Relativistic Heavy–Ion Collider (RHIC) is successfully being built. At CERN, a large research program dealing with the study of relativistic nuclear collisions is being performed at SPS, and a nuclear research program is being elaborated at the Large Hadronic Collider (LHC). Special attention to relativistic nuclear physics is explained by the fact that one well understands the necessity of studying the laws in this area of science which are irreducible to the Standard Model and are very close to the human practice in comparison with the laws of superhigh energy physics.

The quantitative study of the processes of relativistic nuclear collisions began about twenty five years ago, after the beams of nuclei moving with velocities close to the velocity of light had been obtained in Dubna and Berkeley. Till then, the relativistic nuclei were thought of as a component of cosmic rays. A great growth of interest in this domain is due to the hope of discovering the laws governing strongly excited nuclear matter. The transitions of nuclear matter to quark–gluon one and the mechanisms of violation of gauge and chiral symmetries are being studied. Some interesting considerations concerning the possibility of studying the quark–gluon plasma and describing the phenomena occurred at the moment of the Big Bang have been suggested. The discovery of the laws of strongly excited matter is very important for astrophysics, in particular for the description of the dynamics of supernova explosion, as well as for the explanation of stability of neutron stars, and so on.

In this connection, there arise two question: i) what are the regularities, studied in relativistic nuclear physics, which do not reduce in principle to the Standard Model consequences, and ii) to what extent the dynamics of multihadron systems studied at accelerators and the hadron thermodynamics used for the description of interstellar processes, the early universe, and so on obey the same laws. Both questions are related to the principles of the construction of the mathematical models (laws) for physical phenomena and processes.

The physical processes are described in terms of observable quantities. Complicated real situations require simplified descriptions on the basis of the criteria of validity of the models. Mathematics deals with the use of symbolic models embracing a wide class of abstract mathematical objects, for example, such as numbers, vectors, and groups. The concept of the group is the proper mathematical representation of the concept of symmetry which is the main notion of all modern physics.

G.Weyl often noted that all the a priori assertions of physics arise from symmetry. The major goal of the fundamental investigations is known to be reduced to the formulation of a minimal set of concepts and assertions on the basis of which, using some logical arguments, it is possible to construct an experimentally observable picture of the world.

The symmetry principles provide the laws of nature with such a structure that, starting from it, it is possible sometimes to obtain new laws of nature by pure deduction, without recourse to auxiliary observations of physical objects. In this sense, sometimes the symmetry principles are referred to as superlaws of nature, or the foundation of science. In particular, the principle of relativity may be formulated as follows: the laws of nature must represent the relations between the group invariants. Many of these relations are not consequences of the Hamiltonian symmetry. It was a time when one even proposed to forget the Hamiltonian method as far as the nonhamiltonian ones were found to be more effective in fundamental science.

In the 1970s and 1980s physicists run to opposite extremes: the gauge theories, and especially the Standard Model were declared to be a "theory of everything". The Standard Model contains only those axioms which deal with the Lagrangian symmetry, but they are insufficient to describe physical processes. Some additional conditions (hypotheses) such as initial and boundary conditions, assumptions about the constants entering Lagrangians (masses, charges, and so on) are needed. For example, the assumption about the existence of a renormalization group (this is the symmetry of the solutions rather than that of the Lagrangian!) made it possible to introduce a running coupling constant and the concept of the asymptotic freedom which turned chromodynamics into a quantitative theory in a definite range of the parameters. Higg's mechanism is an additional principle defining the property of vacuum as the lowest ground state of the quantum field.

