IN SEARCH OF AN "IRRATIONAL" IDEA

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OF all branches of physics the investigations of elementary particles are seemingly least related to the present-day practical activities of mankind. The importance of investigating the basic laws governing the structure of all moving matter is clear to a comparatively small group of people and its future practical significance appears so far only in its general and vague outlines. It would seem that with this state of affairs elementary particle physics could develop successfully only if no large material expenditure were required for its experimental study. However, as is generally known, it is precisely this most abstract field of physics, in contrast to mathematics, for example, which cannot develop only through the enthusiasm of a handful of people with an extremely well-developed curiosity, without material expenditure for experimental investigation. The investigation of the fundamental laws of the microworld is impossible without constructing enormous facilities for accelerating particles to ever increasing energies, and with the construction of complex apparatus for observing high-energy particle collisions which contain valuable information about deeply hidden properties of matter. It is precisely for this reason that elementary-particle physics is at present identified with high-energy physics, further progress in which is unthinkable without constant renewal of all its expensive experimental basis. Even disregarding this organic necessity for ever increasing expenditure, we cannot at present say that the development of elementary particle physics is held back by limitations on the funds spent on it. On the contrary, the rapid growth of high-energy physics during the course of the past two decades was a direct result of large expenditure, growing from year to year, in such countries as the United States, the Soviet Union, England, France and Italy, for the building of research centers and laboratories equipped with proton and electron accelerators.

The scope of investigation, unprecedented in the history of the development of human knowledge, undertaken in this fundamental branch of science which is as yet not directly related to practical matters exceeds in its cost the total past expenditure during centuries for such fundamental sciences as astronomy and mathematics. Our descendants will have no difficulty in explaining the present turn of events. They will, undoubtedly, see in the rapid development of modern elementary-particle physics, which requires this enormous expenditure, an irrefutable proof of our profound understanding of the importance of the development of this fundamental branch of science, and its colossal significance in the life of future generations. Among our contemporaries themselves, there is unfortunately no such clear explanation of the rapid development of elementary particle physics. L. A. Artsimovich, for example, expressed the opinion that the privileged position of nuclear physics with its enormously important role in the life of society has also extended through inertia to elementary-particle physics.[1] But if this were so, then we would be dealing with a rather strange inertia, increasing in time, because the expenditures for this branch of physics increase each year in all the larger countries of the world. We are, rather, dealing with the fact that the historical example of nuclear physics has rightly convinced many that physicists should and successfully can be granted resources on credit.

A fairly important role in accelerating the pace of development of high-energy physics has been assumed by the peculiar competition which prevails between the various countries in their national contribution to the construction of new experimental facilities for this branch of science. Physicists all over the world now await with impatience the next contributions of the two leading states: the completion of the construction of the 70-GeV proton accelerator in the U.S.S.R. and a 40-GeV electron accelerator in the U.S.A. True, when such competition becomes a purpose in itself it may lead to curious incidents, like the construction of a costly accelerator for whose utilization nobody bothered to build a specially equipped essential-apparatus laboratory.

Of course, the construction of an accelerator in itself is not, just as the experimental investigations in the field of elementary particle physics are not, the ultimate goal. Only subsequent theoretical investigations of all the accumulated experimental material in which the essence of the unusual laws of the microworld will be discovered and the establishment of their rigorous mathematical description can justify all the previous expenditure. In their understanding of the basic and final goals of this branch of science, physicists indeed do not differ seriously. All are united in their opinion that the establishment of the laws of the world of elementary particles will be connected with a revolutionary and radical break with fundamental present-day physical conceptions. The general belief in such a final outcome of these investigations is based on the historical experience of the development of physics which exhibits the general rules of cognition of moving matter. With each penetration into a new field of physical investigations, the scientists become convinced that a radical reorganization of the whole system of conceptions about the physical world is essential. In doing this, not only are theories constructed based on the new physical principles in the fields of the corresponding phenomena, but a considerable reevaluation takes place of all previous theoretical constructions in other fields of physics investigated long ago. This happened in studying phenomena in fast-moving systems, where the solution of the problem was completed by the creation of the theory of relativity, which changed radically our physical conceptions of space and time. The investigations of the atomic world resulted in an even greater break with previous physical views.

