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The Birth of the Meson Theory*

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DURING the Symposium at the University of Michigan in the summer of 1948, the junior author had the good fortune to obtain a copy of Professor Hideki Yukawa's autobiographical sketch, a small booklet written in Japan in 1941. His name is inseparably associated with mesons and the meson theory of nuclear forces and his theoretical deductions concerning this particle in 1935 are one of the many brilliant chapters in the history of physics. The origin of the meson theory is of interest not only to those who are active in that field of research but also to those who are interested in the development of the ideas and concepts of modern physics. Because Professor Yukawa's writing is in Japanese, the writer has taken the liberty of making a free translation with the hope that English-reading physicists may have a clear appreciation of the development of the meson theory and obtain a glimpse of the life and personality of a man who gave a new idea to the world of physics. The author wishes to express his sincere appreciation to Professor H. Wergeland of the Technical Institute at Trondheim, Norway, without whose constant encouragement the translation would not have been completed.

Life in Kyoto

"I was born in Tokyo in 1907. The following year, my father, Takuji Ogawa, accepted a position at Kyoto University, and for the next twenty-odd years, until the spring of 1932, we lived in Kyoto. Although my father's field was geology and geography, he was a man of a great many interests, which included archeology, Chinese studies, art, swords, chess, etc. As a consequence, not only his study, but also the storage house and the living rooms of our home literally overflowed with books. Since we moved frequently, the ever-increasing number of books was a source of constant headache to the family. Being in this kind of atmosphere, I naturally grew up to like books and to read omnivorously. It is difficult to know exactly just what effect this kind of a home atmosphere had upon me, but probably it contributed a great deal to the fact that my life has been devoted mainly to reading, thinking, and writing.

"My father did not attempt to direct my interests. Consequently I had trouble in making up my mind about the subject to take up at the University. In the first application made out during my third year in junior college, I indicated geology as my preferred major. But when the time came to make my final decision, I suddenly changed my mind and wrote "physics" in the application blank.

"During my third year in the University, I again had a little trouble making up my mind. I finally decided to take up quantum theory and subsequently asked Dr. K. Tamaki, professor of theoretical physics, to guide my work. Professor Tamaki's principal interests then were in hydrodynamics and the theory of relativity and so perhaps he felt a little annoyed at my request. However, he gladly accepted. I studied in the pleasant atmosphere of his laboratory until 1933 when I went to the Osaka University. During this time, many were the books that I had to ask my parents to buy for me. I did not publish any results that I obtained during the four years there, but it turned out to be an extremely valuable preparatory period for my life to come in Osaka.

"When I was attending the University, it was only a short time after de Broglie and Schroedinger had published their works on wave mechanics and Heisenberg his paper on quantum mechanics. Consequently, in Japan there were

* From a chapter of Hideki Yukawa's *Me-ni-mie-nai-mono* (Of things that cannot be seen); title, introduction, and translation by Chihiro Kikuchi, Michigan State College, East Lansing, Michigan.

then no specialists in this field. So I read indiscriminately the papers on quantum mechanics as fast as they were published, although many were the times I could not understand what I was reading.

"Fortunately, just before and after graduating from the University, a number of European physicists were invited to come to Japan. First a student of Sommerfeld, Dr. Laporte, came to give a discourse on quantum dynamics for several days. Then Sommerfeld himself came to Kyoto University and gave lucid lectures on quantum mechanics. And a little later on, I had the opportunity to hear Heisenberg himself discuss the uncertainty principle and Dirac his relativistic theory of the electron. Also about this time, the Japanese physicists Arakatsu, Sugiura, and Nishina, who had returned from abroad, came to give a series of lectures. It is difficult to put into words how much I was stimulated and inspired by these lectures. I felt as if I had been entrusted with the task of nurturing the bud of new physics which they had planted in me.

Life in Osaka

"In 1932, I was adopted by Genyo Yukawa and subsequently moved to Osaka. My foster father had by then retired from a strenuous doctor's life because of a heart condition. In 1935, he passed away, knowing very little about the results of my work.

"In April of 1933, at the Sendai meeting of the Physico-Mathematical Society of Japan, I presented my first paper. The subject was, as I remember it, 'On the Theory of Nuclear Electrons.' The neutron had been discovered just a year before, and the theory that the nuclei consist of protons and neutrons was becoming better known. Those were the days before Fermi formulated the neutrino theory of beta-decay. Some people were doubting that quantum mechanics would be applicable to the nucleus, and others felt that perhaps energy was not conserved in nuclear transmutations.