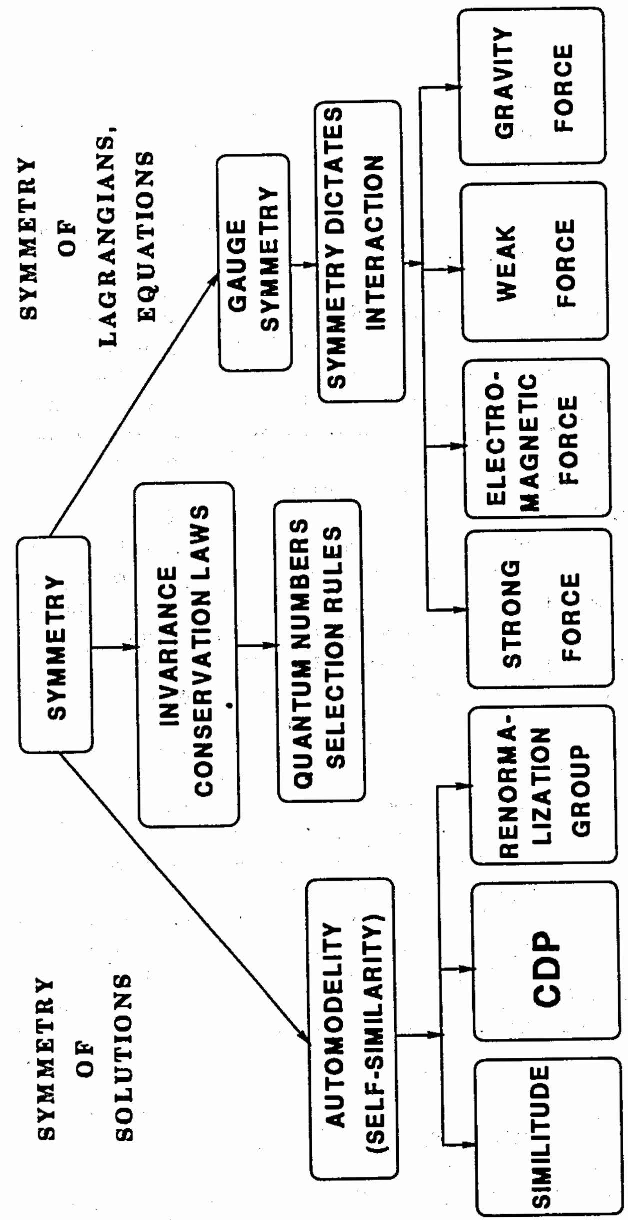

Fig.1. Schematic diagram illustrating the role of symmetry in fundamental physics.

The laws of self-similarity and dimensionality, widely used in mechanics of continuous media, non-linear theories, the theories of turbulence and chemical reactions, etc. are consequences of the symmetries which supplement the symmetry of Lagrangians and equations. The treatment of experimental data and the analysis of the results of numerical calculations and multidimensional processes show that the points lying in disorder in the usual coordinate frame, occupy a common curve plotted in properly chosen coordinates named the similarity parameters. The latter are the group invariants. For example, Reynolds' number is an invariant of the multiplicative group corresponding to the self-similarity symmetry of the solutions of hydrodynamics.

Nuclear physics, including relativistic nuclear physics, cannot arise from QCD without subsidiary hypotheses which need to be tested experimentally. The test of these hypotheses of a rather general character is not less important than that of QCD. This is just the answer to the first question.

The answer to the second question is that the possibility to generalize the regularities of nuclear processes studied at accelerators to astro-physical processes and to the description of the early Universe essentially depends on the coincidence of the symmetries of the boundary and the initial conditions. Many properties of the processes can be deduced directly from symmetry of solutions. Kepler's method of approach to the description of the motion of planets is entirely similar to a method in use today in elementary particle physics: deduction of laws directly from symmetry considerations.

A schematic diagram in fig.1 illustrates the use of symmetry in fundamental physics. The right-hand part shows an essentially new role of symmetry: symmetry and invariance define the interaction Hamiltonian. Chen Ning Yang, one of the originators of gauge symmetry, called this role as follows "symmetry dictates interaction". The middle part of the diagram includes what one usually calls kinematics and needs not be commented. The left-hand part, which I call symmetry of solutions, contains principles supplementing the Lagrangian symmetries. These additional principles define the structure of the laws of nature.

In relativistic nuclear physics, the Lagrangian includes a few effective Lagrangians, in addition to QCD, and a very large number of dynamical variables. Therefore, the research goal consisting in the test of the hypotheses about the Lagrangian structure is complicated and not efficient. At the same time, the study of the symmetries of the final state of nucleus-nucleus collisions (symmetry of solutions) made it possible to establish a number of asymptotic regularities and propose simple mathematical models describing a huge amount of experimental material. The established symmetry properties render many suggested experiments unnecessary and essentially restrict the discussed in literature multiplicity of models describing nucleus-nucleus collisions. These properties define the structure of the laws of multiple particle production, i.e. new theoretical and experimental results, being expressed in terms of the invariants of the mentioned symmetries, must satisfy them.

