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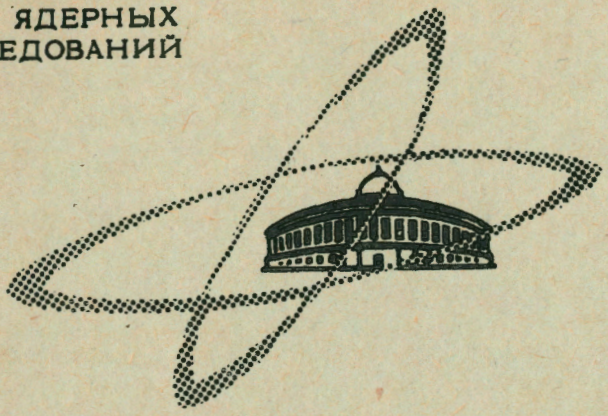

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G.V.Efimov, M.K.Volkov

ЛАБОРАТОРИЯ ТЕОРЕТИЧЕСКОЙ ФИЗИКИ

A BRIEF REVIEW OF THE REPORTS Submitted to THE II INTERNATIONAL SYMPOSIUM ON NONLOCAL QUANTUM FIELD THEORY (Azau, March 15-24, 1970)

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Submitted to УФН

The II International Symposium on Nonlocal Quantum Field Theory organized by the Joint Institute for Nuclear Research was held on March 15-24, at Azau (Kabardino-Balkar Autonomous Republic). A total of about 80 scientists from eleven countries, including those from 8 member-countries as well as from Italy, France and Germany Federal Republic have participated in it.

The range of problems discussed at this Symposium has become far wider compared with the I International Symposium on Nonlocal Quantum Field Theory (Dubna, July 1967). On the whole, the Azau Symposium was devoted to the main problems of quantum field theory: nonlocal and local quantum theory, essentially nonlinear and nonrenormalizable interactions, chiral symmetry and the Yang-Mills interaction, functional method in field theory, review of recent experimental information and a number of related topics [1].

About 50 reports have been given in nine of which recent achievements in various fields of quantum field theory have been reviewed.

The Symposium was opened by the Chairman of the Organizing Committee, Professor D.I.Blokhintsev. In his talk he stressed the importance of the Symposium in the general progress of theoretical physics and the increasing interest in the problems discussed here. The evidence for this is an essentially increased number of reports submitted to the Symposium compared to the first one, held at Dubna in 1967.

On behalf of the Organizing Committe D.I.Blokhintsev thanked the representatives of the authorities of the Kabardino-Balkar Autonomous Republic of the Russian Federation for the hospitality and the help in organizing the Symposium.

In his introductary talk "Present-Day State of Nonlocal and Nonrenormalizable Field Theory " D.I.Blokhintsev has stressed that it is a general tendency in all the nonlocal theories in the region of small distances to refuse in one or another way the law of "signal" propagation in vacuum with the light velocity.

The review talk was devoted to the work performed at the Laboratory of Theoretical Physics of the JINR. A special emphasis was placed on the problems concerning the construction of a nonlocal scattering matrix satisfying the macroscopic causality and unitarity and on the investigations of field theory describing essentially nonlinear interactions. The reporter has indicated a number of papers performed at Dubna in which one studies the role of gravitation in the elementary particle theory, the problem of quantization in the curved space and a possible role of gravitation in constructing a particle theory without divergences.

Investigations on the quantization in the curved momentum space have also been noted.

M.A.Markov (USSR) has reported on the extended particle model in the general theory of relativity, on the so-called friedmon. It may be considered as a specific example of the model with form factor when the signal propagates with a velocity smaller than the velocity of light due to the change of the metric. In a flat space the form factor leads, as a rule, to the appearance of superlight signals.

M.A.Markov has paid attention to the fact that in the general theory of relativity there arise peculiar possibilities of introducing particles sizes.

D.Yu.Bardin and S.M.Bilenky and B.M.Pontekorvo(Dubna) have indicated in their report that the available experimental investigations in the physics of neutrino do not contradict the hypothesis on the existence of a strong neutrino-neutrino interaction.