"I was then trying to formulate mathematically Heisenberg's idea that the interaction between a neutron and a proton arises from the exchange of an electron. I introduced the hypothesis that the proton and neutron are the sources of the electron field. As a consequence, it was possible to obtain an expression that looked very much like nuclear forces. But I was unable to carry my idea further because the force range was too long and the electron would have to obey Fermi statistics. Dr. Nishina, who was present at the meeting, then suggested that it might be possible to postulate the existence of electrons satisfying Bose statistics. This was the first hint toward the meson theory. From that day on, Dr. Nishina took the most active part in encouraging my investigations.

"At this meeting, I was introduced to Dr. Yagi, the physics department head of Osaka University, and was subsequently invited to join his staff. This proved to be a valuable association because the physics laboratory at Osaka University had just been built and the laboratory was alive with young instructors. A Cockcroft high-voltage apparatus had just been completed. The following year Dr. S. Kikuchi was called from the Tokyo Institute of Physical and Chemical Research to direct the program on nuclear research.

"Surrounded by this active atmosphere, I was racking my brains trying to solve the difficulties that I mentioned before. In the meantime, Fermi published his theory of beta-decay. His theory differed from mine in that an electron-neutrino pair was used. In this way he was able to remove the statistics difficulty, but his theory, like mine, could not account for nuclear forces and beta-decay simultaneously.

"In the fall of 1934, when my second son was born, I became so engrossed in thinking about nuclear forces, that I began to find it difficult to fall asleep at nights. My mind would become clearer and clearer, and one idea after another would race through my mind. And so not to forget them, I kept a note pad at my bedside and jotted down the ideas as they came to me. But the next morning when I went over the notes, I had the strange experience of not being able to make sense of the ideas that seemed so clear to me the night before. Anyway, after repeated attempts of this kind, my ideas of the nuclear force field began to crystallize and so I was able in October to present my ideas at a seminar. I concluded that in this new field the rest mass of the new quanta should be about two hundred

times the electron mass and obey Bose statistics. At that time, Dr. Kikuchi[1] commented that the new quanta should carry electric charge, and therefore if such particles do exist, the particles should be observable in cloud chambers. However, because it would be difficult to create such particles in the laboratory, perhaps one should look for them in cosmic rays. But, at that time, very little was known about the nature of cosmic radiation.

"At the Tokyo meeting of the Physico-Mathematical Society of Japan, I presented my new theory, and in the following year, in February 1935, the paper was published in the Proceedings of the Society. I wish to thank my fellow physicists for showing their interest in my theory and particularly Drs. Nishina and Kikuchi for their encouragement, although it was difficult to accept the theory *in toto* without experimental evidence.

"The theory was thus constructed but experimental evidence was still lacking. The following year, in 1936, C. Anderson, the discoverer of the positron, reported having observed an unusual particle in a cosmic-ray cloud-chamber photograph of mass intermediate between that of the electron and of the proton. Upon reading this report, I immediately concluded that this must be the new particle I had been looking for. However, it now appears that the particle that Anderson observed was not an ordinary meson, because its mass appears to be much closer to the proton mass. The identity of that particle is still a puzzle. In the years 1937 and 1938, clear-cut evidence of mesons was obtained in the United States by Anderson, Street, and others; in other countries; and in Japan by Nishina.

"Finally, I wish to add that a greater portion of the credit for the development of the meson theory since 1937 should go to those who explored the various aspects of the theory. Notably, Dr. Sakata (Nagoya University) solved one knotty problem after another. I am also greatly indebted to the efforts of Dr. Kobayashi (Kyoto University) and Mr. Taketani (Tokyo Institute of Physical and Chemical Research). Later, a number of young men tackled different aspects of the problem. And I owe a great deal to many theoretical physicists in Europe and in the United States, who developed the theory more or less independently of the Japanese physicists. So I feel embarrassed when I am given the sole credit for the development of the meson theory.

"The meson theory today is at an impasse. If I succeed in solving the difficult problems of the theory, I will have repaid, in a small way, my indebtedness to my parents, to my teachers, and to all my friends in Japan and in other countries. · · · November, 1941, Kyoto, Japan."

[1] Not to be confused with the translator, C. Kikuchi.