2 The Correlation Depletion Principle

Symmetry was thought of by ancien Greek philosophers as a particular case of harmony, i.e. concordance of the parts inside a whole. Among the principles, which enable one to examine and compare the parts of a large system, of special importance is the Correlation

Depletion Principle denoted by the letters CDP on the diagram. This principle is formulated as a principle of symmetry of solutions.

In statistical physics, the Correlation Depletion Principle has been suggested by Bogolubov [2] for the particle distribution in the ordinary space-time. The principle is based on an intuitive idea that the interaction between the groups of particles of a macroscopic system becomes small when these groups become far apart. The asymptotics of the Green functions as universal (independent of specific features of the system) linear forms

$$F(t_1,x_1,...,t_n,x_n) = < ...\Psi^+(t_j,x_j)...,\Psi^+(t_s,x_s)... >$$

where $x = (\mathbf{r},\sigma)$ are the three-dimensional coordinates and the particle spins, and $t_1,...t_n$ the time moments, is considered by Bogolubov in the range where all the time moments $t_1,...t_n$ are fixed, and the distances between the points **from various groups** $\{...t_\alpha,x_\alpha...\}$ and $\{...t_\beta,x_\beta...\}$ tend to infinity. As is known, in quantum field theory, all the field functions $\Psi(t_i,x_i)$ must exactly commute or anticommute if the interval $-(t_i-t_k)^2+(\mathbf{r}_i-\mathbf{r}_k)^2$ is a space-like one. To obtain an asymptotic form of F for fixed t_i,t_k and at $|\mathbf{r}_i-\mathbf{r}_k|\to\infty$ it is possible to permute the field functions **from various groups** and thereby reach a situation when the field functions for each group of arguments are found to be together in the same complex (cluster). Thus we have

$$F(t_1,x_1,...,t_n,x_n) - \eta < U_1(...,t_\alpha,x_\alpha...)\cdot U_2(...t_\beta,x_\beta...) > \to 0$$

$$\eta = \pm 1$$

where $U_1(...,t_\alpha,x_\alpha...)$ is the product of the field functions with the arguments from only the first group, $U_2(...,t_\beta,x_\beta...)$ is a similar product with the arguments from only the second group.

Since the correlation between the dynamical quantities U_1, U_2 must become weaker and must practically vanish for rather large distances, the asymptotic form of the expression

$$< U_1(...,t_\alpha,x_\alpha...)\cdot U_2(...t_\beta,x_\beta...) >$$

breaks down into products of the form

$$< U_1(...,t_\alpha,x_\alpha...) > \cdot < U_2(...t_\beta,x_\beta...) > \tag{1}$$

In this formulation of the correlation depletion principle Bogolubov has paid attention to the fundamental role of the degeneration of the states over which averaging is carried out. We consider e.g. a crystalline state. Applying the previous reasoning to this case, we naturally assume that the crystalline lattice as a whole is fixed in space arbitrarily but equally for different clusters $< U_1 >, < U_2 >$ and so on. In other words, all the averages in question are assumed to belong to the same fixed position of the lattice. We are dealing with quasi-averages, rather than with the ordinary averages, which are obtained from the quasi-averages by means of a subsidiary averaging over all the possible positions and orientations of the crystalline lattice. The factors $< U_1 >, < U_2 >$ are found to be not quite independent. They depend on the parameters over which some additional averaging needs to be carried out. As examples of the parameters remaining equally fixed for all the parts of a macroscopic system, Bogolubov gives magnetic moment (ferromagnetism), phase angle (superfluidity or superconductivity) and so on.

It is interesting to note that the well-known attempt of Dirac to formulate the relativistic theory of dynamical systems [3] had led him to the conclusion that one had succeeded in formulating only necessary, but not sufficient, conditions for such a theory to exist. At the end of his famous paper [3] Dirac write: "Some further condition is needed to ensure that the interaction between two physical objects becomes small when the objects become far apart. It is not clear how this condition can be formulated mathematically".

As we see, Bogolubov's Correlation Depletion Principle has resolved this classical problem which was stated by Dirac in 1949.