On the other hand, these radical changes in the field of seemingly completely abstract theoretical constructions each time exerted a fertile influence on other sciences and introduced fundamental changes into the entire activity of human society. As far as elementary particle physics is concerned, although the basic theoretical problem confronting it is far from solved, it has in the initial stage of its development as nuclear physics already given rise to nuclear energetics and a whole isotope industry. For this very reason, there can be no doubt of the enormous practical value of the revolutionary transformations of present-day physical conceptions expected from the physics of elementary particles. In this aspect lies the difference between it and astronomy, which has as yet not found it possible to prove so manifestly the connection between practice and the solution of the grandiose and fascinating astronomical problems of the birth of the universe.

The radical reorganization of fundamental physical conceptions expected of elementary particle physics will occur on the basis of ideas and principles which from the point of view of present-day preconceived conceptions cannot but seem "irrational." Niels Bohr therefore advanced the seeming "irrationality" of a theoretical construction as a criterion according to which we can separate the expected radical solution of the most difficult problems posed by elementary-particle physics. However paradoxical it may be, the basic problem of present-day physics consists in just such a search of an "irrational" idea. The criterion of "irrationality" can unfortunately be used only unilaterally for excluding from consideration insufficiently "irrational" theoretical constructions in the field of elementary particle physics. The editors of physics journals who have much practice in selecting sufficiently "rational" papers do not resort to a utilization of this criterion, apparently in order not to create among their readers the impression that there is actually no search of the essential "irrational" idea.

It is difficult to underestimate the problematic nature of the theoretical generalization of the accumulated extensive experimental material in high-energy physics. The search for the "irrational" idea is carried out in the most varied directions.

By investigating the interactions of elementary particles at high energies, present-day physics obtains most important data on the fundamental properties of matter, including the properties of space and time in the region of ultra-small dimensions. With increasing energy of the electron and proton accelerators there appear experimental possibilities of penetrating deep into matter, into regions of ever decreasing spatial dimensions of elementary particles. In this way, physicists hope to obtain that useful information which will help to remove the difficulties of principle in the theoretical description of various fundamental interactions of elementary particles. In particular, great hopes are entertained of obtaining information on the necessity of reconsidering the space-time metric in connection with the existence of a fundamental unit of length and time, quanta of space and time.

In this connection it must be noted that such changes in the metric in the range of small dimensions can occur only as a result of a general interaction to which all elementary particles are subject. Of the known interactions, only the weak interaction can claim such generality, and this means that deviations from the usual metric should be expected at distances of the order of a few units of 10^{-17} cm characteristic for the weak interaction of elementary particles. Any features in the range of larger dimensions can appear only as properties of a given, not general, interaction of elementary particles, for example of only the electromagnetic or nuclear (strong) interaction. Such features cannot from their very definition be reduced to the properties of the space-time metric.

It should be understood that a single analysis of the experimental facts may turn out to be by far insufficient in order to decide specifically which of the existing theoretical ideas should be radically reconstructed. This also requires a profound understanding of the very essence of the theoretical formalism used in present-day physics to describe physical phenomena. There could have been no question of the reorganization of classical mechanics at the beginning of the century if, for example, the motion of an engine were described and explained in this theory only from the point of view of the operations carried out by the engine driver. Therefore, one of the most important problems confronting the physicists of our generation is the further development of the understanding of the existing physical theories. Even from the example of the special theory of relativity (by the way, the simplest of the theories fundamental for contemporary physical views) one can see the possibility of a considerable deepening of its understanding by clarifying some of the formally accepted assumptions.

