PONTIFICIA
ACADEMIA
SCIENTIARVM

COMMENTARII

Vol. I N. 11

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EX AEDIBVS ACADEMICIS IN CIVITATE VATICANA

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Vol. I - N. 11
pag. 1-4

THE NATURE OF THE ELEMENTARY PARTICLES

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SVMMARIVM — Quae nunc de primariis particulis novimus comparantur cum generalibus ideis ab EINSTEIN paucis ante decenniis expositis in eius hypothesi de theoria campi unificati.

When the constituents of atoms and atomic nuclei, protons, neutrons and electrons were called « elementary » particles, this term 'elementary' was meant to say that such particles are the fundamental building stones of matter, not composed of any other smaller units; and frequently the elementary particles were thought of as immutable, fixed units of matter very much like the atoms of the philosophy of DEMOCRITUS. Recent research during the last two decades has however shown that this picture of the elementary particles is not correct. The elementary particles can be transmuted into each other. In high energy collisions between any two of these particles any kind and any number of new particles may be created, the processes being restricted only by the well known laws of conservation, e.g. conservation of energy, momentum, charge, isospin etc.

Therefore the nature of the elementary particles is described better by saying that they all consist of the same substance:

Communication presented of October 4, 1962 during the Plenary Session of the Pontifical Academy of Sciences.

'energy' or 'matter', and that they are just different forms of matter. Energy becomes matter by assuming the form of an elementary particle. The different elementary particles may therefore be compared with the different stationary states of an atomic system e.g. the iron atom. These 'stationary' states are distinguished mainly by their energy and by their mean lifetime. The lowest state or normal state of an atom is stable, excited states may sometimes have a very long mean life and are then called metastable, most states of higher energy have a rather short life and decay usually by emission of a photon. In a similar manner the elementary particles are different in mass and in lifetime. Very few elementary particles are stable, like proton or electron; others have a rather long lifetime like neutron or μ-meson; and in fact most of those particles that had been known already a few years ago have lifetimes which are much longer than the 'normal' lifetime of 10^{-22} to 10^{-24} sec and may therefore be called metastable. Very many particles or 'excited states' or 'resonance states' however have short lifetimes below 10^{-22} sec. These particles of short lifetime have only recently been shown to exist; but the experiments carried out by means of the big accelerators leave no doubt, that the number of short lived resonance states is actually very large.

The different stationary states of an atom may be considered as the consequence of and can be determined by a natural law which mathematically may be expressed by the Schrödinger equation of quantum mechanics or by a simple non linear field equation, first given by KLEIN, JORDAN and WIGNER. In a similar way the different stationary states of 'matter', the elementary particles, should be the consequence of a fundamental natural law, and the mathematical form of this law is one of the important problems of contemporary theoretical physics.

Quite aside from the special mathematical form of this law its very existence opens up some interesting aspects concerning the relations between different parts of physics. Already several decades ago EINSTEIN had emphasized the necessity of understanding the connections between different fields of force like electromagnetic fields and gravitational forces. He had tried to find a common root for these fields in the fourdimensional geometry of the world, and to form a « unified field theory' as a general framework into which the different special disciplines of physics had to be fitted. The present situation suggests that the natural law from which the different elementary particles follow will some day play the rôle of this 'unified field theory', even if it cannot simply be connected with the fourdimensional geometry. Because every elementary particle is just the quantum theoretical counterpart of a corresponding field, and a law which determines all elementary particles will automatically also determine all possible fields. In this sense one may say that EINSTEIN's idea of a 'unified field theory of matter' is already borne out by the existing experimental evidence on the transmutations of elementary particles.

The mathematical form of this natural law describing the elementary particles should primarily represent the symmetry groups responsible for the observed conservation laws and the relativistic 'causality'. Both seem to be contained in the non linear spinor field equation

$$\gamma_\mu \frac{\partial\psi}{\partial x_\mu} \pm l^2 \gamma_\mu \gamma_5 \psi (\bar{\psi}\gamma_\mu \gamma_5 \psi) = 0$$

which may already be a sufficient general frame. It should then be supplemented by commutation relations, boundary conditions and by assumptions about the ground state to form a basis for the theory. Whether such a mathematical formulation in terms of quantum field theory is possible remains to be seen. The application of rough approximation methods to this scheme has led to reasonable agreement with regard to the mass-ratio between π-meson and nucleon and to a correct prediction of the η-meson. But it may also be that more abstract mathematical formalisms are needed to describe the connections between the different particles and fields.

Even if the non linear spinor equation mentioned above is a sufficient frame for the theory of elementary particles, it will probably not be possible to interpret it on the axiomatic basis of conventional quantum theory. Two main changes will be necessary: The local interaction and the relativistic causality in collision processes seem to require the use of an indefinite metric in the Hilbert space representing the state of a system, while in conventional quantum theory a definite metric is sufficient. The existence of conservation laws which are only approximately valid — conservation of isospin is violated in electromagnetic interactions, conservation of parity in weak (radio-active) interactions — suggest the assumption that the ground state 'vacuum' or 'world' should not be symmetrical under the corresponding transformations, it should be degenerate. This assumption could at the same time explain the existence of the so called 'strange particles'. But more experimental work will be needed to see, whether all the details of this part of the particle spectrum can be explained by such a hypothesis.

It was however not the purpose of the present remarks to go into the details of elementary particle physics. The intention was only to emphasize that our present knowledge of these particles agrees very well with the general ideas expressed earlier in EINSTEIN's attempt of a 'unified field theory'.

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