The use of the method of quasi-averages and the Correlation Depletion Principle in nonrelativistic nuclear physics is well described in a monograph by V.G.Soloviev [4]. In this connection, we confine ourselves to some problems of relativistic nuclear physics. In what follows, we give a modified version of the Correlation Depletion Principle [5] that has been used in quantum chromodynamics of large distances (or more exactly, of small relative velocities) for the description of multiple particle production processes, and especially in relativistic nuclear physics.

We consider the multiple particle production reactions in the collision of relativistic nuclei I and II

$$I + II \to 1 + 2 + 3 + \ldots$$

in a space whose points are the four-velocities or the four-momenta of particles divided by their masses. The squared distances (intervals) in this space

$$b_{ik} = -(u_i - u_k)^2 = 2[(u_i u_k) - 1] \tag{2}$$

$$i, k = I, II, 1, 2, 3, ..$$

define the interaction magnitude. Experiments show that the invariant distributions (cross sections, inclusive spectra) as functions of the variables b_{ik} possess universal asymptotic properties. In the velocity space the components

$$u_i^0 = \frac{E_i}{m_i}; \; u_i^x = \frac{p_i^x}{m_i}; \; u_i^y = \frac{p_i^y}{m_i}; \; u_i^z = \frac{p_i^z}{m_i}$$

are regarded as the Cartesian coordinates of a point in a four-dimensional space (the end point of the four-vector). As the origin of the space, we can take any point of the velocity space, but not only u_I or u_{II}, as is usually done. Making use of the condition $u_i^2 = 1$, it is possible to introduce a three-dimensional space, the surface of the hyperboloid $u_0 = \sqrt{1 + u_x^2 + u_y^2 + u_z^2}$ embedded in the four-velocity space. The metric of this space in spherical coordinates is

$$g^{11} = 1; \; g^{22} = \frac{1}{sh^2\rho}; \; g^{33} = \frac{1}{sh^2\rho sin^2\theta};$$
$$g_{11} = 1; \; g_{22} = sh^2\rho; \; g_{33} = sh^2\rho(sin^2\theta d\phi^2 + d\theta^2); \tag{3}$$
$$g_{ik} = 0 \;\; at \;\; i \neq k; \; D^2 = ||g_{ik}||; \; D = sh^2\rho sin\theta$$

or for the interval we have

$$db = -(du^0)^2 + (d\mathbf{u})^2 = d\rho^2 + sh^2\rho(sin^2\theta d\phi^2 + d\theta^2)$$

$$b_{ik} = 2(ch\rho_{ik} - 1)$$

Here θ and ϕ are the polar angles, $\rho = \frac{1}{2}ln\left(\frac{E+|\mathbf{p}|}{E-|\mathbf{p}|}\right)$ the (radial) rapidity. This is the metric of Lobachevsky's three-dimensional space. An invariant element of the phase volume is

$$\frac{d\mathbf{p}}{E} = m^2\frac{d\mathbf{u}}{u^0} = m^2 D\, d\rho\, d\theta\, d\phi = \frac{m^2}{2}\sqrt{b + \frac{b^2}{4}}db\; sin\theta d\theta\, d\phi$$

In a non-relativistic limit, $\rho \ll 1$, these formulas turn into the well-known formulas of the Euclidean geometry. We are interested in the limit $\rho \gg 1$ and in the asymptotic regularities in this limit. We are starting from the assumption that the correlation between the parts of a particle system which are separated from one another by large intervals b_{ik} (or ρ_{ik}) practically vanishes. The relative velocity space in question is additional to the usual space of relative distances (in quantum-mechanical sense). Small distances $|\mathbf{r}_i - \mathbf{r}_k|^2$ correspond to large b_{ik}, and vise versa.

It should be stressed that the decrease of the distributions (matrix elements, cross sections) with increasing b_{ik} reflects the basic property of the colour (quark-gluon) interactions — asymptotic freedom — i.e. vanishing of interactions at asymptotically small distances or for $b_{ik} \to \infty$. In this sense, our hypothesis is exactly opposite to Bogolubov's Correlation Depletion Principle. Let us divide the set of points in the velocity space into groups (clusters): $..., b_{ik}^{\alpha}, ..., ..., b_{ik}^{\beta}....$ By cluster we mean a set of points u_k the mean interval between which $\overline{b_{\alpha k}} = -\overline{(V_\alpha - u_k)^2}$ is much smaller than those between the cluster centers $\overline{b_{\alpha\beta}} = -\overline{(V_\alpha - V_\beta)^2}$:

$$\overline{b_{\alpha k}} \ll \overline{b_{\alpha\beta}}$$

Here

$$V_\alpha = \frac{\sum u_k^\alpha}{\sqrt{(\sum u_k^\alpha)^2}}; \;\; V_\beta = \frac{\sum u_k^\beta}{\sqrt{(\sum u_j^\beta)^2}},$$