L.D.Soloviev (USSR) has reviewed the experimental data at high energies obtained on the Serpukhov accelerator. At present these experiments can not be used for checking any definite theory, they are employed for checking very general principles of the theory and very specific models. The report deals with the following problems: check of dispersion relations, constancy of the cross section differences for mesons and antimesons, possible increase of the cross sections, total cross sections and complex momenta, radiational corrections to the total cross sec-

sections, shrinking of the diffractional cone in proton-proton cross sections, differential cross sections and polarization characteristics of elastic meson-nucleon processes, new particles, CPT and experiments with neutrinos and muons.

V.A.Petrun'kin and S.A.Startsev (USSR) have considered the possibility of checking quantum electrodynamics on colliding beams. The account of strong interactions faces theoretical difficulties. It is shown that if the experimental accuracy of measuring the cross sections is assumed to be 10% and the disagreement with theory not less than 20% is believed to be reliable, then the measurement of the cross sections of processes $e^- + e^+ \to e^- + e^+$ and $e^- + e^+ \to \mu^- + \mu^+$ at a total energy in the c.m.s. of 7-10 GeV corresponds to the check of quantum electrodynamics up to distances $10^{-15} \div 6.10^{-16}$ cm.

V.A.Petrun'kin has also reviewed the experimental data on the check of the applicability of local quantum electrodynamics. All the experimental data are in agreement with the conclusions of local theory.

The report by G.V.Efimov (Dubna) has opened the discussion of the important topic of the Symposium - Nonlocal Field Theories. He has reviewed the present-day state of nonlocal quantum field theory. Recently a certain progress has been made in nonlocal theory which has risen the latter on the level of the strictness which we have in local theory. In the framework of perturbation theory the connection was established between the requirements of unitarity and causality of the S-matrix and the admissible class of the form factors. It turned out

that there exists a rather wide class of the form factors by means of which it is possible to construct a finite S-matrix in each perturbation order.

In the framework of the axiomatic approach it turned out to be possible not only to formulate the nonlocal theory axioms on the basis of the extension of the space of admissible distributions but also to get all the most important results of the axiomatics, CPT invariance, relationship between the spin and statistics, existence of asymptotic solutions.

M.Z.Iofa and B.Ya.Faynberg (USSR) have told about the axiomatic approach in nonlocal quantum field theory. Their approach is based on the extension of the space of admissible distributions. The space of test functions contains only analytic functions. It turns out that in nonlocal theory the Wightman functions have also a certain holomorphity domain which contains the Jost points. This makes it possible to prove theorems on CPT invariance, relationship between the spin and statistics, existence of asymptotic states and, consequently, the S-matrix.

In the report by D.I.Blokhintsev and G.I.Kolerov (Dubna) entitled "Perturbation Theory with Cut-Off" an algorithm allowing to construct successive approximations in the coupling constant has been described. The algorithm is based on the introduction of a form factor dependent on the total momentum of each unbound Feynman graph. The method ensures the fulfilment of macroscopic causality and unitarity of the scattering matrix.

N.N.Meiman (USSR) have shown that if the amplitude in nonlocal theory, in the complex plane S, increases not faster

than the exponent of the first order and in the physical domain it grows more slowly than any linear exponent then this amplitude $T(s) = exp\{-i\ell^2 s\} \cdot T_1(s)$ where the function $T_1(s)$ increases more slowly than any linear exponent in the upper half-plane.

G.V.Efimov and S.Z.Sel'zer (Dubna) have introduced a hypothesis in the theory of electromagnetic and weak interactions that the neutrino is a "carrier" of nonlocality which leads effectively in perturbation theory to the change of the neutrino free propagator. The obtained theory is renormalizable and gauge invariant.

E.Kapuscik (Poland) has attempted to apply the Jaffe's methods developed in the Hilbert space when proving the existence of the nontrivial theory $\lambda\varphi^4$ to unrenormalizable spinor theories.

Using simple models of field theory K.D.Nagy (Hungary) has considered the problem of unitarity in connection with the Lee and Wick suggestion to employ the indefinite metric in constructing electrodynamics free of ultraviolet divergences.

V.G.Kadyshevsky (Dubna) has told about the attempt to construct a quantum field theory starting from the geometric modification of the notion of relative momentum. The author starts from the hypothesis that the relative four-momenta in quantum field theory belong to the space of constant curvature which is realized on a five-dimensional hyperboloid :

$$\rho_0^2 - \rho_1^2 - \rho_2^2 - \rho_3^2 = -\frac{\hbar^2}{\ell^2}.$$

The parameter ℓ plays the role of the fundamental length. Letting it tend to zero we return to the usual theory. By the example of the Weightman functions the author shows that the formulation of the field theory in terms of the non-Euclidian relative momenta does not lead to a modification of the notion of total four-momentum and keep the law of conservation of this quantity valid.

