

NUCLEAR RESEARCH AT THE INSTITUTE OF PHYSICS OF AZERBAIJAN NATIONAL ACADEMY OF SCIENCES

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In the field of elementary particles and nuclear physics the research of a number of theoretical and experimental problems is being carried out. Theoretical research by axiomatic, symmetric and field theoretical methods in elementary particles and nuclear physics have obtained wider development. Theorists study the problems of electroweak interaction, investigate relativistic composite models in the framework of a finite-difference version of relativistic quantum mechanics and phenomenological aspects of subquark models, develop a description of fundamental interactions in the axiomatic quantum field theory and investigate non-perturbative methods in gauge field theory.

Using field theoretical methods, a relativistic covariant Hamiltonian quantum field theory on the light cone (on the light-front planes) for fields with arbitrary spin was developed. This Hamiltonian theory allows one to formulate conditions of unitarity and causality for the S matrix in the light-front variables. Its equivalence to the four-dimensional Feynman-Dyson formalism automatically follows from the definition. On the basis of Hamiltonian theory on the light cone, a general formalism for the description of deep-inelastic lepton-hadron scattering was developed.

The research connected to the construction of a scheme in the field theory, based on the hypothesis for the existence of a fundamental length is also being carried out. In this theory the momentum representation is considered in a 4-dimensional space of constant curvature, and all axioms of quantum field theory are fulfilled.

Within the quasi-potential approach to quantum field theory, a version of relativistic quantum mechanics, in many respects similar to the non-relativistic quantum mechanics was developed. Its main difference from conventional quantum mechanics is that the wave functions in it satisfy the finite-difference equations. The various exactly soluble finite-difference models for some important applications of dynamic quantum systems (linear and three-dimensional harmonic oscillators, hydrogen atoms etc.) were investigated. The wave functions, energy spectra and dynamic symmetry were determined; the coherent states and Wigner distribution functions for the stationary states and the states of thermodynamic equilibrium were constructed.

An appropriate finite-difference generalization of the factorization method was proposed. As an application of this method a model q -harmonic oscillators were constructed and investigated.

Valuable results were obtained in the study of the properties of the system of classical q -orthogonal polynomials, from one-parametrical q -Hermite polynomials up to five-parametrical Askey-Wilson polynomials. In particular, it was shown that orthogonality measures corresponding to these polynomials and including one of the theta functions $\theta_i(z, q)$ ($i = 1, 2, 3, 4$) can be replaced by quadratically decreasing exponential functions

of Ramanujan type measures. The Ramanujan type measures thus obtained admit the transformation $q \rightarrow q^{-1}$.

The theory of invariant representations of $SO(p, q)$ group was obtained. A method of construction of the theory of Wigner coefficients of $SO(p, q)$ group was offered. On the basis of this method the obvious expressions of Wigner coefficients of three- and four-dimensional Lorentz and De-Sitter groups were calculated.

Research related to the possible description of lepton and lepton-hadron interactions within the framework of the weak and electromagnetic interaction theories with spontaneously broken of $SU(2) \times U(1)$ gauge symmetry were carried out. The questions of acceptance of different $SU(2) \times U(1)$ models were investigated. Several methods for introducing heavy leptons were also considered. Three new versions of $SU(2) \times U(1)$ models of leptons, representing various versions of extensions to the Weinberg-Salam model to include heavy leptons, were offered and investigated.

It was shown that, in the case of a non-zero neutrino mass, which has the character of spontaneous symmetry breaking, the offered models contain new scalar lepton interactions independent of neutrino mass (in relation to the appropriate models with two types neutrinos). The detection of effects caused by these interactions can serve as a key for the solution of the problem of choosing the true lepton model. For example, within the framework of the Weinberg-Salam model these effects could be noticed in reactions where neutrinos and muons participate. Thus the opportunities for the description of heavy leptons in the frameworks of $SU(2) \times U(1)$ theories were investigated.

