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Nobel Prize in Physics 1949

Hideki Yukawa

The Nobel Prize in Physics 1949 was awarded to Hideki Yukawa *"for his prediction of the existence of mesons on the basis of theoretical work on nuclear forces"*.

RESEARCH INFORMATION:

For many ages, an important aim of science has been to explain the phenomena we observe by the properties of fundamental particles. In modern physics this problem is of first importance. During the last decade, fundamental particles called "mesons" have turned out to be particularly interesting. The mesons are particles heavier than the electrons but lighter than the nuclei of the hydrogen atoms, i.e. the protons.

The mesons were entirely unknown until Hideki Yukawa in 1934 predicted their existence on the basis of a theoretical investigation of the nuclear forces. This is the achievement which has now been rewarded by the Nobel Prize in Physics.

From earlier research by Heisenberg and others one knew that an atomic nucleus, i.e. the central core of an atom, is composed of protons and of other particles which have the same mass as the protons but no charge. These building elements of the atomic nuclei are called "nucleons" and are held together by the so-called nuclear forces.

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Attacking the problem of the nature of the nuclear forces, Yukawa used the electromagnetic field as a model. He found that this field could be modified so as to give forces which like the nuclear forces have a short range. He therefore assumed that the new field corresponds to the nuclear forces. Each field of force is, according to modern theories, associated with some kind of particles. Yukawa discovered that there is a simple relation between the range of the forces and the mass of the corresponding particles. He estimated the range from known experimental data and found that the new particles should be about 200 times heavier than the electrons. The name of mesons for these particles was not introduced until later. According to Yukawa's theory, the nuclear forces can be traced back to an exchange of mesons between the nucleons. These are continually emitting and absorbing mesons.

Yukawa also studied the important question of whether the mesons can appear outside the nuclei. He found that the mesons can be created during the interaction of nucleons if these can deliver a sufficient amount of energy. Therefore, mesons cannot be created in ordinary nuclear reactions. Yukawa emphasized, however, that they can be expected to appear in the cosmic radiation, in which particles of great energy are found.

Yukawa assumed that mesons can have both positive and negative charge and that the magnitude of the charge is the same as that of the electron. A theory of Fermi, which had been proposed some years earlier, led Yukawa to the assumption, that a meson can be transformed into an electron and a light particle without charge called "neutrino". As was pointed out later, free mesons could therefore be supposed to exist only for a very short time, some millionth of a second or less.

As Yukawa had suggested, the study of the cosmic radiation gave the first experimental evidence of the existence of mesons. This evidence was given in 1937 by Anderson and Neddermeyer and other American physicists. Since that time, the mesons in the cosmic radiation have been very much studied. These investigations have been guided by the theory of Yukawa. A new period in meson research began about three years ago. The British physicist Powell and his collaborators then found that there exist two kinds of

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mesons. The mesons of one kind are those found in 1937, whereas the mesons of the other kind are somewhat heavier and different also in other respects. Mesons can now be produced in the large cyclotron in Berkeley, California. This has greatly increased the possibilities of studying them.

These experimental investigations have shown, that the masses of both kinds of mesons agree with Yukawa's prediction as far as the order of magnitude is concerned. The heavier mesons, but not the lighter ones, have an interaction with the nucleons about as strong as Yukawa had postulated. The fact that particles of this kind have been found experimentally provides a brilliant vindication of Yukawa's fundamental ideas. The electric charge of both kinds of mesons agree with Yukawa's prediction. It has also been experimentally confirmed, that the mesons can exist only for a very short time. A heavy meson lives only for about one hundredth of a millionth of a second and is then transformed into a light meson and probably a neutrino. The light meson disappears after a few millionths of a second, and electrons are then created and probably also neutrinos.

After experimental evidence of the existence of mesons had been given the interest in Yukawa's theory rose quickly. Much effort was expanded in developing the theory and investigating its consequences. In this work Yukawa and his Japanese collaborators took the lead. Among other things, they found theoretically that neutral mesons exist besides the charged ones.

It has not yet been possible to give a theory for the nuclear forces, which yields results that are in good quantitative agreement with the experiments. Yukawa's theory has, however, led to many important qualitative results about the nuclei. The theory has also proved to be of great value in cosmic-ray research. It was e.g. possible to understand, that mesons can be created in the upper layers of the atmosphere by the primary cosmic radiation falling on the earth.

The research on mesons will probably lead to new discoveries. The meson theory may develop into other forms. By having predicted the existence of the mesons and many of their essential properties Yukawa has accomplished pioneering research of utmost importance. His ideas have proved to be an enormous stimulus to the research in theoretical as well as experimental physics

Professor Hideki Yukawa. In 1934, when you were only 27 years old, you boldly predicted the existence of new particles, now called "mesons", which you anticipated to be of fundamental importance for the understanding of the forces acting in the atomic nucleus. Recent experiments have provided brilliant support for your essential ideas. These ideas have been exceedingly fruitful and are a guiding star in present-day theoretical and experimental work on atomic nuclei and on cosmic rays. You have also contributed much to other problems in basic theory and you have played a great role in bringing your country to its very high position in modern physical research.

On behalf of the Royal Swedish Academy of Sciences, I wish to congratulate you on your ingenious work, and I now ask you to receive your Nobel Prize from the hands of His Royal Highness the Crown Prince.

For more details please visit:

http://www.nobelprize.org/nobel_prizes/physics/laureates/1949/press.html