In the report by H.P.Dürr (GFR) the problem of unitarity and macrocausality in quantum field theory with indefinite metric is discussed. It is shown that the introduction of "spurious states" with complex mass and certain rules of subtraction conserves unitary and macroscopic causality.

In the report by B.V.Medvedev , V.P.Pavlov and A.D.Sukhanov (USSR) it is shown that, contrary to the traditional point of view, there is no direct correlation between the properties of hermiticity and locality of the interaction Lagrangian, on the one hand, and the properties of unitarity and causality of the scattering matrix , on the other hand. It is demonstrated by a number of concrete models of field theory that the right scattering matrix is ensured by the nonlocal or non-Hermitian Lagrangian. Such anomalies are also present in nonrenormalizable theories at the expense of counterterms with derivatives or the derivatives in the bare Lagrangian.

The next important subject of the Symposium - Essentially Nonlinear and Nonrenormalizable Interaction - was opened by a review talk of M.K.Volkov (Dubna). He has reviewed the methods of quantum field theory with rapidly increasing spectral functions. Such kind of theories comprises, for example, neutral pseudo-

scalar theory with pseudoscalar coupling of scalar and spinor fields, parity nonconserving weak interaction or a neutral vector meson with spinor field, weak four-fermion interaotion, theories with chiral symmetric Lagrangians and so on. In such theories, in constructing the matrix elements, one uses instead of the ordinary propagator, a certain generalized two-point Green function taking into account the possibility of producing an arbitrary number of particles in each vertex. It may be called the superpropagator. In constructing this superpropagator one encounters difficulties of two kinds. The first difficulty is due to the appearance of ultraviolet divergences in the transition to momentum space, since the function contains poles of any order on the light cone and in localized interactions there is even an essential singularity.

The other difficulty is a characteristic feature of nonlocalizable interactions and consists in that the infinite series in the powers of the free particle propagators in terms of which the superpropagator is expressed in the x-space does not converge and is an asymptotic series.

The main requirements which should be satisfied in solving these problems consists in that the S-matrix of a final version of the theory should be finite and unitary. The theories describing localizable interactions must satisfy microcausality conditions and the theories describing nonlocalizable interactions - macrocausality conditions.

All the methods of constructing superpropagators may be divided into four groups :

I. Definition of the superpropagator in the x-space (G.V.Efimov, E.S.Fradkin, B.V.Lee, B.Zumino).

2. Definition of the superpropagator in the (M.K.Volkov, W.Guttinger, A.Salam, H.Lehmann and K.Pohlmeyer).

3. Definition of the superpropagator by solving the appropriate equations (G.Fainberg and A.Pais, B.A.Arbusov and A.T. Filippov).

4. Definition of superpropagators by introducing nonlocal form factors (G.V.Efimov).

The report by A.T.Filippov(Dubna)-"Highest Approximations in Unrenormalizable Field Theories" is a brief review of the methods of summation of the Feynmann graphs used for calculating the highest approximations in unrenormalizable field theories. As a model the author considers the renormalization theory for scattering on a singular potential. The results of this investigation are extended to the field theory in the framework of the two methods : I. summation of "ladder" diagrams, 2. method based on particle symmetries of a gauge type and the equivalence theorems. In both cases one succeeds in obtaining linear integral equations for the Green functions which in the Euclidian momentum space are reduced to linear differential equations with definite boundary conditions. In unrenormalizable theories the solutions of these equations have a branch point in the coupling constant g for $g=0$ and an essential singularity in the momentum at infinity which explains the complete invalidity of the usual perturbation theory.

We note that the methods based on particle symmetries

lead to the same results as the Okubo, Efimov, Fradkin and Volkov 's methods. In particular, the definitions of the superpropagators (i.e. expressions like $exp\{\lambda \Delta_F(x)\}$ etc.) coincide.

In the report by H.Lehmann and K. Pohlmeyer (GFR) a propagator with exponential coupling in the field theory model (the so-called superpropagator) is discussed. They have given some physical arguments in support of the choice of the propagator in the form proposed by M.K.Volkov et al. They have required for the propagator to be maximum regular and proved that with such a choice of the superpropagator the dynamics of the model has the most simple structure.