Since, according to the hypothesis, the correlation between dynamical quantities belonging to different clusters must vanish, then for $b_{\alpha\beta} \to \infty$ the asymptotic form of distributions (squared matrix elements, inclusive distributions, cross sections) breaks down into products of the form:

$$W(b_{\alpha k}, b_{\alpha\beta}, b_{\beta k}, ...) \to W^\alpha \cdot W^\beta \tag{4}$$

In just the same way as in the case of the above-considered description of the crystalline state, the factors $W^\alpha, W^\beta, W^\gamma ...$ turn out to be not quite independent. The quantities $b_{\alpha,\beta}, b_{\beta k}$ and $b_{\alpha k}$ are the sides of a triangle in a non-euclidean space. At $b_{\alpha\beta} \to \infty$ in the system $\mathbf{V}_\alpha = 0$ we have

$$b_{\alpha\beta} = 2(V_\alpha^0 - 1) \to \infty$$
$$b_{\alpha k} = 2(u_k^0 - 1)$$
$$b_{\beta k} = 2[V_\beta^0 u_k^0 - (\mathbf{V}_\beta \cdot \mathbf{u} - 1)] \to 2V_\beta^0(u_k^0 - u_k^z) = b_{\alpha\beta} x_k \to \infty$$

where $x_k = u_k^0 - u_k^z$ is the well-known variable of the light cone, $u_k^z = \sqrt{(u_k^0)^2 - 1}cos\theta$ is the projection of the velocity onto the direction of the vector $\mathbf{V}_\beta$. Thus in the factorization of the distributions at $b_{\alpha\beta} \to \infty$ there remains a dependence of W^α on the direction to an infinitely distant point $\mathbf{V}_\beta$. This anisotropy of the cluster decay in its proper system has a purely geometrical character. In going over to the non-relativistic approximation, that is from Lobachevsky's geometry to the Euclidean one, the dependence of W^α on the angle θ degenerates to isotropy. The dependence of W^α on the variable x_k vanishes because

$x_k \to 1$. This remark shows that it is impossible to discover quasistationary objects basing on the idea about decay isotropy in their rest frame. In relativistic dynamics, such decays are **always anisotropic.** The consequences of the Correlation Depletion Principle used for the description of multiple particle production processes are extremely fruitful and numerous. Unification of the Correlation Depletion Principle with the principle of self–similarity of the second kind [7] made it possible to suggest a method of analysis which was used to discover simple and universal regularities of multiple particle production, establish their relationship with QCD, and demonstrate observability of colour charges [6].

The principle of self–similarity of the second kind (also named "incomplete self–similarity") is being widely used in the mechanics of continuous media, hydrodynamics, the theory of explosions and so on [7, 8]. From the mathematical point of view, this principle consists in that the dimensionality and invariance theories are supplemented with definite properties of the asymptotic behavior of the solutions of mathematical physics. In the case in question at $b_{\alpha\beta} \to \infty$ it is formulated as follows [9]

$$W(b_{\alpha k}, b_{\beta k}, b_{\alpha\beta}) \to \frac{1}{b_{\alpha\beta}^n} W^\alpha \left(b_{\alpha k}, \frac{b_{\beta k}}{b_{\alpha\beta}}\right) \tag{5}$$

As is shown above,

$$\frac{b_{\beta k}}{b_{\alpha\beta}} \to x_k$$

where x_k is the light–cone variable. The law (5) is valid to a definite degree of accuracy and within definite limits of changing $b_{\alpha\beta}$. In the mechanics of continuous media, it is given the name "intermediate asymptotics". For fixed $b_{\alpha k}$ and x_k (self–similarity parameters) the quantity $W^\alpha = b_{\alpha\beta}^n W$ remains unchanged with changing all other parameters, including $b_{\alpha\beta}$ similar to itself (self–similar).