A single physical theory can be expounded in different representations, differing in their mathematical and physical form. A search for these possible supplementing constructions of the theory can be of significant value for developing an understanding of the essence of a given theory, and promote thereby the necessary reconstruction of contemporary physical views. The well-known American theoretical physicist R. Feynman, proposing a new, original formulation of quantum mechanics, wrote: "There is always a hope that a new point of view will prompt us how precisely we should alter the existing theory (the necessity of this alteration being dictated by present-day experiment)."[2] A similar thought is expressed by another well-known American theoretician, F. Dyson: "It is quite possible that we should not approach a new theory before we have clearly understood the mathematical nature of the old ones."[3] Unfortunately, however, views of this nature are not widely held, and contemporary physicists are more likely not to understand the fact that with the appearance of a new theory, which has gained the right of independently describing a given range of phenomena, the actual interpretation of the physical theory only begins; the full completion of this interpretation is only possible after the clarification of the limits of its applicability, based on the creation of an even more complete physical theory.

In addition to the objective difficulties of the search for the necessary radical reorganization of contemporary physical conceptions, elementary particle physics is confronted with the serious problem of the timely recognition of the "irrational" idea on which enormous means are now expended. The criterion of "irrationality" turns out to be useless in practice in selecting the correct radical solution of the problem from the innumerable number of really irrational theoretical constructions resulting from a lack of understanding of contemporary physical theories. The fact that the author is unknown should naturally not be a reason for not treating seriously work claiming to be a fundamentally new approach to the problem. A little-known scientist or again, as was the case with Einstein, an engineer of a patent bureau, who has much spare time for thinking over the results obtained in high-energy physics, may arrive at a radical idea for the solution of the problem. The full difficulty of the problem of recognition of the necessary "irrational" idea can be better grasped if one also takes into account Dyson's opinion that "a great discovery at the moment when it appears is almost certain to emerge in a confused, incomplete, and disjointed form. The discoverer himself half understands it, for all others it is a complete mystery"[3] (see p. 96). Obviously, the recognition of such a discovery can only be hoped for after it has been published, so that numerous scientists can acquaint themselves in detail with the new ideas advanced. It is for this reason, that the fate of this decisive stage of elementary particle physics depends to a large extent on the work of the editors of physics journals. In the same article Dyson remarks that the editors of the "Physical Review" have accepted the rule to print papers which are unintelligible. This measure decreases, of course, the probability of rejection of the "irrational idea" awaited by all, but by far does not exclude this. The point is that a work which overthrows the preconceived concepts of the presently prevailing basis has a good chance of being intelligible to us in its "irrational" encroachment. My own experience afforded me the opportunity to convince myself of the serious difficulties of this type in an attempt to overcome the old error implicit in our notions on the uniqueness of the experimental determination of the isotropic propagation velocities in the space of physical processes, and the establishment on this basis of the trivial truth concerning the identity of the relativity of the isotropy of the propagation velocities of physical processes with the generally known relativity of the concept of simultaneity.[4]

Numerous examples from the history of science speak of the conservatism of human thought and man's amazingly strong reluctance to part with old notions. The enormous means spent at present for a search of new physical concepts to explain the puzzling phenomena of the world of elementary particles are sufficient for evincing concern about the problem of the timely recognition of the expected "irrational" idea. It is essential to admit consciously to the physics journals, in addition to papers unintelligible to the editors, a small number of papers which were the object of negative comments.

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[1] L. A. Artsimovich, Vestnik AN SSSR 2, 3 (1965).

[2] R. Feynman, in coll. Voprosy prichinnosti v kvantovoĭ mekhanike (Problems of Causality in Quantum Mechanics), Moscow, IL, 1955, p. 168.

[3] F. J. Dyson, in coll. Nad chem dumayut fiziki (What Do Physicists Think About), issue 2, Elementary Particles, Moscow, Fizmatgiz, 1963, p. 103.

[4] A. A. Tyapkin, The Expression of General Properties of Physical Processes in the Relativistic Metric, Preprint OIYaI-766 (Joint Institute for Nuclear Research), 1961.

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