D.I.Blokhintsev (Dubna) in his report "On Quantization of an Essentially Nonlinear Field" considers the problem of quantization of a field obeying the equation with characteristics which depend on the field itself and its derivatives. First, he considers the quantization of such a system with one degree of freedom. Then, a method of quantization of an essentially nonlinear field of the Born-Infeld type is described. The method is based on the introduction of the notion "effective Plank constant".

In the talk of A.V.Efremov (Dubna) an example of the interaction of a π meson field with a δ-shape potential has been considered. This model is an exactly soluble version of nonrenormalizable theory. It illustrates one of the particular features of nonrenormalizable theories : the decrease of the total scattering amplitude in spite of its increase in each perturbation order.

J.Rayski (Poland) has discussed the appearance of effects, like nonlocality, due to the introduction of nonlinear Lagrangians $\mathcal{L}' = \frac{1}{a} arctg\, a\mathcal{L}$, where $\mathcal{L}$ is the ordinary total Lagrangian of the field under consideration.

In the talk by F.Kashluhn and E.Wieczorek (GDR) the singularities of the Wightman function have been studied for different asymptotic behavior of spectral functions. In the case of increase of the spectral function of the type $\sigma(q^2) = exp\{\alpha q^2\}$ the Borel method's of summation were applied.

M.A.Braun (USSR) has indicated a number of difficulties in nonpolynomial quantum field theory, but unfortunately has not suggested any method of overcoming them.

The next section of the Symposium - "Physical Symmetries in Quantum Field Theory" was opened by a review talk of D.V. Volkov (USSR) entitled "Geometrical Approach to the Method of Phenomenologic Langrangians". This is connected with the idea about dynamic symmetry in systems with Goldstone particles. The presence of Goldstone particles in any system is qualitatively interpreted as a reaction of the system to reconstruct the symmetry violated due to vacuum degeneracy. The Goldstone particles reconstruct the symmetry of the system. The transformation properties are determined by means of nonlinear transformations which corresponds to the transition to a symmetry of the dynamic type.

In the method of phenomenological Lagrangians, to the Goldstone particle fields there correspond the coordinates of a certain homogeneous with respect to a group G space. Then some relations are established which are sufficient for determining

the G-group invariants and constructing on the basis of them simple matrix elements.

In the report by L.D.Faddeev (USSR) " Geometrical Meaning of Nonlinear Symmetry" the author gives an interpretation of nonlinear fields of the Weinberg or Sugavara type as functions assuming values in a nonlinear interval (say, isotopic) space. The simplest example of such a space is given by an orthogonal O_3 group. Transformations of the left and right shifts generate appropriate currents and thereby realize the natural representation of the chiral group. It is stressed that explicitly covariant coordinate-independent methods are convenient since all the physical quantities are independent of parametrization of the internal space.

A.A.Slavnov and L.D.Faddeev (USSR) have suggested an invariant method of quantization of the Sugavara model. They have obtained an expression for the S-matrix explicitly independent of parametrization. Contrary to the usual scheme, the Feynmann rules contain only a finite number of vertices.

The talk by A.A.Slavnov (USSR) " The Yang-Mills fields" is devoted to the gauge fields with arbitrary mass. A general expression is obtained for the S-matrix of the gauge field in the form of the Feynmann integral. At zero mass this expression coincides with the Faddeev and Popov' s results. The case of nonzero mass is discussed in detail. It is shown that the S-matrix of the massive theory at zero mass does not transform to the S-matrix of massless theory. To obtain a right limiting value it is necessary in addition to subtract the oontribution of zero-mass scalar particles corresponding to longitudinally polarized quanta. The problem of field renormalizability is discussed.

The report by A.M.Vainshtein and I.B.Khriplovitch (USSR) " On the Problem of Transition to the limit of zero mass and nonrenormalizability in the theory of the massive Yang-Mills field " was devoted to the theory of the Yang-Mills field. It is shown that in perturbation theory there is no transition to the limit of zero mass which is in agreement with the results by Slavnov and Faddeev and Boulware. The explicit calculation of the diagrams in higher orders shows the presence of singularities in mass. The problem of field renormalizability and the possibility of the transition to the limit in mass outside the framework of perturbation thec ry are discussed.