Self–similarity introduced by Matveev, Muradian and Tavkhelidze [10] in particle physics implies the invariance of the cross sections in the four–momentum transformation $P_i \to \lambda P_i$. As is seen from eq.(5), the self–similarity laws under consideration are much larger than the self–similarity based on the simple scale invariance.

Thus by using the self–similarity theory we can formulate the Correlation Depletion Principle for the two clusters α and β in hadron physics in the form of the following regularity

$$W(b_{\alpha\beta}, b_{\alpha k}, b_{\beta j}, b_{\beta k}, b_{\alpha j}) \to \frac{1}{b_{\alpha\beta}^n} W^\alpha \left(b_{\alpha k}, \frac{b_{\beta k}}{b_{\alpha\beta}}\right) W^\beta \left(b_{\beta j}, \frac{b_{\alpha j}}{b_{\alpha\beta}}\right) \tag{6}$$

The arguments of W^α and W^β contain the dependence on the velocity projections on the axis connecting the centers of the clusters:

$$V_\alpha = \frac{\sum u_k}{\sqrt{(\sum u_k)^2}}; \quad V_\beta = \frac{\sum u_j}{\sqrt{(\sum u_j)^2}}$$

Eq.(6) and similar equations obtained on the basis of symmetry considerations define the structure of the laws of multiple particle production strongly restricting the model building. They allow one to put in order a very large amount of experimental material on multiple hadron processes reducing it to similar parametrizations of universal relativistic

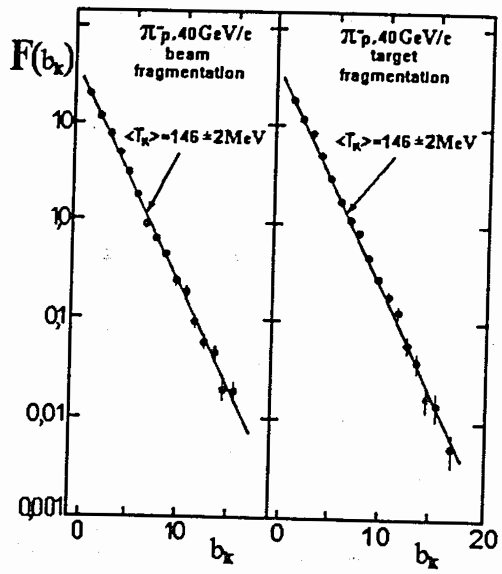

Figure 2.

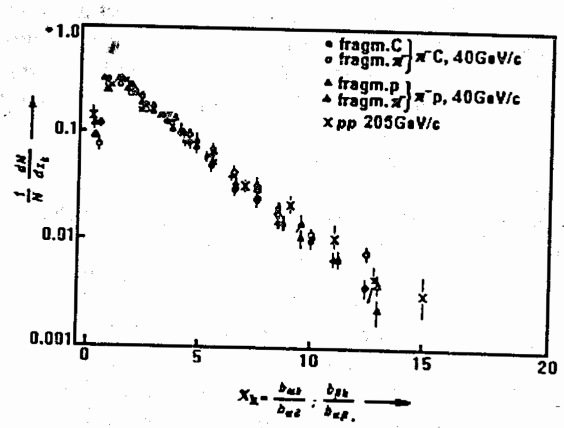

Figure 3. The x_k distributions of π^- mesons in the jets produced in the beam and target fragmentation regions in various interaction types

invariant functions W^{α}, to show that many statements of problems of high-energy physics are redundant, and to optimize the conditions of expensive experiments at large accelerators. Of special importance is a direct experimental check of the Correlation Depletion Principle.

The analysis of experimental data on multiple particle production in different reactions at different accelerators [6] shows the universal character of the distribution W^{α}. Figure 2 gives the particle distributions $F_2(b_k)$ with respect to the self-similarity parameter $b_k = -(V_{\alpha} - u_k)^2$ where

$$F_2(b_k) = \int W^{\alpha} d\Omega_k; \;\; T_k = \frac{m_k b_k}{2}; \;\; d\Omega_k = sin\theta_k d\theta_k d\phi_k$$

$$W^{\alpha} = \frac{1}{N_0}\frac{2}{m_k^2}\frac{d^3N}{\sqrt{b_k + \frac{b_k^2}{4}} db_k d\Omega_k} = \frac{1}{N_0}\frac{2}{m_k^2}\frac{d^3N}{db_k dx_k d\phi_k}$$