The processes $\nu_\mu e \rightarrow e \nu_\mu \gamma$, $\nu_e e \rightarrow e \nu_e \gamma$, $\bar{\nu}_\mu e \rightarrow e \bar{\nu}_\mu \gamma$, $\bar{\nu}_e e \rightarrow e \bar{\nu}_e \gamma$ of radiative scattering of neutrino and antineutrino on electron were investigated. Registration of the emitted photons can be used to identify these processes. The process of neutrino production from electron-positron pair annihilation was investigated: i.e. $e^+ e^- \rightarrow \nu_\mu \bar{\nu}_\mu \gamma$, $e^+ e^- \rightarrow \nu_e \bar{\nu}_e \gamma$. Observation of these processes in colliding electron-positron beams would open a unique opportunity for the study of neutrino-electron interactions over a wide range of energies. The processes $\gamma e \rightarrow e \nu_\mu \bar{\nu}_\mu$, $\gamma e \rightarrow e \nu_e \bar{\nu}_e$ of the photoproduction of neutrino-antineutrino pairs on electrons were investigated. These processes can give valuable information about the nature of the weak interaction. Their study within the framework of different models is also of interest because they, alongside with neutrino production from electron-positron pair annihilation and plasma neutrinos, are considered one of the basic sources of neutrino radiation in stars.

Research on nucleon-nuclei scattering to explore the contribution of back-orbital interaction and the nuclear potential were also carried out. The results of the study on polarized effects in odd nuclei allow one to construct models describing the properties of collective nuclear states. It was shown that, the spin interactions in even deformed nuclei generate a new collective branch of monopole excitations, and are responsible for the formation of observables in experiments on magnetic dipole and Gamov-Teller resonances.

There was also systematic research into $\pi^- C^{12}$ interactions. The data collected includes information about average multiplicities of distribution on a pulse, angle of departure, the Feynman variable and rapidity, azimuthally and two-particle correlations for $\pi^- C^{12}$ and $\pi^- N$ interactions.

The following theoretical and experimental problems in nuclear research are being investigated:

1. Theoretical studies:

- A version of relativistic quantum mechanics wherein a finite-difference Schrödinger-type equation is used to describe the composite models and scattering processes of elementary particles;
- Properties of quantum systems with the help of an algebraic approach based on the dynamical symmetry of systems;
- Dynamics of quantum systems in the Wigner representation;
- Exactly solvable difference models of quantum systems;
- The properties of classical orthogonal and q -orthogonal polynomials;
- Problems of the Standard Model;
- Problems of Higgs particles;
- Construction and investigation of SUSY models;
- Investigation of the different measurable characteristics of the processes (such as polarization effects, asymmetry, etc.) in the framework of Standard and SUSY models.

2. The experimental studies are primarily focused on the investigation of the following problems:

a) ATLAS collaboration (LHC, CERN):

Detector performance and physics performance studies, such as:

- Jet reconstruction;
- Absolute jet scale calibration;
- Luminosity measurements;
- Simulation and reconstruction software development;
- Physics simulations of various processes in pp-collisions at LHC, including:
- SM single Top quark production;
- SUSY Top quark decay;
- Excited quark and lepton production;
- Compositeness and contact interactions of quarks;
- Trigger DAQ system studies;
- Liquid Argon Calorimeter and Transition Radiation Tracker test-beam run participation and data analyses.

b) ALEPH collaboration (CERN):

- A study of electron-positron collision at LEP;
- Charm production in photon-photon collisions;
- Investigation of muon bundles in cosmic rays using the ALEPH detector.

c) ALICE collaboration (LHC, CERN):

- Investigation of different characteristics of secondary particles depending on the centrality degree of collisions.

d) WA98 collaboration.

- Study of 158 GeV/A Pb-Pb collisions at CERN SPS.
- e) Particle Physics Division's Experimental Physics Projects (FNAL);
- f) Muon Collider / Neutrino Factory research and development, especially in the area of detector simulations.

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