E.A.Tagirov (Dubna) has given a report "Conformal-Covariant Interactions ". In the framework of the general theory of relativity the author formulates and discuss the condition of an approximate conformal covariant of equation of motion. It is established that the conformal-covariant interactions of fields with spin 0, I/2, I coincide with minimum interactions in the transition to the plane space. Thus, it is found that the requirements for the coupling constants to be gauge invariant and dimensionless which underly modern theory of elementary particle symmetry, follow themselves from a geometrical principle tightly connected with the general theory of relativity.

J.T.Lopuszanski (Poland) in "Some Remarks on Physical Symmetries " has reported on physical symmetries of the system of n scalar real fields. A number of generalizations of the formalism due to weakenning of certain generally accepted axioms has been found.

H.P.Dürr (GFR) has spoken about "Local Symmetries in Spinor Theories.". The author has shown that there exist formulations of spinor fields with four-fermion interaction invariant with respect to local symmetry groups without introducing additional fields.

In the report by C.Guerghe and E.Mihul (Romania) "Causal Extensions of Poincaré Group " the authors discuss a possible mixing between the orthochronous Poincaré group with internal symmetry groups imbedded in the causal extentions of space-time group with respect to Zeeman's causality. A theorem refering to their structure is deduced and some current algebras are obtained.

A series of reports has been devoted to functional methods. In the report by B.M.Barbashov (Dubna) the application of functional methods to the study of the infrared and high-energy asymptotics in quantum theory has been considered. In the framework of the functional integration method the author has developed a method of approximating integrals which allows one to obtain in particular the eikonal representation of the scattering amplitude for high-energy particles and to take into account the effect of radiation corrections. In the report recent achievements in the field of the functional integration method have been reviewed.

O.I.Zavialov (USSR) has investigated the problem of proving the standard scheme of the Feynmann quantization in the framework of a continuum integral in the relativistic case of an infinite number of degrees of freedom.

In the report by J.Rzewuski (Poland) the Hilbert space of entire functionals which are often used in quantum field theory and quantum mechanics has been studied. Mathematical estimates of the analyticity domain and the asymptotic behavior of formal power series of generalized functionals and their functional derivatives are presented. Some applications of these estimates to the operators in quantum field theory are considered.

An interest has been excited by the talk of G.I.Fomin (USSR) " On the Character of Divergences in Quantum Electrodynamics outside Perturbation Theory ". The author has paid attention to the fact that when one goes beyond the framework of perturbation theory, at least partially, the situation with divergences essentially changes compared to a similar situation in usual perturbation theory in electrodynamics which, as is known, leads to these logarithmically divergent quantities δm, $Z_1 = Z_2$ and Z_3. If outside the usual perturbation theory one restricts oneself to, say, "three Γ " or " five Γ " approximations, the self-energy of the electron turns out to be linearly divergent while Z_2 and Z_3 become finite. Under a certain assuption these conclusions are also valid in taking into account highest approximations. Such an approach does not lead to vanishing of renormalized charge and unphysical pole of the photon Green functions.

M.K.Polivanov, B.M.Medvedev and A.D.Sukharnov (USSR) have discussed the connection between different formulations of the causality condition. In the framework of dispersion ap-

proach a "current" extension of the S-matrix off the energy shell has been considered. The correspondance between the causality conditions of Bogolubov and Lehmann-Simanzik-Zimmermann has been established.

A.Visconti (France) has told about the work performed in the Centre National des Recherches Scientifiques, in Marseille, concerning the application of computers in calculating radiation corrections in scalar theories and quantum electrodynamics and in solving integral nonlinear equations.

L.B.Prokhorov (USSR) in his report "Unitarity and Massless Particle Interactions" has studied conditions imposed by the unitary relation on the mode of interaction of zero-mass particles and has attempted to classify different theories from the point of view of unitarity conditions.

A.Uhlman (GDR) has told about some interesting properties of the representation of the algebra of C* new mathematical formalism which is being extensively used in physics for describing systems with infinite number of degrees of freedom.

Yu.M.Lomsadze and S.P.Sabad (USSR) has devoted their report to the study of the restrictions on the amplitude following from principle of microcausality and to the proof of the asymptotic relations of the type of the Pomeranchuk theorem.

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