Fig.3 gives the distribution $\frac{1}{N_0}\frac{dN}{dx_k}$ with respect to the other self-similarity parameter

$$x_k = \frac{b_{\alpha k}}{b_{\alpha\beta}}; \;\; x_k = \frac{b_{\beta k}}{b_{\alpha\beta}}$$

The normalization:

$$\frac{1}{N_0}\int \frac{dN}{dx_k} dx_k = 1$$

The universal pion clusters W^{α} for $b_{\alpha\beta} \geq 50$ turned out to be the well-known jets. The intermediate asymptotic was tested in the range $20 \leq b_{\alpha\beta} \leq 10^5$. The parameter n of the measured dependence $\frac{dN}{db_{\alpha\beta}} = \frac{A}{b_{\alpha\beta}^n}$ was found to be universal and equal to about 3 to an accuracy higher than 10%. The baryon clusters (one investigated mainly the proton clusters) are also universal relativistic invariant objects located in close vicinity of the points u_I and u_{II}. This fact is in satisfactory agreement with the well-known limiting fragmentation hypothesis of C.N.Yang and his colleagues [11] that is a particular case of the law (6) for $\alpha = I$, $\beta = II$ and $n = 0$.

The limiting fragmentation hypothesis had been tested by V.S.Stavinsky and his colleagues [12] in connection with the discovery of cumulative effect. Of special importance is the observation that the asymptotic regime in the relativistic nuclear collisions is setting for $b_{I\ II} \geq 5$ which corresponds to the kinetic energy of nuclei equal to 3.5 A. GeV. The pre-asymptotic regime was being studied by L.Schroeder's team (Berkeley) [13]. These results have played the decisive role in the final choice of the Nuclotron parameters, the development of the research program in the domain of relativistic nuclear physics, and the determination of the limits of applicability of the proton–neutron nuclear model. The possibility of predicting regularities of the type (6) was found to be very ample. Of special interest is the study of cumulative jets (knockout of colour charges from nuclei), fig.4.

Experimental data obtained at DELPHI were used to pick out and measure a three-gluon vertex [14] (gluon self-acting) when studying four-jet events $e^+e^- \rightarrow q_{\alpha}\bar{q}_{\beta}g_{\gamma}g_{\delta}$. That was just the way in which one had succeeded in testing experimentally the group structure of chromodynamics, that is in defining the ratio of the number of the colour variables of a quark N_C to that of a gluon N_A, $N_C/N_A = 3/8$. Further investigations of such reactions will make it possible to perform a separate study of the fragmentation functions for quarks $W^{\alpha,\beta}(b_k, x_k)$ and gluons $W^{\gamma,\delta}(b_k, x_k)$. They are expected to differ from

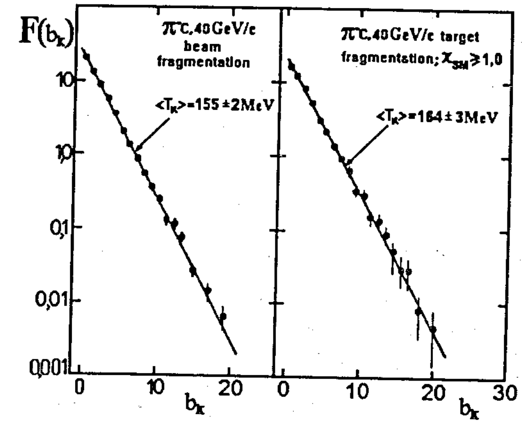

Figure 4.

the universal distributions $W^{\alpha}(b_k, x_k)$ obtained earlier without distinguishing between the quark and gluon jets [6].

The final state symmetry, eq. (6), may serve as a criterion of validity for the mathematical models and ideas related to relativistic nuclear collisions. In particular, the models describing the appearance of large densities and a quark-gluon plasma in ultra-relativistic nuclear collisions contradict the asymptotic character of eq.(6).

In the transition regime, nucleon matter $\rightarrow$ quark-gluon matter: $b_{I\ II} \leq 10$ symmetry (6) has been observed to be violated. The study of the secondary particle spectra in this region can give some unexpected results. Of much interest is the study of antimatter production in relativistic nuclear collisions. The approximate law [15]

$$E_1 \frac{d\sigma}{dp_1} \propto f(\Pi)$$

describes subthreshold and cumulative production of $\bar{p}$ and K^-'s, including the angular and energy distribution in the region $2 \leq b_{I\ II} \leq 400$. The universal parameter Π has the physical meaning of the effective mass of nucleons – participants of the reaction from both nuclei I and II. The same parameter is expected to describe production of antinuclei at asymptotically large energies.

3 Conclusion

The suggested point of view on the role of symmetry in physics makes it possible to single out a special class of symmetry principles not reduced to the symmetry of Lagrangians and in particular to that of the Standard Model. The principles of "symmetry of solutions" introduced here are abstracted directly from experiment and are to a large extent a method, alternative to Hamiltonian one, for the construction of mathematical models.

In relativistic nuclear physics the Correlation Depletion Principle, self-similarity and intermediate asymptotics formulated in the relative velocity space serve as a basis for planning experiments in a wide energy range. This is connected with the fact that the initial state of nucleus-nucleus collisions is given by many parameters the relationship between which is regulated by the symmetry of solutions.

References

[1] A.M. Baldin. Proc. of Intern. Seminar on High Energy Phys.Problems. Dubna, Russia 7-12 Sept. 1992 p.672-687.

[2] N.N. Bogolubov, JINR Communications, JINR D-781, Dubna 1958. N.N.Bogolubov. Physica v. 265, 1960, p.1.

[3] P.A.M. Dirac, Rev.Mod.Phys., v.21, N3, 1949, p.392-399.

[4] V.G. Soloviev, Teorija slozhnykh yader, M. Nauka 1971, p.214

[5] A.M. Baldin. Nucl.Phys. A447, 1985, p.203c.

[6] A.M. Baldin and L.A. Didenko, Fortschr. Phys., v.38, 1994, p.261-332.

[7] G.I. Barenblat, Podobije, avtomodlenost', promezhutochnaya asimptotica, L.Gidrometioizdat, 1982, p.16, 93.

[8] G. Birkhoff. Hydrodynamics. A study in logic, fact and similitude, Princeton, New Jersey, Princeton University Press 1960.

[9] A.M. Baldin, A.A. Baldin. JINR Rapid Communication 17-86, Dubna 1986, p.19.

[10] V.A. Matveev, R.M. Muradyan, A.N. Tavkhelidze, Lett. Nuovo Cim., v.5 (1972), p.907

[11] Benecke J. et al, Phys. Rev., v.188 (1969), p.2159.

[12] V.S. Stavinsky, Elementarn. chastitsy i atom. yadro, v.10, 1979, p.949.

[13] L.S. Schroeder et al. Phys.Rev.Lett. v.43, 1979, p.1787.

[14] DELPHI Collaboration Z.Phys. C59, 1993, p.357-368.

[15] A.A. Baldin. Phys.At.Nucl. 56 (3) March 1993, p.385-388.

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Релятивистская ядерная физика:
симметрия и принцип ослабления корреляций

Представлен взгляд автора на роль симметрии в фундаментальной физике. Анализируется концепция симметрии решений. Подчеркивается, что невозможно вывести основные законы релятивистской ядерной физики из лагранжианов КХД без обращения к дополнительным гипотезам о симметрии решений (функций Грина). Проверка этих гипотез является важным направлением в изучении адронных и ядерных столкновений. Особое значение имеет принцип ослабления корреляций, позволяющий конструировать модели релятивистской ядерной физики и анализировать, используя простые выражения, топологически сложные события в ядро-ядерных столкновениях.

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Relativistic Nuclear Physics:
Symmetry and the Correlation Depletion Principle

The author's view on the role of symmetry in fundamental physics is presented. The concept of the «symmetry of solutions» is analyzed. It is stressed that it is impossible to deduce the basic laws of relativistic nuclear physics from the QCD Lagrangians without recourse to additional hypotheses about the symmetry of solutions (Green's functions). The test of these hypotheses is the major prospect of the study of hadron and nuclear collisions. Special importance is given to the Correlation Depletions Principle that makes it possible to construct mathematical models of relativistic nuclear physics, and analyze, by using simple terms, topologically complicated events of nucleus-nucleus collisions.

The investigation has been performed at the Bogoliubov Laboratory of Theoretical Physics, JINR.

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